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Possibilities for Applying Blockchain Technology – a Survey

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The blockchain technology has the potential to be applied in a variety of areas of our daily life. From the original Bitcoin cryptocurrency to the current smart contracts, the blockchain has been applied to many domains. Its numerous applications result in much ongoing research in different practical and scientific areas. This new technology is being seen as a revolutionary solution in finance, decentralization, trust, identity, data ownership and data-driven decisions. This paper presents the novel solutions associated with some of the big data areas that can be empowered by the blockchain technology such as healthcare, decentralized personal data protection, digital property, Internet of Things, digital identity, financial services and infrastructure, e-commerce, educational records, educational system, knowledge sharing, insurance, food industry, accounting, auditing and e-voting. Blockchain technology could be used in electronic health records and the establishment and maintenance of birth registers, deaths, marriages, registration of business activities, but also in the organization of elections. The features of this technology can be the redefinition of Internet 3.0 defined as a new type of decentralized infrastructure or network of networks.

Povzetek: Pregledni članek prikazuje možnosti uporabe tehnologij veriženja.

1 Introduction

In 2008, powerful American financial institutions and insurance companies were on the edge of bankruptcy. These circumstances called for immediate intervention by the federal government to avoid domestic and possibly global financial collapse. These events illustrated the dangers of living in a digital, interconnected world that depends on transactional intermediaries and leaves people vulnerable to digital exploitation, greed, and crime.

Blockchain technology is a relatively new concept and a fast-growing part of the Internet and cloud computing. Similar data structures existed long before the famous bitcoin was conceived, but the main theories about blockchain architectures used today were originally defined in the original article on bitcoin written and published by a person (or a group of people) under the pseudonym Satoshi Nakamoto in 2008 [1]. The first blockchain innovational application was Bitcoin. Beyond their use in the economic domain, Bitcoin and blockchain technology as articulated by Nakamoto solve an important computer science problem that had been a barrier to having a functional digital monetary system for years: the double-spending problem. The double-spending problem refers to a case where money should only be spent once. The first Bitcoin transactions occurred in January 2009. With the first "release" of the Bitcoin network on January 3, 2009, the first Bitcoins (cryptocurrency units) were created. Nakamoto developed the software and he was the lead developer until the mid-2010s. Bitcoin was the first cryptocurrency created on blockchain technology basis in 2009. Later, it was noticed that blockchain as a technology could be used for other purposes than the realization of cryptocurrencies. Since 2015, many international financial organizations have planned to further develop the blockchain system. In 2014, a consortium called R3 was established to start research and development of blockchain technology. In March 2017, this group counted about 75 companies to reach 200 in March 2018, including Bank of America, Merrill Lynch, UniCredit Group and many other real estate companies with the goal of better education, law and technology development in blockchain technology [2].

This paper describes the interesting implementations of blockchain technology in various domains such as healthcare. That includes all healthcare stakeholders such as hospitals, healthcare facilities and physicians. Then, a proposed solution for protecting data privacy is described by finding a solution for the digital property register.

Next, a secure and distributed blockchain technology system is displayed that can serve as an IoT platform in which devices are connected reasonably and securely. The potential of this technology to replace all existing physical identities such as passports, driver's licenses and ID cards and to move them to a digital platform is presented. It is described how the application of this technology can improve financial services and payment opportunities, provide a clear and transparent supply chain management system in the retail industry. By using this technology, student records, as well as completed courses, test results, diplomas and more, can be stored in the form of a digital record. Also the attendance of online classes and the

realization of online teaching during the COVID-19 pandemic can be stored in digital form that cannot be changed.

Moreover, this paper depicts the decentralization of Wikipedia's knowledge base. This is followed by applications of blockchain technology in the insurance sector, the food industry, accounting, auditing and election management.

The remainder of the paper is organized as follows. Section 2 highlights the principles of blockchain technology. The application of blockchain technology is described in the subsequent section. Section 4 describes the key challenges in the implementation of blockchain technology. Finally, concluding remarks and directions for further works are given in the last section.

2 Blockchain technology

“Blockchain" is a coined word, composed of the words "block" and "chain". Blockchain is a distributed replicated database organized in the form of a single linked list - chain, where nodes are blocks of data for transactions. These blocks, after grouping, are protected by using cryptographic methods. Blockchain technology enables the accomplishment of digital transactions without intermediaries. Linking blocks use a cryptographic hash function, in a way that makes it impossible to change the content of a block without changing the contents of all subsequent blocks. This is a very important feature of the blockchain, as it ensures the unchangeability of the data which it contains. The SHA-256 hash function for the same input data always produces the same output with a fixed length. Regarding the blockchain technology, the benefit of using cryptographic hash functions is that they are cryptographically strong hash functions with requirements such as second pre-image resistance and can serve as a digital fingerprint.

Blockchain technology is based on P2P architecture, where the nodes involved in the implementation of the service have a copy of all records and they constantly communicate with each other and synchronize new records [41]. Blockchain technology covers techniques from several disciplines: cryptography, mathematics, algorithms and economic theory. They are combining P2P networks and use a distributed consensus algorithm to solve traditional distributed database synchronize problem. Blockchains are integrated multi-user databases that form a type of decentralized infrastructure. The blockchain technology is specified of the following six key features [7] [10]:

Decentralization. The basic feature of blockchain, which means that blockchain does not have to rely on a centralized node anymore, the data can be entered, stored and updated in a distributed manner.

Transparency. The data's record by blockchain system is transparent to each node. It is also transparent to update the data, enabling the blockchain to be a trustworthy technology.

Open Source. Most blockchain systems are open to everyone. The record can be check publicly and people can also use blockchain technologies to create any desired application.

Autonomy. Because of the principle of consensus, every node on the blockchain system can transfer or update data safely. The idea is to distrust individual network participants and to trust the integrity of the whole blockchain.

Immutable. Any records will be preserved forever, and cannot be changed unless someone can take control more than 51% of peer network nodes at the same time.

Anonymity. Blockchain technologies solve the trust problem between a node to node, so data transfer or even transaction can be anonymous. They only need to know the person's blockchain address.

The blockchain database is managed autonomously using a P2P network and a distributed timestamping server. It is empowered by mass collaboration driven by collective self-interest. The result is a robust workflow, where participants' uncertainty about data security is marginal. Blockchain removes the features of endless duplication of digital assets. This forms a consensus system which ensures that each unit of value is transferred only once, solving the longstanding problem of double spending and blockchain-based value exchange system can be faster, safer and cheaper than traditional systems.

2.1 Decentralization of the blockchain

Blockchain (distributed ledger technology) is a network software protocol that enables the secure transfer of money, assets, and information through the Internet, without a third-party organization as an intermediary [3]. It can safely store transactions such as digital cryptocurrencies or data/information about debt, copyrights, equity, and digital assets. The stored information cannot be easily forged and tampered because it requires individual approval of all distributed nodes. This significantly reduces the cost of trusting and accounting that commonly exist in non-digital economies and other social activities. Blockchain has four components [43]:

(1) hash, which uses one-way mathematical functions to assign unique indexes;

(2) a digital signature, which is implemented as a public cryptographic key;

(3) P2P network, which serves as a routing structure for nodes to use the distributed hash; and

(4) consensus mechanism, which is a set of digital procedures designed to ensure the accuracy and consistency of the stored information across the participating nodes.

The blockchain data structure is depicted in Fig.1 [4].

In the Blockchain Body, the bottom is a part of Merkle Hash Tree which can be either a binary tree or a multi-tree in the data structure. Specifically, data or information is recorded as the hash value stored in the Blockchain Body, and the generated Merkle root through Merkle tree's hash process will be recorded in Blockchain Head [42].

The blockchain technology platform is gradually shaping up into three directions: (1) underlying infrastructure which includes facilities for mining and

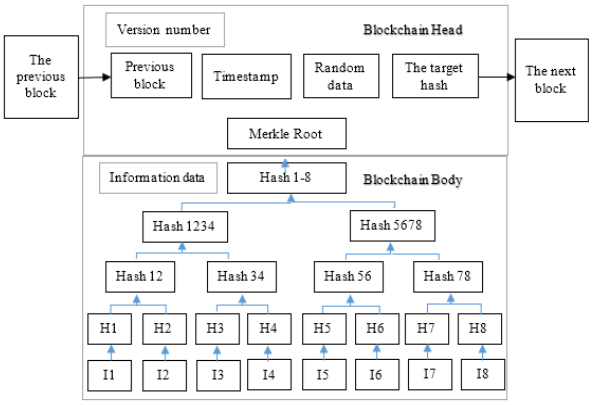

Figure 1: The blockchain data structure.

manufacturing of specialized computer hardware to perform blockchain-related tasks; (2) middle layer between the blockchain platform and client application services, including smart contracts, a blockchain platform, financial software, and other services; and (3) hotspot distributed applications in various industries, including finance (e.g., cross-border payments, liquidation, financial services, and asset digitization), cybersecurity (e.g., identity protection, data authenticity protection, and critical infrastructure protection), and supply chain management (e.g., logistics tracking and digital works tracking).

This distributed general ledger is replicated to thousands of computer nodes around the world and is publicly available. Despite its openness, it is also confidential and reliable. This is achieved through a mathematical puzzle and computer power embedded in its "consensus mechanism" - the process in which the nodes agree on how to update the blockchain with each transaction of moving the value from one person to another. Users use public and private keys to digitally sign and make transactions in the system in a secure way. Blockchain users can solve puzzles using cryptographic hash methods hoping to be rewarded with a fixed amount of cryptocurrency [5].

Blockchain systems seem very complex. However, they can be easily understood by examining each technology component individually. At a high level, blockchains utilize well-known computer science mechanisms (linked lists, distributed networking) as well as cryptographic primitives (hashing, digital signatures, public/private keys) mixed with financial concepts (such as ledgers) [6].

A ledger is a collection of transactions. Ledgers are often stored digitally in large databases owned and operated solely by centralized "trusted" third parties. However, we must trust the third party that the data are backed up, transactions are validated and complete, and the history is not altered. A ledger implemented using a blockchain can mitigate these issues through the use of a distributed consensus method. One of the aspects is that the blockchain ledger will be copied and distributed amongst every node within the system. When new transactions are submitted to a node, the rest of the network is alerted that a new transaction has arrived and at this point, this is a pending transaction. Eventually, one of the nodes will include this new transaction within a block and complete the system's required consensus method. This new block will be distributed across the network and all ledgers will be updated to include the new transaction. When new users join the system, they receive a full copy of the blockchain, making loss or destruction of the ledger to be difficult. Each transaction submitted to the network passes through several steps to be included and published in a block of the blockchain:

A transaction is a record of a transfer of assets (digital currency, units of inventory, etc.) between involved parties. For each input transaction A, an output hash value #A is created using a cryptographic function.

Hashing is a method of calculating a relatively unique fixed-size output for an input of nearly any size (e.g., a file, some text, or an image). Even the smallest change of input will result in a completely different output digest. Hash functions are designed to be one-way: they are computationally infeasible to find any input that maps to any pre-specified output. If a particular output is desired, many inputs must be tried by passing them through the hash function until input is found that gives the desired result. Moreover, hash algorithms are designed to be collision-resistant, they are computationally infeasible to find two or more inputs that produce the same output. A commonly used hashing algorithm in many blockchain technologies is the Secure Hash Algorithm (SHA) with an output size of 256 bits (SHA-256).

Each block in a blockchain contains multiple transactions, which are grouped in sets. Hash values are further combined in a system called a Merkle tree [5].

Merkle tree is a data structure where the data is hashed and combined until there is a singular root hash that represents the entire structure. The root is an efficient mechanism used to sum up the transactions in a block and verify the presence of a transaction within a block. This structure ensures that the data sent in a distributed network are valid since any alteration to the underlying data would be detected and can be discarded. The result of all the hashing then goes into the block’s header, and it is combined with the hash of the previous block’s header and a timestamp. This combination becomes a part of the cryptographic puzzle. The solution for the puzzle is to find a nonce value. The nonce value is a number manipulated by the mining node to solve the hash puzzle and with this, it gives them the right to publish the block [5].

After creation, each block is hashed thereby creating a digest that represents the block. The change of even a single bit in the block would completely change the hash value. The block's hash digest is used to prevent the block from changes since all nodes will have a copy of the block's hash and can then check to make sure that the block has not been changed. An additional feature of blockchain systems is that they can run so-called smart contracts [6], which is an auto executable code that fires off once certain conditions occur. A smart contract is computer protocol or collection of code and data which runs automatically under defined criteria when deployed on the blockchain. The contract executes the appropriate method with the user-provided data to perform a service.

The code, being on the blockchain, is immutable and therefore can be used (among other purposes) as a trusted third party for financial transactions that are more complex than simply sending money between accounts. A smart contract can perform calculations, store information, and automatically send money to other accounts. It doesn't necessarily even have to perform a financial function.

Instead of relying on a central authority to securely deal with other users, blockchain uses innovative nodes consensus protocols, verifies transactions, and seamlessly records data. Because blockchain is a distributed ledger, similar to a database, the data stored must be authentic and accurate. Separate nodes in the network constantly confirm the authenticity of the entries in the chain and reject the proposed data blocks, if they do not pass verification. Taking control of a large number of nodes in the network (more than 50%) would be extremely complicated and expensive for attackers and is much more difficult than compromising any centralized service. Therefore, this approach to data storage is considered far more secure compared to centralized databases. Theoretically, it is possible to break a blockchain, if the attacker controls more than half the total network power, in which case it is called a 51% attack. But if someone succeeds to change the blockchain, it will destroy it and hence it will have no value.

2.2 Types of blockchain systems

Blockchain is a technology that is constantly evolving. Due to its basic technological features, new applications are constantly being developed using its framework. The most common types of blockchains are:

- public blockchain;
- private blockchain and
- hybrid blockchain.

2.2.1 Public blockchain

A public blockchain is one that contains absolutely no restrictions. Public blockchains allow anyone to submit data to the general ledger with all participants holding an identical copy of the general ledger. As there is no single owner of the general ledger, this methodology is more suitable for anti-censorship applications (for instance, Bitcoin) 0. The public blockchain has the following features:

• Anyone can access it, i.e. see all the transactions that appear on the block. Several services allow you to view the public blockchain (known as block explorers), and the most famous is blockchain.info, which can track bitcoin blockchain.

• Anyone can make transactions. It is enough to download a mobile or desktop wallet (Wallet) or to use one of the online wallets and to carry out transactions freely.

• Anyone can participate in the creation of blocks and in the distribution of the reward that follows for adding blocks. Alternatively stated anyone can be a "miner".

• Everyone can have a say in deciding whether to amend the cryptocurrency protocol. In some cryptocurrencies, miners make decisions, but there are cryptocurrencies in which other participants have a controlling stake.

• The protocol that controls the system is in the form of open source. Anyone can view this code, but anyone can suggest changes to that code. If the majority accepts the proposed changes, those changes become an integral part of the protocol. It is also very common to take the protocol from one cryptocurrency, modify it slightly and then launch it as a new cryptocurrency. The full openness of public blockchains reveals some of their advantages and disadvantages.

The main advantages of public blockchains are:

• Blockchain is resistant to potential attacks.

• Because anyone can be a node in a P2P network, the number of these nodes is very large and therefore it is more difficult to have more than 50% "unfair players", which is very expensive.

The main disadvantages of public blockchains are:

• The capacity of the blockchain is very limited, both in terms of the number of transactions that can be processed per unit time and the amount of data that can be stored in the blockchain. For more people to participate in network maintenance, the requirements must be relatively modest, both in the amount of hard disk space occupied by the blockchain and in the speed of the Internet connection. The Bitcoin network can currently process only a few transactions per second, and by comparison, Visa can process tens of thousands of transactions per second 0.

Management mode is inefficient. To implement any, even the slightest changes of the system, it is necessary for the majority of the members of the network to agree to this change. In comparison, this would be roughly how a referendum would be organized for each decision in the country 0.

2.2.2 Private blockchain

In private blockchains, only invited participants are allowed to join the network. These networks are controlled by one or more designated network administrators. Private blockchains allow distributed duplicates of the registry, but only to a limited number of trusted users. Because the network may have an owner, this methodology is better for applications that require simplicity, speed, and greater transparency.

What companies do not like is the transparency and the fact that the system is accessible to everyone. That is why the idea of a private blockchain has emerged that will retain most of the benefits of the public blockchain, but will also eliminate the disadvantages that do not suit companies 0.

2.2.3 Hybrid blockchain

Hybrid blockchains, called consortium blockchains, are considered as semi-decentralized and use the characteristics of public and private blockchains. Hybrid blockchains contain licensing groups similar to private blockchains, but instead of one controlling organization, they are controlled by a group of contracted organizations to ensure the validation of transactions [42]. The consortium blockchain allows a group of individual

organizations to validate blocks, instead of having everyone participate in the process, or having only a single entity to decide the validation process. Hyperledger Fabric [38] and Hyperledger Burrow [39] are examples of consortium blockchain frameworks. For the consensus mechanism, the consortium blockchain uses consensus algorithms to validate transactions, such as Byzantine fault tolerance (BFT) and practical BFT (PBFT) consensus through the Tendermint algorithms, which are not expensive computationally.

2.3 Smart contracts

A smart contract is a code in a programming language that facilitates the exchange of money, real estate, shares, or any value [39]. Smart contracts are computer programs that automatically execute the terms parties have agreed on, to regulate their relations**.** This code can be written to a blockchain and executed on any computer in a distributed network. The smart contract is automatically executed when specific conditions are fulfilled. Because the code of the smart contract is written on the blockchain, the execution takes place without any possibility of censorship, interruptions, fraud or intrusion by third parties. We can say that the block on which smart deals are stored is a distributed operating system.

In the context of blockchain, smart contracts have existed before Ethereum. American developer Nick Shabo defined the concept back in 1996 in the book Smart Contracts: Building Blocks for Digital Markets. He wrote that the basic idea of smart contracts is that many types of contract clauses can be embedded in the hardware and software we communicate with, in such a way that breach of contract is costly for the offender [6].

3 Application of blockchain technology

Besides the first application of blockchain technology in the creation of cryptocurrencies such as bitcoin and many other altcoins, it is widely used in different domains of daily living where new innovative ways of working are introduced.

3.1 Healthcare system

One challenging implementation of blockchain technology is in the healthcare involving all stakeholders such as hospitals, healthcare authorities and clinicians by satisfying patient needs and protecting patients' privacy by using blockchain to pay fees with bitcoin [8].

Until now, doctors have faced many obstacles when it comes to digital storage and information sharing for patients. The authors in [10] identified three major barriers to effective digital record management:

- easy access to medical records;
- maintaining the patient's privacy and
- ensuring the sharing of records between different platforms without losing their meaning and proving their authenticity and credibility.

With blockchain technology, all three obstacles are reduced to an acceptable level or eliminated.

Firstly, decentralized blockchain databases can be accessed by authorized persons, whether they are healthcare providers, insurance companies or patients - anywhere, anytime, and in a format that can be used by all parties. An additional advantage of such a system would be the elimination of centralized data controllers. Secondly, blockchain technology provides security measures that are not available for other digital sharing methods, making it easier to address privacy concerns.

Finally, blockchain technology reduces the number of agents that manage each entry and maintains a consistent, timely record of each transaction, reducing the possibility of error while providing a high level of transparency and trust.

In the current system, where full records are kept on paper, if information seekers need to see a personal health record (PHR), they must complete a request form and send it to the registration office for approval. Upon approval, the information requester will pay for a copy at the cashier and receive a payment confirmation account. The information seeker then shows the account to the registration office to obtain a copy of the PHR. However, the PHR may be lost or duplicated for illegal purposes.

When the information seeker sends a PHR request to the publisher (hospital or healthcare institutions) and the publisher agrees with the information requestor, Bitcoin will be placed. Before sending a PHR to the information seeker, it requires the approval of a family doctor and the patient, so that only specific anonymized records are required for the patient to be sent [8].

Rapke in his approach to healthcare discussed that perhaps changes should come from a point where people own and can access data about their health [10]. With his working concept blockchain has a way of bringing this consumer-oriented approach to the healthcare sector. Data from the results and procedures can be stored on the blockchain, which will not rely on a single central storage facility. This will help the governments and other companies to be held accountable for that data. At the same time, the data will reside on the latest secure technology using cryptography. As data owners, patients will have the authority to decide with whom they share their data. Healthcare will be more patient-oriented, but it is still in balance with other important players in the healthcare system. In [12] authors explained how blockchain can enable the interoperable and secure exchange of electronic health records (EHR) in which health consumers are the ultimate owners. The proposed scenario is to store only health and medical metadata on the blockchain. Otherwise, blockchain's infrastructure storage capacity would have to be massively expanded to support full health records. So, metadata such as patient identity, visitor ID, provider ID, customer ID, etc. can be stored on blockchain but the actual records should be stored in a separate universal health cloud, as shown in Fig. 2. For instance, if a patient visits two hospitals today, they will store their data in two databases that the patient does not own. If hospitals need to communicate, they will use a standardized communication mediator such as web services, e-mail, or a shared file repository. In a scenario where blockchain is applied, the first hospital creates a

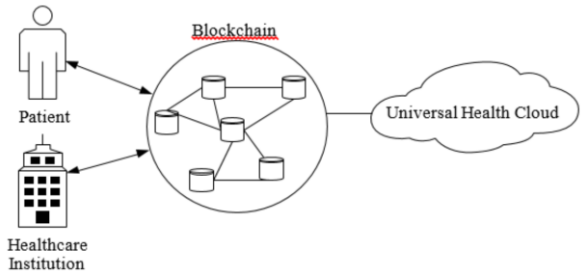

Figure 2: Overview of the Blockchain Healthcare System [13].

record of the universal health cloud. The hospital then creates a transaction in blockchain with metadata for visits and a URL (Uniform Resource Locator) for the cloud entry. The patient signs this transaction with his/her key. When a patient now visits a second hospital, he/she must provide his/her key reading blockchain transactions. Only those affected by the patient's key can decrypt the transactions. So this is an example of how people can own data and approve access. Even smart contracts can be encoded in blocks to carry insurance instructions, emergency contacts, wills etc. These smart contracts will be activated with events that a blockchain can read from another web service.

Transactions in blocks should contain a unique user identifier, a coded link to the health record, and a timestamp for the time when the transaction was made. The transaction may also contain the type of stored data. Depending on the implementation, this can help search and process the access data. This blockchain will contain a history of all medical data, including formal medical records, as well as data from mobile applications and various sensors being carried. Keeping data away from blockchain in a cloud pool can be a good basis for exploration, mining, analytics and machine learning. This type of analysis does not have to affect the privacy of each patient. These data have to be encrypted and digitally signed to ensure the privacy and authenticity of the information. The user will have the option to assign a set of access permissions and specify who can request and write data to their blockchain. Further development of the user interfaces for the patient to review their healthcare data and manage access privileges is entirely possible [14].

Another blockchain case study in healthcare uses Ethereum's smart contracts to create representations of existing medical records [15]. These contracts are stored directly in separate nodes on the network. The proposed solution called MedRec structures large amounts of data into three types of contracts. The first one is the Registrar Contract. It holds the identity of the participants with all the necessary details and of course the public keys. This type of identity registration can be restricted to authorized institutions only. The second contract is the relationship between the healthcare provider and the patient. The main use will be when there is a smart agreement between the care provider and the patient. A third type is a contract that helps the patient to locate his/her medical history. As a result of this agreement, all previous and current engagements with other nodes in the system are listed. MedRec also proposes a data mining model that incorporates the entire healthcare community into data mining. Medical researchers and healthcare stakeholders can work in the network.

Big data in healthcare come from a variety of sources, such as clinical trials, EHRs, patient databases, medical measurements and imaging. All these data come in a wide range of formats and from different data streams. The data should be evaluated and interpreted temporally to benefit patients. But doctors need new tools to monitor, track, and provide quick feedback to individual patients. Appropriate data management will also help with prediction strategies, interventions, healthcare services and healthcare policies. Because medicine is always on the cutting edge of technology, moving forward with many innovations, healthcare data need a crucial transformation, as do big data.

3.2 Decentralized protection of personal data

From social networks, personal data, activities and behaviours of users are constantly being collected, without users to be conscious about the privacy issues. Users still do not have a clear idea of what precise data is being collected and for what purpose, they are losing whole control of what is happening with the data afterwards and cannot withdraw the permissions. Concerns about data privacy grow when faced with the consequences of what others have seen or learned about us. Zyskind in [16] has proposed a solution that is an access control management system that mainly focuses on mobile platforms and the inability of the user to recall authorized access to private data. By installing a mobile application, permissions are granted indeterminately and the users must uninstall the application and stop using the services if they want to revoke the access. The purpose of the new solution is for the user to be able to control and revise what data are stored and how they are used. The idea is to keep the personal data access policies on blockchain and then the nodes in the blockchain to control access to the DHT (distributed hash table).

The solution consists of three entities: the user, the company providing the service and blockchain. When a user wants to allow or block access to his/her data, blockchain comes into play as an intermediary. Here blockchain supports two types of transactions: access transaction and data transaction. These types of transactions allow access control management, data storage, and data extraction. When the user installs a new application, a shared identity is created and sent to blockchain along with the configured permissions at the user's request. All assigned permits are listed in the so-called policy. The shared keys, the public key of the user and the public key of the service, and the policy are sent through an access transaction in the blockchain. A new complex identity is being introduced into the proposed system. Complex identity is a shared identity between the user and the service. The user is the owner of the key, and the service is a guest. The complex key is composed of

pairs for signing on both sides, so that the data will be protected by all other parties in the system, except the owner and all his/her guests.

Sensitive user data are encrypted with the shared encryption key and sent with transaction data for storage. Blockchain sends data to a DHT and retains only the hash value as a pointer to the data. The value set in DHT is encrypted with the complex key. The value indicator is known to the user and the service. DHT only performs the already approved read and write functions. Both the user and the service can search the data using the data pointer. Each time the service accesses the data, its permissions are checked compared to the last access transaction. The user can revoke permissions at any time or modify them by initiating a new access transaction. To track this, it is possible to easily develop a web table showing the user's current permissions. Overview of the decentralized permitting system using blockchain is shown in Fig. 3.

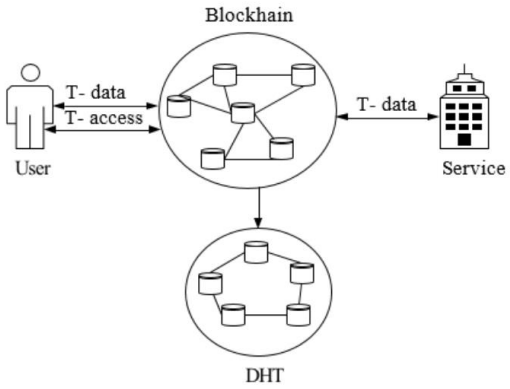

Figure 3: Overview of the decentralized permitting system [13].

Another study based on social media controlled by users on the blockchain is described in [17] by Ushare. Ushare's vision is that users should control their presence over the Internet by affecting the posts they share and controlling the ability to share again. Using P2P capabilities, Ushare created a decentralized content distribution network. The tool that blockchain manages, in this case, is the data that users publish. Ushare's proposed solution consists of a user-encrypted hash table, a system for controlling the maximum number of actions performed by user circles, a local Certificate Authority (PCA) that manages user circles and blockchain.

When a user shares a post with his/her circle, his/her PCA encrypts the data with the public key on the circle. Encrypted data are stored in a DHT. This table has three columns that allow users to share already published data they see. Each time a user shares a post, the first column stores hacked encrypted data about the post that is being viewed and shared. The second column records the hash of the encrypted data with the public key on its circle. The third column stores the encrypted data item.

The reason for using DHT in this second solution is the same - large data such as documents, images and videos should be stored in a decentralized manner. Blockchain only stores transactions for sharing user posts. The actual data cannot be stored because downloading the entire chain to all nodes will create limitations in computer calculations and time constraints. When the user creates a post, he/she sends a new transaction to the blockchain with his/her identity, the hash key of the encrypted data and the token in which he/she states the allowed number of shares. Afterwards, the user sends a separate transaction to each member of his/her circle with the data encryption key. If another user who has received the post wants to share it, he/she sends a new transaction with his/her identity and the data key encrypted with the key to this new user's circle.

Again, more new transactions are sent to the subsequent users who can review the re-shared transaction. The number of tokens decreases with each action. All efforts to create these two blockchain solutions are because personal and sensitive data should not be entrusted to third parties. Because users create and publish data, they need to remain the main owners of the data. Regarding the monitoring done by following the procedures and interests of the users, the users should at least know that. A blockchain can be a filter for permissions to access private data or it can implement a fully decentralized social network, as shown in the second solution.

3.3 Digital property

The World Wide Web (www) started with simple links and laid the groundwork for making it visible what is original and what is being copied. After that, people thought of a way to preserve authorship by mentioning the author in references. But this system is far from perfect. People can always find a way to copy things, and the author will not know and will not be notified. Or, people may assign the copyright, but it's in one direction, so the author still won't know that someone has addressed his work. Or even worse, people may cite someone else who is not the original author. It is concluded that the main tool for digital content and digital sharing (www) ignores the need for digital ownership. But at the beginning of the development of the service www was different. The Xanadu Project was the first hypertext project, founded in 1960 by Ted Nelson [18]. Even then, the problem of digital ownership was approached by introducing a copyright scheme based on copyright, in a system that would provide storage and publishing services. The granting of copyright is built into this system. Two-way connections should be set up automatically each time someone uses another user's data. It was concluded that it was a complicated, unfeasible technology and the project was closed.

With blockchain technology, Ascribe [19] tries to achieve Xanadu's goals by finding a solution for the digital property registry and copy visibility. In terms of visibility, they try to find all the copies of the protected content that exist on the Internet. This can be done by searching the entire Internet and performing a match to match the content of the creator. This problem would be solved by machine learning techniques. When the copies are found, the system performs two-way automatic connections. The

author must then decide whether to apply for a license or perhaps a revocation request.

When it comes to selling intellectual property of digital art, it is not just selling a copy, it is selling property and the right to use, modify or resell the content. To make this type of sale of a property, it is necessary to conclude a legal agreement, hire a lawyer, etc. The idea of using blockchain to store and sell digital data ownership will be as simple as sending a signature e-mail that the user transfers ownership of its content. The terms of service provided by Ascribe are made in consultation with specialized lawyers. The complexity of legal licensing and ownership processes is achieved by accepting the terms of service. Blockchain is a publicly trusted book and will provide copyright to all users. Transaction time stamps can be used as evidence in court in the event of a property dispute.

Regarding blockchain implementation, Ascribe has created its protocol called SPOOL - Secure Public Online Ownership Ledger [20]. This protocol is made specifically for documenting digital ownership transactions. Ascribe allows the artist to set a fixed number of editions of the work that can then be transferred, ensuring that each edition is authentic to the artist. So, when a transaction with transfers is made, the user can transfer ownership for one or more editions. The editions are under a work preserved in BigchainDB [21] and used for use in the blockchain. So, when transferring ownership, the users create a transaction for one of their works, includes the value of the hash, the issue and the new owner. The user signs the transaction and sends it. Because Ascribe uses the Bitcoin blockchain, a public researcher who knows the hashtag of the work can track the ownership of the work and find all the addresses that each edition has.

Another blockchain implementation is Monegraph, which is proof that a new, modern and digital marketplace can be built that is easy for users. From the users' point of view, with Monegraph, it is easy to buy and sell fully licensed digital media directly with terms, rights and prices controlled by the authors. Monegraph facilitates the process of licensing and receiving revenue of art in many digital forms created by photographers, designers, illustrators and other media creators [24].

Monegraph allows authors to create and customize a license agreement that sets out the usage parameters for their media. There are four types of licenses:

- license for works of art - for non-commercial usage,
- photo news license - for editing,
- product image license - commercial license and
- picture of the situation is a license that gives all the rights.

The authors have a public catalogue as a portfolio of their work that is publicly available and sold. Blockchain takes into account the history of ownership. But storing only information for owners may not be enough in the market. There is a lot of data on the sales' contracts and product metadata that is just as important as the product. Due to the size of that data, these data cannot be included in the blockchain. That's why Monegraph sees the need for a blockchain system that can be implemented in other digital markets. What is needed for the solution is integration with other services. So, ownership data are stored in the blockchain to remain confidential, traceable and irreversible. But other documents related to the product can be stored in the database, such as MongoDB or CouchDB. Documents can be public, encrypted or not. Digital art itself can be stored in a document repository that can be accessed with HTTP or P2P. For example, the file can be stored in the Amazon Simple Storage Service (S3). The ecosystem, shown in Fig. 3, needs to find a way to connect blockchain, the document repository, and the digital art repository.

The Bitmark real estate transfer system allows the

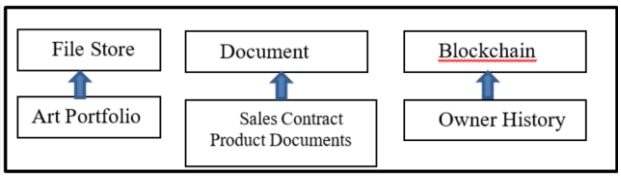

Figure 4: Blockchain ecosystem [13].

transfer of both digital and physical objects [22]. When storing information about physical objects as an abstract property, a problem arises. Digital fingerprint can be easily traced using the hashtag algorithm, but when it comes to physical objects, there is a new solution called ObjectMinutiae [24].

It can be concluded that so far the Internet has left a lot of material with lost authorship. But looking to the future, blockchain can provide reliable proof of ownership by preserving the hash value of digital art in a time frame for a transaction. The concept is the same for all examples: the owner will have the private key and the original copy of the hashed art. No one can prove otherwise and no institution can change the data. The author can sell digital work, and the new owner will now have the private key to the digital work.

3.4 Internet of Things (IoT)

Current IoT systems rely on a centralized client-server architecture. All devices are identified, authenticated and connected via cloud servers. The connection between the devices goes through the Internet. Even if this solution works well, for now, it may not be able to meet the needs of larger IoT systems in the future [25]. Blockchain technology can become an ideal component and a basic element for tracking billions of connected devices, processing transactions, and coordinating devices. Because blockchain is a decentralized mechanism, it allows the distribution of digital information between different nodes without copying. This can create a new kind of Internet that is safe and resistant to unauthorized modification.

A secure and distributed blockchain system can serve as a platform for the IoT to connect devices seamlessly and securely. Blockchain will allow P2P messaging, file distribution, and autonomous coordination between devices without the need for a centralized cloud. Each device will have its role and will manage its behaviour in the new Internet in a decentralized and autonomous way [26]. The user controls IoT devices from a central point.

The central point may be the user's mobile device. All activities, commands and rules are set by the user. Although this is good for personal control, it is not automated in many ways. The secure model of blockchain technology allows easy human interaction with devices without the need for a central cloud-based central system, which is usually more expensive.

Additionally, because there will be no central control, such as a cloud, the possibility of damaging or stopping the entire IoT system is negligible. This ensures continuity, ease of operation, robustness, scalability and IoT security at a very low cost. A real revolution can happen if all devices are controlled by blockchain instead of direct user control. This is possible by using smart contracts. A smart contract is a code which enforces conditions and business rules that must be met before a transaction can be included in the blockchain. A transaction written in blockchain can be more complex than just transferring ownership. Smart contracts have an integrated mechanism for implementing different types of agreements between nodes. The smart deal is also autonomous and technically it is a computer code that can be self-sustaining and self-executing. Once in force, no human factor is needed to control it [27].

Execution of smart contracts is made possible by Ethereum, which is a platform for creating blockchain systems. Ethereum has its network of nodes and miners, just like Bitcoin. Slock.it is the first implementation of IoT and blockchain using the Ethereum platform [28]. The so-called Slocks are real physical objects that can be controlled by blockchain. They use a computer, Ethereum, which is a piece of electronics that brings blockchain technology into the whole home, allowing to rent access to any compatible smart object and accept payments without intermediaries. Slock.it allows anyone to rent, sell or share anything - without intermediaries. It works as follows: the owner of a smart object (Slock) creates a smart agreement for its use by setting the price and the deposit. Users can find Slock and then pay using Ethereum blockchain, which will allow them to open or close that Slock, which means using it as agreed. The smart contract is implemented automatically, and the deposit is returned to the user minus the rental price. In practice, this means that by installing a smart door lock for the apartment, users can rent an apartment on the blockchain. The smart contract will unlock it and make it available, as stipulated in the contract. In addition to smart doors, this system allows you to rent, sell or share any smart item that has built-in Slock.it technology. Bicycles, cars and any item that can be provided with a physical lock is a case of potential use. Due to the shortcomings of existing IoT architectures, a new secure, private and easy-to-use IoT architecture for a smart home based on the blockchain technology is being proposed [29]. Here, block mining is considered the first problem because IoT devices are devices with limited resources and cannot perform such an operation. IoT devices must also operate at the same time for a detected or assigned command. The time required for mining in blocks, in most cases, may not be acceptable. The proposed solution [29] contains three levels: local network, folding network and cloud storage.

The local network contains all the smart home objects and a local computer that acts as a local blockchain that is constantly on the Internet. This local blockchain is centrally managed by its owner. When there is a new smart device in the home, the user adds it to the blockchain. All transactions related to a particular device are linked to a chain. The folding network is a P2P network that connects multiple smart homes and users. This network manages public keys, allowing users access to smart home data and public keys to smart homes that provide accessible data. Cloud storage is included as a solution for devices that may want to store data in the cloud so that a third party can access the data and provide certain smart services. Using blockchain, the IoT can switch to a network of devices that can communicate with each other and the environment without human intervention. The devices will also make smart decisions, so that many workflows will be automated in new ways, achieving significant time and cost savings.

3.5 Digital identity

Due to a security mechanism that protects against disruption, blockchain can play a key role in securing digital identities 0. Blockchain can protect identity by encrypting. Also, blockchain can be used to build a very strong, secure and impenetrable identity system, which can prevent unauthorized activity. Blockchain technology has the potential to replace all existing physical identities and move them to a digital platform. Identity ranges, such as passports, driver's licenses, ID cards, and even votes election, can be digitally generated using blockchain technology [30]. It is also possible for all identities to be kept together and secured with a blockchain. The use of blockchain, unauthorized modification of various certificates, such as educational, marital, death certificates or registry books, cannot be performed, thus preventing unauthorized and malicious modification.

3.6 Financial services and infrastructure

Blockchain technology can provide a platform for better financial services and payment opportunities. The use of cryptocurrencies such as bitcoin can restore existing payment systems and other financial services [31].

For example, if one person sends money to others in another country, possible transfer funds are banks, payment applications (such as PayPal) or other intermediary organizations. But their service costs are high, even for small transactions.

All of these intermediaries can be eliminated and the money can be transferred directly from the sender to the recipient using cryptocurrencies such as bitcoin, without the involvement of an intermediary. Tracking transactions and property rights can also be implemented in the financial sectors using blockchain. The use of blockchain technology in the financial sector will not only provide a free payment system but will also provide a secure way to conduct online transactions.

3.7 E-commerce

If implemented properly, blockchain technology can massively support e-commerce and retail in terms of growth, sales and marketing. Retail has already begun to witness the growth and profit from the sale of consumer goods and services using blockchain technology.

The Internet acts as a great platform for promoting local businesses and other content, but there is always a risk that the content will be used without proper permission. Overall plagiarism can be limited with timestamping techniques of blockchain and thus preserve the originality of any content. Implementing blockchain technology in the retail industry will also provide a clear and transparent supply chain management system that will allow users to gain insight into the origins of their food and other products.

E-commerce websites and other companies such as OpenBazaar, Provenance, Everledger, Ascribe, and BlockVerify are some of the business activities supported by blockchain involved in the retail industry [30]. This eliminates brokers and commissions and can set up a direct transaction channel between the buyers and sellers. In this way, online sales will promote retail business transactions and the economy.

3.8 Educational records

Sony Corporation, in partnership with Sony Global Education, recently applied for a blockchain-based repository patent that would include student records, including completed courses, test scores, diplomas, and more, in the form of a digital record 0. Such a system can allow teachers and students to access relevant data while maintaining privacy. It can also provide potential educational institutions and potential employers with a transparent, secure place to acquire applicants' credentials.

3.9 Education system

In this time of pandemic when teaching in schools takes place online, many problems arise. Classes are shortened and the teacher has to spend valuable time constantly checking which students are present in the class. Also, the principal of each school wants to know if the staff teachers hold their classes regularly and on time. These problems could be overcome if the data from each class was recorded on a blockchain. In that way, no one will be able to manipulate that data. You can check at any time which professor and when he/she taught and which student attended the class. If students knew that everything was recorded and the data could not be changed, they would surely attend classes more regularly. And that is the most important condition for them to improve their success. Improved student achievement is the best satisfaction for teachers. Parents would also be more satisfied with such behaviour of their children. The whole society would benefit the most from a good education because knowledge is strength and power.

3.10 Sharing knowledge

Everipedia, the world's first blockchain encyclopedia, has announced plans to build a new open-source wiki network that decentralizes the Wikipedia knowledge base, allowing any editor to become a webmaster. According to Larry Sanger, one of the founders of Wikipedia and now acting director of information at Everipedia, it will rely on a blockchain program that allows users to contribute more responsibly. Editors will start earning "tokens" based on their "IQ" (earned points for useful contributions) that will represent the virtual shares of the platform [35].

Theodor Forselius, co-founder and CEO of Everipedia, noted that the ability of the individual to be a stakeholder in the encyclopedia, he/she edits and in turn to gain real monetary value is an exciting idea. Customers will have to pay a deposit before making contributions. If their changes are considered incorrect, they will lose the token and those whose changes are correct will receive an original deposit and additional tokens as a reward.

Forselius also listed two additional benefits of moving Everipedia to the blockchain. The first benefit is that the data will no longer be stored on a centralized server, which means that they will survive even if the central organization, Everipedia, ceases to exist. The second benefit is that it will be impossible to censor the data, which means that governments that currently censor Wikipedia will not be able to prevent users from contributing to the platform.

3.11 Insurance

Blockchain technology has many applications in the insurance sector because the sector is based on agreements and trust between two parties. The use of blockchain in this regard would mean that both the insurance contract and the consumer's personal information can be stored in the distributed book, while the consumer controls who has access. The data remains on the user's device and this can eliminate the need for brokers and other intermediaries between insurance companies and consumers.

The presence of smart contracts is already being felt in the insurance sector. The insurance company AXA worked with a website called Fizzy, which ensured consumers against flights delayed by two or more hours 0. Fizzy noted the procurement of airline tickets on Ethereum blockchain and linked the resulting smart contracts to global air traffic databases. If sufficient delay is observed, the fee was paid automatically. Another example of using smart contracts in the insurance sector is to compensate farmers in the event of a drought or other disaster that harms their property. The other application of blockchain in the insurance industry is its role in potentially reducing fraud 0. In this case, the blockchain records all policies and all claims in a single distributed book.

3.12 Food industry

This technology is potentially beneficial for everyone in the food industry. When foodborne illness occurs, restaurants serving food or grocery stores often have

difficulty discovering the source of the contamination. Monitoring with blockchain will help to immediately track affected objects and their origins, quickly locate the problem so that contaminated products can be removed from menus, shelves and supply chains 0.

The standards and reputation of blockchain-based vendors will ensure the integrity of marketing claims. Certificates and reports on the existing audit of existing facilities will be registered on the site to prove the above claims. If all suppliers in the supply chain follow these rules and write down the data on the origin of food in decentralized monitoring systems, those who make false claims or misrepresent the origin of their products will be destroyed. Blockchain technology allows farmers and producers real-time access to commodity prices and market data. In this way, farmers have better information about the market and they can be more competitive and more productive. More and more people want to know what the products they consume contain. They want to be able to make reliable food choices for themselves, their families, and their communities. Blockchain technology will help build that trust.

3.13 Accounting and audit

Because changing transactions or whole blocks are almost impossible in blockchain, the use of blockchain technology makes it easy to prove the integrity of electronic files. One approach is to generate hash arrays for existing evidence, such as invoices. This set of hash strings is a digital print. Furthermore, this imprint is immutable and is recorded on the blockchain through a transaction. At any later time, it is possible to prove the integrity of that file by re-creating a digital fingerprint and comparing it to the digital fingerprint stored in the block. In case the digital prints are identical, it is proved that the document remained unchanged since the first block placement in the blockchain [34]. Companies will benefit from this type of blockchain implementation. Standardization will allow financial auditors to automatically verify much of the most important financial reporting data. The costs and time required to carry out the audit will be significantly reduced and the time-released can be spent on checking very complex transactions or internal control mechanisms.

3.14 Cross-border payment

Cross-border payments generally refer to the transnational and transregional transfer of funds between two or more countries or territories through international trade, international investment, and other international claims and debts using certain settlement instruments and payment systems. The traditional cross-border payment is based on the banking system which has such characteristics as time-consuming, high cost, more funds occupied, and low security. However, all these bottlenecks can be effectively overcome by applying blockchain to reconstruct the credit system and expand the payment boundary. Researchers pointed out that applying blockchain technology to the cross-border payment has a high potential effect. Holotiuk et al. in [44] stated that the blockchain technology will improve the payment system by providing a solid structure for cross-border transactions and removing expensive intermediary costs and gradually weaken or alter the business model of the existing payment industries. Yao and Zhu have proposed that the blockchain technology can be adopted for the cross-border payment based on the application of VISA and SWIFT blockchain. R3 has been working with 22 of its member banks to build a real-time, cross-border payments solution on Corda that is the consortium's "blockchain-inspired" distributed ledger [51].

3.15 SARS-CoV-2 virus vs. the Red Cross: better solutions via blockchain and artificial intelligence

Beijing has ordered all public donations for the Wuhan crisis to be funnelled to five government-backed charity organizations. This is a throwback to pre-2016 China before the Charity Law of China was introduced to enable the establishment of private charities. The Charity Law was intended to develop the charity field and protect the interests of relevant stakeholders. Although all charities in China are required to have in place sound internal governance structures, the funnelling order implicitly assumes that the five government-backed charities are fit for purpose and better able to manage the current crisis. That assumption may be at odds with historical and more recent evidence suggesting organizations responsible for responding to crises appear to struggle to manage their core responsibilities. And if Beijing's implicit assumption is wrong then the centralizing effect produced by funnelling merely serves to compound the problem [46].

In this instance, and not for the first time, the Red Cross in China is in the crosshairs of public anger. 'One of the lessons learned was that emergency response must be better developed at the local level'. This is what the Red Cross said in 2017 on the 10th anniversary of the deadly Wenchuan earthquake in Sichuan province in western China. Billions of dollars had been donated following the Sichuan earthquake but had been 'mishandled'. What has been learned? The public in China has again been angered by the mishandling of donations, and this impacts on the willingness to donate, which retards the objective of addressing a problem.

Blockchain and AI are now in frequent use by global technology companies and represent tools that can be used to better manage crises. A private blockchain network would enable the recording and tracking of anything that is donated, from donation to N95 masks. It also creates clear points at which it is possible to hold a person or organization to account, from the loading of donations for delivery through to its final end-use. Importantly, the blockchain can also be given public visibility, providing transparency to all stakeholders - donors and donees, as well as public oversight bodies. Anyone could track the progress and use of their donation.

3.16 E-voting

The use of blockchain technology would prevent any participant from fraud, from the voters themselves to the vote counters in conducting the election. Blockchain technology would make sure that the individual could not vote several times because there is an unchanging record of their voice and identity. Also, no one could delete votes because, as has been said, blockchain is immutable. Those responsible for counting votes will have a final record of the number of votes that regulators or auditors can control at any one time. The results can be encrypted, which would enhance transparency while maintaining a key sense of privacy. The results entered and saved in the blockchain are not only immutable and transparent but also available. This means that voting with blockchain is more efficient than traditional voting 0. Blockchain technology can also be used to improve voting processes in public and private companies and organizations.

4 Key challenges in the implementation of blockchain technology

Implementation of blockchain in all industrial sectors will potentially lead to several issues as well as new dependencies [44]:

Awareness and understanding. The principal challenge associated with blockchain is a lack of awareness of the technology, especially in sectors other than banking, and a widespread lack of understanding of how it works. This is hampering investment and the exploration of ideas.

Organization. The blockchain creates the most value for organizations when they work together on areas of shared pain or shared opportunity – especially problems particular to each industry sector. The problem with many current approaches, though, is that they remain stove-piped: organizations are developing their blockchains and applications to run on top of them. In any one industry sector, many different chains are therefore being developed by many different organizations to many different standards. This defeats the purpose of distributed ledgers, fails to harness network effects and can be less efficient than current approaches.

Culture. A blockchain represents a total shift away from the traditional ways of doing things – even for industries that have already seen a significant transformation from digital technologies. It places trust and authority in a decentralised network rather than in a powerful central institution. And for most, this loss of control can be deeply unsettling.

Cost and efficiency. The speed and effectiveness with which blockchain networks can execute P2P transactions come at a high aggregate cost, which is greater for some types of blockchain than others. This inefficiency arises because each node performs the same tasks as every other node on its copy of the data in an attempt to be the first to find a solution.

Regulation and governance. Regulations have always struggled to keep up with advances in technology. Indeed, some technologies like the Bitcoin blockchain bypass regulation completely to tackle inefficiencies in conventional intermediated payment networks. One of the other challenges of the blockchain approach, which was also one of its original motivations, is that it reduces oversight.

Security and privacy. While cryptocurrencies like Bitcoin offer pseudonymity (Bitcoin transactions are tied to ‘wallets’ rather than to individuals), many potential applications of the blockchain require smart transactions and contracts to be indisputably linked to known identities and thus raise important questions about privacy and the security of the data stored and accessible on the shared ledger.

5 Conclusion and further work

Blockchain is as much a political and economic hypothesis as a technological one. Blockchain technology provides a new way to think about how we agree on things. For the first time, multiple untrusted parties can create and agree on a single source of truth, without the use of a middleman. The advance of blockchain technology claims and has the potential to revolutionize many areas of human activity, especially the financial and business worlds. Other applications of blockchain technology discussed previously are equally important. Some of the displayed applications are already implemented, and some can be very easily implemented soon. A major area of future work will focus on implementing blockchain technology for use in EHRs. It will consider how an external stakeholder can use or request a patient’s health records from the hospital or health authority without violating patient privacy.

The technology can also be used to maintain birth registers for births, deaths, marriages, business registrations, but also to enable the right to vote in elections without the physical presence of the polling station and to prevent fraud during the voting process. With the application of decentralization enabled by Blockchain technology, stock market fraud would no longer be possible, preventing the emergence of issuing more shares than the presented number, and companies will not be able to hide the profit.

Large companies have a monopoly on electricity sales. But with the help of blockchain, everyone can be involved in the production of electricity through the possibility of micro-transactions. The surplus electricity produced by solar panels in an individual house can be sold to someone who needs it, and the transaction can be done through a crypto-wallet. The application of blockchain in smart contracts allows executing certain simple contracts when all the conditions are met. This innovation can have enormous implications for any kind of agreement that has the potential to digitize output. Without control and supervision, smart contracts can revolutionize the work done by lawyers. Crowdfunding is a very interesting concept that shows that people want to invest in new products and ideas and contribute to their development. Using smart contracts would make it impossible to sell the same things over and over again,

which would give a new dimension to this type of financing.

Another application of blockchain technology is the platform for predicting market movements. When asking a particular question, many people answer it. It is known that 100 thousand average intelligent people will give a better answer to the question than one very intelligent person on the same topic. Such systems provide accuracy and reward if you have given an answer that turned out to be accurate. Such applications already exist - the Augur platform, on which in just a few dollars, a question can be asked, and there is no cost for agency intermediaries, and the answer is always correct and unchanging 0.

With the numerous blockchain technology applications, it should be noted that it requires a lot of resources and is currently not the most cost-effective option for achieving most of these technological advances. It is about spending huge amounts of computing power to implement and verify the information. Blockchain technology is trying to enter revolutionizing many of today's systems, enabling the development of many previously unimaginable technologies. An interesting offspring of this technology can be the redefinition of Internet 3.0 defined as a new type of decentralized infrastructure or network of networks.

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Cybersecurity Awareness: A Critical Analysis of Education and Law Enforcement Methods

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According to the international Anti-Phishing Work Group (APWG), phishing activities have abruptly risen over the last few years, and users are becoming more susceptible to online and mobile fraud. Machine Learning techniques have potential for building technical anti-phishing models, with a handful already implemented in the real time environment. However, majority of them have yet to be applied in a real time environment and require domain experts to interpret the results. This gives conventional techniques a vital role as supportive tools for a wider audience, especially novice users. This paper reviews in-depth, common, phishing countermeasures including legislation, law enforcement, hands-on training, and education among others. A complete prevention layer based on the aforementioned approaches is suggested to increase awareness and report phishing to different stakeholders, including organizations, novice users, researchers, and computer security experts. Therefore, these stakeholders can understand the upsides and downsides of the current conventional approaches and the ways forward for improving them.

Povzetek: Prispevek preučuje ukrepe proti ribarjenju vključno z izobraževanjem in praktičnim usposabljanjem.

1 Introduction

Phishing is an attempt to gain sensitive personal and financial information (such as usernames and passwords, account details, and social security numbers) with malicious intent via online deception [1][2][3]. Phishing typically employs identity theft and social engineering techniques, such as creating websites that replicate existing authentic ones. Through a seemingly legitimate email that contains a hyperlink, potential users are redirected to the malicious website in order to divulge their private information and credentials [4]. Phishing techniques include *spear phishing*, which is a directed attack where emails that appear legitimate are sent to employees of a certain company in an attempt to access a company's computer system and hence gain their sensitive credentials, or *whaling,* that targets senior corporate executives [5]. These attacks require a proper understanding of the organisational structure in order for the phishing attack to be in its proper context.

Advancements in computer networks and cloud technology in recent years have resulted in an exponential growth of online and mobile commerce, where customers perform substantial online purchases [6]. This online growth has led to phishing activities reaching unprecedented levels in recent months. The Anti-Phishing Work Group (APWG), which aims to minimize online threats (including pharming, spoofing, phishing, malware, etc.) has published there Q4 report about phishing activities of 2019 [7]. The report showed that there were approximately 162,155 unique phishing websites detected in the fourth quarter of 2019, with industries providing software as a service (SaaS) and Webmail followed by payments and financial institutions as the most targeted ones. More and more users become prone to information breaches and identity theft, their trust in e-commerce or mobile commerce platforms will deteriorate, thus resulting in a huge loss of financial gains [8].

So, why is there an alarming increase in phishing activities and more users becoming susceptible to phishing scams? The answer to this can be due to inexperienced users and limited knowledge about the severity of phishing. Since phishing can be seen partly as a social problem, software tools are not able to provide a

permanent solution to it. The problem can be minimised by addressing it in three ways: educating the public on identifying fraudulent phishing websites, enforcing the law to punish scammers, and developing more intelligent intervention techniques. There are claims that anti-phishing solutions that adopt Machine Learning (ML) tend to be more practical and effective in combating phishing [9][10]. Nevertheless, the majority of the ML solutions deal with phishing as a static problem in which they only produce the classification decision from an historical dataset [11]. Continuing, the dynamic nature of phishing that involves users browsing in real time necessitates the decision to be on the fly, which makes ML approaches not fully suitable despite being around for the last decade. There are also needs to educate the online community, especially novice users, on phishing as well as to revise existing legislation.

Existing reviews on website and email phishing, such as [10] [12] [13] [14] [15] [16] have dealt with the problem from a technological solution perspective. Their reviews focused on broad anti-phishing techniques based on data mining, ML, databases, and toolbars, and only briefly discuss solutions such as law enforcement, awareness programs, user education, and training among others. To be clear, there are few discussions and critical analyses on the benefits gained by legislative law and simulated training to combat phishing. Other reviews have dismissed conventional solutions and just reviewed ML solutions [9] [17]. Therefore, the key objective of this paper is to reveal the benefits and drawbacks of the classic anti-phishing countermeasures and provide an in depth discussion on legislation, law enforcement, and user training.

The remainder of this paper is organized as follows: section 2 briefly outlines the phishing attacks procedure. In section 3, adding an anti-phishing preventive layer that includes some of the conventional countermeasures is discussed. In Section 4, some of the pros and cons of each of the countermeasures are analyzed. Section 5 then looks into an emerging phishing threat. Finally, a brief summary and conclusion are provided in Section 6.

2 Phishing attacks procedure

Phishing attacks are often initiated when an attacker sends an email to potential victims with a link that can direct them to a phony website that resembles one that is legitimate. Other initiation processes include online blogs, short message services (SMS), social media websites using web 2.0 services (such as Facebook and Twitter), peer to peer (P2P) file sharing services, and Voice over IP (VoIP) systems where spoofing caller IDs are used by attackers [18]. Each of these phishing methods have a slight variation on how the procedure is done all with the goal of defrauding the unsuspecting user. To see how the phishers design their scheme, Figure 1 below shows an example of the life cycle of a phishing attack by email where the phisher uses a common technique of adding a hyperlink to route unsuspecting users to a phony website. The procedure can be summarized as follows:

1) Phishers set up a phony website resembling a legitimate one.
2) A hypertext link is sent via email to potential victims to take immediate action such as updating their account information, resetting their password, etc. Urgency is a vital element in such an email in order to bait unsuspecting users.
3) Once the link is clicked, this action will route users to the fraudulent phishing website.
4) The fraudulent website collects vital sensitive information such as user name and password.

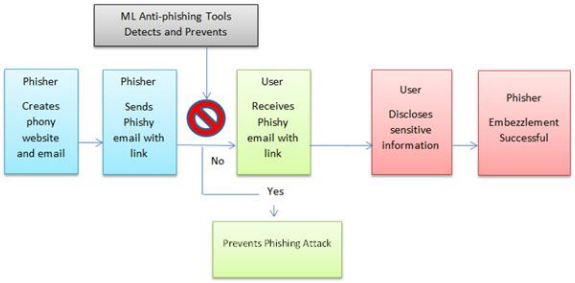

Figure 1: Phishing Attack Life-cycle.

Embezzled information can be used to access other platforms such as ebanks, emails, etc., for financial gain, identity theft, or other cybercrimes. Text of the second section.

Conventional Anti-Phishing Prevention Layer due to the broad nature and severity of phishing scams for individuals, businesses, government entities, and non-profit organisations, there have been different methods proposed in the literature to combat phishing. Among these are technical solutions that address the role of ML techniques to identify phishing features [3] [18] [19] [20] [21] [22] [23] [24] [25].

ML approaches can be seen as the first layer of prevention addressing the menace of phishing attacks. However, ML solutions alone cannot eradicate the problem due to the dynamic nature of it as well as the complexity of the outcomes that ML techniques offer to the end-user. Usually ML technique outcomes are hard to interpret by novice users, and thus are rarely applied when phishing attacks are occurring in real time. These two drawbacks limit the use of ML in commercial anti-phishing tools. There is a need to address other social approaches, such as user training and education, to raise awareness among different types of users. These conventional approaches provide an additional layer in combating phishing, as shown in figures 2 and 3.

Furthermore, developing social online communities' enables rapid data growth through users reporting their phishing experience, and thus similarities between new deceptive scams can be shared by the different stakeholders. Lastly, new legislation that can introduce harsher jail time for cybercrimes can help in reducing phishing attacks. While there is a push by government entities and academic institutions to educate the public and raise awareness about security issues, little research has been done to educate them on how to protect themselves from phishing attacks [26]. These conventional

approaches provide an additional layer in combating phishing, as shown in figures 2 & 3.

In the next section, how government and law enforcement have come around with other conventional anti-phishing approaches are examined.

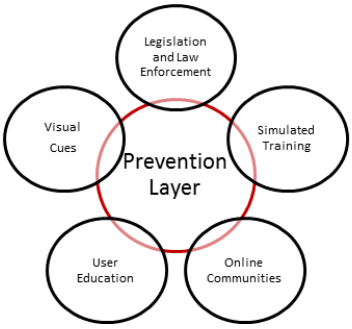

Figure 2: Complete Prevention Layer based on conventional approaches.

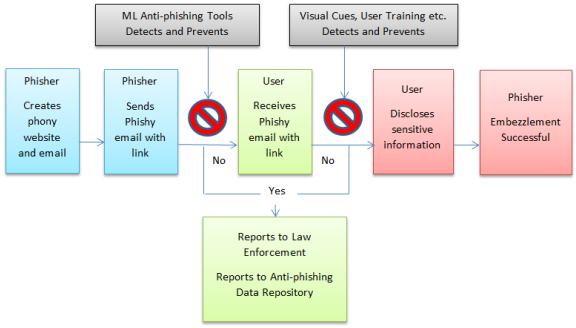

Figure 3: Phishing attack life-cycle with added layer of non-intelligent preventive techniques.

2.1 Legislation and law enforcement

Phishing scammers have the potential to target individual users and businesses, therefore legislative bills must be designed to protect different stakeholders. In the United States of America (USA) and Canada, a joint task force was formed between the U.S Department of Justice (DoJ) and the Public Safety and Emergency Preparedness Canada (PSEPC) in 2004. The primary purposes of the task force were to define the nature and scope of phishing, its impact on cross-border criminality, and to provide the public with information about common phishing techniques [27]. Later that year, the US Senate introduced a bill known as the Anti-Phishing Act of 2004 in order to have legislation at the federal level tackling phishing. After failing to make it through the senate's calendar that year, the bill was re-introduced as the Anti-Phishing Act of 2005. The aim of the bill was to amend the federal criminal code to include phishing and impose an imprisonment of up to five years for anyone found guilty of phishing. However, this bill died in the senate sub-committee reviews and never made it into law. While this legislation tried to address phishing specifically, there are other laws such as "18 U.S.C. section 1028" which do not mention phishing specifically but covers topics such as fraudulency, identity theft, and organized crime, which can be used to address phishing scams [28][29]. Adopting organized crime laws to combat cybercrimes may give law enforcement enhanced investigative powers [30][31].

At the State level, California was able to enact the Anti-Phishing Act of 2005 (named after the failed senate bill) that criminalizes phishing attacks. Businesses under this law are able to sue phishing scammers for financial damages. Individuals can claim the greatest of three times of the actual damages or five thousand dollars for every violation cited. Many other states (such as Arizona, Florida, Connecticut, Michigan, Texas, etc.) followed California's lead and enacted their own cybercrime legislations.

The United Kingdom (UK) strengthened its legal system against cybercrimes, including fraud and identity theft, by introducing a new law in 2006 called the Fraud Act. The act increased prison sentences (up to ten-years) for online fraud offences that included phishing [29][32]. The government also set up *Action Fraud*, a website dedicated to national fraud and cybercrime where users can find educational materials on different cybercrimes and have a forum for reporting any suspicious activities.

Other countries such as Canada passed a broad Anti-Spam law in December of 2010 that included phishing among other cybercrimes. The law allowed three government agencies (Canadian Radio-Television and Telecom Commission, the Competition Bureau, and The Office of the Privacy Commission) to enforce it, and even allowed the agencies to share information with other foreign states if such information is relevant to an investigation. The government of Canada has also posted information online to educate the public on the different cybercrimes, and also encourages them to report any fraud through their website.

Many other countries have enacted similar laws for combatting phishing and other cybercrimes. According to [33] [34], legislation should be designed to provide large-scale damage against individual phishers or secondary liability against Internet Service Providers (ISPs) in hopes that ISPs will be motivated to play their role in fighting phishing. The authors suggested that it can be done under the auspices of intellectual property or unfair competition laws. However, cybercrime is mostly done cross-border, and many phishing attacks have a short life-span. This brings us to two main challenges: locating the phisher and obtaining jurisdiction to enforce the law.

a) Finding and locating the phishing source:

1) Online scammers hide their identities and use secure servers in their activities. Back-tracing the IP of phishers becomes very difficult over the network.

2) Many use fake emails and register malicious domain names for their activities. There are no authentication requirements for any user when opening an email account to verify their identities. Since the internet allows a user to communicate anonymously, it is virtually impossible to locate them.

3) Even when the source is located, it has become increasingly difficult and time consuming for law enforcement to find evidence from their computer systems due to data encryption.

According to the latest APWG report, more than 195,000 domains were used for phishing in 2016, of which

more than half (95,424) were registered maliciously by phishers with 75% of them having top level domains (TLDs) from the Cocos Islands (.cc), pacific island of Palau (.pw), and Tokelau (.tk)[35]. The report also found that many phishing attacks originate from countries such as China and North Korea.

b) Obtaining jurisdiction in order to enforce the law:

1) Many online phishers tend to conduct their activities in countries that have weak cyber laws and law enforcement, and a foreign state may not have jurisdiction over those countries. In the same APWG report, more than half of those phishing domains were registered in China. A country may have strict laws on phishing and other cybercrimes yet enforcing that law will become very difficult if the cybercrime is crossing borders where they do not have any jurisdiction.

2) Phishers and other cyber criminals can simply declare bankruptcy, appeal any conviction, or deny any criminal engagement if the host country is not able to prove so or does not have cybercrime laws.

3) Requesting cyber criminals to be extradited in order to face trial is a lengthy and expensive process that could require years. Since these countries have their own sovereign jurisdiction and borders, internal investigation and prosecution is essential in order to find the culprit guilty of cybercrimes before they can even engage in the extraditing process.

These hurdles have allowed phishers to thrive under the cover of cyber networks while government agencies and law enforcement officials find it difficult to locate and prosecute the perpetrators of cybercrimes. It is therefore imperative that users are better equipped with information and hands-on training to make them aware of this problem.

2.2 Simulated training, visual cues, and user education

Phishers prey on the lack of security knowledge and computer self-efficacy of users. User education, therefore, refers to raising awareness to keep users from becoming victims of phishing attacks [36]. This can be done for instance by providing materials (online, mobile, or hard copy) on how phishing attacks occur, especially during regular work activities. On the other hand, simulated training involves techniques that are used where researchers or organizations simulate real-world phishing scenarios on their users in an experimental, safe, environment in order to track their susceptibility to phishing [37].

Research works by [38] [39] [40] [41] utilize the Elaboration Likelihood Model (ELM), designed by Petty and Cacioppo [42], which suggests that user's cognitive processing is a key reason why many fall victims to deception. How a user pays attention to cues in emails (i.e. initially noticing something fishy, what ELM classifies as "attention") and thus consequently digs deeper to search for more cues (what ELM classifies as "elaboration process"), are key factors for identifying a fraudulent website. In the next sub-section, simulated training, visual cause, and user education techniques are critically analyzed.

a) Simulated Training

A number of research studies have been conducted on simulated user training for phishing awareness [43] [44] [45] [46] [47] [48] [49] [50] [51] [52] [53]. These studies involved either sending users an email with links and monitoring how they responded or making the participants aware that a simulated phishing experiment was to be conducted and are gauged on their abilities to correctly identify phishing emails. At the end of the training, users were normally given the materials and informed about their vulnerability to phishing.

Harrison, et al. [52], conducted a study at North-eastern University in the USA, where he exposed students to real-world phishing attacks in a safe simulated environment. The study used five measures: elaborations, attention, subjective email knowledge and experience, objective phishing knowledge, and individual personality-based technological innovativeness. After two weeks of students registering their email addresses, they received an email message with a hyperlink that routed them to the phishy webpage where they were asked to log in using their university credentials. Those who did not respond to the initial email were sent a second reminder to participate. The authors wanted to experiment how message factors, elaboration, and attention predicted the participant's susceptibility to phishing attacks. The authors concluded that anti-phishing efforts should focus on refining the quality of initial attention to the e-mail. They suggested that this can be attained and enhanced through educating users to pay attention to just a few key elements in the message, such as noticing red flag elements such as a hyperlink and knowing where to find the actual address that the e-mail was sent from.

Jensen, et al.[53], designed a study at a midwestern university in the USA. A generic and customized phishing message was distributed to students and staff at the university after they were asked to participate in the study. The authors created a fictitious employee email account for the study and sent two types of emails: a generic one that asked the participants to log in and try a new web portal, and a customized one with a similar message but containing the university mascot, displaying a local phone number, etc. A URL in the email directed the participants to a fictitious website where the participant's credentials were collected. The study showed that most of those who fell victim to the attack did so in the first 24 hours of the experiment. The study also concluded that brief online training was effective, and that it should be included as part of a layered set of defences to accompany automated intelligent tools in fighting phishing attacks.

An earlier study by [45], of 921 students from the University of Indiana revealed that students who received an email that was perceived to be from a friend clicked on the link 72% of the time compared to 16% when it was from an unknown address. A similar pilot study was conducted by [43], using embedded training methodology to measure phishing awareness at a university. Malicious emails were urging users to click on a link that would redirect them to a phoney website where they would input their login credentials. During the experiment, the users were interrupted immediately when they clicked the link

and were subsequently provided with training material on phishing.

[47] [48] conducted a study using an embedded training methodology where users were immediately alerted and trained after they fell victim to a simulated phishing attack. The authors argued that users become more motivated to learn about phishing attacks once they have realized that they are victims of such attacks. The authors also wanted to see how effective such a methodology was for user knowledge retention. They concluded that users will be better equipped and can learn more effectively in embedded training simulation as opposed to training sent via regular emails. In their 2009 study using PhishGuru, the authors found that this method allowed users to retain and transfer their knowledge better than with non-embedded training.

An example of a real-life application of simulation training is PhishMe Simulator [54] that was designed to enhance employee awareness and equip them with the proper tools to recognize and report phishing emails by immersing them in simulated phishing scenarios. The tool allows real-time educational opportunities the moment users take the phishing bait.

b) Visual Cues and User Education

In the Elaboration Likelihood Model (ELM), initial notice of something fishy is a crucial first step in how a user pays attention to other cues. Visual cues tend to mimic an alert system where a red flag is raised and a user who picks up on that red flag may dig deeper to search for more cues and potentially identify threats. One of the classical suggestions of human interactive proof (HIP), where online users are required to identify and verify visual cues and contents, was proposed by [55] and is known as dynamic security skins (DSS). In DSS a random image is displayed that is personal to the user prior to the user entering their password. This image can be overlaid on top of the password textboxes, making sure the user sees it and thus making it difficult for phishers to spoof the password entry.

[56] queried users to analyse some emails and gauge whether their understanding of virus attacks gave them a better understanding of web threats. The results indicated that their knowledge of negative consequences resulting from computer related crimes did not prevent the users from being vulnerable to phishing attacks. It was concluded that more specific training should be conducted, focusing on phishing attacks as opposed to providing warnings.

[57] proposed a system that embeds key information on the clients' side for the user to enter, which can then be verified at the server side. The authors introduced what is known as the completely automated public turing test to tell computers and humans apart (CAPTCHA). [58] extended this concept by adding an additional security layer consisting of a time-sensitive restriction of one-time-password (OTP).

[59] developed a game-based tutorial called *Anti-phishing Phil* that trained users on how to avoid phishing scams. The interactive game showed users how to identify phishing URLs, identify other cues on the browser, and how to distinguish between legitimate and fraudulent sites. The study concluded that users who played the game were better equipped to identify a phishing attack. A later study by [60] investigated whether an interactive mobile platform is more effective in educating users in contrast to traditional security training. A comparison of users' responsiveness to phishing was conducted, using a mobile game developed by [61] versus training through a website designed by APWG. Results indicated that users trained through the mobile application had a higher success rate of identifying phishing sites compared to their counterparts who only used the APWG website. In their recent study on phishing threat avoidance using games, [51] concluded that all their participants were convinced that the mobile game was somewhat effective compared to articles and lecture notes for enhancing their avoidance behaviour through motivation to protect themselves from phishing threats. The participants argued that mobile game-based education was fun and gave them immediate feedback, whereas lecture notes or articles provided them with little practical experience.

[50] conducted a study based on the conceptual model of Theoretical Threat Avoidance Theory (TTAT) by [62] to assess the level of computer user's knowledge on how to thwart phishing attacks. Participants were given 5 phishing URL's to assess their procedural knowledge (identify if the given URL is legitimate or suspicious) and another 5 phishing URL's to assess their conceptual knowledge (identify which part of the URL is suspicious). The results of the study concluded that the combination of procedural and conceptual knowledge positively affected self-efficacy, which enhanced the user's avoidance behaviour.

A study by [63], using improved browser security indicators and visual cues to attract attention by users in order to identify phishing websites found that there was a correlation between users gazing at the visual cues and detecting phishing sites. The study showed that users that paid attention to the visual cues had a 53% greater chance of identifying phishing websites.

These visual cues rely solely on human interventions and their abilities to utilize them at the right time. This provides a major challenge as many users tend to ignore the visual cues on the toolbars or fail to interpret some of the security cues appropriately [64][65][66]. Moreover, based on the majority of training and education research, most users are unaware of how phishing attacks start or how to visually recognise and differentiate between a fraudulent and legitimate website [22][64][67]. Many educational and training materials let users become aware of the threats, but do not necessarily provide them with the necessary skills or knowledge for protecting themselves or their organisations from such attacks [9]. While many of the educational materials used to train users on web attacks are readily available online, the vast majority of users ignore them. Some argue that of those who actually train themselves on security and cyber threats, many tend to develop a fear of doing online commerce as opposed to learning how to protect themselves and engage in it [36].

2.3 Online user communities

As users become more aware and are able to identify online scams or fall victim to phishing attacks, they may report their experience in order to prevent others from similar attacks. Users can report fraudulent websites or URL links that can then be stored in online databases. Such accumulated resources can also be used by researchers to study phishing scammers and their evolving ways of devising their scams. These online communities can also be a vital source of information regarding what different types of phishing attacks exist and their potential threats to individuals and organizations. For example, figure 4 below from the user community website Cofense, reveals that more than 90% of IT executives in the US worry about email related phishing [54].

Individuals who recognise phishing activity may report it via public anti-phishing communities. This collection of previously identified and detected phishing domain names, or URLs, is commonly referred to as a "blacklist".

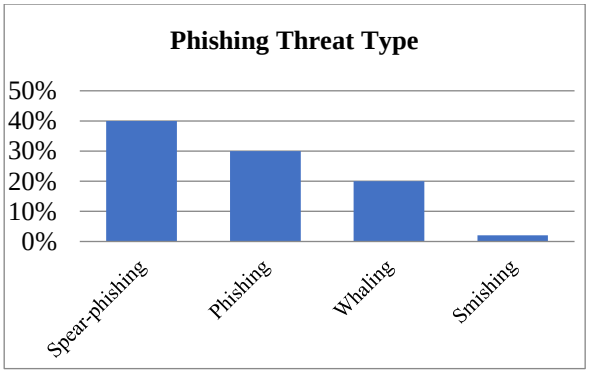

Figure 4: USA IT Executives Concerns Over Phishing Threats [54].

A blacklisted website significantly loses its user traffic and any potential revenues. However, according to [59], effectiveness of blacklists depends on:

a) frequency of the database update,

b) an accurate phishing detection rate (i.e. correctly detecting phishing instances, also known as the True Positive (TP) rate).

Google and Microsoft blacklists are commonly used by marketers, users, and businesses because of their lower false positive (FP) rates (legitimate instances that are incorrectly identified as phishing) compared to other publicly available blacklists and due to their frequency of database updates. Microsoft's blacklist is updated between every nine hours and six days, whereas Google's blacklist gets updated between twenty hours and twelve days [10]. This is a definite limitation on the blacklist approach, as phishing campaigns take significantly lower times to make their attacks before they can be detected and blocked [18] [59][68].

The online communities play an important role in raising anti-phishing awareness and keeping the conversation progressing. However, the vital part of these databases is the ability of the users to identify the fraudulent website before it could be blacklisted. Thus, users are potentially vulnerable until the URL is reported. This also highlights the importance of proactive user education and training.

3 Analysis and discussions

Table 1 below provides a brief summary of the pros and cons of the different approaches identified and discussed in section 3. A thorough analysis and discussion of the table is presented below. Some recommendations are provided as a way forward and are given in the sub-sequent sections.

3.1 Legislation and law enforcement

Many developed countries have adjusted their criminal laws to include online computer fraud, such as phishing. One of the major benefits of legislation and law enforcement is that when phishing activities are criminalized; it brings this problem to the forefront of the public eye as a criminal activity. This in turn facilitates the other two approaches discussed in this paper. Users are therefore able to engage in training in order to become aware of this criminal activity and may participate in reporting any phishing scams to the government run databases or commercial ones. Businesses that suffer from spear phishing may conduct their internal investigations, and if they are able find the perpetrator seek compensation, retribution, or protection of their brands by filing a law suit when such laws exist. Harsh jail terms and steep fines are crucial for deterring potential phishers from initiating an attack. However, some of the negatives to this approach is that many phishers are smart enough to hide their identities by using secure servers. There are no specific laws or requirements that check and verify a users' identity and details when opening an email account or registering a website [69]. Phishers therefore tend to register their websites maliciously and use fake email accounts, making it difficult to locate them. Since many attacks have a short life span, phishers can successfully defraud users and quickly shut down their activities and disappear before law enforcement is able to even begin investigating a phishing attack. While any law enforcement cannot begin before the perpetrator is caught, which as indicated can be very difficult, other issues may arise such as jurisdiction to even implement the law. If such laws cannot be enforced, then they will have little deterrent effect. It can be seen that according to the APWG, many phishing attacks originate from countries that have very lenient or weak cyber laws. Extraditing such criminals would thus be virtually impossible when such treaties do not exist between foreign states.

Countries that do not have cybercrime laws need to act and enact legislation that will criminalize these activities. A globally harmonized policy will be required in order to have a uniform definition of what amounts to cybercrime which can be implemented across all countries with similar legislations. Extradition treaties that can be enforced through law enforcement agents such as the International Police organization (INTERPOL) should then be encouraged among member countries. It is quite obvious that extradition is time consuming, not a cost-

effective process, and may require a lengthy court process in the native countries (even on crimes where the suspects have physical addresses or business), yet nonetheless, is a necessary first step toward combating this menace at a global scale. Information sharing among countries is also critical to fighting cyber criminals.

The following are a few examples of coordinated efforts from different law enforcement agencies, covering different jurisdictions, to indict cyber criminals and phishers.

i) A Florida man was indicted in Pennsylvania for a phishing scam, pretending to be a legitimate Hurricane Katrina relief website [70].

ii) A collaboration between the FBI of the US and law enforcement in Egypt netted around 80 phishers working together in an elaborate banking scam. The FBI made about 33 arrests from phishers based in Southern California, North Carolina, and Nevada [71].

iii) Indian police arrested a ring leader and mastermind of phishers who impersonated agents from the Internal Revenue Service (IRS) and US Citizenship and Immigration Services (USCIS). Following his arrest, the Department of Justice (DoJ) together with the IRS and Department of Homeland Security announced the arrest of 20 individuals in the United States in connection with the same scam and proceeded with extradition requests for the Indian arrests to be charged in the US [72].

3.2 Simulated training and user education

There are many pros as well as cons to user education and training. User training enables the user to identify phishing attacks in a simulated experiment. When the user is well trained, they are better prepared and are aware of phishing scams and other cybercrimes. Users should be trained on specifics, such as phishing attacks and how they work, as opposed to general knowledge of negative consequences to cybercrimes such as identity theft. Specific training will raise awareness and understanding of phishing, and in turn minimise users' vulnerability to phishing attacks. Some of the cons in this approach is that in the general sense, many non-technical users will resist training and learning. Researchers who utilised the Elaboration Likelihood Model (ELM) suggested that attention and elaboration is critical to identifying a fraudulent website. While these are cognitive processes, it requires behavioural adjustment to adapt the two strategies in order for a new user to not continually fall victim to numerous phishing attacks. Changing users' online interactive behaviour is not an easy feat. Users tend to ignore or pay less attention to training materials and visual cues, and many have a difficulty visually recognizing and distinguishing fraudulent sites from legitimate ones.

Awareness can be raised, and users trained on how to identify and appropriately deal with phishing scams in three ways. This can be attained through a traditional medium such as in schools and universities, through the enforcement and participation by the Internet Service Providers, or through a mobile game platform.

i) The traditional medium may raise awareness through the introduction of cybercrimes in high school, university curriculums, or even short courses offered to the community at large.

Technique	Pros	Cons	Reference
Legislation and Law Enforcement	- Incriminate phishers - Harsh jail terms, penalties and fines are a deterrent	- Difficulty in locating phishers - Jurisdiction issues when trying to implement the law	[30] [32] [33] [34]
User Education and Training	- Minimizes susceptibility to phishing attacks - Raises awareness and understanding of phishing attacks and other cybercrimes - Sharing information among organisations, employees, and other stockholders	- Users do not pay attention to visual cues - Users deal with the training as any other annual training conducted - Users ignore training materials - Users do not learn skills on how to combat phishing attacks	[11] [51] [52] [53] [63]
Online social communities approach	- Prevents users from falling victim to identified phishing URLs - Information is shared in a single platform - Data is collected that can be used for further analysis to understand causes of phishing - Past experiences are helpful for other users	- reactive approach and phishers are only blacklisted after an attack has already occurred - lack of real time blacklist update mechanism - Not possessing a high accurate phishing detection rate - Requires user intervention to make it work (users may or may not have proper education and training on phishing attacks)	[18] [10] [35]

Table 1: Summary of Anti-Phishing Countermeasures Pros and Cons.

While this can be a daunting task and require educational institutions to adopt and adjust their curricula, the strategy has proven to be effective.

This approach was partially experimented by [73] in the introduction to computing courses taken by students not pursuing a computer science education. The authors concluded in the class assessment that students had an increased level of awareness and were better able to recognise phishing scams. [74] also concluded that user education is crucial for elevating defences against phishing attacks.

ii) Internet Service Providers (ISPs) are in a position to play a larger role in the prevention of phishing attacks. By putting some of the liabilities on ISPs, [33][34] suggest that this may put pressure on the ISP to take a more proactive stance in training their employees and users and may require them to cascade such knowledge to companies using their services. This can be in the form of embedded training where employees will continuously learn as they conduct their daily work activities. Such training materials can be placed in emails, on company intranet sites, or through simulated text messaging over regular social media platforms.

iii) Mobile game platforms bring an interactive and fun approach to education and training and are somewhat more effective compared to traditional articles or lectures. Users who participated in mobile game studies argued that mobile game-based education was fun and gave them immediate feedback so that they were better equipped to identify a phishing attack after completing the game [59] [60]. Users trained through mobile application had a higher success rate of identifying phishing sites compared to their counterparts who used traditional mediums [61].

3.3 Online communities

The online communities' database approach helps prevent users from falling victim to previously blacklisted sites. This strategy can reduce the amount of people being defrauded by phishers and cut their potential revenues. However, the con for this approach is that it does not protect from zero-hour phishing. New phishing attacks need to be detected first and then blacklisted. This process takes time, and many of the well-known databases have a slow database update rate. The lack of real-time blacklist updating is a major drawback to this approach [10][18] [59][68]. This lag time is enough for the phishers to complete their attacks and move on to something else as the phishing life span is very short. Accuracy in phishing detection is very critical, and failure in this may result in legitimate sites being blacklisted.

These online communities play an important role in raising anti-phishing awareness. It serves the online community in two ways:

i) The accumulated resources can be used by researchers to study phishing scammers and their evolving ways of devising their scams.

ii) It provides a platform for novice users to share experiences and keep the conversation about phishing and other cybercrime progressing.

4 Conclusions and future work

This paper investigated common conventional anti-phishing prevention techniques, including law enforcement, legislative bills, education, simulated training, and online communities. While many countries such as the USA, Canada, and the UK have taken a lead to criminalise phishing attacks and put together harsh legislations, it is still difficult to locate attackers. This is since phishing attacks have a short life span, allowing attackers to change identity or move on before law enforcement agencies can locate them. Despite these limitations, it is still vital that government and other enforcement agencies improve their services to reduce phishing rates by sharing information and removing jurisdiction barriers.

User training and visual cues partially improve users' abilities to identify phishing. However, many novice users are still not paying high enough attention to visual cues when browsing websites, making them vulnerable to phishing attacks. Users need to be exposed, in a repetitive manner, to training about phishing since phishers continuously change their deception techniques. This approach of preventing phishing is useful for novice users, but it has proved to not be cost effective.

Online phishing communities accumulate data repositories that allow users to share useful information about phishing incidents, such as URLs that have been blacklisted and phishing experiences. This does create a knowledge base for users' online communities but requires some computer literacy as well as awareness about security indicators. In addition, due to the nature of the phishing attacks, these blacklists frequently become outdated as updates are only performed periodically rather than in real-time.

While each of the conventional methods has their own deficiencies, as a whole they reinforce each other and provide an additional layer of protection against phishing scams. Novice users can benefit tremendously by combining some of the approaches discussed in order to improve their effectiveness in identifying phishing attacks and should not rely solely on a single method. This paper also provides a clear thorough analysis and discussion on each of the countermeasures proposed as a preventive layer to better equip companies, security experts, and researchers in selecting what can work well and equip individuals with knowledge and skills that may prevent phishing attacks on a wider context within the community.

In future work, it is planned to present an anti-phishing framework in the context of IoT that integrates automated knowledge produced by computational intelligence in visual cues besides using human expert knowledge as a base.

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Machine Learning with Remote Sensing Image Datasets

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Computer vision, as a part of machine learning, gains significant attention from researches nowadays. Aerial scene classification is a prominent chapter of computer vision with a vast application: military, surveillance and security, environment monitoring, detection of geospatial objects, etc. There are several publicly available remote sensing image datasets, which enable the deployment of various aerial scene classification algorithms. In our article, we use transfer learning from pre-trained deep Convolutional Neural Networks (CNN) within remote sensing image classification. Neural networks utilized in our research are high-dimensional previously trained CNN on ImageNet dataset. Transfer learning can be performed through feature extraction or fine-tuning. We proposed a two-stream feature extraction method and afterward image classification through a handcrafted classifier. Fine-tuning was performed with adaptive learning rates and a regularization method label smoothing. The proposed transfer learning techniques were validated on two remote sensing image datasets: WHU RS datasets and AID dataset. Our proposed method obtained competitive results compared to state-of-the-art methods.

Povzetek: Metoda prenesenega učenja je uporabljena za analizo posnetkov iz zraka na nekaj referenčnih bazah.

1 Introduction

Scene classification is a process of assigning a semantic label to remote sensing (RS) images [1, 2]. It is one of the crucial tasks in aerial image understanding. Aerial scene classification is possible due to the existence of several RS images datasets collected from satellites, aerial systems, and unmanned aerial vehicles (UAV). Remote sensing image classification has located its utilization in many fields: military, traffic observation, and disaster monitoring [3, 4]. The problem of aerial scene classification is complex because the composition of remote sensing images is compound, and it is rich in features: space and texture. This is the reason for developing numerous scene classification methods.

Remote sensing image classification methods that rely on feature extraction can be categorized in one of the following groups: methods that use low-level image features, methods that use mid-level image features and methods that utilize high-level image representation. Methods using low-level image features operate on aerial scene classification with low-level visual descriptors: spectral, textural, structural, etc. Scale Invariant Feature Transform (SIFT) is a local descriptor that simulates local fluctuation of structures in remote sensing images [5]. Statistical and global allocation of certain image characteristics: color [6] and texture data [7] are utilized by other descriptors. Different color and texture descriptors, like color histograms and local binary pattern (LBP) descriptors, are comparatively analyzed in [8]. Remote sensing classification in [9] is performed by compound-feature figures of 6 different types of descriptors: SIFT, radiometric features, Grey Level Co-Occurrence Matrix (GLCM), Gaussian wavelet features, shape features, and Gabor filters, with varying spatial resolution. Other descriptors used by researches are the orientation difference descriptor [10], and the Enhanced Gabor Texture Descriptor (EGTD) [11]. For aerial scene classification, authors in [12] use completed local binary patterns with multi-scales (MS-CLBP) and achieved state-of-the-art-results compared to other methods based on low-level image features.

Mid-level image features methods try to represent aerial images with a statistical representation of a high degree obtained from the extracted local image features. The first step within these methods is to extract local image features from local patches employing descriptors like SIFT or color histograms. The second step is to encode those features to obtain a mid-level representation for remote sensing images. A widely used mid-level method is bag-of-visual-words (BoVW) [13]. The first step of BoVW is to extract features with SIFT from local image patches [14], and afterward, to learn so-called visual dictionary or visual codebook, that is a vocabulary

of visual words. In aerial scene classification tasks, the basic BoVW technique can be combined with various local descriptors [14]: GIST, SIFT, color histogram, LBP. Another mid-level method relies on a sparse coding method [15] where low level extracted features such as structural, spectral, and textural are encoded. Improvement of the classification accuracy can be obtained with Principal Component Analysis (PCA) which enables dimensionality reduction of extracted features before fusing them in compound-representatives, or with methods such as the Improved Fisher Vector (IFK) [16] and Vectors of Locally Aggregated Tensors (VLAT) [17]. In the literature can be found improved models of BoVW like spatial pyramid co-occurrence kernel (SPCK) [18], which integrates the absolute and relative spatial data. This method combines concepts of spatial pyramid match kernel (SPM) [19] and spatial co-occurrence kernel (SCK) [13]. In [20] pyramid-of-spatial-relations (PSR) model is presented, which includes absolute and relative spatial connections of local low-level features.

The third group of feature extraction methods for image classification relies on high-level vision information. The latest techniques that include high-level features based on CNN learning have shown significant improvement of classification accuracies compared to older low-level and mid-level image features methods. High-level methods can acquire more abstract and discriminative semantic representations, which guides in improved classification performance. Feature extraction with deep neural networks, previously trained on ImageNet data set [21], results in significant performance for aerial scene classification [22]. Remote sensing image classification accuracy achieved with GoogleNet [23] can be improved with an input strategy of multi-ratio for multi-view CNN learning. Multi-scale image features are extracted from the last convolutional layer of CNN [24] and then encoded with BoVW [25], Vector of Locally Aggregated Descriptors (VLAD) [26] and Improved Fisher Kernel (IFK) [16] to compose the final image representation. Nogueira et al. [27] extracted global features from CNN architectures and guided them to a classifier. In all of the examples mentioned above, the global or local extracted features were obtained from CNNs previously trained on massive data sets like ImageNet, formed of natural images. Extracted features were utilized for remote sensing image classification.

Another method of transfer learning is the fine-tuning of CNN weights. It is a technique where the original classification layer of the pre-trained CNN (usually softmax layer) is replaced with a new one, which contains a number of nodes equal to a number of classes of the target dataset. Altered CNN is trained with a random initialization of new layers, but the remaining layers begin with the pre-trained weights. Compared to a neural network training with random weight initialization, fine-tuning achieves a better minimum of the lost function. Authors in [28] achieved significant performance improvement by fine-tuning a pre-trained CNN. They experimented with AlexNet [29] and obtained a better outcome for semantic segmentation. Also, there are several papers in the remote sensing community [30], [31], that surveyed the benefits of fine-tuning CNNs. A comparison between CNN trained from scratch, and fine-tuned one showed the advantages of using aerial scene data [31]. The fine-tuning method could be useful for the classification of hyperspectral images [30]. Fine-tuning weights of pre-trained CNNs results in the extraction of better scene features [32]. This transfer learning technique, performed on neural networks previously trained on the ImageNet dataset, results in good classification accuracy on remote sensing image data sets [24], [27]. Our previous work, [53], [54], showed that transfer learning techniques, feature extraction as well as fine-tuning, are superb methods for aerial scene classification.

Despite the two transfer learning methods described above, the other alternative is to train CNN from scratch, i.e., with random initialization of network weights. This solution shows low classification accuracy for small-scale aerial scene datasets [27]. Full network training of CaffeNet and GoogLeNet resulted in poor classification results for the UC-Merced dataset [13] and the WHU-RS19 dataset [33]. But, full CNN training using large-scale datasets like AID [34] and NWPU-RESISC45 [35] has obtained good results.

In this paper, we evaluate miscellaneous CNN models on resolving the task of high-resolution aerial scene classification. We utilize convolutional neural networks pre-trained on ImageNet data set with a twofold purpose: like feature extractors and for fine-tuning on particular remote sensing datasets. When we use pre-trained CNN as feature extractors, we try to form better features for aerial imagery. Thus, we acquire activations from different CNN layers: the average pooling layer, the last, and one of the intermediate convolutional layers. In order to enable the fusion of features from convolutional layers with ones from average pooling layers, the feature dimensionality reduction method is utilized on those from convolutional layers. Compound features of the image scenes are processed by a linear classifier to determine image classes.

In the second experimental setup, we explore the fine-tuning of network weights on the remote sensing imagery. We trained CNNs with adaptive learning rates: linear decay schedule and cyclical learning rates and assessed if they are appropriate for fine-tuning of pre-trained CNN on aerial scene imagery. In order to achieve classification accuracy comparable to state-of-the-art methods, we included label smoothing as a regularization technique and assessed its impact on the experimental results.

The main contributions of this paper are (1) evaluation of transfer learning techniques with various CNN models on two remote sensing image datasets, (2) analysis of the impact of fused features obtained by concatenation of activations from different pre-trained CNN layers on classification accuracy, (3) assessment of the influence of adaptive learning rates at the fine-tuning method from the aspect of classification accuracy, and (4) the proposed transfer learning techniques are compared to state-of-the-art methods and provide a baseline for aerial imagery classification.

The remainder of this article is organized as follows. In Section 2, the methodologies used for transfer learning

from CNN are presented. Experimental results obtained from the examined remote sensing images classification methods are presented in Section 3. Discussion of impact factors on our method's results, as well as summarization and conclusion of the paper, is given in Section 4.

2 Materials and methods

This section of the article gives a short description of the pre-trained CNNs used for transfer learning: InceptionV3, ResNet50, Xception, and DenseNet121. Following that, we introduce the PCA for dimensionality reduction, linear decay scheduler, and cyclical learning rates as methods for transfer learning. Next, we present the two publicly available data sets: WHU-RS19 and AID included in our experiments. Finally, the utilized experimental setup and the evaluation metrics are given.

2.1 Convolutional neural networks

ResNet won the classification task part of ILSVRC-2015. ResNet is a deep CNN that can have up to 152 layers [49]. It is similar to the VGG model because it contains mostly 3x3 filters, but the number of filters is smaller, and CNN is simpler [49]. Deep learning architectures can have high training error and vanishing gradient problem. The solution to the vanishing gradient problem is including a residual module in the neural network. The deep learning residual module, as shown in Figure.1, has a short connection between the input and the output.

The first inception based network was named Inception-v1 or GoogleNet [50].

In GoogleNet architecture, inception modules are included, and thus the number of learning parameters is decreased. The original inception module, Figure.2, has a pooling layer and convolutional layers with dimensions 1x1, 3x3, and 5x5. Module output is got by concatenating the outputs of these layers. Inception based networks relay on the detail that the correlation within the image pixels is local. The number of learning parameters is reduced based on the local correlations. Inception-v3 [37] is the third iteration of inception based networks. It contains three different types of inception modules: type 1, got by dividing into smaller convolutions; type 2, got by dividing into asymmetric convolutions; and type 3, that was included to improve representations with high dimensions.

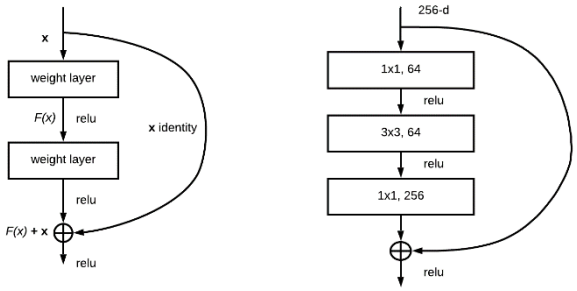

Figure 1: Residual block (left) and "bottleneck" block (right) of ResNet.

Another deep CNN, which is similar to Inception, is Xception. In the Xception, the inception module is replaced with depth-wise separable convolutional layers [51]. This CNN is a cluster of depth-wise separable convolutional layers with shortcut connections. A depthwise separable convolution is separated into two phases. The first phase is a spatial convolution applied separately on each input channel, so-called depthwise convolution. After that, pointwise convolution follows, which is 1x1 convolution for conveying the output of depthwise convolution output channels to a new channel space.

Dense Convolutional Network (DenseNet) [52], enables highest data flow between network layers, by attaching layers to each other in a feed-forward manner. The only condition for such connections is the layers to have corresponding dimensions of feature maps. The input for each layer are the feature maps of the preceding layers, and its own feature maps are carried into all layers ahead, as their input. Opposite to ResNets, here the authors [52] fuse features with concatenation, but don't add together the features to lead them afterward into the following layer. This neural network got its name after the dense connectivity pattern, Dense Convolutional Network (DenseNet). The dense pattern suggests that there is no need to relearn redundant feature maps, which leads DenseNet to have a smaller number of parameters than other deep CNN.

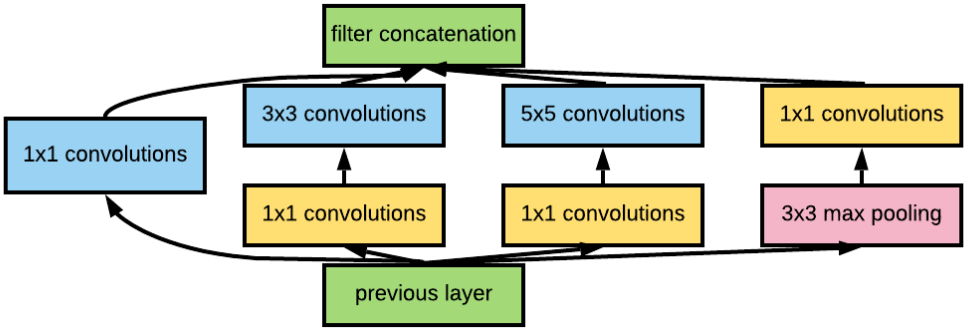

Figure 2: The architecture of a basic inception module.

2.2 Principal Component Analysis

In our experiments, we used Principal Component Analysis (PCA) as a dimensionality-reduction technique. It establishes a new group of the basis of view, and then project the data from the original representation to a representation with fewer dimensions. The new dimensions are orthogonal to each other, independent and ordered, depending on the variance of data they contain. The first principal component is the one with the highest variance. The new data matrix consists of n data points with k features for each of them:

$$[new\ data]_{k*n} = [top\ k\ eigenvectors]_{k*m}[original\ data]_{m*n} \quad (1)$$

The covariance matrix is symmetric. The variance of every dimension is on the main diagonal, and the covariances of dimensions are placed elsewhere. PCA is a dimensionality reduction method that spreads out data to have high variance within a fewer number of dimensions.

2.3 Adaptive learning rates

The most crucial hyperparameters for CNN training are initial learning rate, number of training epochs, learning rate schedule, and regularization method (L2, dropout). The invariable learning rate for network training might be a reasonable choice in some instances, but more often, an adaptive learning rate is more beneficial. When training CNN, we are trying to find global, local minima, or only a part of the loss surface with adequate low loss. If we train the network with a constant but large learning rate, we can't reach the desired valley of loss terrain. But if we adapt (decrease) our learning rate, the neural network can descend into more optimal parts of the loss landscape.
In our proposed fine-tuning method, we use a linear decay schedule, which decays our learning rate to zero at the end of the network training. The learning rate α in every training epoch is given with:

$$\alpha = \alpha_I * (1 - \frac{E}{E_{max}}) \quad (2)$$

where αI is the learning rate at the beginning of training, E is the number of the current epoch, and Emax is the overall number of epochs.

Cyclical Learning Rates (CLR) are another form of adaptive learning rates. In this case, there is no need to determine the optimal initial learning rate and schedule for the learning rate when we train CNN [36]. When the network is trained with learning rate schedules, the learning rate is being continuously reduced, but CLR allows the learning rate to oscillate among pre-defined limits. The network training with CLR convergences faster with fewer hyperparameter updates.

Authors in [36] define a few CLR policies: triangular shown in Figure 3, triangular2, and exponential range policy. The triangular policy, as can be seen in Figure 3, is a triangular pattern: the learning rate oscillates linearly between the fixed lower limit and the upper limit. Triangular2 policy looks similar to triangular policy, except that the upper limit of a learning rate is twice lower after every cycle. As a result of this, triangular2 policy training is more stable. The exponential range policy

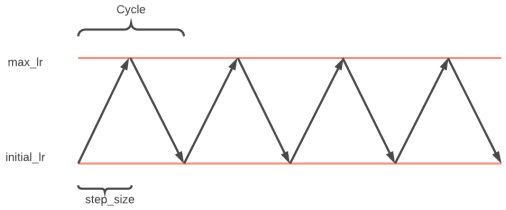

Figure 3: Cyclical learning rate with a triangular policy model.

Figure 4: Some images of different classes from (i) WHU RS and (ii) AID data set.

encompasses exponential declination of a maximum learning rate.

2.4 Remote sensing datasets

We test our proposed transfer learning techniques on two common aerial scene data sets; the WHU RS data set [43] and the aerial image dataset (AID) [34].

The WHU-RS data set [43] is selected from Google Earth imagery, and the images are collected from all over the world. There are 19 image classes, with at least 50 images per class, entirely 1005 images. Image dimensions are 600x600 pixels. WHU-RS data set has been extensively used in experimental studies of remote sensing classification tasks. Image classes in the WHU-RS data set are airport, beach, bridge, commercial, desert, farmland, football field, forest, industrial, meadow, mountain, park, parking, pond, port, railway station, residential, river, and viaduct.

The aerial image dataset (AID) has approximately 10,000 remote sensing images assigned to 30 classes: airport, bare land, baseball field, beach, bridge, center, church, commercial, dense residential, desert, farmland, forest, industrial, meadow, medium residential, mountain, park, parking, playground, pond, port, railway station, resort, river, school, sparse residential, square, stadium, storage tanks, and viaduct. Image dimensions are 600×600 pixels with a pixel resolution of half a meter. Images are obtained from Google Earth imagery. They are picked from various world regions at different times of the year and climate conditions: mostly from China, Japan, Europe, and the United States.

2.5 Experimental setup and evaluation metrics

The first proposed transfer learning method was based on feature extraction. We involved four different pre-trained CNNs and extracted features from three various layers of each of them. For ResNet50 the layers were: bn4f_branch2c, the last convolutional layer, and average pooling layer; for InceptionV3: mixed_8, mixed_10 and average pooling layer; for Xception: block14_sepconv1_act, block14_sepconv2_act, and average pooling layer; and for DenseNet121 the layers were: conv4_block24_concat, the last convolutional layer, and average pooling layer. Before feature extraction, data set images were resized and pre-processed according to the demands of each pre-trained CNN. Data augmentation was applied to the images of the training set. Five patches of each training image were made with rotation, shifting, shearing, zooming, and flipping. The feature extraction was performed for the WHU-RS data set, for 60%/40% and 40%/60% training/test split ratio. The splits are random and without stratification. We included feature fusion to improve the classification performance of the proposed method. At first, image features were extracted from two various layers of two CNNs, so that one layer was the average pooling layer, and the other was some of the aforementioned convolutional layers. Then, we applied PCA transformation on convolutional layer features. Before the features are concatenated, we performed L2 normalization on PCA transformed convolutional layer features and the average pooling layer features. After the features fusion, a linear Support Vector Machine SVM classifier is trained with compound features.

The SVM is a classifier described by a separating hyperplane. SVM model has four hyperparameters: type of kernel, the influence of regularization, gamma, and margin. The kernel can be linear, exponential, polynomial, etc. We used a linear kernel in our experimental setup. The prediction of a classifier for linear kernel is given with

$$f(x) = B(0) + \mathrm{sum}(a_i * (x, x_i)) \quad (3)$$

The output of the classifier is acquired with the dot product of the input (x) and each of the support vectors (xi). The model computes the inner products of each input vector (x) with all support vectors in training images. The learning algorithm determines coefficients B(0) and ai from the training data.

In our proposed feature extraction method, we tuned the regularization parameter. During SVM optimization, the regularization parameter regulates to what extent to take into consideration the misclassification of each training image.

Our proposed fine-tuning method for aerial scene classification, as a form of transfer learning, is carried out with adaptive learning rates, as well as label smoothing. Label smoothing is a regularization method that fights against overfitting and leads to a better generalization of the CNN model. It is expectable our model to overfit because we use pre-trained CNN with high dimensionality and fine-tune them with a data set that has only a couple of thousands of images. Label smoothing [37] magnifies classification accuracy evaluating the cost function with "soft" labels from the data set (weighted sum of the labels with equal distribution) instead of "hard" labels. When we apply label smoothing with parameter α, we reduce the cost function between the 'smoothed' labels y_k^LS and the network outcome pk, smoothed labels are as follows:

$$y_k^{LS} = y_k\,(1 - \alpha) + \alpha/K \quad (4)$$

where the real labels are y_k, and K is the number of classes. Label smoothing was applied only to the training images. In-place data augmentation was used for training images as well. In the simulation scenario, we included four pre-trained CNN: ResNet50, InceptionV3, Xception, and DenseNet121, and images of the target data set were resized according to the requirements of each CNN. The fine-tuning method was applied to the AID data set, and the experiments were performed with 50%/50% and 20%/80% train/test data split ratios. To prepare pre-trained CNN for fine-tuning, we removed from each network the layers after the average pooling layer. On top of this, a new CNN head was constructed by adding a fully connected layer, dropout layer, and softmax classifier.

We started fine-tuning with warming-up the new CNN head. We warmed new network layers with an RMSprop optimizer and a constant learning rate. The fine-tuning continued with Stochastic Gradient Descent (SGD), and training was performed on all network layers. Different simulations scenarios were carried out with a linear decay schedule and cyclical learning rates with triangular policy. When it comes to the linear decay learning rate, the initial learning rate was selected relatively small, 1-2 orders of magnitudes lower than the initial learning rate of the originally trained CNN. Cyclical learning rates oscillated between the maximum and minimum bound with the optimal learning rate somewhere in between. The step size is equal to 4 or 8 times the number of training iterations in the epoch, and the number of epochs is chosen to contain integer of cycles.

In our paper, we use the following evaluation metrics: Overall Accuracy OA (classification accuracy) and confusion matrix. OA is the ratio between the number of correctly classified test images and the total number of test images. It is always lower than 1 (lower than 100%). The confusion matrix is a table that represents the partial accuracy of each image class. This graphical display shows the errors of every single different class and confusion between the classes. Here the columns appear for the predicted classes, and the rows appear for the real classes. Better classification accuracy leads to higher values of the main diagonal of the confusion matrix and lower values for other entries. To check the reliability of the results, all cases are repeated ten times (five times for fine-tuning method). After that, the mean value and the standard deviation (SD) for each experiment are calculated.

3 Results

3.1 Classification of WHU-RS dataset

The feature extraction transfer learning method was evaluated on the WHU-RS data set. Accuracy of SVM classification of compound features from the average pooling layer and PCA transformed convolutional layer features is shown in Table 1.

Table 2 presents a comparative analysis of the proposed feature extraction method to competitive classification methods. It can be concluded that feature fusion with PCA transformation is a technique that achieves state-of-the-art classification accuracies. Under a training ratio of 40% of the WHU-RS data set, this method outperforms all the other classification methods.

Figure 5 and Figure 6 show the confusion matrices without normalization obtained from the classification of WHU-RS data set under 60% training data with InceptionV3 mixed_8 (PCA) and ResNet50 average pooling, and under 40% training data with DenseNet121 conv5_block16_concat (PCA) and ResNet50 average pooling.

3.2 Classification of AID dataset

The experimental results of the fine-tuning method for classification of the AID dataset are displayed in Table 3. As can be seen from Table 3, the linear decay scheduler gives better classification results for a 50%/50% train/test split ratio for ResNet50 and InceptionV3. Cyclical learning rate works better for Xception and DenseNet121. For 20%/80% train/test split ratio linear decay scheduler is a better option for ResNet50, Xception and DenseNet121, and cyclical learning rates for InceptionV3.

Table 4 is a comparative display of our fine-tuning method with other state-of-the-art techniques. Our method achieved the best classification results on the AID dataset

Method	60% training ratio	40% training ratio
ResNet50 last conv layer (PCA) and InceptionV3 average pool	98.26	95.02
ResNet50 last conv layer (PCA) and Xception average pool	97.62	96.52
InceptionV3 mixed_10 (PCA) and ResNet50 average pool	96.27	95.85
InceptionV3 mixed_8 (PCA) and ResNet50 average pool	98.01	98.67
InceptionV3 mixed_10 (PCA) and Xception average pool	96.77	96.02
InceptionV3 mixed_8 (PCA) and Xception average pool	98.01	96.35
DenseNet121 conv5_block16_concat (PCA) and ResNet50 average pool	98.76	98.34
DenseNet121 conv4_block24_concat (PCA) and ResNet50 average pool	96.77	96.52

Table 1: Classification accuracy of feature extraction method with WHU-RS data set.

Method	60% of WHU-RS data set as a training set	40% of WHU-RS data set as a training set
Bag of SIFT [20]	85.52 ± 1.23	/
Multi Scale Completed LBP + BoVW [44]	89.29 ± 1.30	/
GoogLeNet [34]	94.71 ± 1.33	93.12 ± 0.82
VGG-VD-16 [34]	96.05 ± 0.91	95.44 ± 0.60
CaffeNet [34]	96.24 ± 0.56	95.11 ± 1.20
salM^{3}LBP-CLM [45]	96.38 ± 0.82	95.35 ± 0.76
TEX-Network-LF [46]	96.62 ± 0.49	95.89 ± 0.37
InceptionV3 mixed_8 (PCA) and ResNet50 average pool (Ours)	**98.13 ± 0.51**	/
DCA by concatenation [47]	98.70 ± 0.22	97.61 ± 0.36
Addition with saliency detection [48]	98.92 ± 0.52	98.23 ± 0.56
DenseNet121 conv5_block16_concat (PCA) and ResNet50 average pool (Ours)	**/**	**98.26 ± 0.40**

Table 2: Classification accuracy (%) and standard deviation of the state-of-the-art methods with WHU-RS data set.

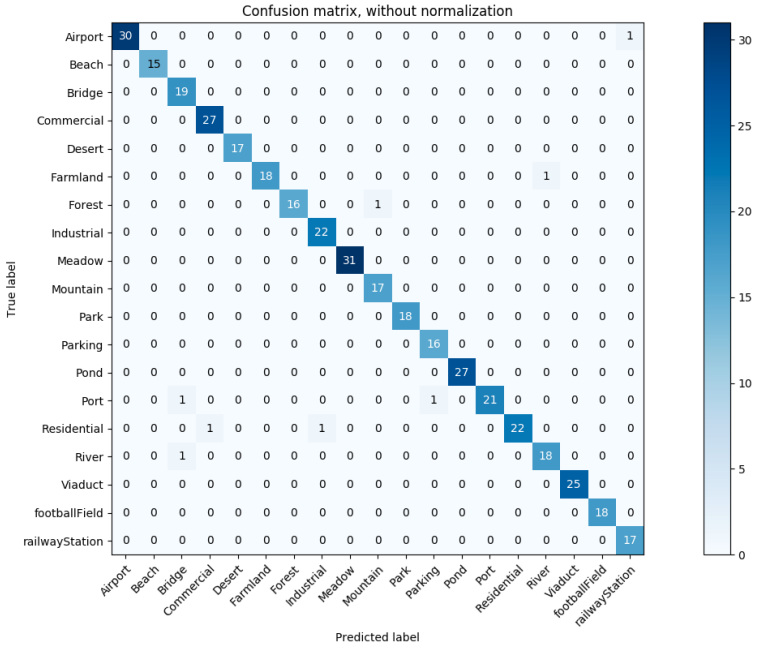

Figure 5: Confusion matrix of the feature extraction method under 60% training data of WHU-RS data set.

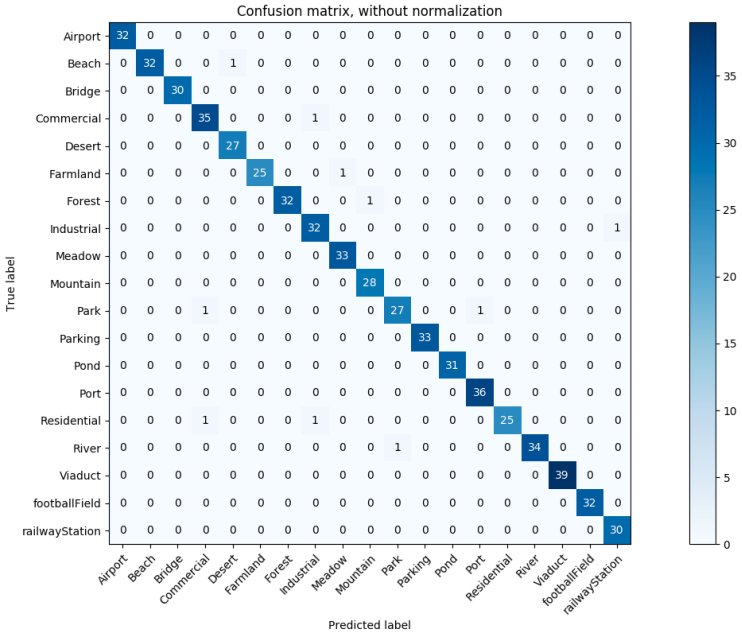

Figure 6: Confusion matrix of the feature extraction method under 40% training data of WHU-RS data set.

for InceptionV3, under 50% training data with a linear decay scheduler, and under 20% training data with cyclical learning rates. As can be concluded from Table 4, some methods outperformed the proposed fine-tuning technique, like EfficientNet-B3-aux [38]. Authors in [38] used the fine-tuning of the EfficientNet-B3 network with auxiliary classifier. The explanation for better classification results might be that the network mentioned above has achieved better top-1 classification accuracy on ImageNet data set than CNNs we utilized in our experimental setup.

Figure 7 displays the confusion matrix of the AID dataset classification for the proposed fine-tuning method with a 20%/80% train/test split ratio for ResNet50, cyclical learning rates, and softmax classifier. The main diagonal shows the number of properly predicted test images; the other elements give misclassified test images.

Method	50% training ratio	20% training ratio
ResNet50		
Linear decay scheduler	95.62±0.15	93.06±0.16
Cyclical learning rate	95.52±0.28	92.91±0.35
InceptionV3		
Linear decay scheduler	96.41±0.23	93.7±0.33
Cyclical learning rate	95.95±0.2	93.79±0.24
Xception		
Linear decay scheduler	96.14±0.12	93.67±0.18
Cyclical learning rate	96.15±0.17	93.44±0.10
DenseNet121		
Linear decay scheduler	96.03±0.16	93.74±0.24
Cyclical learning rate	96.21±0.19	93.54±0.15

Table 3: Overall accuracy (%) and standard deviation of the fine-tuning method with the AID data set.

Method	50% training ratio	20% training ratio
CaffeNet [34]	89.53±0.31	86.86±0.46
MCNNs [55]	91.80±0.22	/
Fusion by concatenation [39]	91.87±0.36	/
TEX-Net-LF [46]	92.96±0.18	90.87±0.11
VGG-16 (fine-tuning) [40]	93.60±0.64	89.49±0.34
Multilevel fusion [56]	95.36±0.22	/
GBNet +global Feature [40]	95.48±0.25	92.20±0.23
InceptionV3-CapsNet [41]	96.32±0.12	93.79±0.13
InceptionV3 with linear decay scheduler (ours)	**96.41±0.23**	93.7±0.33
InceptionV3 with cyclical learning rate (ours)	95.95±0.2	**93.79±0.24**
EfficientNet-B3-aux [38]	96.56±0.14	94.19±0.15
GCFs + LOFs [42]	96.85±0.23	92.48±0.38

Table 4: Overall accuracy (%) and standard deviation of the fine-tuning method compared to state-of-the-art methods for the AID data set.

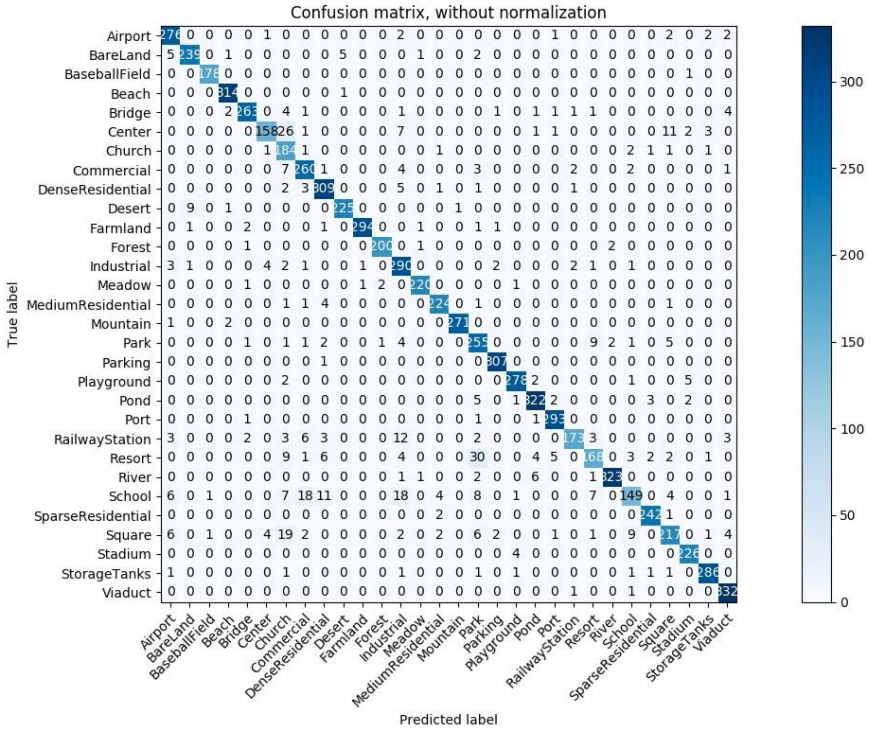

Figure 7: Confusion matrix of the fine-tuning technique under 20% training data of AID dataset for ResNet50, cyclical learning rates, and softmax classifier.

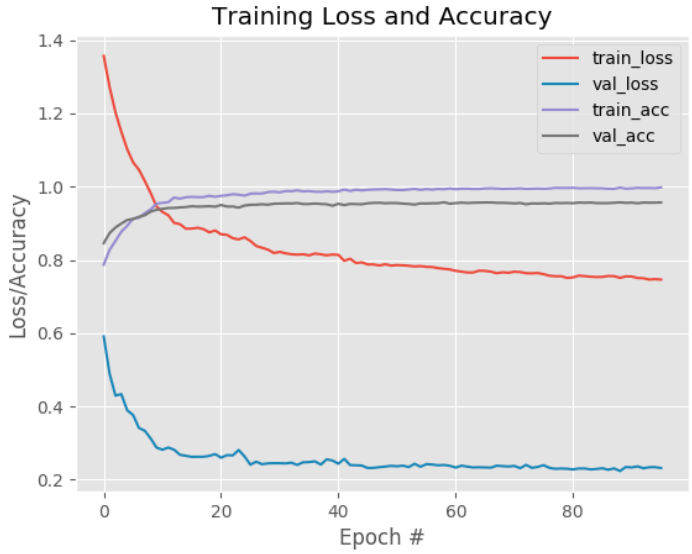

Figure 8: Training plot of the fine-tuning technique under 50% training data of AID data set for InceptionV3, cyclical learning rate, and softmax classifier.

with a 50%/50% train/test split ratio of AID data set with cyclical learning rates and softmax classifier. The plot shows the fine-tuning when all layers are "trainable" with an SGD optimizer. The plot has a characteristic shape for training with cyclical learning rates; the form of training and validation loss lines is "wavy." Because we fine-tuned the network with smoothed train labels, the training loss is higher than validation loss.

4 Discussion and conclusion

From the completed simulations and obtain results, the following valuable concepts can be summed up:

- When it comes to feature extraction method, Inception V3, and DenseNet121 are the pre-trained CNN that give the highest classification accuracies. As it is presented in Table 1, the best experimental

results on the WHU-RS dataset are obtained when features from these networks' layers are fused. From Table 3 it is evident that InceptionV3 outperforms other pre-trained CNNs in transfer learning through fine-tuning for the AID data set;
- The most suitable layer for feature extraction is mixed_8 from Inception V3. It gives good classification results with ResNet50, as well as DenseNet121 average pooling layer. ResNet50 average pooling layer also gives significant classification results when it is combined with DenseNet121 convolutional layers, the last or the intermediate ones;
- For the fine-tuning method, under 50% training data ratio linear learning rate decay scheduler gives better classification results for ResNet50 and Inception V3 pre-trained networks, and cyclical learning rates are a better choice for Xception and DenseNet121. Under 20% training data ratio, learning rate decay scheduler works better for Xception and DenseNet121, and cyclical learning rates are a better choice for ResNet50 and Inception V3;
- Our proposed transfer learning methods give classification accuracies comparable to state-of-the-art techniques. The feature fusion method with PCA transformation gives the classification accuracy of 98.26 ± 0.40 under a 40% training ratio of the WHU-RS dataset, which outperforms other methods in the literature. For the fine-tuning method applied to the AID dataset, some methods obtain better experimental results compared to ours, like EfficientNet-B3-aux [38], and the reason for better classification accuracy might be the type of pre-trained CNN utilized in the scenario.

In our paper, we proposed two distinct transfer learning techniques for remote sensing image classification. The feature extraction method utilizes the concatenation of extracted features from different CNNs' layers with prior PCA transformation. The fine-tuning method includes adaptive learning rates and label smoothing. With both transfer learning methods, we have achieved significant classification results on the two datasets. The proposed feature extraction technique can be further explored with feature extraction from lower layers of pre-trained CNN, as well as with stratification of train/test data split. For future development of the fine-tuning method, we suggest including different types of pre-trained CNNs apart from the ones used in this article, like EfficientNets, and involving of learning rate finder [36] to discover optimal values for initial learning rate or limits for cyclical learning rates.

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Relation Extraction Between Medical Entities Using Deep Learning Approach

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Medical discharge summaries or patient prescriptions contain a variety of medical terms. The semantic relation extraction between medical terms is essential for the discovery of significant medical knowledge. The relation classification is one of the imperative tasks of biomedical information extraction. The automatic identification of relations between medical diseases, tests, and treatments can improve the quality of patient care. This paper presents the deep learning based proposed system for relation extraction between medical entities. In this paper, a convolution neural network is used for relation classification. The system is divided into four modules: word embedding, feature extraction, convolution, and softmax classifier. The output contains classified relations between medical entities. In this work, data set provided by I2b2 2010 challenge is used for relation detection which consisted of total 9070 relations in test data and 5262 total relations in the train dataset. The performance evaluation of relation extraction task is done using precision and recall. The system achieved an average of 75% precision and 72% recall. The performance of the system is compared with the awarded i2b2 participated systems.

Povzetek: Metoda globokega učenja je uporabljena na iskanju relacij med zdravstvenimi entitetami.

1 Introduction

Relation extraction is an essential task of biomedical text mining. How any medical difficulty is related to symptoms, syndrome, and treatment, which tests will be required for disease diagnosis? These types of information are required in health care and clinical procedures. Relation extraction is the task of classification in which a pair of relations between medical entities can be identified. It is the core clinical information identification problem that identifies semantic relations between medical concepts problem, test, and treatment in discharge summaries [13]. It is one of the challenging tasks of i2b2 2010 NLP challenges. Relation extraction is divided into various types according to their usage such asTrIPindicates treatment improvement with problem, TrWP (treatment worsen the medical problem), TrCP (treatment causes the medical problem), TrAP (treatment is administered for the medical problem) and TrNAP(treatment is not administered because of the medical problem), other for test with problem TeRP (test shows the medical problem), TeCP (test conducted to investigate medical problem) and the problem with other problem indicates PIP (problem indicates problem) [1]. Examples of relations are: c="pacemaker" || r="TrAP"|| c="sinus node dysfunction", c="an angiography"|| r="TeRP"|| c="bleeding in two vessels" etc.Medical relations are classified into categories which shown in table I.

Remainder sections of this paper are organized as follows: Section 2 shows the review of papers related to medical relation extraction, Section 3 describes the proposed method and dataset, Section 4 gives experimental results and discussion and Section 5 conclude the results of proposed approach and give some novel directions for added research work.

Type of Relation	Categories of Relations
Medical Problem-Treatment	TrIP (Treatment improves medical problem)
	TrWP (Treatment worsens medical problem)
	TrCP (Treatment causes medical problem)
	TrAP (Treatment is Administered for medical problem)
	TrNAP (Treatment is not Administered because of medical problem)
	Relation between Treatment and Medical problem does not exist other than above types
Medical Problem-Test	TeRP (Treatment reveals medical problem)
	TeCP (Test conducted to investigate medical problem)
	Relation between Testand Medical problem does not exist other than above types
Medical Problem-Problem	PIP (Medical problem indicates medical problem)
	Relation between Medical problem and Medical problem does not exist other than PIP

Table 1: Relation categories provided in i2b2 2010 challenge [22].

2 Literature review

2.1 Review of i2b2 NLP challenge work

In 2010 i2b2 challenge, enormous work is done by authors in the field of relation extraction for medical text. In this NLP challenge several supervised and unsupervised machine learning classifiers are used. Various effective relation classification systems have been used such as CRF classifiers, Semi Markov models,SVM classifiers, Naive bayes classifier and SSVM (structural support vector machine)[2-5]. Some authors have used machine learning based modulesfor train data followed by post processing rules.

Maximum entropy (ME) classifier is trained using semantic and syntactic features in[6]. In this paper, results given by ME classifiers are relatively less memory demanding as compare to kernel based k-nearest neighbour (kNN) classifier and less computationally expensive than support vector machine (SVM) classifier. Other than these given reasons, did not detect a major difference in performance between these classifiers. This system attained top rank in the i2b2 NLP challenge. SVM classifier is used to train on dataset using word as features in [7], and classify the data into different relation types. Syntactic features are also taken as important feature in the paper but recall can be improved using full parse tree implementation.

In [8], the system combines supervised classifier with rule based method. Entity and relation extraction in a joint framework is proposed using card pyramid parsing approach in [9]. Syntactic analysis of sentences is done by using the concept of bottom up parsing with SVM relation classification [10]. Few authors had used SVM classification algorithm with various features like syntactical, lexical, medical semantics and sentence level context information [11][12][13]. ConText algorithm is also designed for contextual feature creation [14], which recognizes context of patient's medical condition such as family history, previous record of disease or disease related treatment and symptoms etc. Relation extraction between treatment and problem concepts is explored in [15], and SemRep method is used for detection of semantic and lexical features associated with concepts [16]. But SemRep is trained for semantic representation of entities for general English text, so it is unable to extract treatment concepts in clinical domain precisely.

Semantic relation discovery on clinical records is presented in [17], in which SVM is used for classification of disease-test, disease–treatment, and symptom–treatmentrelation types. The performance of this work is dependent on semantic types of a particular domain.REMed is a learning-based approach which is introduced for automatic relation discovery in the work presented in paper [18]. Relation extraction from clinical notes is also given by the usage of parse tree enhancement with semantic features [19]. Performance of relation extraction system can be improved by the integration of semantic features into parse trees.

In [20], authors had used three different classifiers to classify problem-test, problem-treatment and problem-problem relations respectively. Maximum entropy framework is used as classifier and implemented in the maximum entropy OpenNLP toolkit. In the paper [1], Hybrid approach is explored which integrates the linguistic pattern matching with SVM classifier. SVM classifier is trained with libsvm tool and created linguistic patterns manually. It is found that, the usage of patterns with SVM classifier improves the relation extraction.

I2b2 challenge participants had used different set of features for relation classification. Features such as context features, semantic features, concepts co-occurrence, N-gram sequential feature and parser output are used for medical relation extraction in previous papers [4, 5,20,21]. Relationship between Coronary Obstructive Pulmonary Disease and cardiovascular diseases is detected through various machine learning classifiers in paper [22]. Diabetes complications are also detected by using various machine learning classifiers in paper [23].

2.2 Performance of Existing Systems

Performance evaluation of relation extraction for every relation category is done using recall, precision and F-score. Table II presents F-score of various relation

Relation Detection		
Authors of Systems	**Methods**	**F-Score (%)**
Roberts	Supervised method	73.7
DeBruijn	Semi Supervised method	73
Grouin	Hybrid method	71
Patrick	Supervised method	70.2
Jonnalagadda*and* Gonzalez	Supervised method	69.7
Divita	Supervised method	69.5
Solt	Supervised method	67
Demner-Fushman	Supervised method	66.6
Anik	Supervised method	66
Cohen	Supervised method	65.6

Table 2: Performance evaluation of Relation detection systemsin i2b2 challenge (2010) [24].

Relation Type	**Training Data (figure)**	**Testing Data (figure)**	**Test data Recall, Train data Recall, In (%)**	**Test data Precision, Train data Precision, In (%)**	**Test data F-Score, Train data F-Score, In (%)**
PIP Relation	1239	1986	62.5% 64%	67.7% 73%	65% 68%
TrWP Relation	56	143	2.8% 3.7%	80% 100%	5.4% 7%
TrAP Relation	1422	2487	72% 78%	70% 68.4%	71% 72.8%
TrNAP Relation	106	191	13% 26.4%	55.5% 70%	21% 38%
TrCP Relation	296	444	48% 44.9%	49.5% 63.6%	48% 52%
TrIP Relation	107	198	15.7% 23.3%	86% 69%	26.5% 35%
TeCP Relation	303	588	43% 47.8%	61% 77%	50% 59%
TeRP Relation	1733	3033	84% 87%	84% 82.3%	84% 84.6%
Overall Result	5262	9070	67.5% 70.9%	73% 74.5%	70% 72.6%

Table 3: Evaluation of Relation Extraction System [2].

extraction systems contributed in challenge 2010 [24]. Table 3 presents recall, precision and F-score for each relation class label shown by Patrick et al [4], in whichTeRP, TrAP and PIP relations got highest F-score; while TrWP relation got very low F-Score.

2.3 Summary and research gaps

Extensive review is done in the field of medical relation detection. In i2b2 challenge, participants have used

Relation Type	**Training Data (figure)**	**Testing Data (figure)**
PIP Relation	1239	1986
TrWP Relation	56	143
TrAP Relation	1422	2487
TrNAP Relation	106	191
TrCP Relation	296	444
TrIP Relation	107	198
TeCP Relation	303	588
TeRP Relation	1733	3033
Overall Result	**5262**	**9070**

Table 4: Summary of Relation Types of train and test data [1].

machine learning methods with feature of the engineering module. Machine learning methods performed well but feature engineering module is time taking and requires domain knowledge. The importance of feature design and usefulness of rich features influences the results. SVM classifier is used in relation extraction. It is observed that the use of patterns with SVM classifier improves the relation extraction. Medical relations in intra-sentences are extracted in existing systems accurately but relations in inter-sentences require more attention.

3 Proposed methodology

An extensive discussion on existing work in clinical relation extraction is done in related work. Different tools, techniques, and methods are discussed for the medical domain. The system is proposed for medical relation extraction which is based on the concept of deep learning.

3.1 Dataset

I2b2 2010 challenge organizers provided data set for relation classification which consisted of total 9070 relations in test data and 5262 total relations in the train dataset. The summary of each relation type for train and test data is shown in table 4. Example of annotated dataset for relation extraction is shown in table5.

3.2 Proposed deep learning based relation extraction system

The extraction of semantic relations is essential for the discovery of significant medical knowledge. Relation extraction is an important task in the field of biomedical text mining. For improving the relation between medical entities, Deep Learning based method CNN (convolution neural network) with word2vec is used [25]. The method is divided into four steps: word embedding, feature extraction, convolution, and softmax classifier. The word embedding model takes word tokens as input, so initially the sentences divided into word tokens. Then the word token are converted into vectors using word embedding. In this work, new word embedding model is trained

```
c="coronary artery bypass graft"
115:4 115:7||r="TrAP"||c="coronary
artery disease" 115:0 115:2
c="a amiodarone gtt" 75:11
75:13||r="TrAP"||c="burst of atrial
fibrillation" 75:3 75:6
c="antibiotics" 80:15
80:15||r="TrAP"||c="left arm
phlebitis" 80:8 80:10
c="creams" 124:1
124:1||r="TrNAP"||c="incisions"
124:10 124:10
c="cath" 19:14
19:14||r="TeCP"||c="abnormal ett"
19:9 19:10
c="powders" 124:5
124:5||r="TrNAP"||c="incisions"
124:10 124:10
c="lotions" 124:3
124:3||r="TrNAP"||c="incisions"
124:10 124:10
c="ointments" 124:8
124:8||r="TrNAP"||c="incisions"
124:10 124:10
c="oxycodone - acetaminophen" 92:1
92:3||r="TrAP"||c="pain" 92:21 92:21
c="drugs" 12:8
12:8||r="TrCP"||c="known allergies"
12:5 12:6
c="cath" 20:0
20:0||r="TeRP"||c="severe 3 vessel
disease" 20:2 20:5
c="cxr" 56:0 56:0||r="TeRP"||c="left
lower lobe atelectasis" 56:3 56:6
c="cabg" 28:8 28:8||r="TrAP"||c="mi"
28:2 28:2
c="po amiodarone" 79:9
79:10||r="TrIP"||c="further episodes
of afib" 79:3 79:6
c="overall left ventricular systolic
function" 44:0
44:4||r="TeRP"||c="mildly depressed"
44:6 44:7
c="wounds" 121:1
121:1||r="PIP"||c="infection" 121:3
121:3
c="wounds" 121:1
121:1||r="PIP"||c="redness" 121:5
121:5
c="wounds" 121:1
121:1||r="PIP"||c="drainage" 121:7
121:7
```

Table 5: Example of Annotated Relation Corpus.

using clinical 2010 i2b2 dataset. Then lexical and sentence level feature vectors are created separately and then concatenated into the final feature vector. In progression, the final feature vector is fed into the softmax classifier for the relation classification. The dimension of output vector is equal to number of predefined relation types. Figure 1 shows the architecture of deep learning based proposed relation extraction system. The description of each component is mentioned below.

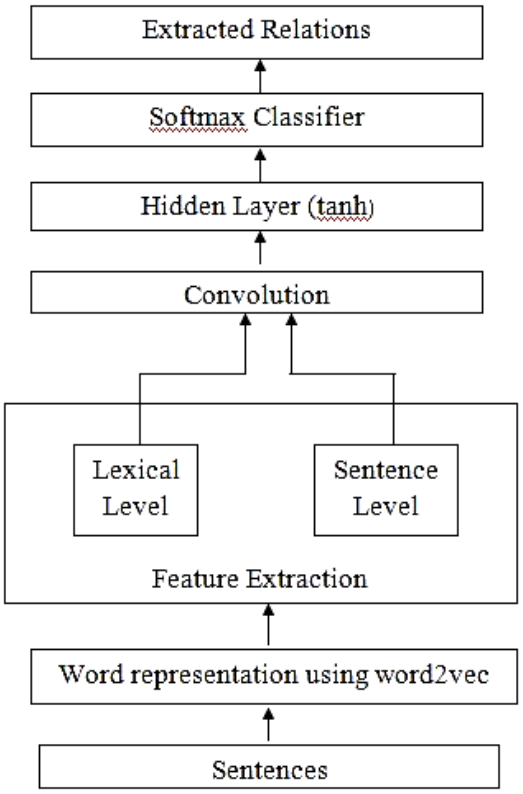

Figure 1: Architecture of proposed relation extraction system.

3.2.1 Word embedding

Word embedding is the word representation method which represents same context words in a similar representation [26]. Word2Vec is the technique to represent word embedding concept. In this component, Word2Vec takes word tokens as input and generates the vector of words as output. It constructs vocabulary from training text data and then creates vector of context similar words. However, there are many trained word embedding models are available which can directly used in the data set [27]. But these models are trained on general text. In the proposed work, new word embedding model is generated using clinical i2b2 data set. The size of vocabulary is 9060 of i2b2 test data set. Word2vec results are not entirely dependent on the corpus but also on the parameters used. Basic parameters for training the model are:

- CBOW (continuous bag of words) and SG (skip gram) vector model architectures
- Dimensionality of vector space such as 200, 300, 500 and 800
- Word windows size such as 5, 10 and 20

- min_count represents (Ignores all words with total frequency lower than this)

3.2.2 Feature extraction

In this component, lexical level and sentence level features are identified. Lexical level features are important indication for relation identification. In the proposed system, lexical features are identified by using word embedding method. For lexical features, clinical entities are also important, which identified by existing deep learning method proposed in [28]. Window and semantic features are identified by word2vec method. For medical semantic types mapping, UMLS (unified medical language system) is used [29]. These features are concatenated into lexical feature vector. Here lexical feature vector is denoted as:

L = {< l1, w1 >,< l2, w2 >, ..., <lk, wk>}

where li is a semantic concept in the UMLS, and wi is a weight to symbolize the importance of the clinical text associated with li. Lexical feature vector is obtained using the semantic types mapping with UMLS from given clinical text. This component has several layers: input layer, convolution layers, pooling layers and hidden layers.

Input Layer - The input layer converts the clinical text into a matrix of embedding, indicated as $W \in R^{(k+n)\times m}$, where k and n is the semantic types of word and maximum number of words respectively, and m is the dimension of word embedding. W is obtained by concatenating the embedding of words and semantic types together: $W = Ww \oplus Wl$. Here Wl and Ww are the embedding of the semantic types and words, respectively. And concatenation operation is denoted as $\oplus$.

Convolution Layer -In neural network model, the convolution approach is used to merge all the features. Convolution layer uses the filters to create features maps.

For predicting relation types, features are identified globally on complete data. The convolution layer is used to find out high level features from the input layer. To find different varieties of features, apply filters with different sizes. ReLU function is usedfor convolution layers asnon-linear function. The filter is applied to all possible windows of words and semantic types in W and produced a feature map $s \in R^{n+k-h+1}$.

Pooling Layer-Best feature can be extracted through max pooling operation of features. The pooling layer is used to further abstract the features by aggregating the score for each filter which produced from convolution layer. In this work, over each feature map, max-over-time pooling operation is applied. Important features are identified by selecting the uppermost value on each dimension of vector. Pooling layers are used to induce a fixed-length vector from feature maps.

Hidden Layer - Hidden layer is used to combine different features after getting from pooling layers.

In the present work, tanh is used as an activation function.

Sentence level feature vector is also generated like lexical level feature vector. It also consists of several layers: input layer, convolution layers, pooling layers and hidden layers. The input of this component is the word and its position in the sentence. Again W is obtained by concatenating the embedding of words and position together: $W = Ww \oplus Wp$. Here, Ww and Wp are the embedding of the words and position of words, respectively. Finally, combine the output vectors of the lexical level features and sentence level features by concatenating them.

Softmax classifier – It is used as the final layer of neural network. It gives the confidence of each relation type. In the work, softmax classifier is used as multi class identification of relations.The output layer is applied on the combined vector to transform the output values into probabilities for relation detection.It returns the probabilities of each relation and target relation is having highest probability.

Training - In the present work, parameters are trained as a set Θ, in which the training data set is denoted as M and the class label as N. For each $m \in M$, the component computes a score s(n; m, Θ) for each class $n \in N$. The softmax operation is used to transform scores into a conditional probability distribution in the output layer which over the scores for all $n \in N$, Shown in Eq. (1).

$$\mathbf{p(n/m,\Theta)} = \frac{\mathbf{exp(s(n;m,\Theta))}}{\sum_{\forall T \in \mathbf{N}} \mathbf{(s(T;m,\Theta))}} \quad (1)$$

The training target of the model is to maximize the loglikelihood over the training set with respect to Θ. Shown in Eq. (2).

$$\Theta \mapsto \sum_{\mathbf{m} \in \mathbf{M}} \mathbf{\log p(n/m,\Theta)} \quad (2)$$

The architecture of sentence level feature generation is shown in fig 2. First component is feature extraction of word features and position features. Word features are representation of contextual similar words associated with the index of word in a sentence. Whole sentence is represented as list of word vectors with its ranking. Pair wise ranking is used to train word embedding model. Position features are relative distance (d1 and d2) of current word with left and right word, which is w1 and w2. Combination of word and position feature vector is fed into convolution component for extracting sentence level features. Table 6 shows different hyperparameters with its values which are tuned for convolutional neural network for relation extraction. The results are using 10 cross fold validation in which the model is trained for 10 times.

4 Results and discussions

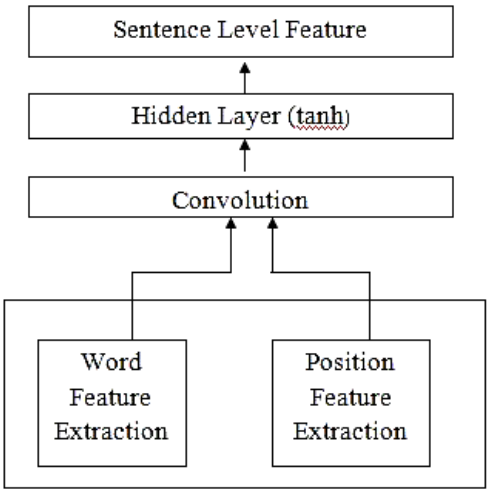

Figure 2: Architecture of Sentence level feature component.

Description	Values
Activation Function	ReLU, Sigmoid, Softmax, Tanh
Feature Maps	50, 100, 128
Dropout rate	0.5, 0.7, 0.9
Pooling	1-Max

Table 6: Setup of Hyperparameters.

Relation Types	Precision (%)	Recall (%)
PIP	90	95
TrWP	10	5
TrAP	73	85
TrNAP	59	10
TrCP	60	30
TrIP	50	20
TeCP	70	35
TeRP	82	86
Overall Result	**75**	**72**

Table 7: Summary of result of medical relation types.

Authors of the Systems	Methods	F-Score (%)
Roberts *et al*[7]	Supervised method	73.7
DeBruijn*et al*[3]	Semi Supervised method	73.1
Grouin*et al*[8]	Hybrid method (Machine learning and linguistic pattern matching)	71
Proposed System	Convolution Neural Network	74

Table 8: Comparison of performance of proposed system with awarded i2b2 participated systems.

Performance evaluation of relation detection is done using recall and precision for every relation category. Table VII presents results of relation types in which TeRP, TrAP and PIP relations got highest precision and recall; while TrWP relation precision and recall is very low. Because training data contains less TrWP (treatment worsen problem) relations. Using convolution neural network, the performance of the system has improved for few relations. The F-score of PIP relation is increased from 68% to 92% and TrAP relation is increased from 73% to 79%. It is observed that relation types which are more presented in training data, gave best results. Table VIII shows the comparison of proposed system with existing i2b2 challenge systems.

5 Conclusion

Biomedical information is necessary for doctors, health care professionals, and clinical researchers. The information growing exponentially and scattered in published literatures and patient health records. The need is to identify appropriate tools and techniques for extracting knowledge from medical text. In this paper, medical relations are extracted between clinical concepts using word embedding and CNN based deep learning method. The system is trained using word embedding model with lexical and sentence level features. The performance of the system is compared with existing relation extraction systems. Medical relations in intra-sentences are extracted in existing systems accurately but relations extraction in inter-sentences has more scope for future work.

6 Acknowledgement

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A Classifier Ensemble Approach for Prediction of Rice Yield Based on Climatic Variability for Coastal Odisha Region of India

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Agriculture is the backbone of Indian economy especially rice production, but due to several reasons the expected rice yields are not produced. The rice production mainly depends on climatic parameters such as rainfall, temperature, humidity, wind speed etc. If the farmers can get the timely advice on variation of climatic condition, they can take appropriate action to increase the rice production. This factor motivate us to prepare a computational model for the farmers and ultimately to the society also. The main contribution of this work is to present a classifier ensemble based prediction model by considering the original rice yield and climatic datasets of coastal districts Odisha namely Balasore, Cuttack and Puri for the period of 1983 to 2014 for Rabi and Kharif seasons. This ensemble method uses five diversified classifiers such as Support Vector Machine, k-Nearest Neighbour, Naive Bayesian, Decision Tree, and Linear Discriminant Analysis. This is an iterative approach; where at each iteration one classifier acts as main classifier and other four classifiers are used as base classifiers whose output has been considered after taking the majority voting. The performance measure increases 95.38% to 98.10% and 95.38% to 98.10% for specificity, 88.48% to 96.25% and 83.60% to 94.81% for both sensitivity and precision and 91.78% to 97.17% and 74.48% to 88.59% for AUC for Rabi and Kharif seasons dataset of Balasore district and also same improvement in Puri and Cuttack District. Thus the average classification accuracy is found to be above 96%.

Povzetek: Opisana je ansambelska metoda napovedovanja pridelka riža v Indiji.

1 Introduction

Agriculture is the pivot of Indian economy. Around 58% of rural households are dependent on agriculture as their major means of livelihood. However, the share of agriculture has changed considerably in the past 50 years. In 1950 55% of GDP came from agriculture while in 2009 it is 18.5% and during the financial year 2015-2016 it is 16.85% [1]. Indian agriculture has made great progress in ensuring food security to its huge population with its food grains production reaching a record level of 236 million ton in 2013-2014. While the required amount for 2030 and 2050 are 345 and 494 million ton respectively. In India rice is grown in different agro climatic zones and altitudes. Rice grown in India has extended from 8 to 35°N latitude and from sea level to 3000 meter. Rice required a hot and humid climate and well suited to the areas which have high humidity, long

sun shine and sufficient water supply. The average temperature required for the crop is 21 to 36°C. It is predicted that the demand for the rice will grow further than other crops. There are various challenges to achieve higher productivity with respect to climate change and its repercussions. In tropical area higher temperature is one of the important environmental factors which limit rice production. Different parts of the country have variable impacts due to climate change. For example by the year of 2080 the numbers of rain days are to be decreased along with narrow rise of 7-10% annual rain fall which will lead to high intensity storm. Moreover, on one hand when monsoon rain fall over the country is expected to rise by 10-15%, on the other hand the winter rain fall is expected to reduce by 5-26% and seasonal variability would be further compounded [2]. Then, cereal production is expected to be reduced by 10-40% by 2100 due to rise in temperature, rising water scarcity and decrease in number of rain days. Higher loss is predicted in *Rabi* crops [3]. Rice productivity may decline by 6 percent for every 10C rising temperature [4]. In general changing climate trends will lead to overall decline agricultural yield. The simulation analysis projected that on all India basis, the consequent of climate change on productivity in 2030s ranges from -2.5 to -12% for crops such as rice, wheat, maize, sorghum, mustard and potato [5, 6]. Climate is the sum of total variation in temperature, humidity, rainfall and other metrological factors in a particular area for a period of at least 25 years [1]. Odisha's climate has also under gone appreciable changes as a result of various factors. The previous six seasons of the year has changed into basically two mainly summer and rainy. The deviation in day temperature and annual precipitation is mainly restricted to 4 months in a year and number of rain days decreased from 120 to 90 days apart from being abnormal. In addition, the mean temperature is increasing and minimum temperature has increased about 25% [2, 3, 4, 5]. Such climate change related adversity is affecting adversely productivity and production of food grains. Agriculture is the backbone of Indian economy. But due to several reasons the expected crop yields are not produced. The production mainly depends on climatic parameters such as rainfall, temperature, humidity, wind speed etc. So the farmer should know the timely variation in climatic condition. If they can get the timely advice then they can increase the production. Before development of the technology the farmers can predict the production just by seeing the previous experience on a particular crop. But gradually the data increases and due to the environmental factors the weather changes. So we can use this vast amount of data for prediction of rice production. For a uniform growth and development assurance in agriculture (the current rate is 2.8% per annum), an exhaustive appraisal of the accountability of the agriculture production owing to predicted type of weather transform is necessary.In this paper the main aim is to create an ensemble model for prediction of climatic variability on rice yield for coastal Odisha. The weather parameters such as rainfall, temperature and humidity etc. are considered because they affect the 95% production of rice crop. Additionally, the classifier's accuracy validity has been measured using specificity, sensitivity/recall, precision, Negative Predictive Value (NPV), False Positive Rate (FPR), False Negative Rate (FNP), False Discovery Rate (FDR) and the probabilistic measures such as; F-Score, G-Mean, Matthews Correlation Coefficient (MCC) and J-Statistics. This paper is organized as follows; section 2 describes the related works, materials and methods or approaches used for experimentation are described in section 3. The framework of the proposed prediction model is given in section 4, section 5 deals with experimentation and model evaluation. The result analysis, discussion and conclusion are given in section 6, 7 and 8 respectively.

2 Related work

While undertaking this work, the existing literature that has been followed during every phase of the entire research work with the intention of clear representation of the machine learning based prediction models. The various approaches are explored and have been addressed to design the ensemble based rice production model based on climatic variability. This section describes few recent works on this are which motivated us to develop an ensemble based model. Narayan Balkrishnan [7] proposed an ensemble model AdaSVM and AdaNaive which is used to project the crop production. Authors compared their proposed model among the Support Vector Machine (SVM) and Naïve Bayes (NB) methods. For prediction of output, two parameters are used such as accuracy and the classification error and it has been observed that AdaSVM and AdaNaive are better than SVM and NB. B Narayanan [8][8] compared the SVM and NB with AdaSVM and AdaNaive and conclude that the later one is better than first two methods. Sadegh Bafandeh [9] studied the detailed historical background and different applications of the method in various areas. If the distribution of the data is not known then the k-Nearest Neighbour (K-NN) method can be applied for classification technique [10, 11, 12]. In the feature space objects can be classified on the basis of closest training examples. It is one of the instance–based learning or lazy learning where computation is done until classification and function is approximated locally [13, 14]. A Bayesian network or Bayes network or belief network or Bayesian model or probabilistic directed acyclic graphical models a type of statistical model. A belief network to assess the effect of climate change on potato production was formulated by yiqun Gu et. al. [15]. Authors have shown a belief network combining the uncertainty of future climate change, considering the variability of current weather parameters such as temperature, radiation, rainfall and the knowledge about potato development. They thought that their network give support for policy makers in agriculture. They test their model by using synthetic weather scenarios and then the results are compared with the conventional math-

ematical model and conclude that the efficiency is more for the belief network. There are various factors influencing the prediction. UnoY et al. [16] used agronomic variables, nitrogen application and weed control using the machine learning algorithm such as artificial neural network and Decision Tree (DT) to develop the yield mapping and to forecast yield. They have concluded that high prediction accuracies are obtained by using ANNs. Veenadhari S et al. [17] described the soybean productivity modelling using DT algorithms. Authors have collected the climate data of Bhopal district for the period 1984-2003. They considered the climatic factors such as evaporation, maximum temperature, maximum relative humidity, rainfall and the crop was soybean yield and applied the Interactive Dichotomizer3 algorithm which is information based method and based on two assumptions. Using the induction tree analysis it was found that the relative humidity is a major influencing parameter on the soybean crop yield. DT formed for influence of climatic factors on soybean yield. Using the if-then-else rules the DT is formulated to classification rules. Relative humidity affects much on the production of soybean and some rules generated which help to in the low and high prediction of soybean. One of the drawbacks was only the low or high yield can be predicted but the amount of yield production cannot be predicted. Due to the diversity of climate in India, agriculture crops are poorly impressed in terms of their achievement from past two decades. Forecasting of crop production and advanced yield might be helpful to policy inventor and farmers to take convenient decision. The forecasting also helps for planning in the industries and they can coordinate their business on account of the component of the climate. A software tool titled 'Crop Advisor' has been developed by Veenadhari et al. [18] which is a client friendly and can forecast the crop yields with the effect of weather parameters.C4.5 algorithm is applied ascertain the most effective climatic parameter on the crop yields of specified crops in preferred district of Madhya Pradesh. The software will be helpful for advice the effect of various weather parameters on the crop yield. Other agro –input parameters liable for crop yield are not accommodating in this tool, since the application of these input parameters differ with individual fields in space and time. Alexander Brenning et al. [19] compared all the classifier including Linear Discriminant Analysis (LDA) for crop identification based on multitemporal land dataset and concluded that stabilized LDA performed well mainly in field wise classification. Minggang Du et al. [20] used the method LDA for plant classification and conclude that LDA with Principal Component Analysis is effective and feasible for plant classification. Renrang Liao [21] classified fruit tree crops using penalized LDA and found that the LDA may not be able to deal with collinear high dimensional data. It has been observed that, most of literature are using single classification model to predict the crop yield leading to increase in misclassification by data biasing, therefore we have been motivated to formulate a multiclassifier based model known as classifier ensemble [22]. This ensemble technique helps to reduce the classification error by considering the outputs of different classifiers by taking the majority of right outputs [23, 24]. In this paper we have tried to consider the collision of the weather transform scenario of Odisha context of the farming yield of the one main fasten food rice using the machine learning methods such as SVM, *K*-NN, NB, DT and LDA [25, 26].

3 Materials and methods

This section briefly describes the machine learning techniques and tools used to develop the ensemble based crop prediction model.

3.1 Support Vector Machine (SVM)

TSVM is one of the supervised machine learning techniques and also known as support vector networks. It analyses data mainly for classification and regression analysis. A set of labelled training data it produces by using input-output mapping functions [27]. For both classification of linear and non linear dataset, SVM method can be used. The original training data transformed a higher dimension by SVM using non linear mapping. Then for the linear optimal separating hyper plane, the new dimension searched by SVM. Thus, a decision boundary formed which separates the different classes from one another [28]. When the SVM is used for the prediction of the crop yield then it is known as support vector regression. The main objective of the SVM is to find non-linear function by the use of kernel that is a linear on polynomial function [29, 30, 30]. The radial basis function and the polynomial function are the widely used kernel functions. In case large input samples space the difficulty of using linear function can be avoided by using SVM. Due to optimization the complex problem can be converted into simple linear function optimization [32].

3.2 *K*-Nearest Neighbour (*K*-NN)

K-NN [33] is one of the simplest supervised learning methods used for both classification and prediction techniques [34, 35]. By using *K*-NN the unknown sample can be classified to predefined classes, based on the training data. It requires more computation than other techniques. But it is better for dynamic numbers that change or updated quickly. For new sample classification the *K*-NN process the detachment among the entire sample in the training data. The Euclidian distance is used for distance measurement. The samples with the smallest distance to the new sample are known as *K*-nearest neighbours [36]. The main idea behind the*K*-NN is to estimate on a fixed number of observations those are closest to the desired output. It can be used for both in discrete and continuous decision making such as classification and regression. In case of classification most frequent neighbours are selected and in case

of prediction or regression the average of k-neighbours are calculated. Besides the Euclidean distance, Manhattan distance and Minkowski distance are used in *K*-NN [37].

3.3 Naïve Bayesian Classifier (NB)

The NB classification technique is developed on the basis of Bayesian theorem. This technique is most suitable when the input value is very high that when the dataset is very high we can use the Naïve Bayes technique. The other names of Bayes classifiers are simple Bayes or idiot Bayes [38]. Naïve Bayes classifier is a simple probabilistic classifier with strong independence assumptions. The classifier can be trained on the nature of the probability model. It can work well in many complex real world situations. It requires a little quantity of training data to calculate the parameter essential for the classification and it is the main advantage of Naïve Bayes classifier. Bayes theorem is based on probabilistic belief. It is based on conditional probability on mathematical manipulation. Therefore, Bayes important characteristics can be computed using rules of probability, more specific conditional probability [39].

3.4 Decision Tree (DT)

DT presents a very encouraging technique for automating most of the data mining and predictive modelling process. They embed automated solutions such as over fitting and handling missing data. The models built by DTs can be easily viewed as a tree of simple decisions and provide well-integrated solutions with high accuracy. DT also known as classification tree is a tree like structure which recursively partitions the dataset in terms of its features. Each interior node of such a tree is labelled with a test function. The best known DT algorithms are C4.5 and ID3 [40].The figure 1 illustrates an example of DT with their IF ... THEN... ELSE ... rules form.

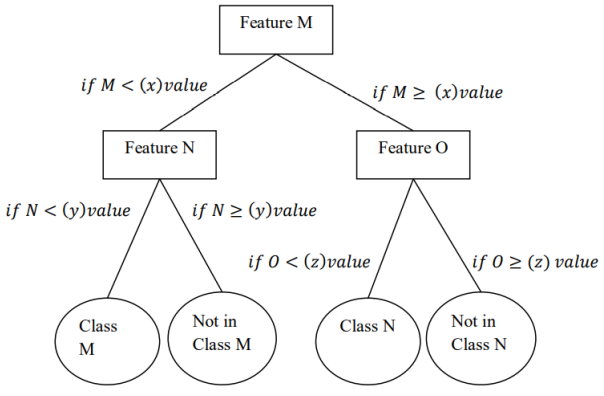


Figure 1: Decision Tree with IF ... THEN ... ELSE ... Rules form

3.5 Linear Discriminant Analysis (LDA)

Discriminant analysis is a multivariate method of classification. Discriminant analysis is similar to regression analysis except that the dependent variable is categorical rather than continuous in discriminant analysis; the intent is to predict class membership of individual observations based on a set of predictor variables. LDA generally attempts to find linear combinations of predictor variables that best separate the groups of observations. These combinations are called discriminant functions. It is one of the dimensional reduction methods, used in preprocessing in pattern-classification and machine learning applications. In order to avoid over fitting we can apply LDA in the dataset for good class separability with reduced computational cost [41]. Linear combinations of the predictors are used by LDA to model the degree to which an observation belongs to each class and discriminant function is used and a threshold is applied for classification [42].

3.6 Majority voting

Majority voting is one of the ensemble learning algorithms, which is a voting based methods. Majority vote is appropriate when each classifier cl can produce class-probability estimates rather than a simple classification decision. *A class-probability estimate* for data point y is the probability that the true class is $k : A(f(x) = m|cl)$, for $m = 1, \cdots, M$. We can combine the class probabilities of all the hypotheses so that the class probability of the ensemble can be found [43]. Sarwesh Site et. al. described about the better performance for better prediction after merging two or more classifier using the voting of data, which is known as ensemble classifier. They described various technique of ensemble classifier both for binary classification and multi-class classification [44]. Xueyi Wang et. al. prepared a model to find the accuracies of majority voting ensembles by taking the UCI repository data and made experiment of the 32 dataset. They made their data into different subsets such as core, outlier and boundary and found result that for better ensemble method or to achieve high accuracy; the weak individual classifier should be partly diverse [45].

3.7 Performance measures

This section discusses the basics of *specificity*, *sensitivity/recall*, and *precision*, NPV, FPR, FNP, FDR, F-Score, G-Mean, MCC and J-Statistics. These are extent to which a test measures what it is supposed to measure; in other words, it is the accuracy of the test or validity of the test and measured using a *confusion matrix* i.e. a two-by-two matrix. There are four elements of a confusion matrix such as; *True Positives (TP)*, *False Positives (FP)*, *False Negatives (FN)* and *True Negatives (TN)* represented in the a, b, c and d cells in the matrix []. *Specificity* is computed as $d(TN)/(FP) + d(TN)$, *sensitivity* as; $a(TP)/a(TP) + c(FN)$. *Sensitivity* and *specificity* are inversely proportional, i.e. as the sensitivity increases, the

specificity decreases and vice versa. *Precision* tells about, how many of test positives are true positives and if this number is higher or closer to 100 then, this test it suggests that this new test is doing as good as the defined standard. It can be computed as; $a(TP)/a(TP)+b(FP)$; NPV tells how many of test negatives are true negatives and the desired value is approximately 100 and then it suggests that this new test is doing as good as the defined standard. Computed as; $d(TN)/c(FN)+d(TN)$. Assuming all other factors remain constant, the PPV will increase with increasing prevalence; and NPV decreases with increase in prevalence.A false positive error or fall-out is a result that indicates a given condition has been fulfilled, when it actually has not been fulfilled, or erroneously a positive effect has been assumed. In other words, it is the proportion of all negatives that still yield positive test outcomes, i.e., the conditional probability of a positive test result given an event that was not present and computed as $b(FP)/b(FP)+d(TN)$ or 1-*Specificity*. An FNR is a test that result indicates a condition failed, while it actually was successful, or erroneously no effect has been assumed. In other words, it is the proportion of events that are being tested for which yield negative test outcomes with the test, i.e., the conditional probability of a negative test result given that the event being looked for has taken place and can be computed as, $c(FN)/a(TP)+c(FN)$ or 1-*Sensitivity*. FDR is a way of conceptualizing the rate of type I errors in null hypothesis testing when conducting multiple comparisons. FDR-controlling procedures are designed to control the expected proportion of rejected null hypotheses that were incorrect rejections or false discoveries and computed as, $b(FP)/b(FP)+a(TP)$ or 1-PPV. F-Score measure considers both the precision and the recall of the test to compute the score. It can be interpreted as a weighted average of the precision and recall, where an F-Score reaches its best value at 1 and worst at 0. It can be computed as: $2\times((Precision\times Recall)/(Precision\times Recall))$. MCC is used to measure the quality of binary classification. It takes into account true and false positives and negatives and is generally regarded as a balanced measure and can be used in case of imbalanced datasets. This is a correlation coefficient between the observed and predicted binary classification results. While there is no perfect way of describing the confusion matrix of true and false positives and negatives by a single number, MCC is generally regarded as being one of the best such measures and can be computed as: $((a\times d)-(b\times c))/\sqrt{(a+b)\times(a+c)\times(d+b)\times(d+c)}$. The accuracy determined for the classifiers may not be an adequate performance measure when the number of negative cases is much greater than the number of positive cases i.e. the imbalanced classes. Suppose, there are 1000 cases, 995 of which are negative cases and 5 of which are positive cases. If the system classifies them all as negative, the accuracy would be 99.5% even though the classifier missed all positive cases, in such cases G-mean comes into action. G-mean has the maximum value when sensitivity and specificity are equal and can be computed as: $\sqrt{Precision\times Recall}$. Youden's J Statistics is a way of summarizing the performance of a diagnostic test. For a test with poor diagnostic accuracy, Youden's index equals 0, and in a perfect test Youden's index equals 1. The index gives equal weight to false positive and false negative values, so all tests with the same value of the index give the same proportion of total misclassified results. This is $Sensitivity+Specificity\breve{}1$.

4 Structural and functional representation of proposed ensemble based prediction model

The schematic representation of the proposed model is shown in Figure 2. First the datasets are collected from three coastal district of Odisha and different parameters collected from the Odisha Agriculture Statistics, Director of Agriculture and Food Production, Govt. of Odisha, Bhubaneswar sources, and then the datasets are pre-processed. The proposed methodology is based on classifier ensemble method. The intension is to predict the rice yield for two seasons such as Rabi and Kharif with respect to the climatic variability of the coastal Odisha. This model uses five classifiers where four classifiers act as base classifier and one act as main classifier. List of classifier used are SVM, k-NN, DT, NB and LDA. Experiments are conducted by considering each classifier once as main classifier and remaining four as base classifiers by using MATLAB 10 at windows OS. Then, we get five different predicted outputs for rice production. Each classifier is build according the basic algorithm defined in literature [26] [31] [36] [38] [40] [43].

Let $B=\{b_1,\cdots,b_4\}$ be the four base classifiers, and $C=\{c_1,\cdots,c_4\}$ be the output of those four base classifiers. The output of each classifier is passed through a conversion function f to retrieve the production denoted as $\hat{S}$ as given below and this acts as input to main classifier.

$$\hat{S}_l=f(c_i) \tag{1}$$

Where f can be computed using equation (2)

$$f(c_i)=\frac{N}{|N|} \tag{2}$$

Where N is the sum of S_i which belongs to class c_i

Hence, main classifier will have input having *vector* $D=\{dataset,\hat{S}_1,\hat{S}_2,\hat{S}3,\hat{S}_4\}$. Result obtained after processing D by main classifier is compared expected output (y). Again equation (2) is used to compute the production based upon the class labels predicted.

Final prediction is made by using majority voting on the class label predicted by each classifier as main classifier (Figure 3). Throughout the paper **#** symbol is used before classifier for differentiating it with base classifiers

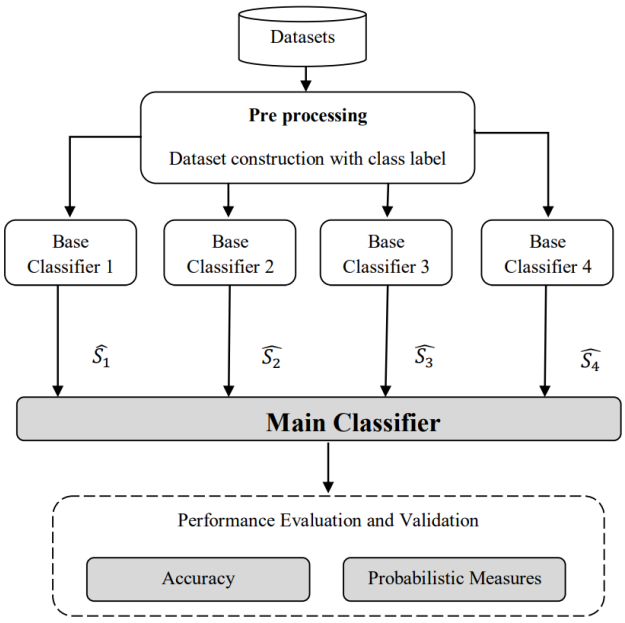


Figure 2: Schematic representation of proposed ensemble based prediction model

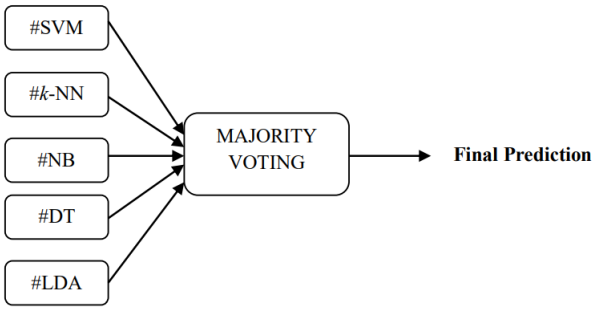


Figure 3: Majority voting applied on the main classifiers

5 Experimentation and model evaluation

This section elaborates the experimentation process starting from datasets chosen with their description, step wise representation of the working principle of proposed method and also the results are analyzed with respect to the average classification accuracy and the predictive performances used to validate the model.

5.1 Dataset description

Real dataset D is collected from three coastal regions of Odisha such as Balasore, Puri, Cuttack district. Let $d_i \in D \ \forall i = 1, \cdots, 31$ features where $|d_i| = 25$ represents the attributes of the datasets. Different parameters collected from the Odisha Agriculture Statistics, Director of Agriculture and Food Production, Govt. of Odisha, Bhubaneswar [46]; such as $p = \{max\ temperature, min\ temperature, rain\ fall, humidity\}$ that effect the rice production. Since, there are two types of rice production seasons such as; *Rabi* and *Kharif* produced between months "January - June" and "July –December", hence p_i is collected over the range of six months each resulting 24 set of attributes and 25$^{\text{th}}$ attribute is the production in hector of crops for particular year. The rice production graph for those three coastal areas of Odisha from the year 1983-2014 is shown in Figure (4a) and Figure (4b) for *Rabi* and *Kharif* season respectively. The detail description of datasets with standard deviation (Std. Dev) for three areas is shown in Table 1.

5.2 Construction of dataset for classification

Raw data collected have some missing value, and without class. One way is to deal with missing value is to simply replace it with most negligible positive real number. For classification, D must be in the form $D = \{d, y\}$, where d_i refers to *features* and y_i refers to *class label*. In order to predict the production of rice crop, one needs to properly define class label. One way is to use clustering and allocate each feature a class label similar to their cluster number. Looking to the random cluster index formed makes it difficult to build common class label for the feature. Hence, in our work we have proposed a *range based class label formation*. Let Sdenote the production column vector of dataset D and y_i can be formulated using equation (3).

$$y_i = \begin{cases} u \leq s_i < r & 1 \\ r \leq s_i < 2 \times r & 2 \\ r \leq s_i < 3 \times r & 3 \\ \cdots \quad \cdots & \cdots \\ k \times r \leq s_i < v & k \end{cases} \tag{3}$$

Where, $[u, v]$ is the min and max value of S given by equation (4), r is the offset for range formation given by equation (5) and $k = 5$. **Table 2** shows the number of year

Table 1: Description of real datasets collected over period 1983-2014 for Rabi and Kharif production

District	**Dimension**	**Rabi**		**Kharif**	
		Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
Balasore	31×25	47.8386	20.84	81.6430	43.7791
Cuttack	31×25	44.7391	18.43	80.6577	50.6339
Puri	31×25	47.6373	25.77	78.9684	44.2095

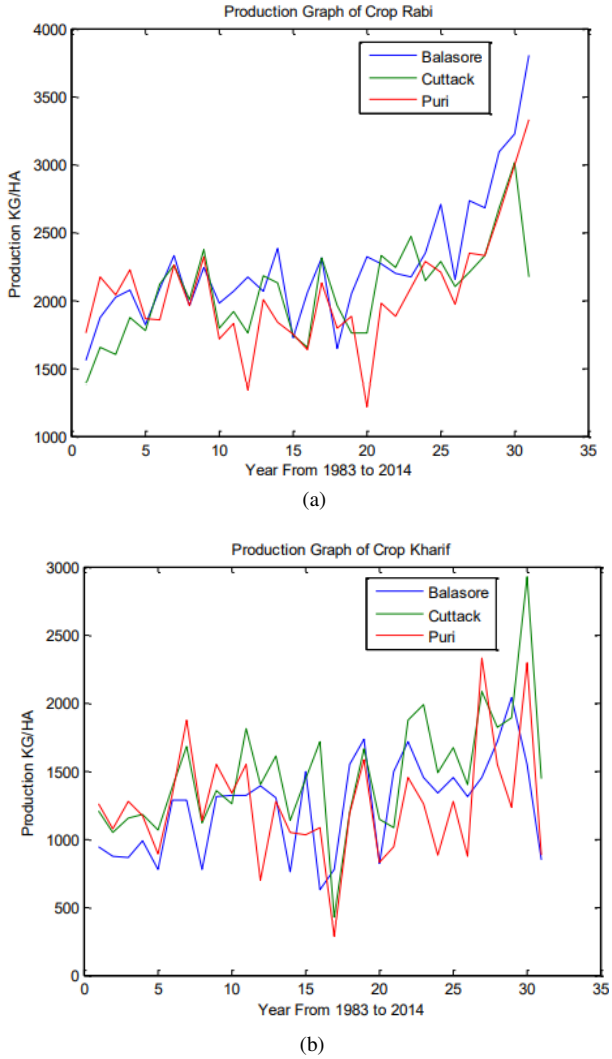


Figure 4: Graphical representation of rice production of three regions for *Rabi* and *Kharif* seasons

belonging to different k classes. That means, the total data of 31 years is divided into 5 classes.

$$u = min(S), \quad v = max(S) \tag{4}$$

$$r = (u - v)/k \tag{5}$$

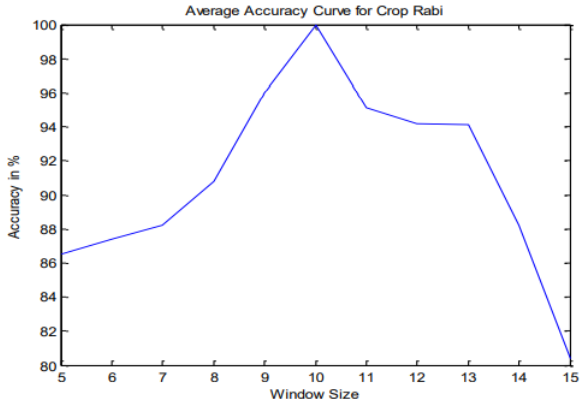
6 Result and performance analysis

Proposed architecture is implemented on Matlab 10 at Windows OS with min 2GB RAM and 2 GH Intel Processor. Dataset is given as input to the proposed architecture using sliding window concept. Window size of w feature is used for training and feature $w + 1$ is used for testing. **Figure (5a)** and (**5b**) shows the average accuracy curve gained by different set of window sizes w for *Rabi* and *Kharif* season crop productions respectively. From the both the figures it can be observed that for the window size of 10 and 12 the proposed architecture accuracy reaches 100% for *Rabi* and *Kharif* season datasets respectively.

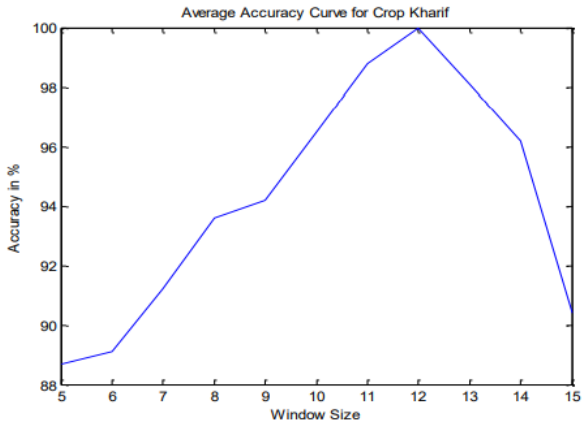
During the literature survey, we have explored various methods already used and found that the ensemble methods give better result in most of the cases. Then we have analysed all the ensemble methods and consider SVM, *K*-NN, NB, DT and LDA classifiers for our experimentation. At each iteration; four classifiers are chosen as base classifiers and the output of those base classifiers ($\hat{S}$) are passed though the conversion function f as given in equation (1) and (2) to the main classifier. The main classifier containing the input vector $D = \{dataset, \hat{S}_1, \hat{S}_2, \hat{S}_3, \hat{S}_4\}$, does the prediction. The result obtained after processing D by main classifier is compared expected output y. Final prediction is made by using *majority voting* on the class label

Table 2: Class label determination according to $k = 5$

Datasets/ Seasons	**District**	**Class**				
		1	**2**	**3**	**4**	**5**
Rabi	Balasore	8	12	4	3	4
	Cuttack	4	8	13	3	3
	Puri	3	12	10	3	3
Kharif	Balasore	9	3	9	7	3
	Cuttack	3	11	12	2	3
	Puri	3	8	12	5	3



(a)



(b)

Figure 5: Accuracy curve for selection of window size (w) for training data (**a**) *Rabi* and (**b**) *Kharif* seasons

predicted by each classifier as main classifier after each iteration. This process has been implemented by considering the window size $w = 10$ and $w = 12$ for both the *Rabi* and *Kharif* seasons datasets respectively. The average accuracy obtained for prediction of rice production in hector for *Rabi* season in hectors is shown in **Table 3**. The prediction curve of rice for *Rabi* season dataset for Balasore, Cuttack and Puri is shown in **Figure (6a), (6b)** and **(6c)**. From the **Figure 7** we can see that, the MV line touches the actual value of production line more than other classifiers and it proves that the ensemble MV method is better than the individual classifier.

It is clear from the **Table 3** that if we are applying each individual four classifier such as SVM, K-NN, NB, DT and LDA as main classifier then with majority voting (MV) then the accuracy of MV gives better accuracy. In case of Balasore, MV gives 98.21% accuracy than the other classifiers. Similarly, the same improved performance in case of Cuttack and Puri district also. From the figure 7 we can see that, the MV line touches the actual value of production line more than other classifiers and it proves that the ensemble MV method is better than the individual classifier.

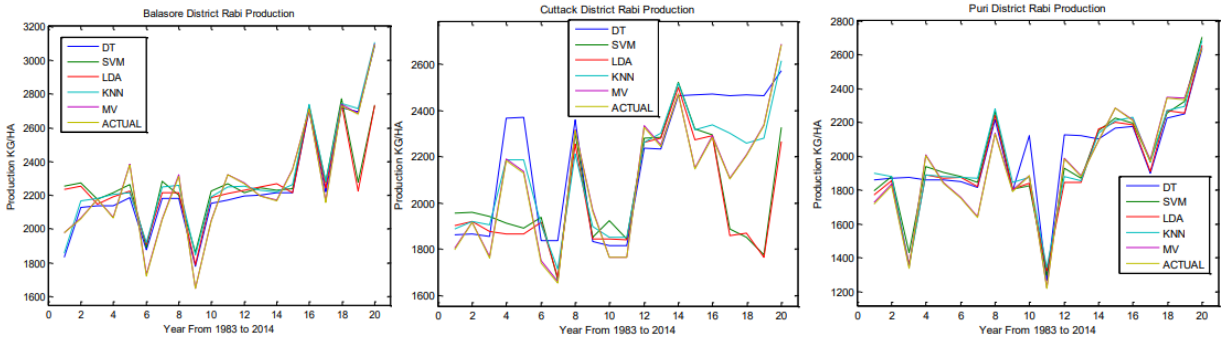
The average accuracy obtained for prediction of rice production in hector for Kharif season is shown from **Table 4**. The prediction curve of rice for Kharif season dataset for Balasore, Cuttack and Puri is shown in **Figure (7a), (7b)** and **(7c)**. In the **Table 4**, it shows that as in case of *Kharif* season dataset, the MV in the ensemble classifier gives better accuracy exceeding 96% for all three districts such as: Balasore, Cuttack, Puri like *Rabi* season. **Figure 7** shows that the MV line is touching the actual data line and gives the better result.

The datasets are imbalanced in nature i.e. the distribution of data elements for the classes varies a large giving rise to biased opinion and over generalization of classifiers towards a single class having large elements. In such type of situations, the average classification accuracy is not enough to prove the stability and validity of the classifiers. Therefore, in this paper, we have tried to establish the performance of proposed model by considering the specificity, sensitivity/recall, precision, NPV, FPR, FDR, F-Score, G-Mean, MCC and J-Statistics, and AUC. The value of each measure should lie between $[0 - 1]$, where 0 represents lower prediction ability and 1 represents the high prediction ability. The performance of the proposed prediction model for all three districts such as Balasore, Cuttack and Puri for *Rabi* season datasets are shown from **Table 5** to **Table 7** and from **Table 8** to **Table 10** for *Khariff* season datasets.

In the **Table 5** it shows that, the improvements of performance measures approaches towards 95.09% to 98.10% for specificity, 88.48% to 96.25% for both sensitivity and precision and 91.78% to 97.17% for AUC for *Rabi* season dataset of Balasore district. So we can see comparing all other main classifier, when SVM choosen as main classifier it gives better performance. Similarly for other performance measure the result is also like specificity.

Table 3: Average classification accuracy (%) of each classifier and one classifier as main classifier (preceded with **#**) for prediction of rice production in hector for *Rabi* season dataset

District	SVM	k-NN	NB	DT	LDA	# SVM	# k-NN	# NB	# DT	# LDA	MV
Balasore	86.29	80.61	82.25	84.88	81.25	97.48	95.91	93.11	95.62	93.40	98.21
Cuttack	87.99	84.06	86.48	86.45	85.93	95.67	94.55	94.08	96.79	95.16	97.13
Puri	89.61	88.99	87.60	90.39	92.02	99.25	96.11	95.83	98.33	94.60	99.61

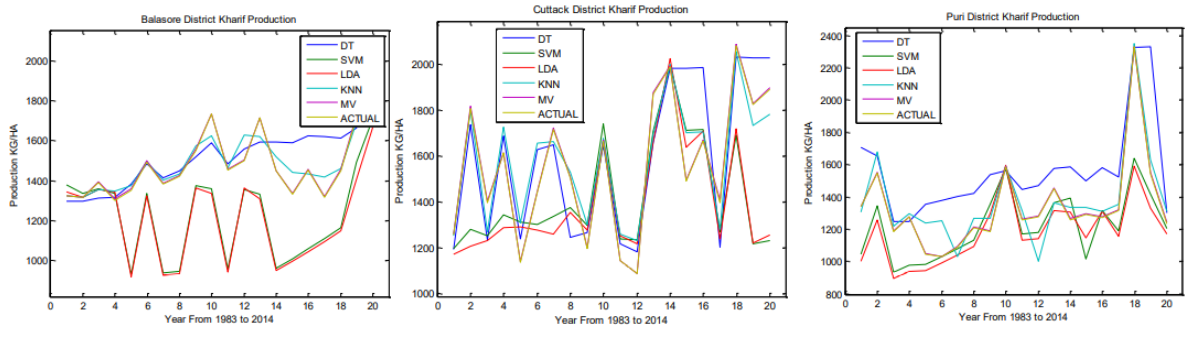


(a) (b) (c)

Figure 6: Rice production prediction curve for *Rabi* season dataset at (**a**) Balasore, (**b**) Cuttack, and (**c**) Puri districts

Table 4: Average classification accuracy (%) of each classifier and one classifier as main classifier (preceded with **#**) for prediction of rice production in hector for *Kharif* season dataset

District	SVM	k-NN	NB	DT	LDA	# SVM	# k-NN	# NB	# DT	# LDA	MV
Balasore	79.41	67.00	69.96	75.05	65.77	96.46	94.05	89.34	93.38	89.49	97.82
Cuttack	81.84	73.50	78.15	77.62	76.03	93.73	91.84	90.94	95.24	92.51	96.12
Puri	86.37	85.19	82.68	86.96	89.28	99.08	94.95	94.50	97.85	92.55	99.21



(a) (b) (c)

Figure 7: Rice production prediction curve for *Kharif* season dataset at (**a**) Balasore, (**b**) Cuttack, and (**c**) Puri districts

Table 6 shows the performance measure of *Rabi* season of Cuttack district. It seen that, the improvements of performance measures approaches towards 96.18% to 97.14% in case of specificity and NPV, 86.85% to 93.14% in case of sensitivity and precision. In this case when DT choosen as mainclassifier gives better result and in other performance measure also the same case. From the **Table 7** it can be seen that, the performance value improves from 96.80% to 99.54% in case of specificity, 82.55% to 98.02% in case of sensitivity and precision, 89.68% to 98.78% in case of AUC. Similarly others can be seen. In all case the SVM main classifier gives better result for Rabi season of Puri district.

In the **Table 8**, it is clear that, in case of *Kharif* season of Balasore district, SVM main classifier gives better performance than others in all performance measures.

In **Table 9** also the main classifier gives better performance than the individual classifier and the performance of specificity improves from 96.18% to 97.90%, 85.69% to 92.57% for sensitivity, precision and NPV. Here DT main

Table 5: Performance measures of rice production for *Rabi* season at Balasore district

Measures	SVM	k-NN	NB	DT	LDA	# SVM	# k-NN	# NB	# DT	# LDA
Specificity	89.83	86.39	87.57	89.35	87.27	98.10	96.99	95.09	96.85	95.38
Sensitivity	78.99	66.29	69.00	73.95	64.41	96.25	93.62	88.48	92.80	88.48
Precision	78.99	66.29	69.00	73.95	64.41	96.25	93.62	88.48	92.80	88.48
NPV	89.83	86.39	87.57	89.35	87.27	98.10	96.99	95.09	96.85	95.38
FPR	10.17	13.61	12.43	10.65	12.73	1.90	3.01	4.91	3.15	4.62
FNR	21.01	33.71	31.00	26.05	35.59	3.75	6.38	11.52	7.20	11.52
FDR5	21.01	33.71	31.00	26.05	35.59	3.75	6.38	11.52	7.20	11.52
F-Score	70.12	57.60	60.27	65.14	55.76	87.19	84.59	79.49	83.77	79.49
G-Mean	68.26	55.39	58.15	63.16	53.49	85.67	83.02	77.84	82.19	77.84
MCC	68.82	52.67	56.57	63.30	51.69	94.35	90.62	83.56	89.65	83.86
J-Statistics	65.76	49.84	53.68	60.31	48.90	91.13	87.41	80.39	86.45	80.68
AUC	84.41	76.34	78.28	81.65	75.84	97.17	95.31	91.78	94.83	91.93

Table 6: Performance measures of rice production for *Rabi* season at Cuttack district

Measures	SVM	k-NN	NB	DT	LDA	# SVM	# k-NN	# NB	# DT	# LDA
Specificity	92.18	89.96	91.42	91.46	91.22	97.14	96.45	96.18	97.9	96.89
Sensitivity	74.07	61.30	68.19	67.22	64.63	91.08	88.25	86.85	93.14	89.07
Precision	74.07	61.30	68.19	67.22	64.63	91.08	88.25	86.85	93.14	89.07
NPV	92.18	89.96	91.42	91.46	91.22	97.14	96.45	96.18	97.90	96.89
FPR	7.82	10.04	8.58	8.54	8.78	2.86	3.55	3.82	2.10	3.11
FNR	25.93	38.70	31.81	32.78	35.37	8.92	11.75	13.15	6.86	10.93
FDR	25.93	38.70	31.81	32.78	35.37	8.92	11.75	13.15	6.86	10.93
F-Score	65.26	52.71	59.46	58.51	55.97	82.07	79.26	77.88	84.11	80.08
G-Mean	63.28	50.32	57.32	56.34	53.71	80.46	77.60	76.19	82.53	78.43
MCC	66.25	51.26	59.60	58.67	55.85	88.22	84.70	83.03	91.04	85.96
J-Statistics	63.06	48.37	56.54	55.63	52.87	84.81	81.31	79.65	87.62	82.57
AUC	83.13	75.63	79.80	79.34	77.92	94.11	92.35	91.51	95.52	92.98

Table 7: Performance measures of rice production for *Rabi* season at Puri district

Measures	SVM	k-NN	NB	DT	LDA	# SVM	# k-NN	# NB	# DT	# LDA
Specificity	93.83	93.51	92.78	94.33	95.27	99.54	97.66	97.50	98.99	96.80
Sensitivity	67.25	63.74	56.15	68.38	74.56	98.02	88.64	87.50	95.27	82.55
Precision	67.25	63.74	56.15	68.38	74.56	98.02	88.64	87.50	95.27	82.55
NPV	93.83	93.51	92.78	94.33	95.27	99.54	97.66	97.50	98.99	96.80
FPR	6.17	6.49	7.22	5.67	4.73	0.46	2.34	2.50	1.01	3.20
FNR	32.75	36.26	43.85	31.62	25.44	1.98	11.36	12.50	4.73	17.45
FDR	32.75	36.26	43.85	31.62	25.44	1.98	11.36	12.50	4.73	17.45
F-Score	58.54	55.10	47.66	59.65	65.74	88.95	79.65	78.53	86.22	73.63
G-Mean	56.37	52.81	45.05	57.51	63.78	87.45	78.00	76.86	84.68	71.86
MCC	61.08	57.25	48.93	62.71	69.83	97.56	86.29	85.00	94.25	79.36
J-Statistics	57.55	53.83	45.75	59.16	66.13	93.57	82.36	81.09	90.27	75.51
AUC	80.54	78.63	74.46	81.36	84.92	98.78	93.15	92.50	97.13	89.68

Table 8: Performance measures of rice production for *Kharif* season at Balasore district

Measures	SVM	k-NN	NB	DT	LDA	# SVM	# k-NN	# NB	# DT	# LDA
Specificity	89.83	86.39	87.57	89.35	87.27	98.10	96.99	95.09	96.85	95.38
Sensitivity	68.99	47.60	52.36	60.76	44.26	94.81	91.10	83.60	89.92	83.60
Precision	68.99	47.60	52.36	60.76	44.26	94.81	91.10	83.60	89.92	83.60
NPV	68.99	47.60	52.36	60.76	44.26	94.81	91.10	83.60	89.92	83.60
FPR	89.83	86.39	87.57	89.35	87.27	98.10	96.99	95.09	96.85	95.38
FNR	10.17	13.61	12.43	10.65	12.73	1.90	3.01	4.91	3.15	4.62
FDR	31.01	52.40	47.64	39.24	55.74	5.19	8.90	16.40	10.08	16.40
F-Score	31.01	52.40	47.64	39.24	55.74	5.19	8.90	16.40	10.08	16.40
G-Mean	60.25	39.34	43.96	52.17	36.10	85.77	82.09	74.67	80.92	74.67
MCC	58.13	36.25	41.16	49.76	32.77	84.22	80.48	72.92	79.29	72.92
J-Statistics	58.81	33.99	39.93	50.11	31.53	92.91	88.09	78.69	86.77	78.98
AUC	54.94	30.91	36.63	46.49	28.61	88.59	83.80	74.48	82.48	74.78

Table 9: Performance measures of rice production for *Kharif* season at Cuttack district

Measures	**SVM**	**k-NN**	**NB**	**DT**	**LDA**	**# SVM**	**# k-NN**	**# NB**	**# DT**	**# LDA**
Specificity	92.18	89.96	91.42	91.46	91.22	97.14	96.45	96.18	97.90	96.89
Sensitivity	71.50	57.05	64.88	63.78	60.84	90.32	87.23	85.69	92.57	88.13
Precision	71.50	57.05	64.88	63.78	60.84	90.32	87.23	85.69	92.57	88.13
NPV	71.50	57.05	64.88	63.78	60.84	90.32	87.23	85.69	92.57	88.13
FPR	92.18	89.96	91.42	91.46	91.22	97.14	96.45	96.18	97.90	96.89
FNR	7.82	10.04	8.58	8.54	8.78	2.86	3.55	3.82	2.10	3.11
FDR	28.50	42.95	35.12	36.22	39.16	9.68	12.77	14.31	7.43	11.87
F-Score	28.50	42.95	35.12	36.22	39.16	9.68	12.77	14.31	7.43	11.87
G-Mean	62.73	48.54	56.21	55.14	52.26	81.32	78.25	76.73	83.55	79.15
MCC	60.69	45.97	53.96	52.84	49.85	79.70	76.58	75.03	81.96	77.49
J-Statistics	63.69	47.01	56.30	55.24	52.06	87.47	83.68	81.87	90.48	85.02
AUC	60.32	44.04	53.09	52.06	48.97	83.81	80.05	78.26	86.80	81.38

Table 10: .Performance measures of rice production for *Kharif* season at Puri district

Measures	**SVM**	**k-NN**	**NB**	**DT**	**LDA**	**# SVM**	**# k-NN**	**# NB**	**# DT**	**# LDA**
Specificity	93.83	93.51	92.78	94.33	95.27	99.54	97.66	97.50	98.99	96.80
Sensitivity	78.91	76.87	72.58	79.58	83.29	98.61	92.24	91.49	96.70	88.29
Precision	78.91	76.87	72.58	79.58	83.29	98.61	92.24	91.49	96.70	88.29
NPV	78.91	76.87	72.58	79.58	83.29	98.61	92.24	91.49	96.70	88.29
FPR	93.83	93.51	92.78	94.33	95.27	99.54	97.66	97.50	98.99	96.80
FNR	6.17	6.49	7.22	5.67	4.73	0.46	2.34	2.50	1.01	3.20
FDR	21.09	23.13	27.42	20.42	16.71	1.39	7.76	8.51	3.30	11.71
F-Score	21.09	23.13	27.42	20.42	16.71	1.39	7.76	8.51	3.30	11.71
G-Mean	70.04	68.03	63.79	70.69	74.37	89.53	83.22	82.48	87.64	79.30
MCC	68.18	66.12	61.78	68.86	72.61	88.05	81.63	80.88	86.13	77.65
J- Statistics	72.74	70.38	65.36	73.91	78.56	98.15	89.89	88.99	95.69	85.09
AUC	70.03	67.70	62.74	71.19	75.80	95.30	87.06	86.16	92.84	82.28

classifier gives better performance. In other performance cases also DT gives better. So it is seen that in case of Kharif season also DT gives better as in case of Rabi season of Cuttack district.

In **Table 10** it is seen that, the performance of specificity improves from 96.80% to 99.54%, 88.29% to 98.61% in case of sensitivity, precision and NPV. Here also SVM main classifier gives better performance than others. Also in case of all other performance measures, SVM gives better result than other main classifiers.

By summarizing the result part we can get that the main classifier of the ensemble method gives better result than the individual classifier. From all the main classifiers, the SVM gives better in case of Balasore and Puri district but DT gives better result in case of Cuttack district. But DT result is not more enough than the SVM. So we can conclude that, when we are considering SVM as main classifier then getting better result. So overally it concludes that the ensemble method gives better performance than the individual classifiers.

7 Discussions

This work aimed at development of a computational model for prediction of rice yield by considering the effect of climatic variability for the coastal state of India i.e. Odisha. The districts such as Balasore, Cuttack and Puri were considered for Rabi and Kharif seasons. For experimentation we have used five classifiers such as SVM, k-NN, NB, DT and LDA. The following points summarize this work;

- The datasets were first constructed and class labels are identified.
- The window size for training is chosen for Rabi ($w = 10$) and Kharif ($w = 12$) season datasets experimentally.
- A multi-classifier based ensemble model has been proposed where, four classifiers are chosen as base classifiers and the output of those base classifiers ($\hat{S}$) are passed though the conversion function f as to the main classifier.
- The main classifier containing the dataset augmented with the output of base classifiers is used for the prediction.
- The result obtained after processing augmented dataset by main classifier is compared expected output.
- Final prediction is made by using majority voting on the class label predicted by each classifier as main classifier.
- The effectiveness of proposed model has been verified by measuring the average classification accuracy for all the individual classifiers, main classifiers and the final result obtained after majority voting.

- It can be observed from **Table 3** and **Table 4** that, the average classification accuracy obtained after majority voting is above 96% for both *Rabi* and *Kharif* season datasets, because in this model it considers the best classifiers predicted output for finding the final predicted output.
- It is also evident that, the improvements of performance measures approaches towards 95.09% to 98.10% and 95.38% to 98.10% for specificity, 88.48% to 96.25% and 83.60% to 94.81% for both sensitivity and precision and 91.78% to 97.17% and 74.48% to 88.59% for AUC for Rabi and Kharif seasons dataset of Balasore district which is observed in the **Table 5** and **Table 8**.
- The improvements of performance measures are 96.45% to 97.14% and 96.18% to 97.90% for specificity, 86.85% to 93.14% and 87.23% to 92.57% for both sensitivity and precision and 91.51% to 95.52% and 78.26% to 86.80% for AUC for *Rabi* and *Kharif* seasons dataset of Cuttack district described in the **Table 6** and **Table 9**.
- Similarly, the improvements of performance measures are 96.80% to 99.54% and 96.80% to 99.54% for specificity, 82.55% to 88.64% and 88.29% to 98.61% for both sensitivity and precision and 89.68% to 98.78% and 82.28% to 95.30% for AUC for *Rabi* and *Kharif* seasons dataset of Puri district which can be observed in the **Table 7** and **Table 10**.

8 Conclusion

Due to variation in temperature, humidity, precipitation and other metrological variable in a particular area for a period of at least 25 years the expected crop yields are not produced in India. Odisha's climate has also under gone appreciable changes due to various factors. The deviation in day temperature and annual rain fall is mostly restricted to 4 months in a year and number of rain days decreased from 120 to 90 days besides being erratic. In addition, the mean temperature is increasing and minimum temperature has increased about 25 %. Such climate change related adversity is affecting adversely productivity and production of food grains. The production of rice mainly depends on climatic parameters such as rainfall, temperature, humidity, wind speed etc. If the farmers will be able to know the timely variation in climatic conditions they can get the timely advice to increase the production. Therefore, in this work we have proposed machine learning based multi-classifier approach of ensemble learning mechanism using majority voting approach to predict the rice yield based on thirty years rice production as well as climate original datasets. Our model shows above 96% classification accuracy and also the performance of the proposed model has been compared with individual classifiers and shows that the main classifier gives better result than the individual classier. Additionally, the classifier's accuracy validity and statistical test are conducted to establish the performance of the model. This model can give prediction value of the rice production, but can't explain which parameter affect mostly for the production. This limitation can be extended by the researcher. This ensemble based prediction model can also be extended for prediction of different crop yield.

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Extreme Learning Machines with Feature Selection Using GA for Effective Prediction of Fetal Heart Disease: A Novel Approach

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Heart disease is considered to be the most life-threatening ailment in the entire world and has been a major concern of developing countries. Heart disease also affects the fetus, which can be detected by cardiotocography tests conducted on the mother during her pregnancy. This paper analyses the presence of heart disease in the foetus by optimizing the Extreme Learning Machine with a novel activation function (roots). The accuracy of predicting the heart condition of the foetus is measured and compared with other activation functions like sigmoid, Fourier, tan hyperbolic, and a user-defined function, called "roots". The best features from the Cardiotocography data set are selected by applying the Genetic Algorithm (GA). ELM with activation functions sigmoid, Fourier, tan hyperbolic, and roots (a novel function), have been measured and compared on accuracy, sensitivity, specificity, precision, F-score, area under the curve (AUC), and computation time metrics. The GA uses three types of regression: linear, lasso, and ridge, for cross-validation of the features. ELM with user-defined activation function shows comparable performance with sigmoid and hyperbolic tangent functions. Features selected from linear and lasso produce better results in ELM than those selected from the ridge. It gives an accuracy of 96.45% as compared to 94.56% and 94.56% respectively with the best features selected from both linear and lasso. The roots activation function also takes 2.50 seconds computation time versus 3.27 seconds and 2.67 seconds for sigmoid and hyperbolic tangent respectively and scores better on all other metrics in designing an efficient model to classify fetal heart disease.

Povzetek: Z metodami strojnega učenja in genetskih algoritmov je analizirana bolezen srca pri fetusih.

1 Introduction

Cardiovascular disease is growing at a very fast rate and as per WHO, 30% of world population deaths occur due to cardiovascular heart diseases, and 23.6 million are expected to be affected by this disease by 2030 [3]. Cardiac disease is not only present in adults but can also be present as a birth anomaly in a newborn child and causes neonatal fatalities. The heart health of the fetus can be monitored to detect abnormal heartbeats and predict diseases affecting the fetus. Thus, predicting the cardiac health of a fetus is the need of the hour. Cardiotocography is one of the most commonly used Nonstress Tests which helps in determining the fetus's well-being in the womb and during labor. Cardiotocography consists of uterine contractions and fetal heart rate. Fetal heart rate includes attributes like baseline heart rate, variations in baseline heart rate, accelerations, decelerations, and uterine contractions. This test is very useful in studying the base heart rate and uterine contractions pattern and is a vital tool for medical experts to know when a fetus is suffering from an inadequate supply of blood or oxygen to the body or any of its parts. As per the important factors identified by the National Institute of Child Health and Human Development (NICHD), baseline heart rate and its variability, accelerations, deceleration and Nonstress test (NST) are important factors to be considered while examining the well-being of the fetus [24].

The cardiotocography test is carried out by a device

called Electronic Fetal Monitor [27] which gives two signals fetal heart rate (FHR) and uterine contractions (UC). NST and contraction stress test (CST) are two main components of a CTG [8]. The NST determines whether the fetus is distressed and CST determines the placenta's respiratory function.

The normal range of FHR baseline lies between 110 bpm and 160 bpm. If the FHR baseline is higher than 160 bpm for more than 10 minutes, the fetus is considered to be suffering from tachycardia. On the other hand, if the FHR baseline is less than 110 bpm for more than 10 minutes is called bradycardia [6]. Both tachycardia and bradycardia are signs of fetal distress. The conditions are found out from NST which determines the fetal reactivity i.e. the interaction between the sympathetic and parasympathetic autonomous nervous system of the fetus.

Recently machine learning with the use of artificial intelligence has become an important and powerful tool for predicting the heart health of patients. They are effective in both binary and multi-class classification and are effective in predicting cardiac disease. One of the effective tools which are being used for the learning process for single hidden layer feeds forward neural networks (SLFNs) is called extreme learning machine (ELM) [2]. The prime benefit of ELM is that the hidden layer of SLFNs does not require tuning and it also has a fast rate of convergence [13]. The learning speed of ELM is considered to be thousands of times faster than the traditional feed-forward network learning algorithms [11]. Our study mainly focuses on using GA for feature selection and studying the accuracy of ELM using different activation functions.

The following section describes the details of the data set, implementation of ELM as a Classifier that uses the best features identified by the Genetic algorithm. The cross-validation methods used for obtaining the best features are studied thoroughly to study the impact of ELM with four activation functions. The purpose is to study the effectiveness of the novel activation function by comparing it with existing activation functions.

2 Methods

2.1 Workflow diagram

The process flow of our proposed model is as described below in Figure 1. The data set is considered with output class NSP and is pre-processed to remove duplicate entries. Using GA for obtaining the best features, the model is cross-validated with 3 regression models and the performance of ELM is studied before and after feature selection with the existing and novel activation function.

2.2 Dataset details

The Cardiotocography Data Set, obtained from UCI repository [9], has been used for our study and experimentation. The data set originally has 2126 instances with 23 attributes. The CTGs were also classified by three expert obstetricians into 2 types of classes including the class pattern (1-10) and fetal state class (N=Normal, S=Suspect, P= Pathologic). The data set has 21 attributes and two output classes. Our experiment is focused on considering all 21 attributes along with one output class. Similar to other studies conducted on this data set, our experiment also considers 22 attributes where 21 attributes are inputs and the 22nd attribute is the output class "NSP". We have not considered the other output class "CLASS" for our study. 21 attributes with NSP as the output class, described in Table 1.

2.3 Data pre-processing and splitting of data sets for model training

Other than the aforementioned 21 features and the output columns, 'CLASS' and 'NSP', the original database has 23 other columns, which were removed. Thereafter, the data set, named 'DT', were split into two subset data sets 'DT_CLASS' and 'DT_NSP' containing 'CLASS' and 'NSP' respectively. 12 duplicate rows were deleted, and the last four rows containing null values were also removed.

The data set of DT_NSP was split to an 80:20 ratio to train the classifiers on 80% of the data and perform the testing on the remaining 20% of the data.

2.4 Feature Selection and classification

Feature Selection is an important part of designing a predictive model to reduce unwanted features and also to reduce the training time of classifiers. In this paper, the important features are identified by using the Genetic Algorithm.

The training data set were given as input to ELM with different activation functions and their accuracy was studied. Linear, lasso, and ridge regression models have been used for cross-validation of candidate feature subsets generated by GA. The attributes selected are considered as best features and the classification algorithms performance has been tabulated.

2.4.1 Genetic Algorithm (GA)

The genetic algorithm is a simple Evolutionary search heuristic algorithm that randomly generates a new population. Its basic objective is to find the attributes with maximum fitness value in the population [14]. Based on the Darwinian Principle, it tries to find the fittest individuals. The entire set of candidate solutions is called a population and each solution is called an individual. Our Genetic algorithm searches for the solution which gives the minimum cross-validation error through linear, lasso, and ridge regression models. The chromosomes are generated with fitness values as true or false for each attribute and after iterating for the total number of generations the features are determined which are best fit to predict the outcome. GA

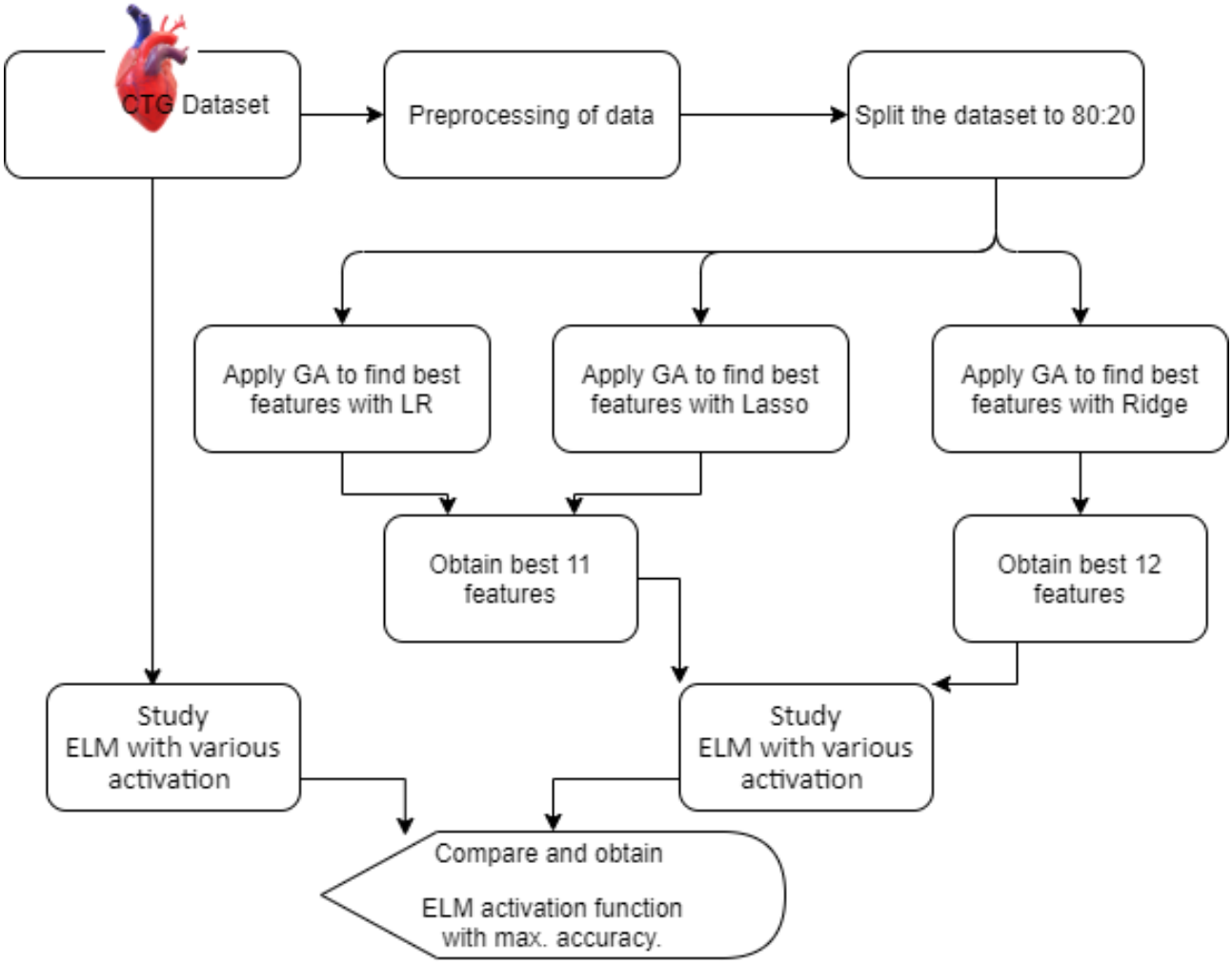

Figure 1: Process flow diagram to study impact of feature selection on ELM with various activation functions.

depends upon the number of generations, number of chromosomes, number of children created during the crossover, and best chromosomes. Depending upon the best fitness values, parents are selected for mating [1]. Crossover has been carried out with 2 parents and mutated to generate the new population and the process was repeated for 20 generations after which the fitness value of features remained constant. Finally, the features with the best fitness values are obtained.

Regression models: It is a supervised method in machine learning to find the correlation of dependant variables in terms of the independent variables. It is effectively used for dimensionality reduction of collinear or multi-collinear variables. The following regression models are used in GA:

Linear Regression: The equation can be written as shown in Equation 1.

$$y = \beta_0 + \sum_{k=1}^{p} of \beta_{ik} x_{ik} \tag{1}$$

Ridge: This method uses L2 regularization, where L2 is the penalty equivalent [23] to the sum of the magnitude of coefficients. This type of regression [22] helps in dealing with a variance that is resultant of the multi-collinearity of variables. It helps in reducing the variance which is a resultant of non-linear relationships between two independent variables.

Lasso: This model is based on L1 regularization in which the least related variables are treated as zero. So, it helps minimize irrelevant features. It adds a penalty to minimize the loss of a model. L1 is the penalty added to the sum of the absolute value of coefficients. For the objective function (Equation 2),

$$\frac{\sum_{I=1}^{N} off(x_i,\ y_i,\ \alpha,\ \beta)}{N} \tag{2}$$

the lasso regularized version of the estimator will be the solution to the Equation 3.

$$\min_{\alpha,\ \beta} of \frac{\sum_{I=1}^{N} off(x_i,\ y_i,\ \alpha,\ \beta)}{N}, \text{subject to } \|\beta\|_1 < t \tag{3}$$

Attributes	Description
LB	Fetal base line heart rate
AC	Accelerations per second
FC	Fetal movements per second
UC	Uterine contractions per second
ASTV	percentage of time with abnormal short-term variability
mSTV	mean value of short-term variability
ALTV	percentage of time with abnormal long-term variability
mLTV	mean value of long-term variability
DL	mean light decelerations per second
DS	mean severe decelerations per second
DP	mean prolonged decelerations per second
Width	mean histogram width
Min	low frequency of the histogram
Max	high frequency of the histogram
NMax	number of histogram peaks
Nzeros	number of histogram zeros
Mode	histogram mode
Mean	histogram mean
Median	histogram median
Variance	histogram variance
Tendency	histogram tendency: -1=left asymmetric; 0=symmetric; 1=right asymmetric

Table 1: Cardiotocography (CTG) Data set with detail description of attributes.

where only β is penalized while α is free to take any allowed value, just as β_0 was not penalized in the basic case, and t is a pre-specified free parameter that determines the amount of regularisation.
The basic algorithm used for feature selection through GA is as follows:

1. The initial population was randomly initialized by creating individuals that included/excluded certain features. One particular individual may have the chromosome, as shown in Figure 2, where each box represents a gene, or feature in the data set, green indicates "True" (the feature is included in the chromosome) and red indicates "False" (the feature is excluded from the chromosome).

2. For each generation:

   (a) The fitness score is calculated for an individual as follows:

      i. Using regression models, the presence or absence of the feature is determined. The target is modeled with the features with values like 1 for being present and 0 for being absent.
      For example, if the individual illustrated in Figure 2 is taken, then all the features, excluding the 2nd, 8th, 12th, and 17th features, are taken for modeling.

      ii. The cross-validation scores were determined using negative mean square error (NMSE), calculated as shown in Equation 4.

$$NMSE = -\frac{\sum_{i=1}^{n} of\left(x_i - \frac{\sum_{i=1}^{n} ofx_i}{n}\right)^2}{n} = \left(\frac{\sum_{i=1}^{n} ofx_i}{n}\right)^2 - \frac{\sum_{i=1}^{n} ofx_i^2}{n} \quad (4)$$

      iii. The mean of the cross-validation scores was assigned to the fitness value.

   (b) The individuals were sorted in the increasing order of their fitness values.

   (c) The last n individuals (which are the best n individuals of the population) were selected out of the population.

   (d) In the selected individuals, for number i in the range of $\lfloor \frac{n}{2} \rfloor$, the i^{th} and $(n-i)^{th}$ individuals were crossed as shown in Figure 3.

   (e) The daughter chromosome was mutated as shown in Figure 4 to generate new population:

3. The fittest individual was selected and its genes were recorded.

2.5 ELM for multi class classification

Extreme Learning Machines are effective single-layer feed-forward networks (SLFNs) with hidden neurons that do

Figure 2: A typical chromosome with 21 features

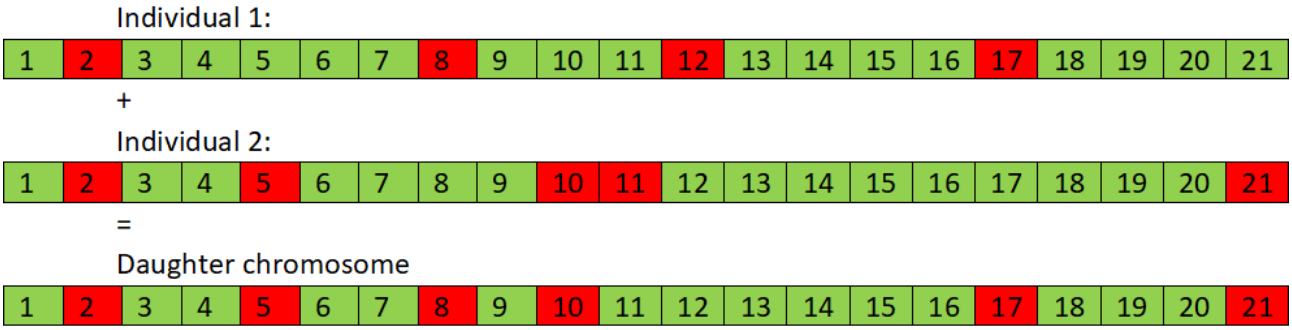

Figure 3: Crossing over of two chromosomes

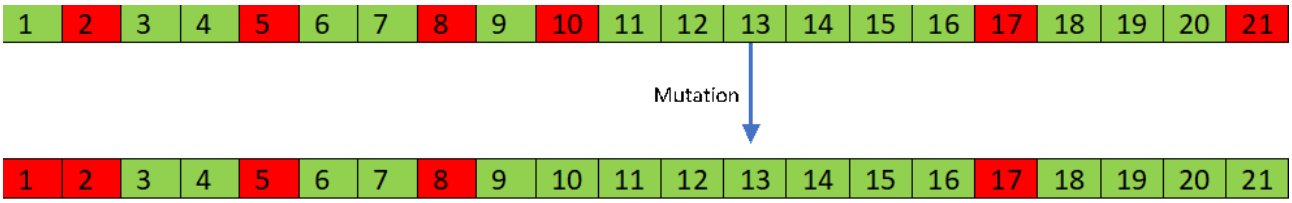

Figure 4: Daughter Chromosome with 21 features undergoing mutation

not require further tuning [17] and can very effectively be trained with minimum time for classification, regression, and feature selection. ELM randomly assigns connections between the input layer and the hidden neurons and they do not change further during the learning process. The output connections are then adjusted to obtain the solution with minimum cost [12]. There are various types of ELM like Simple ELM, ELM of ensembles, Pruned ELM, and incremental ELM [17][12].

In our study, a simple ELM is studied with [5][19] sigmoid, hyperbolic tangent, Fourier and roots activation functions, and their performances have been compared based on training time, accuracy, specificity, F measure score, sensitivity, precision, and AUC.

Basic ELM can be represented as:

For N arbitrary distinct samples $(x_i,\ t_i) \in R^d \times R^m$, SLFNs with L hidden nodes having parameters $(a_i,\ b_i),\ i \in \{1,\ 2,\ \ldots,\ L\}$ are mathematically modelled as in Equation 5.

$$\begin{aligned}\sum_{i=1}^{L} of\beta_i\ g_i(x_j) &= \sum_{i=1}^{L} of\beta_i G(a_i, b_i, x_j) \\ &= o_j,\ j \in \{1, 2, \ldots, N\}\end{aligned} \tag{5}$$

Where β_i, is the output weight of the i^{th} hidden node and $g(x)$ is an activation function.

SLFNs approximates these N samples with zero error. Mathematically, it can be represented as in Equations 2.5 and 2.5

$$\sum_{j=1}^{L} of\|o_j - t_j\| = 0 \tag{6}$$

$$\begin{aligned}&\exists\ (a_i,\ b_i),\ \beta_i\ | \\ &\sum_{i=1}^{L} of\beta_i\ G(a_i,\ b_i,\ x_j\ ) = t_j, j \in \{1, 2, \ldots, N\}\end{aligned} \tag{7}$$

equations and can be written compactly as in Equations 8

$$H\beta = T \tag{8}$$

where,

$$\begin{aligned}H\ &= \begin{bmatrix} h_1 \\ \vdots \\ h_n \end{bmatrix} \\ &= \begin{bmatrix} G(a_1, b_1, x_1) & \ldots & G(a_L, b_L, x_1) \\ \vdots & \ddots & \vdots \\ G(a_1, b_1, x_N) & \vdots & G(a_L, b_L, x_N) \end{bmatrix}_{N \times L}\end{aligned} \tag{9}$$

$$\beta = \begin{bmatrix} \beta_1^T \\ \vdots \\ \beta_N^T \end{bmatrix}_{L \times m} \tag{10}$$

$$T = \begin{bmatrix} t_1^T \\ \vdots \\ t_N^T \end{bmatrix}_{N \times m} \tag{11}$$

If X and Y denote the input and output of the function, W_1 and W_2 denote the weight and bias matrices, and G denotes the activation function, then for an ELM learning a model of the form given in Equation 12, W_1 is initialized randomly and W_2 is estimated as shown in Equation 13

$$Y = W_2 G(W_1 X) \tag{12}$$

$$W_2 = G(W_1 X)^{+} Y \tag{13}$$

where $+$ denotes Moore-Penrose inverse.

Four different non-linear activation functions have been used in our experiment out of which one function is user-defined. The list of functions used are mentioned in Equations 14-17.

Sigmoid Function:

$$G(a, b, x) = \frac{1}{1 + e^{-(ax+b)}} \tag{14}$$

Fourier Function:

$$G(a, b, x) = \sin(ax + b) \tag{15}$$

Hyperbolic Tangent Function:

$$G(a, b, x) = \tanh(ax + b) \tag{16}$$

Roots Function (User-defined):

$$G(a, b, x) = \begin{cases} 0, x = \frac{-b}{a} \\ \frac{|ax+b|^{n+1}}{ax+b}, x \neq \frac{-b}{a} \end{cases} \tag{17}$$

where $n \in R$ is a parameter, which can take any value between 0 and 1. If the value of n is given as 1, then it becomes a linear function.

The various activation function graph is attached in Fig.5.

3 Results

3.1 Experimental setup

All computations are performed on Intel (R) Core (TM) i5-10210U CPU @2.11GHz with 64bit Windows 10 operating system. Moreover, Python 3.6.5 software package is used to simulate the experiments.

3.2 Metrics and analysis

In the CTG dataset, the output class with value 3 is pathological cases, and our experiment focuses on finding out pathological cases so that they can be used to predict the heart disease of the fetus.

The features selected from GA by applying linear regression and lasso for cross-validation, yield the same set of features and the best 11 features are considered, which are LB, UC, DS, DP, ASTV, ALTV, MLTV, Width, Max, Median, and Variance. The model performance is also measured by applying ridge regression, which considers the best 12 features, which are LB, UC, DS, DP, ASTV, ALTV, MLTV, Min, Max, Nmax, Median, and Variance.

The roots function has been tested with values for n as 0.25, 0.4, and 0.5. The number of hidden units considered for the study is 200. The various metrics used for comparison include confusion matrix, precision, accuracy, F measure, and AUC.

The confusion matrix taken for the classification of pathological cases in the CTG data set is shown in Table 2.

Predicted → Actual ↓	1	2	3
1	TN	TN	FP
2	TN	TN	FP
3	FN	FN	TP

Table 2: Confusion matrix

where,

- TP: True positive, where output class 3 is predicted as pathological case
- TN: True negative, where output classes 1 and 2 are predicted as non-pathological (normal or suspect) case
- FP: False positive, where output classes 1 and 2 are predicted as pathological case, and
- FN: False-negative, where output class 3 is predicted as non-pathological case.

The metrics used for measuring classification success are mentioned in Equations 18-23.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{18}$$

$$Sensitivity = \frac{TP}{TP + FN} \tag{19}$$

$$Specificity = \frac{TN}{TN + FP} \tag{20}$$

$$Precision = \frac{TP}{TP + FP} \tag{21}$$

$$F\ measure = \frac{2 \times Precision \times Sensitivity}{Precision + Sensitivity} \tag{22}$$

$$AUC = \frac{Sensitivity + Specificity}{2} \tag{23}$$

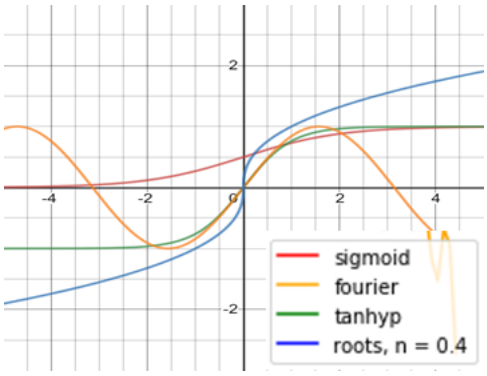

Figure 5: Graph of various activation functions in ELM

The inbuilt ELM module python has been compared with ELM models with sigmoid, Fourier, hyperbolic tangent, and roots (n = 0.25, 0.4, 0.5) based on their accuracy for predicting heart disease before and after feature selection. The results are tabulated as shown in Table 3.

The built-in ELM function in python suffers from the problem of under-fitting for which our study focuses on an alternate set of activation functions to be used for building the model. The graph to measure the accuracy of different activation functions with varying hidden nodes before feature selection is shown in Figure 6. The user-defined activation function, which has been named as "roots" is plotted against the other available functions of ELM. Our model outperforms other in-built functions in terms of accuracy in many instances when hidden inputs are varied from 0 to 1000.

When hidden inputs cross 200 units, the graphs of a sigmoid, hyperbolic tangent and roots activation functions are almost consistent. The hidden inputs are fixed at 200, to study other metrics for evaluating the roots function performance.

It is also observed from Table 3, the function of that root with n=0.4 has given optimum results. The graphs have been plotted with n=0.4 while using the function of the root for ELM. Figure 7 shows the graph after using selected features from linear regression and Lasso in GA. Figure 8 shows the results of ELM with features selected from Ridge regression in GA.

The results showed that ELM with Sigmoid, Roots and Hyperbolic tangent activation functions performed better than the Fourier activation function. The Fourier activation function is not considered for further study as it is not sensitive to feature selection. The three functions were then analyzed based on their computation time and other metrics for classifying pathological cases. It depicts that the function of the roots takes lesser time than sigmoid and tan hyp to compute the results for the testing samples. The activation functions of ELM were studied with the original feature set and a reduced feature set by applying GA and results have been tabulated in Table 4 and Table 5.

When compared to selected features using GA with ridge, GA with Linear and Lasso regression yielded better performance on all metrics. The graph in Figure 6 shows the performance of the 4 activation functions before applying feature selection. The performance of ELM models improved after feature selection using the three activation functions sigmoid, hyperbolic tan, and roots(n=0.4). The roots activation function performed better than the other 2 activation functions. Figure 7 depicts the graph for measuring the performance of ELM after feature selection. The best features derived from Linear and Lasso cross-validation in GA have been used to plot the graph. Another graph shows the improved performance of ELM after using feature selection from best features obtained from Ridge with GA and is shown in Figure 8. The results are dependent upon the number of hidden inputs taken and can change. It has also been observed that by varying the hidden inputs from 0 to 1000, ELM with roots activation function, has outperformed in classification in the majority of the cases.

The standard inbuilt ELM remains unaffected and even the performance degrades after feature selection. Its performance reduced from 11.11% to 10.17% after using feature selection. However, the customized ELMs show improvement in terms of accuracy. The ELM with sigmoid function has improved from 92.67 to 94.56%, with hyperbolic tangent function the performance improved from 93.14 to 94.56% and with roots activation function (n=0.4) the accuracy improved from 94.33 to 96.45%. The ELM with Fourier activation function remains unchanged before and after feature selection and has given 90.07% accuracy throughout the experiment.

4 Discussion

Various fetal disease prediction systems have been proposed for diagnosing the fetus's health. The works have been carried out on Cardiotocography data set using either all the features or a subset of them. One of the study [30] focuses on using various types of ANN like MLPNN, PNN, and GRNN models using the entire data set to identify the fetal state and have reported the overall classification accuracy's for MLPNN, PNN, and GRNN as 90.35, 92.15, and

Classifier	Before Feature Selection	After Feature Selection		
		Linear	Lasso (α = 0.0001)	Ridge (α = 0.0001)
ELM inbuilt in Python	11.11	10.17	10.17	10.16
ELM with new activation function(n=0.25)	94.56	95.98	95.98	95.74
ELM with new activation function(n=0.4)	94.33	96.45	96.45	95.04
ELM with new activation function(n=0.5)	94.8	96.21	96.21	95.04
ELM with sigmoid activation	92.67	94.56	94.56	94.33
ELM with Fourier activation	90.07	90.07	90.07	90.07
ELM with hyperbolic tangent activation	93.14	94.56	94.56	93.85

Table 3: Classification Performance of ELM (Accuracy%) with best features obtained by applying Genetic Algorithm (GA) using Linear, Lasso and Ridge regression models.

ELM activation functions →/	sigmoid		roots (n=0.4)		Hyperbolic tangent	
	Original DT	Best features (11 attributes)	Original DT	Best features (11 attributes)	Original DT	Best features (11 attributes)
Confusion Matrix	294 29 2 26 28 2 4 23 15	299 25 1 24 30 2 2 18 22	306 19 0 21 32 3 4 17 21	301 24 0 24 32 0 2 13 27	295 30 0 24 30 2 3 24 15	299 26 0 24 29 3 1 19 22
Accuracy	92.67	94.56	94.33	96.45	93.14	94.56
Sensitivity	35.71	52.38	50.00	64.29	35.71	52.38
Specificity	98.95	99.21	99.21	100.00	99.48	99.21
Precision	78.95	88.00	87.50	100.00	88.24	88.00
F-measure	49.18	65.67	63.64	78.26	50.85	65.67
AUC	67.33	75.80	74.61	82.14	67.59	75.80
Computation Time in secs	3.05	3.27	2.31	2.50	2.67	2.67

Table 4: Measurement Metrics for Sigmoid, Roots, and Hyperbolic Tangent activation functions before and after feature selection by GA through linear/lasso regression with 200 hidden inputs (in %).

ELM activation functions →/	sigmoid		roots (n=0.4)		Hyperbolic tangent	
	Original DT	Best features (12 attributes)	Original DT	Best features (12 attributes)	Original DT	Best features (12 attributes)
Confusion matrix	294 29 2 26 28 2 4 23 15	295 25 1 25 30 1 6 16 20	306 19 0 21 32 3 4 17 21	297 27 1 21 33 2 2 16 24	295 30 0 24 30 2 3 24 15	294 30 1 25 30 1 6 18 18
Accuracy	92.67	94.33	94.33	95.04	93.14	93.85
Sensitivity	35.71	47.62	50.00	57.14	35.71	42.86
Specificity	98.95	99.48	99.21	99.21	99.48	99.48
Precision	78.95	90.91	87.50	88.89	88.24	90.00
F-measure	49.18	62.50	63.64	69.57	50.85	58.06
AUC	67.33	73.55	74.61	78.18	67.59	71.17
Computation Time in secs	3.05	3.17	2.31	2.55	2.67	2.71

Table 5: Measurement Metrics for Sigmoid, Roots, and Hyperbolic Tangent activation functions before and after feature selection by GA through ridge regression with 200 hidden inputs (in %).

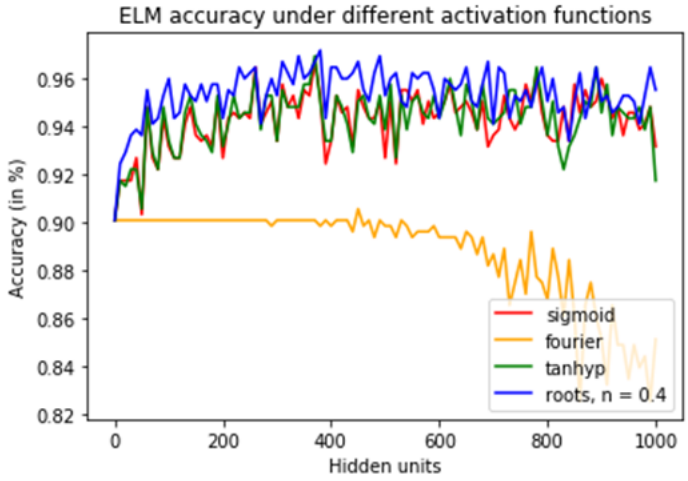

Figure 6: ELM accuracy before feature selection with Sigmoid, Fourier, Hyperbolic tangent(tanhyp) and Roots(user-defined) activation functions.

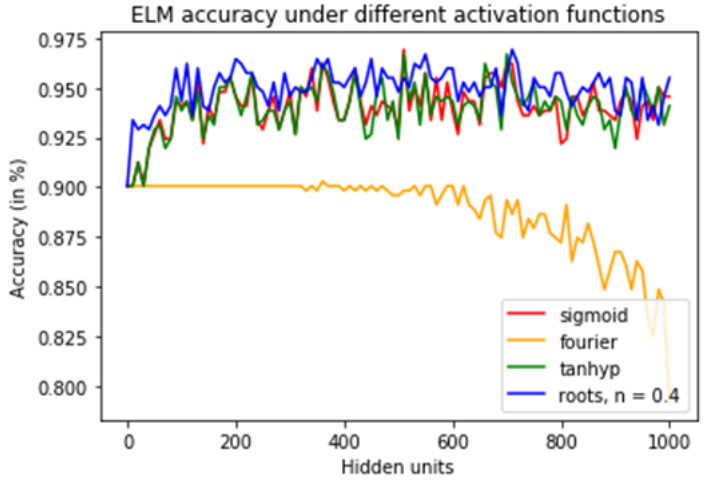

Figure 7: ELM accuracy with sigmoid, Fourier, hyperbolic tangent (tanhyp) and roots(user-defined) activation functions, after feature selection with best 11 features selected through GA with linear/lasso regression for cross-validation.

91.86%, respectively. Another work proposes using Discriminant Analysis, Decision Trees, and Artificial Neural network for identifying the fetal status [15] using all features of the CTG data set and have reported 82% accuracy for DA, 86.4% for DT, and 97.8% accuracy for ANN. The work also establishes the fact that giving rules for identification is always better i.e DT even with lower accuracy is better interpretative for results rather than an Artificial neural network which resembles a black box where processes involved are unknown. Another work including all the features [31], focuses on studying fetal well-being using The Least Square SVM method with Particle Swarm Optimization and Decision Trees. This method yielded 91.62% accuracy with all 2162 instances and had been validated using 10-fold cross-validation. The PSO played a major role in optimizing the penalty factor of LS-SVM. A similar work proposed using Adaptive Neuro-Fuzzy inference Systems (ANFIS) [21] to differentiate pathological cases from normal ones and reported accuracy of 97.2% for normal cases and 96.6% accuracy for pathological states. Rough Neural Networks suggested in another study for fetal risk assessment [4] was provided with upper and lower boundaries in input layer as well as hidden layers and gave an accuracy of 92.95% for pathological cases using the entire set of features.

The above works have reported a maximum accuracy of 97.8% and have used all the features for the experiment. In comparison, our work has yielded 96.45% accuracy with only 11 features, thus reducing the computation cost and time.

Our paper focuses on studying the efficiency of ELM with novel activation function for the effective classification of fetal heart disease. The accuracy of our model is compared before and after feature selection using GA. GA uses regression models for cross-validation of the best features and linear as well lasso have yielded the same 11

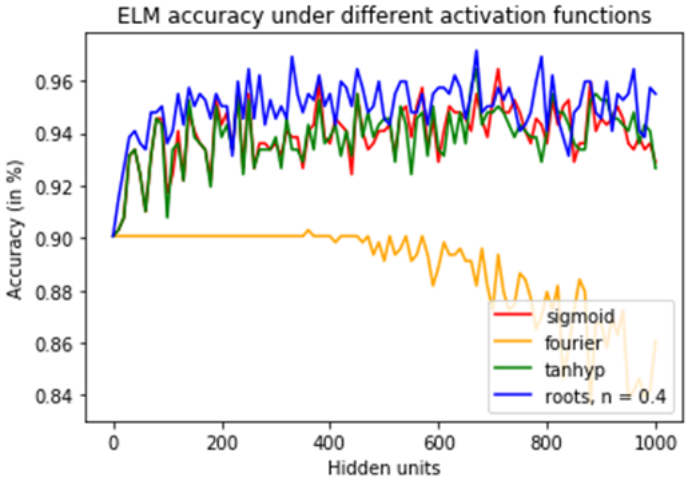

Figure 8: ELM accuracy with sigmoid, Fourier, hyperbolic tangent (tanhyp) and roots(user-defined) activation functions, after feature selection with best 12 features selected through GA with ridge regression for cross-validation.

best features in our experiment and have given better accuracy than the 12 features selected with ridge regression. As compared to a study [29], the features selected by convolution neural networks, MKNet and MKRNN which resulted in classification accuracy of 90%, our feature selection has given better performance and accuracy has improved by almost 6%.

For classification of heart disease, extraction of important features plays an important role as evident from [28], [20], [32]. Generalized discriminant analysis has been used with the Radial basis kernel function or Gaussian function of ELM to analyze heart rate signals and the process has achieved 100% accuracy. The impact of feature selection was therefore explored in our study using GA as GA in the study [20]. gave improved results for the classification of heart disease. Our accuracy also improved from 94.33% to 96.45% after using the best features obtained from GA with a lasso and linear regression models, similar to [32] where accuracy improved by 5.6% using PCA.

Our model has given improved results of 96.45% accuracy as compared to another work [7] which used ANN with ELM for classifying fetal heart disease and have given 93.42% and 91.84% using ELM and ANN respectively.

ELM with our novel activation function roots (n=0.4), also outperformed the results of classification using various other classifiers given in [10], where XGBoost gave the best results with (>92%) and was comparable with other optimized ELM models used for classification of various other diseases.[18]

The number of hidden inputs in our study has been considered to be 200 as compared to 2 to 3 input units suggested in the work [16] and the inputs have been selected by varying the units from 0 to 1000 and the optimized value has been considered for the ELM.

Our novel approach gave 100% specificity and 100% sensitivity as compared to other classification models [26]. The best features selected by other studies [25] are also the common features that have been selected by using GA with cross-validation using linear and lasso and have obtained accuracy >2% as compared to classification and regression decision trees and Self-organizing maps.

5 Conclusion

ELM with sigmoid and roots activation functions produced accuracy above 95%. ELM takes less time than other neural networks to get trained as their input weights and biases do not need to be tuned further, but it depends on the activation function used. In this experiment, the function of the roots was faster than other functions when hidden units were set to 200. The Genetic Algorithm has played an important factor in improving the accuracy of ELMs through feature selection. Other activation functions can also be used to see the effect on various parameters for classifying pathological cases in Cardiotocography data sets. The models can be used as an effective tool to aid medical experts in detecting cardiological abnormalities in the fetus.

Future work can be carried out on the optimization of various other activation functions of ELM to analyze the impact of the selection of hidden units on computation time and accuracy. Depending upon the dataset, the number of hidden units, and the number of generations, the activation function can be optimized to find the value of n in the function of the user-defined roots, which will determine the best results. The current study has used regression techniques for cross-validation in GA and in the future other techniques can be used to examine the model.

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Determining of the User Attitudes on Mobile Security Programs with Machine Learning Methods

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Security plays an important role in today's virtual world. Cybersecurity software has been widely used by the development of portable virtual environments. Smartphones occur in an important part of our lives. Daily routines are performed over mobile phones, especially after the COVID-19 pandemic process. Due to its ease of use, compulsory or optional mobile phone use also brought about many security concerns. Mobile security software is used for different purposes such as virus removal and protection of personal information according to user preferences. In the field of natural language processing, user preferences can now be analyzed on the basis of machine learning methods with sentiment analysis. In this paper, the preference reasons for mobile security software have been analysed with machine learning methods based on user comments and sentiment analysis. In the study, all user comments have been classified into 10 main categories and the user preferences of mobile security programs have been analysed.

Povzetek: Prispevek opisuje ugotavljanje uporabniškega odnosa do programov mobilne varnosti z metodami strojnega učenja.

1 Introduction

Security plays an important role in the several web applications. Mobile applications are widely used by users, especially after the Covid-19 pandemic process. While mobile applications convenience people, they also bring about some security problems. Due to security gaps, users become the main target of hackers. While the number of mobile phones increases each day, security threats, which capture personal information with social engineering methods, also increase at the same rate.

Nowadays, there are many security threats for smartphones, such as advertisements, undesired information sharing with synchronization, or fake links. Smartphone users try preventing security threats with mobile security applications and firewalls. Mobile security programs carry vital importance to the users for providing protection. While some users prefer security programs for cleaning trash files and folders, many prefer them for personal information privacy. Over the past decade, phone manufacturers have developed many smartphone models and many users have bought a smartphone for their routines. The hackers have also targeted mobile applications recently due to the trending usage. This situation also brought about mobile security concerns. Due to the security gaps, threats increased in vulnerable mobile phones. Several mobile security programs have been developed against threats and they have used by users for different reasons.

On the other hand, evaluation scales based on different structures such as questionnaire, comment text or rating star are also widely used among web and mobile users recently. A comment or rating can be useful for other users in terms of buying a product or installation a program because users have an idea for product or application quality. Google Play Store (GPS), which offers various digital content to its consumers, offers an evaluation possibility of the applications to the users. While user attitudes on mobile security in the literature are handled classical methods such as generally surveys, the GPS comments on mobile security programs are analysed with a new approach based on machine learning methods in this paper.

2 Methodology

Different kinds of contents such as music, movies, books, programs, and games are used on GPS due to the smartphone's popularity. Additionally, mobile security programs have also been preferable among users due to security concerns. Android developers have developed several mobile security applications to meet these requirements for different purposes. At the same time, a

lot of research has also been made about the user attitudes on mobile security recently. Most of these researches have been made by either being handled for a group of people or a local area by using classical methods.

In 2008, a study that is conducted with a survey on 300 mobile-phone users in Oman investigated user attitudes toward e-commerce and other mobile devices [1]. On the other hand, Tambe and Kulal developed an offline Android mobile security application when the smartphone is stolen or lost by a thief [2]. In 2016, another survey that is performed with 301 attendees is made of awareness of mobile device security [3]. Özkan and Bıçakçı performed an analysis for two-factor authentication against account-hijacking attacks. They analysed eleven different Android authenticator applications and used different engineering techniques and open-source tools in their study [4]. Ophoff and Robinson made an online survey with 619 South African mobile users for exploring end-user smartphone security awareness. Moreover, the survey questions based on mobile security have been prepared by these researchers [5]. Ziqiang et al. proposed an approach combining the static and dynamic security detection methods to detect client-side. They divided the mobile application security detection into two parts server and client security detection. Additionally, they developed an automated platform for mobile threat detection [6]. Benenson et al. made an interview with 24 mobile users that are between 18 and 50 years old for satisfying the sentiment analysis requirement. He consulted security experiments and attitudes of these 24 mobile users for his study. As a result of the interviews, he suggested some hypotheses [7].

Several mobile security user attitudes have been determined by using classical methods, such as surveys, interviews as it is seen in the literature. In our study, we proposed a new approach by using sentiment analysis based on machine learning and classification methods based on word analysis. The GPS comments are investigated by confining with Turkish comments as a prototype study in study. Additionally, the study can be also extended with different languages such as English, Italian, Hungarian, or Slovenian provided that the categories and searched words should be defined in the desired language.

In the application, 249 mobile security programs on GPS are examined and a sentiment analysis based on the combination of user comments and ratings has been conducted. The received information with scraped method on GPS is processed and the user comments with ratings are analysed as positive, negative, and neutral with sentiment analysis.

Moreover, the criteria by which the users use the programs were analysed by being categorized into 10 categories. The aim of the study is to propose a new approach based on the machine learning method that contains sentiment analysis by considering user ratings instead of the classical methods. The working principle of the proposed method is shown in Figure 1.

3 Materials and methods

3.1 Baseline algorithm

Sentiment analysis has a baseline algorithm with different classification approach. Firstly, the tokenization process is applied for the words of each comment text. Phone numbers, dates, special markups such as user names, and emoticons that are required are examined and extracted in text. Emoticons of the text are also examined for sentiment tokenization because of they can express a positive such as smile face or negative sentiment such as sad face. Moreover, the stopwords are also extracted from the text. Negation is another important process for extracting features for sentiment classification [8]. The negation is determined by using adjectives or all words in sentence. The last process is classification by using a classifier in the model.

There are different classifiers for sentiment analysis.

1- Naïve Bayes,
2- Maximum Entropy
3- Support Vector Machine (SVM)

Maximum Entropy (MaxEnt) and SVM tend to do better than Naïve Bayes algorithm. In this study, SVM algorithm is preferred for sentiment classifier due to the ease of use.

3.2 Support vector machine (SVM)

SVM is a supervised machine learning algorithm that can be used for both classification or regression challenges [9]. The sentiment analysis, which is based on natural language processing (NLP) and machine learning algorithms, is made by the Support Vector Machine (SVM). SVM basically divided into two classes and it is a binary classification method. For multiclass classification, the same principle is utilized after breaking down the multi-classification problem into smaller subproblems, all of which are binary classification problems [10]. The multiclass problem is broken down to multiple binary classification cases, which is also called one-vs-one. This method is called linear SVM for multi-class classification. The comment sentiment is investigated as three main emotions that are positive, negative and neutral by using linear SVM. Additionally, the Stochastic Gradient Descent (SGD) algorithm is used for the text classification in each comment of determined sentiment.

3.3 Stochastic gradient descent (SGD)

SGD is a fundamental machine learning approach that can be applied to large-scale and diluted machine learning problems frequently encountered in text classification and natural language processing [11]. SGD is also a good optimization algorithm by productivity and ease of application. The advantage of SGD is to update each

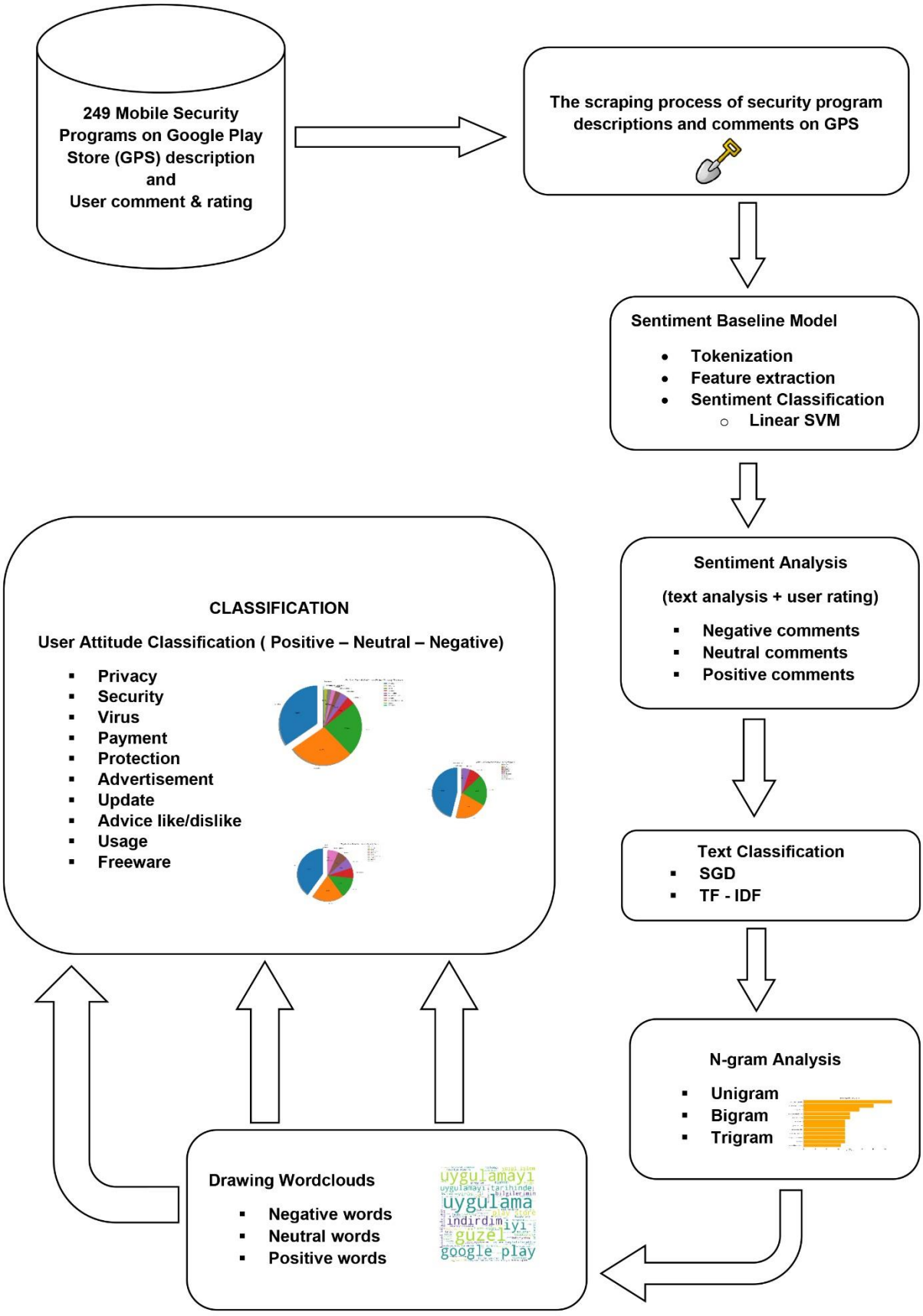

Figure 1: Working principle of the proposed method.

sample in each step by decreasing optimization calculations, especially in big datasets. SGD refers to calculating the derivative from each training data instance and calculating the update immediately [12]. SGD

algorithm is used based on Term Frequency – Inverse Document Frequency (TF-IDF) weight factor in text classification.

TD-IDF is a calculated weight factor of a word that shows the importance in a text by using a statistical method .Thanks to TF-IDF, it is determined in which reason the GPS users write their ratings about mobile security programs. TF-IDF weights [13] are calculated as follow:

$$weight_{w,t} = \begin{cases} \log(tf_{w,T} + 1) \log \frac{n}{x_w}, & f_{w,T} \geq 1 \\ 0, & otherwise \end{cases} \quad (1)$$

3.4 N-gram model

N-gram means a sequence of N words and it helps predict the next item in a sequence. Although the n-gram model has more than one method, it consists of 3 main methods. Unigram express n-gram of size 1, bigram refers to n-gram of size 2 and trigram means n-gram of size 3 [14]. The size of n-gram can also be increased, such as four-gram, five-gram. The n-gram model can be explained with a simple sentence as following:

Example sentence:

"The mobile security application is very good."

1- Unigram: Each single word is considered for the recurrent calculation.
2- "The", "mobile", "security", "application", "is", "very", "good"
3- Bigram: Each pair of words is considered for the recurrent calculation.
4- "The mobile", "mobile security", "security application", "application is", "is very", "very good".
5- Trigram: Each three sequence of words are considered for the recurrent calculation.
6- "The mobile security", "mobile security application", "security application is", "application is very", "is very good"

In the study, the n-gram analysis is performed as unigram, bigram and trigram for all comments. Additionally, the keyword-processing algorithm is separately used at positive, negative and neutral comments. Keyword processing assigns a rate to a word and it gives a score to the word. Finally, it gives a percentage score to the text as a whole. The words are drawn by starting from the highest score word by word cloud [15]. This process is executed all positive, negative and neutral text separately and the most used words are shown in each sentiment group as a word diagram.

3.5 Model accuracy

The classification model that follows the working principle was evaluated with standard metrics called accuracy, precision, recall and F1-score where TP is true positive, TN is true negative, FP is false positive and FN is false negative [16]. Accuracy is a statistical measure which is defined as the division of the correct predictions (TP & TN) made by a classifier divided by the sum of all predictions made by the classifier, including FP and FN [17]. The accuracy is computed as follow:

$$accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (2)$$

Precision is defined as the ratio of the correctly identified positive cases in all predicted positive cases [18]. Precision is computed as follow:

$$precision = \frac{TP}{TP+FP} \quad (3)$$

Recall is the sensitivity of the model and it is defined as the ratio of the correctly identified positive cases to all the actual positive cases, which is the sum of FN and TP [19]. Recall is also shown as follow:

$$recall = \frac{TP}{TP+FN} \quad (4)$$

F1-Score is the harmonic meaning of the precision and recalled by taking into FP and FN cases [20]. It shows quality performance in an unbalanced data set. It is calculated as follow:

$$F_1 score = \frac{2 \times (precision \times recall)}{(precision \pm recall)} \quad (5)$$

4 System design and components

4.1 Dataset

In our study, the mobile security programs on Google Play Store are examined with Turkish user comments and votes. The user comments and votes are evaluated for the sentiment analysis together. Initially, 249 mobile security programs and related comments are handled as metadata. Google play scraper based on PHP composer is used for extracting metadata and all program names, application ids and user comments and votes are written in an Excel file [21]. Thanks to Google Play scraper, 45617 comments that belong to 249 mobile security programs have been examined with a written Python script in the application. The dataset is randomly divided into train set as 80% and test set as 20%.

4.2 Pre-process

In dataset, a sequence pre-process is performed for sentiment and text classification. Initially, the all-meta data text is translated to English for sentiment analysis [22]. The normalization pre-process is applied both Turkish and English comment texts. Firstly, all html and xml markups are examined and cleaned from texts. Secondly, the usernames, web addresses, phone numbers are also cleaned. Secondly, all comment texts are examined for the feature extraction [23]. Emoticons is the important feature for sentiment analysis and it is taken into account for emotion detection. The all words are examined for negation detection. Finally, the sentiment classification is performed for all dataset. Additionally, the user ratings are also considered for an efficiency sentiment analysis in our study.

4.3 Sentiment analysis

Sentiment analysis has been realized based on three main emotions as negative, positive, and neutral. Moreover, the user votes as rating stars are also counted in sentiment analysis examination. In literature, the sentiment analysis is made in English and there are a few sentiment analysis

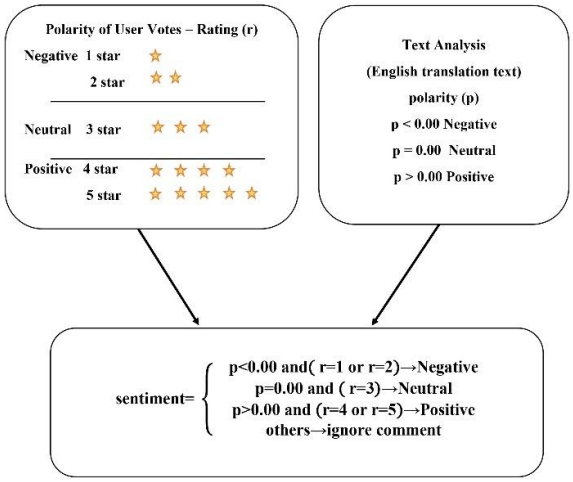

Figure 2: Sentiment analysis of the proposed method.

studies with other languages such as Spanish or Turkish [24][25]. The sentiment analysis studies based on other languages do not reflect sentiment analysis as successfully as English [26]. The diagram used in this study for the sentiment analysis is shown in Figure 2.

Instead of the usage of non-English sentiment analysis, the comments that are written as non-English are translated to English. Moreover, the sentiments are supported with the user votes related to mobile security programs for decreasing translation errors. Thanks to the translation process, the application can be executed with the other languages provided that the category names and searched words used for classification are written in the desired language.

The sentiment analysis of each comment is basically determined by sentiment polarity. Additionally, the user votes are also considered for a higher accuracy analysis in this study. As a hypothesis, the user ratings are accepted as 1 or 2 stars for negative, 3 stars for neutral, and 4 or 5 stars for positive [27]. Furthermore, when the comment text is evaluated with sentiment polarity, a polarity less than 0 is considered as negative, a polarity equal to 0 is considered as neutral, and a polarity greater than 0 is considered as positive [28]. If any user evaluation doesn't follow both rules, that comment is ignored for sentiment analysis and classification. Moreover, some users can make a negative comment and give a positive vote. These kinds of comments have been ignored by means of the proposed method.

Due to the user comments and star ratings, the user reactions are also shown in Table 1. According to the evaluation, the GPS users thought about security programs as positive 76.39 %, neutral 3.32%, and negative 1.89%. The 8395 comments are ignored according to that they don't follow the rules of the proposed method. Additionally, the numbers of positive, negative and neutral ratings according to the user ratings are also shown in Table 1.

In each original Turkish comment that follows to proposed method, the most used words (unigrams), bigrams and trigrams are determined by n-gram analysis. In addition to n-gram analysis, word clouds that contain positive, negative and neutral comment words have been also separately drawn. Finally, all comments are classified with 10 user attitude categories according to the sentiment and it has been determined whether the users like or not the security programs according to which criteria. The algorithm accuracy is evaluated with linear SVM algorithm.

4.4 Classification

When the mobile security comments are observed as a whole, 10 main Turkish classes are determined for the user attitude classification. The classification is made based on these classes. The class names (categories) based on user attitude are shown in Table 2. The class names weren't only searched, but also other words denoting the class name in each comment.

A searched word can belong to more than two classes. These searched words were taken into account for each related class. For example, let a Turkish comment is as follow:

Turkish Comment:

"Virüsü iyi temizliyor, kişisel bilgilerimi kurtardım, koruma sağlıyor, kullanışlı bir program. tavsiye ederim."

English Translation:

Comments	**Rating 1**	**Rating 2**	**Percentage (%)**	**Total Percentage (%)**	**Comment Numbers**
Negative	760	104	1,89 %	81,6 %	37222
	Rating 3		**Percentage (%)**		
Neutral	1513		3,32 %		
	Rating 4	**Rating 5**	**Percentage (%)**		
Positive	4293	30552	76,39 %		
Ignored Comment Numbers				18,4 %	8395
Total Comment Numbers					45617

Table 1: The numbers of rating and comments.

Class No	Class Name (Turkish Class Name)	Searched Words (Translation)
1	Virus (Virüs)	Temiz (clean), virüs, virus (virus), yok (not), bahis (bet), reklam (advertisement), sil (delete)
2	Security (Güvenlik)	Temiz (clean), güven (secure), kişisel (personal), bilgi (info), siber (cyber), saldırı (attack), koruma (protection), virüslü (infected)
3	Privacy (Gizlilik)	Kişisel (personal), bilgi (info), şahıs (person), paylaş, paylas (share)
4	Freeware (Ücretsiz)	Ücretsiz, ucretsiz (freeware), bedava (free) ,parasız (no charge), free
5	Paid (Ücretli)	Para (money), ücret (fee), kazan (win), reklam (advertisement), yıllık (annual), uyelik, üyelik (membership), abone (subscriber), deneme (trial), satış (sales), satma (sell), kart (card), sürüm (version), premium, ödeme (payment), satin (buy), fiyat (price)
6	Advertisement (Reklam)	Reklam (advertisement), afis, afiş (banner), pano (board), sürekli (permanent), izle (watch), gereksiz (unnecessary)
7	Protection (Koruma)	Virus (virus), sil (delete), tehdit (threat), koru (secure), etkili (effective), karşı (against)
8	Update (Güncel)	Performans (performance), güncel (update), otomatik (automatic), son (final), indirme (download)
9	Usage (Kullanım)	Performans (performance), kullanışlı (useful), yararlı (benefit), zararlı (harmful), işlevsel (functional), kasmıyor (twitch), ısınma (warming),şarj (charge), gereksiz (unnecessary), tüketim (consumption), bildirim (notification)
10	Advice like/dislike (Tavsiye beğeni)	öneri (offer), beğen (like), tavsiye (advice), çok iyi (very well), maşallah, harika (wonderful), kötü (bad), hiç (any)

Table 2: The categories of the study on user attitude.

"It cleans the virus well; I recovered my personal information and it provides protection. It is a useful program. I advise everybody"

In this study, all words are searched as Turkish.

1- "Virus" and "clean" words will belong to virus class,
2- "personal" and "information" words will belong to privacy and security classes
3- "protection" word will belong to protection class,
4- "useful" word will belong to usage class
5- "advise" word will belong to advice like/dislike class.

In addition to searched words, the root of the word such as "protect" word in protection class or "pay" word in paid class is also evaluated within the classes. Thereby, the frequency of the word is determined in the comment text. Even if this prototype study is prepared in the Turkish language, the word search process can be made with different languages such as Spanish or Slovenian languages. If the searched words and classes are prepared in Slovenian, the search can also be made in Slovenian.

5 Experimental results

5.1 User attitudes

When the experiment on user ratings and comments is observed, it is stated that most of the users thought positive about mobile security programs. Moreover, users have installed programs for different reasons such as privacy, security or freeware. When the comments have been separated by the sentiment analysis, the most used words have been shown by word cloud at each sentiment group. The most used positive (a), negative (b) and neutral (c) Turkish words are shown in Figure 3.

(a) Positive *(b) Neutral* *(c) Negative*

Figure 3: (a) Positive (b) Neutral (c) Negative Turkish words.

Categories	Positive User Attitudes		Neutral User Attitudes		Negative User Attitudes	
	Percentage	Number	Percentage	Number	Percentage	Number
Virus	28,1 %	9171	20,7 %	624	29,4 %	426
Security	23,7 %	7732	26,9 %	811	8,9 %	129
Privacy	22,7 %	7410	29,3 %	882	5,0 %	73
Payment	6,8 %	2220	6,0 %	180	12,4 %	179
Protection	5,0 %	1635	5,3 %	159	14,1 %	204
Advertisement	4,9 %	1590	4,9 %	149	8,7 %	126
Usage	3,3 %	1089	2,2 %	67	3,5 %	50
Update	2,5 %	827	2,3 %	69	8,8 %	128
Advice like/dislike	2,5 %	827	2,3 %	69	8,8 %	128
Freeware	0,3 %	99	0,1 %	4	0,3 %	4

Table 3: The positive (a), neutral(b) and negative (c) classified user attitudes.

When all comment texts are also investigated based on 10 categories, the user attitudes are also shown in a list for each sentiment group in Table 3. In the positive comments, it is observed that the users mostly preferred mobile security programs for privacy, security and cleaning virus. In the negative comments, it is observed that the users mostly complained about mobile security programs for privacy, security and cleaning virus. In the neutral comments, it is observed that the users mostly stayed neutral on mobile security programs about privacy and virus. The numbers and percentages of the positive, neutral and negative attitudes are also shown in Table 3.

The association probability of the words is also examined by n-gram analysis as unigram, bigram and trigram. The stop words such as “Google”, “Play”, “Store”, “very”, “for” are ignored at n-gram analysis. For all comments that follows the proposed method, the unigram, bigram and trigram analysis are shown in Table 4. The numbers of most used 10 Turkish words, pair-words, and triple-words are also shown in Table 4.

5.2 Model evaluation

In the study, the sentiment analysis based on linear SVM is performed with standard metrics which are precision, recall, and F1 score [29]. Moreover, the other classifiers that are sentiment analysis based on Naïve Bayes and Maximum Entropy are also applied for the performance test [30]. In our study, the comment text that has the positive, neutral and negative polarity are examined for the comment texts that follows the proposed method. The Linear SVM, Naïve Bayes, and Maximum Entropy classifiers are performed for three classes by using sklearn metrics library in Python. The non-normalization TP, FP, TN, and FN values that are required for the confusion matrix for each model are shown in Table 5. The total accuracy, precision, recall and F1-score values of the

UNIGRAM		**BIGRAM**		**TRIGRAM**	
***Word* (Translation)**	**Number**	***Word* (Translation)**	**Number**	***Word* (Translation)**	**Number**
Uygulama (application)	10823	*Güzel uygulama* (beautiful, application)	2718	*Yasal işlem başlatılacaktır* (The juristicial act will be start)	520
Güzel (beautiful)	9277	*Tavsiye ederim* (I advice)	2297	*Herkese tavsiye ederim* (I advice everybody)	431
Uygulamayı (to application)	5833	*İznim yoktur* (I don't allow)	1270	*Uygulamayı telefonumun güvenliği* (application for security of my phone)	429
İyi (nice)	5729	*Yasal işlem* (juristicial act)	1016	*Telefonumun güvenliği indiriyorum* (I download for my phone security)	420
Ederim (I do)	3515	*Uygulama güzel* (application is beautiful)	960	*Uygulama tavsiye ederim* (application I advice)	357
Program (program)	3492	*Telefonumun güvenliği* (security of my phone)	914	*Uygulama güzel uygulama* (application beautiful application)	302
Kişisel (personal)	3335	*İşlem başlatılacaktır* (the act will be started)	822	*Güzel uygulama güzel* (Beautiful application beutiful)	292
Virüs (virüs)	3209	*İyi uygulama* (nice application)	746	*İznim yoktur aksi* (I don't allow, otherwise)	283
Sorumludur (responsible)	3035	*Kişisel bilgilerimin* (my personal info)	679	*Avast, antivirüs, 2021* (Avast, antivirus, 2021)	254
Tavsiye (advice)	3015	*Güvenliği indiriyorum* (I download security)	623	*Tavsiye ederim güzel* (I advice beautiful)	253

Table 4: The unigram, bigram and trigram analysis of the proposed method.

different classifiers (Naïve Bayes, Maximum Entropy and Linear SVM) are also shown in Table 6.

According to Table 6, while the accuracy of the Naïve Bayes classifier is 85 % with the proposed method, the accuracy of the Maximum Entropy is 90%. Our proposed model accuracy which is supported by linear SVM is %93. The performance results show that the proposed model that is supported by Linear SVM generates higher accuracy.

6 Conclusion

Nowadays, security plays an important role in every virtual platform. With the development of mobile phones, security concerns have become more important in mobile devices. The advantages such as usage of ease, fast accessibility of the information, and portability caused to use phones by the people at more.

After the Covid-19 pandemic, phone usage noticeably increased worldwide. As a result of this situation, the

Classifier	Sentiment	True Positive (TP)	True Negative (TN)	False Positive (FP)	False Negative (FN)
Naïve Bayes	***Negative***	3	3531	3	186
	Neutral	37	3315	142	229
	Positive	3129	46	409	139
Maximum Entropy	***Negative***	11	3575	10	128
	Neutral	2	3492	5	225
	Positive	3348	18	348	10
Linear SVM	***Negative***	37	3594	42	49
	Neutral	7	3532	38	145
	Positive	3414	54	184	70

Table 5: The confusion matrix (non-normalization) values of the proposed model with Linear SVM, Naïve Bayes and Maximum Entropy.

Classifier	Metric	Negative	Neutral	Positive	Total Accuracy
Naïve Bayes	Precision	0,01	0,14	0,96	85%
	Recall	0,5	0,21	0,88	
	F1-Score	0,03	0,17	0,92	
	Support	85	198	3439	
Maximum Entropy	Precision	0,07	0,008	0,99	90%
	Recall	0,52	0,33	0,91	
	F1-Score	0,14	0,017	0,95	
	Support	87	158	3477	
Linear SVM	Precision	0,47	0,16	0,95	93%
	Recall	0,43	0,05	0,07	
	F1-Score	0,95	0,98	0,96	
	Support	86	152	3484	

Table 6: The performance results with Naïve Bayes, Maximum Entropy, and linear SVM.

mobile security requirement also increases at the same rate. Mobile phone users share their ratings about phone

features and mobile application at application store markets and other platforms. The shared information has become of vital importance for the other users. By observing the user attitudes, both the developers can develop different security mobile software and the users can use the security application for the most desired request. Moreover, the user attitudes on the virtual world are not only important for security but also becomes an indispensable element for marketing, politics and society.

In our study, the usage of mobile security programs has been examined with machine learning methods and user attitudes on mobile security are also investigated by predetermined criteria. A user analysis has been made by considering the Turkish user attitudes on mobile security software as a prototype study. The study can also be expanded with user attitudes that are in different languages and topics.

Additionally, the user attitudes can be evaluated with higher accuracy by the development of machine learning techniques and a lot of prediction can be made by using the previous user attitudes. In the near future, mobile security will become an indispensable element of our lives

with the minimization of communication tools and this situation will more required investigation of user attitudes.

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Categorization of Event Clusters from Twitter Using Term Weighting Schemes

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A real-world event is commonly represented on Twitter as a collection of repetitive and noisy text messages posted by different users. Term weighting is a popular pre-processing step for text classification, especially when the size of the dataset is limited. In this paper, we propose a new term weighting scheme and a modification to an existing one and compare them with many state-of-the-art methods using three popular classifiers. We create a labelled Twitter dataset of events for exhaustive cross-validation experiments and use another Twitter event dataset for cross-corpus tests. The proposed schemes are among the best performers in many experiments, with the proposed modification significantly improving the performance of the original scheme. We create two majority voting based classifiers that further enhance the F1-scores of the best individual schemes.

Povzetek: V prispevku je opisana kategorizacija gruč dogodkov na Twitterju.

1 Introduction

Twitter is a popular microblogging platform with millions of active users [1] posting (publishing) messages (tweets) every day [18]. In microblogging, there is a limit to the maximum allowed length of a message (e.g. Twitter restricts the length to 280 characters). Since a large number of users access Twitter using mobile devices, real-world news is often shared first on Twitter. In this paper, we consider an event as any newsworthy real-world occurrence discussed on Twitter. For this reason, we use the terms *event* and *news* interchangeably. There can be a large number of tweets discussing an event. The set of event-related tweets has very high-dimensional vocabulary (features), is repetitive and noisy. We refer to a collection of related tweets (in English) discussing an event as an event cluster, an event or a document.

The number of real-world events that are detected online during a fixed time duration is generally limited. For example, Kalyanam et al. [7] were able to detect about 5000 real-world events in a year (including duplicates). Since event datasets are not huge, advanced neural network techniques are not applicable, and we need to use traditional methods for classification.

Term-weighting schemes have traditionally been one of the most popular pre-processing methods for text categorization. These schemes are applicable even when the dataset is not very big. There are two types of term-weighting: unsupervised term weighting (UTW) and supervised term weighting (STW). UTW schemes such as *tf*idf* do not consider the category of a term's containing-document, while STW schemes depend on the category information. A classifier is trained on the labelled dataset consisting of documents with weighted words and the corresponding document category labels. Fig. 1 gives an overview of event categorization using term weighting schemes. Note that event category is a conceptual grouping that contains a similar type of events (*e.g.* sports category). Human annotators assign a category label to each event (we discuss the process in Section 4).

We ask the following research questions in this paper. Can the existing term weighting schemes categorize noisy and repetitive Twitter event clusters effectively? Can we create a new term weighting scheme or improve existing ones? Would the proposed method and modification be effective in general text categorization? Can we improve event categorization by creating voting classifiers using term weighting schemes?

To this end, we make the following contributions:

- We propose a new term weighting scheme and a modification to an existing scheme for event categorization. We perform cross-validation and cross-corpus classification using two different datasets. We also evaluate the proposed schemes on multiple balanced and imbalanced sub-datasets.

- We show that the proposed term weighting schemes

[1] www.twitter.com

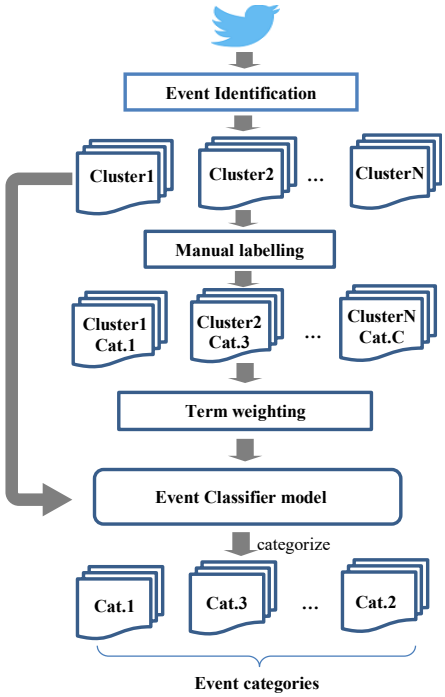

Figure 1: Overview of the process of Twitter event categorization.

and an existing scheme statistically make significantly different predictions. Consequently, we propose a voting-based classifier using these schemes that achieves the highest F1-scores.

We have organized the rest of this paper as follows. We discuss the related work and existing term weighting schemes in Section 2. We propose a term weighting scheme in Section 3.1 and modification to an existing scheme in Section 3.2. In Section 4, we discuss the datasets, experimental setup and the evaluation metrics. We present experimental results and analysis in Section 5 followed by conclusion in Section 6.

2 Related work

We now discuss a few state-of-the-art term weighting schemes that have been previously used by researchers for text categorization.

2.1 Unsupervised methods

These methods make an assumption that terms important to a document are frequently present in it. Another common assumption is that a term is important to a document if it is not present in many documents. Raw count (frequency) *tf* and its variations are often used as term weighting schemes. The *tf*idf* and its variations additionally consider inverse document frequency (*idf*) for weight assignment. The *idf* of a term is defined in inverse proportion to the fraction of documents in which it is present. Let N be the total number of documents in a corpus, and n be the number of documents that contain a term t, then (1) is used to calculate its *tf*idf*.

$$\text{w} = tf * idf, \text{ where idf} = log\Big(\frac{N}{n}\Big) \tag{1}$$

There are a few popular variants of *tf*. Binary weight can be 1 or 0 depending on whether a term is present or absent in a document:

$$\text{w} = \begin{cases} 1, \text{if } tf > 0 \\ 0, \text{otherwise} \end{cases} \tag{2}$$

Another variant is calculated by dividing *tf* by the length of the document. Yet another variation is the log-normalized *tf* in which the log of *tf* is calculated, as shown in (3).

$$\text{w} = log(1 + tf) \tag{3}$$

There are many variations of *idf* scheme. In smoothed *idf*, weight is calculated using (4).

$$\text{smooth-idf} = log\Big(1 + \frac{N}{n}\Big) \tag{4}$$

Probabilistic *idf* is calculated using (5)

$$\text{idf} = log\frac{(N-n)}{n} \tag{5}$$

These schemes have been used by many researchers for text categorization ([6], [22]).

2.2 Supervised methods

Assume there are N training documents in $|C|$ categories, the following notations are used in STW schemes:

- *tp*: number of positive category documents that contain *w*.
- *fp*: number of positive category documents that do not contain *w*.
- *tn*: number of negative category documents that do not contain *w*.
- *fn*: number of negative category documents that contain *w*.
- *cf*: number of categories that have *w* present in at least one document.

Debole and Sebastiani [4] compared unsupervised *tf*idf* method with supervised term weighting methods *tf*χ2*, *tf*ig* and *tf*gr* using (6), (7), and (8), respectively. They used news categorization dataset Reuters-21578 and found *tf*gr* to perform the best among the three schemes. The results were mostly inconclusive when compared to *tf*idf*.

$tf*\chi^2$ measures independence of a term from a category.

$$tf*\chi^2 = \frac{tf * N * (tp * tn - fp * fn)^2}{(tp + fp)(fn + tn)(tp + fn)(fp + tn)} \tag{6}$$

*tf*ig* measures the information a term contains about a category.

$$\begin{aligned} tf*ig = tf * \Big(&- \frac{tp+fp}{N}\log\frac{tp+fp}{N} - \frac{fn+tn}{N}\log\frac{fn+tn}{N} \\ &+ \frac{tp}{N}\log\frac{tp}{tp+fn} + \frac{fn}{N}\log\frac{fn}{tp+fn} \\ &+ \frac{fp}{N}\log\frac{fp}{fp+tn} + \frac{tn}{N}\log\frac{tn}{fp+tn}\Big) \end{aligned} \tag{7}$$

*tf*gr* is similar to *tf*ig* with a normalization factor added to give weights to a term on an equal basis across different categories [21].

$$tf{*}gr = \frac{tf * ig}{-\frac{tp+fp}{N}\log\frac{tp+fp}{N} - \frac{fn+tn}{N}\log\frac{fn+tn}{N}} \quad (8)$$

Lan et al. [8], the authors proposed a term weighting method based on the relevance frequency (*rf*) of a term. They argued that relevance of a term in a document should only be affected by *tp* and *fn*, while *tn* and *fp* should not have any role in term weighting. They used k-NN and SVM classifiers on Reuters-21578 and 20 Newsgroups datasets to compare the methods against other supervised and unsupervised methods. The weight of a term in *tf*rf* is calculated using (9).

$$tf{*}rf = tf * \log\Big(2 + \frac{tp}{Max(1, fn)}\Big) \quad (9)$$

An Odds Ratio based method *tf*OR* has been found to perform well by researchers [8, 15]. Odds-Ratio is used to measure the strength of association between a term and a category. It is calculated by using (10).

$$tf{*}OR = tf * \log\Big(\frac{tp * tn}{fp * fn}\Big) \quad (10)$$

Quan et al. [15] proposed *iqf*qf*icf* (inverse question frequency, question frequency, inverse category frequency) for the question categorization task. They argued that words in a question mostly have *tf* of 1, which is equivalent to using binary features (presence or absence of words). Hence, the scheme did not use *tf*. The performance of this scheme in news categorization and general document categorization was better than other schemes. Term weights in *iqf*qf*icf* are calculated using (11).

$$\begin{aligned} iqf{*}qf{*}icf &= \log\Big(\frac{N}{tp+fn}\Big) * \log(tp+1) * icf \\ &\text{where } icf = \log\Big(\frac{|C|}{cf} + 1\Big) \end{aligned} \quad (11)$$

Wu et al. [20] proposed a scheme called regularized-entropy that attempts to avoid overweighting and underweighting of terms. They reported that the scheme gives better results on multiple text categorization and sentiment analysis dataset as compared to schemes such as *tf*$*\chi 2$, *tf*ig*, and *tf*rf*. In this method, (12) is used to compute the weight of a term.

$$\begin{aligned} &g = b + (1-b) * (1-h) \text{ , where} \\ &b \in [0,1] \text{ tradeoff between over/under weighting} \\ &h = -p^{+} * \log p^{+} - p^{-} * \log p^{-} \text{ , where} \\ &p^{+} = -\frac{tp/(tp+fp)}{tp/(tp+fp) + tp/(fn+tn)}, \\ &p^{-} = -\frac{fn/(fn+tn)}{tp/(tp+fp) + tp/(fn+tn)} \end{aligned} \quad (12)$$

Apart from term weighting schemes, other types of term weighting methods have similarly been proposed in the literature. [9] and [13] proposed term-weighting schemes suited for imbalanced datasets. A graph-based term weighting scheme was proposed by Malliaros et al. [11], in which documents are represented as graphs that encode relationships between the different terms. Wang et al. [19] proposed entropy-based term weighting schemes that use a term's global distributional concentration in the categories to measure its discriminating power. Reed et al. [17] proposed a term weighting scheme called term frequency-inverse corpus frequency (*tf-icf* for clustering of document streams. They used this weighting scheme for unsupervised document clustering. An interesting non-conventional method was proposed by Escalante et al. [5]. In contrast to other schemes, their method uses genetic programming to learn effective term weighting schemes.

Category size	*tp*	*tpr*
200	100	500
50	25	500

Table 1: Example of *tp* bias towards important terms in bigger categories.

In this paper, we use *log* to mean log_2. We use cosine normalization in which a term t_i in document D is converted into its cosine normalized form using (13). It is done to prevent the terms in bigger events from overwhelming the terms in smaller events.

$$t_{cosine} = \frac{t_i}{\sqrt{\sum_{i \in D} t_i^2}} \quad (13)$$

3 Proposed schemes

In this section, we propose a term weighting scheme specific to imbalanced datasets, and two improvements to existing schemes.

3.1 Proposed method

The first observation is that the many existing term weighting schemes do not consider the imbalance of categories in a dataset into account. As a result, *tp* suffers from a bias towards the words in bigger categories with more events. The range of values for *tp* is much smaller for categories with fewer events (smaller categories) than bigger categories. If we use *tp* directly in computing weights, it is likely to give higher weights to terms (words) in the bigger categories.

Table 1 shows an example where the smaller category contains 50 events and the bigger includes 200. Let us call a term *important* to a class if it is present in half of the category documents. In the example, the term relevant to the smaller category has *tp* of 25, while the term relevant to the bigger group has *tp* of 100. All terms important in more prominent categories have higher *tp* than equally important words in smaller classes. As *tp* is a component of many term weighting schemes, this may lead to a scenario where events belonging to the smaller categories get wrongly classified as a bigger category.

From this observation, we need to assign weights inversely proportional to the size of the category. If N is the

total number of events, we introduce *tp* ratio (*tpr*) computed as (14).

$$tpr = tp * \frac{N}{tp + fp} \tag{14}$$

In Table 1, with N as 1000, the terms equally important to their respective categories now have the same *tpr* value 500. The *tpr* component has removed the bias of *tp* towards the bigger categories.

The second observation is that there should be a penalty factor for a term if and only if it is present in negative category documents. The presence of a term in positive category documents should not be considered in computing the penalty factor. This is in contrast to *tf*idf* and its derivative schemes that penalize a term solely based upon the number of the containing documents, irrespective of the category. This observation leads to the penalty factor *ifn* (inverse fn) computed by (15) where *Cn* is the number of documents in the negative category. Note that in *ifn*, the penalty is proportional to the size of the negative category. This ensures that bigger category documents are not disproportionately penalized. In (15), we perform add-one smoothing to avoid zero division. Also, 1 is added before log calculation to avoid a term weight from becoming zero due to penalty factor.

$$ifn = \log\Big(\frac{Cn + 1}{fn + 1} + 1\Big) \tag{15}$$

Combining (14) and (15) with term frequency *tf*, we propose the term weighting scheme given by (16)

$$proposed = tf * \log(tpr + 1) * \log\Big(\frac{Cn + 1}{fn + 1} + 1\Big) \tag{16}$$

The first component in the proposed scheme assigns weight locally within a document. It assigns higher weights to the more frequent terms in a document. The remaining part of the equation are the category level global components. They assign higher weights to the terms that are present in the more positive category documents, but penalize terms that are present in the negative category documents.

3.2 Proposed modification to $\chi 2$

The $\chi 2$ based term weighting scheme results in a disproportionate increase in weight even for a small increase in *tp*. We can see this in Fig. 2 where we compare the term weights assigned by $\chi 2$ and the Odds-Ratio (OR) scheme. The weight assigned by $\chi 2$ varies much faster with an increase in *tp* resulting in overweighting of terms and ultimately affects the classifier accuracy.

Another problem with $\chi 2$ scheme is shown with an example in Table 2. In the example, the number of documents is 1000. The term *t2* is assigned a higher weight than term *t1* even though *t1* has a higher *tp* and lower *fn* as compared to *t2*. Ng. et al. [14] have noted that $\chi 2$ (see (6)) not only picks out the set of words indicative of category membership but also those words indicative of non-membership. They suggested using the square root of $\chi 2$ (correlation coefficient CC) as it gives more weight to words that are highly indicative of category membership. We observe that

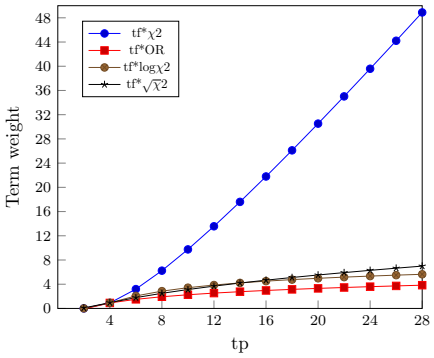

Figure 2: Term weights assigned by $\chi 2$ and others as *tp* is varied (assume that *N*=1000, *tn*=695, *fn*=5). Weights assigned by $log\chi 2$ and *OR* are comparable.

Term	*tp*	*fp*	*tn*	*fn*	*tf*χ2*
t1	20	280	695	5	30.52
t2	2	298	600	100	42.52

Table 2: Example of inappropriate weight assignment by $\chi 2$.

the log of $\chi 2$ gives better accuracy as it smoothens the weights more than CC (Fig. 2).

Table 3 summarizes the different term weighting schemes used in our research.

4 Datasets and experimental setup

4.1 Twitter datasets

The only public Twitter dataset (of tweet ids) of sufficient size contains 506 event clusters [12]. As the event classification task needs a bigger dataset, we labelled a news dataset by Kalyanam et al. [7]. Also, we created many sub-datasets from the self-labelled dataset for a more extensive set of experiments. We now briefly discuss the Twitter datasets and the sub-datasets.

The dataset by Kalyanam et al. [7] contains collections of event clusters. There are more than 40 million tweets collected during the period from August 2013 to June 2014. It covers 5234 news events in chronological order. As the collection contains an enormous volume of tweet ids, we requested from Twitter the first 1000 tweets for each event cluster.

We manually labelled the dataset of 5234 event clusters into eight categories using the following process. We discarded duplicate event clusters, clusters containing less than ten tweets, and other clusters that did not contain real-world events. Two human annotators labelled the remaining event clusters. We selected 1461 event clusters (Events1461) on which there was an agreement between the two annotators. The annotators have a good agreement with Kohen's Kappa of 0.8. The categories are the same as used by [12] and partly resemble the categories used by

Method	Type	Brief description
tf	Unsupervised	log of frequency count
*tf*idf*	Unsupervised	popular method in IR
tfχ2*	Supervised	$\chi 2$
*tf*ig*	Supervised	information gain
*tf*gr*	Supervised	gain ratio
*tf*OR*	Supervised	Odds Ratio
*tf*rf*	Supervised	relevance frequency
*iqf*qf*icf*	Supervised	uses category frequency
proposed	Supervised	proposed scheme
*tf*logχ2*	Supervised	log *tf*χ2*
voting	Supervised	two voting-based schemes

Table 3: List of term weighting schemes.

Notation	Category Name; Examples
law	Law, politics, and scandals
spo	Sports; players, clubs, etc.
arm	Armed conflicts & attacks; terrorism
bus	Business & Finance; mergers
arts	Arts & entertainment; actors, movies
dis	Disasters; floods, hurricanes
sci	Science & technology; space, phone launch
misc	Miscellaneous; Pope's visit, Queen's birthday

Table 4: The eight categories of events.

online news aggregators such as Google News [2]. The eight categories are shown in Table 4.

For cross-corpus evaluation, we use the pre-labelled Events2012 dataset by [12]. It contains 506 events labelled into eight categories. After pre-processing, only 384 suitable events remain (Events384).

Fig. 3 shows the distribution of events in different categories in the two datasets.

4.1.1 Sub-datasets

The first sub-dataset contains equal number of events from each category. We randomly selected 90 events from each category of Events1461 to create the dataset. This sub-dataset is used to evaluate the performance of the proposed schemes on balanced datasets. A good score on the dataset would suggest that the proposed term-weighting schemes are overall good performers on any kind of dataset.

For more extensive experiments to test the robustness of the different schemes on balanced and imbalanced datasets, we created many sub-datasets out of Events1461 as follows. We created six sub-datasets from Events1461 with top 2, 3, 4, 5, 6, and 7 categories having the most events. We created the another sub-dataset by splitting the shuffled Events1461 in a stratified manner into seven increasing-sized sub-datasets. The first sub-dataset contains 30% of events from each category and each subsequent sub-dataset adds 10% additional event clusters. So, the biggest sub-dataset contains 90% of the events from each category.

[2]http://news.google.com

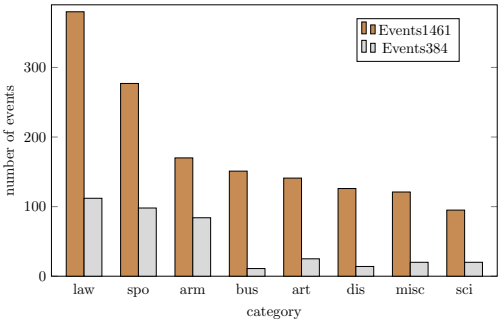

Figure 3: Number of events in each category of Events1461 and Events384 datasets.

4.1.2 Normalized event clusters

We use a centroid-based approach ([16], [1]) to extract the T most relevant tweets from each event. In this, we first compute the centroid of the cluster, followed by the extraction of tweets nearest to the centroid (one by one) in decreasing order of cosine similarity to the centroid. To avoid near-duplicates, we select a tweet only if it is less than 80% similar to already selected tweets. Finally, each event cluster contains an equal number of relevant non-duplicate tweets. We call them normalized clusters as the events contain an equal number of tweets. We used T from the set {10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200}.

4.2 Experimental setup

We briefly discuss the pre-processing steps, classifiers and policy used in the experiments.

4.2.1 Preprocessing

For all experiments, discard all the information except the text of the tweet. The removed information includes timestamp, tweet identity and user identity. We remove stopwords and perform stemming using Porter stemmer. We discard a word present in less than two documents (event clusters) as non-informative. Also, we discard a word as noise if it is present in more than half the documents.

We use three different classifiers: Support Vector Machine (SVM), Logistic Regression (LR), and K-Nearest Neighbours (k-NN) as these have been used widely by researchers ([8], [15], [2]).

We use the MAX global policy as it has given the best performance in earlier studies ([4]). In MAX, all categories share a common weight vector TW. Each term weight in the vector is the maximum of the term's weights among all classes.

5 Experiments and results

We now present the experimental results.

5.1 Cross validation experiments using Events1461

First, we discuss the results of the experiments on the self-labelled Events1461 dataset and its sub-datasets.

We performed 10-fold cross-validation (10-CV) experiments on the full Events1461 dataset. Using grid-search, we selected the hyperparameters for the SVM and logistic regression classifiers. For SVM, the linear kernel performs the best with C=10, and for logistic regression, solver='newton-cg' and C=1000 gives the best scores. For k-NN classifier, we used different values of k, as shown in Fig. 4. The value of k=7 gives the best scores for most of the term weighting schemes.

Table 5 displays the 10-CV scores of the term weighting schemes on the full Events1461 dataset. Looking at the macroF1 scores, *tf*OR*, the proposed scheme, *tf*log*χ2 and *tf*rf* have scored better than other schemes. We call these better performing schemes *strong* term weighting schemes. The proposed modification has significantly improved the performance of the original scheme. As SVM has given the best scores in this experiment, we report results based on SVM for the remaining 10-CV experiments.

An interesting observation is that *tf* macroF1 scores are better than *tf*idf*. Apart from signifying the importance of *tf* in event categorization, it also highlights the limitation of *tf*idf* in this context. The *idf* component adversely affects the score as it penalizes the terms present in other documents without considering the category information.

5.1.1 Cross validation on sub-datasets

Table 6 shows the results of the term-weighting schemes using the balanced Twitter dataset. The proposed term-weighting schemes have given the best overall score on the sub-dataset. Among the existing schemes, *tf*OR* and *tf*rf* have given achieved F1-scores. These results show that the proposed scheme performs well on balanced datasets.

The second set of experiments tests the performance of STW schemes on the other two sub-datasets (described in Section 4.1.1). Fig. 5 shows the 10-CV scores of different STW methods for various subset sizes. Fig. 6 shows the 10-CV scores in sub-datasets containing different number of categories. To remove clutter from the figures, we have not shown scores of *tf*, *tf*ig* and *tf*gr* as these schemes have low scores. Among the *weaker* schemes, we show scores of the *tf*idf* and *tf**χ2 scheme for comparison. In these figures, the horizontal axis signifies the percentage of events taken from Events1461.

Both the microF1 and macroF1 scores improve with the size of the subsets. It is as expected since the term weighting schemes can perform better weight assignment with the increase in the number of event clusters. The proposed scheme *tf*log*χ2 has good scores. As expected, the scores of the term weighting schemes monotonically increase as the number of categories decrease.

	SVM		k-NN		LR	
	Micro	*Macro*	*Micro*	*Macro*	*Micro*	*Macro*
tf	83.19	80.40	81.16	79.25	82.14	79.12
tf*idf	83.27	80.28	80.36	77.69	81.49	78.01
tf*χ2	81.20	79.03	77.08	74.23	81.70	79.16
tf*ig	81.01	78.10	76.54	72.11	81.32	78.43
tf*gr	80.97	78.20	77.94	75.05	81.75	79.33
tf*OR	**84.20**	**81.68**	81.88	79.38	**83.66**	**80.86**
tf*rf	83.75	80.98	**83.49**	**81.45**	82.63	79.14
tf*logχ2	83.96	81.27	81.51	79.02	83.19	80.36
iqf*qf*icf	83.92	80.93	82.58	80.26	82.04	78.66
proposed	84.13	81.55	82.72	80.65	82.86	79.65

Table 5: 10-fold cross-validation scores of the term weighting schemes using the three classifiers on the full Events1461 dataset.

	SVM		k-NN		LR	
	Micro	*Macro*	*Micro*	*Macro*	*Micro*	*Macro*
tf	72.22	70.88	69.88	67.12	71.32	69.96
tf*idf	72.89	71.06	70.80	69.16	72.14	70.11
tf*χ2	71.80	70.78	70.12	68.98	72.28	70.12
tf*ig	71.21	69.88	70.42	68.36	71.34	68.42
tf*gr	71.77	70.02	70.44	69.08	72.54	70.03
tf*OR	75.12	73.38	73.98	71.86	74.66	**72.66**
tf*rf	75.08	72.88	74.20	**72.99**	74.78	72.43
tf*logχ2	74.88	72.24	73.25	71.24	74.09	72.59
iqf*qf*icf	74.81	72.83	73.95	71.86	73.14	71.52
proposed	**75.17**	**73.55**	**74.23**	72.88	**74.86**	72.56

Table 6: 10-fold cross-validation scores of the term weighting schemes using the three classifiers on the balanced sub-dataset of Events1461.

5.1.2 Cross-validation on normalized event clusters

In this experiment, we used the normalized event clusters with different number of tweets (see section 4.1.2).

Fig. 7 displays the results. The proposed scheme has given the best scores in many normalized clusters. The *tf*log*χ2 and *tf*OR* schemes have also performed well. Specifically, the proposed scheme and *tf*log*χ2 have the best macroF1 scores for most of the normalized clusters. Among the normalized subsets of events, none has better scores than the full dataset. Hence, we use the full dataset for the remaining experiments.

We used the normalized event clusters to compare the scores of the raw term count, binary count (1/0 for presence/absence of a term) and log_2(raw count) as *tf* on the proposed scheme. Fig. 8 shows the results using the SVM classifier. The log_2(raw count) as *tf* has given the best scores, while raw count as *tf* has the worst. We have observed similar results for all the schemes that use *tf*. In fact, the baseline *tf*idf* using log_2(raw count) as *tf* outperforms many STW schemes using raw count as *tf*. Hence, we have used log_2(raw count) as *tf* in this work.

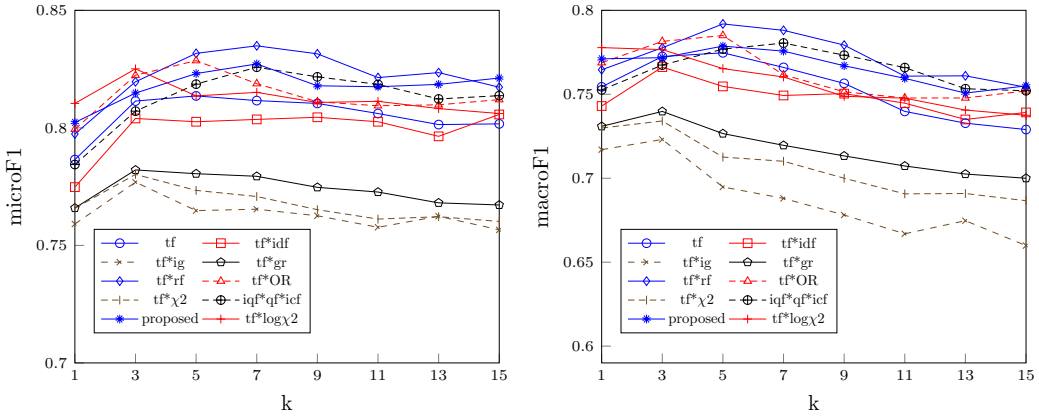

Figure 4: MicroF1 and macroF1 scores for different values of k in k-NN.

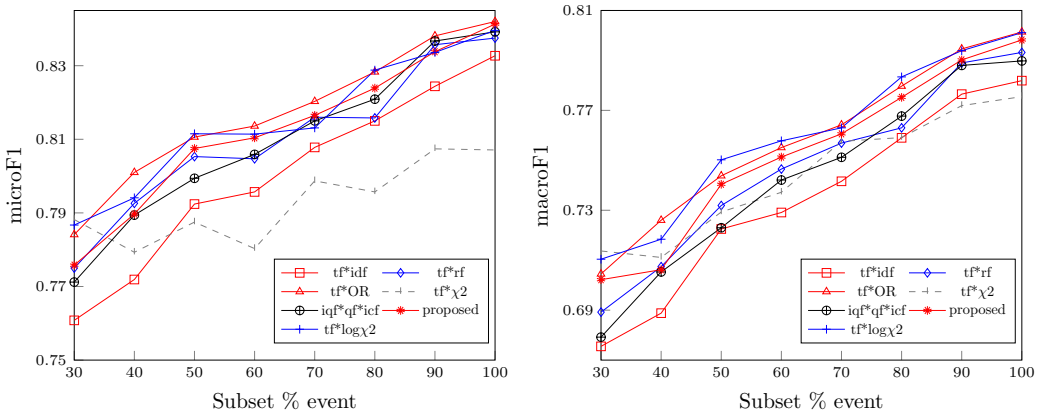

Figure 5: 10-CV scores of the term weighting schemes with subsets of different sizes. The x-axis represents the percentage of events used for each category.

5.2 Cross-corpus event classification

We performed this experiment to test the generalization capability of the term weighting schemes. We use Events1461 dataset for training and Events384 for testing. The two datasets contain the same categories of events from two non-overlapping periods, resulting in low statistical dependence of text. Table 7 shows the results using the SVM, k-NN and logistic regression classifiers. We use the same set of hyperparameters for the classifiers, as discussed in section 5.1.

The results are shown in Table 7. The *tf*OR* and *tf*log*χ2 schemes have the best macroF1 scores, followed by the proposed scheme. Among the classifiers, k-NN has the best categorization scores. Overall, the cross-corpus categorization scores are good considering the fact that the datasets used for training and testing are from different times and labelled by two unrelated groups of annotators.

	SVM		**k-NN**		**LR**	
	Micro	*Macro*	*Micro*	*Macro*	*Micro*	*Macro*
tf	79.47	72.28	82.96	75.11	79.33	71.37
tf*idf	78.07	72.75	79.89	75.88	72.85	61.57
tf*χ2	77.79	70.40	79.01	72.99	78.57	71.88
tf*ig	76.22	69.75	78.43	71.21	78.67	71.17
tf*gr	77.78	72.22	77.64	71.09	78.92	72.26
tf*OR	82.53	**79.29**	83.63	80.85	79.20	73.57
tf*rf	81.47	74.02	83.93	76.60	80.18	70.30
tf*logχ2	**82.64**	78.35	**84.72**	**80.97**	**80.77**	**74.36**
iqf*qf*icf	80.00	72.62	82.45	78.52	77.09	66.95
proposed	80.48	74.65	83.58	79.82	77.74	70.24

Table 7: Cross-corpus F1-scores where Events1461 is used for training and Events384 for testing.

5.3 General text categorization

We use three standard datasets to evaluate the performance of the term weighting schemes in general text categorization: 20 Newsgroups (20NG), Cade12, and WebKB. We remove the headers from the email documents in 20NG as they contain category information. The other two datasets are pre-processed versions available from the research by [3]. Cade12 contains twelve categories of documents of Brazilian web pages while WebKB contains four categories of webpages of computer science departments from different universities.

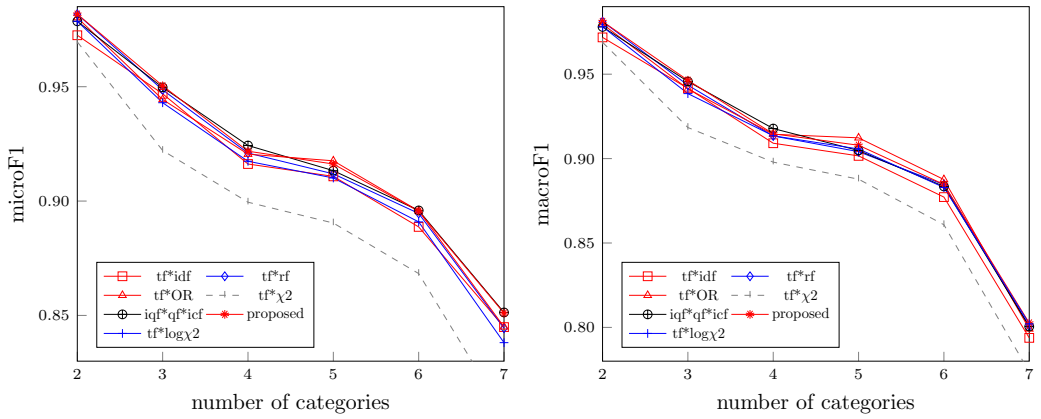

Figure 6: 10-CV scores of the term weighting schemes with different number of categories.

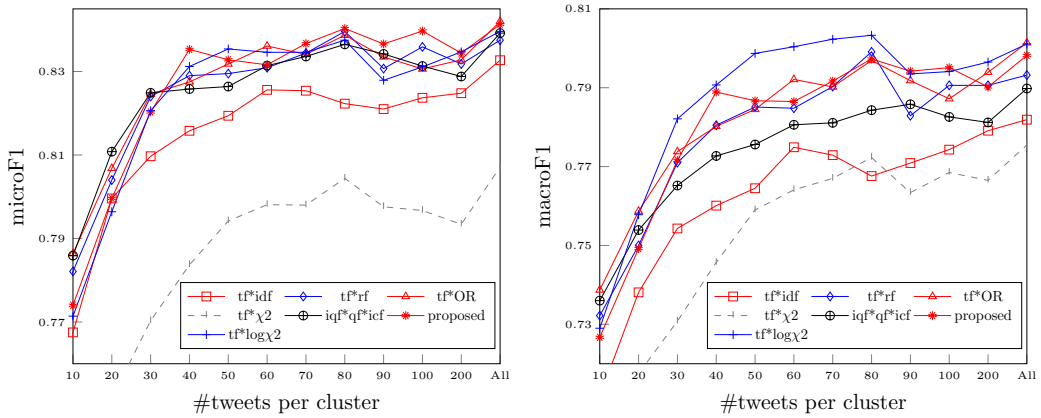

Figure 7: 10-fold cross-validation scores using SVM classifier on the normalized event clusters.

	20NG		Cade12		WebKB	
	Micro	*Macro*	*Micro*	*Macro*	*Micro*	*Macro*
tf	75.62	74.91	56.00	49.54	90.86	89.60
tf*idf	76.29	75.67	55.92	49.41	90.01	88.40
tf*χ2	75.82	75.01	52.50	46.93	88.02	86.59
tf*ig	74.64	73.66	51.23	44.99	87.98	86.60
tf*gr	74.85	73.94	51.75	45.85	87.84	86.52
tf*OR	**79.54**	**78.90**	**57.30**	**51.35**	90.74	89.63
tf*rf	78.74	78.11	56.92	50.47	**90.85**	**89.73**
tf*logχ2	77.12	76.40	56.76	50.70	90.36	89.32
iqf*qf*icf	79.16	78.60	57.11	50.79	90.69	89.33
proposed	78.28	77.61	57.03	51.09	90.65	89.23

Table 8: F1-scores of term weighting schemes on the standard text categorization datasets.

We use the SVM classifier for this experiment. Table 8 displays the results. The *tf*OR* scheme has yet again proven to be a versatile scheme with good macroF1 scores. The proposed scheme has better scores in Cade12 and WebKB, but its scores in 20NG are lower than other *strong* schemes. The results achieved on general text categorization are different from event categorization.

	idf	χ2	ig	gr	OR	rf	logχ2	iqf	proposed
tf	y	y	y	y	y	y	y	y	y
tf*idf		y	y	y	y	y	y	y	y
tf*χ2			y	y	y	y	y	n	y
tf*ig				y	y	y	n	y	y
tf*gr					y	y	n	y	y
tf*OR						y	y	y	y
tf*rf							y	y	y
tf*logχ2								y	y
iqf*qf*icf									y

Table 9: Pairwise significance difference with p-value of 0.05. y represent a significant difference, while n represents no difference in predictions.

5.4 Voting-schemes based classifiers

We used Mcnemar's test with continuity correction to measure the statistically significant difference between predictions of term weighting schemes. This is a standard test that researchers have used to compare two classifiers ([8], [15]).

Since this test needs a dataset with many categories, with each having hundreds of examples, we use 20NG. Table 9 displays the results of this test. For most pairs of

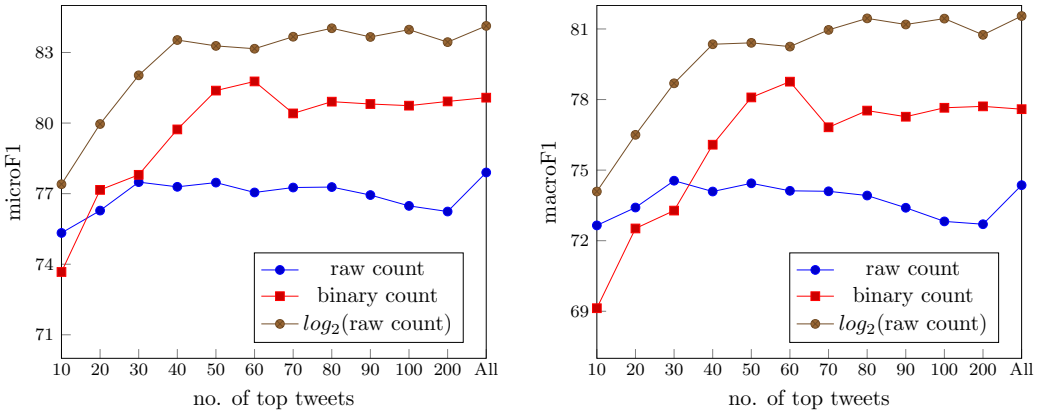

Figure 8: Comparison of raw count (tf), binary and log_2(tf) schemes using SVM.

	SVM		k-NN	
	Micro	*Macro*	*Micro*	*Macro*
best-scores	82.64	79.29	84.72	80.97
Voting	83.28	80.41	84.97	81.25

Table 10: Result of cross-corpus test using voting classifiers.

term weighting schemes, it shows statistical significance. Specifically, our proposed scheme, *tf*log*χ2 and *tf*OR* disagree significantly in their predictions.

We create a voting classifier [10] from these schemes. We use SVM and k-NN classifiers. In a voting classifier, the category label of an event cluster is selected by majority decision among the three schemes (*i.e.* each cluster's category prediction is common to at least two of the schemes).

We repeat the cross-corpus test using the voting classifiers. Table 10 displays the F1-scores. The row labelled *best-scores* represents the best individual scores in cross-corpus test (from Table 7) by the respective classifiers. Both the voting classifiers have given achieved better scores than the individual schemes. We can say that the voting classifiers may be effective in event classification.

6 Conclusion and future work

In our experiments, among the existing term weigthing schemes, *OR* has the best performance, followed by *iqf*qf*icf* and *RF*. We observed that the proposed method has given good F1-scores and the proposed modification to χ2 improves the classification scores of the original scheme. We also observed that voting-based classifiers created from the term weighting schemes that significantly differ in their predictions have the best F1-score. We may suggest *OR* and the proposed schemes for improving the classifier performance on similar datasets. However, a limitation of the study is the use of a self-labelled twitter dataset and a few standard datasets. Hence, even though the results of this study are encouraging, further experiments need to be conducted in the future on more datasets.

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Towards NoSQL-based Data Warehouse Solution Integrating ECDIS for Maritime Navigation Decision Support System

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Maritime shipping is a complex process because it requires a continuous analysis of huge amounts of information. Much of this information has variable spatial and temporal properties. Besides, the analysis must be effective to help in making decisions promptly. Generally, the analysis is applied with Spatial On-Line Analytical Processing (SOLAP) basing on spatial data warehouses SDW. Data warehousing by current technologies with relational database management systems (RDBMS) cannot be applied effectively to manage the increasing complexity and volume of geo-referenced data. To increase the performance and availability of services, NoSQL databases technologies have appeared. This paper presents the modeling and the realization of a spatial decision support system (SDSS) for maritime navigation namely "Maritima", basing on the integration of the ECDIS and OLAP systems. Indeed, the spatio-multidimensional analysis of the stored data can benefit from the expressive power of the electronic navigation chart offered by the ECDIS system. To benefit from the NoSQL model advantages, we try to apply transformations for the conceptual model to create a document NoSQL DW for maritime data. In addition to that, the multidimensional analysis at different dimensions and aggregation levels can generate beneficial indicators for the decision aid and can be very useful besides other steering systems for secure maritime navigation. Finally, "Maritima" is tested with a set of spatial data related to two different harbors "Arzew" and "Oran" in western Algeria.

Povzetek: Prispevek predstavlja modeliranje in izvedbo prostorskega sistema za podporo odločanju (SDSS) za pomorsko plovbo, in sicer "Maritima", ki temelji na integraciji sistemov ECDIS in OLAP.

1 Introduction

The safety of shipping with minimal costs is the main problem of shipping for all companies around the world. This explains the complexity of the navigation process, which requires a continuous analysis of huge amounts of multisource information.

Nowadays, human errors are more and more responsible for accidents in marine navigation [1]. Taking into account all the decision support parameters in such a system will allow the number of ship accidents to be reduced. This will contribute to the protection of human life, the transported goods, and the marine ecological environment.

The role of the decision support system (DSS) is to help to choose the right maneuver that does not lead to an accident. Besides, this maneuver will allow benefiting from the optimal conditions of the trajectory.

Geographical information is the representation of an object or a phenomenon a real or imaginary, located in space at a given moment. The Geographic Information System (GIS) is a technology that allows the manipulation of geographic information at different levels of detail. GIS allows the user entering, managing, manipulating, analyzing and displaying geographically referenced data. GIS allows synthesizing huge amounts of different data in different layers to manage and extract useful information. This helps to answer questions and make better decisions to implement planning for different activities.

Furthermore, spatial data warehouses and spatial OLAP systems are decision support systems that enable the spatial and multidimensional analysis of large volumes of spatial and non-spatial data. SOLAP technology offers users a very intuitive client interface for spatio-temporal analysis. However, its operation did not allow quickly adding new data obtained from GPS observations.

Safety is indisputable anxiety of shipping, considering the constant growth of maritime traffic. This has made it necessary to develop monitoring systems such as the Electronic Chart Display and Information System (ECDIS), which provide continuously the position of ships and various maritime safety data.

However, there will still be a need to develop solutions and advanced decision support that will benefit from GIS and on-line analysis.

In this work, we propose a solution that allows the integration of geo-localization technologies including GIS, ECDIS, and on-line data analysis on the one hand, and other systems installed onboard and at ground control stations on the other hand.

This integration will help for realizing the spatial decision support system (SDSS) for maritime navigation namely "*Maritima*". In fact, the spatio-multidimensional analysis of the information at different dimensions and aggregation levels allows benefiting from the expressive power of the electronic navigation chart offered by the ECDIS system. This enables generating beneficial indicators for the decision-aid and may be very useful in addition to other steering systems for secure maritime navigation.

Several authors proposed Unified Modeling Language (UML)-based models for the conceptual modeling of such applications. Within the literature, for the conceptual modeling, different authors have proposed models that supported UML. This because it allows representing static and dynamic aspects with powerful components and tools. Also, we can easily extend UML using profiles for handling specific complex aspects of applications namely spatial data warehousing and decision support systems (DSS) [11, 15].

We propose a conceptual model for spatial data cubes supported UML and its extension "UML-profile". This profile has been implemented with the UML-based tool called *Papyrus*.

In the area of maritime management, the amount of information is increasing rapidly. Indeed, huge amounts of data that reach petabytes of storage are stored and processed daily. The employment of relational databases becomes difficult and mediocre within the processing of the data exchanged. Additionally, decision support systems must not only have an outsized storage capacity but must also respond correctly and quickly to different cases.

For this purpose, the power to respond to complex queries promptly represents the most criteria in choosing the NoSQL model. Indeed, for profiting from the benefits of the NoSQL model, the objective of this paper is to apply different transformations to the relational model for the creation and implementation of NoSQL DW for maritime data. The "*Maritima*" system we developed is experimented with two different case studies and tested with a set of spatial data related to "*Arzew*" and "*Oran*" harbors in western Algeria. Finally, results are discussed.

This paper is organized as follows. In Section 2, we present a state of art. In Section 3, we present the most concepts of OLAP and Spatial OLAP. In section 4, we present NoSQL databases. An outline of the spatial decision support system "Maritima" is presented in Section 5. Multidimensional modeling of the maritime spatial data warehouse is presented in Section 6. Our tool for maritime navigation is implemented and discussed in Section 8. In Section 9, conclusions and future work are outlined.

2 State of the art

Decision support is usually solicited by organizations when they face different issues, such as location, allocation and management of resources, choice, and evaluation, and so on. A decision support process is comprised of the analyst and the decision-making process that aims to address the concerns related to this issue [2].

The role of the decision support system for maritime navigation is to help the entire team concerned by this mission to choose the anti-collision maneuver, which offers a better trajectory either at ports or in the open sea.

In [3] the author develops a system allowing the transmission of navigation data from the radar system. For this aim, the author uses the dynamic programming algorithm to determine the optimal safe trajectory of the ship. In [4], the author discusses the role of geo-informatics in maritime transport. Indeed, he considers it a new independent scientific discipline whose purpose is to process geospatial information. The authors in [5] present a prototype of a decision support system for operational ship routing using meteo-oceanographic fields as a function of time. In [6], the author describes the tasks of *the Intelligent Maritime Transport System*, as well as the place and functions of decision support systems for navigation. In addition to the information functions, these systems include the task of identifying hazards related to the movement of ships. In [7], the authors present a decision support system for navigation on board a seagoing vessel. They have highlighted the functionality of this system in the hope that it can contribute to navigation safety.

Authors in [8] propose a GIS system for maritime navigation safety. Their system aims at tackling the main cause of marine accidents, namely human errors, by providing navigational aid and decision support to mariners. In [9], an onboard decision support system to support ship operation is developed by the authors.

Several authors proposed solutions for the safety of maritime navigation. However, to the best of our knowledge, none of them had referred to the spatial and multidimensional analysis of the huge amount of big data stored. Indeed, we see that the multidimensional analysis at different axes and aggregation levels can generate indicators for the decision-aid. Indeed, it can be very useful, besides other steering systems for secure maritime shipping.

On the other hand, Data Warehousing and OLAP on Big Data are becoming one of the emerging challenges for the research of the next generations. We present in the following a set of works on NoSQL modeling:

Authors in [52] addressed current research issues and trends in Data Warehousing and OLAP on Big Data. In [51], the authors propose new rules to transform a multidimensional conceptual model into two NoSQL models: column-oriented and document models. In [54], the authors propose a database design and modeling methodology for NoSQL systems. The author in [55] explains how to build OLAP cubes from data warehouses with the NoSQL columnar model. The authors in [56, 57]

propose a NoSQL Implementation of a multidimensional database.

Basing on the above, our proposal is based on the integration of geo-localization technologies (GIS), the electronic navigation chart (ECDIS), and Spatial On-Line Analytical Processing (SOLAP). This is for the multidimensional analysis of data into a Spatial Decision Support System (SDSS) for secure maritime navigation. We propose also, a mapping of the multidimensional model into a document NoSQL model.

3 Main concepts of OLAP and spatial OLAP

Data warehouses (DW) and On-Line Analytical Processing (OLAP) are systems that allow analyzing large amounts of data and allow decision-makers to have a global and detailed view of their activities.

OLAP is a collection of tools for multidimensional analysis and rapid data exploration at multiple levels of aggregation [10]. OLAP systems allow decision-makers to manipulate data in a Data warehouse (DW) by specifying the analysis dimensions, hierarchies, and the subject of the analysis.

The use of operations, such as *roll-up* and *drill-down*, allows obtaining a general view and detailed view of the data stored in the DW, while *the Slice* operation allows the user to choose a subset of members across all dimensions.

As shown in Fig.1, The architecture of a Decisional Support System (DSS) is typically composed of the following parts namely: data sources, ETL, data warehouse, OLAP server, and OLAP client [11]:

1. ***Data sources:*** They can be of various types, such as OLTP databases, XML files, Excel files ... etc.
2. ***ETL tools***: They are a class of tools that specialize in homogenization, cleaning, and loading data on the warehouse. The essential tasks of an ETL are Extraction, Transformation, and loading.
3. ***The Data Warehouse (DW) part***: This part includes the data warehouse, metadata, as well as any data stores (Datamarts). A data warehouse can be defined as a collection of thematic, integrated, non-volatile, and historical data use for decision-making [12].
4. ***The OLAP server***: The OLAP server enables analyzing data basing on the multidimensional model. It provides OLAP operators, which allow decision-makers to have a multidimensional view of information.
5. ***The OLAP client***: The OLAP client must provide an intuitive and interactive interface that allows for multidimensional data exploration using OLAP operators in a simple manner.

In another hand, cartographic visualization provides significant benefits in analysis for decision-making. As a result, Spatial OLAP (SOLAP) is defined by Bédard [13] as "a platform for supporting fast and efficient spatio multidimensional analysis through modeling that integrates cartographic, graphical and tabular aggregation levels".

Indeed, cartographic visualization makes it possible to understand the distribution of a phenomenon over a geographical area in a multidimensional context.

3.1 Multidimensional modeling

Multidimensional Modeling according to Teste [14] consists of considering a subject analyzed as a point in a space with several dimensions. The data are organized in such a way as to highlight the analyzed subject and the different perspectives of the analysis.

The goal of multi-dimensional modeling is to enable analysts to have a view of the data that supports and helps their decision-making process. The data is then stored in a multidimensional structure. At the intersection of several dimensions, there are values named indicators or variables. These values are calculated by the OLAP engine through more or less complex mathematical or statistical operations.

We can distinguish different types of multidimensional modeling. It can be conceptual, logical, or physical [15].

1) Conceptual modeling

Conceptual modeling refers to the concepts defined by the authors in [16] and used in different types of data schemas [17].

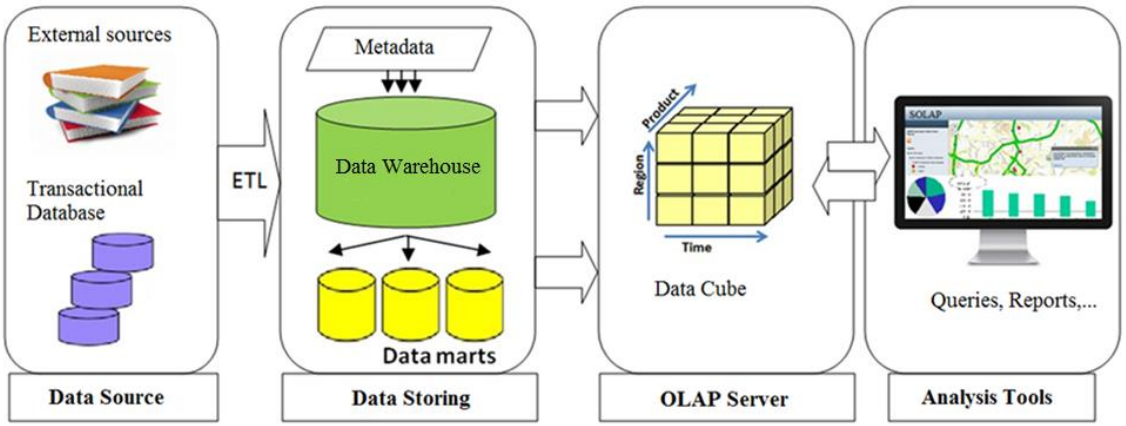

Figure 1: Architecture of a decision system.

A set of concepts are used to design a multidimensional data model. In the literature, some authors propose other definitions [18]. They are related to fact, measure, dimension, aggregation of measures, hierarchies, data cube …etc.

The above-mentioned concepts can be represented using different schemas namely: star, snowflake, constellation, and mixed [19].

Fig. 5 illustrates the constellation schema for the Spatial Data Warehouse of the current study. It is composed of two fact tables sharing a set of dimensions.

2) Logical modeling

Logical modeling represents the technique of physical data storage according to the database management system (DBMS) used which gives rise to three logical models [21]:

a) Relational OLAP (ROLAP)

In this type of implementation, a Relational Database Management System (RDBMS) is used for data storage. The ROLAP server simulates the multidimensional view and communicates between the RDBMS and the OLAP client tools. The ROLAP architecture allows great flexibility in managing large volumes of data and better data administration.

b) Multidimensional OLAP (MOLAP)

In this type of implementation, a native Multidimensional Database Management System (DBMS) is used. In this case, the decision data are maintained in multidimensional structures. The cells of the different data cubes (hypercubes) are pre-calculated from the DW or source bases and stored in these structures. As a result, OLAP operators can explore these cells in a simple and fast way. The MOLAP architecture offers less performance than the previous one concerning the data administration because of the precalculation of the cells.

c) Hybrid OLAP (HOLAP)

This type of implementation combines both ROLAP and MOLAP technologies. Indeed, some of the data that users access most frequently is stored in multidimensional structures managed by a DBMS. Another part is stored in relational structures managed by an RDBMS. HOLAP systems offer a compromise of the advantages and disadvantages of ROLAP and MOLAP systems.

3) Physical modeling

After having carried out the first two conceptual and logical modeling, we must proceed to the physical modeling of the DW. The purpose of this phase is to apply adequate techniques efficiently to store data for fast access.

This corresponds to the translation of the logic model into the language of the implementation platform (eg Oracle, MS SQLServer, etc.), [22]. Then, optimization techniques can be applied to optimize performance [15]:

- ***The materialization of views***: some of the most used queries are calculated and stored physically to improve the response time. Nevertheless, some problems can arise such as the choice of the requests and their update.
- ***Indexing***: This technique aims to ensure direct access to data. We distinguish the binary indexes in simple tables, and join indexes between two tables.
- ***Fragmentation***: This technique consists of dividing large tables into several fragments to speed up access to the data.

3.2 Spatial-multidimensional modeling

Spatial-multidimensional modeling is an extension of the multidimensional modeling used for data warehouses and OLAP. This enriches the concepts of the multidimensional model with spatial concepts such as spatial dimensions, spatial measures, etc.

- ***Spatial measure*****:** A spatial measure is a measure whose data type is geometric and/or numeric. For example, the area of a burned forest area, the circumference of a protected forest area, the distance between spatial regions, etc.
- ***Level of spatial aggregation*****:** A spatial aggregation level is an aggregate level representing a set of members. They have spatial attributes that allow them to represent the data in cartographic form. [23], [24].
- ***Spatial dimension*****:** The spatial dimension is a dimension, which can have one level of spatial aggregation at least. It makes it possible to represent the spatial information of the facts in axes of analysis. [25]
- ***Hierarchy of spatial dimension*****:** A spatial dimension hierarchy is defined as a hierarchy that contains at least one level of spatial aggregation [15].
- ***Spatial fact*****:** A spatial fact is defined as a fact containing at least one spatial measure or a level of spatial aggregation. [26].
- ***Spatial hypercube*****:** A spatial hypercube (or data cube) can be defined as a hypercube with at least one spatial or spatial dimension. [26]
- ***Spatial Data Warehouse (EDS)*****:** A Spatial Data Warehouse can be defined as a multidimensional model which can contain one spatial hypercube at least, [15];
- ***SOLAP navigation operators:*** These operators are the extension of the OLAP operators. They enable exploring the hypercubes with spatial data. [25]:

a) *Spatial Roll-up*: This operator is used for navigation in a dimension hierarchy from one level of spatial aggregation to another less detailed one.
b) *Spatial Drill-down*: This operator is used for navigation in a dimension hierarchy from one level of spatial aggregation to another more detailed one.
c) *Spatial Slice*: this operator is used to select a subset of the cells of the spatial hypercube by applying a spatial predicate on the members of a spatial dimension.
d) *Spatial Dice*: this operator is used for the selection of a subset of data by the application of spatial predicates to spatial members of several spatial dimensions. [15]

4 Nosql databases

NoSQL databases are characterized by flexibility in data storage and handling, performance improvements, and greater scalability. Among the numerous capabilities of NoSQL databases, there is the management of enormous non-relational and unstructured data flows, fast data access speeds, data availability. However, such plenty of various options, choosing the proper NoSQL database is difficult.

4.1 NoSQL database categories

In general, the foremost important factors to remain in mind are:

1) *Scalability*: Adopting the sharding technique is often useful in reaching scale, regardless of the database technology used.
2) *Performance:* Interactive applications require very low read and write latencies. Performance is obtained by distributing the load over several servers.
3) *Availability*. Interactive applications need a highly available database
4) *Ease of development*. NoSQL databases offer numerous important advantages that allow you to alter the data structure without affecting your application.

We distinguish four categories of model stores in NoSQL databases, namely Key-Value, Document, Column, and Graph [43]:

1) Key-Value: The key-value is that the most intuitive NoSQL data store. Each item within the database is stored as a key-value pair, sort of a standard dictionary. A key is usually a unique value that points to the data associated with it. The value is often any object like string, number, date, array, etc. [44]
2) Document store: The document store requires that its value to be structured and encoded (XML, JSON, and BSON). For spatial data, GeoJSON is well accepted. MongoDB and Apache CouchDB are samples of this category. [45]
3) Column-oriented: A column-oriented database is often a group of tables that are defined line by line, but whose physical storage is organized vertically by a group of columns, called "families of columns". A column family can contain an awfully sizable amount of columns [46].
4) Graph-oriented: The graph-oriented model relies on three concepts including node, relationship, and property. Each node has properties. Relationships connect nodes and possibly have properties. This sort of approach facilitates navigational queries between nodes by following the relationships between them. [47].

4.2 Spatial data in NoSQL databases

Spatial data are often manipulated with many NoSQL databases like Casandra, MongoDB CouchDB, etc. In the literature, the utilization of NoSQL databases in GIS is increasing. In fact, performance is tested and new architectures are developed for NoSQL spatial databases. In [48], the authors examined MongoDB's capability for storing sensor data. They found that MongoDB has the most effective performance for single database operations after comparing with Postgres. In [49], the authors designed HBase Spatial, a solution built on a NoSQL database. In [50], the authors created HGrid a data model directed for huge amount of geospatial data.

Different studies consider that there are advantages of using NoSQL databases to manage the challenges typical of big data. This because of the huge amount of data being gathered every moment related to locations from GPS (Global Positioning System) and mobile devices …etc. Additionally to the volume, there is also variety, which is the structure of the data collected in different structures. Thanks to the schema-less nature of NoSQL databases, different spatial data formats are enabled. We need Velocity also when processing or querying spatial data for applying predictive algorithms in real-time.

Generally, a NoSQL database may be a better solution to big data, which needs high scalability, high flexibility, and high-performance characteristics.

4.3 NoSQL data warehouse

In literature, research geared toward implementing multidimensional models of the conceptual level using NoSQL models may be classified into two categories:

1) The first category consists of translating multidimensional diagrams indirectly. The process reuses the conceptual translation rules to ROLAP then is extended by new rules allowing a transition from the intermediate ROLAP model to the target NoSQL model. The goal is to provide a storage scheme to avoid the use of joins for which NoSQL systems are poorly suited.
2) The second category consists of translating multidimensional schemas directly from the conceptual level to the target NoSQL model. Column and document-oriented models are used as an alternative to the relational model to build multidimensional data warehouses. Column-oriented storage is generally based on the HBase DBMS, which can manage large volumes of data in a distributed environment. The second approach, based on the document-oriented model, often uses the MongoDB system.

In the current study, we apply transformation rules allowing passing directly from a multidimensional conceptual model, which is Snowflake schema to a NoSQL logical model, which is a document-oriented model.

5 Description of the spatial decision support system "Maritima"

A Spatial Decision Support System (SDSS) can be defined as an interactive system that allows assisting the decision-making process. It is developed to solve problems with a spatial database or when the solution will have a spatial dimension.

The SDSS we propose, namely "Maritima", is based on the determination of the role of SOLAP and electronic

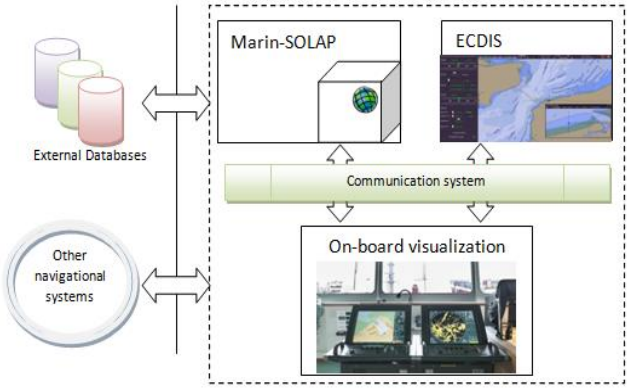

Figure 2: "*Maritima*" system components - an over view.

chart in a decision support process for secure maritime navigation as shown in Fig. 2.

The development of the spatial decision support system "*Maritima*" results from the combination of three subsystems, namely: *Marin-SOLAP Subsystem, ECDIS subsystem*, and *On-board visualization subsystem.*

These subsystems are related through the communication system represented by the Electronic Navigation (E-NAV) system, which is based on the interconnection of ships and coastal installations by high-speed data links, to guarantee the safety of navigation, especially in coastal areas.

E-NAV provides the mariner on board the ship and officials in the harbors, high-speed data, and updated information in real-time.

1) Marin-SOLAP Subsystem

The *Marin-SOLAP* Subsystem includes a spatial data warehouse (SDW) containing all conventional and spatial data related to maritime navigation. Data sources come from the operational process, the geographic database for GIS applications, and other sources such as remote sensing. The ETL process is applied for extracting, transforming, and loading data into the SDW. The SOLAP application uses the SDW for making multidimensional analysis. Our work focuses on the modeling and implementation of the *Marin-SOLAP* Subsystem [53]**.**

2) ECDIS subsystem

Thanks to the *ECDIS* subsystem coupled with the Global Positioning System (GPS), it is possible to display the position of a ship and various maritime safety information instantaneously with the superposition of an electronic chart.

3) Onboard visualization subsystem

The Onboard visualization subsystem is a human-machine interface primarily used by the ship captain and ground station controllers for the introduction of MDX queries and electronic chart. Results are then coming from the Marin-SOLAP subsystem and the ECDIS subsystem; and have a tabular, graphic, and cartographic display. This manipulation is automated thanks to the graphical interface developed for this aim.

```
context Hypercube inv AtLeastOneSpatialDimensionAndOneSpatialMeausure:
isSpatial=true implies (
ownedMember->select (m|m.oclIsTypeOf(SpatialDimension))->size()>0
and ownedMember->exists (m|m.oclIsTypeOf(Fact) and
      m.ownedAttribute->select (a|
            a.oclIsTypeOf(SpatialMeasure))->size()>0)))
```

Figure 4: OCL constraint in the context of the hypercube stereotype [32].

6 Multidimensional modeling of the maritime spatial data warehouse

SDW modeling relies on the extension of UML for Multidimensional (MD) modeling. This enables the outline of all Multidimensional concepts that our approach includes just like the facts tables, dimensions and hierarchy levels …etc. [26], [28]. During this section, we describe a way to create the relational model for OLAP,

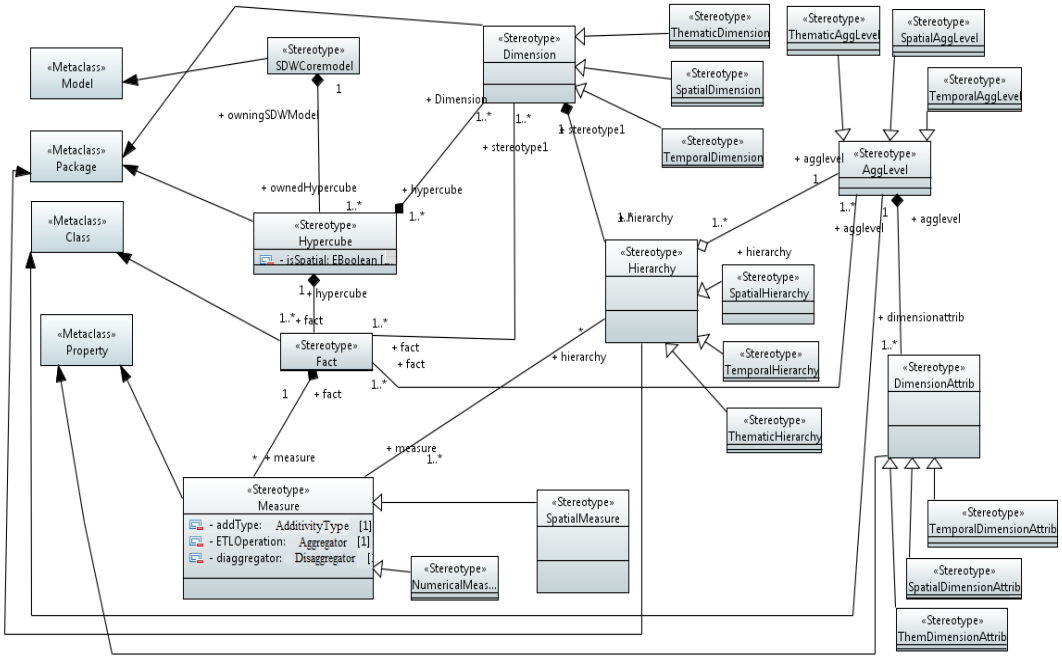

Figure 3: SDW profile stereotypes.

and then we apply transformation rules to get the document-oriented NoSQL model.

6.1 UML profile for spatial data cubes

The use of UML for MD modeling will be achieved by extending it with a profile to suit specific platforms or domains. This method allows customizing UML metaclasses with three mechanisms: stereotypes, tagged values, and constraints [29].

The OCL (Object Constraint Language) will be used for formalizing constraints that may refine the definitions of stereotypes and tagged values [30].

In our proposal, the essential SDW model is tailored from that presented by the authors in [31] and [32]. It allows the representation of the main static concepts of the SDW. We suggest it is complete and clear. The UML profile we propose is based on the extension of four metaclasses: Model, package, class and property as shown in Fig. 3. However, unlike the standard OLAP world, the Unified Dimensional Model (UDM)[1] allows to form multiple fact tables during a cube [33]. Therefore, basing on this principle, we propose that the cardinality within the composition relationship between the stereotype of the hypercube package and that of the facts class are going to be "one to many", as depicted in Fig. 3. [32].

In addition to the composition relation between hypercube and dimension stereotypes, an association between facts table and dimension stereotypes is proposed, because a hypercube (data cube) can contain several fact tables. Therefore, we will define which facts table will concern which dimensions of the identical hypercube. In addition, an association relationship is formed between the facts stereotypes and AggLevel to facilitate dimensioning. Measures are two types: spatial and thematic. The latter will be textual or numeric. [31].

To define which aggregation function is applicable during which hierarchy, an association relationship is formed between measure and hierarchy stereotypes [32].

To avoid incorrect modeling in our proposal, an OCL constraint is defined within the hypercube stereotype context. This can consider that a spatial hypercube will contain one spatial dimension at least, and one spatial measure within every fact table at least (see Fig. 4). Indeed, we think we must perform spatial analysis with each spatial measure, such as the location, the area, etc.

For the profile implementation, we use ***Papyrus***[2], the UML-based tool, when the constraints are verified by ***USE*** [3] at the conceptual abstraction level to avoid incorrect modeling.

Constellation schema for the maritime SDW

We implement the SDW which allows answering all questions related to the harbor, ships, and all other maritime data. We need the modeling of all measures and dimensions required in the MD analysis process. We must take into account the modeling of the hierarchies used for data aggregations [34]. To select the dimensions and measures based on the collected data, we must take into account the objectives of the maritime data analysis:

1) **Dimensions**: the facts are analyzed according to a set of dimensions describing three categories:

— Temporal dimension: we need a time dimension is required to perform a monthly, quarterly, or annual analysis.

— Spatial dimensions: We use the spatial dimension, which is related to the *position* of the ship, a *portion of* the *trajectory*, and the *trajectory* entirely.

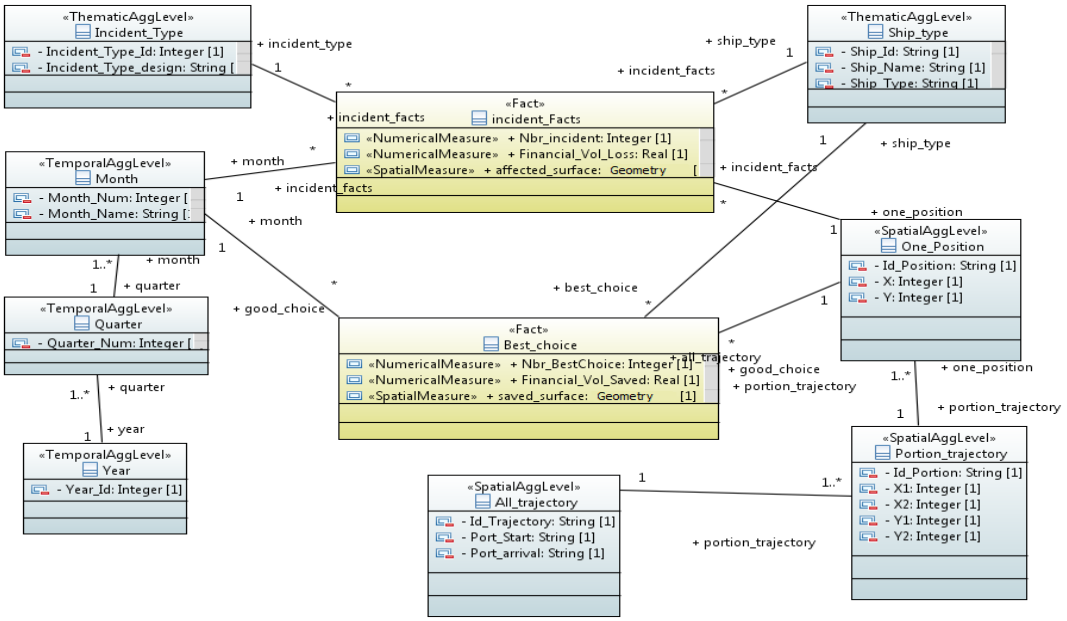

Figure 5: Class diagram of Maritime navigation SDW:

[1] The model for data in a Microsoft SQL Server Analysis Services (SSAS).

[2] open-source UML 2 tool based on Eclipse and licensed under The Eclipse Public License (EPL)

[3] a system for the specification and validation of information systems based on a subset of the Unified Modeling Language (UML) and the Object Constraint Language (OCL)

— Thematic dimensions: These dimensions are numerous and are related to business processes. They can be related to the *ship type*, *incident type*…etc.

Fig. 5 shows the dimensions of the maritime SDW. The dimensions are organized at several aggregation levels. They are formed by grouping the attributes of dimensions into disjoint subsets. This will be relating to the requirements of the analysis [31].

For example, the spatial dimension consists of a hierarchy composed of three levels of aggregation *One_position*, a *portion of trajectory*, and *All_trajectory*. In another hand, we use the temporal dimension with three levels: *month*, *quarter*, and *year*.

2) **Measures**: They are based on questions to be formulated by the *Captain of the ship, On-board Analyst, or Ground station controllers.* They can be numerical or spatial.

In our case studies, ***Onboard Analyst*** and ***Ground station controllers*** are interested in analyzing two aspects of their work, namely: ***Incidents*** and ***Best_Choices***. These aspects are defined using a hypercube with two fact tables sharing some dimension tables, which allows drawing the constellation schema.

The SDW for the maritime navigation class diagram is presented in Fig. 5. It is considered spatial because it includes at least one spatial measure in addition to the spatial dimension. The "Incident" fact table is described using three measures, one is spatial "affected_surface" and two are numeric "Nbr_Incident" and "Financial_Vol_Loss". The facts of "Best_Choice" are described using two numerical measures Nbr_BestChoice and Financial_Vol_Saved, in addition to a spatial measure "Saved_surface".

6.2 Transformation rules for document-oriented NoSQL

In this section, we use the transformation rules to NoSQL DWs defined in [51] since its completeness. Our choice is to use simple transformations since we have not hierarchies.

This type of transformation uses different collections for storing facts and dimensions; and uses the simple documents for representing measure and the composed attributes for representing dimension attributes.

So during this transformation, we transform the multidimensional schema MS to a documents collection where the collection is named after the multidimensional schema. Also, we transform each fact table to a document that is named after the fact name; and that we transform each measure and identifier of the related dimensions to a simple attribute. Then, each dimension is transformed into a document and it'll have an identical name; and every attribute of dimension is transformed to a simple attribute with the same name.

In Fig.6, these rules are depicted. Implementation and results discussion

6.3 Implementation

For the implementation of the solution, we propose two solutions namely: i) with RDBMS and ii) with document NoSQL solution.

1) RDBMS Implementation Environment

After we define the SDW model, we process its implementation. We use Relational OLAP architecture composed of a relational database management system (*MS SQL Server*[4]) for the database creation; and the SQL Server Analysis Service (*SSAS*) which provides OLAP operators such as Roll up, Drill down, Slice, Dice, etc. *ArcGIS*[5] software is used for preparing information layers and applying spatial analysis.

The relational OLAP architecture is composed of four tiers: *i)* Extract-Transform-Load tier (ETL), *ii)* data storage tier, *iii)* OLAP server and *iv)* OLAP client. However, the ETL techniques used in this phase are beyond the scope of this paper.

We create the project (Multidimensional Project_maritim) with Microsoft Visual Studio6 as shown

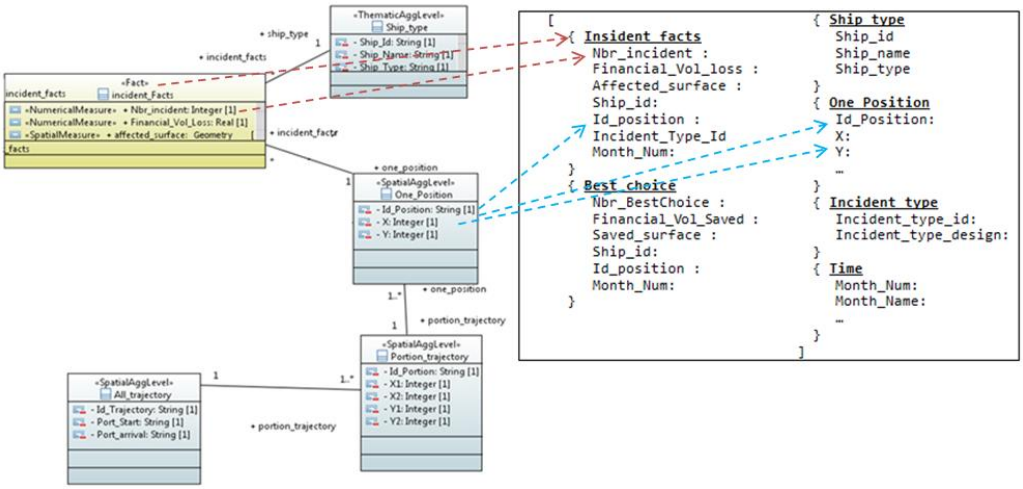

Figure 6: Transformation to Document-oriented model.

[4] https://www.microsoft.com/en-us/sql-server/
[5] https://www.arcgis.com
[6] https://visualstudio.microsoft.com

in Fig. 7. Once created, the data cube Maritime_Navigation can be visualized and tested with SQL Server Management Studio.

2) NoSQL DW Implementation Environment

For implementing the document-oriented DW, our choice is oriented towards MongoDB because it is the fastest-growing database. It enables dividing data into collections. MongoDB provides a rich document-oriented structure and allows dynamic queries. MongoDB is, also characterized by its aggregation engine. Another significant advantage is the integration of a "*geospatial data manipulation engine"*.

Therefore, based on the "Transformation Rules for document-oriented NoSQL" explained above, we create then the document NoSQL collections with *Robomongo*[7] as depicted in Fig.8. It will be connected to *JAVA Eclipse* to be used with the SOLAP solution.

We develop the SOLAP client namely "Marina" with *JAVA Eclipse*, the object-oriented programming language. Indeed, thanks to the integration of *ArcGIS RunTime SDK* (Software Development Kit) the solution provides cartographic synchronization with tabular and diagram displays as shown in Fig. 11 and Fig. 12.

In what follows, we test "*Maritima*", the system for maritime navigation in our proposal, with a dataset concerning "*Arzew*" and "Oran" harbors located in northwestern Algeria.

6.4 Case study 1: "Arzew" harbor

1) *Presentation of "Arzew*" harbor

Arzew is one of the most important petrochemical areas of Algeria. Its industrial zone covers a total area of 961.69 ha, allowing the establishment of several production units and oil services units such as: Refinery, Gas and Chemical.

The *Arzew* harbor is mainly used for the transport of petrochemical products. We have chosen this port for a first case study due to the importance of the presence of a decision-making system for the management of ship movements to avoid different risks. *Processing*

First, we note that the decision-maker which is the "ship's captain" asks the question: "**what is the best path to choose basing on the current dataset?**" and therefore, "**what is the maneuver to perform**". Then, the Onboard and Ground station analysts collect and exchange current data related to the ship, the coastal installations, the weather, and other data.

The electronic chart obtained by ECDIS represents the most important spatial data used in our proposal. This chart illustrates the current position of the ship, and information of all objects of the entourage, see Fig. 9.

Other spatial data related to the harbor as topographic and risk charts … etc, can be added in form of information layers. We note two important spatial data, which must present.

1- Vector information layer containing coordinates of all locations of different incidents as shown in Fig. 9.
2- Vector information layer containing a set of trajectories (*Tr112, Tr352, Tr251, Tr254*, and *Tr215*) which can be followed. They are traced by the ship's captain as shown in Fig. 10.

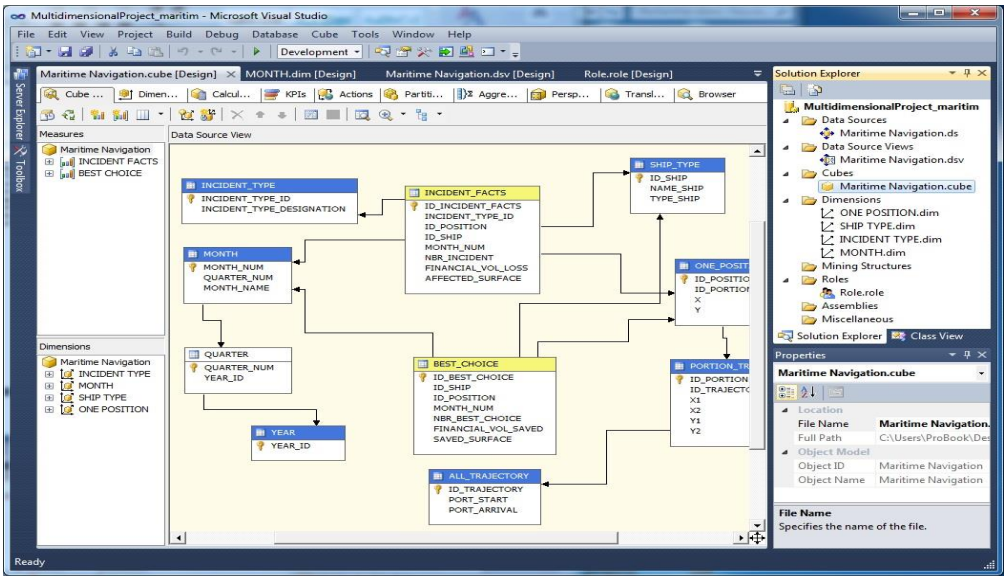

Figure 7: The Multidimensional Project _ maritime creation.

[7] www.robomongo.org

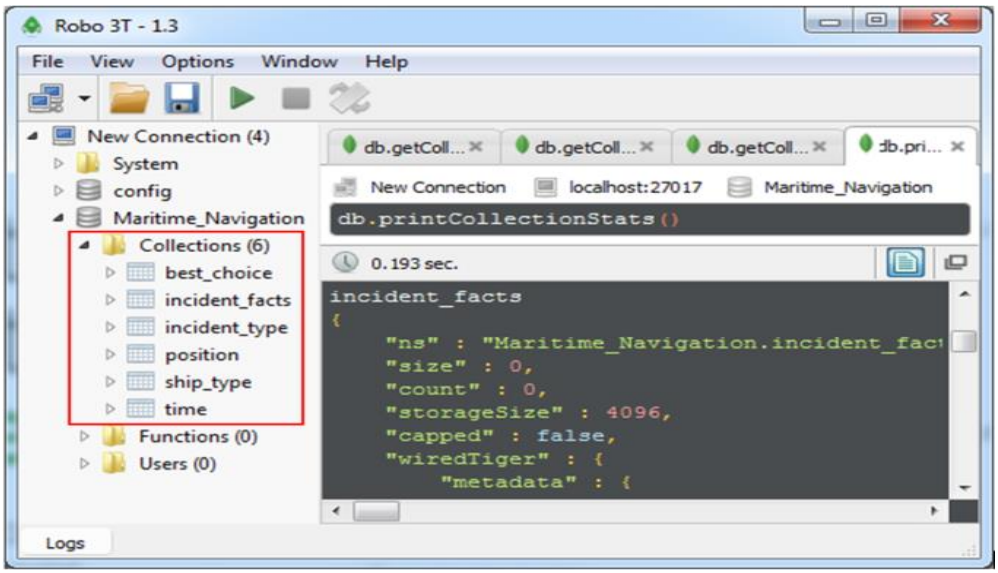

Figure 8: The Maritime Navigation DW in MongoDB.

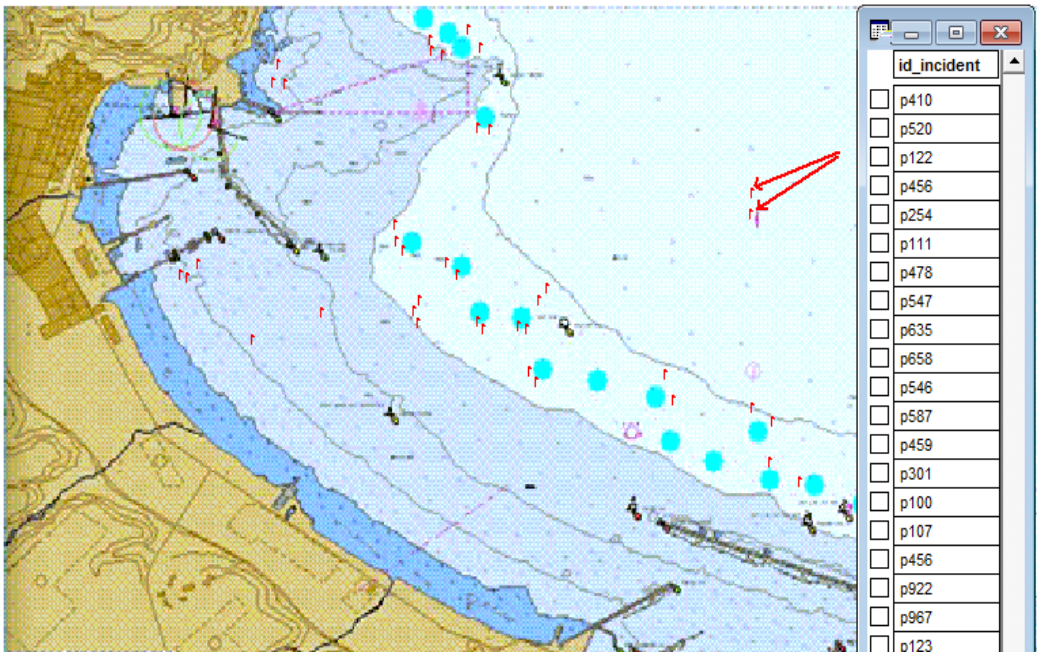

Figure 9: Electronic chart of Arzew harbor with incidents information layer.

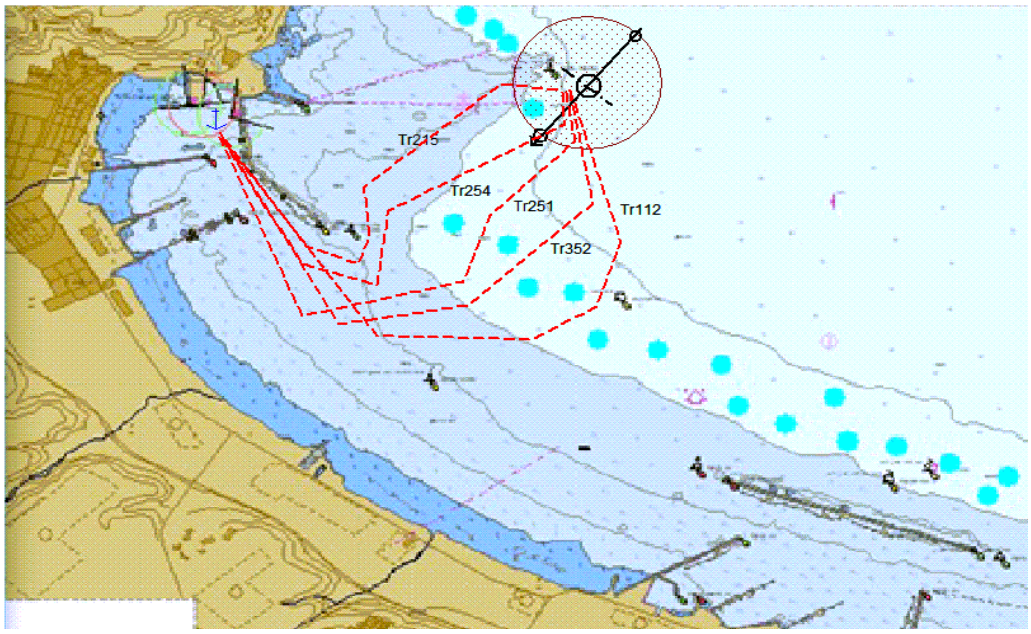

Figure 10: Electronic chart of Arzew harbor with trajectories information layer.

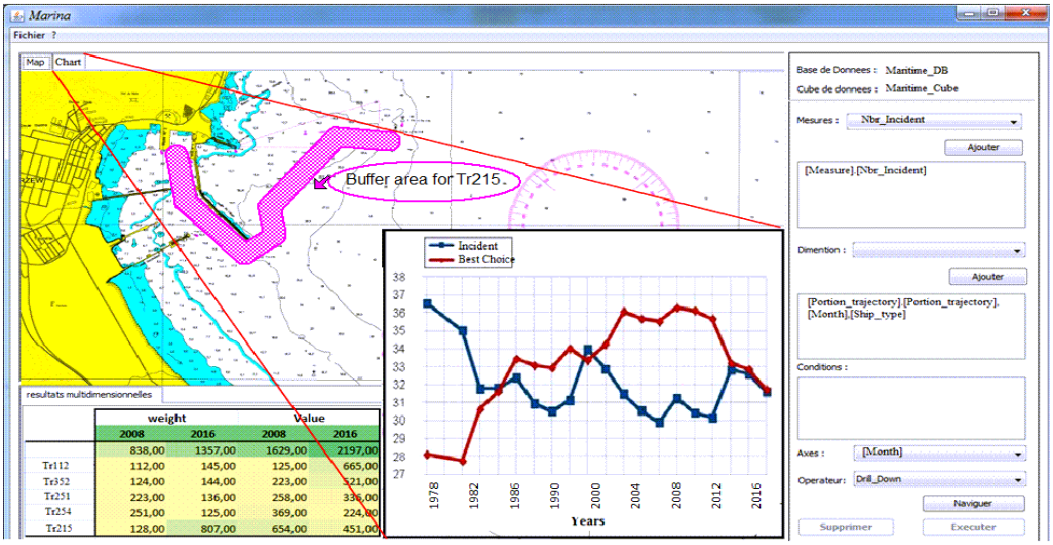

Figure 11: Multidimensional analysis with "Marina" Tr215.

So the ship's captain has to make a decision about which trajectory to choose in order to arrive at the port with the best conditions. Using the SOLAP prototype, the *onboard and Ground station analysts* make multidimensional analyses on points or a list of points, which intersect buffer areas. In this case, the *incident* fact table is concerned. If there is no intersection, the *best_choice* fact table is concerned. Once the results are obtained, they are transferred to the *Captain*. The latter is the only one who can take responsibility to make a decision about the trajectory and therefore, the decision about the maneuvers to be performed.

2) *Discussion*

As illustrated in Fig. 11, the analyst connects to the data cube "*Maritime_Cube*", and then he can launch MultiDimensional eXpression (MDX). In this example, the analyst wants to know the amount of incident "*Nbr_incident*" measure from the "*incident*" fact table and "*Nbr_BestChoice*" measure from the "*BestChoice*" fact table. This analysis is effectuated through the temporal and spatial dimensions.

The results of the multidimensional analysis can illustrate that for a *buffer area* around *Tr215*, the number of incidents was very important until 1986 because of fewer safety measures at this epoch. Next, *Tr215* choice becomes safe until 2000 when the number of incidents increases. That may be because of the presence of expansion works in the harbor. After that, this choice becomes again safe but not after 2014 until now. The same work will be applied for each trajectory.

We note the importance of the *buffer area*, which will intersect, or not a prospective incident. For the reason of space constraint, we will not illustrate all experimentations. However, Fig. 12 illustrates the best case related to *Tr251*. It is clear that this trajectory presents

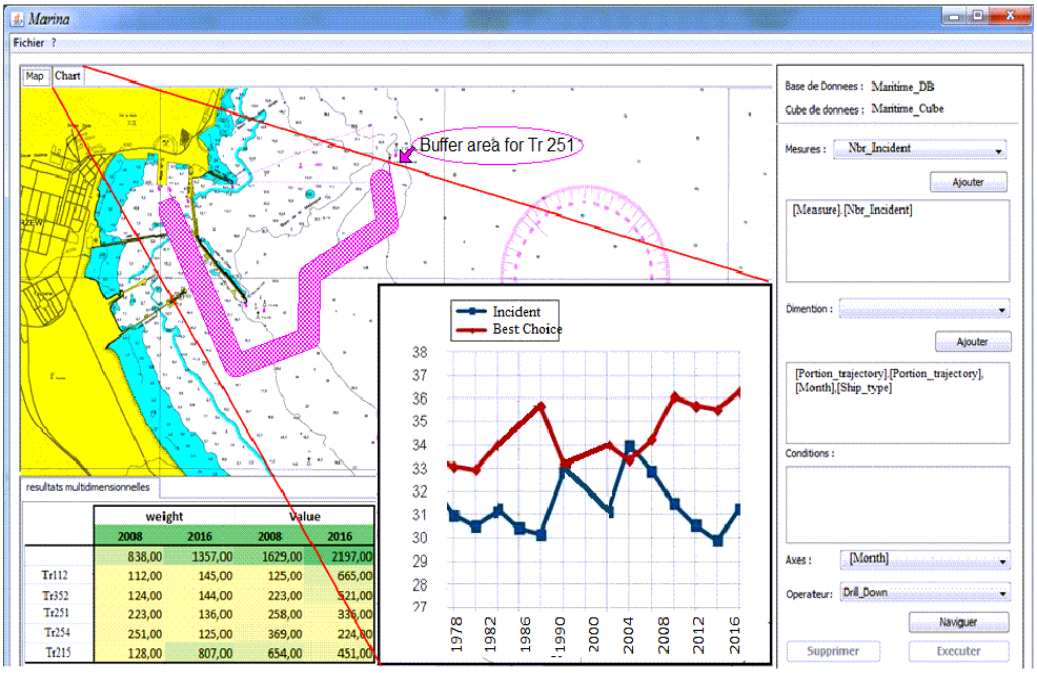

Figure 12: Multidimensional analysis with "Marina" Tr251.

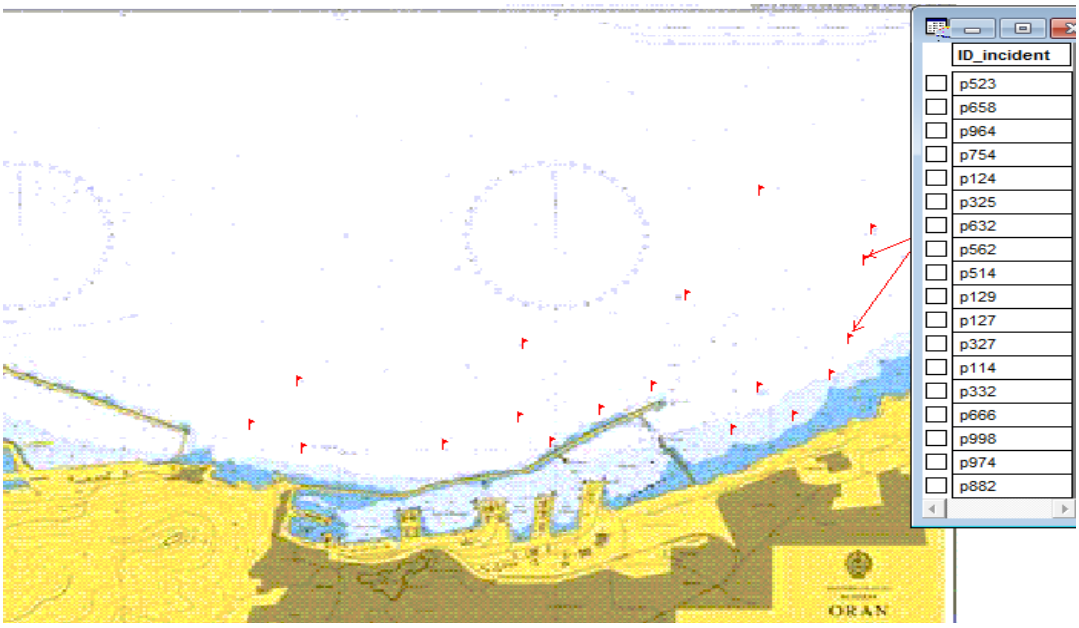

Figure 13: Electronic chart of Oran harbor with incidents information layer.

fewer incidents and is considered the best choice several times.

Besides, we note the importance of the electronic chart, which provides updated information, and an actualized chart. It is very useful and the presence of a new object in the sea will be taken into account during the spatial and temporal analysis.

6.5 Case study 2: "Oran" harbor

1) *Presentation of "Oran" harbor*

Oran is a port city in the Mediterranean, located in northwestern Algeria. It is the first coastal city in the west of the country. The Port Company "*Port Company of Oran"* (EPO), manages the commercial port of the city of Oran, under the tutelage of the Port Services Group and the Algerian Ministry of Public Works and Transport. With its many specialized facilities, the port of Oran can be considered polyvalent, since EPO treats containers, general merchandise, and cereals of all kinds in addition of passenger transport. The port of Oran is divided into several zones according to the existing specialized facilities.

We have chosen this port for a second case study due to the importance of the presence of an SDSS for the management of different kinds of ships coming in and out of the harbor to avoid different risks.

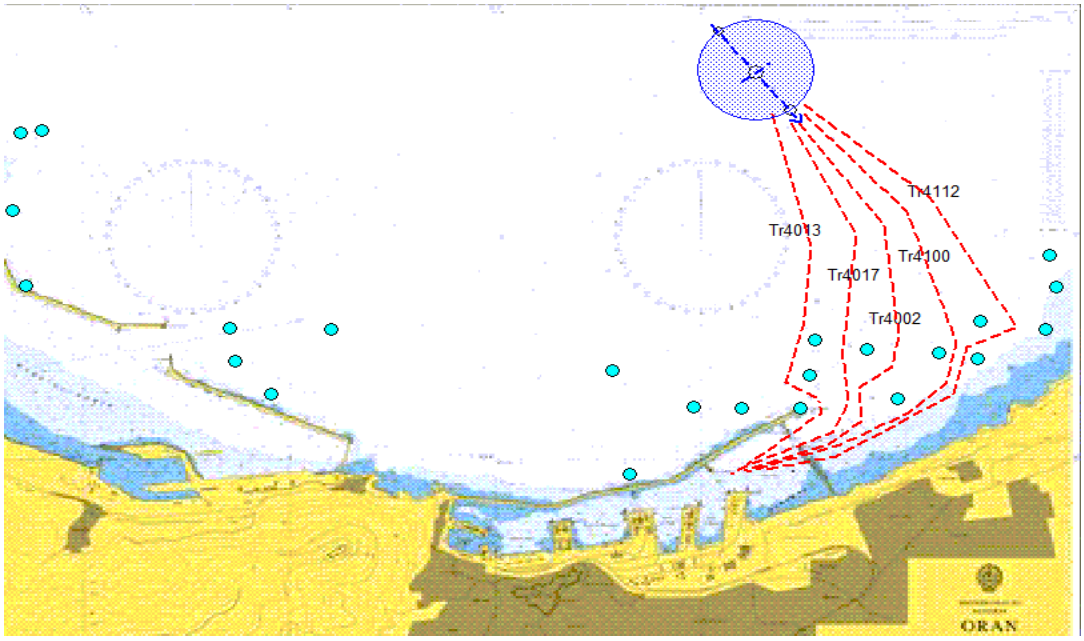

Figure 14: Electronic chart of Oran harbor with trajectories information layer.

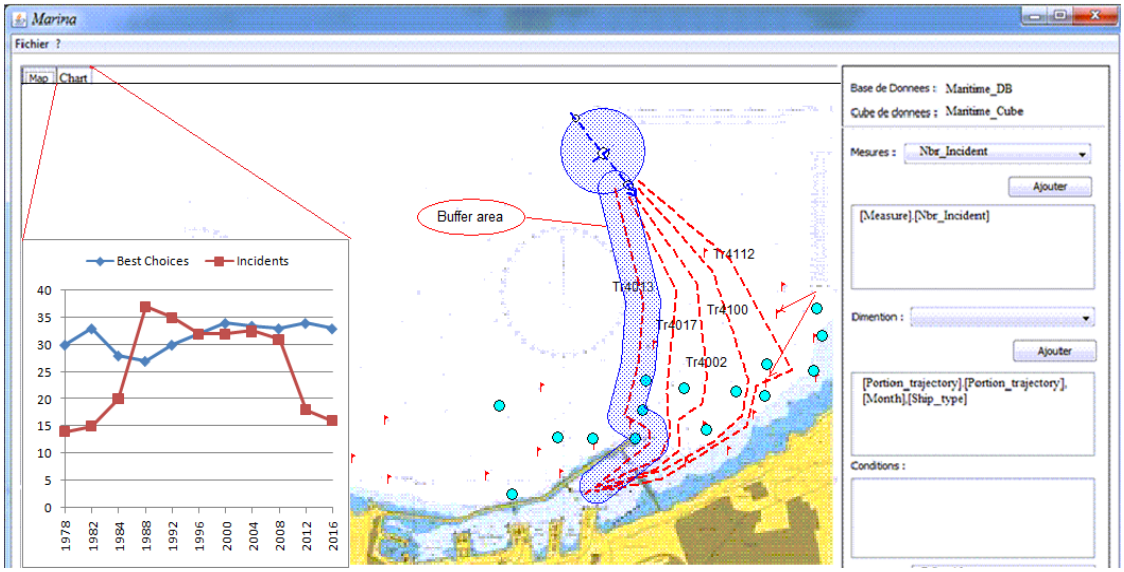

Figure 15: Multidimensional analysis for *Tr4013*.

2) *Processing*

First, the decision-maker which is the "ship's captain" wants to know: "**what is the best path to choose basing on the current dataset?**" this will help him knowing "**what is the maneuver to perform**".

In addition to other spatial data related to the harbor as topographic and risk charts … etc, we need the following:

1- The electronic chart of *Oran* harbor obtained by ECDIS, which illustrates the current position of the ship and information of all objects of the entourage.
2- Vector information layer containing coordinates of all locations of different incidents as shown in Fig. 13.
3- Vector information layer containing a set of trajectories (*Tr4013, Tr4017, Tr4002, Tr4100,* and *Tr4112*) which can be followed. They are traced by the ship's captain as shown in Fig. 14.

A buffer area is defined around every trajectory. The ship's captain has to make a decision about which trajectory to choose as the best solution. The *onboard and Ground station analysts* make multidimensional analyses on points or a list of points, which intersect buffer areas. They transfer the results to the *Captain* who is the only one who can take responsibility to make a decision about the trajectory and the maneuvers to be performed.

3) *Discussion*

As illustrated in Fig. 15, the analyst connects to the data cube "*Maritime_Cube*", and then he can launch multi-dimensional analysis through measure from the "*incident*" and "*BestChoice*" fact tables. The results of the multidimensional analysis illustrate that for a *buffer area* around *Tr4013*, we note the number of *incidents* is low since 2012 when the number of "*Best choice*" is very important. We note that these amounts were relatively

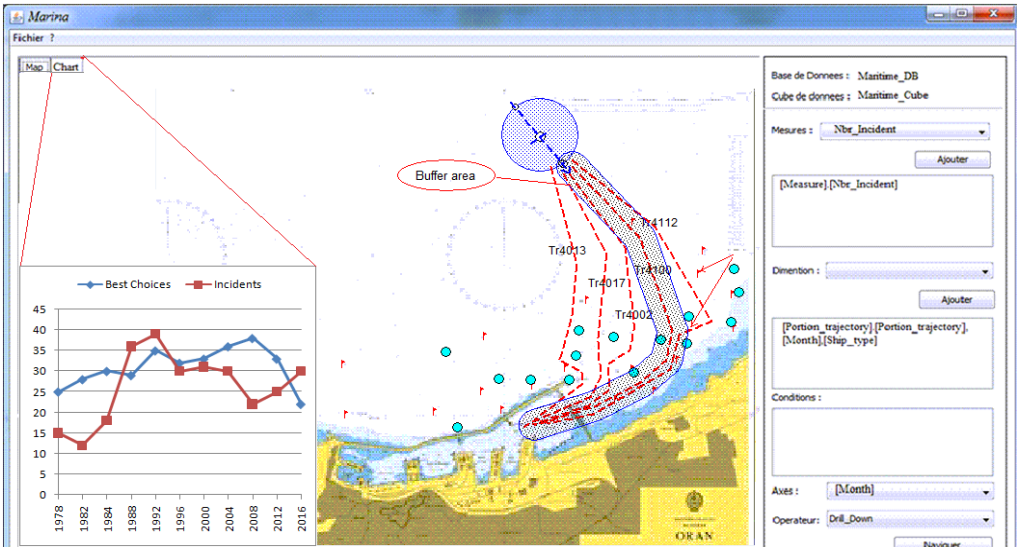

Figure 16: Multidimensional analysis for *Tr4100*.

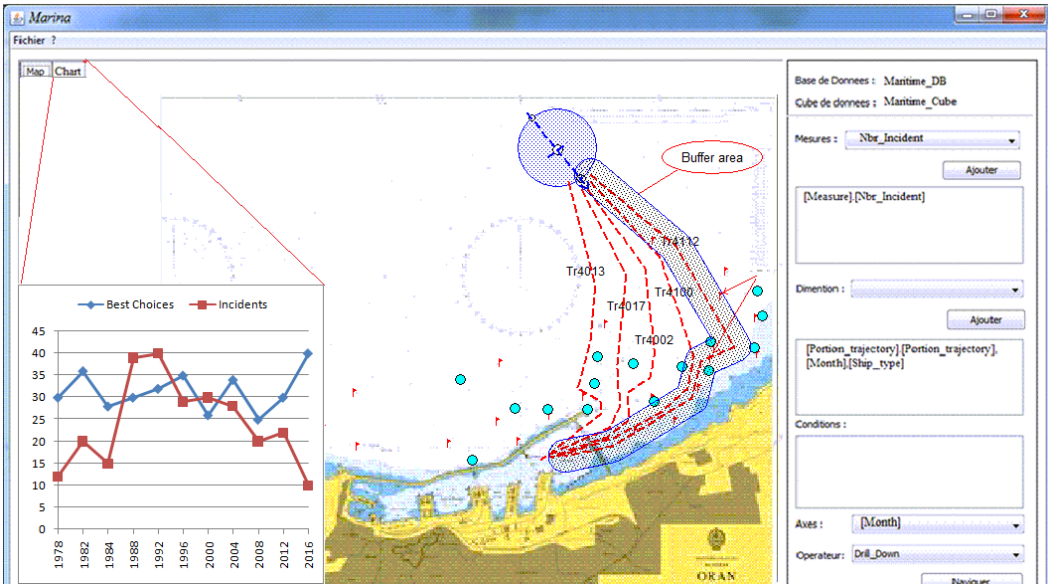

Figure 17: Multidimensional analysis for *Tr4112*.

close. For that, the ship's captain will consider his experience and the ECDIS system.

In Fig. 16, the results of the multidimensional analysis illustrate that for a buffer area around *Tr4100;* show that after 2016, the number of incidents is very important. This will eliminate this choice.

However, In Fig. 17, the results of the multidimensional analysis illustrate that for a buffer area around *Tr4112* we note relatively the same results as those of *Tr4013*. In this case, the ship's captain will consider his experience and the actualized electron chart offered by ECDIS.

We note that our system, in some cases, can provide several alternatives to the solution. It is theoretically possible when many trajectories present results of the multidimensional analysis, which can be considered as acceptable.

In this case, a solution can be by providing mechanisms for helping the *captain* to make the decision, for example by introducing multi-criteria analysis.

7 Conclusions and future work

For the support of spatial decision-making processes, technologies like Spatial Data warehouses (SDW) and Spatial OLAP tools are used in BI applications [35]. On the other hand, GIS is widely used for managing geographical data, and as a decision-aid system in different fields of knowledge namely epidemiology, forestry, agriculture …etc. [36, 37, 38, and 39].

The main objective of the current study is to develop a spatial decision support system (SDSS), namely "Maritima", by integrating ECDIS and SOLAP systems. This integration can help decision-makers effectively taking the appropriate maneuver for safe maritime navigation. Maritima consists of three subsystems, namely Marin-SOLAP Subsystem and ECDIS subsystem interconnected to the On-board visualization subsystem by data and queries flows. This is to make a decision that

will be taken by the decision-maker which is the ship's captain using the user interface.

We have based our proposal modeling in UML because it is a well-known standard modeling language on the one hand, and it can be easily extended to take into account specific domains such as multidimensional modeling for spatial data warehouses.

We developed "Marina", the SOLAP user interface in Eclipse Java programming language and it is tested with maritime data related to the harbor of Arzew western of Algeria.

In the field of maritime navigation, several works are introduced for providing computerized systems onboard the ship or at ground stations in the harbors [40, 41, 42]. However, they differ from Maritima, our proposal in this paper, in that the latter is based on different techniques, namely multidimensional analysis of data and geographical information system. These tools have proved their efficiency, with the integration of specialized technologies (ECDIS).

Results show that the document NoSQL model with MongoDB is well suitable when dealing with OLAP queries; however, we need to study other types of queries. We have applied transformation rules that ensure the translation from conceptual SDW schema to a logical document-oriented NoSQL model (MongoDB). We can also consider other NoSQL models in particular graph-oriented model, which goes well with geographical information systems (GIS).

We conclude that NoSQL databases are not opposed to relational databases known as SQL or other databases. They rather fill the gaps for cases that promote performance and fault tolerance

Our future work concerns the extension of "Maritima" by including other subsystems providing real-time data to be analyzed. Other simulation applications can be integrated with "Maritima" for providing experimental maneuvering tests.

Besides, the SDW modeling can be enriched by introducing other spatial integrity constraints (IC) and integrating data quality control mechanisms.

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Developing an Efficient Predictive Model Based on ML and DL Approaches to Detect Diabetes

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During the last decade, some important progress in machine learning ML area has been made, especially with the apparition of a new subfield called deep learning DL and CNN networks (Convolutional Neural Networks). This new tendency is used to perform much more sophisticated algorithms allowing high performance in many disciplines such as; pattern recognition, image classification, computer vision, as well as other supervised and unsupervised classification tasks. In this work, we have developed an automatic classifier that permits the classification of a large number of diabetic patients based on some blood characteristics by using ML and DL approaches. Initially, we have proceeded to the classification task using many ML algorithms. Then we proposed a simple DNN model composed of many layers. Finally, we established a comparison between ML and DL algorithms, as well as our model with other existing models. For the programming task, we have used Python, Tensorflow, and Keras which are the most used in the field.

Povzetek: V tem delu smo razvili avtomatski klasifikator, ki omogoča klasifikacijo več bolnikov s sladkorno boleznijo na podlagi nekaterih značilnosti krvi z uporabo ML in DL pristopov.

1 Introduction

Diabetes is one of the chronic diseases which causes an increase in blood sugar. Many serious complications can occur within the patient's body if diabetes remains untreated or unidentified. The best way to identify diabetes results in visiting a diabetes diagnostic center or consulting a specialist doctor. The advance in machine learning ML and deep learning DL can help efficiently in solving this critical problem. The main task to perform using these approaches is to design a predictive model that helps to predict the presence of diabetes in patients with maximum accuracy [1, 2]. In simple words, the machine learning area is based on a set of methods that allow a machine to learn meaningful features (patterns) from data without the interaction of the human. During the last years, many IA tasks like pattern recognition, image classification, computer vision, etc, are based essentially on Machine Learning approaches that gave a high performance. Several algorithms have been developed in this area, including; logistic regression, k-nearest neighbors, naïve Bayes, decision trees, support vector machine, artificial neural networks, etc. Researches on Artificial Neural Networks ANN can be considered as the oldest discipline in ML and AI that dates back to J. McCulloch and W. Pitts in 1943, but these researches were quickly interrupted due to their high requirements in terms of hardware, software, and running time. Many years later, they were revived in parallel with the apparition of a new subfield called deep learning DL. This new approach greatly simplifies the feature engineering process in many vital areas such as; medical imaging. Among the DL methods, CNNs are of special importance. When exploiting local connectivity patterns efficiently which is the case of those used in the ImageNET competition [3]. Many works are trying to apply CNNs on image analysis [4, 5] using a variety of methods like the rectified linear unit [6] and deep residual learning [7].

The present paper is organized as follows: section 1 is a short introduction presenting the area of our work and its advantages and benefits. Section 2 presents the background of deep learning as a new sub-field of ML and AI. Section 3 is a detailed overview of the related works in the same area. In the fourth section, we described our proposed model. The fifth section presents the experimental part we have done to validate our proposed model. In section 6, we illustrated the obtained results when applying the new model. In section 7, we discussed the results obtained in the previous section. In section 8, we established a quick comparison between the ML algorithms and the proposed ANN model. In section 9, we established a large comparison to the existing models. In the last section, we summarized the realized work and suggested some perspectives for future researches.

2 Deep learning background

Deep Learning DL becomes one of the most popular subfields of IA, and ML, especially in speech recognition, computer vision, and some other interesting topics [8]. Its success is motivated by three factors: the increased

amount of available data especially with the massive connection on the internet, the improvement and the lowest cost of hardware and software [6, 7, 9, 8, 10], the increased processing abilities (e.g., GPU units) [11]. DL is based essentially on the use of ANNs with at least two layers or many hidden layers. The convolutional neural network CNN is a specialized feedforward neural network that was developed to process multidimensional data, such as images. Its origins refer to the neo-cognition proposed by Fukushima in 1980 [12]. The first model of CNN was proposed by LeCUN et al., [13] in 1998 for the purpose of character recognition. Furthermore, many other alternative ANN architectures have been developed later, including; recurrent neural networks RNNs, autoencoders, and stochastic networks [14, 15, 16]. Deep learning also provided an efficient solution to the problem of input data representation which is considered as the most critical phase in ML especially when the problem is enough complex such as image or speech recognition [17] where it is difficult to define the best features to process on. In this way, DNNs can learn high-level feature representations of inputs through their multiple hidden layers. The first DNNs had appeared in the 1960s but were abandoned, after that for a long time in favor of the ML approach, due to its high requirements in terms of difficulties in training and inadequate performance [18]. In 1986 RumelHart et al., [19] proposed the back-propagation method to update efficiently neural network weights using the gradient of the loss function through multiple layers. Despite the promising results given by DNNs in the late 1980s [12] and 1990s [20], they were abandoned due to many problems. In 2006, researches in DL were revived especially when researchers have developed new methods for sensibility initializing DNN weights using a supervised layer-wise pretraining procedure [21, 22, 23]. It is the case of deep belief networks DBNs which worked very well through supervised learning and gave high accuracy in image and speech tasks in 2009 and 2012 [11]. In 2012, Krizhevsky et al., [18] proposed a deep CNN for the large-scale visual recognition challenge (LSVRC) [24] reducing significantly the error rate. This CNN has been implemented on multiple graphics processing unit GPUs for the first time. This new technique has since become a common practice in DL work until our days because it allows the training of large datasets and increases significantly the speed of processing. Furthermore, the use of a new activation function RELU (Rectified Linear Unit) was the alternative solution of the gradient that allowed faster training of data. The dropout technique is also used as a regularization method to decrease overfitting in large networks with many layers. All these interesting improvements in DL let the leading technology companies increase the research efforts, producing many other advances in the field. Many DL frameworks using tensor computation [14, 15, 16, 17] and GPU compatibility libraries [18] have been developed and made available to researchers through open-source software [23] and cloud services [24, 25]. On the other hand, many companies have met the challenges of big data when exploring large amounts of data to predict value decisions [26]. The notion of big data refers to data that exceeds the capability of standard data storage and data processing systems [27]. This large volume of data requires also high-performance hardware and very efficient analysis tools [28]. Some other ML challenges appeared with big data including; high dimensionality, distributed infrastructures, real-time requirements. Najafabadi et al [26] discuss the use of DL to solve big data challenges and proved that the capacity of DNNs to extract meaningful features from large datasets is extremely important. The automatic extraction of features from heterogeneous data, e.g., image text, audio is very useful and difficult. But this task becomes easy with the use of DL methods. Other tasks including; semantic-based IRS like semantic indexing and hashing [27, 28] also became possible with these high-level features, furthermore, DL is also used to tag incoming data streams allowing to classify fast-moving data [26]. In general, high-level DNNs are suitable for learning from large data issued of big data sources. In conclusion, we can say that DL is currently growing faster than before.

3 Related work

Diabetes detection is one of the most important topics in the health care field. Many studies have been done in this field and have as a common goal the improvement of the accuracy as well as the speed of detection. Among these studies, we can note the following:

Kayaer and Yeldirim [29] proposed a general regression neural network to detect diabetes and achieved an accuracy of 80.21%. Goncalves et al. [30] developed a system based on a new hierarchical neuro-fuzzy binary space repartitioning method BSP, they achieved an accuracy of 80.08% for the training set and 78.26% for the test set. Polat and Gunes [31] used a generalized discriminant analysis method GDA and the least square support vector machine LS-SVM, they reported an acceptable accuracy of 79.16%. Kim et al. [32] applied SVM with CPONs to obtain the best classification accuracy, they used the following datasets: WISCONSIN Breast Cancer Dataset, Pima Indians Diabetes, BUPA Liver Disorder Dataset, Ionosphere Dataset, and the MNIST Digit dataset from the UCI machine learning repository. They obtained an accuracy of 83.11% for the Pima Indians Diabetes PID dataset. Caliskan et al. [33] developed a simple training strategy for deep neural network classifiers using L-BFGS algorithm on many datasets including the PID dataset, they achieved an accuracy of 77.09%. Dwivedi [34] used machine learning algorithms to predict diabetes mellitus. He used many algorithms including; SVM, ANN, LR, DT, KNN, NB. The highest obtained accuracy was 82% using the Naïve Bayes algorithm. Vijayashree et al. [35] proposed a new system based on the use of recursive feature elimination combined with an analysis component to predict diabetes. Two architectures have been used here: a deep neural network which gave an accuracy of 82.67% and an artificial neural network which gave an accuracy of 78.62%. Ashiquzzaman et al. [36] proposed a prediction framework for diabetes mellitus using a deep learning approach with diminution of the overfitting. They used the

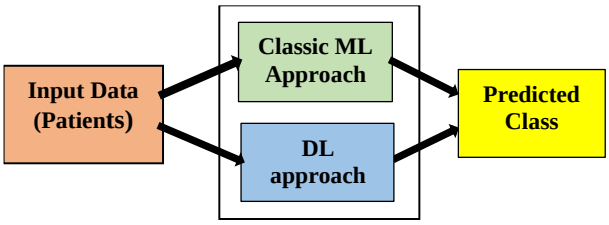

Figure 1: Diabetes Classification Process.

Pima Indians Diabetes dataset and obtained an accuracy of 88.41%. Cheruki et al. [37] proposed an expert system based on PCA and an adaptive neuro-fuzzy inference system ANFIS on the PID dataset for diabetes diagnosis and obtained an accuracy of 89.47%. Kannadasan et al. [38] proposed a new predictive model for type 2 diabetes classification using stacked autoencoders cascaded with a softmax classifier and achieved an accuracy of 86.26%. Kowsher et al. [39] developed a deep ANN and ML classifier using many performance measures such as; accuracy and precision to specify the best DNN model and obtained an accuracy of 95.14% on the training dataset.

Many other studies have been done, but the classification accuracy was within 59.5% and 77.7%.

4 The proposed approach

In the present work, we have developed an automatic binary classifier that permits us to identify people affected by diabetes based on some characteristics (features). Thus, it is a binary classification into two (02) given classes (1: the patient has diabetes, 0: the patient does not have diabetes). All of the input variables that describe each patient are numerical. We note also that to build the best predictive model, we have used two approaches: the classic ML approach and DL approach. Initially, we have proceeded with the classification task using many ML algorithms including; LR, LDA, KNN, CART, NB, and SVM. Then we proposed a DNN model composed of many simple layers: one input layer (180 neurons), eight hidden layers (150, 120, 80, 50, 30, 18, 8, 4 neurons), and finally an output layer (01 neuron). In the last stage, we established a first comparison between the different algorithms and a second comparison between our model and the existing models. As programming tools, we have used Python, Tensorflow, and Keras which are the most used in this field. Fig 1 summarizes the classification task based on the two approaches, while Fig 2 presents a detailed architecture of the proposed DNN model to improve the performance of the classification task.

5 Experimental work

5.1 Used dataset

In our experiments on the scikit-learn toolkit and DNNs, we used the Pima Indians onset of diabetes dataset which is a standard machine learning dataset from the UCI Machine Learning repository. It describes patient medical record data for Pima Indians and whether they had an onset of diabetes within five years. Thus, our problem is a binary classification problem (onset of diabetes as 1 or not as 0). All of the input variables that describe each patient are numerical. This makes it easy to use directly with neural networks that expect numerical input and output values, and ideal to use the neural network in Python, Tensorflow, and Keras. The dataset includes data from 768 women with 8 characteristics, including:

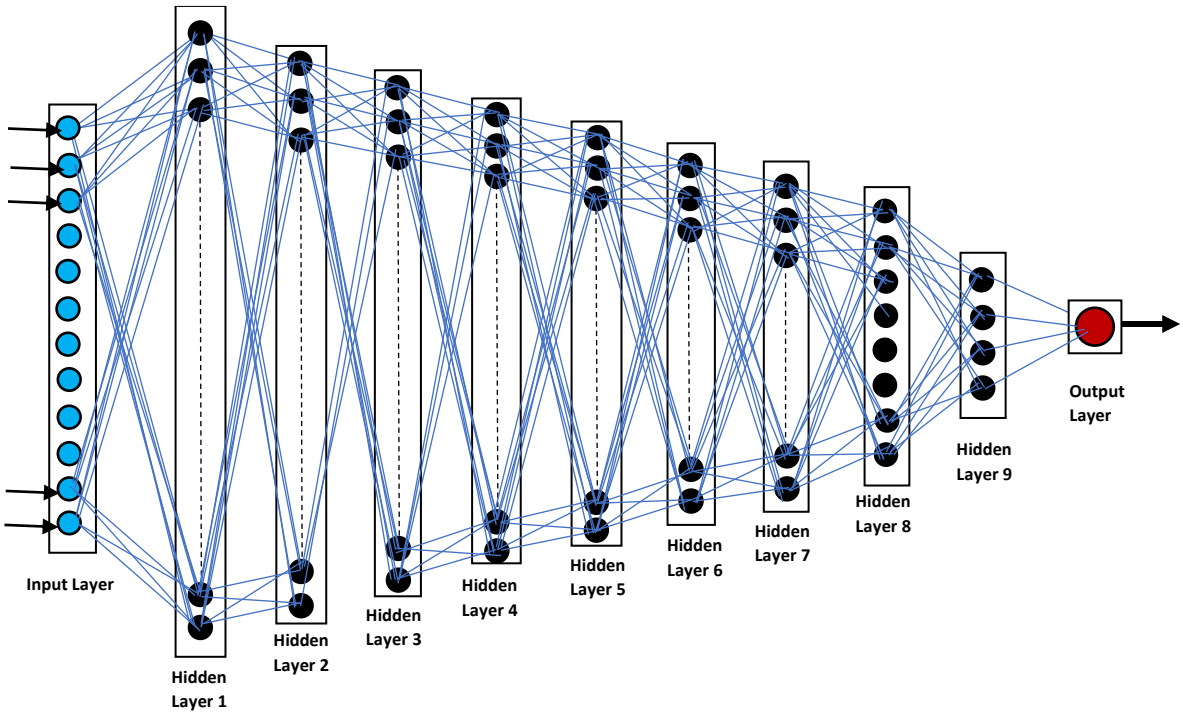

Figure 2: Architecture of the proposed CNN model.

1. Number of times pregnant
2. Plasma glucose concentration within 2hours oral glucose tolerance test.
3. Diastolic blood pressure (mm/Hg)
4. Triceps skinfold thickness (mm)
5. 2-Hour serum insulin (mu U/ml)
6. Body mass index (weight in kg/(height in m)^2)
7. Diabetes pedigree function
8. Age (years)
9. The last column of the dataset indicates if the person has been diagnosed with diabetes (1) or not (0).

5.2 Programming tools

Python: Python is currently one of the most popular languages for scientific applications. It has a high-level interactive nature and a rich collection of scientific libraries which lets it a good choice for algorithmic development and exploratory data analysis. It is increasingly used in academic establishments and also in industry. It contains a famous module called scikit-learn tool integrating a large number of ML algorithms for supervised and unsupervised problems such as; decision trees, logistic regression, Naïve Bayes, KNN, ANN, etc. this package of algorithms allows to simplify ML to non-specialists working on a general-purpose.

Tensorflow: TensorFlow is a multipurpose open-source library for numerical computation using data flow graphs. It offers APIs for beginners and experts to develop for desktop, mobile, web, and cloud. TensorFlow can be used from many programming languages such as; Python, C++, Java, R,…, and Runs on a variety of platforms including; Unix, Windows, iOS, Android. We note also that Tensorflow can be run on single machines (CPU, GPU, TPU) or distributed machines of many 100s of GPU cards

Keras: Keras is the official high-level API of TensorFlow which is characterized by many important characteristics: Minimalist, highly modular neural networks library written in Python, Capable of running on top of either TensorFlow or Theano, Large adoption in the industry and research community, Easy productization of models, Supports both convolutional networks and recurrent networks and combinations of the two, Supports arbitrary connectivity schemes (including multi-input and multi-output training), Runs seamlessly on CPU and GPU.

5.3 Evaluation

To validate the different ML algorithms, and obtain the best model, we have used the cross-validation method consisting of splitting our dataset into 10 parts, train on 9, and test on 1 and repeat for all combinations of train/test splits. For the DNN model, we have used two parameters which are: loss value and accuracy metric.

1.Accuracy metric: This is a ratio of the number of correctly predicted instances divided by the total number of instances in the dataset multiplied by 100 to give a percentage (e.g., 90% accurate).

2.Loss value: used to optimize an ML algorithm or DL model. It must be calculated on training and validation datasets. Its simple interpretation is based on how well the ML algorithm or the DL model is doing in these two datasets. It gives the sum of errors made for each example in the training or validation set.

3.Precision: It is the number of real correct positive results divided by the total number of positive results predicted by the classifier.

4.Recall: It is the number of real correct positive results divided by the number of all relevant samples in the dataset (all samples that should have been identified as positive).

5.F1-Score: is the Harmonic Mean between precision and recall. The range for F1-Score is [0, 1]. It tells you how precise your classifier is (how many instances it classifies correctly), as well as how robust it is.

6.Confusion Matrix: The Confusion matrix is one of the easiest metrics used for finding the correctness and accuracy of the model. It is used for classification problem where the output can be of two or more types of classes and give the correctness for each class.

6 Illustration of obtained results

To build the best predictive model, we performed two tasks:

1. Applying many ML algorithms, including; Logistic Regression LR, Linear Discriminant Analysis LDA, K-nearest Neighbors KNN, Decision Tree (CART variant), Gaussian Naïve Bayes NB, Support Vector Machine SVM. For this purpose, we used the scikit-learn library of python containing the most known learning algorithms.
2. Designing a DNN (Deep Neural Network) model according to the following process:

- We proposed a model composed of ten (10) full connected layers described as follows:
- layer 1(180 neurons and expects 8 input variables), layer 2 (150 neurons), layer 3 (120 neurons), layer 4 (80 neurons), layer 5 (50 neurons), layer 6 (30 neurons), layer 7 (18 neurons), layer 8 (8 neurons), layer 9 (04 neurons), and finally, layer 10 or the output layer has 1 neuron to predict the class (onset of diabetes or not).
- The ten (10) fully connected layers are defined using the Dense class of Keras which permits to specify the number of neurons in the layer as the first argument, the initialization method as the second argument, and the activation function using the activation argument.
- We initialize the network weights to a small random number generated from a uniform distribution (‘Uniform‘), in this case between 0 and 0.05 which is the default uniform weight initialization in Keras. Or ‘normal’ for small random numbers generated from a Gaussian distribution.
- We use the rectifier (‘Relu’) activation function on most layers and the sigmoid function in the output layer.

- We use a sigmoid function on the output layer to ensure our network output is between 0 and 1 and easy to map to either a probability of class 1 or 0.
- We compile the model using the efficient numerical libraries of Keras under the covers (the so-called backend) such as TensorFlow. The backend automatically chooses the best way to represent the network for training and making predictions to run on your hardware (we have used CPU in our application).
- When compiling, we must specify some additional properties required when training the network. We note that training a network means finding the best set of weights to make predictions for this problem.
- When training the model, we must specify the loss function to evaluate a set of weights, the optimizer used to search through different weights of network, and any optional metrics we would like to collect and report during training. Since our problem is a binary classification, we have used a logarithmic loss, which is defined in Keras as "binary_crossentropy".
- We will also use the efficient gradient descent algorithm "adam" because it is an efficient default.
- Finally, since it is a classification problem, we report the classification accuracy as the performance metric.
- Execute the model on some data.
- We can train or fit our model on our loaded data by calling the fit() function on the model, the training process will run for a fixed number of iterations through the dataset called epochs, which we must specify using the n-epochs argument. We can also set the number of instances that are evaluated before a weight update in the network is performed, called the batch size, and set using the batch_size argument. For our case, we fixed the following values: Nb-iter=350, batch-size=10. These are chosen experimentally by trial and reducing the error.
- We trained our DNN on the entire dataset (training set) and evaluated its performance on a part of the same dataset (test set) using the evaluate () function. This will generate a prediction for each input and output pair and collect scores, including the average loss and any metrics you have configured, such as accuracy.

The following tables summarize the obtained results on ML algorithms and the CNN model.

7 Discussion

Table 1 summarizes the obtained results when applying the different ML algorithms including; LR, LDA, KNN, DT (CART), NB, SVM. We observe that LR, LDA, KNN, CART, and NB give a high classification accuracy (> 70%), while SVM gives a relatively low value of accuracy (65%) compared to the previous algorithms.

Table 2 gives the performance of KNN with Minkowski similarity by class. The performance is given in terms of three measures: precision, recall, and F1-score for each class. Class 0 (no diabetes appears on a patient) has high values for the three measures, but class 1 (onset diabetes) not. This can be interpreted by the fact that we meet a con-flict in detecting a diabetic patient. Finally, table 2 calculates the micro-average, the macro-average and the weighted average of the different performance measures. These new metrics represent a kind of harmonic mean that summarizes the different values.

Table 3 presents the obtained results when applying the proposed DNN model on the training set and the test set. Two performance measures are considered in this case, the loss value which calculates the sum of errors after training the model, and the accuracy value which gives the rate of correctness. It is clear, that the loss value is very low against the accuracy which is very high and depends on the size of the used set. It is the reason for which the accuracy of the training set is higher than the accuracy of the test set.

In the same way, Figure 3 shows the evaluation of training loss and validation loss over time and in terms of the number of epochs. It begins very high for the training set and ends very low because of the large number of samples, but its variation for the validation set is not very quick and appears relatively stable.

Similarly, Figure 4 plots the evolution of training accuracy and validation accuracy in terms of the number of epochs. Contrary to the loss value, the accuracy starts very low and ends very high. This property is clearer with the training set because of its large size.

Algorithm	Accuracy
LR	77,09%
LDA	77,61%
KNN (k=5, metric = minkowski)	71,36%
CART	70,49%
NB	75,87%
SVM	65,27%

Table 1: The accuracy average after applying different ML algorithms.

Class	Precision	Recall	F1-score
0	0.75	0.84	0.79
1	0.62	0.49	0.55
Micro Avg	0.71	0.71	0.71
Macro Avg	0.69	0.66	0.67
Weighted Avg	0.70	0.71	0.70

Table 2: Performance report for KNN (k=5, metric = Minkowski).

DNN (180, 150, 120, 80, 50, 30, 18, 8, 4, 1)	
Training set	Loss: 0.0763 ; Accuracy: 97,39%
Test set	Loss: 0.26 ; Accuracy: 94.27%

Table 3: Loss and accuracy values obtained when applying the proposed model.

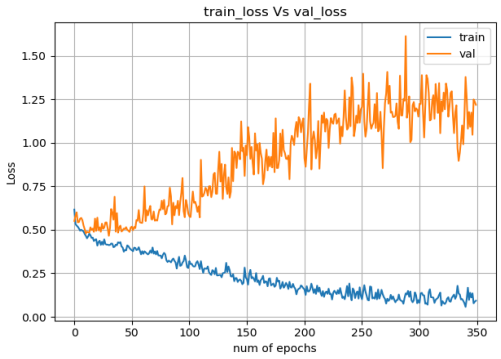

Figure 5: Training loss Vs Validation loss of the DNN model.

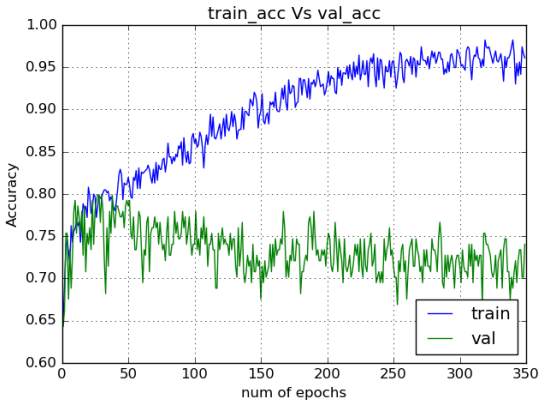

Figure 6: Training Accuracy Vs Validation Accuracy of the DNN model.

We can see also in Figures 3 and 4 representing loss value and accuracy value successively that curves are not continuous but there exist some pics, that because the two values of loss and accuracy don't progress continuously over epochs, but increase and decrease until stabilizing on a specific value.

8 Comparison between ML, and the DNN approaches

In this section, we try to establish a comparison between different algorithms, ML algorithms, and the DNN model. The result of this comparison is illustrated in Table 4.

According to Table 4 and Figure 5, The comparison favors the DNN model over ML algorithms. And we can confirm that the DL approach gives always the best values of accuracy if we choose a suitable architecture.

9 Comparison with other works

In this section, we will establish a comparative study between our proposed model and other models of the state-of-the-art, as illustrated in Table 5 and shown in Figure 6.

10. Conclusion and future suggestions

In the last years, object recognition is based essentially on the ML approach that gives high performance. Many years later, some important progress on the ML area has been

Algorithm	Accuracy rate
LR	77,09%
LDA	77,61%
KNN (k=5, metric = minkowski)	71,36%
CART	70,49%
NB	75,87%
SVM	65,27%
CNN model	Train-Acc: 97,39% Test-Acc: 94,27%

Table 4: Comparison between ML approach and DL Approach.

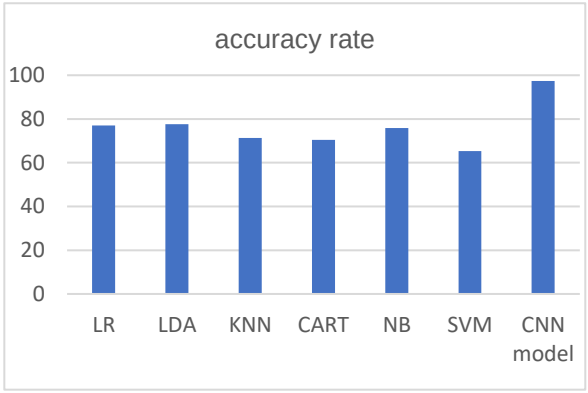

Figure 3: Comparison between different Algorithms.

Author	Year	Accuracy
Kayaer and Yeldirim [29]	2003	80.21%
Goncalves et al. [30]	2006	80.08%
Polat and Gunes [31]	2007	79.16%
Kim et al. [32]	2015	83.11%
Dwivedi [34]	2017	82%
Vijayashree et al. [35]	2017	82.67%
Ashiquzzaman et al. [36]	2017	88.41%
Cheruki et al. [37]	2017	89.47%
Caliskan et al. [33]	2018	77.09%
Kannadasan et al. [38]	2018	86.26%
Kowsher et al.[39]	2020	95.14%
My proposed model	2021	97.39%

Table 5: Comparison with other existing models.

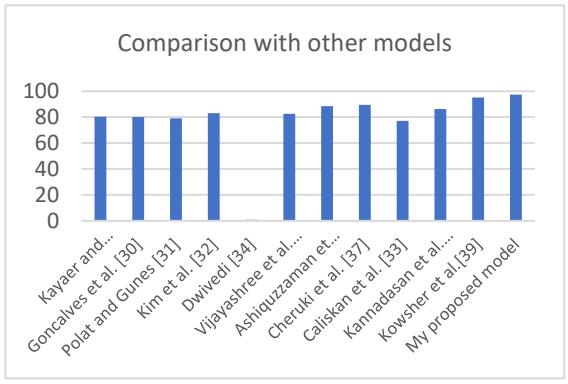

Figure 4: Comparison with other existing models.

made especially with the apparition of a new subfield called deep learning. It is mainly based on the use of many neural networks of simple interconnected units to extract meaningful patterns from a large amount of data to solve some complex problem such as; medical image classification, fraud detection, character recognition, etc. currently, we can use larger datasets to learn powerful models, and better techniques to avoid overfitting and underfitting. Until our days, the obtained results in this area of research are very surprising in different domains. We talk about very high values of accuracy which often exceed the threshold of 90%. For example, the accuracy rate on the digits set is over 97%. In the present paper, we have performed a task of classification on the Pima Indian dataset PID. We have used in the first stage many ML algorithms including; LR, LDA, KNN, DT (CART), NB, SVM. We obtained a good result of accuracy especially, on LR, LDA, KNN. In the second stage, we have built a DNN model to perform the same task of classification. The achieved performance is very surprising. We concluded our work by establishing a large comparison between different algorithms. The result of this comparison was in favor of the DL approach through the DNN model we have built. Furthermore, we have conducted a large comparison of our model with the existing models, our proposed model gives the best performance (a high value of accuracy). As a perspective of this promising work, we propose to improve these results by improving the architecture of the DNN model by studying other ANN architectures, changing some model parameters such as; the number of layers, the number of neurons in each layer, the number of training epochs and the size of data batches. Another suggestion that seems important, is to use other types of DNN or combining CNN with recurrent neural networks RNN.

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Detection and Recognition of Abnormal Data Caused by Network Intrusion Using Deep Learning

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Based on deep learning, this study combines sparse autoencoder (SAE) with extreme learning machine (ELM) to design an SAE-ELM method to reduce the dimension of data features and realize the classification of different types of data. Experiments were carried out on NSL-KDD and UNSW-NB2015 data sets. The results show that, compared to the K-means algorithm and the SVM algorithm, the proposed method has higher performance. On the NSL-KDD data set, the average accuracy rate of the SAE-ELM method was 98.93%, the false alarm rate was 0.17%, and the missing report rate was 5.36%. , The accuracy rate of the SAE-ELM method on the UNSW-NB2015 data set was 98.88%, the false alarm rate was 0.12%, and the missing report rate was 4.31%. The results show that the SAE-ELM method is effective in the detection and recognition of abnormal data and can be popularized and applied.

Povzetek: S pomočjo metod globokega učenja je metoda sposobna prepoznati nenormalne podatke v mreži kot posledico vdora.

1 Introduction

With the expansion of the network and the increasing volume of data [1], the traditional methods are increasingly unable to meet the needs of detection and identification of abnormal data, and cannot achieve effective defense of the network. The detection and recognition of abnormal data can be regarded as a classification problem. Methods such as machine learning were widely used in recognition of abnormal data [2] and achieved good results. Mitchell et al. [3] detected the medical network physical system with a behavior-based method. Through experiments, they found that the method could deal with more covert attacks with a high detection rate. Hosseini et al. [4] designed a method based on multi-criteria linear programming and particle swarm optimization. They performed experiments on the KDD CUP 99 and found that it had obvious advantages in accuracy and computing time. Wei et al. [5] used different neural networks to obtain the characteristics of the data for detection and carried out experiments on DARPA 1998 and ISCX2012. The results showed that the method had a good detection rate. Dubey et al. [6] designed a hybrid method based on K-means, naive Bayes, and back-propagation (BP) neural network. They carried out experiments on KDD CUP99 to verify the performance of the method. At present, in the face of massive data, the performance of detection and recognition is not good enough and is greatly affected by the size of the data. Intelligent methods such as deep learning have good detection ability for multi-dimensional dynamic network data; therefore, this paper used deep learning to detect and recognize abnormal data and verified the reliability of the method. This work makes some contributions to further improving abnormal data detection and recognition ability and realizing network security.

2 Detection and recognition method based on deep learning

2.1 Feature extraction based on sparse autoencoder

Autoencoder (AE) [7] is a deep learning network structure. It is assumed that the input of the encoder is I, the middle layer is Z, and the output is O. The purpose of AE is to make I≈O. In this process, the output of the encoder can be written as:

$$Z = f(I) = f_I(W + b_I)$$

The output of the decoder can be written as:

$$O = g(Z) = g_Z(W^T + b_Z)$$

where f_I and g_Z are activation functions, W is an initial weight, b_I is a forward bias, and b_Z is a reverse bias. AE minimizes reconstruction error by training {W,b_I,b_Z }:

$$E = \sum_{x \in I} J\left(x, g\left(f(x)\right)\right)$$

where J refers to the reconstruction error function. This study uses the mean square error loss function:

$$L(x) = \|x - y\|^2$$

Sparse autoencoder (SAE) [8] is obtained by adding a sparsity limitation to AE, which enables it to give deeper features, i.e., let the node's output be as close to 0 as possible. It is assumed that the mean value of the activation degree of node j in the middle layer is:

$$\hat{\rho}_j = \frac{1}{m}\sum_{i=1}^{m}\left[a_j^{(2)}\left(x^{(i)}\right)\right]$$

where m is the number of data and a_j^((2)) is the output activation value of node j, whose input is x. In the sparsity limitation, to make ρ^_j as close as possible to 0, a decimal ρ that approaches 0 is introduced as the sparsity parameter, and Kullback-Leible divergence is used to perform regularized constraint on the network. The global loss function of the network is written as:

$$J_{sparse}(W,b) = J(W,b) + \beta\sum_{j=1}^{s_2} KL\left(\rho\middle\|\hat{\rho}_j\right)$$

$$KL\left(\rho\middle\|\hat{\rho}_j\right) = \rho log\frac{\rho}{\rho_j} + (1-\rho)log\frac{1-\rho}{1-\rho_j},$$

where s_2 refers to the number of neurons in the middle layer.

2.2 Detection and recognition based on extreme learning machine

In the learning process, an extreme learning machine (ELM) [9] can achieve the desired effect by calculating the output weight only, showing a high learning speed [10]. For a given training sample {x_i,y_i }_(i=1)^N, it is assumed that the number of nodes in the hidden layer is L, then

$$o_j = \sum_{i=1}^{L}\beta_i g\left(W_i \cdot X_j + b_i\right)$$

where g(x) is an activation function, W_i is an input weight, β_i is an output weight, and b_i is a bias.

The objective of the network is to minimize the output error:

$$\sum_{j=1}^{N}\|o_j - y_j\| = 0$$

It can be expressed as Hβ=T by a matrix, where H refers to the node's output in the hidden layer, T is the expected output, and β is the output weight. The solution is:

$$\beta = H^{+}T$$

where H^+ is the Moore-Penrose generalized inverse of H [11].

In the SAE-ELM method designed in this paper, firstly, the dimension of features is reduced by the SAE method. In a given sample set, {(X^1, 〖Y 〗^1),(X^2,Y^2),⋯,(X^i,Y^i)}, X^i is the feature vector, and X^i is the labeled vector. After the dimensionality reduction, a new {X_i,Y_i } is obtained. Then, it was detected by the ELM method.

3 Experimental analysis

3.1 Experimental setup

The experimental platform was MATLAB2014a. The operating system was Win10 64 bits. The processor was Intel(R)Core(TM)i7-9700K CPU @3.6Hz with16GB memory. Nvida RTX 2060 (6 GB) graphic card was used. The activation function was sigmod and the sparsity parameter was set to 0.25. There were 14 hidden layers used.

The experimental data sets were NSL-KDD and UNSW-NB2015. NSL-KDD is a benchmark data set [12, 13], which is usually used to estimate the behavior of the network data. Each data has 41 features; there are one class of normal data and four classes of abnormal data(DOS, Probe, R2L, and U2R). Experiments were carried out with 125973 data in KDDTrain, as shown in Table 1.

	Training set	Test set
Normal	53875	13468
DOS	36742	9185
Probe	9352	2331
R2L	797	198
U2R	42	10
Total	100781	25192

Table 1: NSL-KDD data set.

UNSW-NB2015 is a relatively new data set [14], recording the normal activities and attack behaviors of real modern networks [15], which are as follows:

(1) normal: normal data;

(2) fuzzers: pause the network by providing randomly generated data;

(3) analysis: attacks including port scanning and spam;

(4) backdoors: access the computer by bypassing the system security mechanism;

(5) DoS: users cannot use the server or network resources;

(6) exploits: attack the host through vulnerabilities;

(7) generic: an attack used for password countermeasure;

(8) reconnaissance: collect the information of the victim's host and attack it;

(9) shellcode: attack the computer through vulnerabilities of software;

(10) worms: attackers copy themselves and propagate to other computers.

219160 data in one subset used in the experiment, as shown in Table 2.

	Training set	Test set
Normal	35983	53122
Fuzzers	4885	16852
Analysis	69	636
Backdoors	83	443
DoS	1452	3399
Exploits	8281	21595
Generic	18830	39754
Reconnaissance	3217	8874
Shellcode	378	1133
Worms	44	130
Total	73222	145938

Table 2: UNSW-NB2015 data set.

3.2 Evaluation index

(1) Accuracy: A_C=(T_P+T_N)/(T_P+T_N+F_P+F_N),
(2) false alarm rate: F_A=F_P/(T_N+F_P),
(3) missing report rate: M_A=F_N/(T_P+F_N),
where T_P refers to the number of abnormal data that are classified as abnormal, T_N refers to the number of normal data that are classified as normal, F_P refers to the number of normal data that are classified as abnormal, and F_N refers to the number of abnormal data that are classified as normal.

3.3 Experimental results

Firstly, the binary classification experiment was carried out on NSL-KDD, and the results were compared with the support vector machine (SVM) algorithm [16] and the K-means algorithm [17], as shown in Figure 1.

It was seen from Figure 1 that the SAE-ELM method had the best performance in detecting and recognizing abnormal data. The accuracy A_c of the K-means, SVM, and SAE-ELM algorithms was 74.64%, 86.48%, and 95.64%, respectively; the A_c of the SAE-ELM algorithm was 21.02% higher than the K-means algorithm and 9.16% higher than the SVM algorithm. The F_A of K-means, SVM, and SAE-ELM algorithms was 4.67%, 1.89%, and 0.45%, respectively; the F_A of the SAE-ELM algorithm was 4.22% lower than that of the K-means algorithm and 1.44 % lower than that of the SVM algorithm. The M_A of the SAE-ELM algorithm was 7.41 % lower than that of the K-means algorithm and 4.84 % lower than that of the SVM algorithm. The above results verified that the SAE-ELM algorithm was reliable.

	Accuracy/%	False alarm rate/%	Missing report rate/%
Normal	99.67	0.18	7.42
DOS	99.34	0.27	6.43
Probe	98.77	0.24	5.68
R2L	98.56	0.12	4.21
U2R	98.33	0.02	3.08
Average	98.93	0.17	5.36

Table 3: Results of the five-classification experiment on the NSL-KDD data set.

Then, a five-classification experiment was carried out on the NSL-KDD data set, as shown in Table 3.

It is clear from Table 3 that the SAE-ELM algorithm had the best performance in detecting and recognizing normal data but performes poorly in detecting and recognizing U2R. The samples of U2R were the least among the different kinds of data, which led to the insufficient training of the algorithm. The amount of normal data was the largest; thus, the accuracy of the detection and recognition of normal data was the highest (99.67%). The average A_c, F_A, and M_A of the SEA-ELM algorithm was 98.93%, 0.17%, and 5.36 %, respectively.

A binary classification experiment was carried out on UNSW-NB2015 and compared to SVM and K-means algorithms, as shown in Figure 2.

It can be observed from the Figure 2 that the performance of the SAE-ELM method was the best on the NSW-NB2015 data set. The A_c of the three methods was 80.27%, 92.36%, and 99.42%, respectively. The A_c of the SAE-ELM method was 19.15% higher than the SAE-ELM method and 7.06% higher than that of the SVM method. The F_A of the SAE-ELM algorithm was 2.85% lower than that of the K-means algorithm and 0.95% lower than the SVM algorithm. The M_A of the SAE-ELM method was 6.65% lower than that of the K-means

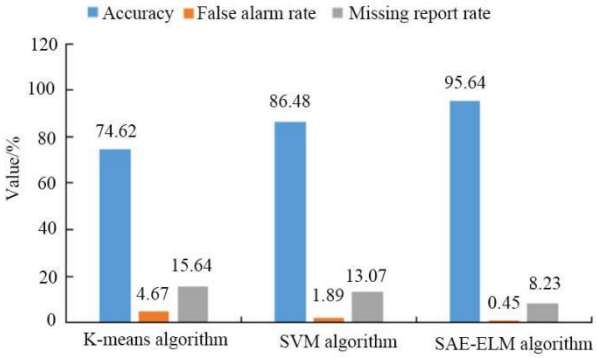

Figure 1: Comparison of results of the binary classification experiment on the NSL-KDD data set.

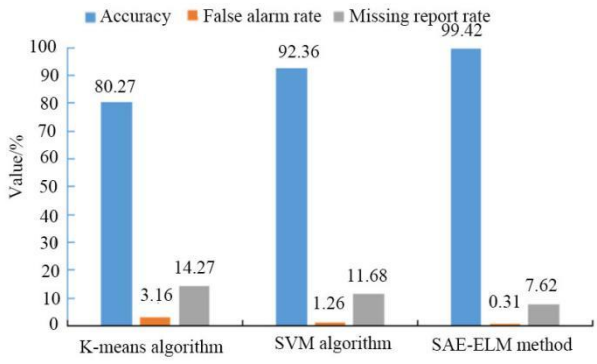

Figure 2: Comparison of results of the binary experiment on the UNSW-NB2015 data set.

	Accuracy/ %	False alarm rate/%	Missing report rate/%
Normal	99.62	0.21	6.48
Fuzzers	98.89	0.16	4.87
Analysis	98.52	0.12	3.55
Backdoors	98.48	0.08	3.51
DoS	98.64	0.11	4.11
Exploits	99.31	0.18	5.12
Generic	99.46	0.17	5.36
Reconnaissance	98.76	0.11	4.36
Shellcode	98.61	0.07	3.61
Worms	98.47	0.01	2.12
Average	98.88	0.12	4.31

Table 4: Results of the multi-classification experiment on the UNSW-NB2015 data set.

algorithm and 4.06% lower than that of the SVM algorithm.

Finally, the polyphenols experiment was carried out on the NSW-NB2015 data set using the SAE-ELM algorithm, as shown in Table 4.

It can be observed from the Table 4 that, similar to the NSL-KDD data set, the SAE-ELM method had better detection and recognition performance in the category with more samples. For the attack type with less number, A_c was relatively small, but all above 95%. The average A_c of the SAE-ELM algorithm was 98.88%, the average F_A was 0.12 %, and the average M_A was 4.31% on the UNSW-NB2015 data set, showing that the SAE-ELM algorithm had a good performance.

4 Discussion

With the development of society, network security has been paid more and more attention [18]. As the data in the network is becoming more and more massive, high-dimensional, and changeable, the traditional detection and protection methods have not been able to meet the current network security needs [19]. Therefore, it is of great significance to find effective detection and identification methods for abnormal data [20]. Deep learning methods have been widely used in image recognition [21], speech recognition [22], intelligent translation [23], etc., which can achieve high classification accuracy in large databases. Therefore, this paper analyzed the application of deep learning in the detection and recognition of abnormal data to know whether it can detect and recognize abnormal data quickly and accurately.

It was found from the experiments on NSL-KDD and UNSW-NB2015 data sets that the A_c and F_A of the SAE-ELM method were better than K-means and SVM algorithms. For the detection and recognition of abnormal data, only larger A_c, small F_A , and low M_A can meet the actual needs. First, in the binary classification experiment, the A_c of the SAE-ELM method was above 98% on the two data sets, and the F_A and M_A were small. In the multi-classification experiment, the average A_c, F_A, and M_A of the SAE-ELM method were 98.93%, 0.17%, and 5.36%, respectively. On the UNSW-NB2015 data set, the A_c, F_A, and M_A of the SAE-ELM method were 98.88%, 0.12%, and 4.31%, respectively. The two experiments showed good performance of the SAE-ELM method.

Although some results were attained on the recognition and detection of abnormal data, more research is still needed:

(1) the usability of additional deep learning methods should be studied;

(2) the actual network operational data should be collected for the detection and identification.

5 Conclusion

Based on deep learning, this paper analyzes the detection and recognition of abnormal data, introducesan SAE-ELM method, and presents carried out experiments on NSL-KDD and UNSW-NB2015 data sets. It was found that the SAE-ELM method has high accuracy and good performance in detecting and recognizing of the abnormal data, which can be further promoted and applied in practice.

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Some Picture Fuzzy Aggregation Operators Based on Frank t-norm and t-conorm: Application to MADM Process

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In this paper, we develop some new operational laws and their corresponding aggregation operators for picture fuzzy sets (PFSs). The PFS is a powerful tool to deal with vagueness, which is a generalization of a fuzzy set and an intuitionistic fuzzy set (IFS). PFSs can model uncertainty in situations that consist of more than two answers like yes, refusal, neutral, and no. The operations of t-norm and t-conorm, developed by Frank, are usually a better application with its flexibility. From that point of view, the concepts of Frank t-norm and t-conorm are introduced to aggregate picture fuzzy information. We propose some new operational laws of picture fuzzy numbers (PFNs) based on Frank t-norm and t-conorm. Further, with the assistance of these operational laws, we have introduced picture fuzzy Frank weighted averaging (PFFWA) operator, picture fuzzy Frank order weighted averaging (PFFOWA) operator, picture fuzzy Frank hybrid averaging (PFFHA) operator, picture fuzzy Frank weighted geometric (PFFWG) operator, picture fuzzy Frank order weighted geometric (PFFOWG) operator, picture fuzzy Frank hybrid geometric (PFFHG) operator and discussed with their suitable properties. Then, with the help of PFFWA and PFFWG operators, we have presented an algorithm to solve multiple-attribute decision making (MADM) problems under the picture fuzzy environment. Finally, we have used a numerical example to illustrate the flexibility and validity of the proposed method and compared the results with other existing methods.

Povzetek: Prispevek se ukvarja z operatorji mehkih množic na osnovi Frankove t-norme in t-konorme.

1 Introduction

In real-life situations, the fuzzy set theory [48] plays a vital role in handling the vagueness of human choices. Then continuous efforts are paid for further generalization of fuzzy set theory. The IFS theory is one of such generalizations, introduced by Atanssov [2]. IFS is characterized by a degree of membership and degree of non-membership such that their sum does not exceed one. However, IFSs are insufficient to handle the possibility with more than two answers as just yes-no type. Consider the case of usual voting where one has the choices like a vote for, vote against, abstain from voting, and refusal. To deal with such situations with high accuracy, Cuong and Krienovich [8] conveyed a novel concept of picture fuzzy set (PFS). PFS is characterized by a membership degree, a non-membership degree, and a neutrality degree such that their sum is less than or equal to one. Cuong [9] examined few properties of PFSs and introduced distance measures between PFSs.

Recently, some research models have been developed on the picture fuzzy (PF) environment. Dinh and Thao [10] introduced some distance measures and dissimilarity measures between PFSs and applied them to MADM problems. Wang and Li [33] proposed a hesitant fuzzy set in the PF environment and developed picture hesitant fuzzy aggregation operators. Wei [39] extended the TODIM method to MADM problems under the PF environment. Wei [40] developed some similarity measures between PFSs such as cosine measure, set-theoretic cosine similarity measure, grey similarity measure and applied these to building material recognition and mineral field recognition. Dutta and Ganju [11] introduced decomposition theorems of PFSs and defined the extension principle for PFSs. Wei [35] introduced PF cross-entropy as an extension of the cross-entropy of fuzzy sets. Xu et al. [45] developed some aggregation operators for fusing PF information. Dutta [12] applied distance measure between PFSs in medical diagnosis. Singh [27] proposed correlation coefficients for PFSs and gave the geometrical interpretation for PFSs. Son [28] and Thong [29] introduced several clustering algorithms with PFSs. Le et al. [21] proposed some dissimilarity measures under PF information and applied them to decision-making problems. Wei et al. [36] introduced the projection models for the MADM problem with PF information. Wei and Gao [42] developed the generalized dice similarity measure under PF environment and applied them to building material recognition. Zeng et al. [50] proposed the exponential Jensen PF divergence measure and applied it in multi-criteria group decision making. Several researchers proposed information aggregation operators under the PF environment [3, 16, 17, 22, 30, 32, 43, 51]. Garg [14] presented some PF aggregation operators and applied them to

multi-criteria decision making. Wei [38] presented cosine similarity measures for PFS and applied them to strategic decision making. Wei [41] proposed PF Hamacher aggregation operators and applied them to the MADM process. Khan et al. [18] investigated the information aggregation operators method under the PF environment with the help of Einstein norm operations. Khan et al. [19] introduced a series of logarithmic aggregation operators under the PF environment. Wang et al. [34] proposed Muirhead mean operators under PF environment and applied them to evaluate the financial investment risk.

A fascinating generalization of probabilistic and Lukasiewicz t-norm and t-conorm [23] are Frank t-norm and t-conorm [13], which form an ordinary and adequately flexible family of the continuous triangular norm. The employment of a specific parameter makes the Frank t-norm and t-conorm more resilient along with the procedure of fusion of information. Several works [1, 20] can be found in the literature related to Frank t-norm and t-conorm. The functional equations of Frank and Alsina are thoroughly studied by Calvo et al. [4] for two classes containing commutative, associative, and increasing binary operators. Exploring the additive generating function (AGF) of Frank t-norms, Yager [46] launched a framework in approximate reasoning with Frank t-norms. Casasnovas and Torrens [5] introduced a novel axiomatic approach to the scalar cardinality of Frank t-norms, and they further established the properties of other standard t-norms. Comparing between the Frank t-norms and the Hamacher t-norms up to an extent, Sarkoci [26] concluded that two different t-norms belong to the same family. Xing et al. [44] introduced aggregation operators for Pythagorean fuzzy set based on Frank t-norm and t-conorm and then applied them to solve MADM problems. Zhou et al. [52] investigated some Frank aggregation operators of interval-valued neutrosophic numbers and analyzed a case study of selecting agriculture socialization. Qin and Liu [24] introduced Frank aggregation operators for a triangular interval type-2 fuzzy set and applied it to solve multiple attribute group decision making (MAGDM) problems. Qin et al. [25] developed some hesitant fuzzy aggregation operators based on Frank t-norm operations.

Evidently, a general t-norm and t-conorm can be used for shaping both the intersection and union of PFS. The PFS is compatible to reveal uncertain information. Since the Frank aggregation operators involve a parameter so the operators make the information process more flexible and strong. The investigation on the applications of Frank operators is rare, specifically in the area of information aggregation and decision making. Keeping this in mind, it is worthy to prolong Frank t-norm and t-conorm to handle the PF environment. With such motivation of aforementioned analysis, we have introduced new operational rules of PFNs based on Frank operators and exhibited their characteristics.

In this paper, we have introduced some new operational laws for PFNs based on Frank t-norm and Frank t-conorm. Then using these operational laws, we have developed Frank t-norm and t-conorm based PFFWA, PFFOWA, PFHWA, PFFWG, PFFOWG, and PFFHG aggregation operators. We have also investigated some of their desirable properties. Utilizing PFFWA and PFFWG operators, we have developed an algorithm to solve an MADM problem under the PF environment. To illustrate the validity and superiority of the proposed method, a numerical example is considered, solved, and the obtained results are compared with other existing well-known methods.

The rest of the paper is organized as follows.

In Section 2, some basic definitions and preliminaries are recalled, which help us to make the concept about the present article. In Section 3, some new operational laws for PFNs based on Frank t-norm and t-conorm have been proposed, and using those operational laws, some new aggregation operators are defined in the PF environment. An algorithm to solve the decision-making problems based on Frank aggregation operators is presented in Section 4. In Section 5, we have checked the validity of the proposed method through a real-life example. Section 6 analyze the effect of the parameters on the decision-making result. Section 7 presents a useful comparison between the results of our proposed method and other significant models. Finally, the conclusion is made in Section 8.

2 Preliminaries

In this section, we recall some basic definitions and preliminaries.

Definition 2.1. [6, 7] Let us consider X as a universal set. The PFS $\tilde{P}$ over the universal set X is interpreted as

$$\tilde{P} = \{\langle x, \mu_{\tilde{P}}(x), \eta_{\tilde{P}}(x), \nu_{\tilde{P}}(x)\rangle | x \in X\}$$

where $\mu_{\tilde{P}} : X \to [0,1]$, $\eta_{\tilde{P}} : X \to [0,1]$ and $\nu_{\tilde{P}} : X \to [0,1]$ are called the positive degree of membership, neutral degree of membership and the negative degree of membership to the set $\tilde{P}$ respectively, with the condition $0 \leq \mu_{\tilde{P}}(x) + \eta_{\tilde{P}}(x) + \nu_{\tilde{P}}(x) \leq 1$ for every $x \in X$. Also the degree of hesitancy for $x \in X$ is defined as $\pi_{\tilde{P}}(x) = 1-\mu_{\tilde{P}}(x)-\eta_{\tilde{P}}(x)-\nu_{\tilde{P}}(x)$. For our convenience, we denote $p = (\mu_p, \eta_p, \nu_p)$ as a picture fuzzy number (PFN).

Definition 2.2. [6, 37] Let $p = (\mu_p, \eta_p, \nu_p)$ and $q = (\mu_q, \eta_q, \nu_q)$ be two PFNs over the universal set X and $\xi > 0$ be any real number, then the corresponding operations are defined as follows:

1. $p \leq q$, if $\mu_p \leq \mu_q$, $\eta_p \leq \eta_q$ and $\nu_p \geq \nu_q$
2. $p \bigvee q$=$(max\{\mu_p, \mu_q\}, min\{\eta_p, \eta_q\}, min\{\nu_p, \nu_q\})$.
3. $p \bigwedge q$=$(min\{\mu_p, \mu_q\}, max\{\eta_p, \eta_q\}, max\{\nu_p, \nu_q\})$.
4. $p^c = (\nu_p, \eta_p, \mu_p)$.
5. $p \wedge q$=$(min\{\mu_p, \mu_q\}, max\{\eta_p, \eta_q\}, max\{\nu_p, \nu_q\})$.
6. $p \vee q$=$(max\{\mu_p, \mu_q\}, min\{\eta_p, \eta_q\}, min\{\nu_p, \nu_q\})$.
7. $p \oplus q = (\mu_p + \mu_q - \mu_p\mu_q, \eta_p\eta_q, \nu_p\nu_q)$.
8. $p \otimes q = (\mu_p\mu_q, \eta_p + \eta_q - \eta_p\eta_q, \nu_p + \nu_q - \nu_p\nu_q)$.
9. $\xi p = (1 - (1 - \mu_p)^{\xi}, \eta_p^{\xi}, \nu_p^{\xi})$.
10. $p^{\xi} = (\mu_p^{\xi}, 1 - (1 - \eta_p)^{\xi}, 1 - (1 - \nu_p)^{\xi})$.

Definition 2.3. [16] The score function of the PFN $p = (\mu_p, \eta_p, \nu_p)$ is defined by

$$\Delta(p) = \frac{1 + \mu_p - \nu_p}{2}$$

where $\Delta(p) \in [0, 1]$.

Definition 2.4. [16] The accuracy function of the PFN $p = (\mu_p, \eta_p, \nu_p)$ is defined by

$$\nabla(p) = \mu_p + \nu_p$$

where $\Psi(p) \in [-1, 1]$.

According to Definitions 2.3 and 2.4, if $p = (\mu_p, \eta_p, \nu_p)$ and $q = (\mu_q, \eta_q, \nu_q)$ be any two PFNs then

1. If $\Delta(p) > \Delta(q)$ then $p > q$,
2. If $\Delta(p) < \Delta(q)$ then $p < q$,
3. If $\Delta(p) = \Delta(q)$, then
   - If $\nabla(p) > \nabla(q)$, then $p > q$,
   - If $\nabla(p) = \nabla(q)$, then $p = q$.

Wei [37] introduced the PF aggregation operators depicted in the upcoming definitions.

Definition 2.5. Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i})$ $(i = 1, 2, \ldots, n)$ be a number of PFNs. Then the aggregated value of them using PF weighted averaging (PFWA) operator is also a PFN and $PFWA(p_1, p_2, \ldots, p_n) = \bigoplus_{i=1}^{n}(w_i p_i) = \left(1 - \prod_{i=1}^{n}(1 - \mu_{p_i})^{w_i}, \prod_{i=1}^{n} {\eta_{p_i}}^{w_i}, \prod_{i=1}^{n} {\nu_{p_i}}^{w_i}\right)$, where $w = (w_1, w_2, \ldots, w_n)^t$ be the weight vector of $p_i (i = 1, 2, \ldots, n)$, $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$.

Definition 2.6. Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i})$ $(i = 1, 2, \ldots, n)$ be a number of PFNs. The PF order weighted averaging (PFOWA) operator of dimension n is a function $p^n \to p$ such that, $PFOWA(p_1, p_2, \ldots, p_n) = \bigoplus_{i=1}^{n}(w_i p_{\rho(i)}) = \left(1 - \prod_{i=1}^{n}(1 - \mu_{p_{\rho(i)}})^{w_i}, \prod_{i=1}^{n} {\eta_{p_{\rho(i)}}}^{w_i}, \prod_{i=1}^{n} {\nu_{p_{\rho(i)}}}^{w_i}\right)$, where $w = (w_1, w_2, \ldots, w_n)^t$ be the weight vector of $p_i (i = 1, 2, \ldots, n)$, $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$, $(\rho(1), \rho(2), \ldots, \rho(n))$ is the permutation of $(i = 1, 2, \ldots, n)$, for which $p_{\rho(i-1)} \geq p_{\rho(i)}$ for all $i = 1, 2, \ldots, n$.

In the following, we recall the definition of Frank t-norm and t-conorm.

Definition 2.7. [13] Let us assume that a and b be two real numbers. Then, Frank t-norm and Frank t-conorm are defined by,

$Fra(a, b) = \log_r \left(1 + \frac{(r^a - 1)(r^b - 1)}{r - 1}\right)$

$Fra'(a, b) = 1 - \log_r \left(1 + \frac{(r^{1-a} - 1)(r^{1-b} - 1)}{r - 1}\right)$

respectively, where $(a, b) \in [0, 1] \times [0, 1]$ and $r \neq 1$.

Based on limit theory, we observe some interesting results [31]:

1. If $r \to 1$, then $Fra'(a, b) \to a + b - ab$ and $Fra(a, b) \to ab$. Therefore, if r tends to 1 the the Frank sum and Frank product reduced to the probabilistic sum and probabilistic product.

2. If $r \to \infty$, then $Fra'(a, b) \to min\{a + b, 1\}$ and $Fra(a, b) \to max\{0, a + b - 1\}$. So, for r tends to infinity the Frank sum and the Frank product reduced to the Lukasiewicz sum and Lukasiewicz product.

EXAMPLE **1.** Let $a = 0.29$, $b = 0.56$ and $r = 4$, then,
$Fra(0.29, 0.56) = \log_4 \left(1 + \frac{(4^{0.29} - 1)(4^{0.56} - 1)}{4 - 1}\right)$
=0.1276.
$Fra'(0.29, 0.56)$=
$1 - \log_4 \left(1 + \frac{(4^{1-0.29} - 1)(4^{1-0.56} - 1)}{4 - 1}\right)$=0.8723.

3 Picture fuzzy Frank aggregation operators

In this section, we develop some operational rules under the PF environment with the assistance of Frank t-norm and t-conorm. Further, we propose the PFFWA, PFFOWA, PFFHWA, PFFWG, PFFOWG and PFFHWG aggregation operators using our developed operational rules.

Definition 3.1. Let $p = (\mu_p, \eta_p, \nu_p)$, $p_1 = (\mu_{p_1}, \eta_{p_1}, \nu_{p_1})$ and $p_2 = (\mu_{p_2}, \eta_{p_2}, \nu_{p_2})$ be any three PFNs, $r > 1$ and $\xi > 0$ be any real number. Then Frank t-norm and t-conorm operations of PFNs are defined as:

1. $p_1 \oplus p_2 =$
$\Bigg(1 - \log_r \left(1 + \frac{(r^{1-\mu_{p_1}} - 1)(r^{1-\mu_{p_2}} - 1)}{r - 1}\right),$
$\log_r \left(1 + \frac{(r^{\eta_{p_1}} - 1)(r^{\eta_{p_2}} - 1)}{r - 1}\right),$
$\log_r \left(1 + \frac{(r^{\nu_{p_1}} - 1)(r^{\nu_{p_2}} - 1)}{r - 1}\right)\Bigg).$

2. $p_1 \otimes p_2 = \Bigg(\log_r \left(1 + \frac{(r^{\mu_{p_1}} - 1)(r^{\mu_{p_2}} - 1)}{r - 1}\right),$
$1 - \log_r \left(1 + \frac{(r^{1-\eta_{p_1}} - 1)(r^{1-\eta_{p_2}} - 1)}{r - 1}\right),$
$1 - \log_r \left(1 + \frac{(r^{1-\nu_{p_1}} - 1)(r^{1-\nu_{p_2}} - 1)}{r - 1}\right)\Bigg).$

3. $\xi p = \Bigg(1 - \log_r \left(1 + \frac{(r^{1-\mu_p} - 1)^{\xi}}{(r - 1)^{\xi - 1}}\right), \log_r \left(1 + \frac{(r^{\eta_p} - 1)^{\xi}}{(r - 1)^{\xi - 1}}\right), \log_r \left(1 + \frac{(r^{\nu_p} - 1)^{\xi}}{(r - 1)^{\xi - 1}}\right)\Bigg).$

4. p^{ξ}=$\Bigg(\log_r\Big(1+\frac{(r^{\mu_p}-1)^{\xi}}{(r-1)^{\xi-1}}\Big)$,
$1-\log_r\Big(1+\frac{(r^{1-\eta_p}-1)^{\xi}}{(r-1)^{\xi-1}}\Big)$,
$1-\log_r\Big(1+\frac{(r^{1-\nu_p}-1)^{\xi}}{(r-1)^{\xi-1}}\Big)\Bigg)$.

EXAMPLE **2.** *Let* $p_1 = (0.60, 0.20, 0.08)$ *and* $p_2 = (0.50, 0.20, 0.15)$ *be two PFNs, then by using Frank operations on PFNs as defined in Definition 3.1, for* $r = 3$ *and* $\xi = 4$ *we have*

1. $p_1 \oplus p_2$=$(0.7325, 0.0270, 0.0074)$.
2. $p_1 \otimes p_2$=$(0.2674, 0.9729, 0.9925)$.
3. $4p_1$=$(0.9947, 0.0002, 0)$.
4. ${p_1}^4$=$(0.0421, 0.7999, 0.5819)$.

THEOREM **3.1.** *Let* $p = (\mu_p, \eta_p, \nu_p)$, $p_1 = (\mu_{p_1}, \eta_{p_1}, \nu_{p_1})$ *and* $p_2 = (\mu_{p_2}, \eta_{p_2}, \nu_{p_2})$ *be any three PFNs,* $r > 1$ *and* ξ, ξ_1, ξ_2 *be any three positive real numbers, then we have*

1. $p_1 \oplus p_2 = p_2 \oplus p_1$;
2. $p_1 \otimes p_2 = p_2 \otimes p_1$;
3. $\xi(p_1 \oplus p_2) = \xi p_1 \oplus \xi p_2$;
4. $\xi_1 p \oplus \xi_2 p = (\xi_1 + \xi_2)p$;
5. $(p_1 \otimes p_2)^{\xi} = {p_1}^{\xi} \otimes {p_2}^{\xi}$;
6. $p^{\xi_1} \otimes p^{\xi_2} = p^{\xi_1+\xi_2}$.

Proof: For three PFNs $p = (\mu_p, \eta_p, \nu_p)$, $p_1 = (\mu_{p_1}, \eta_{p_1}, \nu_{p_1})$ and $p_2 = (\mu_{p_2}, \eta_{p_2}, \nu_{p_2})$ and $\xi, \xi_1, \xi_2 > 0$, according to Definition 3.1, we can obtain

1. $p_1 \oplus p_2 =$
$\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_1}}-1)(r^{1-\mu_{p_2}}-1)}{r-1}\Big)$,
$\log_r\Big(1+\frac{(r^{\eta_{p_1}}-1)(r^{\eta_{p_2}}-1)}{r-1}\Big)$,
$\log_r\Big(1+\frac{(r^{\nu_{p_1}}-1)(r^{\nu_{p_2}}-1)}{r-1}\Big)\Bigg)$
$=\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_2}}-1)(r^{1-\mu_{p_1}}-1)}{r-1}\Big)$,
$\log_r\Big(1+\frac{(r^{\eta_{p_2}}-1)(r^{\eta_{p_1}}-1)}{r-1}\Big)$,
$\log_r\Big(1+\frac{(r^{\nu_{p_2}}-1)(r^{\nu_{p_1}}-1)}{r-1}\Big)\Bigg) = p_2 \oplus p_1$.

2. $p_1 \otimes p_2 = \Bigg(\log_r\Big(1+\frac{(r^{\mu_{p_1}}-1)(r^{\mu_{p_2}}-1)}{r-1}\Big)$,
$1-\log_r\Big(1+\frac{(r^{1-\eta_{p_1}}-1)(r^{1-\eta_{p_2}}-1)}{r-1}\Big)$,
$1-\log_r\Big(1+\frac{(r^{1-\nu_{p_1}}-1)(r^{1-\nu_{p_2}}-1)}{r-1}\Big)\Bigg)$
$=\Bigg(\log_r\Big(1+\frac{(r^{\mu_{p_2}}-1)(r^{\mu_{p_1}}-1)}{r-1}\Big)$,
$1-\log_r\Big(1+\frac{(r^{1-\eta_{p_2}}-1)(r^{1-\eta_{p_1}}-1)}{r-1}\Big)$,
$1-\log_r\Big(1+\frac{(r^{1-\nu_{p_2}}-1)(r^{1-\nu_{p_1}}-1)}{r-1}\Big)\Bigg)$
$= p_2 \otimes p_1$.

3. $\xi(p_1 \oplus p_2)$=
$\xi\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_1}}-1)(r^{1-\mu_{p_2}}-1)}{r-1}\Big)$,
$\log_r\Big(1+\frac{(r^{\eta_{p_1}}-1)(r^{\eta_{p_2}}-1)}{r-1}\Big)$,
$\log_r\Big(1+\frac{(r^{\nu_{p_1}}-1)(r^{\nu_{p_2}}-1)}{r-1}\Big)\Bigg)$
$=\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_1}}-1)^{\xi}(r^{1-\mu_{p_2}}-1)^{\xi}}{(r-1)^{2\xi-1}}\Big)$,
$\log_r\Big(1+\frac{(r^{\eta_{p_1}}-1)^{\xi}(r^{\eta_{p_2}}-1)^{\xi}}{(r-1)^{2\xi-1}}\Big)$,
$\log_r\Big(1+\frac{(r^{\nu_{p_1}}-1)^{\xi}(r^{\nu_{p_2}}-1)^{\xi}}{(r-1)^{2\xi-1}}\Big)\Bigg)$.
Now,
$\xi p_1 \oplus \xi p_2 = \Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_1}}-1)^{\xi}}{(r-1)^{\xi}}\Big)$,
$\log_r\Big(1+\frac{(r^{\eta_{p_1}}-1)^{\xi}}{(r-1)^{\xi}}\Big), \log_r\Big(1+\frac{(r^{\nu_{p_1}}-1)^{\xi}}{(r-1)^{\xi}}\Big)\Bigg)\oplus$
$\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_2}}-1)^{\xi}}{(r-1)^{\xi}}\Big)$,
$\log_r\Big(1+\frac{(r^{\eta_{p_2}}-1)^{\xi}}{(r-1)^{\xi}}\Big), \log_r\Big(1+\frac{(r^{\nu_{p_2}}-1)^{\xi}}{(r-1)^{\xi}}\Big)\Bigg)$
$=\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_1}}-1)^{\xi}(r^{1-\mu_{p_2}}-1)^{\xi}}{(r-1)^{2\xi-1}}\Big)$,
$\log_r\Big(1+\frac{(r^{\eta_{p_1}}-1)^{\xi}(r^{\eta_{p_2}}-1)^{\xi}}{(r-1)^{2\xi-1}}\Big)$,
$\log_r\Big(1+\frac{(r^{\nu_{p_1}}-1)^{\xi}(r^{\nu_{p_2}}-1)^{\xi}}{(r-1)^{2\xi-1}}\Big)\Bigg)$.
Therefore, $\xi(p_1 \oplus p_2) = \xi p_1 \oplus \xi p_2$.

4. $\xi_1 p \oplus \xi_2 p =$
$\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_p}-1)^{\xi_1}}{(r-1)^{\xi_1}}\Big)$,
$\log_r\Big(1+\frac{(r^{\eta_p}-1)^{\xi_1}}{(r-1)^{\xi}}\Big)$,
$\log_r\Big(1+\frac{(r^{\nu_p}-1)^{\xi_1}}{(r-1)^{\xi}}\Big)\Bigg)\oplus$
$\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_p}-1)^{\xi_2}}{(r-1)^{\xi_2}}\Big)$,

$$\log_r\Big(1+\frac{(r^{\eta_p}-1)^{\xi_2}}{(r-1)^{\xi_2}}\Big),\log_r\Big(1+\frac{(r^{\nu_p}-1)^{\xi_2}}{(r-1)^{\xi_2}}\Big)\Bigg)$$
$$=\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_p}-1)^{\xi_1+\xi_2}}{(r-1)^{\xi_1+\xi_2}}\Big),$$
$$\log_r\Big(1+\frac{(r^{\eta_p}-1)^{\xi_1+\xi_2}}{(r-1)^{\xi_1+\xi_2}}\Big),$$
$$\log_r\Big(1+\frac{(r^{\nu_p}-1)^{\xi_1+\xi_2}}{(r-1)^{\xi_1+\xi_2}}\Big)\Bigg)$$
$$=(\xi_1+\xi_2)p.$$

5. $(p_1\otimes p_2)^{\xi}=$
$$\Bigg(\log_r\Big(1+\frac{(r^{\mu_{p_1}}-1)(r^{\mu_{p_2}}-1)}{r-1}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\eta_{p_1}}-1)(r^{1-\eta_{p_2}}-1)}{r-1}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\nu_{p_1}}-1)(r^{1-\nu_{p_2}}-1)}{r-1}\Big)\Bigg)^{\xi}$$
$$=\Bigg(\log_r\Big(1+\frac{((r^{\mu_{p_1}}-1)(r^{\mu_{p_2}}-1))^{\xi}}{(r-1)^{2\xi-1}}\Big),$$
$$1-\log_r\Big(1+\frac{((r^{1-\eta_{p_1}}-1)(r^{1-\eta_{p_2}}-1))^{\xi}}{(r-1)^{2\xi-1}}\Big),$$
$$1-\log_r\Big(1+\frac{((r^{1-\nu_{p_1}}-1)(r^{1-\nu_{p_2}}-1))^{\xi}}{(r-1)^{2\xi-1}}\Big)\Bigg)$$
$$=\Bigg(\log_r\Big(1+\frac{(r^{\mu_{p_1}}-1)^{\xi}}{(r-1)^{\xi}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\eta_{p_1}}-1)^{\xi}}{(r-1)^{\xi}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\nu_{p_1}}-1)^{\xi}}{(r-1)^{\xi}}\Big)\Bigg)\otimes$$
$$\Bigg(\log_r\Big(1+\frac{(r^{\mu_{p_2}}-1)^{\xi}}{(r-1)^{\xi}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\eta_{p_2}}-1)^{\xi}}{(r-1)^{\xi}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\nu_{p_2}}-1)^{\xi}}{(r-1)^{\xi}}\Big)\Bigg)$$
$$={p_1}^{\xi}\otimes{p_2}^{\xi}.$$

6. $p^{\xi_1}\otimes p^{\xi_2}=$
$$\Bigg(\log_r\Big(1+\frac{(r^{\mu_p}-1)^{\xi_1}}{(r-1)^{\xi_1-1}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\eta_p}-1)^{\xi_1}}{(r-1)^{\xi_1-1}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\nu_p}-1)^{\xi_1}}{(r-1)^{\xi_1-1}}\Big)\Bigg)\otimes$$
$$\Bigg(\log_r\Big(1+\frac{(r^{\mu_p}-1)^{\xi_2}}{(r-1)^{\xi_2-1}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\eta_p}-1)^{\xi_2}}{(r-1)^{\xi_2-1}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\nu_p}-1)^{\xi_2}}{(r-1)^{\xi_2-1}}\Big)\Bigg)$$
$$=\Bigg(\log_r\Big(1+\frac{(r^{\mu_p}-1)^{\xi_1+\xi_2}}{(r-1)^{\xi_1+\xi_2-1}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\eta_p}-1)^{\xi_1+\xi_2}}{(r-1)^{\xi_1+\xi_2-1}}\Big),$$
$$1-\log_r\Big(1+\frac{(r^{1-\nu_p}-1)^{\xi_1+\xi_2}}{(r-1)^{\xi_1+\xi_2-1}}\Big)\Bigg)$$
$$=p^{\xi_1+\xi_2}.$$ □

3.1 Picture fuzzy Frank arithmetic aggregation operators

Definition 3.2. Let $p_i=(\mu_{p_i},\eta_{p_i},\nu_{p_i})(i=1,2,\ldots,n)$ be a number of PFNs. Then PFFWA operator is a function $p^n\to p$ such that,

$$PFFWA(p_1,p_2,\ldots,p_n)=\bigoplus_{i=1}^{n}w_ip_i$$

where $w=(w_1,w_2,\ldots,w_n)^t$ be the weight vector of $p_i(i=1,2,\ldots,n)$, $w_i\in[0,1]$ and $\sum_{i=1}^{n}w_i=1$.

Hence, we get consequential theorem that follows the Frank operations on PFNs.

THEOREM **3.2.** *Let $p_i=(\mu_{p_i},\eta_{p_i},\nu_{p_i})(i=1,2,\ldots,n)$ be a number of PFNs, then aggregated value of them using PFFWA operator is also a PFN, and*

$$PFFWA(p_1,p_2,\ldots,p_n)=\bigoplus_{i=1}^{n}w_ip_i$$
$$=\Bigg(1-\log_r\Big(1+\prod_{i=1}^{n}(r^{1-\mu_{p_i}}-1)^{w_i}\Big),$$
$$\log_r\Big(1+\prod_{i=1}^{n}(r^{\eta_{p_i}}-1)^{w_i}\Big),$$
$$\log_r\Big(1+\prod_{i=1}^{n}(r^{\nu_{p_i}}-1)^{w_i}\Big)\Bigg).$$

Proof: We prove this theorem by the method of mathematical induction.

For $n=2$, based on Frank operations of PFNs we get the corresponding result

$$PFFWA(p_1,p_2)=\bigoplus_{i=1}^{2}w_i=w_1p_1\oplus w_2p_2$$
$$=\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_1}}-1)^{w_1}}{(r-1)^{w_1-1}}\Big),$$
$$\log_r\Big(1+\frac{(r^{\eta_{p_1}}-1)^{w_1}}{(r-1)^{w_1-1}}\Big),\log_r\Big(1+\frac{(r^{\nu_{p_1}}-1)^{w_1}}{(r-1)^{w_1-1}}\Big)\Bigg)$$
$$\oplus\Bigg(1-\log_r\Big(1+\frac{(r^{1-\mu_{p_2}}-1)^{w_2}}{(r-1)^{w_2-1}}\Big),$$
$$\log_r\Big(1+\frac{(r^{\eta_{p_2}}-1)^{w_2}}{(r-1)^{w_2-1}}\Big),\log_r\Big(1+\frac{(r^{\nu_{p_2}}-1)^{w_2}}{(r-1)^{w_2-1}}\Big)\Bigg)$$

$$= \left(1 - \log_r\left(1 + \prod_{i=1}^{2}(r^{1-\mu_{p_i}} - 1)^{w_i}\right),$$
$$\log_r\left(1 + \prod_{i=1}^{2}(r^{\eta_{p_i}} - 1)^{w_i}\right),$$
$$\log_r\left(1 + \prod_{i=1}^{2}(r^{\nu_{p_i}} - 1)^{w_i}\right)\right) [\because \sum_{i=1}^{2} w_i = 1]$$

Hence, the result is valid for $n = 2$.

Let us assume that, the given result is true for $n = s$. Therefore, we have,

$$PFFWA(p_1, p_2, \ldots, p_s) = \bigoplus_{i=1}^{s} w_i p_i$$
$$= \left(1 - \log_r\left(1 + \prod_{i=1}^{s}(r^{1-\mu_{p_i}} - 1)^{w_i}\right),$$
$$\log_r\left(1 + \prod_{i=1}^{s}(r^{\eta_{p_i}} - 1)^{w_i}\right),$$
$$\log_r\left(1 + \prod_{i=1}^{s}(r^{\nu_{p_i}} - 1)^{w_i}\right)\right)$$

Now, for $n = s + 1$

$$PFFWA(p_1, p_2, \ldots, p_s, p_{s+1}) = \bigoplus_{i=1}^{s+1} w_i p_i = \bigoplus_{i=1}^{s} w_i p_i \bigoplus w_{s+1} p_{s+1}$$
$$= \left(1 - \log_r\left(1 + \frac{\prod_{i=1}^{s}(r^{1-\mu_{p_i}} - 1)^{w_i}}{(r-1)^{\sum_{i=1}^{s} w_i - 1}}\right),$$
$$\log_r\left(1 + \frac{\prod_{i=1}^{s}(r^{\eta_{p_i}} - 1)^{w_i}}{(r-1)^{\sum_{i=1}^{s} w_i - 1}}\right),$$
$$\log_r\left(1 + \frac{\prod_{i=1}^{s}(r^{\nu_{p_i}} - 1)^{w_i}}{(r-1)^{\sum_{i=1}^{s} w_i - 1}}\right)\right) \bigoplus$$
$$\left(1 - \log_r\left(1 + \frac{(r^{1-\mu_{p_{s+1}}} - 1)^{w_{s+1}}}{(r-1)^{w_{s+1}-1}}\right),\right.$$
$$\log_r\left(1 + \frac{(r^{\eta_{p_{s+1}}} - 1)^{w_{s+1}}}{(r-1)^{w_{s+1}-1}}\right),$$
$$\left.\log_r\left(1 + \frac{(r^{\nu_{p_{s+1}}} - 1)^{w_{s+1}}}{(r-1)^{w_{s+1}-1}}\right)\right)$$
$$= \left(1 - \log_r\left(1 + \prod_{i=1}^{s+1}(r^{1-\mu_{p_i}} - 1)^{w_i}\right),\right.$$
$$\log_r\left(1 + \prod_{i=1}^{s+1}(r^{\eta_{p_i}} - 1)^{w_i}\right),$$
$$\left.\log_r\left(1 + \prod_{i=1}^{s+1}(r^{\nu_{p_i}} - 1)^{w_i}\right)\right) [\text{as} \sum_{i=1}^{s+1} w_i = 1]$$

Therefore, the result is true for $n = s + 1$ if it is true for $n = s$. Also it is true for $n = 2$. Hence, by the method of induction the given result is true for any natural number n. □

THEOREM **3.3.** *(Idempotency Property). If $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i})(i = 1, 2, \ldots, n)$ be a number of identical PFNs, i.e., $p_i = p$ for all i, where $p = (\mu_p, \eta_p, \nu_p)$, then $PFFWA(p_1, p_2, \ldots, p_n) = p$.*

Proof: Since $p_i = p$ for all i then, we have

$$PFFWA(p_1, p_2, \ldots, p_n)$$
$$= \left(1 - \log_r\left(1 + \prod_{i=1}^{n}(r^{1-\mu_{p_i}} - 1)^{w_i}\right),\right.$$
$$\log_r\left(1 + \prod_{i=1}^{n}(r^{\eta_{p_i}} - 1)^{w_i}\right),$$
$$\left.\log_r\left(1 + \prod_{i=1}^{n}(r^{\nu_{p_i}} - 1)^{w_i}\right)\right)$$
$$= \left(1 - \log_r\left(1 + \prod_{i=1}^{n}(r^{1-\mu_p} - 1)^{w_i}\right),\right.$$
$$\log_r\left(1 + \prod_{i=1}^{n}(r^{\eta_p} - 1)^{w_i}\right),$$
$$\left.\log_r\left(1 + \prod_{i=1}^{n}(r^{\nu_p} - 1)^{w_i}\right)\right)$$
$$= \left(1 - \log_r\left(1 + (r^{1-\mu_p} - 1)^{\sum_{i=1}^{n} w_i}\right),\right.$$
$$\log_r\left(1 + (r^{\eta_p} - 1)^{\sum_{i=1}^{n} w_i}\right),$$
$$\left.\log_r\left(1 + (r^{\nu_p} - 1)^{\sum_{i=1}^{n} w_i}\right)\right)$$
$$= \left(1 - \log_r\left(1 + (r^{1-\mu_p} - 1)\right),\right.$$
$$\log_r\left(1 + (r^{\eta_p} - 1)\right),$$
$$\left.\log_r\left(1 + (r^{\nu_p} - 1)\right)\right) = \left(\mu_p, \eta_p, \nu_p\right) = p.$$

Hence the result follows. □

THEOREM **3.4.** *(Boundedness property). Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i})(i = 1, 2, \ldots, n)$ be a number of PFNs. Let $p^- = min\{p_1, p_2, \ldots, p_n\}$ and $p^+ = max\{p_1, p_2, \ldots, p_n\}$. Then, $p^- \leq PFFWA(p_1, p_2, \ldots, p_n) \leq p^+$.*

Proof: Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i})(i = 1, 2, \ldots, n)$ be a number of PFNs. Let $p^- = min\{p_1, p_2, \ldots, p_n\} = (\mu^-, \eta^-, \nu^-)$ and $p^+ = max\{p_1, p_2, \ldots, p_n\} = (\mu^+, \eta^+, \nu^+)$. We have $\mu^- = \min_k\{\mu_{p_k}\}$, $\eta^- = \max_k\{\eta_{p_k}\}$, $\nu^- = \max_k\{\nu_{p_k}\}$, $\mu^+ = \max_k\{\mu_{p_k}\}$, $\eta^+ = \min_k\{\eta_{p_k}\}$ and $\nu^+ = \min_k\{\nu_{p_k}\}$.

Now,

$$1 - \log_r\left(1 + \prod_{i=1}^{n}(r^{1-(\mu^-)} - 1)^{w_i}\right) \leq$$
$$1 - \log_r\left(1 + \prod_{i=1}^{n}(r^{1-\mu_{p_i}} - 1)^{w_i}\right) \leq$$
$$1 - \log_r\left(1 + \prod_{i=1}^{n}(r^{1-(\mu^+)} - 1)^{w_i}\right),$$
$$\log_r\left(1 + \prod_{i=1}^{n}(r^{(\eta^+)} - 1)^{w_i}\right)\right) \leq$$
$$\log_r\left(1 + \prod_{i=1}^{n}(r^{\eta_{p_i}} - 1)^{w_i}\right)\right) \leq$$

$\log_r\left(1+\prod_{i=1}^{n}(r^{(\eta^-)}-1)^{w_i}\right)\Big),$
$\log_r\left(1+\prod_{i=1}^{n}(r^{(\nu^+)}-1)^{w_i}\right)\Big) \leq$
$\log_r\left(1+\prod_{i=1}^{n}(r^{\nu_{p_i}}-1)^{w_i}\right)\Big) \leq$
$\log_r\left(1+\prod_{i=1}^{n}(r^{(\nu^-)}-1)^{w_i}\right)\Big).$
Therefore, $p^- \leq PFFWA(p_1,p_2,\ldots,p_n) \leq p^+$. □

THEOREM **3.5.** *(Monotonicity property) Let p_i and p_i'(i=1, 2,..., n) be two sets of PFNs, if $p_i \leq p_i'$ for all i, then $PFFWA(p_1,p_2,\ldots,p_n) \leq PFFWA(p_1',p_2',\ldots,p_n')$.*

Proof: Since $p_i \leq p_i'$ for all $i=1,2,...,n$, then, we have $\mu_{p_i} \leq \mu'_{p_i}$, $\eta_{p_i} \leq \eta'_{p_i}$ and $\nu_{p_i} \geq \nu'_{p_i}$ for all $i=1,2,\ldots,n$.
Now, $(r^{1-\mu_{p_i}}-1)^{w_i} \geq (r^{1-\mu'_{p_i}}-1)^{w_i}$
$\Rightarrow \log_r\left(1+\prod_{i=1}^{n}(r^{1-\mu_{p_i}}-1)^{w_i}\right) \geq$
$\log_r\left(1+\prod_{i=1}^{n}(r^{1-\mu'_{p_i}}-1)^{w_i}\right)$
$\Rightarrow 1-\log_r\left(1+\prod_{i=1}^{n}(r^{1-\mu_{p_i}}-1)^{w_i}\right) \leq$
$1-\log_r\left(1+\prod_{i=1}^{n}(r^{1-\mu'_{p_i}}-1)^{w_i}\right).$
Similarly, it can be shown that
$\log_r\left(1+\prod_{i=1}^{n}(r^{\eta_{p_i}}-1)^{w_i}\right) \leq$
$\log_r\left(1+\prod_{i=1}^{n}(r^{\eta'_{p_i}}-1)^{w_i}\right)$
and
$\log_r\left(1+\prod_{i=1}^{n}(r^{\nu_{p_i}}-1)^{w_i}\right) \geq$
$\log_r\left(1+\prod_{i=1}^{n}(r^{\nu'_{p_i}}-1)^{w_i}\right).$
Therefore, $PFFWA(p_1,p_2,\ldots,p_n) \leq PFFWA(p_1',p_2',\ldots,p_n')$. □

Now, we would like to introduce PFFOWA operator.

Definition 3.3. Let $p_i=(\mu_{p_i},\eta_{p_i},\nu_{p_i})(i=1,2,\ldots,n)$ be a number of PFNs. The PFFOWA operator of dimension n is a function $p^n \to p$ such that,

$$PFFOWA(p_1,p_2,\ldots p_n)=\bigoplus_{i=1}^{n} w_i p_{\rho(i)}$$

where $w=(w_1,w_2,\ldots,w_n)^t$ be the weight vector of $p_i(i=1,2,\ldots,n)$, $w_i \in [0,1]$ and $\sum_{i=1}^{n} w_i = 1$, $(\rho(1),\rho(2),\ldots,\rho(n))$ is the permutation of $(i=1,2,\ldots,n)$, for which $p_{\rho(i-1)} \geq p_{\rho(i)}$ for all $i=1,2,\ldots,n$.

Based on Frank product of PFNs the following theorem is developed.

THEOREM **3.6.** *Let $p_i=(\mu_{p_i},\eta_{p_i},\nu_{p_i})(i=1,2,\ldots,n)$ be a number of PFNs. The PFFOWA operator of dimension n is a function $p^n \to p$ with the corresponding weight vector $w=(w_1,w_2,\ldots,w_n)^t$ such that $w_i \in [0,1]$ and $\sum_{i=1}^{n} w_i = 1$. Then,*

$PFFOWA(p_1,p_2,\ldots,p_n)=\bigoplus_{i=1}^{n} w_i p_{\rho(i)}$
$=\Bigg(1-\log_r\left(1+\prod_{i=1}^{n}(r^{1-\mu_{p_{\rho(i)}}}-1)^{w_i}\right),$
$\log_r\left(1+\prod_{i=1}^{n}(r^{\eta_{p_{\rho(i)}}}-1)^{w_i}\right),$
$\log_r\left(1+\prod_{i=1}^{n}(r^{\nu_{p_{\rho(i)}}}-1)^{w_i}\right)\Bigg)$
where $(\rho(1),\rho(2),\ldots,\rho(n))$ are the permutation of $(i=1,2,\ldots,n)$ for which $p_{\rho(i-1)} \geq p_{\rho(i)}$ for all $i=1,2,\ldots,n$.

With the help of PFFOWA operator we can easily prove the following properties.

THEOREM **3.7.** *(Idempotency property). If $p_i=(\mu_{p_i},\eta_{p_i},\nu_{p_i})(i=1,2,\ldots,n)$ be a number of PFNs all are identical, i.e., $p_i=p$ for all i. Then, $PFFOWA(p_1,p_2,\ldots,p_n)=p$.*

THEOREM **3.8.** *(Boundedness Property). Let $p_i=(\mu_{p_i},\eta_{p_i},\nu_{p_i})(i=1,2,\ldots,n)$ be a number of PFNs. Let $p^-=min\{p_1,p_2,\ldots,p_n\}$ and $p^+=max\{p_1,p_2,\ldots,p_n\}$. Then, $p^- \leq PFFOWA(p_1,p_2,\ldots,p_n) \leq p^+$.*

THEOREM **3.9.** *(Monotonicity Property). Let p_i and p_i'(i=1, 2,..., n) be two sets of PFNs, if $p_i \leq p_i'$ for all i, then $PFFOWA(p_1,p_2,\ldots,p_n) \leq PFFOWA(p_1',p_2',\ldots,p_n')$.*

THEOREM **3.10.** *(Commutative Property). Let p_i and p_i'(i=1, 2,..., n) be two sets of PFNs, then $PFFOWA(p_1,p_2,\ldots,p_n) = PFFOWA(p_1',p_2',\ldots,p_n')$ where p_i' is any permutation of $p_i(i=1,2,\ldots,n)$.*

In Definition 3.2, we find that the weights associated with the PFFWA operator are the simplest form of PF value and in Definition 3.3 the weights associated with the PFFOWA operator is the original form of the ordered positions of the PF values. In this way, the weights disclosed in the PFFWA and PFFOWA operators, present various perspectives which are conflicting with one another. But, these perspectives are deliberated to be the same in a general approach. Only to be rescued of such drawback, we now introduce PFFHA operator.

Definition 3.4. Let $p_i=(\mu_{p_i},\eta_{p_i},\nu_{p_i})(i=1,2,\ldots,n)$ be a number of PFNs. The PFFHA operator of dimension

n is a function $p^n \to p$ such that,

$$\begin{aligned} & PFFHA(p_1, p_2, \ldots, p_n) \\ = & \bigoplus_{i=1}^{n} \bar{w}_i \dot{p}_{\rho(i)} \\ = & \left(1 - \log_r \left(1 + \prod_{i=1}^{n} (r^{1-\dot{\mu}_{p_{\rho(i)}}} - 1)^{\bar{w}_i} \right), \right. \\ & \log_r \left(1 + \prod_{i=1}^{n} (r^{\dot{\eta}_{p_{\rho(i)}}} - 1)^{\bar{w}_i} \right), \\ & \left. \log_r \left(1 + \prod_{i=1}^{n} (r^{\dot{\nu}_{p_{\rho(i)}}} - 1)^{\bar{w}_i} \right) \right) \end{aligned}$$

where $\bar{w} = (\bar{w}_1, \bar{w}_2, \ldots, \bar{w}_n)^t$ is the aggregation associated weight vector, $\sum_{i=1}^{n} \bar{w}_i = 1$, $w = (w_1, w_2, \ldots, w_n)^t$ be the weight vector of $p_i (i = 1, 2, \ldots, n)$, $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$. $\dot{p}_{\rho(i)}$ is the i^{th} biggest weighted PF values of $\dot{p}_i (\dot{p}_i = n w_i p_i, i = 1, 2, \ldots, n)$, n is the balancing coefficient.

Deduction 3.1. *When $w = (\frac{1}{n}, \frac{1}{n}, \ldots, \frac{1}{n})^t$, then $\dot{p}_i = n \times \frac{1}{n} \times p_i = p_i$ for $i = 1, 2, ..., n$. Then the PFFHA operator degenerates into PFFOWA operator. If $\bar{w} = (\frac{1}{n}, \frac{1}{n}, \ldots, \frac{1}{n})^t$, then PFFHA operator reduces to PFFWA operator. Hence, PFFWA and PFFOWA operators are a specific type of PFFHA operator. Thus, PFFHA operator is a generalization of both the PFFWA and PFFOWA operators, which reflects the degrees of the stated disagreements and their organized situations.*

3.2 Picture fuzzy Frank geometric aggregation operators

Definition 3.5. Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i}) (i = 1, 2, \ldots, n)$ be a number of PFNs. Then PFFWG operator is a function $p^n \to p$ such that,

$$PFFWG(p_1, p_2, \ldots, p_n) = \bigotimes_{i=1}^{n} (p_i)^{w_i}$$

where $w = (w_1, w_2, \ldots, w_n)^t$ be the weight vector of $p_i (i = 1, 2, \ldots, n)$, $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$.

Hence, we get consequential theorem that follows the Frank operations on PFNs.

THEOREM **3.11.** *Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i}) (i = 1, 2, \ldots, n)$ be a number of PFNs, then aggregated value of them using PFFWG operator is also a PFN, and*

$$\begin{aligned} & PFFWG(p_1, p_2, \ldots, p_n) = \bigotimes_{i=1}^{n} (p_i)^{w_i} \\ = & \left(\log_r \left(1 + \prod_{i=1}^{n} (r^{\mu_{p_i}} - 1)^{w_i} \right), \right. \\ & 1 - \log_r \left(1 + \prod_{i=1}^{n} (r^{1-\eta_{p_i}} - 1)^{w_i} \right), \\ & \left. 1 - \log_r \left(1 + \prod_{i=1}^{n} (r^{1-\nu_{p_i}} - 1)^{w_i} \right) \right). \end{aligned}$$

Proof: The proof of this theorem emulates from Theorem 3.2. □

The following properties may be easily proved by PFFWG operator.

THEOREM **3.12.** *(Idempotency Property). If $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i}) (i = 1, 2, \ldots, n)$ be a number of identical PFNs, i.e., $p_i = p$ for all i. Then, $PFFWG(p_1, p_2, \ldots, p_n) = p$.*

THEOREM **3.13.** *(Boundedness Property). Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i}) (i = 1, 2, \ldots, n)$ be a number of PFNs. Let $p^- = min\{p_1, p_2, \ldots, p_n\}$ and $p^+ = max\{p_1, p_2, \ldots, p_n\}$. Then, $p^- \leq PFFWG(p_1, p_2, \ldots, p_n) \leq p^+$.*

THEOREM **3.14.** *(Monotonicity Property). Let p_i and p_i'(i=1, 2,..., n) be two sets of PFNs, if $p_i \leq p_i'$ for all i, then $PFFWG(p_1, p_2, \ldots, p_n) \leq PFFWG(p_1', p_2', \ldots, p_n')$.*

Now, we would like to introduce PFFOWG operator.

Definition 3.6. Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i}) (i = 1, 2, \ldots, n)$ be a number of PFNs. The PFFOWG operator of dimension n is a function $p^n \to p$ such that,

$$PFFOWG(p_1, p_2, \ldots p_n) = \bigotimes_{i=1}^{n} (p_{\rho(i)})^{w_i}$$

where $w = (w_1, w_2, \ldots, w_n)^t$ be the weight vector of $p_i (i = 1, 2, \ldots, n)$, $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$, $(\rho(1), \rho(2), \ldots, \rho(n))$ are the permutation of $(i = 1, 2, \ldots, n)$, for which $p_{\rho(i-1)} \geq p_{\rho(i)}$ for all $i = 1, 2, \ldots, n$.

The following theorem is developed based on Frank product operation on PFNs using PFFOWG operator.

THEOREM **3.15.** *Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i}) (i = 1, 2, \ldots, n)$ be a number of PFNs. The PFFOWG operator of dimension n is a function $p^n \to p$ with the corresponding weight vector $w = (w_1, w_2, \ldots, w_n)^t$ such that $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$. Then,*

$$\begin{aligned} & PFFOWG(p_1, p_2, \ldots p_n) = \bigotimes_{i=1}^{n} (p_{\rho(i)})^{w_i} \\ = & \left(\log_r \left(1 + \prod_{i=1}^{n} (r^{\mu_{p_{\rho(i)}}} - 1)^{w_i} \right), \right. \\ & 1 - \log_r \left(1 + \prod_{i=1}^{n} (r^{1-\eta_{p_{\rho(i)}}} - 1)^{w_i} \right), \\ & \left. 1 - \log_r \left(1 + \prod_{i=1}^{n} (r^{1-\nu_{p_{\rho(i)}}} - 1)^{w_i} \right) \right) \end{aligned}$$

where $(\rho(1), \rho(2), \ldots, \rho(n))$ are the permutation of $(i = 1, 2, \ldots, n)$ for which $p_{\rho(i-1)} \geq p_{\rho(i)}$ for all $i = 1, 2, \ldots, n$.

The following properties can be investigated by using PFFOWG operator.

THEOREM **3.16.** *(Idempotency property). If* $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i})(i = 1, 2, \ldots, n)$ *be a number of PFNs all are identical, i.e.,* $p_i = p$ *for all i. Then,* $PFFOWG(p_1, p_2, \ldots, p_n) = p$.

THEOREM **3.17.** *(Boundedness Property). Let* $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i})(i = 1, 2, \ldots, n)$ *be a number of PFNs. Let* $p^- = min\{p_1, p_2, \ldots, p_n\}$ *and* $p^+ = max\{p_1, p_2, \ldots, p_n\}$. *Then,* $p^- \leq PFFOWG(p_1, p_2, \ldots, p_n) \leq p^+$.

THEOREM **3.18.** *(Monotonicity Property). Let* p_i *and* p_i'*(i=1, 2,..., n) be two sets of PFNs, if* $p_i \leq p_i'$ *for all i, then* $PFFOWG(p_1, p_2, \ldots, p_n) \leq PFFOWG(p_1', p_2', \ldots, p_n')$.

THEOREM **3.19.** *(Commutative Property). Let* p_i *and* p_i'*(i=1, 2,..., n) be two sets of PFNs, then* $PFFOWG(p_1, p_2, \ldots, p_n) = PFFOWG(p_1', p_2', \ldots, p_n')$ *where* p_i' *is any permutation of* $p_i(i = 1, 2, \ldots, n)$.

In Definition 3.5, we find that the weights associated with the PFFWG operator are in the simplest form of PF value and in Definition 3.6 the weights associated with the PFFOWG operator are in the actual form of the ordered positions of the PF values. In this way, the weights disclosed in the PFFWG and PFFOWG operators, present various perspectives which are conflicting with one another. But, these perspectives are deliberated to be the same in a general approach. Only to be rescued of such drawback, we at this moment introduce PFFHG operator.

Definition 3.7. Let $p_i = (\mu_{p_i}, \eta_{p_i}, \nu_{p_i})(i = 1, 2, \ldots, n)$ be a number of PFNs. The PFFHG operator of dimension n is a function $p^n \to p$ such that,

$$PFFHG(p_1, p_2, \ldots, p_n) = \bigotimes_{i=1}^{n} (\dot{p}_{\rho(i)})^{\bar{w}_i}$$

$$= \left(\log_r \left(1 + \prod_{i=1}^{n} (r^{\dot{\mu}_{p_{\rho(i)}}} - 1)^{\bar{w}_i}\right), \right.$$

$$1 - \log_r \left(1 + \prod_{i=1}^{n} (r^{1-\dot{\eta}_{p_{\rho(i)}}} - 1)^{\bar{w}_i}\right),$$

$$\left. 1 - \log_r \left(1 + \prod_{i=1}^{n} (r^{1-\dot{\nu}_{p_{\rho(i)}}} - 1)^{\bar{w}_i}\right) \right)$$

where $\bar{w} = (\bar{w}_1, \bar{w}_2, \ldots, \bar{w}_n)^t$ is the aggregation associated weight vector, $\sum_{i=1}^{n} \bar{w}_i = 1$, $w = (w_1, w_2, \ldots, w_n)^t$ be the weight vector of $p_i(i = 1, 2, \ldots, n)$, $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$. $\dot{p}_{\rho(i)}$ is the i^{th} biggest weighted PF values of $\dot{p}_i(\dot{p}_i = nw_i p_i, i = 1, 2, \ldots, n)$, n is the balancing coefficient.

Deduction 3.2. *When* $w = (\frac{1}{n}, \frac{1}{n}, \ldots, \frac{1}{n})^t$, *then* $\dot{p}_i = n \times \frac{1}{n} \times p_i = p_i$ *for* $i = 1, 2, \ldots, n$. *Then the PFFHG operator degenerates into PFFOWG operator. If* $\bar{w} = (\frac{1}{n}, \frac{1}{n}, \ldots, \frac{1}{n})^t$, *then PFFHG operator reduces to PFFWG operator. Hence, PFFWG and PFFOWG operators are specific types of PFFHG operator. Thus, PFFHG operator is a generalization of both the PFFWG and PFFOWG operators, which reflects the degrees of the stated disagreements and their organized situations.*

4 Model for MADM using picture fuzzy data

In this section, we introduce a novel approach for decision-making problems using PF information manipulating PFFWA and PFFWG operators, where attribute values are PFNs and attribute weights are real numbers. For an MADM problem, let $F = \{F_1, F_2, \ldots, F_m\}$ be a discrete set of m alternatives to be selected and $H = \{H_1, H_2, \ldots, H_n\}$ be the arrangement of attributes to be assessed. Let $w = \{w_1, w_2, \ldots, w_n\}$ be the weight vector of the attributes $H_j(j = 1, 2, \ldots, n)$ where $w_k(k = 1, 2, 3, \ldots, n)$ are all real numbers such that $w_k > 0$ and $\sum_{k=1}^{n} w_k = 1$. Assume that $P = (\gamma_{ij})_{m\times n} = ((\mu_{ij}, \eta_{ij}, \nu_{ij}))_{m\times n}$ is the PF decision matrix, where γ_{ij} is the possible value for which the alternative F_i satisfies the attribute H_j where $\mu_{ij} + \eta_{ij} + \nu_{ij} \leq 1$ and $\mu_{ij},\ \eta_{ij},\ \nu_{ij} \in [0, 1]$.

To achieve the final ranking of the alternatives, we propose an algorithm which is shown in the following.

4.1 Algorithm

The proposed MADM problem with PF data based on the proposed PFFWA and PFFWG operators is now presented as follows:

Step I: Construct the PF decision matrix $P = (\gamma_{ij})_{m\times n} = ((\mu_{ij}, \eta_{ij}, \nu_{ij}))_{m\times n}$.

Step II: Transform the matrix $P = (\gamma_{ij})_{m\times n} = ((\mu_{ij}, \eta_{ij}, \nu_{ij}))_{m\times n}$ into a normalize PF matrix $P' = (\gamma_{ij}')_{m\times n} = ((\mu_{ij}', \eta_{ij}', \nu_{ij}'))_{m\times n}$ by Equation (1).

$$\gamma_{ij}' = \begin{cases} (\mu_{ij}, \eta_{ij}, \nu_{ij}), & \text{if } H_j \text{ is benefit attribute;} \\ (\nu_{ij}, \eta_{ij}, \mu_{ij}), & \text{if } H_j \text{ is cost attribute.} \end{cases} \quad (1)$$

Step III: Calculate the collective information σ_k of the alternative F_k by Equations (2) and (3).

$$\begin{aligned} \sigma_k &= PFFWA(\gamma_{k1}', \gamma_{k2}', \ldots, \gamma_{kn}') \\ &= \bigoplus_{j=1}^{n} (w_j \gamma_{kj}) \\ &= \left(1 - \log_r \left(1 + \prod_{i=1}^{n} (r^{1-\mu' p_{kj}} - 1)^{w_j}\right), \right. \\ &\quad \log_r \left(1 + \prod_{i=1}^{n} (r^{\eta' p_{kj}} - 1)^{w_j}\right), \\ &\quad \left. \log_r \left(1 + \prod_{i=1}^{n} (r^{\nu' p_{kj}} - 1)^{w_j}\right) \right). \end{aligned} \quad (2)$$

and

$$\begin{aligned}\sigma_k &= PFFWG(\gamma'_{k1}, \gamma'_{k2}, \ldots, \gamma'_{kn}) \\ &= \bigotimes_{j=1}^{n} (\gamma_{kj})^{w_j} \\ &= \Bigg(\log_r \Big(1 + \prod_{i=1}^{n} (r^{\mu'^{p_{kj}}} - 1)^{w_j}\Big), \\ &\quad 1 - \log_r \Big(1 + \prod_{i=1}^{n} (r^{1-\eta'^{p_{kj}}} - 1)^{w_j}\Big), \\ &\quad 1 - \log_r \Big(1 + \prod_{i=1}^{n} (r^{1-\nu'^{p_{kj}}} - 1)^{w_j}\Big)\Bigg). \quad (3)\end{aligned}$$

Step IV: Compute the score function $\Delta(\sigma_i)$ for each alternative using Definition 2.3.

Step V: The optimal decision is to select F_k if $\Delta(\sigma_k) = \max_l\{\Delta(\sigma_l)\}$.

5 Numerical illustration

In this section, we are willing to sketch a numerical problem to illustrate the possible assessment of commercialization with the help of PF data.

Suppose a renowned multi-tasking company has decided to utilize a part of its total annual profit in some improvement of the company's good-will. The managing board has selected some alternative choices to invest the fund, such as

1. F_1 : Air conditioning and furnishing the whole floor.
2. F_2 : Purchasing of some advanced gadgets.
3. F_3 : Constructing a parking zone.
4. F_4 : Advertising.
5. F_5 : Security facility.

Now, since each alternative satisfies different requirements so, confusion arises to make a decision. Thereby, the managing board has determined the following considerable attributes,

- H_1 : Enhancement of profit.
- H_2 : Customer's benefit.
- H_3 : Maintenance cost.
- H_4 : Ecofriendliness.

Now the decision making in this case is difficult because each alternative promises to maximize a different attribute. The managing board defines the weight vector of the attribute $H_j(j = 1, 2, 3, 4)$ as $(0.30, 0.25, 0.20, 0.25)$. Meanwhile, H_1, H_2, H_4 are benefit attributes and H_3 is a cost attribute. Assume that the alternative F_i with respect to the attribute H_j is expressed as PF matrix $P = (\gamma_{ij})_{m\times n} = ((\mu_{ij}, \nu_{ij}))_{m\times n}$. The assessment for the alternatives are shown in the Table 1.

In order to select the most preferable alternative $F_i(i = 1, 2, 3, 4, 5)$ we exploit the PFFWA and PFFWG operators to develop an MADM theory with PF data, which can be evaluated as follows:

Step 1: We input the PF decision matrix given in Table 1.

Step 2: By normalizing of PF decision matrix with the help of Equation (1) we get the matrix N.

Step 3: We take $r = 2$ and use PFFWA operator to compute overall performance values $\sigma_i(i = 1, 2, 3, 4, 5)$ of alternatives F_i's using Equation (2)

- $\sigma_1 = (0.6188, 0.1800, 0.0879)$
- $\sigma_2 = (0.6517, 0.1827, 0.1214)$
- $\sigma_3 = (0.5441, 0.2861, 0.0559)$
- $\sigma_4 = (0.6006, 0.2100, 0.0713)$
- $\sigma_5 = (0.5823, 0.1456, 0.1478)$.

Step 4: We compute the values of the score functions using Definition 2.3, $\Delta(\sigma_i)(k = 1, 2, 3, 4, 5)$ of the overall PFNs $\sigma_i(i = 1, 2, 3, 4, 5)$ as

- $\Delta(\sigma_1) = 0.7654$
- $\Delta(\sigma_2) = 0.7651$
- $\Delta(\sigma_3) = 0.7441$
- $\Delta(\sigma_4) = 0.7646$
- $\Delta(\sigma_5) = 0.7172$.

Therefore, with respect to the score values, we rank all the alternatives as $F_1 > F_2 > F_4 > F_3 > F_5$.

Step 5: Therefore, F_1 should be selected as the most preferable alternative by the company.

Again, if PFFWG operator is used instead of PFFWA operator, then the problem can be solved similarly as above.

Step 1: We input the PF decision matrix given in Table 1.

Step 2: The normalized matrix is same as the matrix N.

Step 3: We take $r = 2$ and use PFFWG operator to compute overall performance values $\sigma_i(i = 1, 2, 3, 4, 5)$ by Equation 3 of the alternatives F_i's.

- $\sigma_1 = (0.4210, 0.2959, 0.1067)$
- $\sigma_2 = (0.5968, 0.2118, 0.1277)$
- $\sigma_3 = (0.2922, 0.4242, 0.0580)$
- $\sigma_4 = (0.3057, 0.3727, 0.0778)$
- $\sigma_5 = (0.4545, 0.2031, 0.1600)$.

Step 4: We compute the values of the score function using Definition 2.3, $\Delta(\sigma_i)(i = 1, 2, 3, 4, 5)$ of the overall PFNs $\sigma_i(i = 1, 2, 3, 4, 5)$ as

- $\Delta(\sigma_1) = 0.6571$
- $\Delta(\sigma_2) = 0.7345$
- $\Delta(\sigma_3) = 0.6170$
- $\Delta(\sigma_4) = 0.6139$
- $\Delta(\sigma_5) = 0.6472$.

	H_1	H_2	H_3	H_4
F_1	(0.60,0.25,0.12)	(0.91,0.03,0.05)	(0.22,0.20,0.38)	(0.12,0.59,0.05)
F_2	(0.72,0.15,0.10)	(0.32,0.40,0.20)	(0.11,0.15,0.70)	(0.75,0.12,0.10)
F_3	(0.80,0.10,0.04)	(0.09,0.70,0.05)	(0.08,0.60,0.07)	(0.70,0.20,0.07)
F_4	(0.85,0.05,0.04)	(0.76,0.15,0.07)	(0.09,0.70,0.07)	(0.09,0.53,0.12)
F_5	(0.71,0.10,0.11)	(0.56,0.20,0.19)	(0.09,0.50,0.09)	(0.69,0.03,0.24)

Table 1: Picture fuzzy decision matrix

Therefore, with respect to the score values, we rank all the alternatives as $F_2 > F_1 > F_5 > F_3 > F_4$.

Step 5: Therefore, F_2 should be selected as the most preferable alternative by the company.

As we have demonstrated above, the score values of the alternatives are different from each other. But the ranking orders corresponding to various alternatives are the same, and the preferable alternative is always F_2.

$$N = \begin{pmatrix} (0.60, 0.25, 0.12) & (0.91, 0.03, 0.05) & (0.38, 0.20, 0.22) & (0.12, 0.59, 0.05) \\ (0.72, 0.15, 0.10) & (0.32, 0.40, 0.20) & (0.70, 0.15, 0.11) & (0.75, 0.12, 0.10) \\ (0.80, 0.10, 0.04) & (0.09, 0.70, 0.05) & (0.07, 0.60, 0.08) & (0.70, 0.20, 0.07) \\ (0.85, 0.05, 0.04) & (0.76, 0.15, 0.07) & (0.07, 0.70, 0.09) & (0.09, 0.53, 0.12) \\ (0.71, 0.10, 0.11) & (0.56, 0.20, 0.19) & (0.09, 0.50, 0.09) & (0.69, 0.03, 0.24) \end{pmatrix}$$

Next, we will show how the parameter r affects the ranking results obtained by utilizing PFFWA and PFFWG operators.

6 Analysis of the effect of the parameter r on decision making

We can utilize different values of the operational parameter r, for ranking the given alternatives in our proposed method.

For exploring the flexibility and sensitivity of the parameter r, we fix different values of r to categorize the novel numerical MADM example. Depending on PFFWA operator and PFFWG operator, the consequences of ranking orders of the alternatives F_1, F_2, F_3, F_4, F_5 for different values of the parameter r are shown in the Table 2 and Table 3.

To provide a better view of the aggregation results, we show the results of the rankings of the alternatives by the proposed PFFWA and PFFWG operators in Figure 1(a) and Figure 1(b) respectively.

From Table 2 and Figure 1(a) we can easily see that when $3 \leq r \leq 10, r = 15, 20, 25, 50$ the aggregation score values using PFFWA operator with different parameter r are different, but the ranking orders of the alternatives $F_i (i = 1, 2, 3, 4, 5)$ are same and the ranking order is $F_2 > F_1 > F_4 > F_3 > F_5$. However, when $r = 2$, we obtain $F_1 > F_2 > F_4 > F_3 > F_5$ and in that case the optimal alternative is F_1.

From Table 3 and Figure 1(b), we can see that the aggregation score values using PFFWG operator with different parameter r are different, but the optimal alternative is always F_2. When $2 \leq r \leq 9$, we obtained $F_2 > F_1 > F_5 > F_3 > F_4$, when $r = 10$, we get $F_2 > F_1 > F_5 > F_3 \sim F_4$ and for $r = 15, 20, 25, 50$, we obtained $F_2 > F_1 > F_5 > F_4 > F_3$. Hence, the overall best alternative is F_2.

In general, different decision-makers can set different values of the parameter r based on their preferences.

In this MADM problem based on PFFWA and PFFWG operators, we can notice that for PFFWG operator the ranking orders of the alternatives can be changed by the variation of values of the parameter r. Therefore, the PFFWG operator has responded more to r in this MADM method. At the same time, in correspondence with PFFWA operator according to different values of working parameter r, ranking forms can be changed. So PFFWA operator is less responsive to r in this case of the MADM procedure.

7 Comparison analysis

In order to verify the utility of the proposed method and to pursue its advantages, we compare our proposed Frank aggregation operators with other existing well-known aggregation operators under the PF environment. The comparative results are shown in Table 4. We compare our proposed method with PFWA operator [37] and PFWG operator [37].

Making a comparison with PFWA or PFWG operators introduced by Wei [37], we can find that PFWA or PFWG operator is only a particular case of our proposed operators when the parameter $r \to 1$. Therefore, indeed, our introduced procedures are more generalized. Moreover, our proposed operators, based on Frank t-norm and Frank t-conorm are more nourished and can adopt the relationship between various arguments. Also, our proposed operators present the Lukasiewicz product and Lukasiewicz sum when the parameter $r \to \infty$. Therefore, we have ar-

r	$\Delta(\sigma_1)$	$\Delta(\sigma_2)$	$\Delta(\sigma_3)$	$\Delta(\sigma_4)$	$\Delta(\sigma_5)$	Ranking order	Optimal alternative
2	0.7654	0.7651	0.7441	0.7646	0.7172	$F_1 > F_2 > F_4 > F_3 > F_5$	F_1
3	0.7610	0.7640	0.7396	0.7594	0.7153	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
4	0.7581	0.7632	0.7365	0.7559	0.7140	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
5	0.7558	0.7626	0.7342	0.7532	0.7130	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
6	0.7541	0.7622	0.7324	0.7511	0.7122	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
7	0.7526	0.7618	0.7309	0.7493	0.7115	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
8	0.7514	0.7614	0.7297	0.7478	0.7110	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
9	0.7503	0.7611	0.7286	0.7465	0.7105	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
10	0.7494	0.7609	0.7277	0.7454	0.7101	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
15	0.7459	0.7599	0.7243	0.7412	0.7085	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
20	0.7436	0.7593	0.7221	0.7385	0.7075	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
25	0.7419	0.7588	0.7204	0.7364	0.7068	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2
50	0.7370	0.7575	0.7160	0.7308	0.7046	$F_2 > F_1 > F_4 > F_3 > F_5$	F_2

Table 2: Effect of the parameter r on decision making result using PFFWA operator

r	$\Delta(\sigma_1)$	$\Delta(\sigma_2)$	$\Delta(\sigma_3)$	$\Delta(\sigma_4)$	$\Delta(\sigma_5)$	Ranking order	Optimal alternative
2	0.6571	0.7345	0.6170	0.6139	0.6472	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
3	0.6613	0.7361	0.6220	0.6197	0.6514	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
4	0.6641	0.7372	0.6255	0.6238	0.6541	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
5	0.6663	0.7380	0.6282	0.6269	0.6562	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
6	0.6679	0.7386	0.6304	0.6294	0.6577	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
7	0.6693	0.7391	0.6322	0.6315	0.6590	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
8	0.6704	0.7395	0.6337	0.6333	0.6601	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
9	0.6714	0.7398	0.6351	0.6349	0.6611	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
10	0.6732	0.7401	0.6363	0.6363	0.6619	$F_2 > F_1 > F_5 > F_3 \sim F_4$	F_2
15	0.6755	0.7412	0.6408	0.6415	0.6648	$F_2 > F_1 > F_5 > F_4 > F_3$	F_2
20	0.6776	0.7419	0.6438	0.6450	0.6668	$F_2 > F_1 > F_5 > F_4 > F_3$	F_2
25	0.6791	0.7424	0.6461	0.6476	0.6682	$F_2 > F_1 > F_5 > F_4 > F_3$	F_2
50	0.6833	0.7437	0.6528	0.6551	0.6720	$F_2 > F_1 > F_5 > F_4 > F_3$	F_2

Table 3: Effect of the parameter r on decision making result using PFFWG operator

rived at the decision that all of the arithmetic and geometric aggregation operators for PFNs are contained in PF Frank aggregation operators, concerning the different values of r.

If we modify the value of the parameter r in the problem, we get different ranking results for the alternatives. For example, if we modify the value of the parameter r from 2 to 50, then using PFFWG operator we get the score values of the alternatives as $\Delta(\sigma_1) = 0.6833$, $\Delta(\sigma_2) = 0.7437$, $\Delta(\sigma_3) = 0.6528$, $\Delta(\sigma_4) = 0.6551$ and $\Delta(\sigma_5) = 0.6720$. Obviously, it can be obtained that the ranking position of the alternative F_4 changed from a bad position to a good position. But the PFWA and the PFWG operators are independent of the parameter r. So, the ranking order obtained with the help of those operators remains the same.

Based on the above comparison analysis, the approach in the present study is proved to be more flexible, compatible, and reliable than other existing procedures to control PF environment based MADM problems.

8 Conclusions

In this paper, we have studied MADM problems using PF information. We have developed Frank operations for PFSs and proposed a series of new aggregation operators, like, PFFWA operator, PFFOWA operator, PFFHA operator, PFFWG operator, PFFOWG operator, and PFFHG operator. Then, we have proposed an algorithm to deal with the MADM problem under the PF environment by using the PFFWA operator and the PFFWG operator. Finally, we have compared our proposed method with the existing approaches to exhibit its benefits and applicability.

In further research, we can study some new extensions of PFS, such as complex PFS, rough PFS. We can also extend them to other decision-making methods, such as COPRAS method [49], TOPSIS method [15], VIKOR [47] method, and so on, and apply them to deal with some real-life decision-making problems. We shall continue to investigate PF aggregation operators with the help of various t-norms and t-conorms.

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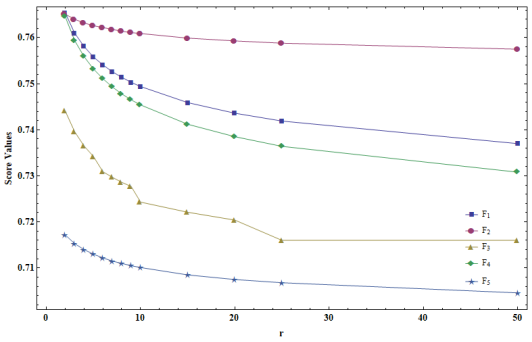
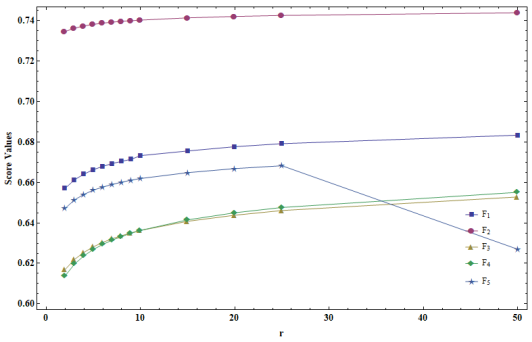


(a) Score of alternatives when $r \in [2, 50]$ based on PFFWA operator



(b) Score of alternatives when $r \in [2, 50]$ based on PFFWG operator

Figure 1: Pictorial representation of the ranking of the alternatives with different values of r

Aggregation Operators	$\Delta(\sigma_1)$	$\Delta(\sigma_2)$	$\Delta(\sigma_3)$	$\Delta(\sigma_4)$	$\Delta(\sigma_5)$	Ranking order	Optimal alternative
PFWA [37]	0.7731	0.7671	0.7522	0.7737	0.7206	$F_4 > F_1 > F_2 > F_3 > F_5$	F_4
PFWG [37]	0.6494	0.7312	0.6085	0.6040	0.6394	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2
Proposed method	0.6571	0.7345	0.6170	0.6139	0.6472	$F_2 > F_1 > F_5 > F_3 > F_4$	F_2

Table 4: Comparison table

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Formal Verification of Emergent Properties

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Complex systems and systems of systems (SoS) are systems characterized by the interconnection of a large number of components or sub-systems. The complexity of such systems increases with the number of components and their manner of connectivity. The global behaviour of complex systems and SoS exhibits some properties that cannot be predicted by analysing components or sub-systems in isolation. The verification of these properties called "emergent properties" is considered a crucial issue when engineering such systems. The purpose of this paper is to give an overview and verify emergent properties. In a first step, we have taken the blinker and the traffic light of the game of life as examples to verify emergence by using refinement techniques; in a second step, since the refinement is not straightforward, we have taken another example, the Boids model, and by using timed automata and UPPAAL model checking techniques, we have been able to simulate and verify emergent properties.

Povzetek: Prispevek podaja pregled emergentnih lastnosti v kompleksnih sistemih.

1 Introduction

Technological development in various domains, especially the decrease in size and cost of electronic devices, like microprocessors and storage devices, leads to the development of distributed, decentralized, complex systems and systems of systems (SoS) [6]. A complex system is any system characterized by the interconnection of a large number of components with non-linear aggregate behaviour, *i.e.*, global behaviour is not derivable from the sum of the local or individual behaviours of components. Generally, these components have limited access or mostly they do not have any access to global information, which makes them operate on information obtained from the interaction with other components. Hence, their complexity increases with the number of components, in particular, when these later are highly interconnected.

This kind of what we call complex systems often exhibits properties that are not easily predictable by analysing the behaviour of their individual interacting components. In other words, complex systems exhibit emergent behaviours at the macro-level: behaviours that cannot be inferred from local behaviours or from behaviours at micro-levels. When engineering such systems, the verification of emergent properties is considered as a difficult issue for designers. These properties that cannot be deduced from components or systems when considered in isolation can be beneficial or harmful. Simulation is a good and powerful manner to detect emergence, but it is still not sufficient (a random exploration of behaviour is not guaranteed to exhibit the emergent ones). Hence, the use of formal techniques to detect and verify emergence becomes mandatory. In this paper, we present an overview of some definitions of emergence in the literature giving a distinction between weak and strong emergence and providing some works that have been carried out for the verification of emergent properties. On the one hand, we have taken examples of weak emergent properties from the game of life and verified them using standard techniques of refinement. On the other hand, since refinement is very difficult to apply for some examples which makes it undesirable for most designers, we have taken another example of the Boids model. By using timed automata [20, 21], we have been able to model, simulate and verify emergent properties using UPPAAL model checking techniques [19].

2 Emergence

The concept of emergence is widely used in various domains, and has different significations, from philosophical, social sciences, arts, biology to computer science [17, 25, 34, 35]. In the following, we will provide some definitions in the area of computer science, in particular in complex systems and SoS.

2.1 Definitions of emergent property

Despite several researches that have been done on the domain of complex system and SoS focusing on emergence, there is no consensus on the definition of emergence [1, 7, 25, 26]. However, many works are inspired from Aristotle's definition: *"the whole is greater than the sum of its parts"*. An emergent property can be defined as "a property of an assemblage that could not be predicted by examining the components individually [10, 12]. Paul Teller [1, 8] said: "a property of a whole is an emergent property of a whole when it is not reducible to the non-relational properties of the parts ". In [1], Kopetz et al. preserve Paul's definition replacing the word "property" by "phenomenon": a phenomenon of a whole at the macro-level is emergent if and only if it is new with respect to the non-relational of any of its proper parts at the micro-level. In [2], Yong Meng defined emergent properties in complex systems as properties that are irreducible from knowledge of the interconnected components. In [5], Polack and Stepney define emergence as a discontinuity between global and local system descriptions. Sanders and Smith [6] defined emergent behaviour as a behaviour that is not determined by the behaviour of the constituents when considered in isolation. Isodora [4] characterized emergence of agents that operate in two or three-dimensional space as "a pattern appearing in the agents' configuration at some instance during the operation of the system".

2.2 Weak and strong emergence

As it is presented in many works in the literature and from different views in different domains, emergence is not an absolute concept, it can be classified on a scale from weak to strong [9].

2.2.1 Weak emergence

Weak emergence is a type of emergence in which the emergent property is amenable to computer simulation, it describes new properties arising in systems as a result of the interactions at an elemental level. However, it is stipulated that the properties can be determined by observing or simulating the system, and not by any process of a priori analysis [1, 10, 11]. *I.e.*, weak emergence is deducible but unexpected from the laws of the low-level domain. Bedau [11] describes deducible features of weak emergence in terms of derivability by simulation.

2.2.2 Strong emergence

Strong emergence is a type of emergence in which the emergent property cannot be simulated by a computer. It describes the direct causal action of a high-level system upon its components; qualities produced this way are irreducible to the system's constituent parts, *i.e.*, there is no theory, concept, or principle that can explain or deduce the behaviour of the system based on the properties or behaviour of its micro level components (the whole is greater than the sum of its parts). It follows that no simulation of the system can exist, for such a simulation would itself constitute a reduction of the system to its constituent parts [1, 10, 11].

3 Related work

In this section, we will show some research works in which emergence has been studied.

In [1], Kopetz et al. explained the phenomenon of emergence in systems of systems (SoS)[13]. Compared to monolithic systems, they noticed that emergent phenomena are the most differentiating characteristic of an SoS. They elaborated a short overview of emergence in two fields. In the field of philosophy: "how the emergence of a new properties of complex systems, such as life or the mind can be explained?". To answer this question, there were basically two camps. The first is the reductive physicalism view which claims that physical sciences can explain all that exists in the world. The second holds the opposite view of non-reductive physicalism, which claims that some new properties at the higher level cannot be reduced to mere physical phenomena.

In the domain of computer science, Kopetz et al. said that there is no consensus of emergence according to the remark of John Holland, a computer scientist working in the area of complex systems, saying *"Despite its ubiquity and importance, emergence is an enigmatic and recondite topic, more wondered at than analysed... It is unlikely that a topic as complicated as emergence will submit meekly to a concise definition and I have no such definition to offer"* [14].

In the European project TEREA SoS [1, 33], a roadmap for future research in SoS has been proposed, where the topics of theoretical foundation of SoS and emergence are in prominent position. They distinguished four cases in addition to the two types of emergence (weak and strong): expected and beneficial so emergent behaviour is a normal case; unexpected and beneficial: emergent behaviour is a positive surprise; expected and detrimental: emergent behaviour can be avoided by adhering to proper design rules; and unexpected and detrimental: emergent behaviour is a problematic case or a catastrophe.

They noticed that the type of emergence that is occurring in an SoS is weak emergence even if we are surprised and cannot explain the occurrence of an unexpected emergent phenomenon at the moment of its first encounter. After

lighting both types of emergence phenomena, Kopetz et al. explained the causality of emergent phenomena in an SoS, finally, they proposed a new methodology for the design of complex systems based on the explanation of emergence engineering.

In [2], Yong Meng et al. proposed a grammar-based approach for verifying emergence in multi-agent systems. According to some works on emergence [7, 15, 16], they said that complex systems exhibit emergent properties that are irreducible from knowledge of the interconnected components. They provided an overview of emergence in three main perspectives: philosophy, natural and social sciences and computer science.

Computer science aims to predict, verify, validate and reason about emergence. Prediction is done before the observation of emergence, while verification is done only when emergence is observed. Verification of emergent properties is a complex task because it may lead to combinatorial explosion in terms of the system states. More importantly, emergent properties should be defined first before verifying. Validation allows determining whether an emergent property is beneficial or harmful [18]. Finally, reasoning enables the understanding of the cause-and-effect of emergence. Yong Meng et al. noticed that the only studied type of emergence in computer science is weak emergence. They classify formalization of emergence in three mainly categories: Variable-based, event-based and grammar based. They extended Kubik's grammar-based approach [17], which does not require a prior definition of emergence, in order to derive emergent property states.

In [3], Rouff et al. made an investigation into formal methods techniques that can be applicable to swarm based missions. They made a survey of some works in formal methods and extract a few ones for applying them in NASA swarm based systems. NASA future mission 2020-2030 will be the prospective ANTS (Autonomous Nano Technology Swarm). They argued that formal methods are very interesting to use for assuring the correctness of this mission. One of the most challenging aspects of using swarms is how to verify that the emergent behaviour of such a system will be proper and that no undesirable behaviour will occur. They cited several formal methods that have been used in the literature, but very few of them are used for verifying emergent behaviour of swarms. Based on the survey results, they selected four methods to do sample specification of parts of the ANTS mission and provided some advantages and inconveniences for each one. Finally, they suggested necessary properties of formal methods in order to specify swarm-based systems:

- modelling and reasoning about aggregate behaviour based on future actions of the individual agents of a swarm [27]
- modelling states of an agent of the swarm to assure correctness[28]
- modelling and reasoning about concurrent processes for detection of race conditions[29]
- modelling and reasoning about persistent information for verifying adaptive behaviour [28].

They conclude that the use of methods together is the best approach for the specification and the analysis of swarm-based systems.

In [4], Isodora et al. claimed that the verification of emergent behaviour of multi-agent system (MAS) is a very complex task, due to the fact that emergent behaviour must be detected and identified before starting its verification process. Unfortunately this identification is not an easy thing that requires the combining of formal and informal methods in order to verify MAS. They took an example of the aggressor defender game and proposed a research framework starting by formal modelling of agents which distinguish between spatial behaviour and other behaviours. Firstly, spatial behaviour leads to visual animation which can help to observe potential emergent properties. Then, spatial behaviour together with other behaviours can lead towards simulation and saving time series data. These can be used to identify patterns of behaviours combined with visual animation that produces desired properties. The desired properties, including emergence, can be verified in the original spatial agent model by model checking. They presented a superficial framework without details as well as a definition of spXMachine and a tool for automatic transformation to Net Lego (only results of animation were shown). They proposed future steps for this framework using some tools like spXM, FLAME [30] and DAIKON [31].

In [5], Polack and Stepney said that there is a discontinuity between global and local system descriptions for emergent systems which presents a challenge in terms of demonstrably-correct development (refinement) from an abstract specification. They gave a short review of refinement, which is a relationship between an abstract program and an equivalent concrete one. Such a refinement is discharged by simulation. The refinement proof must demonstrate that functional properties in the abstract model preserved in the concrete model. They took the example of cellular automata producing gliders. They argue that the behaviour rather than the movement of the glider cannot be refined to the rules of the game of life. They justified their argument by the disparate of languages in which specification and implementation are expressed. Finally, they gave tentative design guidelines for emergent systems. The first two guidelines are to identify the three key elements of the emergent system: required system specification, functional component specification and specification of the integration representation and to identify elements with common vocabulary and then identifying intermediate elements. They proposed a guideline to establish how the emergence is detected.

In [6], Sanders and Smith provided an approach for refining emergent properties. They said that during the modelling of an existing system, unknown discontinuities in behaviour may not be modelled. Consequently, proof techniques cannot be successful in detecting emergent be-

haviour. In addition, they noticed that when engineering new systems, we are not trying to prove the existence of emergent behaviour, we merely commence with the required emergent behaviour, which can be undesired behaviour that we must avoid, and then develop a design which gives rise to these new systems. The emergent behaviour must be a consequence of the component interactions within the design.

In [6], Sanders and Smith are only interested in systems with weak emergence. Their challenging effort was an answer for the question: Are standard formal methods and in particular refinement applicable to the engineering of systems with weak emergence? This question had been negatively answered in [5]. They took the same example of the glider to show how a positive answer for the above question can be made.

They started by specifying a simple game of life in one dimension and gave a specification of one-dimensional glider with its suitable implementation. Then they proved that such an implementation was a refinement of the specification. They demonstrated three examples (glider, floater and k-glider) in one-dimensional game of life that can be refined. The second step was a two-dimensional game of life. They took the same example of a glider specified in two dimensions using some helpful geometric results: They defined a rectangle in the plane as a Cartesian product of two finite intervals. A subset of the plane is said to be bounded iff it is contained in some rectangle, basing on this, they gave conditions for which a bounded sub set has a heading. According to this, they were able to prove that the two-dimensional implementation of the glider was the refinement of its specification, which is a positive challenging answer to what many researchers thought negatively. Hence, they argued that standard refinement is widely applicable for systems with weak emergent behaviours.

4 Refining emergent properties

In this section, in addition to Sanders' approach[6] to which we will add the time concept, we will take two different examples of weak emergent properties in the game of life in order to verify them using refinement techniques.

4.1 Game of life

The game of life [24], developed by the British mathematician J. H. Conway from the university of Cambridge in 1970, is a zero player game, its evolution is determined only by its initial configuration (initial state). Starting with the initial configuration we can see the game evolving during time.

4.1.1 Rules of the game

To update the state of the cell in the game, four rules are used:

1. Any live cell with fewer than two live neighbours die by isolation (solitude) or under-population.
2. Any live cell with more than three live neighbours die by overcrowding or over population
3. Any live cell with two or three live neighbours lives on to the next generation (survives).
4. Any dead cell with exactly three neighbours becomes a live cell as if by reproduction.

4.1.2 Game model

We model Conway's game of life using cellular automata in a two-dimensional infinite space. A cell has a state: a live cell is represented by true or 1, and a dead cell is represented by false or 0. For any cell, we use the Moore neighbourhood which is defined to consist of the current (central) cell and the eight cells surround it, as it is pictured in the figure 1.

North-West (-1,1)	*North (0,1)*	*North –East (1,1)*
West (-1,0)	*Central Cell (0,0)*	*East (1,0)*
South-West (-1,-1)	*South (0,-1)*	*South-East (1,-1)*

Figure 1: Moore neighbourhood cells with coordinates (x, y) on the plane

To describe shapes or patterns, consider a system whose state is a Boolean function on $\mathbb{Z}^2 \times \mathbb{N}$. At any discrete time $t : \mathbb{N}$, the state of the cell (n, m, t) in $\mathbb{Z}^2 \times \mathbb{N}$ is either true or false. We write

$$s[n, m, t] : \mathbb{B}$$

The state s can be updated according to the rules of the game, let $s\prime : \mathbb{B}$ be the updated state or the state after a transition of the state s.

Since states are updated synchronously in the game, we can write

$$s\prime = s[n, m, t + 1]$$

A cell has eight neighbours as defined previously in Figure 1. Let the central cell be the one whose coordinates in the two-dimensional infinite space are (l, c). (l for line and c for column). In order to explain behaviours in the game, we add time. Let $t : \mathbb{N}$ be the variable which represents discrete time. For a cell (l, c, t) we can write the Moore neighbours as follows:

$$N(l, c, t) = \{(i, j, t) : \mathbb{Z}^2 \times \mathbb{N} \mid (\mid i - l \mid < 2) \wedge (\mid c - j \mid < 2)\}$$

that means a set of nine cells, the central one and the eight others surrounding it. In such a set, states are not taken into consideration.

In order to update a cell state at time t, the key operation is to calculate the number of live adjacent cells of this one at time t. Let $\Omega(l, c, t)$ be the function that calculates this number.

$$\Omega(l, c, t) : \mathbb{Z}^2 \times \mathbb{N} \to \mathbb{N}$$

$$\Omega(l, c, t) = \sum_{\substack{l-1 \leq i \leq l+1 \\ c-1 \leq j \leq c+1 \\ i \neq j}} s[i, j, t]$$

That can be specified in CSP as follows, [22, 23].

$$\Omega(l, c, t) := \#\{(i, j, t) \in N(l, c, t) \mid (i, j) \neq (l, c) \wedge s[l, c, t]\}$$

Let $\overline{\Omega}$ be the complement of Ω in 3×3 array which denotes the number of the dead adjacent cells of the central cell at time t.

$$\overline{\Omega}(l, c, t) = 8 - \Omega(l, c, t)$$

In order to update cells, first, we specify the four game rules in a formal manner.

Rule one: Any live cell with fewer than two live neighbours dies, that means:

$$\forall\, (l, c) \in \mathbb{Z}^2, t \in \mathbb{N} \cdot s[l, c, t] \wedge \Omega(l, c, t) < 2 \Rightarrow \neg\, s[l, c, t + 1] \quad (1)$$

Rule two: Any live cell with more than three live neighbours dies

$$\forall\, (l, c) \in \mathbb{Z}^2, t \in \mathbb{N} \cdot s[l, c, t] \wedge \Omega(l, c, t) > 3 \Rightarrow \neg\, s[l, c, t + 1] \quad (2)$$

Rule three: Any live cell with two or three live neighbours lives on to the next generation

$$\forall\, (l, c) \in \mathbb{Z}^2, t \in \mathbb{N} \cdot s[l, c, t] \wedge (\Omega(l, c, t) = 2 \vee \Omega(l, c, t) = 3) \Rightarrow s[l, c, t + 1] \quad (3)$$

Rule four: Any dead cell with exactly three neighbours becomes a live cell

$$\forall\, (l, c) \in \mathbb{Z}^2, t \in \mathbb{N} \cdot \neg s[l, c, t] \wedge \Omega(l, c, t) = 3 \Rightarrow s[l, c, t + 1] \quad (4)$$

To update cells, one of the four rules must be satisfied thus:

$(1) \vee (2) \vee (3) \vee (4)$ must be satisfied. From $(1) \vee (2)$ we write:

$$\forall\, (l, c) \in \mathbb{Z}^2, t \in \mathbb{N} \cdot s[l, c, t] \wedge (\Omega(l, c, t) < 2 \vee \Omega(l, c, t) > 3) \Rightarrow \neg\, s[l, c, t + 1] \quad (5)$$

From $(3) \vee (4)$ we can write:

$$\forall\, (l, c) \in \mathbb{Z}^2, t \in \mathbb{N} \cdot \Omega(l, c, t) = 3 \Rightarrow s[l, c, t + 1] \quad (6)$$

From $(5) \vee (6)$ we can write:

$$s[l, c, t + 1] := s[l, c, t] \wedge \Omega(l, c, t) = 2 \vee \Omega(l, c, t) = 3 \quad (7)$$

The later formula (7) means that the cell at time t, on the line l and column c will be a live cell for the next generation at time $t + 1$ for two cases:

- If it was a live cell at time t and has two live neighbours (it survives)
- It has three live neighbours(it survives if it was a live cell, or it gets born if it was a dead one).

Otherwise, this cell will be or will remain dead for the next generation.

4.1.3 Game state and initialization

The state of the game consists of the whole states of cells, which is an infinite set since the space is infinite.

Let I be the state which represents the initial configuration of the game and which assumed to be well-defined at the initial time t_0.

At the initial time, we assume that I is consisted of two sets; let I_0 be the one contains all live cells and $\overline{I_0}$ be the complement of I_0 in $\mathbb{Z}^2 \times \mathbb{N}$ that contains all dead cells, Thus, we write

$$I_0 := \{(i, j, t_0) \in \mathbb{Z}^2 \times \mathbb{N} \mid\ s[i, j, t_0]\}$$

$$\overline{I_0} := \{(i, j, t_0) \in \mathbb{Z}^2 \times \mathbb{N} \mid\ \neg s[i, j, t_0]\}$$

Assuming that I_0 is known, we can define the initial state of the game. The initialization is not easy to undertake because it depends on the purpose of the implementation and of the example to deal with; we have assumed that I_0 will be known in order to facilitate the treatment and the refinement of the following case studies.

4.2 Case study one: Blinker of period two

In this subsection, we will study a benchmark case known as a blinker of period two. Blinker is the smallest and most common oscillator, found by John Conway. The blinker pattern (behaviour) is like an oscillation of two line segments of period two. Only one line segment appears at time (line segments appear alternatively). To explain its behaviour, let us assume –as cited previously– that I_0 is known, which contains three consecutive live cells on the same line l at time t_0; and let the central cell be on column c

$$I_0 := \{(i, j, t_0) \in \mathbb{Z}^2 \times \mathbb{N} \mid\ s[i, j, t_0]\}$$

$$I_0 = \{(l, c - 1, t_0), (l, c, t_0), (l, c + 1, t_0)\}$$

$$\overline{I_0} := \{(i,j,t_0) \in \mathbb{Z}^2 \times \mathbb{N} \mid \ (i,j,t_0) \notin I_0\}$$

Using the transition rules, and by simulation, we can see the behaviour of the blinker at consecutive discrete times. Let I_1 be the set of all live cells after the first transition at time $t_1 = t_0 + 1$. According to the game rules (7) and to the simulation,

$$I_1 = \{(l-1,c,t_1),(l,c,t_1),(l+1,c,t_1)\}$$

Blinker behaviour is described as a switch between I_0 and I_1 during time $t : \mathbb{N}$; in addition, we can observe from simulation that I_0 consists of cells that constitute a horizontal line segment, whereas I_1 consists of cells that compose a vertical one; in other words, blinker behaviour will be described by the alternative appearance (emergence) of the horizontal line segment at even times and the vertical one at odd times.

Let I_n be the set of all live cells after $n : \mathbb{N}$ transitions at time $t_n = t_0 + n$. According to the game rules (7) and to the simulation, we can write

$$\forall\, t : \mathbb{N} \cdot \ t \ mod\ 2 = 0 \ \Rightarrow I_t = I_0$$

$$\forall\, t : \mathbb{N} \cdot \ t \ mod\ 2 = 1 \ \Rightarrow I_t = I_1$$

Figure 2 shows the blinker behaviour during discrete time.

If I_t, for $t : \mathbb{N}$, is a set of all live cells at time t, then ΘI_t will be the set of all live cells at the next generation (after one transition) at time $t + 1$.

From figure 2, on the one hand we can write

$$\Theta I_0 = I_1$$
$$\Theta I_1 = I_2$$
$$\Theta I_2 = I_3$$
$$\vdots$$
$$\Theta I_{n-1} = I_n$$

and on the other hand, we can write [1]

$$\forall\, t : \mathbb{N} \cdot \ I_t = I_0 \lhd \ even(t) \rhd \ I_1$$

$$\forall\, t : \mathbb{N} \cdot \ \Theta^t I_0 = I_0 \lhd even(t) \rhd I_1$$

$$\forall\, t : \mathbb{N} \cdot \ \Theta^t I_0 = I_{t \ mod\ 2}$$

$$\forall\, n,t : \mathbb{N} \cdot \ \Theta^n I_t = I_{(n+t) \ mod\ 2}$$

Informally, the behaviour of the blinker is represented by a horizontal line segment at even times and by a vertical one at odd times.

$$\forall\, (l,c,t),(l_1,c_1,t) \in \mathbb{Z}^2 \times \mathbb{N} \cdot$$
$$(l,c,t) \in I_0 \wedge (l_1,c_1,t) \in I_0 \Rightarrow (l = l_1)$$

$$\forall\, (l,c,t),(l_1,c_1,t) \in \mathbb{Z}^2 \times \mathbb{N} \cdot$$
$$(l,c,t) \in I_1 \wedge (l_1,c_1,t) \in I_1 \Rightarrow (c = c_1)$$

So far, we have explained the behaviour of the blinker of period two, now we specify it as follows

[1] Note that in CSP, $(a \lhd b \rhd c)$ means if b then a else c.

$$Blinker := \exists\, (l,c) \in \mathbb{Z}^2,\ \forall\, (x,y) \in \mathbb{Z}^2, t \in \mathbb{N} \cdot$$
$$s[x,y,t] = |x-c| < 2 \wedge y = l$$
$$\lhd even(t) \rhd |y-l| < 2 \wedge x = c$$

4.2.1 Initialization

To implement the blinker, we first initialize the game as expressed previously, so, at time $t = 0$, we put three consecutive live cells in the same line l, in such a way that the middle one assumed to be on the column c, [2],thus,

$$I_0 = \{(l,c-1,t),(l,c,t),(l,c+1,t)\}$$

represents all live cells at the initial time; all other cells are dead (infinite set represented by $\overline{I_0}$ as it is expressed above).

Since at the initial time, $(t = 0)$ is even we simply write

$$init1 := \forall\, (x,y) \in \mathbb{Z}^2 \cdot$$

$$s[x,y,0] = |x-c| < 2 \wedge y = l$$

4.2.2 Implementation

Previously we have seen that $s\prime$ is the state of s after one transition (update). According to the game rules, we can update cells as follows:

$$s[l,c,t+1] := s[l,c,t] \wedge \Omega(l,c,t) = 2 \vee \Omega(l,c,t) = 3$$

An easier choice of design expressed by a conditional transition knowing the positions of the central cell (line l and column c) is

$$s[x,y,t+1] = (y = l) \ \wedge |\ x-c| \ < 2$$

$$\lhd even(t) \ \rhd \ (x = c) \ \wedge \ |y-l| \ < 2$$

Thus, the implementation of the blinker of period two is as follows:

$$Bl1 := init1 \ ; \ \textbf{do}\ true \rightarrow \ \forall\, (x,y) \in \mathbb{Z}^2,$$
$$t \in \mathbb{N} \ \cdot \ s\prime[x,y,t] := s[x,y,t+1] \ \textbf{od}$$

4.2.3 Refinement

So far, we have specified and implemented the blinker of period two as it is expressed previously. Thus, $Blinker \sqsubseteq Bl1$ is a required refinement.

At the initial time $(t = 0)$ we have

$$\forall\, (x,y) \in \mathbb{Z}^2 \ \cdot s[x,y,0] = |x-c| < 2 \wedge y = l$$

which is assumed to be satisfied by the initialization for the condition at even time t, thus,

$$init1 = blinker[0/t].$$

[2] Note that it is possible that one can also initialize the blinker by putting three consecutive live cells on the same column c at time $t = 0$, in such a way that the middle one assumed to be on line l.

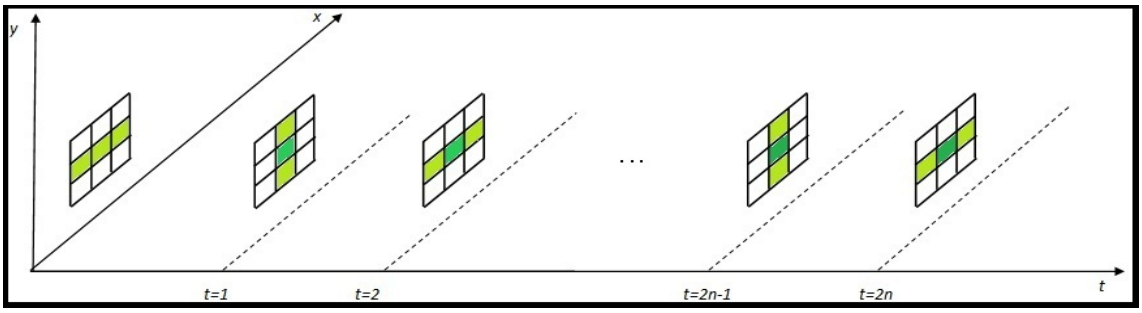

Figure 2: Blinker behaviour in the plane (x, y) during time t

Starting from the initial set at time $t_0 = 0$ we have

$$I_0 = \{(l, c-1, t_0), (l, c, t_0), (l, c+1, t_0)\}$$

At the initial state, all the live cells are located on the line l. According to the game rule specified previously by the formula(7) we have:

$\forall\ (l,c) \in \mathbb{Z}^2 \mid (t=0) \wedge ((l>1) \vee (l<-1)) \wedge$
$((c>1) \vee (c<-1)) \cdot \Omega(l,c,t_0) < 2$
$\Rightarrow \forall\ (l,c),(x,y) \in \mathbb{Z}^2 \mid (t=1) \wedge |y-l| > 1 \vee |x-c| >$
$1 \cdot \neg s[l,c,t_0+1]$

It means that all the cells located outside the (3×3) box whose central cell is $(l, c, t_0 + 1)$ are dead.
Now, if we look inside this box, at time t_0 we have only three live cells; according to the preceding definition of Ω and by using the rule(7) we can write

$\Omega(l,c,t_0) = 2 \wedge\ s[l,c,t_0] \Rightarrow s[l,c,t_0+1]$
$\Omega(l-1,c,t_0) = 3 \Rightarrow\ s[l-1,c,t_0+1]$
$\Omega(l+1,c,t_0) = 3 \Rightarrow\ s[l+1,c,t_0+1]$
$\Omega(l,c-1,t_0) = 1 \Rightarrow\ \neg s[l,c-1,t_0+1]$
$\Omega(l,c+1,t_0) = 1 \Rightarrow\ \neg s[l,c+1,t_0+1]$
$\forall\ (l,c) \in \mathbb{Z}^2 \mid (t=0) \wedge (|l| = |c| = 1) \Rightarrow\ \neg s[l,c,t_0+1]$

Let I_1 be the set of all live cells at time $t_1 = t_0 + 1$, thus

$I_1 = \{(l-1,c,t_1), (l,c,t_1), (l+1,c,t_1)\}$
$\Leftrightarrow \exists (l,c) \in \mathbb{Z}^2, \forall\ (x,y) \in \mathbb{Z}^2,\ \exists\ (t_1 = t_0+1) \in \mathbb{N} \cdot |y-l| < 2 \wedge\ x = c$

Now, starting from I_1 and by the same approach, we can write

$\forall\ (l,c),(x,y) \in \mathbb{Z}^2 \mid (t=2) \wedge |y-l| > 1 \vee |x-c| >$
$1 \cdot \neg s[l,c,t_1+1]$
$\Omega(l-1,c,t_1) = 1 \Rightarrow\ \neg s[l-1,c,t_1+1]$
$\Omega(l+1,c,t_1) = 1 \Rightarrow\ \neg s[l+1,c,t_1+1]$
$\forall\ (l,c) \in \mathbb{Z}^2 \mid (t=1) \wedge |l| = |c| = 1 \Rightarrow\ \neg s[l,c,t_1+1]$
$\Omega(l,c,t_1) = 2 \wedge\ s[l,c,t_1] \Rightarrow s[l,c,t_1+1]$
$\Omega(l,c-1,t_1) = 3 \Rightarrow\ s[l,c-1,t_1+1]$
$\Omega(l,c+1,t_1) = 3 \Rightarrow\ s[l,c+1,t_1+1]$

Let I_2 be the set of all live cells at time $t_2 = t_1 + 1$, thus

$I_2 = \{(l,c-1,t_2), (l,c,t_2), (l,c+1,t_2)\}$
$\Leftrightarrow \exists\ (l,c) \in \mathbb{Z}^2, \forall\ (x,y) \in \mathbb{Z}^2,\ \exists\ (t_2 = t_1+1) \in \mathbb{N} \cdot |x-c| < 2 \wedge\ y = l$

If we look to the sets in which the time is even (I_0 and I_2), we can observe that both contain the same live cells, consequently, it will be the same for odd times for I_1 and I_3. Generalizing time over $\mathbb{N}$, we simply infer the blinker specification.

Now, we assume that the blinker condition is satisfied at time t, and we prove that it will hold at time $t+1$, thus, we assume that

$$s[x,y,t+1] = |x-c| < 2 \wedge y = l \lhd even(t) \rhd |y-l| < 2 \wedge x = c$$

is satisfied. At time $t+1$ we have

$$s[x,y,(t+1)+1] = |x-c| < 2 \wedge y = l \lhd even(t+1) \rhd |y-l| < 2 \wedge x = c$$

Obviously, if t is even then $t+1$ is odd and hence the second conditional expression holds, and when t is odd, the first expression of the condition holds as well. Replacing t by $t+1$ we generalize over $\mathbb{N}$ to infer the blinker period-two specification.

4.2.4 Another implementation

Another choice of implementation is that one may think that the behaviour of blinker during time is like a composition of two functions (see Figure 2). The first one takes the set of live cells and translates each cell (location) in the plane by one unit of time, the second takes the result of the first and rotates each cell (except the central one) by an angle θ equals ninety degrees in counter-clockwise direction (this direction is chosen for simplicity) [3].
Preserving the cell state and taking the same initialization expressed previously in section (4.2.1), the blinker can be implemented as follows

$$Bl2 := init1\ ;\ \textbf{do}\ true \rightarrow\ \forall\ x,y : \mathbb{Z},$$
$$t : \mathbb{N} \cdot\ \ s[-y,x,t+1] := s[x,y,t] \textbf{od}$$

4.2.5 Refinement

The required refinement is $blinker \sqsubseteq\ Bl2$

[3]Note that the clockwise direction is possible for design, in addition, alternative directions are also possible

At the initial time, it is the same as $(4.2.3)$

$$init1 = blinker[0/t].$$

Using the same approach as the preceding refinement, based on the formula(7), we can obtain sets I_0, I_1 which consist of cells representing a perpendicular line segments sharing the same cell centre in successive times.
At time $t+1$, we have

$$s\prime[x,y,t] = s[x,y,t+1] = s[-y,x,t+1]$$

In order to make an easier proof, we assume that $l = c = 0$. Assume that τ be the function translating the cell location by one time unit, and let ρ be the function that rotates the cell by 90 degrees; thus

$$\rho := \mathbb{Z}^2 \times \mathbb{N} \rightarrow \mathbb{Z}^2 \times \mathbb{N}$$
$$\rho\,(x,y,t) = \begin{pmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ t \end{pmatrix}$$
$$\tau : \mathbb{Z}^2 \times \mathbb{N} \rightarrow \mathbb{Z}^2 \times \mathbb{N}$$
$$\tau(x,y,t) = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} + \begin{pmatrix} x \\ y \\ t \end{pmatrix} = \begin{pmatrix} x \\ y \\ t+1 \end{pmatrix}$$

The composition of these functions is commutative.

$$\rho \circ \tau : \mathbb{Z}^2 \times \mathbb{N} \rightarrow \mathbb{Z}^2 \times \mathbb{N}$$
$$\rho \circ \tau(x,y,t) = \begin{pmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ t+1 \end{pmatrix}$$

Since the angle θ equals $90°$, then we have

$$\rho \circ \tau(x,y,t) = \begin{pmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ t+1 \end{pmatrix}$$
$$= \begin{pmatrix} -y \\ x \\ t+1 \end{pmatrix}$$
$$s\prime[x,y,t] = s\,[-y,x,t+1] = s[x,y,t+1]$$

We can see that at successive times, line segments are always perpendicular, which satisfies the blinker specification $(y = l)$ when t is even and $(x = c)$ for the other case; whereas the bounded conditions $(|y-l| < 2)$ and $(|x-c| < 2)$ are satisfied at the moment of the initialization.

4.3 Case study two: traffic light

The traffic light is a well known example in the game of life. It is an oscillator formed by four synchronous blinkers of period two that do not encounter each other. The four blinkers of different directions (East, West, North and South) are bounded by a box of 9×9 cells. More precisely, they surround a box of 3×3 dead cells. If we consider $d = (l,c)$, (l for line and c for column) to be the central cell of these boxes, then the central cells of both blinkers (East and West) are on the same line l and symmetrical with respect to the cell d, the other blinkers (North and South) have central cells on the same column c and symmetrical with respect to d, as illustrated in Figure 3.

4.3.1 Specification

First, we need to specify the four blinkers, each in isolation from the others. Let $(l_e,c_e),(l_w,c_w),(l_n,c_n),(l_s,c_s)$ be the central cells for the east, west, north and south blinkers respectively.

Since the central cells of the east blinker $Eblinker$, and the west blinker $Wblinker$, are located on line $l_e = l_w = l$ and column $c_e = c+3$ and $c_w = c-3$ respectively, we have

$$Eblinker := \exists\, l,c : \mathbb{Z},\ \forall\, x,y : \mathbb{Z}, t : \mathbb{N} \cdot$$
$$s[x,y,t] = (|x-c_e| < 2) \wedge (y = l)$$
$$\lhd even(t) \rhd (|y-l| < 2) \wedge (x = c_e)$$

$$Wblinker := \exists\, l,c : \mathbb{Z},\ \forall\, x,y : \mathbb{Z}, t : \mathbb{N} \cdot$$
$$s[x,y,t] = (|x-c_w)| < 2) \wedge (y = l)$$
$$\lhd even(t) \rhd (|y-l| < 2) \wedge (x = c_w)$$

Since the central cells of the north blinker $Nblinker$ and the south blinker $Sblinker$ are located on the column $c_n = c_s = c$ and the line $l_n = l+3$ and $l_s = l-3$ respectively, we have

$$Nblinker := \exists\, l,c : \mathbb{Z},\ \forall\, x,y : \mathbb{Z}, t : \mathbb{N} \cdot$$
$$s[x,y,t] = (|y-l_n| < 2) \wedge (x = c)$$
$$\lhd even(t) \rhd (|x-c| < 2) \wedge (y = l_n)$$

$$Sblinker := \exists\, l,c : \mathbb{Z},\ \forall\, x,y : \mathbb{Z}, t : \mathbb{N} \cdot$$
$$s[x,y,t] = (|y-l_s| < 2) \wedge (x = c)$$
$$\lhd even(t) \rhd (|x-c| < 2) \wedge (y = l_s)$$

So far, each blinker is specified in isolation. A traffic light $Tlight$ is a synchronous composition of the four blinkers specified previously.

$$Tlight := Eblinker \wedge Wblinker \wedge Nblinker \wedge Sblinker$$

$$Tlight := \exists\, l,c : \mathbb{Z},\ \forall\, x,y : \mathbb{Z}, t : \mathbb{N} \cdot$$

$$(|x-c_e| < 2) \wedge (y = l) \bigwedge (|x-c_w| < 2) \bigwedge (|y-l_n| < 2) \wedge (x = c) \bigwedge (|y-l_s| < 2)$$

$$\lhd\ even(t) \rhd$$

$$(|y-l| < 2) \wedge (x = c_e) \bigwedge (x = c_w) \bigwedge (|x-c| < 2) \wedge (y = l_n) \bigwedge (y = l_s)$$

Replacing c_e by $(c+3)$, c_w by $(c-3)$, l_n by $(l+3)$, and l_s by $(l-3)$ we obtain

$$Tlight := \exists\, l,c : \mathbb{Z},\ \forall\, x,y : \mathbb{Z}, t : \mathbb{N} \cdot$$

$$(|x-c-3| < 2) \wedge (y = l) \bigwedge (|x-c+3| < 2) \bigwedge (|y-l-3| < 2) \wedge (x = c) \bigwedge (|y-l+3| < 2)$$

$$\lhd\ even(t) \rhd$$

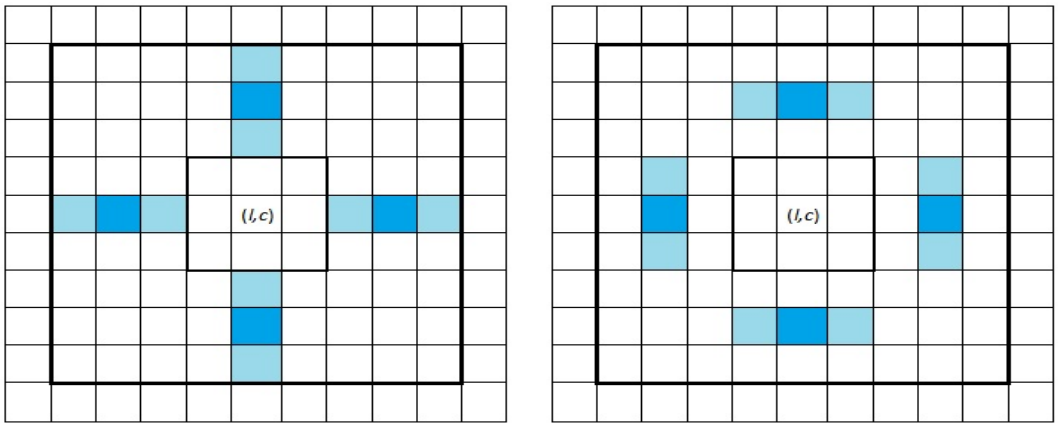

Figure 3: Traffic light behaviour: from the left to the right : behaviour at even and odd times respectively

$(|y-l|<2)\wedge(x=c+3)\bigwedge(x=c-3)\bigwedge(|x-c|<2)\wedge(y=l+3)\bigwedge(y=l-3)$

4.3.2 Initialization, implementation and refinement

The initialization, the implementation as well as the required refinement could be inferred easily from the preceding Blinker period-two example.

5 Verification of emergent property using model checking

A well known example of weak emergence is the Boids model, which captures the motion of flocking birds. Boids is an artificial life program, developed by Craig Reynolds in 1986, which simulates the flocking behaviour of birds [32]. In our case study, we propose a number of ducks that can swim together in a lake. Each duck can be anywhere in the lake moving in different directions with various speeds. The global behaviour (at the macro level) is a movement (swimming) of ducks together forming a flock. At the micro level (local behaviour), each duck swims according to three rules:

1. Alignment: swim towards the average heading of local flock-mates
2. Separation: swim to avoid crowding neighbours
3. Cohesion: swim to move towards the average position (centre of mass) of local flock-mates.

5.1 System model

To demonstrate our method, we have taken the Boids model as in [2]. We have taken a set of similar ducks swimming in a large lake (represented by an infinite two-dimensional space of cells). In order to capture the behaviour of the set of ducks, we modelled the system as a set of processes behaving in concurrency. Each process is modelled by a timed automaton. The calculation of the distance between ducks as well as speeds and directions is done by another process, called a *"controller"*, which gets information from all ducks then informs them about its state (*Close*, *Far* or *Collision*). The *controller* is used just for some calculations needed by ducks.

Initially all ducks have random positions on the lake. A duck may take from an initial state and according to the distance between other ducks, another state that can be in the state *Collision* when it runs into at least another duck (distance is nil or smaller than a minimal value); it may approach the flock and go to the state *Close* when it is in the flock (distance is between a minimal and maximal value); and it can go to a *Far* state when it is far from the flock (distance is greater than a maximal value).

In order to make an easier model, we have assumed that a duck can move with only two speeds, (one or two cells per time unit). It can slow down when it approaches the flock in order to keep the average speed of the flock. It may speed up to reach the flock when it is far from it. In addition to the eight directions implemented in [2], we have modelled all possible directions to move from a current cell to a neighbour one, hence, sixteen directions are allowed.

A cell c_{ij} is considered a neighbour to a cell c_{mn} if and only if
$|i-m|<3\wedge|j-n|<3$. Hence, a cell has 24 neighbours.

Figure 4 shows the general duck process represented by timed automata in UPPAAL.

At the *Initial* state, a $duck_i$ has a position in the lake, waiting for an event from the $controler$ in one of the three channels (far, close, collision). Depending on which channel the duck receives an event, it changes the state updating the speed (speed up, slow down). The state *"Collision"* is disliked, it will make the duck in hazard, consequently it deadlocks the system. In the other two states, the duck is always waiting for an event from the controller in the three channels cited above.

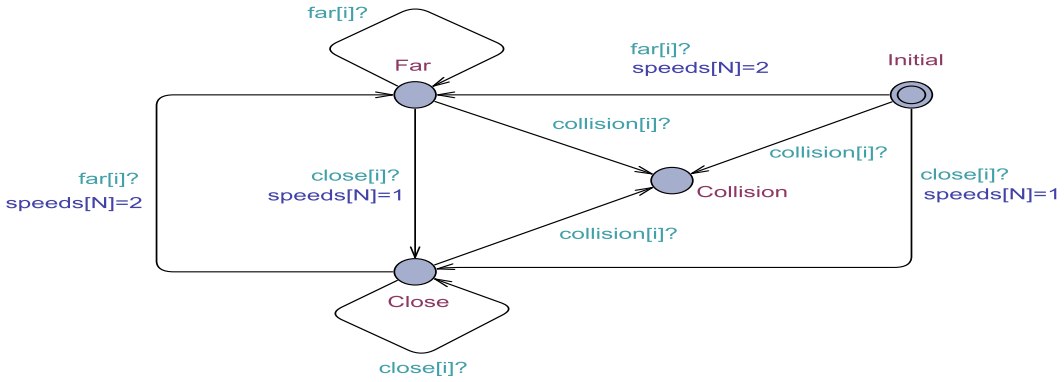

Figure 4: Timed automata modelling the general process of duck

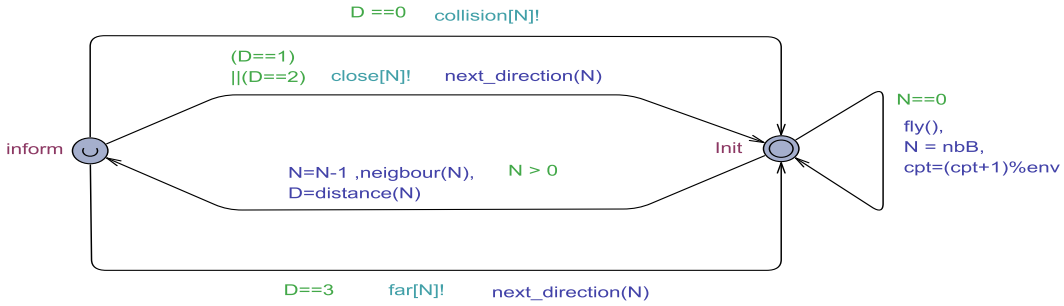

Figure 5: Timed automata modelling the controller process

The process *controller* (see Figure 5), has two states. At the initial state, it chooses a duck and determines its neighbours and calculates the distance separating it from the other ducks. After that, it goes to an urgent location[19]. Depending on the value of that distance, it informs the duck in question about its state via channels. These operations are repeated for all ducks.

After finishing the calculation for the whole set of ducks, the *controller* informs them to fly in a synchronous manner, updating their positions and directions and consequently updating their velocities. The process *controller* will be executed infinitely.

A duck's position is calculated taking in account the duck's speed and direction, whereas the direction (alignment) is deduced from the sum of all direction vectors of neighbours of the duck if it is in a *Close* state. When the duck is in a *Far* state, it will take the direction of the vector that starts from the current position toward the centre of the flock. Since the duck has an internal separation rule, it can change the direction as well as the speed one or many times, in order to forbid collision with other ducks whenever there is a free neighbour position.

5.2 Simulation and verification

We have implemented the system model based on timed automata using the UPPAAL model checker. Running the processes in concurrency and starting simulation with UPPAAL, we see that ducks starting from different initial positions (that can be a known configuration of ducks by the designer at initial time) can be all at the *Close* state. This represents a property of a whole (global property at the macro level), meaning that ducks will swim together, which represents an emergent property that we would like to verify.

Using the UPPAAL verifier, we have checked for some safety and emergent properties. For the safety property, we have checked the system deadlock $A[]not\ deadlock$, and executed the query that all ducks never reach a collision state. $A[]forall(i : id\_B)\ !Bird\_body(i).Collision$.

For the emergent property, we checked that all ducks swim one close to each other or ducks form a flock. In this paper we are only interested in this property; we have executed the query that eventually all ducks can reach simultaneously the state *Close*, $E <> forall(i : id\_B)\ Bird\_body(i).Close$. We changed the number of ducks in the model using a laptop of dual processors with 2.2 G. Hertz each and 4 G. Bytes of RAM. The results are summarized in Table 1.

6 Conclusion

The use of formal methods, in particular formal verification, becomes very important for engineering complex systems and SoS. Simulation is very useful for detecting emer-

Number of ducks	Property	Verification	Kernel	Elapsed time used
2	Deadlock	0.14	0.031	0.234
	Collision	0.062	0.031	0.134
	Emergence	0.0	0.0	0.016
3	Deadlock	0.25	0.031	0.312
	Collision	0.187	0.0	0.234
	Emergence	0.0	0.0	0.015
4	Deadlock	0.749	0.062	0.826
	Collision	0.374	0.031	0.405
	Emergence	0.0	0.0	0.016
5	Deadlock	2.137	0.016	2.153
	Collision	1.108	0.078	1.263
	Emergence	0.0	0.0	0.0
10	Deadlock	4.118	0.093	4.29
	Collision	1.748	0.078	1.841
	Emergence	0.0	0.0	0.0
20	deadlock	112.414	0.297	113.568
	Collision	48.329	0.343	48.894
	emergence	0.0	0.0	0.0
40	Deadlock	explosion	/	/
	Collision	explosion	/	/
	Emergence	0.016	0.0	0.015
50	Deadlock	explosion	/	/
	Collision	explosion	/	/
	Emergence	0.016	0.0	0.02
60	Deadlock	explosion	/	/
	Collision	explosion	/	/
	Emergence	0.031	0.0	0.022
70	Deadlock	explosion	/	/
	Collision	explosion	/	/
	Emergence	0.032	0.0	0.024
90	Deadlock	explosion	/	/
	Collision	explosion	/	/
	Emergence	0.032	0.0	0.033
100	Deadlock	explosion	/	/
	Collision	explosion	/	/
	Emergence	0.047	0.0	0.056

Table 1: Verification time (in seconds) for properties per number of ducks: 0 means smaller than a millisecond or neglected time.

gent behaviours but is not sufficient for ensuring system correctness, especially for critical systems, when emergent properties are detrimental. Unfortunately, verifying such systems is not straightforward, not only because of the large number of components or sub-systems that are highly interconnected which leads to state explosion during the model checking, but also due to unknown and unexpected behaviours that can be beneficial or harmful leading to a fault in the system. The technique of refinement based on mathematical theory is very powerful, but, on the one hand, it is still undesirable for designers because of their difficulties of understanding, and on the other hand, it is not obvious for complex examples. The use of model checking techniques which needs some experiences and knowledge of the model in question ensures the correctness of the system design. Unfortunately, model checking suffers from state explosion when the system is composed of a big number of constituents or sub-systems. The method developed in this paper based on the Uppaal model checker shows very good results for verifying emergent properties. Unfortunately it has limitations for the verification of deadlock properties when the number of sub-systems becomes important.

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IBchain: Internet of Things and Blockchain Integration Approach for Secure Communication in Smart Cities

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Introducing IBchain, a new blockchain architecture with the Internet of Things (IoT), could be an attractive framework regarding improvements in connectivity implementation through the smart cities. Instead of meriting innovation and security, the IoT links people, sites, and products and provides opportunities. Everything that transfers information to the IoT system is integrated by advanced microchips, sensors, and actuators in actual things. The analytical ability of the IoT converts observations into actions, impacting business advancements and significant ways of activity. IoT enables connected objects to transmit information to personal blockchain systems to create tamper-resistant transaction records. The information from sensors and microchips is progressing rapidly with blockchain ledgers, making them more portable and relevant for immediate conversations. In IBchain methodology, the smart objects are permissible to connect securely with other smart objects in diverse situations. IBchain creates an innovative blockchain-based processing configuration through the IoT. The IBchain could analyze blockchain to the main expertise or supports the IoT validation and trustworthiness. It reinforces blockchain and cloud to build an empowering IoT ubiquitous situation for secure communication among the smart devices.

Povzetek: Prispevek opisuje novo arhitekturo veriženja IBchain, ki uporablja internet stvari in verigo blokov za varno komunikacijo.

1 Introduction

The IBchain is an approach for secure communications between physical objects using the integration of IoT and blockchains. This approach is useful for smart cities. The IBchain is becoming a revolutionary invention that operates on a decentralized, dispersed, open, and instantaneous network to collect IoT nodes' activities. Throughout fact, the blockchain is a sequence of blocks, every block is connected to the previous nodes [1]. Each block will have a public key, a preceding block hashing code, along with the metadata [2]. IBchain processes would be the specific sections that have been developed to convey data between IoT nodes [3]. Each IoT device appears to have been various types of potential but smart devices, including embedded sensors, cameras, networks, and the ability to communicate with various other IoT nodes [4]. IoT links individuals, sites, objects or resources for increased efficiency and security. Advanced devices, transceivers are integrated into physical things, every transferring information to the IoT devices. Then IoT analytical tools use this obtained information to transform ideas towards outcomes, improve workflows, and contribute to innovations. Smart cities will deliver the best facilities to promote residents' everyday lives in the areas of medicine, traffic, power use, and skills training. Interestingly, the idea of smart cities is emerging, and, considering its desired future, security measures are on the emergence. Blockchains can encourage the growth of smart cities due to their positive characteristics like accountability, openness, flexibility as well as integration.

The function of IBchain will provide an approach to analysing secure transaction data by IoT nodes [5]. IBchain tends to be a comfortable place that may be used both publicly and privately [6]. The connectivity allows

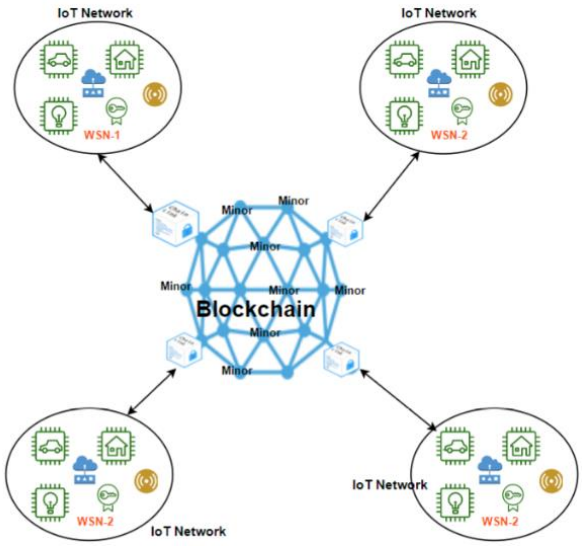

Figure 1: IoT network and Blockchain.

the devices to enable the cryptographic operations between IoT nodes under the complicated network [7].

The activities could be tracked and moved anywhere accessible to communicate in the IoT network [8]. The Blockchain tends to be a sequence of authenticated or cryptographical blocks controlled through a computer linked to the entire network [9]. Such blocks of data are stored digitally as well as sending data to a blockchain [10]. There are several remarkable possibilities for the integration approach. Figure 1 shows the IoT network connectivity with blockchains.

i) Building trust between the stakeholders: The IBchain approach will establish relationships between numerous wireless technologies due to its extensive additional functionality. Only verified devices can communicate with the framework since a miner would first verify each transaction block and then connect to the blockchain [11].

ii) IBchain technique may reduce costs because it works efficiently without a third-party vendor. This erases the entire third-party clusters among the transmitter and the recipient. Such an approach offers great conversation.

iii) IBchain helps in reducing a lot of time. Such an approach minimizes transaction time from hours to seconds.

iv) IBchain approach ensures privacy and security to devices and information.

v) IBchain approach provides connected networks for both social and community facilities. Connected devices can communicate with each other and share data.

vi) This approach can securely exchange money without the use of a third person. This offers rapid, secure, and economic details services. Also, this can reduce the transmission time and charge.

vii) This strategy performs a significant responsibility in investigating or eliminating the potential for loss of the asset or activity.

IBchain approach may face several challenges, such as scalability, storage, skill levels, and detection, etc.

1. It can be hanged due to the huge transaction volume. Expect that since IoT is integrated with Blockchain, the capacity would be stronger than that of the existing condition.

2. IoT node would maintain a digital transaction in IBchain. During most of the period, it will enhance its processing power, and it will be a difficult mission or turn out to be a huge burden on the linked devices or routers.

3. Blockchain has become a radical revolutionary innovation with the IoT [12]. Some people worldwide know this technology

4. Discovering the nodes is a challenge across all smart devices in this strategy [13]. IoT can discover their connected nodes, but this task will be challenging when it integrates with the blockchain [14].

5. The ledger will be freely distributed through all connected nodes [15]. Each node may look at the blockchain activities. Therefore, privacy has been a big challenge in the integrated solution.

6. Blockchain may be either personal or public kind. Interoperability among public and private blockchains [16] will thus be an obstacle under the integrated approach.

7. IBchain will operate globally and is thus faced with several regulations to execute the policy.

Blockchain can also contribute to reducing operational expenses by removing intermediaries or agents.

Blockchain is broader than the period of shared ledgers, which are based on Bitcoin's cryptocurrency capacity. The system is being utilized in fixed areas such as retailers to improve sales relaxation using supply chains and prescription medicines to assure the completeness of agreements, scientific investigations, and medicines. The finest product and service categories are closely watched with the integration in various areas. The major challenge for the constructions on the boundaries of the IoT, assuming the existing description, its protective structure, with the central authorities monitoring the end-user model allowing for detecting a single fault source. By enabling decisions in a network of shared devices, Blockchain addresses such issues. However, there are three big obstacles to consider while building IoT devices next to the blockchain ladder: One of the most challenging parts of the IoT method is the measuring of the enormous amount of information acquired through a huge variety of information that is acquired by the wide sensory networking to unambiguously lower speed or latency of the transactions. Creating a preliminary comprehensive knowledge model might save time when delivering a solution. In public blockchains, the privacy of transaction history for IoT devices is not simply possible in the shared blockchain network. This is because activity sequence checks may be utilized to assume that users or devices are identical behind authentication tokens.

The rest of the paper is structured as below. Section 2 represents the related works, section 3 represents the IBchain methodology and results, section 4 represents the IBchain for Smart Cities, section 5 represents the discussion and section 6 represents the conclusion.

2 Related works

The IoT is frequently associated with the exploitation of connected gadgets which include surveillance cameras, execute malicious actions, which is related to serious cyber assaults. To assist them, questions regarding the comfort of IoT’s uninterrupted Internet-connected devices were raised in search of realistic solutions to address the security imbalance. This is the extremely creative technology blockchain, which assures that the agency has less danger of technical harm and improves the damage of IoT execution. It will constitutionally enable the security of IoT connections in various ways, including generating a human behaviour agreement that does not help to separate any nodes that may be misrepresented.

In 2016, Mayra Samaniego et.al. have presented the blockchains as a service. The blockchains is a public or shared repository containing linked blocks of data. In comparison to all various ledger strategies, blockchains ensure revocability evidence security of

authorized activities. according to the shared and distributed structure, blockchains have been used in IoT, – for example, to control network settings, storing device data, and allow multi-payments. It introduces the concept that uses blockchains as an IoT service which examines the efficiency of a blockchain-enabled execution [17].

In 2017, Ahmad Banafa has published an article on IoT and Blockchain Convergence. He has presented the integration of Blockchain and IoT in this article. Blockchains could be used to monitor billions of smart devices, allowing exchange management and collaboration among connected objects. It enables substantial benefits to IoT technology producers. Such a collaborative approach can remove specific failures, providing a more stable environment for gadgets to operate through. Cryptosystems used throughout blockchains will directly activate information more securely. Blockchains allow secure, peer-to-peer communication permissible and has shown their utility in the context of business transactions via digital currencies, offering assured peer-to-peer payments processing without third-party agents [18].

The primary objective of blockchains is to enable secure communications among parties via a peer-to-peer infrastructure utilizing a shared database. Its purpose is to remove all third - parties verification and replacement the trust of the central authority for verification of transactions for authentication evidence. although several blockchains app revolves around cryptocurrency, blockchains may be used in several other areas, like banking, storage systems, healthcare, robotics, and so on. The blockchains could be used to build distributed apps by building an accessible distributed system [19].

IoT and blockchains are rising in aspects of the advanced social system and are key consideration societies and cultures, whether individually or combined. Moreover, both techniques for health monitoring allow open transmission of information between the group members. The features of centrally consolidated and worldwide decentralized measurement are being accessed throughout this blockchain-IoT network by separating others into the base or edge platforms. The whole association improves efficiency and network performance. This same new plan was successful in the experiment of autonomy systems management and surveillance [20]. The blockchains-based trust platform for IoT devices is explained in the article [21].

The execution of IoT consists in a moving object of risk requiring authentication measures. Smart devices range from highly scalable situations to business-oriented frameworks. Extensive coverage of IoT protection is required, in particular for highly scalable situations, but related enterprise systems. A variety of security processes and strategies were introduced and used. Blockchains frameworks contribute to protecting several IoT-oriented technologies by being key to the success of a security matrix in the sense of a technique. The blockchain is a ledger that records all evidence activities [22]. Businesses must consider whether hybrids or blockchains better match their privacy requirements.

The integrity of IoT sensors may necessitate the destruction of the IoT sensor by interacting with the relevant process volume required to complete the transactions. A safe situation for information collection and transactions should be protected by measures to ensure IoT devices' dependability that cannot be changed by exterior manipulations. In summary, blockchain and IoT are two technologies with large potential, however, owing to technological and safety problems they currently need considerable acquisition.

3 IBchain methodology and results

There is a combination of two major forces: when the blockchain combines IoT, in the long term, the availability of IoT expanded considerably and connected numerous gadgets and networks with homes, offices, travel systems, or whole cities. The blockchain over the last decade will once again change the business model with its encrypted and transportable manual for annoying data and real-time statistics.

The success of this research is the development of the Integration system for smart objects using cloud and blockchains on the IoT. The whole structure is mainly designed for applications where information is accurately conveyed to smart objects at IoT platforms [23], [24]. Also, it is using a re-transmit method, participants' width, or congested traffic problems to strengthen the present framework. The implementation plan for this research is being described. Throughout able to develop content on the internet, the IBchain system must be designed to communicate securely among IoT-connected systems [25]. Figure 2 shows the transaction processing in IBchain. The last one is expected to give verified and accessible monitoring approaches for devices and processes, according to the previous, as IoT and blockchain operate jointly. Blockchain operates as an extensible text where numbers or subtitles are taken and several times is produced when more entries, also known as blocks, are introduced. All done by a digital signature becomes viewed and can never be changed or deleted. In essence, the blockchain may protect the IoT nodes from an environment where incorrect information can be suppressed and the public environment disrupted, whether a smart or intelligent automotive unit. This entire analysis will be carried out as a 3-layer architecture, with these layers being clouds, Blockchain, and IoT. Such a study proves data transmission in terms of developing an IBchain framework among several smart devices. This architecture has the key sections: a) IoT Nodes b) Internet

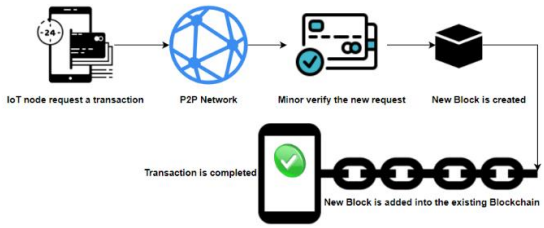

Figure 2: Transactions in IBchain.

c) Technology tools d) Blockchains [26]. It creates a basis for accessing secure data documents through IoT nodes.

Blockchain exchanges can be controlled or approved by another node confirmed to communicate with the IoT network [27]. IBchain can improve communication protection. The main advantages of IBchain are:

1) Communication between IoT devices or minimizing the chance of confrontations.

2) To minimize operating costs by having conversations without a third - party.

3) accelerating transaction data.

Many transactions are issued in the permitted blockchain-based file via simulation services, service providers, or cloud holders. The IoT nodes find smart contacts from inside the approved blockchain-based archive [28]. This approved blockchain-based archive creates the token for IoT nodes. This IoT node demands its key in the development tools from the remote system and guides the request key [29]. The main system authenticates the tokens from an authorized blockchain archive or generates a key per IoT node and system reaction [30]. An IoT node is enabled to collect data on the network. IoT is becoming an innovation of significant impact throughout many market sectors. Most IoT systems are designed to have worldwide coverage through thousands of easy and often embedded systems. Also, the limited capacities of many IoT devices, and the existing communications systems focused on centralized frameworks, are posing major issues in the IoT environment [31]. The blockchain has gained popularity in the IoT environment [32]. A business entity has indeed created the activewear platform for the internet bedding element [33]. Considered as the first and only one of such types, the solutions aimed to deal with the major IoT assaults with more participants and structural breakups than conventional aspects [34]. The research facility is aimed to further enhance the development and distribution of technology and its ability to change IoT. Blockchain on IoT is booming but does not have a few blocks.

In the experiment, three devices are considered to evaluate the method, however, in the future, we can enhance it for several IoT nodes [35]. After generating the session, the IoT nodes can communicate directly. Consider the D1, D2 and D3 are three IoT devices, connected in IBchain network with the shared hash code H. The Encryption key for D1 is D1E and the Decryption key for D1 is D1D. Consider D1 device is sending information to D2 and D3. IoT nodes D1, D2, and D3 are used in the challenges (ch)D1, (ch)D2, and (ch)D3 for confirming the secret hash code H generated by the blockchain. In the end, the IoT nodes will generate the final session key S = (SA, SB, SC) and distribute it to all connected nodes in the network. The following procedure will perform.

(1) D1 → D2: A, C(D1E),
D1 → D3: A, C(D1E) and so on.

(2) D2→D1: C(D1E (ACK, SD2)).
D3→D1: C(D1E (ACK, SD3)).

(3) D1 →D2, D3: ACK(SD1).

(4) D1 → D2, D3: K(SD1, h(SD1, SD2, SD3)).

In (4), D1 is the sender, and D2, D3 are the receivers.

(5) D2 →D1: K(SD2, h(SD1, SD2, SD3))
D3 →D1: K(SD3, h(SD1, SD2, SD3)).

In (5), D2, D3 are senders and D1 is the receiver.

Data packets are distributed in the cloud by using IoT devices. All blocks have their cryptographic hash, the previous hash block code, and its information in Blockchain. Blockchain does have a link to the sharing of data. Respectively data holds numerous blocks including the prior hashing with block information. Those blocks have been interconnected through authentication via cryptographic algorithms. Blockchain is like the linked node in the linked list. Its blocks are distributed in a decentralized structure to use a P2P topology framework. Adding a novel block jumps to the system, visits each node associated with the network, and confirms the security.

Information transmission between the IoT devices in the network could pass information from IoT-gateways (IG), cloud gateways (CW), blockchain gateways (BG), or other gateways (OG). OG is the sequence of specific gateways other than the IG. IG is the compilation of accesses between the IoT nodes. Imagine that the interaction wait between IoT nodes is wonder about inconsequential. Think About t_1, t_2, t_3, and t_4 are the communications deferral functions between the IoT gadgets and OG, OG and IG, IG and CG, and CG and BG. L_1, L_2, L_3, and L_4 are the latencies of OG, IG, CG, and BG. Therefore, it implied broadcast latency could be achieved through the next method.

$$\sigma = (t_1\mu + t_2\theta + t_3\tau + t_4\epsilon) + (L_1\mu + L_2\theta + L_3\tau + L_4\epsilon) \quad (2)$$

Here μ, θ, τ and ϵ $(\mu > \theta > \tau > \epsilon)$ are the overall information packets delivered by IoT nodes, OG, IG, and CG. The information is conveyed from IoT nodes to the OG and OG to the IG then it needs power utilization.

The effectiveness of the suggested method is analyzed via a variety of experimentation. Initially, hundreds of blocks of stable amount using an open-source package (Node.js) are designed and IoT system, linked to the amazon cloud, and create the blockchains network.

IBchain uses smart devices on the network edge of blockchain networks to interact, transfer, and distribute data between IoT nodes. Exchanges in the proposed work have been transmitted to the p2p network. Many special IoT nodes are referred to as Miners in the network. It is typically used in the verification of blockchain networks. If the transactions are processed in such a way that they

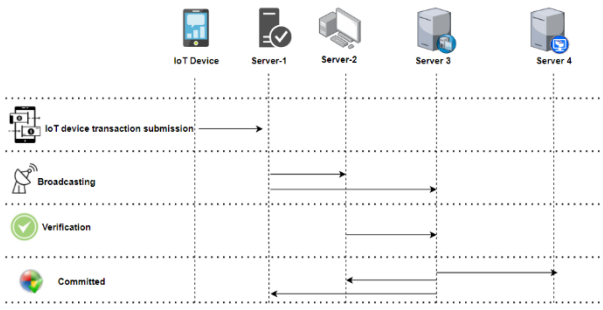

Figure 3: The Sumeragi in Hyperledger IROHA method.

are converted into blocks or agreed to connect to the current blockchains or transferred to the internet.

The miners have a critical role to play in integrating the development of a new block in the blockchains. The hashing technique is designed using the Hyperledger IROHA method. Figure 3 shows the IROHA method.

Stage 1. Transmission: verify, organize, or register transactions or submit information to the program.

Stage 2: verification and sign-up: this validates, queries, or signs transactions or distributes the verified IoT node of the P2P platform.

Stage 3: linked to the having signed.

In the case of system failure, the automatic program leads to a step called error tracking. Throughout fact, the technique performs with the current server to detect discrepancies. Study researchers compared the efficiency of 5 and 10 IoT nodes using investigations. Figure 4 shows the performance of 1 to 20 IoT devices with comparison analysis for discovering, choosing, and analyzing techniques.

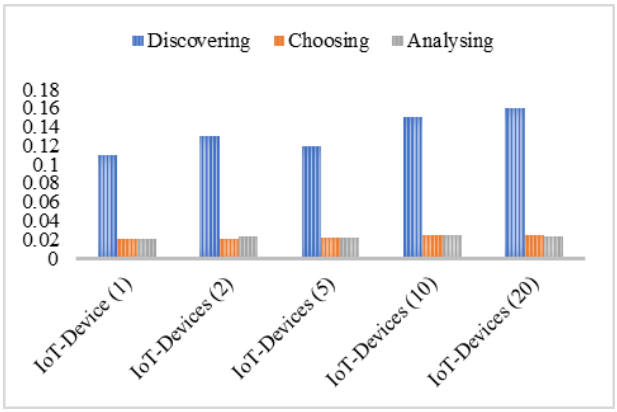

Figure 4: discovering, choosing, and analyzing 1 to 20 IoT devices.

Considering the 5 IoT devices linked to the 500, 1000, 300, 700, and 1500 mining power P2P services. The devices are in a position to carry out exchanges within the suggested technique. The header size 100 bytes and the transaction size 500 bytes are assumed. There are five IoT devices in the network.

IBchain system is evaluated with 5 IoT nearby devices and 2 distanced IoT devices. The blockchain-retrieved information in the cloud of a technology named the OPENSHIFT framework. The FogSim technology is being applied to link the IoT devices to the network. The cloud is provided through the Amazon server. Figure 5 shows the execution factors in the IBchain.

IBchain requires miners in the blockchains network for a result of a study conducted. Initially, two miners were chosen with fixed exchanges (assume 5) as well as establish the nebula specifications with miners. Secondly, three miners of specific transactions (assumes 5) or established the nebula specifications for miners. Unless the cloud market is rising, the probability of mines the miner's block is stronger. Modeling criteria like the use of a processor, use of storage in blockchains compared with cloud, and edge are tested. I realized that its use processors in blockchains were smaller than cloud and

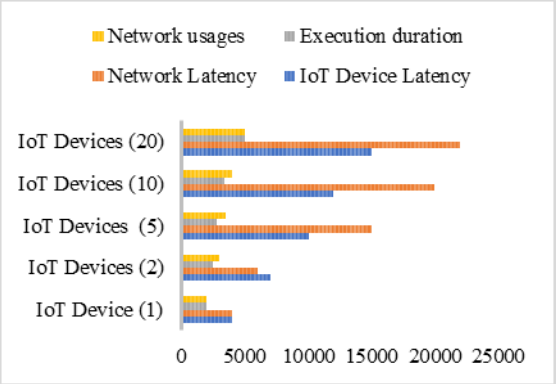

Figure 5: The execution factors in the IBchain.

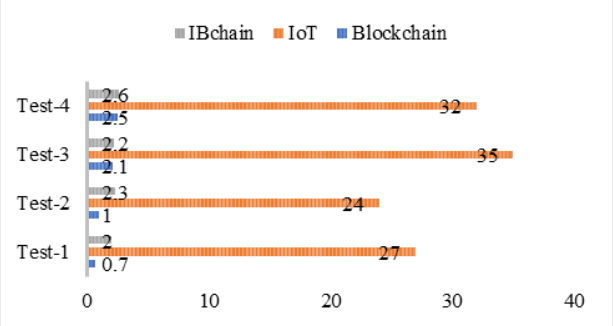

Figure 6: The Transmission delay in IBchain.

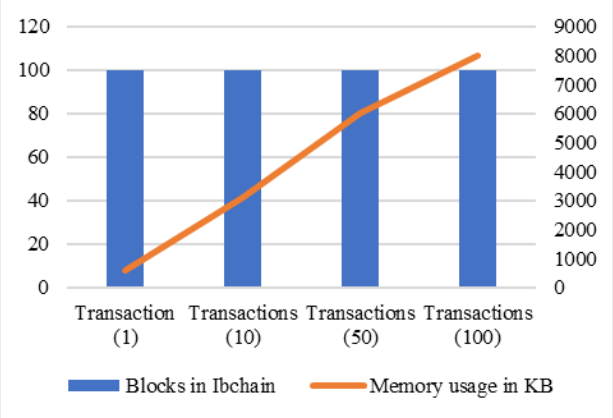

Figure 7: Usage of Memory and blocks in IBchain.

Nodes	Delay in ms	Duration time	Power consumption in KJ
5	146.5	288	5.2
5	12.3	703	5.2
5	99	905	5.5
10	15.1	225	12
10	12.4	499	15.9
10	53.2	293	11.7

Table 1: Power Consumption using different nodes.

IoT. Using storage based on the number of blocks with the volume of data. When the block size increase, storage use may also enhance. Likewise, as the number of transactions increases, storage use would therefore rise. Figure 6 shows the transmission delay in IBchain.

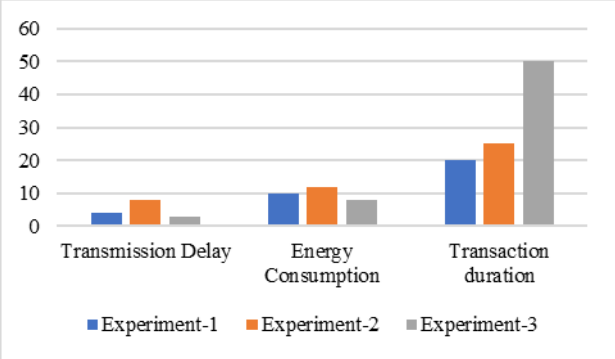

Figure 8: Performing on 10 IoT devices in IBchain.

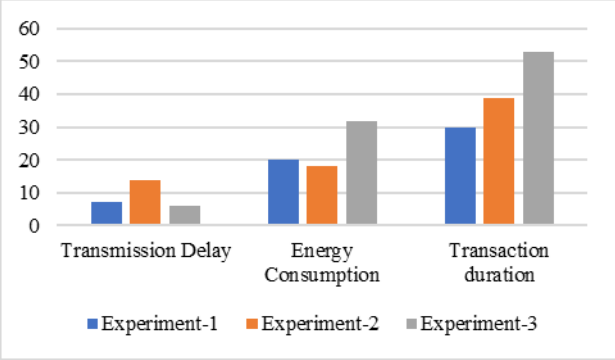

Figure 9: Performing on 20 IoT devices in IBchain.

Figure 7 shows the memory usage and number of blocks. Figure 8 and 9 shows the performance of 10 and 20 IoT nodes with three experiments. Table 1 represents the power consumption using different IoT nodes.

The author is implemented as an interface in JavaScript that assists the IoT devices to link with the IBchain system. This framework applies the web3 JavaScript libraries towards connecting through Ethereum domains via RPC requests and the CoAP JS APIblockchain-based-CoAP 5 to access sensor nodes.

4 IBchain for smart cities

Smart cities are being built and people can be recognized as smart residents pretty soon. Human lives will be exchanged and there are many advantages: smooth, processed public transport operations and vacated traffic, reduced crime rates, automated scheduling, service growth, and beyond.

4.1 Data collection blockchain

Current scientific requirements in the city involve the selection of sensors for data collection. It may be non-driving, delivery drones, city tracking cameras, automated lights, and any other calculating equipment. This makes it necessary to gather personal data, and it is thus essential to store the information. Gathering the personal realities and maintaining them gives the lives of all human beings an opportunity. Smart city solutions developers should provide evident client confidentiality, privacy, and security information. That is why blockchain technology offers all participants of this sort of system the possibility to gather and exchange their information with a very high level of authenticity and security without the participation of one regulator or intermediary.

4.2 Smart cities thrive through blockchain

In future cities, there are several possibilities using blockchain integration. Smart contracts, for instance. Such contracts could be concluded autonomously if pre-mounted circumstances (for example, a person, an object, or gadget with other smart aspects) are satisfied among various occurrences. Due to its security and technological versatility, Blockchain maintains smart contracts. A cloud-enabled parking system is required for assigned vehicle storage. Blockchain chronology may be utilized to make a cloud analog convenient and secure, which ensures responsibility and transparency. Asset management responses and budget management may enhance efficiency and assure visibility by eliminating inefficient verification actions via the use of blockchain generation at the city level. All online-based sensors can identify and transmit data and perform operations in smart cities. Data from city sensors may be transformed into commercial units because of blockchain usage. Consider that the parking sensor generates data on whether it belongs or not at the moment. These statistics are acquired by the parking searches operator in the smart city. The non-public profession of engaging in sensors and restoring nerves chips could be focused on such possibilities. This technology enables a combination of a range of network and robotic offers, prevents safety violations, and guarantees that transactions go uninterrupted.

4.3 Present smart city blockchain software

Developers of smart cities frequently respond to ethical problems, technological integration difficulties, and regulatory restrictions, etc. several intriguing initiatives are excited about IoT integration. For individuals who have strong market positions: IoTA and robonomics. They worked endlessly and transparently and built integration solutions for various areas of smart cities. These are all based on over five years ago. These are both open-ended technologies that enable developers to promote improvements and to construct new projects based mainly on applications. When you think about 2015, IoTA was present and found the solutions by pursuing the "internet of things." This framework involves the authority to transmit important information and data between people and machines. Security violations also lead to insecurity of IoTA by 2020, amongst other deficiencies. It was one of the top five currencies before hacking. Its market value at the time was conserved for more than $13 billion. Robonomics is an open IoT supply chain moderate platform. Professionals strive to create the notion of "robotic industry," in the actual global economic system, using robots and different computer systems as full-service agents. Intelligent devices may choose their storage independently, pay for electricity, and so on. Furthermore, robonomics improves the natural functions of tracking air quality with the assistance of drone sensors and water pollution processes.

4.4 The industry 4.0

The fourth revolution in commerce has arrived in humanity; reproduction is an important part of our life. Building intelligent cities are unavoidable. It is therefore vital for the aesthetic appearance and privacy of the user to expand their timely responses. This estimate could assist with blockchain latency and address various behavioral issues.

5 Discussion

Blockchain is a shared ledger idea that combines with IoT to allow device-to-device interactions. It employs data activities stored in a database which are validated through several resources and included in a standard ledger distributed throughout each node. The combination of IoT and blockchain gives the advantages of distinct technologies and enables an intelligent tool to function autonomously without a central authority. IoT devices employ smart contracts to enable data transmission that resolve the settlement between the two parties [36]. This option allows smart devices to run independently without a central authority. Blockchain can assist to minimize IoT and IoT-related safety problems by a ledger is concerning evidence on a blockchain device, which eliminates the need to rely on the many parties involved. No organization can manage a considerable number of statistics created by IoT devices [37]. Additional security layers, that hackers can breakthrough, may need to be loaded with the usage of a blockchain to maintain IoT data. Blockchain gives a further degree of coding, which does not prevent the bypassing of known information [38]. Blockchain enables transparency, by enabling any authorized individual to access the community through previous content. It could give a safe approach to recognize and undertake brief corrections for a successful move for any verifiable disclosure. Blockchain could enable transactions and communications between billions of connected devices to be processed more quickly. The shared production of the text provides a valuable approach to aid with the largest transactions with the growing range of connected gadgets. By establishing a method for enhancing the confidence of stakeholders, IoT companies may decrease costs by removing high-level processes. Users are strong smart devices with tremendous capabilities to disseminate safety improvements, which will certainly assist safeguard the most susceptible devices [39][40][41]. Blockchain and IoT are also anticipated to endure regulatory problems. For example, for companies, multi-source transactions may be managed in a consistent and visible document, which tracks records and physical assets during the transaction time. A blockchain report should be able to determine the moment – say tool or sensor – when anything has gone wrong during incorrect selection or overloading of a device, and businesses may take a rapid turnaround. IoT enables users to transmit information to blockchains public ledger for participation in public transactions with databases. The Blockchains allow the business participants to connect and distribute IoT data and no need for centralized controlling. The agreement should be checked to avoid conflicts and to ensuring that each participant is kept responsible for certain specific activities. Construct a trustworthy and productive business among individuals and organizations which are working collectively. IoT nodes could engage in exchanges as a decentralized group. Its undeniable activities from devices recorded on the blockchain offer evidence of collaboration between companies and individuals. Improve efficiency for the design, management, and compliance of agreements by exchanging data between different groups. The participant in Hyperledger is the IoT device. The agreement is allowed to consent to the status of a distributed public blockchain network [42][43][44]. Generate a continuous or indelible database provided by the business and industry policies. Enhance exchanges to make it easier for customers and allow emerging technologies. Smart cities will deliver the best services to improve residents' everyday lives in the areas of medical care, mobility, power usage, and learning. Moreover, the idea of smart cities is still emerging, and, considering its desired future, privacy concerns have been on the emergence. distributed ledger provides the opportunity to facilitate the growth of smart cities due to its positive characteristics like accountability, efficiency, flexibility, and distribution. IoT is shaping the direction of businesses by the utilization of sensor nodes as well as other motion-connected technologies. It is a significant strategic initiative that needs to preserve knowledge at all stages of the IoT network. For the number of sensors emerging annually, information security is becoming highly complicated. Blockchains can tackle security risks in the embedded network. Blockchains and IoT are integrating throughout all sectors, involving banks, finance, manufacturing, and agricultural sectors. Also, in smart homes, suppliers, transportation, and agreements. Agreements connect blockchains to IoT systems to immediately enforce each transaction after certain tasks have been completed. The use of these blockchains helps businesses to process the information on sensor nodes in an IoT environment, decreasing the cost related to mobile device improvement and secure communication. This eliminates the risk of information management since there is no centrally controlled repository of information. In addition to safety, the blockchain gives clever city inhabitants the opportunity of earning more funds, secure agreements, machine communication, and other possibilities. The sophisticated technology in the market and use of IoTA and robonomics offer solutions for the interconnection of connected devices, their integration into the human economic system as contributors, transparent and convenient records administration, and much more. In keeping with the global financial forum research, efforts to create blockchain solutions for smart cities retain the best market potential

6 Conclusion

This research approach is developed and constructed using IoT, clouds, and blockchains. It is an integration of IoT and Blockchains. Blockchains technology is used to generate a highly distributed public realistic database for

transaction processing. Analysis has created an entirely new possibility throughout this field. A methodology is designed and evaluated to use a wide variety of IoT devices. This research could be a useful tool for improving the efficiency of the IoT system in an interconnected context. The method is designed to provide interaction security where big data are exchanged in a complex context in the long run. Researchers have evaluated the system in several situations, like memory and storage use in the integrated system and its effect on the secure operation. Researchers find that the suggested method improves the performance and removes the direct relation between IoT devices, making this method further reliable. Its research findings set out an innovative IoT framework with blockchains.

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https://doi.org/10.31449/inf.v45i3.3313 Informatica **45** (2021) 487–488 **487**

Heterogeneous Face Recognition from Facial Sketches

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Thesis summary

Keywords: generative adversarial networks, image translation, neural networks, machine learning

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This paper presents a short summary of a dissertation thesis [1]. The thesis presents a novel approach named X-Bridge for image-to-sketch translation for automatic heterogeneous face recognition. X-Bridge is based on a conditional adversarial network with an additional reconstruction path and a shared-latent space assumption between the original and the reconstruction path. With these modifications, the results provided by X-Bridge overcome other tested state-of-the-art methods. Code is available at: https://github.com/YvanG/Cross-modal-Bridge.

Povzetek: Povzetek doktorske disertacije na kratko opisuje prepoznavanje obrazov iz skic.

1 Introduction

Generative adversarial networks (GANs) [2] have gained a huge amount of popularity in recent years thanks to their ability to generate photo-realistic results and the ability to capture important image details during image-to-image translation task. In this paper, a novel approach called X-Bridge is presented. X-Bridge is designed specifically as a cross-modal bridge in the heterogeneous face recognition task. X-Bridge is a supervised method and its structure is based on a conditional GAN, however, it also assumes shared-latent space across two different domains. To fully demonstrate the abilities of the X-Bridge approach, we test it on the arguably very challenging task of facial sketch-to-image translation using CUFSF dataset [3].

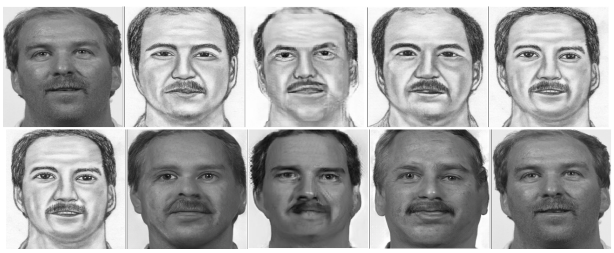

Figure 1: Cross-domain translation comparison. There are input images (the first column), translated corresponding sketches using Pix2pix (the second column), MUNIT (the third column), X-Bridge (the fourth column), and ground-truth outputs (the last column).

Figure 2: Cross-domain translation comparison for non-frontal view. The order of methods is the same as in Fig. 1.

2 X-Bridge method

X-Bridge contains two main paths based: translation path, and reconstruction path. These paths can be imagined as two separate GANs. They both have their own generator and discriminator, whereas both of them share one shared encoder. Each path has its own specific task. The task of the translation path, based on the conditional GAN, is to translate an input image from its domain into the other domain. On the other hand, the task of the reconstruction path, based on vanilla GAN, is to reconstruct the original input. Via this process, the reconstruction path motivates the shared encoder to preserve important features, to generalize better, and to learn important regularities. To further improve features propagation through the networks, skip connections in the form of channel concatenation between the last four layers of the encoder and the first four layers of the generators are added. Both of the paths utilize traditional adversarial loss, which can be for the domain translation problem expressed as follows:

$$L(EG, D) = \mathbb{E}_{\hat{x}}[\log D(\hat{x})] + \\ + \mathbb{E}_{x,z}[\log(1 - D(EG(x, z)))],$$

where x is a real image from the first domain, $\hat{x}$ is a real im-

age from the second domain, the encoder, and the generator are together denoted as EG and D stands for the discriminator, and z is a vector from the shared-latent space.

Moreover, both paths utilize L_1 distance defined as follows:

$$L_1(EG) = \mathbb{E}_{x,\hat{x},z}\left[\|\hat{x} - EG_1(x,z)\|_1\right].$$

The final loss is then defined as a sum of both losses for both paths.

3 Experiments

Several deep generative models were proposed for image-to-image translation in recent years. Most of existing approaches are based on supervised learning, however, models based on unsupervised learning became very popular lately. To benchmark X-Bridge, we decide to use two significant methods, one from each group. We compare it with the Pix2pix approach [4] and the MUNIT approach [5]. Both of these methods provide state-of-the-art results in image-to-image translation tasks, where Pix2pix is a supervised method the same as X-Bridge, whereas MUNIT is unsupervised. All the methods were trained and tested on the CUFSF dataset containing 1194 facial photo-sketch pairs.

In the first experiment, we test the translation of frontal views, see Fig. 1. All methods provide very realistic and precise results, however, we argue that both supervised models outperform the MUNIT approach, which has problems generating sharp images and therefore also small details. Pix2pix and X-Bridge reach comparable results. In the second experiment, where we test non-frontal cases, X-Bridge over-performed other methods, see Fig. 2 in terms of generalization, precision, and facial features preservation. All the methods were also tested on the IIIT-D Sketch dataset with comparable results.

4 Conclusion

We argue that qualitative results provided by X-Bridge overcome other tested methods. In our future research, firstly, we would like to propose a suitable metric to objectively compare the performance of methods in the image-to-image translation tasks, which is, to this day, non-existent. Secondly, we would like to address the ambiguity issue, which is a critical problem in the heterogeneous face recognition task.

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Automated Planning with Induced Qualitative Models in Dynamic Robotic Domains

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Thesis summary

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Various methods of learning qualitative models by autonomous robots have previously been proposed as a viable alternative to traditional numerical modeling, but an efficient way of using such models for planning still remained an open problem. This paper summarizes a doctorat thesis, which proposes a novel domain-independent qualitative approach to automated planning and execution of robotic plans. The proposed method is demonstrated in five different robotic domains.

Povzetek: Različne metode učenja kvalitativnih modelov v avtonomni robotiki so bile v preteklosti predlagane kot možna alternativa tradicionalnemu numeričnemu modeliranju, toda učinkovit način uporabe takšnih modelov za planiranje je še vedno ostal odprt problem. Ta članek povzema doktorska disertacijo, ki predlaga nov, domensko neodvisen kvalitativen pristop k avtomatiziranemu planiranju in izvedbi robotskih planov. Disertacija predlagano metodo demonstrira v petih različnih robotskih domenah.

1 Introduction

Cognitive robotics aims to bring robots out of their typical industrial environments and closer to a human type of reasoning and cognition. Some researchers in this area have proposed the use of qualitative modeling as a viable alternative to the traditional numerical modeling. Various experiments showed a better training sample efficiency and a lower susceptibility to noise when learning qualitatively. Moreover, since qualitative models tend to be closer to human intuition, they can provide a more comprehensive explanation of the learned theory.

Qualitative models may have a certain explanatory significance to humans, but to robots, they are generally far less useful than numerical models. To perform some task, a robot needs to plan, and planning in continuous robotic domains is typically a numerical problem. Qualitative models abstract away most if not all numerical data, so an important part of information needed by a planner is missing from the model.

To answer the question of how qualitative models can still assist with the robotic performance, Wiley et al. [1] proposed to qualitatively constrain the search space of a *trial-and-error* learning, thus shorten the time to find a working solution in a numerical way. However, the question whether qualitative models could be used to plan and execute a robotic task without additional numerical training still remained open.

This paper summarizes a doctoral thesis [2], which shows that certain robotic tasks can be planned and executed within continuous domains using qualitative information alone. The performance can improve over time through on-line numerical adaptation. The proposed method was demonstrated in five different robotic domains.

2 Methodology

The thesis focuses on a specific type of qualitative models that encode information through *monotonic qualitative constraints* (MQC), which were proposed by Benjamin Kuipers [3]. These constraints abstract differentiable functions of one or more variables to intervals of monotonically increasing and decreasing values. A system modeled in such a way can be simulated qualitatively using Kuipers' program called QSIM. The thesis shows how QSIM can be transformed into a qualitative robotic planner that can devise symbolic plans based on a given qualitative model and with some given initial and goal conditions. Such plans determine a sequence of symbolic actions that should be taken (e.g. *accelerate*, *turn right*, etc.), but do not determine their numerical outputs and durations.

To execute qualitative plans on a numerical system, the thesis proposes a novel algorithm that reactively decides the numerical outputs based on the current and past numerical observations, while following a qualitative plan. Numerical observations such as speeds and accelerations of individual robot's attributes (typically translations and ro-

tations of the robot or its individual parts) are used by the algorithm to internally construct a smooth hypersurface, to which it maps the planned qualitative states, so that the targeted state is always lower on the hypersurface than the current state. The output signals are then determined dynamically by following the steepest descent along the hypersurface. The performance of the algorithm has been successfully evaluated for real-time execution on embedded systems.

To demonstrate domain independence of the proposed method, the implementation strictly separates the method from the model. A new language called QDDL (Qualitative Domain Description Language) is defined and used to conduct the experiments.

3 Results

The proposed method was demonstrated with five different robotic problems, each exposing a different aspect of qualitative planning and execution. Some experiments emphasize the dynamic adaptability of qualitative models to the given environmental parameters, while others focus more on conceptual reasoning about the given numerical problem through qualitative planning.

Two-wheled autonomous vehicle learned a qualitative model of differential drive by motor babbling. Using the learned model the robot was able to pursuit a moving target and avoid collisions [4].

Pushing objects by a robot. A wheeled robot learned a qualitative model that encoded the physics behind pushing a rectangular box. Qualitative abstraction made the learned model general enough to enable the robot to push boxes of different shapes to the designated locations. [5]

Flying a quadcopter. A quadcopter autonomously learned a qualitative model for navigating through space and qualitatively planned and executed an escape out of an enclosed space. [6]

Controlling the cart-pole system. The well known *inverted pendulum* problem was implemented as a *cart-and-pole* system, which learned to stabilize within seconds. The devised qualitative plan offered a comprehensive explanation of the used control strategy. [7]

Discovering bipedal walking. A humanoid robot was given a task to move forward a certain distance. As a means to achieve this goal, the robot discovered a qualitative concept of bipedal walking, which was successfully executed.

4 Conclusion

The thesis proposes a novel approach to qualitative planning and plan execution in continuous robotic domains. The proposed method is domain independent and allows qualitative models to be used without additional numerical training. While the proposed qualitative approach might not be feasible for all robotic problems, it has been successfully demonstrated with a variety of problems on different types of robots. The results were published in several peer-reviewed publications.

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JOŽEF STEFAN INSTITUTE

Jožef Stefan (1835-1893) was one of the most prominent physicists of the 19th century. Born to Slovene parents, he obtained his Ph.D. at Vienna University, where he was later Director of the Physics Institute, Vice-President of the Vienna Academy of Sciences and a member of several scientific institutions in Europe. Stefan explored many areas in hydrodynamics, optics, acoustics, electricity, magnetism and the kinetic theory of gases. Among other things, he originated the law that the total radiation from a black body is proportional to the 4th power of its absolute temperature, known as the Stefan–Boltzmann law.

The Jožef Stefan Institute (JSI) is the leading independent scientific research institution in Slovenia, covering a broad spectrum of fundamental and applied research in the fields of physics, chemistry and biochemistry, electronics and information science, nuclear science technology, energy research and environmental science.

The Jožef Stefan Institute (JSI) is a research organisation for pure and applied research in the natural sciences and technology. Both are closely interconnected in research departments composed of different task teams. Emphasis in basic research is given to the development and education of young scientists, while applied research and development serve for the transfer of advanced knowledge, contributing to the development of the national economy and society in general.

At present the Institute, with a total of about 900 staff, has 700 researchers, about 250 of whom are postgraduates, around 500 of whom have doctorates (Ph.D.), and around 200 of whom have permanent professorships or temporary teaching assignments at the Universities.

In view of its activities and status, the JSI plays the role of a national institute, complementing the role of the universities and bridging the gap between basic science and applications.

Research at the JSI includes the following major fields: physics; chemistry; electronics, informatics and computer sciences; biochemistry; ecology; reactor technology; applied mathematics. Most of the activities are more or less closely connected to information sciences, in particular computer sciences, artificial intelligence, language and speech technologies, computer-aided design, computer architectures, biocybernetics and robotics, computer automation and control, professional electronics, digital communications and networks, and applied mathematics.

The Institute is located in Ljubljana, the capital of the independent state of S**love**nia (or S♡nia). The capital today is considered a crossroad between East, West and Mediterranean Europe, offering excellent productive capabilities and solid business opportunities, with strong international connections. Ljubljana is connected to important centers such as Prague, Budapest, Vienna, Zagreb, Milan, Rome, Monaco, Nice, Bern and Munich, all within a radius of 600 km.

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The promoters and operational entities of the project are the Republic of Slovenia, Ministry of Higher Education, Science and Technology and the Jožef Stefan Institute. The framework of the operation also includes the University of Ljubljana, the National Institute of Chemistry, the Institute for Electronics and Vacuum Technology and the Institute for Materials and Construction Research among others. In addition, the project is supported by the Ministry of the Economy, the National Chamber of Economy and the City of Ljubljana.

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