The Application of Logistics Robot in the Solution of Locating Route Problems in Trans CAD

Chaoying Tan[1*], Panke Li[2]
[1*]Tan Chaoying, Sichuan Vocational College of Finance and Economics, Chengdu Sichuan, 610101, China
[2]Zhengzhou Railway Vocational & Technical College, Zhengzhou, Henan, China, 451460
E-mail: 220206@scvcfe.edu.cn, 10816@zzrvtc.edu.cn
*Corresponding author

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Intelligent production enterprises globally are advancing smart vehicles, necessitating improved location-transport routing for multi-robot systems. TransCAD allocation and scheduling techniques are pivotal for this purpose, aiming to enhance stability, speed, and accuracy in routing. This study investigates multi-robot TransCAD scheduling within a Flexible Manufacturing System (FMS), focusing on challenges like task distribution, autonomous navigation, and precision in complex multi-process, multi-workpiece environments. By applying a clonal screening algorithm for multi-robot allocation and sorting, the study achieved optimal stability and performance in simulated environments. A novel composite structure for multi-robot transport in FMS is proposed, integrating a Communication and Information System (CIS) with P2P communication for effective multi-robot coordination. The study examines the complexity of Locating Route Problems (LRP) by analyzing nodes, vehicle count, and network size, highlighting increased complexity with additional locations. Using access techniques for multi-robot transport, the study proposes a minimum delay access strategy, optimizing communication time efficiency through MAC and RTS/CTS mechanisms. Compared with traditional algorithms, the proposed method achieved significant performance metrics, with 98.5% accuracy, 97.8% precision, and 98.2% recall, demonstrating its effectiveness in multi-robot transport.

Povzetek: Raziskana je uporaba logističnih robotov za optimizacijo načrtovanja poti v TransCAD sistemu. S pomočjo klonskega selekcijskega algoritma in večrobotne komunikacije izboljšuje usmeritev robotov v kompleksnih proizvodnih okoljih, kar povečuje avtomatizacijo in operativno učinkovitost logističnih sistemov.

1 Introduction

In the domestic logistics industry, the rapid development of the intelligent transportation industry, and the establishment of a flexible production workshop logistics system have become an important trend in the development of the current logistics industry. Intelligent production workshop logistics is a kind of logistics system with automation, intelligence, and intelligence as the core. In intelligent production, transportation is an important link to realizing intelligent production. Industry is the industry and industry introduced at the earliest stage, which is currently in the greatest demand and whose technology urgently needs to be improved. This kind of robot transportation uses the battery as transportation power, coordinates movement with the chassis gear train, and realizes autonomous driving through sensors and controllers such as laser radar. Under the control of the controller, it operates according to the predetermined path, transports the material to a specific location, and carries out a set of handling and auxiliary loading and unloading TransCAD. The multiple TransCAD scheduling problems in FMS are discussed. Aiming at the situation of multi-station, multi-workpiece, multi-process, and multi-robot in FMS, a mathematical model of multi-station, multi-workpiece, multi-process, and multi-robot transportation is established, and the clonal screening algorithm is used to allocate and sort the multi-robot TransCAD. The superiority of the proposed control strategy in terms of stability, stability, and optimal solution is demonstrated by the simulation tests performed on multi-robot transportation [1-4].

The route of multiple robot transportation in logistics distribution is discussed. Based on ROS, the movement and entity of multiple mobile robots are constructed, and two planar grid graphs are constructed. A modified A* method combined with diagonal spacing is introduced to reduce the number of search nodes in the path plan, to realize the optimal route. The test results show that the proposed multi-robot integrated cost and multi-robot TransCAD cycle reduce multi-robot TransCAD cost, reduce TransCAD cost, and reduce TransCAD cycle.

In the real scenario of the FMS factory, several robot transportation simulations and scheduling experiments are carried out. Firstly, the Gazebo algorithm was used to simulate multiple vehicles, and a multi-path optimization algorithm was given to reduce the reliability of vehicle intersection and operation. The stability, rapidity, and accuracy of the scheduling system are tested by measuring the time of fixed-point scheduling, the measurement of fixed point stopping, the measurement of fixed point stopping, and the calculation of the handover of vehicles. Over ten years ago, the logistics business only required mobile logistics robots with defined nodes and routes. With the popularity of high-performance chips, controllers, and high-precision sensors, a variety of sensors can be supported at a specific price, and various sensors can be analyzed to achieve a comprehensive judgment of the surrounding environment and an accurate judgment of specific transportation targets. Therefore, the performance of the same price order type robot has been further improved. This is a patrol machine consisting of a variety of detectors such as lidar, MU, RGB-D camera, encoder, thermometer, and gyroscope. The system has strong performance and can perform various security monitoring and surveillance work independently [5]. Traditional robotic transportation for logistics transportation focuses on environmental perception, autonomous navigation and localization, map building, and route selection. However, under complex work tasks and dynamic external conditions, the working obstacles of a single robot are gradually emerging. A single robot has great difficulties in obtaining information, analyzing the environment, and executing force, and it is difficult to make new progress. The number of multiple robots is larger than a single multiple robots, they can work at the same time, and can effectively perform more work at the same time; multi-robot transport can take full advantage of the synchronization of data, and can also provide more comprehensive information for the monitoring of the whole system. Multi-robot transportation must maintain its stability, speed, and accuracy in production, logistics, and transportation. The multi-robots produced in multi-warehouses, warehouses, and factories are demonstrated. The multi-robots can not only complete the information exchange between multi-robots and users but also complete the assignment and cooperative work of multi-tasks so that they can accurately and effectively complete various productions of Trans CAD [6-7]. In some industrial fields, the work distribution and scheduling of multiple robots, in some production lines, has achieved a high degree of automation. For example, in the intelligent assembly workshop of GAC Yichang Automobile Co., LTD., multiple robots work together to install all components such as car chassis, window glass, seats, and so on to 100%, and a new car can be pulled off the production line in 52 seconds at the fastest. In FAW JiefangHuishan intelligent factory, Aowei heavy-duty diesel powertrain area of 50000 square meters of intelligent TransCAD plant, intelligent Trans CAD proportion is 67%, intelligent Trans CAD proportion is 78%, an engine can be assembled in an average of 110 seconds, compared with 2012 semi-automatic production line, Production increased by 117%. However, the level and proportion of mechanization of the whole society are still insufficient [8]. Due to the site environment, process requirements, enterprise capabilities development level, and other factors, especially in some complex processes, production rhythm changes, high transformation costs, high maintenance costs, applicability, and reliability is difficult to ensure the production process, still relies on manual labor. Summary of literature survey is presented in Table 1.

Table 1: Summary of literature survey

References	Methods/Algorithm	Merits	Limitations
[9]	The Integrated Logistics Platform (ILP 4.0), a software architectural model that this author introduced, aims to integrate warehouse logistics with AR and VR while also pushing warehouse logistics to new heights of efficiency.	By integrating these technologies, warehouse logistics issues including inventory automation, movement management, and logical and physical security of the property can be lessened.	To lessen the lack of information needed to address certain security and safety issues in the logistic area.

[10]	One of the more significant qualitative changes in the automation of transport activities in the production, assembly lines, and storages is the introduction of service robots, or AGVs (automated guided vehicles), into manufacturing processes in this study.	In addition to uses of AGV service robots with various structures in manufacturing processes, in restricted spaces and open regions, like shipping containers in ports, this article covers the annual application of service robots in logistics.	These robotic systems are inexpensive to invest in.
[11]	This paper looked at the influence of transportation revolutions as well as developments in robot-assisted mobility systems.	For academics, decision-makers, and business experts interested in determining the direction of transportation in the future, the study is a useful resource.	Absence of human-robot cooperation and artificial intelligence's function in traffic flow optimisation data.
[12]	The purpose of this work was to develop an A-star algorithm-based intelligent logistics management system using the ROS robot.	The ROS robot's power consumption and response delay performance are good, and the logistics transit speed has significantly increased, according to the results.	To get more reliable results, the simulation experiments should be split into multiple groups and compared numerous times, as the A-star method is not deep enough. Therefore, there is still room for improvement in this paper.
[13]	This paper shows UAV route planning architecture that makes use of the augmented ant colony technique.	examining the UAV in person and demonstrating that even with its lower weight	, It still needs to meet its durability standards.
[14]	An A* algorithm was utilised in this paper to globally direct the path planning in the large-scale grid using the heuristic elastic PSO algorithm.	In order to enable fast particle convergence, the elastic PSO method employed the contraction operation to find the globally optimum path formed by the local optimal nodes.	The A* algorithm's drawback is that it cannot generate the shortest path, but it also avoids the issue of its inability to converge to the globally optimal path because it lacks heuristics.
[15]	The acquired knowledge results in the development of linear control laws and a two-stage Kalman filter-	The effectiveness and low sensing requirements are the main advantages. The	R vision-based techniques in larger robots to enhance flight

	based estimate technique that can effectively handle an underactuated leader-payload-follower system.	suggested technique was validated in both indoor and outdoor contexts through flying experiments, employing two sub-100-g MAVs with severely constrained computational power.	performance or as a fallback in the event of hardware malfunction or poor sight.
[16]	This work provides a revolutionary path planning to guide the self-reconfigurable sTetro staircase cleaning robot with optimal energy consumption. We make use of the grid-based optimisation method's temperature gradient.	A Staircase cleaning robot that can adjust on its own and uses the least amount of energy	This system has lower efficiency when compared to other approaches.
[17]	The indoor environment can be recreated using SLAM algorithms. This study proposed the intralogistic application of UAVs, or quadcopter drones.	A sophisticated low-cost localisation technique along with usual sensors present on even low-cost UAVs can be used to study controller design and simulation in order to attain the most critical goal of navigation accuracy, which is normally better than 10 mm. Triangulation sensors, whether laser-based or otherwise, appear to be a promising solution for small- to medium-sized industrial systems.	This Case study, effortlessly avoiding impediments on the ground when travelling in the longitudinal, transverse, or oblique orientations at specific heights inside an assigned working space indoors
[18]	fMmTSP method applied for fixed destination multi-depot multiple travelling salesman problem	In order to optimise task allocation and route planning for many indoor robots with various beginnings and destination depots—where each robot starts and terminates at the same depot—this study suggests a new methodology.	Inaccuracy in the techniques.
[19]	Using a topological map as the unifying representation and computational model.	Ex-situ modelling and analysis of activities are made possible by this topological abstraction of	However, this work only tests a subset of test cases

		the system state, which results in an effective representation of large-scale settings and scalable and efficient operation for the entire fleet.	for topology change methodologies.

1.1 Motivation

- Logistics robots automate the movement of goods, which can greatly improve the efficiency of delivery and transportation operations.
- Businesses may save money by using logistics robots as part of the LRP solution.
- Sophisticated methods for modeling transportation networks, taking into account variables like road conditions, traffic patterns, and periods, are available in TransCAD and related applications.

1.2 Research gap

The lack of investigation into the fusion of cutting-edge technology like robotics with well-known transportation planning software like TransCAD is the research gap in the use of logistics robots to resolve identifying route issues in TransCAD. There aren't many thorough studies that particularly look into the use of logistics robots inside the TransCAD framework, despite the increased interest in streamlining logistics operations and route planning. The subject of potential synergies between logistics robots and TransCAD is frequently overlooked in favor of standard route optimization techniques and software solutions. The ways in which TransCAD might be improved to solve route placement problems by including logistics robot skills like autonomous navigation and real-time data collection are not well understood.

1.3 Contribution of the study

- The paper presents TransCAD scheduling and allocation strategies as the fundamental approaches for maximizing the location-transport routing of many intelligent robots. The limits of single robot operations are intended to be addressed by these strategies.
- The paper suggests a composite construction with multi-level and multi-robot capabilities for multi-robot transportation, based on the experimental results. The development of a multi-robot transportation communication system integrating peer-to-peer (P2P) and Communication and Information System (CIS) modalities is also suggested.

1.4 Research methods

Localization and transportation route selection are important issues in the design of mobile logistics robots. Usually, it obtains the predetermined track of robot transportation using the shortest route from the starting point to the end under constraints such as no conflict with obstacles. At present, it has a wide range of applications in many fields, such as cargo and obstacle avoidance of storage AGV, outdoor UAV flight and collision avoidance, underwater navigation of unmanned submarines, and missile and fighter aircraft avoidance. Transportation routing can be applied to transportation routing problems on various terrains in various point-line networks.

1.4 Statistical tests

The ANOVA, t-test for trend, was performed to ascertain if the proportion of infections brought by the most prevalent solution of locating route problems in TransCAD throughout the course of the study period had an independently significant linear trend.

2 Optimization of logistics robot transportation route based on Trans CAD

According to the known environmental information, the transportation route can be divided into a model-based overall transportation route (that is, all the information in the Trans CAD context is known) and a sensor-based regional transportation route (that is, unknown environmental information). Fundamentally, there is no difference between global and local routes. The proposed method can be applied to global route selection as well as local route selection. Functionally, the design of local routes should take into account the influence of the environment, and to ensure the safety of the robot, they are usually dynamic-oriented. From the objective point of view, the goal of the overall route is to produce a route that conforms to a specific optimal index, while local route planning focuses on the practicality and avoidance ability of the route. So, in practice, to realize their advantages and complement each other, the combination of global and local is often used.

The method is mainly divided into three aspects: initial condition analysis, constraint condition analysis, and objective function construction. First, we initialize the subject-object in the following way.

Given the set of robots as$R$

$$R = \{R_1, R_2, \cdots, R_{n_1}\} \tag{1}$$

Given the set of stations as$M$

$$M = \{M_1, M_2, \cdots, M_{n_2}\} \tag{2}$$

Given the set of artifacts as$W$

$$W = \{W_1, W_2, \cdots, W_{n_3}\} \tag{3}$$

The set of all target tasks is$T$

$$T = \begin{Bmatrix} T_1, & T_2, & \cdots, \\ & & n_4 \end{Bmatrix} \tag{4}$$

The transportation cost matrix is

$$\boldsymbol{C} = [c_{ij}] \tag{5}$$

Where the matrix's components provide the consumption numbers for robot movement from the intended location to the intended destination.$\boldsymbol{C}c_{ij}Rij(i, j = 1,2\cdots, m)$Over the past decade or so, there have been two main approaches to road optimization: traditional route optimization approaches and heuristic approaches. The following is a brief explanation of both methods. Traditional transportation route methods include visualization, simulated annealing, artificial potential fields, etc. Pseudocode 1 is as follows.

Pseudocode 1: Locating route problems in TransCAD

```
function Dijkstra (Graph, start_node, end_node):
    distances = {}
    previous_nodes = {}
    unvisited_nodes = Graph
    for each node in Graph:
        distances[node] = infinity
        previous_nodes[node] = null
    distances[start_node] = 0
    while unvisited_nodes is not empty:
        current_node = node in unvisited_nodes with the smallest distance
        remove current_node from unvisited_nodes
        if current_node == end_node:
            break
        for each neighbor_node of current_node:
            if neighbor_node is in unvisited_nodes:
                tentative_distance = distances[current_node] + distance between current_node and neighbor_node
                if tentative_distance< distances[neighbor_node]:
                    distances[neighbor_node] = tentative_distance
                    previous_nodes[neighbor_node] = current_node
    shortest_path = []
    current_node = end_node
    while current_node is not null:
        shortest_path. prepend(current_node)
        current_node = previous_nodes[current_node]
    return shortest_path
```

2.1 The application of Trans CAD in the transportation route of logistics robots

The visual graph method is to make the connection between the robot and the target point, the vertex and the vertex of the polygonal obstacle body, so that the connection between the robot and the vertex of the obstacle, the endpoint, and the vertex become a visual graph. Since the vertices of any two lines are visible, all routes from the starting point to the ending point are conflict-free, and the optimal search method is used to find the minimum route. Its disadvantages are its poor flexibility, the view must be reconstructed when the endpoint obstacle or starting point is changed, and the calculation is more complex due to the increase in the number of obstacles. The simulated annealing algorithm proposed by Kirkpatrik et al in 1982 is an efficient approximation optimization algorithm. Its principle comes from the annealing of solid matter in physics. This method simplifies the optimal solution of the optimal problem to different states, approximates the objective function to the energy or essence of the material, and arranges the optimal solutions according to the state under the optimal conditions so that the optimal solution of the problem can be optimal. The simulated annealing method has the characteristics of simple operation, flexibility, and high efficiency, but it has the disadvantages of slow convergence speed, poor randomness, and instability. The effectiveness of the simulated annealing method depends on the parameter setting.

The artificial potential field method is a simulation calculation method formed according to the natural phenomenon of "water flowing downward". The basic idea of this algorithm is to transform the moving process of the robot on the map into the moving process of the robot in the virtual force field. In this process, the repulsive force of the obstacle and the starting point to the robot, and the attractive force of the ending point to the robot. The driving force together with the gravitational force affects the action of the robot transport, which makes it avoid obstacles and makes it reach the destination smoothly. The artificial potential field method is simple and practical, with real-time processing, mobile obstacles, easy to implement the bottom of the robot motion control, etc, but the traditional artificial potential field method still has many shortcomings, such as near the unrecognized obstacles area, easily in disorder shake in front of, in the narrow tunnel, etc.

Select locating route problem solutions using clonal screening algorithm:

The clonal screening algorithm's steps are described as follows.

Step 1: Let g be the number of generations and g = 0. Initialize the robots P(r). The number of route directions in P(d) is N.

Step 2: Calculate the affinity of each logistics robot in P(r), and sort all routes allocation in order according to their affinities.

Step 3: Each route in P(d) clones, and the number of clones for each robot is proportional to its affinity. N clones are generated to compose the transCAD Pc(t).

Step 4: Each clone in Pc(t) mutates. The mutation rate of each clone is inversely proportional to its affinity, i.e., a clone with a higher affinity will have a lower mutation rate. N mutated clones are produced to form logistics Pm(l).

Step 5: rp antibodies with the highest affinity are selected from P(r) and Pm(g) to compose the population S(g).

Step 6: N–ns randomly generated antibodies are added to S(g). Let P (g + 1) ←S(g), g←g + 1. Return to Step 2 until the stopping criterion is satisfied

Clone operation All antibodies are sorted according to their affinities. Each antibody clones and the clone probability of the ith antibody Abi is calculated by Affinity (Abi) N j=1 Affinity ———————————

Abj, i ∈ {1, 2, . . ., N}

2.2 Heuristic route planning method with optimization performance

The Dijkstra algorithm is a traditional method for resolving the shortest path issue using a single source. The Dijkstra algorithm suggests an iteration technique based on the length of the route's sequence. It is extensively utilized in several disciplines, including operating research, graph theory, data structures, and GIS search. The Dijkstra algorithm's primary principle is to create a root from a fixed beginning node in the tree structure, and then find the shortest path between each node and the root. In the classic Dijkstra algorithm, there is no negative weight between network nodes. The distance and nearby relationship determine whether to add a new node to the spanning tree. Dijkstra is a classical minimum route optimization method, which starts from the starting point, gradually extends to the final goal, and then uses the forward traversal of nodes to obtain the minimum route. The algorithm has a higher success rate and better robustness when the least paths are obtained. However, its shortcoming is that the algorithm must pass through multiple nodes to obtain the shortest path, so the search efficiency is low, the calculation is large, and it cannot effectively solve the inverse boundary problem.

The A* algorithm comprehensively evaluates the generation of each extended node and gives the corresponding heuristic functions. The algorithm compares each expansion node and expands until it reaches the target by choosing the node with the lowest cost. The advantage of A* is that its number of nodes is small, so the search speed is fast, the calculation is small, and it also has high real-time performance. The disadvantage is that in the actual movement, its size will be ignored.

The F1oyd method is also called the interpolation method. The central concept is to insert one or more intermediate points between two vertices and compare the lengths of the intermediate points that pass and those that do not. The specific implementation process is as follows: the path network is transformed into the weight of the weight matrix, and then the intermediate turning point method is used to solve the minimum distance between any node in the weight matrix. This method is easy to understand and suitable for calculating the minimum distance between two nodes. However, it is not suitable for large-scale calculation due to its large amount of calculation and high time complexity.

The constraints are divided into three aspects: station constraints, time constraints, and work constraints. The following is the analysis of the content of these three aspects.

Station restrictions: The work of each section is carried out in a specific section, and the section cannot carry out the processing of multiple sections at the same time.

Time limit: after the end of the previous process of the workpiece, the next process can be carried out, and the time point of the working process is set as the end time of the process, i.e

$$t_A(J_{ia}) < t_A(J_{ib}), a < b \tag{6}$$

The station must complete the previous processing task before it can proceed to the next processing task, i. e$T_1 T_2$

$$\{\forall t_A = a, \forall M_i \in M, \text{count } (T_{Mi}) \leq 1\} \tag{7}$$

The statistical function is represented by the count$(\cdot)$

The workpiece is not allowed to be transported by the robot before the process of the station is completed, i. e$W_i M J_{ij} R$

$$\forall t_A < t_A\big(J_{ij}\big), \forall R_i \in R, \text{count } (T_{Ri}) = 0 \tag{8}$$

Task constraints: complete all tasks and the same task cannot be executed repeatedly, i. eTT

$$\begin{gathered} \left\{T = \textstyle\bigcup_{i=1}^{n} T_i, T_i \cap T_j = \emptyset, \forall i, j \in \{1,2,\cdots,m\}, i \neq j\right\} \\ \textstyle\bigcup_{Ri \in R} T_{Ri} = T \\ \left\{T_i \cap T_j = \emptyset, \forall i \neq j \in R\right\} \end{gathered} \tag{9}$$

(III)Trans CAD limitation: all the work has been completed and the same Trans CAD cannot be further carried out, (or)there are two distinct approaches to route planning: the heuristic method and the conventional method. The classical route planning approach has better scalability and is appropriate for the theoretical study of road planning since it may be used for a range of map-carrying methods and because the challenges involved are more complicated. The heuristic path planning algorithm based on a two-dimensional grid graph usually uses a two-dimensional grid graph to solve, which makes full use of the basic elements of a two-dimensional grid: starting point, obstacle point, operable area, etc., so that it has higher speed and better practicability. Autonomous driving in the ROS system is implemented based on two methods: Dijkstra and A*.

The behavior planning level mainly completes the basic work of autonomous vehicle navigation, behavior planning, target monitoring, and avoidance. In this method, the perception layer is used to obtain the local map of the workshop, the global map, the robot perception information, and the transportation TransCAD information, to realize the localization and trajectory optimization of the robot in the FMS workshop. Based on the results of route planning, a corresponding sequence of actions is produced at the action planning level. To ensure the safety of TransCAD, a local route-based algorithm can be used for vehicle power avoidance.

The proposed method uses both sensing and action control methods. The sensor system includes laser ranging data collected by lidar, positioning data from the odometer, and data collected by the camera. The system can also initialize the collected information and can realize the mapping in the factory. The system operates on the data of the vehicle itself and the external data obtained by the sensors. For example, the motion parameters of the vehicle can be transmitted to the motor, to change the direction and speed of the vehicle.

To achieve the smooth operation of logistics distribution, the information interaction layer, task allocation layer, behavior planning layer, and perception layer four layers of hierarchical structure are used in the FMS to realize the perception and analysis of an unknown dynamic environment, as well as autonomous navigation, avoidance, and other functions. The behavior planning level mainly completes the basic work of autonomous vehicle navigation, behavior planning, target monitoring, and avoidance. In this method, the perception layer is used to obtain the local map of the workshop, the global map, the robot perception information, and the transportation Trans CAD information, to realize the localization and trajectory optimization of the robot in the FMS workshop. Based on the results of route planning, a corresponding sequence of actions is produced at the action planning level. To ensure the safety of TransCAD, a local route-based algorithm can be used for vehicle power avoidance.

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(I) Let the operation time of each station be, and the system duration is determined by the maximum station operation time.$t(x)$If the system persistence time is minimized, then the objective function is

$$\mathrm{m}\ g_1 = \mathrm{m}[\mathrm{m}\ (t(x))] \tag{10}$$

(II) Calculate the consumption of each robot to perform the transportation task, such that the maximum consumption of a single robot is minimized, then the objective function is$R$

$$\begin{gathered}\mathrm{m}\ g_2 = \mathrm{m}\{\mathrm{m}[f(R_1, T_{R1}), \cdots, f(R_n, T_{Rn})]\} \\ f(R_i, T_{Ri}) = \textstyle\sum_{h,k\in T_{Ri}} c_{hk}\end{gathered} \tag{11}$$

Where, is the consumption value of the robot moving from the target to the target along the planned path, which is positively correlated with the transportation time and can be represented by the transportation time $c_{hk}R_ihk$

(III) Let the total consumption value be, such that the total consumption of all robots is the least, then the objective function iscost (x)R

$$\mathrm{m}g_3 = \mathrm{mcost}\ (x) = \mathrm{m}\textstyle\sum_{R_i\in R} f(R_i, T_{Ri}) \tag{12}$$

Considering the above three optimization factors, the total objective function is

$$\mathrm{m}g = \mathrm{m}(C_1 g_1 + C_2 g_2 + C_3 g_3) \tag{13}$$

In the complex workshop logistics Trans CAD, there is obvious communication failure caused by system noise or equipment failure. This problem can be effectively solved by using a shared environment instead of a special communication link. Implicit communication is the use of sensing devices to collect and process the required data in the external environment, to realize the cooperation between multiple robots. Implicit communication includes perceptual communication and situational communication. Perception communication means that in the production process, the robot can sense the surrounding production situation, obtain the surrounding information, and understand and analyze the surrounding situation, to realize the response to various dynamics. Environment communication is when robots keep certain information in the surrounding environment. After sensing the surrounding environment, they can also get other data from other robots, to achieve the purpose of mutual communication. In dark communication, because there is no direct and trusted data exchange, it is impossible to use advanced cooperation methods to execute some complex commands.

Explicit communication and implicit communication are two kinds of communication, both of which have their advantages and disadvantages. By combining their respective advantages, they can adapt to various complex and changeable TransCAD in flexible production workshops. To this end, this paper studies multiple robots in FMS establishes a communication model of explicit and implicit communication, and uses implicit communication in small, high-level cooperation between multiple robot transportation. If there is a conflict that cannot be solved by implicit communication, explicit communication can be used to make minor adjustments. The combination of explicit communication and implicit communication can not only reduce the system consumption caused by a large number of explicit communications, but also reduce the irreconcil conflict caused by implicit communication, improve the efficiency of communication, and maintain the stability of the system.

3 Result analysis

Install Network Simulator 2 (NS-2) on Linux.NS-2 has good simulation performance and provides strong support for the simulation of TCP, routing, and multicast protocols. Since WLAN adopts IEEE802.11g standard, before NS-2 simulation software and development software of NS-2, we must first decide on our network environment. Since EEE802.11g has a data transfer rate of 54 Mbit/s, the simulation must be performed at a network speed of approximately 54 Mbit/s.

The communication delay performance of multi-robot transport in WLAN is affected by two aspects: the size of the robot transport and the communication load (in this paper, the load). Robot size refers to the number of robots in the whole system; Communication load is the length of the load contained in the data packets transmitted and received when the system is communicating.

First of all, in the NS - 2, set the number of machineries to 2,4,6,8,10,12.16,24,29,34,40,48 20 and 60. Next, we set the load value, because each wireless node has to establish a TCP connection and send the same frame length to each other, so we can set the load value separately. In real communication, heavy load and low load are two completely different situations, so they are divided again. Each small load value is set to 100

Bytes, 500 Bytes, 1000 Bytes 2000 Bytes; each group of large load values is set to 10 K, 50 K, 100 K, and 300 K bits.

By comparing and analyzing the communication efficiency of several DCF access methods, it is necessary to measure the basic access mechanism and the latency of the access mechanism. In the same case, the maximum delay was calculated using 10 separate simulation trials, and the average of the maximum delay was obtained. Two access methods are used to obtain the maximum time delay of multiple robot transportation under the limit of the number and load value of multiple robots, and then the mapping is carried out by these data. The maximum delay of the entire network is significantly influenced by the load's size, as evidenced by the variance in load values shown in Table 2, and Figure 1. The number of robots deployed and their respective load values have a considerable impact on the average maximum delay experienced by the system. The average maximum delay in milliseconds (ms) for the various settings is listed in the following Table 1. The findings point to a number of tendencies. First, the average maximum latency tends to rise for all load levels as the number of robots grows. This increase raises the possibility of resource contention or congestion as more robots for the same resources in the system. Secondly, there is a noticeable effect on load value. Increasing the load levels causes the average maximum delay to climb continuously. This result shows how much more work and time the system needs to process to accommodate larger loads. Furthermore, there isn't necessarily a linear relationship between the average maximum delay and the number of robots. In some circumstances, such as those with a moderate load value and a comparatively low number of robots, the increase in delay might not be as noticeable as it would be in circumstances with greater loads or more robots.

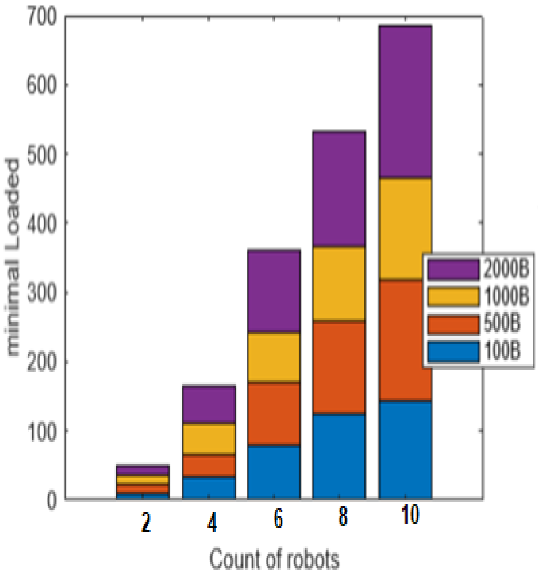

Figure 1: The maximum average delay

Table 2: The average maximum delay

Number of robots	Small load value			
	100B	500B	1000B	2000B
2	9.7	10.6	11.8	14.8
4	32.4	31.7	45.0	50.8
6	77.8	91.0	70.7	118.5
8	121.4	132.6	105.9	163.6
10	139.8	170.0	146.2	213.2

When the load is large, the average maximum delay of multiple robots will increase. When the load is very low, the average maximum delay of multiple robot transportation is also less. However, under the basic access mechanism, the load of 1000 Bytes has the best average maximum latency compared to the other three low load values. Through the above research, it is found that too large or too low a load will cause the robots to compete with each other, resulting in unfairness and increasing the overall delay.

The variation of the number of robots in transportation is studied, and it is found that the maximum time delay increases when the number of robots in transportation increases. Especially in the case of more than 50 units, due to the blocking phenomenon in the network, the delayed growth of the system becomes very slow, so the system cannot smoothly carry out the transmission of data, failing in information exchange. Eventually, a system of multiple robots will break down, making communication and cooperation impossible.

Assume that the robot's left wheel's linear velocity is and its right wheel's linear velocity is, the distance between the centroids of the two differential wheels be, and the linear and angular velocities of the whole robot person be and.$v_1 v_2 D v \omega$. According to the motion analysis of the differential wheel, the equation can be obtained.

$$\begin{aligned} v &= (v_1 + v_2)/2 \\ \omega &= (v_1 - v_2)/D \end{aligned} \tag{14}$$

At each rotation of the differential wheel, the total number of pulses that the encoder produces is indicated as, the left and right differential wheels' encoder increment in units of time is represented by, the angle that exists between the coordinate systems of the robot and the real environment is represented as, and the radius of the differential wheel is denoted as.$s_e \Delta t c_{e1} c_{e2} \theta r$ Subsequently, the formula is used to determine the robot's location coordinates in the world coordinate system and the total value of the encoder's accumulated angle in the world coordinate system's plane.

$$\begin{gathered} X_w = \int_0^t \Delta X_w \mathrm{d}t = \int_0^t (c_{e1} - c_{e2}) \cdot 2\pi r \cdot s_e^{-1} \cdot \cos(\theta) \mathrm{d}t \\ Y_w = \int_0^t \Delta Y_w \mathrm{d}t = \int_0^t (c_{e1} - c_{e2}) \cdot 2\pi r \cdot s_e^{-1} \cdot \sin(\theta) \mathrm{d}t \\ \beta = \int_0^t \Delta\beta \mathrm{d}t = \int_0^t (c_{e1} - c_{e2}) \cdot 2\pi r \cdot s_e^{-1} \cdot D^{-1} \mathrm{d}t \end{gathered} \tag{15}$$

The odometry information of the robot during motion can be represented by a three-dimensional vector.

Compared with the basic access mode, RTS/CTS access mode can effectively improve the system delay performance. Under low load conditions, using basic access technology can significantly reduce the average maximum latency and speed up the system response. Although the RTS/CTS access mechanism can reduce the collision between multiple robot transports, it will increase the load of the system at a low load. Therefore, basic access is a better access mode than RTS/CTS under low-load conditions. So, for the size of the load, a limit must be set. When the load exceeds the limit, the RTS/CTS access mode is adopted. When the load is below the limit, the basic access mechanism is adopted. To improve the delay of multi-robot communication, appropriate constraint values can be selected according to the scale of multi-robots, communication requirements, communication load, and other factors in WLAN.The type of detecting technology, vehicle speed, road width, and application-specific requirements are some of the variables that affect the separation distance for traffic and road lane detection. Figure 2 shows the comparison of Traffic Detection and Road Lane Detection.

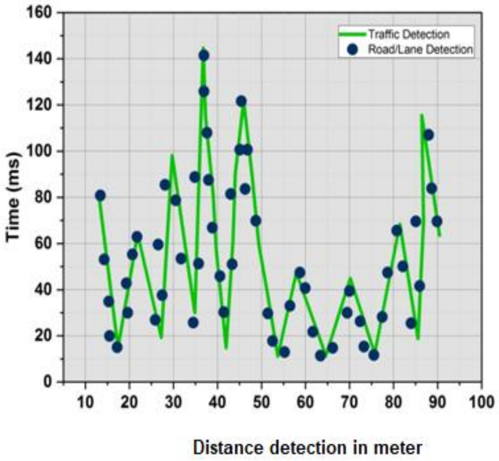

Figure 2: Comparison of traffic detection and road lane detection

3.1 Traffic detection

The Traffic Detection system has impressive accuracy, with rates that ranging from 85% to 95%, under a variety of traffic density and illumination situations. With delays, ranging from 100 to 300 milliseconds, depending on the intricacy of traffic patterns and the processing capacity of the installed hardware, the system demonstrates effective reaction times in terms of latency. However, the traffic detection system consistently maintains a low false positive rate, with an average of 5% to 10% of cases. This demonstrates how consistently the system can distinguish moving items from background noise and identify images.

3.2 Road lane detection

The Road Lane Detection system has strong accuracy levels, with rates ranging from 90% to 98% under a variety of weather and road conditions. With reaction times ranging from 150 to 400 milliseconds, the Road Lane Detection system, however, has a larger latency than the Traffic Detection system. The complexity of lane marker detection and tracking, particularly in dynamic situations, might be blamed for this delay. The false positive rate for the Road Lane Detection system is slightly greater than that of Traffic Detection, averaging between 7% and 12%, although being typically low. This suggests that non-lane characteristics may occasionally be mistaken for lane markings, which may affect driver assistance systems that depend on this information.

The findings highlight the intricate trade-offs that are present in road lane detection and traffic detection systems amongst accuracy, latency, and false positive rates. However, each device operates higher in certain respects than others, maximizing its effectiveness necessitates employing a balanced approach to elements including hardware capabilities, algorithmic complexity, and environmental randomness.

Overall performance of an algorithm:

In this part, the existing algorithm's results were compared with the application of logistics robot in the solution of locating route problems in TransCAD. Here, approaches like Convolutional Neural Network (CNN)[20], simultaneous localization and mapping (SLAM) [17], and Proposed method are evaluated using performance metrics including accuracy, precision and recall as shown in Table 3.

Table 3: The value of performance metrics compared with existing and proposed methods

Algorithm	Performance metrics		
	Accuracy (%)	Precision (%)	Recall (%)
CNN	78.8	77.2	78.3
SLAM	83.7	82.1	83.2
Proposed Method	98.5	97.8	98.2

The proposed Algorithm outperforms the logistics robots using the route problem in transCAD. Figure 3 shows as the algorithm achieves accuracies of CNN as 78.8%, SLAM as 83.7%, and the proposed model achieves the highest 98.5% its shows the scalability and adaptability over real-time data.

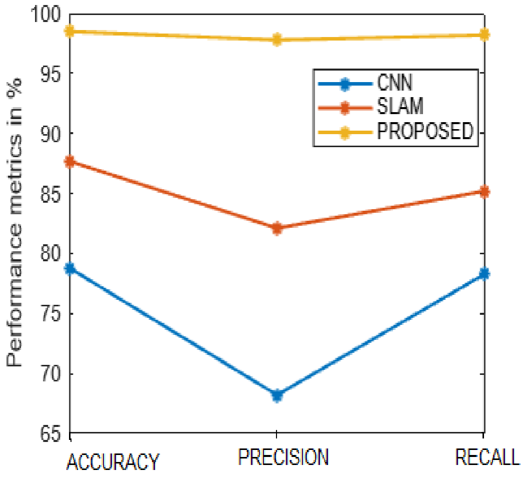

Figure 3: Outcome of the performance metrics with accuracy , precision and recall.

3.3 Discussion

A well-known tool for transportation planning, TransCAD offers efficient network analysis, visualisation, and optimisation features. By combining logistics robots with TransCAD, route planning may be enhanced and several problems facing the logistics sector can be fixed. TransCAD route optimisation can benefit from the data provided by logistics robots equipped with sensors and real-time data transfer capabilities. TransCAD can dynamically adjust routes in response to changing conditions because to the robots' capacity to collect data on weather patterns, traffic congestion, and road conditions. By taking into account these environment space details and making use of TransCAD's capabilities, logistics planners can improve the effectiveness and efficiency of logistics operations by optimising delivery routes, resolving route issues, and integrating logistics robots into the route planning process. Given the complexity and dynamic nature of the proposed system, which employs logistics robots to resolve TransCAD route identification problems, factors pertaining to data security, stakeholder relations, technology, law, and the physical environment must be carefully taken into account. TransCAD users may fully utilise the potential of logistics robots to increase transit efficiency, design routes more effectively, and promote long-term growth in the logistics industry by properly navigating and managing this environment region. To use the logistics robots inside the TransCAD framework, a substantial upfront investment is required for their acquisition and integration with the current TransCAD systems. In order to develop scalable, intelligent logistics solutions that satisfy the shifting needs of modern transportation logistics, future research into the use of logistics robots to resolve route location issues in TransCAD will need to concentrate on continuous innovation, integrating cutting-edge technologies, and cooperating across interdisciplinary domains.The suggested method's efficiency is demonstrated by the following findings: recall is 98.2%, accuracy is 98.5%, and precision is 97.8%.

4 Conclusion

In this study, the architecture and communication mechanism of multi-robot transportation in FMS are discussed in detail, and a clone selection algorithm of Trans CAD allocation and sorting based on WLAN is proposed. The main contents of this paper are as follows: the cooperative trans-CAD in intelligent production trans-CAD is realized by using a multi-robot transportation hierarchical four-level mechanism and multi-robot transportation hybrid mechanism; the communication performance of multiple mobile communication systems can be effectively improved by integrating the communication mode with the implicit communication mode and the CIS model with the P2P model. Through the simulation of IEEE802.11g WLAN multi-robot transport communication system, starting from the number of multiple robots and communication load two parameters, through the research of MAC basic access and RTS/CTS access mechanism, select the shortest access mode in various circumstances. On this basis, the grid graph is constructed by using the movement of multiple robots the simulation of the surroundings, and SLAM technology. To overcome the diagonal motion problem which is ignored by the general route planning method, A new A* method is presented in this paper. The findings demonstrate that, in the current scheduling scenario, the suggested method can lower the overall cost of multiple robots by 18.20% and the cost of multiple robots by 16.32% when compared to the traditional Manhattan distance A* method. A significant upfront expenditure is needed to purchase the logistics robots and integrate them with the current TransCAD systems to use them inside the TransCAD framework.Future research into the use of logistics robots to solve route location issues in TransCAD will need to focus on ongoing innovation, integrating cutting-edge technologies, and collaborating across interdisciplinary domains to create scalable, intelligent logistics solutions that meet the changing demands of contemporary transportation logistics.

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