Volume 20 Number 3 September 1996 ISSN 0350-5596

Informatica

An International Journal of Computing and Informatics

Profile: S. Alagić
Fuzzy Modal Logic for Information Retrieval
Limitations of Intelligent Systems
Another Look at Computability
Journal of Consciousness Studies

The Slovene Society Informatika, Ljubljana, Slovenia

Informatica **20** (1996) Number 3, pp. 291–418

Informatica

An International Journal of Computing and Informatics

Basic info about Informatica and back issues may be FTP'ed from ftp.arnes.si in magazines/informatica ID: anonymous PASSWORD: <*your mail address*>
FTP archive may be also accessed with WWW (worldwide web) clients with
URL: http://www2.ijs.si/~mezi/informatica.html

Subscription Information Informatica (ISSN 0350-5596) is published four times a year in Spring, Summer, Autumn, and Winter (4 issues per year) by the Slovene Society Informatika, Vožarski pot 12, 61000 Ljubljana, Slovenia.
The subscription rate for 1996 (Volume 20) is
- DEM 50 (US$ 35) for institutions,
- DEM 25 (US$ 17) for individuals, and
- DEM 10 (US$ 7) for students

plus the mail charge DEM 10 (US$ 7).
Claims for missing issues will be honored free of charge within six months after the publication date of the issue.

LaTeX Tech. Support: Borut Žnidar, DALCOM d.o.o., Stegne 27, 61000 Ljubljana, Slovenia.
Lectorship: Fergus F. Smith, AMIDAS d.o.o., Cankarjevo nabrežje 11, Ljubljana, Slovenia.
Printed by Biro M, d.o.o., Žibertova 1, 61000 Ljubljana, Slovenia.

Orders for subscription may be placed by telephone or fax using any major credit card. Please call Mr. R. Murn, Jožef Stefan Institute: Tel (+386) 61 1773 900, Fax (+386) 61 219 385, or use the bank account number 900–27620–5159/4 Ljubljanska banka d.d. Slovenia (LB 50101-678-51841 for domestic subscribers only).

According to the opinion of the Ministry for Informing (number 23/216-92 of March 27, 1992), the scientific journal Informatica is a product of informative matter (point 13 of the tariff number 3), for which the tax of traffic amounts to 5%.

Informatica is published in cooperation with the following societies (and contact persons):
Robotics Society of Slovenia (Jadran Lenarčič)
Slovene Society for Pattern Recognition (Franjo Pernuš)
Slovenian Artificial Intelligence Society (Matjaž Gams)
Slovenian Society of Mathematicians, Physicists and Astronomers (Bojan Mohar)
Automatic Control Society of Slovenia (Borut Zupančič)
Slovenian Association of Technical and Natural Sciences (Janez Peklenik)

Informatica is surveyed by: AI and Robotic Abstracts, AI References, ACM Computing Surveys, Applied Science & Techn. Index, COMPENDEX*PLUS, Computer ASAP, Cur. Cont. & Comp. & Math. Sear., Engineering Index, INSPEC, Mathematical Reviews, Sociological Abstracts, Uncover, Zentralblatt für Mathematik, Linguistics and Language Behaviour Abstracts, Cybernetica Newsletter

The issuing of the Informatica journal is financially supported by the Ministry for Science and Technology, Slovenska 50, 61000 Ljubljana, Slovenia.

PROFILES

This issue of *Informatica* presents a profile of *Professor Suad Alagić*, a computer science researcher and educator of international reputation. He was born in Bosnia, and accomplished much of his professional success working at the University of Sarajevo.

Suad Alagić has been a member of the Editorial Board of *Informatica* since 1988 when the younger generation of the Yugoslav computer scientists came to the professional surface. That made it possible for *Informatica* to pursue a course toward becoming an international journal. At that time Suad Alagić was already the most distinguished "computer scientist" (in the traditional sense of the word) not only in Bosnia & Herzegovina, but in the former Yugoslavia as well.

Suad Alagić's international publishing activity, research, and lecturing work has been closely connected with Springer-Verlag, the publisher of three of his books (The Design of Well-Structured and Correct Programs, Relational Database Technology and Object-Oriented Database Programming). He also published in major international Computer Science journals such as Journal of Computer and System Sciences, Information Systems Journal, Computer Journal, Acta Informatica, Transactions on Information and Systems, and Theoretical Computer Science. He had numerous papers at international conferences. Many of them have been published in Springer's Lecture Notes in Computer Science. He has had research grants from NSF, U.S. Department of Defense, and industry. His biographical sketch appeared in several recent editions of Marquis Who's Who in the World, Who's Who in Science and Engineering, and Who's Who in Finance and Industry.

His Ph.D. work at the University of Massachusetts under supervision of Professor Arbib had a decisive influence on his career. Michael A. Arbib was one of the most influential computer scientists in the world at that time. The type of education and exposure that Suad Alagić had while at the University of Massachusetts made it possible for him to meet for many years the highest professional standards of Computer Science excellence. The reader will find plenty of evidence for these strong statements in the references in the curriculum vitae that follows.

I (the Editor of this profile) can speak about Suad Alagić international standing from my personal experience based on my visit to Japan in 1985[1]. When I visited the Institute for New Generation Computer Technology—ICOT (Mita Kusakai Building in Tokyo, on November 11, 1985), Dr. K. Furukawa, the vice president, told me that I am the second person from Yugoslavia to whom permission for visiting ICOT was given: the first one was Suad Alagić. At that time the restrictions for a visit to ICOT were really rigorous, especially for visitors of the Eastern European countries. But Alagić's book "The Design of Well-Structured and Correct Programs" (co-authored with M.A. Arbib) was already translated into Japanese, and in wide use at Japanese universities.

But along with his professional achievements and international recognition *Suad Alagić* belongs to those rare researchers and scholars in Computer Science who experienced the drama of the civil war in the former Yugoslavia. In the war Suad Alagić lost almost everything he worked for many years of professional activity in Sarajevo. Suad Alagić was a professor at the University in Sarajevo, where he lectured on some of the most propulsive fields of computer science at that time (databases, programming languages and programming methodology). He held several important positions at his university, most notably those of Chair of the Department of Computer Science and Informatics, and Pro-rector for Science and Technology of the University of Sarajevo.

When the civil war in the former Yugoslavia finally moved to Bosnia & Herzegovina, Suad Alagić was on a visiting appointment at the University of Vermont. His wife and their two children were with him as well. This was an exceptionally fortunate accident. They did not expect the tragedy that subsequently happened in their home city. They suffered the loss of everything they had in their home in the Sarajevo suburb of Grbavica. The same unfortunate destiny was shared by Suad's department in Sarajevo. His parents, his sister, and his closest friends survived the tragedy.

[1]The aim and the success of the visit was exhaustively described in A.P. Železnikar: *From Sapporo to Tokyo, Back to Ljubljana.* Informatica **10** No. 2: 68–74 (in Slovene).

Although Suad Alagić and his closest family were not in Sarajevo during the war, the experience of helplessly watching the destruction of Sarajevo on the American television was deeply traumatic for him and his family. Those traumas are not likely to ever go away.

The resume that follows provides information on how Suad Alagić continued his successful career in the United States, while hoping be able to provide in the near future yet another contribution to the academic life in his field in Sarajevo.

The profile of Professor

Suad Alagić

which follows is dedicated to the memory of the circumstances in which this unusual individual worked and contributed to the core of Computer Science. Our hope is that such individual careers will again be possible in the Balkans after a period of peaceful life and cooperation of closely related cultures and neighbors.

Current Position

Professor, Department of Computer Science, Wichita State University, Wichita, Kansas 67260-0083.
Phone: (316) 689 3916.
Email: alagic@cs.twsu.edu.

Research Areas

Object-Oriented Systems, Database Systems, and Programming Languages and Systems.

Education:

—*Postdoctoral Fellow*: Department of Computer Science, *University of Edinburgh*, 1977.

—*Ph.D.*: Department of Computer and Information Science, *University of Massachusetts* at Amherst, 1974.

—*M.Sc.*: Department of Computer and Information Science, *University of Massachusetts* at Amherst, 1972.

—*B.Sc.*: Diploma in Electrical Engineering, Department of Control Systems, Faculty of Electrical Engineering, *University of Sarajevo*, 1970.

Books:

—S. Alagić: *Object-Oriented Database Programming.* Springer-Verlag. New York, 1988.

—S. Alagić: *Relational Database Technology.* Springer-Verlag. New York, 1986.

—S.Alagić & M.A. Arbib: *The Design of Well-Structured and Correct Programs.* Springer-Verlag. New York, 1978, 1980. *Translations*: Japanese (1980), Russian (1984), Polish (1983).

Papers published in:

—*Journal of Computer and Systems Sciences,*
—*Information Systems Journal,*
—*Computer Journal,*
—*Acta Informatica,*
—*Transactions on Information and Systems,*
—*Theoretical Computer Science,*
—*Lecture Notes in Computer Science*, etc.

Grants from DOD, NSF and industry.

Biographical sketch in recent editions of:

—*Marquis Who's Who in the World.*
—*Marquis Who's Who in Science and Engineering.*
—*Marquis Who's Who in Finance and Industry.*

Academic Career:

—1993–...: Professor. Department of Computer Science. **Wichita State University**.

—1995, 1996: Faculty Fellow. National Institute for Aviation Research.

—1993–1994: Chair. Department of Computer Science. *Wichita State University.*

—1991–1993: Visiting Faculty. Department of Computer Science and Electrical Engineering. **University of Vermont.**

—1986–1991: Professor. Department of Computer Science and Informatics. ETF—Faculty of Electrical Engineering. *University of Sarajevo.*

—1989–1991: Chairman of ETF.

—1989–1991: Vice-Rector for Science and Technology. **University of Sarajevo.**

—1985: Visiting Researcher. Department of Information Science and Electronics. *University of Tsukuba, Japan.*

—1983–1987: Research Associate. Institute of Computer and Control Systems, Sarajevo.

—1980–1986: Associate Professor.

—1975–1980: Assistant Professor. Department of Computer Science and Informatics. ETF—Faculty of Electrical Engineering. *University of Sarajevo.*

—1977: Postdoctoral Fellow. Department of Computer Science. *University of Edinburgh.*

—1971–1974: Graduate Research Assistant. Department of Computer and Information Science. *University of Massachusetts* at Amherst.

Research

—Object-Oriented Database Technology and Database Programming Languages

The initial research in the area of the object-oriented database technology was mainly related to the design and implementation of Modulex, a database programming environment supporting multiple paradigms (object-oriented and relational in particular). The associated publications are the book Object-Oriented Database Programming and the papers Object-Oriented Database Programming Environment Based on Modula-2, Persistent Meta-Objects and Toward Multiparadigm Database Interfaces.

Applications of the developed technology have been in the area of production management systems and spatial data management with the associated publications: Object-Oriented Geo-Information Processing in Modulex and Advanced Database Programming Languages: A Geo-Information Processing Prospective.

—Database Type Systems

The follow-up research was largely devoted to further developments of the strongly typed database technology with the goal to introduce high-degrees of polymorphism, a sophisticated meta-level support, polymorphic facilities based on kinds (of types), higher-order polymorphism and reflection. The associated publications are: Generic Modules, Kinds and Polymorphism for Modula-2, Joins as Pullbacks, Polymorphic and Reflective Type Structures, tutorial publication: Objects, Modules, Kinds and Reflection in Database Programming Environments, Integrating Inheritance, Subtype and Parametric Polymorphism in Database Type Systems, Object-oriented Type Evolution Using Reflection, Type-Safe Linguistic Reflection: A Generator Technology, Polymorphic and Reflective Type Structures, Duality in Object-Oriented Type Systems, Inheritance Versus Subtyping: Conflict or Duality and F-bounded Polymorphism for Database Programming Languages. An overview of the key issues in these papers is presented in the tutorial Object-Oriented Type Systems.

—Typed Logic-Based Object-Oriented Technology

Further developments are reflected in the most recent collection of papers (Declarative Object-Oriented Programming: Inheritance, Subtyping and Prototyping, A Typed Object-Oriented Database Technology with Deductive and Reflective Capabilities, Expressibility of Typed Logic Paradigms for Object-Oriented Databases, Typed Declarative Object-Oriented Database Programming, A Temporal Object-Oriented Language System with Logic-based Executable Specifications, A Typed and Temporal Object-Oriented Database Technology). These papers deal with a logic-based, typed object-oriented technology. A variety of logic paradigms are explored as a basis for declarative object-oriented languages, prototyping tools and a strongly typed object-oriented database technology.

—Relational Database Technology

The work on the integration of database and programming languages and systems (Relational Pascal Database Interface, Relational Pascal Database Programming Environment, Relational Pascal Model of Soil Database) produced a complete, relational, strongly typed, multi-user database programming environment including a high-level, non-procedural definition, query, manipulation and control language, transaction support, dynamic indices, concurrency control and recovery. The system was in actual commercial use at some ten sites.

The research visit to Japan included presentation of the above work in a number of research institutions involved in the projects of the new generation of computer systems (ETL (Electrotechnical Laboratory), Tokyo University, Tsukuba University, NEC Research Laboratory, Hitachi Systems Laboratory, NTT Computer and Communications Laboratory) as well as a visit to ICOT (Tokyo Institute for the New Generation of Computer Systems).

The integration of the major published results on the relational database technology together with the results in developing a specific, strongly typed relational database technology in the quoted research and development projects have been presented in the book Relational Database Technology.

— Programming Languages and Programming Methodology

Most recent results are in the area of declarative and temporal object-oriented programming, reflected in recent submissions (A Temporal Constraint System for Object-Oriented Databases, Temporal Object-Oriented Programming). But the deepest recent formal results are on the model theory of a temporal constraint language (Order-Sorted Model Theory for Temporal Executable Specifications).

Earlier work, starting with the Ph.D. dissertation (Algebraic Aspects of Programming and Formal Languages) and the follow-up papers (Natural State Transformations, Categorical Theory of Tree Processing) dealt with the categorical approach to some problems in formal language theory (tree transformations) and programming languages (abstract data types).

The first book co-authored with Michael A. Arbib (The Design of Well-Structured and Correct Programs) and related papers (such as Proof Rules for Gotos with M. A. Arbib) belong to the area of programming methodology based on the axiomatic approach (Hoare's logic) and formal verification of program correctness. The research visit to Edinburgh was largely devoted to the related problems.

Grants

— DOD (Army Research Office) Research Grant (1996-1999): *A Typed and Temporal Object-Oriented Technology.*

— DOD Defense University Research Instrumentation Grant (1994-1995): *Integrated Object-Oriented Environment for Modeling; Simulation, Prototyping and Active Databases.*

— NSF Research Grant: *Extended Relational Database Programming Environment.*

— USA-Yugoslav Joint Board for Scientific and Technological Co-operation; Industrial Grant: *Design and Implementation of a Relational Database Management System for a 32-bit Microcomputer.*

— Research grants — Scientific Community of Bosnia and Herzegovina:
Relational Pascal Database Management System; Conceptual Modeling; Relational Technology in Production Management Systems; New Database Technologies; Information Technologies; and Mathematical Aspects of Programming Languages.

Recent Lab Development Work

Object-Oriented Research Lab, DOD Grant, 1994-1995. This is a lab based on SUN, SGI and NCD equipment running a variety of object-oriented systems (C++ and Eiffel compilers, two object-oriented database management systems (ODE and O2) and one object-oriented storage manager (BESS)).

International Consulting — Environmental Databases

Most of it has been done for UNEP — United Nations Environment Program in the capacity of a database expert for the following UNEP projects:

GRID—General Resource Information Database (London, England; Nairobi, Kenya; and Geneva, Switzerland). MAP—Integrated Data System for the Mediterranean Action Plan (Athens, Greece; Sophia Antipolis, France; and La Valleta, Malta). HEM—Harmonization of Environmental Measurements Design of the HEM Metadatabase (Munich, Germany).

The technical problems involved belong to the design of large scale databases (and their metadatabases) with non-standard types (spatial and temporal).

Teaching Activities

Undergraduate courses taught:
Object-Oriented Programming in C++; Introduction to Database Technology; Programming Languages, Concepts of Programming Languages; Database Design, Data Structures; Systems Programming, Programming Methodology; Theory of Algorithms and Automata; and Mathematical Foundation of Computer and Information Science.

Graduate courses taught: Object-Oriented Systems, Object-Oriented Databases, Advanced Topics in Database Systems, Compiler Construction, and Relational Database Technology.

Ph.D. students: Four of them received their degrees so far.

Theses Ph.D. Dissertation: Algebraic Aspects of Programming and Formal Languages, directed by Michael A. Arbib.
M.Sc. Project: Semantics of Algorithmic Languages, directed by Michael A. Arbib.
B.Sc. Diploma Thesis: Regular Languages.

Recent Program Committee Memberships

Software Quality Management, SQM '95, '96.
Extending Database Technology, EDBT '88, International Conference, Venice 1988.
EDBT 92, International Conference, Vienna 1992 .
International Workshop on Foundation of Data Models and Languages, Aigen, Austria, 1991.
TOOLS 91; Technology of Object-Oriented Languages and Systems, International Conference, Paris, 1991.
International Conference on Logical Methods and Tools in Conceptual Design of Information Systems, Nantes, France 1989.

Publications

Books

S. Alagić, **Object-Oriented Database Programming**, Springer-Verlag, New York, 1988.

S. Alagić, **Relational Database Technology**, Springer-Verlag, New York, 1986.

S.Alagić, M.A. Arbib, **The Design of Well-Structured and Correct Programs**, Springer-Verlag, New York, 1978, 1980.

Translations:

Japanese: Kagaku-Gijyutsu, Tokyo, 1980.
Russian: Radio i Svjaz, Moscow, 1984.
Polish: Wydawnictawa Naukowo-Technicze, Warsaw, 1983.

Selected Papers

S. Alagić, A typed and temporal object-oriented database technology, *IEICE Transactions on Information and Systems*, Vol. 78, 1995.

S. Alagić, G. Nagati, J. Hutchinson and D. Ellis, Object-oriented flight simulator technology, Proceedings of AIAA Conference, 1996.

S. Alagić and M. Alagić, Order-sorted model theory for temporal executable specifications, *Theoretical Computer Science*, to appear.

S. Alagić, A temporal constraint system for object-oriented databases, Workshop on Constraints and Databases, Constraint Programming Conference, 1996.

S. Alagić, Flight simulator database: Object- oriented design and implementation, In: A. Chaudhri and M. Loomis, *Object-Oriented Databases* (tentative title), to appear.

S. Alagić, R. Sunderraman and A. Radiya, A Typed declarative object-oriented database programming, In: V. S. Alagar and R. Missaoui, *Object Orientation in Databases and Software Engineering*, World Scientific, 1995.

S. Alagić, R. Sunderraman and R. Bagai, Declarative object-oriented programming: inheritance, subtyping and prototyping, Proceedings of the European Conference on Object-Oriented Programming – ECOOP '94, *Lecture Notes in Computer Science*, Vol. 821, Springer-Verlag, 1994.

S. Alagić and R. Sunderraman, Expressibility of typed logic paradigms for object-oriented databases, Proceedings of the 12th British National Database Conference, BNCOD-12, *Lecture Notes in Computer Science*, Vol. 826, Springer-Verlag, 1994.

S. Alagić, R. Sunderraman and R. Bagai, A typed

object-oriented database technology with deductive and reflective capabilities, Proceedings of the International Symposium on Advanced Database Technologies and Their Integration, ADTI '94, Nara, Japan, 1994.

M. Surendhar and S. Alagić, Object-oriented type evolution using reflection. Proceedings of TOOLS EUROPE '94 (Technology of Object-Oriented Languages and Systems), Paris 1994, Prentice-Hall.

R. Bagai, S. Alagić and R. Sunderraman, A prototyping technology for typed object-oriented software development, Proceedings of the Second International Conference on Software Quality Management, Computational Mechanics, Edinburgh, 1994.

S. Alagić, F-bounded polymorphism for database programming languages, Proceedings of the Second East/West Database Workshop, Linz, Austria, *Workshops in Computing*, Springer-Verlag, 1994.

S. Alagić and A. Radiya, A temporal object-oriented language system with logic-based executable specifications, ECOOP 1994 Workshop: Logical Foundations of Object-Oriented Programming, 1994.

S. Alagić, Duality in object-oriented type systems (abstract), Proceedings of the Workshop on Combining Declarative and Object-Oriented Databases, Washington, D.C., 1993.

S. Alagić and D. Stemple, Inheritance versus subtyping: conflict or duality (abstract), The Fourth International Workshop on Database Programming Languages, New York, 1993.

S. Alagić, Algol 68. A.Ralston and E.D. Reilly (eds.): *Encyclopedia of Computer Science*, Van Nostrand Reinhold, New York, 1976. Second edition 1984. Third edition 1993.

S. Alagić, Polymorphic algorithms for strongly typed relational database operators (abstract), Midwestern Conference on Combinatorics, Cryptography and Computing, 1993.

S. Alagić, Polymorphic and reflective type structures. Proceedings of the International Conference on the Technology of Object-Oriented Languages and Systems, TOOLS USA '92, Santa Barbara, 1992.

S. Alagić, Integrating inheritance, subtype and parametric polymorphism in database type systems, Proceedings of ICSC '92, Second International Computer Science Conference, Data and Knowledge Engineering: Theory and Practice, Hong Kong, 1992.

D. Stemple, R.B. Stanton, T. Sheard, P. Philbrow, R. Morrison, G.N.C. Kirby, L. Fegaras, R.L. Cooper, R.C.H. Connor, M.P. Atkinson and S. Alagić, Type – safe linguistic reflection: A generator technology, Research Report CS/92/6, Department of Mathematical and Computational Sciences, University of St Andrews, Scotland, 1992.

S. Alagić, Persistent metaobjects. In: A. Dearle, G.M. Shaw and S. B. Zdonik (Eds): *Implementing Persistent Object Bases: Principles and Practice*, Proceedings of the Fourth International Symposium on Persistent Object Systems, Walter Kaufman Publishers, 1991.

S. Alagić, Toward multiparadigm database interfaces, In: J.W. Schmidt and A. A. Stogny (eds): Next Generation of Information Systems Technology, Proceedings of the First International East/West Workshop, Kiev, 1990, *Lecture Notes in Computer Science*, Vol. 503, Springer- Verlag, 1991.

S. Alagić, Generic modules, kinds and polymorphism for Modula-2, Proceedings of the Second International Modula-2 Conference, Loughborough, England, 1991.

S. Alagić and M. Alagić, Joins as pullbacks, Proceedings of the Third International Workshop on Foundation of Data Models and Languages, Aigen, Austria, 1991.

S. Alagić and Z. Galić, Object-oriented geo-information processing in Modulex, TOOLS '90, Technology of Object- Oriented Languages and Systems, Proceedings of the Second International Conference, Paris, 1990.

S. Alagić and Z. Galić, Advanced database programming languages: Geo-information processing prospective, Proceedings of CIPS '90, Edmonton, Canada, 1990.

S. Alagić, D. Jurković and M. Kandić, Object-oriented database programming environment based on Modula-2, Proceedings of the First International Modula-2 Conference, 1989.

S. Alagić, M. Kandić and N. Krdzalić, Object-oriented versus conventional database methods and tools, Proceedings of the Third International Conference: Pratique des metodes et outils logiciels d'aide a la conception de systemes d'information, Nantes, France, 1989.

M. Alagić, S. Alagić, Categorical approach to the relational model of data, Journal Informatica 3/1987, Ljubljana.

S. Alagić, Integrated Data System for the Mediterranean Action Plan, United Nations Environment Programme, Athens, 1984.

S. Alagić et al., Relational Pascal model of soil database. Proceeding of the ISS Working Conference on Soil Information Systems Technology, Oslo, 1983, PUDOC, Wageningen, Holland, 1984.

S. Alagić, Database Considerations: A Structural View, Report on GEMS, United Nations Environment Program, London 1983.

S. Alagić and A. Kulenović, Relational Pascal database interface, *The Computer Journal*, Vol. 24. Heyden Son, 1981.

M. A. Arbib, S. Alagić, Proof rules for gotos, *Acta Informatica* 11, 1979, Springer-Verlag.

S. Alagić, On proofs of correctness of well-structured programs, I and II. Journal Matematicki Vesnik, Belgrade, Yugoslavia 1978.

S. Alagić at al., A hierarchical host language system based on B -trees, Proceedings of the Annual Congress AICA, Pisa, Italy, 1977.

S. Alagić, A. Kulenović and M. Sarajlić, Structured extension of Cobol for handling data bases, *Information Systems Journal*, 1976, Pergamon Press.

S. Alagić, Cleaning up unstructured algorithms using invariants, Journal Informatica, Ljubljana, Yugoslavia, 1977.

S. Alagić, Natural state transformations, *Journal of Computer and System Sciences*, 1975, Academic Press.

S. Alagić, Categorical theory of tree processing. Proceedings of the First International Symposium: Category Theory Applied to Computation and Control. San Francisco, 1974, *Lecture Notes in Computer Science*, Vol.25, Springer Verlag, 1975.

S. Alagić, M. A. Arbib and R. W. Taylor, Algebraic models of syntax, semantics and data structures. Computer and Information Science Technical Report, University of Massachusetts, Amherst 1974.

S. Alagić, Algebraic aspects of Algol 68, Computer and Information Science Technical Report 73B-5, University of Massachusetts, Amherst 1973.

Recent submissions

S. Alagić, Temporal object-oriented programming, submitted to a journal, 1995.

Tutorials

S. Alagić, Object-Oriented Type Systems, Tutorial, 8th International Conference on the Technology of Object-Oriented Languages and Systems, TOOLS USA '92, Santa Barbara, 1992.

S. Alagić, Objects, modules, kinds and reflection in database management systems, TOOLS '91, International Conference: Technology of Object-Oriented Languages and Systems, Paris, 1991 (Invited Seminar: Object-Oriented Databases).

Reference manuals

S. Alagić et al., EQUAL: Language Specification and Application Guide, Technical Publication, Institute of Control and Computer Science, Sarajevo, 1985.

S. Alagić et al., PASCAL/E: Language Specification and Application Guide, Technical Publication, Institute of Control and Computer Science, Sarajevo, 1985.

Other Papers

S. Alagić, Categorical analysis of Algol 68, Proceedings of the Symposium Informatica 74, Bled, Yugoslavia, 1974.

S. Alagić, Mathematical foundation of programming languages, Proceedings of the Symposium Informatica 74, Yugoslavia, Bled, 1974.

S. Alagić, A. Kulenović and M. Sarajlić, A Structured extension of Cobol for handling data bases, Proceedings of the Symposium Informatica, Bled, 1975.

S. Alagić, A modest host language system, Proceedings of the Symposium Computer at the University, 1974, Zagreb, Yugoslavia.

S. Alagić, Structured programming and program proving. Proceedings of the Symposium Informatica 75, invited paper, Bled, Yugoslavia, 1975.

S. Alagić et al., Implementing hierarchies of sets using B-trees. Proceedings of the Symposium Informatica 77, Bled, 1977.

S. Alagić et al., On strategies for implementing data structure sets, Proceedings of the Symposium Informatica 77, Bled, 1977.

S. Alagić et al., A relational storage system based on B -trees, Proceedings of the Symposium Informatica 78, Bled.

S. Alagić et al., Implementing CODASYL-type sets using B - trees, VIth Congress of the Balkan Mathematicians, Varna, Bulgaria, 1977.

S. Alagić et al., Manipulating hierarchical databases, Journal Informatica, Ljubljana, Yugoslavia, 1978.

S. Alagić, Developments in programming methodology, invited paper, Proceedings of the Symposium Informatica, Jahorina, Yugoslavia, 1978.

S. Alagić et al., Implementation of binary relational statements and operators in Pascal-R, Technical Report, Faculty of Electrical Engineering, Sarajevo.

A. Kulenović and S. Alagić, Implementation of relational expressions and assignment statements in a Pascal/R system, Proceedings of the Symposium Informatica, Ljubljana, 1982.

S. Alagić, Introducing relational systems in the assembly of products applications, Technical Publication, Research Community of Bosnia and Herzegovina, Sarajevo, 1984.

S. Alagić, An approach to the design of information systems supported by database systems, Proceedings of the Symposium Informatica, Jahorina, Yugoslavia, 1986.

S. Alagić, Spatial data modeling, Proceedings of the Symposium Informatica, Jahorina, Yugoslavia, 1986.

S. Alagić, Conceptual versus relational modeling, invited paper, Proceedings of the Computer at the University Conference, Cavtat, Yugoslavia, 1986.

S. Alagić, Object-oriented database programming in a relational environment extended with modules, Technical Report, Software Development Laboratory, Faculty of Electrical Engineering, University of Sarajevo, 1988.

S. Alagić, Conceptual modeling: the arrow-theoretic perspective, Technical Report, Software Development Laboratory, Faculty of Electrical Engineering, University of Sarajevo, 1988.

S. Alagić et al. Relational systems in production management systems, Journal of Technology, Science and Engineering, 32, Sarajevo, 1989.

S. Alagić, MODULEX: A multiparadigm approach to database management, Technical Report, Software Development Laboratory, Faculty of Electrical Engineering, University of Sarajevo, 1989.

S. Alagić, Integrating relational and object - oriented databases: A multiparadigm approach, Technical Report, 1989.

S. Alagić and M. Alagić, Integrating data models by heterogeneous algebras, Technical Report, 1990.

S. Alagić and N. Krdzalić, Generic low-level strongly-typed support for large scale persistent objects, Technical Report, Software Development Laboratory, Faculty of Electrical Engineering, University of Sarajevo, 1991.

Other Books (in Serbo-Croatian)

S. Alagić, Relational Databases, Svjetlost, Sarajevo, 1984.

S. Alagić, Principles of Programming, Svjetlost, Sarajevo, 1976.

Edited by *Anton P. Železnikar*

Using Fuzzy Modal Logic for Inferential Information Retrieval

Jian-Yun Nie and Martin Brisebois

Departement d'Informatique et Recherche operationnelle
Universite de Montreal
C.P. 6128, succursale Centre-ville
Montreal, Quebec
H3C 3J7 Canada

E-mail: {nie,brisebois}@iro.umontreal.ca

Keywords: Information retrieval, fuzzy modal logic, uncertainty handling

Edited by: Xindong Wu

Received: May 9, 1995 **Revised:** May 17, 1996 **Accepted:** June 7, 1996

Information Retrieval is becoming more and more important due to the information explosion. However, most existing systems only use simple keyword matching to identify relevant documents, resulting in unsatisfactory system performances. Recent approaches to IR dig into the inference process in order to solve this problem. Most of them are investigated within a probabilistic framework. The strict formalism of probability theory often confines our use of knowledge to only statistical knowledge (e.g. term connections based on their co-occurrences). Richer human-defined knowledge (e.g. manual thesauri) has not been incorporated successfully. In this paper, we consider the fuzzy modal logic framework in the definition of our inferential model. A document description is associated to a fuzzy world. Inference is based on the fuzzy accessibility relations between worlds. Due to the flexibility of the fuzzy logic framework, human-defined knowledge may be incorporated into our system. We report our experiments on a test corpus using a general manual thesaurus. It is shown that human-defined knowledge, when adapted to the application area and used adequately, leads to great improvements in system's performances.

1 Introduction

The goal of an Information Retrieval (IR) system is to select the documents relevant to a given information need out of a document database. The present information explosion increases the importance of this area. We are often faced with the problem of finding out relevant information from a huge information mass. Traditional approaches to IR use direct keyword matching between document and query representations in order to select relevant documents. The most critical point goes as follows: if a document is described by a keyword different from those given in a query, then the document cannot be selected although it may be highly related. This situation often occurs in real cases as documents are written and sought by different persons.

In recent work, there is common agreement that more adequate relevance estimation should be based on *inference* rather than direct keyword matching [9, 25, 43, 41]. That is, the relevance relationship between a document and a query should be inferred using available knowledge. This inference, however, cannot be performed with complete certainty as in classical logic due to the uncertainty inherent in the concept of relevance: one often cannot determine with complete certainty whether a document is relevant or not. In IR, uncertainty is always associated to the inference process.

In order to deal with this uncertainty, probability theory has been a commonly used tool in IR [1, 14, 26, 42, 34]. Probabilistic models usually attempt to determine the relationship between a document and a query through a set of terms which are considered as features. Differences between probabilistic models often lie into the connections considered among the terms [14]. Within any of these models, simplifying independence assumptions have always been made about these connections and some of them are inconsistent [8]. Although simplifications facilitate the implementation, they do not correspond to the user's inference process. For example, within the Binary-independent model, terms are assumed to be completely independent. In reality, they are not.

In order to bring the inference process closer to the user's one, more flexible inference such as that in logic should be used in an IR model. Indeed, inference is above all a logical operation. The logical component seems to be diluted in previous models which place much emphasis on the treatment of uncertainty. The framework required for inference in IR would combine a logic with an appropriate handling of uncertainty [34]. The definition of such a framework is the first goal of our study.

Within the strict probabilistic framework, inferential approaches are often confined to using only statistical relations among terms. Two different methods have been used to extract such knowledge automatically:

- by considering term co-occurrences in the document collection [33]. In this case, two terms which often co-occur are considered strongly related.
- by considering user relevance feedback [16, 21]. If two documents are judged relevant simultaneously by a user, then it is considered that there is some relation between the terms of the two documents.

Both methods suffer from poor recovery of the application area. This problem stands out particularly in the second approach based solely on relevance feedback because availability of relevance feedback information is often limited in practice. Relevance feedback only allows to revise a small part of relations among terms. In the first approach, relations obtained from statistics may be very different from the genuine relations: truly connected terms may be overlooked [38] whereas truly independent terms may be put in relation [31].

There is still a third group of term relations used in IR: those established by human experts in some application areas. These relations are often stored in a thesaurus. Due to the lack of strict quantitative measurement of such relations, it is difficult to use them in probabilistic models. However, with the recent development of large thesauri (for example, Wordnet [27]), these relations have quite a good coverage of application areas. A manual thesaurus is then a valuable source of *knowledge* for IR. Thus another goal of this study is to provide a flexible model in which human-defined knowledge can easily be incorporated.

This paper is organized as follows. We briefly review previous work on inferential IR and thesaurus-based approaches in Section 2. Section 3 describes our inferential approach within a fuzzy modal logic framework. This approach is derived from a general idea suggested by van Rijsbergen in [43]. Two alternative approaches are proposed to replace the initial idea of van Rijsbergen, and thus make it more feasible. We then describe, in Section 4, our method of adapting a manual thesaurus for our fuzzy inferential approach. Section 5 comments some experimental results. Finally, concluding remarks are given in Section 6.

2 Previous work on inferential and thesaurus-based IR

A lot of research has been conducted in both inferential and thesaurus-based retrieval. Although they are closely related, they represent two different aspects: the former emphasizes methodology of the document-query comparison while the latter tries to implement a given approach using a thesaurus.

2.1 Inferential retrieval

Inferential approaches have usually been defined in a probabilistic perspective. One of the earliest attempts is to add a term dependence tree in a probabilistic model [42]. This endows the model with more inferential power in comparison with the previous Binary-independent model. A document is considered to be relevant (to some extent) if the requirements of a given query may be inferred from the document through the term dependence tree. However, the inferential power in this model is limited.

More recently, Bayesian networks [30] have been used in IR with great success [41]. This method is based on a pre-established inferential structure, divided into several layers (document, concept, term, query and information need). Elements in one layer may be connected (with a certain probability) to the elements of adjacent layers, but no connection is allowed among elements from the same layer. Two operations are important in this approach: the inference of the relationship between the documents and a given information need, and the revision of the connections established in the structure according to user relevance feedback. The former is a forward probability propagation and the latter a backward probability revision. Although Bayesian networks are able to incorporate quite complex relations, the assumption of independence among elements of the same layer is still too strong. For instance, for the term layer, the independence assumption implies that, for the model to correspond completely to the reality, one has to determine a set of *elementary* terms that are independent of each other. In practice, this assumption is difficult to be satisfied.

There are also attempts to develop a suitable logic for information retrieval coping with inference. The idea proposed by van Rijsbergen [43, 44] has attracted wide attention. It suggests that relevance is indeed a non-classical logical implication: given a document and a query represented by logical sentences d and q, the relevance of the document to the query may be expressed as the implication $d \rightarrow q$ which is different from the material implication $d \supset q$. As $d \rightarrow q$ is uncertain in general, a function $P(d \rightarrow q)$ should be defined to measure the degree of certainty of $d \rightarrow q$. Van Rijsbergen proposes the following *uncertainty principle* guiding the definition of P:

> Given any two sentences x and y; a measure of the uncertainty of $y \rightarrow x$ relative to a given data set, is determined by the minimal extent to which we have to add information to the data set, to establish the truth of $y \rightarrow x$.

It has been shown [29] that, by giving an adequate definition of the evaluation of $P(d \rightarrow q)$, most existing IR models may be generated from the above idea. Nevertheless, the adequate general definition of $P(d \rightarrow q)$ is still an issue.

Wong and Yao [48] try to implement this idea in a more concrete model. They abandon the possible-world semantics suggested by van Rijsbergen, and propose a probabilistic inference instead. However, the logical component becomes diluted as in other probabilistic approaches and the flexibility in inference is much restricted.

Our present work is based on the same general idea, but we will stay within a logical framework for higher inference flexibility.

2.2 Constructing and using thesauri

Thesauri used in IR may be divided into two categories according to their construction: automatically or manually constructed. The former are usually based on statistics on word (co-)occurrences. While this kind of thesaurus may help users to some extent, their utilization in early systems shows that their impact on the global effectiveness is limited [39]. The reason for this is twofold. First, real relations (e.g. synonymy) can hardly be identified statistically. In fact, words very similar in meaning tend to repulse from each other in continuous portions of text [38]. For example, "document retrieval", "text retrieval" and "information retrieval" are rarely used simultaneously. Second, as users are likely to formulate their queries using common words, a statistical thesaurus will expand these queries with other highly frequent terms. These latter have a low discrimination power of relevant documents, similar to the original terms. Expanding a query by adding those terms with the highest co-occurrence frequency may not bring much more new information to it [31]. Even though one restrains the consideration of term co-occurrences within some syntactic contexts (e.g. noun phrases) [15, 18, 19], system performance only benefits marginally [15].

Recent work pays more and more attention to manually constructed thesauri. Initial experiments have been conducted using the vector space model [11, 12]. Related terms were simply added to the query vector according to a weighting factor. By the end of the 1980s, interest increased in manually constructed thesauri. They began were seen as semantic networks in which it was possible to use the *spreading activation* technique to measure similarity between queries and documents [7, 35]. Initiated by Rada [32], a great deal of efforts have been spent in defining a IR suited metric over semantic networks [5, 20, 23, 24]. All these models measure the similarity between two terms mainly according to the topography of the thesaurus (the number and length of links). Moreover, they often consider only "is-a" relations. Two problems may occur in these systems. First, the estimation of the strength of term connections which is based heavily (if not only) on the use of thesaurus topography may fail to reflect the real strength of the connections. This strength also depends on the nature of the relations between them which affects their relevance to some application area. Second, the metrics used to measure term connection are often symmetric: for a metric m, we have $m(a,b) = m(b,a)$ for any pair of terms a and b. This property is obviously counterintuitive. For example, a document about *object-oriented languages* should be more relevant to a query on *programming languages* than in the reverse situation.

Thesaurus-based query evaluation gained in popularity because large general thesauri became available. The use of such a thesaurus in IR has been recently studied by Voorhees [45, 46]. She used the thesaurus Wordnet [27] for query expansion in an IR system based on a vector space model. However, her attempts yield a negative conclusion: when a query is expanded using Wordnet, retrieval performances suffer. In our opinion, these results are due to her particular use of the thesaurus.

1. As Wordnet is a general thesaurus, a relation may lead to either a relevant term or an irrelevant one with respect to the application area. It is then necessary to determine and measure the relevance of the related term before using it in query expansion. A coarse measurement may lead to a complete failure.

2. The vector space model seems inappropriate for this kind of query expansion. In fact, when a related term is added to a query vector, the corresponding sense is artificially enhanced because it is represented several times in the new vector. The enhanced senses are not the ones which are judged important by the user, but those which are involved in many thesaurus relations.

3 Modeling the inferential approach in a fuzzy modal logic framework

Since the late 1980s, several new approaches have been developed in order to base query evaluation on inference [6, 9, 25, 43, 44, 41]. However, only a few theoretical frameworks suggested allow the unification of different approaches in a single formalism. The idea suggested by van Rijsbergen [43, 44] is one of them.

In order to develop a general approach, we adopt the idea of van Rijsbergen. This section will show how the idea may be modified in order to facilitate its implementation. Then the suggested approach will be modeled using fuzzy modal logic. Finally, some implementation aspects will be considered.

3.1 Rationale

Let us first re-express the uncertainty principle of van Rijsbergen as a formula. We identify a document description d as y in the uncertainty principle, a query expression q as x, and the knowledge of the system K as the data set. By knowledge, we mean a set of (weighted) term relations. Applying the uncertainty principle to IR means that relevance should be estimated as the degree of certainty of the following expression:

$$K \models d \rightarrow q$$

Let us denote the degree of certainty of this formula by the function $P_K(d \rightarrow q)$. Suppose there is a function $Ext(K, K')$ which measures the amount of extension from K to K', and a function F which determines the corresponding degree of certainty for an extension amount. Then according to van Rijsbergen, the uncertainty of $K \models d \rightarrow q$ should be determined by the minimal $Ext(K, K')$ such that $K' \models d \rightarrow q$ becomes true i.e.:

$$P_K(d \rightarrow q) = F(inf[Ext(K, K') : K' \models d \rightarrow q])$$

or

$$P_K(d \rightarrow q) = sup[F(Ext(K, K') : K' \models d \rightarrow q)]$$

Although most existing IR models may be re-expressed in terms of the uncertainty principle by a proper definition of the functions *Ext* and F [29], the above formulation is difficult to implement in practice due to the following two facts. First, changes must be made on the system's knowledge K and these changes must be measured in terms of degree of certainty. To do this requires the definition of meta-knowledge handling such changes, which is an extremely difficult task. Second, this formulation still requires the complete satisfaction of $K' \models d \rightarrow q$. In practice, this criterion is almost never met.

In order to transform this general idea into an inferential approach which is easier to implement, we suggest the following two alternative approaches based on modifications of d and q respectively:

Approach 1 In order to estimate the degree of certainty of $K \models d \rightarrow q$, we must identify all the document descriptions d' related to d. The degree of certainty of $K \models d \rightarrow q$ is determined by both the degree of relatedness of d' to d and the degree of certainty of $K \models d' \rightarrow q$ for all the d's.

Approach 2 In order to estimate the degree of certainty of $K \models d \rightarrow q$, we must identify all the query expressions q' related to q. The degree of certainty of $K \models d \rightarrow q$ is determined by both the degree of relatedness of q' to q and the degree of certainty of $K \models d \rightarrow q'$ for all the q's.

As these approaches are based on modifications of the document or the query descriptions respectively, we call them document-driven and query-driven approaches. The two approaches are very similar. So we will base our explanation on the document-driven approach.

In fact, the document-driven approach can also be derived from the following classical inference:

$$(A \supset B) \wedge (B \supset C) \models A \supset C$$

Putting the uncertainty aspect aside, we can expect the following corresponding inference in IR:

$$(d \rightarrow d') \wedge (d' \rightarrow q) \models d \rightarrow q$$

If there are several such d', then we have:

$$\bigvee((d \rightarrow d'_i) \wedge (d'_i \rightarrow q)) \models d \rightarrow q$$

That is, whenever we have a d'_i such that $d \rightarrow d'_i$ and $d'_i \rightarrow q$, then we can conclude $d \rightarrow q$.

Considering the uncertainty involved, the degree of certainty of the left side in the above inference is a good estimate of that of the right side. That is

$$P(d \rightarrow q) = P\left[\bigvee_i ((d \rightarrow d'_i) \wedge (d'_i \rightarrow q))\right]$$

In this study, we consider P as a fuzzy function. In fuzzy contexts, following [10], conjunctions and disjunctions should be evaluated by a triangular norm Δ and its co-norm ∇ respectively.

A triangular norm Δ is a function from $[0,1] \times [0,1]$ to $[0,1]$ that satisfies the following conditions (where $x, x', y, y', z \in [0,1]$):

1. $\Delta(x,y) = \Delta(y,x)$;
2. $\Delta(x, \Delta(y,z)) = \Delta((\Delta(x,y),z)$;
3. If $x \le x'$ and $y \le y'$, then $\Delta(x,y) \le \Delta(x',y')$

The *min* function and multiplication of real numbers are two examples of triangular norm. A co-norm ∇ is defined as:

$$\nabla(x,y) = 1 - \Delta[(1-x),(1-y)].$$

The *max* function is the co-norm of *min*, and $x + y - xy$ is the co-norm of multiplication of real numbers.

Using a triangular norm Δ and its co-norm ∇ in our case, the degree of certainty of $P(d \rightarrow q)$ may be then evaluated as follows:

$$\begin{aligned} P(d \rightarrow q) &= \nabla_i ((d \rightarrow d'_i) \wedge (d'_i \rightarrow q)) \\ &= \nabla_i (\Delta(P(d \rightarrow d'_i), P(d'_i \rightarrow q))) \quad (1) \end{aligned}$$

The two implications found in the right side of formula (1) may be interpreted in the following way:

- $P(d \rightarrow d')$ measures the *degree of relatedness* of a new document description d' to d.
- $P(d' \rightarrow q)$ measures the *satisfiability* of the query q by the new document description d'.

Note that up to now, we have assumed that both the document description d and the query expression q are classical-logic expressions. In fact, although queries are often expressed as Boolean expressions of terms, documents are usually described as a set of weighted terms as follows:

$$\{(p_1, \alpha_1), (p_2, \alpha_2), \ldots, (p_n, \alpha_n)\}$$

where p_i is a term and α_i its weight in the document. If we consider a term as corresponding to a proposition, a query expression corresponds to a Boolean logical expression, but a document description does not. In this context, it is difficult to evaluate directly $P(d \to d')$ for two sets of weighted propositions. One alternative is to define a fuzzy degree of relatedness between the sets d and d' to replace $P(d \to d')$. Yet another solution is to consider a document description as corresponding to a fuzzy world in fuzzy modal logic [37, 49]. The relatedness between two document descriptions can then be modeled as the degree of *accessibility* between their corresponding worlds. This is the approach we take.

3.2 A logical model for inferential IR

Fuzzy modal logic has been first proposed by Schotch [37] and later elaborated by Ying [49]. The main idea underlying this logic is to fuzzify both the characteristic function of a world and the accessibility relation between worlds.

Let $\mathbb{P}$ be a a set of atomic propositions, $\mathbb{F}$ be the language of the classical modal logic [4], and $\mathbb{W}$ be a non-empty set of worlds in the (modified) possible-world semantics.

1. Each world $w \in \mathbb{W}$ is assigned a characteristic function $C : \mathbb{W} \to [0,1]^{\mathbb{P}}$ such that $C_p(w)$ gives the fuzzy truth value of atomic proposition p in world w.

2. The function $\delta : (\mathbb{W} \times \mathbb{W}) \to [0,1]$ is defined in order to measure the fuzzy degree of accessibility from one world to another. This function is reflexive, i.e. $\delta(w,w) = 1$ for any $w \in \mathbb{W}$.

A *model* of the fuzzy modal logic, which is slightly generalized from that in [49], is defined by the triple $(\mathbb{W}, \delta, V)$, where $V : \mathbb{F} \to [0,1]^{\mathbb{W}}$ assigns a truth valuation function $V_w(\bullet)$ to each world $w \in \mathbb{W}$. The function V_w gives each formula a fuzzy value as follows:

- $V_w(p) = C_p(w)$, $p \in \mathbb{P}$;
- $V_w(A \wedge B) = \Delta[V_w(A), V_w(B)]$;
- $V_w(\neg A) = 1 - V_w(A)$;
- $V_w(\Diamond A) = \bigtriangledown_{w \in \mathbb{W}} \Delta[\delta(w,w'), V_{w'}(A)]$.

Note that the evaluation for operators $\vee$ and $\Box$ may be obtained using the following definitions:

$$A \vee B =_{\text{def}} \neg(\neg A \wedge \neg B)$$
$$\Box A =_{\text{def}} \neg\Diamond\neg A$$

To compare the above evaluation with $V_w(\Diamond A)$ and $P(d \to q)$ in formula (1), we can observe the following analogy between d and w, between d' and w', between $P(d \to d')$ and $\delta(w,w')$, and between $P(d' \to q)$ and $V_{w'}(A)$. This analogy strongly suggests that $V_{w_d}(\Diamond q)$ may suitably models $P(d \to q)$ if we could determine a world w_d giving the same evaluation of propositions as d. The identification of such a world will be described in Section 3.3. For the moment, let us assume such a world and see how the model can be applied to IR.

Note that the evaluation modeled by $V_{w_d}(\Diamond q)$ allows only one step of inference, i.e. only the document description directly related to the initial one is considered. This restriction prevents from establishing a connection between a document described by "database" and a query on "natural science" because (at least) two inference steps are required: from "database" to "computer science" and from "computer science" to "natural science". In order to allow longer inference, document relevance should be modeled as

$$V_{w_d}(\Diamond\Diamond q)$$
$$V_{w_d}(\Diamond\Diamond\Diamond q)$$
$$\vdots$$
$$V_{w_d}(\Diamond^n q)$$

which correspond respectively to inference lengths 2, 3, ..., and n. A longer inference process implies the examination of more potential document-query matchings, thus allows the system to consider the documents that are more loosely related to the query. So a longer inference process means a wider range of document examination, thus a higher inferential power. This, however, is beneficial only when the knowledge (term connections) used in the inference is sound.

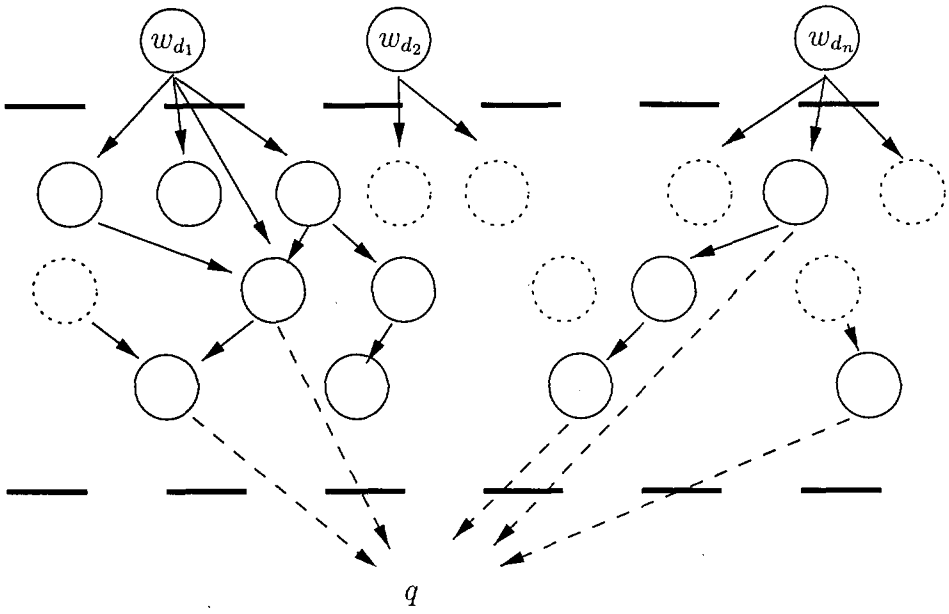


Figure 1: A general inference structure. (In this figure, reflexive derivations are not shown. An arrow indicates a derivation, and a dotted arrow indicates a direct evaluation of the query.)

Otherwise, such an inference would lead to the retrieval of many irrelevant documents. This will be shown in our experiments.

The inference process over all the documents in the collection may be seen in a way similar to that of the Bayesian network model [41] (Figure 1). There are three different layers in our system: at the top level, there are initial document descriptions, each corresponding to a world in fuzzy possible-world semantics. The bottom layer is the query layer. Between them lies the inference layer from which new worlds are derived and connected to the initial ones. Any initial document description from which a connection may be established with the query through the inference layer is a potentially relevant document.

There is an important difference between the Bayesian network approach and ours. In the Bayesian network approach, the inference layer is further divided into two sub layers: term layer and concept layer. Each of them contains elements (terms or concepts) that are assumed to be independent. Connections can only be established from terms to concepts. We can make the following two remarks on this approach.

1. The independence assumption for elements from the same layer is not realistic: Documents cannot be represented by a set of independent terms or concepts. Terms, as well as concepts, are inter-dependent in most application areas.

2. Inference from a document to a query in this approach is limited to three steps: from documents to terms, from terms to concepts, and from concepts to queries. In our approach, we do not make the independence assumption on the elements within the inference layer, nor do we limit inference length to 3. Within the inference layer, worlds can freely connect to each other, provided that the connection is allowed by the system's knowledge and it is within the inference length under consideration.

We can also compare our approach with previous IR models based on fuzzy set theory [3, 22, 33, 47]. These latter are often based on a direct fuzzy matching between documents and queries. They can be easily described in our model by withdrawing the inference process, i.e. they indeed correspond to $V_{w_d}(q)$. In some cases, a fuzzy thesaurus is also incorporated, but only used for matching a document term directly with a query term. This is equivalent to adding an inference layer between documents and queries which contains independent nodes. It can still be considered as a limited case of our model (i.e. $V_{w_d}(\Diamond q)$).

The goal of using fuzzy modal logic is to provide a suitable framework to describe the inferential approach. We do not intend to develop the logic from a formal point of view. For this, one can refer to [37, 49]. We are concerned with the question of how the inferential approach modeled here can be implemented in practice (in particular, by incorporating human-defined thesaurus as the system's knowledge). To accomplish such an implementation, two problems must be solved:

1. the determination of the world w_d which corresponds to a document description d;

2. the determination of the related worlds and the fuzzy relation d between the worlds.

We will deal with these problems in the following section.

3.3 Applying the model to IR

We will use a derivational approach to define $\mathbb{W}$ from the model: a subset of $\mathbb{W}$ corresponding to the initial document descriptions is first defined, and other worlds are derived from them.

The world w_d

In IR, a document is usually described by a set of weighted terms. This result is obtained through an indexing process. In previous fuzzy logic approaches [3, 2, 22, 28, 47], each term is considered to be atomic proposition. In addition, a term which does not occur in a document description is assumed to have a weight of 0 in this document. We make the same hypothesis here. For example, suppose a document is described as follows:

$$\{(p_1, \alpha_1), (p_2, \alpha_2), \ldots, (p_n, \alpha_n)\}$$

where p_i is a proposition (or term) and α_i its weight in the document. Then the propositions p_1, p_2, ..., p_n have the truth values α_1, α_2, ..., α_n respectively, and other propositions absent from this document is assumed to have fuzzy truth value 0.

It follows that the truth value of every atomic proposition is determined within a document description. This means that a document description uniquely determines a fuzzy world w_d which is associated with a characteristic function such that:

$$C_p(w_d) = \begin{cases} \alpha_p & \text{if } p \text{ is weighted } \alpha_p \text{ in } d; \\ 0 & \text{if } p \text{ is absent in } d \end{cases}$$

Given a set of document descriptions, each pertaining to a document in the collection, we can then establish a set of worlds in fuzzy modal logic. We will call these worlds the initial worlds. From the initial worlds, we can derive other worlds by applying domain knowledge. We will see how the derivation may be made.

The function δ

The principle of the derivation goes as follows: From a world w in which a proposition A is asserted to some extent, if another proposition B is related to A to some extent, then the proposition B may be inferred with a degree of certainty, and the addition of the inferred proposition leads to a possible world w'.

This process is very similar to reasoning under uncertainty in fuzzy logic in which uncertain inference is made possible due to the generalized Modus Ponens [10, 50]. An inference rule that we can derive from the generalized Modus Ponens is the following ($\alpha, \beta \in [0,1]$):

$$\frac{\alpha A,\ A \supset_\beta B}{\Delta(\alpha, \beta) B}$$

where αA means "A is true to extent α", and $A \supset_\beta B$ means "$A \supset B$ is true to extent β". The rule may be read: from the uncertain fact αA and the uncertain implication (or knowledge) $A \supset_\beta B$ follows the conclusion $\Delta(\alpha,\beta)B$(i.e. B may be asserted to extent $\Delta(\alpha,\beta)$).

Note that this inference is done in complete certainty although both the fact and the knowledge used as well as the conclusion are uncertain. The problem with this inference rule is that it does not tolerate the use of inconsistent pieces of knowledge. For example, from αA and $A \supset_\beta B$, we may conclude $\Delta(\alpha,\beta)B$; while at the same time, from αA and $A \supset_{\beta'} \neg B$, we can also conclude $\Delta(\alpha,\beta')\neg B$ which may contradict $\Delta(\alpha,\beta)B$. This inconsistency occurs within human-defined knowledge [40] which may contain both $A \supset_\beta B$ and $\Delta(\alpha,\beta')\neg B$. In order to allow the use of weighted or loosely defined knowledge in our inference, we make use of the following fuzzy inference rule instead:

$$\frac{\alpha A, A \supset_\beta B}{\alpha B}\beta$$

where both α and β are within $[0,1]$. This rule says that given the uncertain fact αA and the uncertain implication relation $A \supset_\beta B$, we can infer the uncertain conclusion αB, but the inference itself is certain only to extent β. In this rule, we distinguish the role of a piece of knowledge from that of a fact: an uncertainty on the former affects the validity of the entire inference process while an uncertainty on the latter only affects the certainty of the conclusion.

Applying the new inference rule to our model, we can obtain the following derivation of new worlds and the definition of the function δ. Given a world w in which a proposition p has the truth value α_p and a piece of knowledge $(p \supset_\beta p')$, adding the conclusion $\alpha_p p'$ leads to another world w' in which the truth value of proposition p' is modified to α_p, and the accessibility of w' from w is:

$$\delta(w, w') = \beta$$

Here we only consider propositional modal systems. Thus, from a given world, there must be a finite number of derivations, since we have finitely many propositions. The set $\mathbb{W}$ of worlds is finite.

We can see therefore that the whole approach is based on a set of knowledge represented as fuzzy logical implications (e.g. $p \supset_\beta p'$). The definition of a knowledge set is a crucial problem. We will discuss this problem in detail in Section 4. For the moment, we assume that such a knowledge set is available.

Let us now illustrate world derivation and query evaluation by an example. Suppose that we have five atomic propositions a, b, c, d, and e, and that the initial world w_0 is as shown in Figure 2. Suppose further that we have the following uncertain implication relations in our system: $(a \supset_{\beta_{ac}} c)$, $(b \supset_{\beta_{bd}} d)$ and $(c \supset_{\beta_{ce}} e)$. We can derive the worlds w_1 and w_2 by applying the inference rules using the first two relations. From these worlds, more new worlds are derived, as shown in the figure. The accessibility between the worlds is also illustrated in the figure. For example:

$$\delta(w_0, w_1) = \delta(w_2, w_3) = \beta_{ac}$$

In addition, we have implicitly $\delta(w_i, w_i) = 1$, for any i.

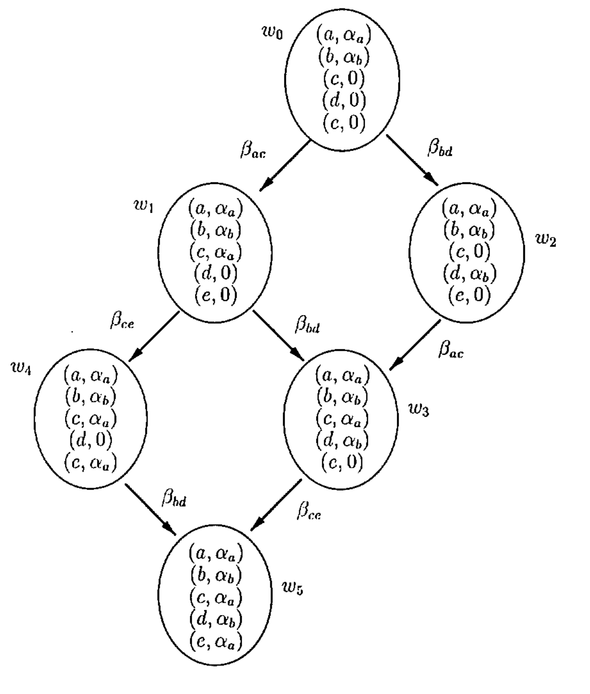


Figure 2: An example of derivation of new worlds. (The accessibility from a world to itself is not shown in this figure.)

Given a sentence $q_1 = (b \wedge c)$, the truth value of q_1 in the possible worlds accessible from w_0 is as follows:

$$\begin{aligned} V_{w_0}(q_1) &= V_{w_2}(q_1) = 0 \\ V_{w_1}(q_1) &= \Delta(V_{w_1}(b), V_{w_1}(c)) = \Delta(\alpha_a, \alpha_b) \end{aligned}$$

So we have the following evaluation of $\Diamond q_1$ in the world w_0:

$$\begin{aligned} V_{w_0}(\Diamond q_1) &= \nabla_{w' \in \{w_0, w_1, w_2\}} [\Delta(\delta(w_0, w'), V_{w'}(q_1))] \\ &= \nabla[0,\ \Delta(\beta_{ac}, \Delta(\alpha_a, \alpha_b)),\ 0] \\ &= \Delta(\beta_{ac}, \alpha_a, \alpha_b) \end{aligned}$$

Now using the same calculation, if we have another sentence $q_2 = (b \wedge e)$, the evaluation of $V_{w_0}(\Diamond q_2)$ will be 0, because in any world directly accessible from w_0, e is valued to 0. However, $V_{w_0}(\Diamond\Diamond q_2)$ has a non-zero value due to w_4:

$$\begin{aligned} V_{w_0}(\Diamond\Diamond q_2) &= \Delta(\beta_{ac}, \Delta[\beta_{ce}, \Delta(\alpha_a, \alpha_b)]) \\ &= \Delta(\beta_{ac}, \beta_{ce}, \alpha_a, \alpha_b) \end{aligned}$$

This second example shows that with a longer inference, more "distant" but "related" documents may be retrieved. Note that both the distance and the relatedness are dependent on the knowledge incorporated in the system. If the incorporated knowledge consists off all and only genuine knowledge in the application area, they are conceptual distance and relatedness. In practice, this is not the case. Nevertheless, we can still expect that the distance and the relatedness are coherent with their conceptual counterparts.

Document-driven vs. query-driven

It is easy to understand the document-driven approach in the modal logic model. A document description corresponds to a world. Any change in the document description using uncertain knowledge defined in the system derives to another document description. Given a query expression q, its evaluation relative to a document described by d is determined by the evaluation of q in all the descriptions accessible from (related to) d, on one hand, and the degree of accessibility of these descriptions from d, on the other.

It is more difficult to describe the query-driven approach in the modal logic model. Instead, query-driven approach may be seen as follows. The query language is extended by allowing weighted propositions. A weighted expression p^β is intended to capture the uncertain relevance between a proposition and another related one. A weighted proposition p^β is evaluated as follows:

$$V_w(p^\beta) = \Delta(\beta, V_w(p)).$$

We make use of this expression in query modification in the following way. Consider a query expressed as a logical sentence q in which proposition p appears. If the system contains the implication relation ($p_1 \supset_\beta p$), i.e. p is implied by p_1 to the extent β, then the proposition p in q can be expanded to ($p \vee p_1^\beta$). This latter expression indicates that to satisfy the proposition p, we can either satisfy p directly, or we can satisfy p_1 instead. However, in the second case, the satisfaction of the initial proposition p is moderated by the extent β to which the two propositions are related. The expansion process is to be applied to any proposition in a query. Longer expansion implies also expansion with respect to the added propositions. For example, if the added proposition p_1^β is to be expanded using the relation $p_2 \supset_{\beta_2} p_1$, then the expanded form is: $p_1^{\beta_1} \vee p_2^{\Delta(\beta_1,\beta_2)}$.

Following such expansions, the query expression q' obtained is to be evaluated relative to an initial document description d (or in the corresponding world w_d) in order to estimate the relevance of the document.

The above query-driven approach is equivalent to the document-driven approach when the inference length is sufficiently high. Indeed, when there is a new proposition added to the query, it is equivalent to take into account a new possible world in a document-driven approach. If the inference length is high enough, then all the possible worlds related to the initial world will be taken into account in the document-driven approach. Equivalently, all the propositions related to those included in the initial query are added to the query in the query-driven approach. In this case, the two approaches result in the same evaluation.

However, when the inference length is limited, there may be differences between the two approaches because an inference length does not restrain to the same scope of consideration in the two approaches. For instance, in the example shown in Figure 2, if inference length is limited to 1, the document-driven approach will consider w_0, w_1 and w_2 in its evaluation of a query. In the query-driven approach, however, w_3 will also be taken into account. If inference length is limited to 2, then the document-driven approach will consider w_0, w_1, w_2, w_3 and w_4, while the query-driven approach will consider w_1, w_2, w_3, w_4 and w_5. Nevertheless, if we assume that Figure 2 shows a complete possible worlds structure (with all the possible worlds), then the two approaches will result in the same evaluation when the inference length is higher than 2 (i.e. all the possible worlds are considered).

Let us give more examples for the query-driven approach. Suppose we are in the same situation as in the example shown in Figure 2. Given a query expressed as $q_1 = (b \wedge c)$, the query may be modified by expanding the proposition c to $(c \vee a^{\beta_{ac}})$, using the implication ($a \supset_{\beta_{ac}} c$). There is no expansion possible on b. Then the new query q_1' is as follows:

$$q_1' = (b \wedge (c \vee a^{\beta_{ac}}))$$

Evaluating this new query with respect to the initial document description (or the corresponding world w_0) yields the following result:

$$\begin{aligned} V_{w_0}(q_1') &= \Delta(\alpha_b, \nabla(0, \Delta(\beta_{ac}, \alpha_a))) \\ &= \Delta(\alpha_b, \Delta(\beta_{ac}, \alpha_a)) \\ &= \Delta(\alpha_a, \alpha_b, \beta_{ac}). \end{aligned}$$

This is the same evaluation as that obtained by a document-driven approach.

In the same way, the query $q_2 = (b \wedge e)$ may be expanded to:

$q_2' = (b \wedge (e \vee c^{\beta_{ce}}))$ (length 1)
$q_2'' = (b \wedge (e \vee c^{\beta_{ce}} \vee a^{\Delta(\beta_{ac}, \beta_{ce})}))$ (length 2)

We can obtain:

$$\begin{aligned} V_{w_0}(q_2') &= 0, \\ V_{w_0}(q_2'') &= \Delta(\alpha_b, \nabla(0, 0, \Delta(\Delta(\beta_{ac}, \beta_{ce}), \alpha_a))) \\ &= \Delta(\alpha_a, \alpha_b, \beta_{ac}, \beta_{ce}) \end{aligned}$$

These results are also the same as those obtained in the document-driven approach. However, if $q_3 = (c \wedge d)$ and the inference length is limited to 1, then using the document-driven approach results in $V_{w_0}(\Diamond q_3) = 0$; whereby using the query-driven approach gives $q_3' = ((c \vee a^{\beta_{ac}}) \wedge (d \vee b^{\beta_{bd}}))$ and $V_{w_0}(\Diamond q_3') = \Delta(\Delta(\alpha_a, \beta_{ac}), \Delta(\alpha_b, \beta_{bd})) \neq 0$. So the two approaches lead to different query evaluations.

It should be noted that the difference between the two approaches is due to the limitation of the consideration scope, i.e. one step of inference in the document-driven approach modifies the characteristic function over only one proposition at a time. However, one step of inference in the query-driven approach may expand any number of atomic propositions found in the query. In the unlimited case (with a high inference length), the modal logic model provides a suitable explanation to the query-driven approach, which is exactly the approach called query expansion. Hence, our model also provides a theoretical framework for this latter operation which, until now, has always been described in an *ad hoc* way.

4 Inference using a manual thesaurus

Although human-defined term relationships are more reliable (in terms of precision and domain coverage) than automatically extracted ones, they do not tell to what degree a document represented by one term is relevant to a query represented by another term. For example, a relationship of meronymy (HAS) between *computer* and *processor* does not determine precisely relevance of a document about *computer* for a query about *processor*. In our discussion we will refer to this relevance as *term relevance* (in contrast to *document relevance*). One term is relevant to another if a document represented by the first term is relevant to the query represented by the second term alone. Indeed, term relevance represents the simplest case of document relevance. In order to estimate more complex cases of document relevance, we first have to make an estimation of the strength of term relevance. Term relevance is uncertain as document relevance. We represent an uncertain term relevance with a fuzzy implication relation such as $a \supset_\beta b$, where $\beta \in [0, 1]$. In this way, the entire thesaurus may be represented as a set of fuzzy term relevance relations:

$$\{(a \supset_\beta b), \ldots\}.$$

The key problem in using a manual thesaurus in our inferential approach lies in the estimation of term relevance strength β given a thesaurus relation between two terms.

Learning term relevance relations from the user

The decision about how relevant one term is to another is closely bound to the application area, the user's opinion and his/her requirements. We cannot expect the system to give a fixed and unique estimation of term relevance that is suited to every situation. Rather, several estimations may be made from a thesaurus, each corresponding to a particular view of a user or a group of users. In order to transform a manual thesaurus to a set of fuzzy relations which are adapted to the user's requirements, we make use of user relevance feedback. The principle goes as follows. The system gives a tentative query evaluation and provides an answer (a set of ordered documents). Then the user is required to give his or her own relevance evaluation of the retrieved documents The user's evaluation is used by the system to revise the strength of term relevance relation in order to better fit the user's evaluation.

More specifically, for a given thesaurus relation between a and b, the strength β of the corresponding relevance relation is determined as follows:

1. If a user's query contains a, the system carries out a tentative evaluation with an initial fuzzy value β for the thesaurus relation, i.e. the query is expanded with b^β.

2. The user examines (possibly part of) the list of retrieved documents and indicates whether they are relevant or not.

3. Then the value β is modified to both

$$\beta' = \min[1, \beta \cdot (1+\epsilon)]$$
$$\beta'' = \beta \cdot (1-\epsilon).$$

   where $\epsilon \in [0,1]$ is the change scale. The query is evaluated again with β' and β''.

4. The fuzzy value for this relation is adjusted to the value which leads to the best answer (best partial average precision, see explanation below), i.e. it either remains as β or it is changed to β' or β''.

The quality of an answer in IR is usually measured by the *average precision* [36]. For this, we need to know the total number of relevant documents in the corpus, and this is often impossible in real applications. So we use a modified measure, *partial average precision*, which measures the average precision with respect to only the documents found in the system's answer.

The approach used to adjust the strength of a relevance relation is simple. However, each adjustment requires three query evaluations (with three tentative strengths). So it is time-consuming. However, the purpose of our experiments is to see whether a manual thesaurus can be incorporated as a knowledge base rather than to achieve efficiency. Nevertheless, the simple adjustment process needs to be improved in efficiency should it be used in a real system.

Learning for a group of thesaurus relations vs. for individual relations

Due to the great number of relations in a thesaurus, if we apply the above learning process to each individual thesaurus relation, the learning process would be very long. This is because for every user relevance judgment, only a small number of relations are concerned. Adjusting all the relations requires a great deal of relevance feedback information. In order to accelerate the learning process, a good compromise is to suppose that relations of the same type correspond to approximately the same relevance strength. For example, given the following two relations of the same type *hypernymy*:

$$\text{computer} \Rightarrow_{\text{hypernymy}} \text{machine}$$
$$\text{maple} \Rightarrow_{\text{hypernymy}} \text{tree}$$

we assume that the relevance strength of "machine" to "computer" is similar to that of "tree" to "maple". Under this assumption, the above process is applied to different types of relations, thus quickly covers every thesaurus relation. However, accuracy may be compromised. Thus, once sufficiently accurate strengths have been obtained from learning for different types of relations, learning for individual relations follows. Our learning process may thus be divided into a quick learning step and a finer adjustment step.

5 Experiments

The manual thesaurus approach in Section 4 has been tested on the CACM corpus [13] which comprises 3204 documents published in the *Communications of the ACM.* Answers to a set of 50 queries are provided by experts, and they are used to evaluate the system's answers. Note that the 50 queries are given both in natural language and in Boolean expression of terms. We used the Boolean queries in our experiments. Document descriptions are obtained using an automatic indexing process based on document's title and abstract and using *tf*idf* weighting method.

Thesaurus and its utilization

The thesaurus *Wordnet* [27] is used to establish term relevance relations. *Wordnet* contains a large set of human-defined relationships among over 54,000 English words and terms. Table 1 shows the types of relations it provides.

In Wordnet, a word (or term) sense is represented by a group of terms that are synonyms under this sense. Such a group is called a *synset.* A given a word (or term) may be comprised in several synsets. The synonymy relation is implicit

relation	example
synonymy	computer ⇔ data processor
antonymy	big ⇔ small
hyponymy (is-a)	tree $\Rightarrow_{\text{hyponymy}}$ maple
hypernymy (a-kind-of)	maple $\Rightarrow_{\text{hypernymy}}$ tree
meronymy (is-part-of)	computer $\Rightarrow_{\text{hypernymy}}$ processor
holonymy (has-a)	processor $\Rightarrow_{\text{hypernymy}}$ computer

Table 1: Some relations offered by Wordnet where the notation $a \Rightarrow_{rel} b$ indicates that b is one of the word meanings for which the relation (b *rel* a) holds.

within each synset. Other relations are established among synsets. Here we give an example to illustrate the organization of Wordnet. We denote a synset by {...}, and a given type of relation by =>$_{\texttt{type}}$.

The word `computer` is included in the following two synsets:

Sense 1:
```
{computer, data processor,
 electronic computer,
 information processing system}
=>hypernymy {machine}
```

Sense 2:
```
{calculator, reckoner, figurer,
 estimator, computer}
=>hypernymy { expert}
```

That is, `computer` has two different meanings: one for a machine (sense 1) and another for an expert (sense 2). The synset after =>$_{\texttt{hypernymy}}$ is the hypernym synset of the given sense.

The hyponymy relation related to `computer` is defined as follows:

Sense 1:
```
computer =>hyponymy
  {analog computer, analogue computer}
  {number cruncher, number-cruncher}
  {digital computer}
  {pari-mutuel machine, totalizer,
   totalizator}
  {tactical computer}
```

Sense 2:
```
computer =>hyponymy
  {number cruncher, number-cruncher}
  {statistician, actuary}
```

The meronymy relation exists only for sense 1:

```
computer =>meronymy
  {cathode-ray tube, CRT}
  {chip, microchip, micro chip,
   silicon chip}
  {computer accessory}
  {computer circuit}
  {busbar, bus-bar, bus}
  {analog-digital converter}
  {disk cache}
  {diskette, floppy, floppy disk}
  {hardware, computer hardware}
  {central processing unit, CPU,
   C.P.U., central, processor,
   mainframe}
  {keyboard}
  {monitor}
```

In Section 3, we have defined both query-driven and document-driven approaches. With the query-drive approach, higher efficiency is expected because

1. a query contains much less terms than a document, thus less inference may be applied to a query than to a document;
2. inferences made in query expansion are global (i.e. applicable to all the documents) while inferences made in a document description are local. When the document-driven approach is used, inferences must be repeated for each document, which is very costly.

Therefore, we implement the query-driven approach as follows. Each term in a Boolean query is used to find out all the synsets connected by each type of relation in Wordnet. Then the terms in a related synset are weighted with the relevance strength of the relation, and connected to the initial term with $\vee$.

For example, if the initial query is $q =$ `'computer'`, and if relevance strengths are set such that the terms within the first synset above are attributed with β_1 and the terms within the second synset with β_2, then the expanded query q' with "synonymy" relation alone is as follows:

$$\begin{aligned} q' = & \text{ `computer'} \\ \vee & \text{ `data processor'}^{\beta_1} \vee \\ & \text{`electronic computer'}^{\beta_1} \vee \\ & \text{`information processing system'}^{\beta_1} \\ & \vee \text{ `computer'}^{\beta_1} \\ \vee & \text{ `calculator'}^{\beta_2} \vee \text{ `reckoner'}^{\beta_2} \vee \\ & \text{`figurer'}^{\beta_2} \vee \text{ `estimator'}^{\beta_2} \vee \\ & \text{`computer'}^{\beta_2} \end{aligned}$$

This query is further expanded with other types of relations from the term `'computer'`. Compound terms are represented as a conjunction of simple terms after expansion. For example, `'data processor'` will be replaced by (`'data'` $\wedge$ `'processor'`). This is necessary since all the documents have been indexed by simple words. The decomposition of compound terms is a source of retrieval noise. For example, when `'data processor'` is broken up, a document about `'data'` will also be considered as an answer to a query about `'computer'`. We believe that a better approach is to allow indexing documents with compound terms and to keep the related compound terms found in the thesaurus unchanged.

The expanded query is very heavy, especially when long inferences are applied. However, many new terms are added with very low weight. Thus, by setting a threshold, the expanded query can be reduced to an acceptable size. Furthermore many added terms do not correspond to any document so they do not contribute to query evaluation.

Learning for different types of relations

The 50 evaluated queries are randomly distributed among 5 groups of 10's queries. Each group is used in turn as the test set of queries while the others are used as training data for the adjustment of term relevance strength. In so doing, we assumed that the 50 queries were evaluated by experts having the same background and judgment criteria. This assumption was made due to the lack of adequate training and test data.

We also assume that relations of the same type share the same relevance strength. At the beginning of each training process, the relevance strength of each type of relation was arbitrarily set to 1. Various values for the change scale ϵ have been tested. It was observed that with a too low value of ϵ, relevance strengths change too slowly while with a too high value of ϵ, relevance strengths become unstable. In our case, the value 0.15 offers a good compromise between learning speed and stabilization. Figure 3 shows the average evolution (over the 5 training processes) of relevance strength for each type of relation as learning proceeds.

Note that this figure is strongly thesaurus- and corpus-dependent. For example, the high relevance strength attributed to meronymy relation may be justified by the fact that only a few among the strongest of such relations are defined in Wordnet. Thus terms connected by those relations are usually highly relevant.

Comparison of the system's performance

We tested the approach with two different triangular norms: min and multiplication of real numbers. We observed that the second gives much better results than the first in all cases. The reason is that min only considers the worst inference step to determine the degree of certainty for an inference path. This is a very partial consideration. On the other hand, by using multiplication of real numbers, every inference step contributes to the whole inference path. So inference is considered from a more detailed scale. In the following, we only report the results for the multiplication of real numbers as our triangular norm.

The fuzzy logic approach which does not have an inference process is used as the baseline model to compare against our approach. The query evaluation in the baseline model is defined as follows:

$$\begin{aligned} V_w(p) &= C_p(w), \qquad p \in P; \\ V_w(A \wedge B) &= V_w(A) \cdot V_w(B); \\ V_w(\neg A) &= 1 - V_w(A) \end{aligned}$$

The system's performance is measured in terms of *average precision* [36] over 11 recall points (0%, 10%, ..., 100%). Table 2 gives a comparison between the system's performance using the baseline approach (Boolean query evaluation), our inferential approach before learning (i.e. with relevance strength for any relation set to 1) and after learning. In the inferential approach, the inference

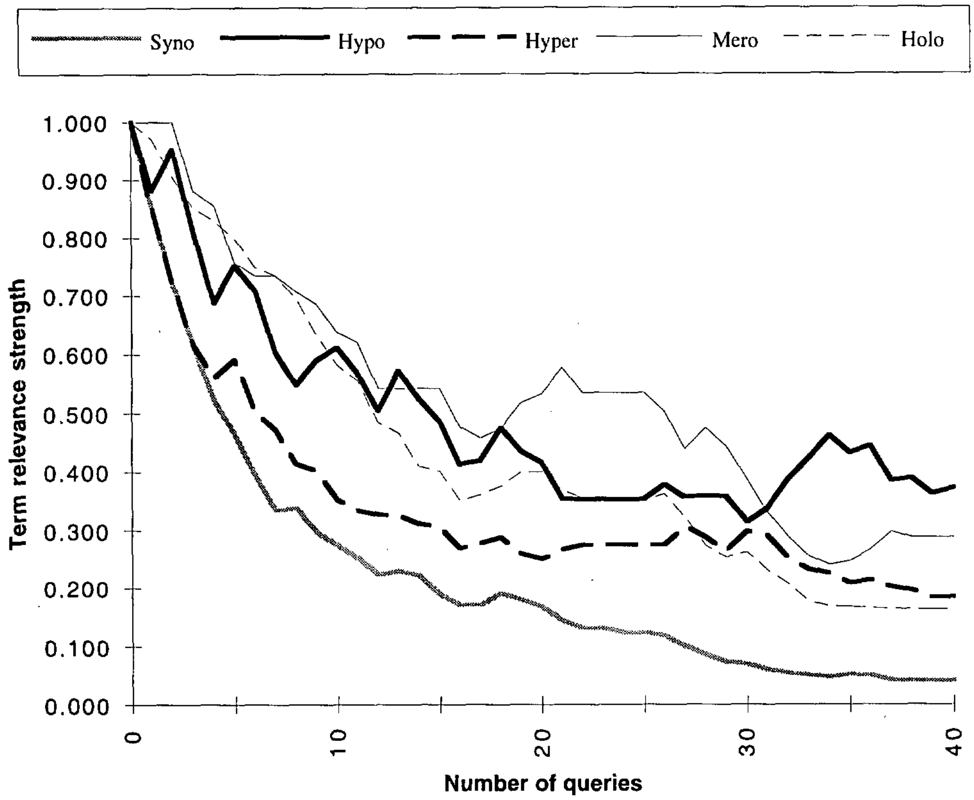


Figure 3: Evolution of relevance strength along with the learning process

Approach		test 1	test 2	test 3	test 4	test 5	Average precision	Increase (%)
Baseline		24.15	21.45	22.10	21.28	10.68	19.93	•
Initial strength	L = 1	24.75	23.90	17.97	13.64	9.00	17.85	-10.43
	L = 2	20.83	18.54	10.80	11.40	6.67	13.64	-31.56
	L = 3	15.01	6.87	4.67	4.20	4.81	7.11	-64.32
After learning	L = 1	29.78	30.48	24.96	25.13	12.26	24.52	23.03
	L = 2	29.70	29.96	27.04	26.56	16.99	26.05	30.07
	L = 3	33.50	31.36	28.59	27.09	16.38	27.38	37.38

Table 2: Comparison of the system performances

process has been applied with lengths 1, 2 and 3 respectively.

The differences among the five tests (from test 1 to 5) are only related to our random distribution of queries among of test groups. They are caused by the different criteria used by human evaluators for the 50 queries. Our experiments do not address this aspect. What is much more significant is the difference between using the initial strengths or the strengths after learning and the evolution of system performances as inference length grows.

The initial strength for all types of relations is set to 1. This may be considered as a coarse utilization of the thesaurus. In this case, the longer the inference is, the more the thesaurus is involved in the inference process, and the worse the system performance is. This observation may explain the negative impact of the same thesaurus over query evaluation found in some previous experiments [45, 46]. On the other hand, with a reasonable assignment of relevance strengths after learning, the use of the thesaurus improves the system's performance. Furthermore, the improvement increases with the inference length. This shows that after learning, the thesaurus is better adapted to the application area and its utilization becomes beneficial. Despite the noise brought by the thesaurus, the global effect is positive.

As long as inference length increases, the time required for query evaluation also increases. When a query is expanded to length 1, the average evaluation time is about 5 seconds on a SPARCstation 10. It becomes 10 seconds at length 2, and it is around 30 seconds at length 3.

Figure 4 gives a closer look at the average system performances. It shows precision vs. recall for the baseline evaluation and for the evaluations with query expansion of various lengths.

Learning for individual relations

In order to compare between learning for types of relations and adapting for individual relations we used the same training data to adjust the relevance strengths of individual relations. In some cases, this individual adjustment succeeds in finding better relevance strength for relations. Here follow some examples.

computer	$\supset_{0.27}$	data processor, electronic computer, information processing system
	$\supset_{0.0045}$	calculator, reckoner, figurer, estimator
file	$\supset_{0.094}$	data file
	$\supset_{0.0113}$	single file, Indian file
	$\supset_{0.0082}$	file cabinet, filing cabinet

In these examples, relevant synsets in computer science are attributed with higher relevance strength than the irrelevant ones. In particular, in the case of computer, the strength for the first synset is sharply increased to 0.27 from around 0.05, while the other synset is decreased to 0.0045. These changes in strength are due to the uneven distribution of the words included in each synset among relevant and irrelevant documents. If the words of a synset appear more often in relevant documents than in irrelevant documents, then the strength for the synset (or for the synonymy relation) is increased. In the opposite case, it is decreased.

However, this further adjustment does not succeed in every case. For the term "hardware", irrelevant synsets are attributed with higher strengths than the relevant one:

hardware		
	$\supset_{0.143}$	hardware "artifacts made of metal"
	$\supset_{0.041}$	hardware "military equipment"
	$\supset_{0.0129}$	hardware, computer hardware

Note that the quoted parts are explanations, but not parts, of the synsets. That is, the individual adjustment succeeds in some cases, but fails in others. Globally, there are about the same number of successes as fails. So, the global system performance after individual adjustment remains almost unchanged. The average precision is slightly changed from 27.38 to 27.73 for inference paths of length 3. The minor difference may be explained by the lack of sufficient training data. It is possible that a greater difference would be produced if more training data were available. The minor difference may also depends on the way the thesaurus terms are incorporated in our expanded queries. In our experiments, compound thesaurus terms are broken into single words in order to match document indices which are single words. In so doing, a relevant compound term may be replaced by a set of ambiguous words. For example, the compound term "hash table" is unambiguously relevant to computer science, but its component words "hash" and "table" are less relevant: "table" may also be a furniture. Thus, from the component words, the system may erroneously conclude that "hash table" is not very relevant to computer science. We see then that the way in which we used the thesaurus in our query expansion is also a possible factor that harms the individual adjustment.

6 Concluding remarks

In this paper, we have first defined an inferential approach to IR within a fuzzy modal logic framework. There are several reasons to replace the strict probabilistic framework by fuzzy modal logic. First, we want to enhance the logical component of our approach and to allow an unrestricted inference structure. Second, when human-

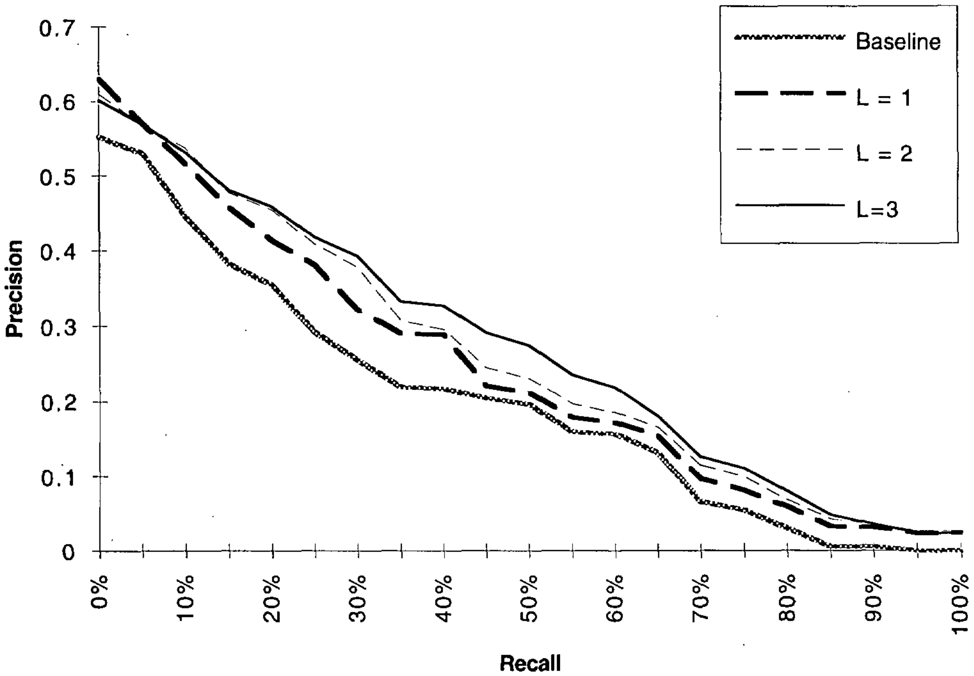


Figure 4: Detail of the comparison of the system performance

defined knowledge is used in the inference process, we cannot expect that the knowledge may be always mapped to strict probabilistic dependencies among terms [40]. Consequently, using human-defined knowledge in a strict probabilistic model may lead to inconsistencies. Fuzzy modal logic is then chosen as an appropriate alternative.

As there is no quantitative measurement of the strength of term connections in a manual thesaurus, a thesaurus should be first transformed into a set of fuzzy relations among terms. We have made use of user relevance feedback in this transformation. This choice is consistent with the findings in [17] that user interaction is one of the main factors affecting the effectiveness of the use of a thesaurus.

Our approach is different from previous inferential approaches due to the use of a more flexible framework which allows a free inference structure. This approach is also different from previous uses of manual thesauri in IR in which the strength of a connection between two terms was often determined according to the topology of the thesaurus (such as the number and length of links between terms). Our approach interacts with users through relevance feedback. Relevance feedback has been used in other IR approaches to expand the user's queries, to revise document representation, or to establish and revise relations among index terms. Although our goal is the same as this last use, there is an important difference: In establishing relations among terms, relevance feedback information has often been used alone in other approaches; in our approach, term relations established are within the scope of relations stored in a thesaurus, thus much less noise is expected. Our experiments showed a significant increase in system performances when a manual thesaurus is incorporated in this way.

Although our experimental results strongly support the hypothesis that a thesaurus-based inference procedure is suitable to the IR reality, several points should be improved in our implementation. First, many Wordnet relations lead to terms that do not correspond to any document. During the first learning step (the coarse learning step), these relations are attributed with the same relevance strength than the others of the same type. During the learning for individual relations, although some of them are attributed with lower strength, the available relevance feedback information is insufficient for their strength to be reduced drastically. A possible solution lies in the elimination of these relations as soon as they are identified to be irrelevant to the document collection (corresponding to no document). The second problem is the determination of a reasonable threshold for keeping terms in expanded queries. A very high threshold value would keep very few terms, thus compromising the inferential power of the approach; but a very low value would result in a long query which is costly to evaluate. In our experiments, we used no threshold value in order to test the impact of the thesaurus when it is fully exploited. The expanded queries are very long, leading to high evaluation cost. Using a threshold would reduce the cost of query evaluation.

Note finally that, although our approach has been described within a fuzzy modal logic framework, it is not incompatible with a probabilistic perspective. If term relevance relations were measured in terms of probability (as dependence probability), then the fuzzy framework should be replaced by a probabilistic framework. To do this, however, we would need to define a more strict inference rule in order to maintain consistency. Whatever the mechanism for addressing the uncertainty, we strongly believe that logic should play the central role in the entire inferential approach.

References

[1] A. Bookstein. Outline of a general probabilistic retrieval model. *Journal of Documentation*, 39:63–72, 1983.

[2] D. A. Buell. An analysis of some fuzzy subset: applications to information retrieval systems. *Fuzzy Sets and Systems*, 7:35–42, 1982.

[3] Duncan A. Buell and Donald H. Kraft. A model for a weighted retrieval system. *Journal of the American Society for Information Science*, pages 211–216, May 1981.

[4] Brian F. Chellas. *Modal Logic: An Introduction.* Cambridge University Press, 1980.

[5] Hsinchun Chen and Vasant Dhar. Cognitive process as a basis for intelligent retrieval system design. *Information Processing & Magement*, 27(5):405–432, 1991.

[6] Yves Chiaramella and Jian-Yun Nie. A retrieval model based on an extended modal logic and its application to the RIME experimental approach. In *Proceedings of 13th ACM-SIGIR Conference*, pages 25–43, 1990.

[7] P.R. Cohen and R. Kjeldsen. Information retrieval by constrained spreading activation in semantic networks. *Information Processing & Magement*, 23(4):255–268, 1987.

[8] W. S. Cooper. Some inconsistencies and misidentified modeling assumptions in probabilistic information retrieval. *ACM Transaction on Information Systems*, 13:100–111, 1995.

[9] W. B. Croft. Approaches to intelligent information retrieval. *Information Processing & Magement*, 23:249–254, 1987.

[10] D. Dubois and H. Prade. Fuzzy logics and the generalized Modus Ponens revisited. *Cybernetics and Systems: A International Journal*, 15:293–331, 1984.

[11] Martha Evens, Yih-Chen Wang, and James Vanderdorpe. Relational thesauri in information retrieval. *Journal of the American Society for Information Science*, 36(1):15–27, 1985.

[12] E.A. Fox. Lexical relations: Enhancing effectiveness of information retrieval systems. *SIGIR Forum*, 15(3):6–35, 1980.

[13] E.A. Fox. Characterization of two experimental collections in computer and information science. Technical Report TR 83-561, Cornell University, Department of Computer Science, 1983.

[14] Norbert Fuhr. Probabilistic models in information retrieval. *The Computer Journal*, 35(3):243–255, 1992.

[15] Gregory Grefenstette. Use of syntactic context to produce term association lists. In *Proceedings of 15th ACM-SIGIR Conference*, pages 89–97, 1992.

[16] V. Güntzer, G. Jüttner, Seegmüller G., and F. Sarre. Automatic thesaurus construction by machine learning from retrieval sessions. *Information Processing & Magement*, 25(3):265–273, 1989.

[17] Micheline Hancock-Beaulieu and Stephen Walker. An evaluation of automatic query expansion in an online library catalogue. *Journal of Documentation*, 48(4):406–421, 1992.

[18] Marti A Hearst. Automatic acquisition of hyponyms from large text corpora. In *Proceedings of the Fourteenth International Conference on Computational Linguistics*, France, 1992. COLING'92.

[19] D. Hindle. Acquiring disambiguation rules from text. In *Proceedings of the 27th Annual Meeting of the Association for Computational Linguistics*, pages 118–125, Pittsburgh, 1989. ACL.

[20] Young Whang Kim and Jin H. Kim. A model of knowledge based information retrieval with hierarchical concept graph. *Journal of Documentation*, 46(2):113–136, 1990.

[21] Haruo Kimoto and Toshiaki Iwaderie. Construction of a dynamic thesaurus and its use for associated information retrieval. In *Proceedings of 13th ACM-SIGIR Conference*, pages 227–240, 1990.

[22] Donald H. Kraft and Duncan A. Buell. Fuzzy sets and generalized boolean retrieval systems. *International Journal of Man-Machine Studies*, 19(45–56), 1983.

[23] Joon Ho Lee, Myoung Ho Kim, and Yoon Joon Lee. Information retrieval based on conceptual distance in IS-A hierarchies. *Journal of Documentation*, 49:188–207, 1993.

[24] Joon Ho Lee, Myoung Ho Kim, and Yoon Joon Lee. Ranking documents in thesaurus-based boolean retrieval systems. *Information Processing & Magement*, 30(1):79–91, 1994.

[25] X. Lu. Document retrieval: A structure approach. *Information Processing & Magement*, 26(2):209–218, 1990.

[26] M.E. Maron and J.K. Kuhns. On relevance, probabilistic indexing and information retrieval. *Journal of the ACM*, 7:216–244, 1960.

[27] G. Miller. Wordnet: an on-line lexical database. *International Journal of Lexicography*, 3, 1990.

[28] S. Miyamoto. Information retrieval based on fuzzy associations. *Fuzzy Sets and Systems*, 38:191–216, 1990.

[29] Jian-Yun Nie. *Un modèle logique général pour les systèmes de recherche d'informations - Application au prototype RIME.* PhD thesis, Université Joseph Fourier de Grenoble, Grenoble, 1990.

[30] J. Pearl. *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference.* Morgan Kaufmann, San Mateo CA, 1988.

[31] Helen J. Peat and Peter Willett. The limitation of term co-occurence data for query expansion in document retrieval systems. *Journal of the American Society for Information Science*, 42(5):378–383, 1991.

[32] Roy Rada, Hafedh Mili, Ellen Bicknell, and Maria Blettner. Development and application of a metric on semantic nets. *IEEE Transaction on Systems, Man, and Cybernetics*, 19(1):17–30, 1989.

[33] Tadeusz Radecki. Fuzzy set theoritical approach to document retrieval. *Information Processing & Magement*, 15:247–259, 1979.

[34] S. Robertson, M. Maron, and W. Cooper. Probability of relevance: a unification of two competing models for document retrieval. *Information Technology: Research and Development*, 1:1–21, 1982.

[35] Gerard Salton and Buckley C. On the use of spreading activation methods in automatic information retrieval. In *Proceedings of 11th ACM-SIGIR Conference*, pages 147–160, 1988.

[36] Gerard Salton and Michael J. McGill. *Introduction to Modern Information Retrieval.* McGraw-Hill, 1983.

[37] P. K. Schotch. Fuzzy modal logic. In *International Symposium on Multiple-Valued Logic*, Indiana University, Bloomington, 1975.

[38] J. Sinclair. *Corpus, concordance, collocation.* Oxford University Press, 1991.

[39] K Sparck-Jones. Notes and references on early automatic classification work. *SIGIR Forum*, 25(1):10–17, 1991.

[40] P. Thompson. Subjective probability and information retrieval: A review of the psychological literature. *Journal of Documentation*, 44:119–143, 1988.

[41] H. Turtle and W. B. Croft. Inference network for document retrieval. In *Proceedings of 13th ACM-SIGIR Conference*, Brussels, 1990.

[42] C. J. van Rijsbergen. *Information Retrieval.* Butterworths, London, 2 edition, 1979.

[43] C.J. van Rijsbergen. A non-classical logic for information retrieval. *The Computer Journal*, 29(6):481–485, 1986.

[44] C.J. van Rijsbergen. Towards an information logic. In *Proceedings of 12th ACM-SIGIR conference*, pages 77–86, Cambridge, 1989.

[45] Ellen M. Voorhees. Using wordnet to disambiguate word senses for text retrieval. In *Proceedings of 16th ACM-SIGIR Conference*, pages 171–180, 1993.

[46] Ellen M. Voorhees. Query expansion using lexical-semantic relation. In *Proceedings of 17th ACM-SIGIR Conference*, pages 61–69, 1994.

[47] W.G. Waller and Donald H. Kraft. A mathematical model of a weighted boolean retrieval system. *Information Processing & Magement*, 15:235–245, 1979.

[48] S. K. M. Wong and Y. Y. Yao. A probabilistic inference model for information retrieval. *Information Systems*, 16:301–321, 1991.

[49] M.S. Ying. On standard models of fuzzy modal logics. *Fuzzy Sets and Systems*, 26:357–363, 1988.

[50] L. A. Zadeh. The role of fuzzy logic in the management of uncertainty in expert systems. *Fuzzy Sets and Systems*, 11:199–227, 1983.

Intelligent Systems: Approaches and Limitations

Mario Radovan
FET Pula, University of Rijeka, Preradovićeva 1/1, 52000 Pula, Croatia
Phone: +385 52 23455 Fax: +385 52 212 034
E-mail: mradov@efpu.hr

Keywords: intelligent systems, mind, cognition, language of thought, neural networks, cognitive models, simulation, computability

Edited by: M. Gams
Received: July 26, 1996 **Revised:** August 15, 1996 **Accepted:** September 4, 1996

An analysis of attitudes and approaches to the development of intelligent systems is given, arguing that (1) the classical and connectionist approaches can be conceived of as two levels of description of the same phenomenon, facing the same essential problems; (2) the language of science is inherently limited, and existing cognitive models cannot include the subjective dimension of the human mind; (3) there is no way to create a system that "really understands" without being personally involved with the proper attitudes and actions; and (4) we should tone down the requirements and expectations which are put before AI if we are to deal with realistic research projects and reasonable discourse.

1 Introduction

A large part of the controversies concerning machine intelligence comes from the fact that we don't have clear and complete answers to the questions "What is *machine*?" and "What is *intelligence*?" (cf. [1, p. 1]). The present paper does not offer precise answers to these questions, but aims to point out the essential impact of language on the controversies concerning AI. We discuss the strengths and limitations of various approaches and attitudes; in this context, we argue that the requirements which are set for AI should be essentially cut down if we don't want to miss the possible by stubbornly searching for the inconceivable. Let us start with a few typical positions concerning the relation between the human mind and machines.

1.1 Mind and Machine

According to Goertzel, "there is no fundamental obstacle to the construction of intelligent computer programs". Goertzel holds that the argument for such a claim "is a simple and familiar one", and that it could be stated like this: (1) "humans are intelligent systems"; (2) humans are "systems governed by the equations of physics"; (3) "the equations of physics can be approximated, to within any degree of accuracy, by space and time discrete iterations that can be represented as Turing machine programs". From these premises, Goertzel concludes that "intelligent behavior can be simulated, to within any degree of accuracy, by Turing machine programs" [17, p. 470]. I find this argument rather vague because it seems to confuse certain essential things such as *to be*, *to represent*, and *to be represented* (or *to be*, *to simulate*, and *to be simulated*).

Speaking of the "very idea" of *artificial intelligence*, Haugeland says: "The fundamental goal [of AI] ... is not merely to mimic intelligence or produce some clever fake. Not at all. AI wants only the genuine article: *machines with minds*, in the full and literal sense. ... Namely, we are, at root, *computers ourselves*" [20, p. 2]. However, Haugeland doesn't offer convincing justification for this starting position. On the other hand, Searle declares: "I want to put a final nail in the coffin of the theory that the mind is a computer program" [25, p. xi]. I hold that Searle is right in insisting that the human mind is not "intrinsically a digital computer" [25, p. 208]. However, he neglects the pragmatic value of the *computa-*

tional interpretation of the human mind in the context of our efforts to develop a useful initial model of the human cognitive system. Finally, Fetzer raises the question of the *worth* of the enterprise aiming at the *ultimate goal* of AI as stated by Haugeland in the above quotation; he says: "it seems to be worth asking whether the replication of the mental processes of human beings should be worth the time, expense, and effort that would be involved in building them. After all, we already know how to reproduce causal systems that possess the mental processes of human beings in ways that are cheaper, faster, and lots more fun" [11, p. 55]. There is a grain of wisdom in Fetzer's reflection; but nevertheless, let us note here that the method of production of the systems with mental processes, which Fetzer has in mind is, in fact, not so cheap, fast, and even not so much fun as it seems at the very beginning of the production process.

I take such claims concerning the relation between the *human mind* and *machine* only as more or less successful rhetoric figures. Namely, by speaking in such a vague manner, everything can be *interpreted* as a machine while nothing can be *proved* to be intrinsically machine (not even computers, if seen on the "wrong level" of description). Hence, I hold that one of the basic tasks of artificial intelligence should be to define in a more precise way the proper goals and language in which they are stated. Without them, a great part of the discussions will continue to belong to one of these three classes: vague speculations, unrealistic promises, and lamentations of failed expectations.

1.2 Intelligence

Concerning the question of intelligence, we face similar problems. For example, it has been claimed that according to "the new approach" to AI, "to design an intelligent system, one has to give it all properties of intelligent creatures", among which belong "intentionality, consciousness and autonomy along with generality and adaptivity" [16, p. 483]. Gams rightly stresses that to obtain all that "will be much more difficult than previously expected" [16, p. 488]. However, I don't know who "previously expected" that to construct a machine with the above stated properties could be less difficult than anything in the world! Furthermore, it is true that "people in general tend to believe that even animals can display certain aspects of intelligence", while on the other hand, although "machines can solve difficult formal problems which are often practically unsolvable even by humans and definitely unsolvable for all animals, they are still regarded as totally unintelligent" [16, p. 488]. However, the above requirements concerning consciousness and intentionality, together with the "general belief" concerning animal and machine intelligence, put AI in an *extremely difficult position*; namely, with such criteria it becomes *virtually impossible* to construct anything that would be at the same time "intelligent" and "machine"! Such requirements are simply so strong that they render it impossible even to try to undertake any reasonable step toward something that could be accepted as a "first approximation" to an intelligent system. I hold that such an attitude towards AI is neither justified nor productive. This attitude could be compared with the claim that medicine has failed since it cannot cure death. Faced with such requirements, we are constrained to abandon the very idea of constructing intelligent systems, or to change our criteria concerning the intelligence of artificial systems. In this context, I hold that as long as we don't know how we could construct a *conscious artificial system* (and we could hardly know that as long as we don't know even how natural consciousness comes about!), we should define the intelligence of an artificial system in a strictly *behavioral fashion*. In other words, if we insist that a chess program which can beat a chess grand master is nevertheless not intelligent then not only do we not actually have intelligent systems but we also don't have any idea how we could construct one.

The criticisms of the results and possibilities of AI primarily concern the classical *symbolic information processing* (SIP) approach. That approach to AI follows the tradition of Western thought which holds that to understand/construct something we must have a *theory*. In that context, to produce an artificial intelligent system one is supposed first to find out the basic elements and laws of the *natural* intelligent (sub)system which one intends to replicate, and then represent that knowledge in a formal language/system which can be suitably implemented on a computer. The first attempts of this kind were limited to selected *micro-worlds* i.e. to selected subsystems of human cognitive abilities. But it turned out that (1) the intelligence of such systems — which did not have a large amount of *common-sense knowledge* — was essentially limited, and (2) that the very possibility of formal representation of common-sense knowledge was highly problematic [27], [7]. However, there are claims that the connectionist approach with its *artificial neural networks* (ANN) constitutes a new, more promising approach to the development of intelligent systems. The connectionist approach departs from the theory-oriented tradition of Western thought and attempts to replicate intelligent behaviour without its explicit formal description of that behaviour. Hubert and Stuart Dreyfus say that the connectionist approach "may show that Heidegger, later Wittgenstein and Rosenblatt were right in thinking that we behave intelligently in the world without having a theory of that world". However, the existing ANN systems are still very limited, so that "the same common-sense knowledge problem, which has blocked the progress of symbolic representation techniques for fifteen years, may be looming on the neural net horizon" [10, pp. 438–39]. Finally, with ANN we meet the same problem as with SIP: namely, if an ANN system is to reach real intelligence, it is supposed that it must also "share our needs, desires, and emotions and have a human-like body with the same physical movements, abilities and possible injures" [10, p. 440]; let us add here that it should be also conscious of its own approaching death. In short, with ANNs we arrive at the same too strong requirements: too strong to permit us even to try to do anything in the direction of their realisation.

Let as now turn to more concrete problems; we start with an analysis of the levels of description of digital computer (as a symbolic machine) and the human cognitive system; we then analyze the strengths and weaknesses of the SIP and ANN approaches to cognition and to the development of the intelligent systems.

2 Levels of Description

To describe a phenomenon, one needs a conceptual system; for describing the human cognitive system, the taxonomy of the classical computer system has been taken as a starting model. Computer systems can be described at different *levels of abstraction*; following Winograd and Flores, let us introduce these five levels of description.

- *Physical level*—At this level, the computer is seen as a set of elements which operate according to the laws of physics. There are no "symbols" or "operations" on this level: at best, there are only signals described in terms of laws of physics.
- *Logical level*—At this level, the system is seen as a network of logical gates ("and", "or", "not" gates); here, the system can be described by some binary language.
- *Representation level*—The level of the symbolic machine language (assembler); at this level, strings of binary signals are interpreted as symbols and operators.
- *Communication level*—The level of programming/query languages by means of which the user exchanges data and instructions/requests with the system.
- *Situation level*—The level at which an activity of the system is interpreted as solving a problem/task.

These levels of description are introduced in accordance with pragmatic needs, and none of them pretend to show the true structure of reality by itself. Let us now try to define an analogous many-level model of the human cognitive system:

- *Physical level*—The level of neuroanatomy; it shows the material and structural aspects of the human neural system.
- *Logical level*—The level of neurophysiology; it shows the neural system as a network of functionally described neurons.
- *Representation level*—This is the controversial point of the model; to follow the computer model, we should assume the existence of some a kind of "assembler" in the human brain. The best known proposal of such an assembler is Fodor's *Language of Thought* [13]; we deal with it in the next section.
- *Communication level*—The level of natural language communication and reasoning; in

keeping with the dominant terminology, we shall often call it *linguistic level.*

- *Situation level*—The level of *understanding* and of goal-directed activity.

The levels of description are defined in *functional* terms, so that the system can be studied (and modelled) on one level of abstraction independently of its descriptions on other levels. The functional properties of a given level must not be inconsistent with the assumed functional properties of the adjacent levels below and above, but within this limitation they can be modelled in various ways. Furthermore, functionally defined systems are *medium independent* in the sense that they can be realised in any medium which allows the realisation of their functions. Consequently, if a proposed model allows the complete description of the human cognitive system, and if all the functions contained in the description are realisable by artificial means, it follows that the human cognitive system could be replicated in ways and media which are structurally and materially different from the human brain. Let us now consider the basic arguments concerning the validity of the five-level description model of cognitive system; the most controversial is the *representation level,* since the two levels below it are subjects of empirical research in the neuroscience, while the two levels above it seem to be determined by it.

3 The Classical Approach

This approach to cognition tries to describe (and replicate) human cognitive abilities by following the model of computer systems given in section (2). In this context, the representation level (i.e. the level of "machine language") seems to be of essential importance, since it is supposed that if we could describe/replicate the human cognitive system on that level, it should be relatively easy to obtain also the two higher levels, i.e. the level of communication and the level of understanding. The language of thought has been taken to be the "machine language" of the human cognitive system.

3.1 Language of Thought

Fodor's Language of Thought (or Mentalese) is well known as a concept but not so well understood as a model of the human mind; hence, let us try to put forward the essentials of Fodor's proposal. We say that thoughts do not depend on any particular natural language because the same thought can be (or *could* be, by some coherent extensions) expressed in various natural languages. On the other hand, the linguistic abilities of speakers of different natural languages have the same *structural* properties. These two assumptions taken together make plausible the idea that the human cognitive system contains an internal lower-level language (innate and common to all humans), in terms of which the cognitive processes take place, while natural languages are only *communication shells* of the system. This internal language (comparable with assembly language) has been called the Language of Thought (LOT). The best way to find out what the hypothetical LOT level of the cognitive system should look like is to start from the outer (natural language) level of the system, and proceed by the following line of thought:

a) Human linguistic abilities are characterised by certain structural properties.

b) Sentences of natural language express/mirror thoughts.

c) Therefore, the cognitive abilities should have the same structural properties.

d) LOT is such a formal system which offers the best explanation of these structural properties.

According to Fodor and Pylyshyn, the basic structural properties of human linguistic abilities are: productivity, systematicity, compositionality, and inferential coherence. The principle of *productivity* says that humans can (in principle) produce an unlimited number of different sentences. By *systematicity* it is meant that a speaker's ability to produce and understand some sentences implies the ability to also produce/understand certain other sentences. The principle of *compositionality* says that lexical items of natural language make nearly the same semantic contribution to each sentence in which they occur, which means that they are context-independent. By *inferential coherence* it is meant that in natural languages, the syntax and semantics of composed assertions mirror one another. (For example, the truth of an assertion of the form 'P and Q' implies the truth of the assertion 'P' and the truth of the assertion 'Q', and vice versa.) All these structural properties can be best explained by assuming a *representational* and *combinatorial* nature of the linguistic system. The concept of "representational nature" says that language units represent entities (in the world), while "combinatorial nature" says that validity/meaning of complex linguistic units is defined in terms of — and can be computed from — the validity/meaning of their constituent parts. In accordance with the starting position concerning the relation between the structural properties of linguistic abilities and the underlying abilities to think, it has been assumed that at *some* thought-producing level the human cognitive system could be defined as a representational and combinatorial system: therefore, that it could be described by a kind of representation language of the combinatorial syntax/semantics. LOT is taken to be that language; with this, LOT figures as the source and explanation of the initial four structural properties of the human linguistic abilities. The LOT hypothesis further holds that:

a) The states of some "points" of the brain form the representation of some proposition, and with it a representation of some state in the world.

b) Propositions are composite entities; the same holds for their mental representations: they are composed of *mental atoms*, the minimal content-bearers.

c) Tokens (i.e. physical items/signs in the brain) which record the same content are of the *same form/type*: that form is the *mental symbol* of that specific semantic content.

d) There is a coherent relation between the syntax/form level and the semantic/content level of the combinatorial operations which take part in LOT seen as formal system.

The LOT hypothesis doesn't say anything about the exact forms and contents of mental atoms. But starting from the *assumed* existence of such minimal representation items of fixed syntax and semantics, it offers an explanation of the reasoning processes. In a nutshell, the LOT hypothesis claims that the syntactic properties of a representation item can be reduced to its *shape*, a physical property. This further means that *causal interactions* of tokens (which depend on their physical properties) are determined by *syntactic* properties of the mental symbols which they token. Fodor says: "the syntax of the symbols might determine the causes and effects of its tokenings in much the way that the geometry of a key determines which locks it will open" [14, pp. 18–19]. It means that although the physical properties "onto which the structure of the symbols is mapped" are those that "cause the system to behave as it does" [15, p. 14], the human cognitive system can be conceived as an *automated symbol system*. In that context, the cognitive process can be equally seen as *causal* sequences of tokenings (of mental symbols) and as *formal* (rule-driven) symbol manipulation.

LOT is the core element of the classical/SIP theory of cognition. To complete the theory, Fodor also introduced a set of functional "boxes", which can be described as special-purpose processors. For example, to *believe* that P means to have a token of the mental symbol 'P' in the *belief box*, and to *hope* that P means to have a token of the same mental symbol in the *hope box*, and so on, "a box for every attitude that you can bear toward a proposition" [14, p. 17]. And for actions, there is an *intention box*: when you intend to make it true that P (i.e. do/make what 'P' says), you put into the intention box a token of the mental symbol for P; the box then "churns and gurgles and computes and causes, and the outcome is that you behave in a way that (ceteris paribus) makes it true that P" [14, p. 136].

The LOT based model of the human cognitive system is a hypothesis, and as every hypothesis it should be evaluated on the ground of its explanatory power and its pragmatic effects. Many hold that the SIP model (based on the LOT hypothesis) is the best theory of cognition we have, and Fodor claims that "the cost of not having a Language of Thought is not having a theory of thinking" [14, p. 147]. However, there are also opponents of the computational approach to cognition in general, and of the LOT hypothesis in particular. Searle, for example, says: "The brain produces the conscious states that are occurring in you and me right now ... But that is it. Where the mind is concerned, that is the end of the story. There are brute, blind, neurophysiological processes and there is consciousness, but there is nothing else ... no mental information processing, ..., no language of thought, and no universal grammar" [25, pp. 228–9]. Searle's position doesn't seem coherent to me. Namely, every theory/model implicitly imposes some structure onto Reality; LOT does this, but so does neurophysiology. It could be a psychological fact that by approaching the level of the physical we *feel* as if we were approaching Truth/Reality, but that is only an illusion: science is a pragmatic enterprise, and *all* theories are in essence only hypotheses.

3.2 Objections to SIP/LOT

The first objection to the SIP approach says that it simply projects the model of the Turing/von Neumann machine onto the realm of the (mysterious) human cognitive system. That is largely true, but it doesn't say much about the explanatory and operational value of the SIP approach. Namely, such tentative projections from the *known* to the *unknown* (felt to be "structurally similar" to the known) are not exceptions in science but the rule, especially in the initial phase of an inquiry. However, it is true that whenever the advocates of SIP need some "box" to complete the model, they simply borrow it from the computer model: and that "solution" could be too easy solution, often grounded only in that need.

One of the essential objections to the LOT hypothesis concerns the mental atoms understood as basic *context-independent content bearers* upon which computational operations are performed. For example, Clark says that the LOT hypothesis is "false" because the "folk solids" (i.e. natural language concepts/propositions) do not have inner mental representations "in the form of context-free syntactic items" [5, p. 13]. Furthermore, the LOT hypothesis assumes the existence of a fixed and innate set of types of mental atoms: we are supposed to work with a fixed repertoire of basic elements, so that any content a human could ever learn, imagine or express should be created (and represented) only by recombination of innate mental contents. That is a strong limitation, because it does not allow the expansion of the initial representation power of the cognitive system. Finally, the very idea of an innate and fixed set of types of basic cognitive items has been qualified as "fundamentally alien" to results in developmental psychology [18, p. 408].

The main weakness of the LOT hypothesis (and of SIP), taken as an *explanation* of human cognitive abilities, concerns the semantics of mental atoms. A LOT-based system is a model of the internal level of the human cognitive system. Now, in order to parallel the syntax/semantic coherence of the outer (linguistic) level, the LOT system cannot be merely a syntactic engine, because such systems can generate only new meaningless marks from the existing ones. To pass from *marks* to thoughts/meanings, the LOT hypothesis must hold that representation items have not only fixed forms, but also *innate fixed meanings.* This step deserves a little more attention; namely, by assigning semantic properties to LOT atoms, Fodor has, in fact, "solved" the perennial *mind-body problem!* A transcendental justification for such an assumption is simple: (1) if thoughts have meanings, then meanings must come from somewhere; (2) let us take it that they come from the semantic properties of the basic mental items. Within Fodor's model, such an argument could suffice, but it makes the model rather speculative; still useful as a working hypothesis in AI, but of limited value as an *explanation* of the human cognitive abilities. However, let us note that adherents of the SIP approach are, in fact, not even supposed to answer what makes the atomic items have semantic properties. The SIP approach is defined in functional terms: it assumes the existence of a set of "basic building blocks" out of which all other items and explanations are constructed, but which are *by definition* cognitively impenetrable. In other words, by having no way to eliminate the perennial gap between the *objective* and the *subjective*, the SIP/LOT approach simply "bridges" it by an assumption which "works" inside the model, but nobody knows how.

One of the objections to the SIP approach concerns the disproportion between the rapidity of some complex cognitive processes and the slowness of the underlying neural operations in the human brain. It has been argued that such rapidity on the linguistic and situation levels of the cognitive system wouldn't be possible (with such a slow neural system), if cognitive processes had the SIP internal structure. But rapid cognitive processes (e.g. fast understanding of complex situations, or face recognition) exist: therefore, the

SIP hypothesis must be false. To such objections the classicists reply that SIP is not concerned with neural operations (i.e. with the *physical* and *logical* level of the system, as defined in section 2); consequently, they can accept that cognitive processes are going on *in parallel* (and so remove the speed objection), but still coherently claim that cognition itself should be conceived as *symbol-processing.* Let us note that such a reply virtually cannot be refuted; however, it reduces the SIP position to the mere insistence that cognition is essentially symbol-processing.

3.3 Plausibility of SIP/LOT

It is often claimed that SIP (with LOT) is the best paradigm we have in the scope of cognitive science. The plausibility of SIP/LOT has been also acknowledged by more cautious authors, and even by opponents. For example, Cummnis holds that although the ways of tokening of symbolic data structures (in the brain) are still not known in detail, SIP "has demonstrated the physical instantiability of such structures and has made ... progress toward demonstrating that at least some cognitive processes can be understood as symbol manipulation" [8, p. 13]. On the other hand, Clark, as one of the opponents of the LOT hypothesis, says that "no one knows" if "human cognition exploits, at least at times, a classically structured text-like symbol system" [5, p. 227]; but elsewhere Clark admits that "something a bit like a language of thought may exist" [18, p. 411]. However, Clark holds that LOT is at best "the symbolic problem-solving tip of a large ... iceberg"; and beneath the symbolic level "lie the larger, less well-defined shapes of our basic cognitive processes": and only the understanding of these processes would "address the fundamentals of cognition" [5, p. 227].

4 The Connectionist Approach

While the classical approach starts from human linguistic and inference abilities, connectionists aim to develop systems with cognitive abilities by following the human brain structure at the neural level. Some (rather uncritical) adherents of this approach claim that "the neurocomputational alternative promises to provide some solutions where the older [classical] view provided only problems" [4, p. 252].

4.1 Artificial Neural Networks

Adherents of the connectionist approach tend to speak of ANNs as panacea for nearly all problems (see e.g. [4]); let us put forward the essentials of this approach. An ANN consists of a set of interconnected units (nodes), typically divided into three subsets: (1) *input units* which receive information from the environment, (2) *output units* which display the result, and (3) *hidden units* which mediate the spread of activation between input and output units. A node is characterised by a variable representing its *level of activation* and by a constant representing its threshold: when the input activation of a node exceeds its threshold, activation propagates to the other nodes with which that node is connected. Links are weighted, with weights determining the relative quantity of activation they may carry. An input to the network is a *vector of signals* (a "pattern of activation values") clamped on input nodes (to every node a value). Triggered by the input, activations spread throughout the network in a way determined by the input pattern, node thresholds, links, and weights of the links. The output of the system is the vector formed of the activation values of the output nodes when the network settles down into a steady state [see 7, 2, 4, 5, 8]. ANNs are also called *vector transformation systems.*

An ANN acquires knowledge by being trained on a set of examples. The system typically starts with a random distribution of unit thresholds and weights. After every exposure to a training exemplar, activations (states) of the output units are compared with the desired output pattern, and the weights/thresholds of the units are gradually changed until the output pattern (for the given input exemplar) becomes equal to the desired one. The same process is repeated with each training exemplar. Adjustments made during training with one exemplar may distort the knowledge acquired through former training exemplars, so that the training process must be cyclically repeated until the network reaches a thresholds/weights configuration which correctly transforms all the exemplars from the training set. It is said that the training process "extracts the *statistical central tendency*" of the training exemplars, forming with it a "*prototype-style* knowledge representation" of the characteristic features of the exemplars [5, p. 20]. An ANN system shows its knowledge (acquired by training) when it is requested to process/transform new inputs of the same type as those with which it was trained. ANNs are characterised by holistic knowledge storing: any piece of knowledge could be distributed throughout the network, so that every node can take part in the encoding of any piece of knowledge contained in the network. In ANNs there are no context-independent data records which could be said to represent natural language semantic units (concepts and propositions): every node can be said to *encode* many things, but it represents no particular thing.

4.2 Objections to ANNs

The two basic problems with ANNs concern the representation of input/output data (because not all data can be easily/suitably stated in vector form), and especially the lack of effective *learning algorithms* which could decide which weights/thresholds should be changed and how. Without satisfactory solutions to these two problems, every excessive enthusiasm with the connectionist approach seems completely ungrounded.

Fodor and Pylyshyn argue that the connectionist model cannot explain the basic structural properties of the human linguistic and cognitive abilities, such as productivity, systematicity, compositionality and inferential coherence. This objection concerns the very idea of the connectionist approach, independently of the problem of learning algorithms. "Nothing in my treatment is sufficient to fully exorcise the ghost of Fodorian systematicity", says Clark; however, he believes that "the way forward is simply to bracket the problem" and to "pursue the connectionist paradigm for all it is worth" [5, p. 224].

Whereas an ANN acquires knowledge only by being trained with an appropriate set of exemplars, humans have the ability of virtually instantaneous learning of an explicitly given rule, and of its immediate application. Hadley offers a simple but effective example; consider the phrase "love ever keeps trying", and the rule, "Proceeding from left to right, mentally extract the second letter from each word and concatenate these letters in sequence" [19, p. 185]. A human of average cognitive abilities can immediately acquire and apply such a rule, even if he has not encountered the rule and the data before. This diminishes the plausibility that the connectionist method of knowledge acquisition (cyclic training to gradually tune the network) could be the method by which humans learn rules.

One of the side effects of holistic knowledge representation is the vulnerability of stored knowledge to new training inputs: if one tries to store some new knowledge into an already trained network (by training it with a new set of exemplars), it can happen that the new adjustments of the thresholds/weights blank out the old knowledge. In such a case, all training exemplars must be "cycled past the net again and again, so it is forced to finds an orchestration of weights which can fit *all* the inputs" [5, 146]. Nothing of that kind happens to humans. Holistic knowledge representation also runs counter to the commonsense idea of how we know/store a fact, for example, that a cat has a tail. We usually suppose that such knowledge should be recorded somewhere in our brain as a kind of fixed record which stands there for years: but there are no fixed records in the connectionist systems.

Finally, connectionists have essential problems with the *explanation* of their results. Namely, in science it is generally not enough to construct a system which gives some results; the results should also be accompanied by a causal explanation of how they have been obtained. However, by renouncing symbols and rules, connectionism has deprived itself of means by which such explanations could be formed: hence, it must borrow "alien" explanatory means to even qualify as a *scientific* activity. Techniques such as *cluster analysis*, by means of which one can generate a "static symbolic description of a network's knowledge" have been used [5, p. 33]. Such descriptions do not mean that symbols (which they use) exist as context-independent syntactic items in the network: they are only *post-hoc* semantic explications of what the network knows/does, and not of what is going on inside the network. In sum, concerning the problem of explanation, the connectionist approach is "both sound and problematic", as Clark rightly observes: it is sound because it avoids projecting a coarse symbolic language onto the cognitive mechanism itself; it is problematic because, by the same token, it deprives itself of explanatory means [5, p. 67].

4.3 Plausibility of ANNs

There are many skills which humans acquire (and exercise) by training, and virtually unconsciously. Such skills — for example, riding a bicycle — do not consist in verbal knowledge, and their exercise does not require explicit rule-driven reasoning; moreover, we usually cannot even describe them in verbal/symbolic form. Consequently, it is claimed that the knowledge of such skills should not be stored in linguistic/symbolic form (so the SIP/LOT approach could not offer a satisfactory description). Humans acquire such skills by practice: therefore, some training-based model could lead us to the understanding of the cognitive background of such skills, or at least to their successful simulation. This is the strongest argument for the connectionist approach.

Connectionists stress the *structural similarities* between the ANNs and the neural networks of the human brain. However, this argument is not decisive because actual ANN systems are quantitatively very much smaller than the human brain, and qualitatively, they are only a "crudest approximation to networks of real neurons" so that they cannot actually offer "any real insight into how the brain functions" [7, p. 222]; consequently, the alleged similarity is still very coarse.

It is often argued that the connectionist approach should confine itself to the level of *physical implementation* (the level of "hardware") of the cognitive system. Reduced to that level, connectionism would not be a cognitive theory, but only an implementational model for the SIP theory of cognition. However, Fodor and Pylyshyn, although adherents of the SIP approach, point out that connectionist systems could be suitable in those cases where "empirical considerations suggest detailed structure/function correspondences ... between different levels of a system's organisation. For example, the input to the most peripheral stages of vision and motor control *must* be specified in terms of anatomically projected patterns ... Thus, at these stages it is reasonable to expect an anatomically distributed structure to be reflected by a distributed functional architecture" [15, p. 63]. In other words, independently of its (un)suitability for hardware implementation of the SIP model, connectionism could be the right approach to the development of *peripheral units* within a global SIP-oriented model of the human cognitive system.

5 Cognition and Computation: the Limits

The models of the human cognitive system which we discussed do not say much (if anything) about the rule of the *subjective* side of cognition nor about subjective mental states in general. Let as now put forward some of the fundamental problems focusing upon the formalizability and expressibility of knowledge and subjective mental states.

5.1 Limits of the Computable

We have discussed the *methodological* and *epistemic* differences between the classical and connectionist approaches: but is there any deeper, *ontological*, difference between these two? Many hold that there should be, but it is hard to say what it consists in. Namely, every ANN can (in principle) be simulated on a SIP system, and every SIP system can (in principle) be simulated by a set of specialised ANNs (e.g. every basic function of the SIP system is simulated by an ANN). Therefore, the two cognitive models have the same expressive power. Indeed, we have already argued that they describe the same phenomenon on two different levels, and that they can be generally conceived of as the "hardware" and the "software" descriptions of the same system.

Computers, as symbol systems, are said to *simulate* (some of) the human cognitive abilities. However, some claim that symbol systems cannot acquire any real cognitive ability. A symbol system can only manipulate that knowledge which can be expressed in some symbolic language; and it has been argued that human knowledge cannot be stated in purely linguistic form. Winograd and Flores hold that the two essentials of the human cognitive situation are:

a man is always already situated in some cognitive *background* which cannot be explicated (and hence not formalised) b knowledge consists in *concernful action* ("care", in Heideggerian terms) and not in mere information possessing (neither in SIP nor in ANN fashion).

According to the *Background hypothesis*, the meaning of an expression is always the result of its *interpretation* against some given background; the unspoken (background) determines the meaning more than what has been said. "Every explicit representation of knowledge", says Winograd, "bears within it a background of cultural orientation that does not appear as explicit claims, but is manifest in the very terms in which the "facts" are expressed and in the judgment of what constitutes a fact" [26, p. 453]. An attempt to explicate all the content of the background would be not only endless but also useless because assertions without any background have no meanings at all [see 24]. Consequently, the category of meaning is not applicable inside formal systems because symbol manipulation, by itself, without an *outer* interpreter, is simply senseless (and so is ANN vector transformation). On the other hand, according to the *Care hypothesis*, human communication is a form of *concernful social action*, and not mere transmission of information. Social action implies *commitment*: A normal human being cannot be said to understand an assertion (heard or said) without being somehow committed to its content. And to be committed, one must be *somebody* (must be an I), which an automated system is not: hence, automated systems cannot really understand. (Such claims challenge the classical approach, but since we don't see ontological differences between SIP and ANNs, we assume that they also equally challenge the connectionist approach.)

On the basis of the *Background* and *Care* assumptions, Winograd and Flores claim that computers cannot even *in principle* acquire any real cognitive ability. Hence, human cognitive abilities could be neither explained nor replicated by any kind of computing system. In other words, human cognition cannot be reduced to mere computing, and even less could the conscious mind as a whole. Let us note that this line of reasoning rejects the independence of cognition from subjective mental states, which was one of the (often tacit) basic assumptions of cognitive science. I hold that Winograd and Flores are right, and that a *Care-less* automated system can neither communicate nor understand in the sense in which people do. And what about thinking and intelligence *without* understanding? With that, we return to the starting problem of how to evaluate (or speak of) the intelligence of artificial systems. As stated in section (1), we hold that the intelligence of such systems should be judged in a *behavioral* fashion (despite all drawbacks of such a decision). Epistemic and methodological changes which bring about the passage from SIP to ANNs are not the decisive step towards *true* understanding and intelligence. And we don't have any idea how the decisive step in that direction should look like.

Let us conclude with a comment on the CYC project started by Lenat in 1984 [21], with the aim to build a system whose knowledge would contain most of what humans call common-sense knowledge. ("CYC" is an abbreviation of encyclopedia; after some initial explicitly inserted amount of knowledge, the system was supposed to continue to learn automatically, from media such as books, newspaper, etc.) The CYC project follows the SIP approach; it uses explicit knowledge representation (by means of a formal language of sentential form) and an extensive formal inference system (with heuristics). It was thought that such a system could serve as the formalized common-sense background for expert systems of various kinds. Although the project is not fully completed, it has been claimed that CYC is not going to attain his mark (or that it has already missed it); for example, Michie holds that CYC has not attained "even the semblance of human-level knowledge and intelligence" [22, p. 464]. In the context of the Background and Care hypotheses stated above, I hold that such criticism, although perhaps premature, should be justified. However, I don't see what else could we do if not keep trying in the hope that, if not an artificial mind, we could at least design more efficient machines.

5.2 Limits of the Expressible

The basic presupposition of science is that reality is objective in the sense that neither its existence nor its structure depend on the observer: to explain a phenomenon one has to describe it from the *neutral* (third-person) point of view. But the phenomenon of conscious mental state resists the neutral (non-personal) description because such a state is essentially a *personal/subjective* state. The ontology of the mental is an *intrinsically first-person* ontology, says Searle [25, p. 95], and there is no place for first-person phenomena in the objective picture of the world. Following Searle's line of thought, one could speak of the ontological gap between the objective and the subjective (because the two are of radically different *nature*); however, be it with ontology as it may, it seems obvious that our *knowledge* of these two kinds of facts are of a radically different nature: hence, I prefer to speak of the epistemic gap.

There are attempts to eliminate the gap by reducing the mental to the physical. However, such attempts are bound to fail because reduction to the physical "dissolves the behaver as well as the behaviour. What's left is atoms and void" [14, p. 9]. And the taxonomy of "atoms and void" cannot express what it's *like* to be me: hence any possible story concerning me, told only in terms of "atoms and void", is incomplete. Researches in neurology indicate that the neural basis of conscious subjective mental states is to be found in certain 40 Hz neural oscillations [12, p. 130]. But how could a 40 Hz neural oscillation explain what it's like to be me? And it is certainly like something to be me, and probably like something to be you, and maybe like something to be a bat, as Nagel would say. "Nothing in any future account of neural microstructure", says Cole, "will make perspicuous *why* that microactivity produces the subjective consciousness that it does" [6, p. 296]. In fact, the question is not so much "why" (or how) the subjective is produced, but *what* is that which the neural activity "produces", and how to speak of it. In sum, we have no clear idea how we should deal with *subjective experience* in an *objective world*: and we can hardly speak of artificial mind as long as we don't know how to deal with the natural one. Trapped between the *ontologically monolithic* scientific picture of the world and the intrinsically *dualistic epistemic situation* of the conscious subject, we are prone to speak of the mental in ways which could often be qualified as banal or incoherent, or both. That doesn't mean that the mental is completely intractable, but it does mean that our actual (and maybe *possible*) taxonomy and understanding of mental phenomena is essentially limited. In that context, decisive claims that humans are machines, or that to become intelligent, machines should share our needs, desire, and emotions, don't tell us so much (especially not in the operational sense) as it would seem at first sight.

6 Conclusion

According to Copeland, the human mind "is coming to be seen as a rag bag ... of ad hoc tools assembled by Mother Programmer, the greatest pragmatist in the universe" [7, p. 241]. However, we should not mix the pragmatism of Mother Nature with the lack of clarity in our descriptions of its products. In other words, we should recognise at least the following: (1) that there are limitations inherent to the objective language of science; (2) that the actual cognitive models are essentially limited because they don't include the subjective dimension of the conscious human mind; (3) that we don't see how to create a system that could "really understand" without being conscious (and *personally involved*) in the world; (4) that the classical and connectionist approaches belong to different levels of description of the same phenomenon (and hence must face the same basic problem); (5) that we are constrained to limit the requirements and expectations of AI if we are to deal with realistic projects and reasonable discourse in that scope.

References

[1] Bojadžiev, D.: 'Godel's Theorems for Minds and Computers', Informatica, Vol. 19 (1995), pp. 627–634.

[2] Butler, K.: 'Neural Constrains in Cognitive Science', Mind and Machines, Vol. 4 (1994), pp. 129–162.

[3] M. P. Churchland: *A Neurocomputational Perspective: The Nature of Mind and the Structure of Science*, The MIT Press, 1992.

[4] Churchland, M. P.: *The Engine of Reason, the Seat of the Soul*, The MIT Press, 1995.

[5] A. Clark: *Associative Engines: Connectionism, Concepts, and Representational Change*, The MIT Press, 1993.

[6] Cole, D.: 'Thought and Qualia', Mind and Machines, Vol. 4 (1994), pp. 283–302.

[7] Copeland, J.: *Artificial Intelligence: A Philosophical Introduction*, Blackwell, 1993.

[8] Cummnis, R.: *Meaning and Mental Representation*, The MIT Press, 1989.

[9] D. C. Dennett: *Consciousness Explained*, Penguin Books, 1993.

[10] Dreyfus, L. H., Dreyfus, E. S.: 'Making a Mind vs. Modeling the Brain: AI Back at a Branchpoint', Informatica, Vol. 19 (1995), pp. 425–441.

[11] Fetzer, J. H.: *Artificial Intelligence: Its Scope and Limits*, Kluwer Academic Publishers, 1990.

[12] O. Flanagan: *Consciousness Reconsidered*, The MIT Press, 1992.

[13] Fodor, J. A.: *Language of Thought*, Harvard University Press, 1975.

[14] Fodor, J. A.: *Psychosemantics*, The MIT Press, 1987.

[15] Fodor, J. A., Pylyshyn, Z. W: 'Connectionism and cognitive architecture: A critical analysis', Cognition, Vol. 28 (1988), pp. 3–71.

[16] Gams, M.: 'Strong vs. Weak AI', Informatica, Vol. 19 (1995), pp. 479–493.

[17] Goertzel, B.: 'Artificial Selfhood: The Path to True AI', Informatica, Vol. 19 (1995), pp. 469–477.

[18] Guttenplan, S.: *A Companion to the Philosophy of Mind*, Blackwell, 1994.

[19] Hadley, R. F.: 'Connectionism, Explicit Rules, and Symbolic Manipulation', Mind and Machines, Vol. 3 (1993), pp. 183–200.

[20] Haugeland, J.: *Artificial Intelligence: The Very Idea*, The MIT Press, 1986.

[21] Lenat, D. B., Guha, R. V.: *Building Large Knowledge-Based Systems*, Addison-Wesley, 1989.

[22] Michie, D.: '"Strong AI": an Adolescent Disorder', Informatica, Vol. 19 (1995), pp. 461–468.

[23] Nagel, T.: *The View from Nowhere*, Oxford University Press, 1986.

[24] Radovan, M.: 'On the Computational Model of the Mind', Informatica, Vol. 19 (1995), pp. 635–645.

[25] J. Searle: *The Rediscovery of the Mind*, The MIT Press, 1992.

[26] Winograd, T.: 'Thinking Machines: Can There be? Are We?', Informatica, Vol. 19 (1995), pp. 443–459.

[27] Winograd, T., Flores, F.: *Understanding Computers and Cognition*, Addison-Wesley, 1987.

Informational Transition of the Form $\alpha \models \beta$ and Its Decomposition

Anton P. Železnikar
An Active Member of the New York Academy of Sciences
Volaričeva ulica 8
1111 Ljubljana, Slovenia (anton.p.zeleznikar@ijs.si)

Keywords: causality, cause-effect philosophy; circular and metaphysicalistic transition $\alpha \models \alpha$; decomposition: canonic, noncanonic, serial, parallel, circular-serial, circular-parallel, metaphysicalistic-serial, metaphysicalistic-parallel; demarcated: frame, gestalt; informational: circle, graph, gestalt, transition $\alpha \models \beta$; metaphysicalistic: circle, graph, gestalt; number of the transitional decompositions: possible, canonic, noncanonic; parenthesized: frame, gestalt; transitional decomposition

Edited by: Vladimir A. Fomichov
Received: December 27, 1995 **Revised:** February 22, 1996 **Accepted:** March 5, 1996

In this paper the complexity and heterogeneity of informational transition occurring between informational entities is studied to some formalistic details, using the technique of informational decomposition [6, 7, 9, 10, 11]. E. Birnbaum [1] has reopened an important problem of the informational theory by a formulation of the informational-causal chain. General informational theory can substantially concern this particular problem, that is, studying the decomposition possibilities of formula $\alpha \models \beta$ and its circular, particularly, metaphysical case $\alpha \models \alpha$. In this paper, the decomposition problems of both $\alpha \models \beta$ and $\alpha \models \alpha$ will be generalized and concretized in the form of several informational systems, which appear to be serial, parallel, circular-serial, circular-parallel, metaphysicalistic-serial, and metaphysicalistic-parallel, but also canonic and noncanonic. Among others, these formula systems are studied by the methodology of informational frames and gestalts [11] showing the possibilities of decomposition. At the end, a case of the social informational transition and its decomposition is discussed to some principled details.

1 Introduction

Informational transition[1] belongs to the basic and most important concepts of the general informational theory [1]. Thus, formula $\alpha \models \beta$, and its circular and metaphysicalistic occurrence $\alpha \models \alpha$, presents the primordial informational problem from which one can start the research of the fundamental concepts of the emerging general informational theory. In this context, particular cases of open and closed transition formulas can be treated as, for example, the externalism $\alpha \models$, the internalism $\models \beta$, the metaphysicalism $\alpha \models \alpha$ (or $\beta \models \beta$), and the phenomenalism $\alpha \models; \models \beta$.

In a particular way, by Birnbaum [1] reopened problem of information transfer (transmission, distribution, broadcasting, receiving), in the form of the disturbance-influenced triad, consisting of the *signal* (or information) *transmitter* (simultaneously, the informational source), *channel*, and *receiver*, can be formally (symbolically, theoretically) generalized by the concept of the informational transition (the *informer* operand, *operator* between the informer and observer, and the *observer* operand). Informational transition concerns not only the problem of information transmitting, channeling, and receiving by machines, media, and living beings, but also the problem of informational arising (emerging of interior and exterior disturbances, impacts) within all transitional components in their spontaneity and circularity, in the framework of the informational serialism and parallelism. Significant examples of informational transition are the following:

1. Transmission and reception of information-carrying signals through a channel between the transmitter and receiver is a *technical system* with the goal to mediate the transmitted signal, as undisturbed (undistorted) as possible, to the receiver. In this way, along the channel, noise and other signal disturbances can appear modifying the originally transmitted signal. Another source of noise and disturbances can appear also in the receiver before the signal is converted (acoustically, visually, digitally or data-likely) for the purposes of various users (the problem of the receiver internalism, e.g., of the filtering of the arrived signal).

2. Another problem is, for instance, the writing down and shaping a message for the public distribution where the author gives his/her initial text to the inspection to his/her colleagues, correctors and editors, who perform in an informationally disturbing (correcting, lecturing) manner. Then, the corrected text is printed (with the removed "failures from the text form and contents"), and as such is distributed to other readers (in general, to the intelligent observers). Here, a strict distinction within the informational triad *informer-mediator-observer* is heavily possible in the sense of a strict separation of the informer, the correcting, editing and mediating channel, and the observer (individual reader, seer, listener, interpreter). The problem is also timely conditioned where the author could have already forgotten what he has written or even did not see his final result in the distribution medium.

3. Another example of informational transition happens in a live discourse, among several discursively interacting speakers, where more than one informer and observer interact in a speaking, listening (observing) and mediating informational environment. In this sense we can understand the informational decomposition of an initial theme which is thrown into a group of informational actors (speakers) and thus, at the end of the discussion, leaves different informational results (impressions) to the participating informational actors.

2 Technical and Theoretical Models of Information Transmission (Mediation)

Technical model of information transmission or mediation proceeds from the well known triad transmitter-channel-receiver[2]. The idealistic case considers an informer, noise-free channel (mediator) and observer. The channel is commonly understood to be a transmission or propagation medium (an informationally active device) between transmitter (informer) and receiver (informer's observer). If information is carried in the form of modulated or coded electromagnetic signals and/or waves, the Maxwellian theory can be applied for the electronic circuits and electromagnetic waves to study the transmission and propagation possibilities in space and/or physical devices.

Such a technical system concerns usually the reliable, true, or exact transmission (mediation) of signals. It does not concern the informational systems of living beings which do not exclude the arising of information on the side of informer, the propagation of information through the informingly active medium and the reception (understanding) of information on the side of informational observer. If the technical problem is first of all a genuine transmission (transfer) of signals irrespective of the loaded information, informational transition in general concerns informational emerging not only in the space and time of the informer but also in the space and time of the channel and the receptor, that is, the channel observer via which information is arriving.

Therefore, the technical problem of information transmission is only a particular, purely technological problem within informational transmission. Technical problems of information transfer are more or less solved within determined technological systems where it is known under which circumstances these systems can function satisfactorily.

[2]The technical (telecommunicational) problem was mathematically formulated by Claude Shannon [4] where, as he said, *meaning* does not travel from a sender to a receiver. The only thing that travels are changes in some form of physical energy, which he called "signals". More important still, these changes in energy are signals only to those who have associated them with a code and are therefore able, as senders, to *encode* their meanings in them and, as receivers, to *decode* them [2].

On the other side, the informational problems of transition, concerning spontaneous and circular information arising within of informationally living actors environments represent substantially different philosophy, methodology and formalism. Informational theory covers essentially this philosophy by a new sort of formalism, implicitly including the informational arising in a spontaneous and circular way. There does not exist a proper theory of this naturally conditioned problem of informing of informational entities. Contemporary philosophies seek their approaches and interpretations within the more or less classical philosophical orientations (doctrines of the so-called rationalism, especially cognitive sciences) performing within natural language discussions and debates and outside promising ways of new formalizations.

3 Information Transmission at the Presence of Noise

Noise as an unforeseeable, spontaneous, chaotic and disturbing phenomenon remains in the realm of informational heterogeneity. A disturbing information does not only mean a distorted, useless or undesired phenomenon, but also the necessary and possible informational realm of changes, formations and origins, for example, in the form of the so-called counterinformation being a synonym for a spontaneously and circularly arising information, its informational generation as a consequence of occurring informational circumstances in space, time and also in brain. In this view, the informational noise carries the possibilities and necessities of informational emerging as a regular, desired or undesired, unforeseeable or expected informing of informational entities.

Instead of *information transmission at the presence of noise* we can use a more general and also more adequate term called *the transition of information in an informationally disturbing environment,* where the spontaneously arising nature of informing of entities comes to the surface. Informational disturbance can be comprehended as a cause generating informational phenomenon from which informational consequences of various kinds are coming into existence. The arising mechanism of the informational roots also in the disturbing, causing and effecting (causing-to-come-into-informing) principles where disturbing is the phenomenon which rises the cause of the consequence.

4 Possible Informational Models of Transition

On the introductory level, we can list and describe shortly the main informational models of transition, marked by $\alpha \models \beta$. Some of this models are very basic and some of them can become more and more complex in a circular, recursive, also fractal[3] manner and, certainly, in this respect, also spontaneous. The discussed models of transition $\alpha \models \beta$ will be nothing else than informational decompositions (derivations, deductions, interpretations) concerning particular elements of the transition and the transition as a whole. So, let us list the most characteristic models of informational transition.

1. A decomposition of $\alpha \models \beta$ can be begun by operator $\models$ which becomes an initial operator frame [10, 11], that is,

$$\alpha \boxed{\models} \beta$$

Usually, at the beginning, we introduce the so-called parenthesized operator frame and, the consequence of this choice is that the operator frame becomes split, in general, into three parts, of the form

$$\boxed{(\cdots(}\,\alpha\,\boxed{\models\cdots\models}\,\beta\,\boxed{)\cdots)}$$

where the left and the right parenthesis frames $\boxed{(\cdots(}$ and $\boxed{)\cdots)}$, alternatively, can be empty.

2. A more expressively compact form of the operator-decomposed transition is obtained by means of the so-called demarcated operator[4]

[3] Fractal is a mathematically conceived curve such that any small part of it, enlarged, has the same statistical character as the original (B.B. Mandelbrot, 1975, in *Les Objects Fractal*). Sets and curves with the discordant dimensional behavior of fractals were introduced at the end of the 19th century by Georg Cantor and Karl Weierstrass. Parts of the snowflake curve, when magnified, are indistinguishable from the whole [12].

[4] The so-called demarcation point, '**.**', was introduced in metamathematics by Whitehead and Russel [5]. The privilege of such denotation is that the sequence of operands and operators in a formula remains unchanged, which does not hold for the Polish prefix or suffix transformation of formulas.

frame, where instead of each parenthesis pair with operator, that is, $(\cdots) \models$ and $\models (\cdots)$, one demarcation point is used, that is, $\cdots . \models$ and $\models . \cdots$, respectively. The consequence of such notation is the disappearance of the parenthesis frames and, in this way, the appearance of only one unsplit operator frame in the decomposed transition (and also other) formulas. In general, the possible demarcated forms of the decomposed transition becomes

$$\alpha \boxed{\models \omega_1 . \models \cdots \omega_n . \models} \beta;$$
$$\vdots$$
$$\alpha \boxed{\models \omega_1 . \models \cdots . \models . \omega_i \models . \cdots \models . \omega_n \models} \beta;$$
$$\vdots$$
$$\alpha \boxed{\models . \omega_1 \cdots \models . \omega_n \models} \beta$$

The first and the last operator frame do not include the demarcated form $. \models .$ because the place of the main operator is at the end or at the beginning of the formula and operands β (the first formula) and α (the last formula) are not parenthesized. Thus, the main informational operator $\models$ is in the first formula at its end and in the last formula at its beginning.

3. The next two examples concern informational transition $\alpha \models \beta$ in its form of operator composition, that is,

$$\alpha \boxed{\models_\alpha} \circ \boxed{\models_\beta} \beta$$

In this way, simultaneously, to some extent, the meaning of the operator composition denoted by $\models \circ \models$, comes to the surface. In this context, it can be decided, where the separation of operators $\models_\alpha$ and $\models_\beta$ actually occurs. The one separation point is certainly the composition operator '$\circ$' and the other two are operands α and β. One must not forget, that operator $\models_\alpha$ is an informationally active attribute of operand α and similarly holds for operator $\models_\beta$ in respect to operand β.

Let us decompose the parenthesized, operator-composed transitional form $\alpha \models_\alpha \circ \models_\beta \beta$. The general form will be

$$\boxed{(\cdots(} \alpha \boxed{\models \cdots \models} \circ \boxed{\models \cdots \models} \beta \boxed{)\cdots)}$$

where $\models_\alpha$ and $\models_\beta$ are split to the left parenthesis frame and the right parenthesis frame, respectively. Parenthesis frames can also be empty. This situation becomes clear when one imagines that the $\circ$-operator stands at the place of the main operator $\models$ of a formula and that just this operator is split in the sense of $\models \circ \models$, where the left $\models$ belongs to $\models_\alpha$-decomposition and the right $\models$ belongs to $\models_\beta$-decomposition.

4. The next possibility of the informational transition decomposition is the one of the previous case when the parenthesized form is replaced by the demarcated one. In this situation, operator frames $\models_\alpha$ and $\models_\beta$ are not anymore split and the expression becomes compact and more transparent. Characteristic cases of such possibility are

$$\alpha \boxed{\models \omega_1 . \models \cdots . \models \omega_n . \models} \circ \boxed{\models} \beta;$$
$$\vdots$$
$$\alpha \boxed{\begin{array}{l} \models \omega_1 . \models \cdots \\ . \models \omega_i . \models \end{array}} \circ \boxed{\begin{array}{l} \models . \omega_{i+1} \models . \cdots \\ \models . \omega_n \models \end{array}} \beta;$$
$$\vdots$$
$$\alpha \boxed{\models} \circ \boxed{\models . \omega_1 \models . \cdots \models . \omega_n \models} \beta$$

No operator frame does include the form $. \models .$ (the place of the main operator of a formula) because this operator is hidden in the operator composition $\models \circ \models$.

5. The next question concerns the so-called circular transition. An informational entity, in itself, can function as a serial circular informational connection of its interior components which inform as any other regular informational entity. There is certainly possible to imagine an exterior circular informing in which a distinguished entity takes over the role to function as the main informational entity in a circle of informing entities. In principle, these circular situations do not differ substantially from the previous cases. The original informational transition $\alpha \models \beta$ is replaced by the initial circular notation $\alpha \models \alpha$.

There are various possibilities of studying decomposed circular transitions. For instance, in Fig. 2, there is a unique simple case of a transitional loop. Fig. 3 offers another interpretation, where to the serially decomposed loop there exists a parallel, yet non-decomposed circle. And lastly, in Fig. 5, the non-decomposed circular path can be replaced by the reversely decomposed first loop, bringing a senseful interpretation and informational examination of the first loop by the second one.

6. The next case provides an additional perturbation of the already decomposed components ω_1, ω_2, $\cdots$, ω_n by means of some disturbing components δ_1, δ_2, $\cdots$, δ_n, respectively, as shown in Fig. 10. These components impact the ω-chain from the interior or the exterior. An interpretation of this disturbance is possible by means of parallel formulas, that is,

$$\delta_j \models \omega_j;\ j = 1, 2, \cdots, n$$

This situation is studied in detail in Section 5.14 and represents an informational extension and theoretical interpretation of the case opened by Birnbaum in [1].

7. Finally, there is possible to expand the basic decomposed informational decomposition with the initial components ω_1, ω_2, $\cdots$, ω_n in a fractal form as shown in Fig. 11. Thus, to the internal components ω_1, ω_2, $\cdots$, ω_n of the first transition similar other transitions take place in an unlimited manner regarding the number of transitions. In this way, a complex transitional fractal is obtained consisting of variously connected informational transitions. In this way, the basic system of decomposed transition is extended by the additional system of informational formulas, that is,

$$\begin{array}{l} (\cdots((\alpha_i \models \omega_{i,1}) \models \omega_{i,2}) \models \cdots \omega_{i,n_i-1}) \models \omega_{i,n_i}; \\ \delta_{i,j} \models \omega_{i,j}; \\ \omega_{i,n_i} \models \omega_i; \\ i = 1, 2, \cdots; n;\ j = 1, 2, \cdots, n_i \end{array}$$

This formula system represents only a part of the graph interpretation in Fig. 11, not being presented in an informational gestalt form yet.

5 Serial, Parallel, and Circular Structure of Informational Transition Decomposition

5.1 Decomposition Possibilities

Informational transition of the form $\alpha \models \beta$ can be decomposed in several informational ways—from the simplest to the most complex ones, but also in a serial, parallel, circular, and metaphysicalistic way. All components of transition $\alpha \models \beta$, that is, operands α and β and operator $\models$, can be decomposed (analyzed, synthesized, interpreted) to an arbitrarily necessary or possible detail. By advancing of decomposition, informational boundaries between the occurring entities α, $\models$, and β can become unclear and perplexed within the complexity of the structure which arises through various decomposition approaches.

One of the basic problems is the systematization of decomposition possibilities (processes, entities) and their symbolic presentation. Decomposition of the general transition $\alpha \models \beta$ or its metaphysicalistic case $\alpha \models \alpha$ can concern the serial, parallel, circular, metaphysicalistic, and any mixed case of the informational deconstruction of $\alpha \models \beta$ and $\alpha \models \alpha$. Let us introduce the following *general decomposition* markers:

${}^{\ell}_{i}\Delta_{\rightarrow}(\alpha \models \beta)$	serial i-decomposition Δ of $\alpha \models \beta$ of serial length ℓ (5.2);
${}^{\ell}\Delta_{\parallel}(\alpha \models \beta)$	parallel decomposition Δ of $\alpha \models \beta$ of parallel length ℓ (5.8);
${}^{\ell}_{i}\Delta^{\circlearrowleft}_{\rightarrow}(\alpha \models \alpha)$	circular serial i-decomposition Δ of $\alpha \models \alpha$ of circular-serial length ℓ (5.9);
${}^{\ell}\Delta^{\circlearrowleft}_{\parallel}(\alpha \models \alpha)$	circular parallel decomposition Δ of $\alpha \models \alpha$ of circular-parallel length ℓ (5.11)

where for subscript i (look at Subsubsection 5.12.6) there is

$$i = 1, 2, \cdots, \frac{1}{\ell + 1}\binom{2\ell}{\ell}$$

Metaphysicalistic decomposition is specifically structured, that is, metaphysicalistically standardized. We introduce

${}^{\ell}_{i}\mathfrak{M}^{\circlearrowleft}_{\rightarrow}(\alpha \models \alpha)$	metaphysicalistic serial i-decomposition $\mathfrak{M}$ of $\alpha \models \alpha$ of circular-serial length ℓ (5.12);
${}^{\ell}\mathfrak{M}^{\circlearrowleft}_{\parallel}(\alpha \models \alpha)$	metaphysicalistic parallel decomposition $\mathfrak{M}$ of $\alpha \models \alpha$ of circular-parallel length ℓ (5.13)

5.2 A Serial Decomposition of $\alpha \models \beta$, that is, ${}^{n+1}_{i}\Delta_{\rightarrow}(\alpha \models \beta)$

Let us start the decomposition process of transition $\alpha \models \beta$ with the simplest and most usual serial case. Let us sketch this simple situation by the graph in Fig. 1. This figure is a simplifica-

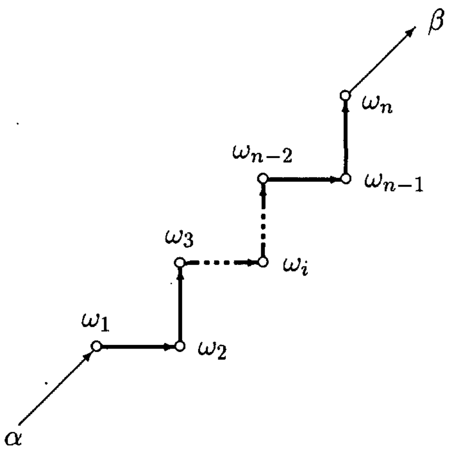


Figure 1: *A simple graphical interpretation of informational transition $\alpha \models \beta$ divided into the informer part (α), serially decomposed channel or internal part with informational structure of ω_1, ω_2, $\cdots$, ω_n, and the observer part (β). This graphical scheme represents the serial gestalt of $\alpha \models \beta$ serial decomposition, that is, all possible serially parenthesized or demarcated forms of the length $\ell = n + 1$. The zig-zag path illustrates the discursive (spontaneous, alternative, also intentionally oriented) way of informing.*

tion of the model given by Fig. 1 in [1]. On the other side, we have studied several forms of serial informational decomposition of informational entities and their transitions (e.g. in [6, 7, 9, 10]). The graph in Fig. 1 represents an informational gestalt [11] because various interpretations of it are possible.

Let us interpret this graph in 'the most logical' manner. This interpretation roots in the understanding of technical systems where we conclude in the following way:

- Transition $\alpha \models \beta$ is understood as a process running from the left to the right side of the formula. We rarely take $\alpha \models \beta$, according to a parallel decomposition possibility, as a parallel process of components α, β, and $\alpha \models \beta$.

- Processing from the left to the right, we come to the conclusion that the adequate informational formulas describing the internally structured decompositions of transition $\alpha \models \beta$ are, according to Subsection 5.1,

$$\begin{array}{l} {}^{n+1}_{\ 1}\Delta_{\rightharpoondown}(\alpha \models \beta) \rightleftharpoons \\ ((((\cdots(\cdots(((\alpha \models \omega_1) \models \omega_2) \models \omega_3) \models \cdots \\ \quad \omega_i) \models \cdots \omega_{n-2}) \models \omega_{n-1}) \models \omega_n) \models \beta); \end{array}$$

$$\begin{array}{l} {}^{n+1}_{\ 2}\Delta_{\rightharpoondown}(\alpha \models \beta) \rightleftharpoons \\ (((\cdots(\cdots(((\alpha \models \omega_1) \models \omega_2) \models \omega_3) \models \cdots \\ \quad \omega_i) \models \cdots \omega_{n-2}) \models \omega_{n-1}) \models (\omega_n \models \beta)); \end{array}$$

$$\vdots$$

$$\begin{array}{l} {}^{\ \ \ \ \ \ \ \ \ n+1}_{\frac{1}{n+2}\binom{2n+2}{n+1}}\Delta_{\rightharpoondown}(\alpha \models \beta) \rightleftharpoons \\ (\alpha \models (\omega_1 \models (\omega_2 \models (\omega_3 \models \cdots (\omega_i \models \cdots \\ \quad (\omega_{n-2} \models (\omega_{n-1} \models (\omega_n \models \beta)))\cdots)\cdots)))) \end{array}$$

where $\rightleftharpoons$ is read as *means* or, also, *informs meaningly*.

- This conclusion delivers $\models$-operator decompositions of $\alpha \models \beta$ which, in the frame-parenthesized form [10, 11], are

$$\boxed{((((\cdots(\cdots(((} \ \alpha \ \boxed{\begin{array}{l} \models \omega_1) \models \omega_2) \models \omega_3) \\ \ \models \cdots \omega_i) \models \cdots \omega_{n-2}) \\ \ \models \omega_{n-1}) \models \omega_n) \models \end{array}} \ \beta;$$

$$\boxed{(((\cdots(\cdots(((} \ \alpha \ \boxed{\begin{array}{l} \models \omega_1) \models \omega_2) \models \omega_3) \\ \ \models \cdots \omega_i) \models \cdots \omega_{n-2}) \\ \ \models \omega_{n-1}) \models (\omega_n \models \end{array}} \ \beta \ \boxed{)};$$

$$\vdots$$

$$\alpha \ \boxed{\begin{array}{l} \models (\omega_1 \models (\omega_2 \models (\omega_3 \\ \ \models \cdots (\omega_i \models \cdots (\omega_{n-2} \\ \ \models (\omega_{n-1} \models (\omega_n \models \end{array}} \ \beta \ \boxed{)))\cdots)\cdots))))}$$

- More clarity could be brought to the surface by the use of the so-called frame-demarcated decomposition [11] which for the the first decomposition formula gives

$$\alpha \ \boxed{\begin{array}{l} \models \omega_1 \centerdot \models \omega_2 \centerdot \models \omega_3 \centerdot \\ \ \models \cdots \omega_i \centerdot \models \cdots \omega_{n-2} \centerdot \\ \ \models \omega_{n-1} \centerdot \models \omega_n \centerdot \models \end{array}} \ \beta$$

- As we see, the operator decomposition in $\alpha \models \beta$ is externally independent; there are only internal components by which the internal structure of operator is interpreted, that is, decomposed into details.

The first formula is actually the strict informer α's view of the transition phenomenon $\alpha \models \beta$. The strict observer β's view of the transition phenomenon $\alpha \models \beta$ is the last formula

$$\begin{aligned}&(\alpha \models \beta) \rightleftharpoons_{\text{dcn}} \\ &(\alpha \models (\omega_1 \models (\omega_2 \models (\omega_3 \models \cdots (\omega_i \models \cdots \\ &\quad (\omega_{n-2} \models (\omega_{n-1} \models (\omega_n \models \beta))) \cdots) \cdots))))\end{aligned}$$

The viewpoint of the observer β proceeds systematically from the right to the left of the transition formula and so delivers a decomposed formula which, in respect to the positions of the parenthesis pairs, is structured in a mirrored form to the formula of the viewpoint of the informer[5].

The graph in Fig. 1 represents a gestalt belonging to any of its informational formula. Gestalt is a set of formulas which can be constructed for an informational graph. The strict informer and the observer viewpoint are only two possibilities: all the other are between the both. We will show how all formulas of a transition gestalt can be, to some extent, differently interpreted by the so-called operator composition $\models_\alpha \circ \models_\beta$.

5.3 A Transparent Scheme of the Canonic Serial Decomposition of $\alpha \models \beta$

Let us introduce the general transparent scheme $\mathfrak{S}$ of the canonic serial decomposition, marked by ${}^{n+1}_{i+1}\Delta^{\text{can}}_{\rightharpoonup}(\alpha \models \beta)$, in the form

$$\mathfrak{S}\left({}^{n+1}_{i+1}\Delta^{\text{can}}_{\rightharpoonup}(\alpha \models \beta)\right) \rightleftharpoons$$
$$\alpha\, \omega_1 \omega_2 \omega_3 \cdots \omega_{i-1} \omega_i \mid \omega_{i+1} \omega_{i+2} \cdots \omega_{n-2} \omega_{n-1} \omega_n \beta$$

where the schemes for the first (*pure informer* or informingly structured informer) and the last (*pure observer* or observingly structured observer), that is, $(n+1)$-th canonic decomposition are

$$\mathfrak{S}\left({}^{n+1}_{1}\Delta^{\text{can}}_{\rightharpoonup}(\alpha \models \beta)\right) \rightleftharpoons$$
$$\alpha\, \omega_1 \omega_2 \omega_3 \cdots \omega_{i-1} \omega_i \omega_{i+1} \omega_{i+2} \cdots \omega_{n-2} \omega_{n-1} \omega_n \mid \beta;$$

$$\mathfrak{S}\left({}^{n+1}_{n+1}\Delta^{\text{can}}_{\rightharpoonup}(\alpha \models \beta)\right) \rightleftharpoons$$
$$\alpha \mid \omega_1 \omega_2 \omega_3 \cdots \omega_{i-1} \omega_i \omega_{i+1} \omega_{i+2} \cdots \omega_{n-2} \omega_{n-1} \omega_n \beta$$

where

$$0 \leq i \leq n$$

Each underline marks one parenthesis pair at its ends, symbol '|' marks the main operator ($\models^*$ or $\boxed{\models}$) of decomposition, and between two operands (e.g., concatenation $\omega_i \omega_{i+1}$) an operator $\models$ appears, according to the underlined formula segments.

A serial decomposition is *canonic* if and only if its informer part is purely informer-canonic and its observer part is purely observer-canonic. For a serial decomposition of $\alpha \models \beta$ of length $\ell = n+1$ there are exactly $n+1$ canonic formulas.

5.4 Introducing Canonic Gestalt of Serial Decomposition of $\alpha \models \beta$

Canonic gestalt Γ^{can} is a particular, reduced form of gestalt Γ, concerning an arbitrary serial decomposition of transition $\alpha \models \beta$, that is (also a non-canonic), ${}^{n+1}_{j}\Delta_{\rightharpoonup}(\alpha \models \beta)$, where

$$1 \leq j \leq \frac{1}{n+2}\binom{2n+2}{n+1}$$

The canonic gestalt is nothing else than an informational system of exactly $n+1$ canonic decompositions

$${}^{n+1}_{1}\Delta^{\text{can}}_{\rightharpoonup}(\alpha \models \beta); \cdots ; {}^{n+1}_{n+1}\Delta^{\text{can}}_{\rightharpoonup}(\alpha \models \beta)$$

Thus, we introduce the following definition of the canonic gestalt of a transition decomposition:

[5] In this respect, there is interesting to mention, that some traditional implication axioms can be structured in a circular-observational manner. E.g., the propositional axiom of *consequent determination*, $A \rightarrow (B \rightarrow A)$, as the first axiom in different proposition and predicate calculi is identically true while $(A \rightarrow B) \rightarrow A$ is not.

$$\Gamma^{\rm can}\left({}^{n+1}_{\;\;j}\Delta_{\rightharpoondown}(\alpha\models\beta)\right)\rightleftharpoons_{\rm Def}$$

$$\begin{pmatrix} ((\cdots(\cdots(((\alpha\models\omega_1)\models\omega_2)\models\omega_3)\models\cdots \\ \quad\omega_i)\models\cdots\omega_{n-2})\models\omega_{n-1})\models\omega_n)\boxed{\models}\beta; \\ ((\cdots(\cdots(((\alpha\models\omega_1)\models\omega_2)\models\omega_3)\models\cdots \\ \quad\omega_i)\models\cdots\omega_{n-2})\models\omega_{n-1})\boxed{\models}(\omega_n\models\beta); \\ (\cdots(\cdots(((\alpha\models\omega_1)\models\omega_2)\models\omega_3)\models\cdots \\ \quad\omega_i)\models\cdots\omega_{n-2})\boxed{\models}(\omega_{n-1}\models(\omega_n\models\beta)); \\ \vdots \\ ((\alpha\models\omega_1)\models\omega_2)\boxed{\models}(\omega_3\models\cdots(\omega_i\models\cdots \\ \quad(\omega_{n-2}\models(\omega_{n-1}\models(\omega_n\models\beta)))\cdots)\cdots); \\ (\alpha\models\omega_1)\boxed{\models}(\omega_2\models(\omega_3\models\cdots(\omega_i\models\cdots \\ \quad(\omega_{n-2}\models(\omega_{n-1}\models(\omega_n\models\beta)))\cdots)\cdots)); \\ \alpha\boxed{\models}(\omega_1\models(\omega_2\models(\omega_3\models\cdots(\omega_i\models\cdots \\ \quad(\omega_{n-2}\models(\omega_{n-1}\models(\omega_n\models\beta)))\cdots)\cdots))) \end{pmatrix}$$

The main operator $\models$ in each of $n+1$ formulas of the array is framed, that is, $\boxed{\models}$, to be easily surveyed.

Let us use, instead of the lengthy denotation for a canonic gestalt $\Gamma^{\rm can}\left({}^{n+1}_{\;\;j}\Delta_{\rightharpoondown}(\alpha\models\beta)\right)$, the symbol $\Gamma^{{\rm can}\,n}_{\alpha\models\beta}$. Canonic gestalt[6] $\Gamma^{{\rm can}\,n}_{\alpha\models\beta}$ is a parallel system of formulas where each formula can be marked by an indexed component $\varphi^{{\rm can}\,n,i}_{\alpha\models\beta}$ representing the adequate canonic decomposition of transition $\alpha\models\beta$. The number of possible decompositions in the gestalt depends on the number of the interior components ω_i, that is, n. By induction, the number of different canonic decompositions of the length $\ell=n+1$ (the number of the occurring binary operators $\models$ in a formula) of transition $\alpha\models\beta$ is $n+1$. Thus,

$$\Gamma^{{\rm can}\,n}_{\alpha\models\beta}\rightleftharpoons\left(\varphi^{{\rm can}\,n,1}_{\alpha\models\beta};\ \varphi^{{\rm can}\,n,2}_{\alpha\models\beta};\ \cdots;\ \varphi^{{\rm can}\,n,n}_{\alpha\models\beta};\ \varphi^{{\rm can}\,n,n+1}_{\alpha\models\beta}\right)$$

where

$$\varphi^{{\rm can}\,n,i}_{\alpha\models\beta}\rightleftharpoons$$

$$\boxed{\begin{array}{l} \underbrace{(\cdots(}_{n+1-i}\ \alpha\models\omega_1)\models\cdots\omega_{n+1-i})\ \overbrace{\boxed{\models}}^{(n+2-i)\text{-th}} \\ \qquad(\omega_{n+2-i}\models\cdots\models(\omega_n\models\beta\underbrace{)\cdots)}_{i-1} \end{array}};$$

$$i=1,2,\cdots,n+1$$

The parenthesized operand gestalt $\Gamma^{{\rm can}\,n}_{\alpha\models\beta}$, as a consequence of serial decomposition of transition $\alpha\models\beta$ by informational components ω_1, ω_2, $\cdots$, ω_n, can be expressed by means of parenthesis gestalts $\Pi^{{\rm can}\,n}_{(}$ and $\Pi^{{\rm can}\,n}_{)}$, discussed in Subsection 5.6, and the particular operator gestalt $\Gamma^{{\rm can}\,n}_{)\models(}$, that is,

$$\Gamma^{{\rm can}\,n}_{\alpha\models\beta}\rightleftharpoons\Pi^{{\rm can}\,n}_{(}\ \alpha\ \Gamma^{{\rm can}\,n}_{)\models(}\ \beta\ \Pi^{{\rm can}\,n}_{)}$$

where

$$\Gamma^{{\rm can}\,n}_{)\models(}\rightleftharpoons\boxed{\begin{array}{l}\phi^{{\rm can}\,n,1}_{)\models(} \\ \phi^{{\rm can}\,n,2}_{)\models(} \\ \vdots \\ \phi^{{\rm can}\,n,n+1}_{)\models(}\end{array}}$$

and

$$\phi^{{\rm can}\,n,i}_{)\models(}\rightleftharpoons$$

$$\boxed{\begin{array}{l} \models\omega_1)\models\cdots\omega_{n+1-i})\ \overbrace{\boxed{\models}}^{(n+2-i)\text{-th}}\ (\omega_{n+2-i}\models \\ \qquad\cdots\models(\omega_n\models \end{array}};$$

$$i=1,2,\cdots,n+1$$

and, finally,

$$\varphi^{{\rm can}\,n,i}_{\alpha\models\beta}\rightleftharpoons\pi^{{\rm can}\,n,i}_{(}\ \alpha\ \phi^{{\rm can}\,n,i}_{)\models(}\ \beta\ \pi^{{\rm can}\,n,i}_{)};$$
$$i=1,2,\cdots,n+1$$

Evidently, for the parenthesis frames there is

$$\pi^{{\rm can}\,n,i}_{(}\rightleftharpoons\underbrace{((\cdots(}_{n+1-i}\quad\text{and}\quad\pi^{{\rm can}\,n,i}_{)}\rightleftharpoons\underbrace{))\cdots)}_{i-1}$$

We can also reverse the process of the right-left enumeration, replacing subscript i by j, reversing

[6] There exist exactly $\frac{1}{n+2}\binom{2n+2}{n+1}-(n+1)$ noncanonic decompositions of length $\ell=n+1$ of transition $\alpha\models\beta$. They can be gathered in the form of a noncanonic gestalt $\Gamma^{{\rm ncan}\,n}_{\alpha\models\beta}$ of length ℓ.

the order of formulas (the last one becomes the first one) in $\Gamma^{\mathrm{can}\,n}_{\alpha\models\beta}$ and setting

$$\varphi^{\mathrm{can}\,n,j}_{\alpha\models\beta} \rightleftharpoons \boxed{\begin{array}{l} \underbrace{(\cdots(}_{j-1}\alpha\models\omega_1)\models\cdots\omega_{j-1})\overbrace{\boxed{\models}}^{j\text{-th}}(\omega_j\models \\ \quad\cdots\models(\omega_n\models\beta\underbrace{)\cdots)}_{n+1-j} \end{array}};$$
$$j = 1, 2, \cdots, n+1$$

For the parenthesis frames one obtains

$$\pi^{\mathrm{can}\,n,j}_{(} \rightleftharpoons \underbrace{((\cdots(}_{j-1} \quad \text{and} \quad \pi^{\mathrm{can}\,n,j}_{)} \rightleftharpoons \underbrace{))\cdots)}_{n+1-j}$$

Partial (inner) frames of particular formulas are

$$\phi^{\mathrm{can}\,n,j}_{)\models(} \rightleftharpoons \boxed{\models\omega_1)\models\cdots\omega_{i-1})\overbrace{\boxed{\models}}^{j\text{-th}}(\omega_j\models\cdots\models(\omega_n\models};$$
$$j = 1, 2, \cdots, n+1$$

and, finally,

$$\varphi^{\mathrm{can}\,n,j}_{\alpha\models\beta} \rightleftharpoons \pi^{\mathrm{can}\,n,j}_{(}\;\alpha\;\phi^{\mathrm{can}\,n,j}_{)\models(}\;\beta\;\pi^{\mathrm{can}\,n,j}_{)};$$
$$j = 1, 2, \cdots, n+1$$

5.5 Demarcated Case of Canonic Gestalt of Serial Decomposition of $\alpha \models \beta$

A compact presentation of the operational effectiveness of a gestalt belonging to informational transition $\alpha \models \beta$ is obtained by the introduction of framed demarcated canonic gestalt. This means that a framed gestalt of framed demarcated particular formulas of length $\ell = n+1$ is used. The effect of such use it to get a vectored gestalt formula of the shape

$$\alpha\;\boxed{\begin{array}{c}
\boxed{\begin{array}{l}\models\omega_1\centerdot\models\omega_2\centerdot\models\omega_3\centerdot\models\cdots\omega_i\centerdot\models\\ \quad\cdots\omega_{n-2}\centerdot\models\omega_{n-1}\centerdot\models\omega_n\centerdot\boxed{\models}\end{array}}\\
\boxed{\begin{array}{l}\models\omega_1\centerdot\models\omega_2\centerdot\models\omega_3\centerdot\models\cdots\omega_i\centerdot\models\\ \quad\cdots\omega_{n-2}\centerdot\models\omega_{n-1}\centerdot\boxed{\models}\centerdot\omega_n\models\end{array}}\\
\boxed{\begin{array}{l}\models\omega_1\centerdot\models\omega_2\centerdot\models\omega_3\centerdot\models\cdots\omega_i\centerdot\models\\ \quad\cdots\omega_{n-2}\centerdot\boxed{\models}\centerdot\omega_{n-1}\models\centerdot\omega_n\models\end{array}}\\
\vdots\\
\boxed{\begin{array}{l}\models\omega_1\centerdot\models\omega_2\centerdot\boxed{\models}\centerdot\omega_3\models\cdots\centerdot\omega_i\\ \quad\models\cdots\centerdot\omega_{n-2}\models\centerdot\omega_{n-1}\models\centerdot\omega_n\models\end{array}}\\
\boxed{\begin{array}{l}\models\omega_1\centerdot\boxed{\models}\centerdot\omega_2\models\centerdot\omega_3\models\cdots\centerdot\omega_i\\ \quad\models\cdots\centerdot\omega_{n-2}\models\centerdot\omega_{n-1}\models\centerdot\omega_n\models\end{array}}\\
\boxed{\begin{array}{l}\boxed{\models}\centerdot\omega_1\models\centerdot\omega_2\models(\omega_3\models\cdots\centerdot\omega_i\\ \quad\models\cdots\centerdot\omega_{n-2}\models\centerdot\omega_{n-1}\models\centerdot\omega_n\models\end{array}}
\end{array}}\;\beta$$

The frame between operands α and β is an operator frame replacing now, after a gestalt-like decomposition, the general informational operator $\models$ in transition $\alpha \models \beta$. The main operator frame of the transition is a parallel frame of $n+1$ serial operator frames constituting the parallel-serial canonic operator decomposition of the original operator $\models$ in $\alpha \models \beta$. As we see, the demarcated style of formula writing brings the advantage of a compact complex informational operator expression.

Instead of the parenthesized, canonic transition-operand gestalt $\Gamma^{\mathrm{can}\,n}_{\alpha\models\beta}$, in which operands α and β are included, the canonic transition-operator gestalt (in demarcated form), $\Gamma^{\mathrm{can}\,n}_{\centerdot\models\centerdot}$ is a parallel array of demarcated decomposed operator frames, $\phi^{\mathrm{can}\,n,i}_{\centerdot\models\centerdot}$, $i = 1, 2, \cdots, n+1$. Thus, a decompositionally complex structure of the simplest transition has the form

$$(\alpha\models\beta) \rightleftharpoons \left(\alpha\;\boxed{\begin{array}{c}\phi^{\mathrm{can}\,n,1}_{\centerdot\models\centerdot}\\ \phi^{\mathrm{can}\,n,2}_{\centerdot\models\centerdot}\\ \vdots\\ \phi^{\mathrm{can}\,n,n+1}_{\centerdot\models\centerdot}\end{array}}\;\beta\right)$$

where

$$\left(\alpha\ \boxed{\begin{array}{c}\phi_{.\models.}^{\mathrm{can}_n,1}\\ \phi_{.\models.}^{\mathrm{can}_n,2}\\ \vdots\\ \phi_{.\models.}^{\mathrm{can}_n,n+1}\end{array}}\ \beta\right) \rightleftharpoons \left(\begin{array}{l}\alpha\ \phi_{.\models.}^{\mathrm{can}_n,1}\ \beta;\\ \alpha\ \phi_{.\models.}^{\mathrm{can}_n,2}\ \beta;\\ \vdots\\ \alpha\ \phi_{.\models.}^{\mathrm{can}_n,n+1}\ \beta\end{array}\right)$$

That what is possible in case of using demarcation points, that is,

$$\alpha\ \Gamma_{.\models.}^{\mathrm{can}_n}\ \beta$$

instead of parenthesis pairs would never be possible in such a compact and clear form. For instance, we can have $\Gamma_{\alpha\models\beta}^{\mathrm{can}_n}$ where operands α and β appear implicitly. But certainly, $\alpha\ \Gamma_{.\models.}^{\mathrm{can}_n}\ \beta \rightleftharpoons \Gamma_{\alpha\models\beta}^{\mathrm{can}_n}$.

5.6 The Meaning of Operator Composition $\models\circ\models$ and Decomposition in Case of the Canonic Serial Decomposition of Informational Transition $\alpha\models\beta$

How could the operator composition of the form

$$\alpha \models_\alpha \circ \models_\beta \beta$$

concern the canonic serial operator decomposition of types $\Gamma_{\alpha\models\beta}^{\mathrm{can}_n}$ and $\Gamma_{.\models.}^{\mathrm{can}_n}$? Could it, in comparison of both cases, come to an informationally meaning equivalence?

Let us introduce the rule by which operator $\models$ can be replaced by the composition $\models\circ\models$ or, formally,

$$\models\ \leftarrow (\models\circ\models)$$

This rule will be used at the places of the framed (main) operator $\models$, that is, $\boxed{\models}$. An operator-framed place will represent the place of the composition operator $\circ$, so, the formula part on the left of it will be something marked as $\models_\alpha$ and the formula part on the right of it will be something marked as $\models_\beta$, when proceeding from the transitional case $\alpha\models\beta$. There is

$$(\alpha \models_\alpha \circ \models_\beta \beta) \rightleftharpoons$$

$$\left(\begin{array}{l}
\boxed{(((\cdots(\cdots(((}_{\pi_{(}^{\mathrm{can}_n,1}}\ \alpha\ \boxed{\begin{array}{l}\models\omega_1)\models\omega_2)\models\\ \omega_3)\models\cdots\omega_i)\models\\ \cdots\omega_{n-2})\models\\ \omega_{n-1})\models\omega_n)\models\end{array}}_{\phi_{)\models\circ}^{\mathrm{can}_n,1}}\\
\qquad\circ\ \boxed{\models}_{\phi_{\circ\models(}^{\mathrm{can}_n,1}}\ \beta\ \boxed{}_{\pi_{)}^{\mathrm{can}_n,1}};\\[2ex]
\boxed{((\cdots(\cdots(((}_{\pi_{(}^{\mathrm{can}_n,2}}\ \alpha\ \boxed{\begin{array}{l}\models\omega_1)\models\omega_2)\models\\ \omega_3)\models\cdots\omega_i)\models\\ \cdots\omega_{n-2})\\ \models\omega_{n-1})\models\end{array}}_{\phi_{)\models\circ}^{\mathrm{can}_n,2}}\\
\qquad\circ\ \boxed{\models(\omega_n\models}_{\phi_{\circ\models(}^{\mathrm{can}_n,2}}\ \beta\ \boxed{)}_{\pi_{)}^{\mathrm{can}_n,2}};\\
\vdots\\
\boxed{(}_{\pi_{(}^{\mathrm{can}_n,n}}\ \alpha\ \boxed{\models\omega_1)\models}_{\phi_{)}^{\mathrm{can}_n,n}\models\circ}\ \circ\\
\quad\boxed{\begin{array}{l}\models(\omega_2\models(\omega_3\models\\ \cdots(\omega_i\models\cdots\models\\ (\omega_{n-1}\models(\omega_n\models\end{array}}_{\phi_{\circ\models(}^{\mathrm{can}_n,n}}\ \beta\ \boxed{)))\cdots)\cdots))}_{\pi_{)}^{\mathrm{can}_n,n}};\\[2ex]
\boxed{}_{\pi_{(}^{\mathrm{can}_n,n+1}}\ \alpha\ \boxed{\models}_{\phi_{)\models\circ}^{\mathrm{can}_n,n+1}}\ \circ\\
\quad\boxed{\begin{array}{l}\models(\omega_1\models(\omega_2\models\\ (\omega_3\models\cdots(\omega_i\models\\ \cdots(\omega_{n-2}\models\\ (\omega_{n-1}\models(\omega_n\models\end{array}}_{\phi_{\circ\models(}^{\mathrm{can}_n,n+1}}\ \beta\ \boxed{)))\cdots)\cdots)))}_{\pi_{)}^{\mathrm{can}_n,n+1}}
\end{array}\right)$$

To obtain the transparency of the last parenthesized formula, we can use the frame subscripts in the last formula, $\pi_{\text{subscript}}^{\text{superscript}}$ and $\phi_{\text{subscript}}^{\text{superscript}}$, where, for example, $\pi_{(}^{\mathrm{can}_n,i}$ marks $n+1-i$ consecutive symbols '(', $\pi_{)}^{\mathrm{can}_n,j}$ marks $j-1$ consecutive symbols ')', $\phi_{)\models\circ}^{\mathrm{can}_n,k}$ marks the k-corresponding operator frame on the left of composition operator '$\circ$' and $\phi_{\circ\models(}^{\mathrm{can}_n,k}$ marks the k-corresponding operator frame on the right of operator '$\circ$'. Thus, for a compact presentation of the last formula we have

$$(\alpha \models_\alpha \circ \models_\beta \beta) \rightleftharpoons$$
$$\begin{pmatrix} \pi_{(}^{\text{can}n,1}\ \alpha\ \phi_{)\models\circ}^{\text{can}n,1} \circ \phi_{\circ\models(}^{\text{can}n,1}\ \beta\ \pi_{)}^{\text{can}n,1}; \\ \pi_{(}^{\text{can}n,2}\ \alpha\ \phi_{)\models\circ}^{\text{can}n,2} \circ \phi_{\circ\models(}^{\text{can}n,2}\ \beta\ \pi_{)}^{\text{can}n,2}; \\ \vdots \\ \pi_{(}^{\text{can}n,n}\ \alpha\ \phi_{)\models\circ}^{\text{can}n,n} \circ \phi_{\circ\models(}^{\text{can}n,n}\ \beta\ \pi_{)}^{\text{can}n,n}; \\ \pi_{(}^{\text{can}n,n+1}\ \alpha\ \phi_{)\models\circ}^{\text{can}n,n+1} \circ \phi_{\circ\models(}^{\text{can}n,n+1}\ \beta\ \pi_{)}^{\text{can}n,n+1} \end{pmatrix}$$

One can introduce the parenthesis-canonic gestalt of the left parenthesis frames, for example,

$$\Pi_{(}^{\text{can}n} \rightleftharpoons \boxed{\begin{array}{l} \pi_{(}^{\text{can}n,1} \\ \pi_{(}^{\text{can}n,2} \\ \vdots \\ \pi_{(}^{\text{can}n,n} \\ \pi_{(}^{\text{can}n,n+1} \end{array}}$$

where the replacement for the right-left or the left-right enumeration is

$$\boxed{\begin{array}{l} \pi_{(}^{\text{can}n,1} \\ \pi_{(}^{\text{can}n,2} \\ \vdots \\ \pi_{(}^{\text{can}n,n} \\ \pi_{(}^{\text{can}n,n+1} \end{array}} \leftarrow \boxed{\begin{array}{c} \overbrace{((\cdots(}^{n} \\ \overbrace{((\cdots(}^{n-1} \\ \vdots \\ (\\ \square \end{array}} \quad \text{or} \quad \boxed{\begin{array}{c} \square \\ (\\ \vdots \\ \overbrace{((\cdots(}^{n-1} \\ \overbrace{((\cdots(}^{n} \end{array}}$$

respectively. Similarly, for the right parenthesis frames there is

$$\Pi_{)}^{\text{can}n} \rightleftharpoons \boxed{\begin{array}{l} \pi_{)}^{\text{can}n,1} \\ \pi_{)}^{\text{can}n,2} \\ \vdots \\ \pi_{)}^{\text{can}n,n} \\ \pi_{)}^{\text{can}n,n+1} \end{array}}$$

with the replacement concerning the right-left or the left-right enumeration

$$\boxed{\begin{array}{l} \pi_{)}^{\text{can}n,1} \\ \pi_{)}^{\text{can}n,2} \\ \vdots \\ \pi_{)}^{\text{can}n,n} \\ \pi_{)}^{\text{can}n,n+1} \end{array}} \leftarrow \boxed{\begin{array}{c} \square \\ ) \\ \vdots \\ \overbrace{))\cdots)}^{n-1} \\ \overbrace{))\cdots)}^{n} \end{array}} \quad \text{or} \quad \boxed{\begin{array}{c} \overbrace{))\cdots)}^{n} \\ \overbrace{))\cdots)}^{n-1} \\ \vdots \\ ) \\ \square \end{array}}$$

respectively. In this way, the gestalt of the partial, main-operator composed, parenthesized left operator frame is

$$\Gamma_{)\models\circ}^{\text{can}n} \rightleftharpoons \boxed{\begin{array}{l} \phi_{)\models\circ}^{\text{can}n,1} \\ \phi_{)\models\circ}^{\text{can}n,2} \\ \vdots \\ \phi_{)\models\circ}^{\text{can}n,n+1} \end{array}}$$

The gestalt of the partial, main-operator composed, parenthesized right operator frame is

$$\Gamma_{\circ\models(}^{\text{can}n} \rightleftharpoons \boxed{\begin{array}{l} \phi_{\circ\models(}^{\text{can}n,1} \\ \phi_{\circ\models(}^{\text{can}n,2} \\ \vdots \\ \phi_{\circ\models(}^{\text{can}n,n+1} \end{array}}$$

The framed components can be recognized from the general parenthesized formula $\alpha \models_\alpha \circ \models_\beta \beta$. This formula is a concatenation of the discussed parenthesis frames, main-operator composed left and right operator frames and the addressed informational operands α and β in the form

$$(\alpha \models_\alpha \circ \models_\beta \beta) \rightleftharpoons$$
$$\left(\Pi_{(}^{\text{can}n}\ \alpha\ \Gamma_{)\models\circ}^{\text{can}n} \circ \Gamma_{\circ\models(}^{\text{can}n}\ \beta\ \Pi_{)}^{\text{can}n}\right)$$

Because of the parenthesis form of basic formulas, the last gestalt formula is split in several segments, which are the left parenthesis gestalt, operand α, the left operator gestalt, operator '$\circ$', the right operator gestalt, operand β, and the right parenthesis gestalt.

To obtain a more compact expression of the formula where the left and the right operational frames are not split and can be, finally, also regularly vectored (in an operator-gestalt manner), we can use the demarcated style of formula notation, that is,

$$\alpha \models_\alpha \circ \models_\beta \beta \,. \rightleftharpoons .$$

$$\boxed{\begin{array}{l}
\alpha \boxed{\begin{array}{l}\models \omega_1 \,.\models \omega_2 \,.\models \omega_3 \,.\\ \models \cdots \omega_i \,.\models \cdots \omega_{n-2} \,.\\ \models \omega_{n-1} \,.\models \omega_n \,.\models\end{array}}_{\phi^{\mathrm{can}\,n,1}_{.\models\circ}} \circ \boxed{\models}_{\phi^{\mathrm{can}\,n,1}_{\circ\models.}} \beta; \\[2ex]
\alpha \boxed{\begin{array}{l}\models \omega_1 \,.\models \omega_2 \,.\models \\ \omega_3 \,.\models \cdots \omega_i \,.\models \\ \cdots \omega_{n-2} \,.\models \omega_{n-1} \\ .\models\end{array}}_{\phi^{\mathrm{can}\,n,2}_{.\models\circ}} \circ \boxed{\models .\,\omega_n \models}_{\phi^{\mathrm{can}\,n,2}_{\circ\models.}} \beta; \\[2ex]
\vdots \\[2ex]
\alpha \boxed{\models \omega_1 \,.\models}_{\phi^{\mathrm{can}\,n,n}_{.\models\circ}} \circ \boxed{\begin{array}{l}\models .\,\omega_2 \models .\,\omega_3 \models \\ \cdots .\,\omega_i \models \cdots \models \\ .\,\omega_{n-1} \models .\,\omega_n \models\end{array}}_{\phi^{\mathrm{can}\,n,n}_{\circ\models.}} \beta; \\[2ex]
\alpha \boxed{\models}_{\phi^{\mathrm{can}\,n,n+1}_{.\models\circ}} \circ \boxed{\begin{array}{l}\models .\,\omega_1 \models .\,\omega_2 \models .\,\omega_3 \\ \models \cdots .\,\omega_i \models \cdots .\,\omega_{n-2} \\ \models .\,\omega_{n-1} \models .\,\omega_n \models\end{array}}_{\phi^{\mathrm{can}\,n,n+1}_{\circ\models.}} \beta
\end{array}}$$

The outmost frame is nothing else than the operand staying on the right of the operator of meaning, $\rightleftharpoons$. Formula is written in the consequent demarcated form where semicolons perform as separation markers between parallel formulas.

To get an extremely compact expression of this formula, one can contract the occurring operator frames into two operator gestalts on the left and the right side of the composition symbol '$\circ$', marked by $\Gamma^{\mathrm{can}\,n}_{.\models\circ}$ and $\Gamma^{\mathrm{can}\,n}_{\circ\models.}$, respectively. Evidently,

$$\Gamma^{\mathrm{can}\,n}_{.\models.} \rightleftharpoons \Gamma^{\mathrm{can}\,n}_{.\models\circ} \circ \Gamma^{\mathrm{can}\,n}_{\circ\models.}$$

where

$$\Gamma^{\mathrm{can}\,n}_{.\models\circ} \rightleftharpoons \boxed{\begin{array}{c}\phi^{\mathrm{can}\,n,1}_{.\models\circ}\\ \phi^{\mathrm{can}\,n,2}_{.\models\circ}\\ \vdots \\ \phi^{\mathrm{can}\,n,n}_{.\models\circ}\\ \phi^{\mathrm{can}\,n,n+1}_{.\models\circ}\end{array}}\,; \quad \Gamma^{\mathrm{can}\,n}_{\circ\models.} \rightleftharpoons \boxed{\begin{array}{c}\phi^{\mathrm{can}\,n,1}_{\circ\models.}\\ \phi^{\mathrm{can}\,n,2}_{\circ\models.}\\ \vdots \\ \phi^{\mathrm{can}\,n,n}_{\circ\models.}\\ \phi^{\mathrm{can}\,n,n+1}_{\circ\models.}\end{array}}$$

and for the informational transition of the form $\alpha \models_\alpha \circ \models_\beta \beta$, finally, one obtains

$$\alpha \boxed{\begin{array}{c}\phi^{\mathrm{can}\,n,1}_{.\models\circ}\\ \phi^{\mathrm{can}\,n,2}_{.\models\circ}\\ \vdots \\ \phi^{\mathrm{can}\,n,n}_{.\models\circ}\\ \phi^{\mathrm{can}\,n,n+1}_{.\models\circ}\end{array}} \circ \boxed{\begin{array}{c}\phi^{\mathrm{can}\,n,1}_{\circ\models.}\\ \phi^{\mathrm{can}\,n,2}_{\circ\models.}\\ \vdots \\ \phi^{\mathrm{can}\,n,n}_{\circ\models.}\\ \phi^{\mathrm{can}\,n,n+1}_{\circ\models.}\end{array}} \beta$$

In the last formula, there must be a strict correspondence between the elements of the enframed left and right operator gestalt in respect of the superscript i, where

$$\phi^{\mathrm{can}\,n,i}_{.\models\circ} \rightleftharpoons$$
$$\boxed{\models \omega_1 \,.\models \omega_2 \models .\cdots \omega_{n-i} \,.\models \omega_{n+1-i} \models}\,;$$
$$\phi^{\mathrm{can}\,n,i}_{\circ\models.} \rightleftharpoons$$
$$\boxed{\models .\,\omega_{n+2-i} \models .\,\omega_{n+3-i} \cdots \models .\,\omega_{n-1} \models .\,\omega_n \models}\,;$$
$$i = 1, 2, \cdots, n+1$$

and ω_j for $j \leq 0$ and $j > n$ does not exist.

The symbolism concerning canonically decomposed gestalts and their formulas for transitional cases $\alpha \models \beta$ and $\alpha \models_\alpha \circ \models_\beta \beta$ is shown in Table 1.

5.7 Noncanonic Serial Decomposition of $\alpha \models \beta$, that is, ${}^{n+1}_{\;\;q}\Delta^{\mathrm{non}}_{\rightarrow}(\alpha \models \beta)$

Both canonic and noncanonic serial decompositions constitute the realm of all possible serial decompositions of transition $\alpha \models \beta$. As one has learned, there are exactly $\frac{1}{n+2}\binom{2n+2}{n+1}$ possible decompositions of one and the same decomposition components $\omega_1, \cdots, \omega_n$, that is, of length $n+1$.

Noncanonic decompositions are exactly those which are not canonic, that is,

$$\frac{1}{n+2}\binom{2n+2}{n+1} - (n+1)$$

of them.

Let us introduce the general transparent scheme $\mathfrak{S}$ of the noncanonic serial decomposition, marked by ${}^{n+1}_{\;\;q}\Delta^{\mathrm{non}}_{\rightarrow}(\alpha \models \beta)$, in the form

$$\mathfrak{S}\left({}^{n+1}_{\;\;q}\Delta^{\mathrm{non}}_{\rightarrow}(\alpha \models \beta)\right) \rightleftharpoons$$
$$\underline{\underline{\alpha\, \omega_1\omega_2\omega_3 \cdots \underline{\omega_{i-1}\omega_i}}} \mid \underline{\underline{\underline{\omega_{i+1}\omega_{i+2}} \cdots \omega_{n-2}\omega_{n-1}\omega_n\beta}}$$

Canonic Gestalts for $(\alpha \models \beta)$-Decomposition	Gestalt Formulas: $i = 1, 2, \cdots, n+1$	Canonic Gestalts for $(\alpha \models_\alpha \circ \models_\beta \beta)$-Decomposition	Gestalt Formulas: $i = 1, 2, \cdots, n+1$
$\Gamma^{\mathrm{can}_n}_{\alpha\models\beta}$	$\varphi^{\mathrm{can}_{n,i}}_{\alpha\models\beta}$	$\Gamma^{\mathrm{can}_n}_{\alpha\models\circ\models\beta}$	$\varphi^{\mathrm{can}_{n,i}}_{\alpha\models\circ\models\beta}$
$\Gamma^{\mathrm{can}_n}_{\alpha.\models.\beta}$	$\varphi^{\mathrm{can}_{n,i}}_{\alpha.\models.\beta}$	$\Gamma^{\mathrm{can}_n}_{\alpha.\models\circ\models.\beta}$	$\varphi^{\mathrm{can}_{n,i}}_{\alpha.\models\circ\models.\beta}$
$\Pi^{\mathrm{can}_n}_{(}\ \alpha\ \Gamma^{\mathrm{can}_n}_{)\models(}\ \beta\ \Pi^{\mathrm{can}_n}_{)}$	$\pi^{\mathrm{can}_{n,i}}_{(}\ \alpha\ \phi^{\mathrm{can}_{n,i}}_{)\models(}\ \beta\ \pi^{\mathrm{can}_{n,i}}_{)}$	$\Pi^{\mathrm{can}_n}_{(}\ \alpha\ \Gamma^{\mathrm{can}_n}_{)\models\circ} \circ \Gamma^{\mathrm{can}_n}_{\circ\models(}\ \beta\ \Pi^{\mathrm{can}_n}_{)}$	$\pi^{\mathrm{can}_{n,i}}_{(}\ \alpha\ \phi^{\mathrm{can}_{n,i}}_{)\models\circ} \circ \phi^{\mathrm{can}_{n,i}}_{\circ\models(}\ \beta\ \pi^{\mathrm{can}_{n,i}}_{)}$
$\alpha\ \Gamma^{\mathrm{can}_n}_{.\models.}\ \beta$	$\alpha\ \phi^{\mathrm{can}_{n,i}}_{.\models.}\ \beta$	$\alpha\ \Gamma^{\mathrm{can}_n}_{.\models\circ} \circ \Gamma^{\mathrm{can}_n}_{\circ\models.}\ \beta$	$\alpha\ \phi^{\mathrm{can}_{n,i}}_{.\models\circ} \circ \phi^{\mathrm{can}_{n,i}}_{\circ\models.}\ \beta$

Table 1: *A systematic overview of possibilities (and possible markers) of the serially decomposed parenthesized and demarcated gestalts and framed formulas belonging to the informational transition* $\alpha \models \beta$, *where there are n decomposing operands, that is, transition-interior informational components* $\omega_1, \omega_2, \cdots, \omega_n$. *A gestalt* $\Gamma^{\mathrm{can}_n}_{\ldots}$ *is a parallel system of n formulas consisting of different frames* $\phi^{\mathrm{can}_{n,i}}_{\ldots}$ *and operands* α *and* β.

where the characteristic schemes of the pure observingly structured informer part and the pure informingly structured observer part noncanonic decompositions are

$$\mathfrak{S}\left({}^{n+1}_{\;q_1}\Delta^{\mathrm{non}}_{\rightarrow}(\alpha \models \beta)\right) \rightleftharpoons$$
$$\alpha\, \omega_1\omega_2\omega_3 \cdots \omega_{i-1}\omega_i\omega_{i+1}\omega_{i+2} \cdots \omega_{n-2}\omega_{n-1}\omega_n \mid \beta;$$

$$\mathfrak{S}\left({}^{n+1}_{\;q_2}\Delta^{\mathrm{non}}_{\rightarrow}(\alpha \models \beta)\right) \rightleftharpoons$$
$$\alpha \mid \omega_1\omega_2\omega_3 \cdots \omega_{i-1}\omega_i\omega_{i+1}\omega_{i+2} \cdots \omega_{n-2}\omega_{n-1}\omega_n\beta$$

where

$$n + 2 \leq q, q_1, q_2 \leq \frac{1}{n+2}\binom{2n+2}{n+1}$$

Each underline marks one parenthesis pair at its ends, symbol '|' marks the main operator ($\models^*$ or $\boxed{\models}$) of decomposition, and between two operands (e.g., concatenation $\omega_i\omega_{i+1}$) an operator $\models$ appears, according to the underlined formula segments.

What could the last example (subscript q) of noncanonic decomposition represent? If one considers that the decomposition components $\omega 1, \cdots, \omega_1$ belong to the informer entity α, the last component, ω_i, is the final observer of the informing on the way from α (the topic informer) to ω_i itself, so, it can decide upon that which will be mediated to the topic observer β. In this respect, ω_i functions as a decisive output filter or a censor of that what α informs. On the other hand, the decomposition components $\omega_{i+1}, \cdots, \omega_n$ can be understood as belonging to the observing entity β where ω_{i+1} functions as a decisive input filter or a censor of that what will be informed through the informing chain from ω_{n+1} to β. While in the informer part $(\alpha, \omega_1, \cdots, \omega_n)$ the censorship functions observingly, in the observing part of the decomposition $(\omega_{n+1}, \cdots, \omega_n, \beta)$ the censorship functions informingly.

A serial decomposition is *noncanonic* if and only if its informer part is not purely informer-canonic and its observer part is not purely observer-canonic.

Some of the noncanonic decompositions deserve a particular attention because they can be grasped as characteristic cases which can be interpreted by some conventional notions of informing like conscious, informer and observer controlled, intelligent and, first of all, senseful and causally structured informing of entities.

The next example of a noncanonic decomposition illustrates an arbitrarily structured formula where the informer as well as the observer part of decomposition explicate embedded informer and observer structures. In this way

$$\mathfrak{G}\left({}^{n+1}_{\;q_3}\Delta^{\text{non}}_{\rightarrow}(\alpha \models \beta)\right) \rightleftharpoons$$

$$\alpha \,|\, \underline{\underline{\underline{\underline{\omega_1\omega_2\omega_3\cdots\omega_{i-1}\omega_i}}\;\underline{\underline{\omega_{i+1}\omega_{i+2}\cdots\omega_{n-2}\omega_{n-1}}\;\underline{\omega_n\beta}}}}$$

is one of the possible diverse decompositions where informer and observer views are hiddenly present in the informer and observer part of the decomposition.

5.8 A Parallel Decomposition of $\alpha \models \beta$, that is, ${}^{n+1}\Delta_{\|}(\alpha \models \beta)$

How can a transition $\alpha \models \beta$ be decomposed in a parallel way and what does such a decomposition represent? In which way does it differ substantially from a serial decomposition?

As one can grasp, informational parallelism conceals some very complex serialism which is again nothing else than a parallelism of serialism. That which is significant for one's comprehension roots in the simplest possible parallelism, that is not in a parallelism of long serial decompositions but in the shortest ones. So, which is the shortest (simplest) part of a decomposition? The answer is: the basic possible transition from one operand to the other. The study of a parallel decomposition system of such basic transitions is the topic of this subsection.

Thus, let us introduce the basic parallel decomposition of informational transition in the form

$${}^{n+1}\Delta_{\|}(\alpha \models \beta) \rightleftharpoons \begin{pmatrix} \alpha \models \omega_1; \\ \omega_1 \models \omega_2; \\ \vdots \\ \omega_{n-1} \models \omega_n; \\ \omega_n \models \beta \end{pmatrix}$$

What does this decomposition represent?

Informational system ${}^{n+1}\Delta_{\|}(\alpha \models \beta)$ can be interpreted in the following ways:

1. ${}^{n+1}\Delta_{\|}(\alpha \models \beta)$ is a parallel system of consequently followed, the most basic transitions, between the initial informer operand α and the final observer operand β;

2. ${}^{n+1}\Delta_{\|}(\alpha \models \beta)$ represents the serial causal chain (decomposition) of consequently followed operands $\alpha, \omega_1, \cdots, \omega_n, \beta$, and all from this decomposition derived decompositions belong to the gestalt $\Gamma({}^{n+1}\Delta_{\|}(\alpha \models \beta))$, where the number of serial decompositions of length $n+1$ is $\frac{1}{n+2}\binom{2n+2}{n+1}$; and

3. ${}^{n+1}\Delta_{\|}(\alpha \models \beta)$ is the formal counterpart (equivalent) of the informational graph $\mathfrak{G}$ (Fig. 1), by which all decompositions belonging to the informational gestalt $\Gamma({}^{n+1}\Delta_{\|}(\alpha \models \beta))$ are determined.

5.9 A Circular Serial Decomposition of $\alpha \models \alpha$, that is, ${}^{n+1}\Delta_{\|}^{\circlearrowleft}(\alpha \models \beta)$

What does happen if the graph in Fig. 1 is circularly closed according to Fig. 2? Which are the possible interpretations of the graph?

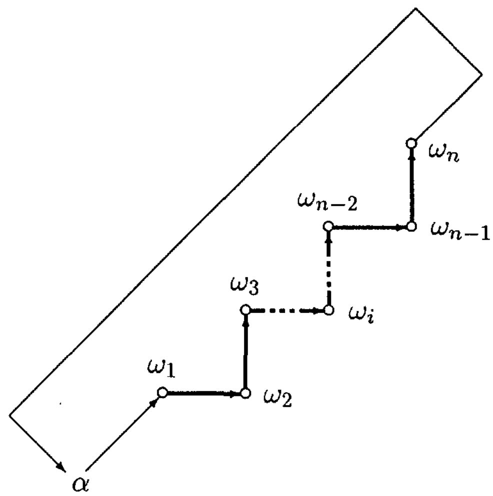


Figure 2: *A simple graphical interpretation of the circular transition $\alpha \models \alpha$ divided into the informer part (α), serially decomposed internal part with informational structure of $\omega_1, \omega_2, \cdots, \omega_n$, and the observer part which is α itself. This graphical scheme represents the simplest gestalt of $\alpha \models \alpha$, that is, all possible serial parenthesized or demarcated forms of the length $\ell = n + 1$.*

Formally, there is not a substantial difference between transitions $\alpha \models \beta$ and $\alpha \models \alpha$ and, for the circular case, where β was replaced by α, operand α becomes the informer and, simultaneously, the observer of itself. The ω-structure can be understood both to be its interior or interior informational structure or even a mixed interior-exterior structure.

For us, the circular interior structure is significant in the so-called metaphysicalistic case. Further, if an ω is an interior structure, the principles of informational Being-in [9] hold, so,

$$\omega_1, \omega_2, \cdots, \omega_n \subset \alpha$$

Further, we must not forget the separation possibilities between the informing and the informed part of α. In the circular case, there is,

$$\alpha \models_\alpha \circ \models_\alpha \alpha$$

where the operator composition operator '$\circ$' is a unique separator between the informing and the observing part of α. This informer-observer distinction becomes extremely significant in the metaphysicalistic case when, for instance, information produced by counterinforming of an intelligent entity α has to be informationally embedded, that is, observed and connected to the existing informational body of entity α. Thus, a circular informational structure is not only a trivial, nonsense, or an abstract entity: it has its own function of informational production and evaluation in the sense of spontaneous and circular informational arising, that is, changing, generating and amplifying the informational change.

In circular informational structures, the problem of the informing and the observing part within a cyclically informing entity come to the surface. This problem is significant at the conceptualization (structure, design) of a circular informational entity. In principle, each entity informs also cyclically, for instance, preserving its form and content and changing it in an arisingly spontaneous an circular way. This principle belongs to the basic axioms of informing of entities (see, for example, [6, 8]).

Let us proceed from the operand frame of the gestalt $\Gamma^{\mathrm{can}_n}_{\alpha\models\alpha}$, that is, of a circularly decomposed informational transition

$$\varphi^{\mathrm{can}_{n,i}}_{\alpha\models\alpha} \rightleftharpoons$$

$$\boxed{\begin{array}{l} \underbrace{(\cdots(}_{n+1-i}\,\alpha \models \omega_1) \models \cdots) \overset{(n+2-i)\text{-th}}{\overbrace{\boxed{\models}}} (\omega_{n+2-i} \models \cdots \\ \qquad \models (\omega_n \models \alpha\underbrace{)\cdots)}_{i-1} \end{array}} ;$$

$$i = 1, 2, \cdots, n+1$$

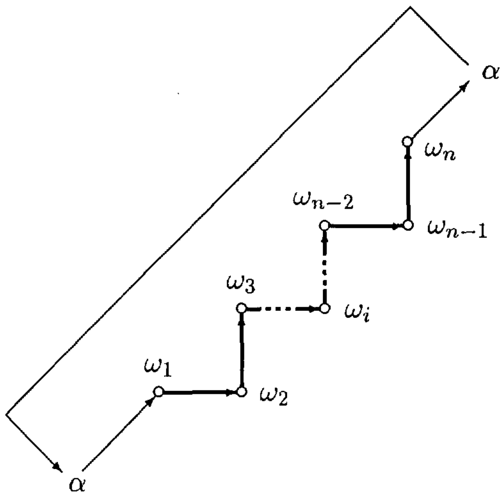


Figure 3: *Another graphical interpretation of the circular transition $\alpha \models \alpha$, which is divided into the informer part (α), serially decomposed internal part with informational structure of ω_1, ω_2, $\cdots$, ω_n, and the observer part which is α itself in the decomposed path and, with the non-decomposed backward path.*

The framed operator, $\boxed{\models}$, is at the $(n+2-i)$-th position of the framed formula and represents the so-called main formula operator, at the place where formula is split into the left informing part (informer α) and the right observing part (observer α). But, the framed operator, $\boxed{\models}$, can be further split and, according to Table 1 (and the previous discussion), there is,

$$\varphi^{\mathrm{can}_{n,i}}_{\alpha\models\alpha} \rightleftharpoons \boxed{\pi^{\mathrm{can}_{n,i}}_{(} \; \alpha \; \phi^{\mathrm{can}_{n,i}}_{)\models\circ} \circ \phi^{\mathrm{can}_{n,i}}_{\circ\models(} \; \beta \; \pi^{\mathrm{can}_{n,i}}_{)}} ;$$
$$i = 1, 2, \cdots, n+1$$

where partial frames $\pi^{\mathrm{can}_{n,i}}_{(}$, $\phi^{\mathrm{can}_{n,i}}_{)\models\circ}$, $\phi^{\mathrm{can}_{n,i}}_{\circ\models(}$ and $\pi^{\mathrm{can}_{n,i}}_{)}$ can be easily identified from the previous discussion. Thus, the separated informing and observing parts of circularly decomposed transition $\alpha \models \alpha$ are

$$\overbrace{((\cdots(}^{n+1-i}\alpha \models \omega_1) \models \cdots) \models \omega_{n+1-i}) \quad \overbrace{\models}^{(n+2-i)\text{-th}} \; ;$$

$$\models (\omega_{n+2-i} \models \cdots \models (\omega_{n-1} \models (\omega_n \models \alpha\overbrace{)\cdots))}^{i-1};$$
$$i = 1, 2, \cdots, n+1$$

Another, slightly modified graphical presentation in Fig. 3, following from Fig. 1 and Fig. 2, offers

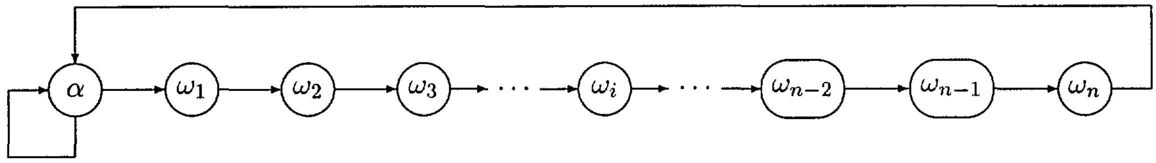


Figure 4: *The circular informational graph corresponding the graphical interpretation in Fig. 3. In an informational graph, the one and the same operand must appear only once (concerns α).*

an essential interpretation, namely, the parallelism of the ω-decomposed path and the backward non-decomposed path $\alpha \models \alpha$. It does not represent the so-called informational graph in which each operand must appear only once. The correct informational graph is shown in Fig. 4. The formal parallel presentation of this graph is the formula system

$$\begin{array}{lll} \alpha \models \alpha; & & \\ \alpha \models \omega_1; & \omega_1 \models \omega_2; & \omega_2 \models \omega_3; \\ \cdots & \omega_i \models \omega_{i+1}; & \cdots \\ \omega_{n-2} \models \omega_{n-1}; & \omega_{n-1} \models \omega_n; & \omega_n \models \alpha \end{array}$$

using, entirely, the basic transitions only (from one operand to the other, or the same).

5.10 A Circular Forward and Backward Serial Decomposition of Informational Transition

The problem of the circular forward and backward serial decomposition emerges in cases of the so-called metaphysicalistic informing when entities inform in an intelligent way and the question of the informing and the observing parts of entities becomes significant. In this situation, we have a general scheme of informing as shown in Fig. 5. Before we begin to discuss the circular and the reversely circular form of informational transition, let us construct Table 1 in which, in a surveying way, the operand and operator gestalts of different sorts, as the result of serial decomposition, are listed. In this table, the parenthesis gestalt pairs of the form $\phi_(^{\text{can}\, n+1-i}$ and $\phi_)^{i-1}$ are replaced by systematically marked pairs $\pi_(^{\text{can}\, n,i}$ and $\pi_)^{\text{can}\, n,i}$ where $\pi_(^{\text{can}\, n,i} \rightleftharpoons \boxed{\underbrace{((\cdots(}_{n+1-i}}$ and $\pi_)^{\text{can}\, n,i} \rightleftharpoons \boxed{\underbrace{))\cdots)}_{i-1}}$ for $i = 1, 2, \cdots, n+1$.

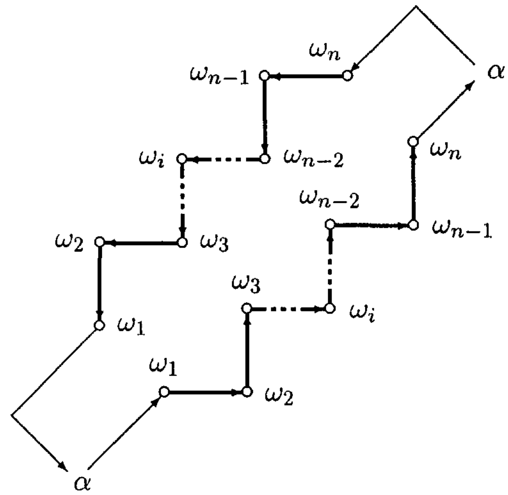


Figure 5: *A graphical interpretation of the forward and backward circular transition $\alpha \models \alpha$, representing a parallel system of a forward and backward loop, being appropriate for an intelligent entity (e.g. forward and backward analysis and informational synthesis).*

5.11 A Circular Parallel Decomposition of $\alpha \models \alpha$, that is, ${}^{n+1}\Delta_{\|}^{\circlearrowleft}(\alpha \models \alpha)$

There is not an essential difference between parallel and circular parallel decomposition in respect to the formal informational scheme

$${}^{n+1}\Delta_{\|}^{\circlearrowleft}(\alpha \models \alpha) \rightleftharpoons \begin{pmatrix} \alpha \models \omega_1; \\ \omega_1 \models \omega_2; \\ \vdots \\ \omega_{n-1} \models \omega_n; \\ \omega_n \models \alpha \end{pmatrix}$$

But, the essential difference occurs in the following:

1. ${}^{n+1}\Delta_{\|}^{\circlearrowleft}(\alpha \models \beta)$ is a circular parallel system of

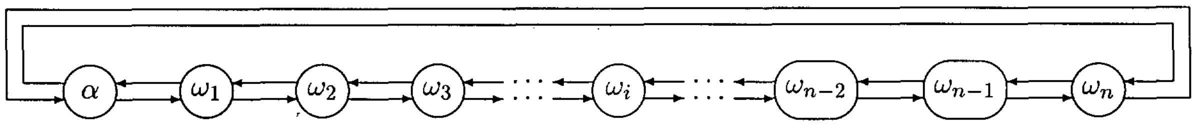


Figure 6: *The bicircular informational graph corresponding to the graphical interpretation in Fig. 5. In an informational graph, the one and the same operand must appear only once (concerns α, ω_1, $\cdots$, ω_n).*

consequently followed, the most basic transitions, between the initial informer operand α and the final observer operand, which is the same α;

2. ${}^{n+1}\Delta_{\|}^{\circlearrowleft}(\alpha \models \beta)$ represents the circular (serial) causal chain (decomposition) of consequently, in a circle followed operands $\alpha, \omega_1, \cdots, \omega_n$, and all from this decomposition derived decompositions belong to the circular gestalt $\Gamma({}^{n+1}\Delta_{\|}^{\circlearrowleft}(\alpha \models \beta))$, where the number of decompositions is $\frac{n+1}{n+2}\binom{2n+2}{n+1}$; and

3. ${}^{n+1}\Delta_{\|}^{\circlearrowleft}(\alpha \models \beta)$ is the formal counterpart (equivalent) of the circular informational graph $\mathfrak{G}$ (Fig. 2), by which all decompositions belonging to the informational gestalt $\Gamma({}^{n+1}\Delta_{\|}^{\circlearrowleft}(\alpha \models \beta))$ are determined.

5.12 Standardized Metaphysicalistic Serial Decomposition of $\alpha \models \alpha$, that is, ${}^{\ell}_{j}\mathfrak{M}^{\circlearrowleft}_{\rightharpoondown}(\alpha \models \alpha)$

5.12.1 Introduction

Metaphysicalism means circular informing originating in the initial transition $\alpha \models \alpha$ and its metaphysicalistic decomposition which, to some extent, was standardized [6] in a reductionistic manner. In this Subsection, our attention will concentrate on parenthesized, demarcated, normal and reverse cyclic, operator-compositional canonic and noncanonic metaphysicalistic informational decompositions and the corresponding gestalts. As we see, there is a couple of metaphysicalistic gestalts of a decomposed entity α which can be investigated from the standard metaphysicalistically generalized and reasonably reductionistic point of view considering the variety of possible decompositions and gestalts.

5.12.2 Generalized Metaphysicalistic Decomposition of an Informational Entity

Let α represent an informational entity concerning something β. Let this entity be metaphysically decomposed in its serially connected but also in its parallel informing components:

- *informing components* (superscript i)

$$\alpha_1, \alpha_2, \cdots, \alpha_j$$

- *counterinforming components* (superscript $\mathfrak{c}$)

$$\alpha_1, \alpha_2, \cdots, \alpha_p$$

and

- *informationally embedding components* (superscript $\mathfrak{e}$)

$$\alpha_1, \alpha_2, \cdots, \alpha_q$$

Besides, some circular forms of informing of involved metaphysicalistic components, including entity α, occur, thus obligatory, different loops exist regarding the metaphysicalistic components. Let this situation be concretized by the informational graph in Fig. 7. As a standardized (artificially constructed) situation, three substantial groups of an entity's metaphysicalism exist: *intentional informing* ensures the preservation (physical, mental, informational character) of the entity; *counterinforming* represents the emerging and essentially changing possibilities and character of entity's informing intention, so that the character of the entity can emerge and change as a consequence of the exterior and interior impacts concerning the entity; *informational embedding* is a sort of final acceptance and confirmation of the emerged and changed possibilities and state of the entity's character.

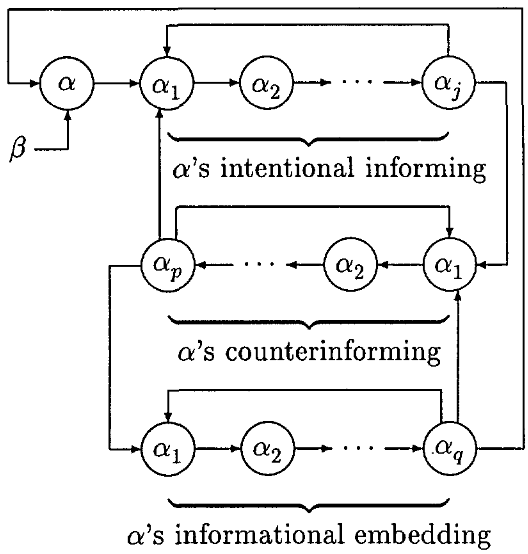


Figure 7: *A generalized metaphysicalism of entity α with interior informing, counterinforming and informational embedding, concerning something β.*

Another comment of Fig. 7 concerns the loops of the informational graph. Six basic loops are recognized, however, this does not mean that in a concrete case additional loops between metaphysicalistic components can be introduced. The following principle seems reasonable:

Principle of Metaphysicalism of Metaphysicalism. *Components of a metaphysicalistic entity are, in principle, metaphysicalistic entities. Such a determination causes an endless fractalness of metaphysicalism (metaphysicalistic fractalism).* □.

Let us study some basic properties of the graph in Fig. 7.

5.12.3 Reductionistic Basic Metaphysicalistic Model of an Informational Entity

Let us begin with the basic (most primitive) case, where the metaphysicalistic decompositional components of operand α within transition $\alpha \models \alpha$ are

$$\mathfrak{I}_\alpha, \mathfrak{i}_\alpha, \mathfrak{C}_\alpha, \mathfrak{c}_\alpha, \mathfrak{E}_\alpha, \mathfrak{e}_\alpha$$

called

1. (intentional or entity's characteristic) informing,
2. intention of the entity (its instantaneously arising character, concept, definition),
3. counterinforming (opposing, synonymous, antonymous, questioning intentional informing),
4. counterinformational entity (informational opposition, synonyms, antonyms, questions requiring answers as consequences of the intention),
5. embedding (the process of the connection of new information arisen by counterinforming, e.g., in the form of answering), and
6. embedding entity (information) by which new products are regularly connected with the existing informational body of the entity,

respectively. These operands come at the places of the decomposition components ω_1, ω_2, ω_3, ω_4, ω_5, and ω_6, in this order, so, $n = 6$ and the number of formulas in the canonic gestalt concerning solely the topic circular entity α is 7, in noncanonic gestalt 422, and altogether 429. The same number of formulas appear in gestalts belonging to the remaining six circular (metaphysicalistic) operands (components).

5.12.4 Canonic Metaphysicalistic (Reductionistic) Gestalts

Let us construct the canonic (informer-observer regular) gestalts according to Table 1 on one side and, then, in the next Subsubsection, sketch the structure of and determine the number of the remaining noncanonic gestalts.

There are the following cases of the reduced (standardized) canonic metaphysicalistic (the front superscript 'met') gestalts:

- metaphysicalistic, parenthesized reductionistic canonic gestalt (PRCG for short) ${}^{\mathrm{met}}\Gamma^{\mathrm{can}\,6}_{\alpha\models\alpha}$;
- metaphysicalistic, demarcated reductionistic canonic gestalt (DRCG) ${}^{\mathrm{met}}\Gamma^{\mathrm{can}\,6}_{\alpha.\models.\alpha}$;
- metaphysicalistic, parenthesized, operator-composed reductionistic canonic gestalt (POCRCG) ${}^{\mathrm{met}}\Gamma^{\mathrm{can}\,6}_{\alpha\models\circ\models\alpha}$; and
- metaphysicalistic, demarcated, operator-composed reductionistic canonic gestalt (DOCRCG) ${}^{\mathrm{met}}\Gamma^{\mathrm{can}\,6}_{\alpha.\models\circ\models.\alpha}$

The PNCG consists of canonic formulas only and the number of formulas in a PNCG depends on the length ℓ being equal to the number of binary operators in a canonic formula of PRCG. In a standard metaphysical case this number is always $\ell = n + 1 = 7$. Thus,

$$
{}^{\mathrm{met}}\Gamma^{\mathrm{can}6}_{\alpha\models\alpha} \rightleftharpoons
\left(
\begin{array}{l}
((((((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \\
\quad \mathfrak{c}_\alpha) \models \mathfrak{E}_\alpha) \models \mathfrak{e}_\alpha) \boxed{\models} \alpha; \\
(((((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \\
\quad \mathfrak{c}_\alpha) \models \mathfrak{E}_\alpha) \boxed{\models} (\mathfrak{e}_\alpha \models \alpha); \\
((((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \\
\quad \mathfrak{c}_\alpha) \boxed{\models} (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha)); \\
(((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \boxed{\models} \\
\quad (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha))); \\
((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \boxed{\models} (\mathfrak{C}_\alpha \models \\
\quad (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha)))); \\
(\alpha \models \mathfrak{I}_\alpha) \boxed{\models} (\mathfrak{i}_\alpha \models (\mathfrak{C}_\alpha \models \\
\quad (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha))))); \\
\alpha \boxed{\models} (\mathfrak{I}_\alpha \models (\mathfrak{i}_\alpha \models (\mathfrak{C}_\alpha \models \\
\quad (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha))))))
\end{array}
\right)
$$

The structure philosophy of this gestalt can be understood by means of Fig. 8 which represents the specific (canonic) arrangement of parenthesis pairs within a metaphysicalistic formula of length $\ell = 7$. The reader can see that the so-called canonic formulas are nothing else than a strict consideration of a systematic informer-observer principle which is consequently sequential from the view of the informer and the view of the observer informing on the left and on the right side of the main operator $\models^*$. Sketches $1, \cdots, 7$ in Fig. 8 show this regular (canonic) principle in a transparent and instructive manner.

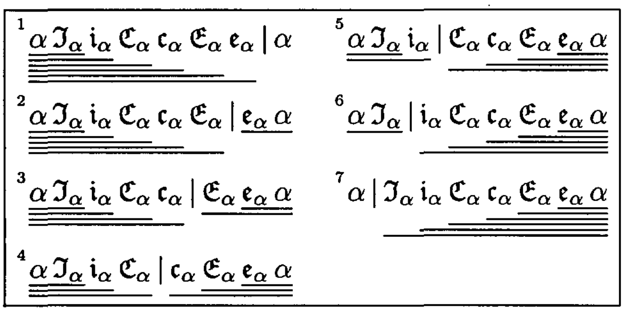


Figure 8: *A schematic presentation of the seven metaphysicalistic reductionistic canonic gestalts of different forms, that is,* ${}^{\mathrm{met}}\Gamma^{\mathrm{can}6}_{\alpha\models\alpha}$, ${}^{\mathrm{met}}\Gamma^{\mathrm{can}6}_{\alpha.\models.\alpha}$, ${}^{\mathrm{met}}\Gamma^{\mathrm{can}6}_{\alpha\models\circ\models\alpha}$, *and* ${}^{\mathrm{met}}\Gamma^{\mathrm{can}6}_{\alpha.\models\circ\models.\alpha}$. *Symbol '|' marks the place of the main operator and a line marks a subformula which is inside of a parenthesis pair.*

Another comment to the sketches in Fig. 8 concerns the recognition process when the informer appears in the scope of the observer, that is, when it is gradually recognized into more and more details by the observer. This process can be understood as the shifting from the initial, informer-governed situation when the observing entity just senses the informer and becomes aware of its presence (sketch 1 in Fig. 8). But, that what is initially hidden in the informing of the informer, progressively transits to the observer site building up the recognition of the informer by the observer and, in this way, shifting to the transitions sketched and marked by 2 to 7.

The sketch 7 in Fig. 8 demonstrates the situation in which the observer α observes metaphysically all its inner components, that is, $\mathfrak{I}_\alpha$, $\mathfrak{i}_\alpha$, $\mathfrak{C}_\alpha$, $\mathfrak{c}_\alpha$, $\mathfrak{E}_\alpha$, and $\mathfrak{e}_\alpha$. The reader can comprehend how the case 1 is important for the informer's point of view where information about the components is mediated to the observer site. In the case 7, the observers point of view comes to the surface when the inner components have already become a part of the observing entity α. Of course, both situations can have a permanent importance during the metaphysical cyclic informing, so they can coexist equally, together with other possibilities.

The next gestalt form corresponding to the parenthesized metaphysicalistic gestalt is the demarcated one (DRCG) and we show it exclusively for the sake of the completeness of the metaphysicalistic case of informational transition. Thus,

$$
{}^{\mathrm{met}}\Gamma^{\mathrm{can}6}_{\alpha\,.\models.\,\alpha} \rightleftharpoons
\left(
\begin{array}{l}
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \,.\models \mathfrak{C}_\alpha \,.\models \\
\quad \mathfrak{c}_\alpha \,.\models \mathfrak{E}_\alpha \,.\models \mathfrak{e}_\alpha \boxed{.\models.}\, \alpha; \\
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \,.\models \mathfrak{C}_\alpha \,.\models \\
\quad \mathfrak{c}_\alpha \,.\models \mathfrak{E}_\alpha \boxed{.\models.}\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \,.\models \mathfrak{C}_\alpha \,.\models \\
\quad \mathfrak{c}_\alpha \boxed{.\models.}\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \,.\models \mathfrak{C}_\alpha \boxed{.\models.} \\
\quad \mathfrak{c}_\alpha \models.\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \models \mathfrak{I}_\alpha \models \mathfrak{i}_\alpha \boxed{.\models.}\, \mathfrak{C}_\alpha \models. \\
\quad \mathfrak{c}_\alpha \models.\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \models \mathfrak{I}_\alpha \boxed{.\models.}\, \mathfrak{i}_\alpha \,.\models.\, \mathfrak{C}_\alpha \models. \\
\quad \mathfrak{c}_\alpha \models.\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \boxed{.\models.}\, \mathfrak{I}_\alpha \models.\, \mathfrak{i}_\alpha \models.\, \mathfrak{C}_\alpha \models. \\
\quad \mathfrak{c}_\alpha \models.\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha
\end{array}
\right)
$$

The parenthesized, operator-composed reductionistic canonic gestalt (POCRCG) for the reductionistic metaphysicalistic case is

$$
{}^{\mathrm{met}}\Gamma^{\mathrm{can}6}_{\alpha\models\circ\models\alpha} \rightleftharpoons
\left(
\begin{array}{l}
((((((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \mathfrak{c}_\alpha) \\
\quad \models \mathfrak{E}_\alpha) \models \mathfrak{e}_\alpha) \boxed{\models\circ\models}\, \alpha; \\
(((((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \mathfrak{c}_\alpha) \\
\quad \models \mathfrak{E}_\alpha) \boxed{\models\circ\models}\, (\mathfrak{e}_\alpha \models \alpha); \\
((((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \mathfrak{c}_\alpha) \\
\quad \boxed{\models\circ\models}\, (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha)); \\
(((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \boxed{\models\circ\models} \\
\quad (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha))); \\
((\alpha \models \mathfrak{I}_\alpha) \models \mathfrak{i}_\alpha) \boxed{\models\circ\models} \\
\quad (\mathfrak{C}_\alpha \models (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha)))); \\
(\alpha \models \mathfrak{I}_\alpha) \boxed{\models\circ\models}\, (\mathfrak{i}_\alpha \models \\
\quad (\mathfrak{C}_\alpha \models (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha))))); \\
\alpha \boxed{\models\circ\models}\, (\mathfrak{I}_\alpha \models (\mathfrak{i}_\alpha \models \\
\quad (\mathfrak{C}_\alpha \models (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha))))))
\end{array}
\right)
$$

Finally, we can write down the demarcated, operator-composed canonic gestalt (DOCCG) in the form

$$
{}^{\mathrm{met}}\Gamma^{\mathrm{can}6}_{\alpha\,.\models\circ\models.\,\alpha} \rightleftharpoons
\left(
\begin{array}{l}
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \,.\models \mathfrak{C}_\alpha \,.\models \mathfrak{c}_\alpha \\
\quad .\models \mathfrak{E}_\alpha \,.\models \mathfrak{e}_\alpha \boxed{.\models\circ\models}\, \alpha; \\
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \,.\models \mathfrak{C}_\alpha \,.\models \mathfrak{c}_\alpha \\
\quad .\models \mathfrak{E}_\alpha \boxed{.\models\circ\models.}\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \,.\models \mathfrak{C}_\alpha \,.\models \mathfrak{c}_\alpha \\
\quad \boxed{.\models\circ\models.}\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \,.\models \mathfrak{C}_\alpha \boxed{.\models\circ\models.} \\
\quad \mathfrak{c}_\alpha \models.\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \models \mathfrak{I}_\alpha \,.\models \mathfrak{i}_\alpha \boxed{.\models\circ\models.} \\
\quad \mathfrak{C}_\alpha \models.\, \mathfrak{c}_\alpha \models.\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \models.\, \mathfrak{I}_\alpha \boxed{.\models\circ\models.}\, \mathfrak{i}_\alpha \models. \\
\quad \mathfrak{C}_\alpha \models.\, \mathfrak{c}_\alpha \models.\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha; \\
\alpha \boxed{\models\circ\models.}\, \mathfrak{I}_\alpha \models.\, \mathfrak{i}_\alpha \models. \\
\quad \mathfrak{C}_\alpha \models.\, \mathfrak{c}_\alpha \models.\, \mathfrak{E}_\alpha \models.\, \mathfrak{e}_\alpha \models \alpha
\end{array}
\right)
$$

Evidently, there exist many other metaphysicalistic formulas of length $\ell = 7$ which can become senseful in a particular situation. The canonical concept follows a strict (systematic) sequential 'propagation' of parenthesis pairs from the left side for the informer point of view and from the right side for the observer point of view, simultaneously. Between these points of view lies the main (informer-observer-separating) operator.

5.12.5 Gestalts and Schemes Belonging to the Partial Decomposition of Canonic Metaphysicalistic Formulas

Partial decomposition of a canonic formula of any length means that the main operator retains its position, and only the left and the right part of the formula can be decomposed arbitrarily. In this manner, the number of the obtained formulas for a canonic formula is equal to the product of numbers of formulas proceeding from the left and the right part of the original canonic formula.

Noncanonic metaphysical gestalts can be, similarly as canonic ones, marked in the following way:

- parenthesized normal noncanonic (superscript 'non') gestalt (PNNCG) $^{\text{met}}\Gamma^{\text{non}6}_{\alpha\models\alpha}$;
- demarcated normal noncanonic gestalt (DNNCG) $^{\text{met}}\Gamma^{\text{non}6}_{\alpha.\models.\alpha}$;
- parenthesized, operator-composed noncanonic gestalt (POCNCG) $^{\text{met}}\Gamma^{\text{non}6}_{\alpha\models\circ\models\alpha}$; and
- demarcated, operator-composed noncanonic gestalt (DOCNNG) $^{\text{met}}\Gamma^{\text{non}6}_{\alpha.\models\circ\models.\alpha}$.

Let us show systematically which canonic and noncanonic formulas follow by decomposition from each canonic formula according to Fig. 8 and Table 2.

1. Possible noncanonic decompositions of the first metaphysicalistic canonic formula

Let us analyze systematically the first canonic formula in respect to all possible canonic and noncanonic formulas which can be derived according to the scheme superscribed by 1 in Fig. 8. In this way, the causal analysis answers the question of all possibilities concerning the pure metaphysicalistic informer situation, presented by formula

$$((((((\alpha \models \mathfrak{J}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \mathfrak{c}_\alpha) \models \mathfrak{E}_\alpha) \models \mathfrak{e}_\alpha) \boxed{\models} \alpha$$

The position of the main operator remains preserved and the subformula

$$(((((\alpha \models \mathfrak{J}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \mathfrak{c}_\alpha) \models \mathfrak{E}_\alpha) \models \mathfrak{e}_\alpha$$

with exception of its own parenthesis configuration, which is embedded in the original formula, has to be presented by all possible other configurations. This means that the original scheme

$$^{1/1}\alpha\,\mathfrak{J}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha \,|\, \alpha$$

has to be varied, keeping the informer principle, where all decomposition content is within the informer part of the decomposition of $\alpha \models \alpha$. Thus, according to Table 2, the informational schemata of noncanonic decompositions are

$$^{1/2}\alpha\,\mathfrak{J}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha \,|\, \alpha$$

$$^{1/3}\alpha\,\mathfrak{J}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha \,|\, \alpha$$

$$\ldots$$

$$^{1/132}\alpha\,\mathfrak{J}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha \,|\, \alpha$$

In these schemes, various possible causal situations of the so-called pure-informingly structured metaphysicalism of entity α come to the surface.

Let us introduce the general gestalt marker

$$^{\text{met}}\Gamma^{n}_{\alpha\models\beta} \rightleftharpoons \Gamma\left({}^{n+1}_{\;\;j}\mathfrak{M}_{\rightharpoondown}(\alpha \models \beta)\right)$$

What does the formula $^{\text{met}}\Gamma^{5}_{\alpha\models\alpha} \models \alpha$ mean at all? Evidently, the previous discussion of the decomposition, regarding the first metaphysicalistic canonic formula, can be interpreted by the introduced formula, where

$$\left({}^{\text{met}}\Gamma^{5}_{\alpha\models\alpha} \models \alpha\right) \rightleftharpoons \left(\begin{pmatrix} (((((\alpha \models \mathfrak{J}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \mathfrak{c}_\alpha) \models \\ \quad \mathfrak{E}_\alpha) \models \mathfrak{e}_\alpha, \\ ((((\alpha \models \mathfrak{J}_\alpha) \models \mathfrak{i}_\alpha) \models \mathfrak{C}_\alpha) \models \mathfrak{c}_\alpha) \models \\ \quad (\mathfrak{E}_\alpha \models \mathfrak{e}_\alpha), \\ \vdots \\ \alpha \models (\mathfrak{J}_\alpha \models (\mathfrak{i}_\alpha \models (\mathfrak{C}_\alpha \models (\mathfrak{c}_\alpha \models \\ \quad (\mathfrak{E}_\alpha \models \mathfrak{e}_\alpha))))) \end{pmatrix} \models \alpha\right)$$

where $^{\text{met}}\Gamma^{5}_{\alpha\models\alpha}$ represents the union of the canonic gestalt $^{\text{met}}\Gamma^{\text{can}5}_{\alpha\models\alpha}$ and the noncanonic gestalt $^{\text{met}}\Gamma^{\text{non}5}_{\alpha\models\alpha}$ or, formally,

$$^{\text{met}}\Gamma^{5}_{\alpha\models\alpha} \rightleftharpoons \begin{pmatrix} ^{\text{met}}\Gamma^{\text{can}5}_{\alpha\models\alpha}; \\ ^{\text{met}}\Gamma^{\text{non}5}_{\alpha\models\alpha} \end{pmatrix}$$

The number of different formula decompositions is $\frac{1}{7}\binom{12}{5} \times \frac{1}{1}\binom{0}{0} = 132$, where $\binom{0}{0} = 1$.

2. Possible noncanonic decompositions of the second metaphysicalistic canonic formula

One of the basic question is how many formulas can follow from the second metaphysicalistic canonic formula when the position of the main operator remains preserved. Evidently, in the form of the informational schemes, according to Fig. 8 and Table 2,

$$^{2/1}\alpha\,\mathfrak{J}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha \,|\, \mathfrak{e}_\alpha\,\alpha$$

$$^{2/2}\alpha\,\mathfrak{J}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha \,|\, \mathfrak{e}_\alpha\,\alpha$$

$$\ldots$$

$$^{2/42}\alpha\,\mathfrak{J}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha \,|\, \mathfrak{e}_\alpha\,\alpha$$

where formula schemes 2/2, 2/3, ... , 2/42 are noncanonic. One can observe that the number of different formula decompositions is $\frac{1}{6}\binom{10}{5} \times \frac{1}{2}\binom{2}{1} =$ 42 (the product of the formula left and right part possibilities).

3. Possible noncanonic decompositions of the third metaphysicalistic canonic formula

Evidently, in the form of the informational schemes, according to Fig. 8 and Table 2, for the third metaphysicalistic canonic formula decomposition, there is

$$^{3/1}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha \mid \mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

$$^{3/2}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha \mid \mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

$$\ldots$$

$$^{3/28}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha \mid \mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

where formula schemes 3/2, 3/3, ... , 3/28 are noncanonic. One can observe that the number of different formula decompositions is $\frac{1}{5}\binom{8}{4} \times \frac{1}{3}\binom{4}{2} =$ 28 (the product of the formula left and right part possibilities).

4. Possible noncanonic decompositions of the fourth metaphysicalistic canonic formula

Further, in the form of the informational schemes, according to Fig. 8 and Table 2, for the fourth metaphysicalistic canonic formula decomposition, there is

$$^{4/1}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha \mid \mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

$$^{4/2}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha \mid \mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

$$\ldots$$

$$^{4/25}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha\,\mathfrak{C}_\alpha \mid \mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

where formula schemes 4/2, 4/3, ... , 4/25 are noncanonic. One can observe that the number of different formula decompositions is $\frac{1}{4}\binom{6}{3} \times \frac{1}{4}\binom{6}{3} =$ 25.

5. Possible noncanonic decompositions of the fifth metaphysicalistic canonic formula

The case of the fifth metaphysicalistic canonic formula is scheme-symmetric to the case 3. Thus,

$$^{5/1}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha \mid \mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

$$^{5/2}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha \mid \mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

$$\ldots$$

$$^{5/28}\ \alpha\,\mathfrak{I}_\alpha\,\mathfrak{i}_\alpha \mid \mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

where formula schemes 5/2, 5/3, ... , 5/28 are noncanonic. One can observe that the number of different formula decompositions is $\frac{1}{3}\binom{4}{2} \times \frac{1}{5}\binom{8}{4} =$ 28.

6. Possible noncanonic decompositions of the sixth metaphysicalistic canonic formula

The case of the sixth metaphysicalistic canonic formula is scheme-symmetric to the case 2. Thus,

$$^{6/1}\ \alpha\,\mathfrak{I}_\alpha \mid \mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

$$^{6/2}\ \alpha\,\mathfrak{I}_\alpha \mid \mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

$$\ldots$$

$$^{6/42}\ \alpha\,\mathfrak{I}_\alpha \mid \mathfrak{i}_\alpha\,\mathfrak{C}_\alpha\,\mathfrak{c}_\alpha\,\mathfrak{E}_\alpha\,\mathfrak{e}_\alpha\,\alpha$$

where formula schemes 6/2, 6/3, ... , 6/42 are noncanonic. One can observe that the number of different formula decompositions is $\frac{1}{2}\binom{2}{1} \times \frac{1}{6}\binom{10}{5} =$ 42.

7. Possible noncanonic decompositions of the seventh metaphysicalistic canonic formula

Let us analyze systematically the last canonic formula in respect to all possible noncanonic formulas which can be derived according to the scheme superscripted by 7 in Fig. 8. In this way, the causal analysis answers the question of all possibilities concerning the pure metaphysicalistic observer situation, presented by formula

$$\alpha \boxed{\models} \\ (\mathfrak{I}_\alpha \models (\mathfrak{i}_\alpha \models (\mathfrak{C}_\alpha \models (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha \models \alpha))))))$$

The position of the main operator remains preserved and the subformula

$$\mathfrak{I}_\alpha \models (\mathfrak{i}_\alpha \models (\mathfrak{C}_\alpha \models (\mathfrak{c}_\alpha \models (\mathfrak{E}_\alpha \models (\mathfrak{e}_\alpha)))))$$

with exception of its own parenthesis configuration, which is embedded in the original formula, has to be presented by all possible other configurations. This means that the original scheme

$$ {}^{7/1}\alpha \mid \mathfrak{I}_\alpha\, \mathfrak{i}_\alpha\, \mathfrak{C}_\alpha\, \mathfrak{c}_\alpha\, \mathfrak{E}_\alpha\, \mathfrak{e}_\alpha\, \alpha $$

has to be varied, keeping the observer principle, where all decomposition content is within the observer part of the decomposition of $\alpha \models \alpha$. Thus, according to Table 2,

$$ {}^{7/2}\alpha \mid \mathfrak{I}_\alpha\, \mathfrak{i}_\alpha\, \mathfrak{C}_\alpha\, \mathfrak{c}_\alpha\, \mathfrak{E}_\alpha\, \mathfrak{e}_\alpha\, \alpha $$

$$ {}^{7/3}\alpha \mid \mathfrak{I}_\alpha\, \mathfrak{i}_\alpha\, \mathfrak{C}_\alpha\, \mathfrak{c}_\alpha\, \mathfrak{E}_\alpha\, \mathfrak{e}_\alpha\, \alpha $$

$$ \cdots $$

$$ {}^{7/132}\alpha \mid \mathfrak{I}_\alpha\, \mathfrak{i}_\alpha\, \mathfrak{C}_\alpha\, \mathfrak{c}_\alpha\, \mathfrak{E}_\alpha\, \mathfrak{e}_\alpha\, \alpha $$

In these schemes, various possible causal situations of the so-called pure-observingly structured metaphysicalism of entity α come to the surface. The number of different formula decompositions is $\frac{1}{1}\binom{0}{0} \times \frac{1}{7}\binom{12}{6} = 132$, where $\binom{0}{0} = 1$.

5.12.6 The Number of All Possible Formulas in Metaphysicalistic and Sub-metaphysicalistic Gestalts

The question, how many formulas can be derived from an informational formula of length ℓ, is certainly righteous. If we know this number we are able to conclude how many noncanonical formulas are possible. And we can expect that this number will rise with the length ℓ of a formula.

Let N_ℓ represent the number of all possible formulas of length ℓ. An analysis of this case where parenthesis pairs and their possible displacements within a formula perform as binary operator permutations [11] gives

$$ N_\ell = \frac{1}{\ell+1}\binom{2\ell}{\ell} = \frac{2\ell\,(2\ell-1)\cdots(\ell+2)}{\ell!} $$

We get the short overview in Table 2.

Standard metaphysicalistic formulas of length $\ell = 6$ represent shells which can be further analyzed ($\ell < 6$) and filled with concrete, e.g. concrete intelligent subformulas, so the length of a formula becomes $\ell > 6$. Under such circumstances the number of other senseful possibilities can, according to the ℓ/N_ℓ-table, rise extensively.

ℓ	N_ℓ	ℓ	N_ℓ	ℓ	N_ℓ
1	1	6	132	11	58 786
2	2	7	429	12	208 012
3	5	8	1 430	13	742 900
4	14	9	4 862	14	2 674 440
5	42	10	16 796	15	9 694 845

Table 2: *The dependence of the number of formulas N_ℓ on the length ℓ (number of binary operators) of a formula.*

Because the number of canonic formulas of length ℓ is $N_\ell^{\text{can}} = \ell = n + 1$, where n is the number of decomposed components in the transition $\alpha \models \alpha$ (or $\alpha \models \beta$, in general), the number of noncanonic formulas of length ℓ is

$$ N_\ell^{\text{non}} = N_\ell - \ell $$

Let in a formula, divided by the main operator into the left and the right part, mark by ℓ_{left} the length of the left part and by ℓ_{right} the right part of the formula, where $\ell_{\text{left}} + \ell_{\text{right}} = \ell - 1$. Then, the number of possible decompositions when the position of the main operator remains preserved, is, evidently,

$$ \frac{1}{\ell_{\text{left}}+1}\binom{2\ell_{\text{left}}}{\ell_{\text{left}}} \times \frac{1}{\ell_{\text{right}}+1}\binom{2\ell_{\text{right}}}{\ell_{\text{right}}} $$

After that, from the noncanonic decomposition of canonic formulas, for a formula of length ℓ, with $\binom{0}{0} = 1$, immediately follows

$$ \frac{1}{\ell+1}\binom{2\ell}{\ell} = $$

$$ \sum_{k=1}^{\ell} \frac{1}{\ell-k+1}\binom{2(\ell-k)}{\ell-k} \times \frac{1}{k}\binom{2(k-1)}{k-1} $$

Thus, for the debated metaphysicalistic case, where $\ell = 7$, there is $429 = 132 + 42 + 28 + 25 + 28 + 42 + 132$.

5.12.7 Canonic and Noncanonic Metaphysicalistic Gestalts

The canonic metaphysicalistic gestalt presents all possible pure informer-observer decompositions of the standardized metaphysicalistic structure α,

$\mathfrak{I}_\alpha$, $\mathfrak{i}_\alpha$, $\mathfrak{C}_\alpha$, $\mathfrak{c}_\alpha$, $\mathfrak{E}_\alpha$, and $\mathfrak{e}_\alpha$. The number of canonic formulas, within this structure, is 7 (equal to the number of metaphysicalistic components).

The noncanonic metaphysicalistic gestalt unites all possible causal cases of the parenthetically structured standardized metaphysicalism of entity α. The number of noncanonic formulas, within this structure, is $\frac{1}{8}\binom{14}{7} - 7 = 422$.

The presented discussion of standardized metaphysicalism of an entity α did not consider other possible loops (with exception of the main loop) which can be introduced between the standard metaphysicalistic components. This, standardized situation too, is presented by the informational graph in Fig. 9.

5.13 The Metaphysicalistic Parallel Decomposition of $\alpha \models \alpha$, that is, ${}^{\ell_k}\mathfrak{M}^{\circlearrowleft}_{\parallel}(\alpha \models \alpha)$

5.13.1 The Generalized Case

Any serial metaphysicalistic formula ${}^{\mathrm{met}}_{k}\varphi^{\circlearrowleft}_{\rightarrow}(\alpha \models \alpha)$ belonging to the metaphysicalistic gestalt can be parallelized, that is $\Pi\left({}^{\mathrm{met}}_{j}\varphi^{\circlearrowleft}_{\rightarrow}(\alpha \models \alpha)\right)$. The result is, according to Fig. 7, for the parallelization of the main (the longest) decomposition,

$$\Pi\left({}^{j+p+q+1}\mathfrak{M}^{\circlearrowleft}_{\parallel}(\alpha \models \alpha)\right) \rightleftharpoons \begin{pmatrix} \alpha \models \alpha_1; \\ \alpha_1 \models \alpha_2; \alpha_2 \models \alpha_3; \cdots ; \alpha_{j-1} \models \alpha_j; \\ \alpha_j \models \alpha_1; \\ \alpha_1 \models \alpha_2; \alpha_2 \models \alpha_3; \cdots ; \alpha_{p-1} \models \alpha_p; \\ \alpha_p \models \alpha_1; \\ \alpha_1 \models \alpha_2; \alpha_2 \models \alpha_3; \cdots ; \alpha_{q-1} \models \alpha_q; \\ \alpha_q \models \alpha \end{pmatrix}$$

5.13.2 The Reductionistic (Standardized) Metaphysicalistic Case

Virtually, the so-called standardized metaphysicalistic case is the minimal one, which appears to be senseful in the context of informing, counterinforming, and informational embedding. These three components, each of them including the component of informing and informing entity, should guarantee the informational arising in a spontaneous and circular way, together with the topic(s) entity α. Thus, the parallelization of any metaphysicalistically decomposed formula of length 7 delivers the result in the form

$$\Pi\left({}^{7}\mathfrak{M}^{\circlearrowleft}_{\parallel}(\alpha \models \alpha)\right) \rightleftharpoons \begin{pmatrix} \alpha \models \mathfrak{I}_\alpha; \\ \mathfrak{I}_\alpha \models \mathfrak{i}_\alpha; \mathfrak{i}_\alpha \models \mathfrak{C}_\alpha; \\ \mathfrak{C}_\alpha \models \mathfrak{c}_\alpha; \mathfrak{c}_\alpha \models \mathfrak{E}_\alpha; \\ \mathfrak{E}_\alpha \models \mathfrak{e}_\alpha; \mathfrak{e}_\alpha \models \alpha \end{pmatrix}$$

The graph corresponding to the right part of the last formula is presented in Fig. 9.

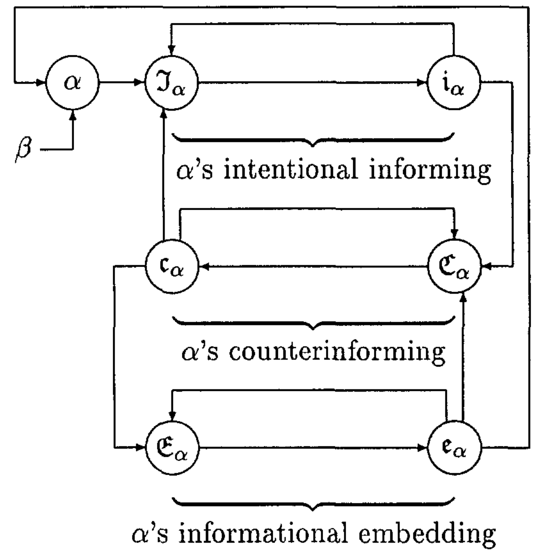


Figure 9: *A standardized (reductionistic) metaphysicalism of entity α with basic interior informing, counterinforming and informational embedding, concerning something β.*

The whole content of the graph in Fig. 9 must consider the externally impacting operand β, that is, $\alpha^{\circlearrowleft}_{\parallel}(\beta)$, and the additional internal feedbacks. The most general symbolic solution for the graph in Fig. 9 upon α, in which all of the possible metaphysicalistic decompositions are included, is

$$\alpha^{\circlearrowleft}_{\parallel}(\beta) \rightleftharpoons \begin{pmatrix} \beta \models \alpha; \\ \alpha \models \mathfrak{I}_\alpha; \\ \mathfrak{I}_\alpha \models \mathfrak{i}_\alpha; \mathfrak{i}_\alpha \models \mathfrak{C}_\alpha; \\ \mathfrak{C}_\alpha \models \mathfrak{c}_\alpha; \mathfrak{c}_\alpha \models \mathfrak{E}_\alpha; \\ \mathfrak{E}_\alpha \models \mathfrak{e}_\alpha; \mathfrak{e}_\alpha \models \alpha; \\ \mathfrak{i}_\alpha \models \mathfrak{I}_\alpha; \mathfrak{c}_\alpha \models \mathfrak{C}_\alpha; \\ \mathfrak{e}_\alpha \models \mathfrak{E}_\alpha; \\ \mathfrak{c}_\alpha \models \mathfrak{I}_\alpha; \mathfrak{e}_\alpha \models \mathfrak{C}_\alpha \end{pmatrix}$$

Solution $\alpha^{\circlearrowleft}_{\parallel}(\beta)$ describes the entirety of the graph in Fig. 9, and this informational system can be solved upon any other component of the system, with exception of the exterior component β, in a particular or serial way, or in a universal or parallel way.

5.14 A Straightforward Heterogeneous Serial Decomposition of Informational Transition

Let us introduce the complexity of informational decomposition of transition $\alpha \models \beta$ by the graph in Fig. 10. This figure is a modification of the model

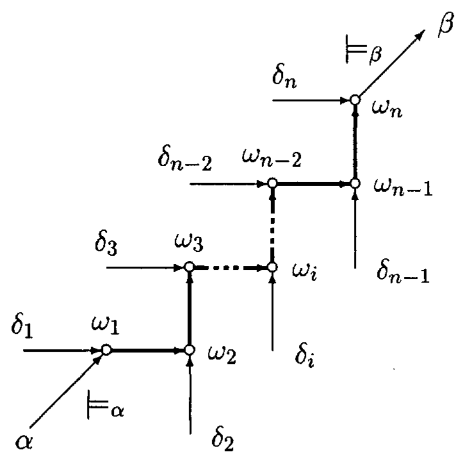


Figure 10: *A graphical interpretation of the informational transition $\alpha \models \beta$ divided into the informer part (α with operator $\models_\alpha$), the channel part with its internal informational structure of ω_1, ω_2, $\cdots$, ω_1 for the acceptance of the exterior informational disturbers δ_1, δ_2, $\cdots$, δ_n, and the observer part (β with preceding operator $\models_\beta$). In fact, this graphical scheme represents the so-called gestalt of $\alpha \models \beta$, that is, all possible serial parenthesized forms of the length $\ell = n + 1$.*

given by Fig. 1 in [1]. As one can see, at each internal component ω_1, ω_2, $\cdots$, ω_n, inner and/or outer disturbing entities δ_1, δ_2, $\cdots$, δ_n come into game and can be differently metaphysically or in some other way (linearly, circularly) decomposed.

In this sense, a more complex, fractal-like decomposition of the general transitional form $\alpha \models \beta$ is presented in Fig. 11, certainly, in its most straightforward form. In this figure, each component α_i ($i = 1, 2, \cdots, n$) is linearly decomposed, however, this does not mean that arbitrary circular connections cannot exist. By this graph, the possibilities of the informational (causal, inner and outer impacting) complexity, which could come into existence, become conceptually and formalistically evident.

6 A Concept of the Decision-Making System Concerning the Transition of a Social System

Today, various forms of social transitions (also in capitalist systems [3]) are taking place. One of the most characteristic one is that of proceeding from the communist to capitalist system, e.g. in the countries of Middle Europe and Eastern Europe. The question is which are the most remarkable phenomena and how could they be captured by informational means, that is, in forms of informational formula systems. So, let us study, only in an initial way, the most remarkable terminology and basic informational processes, by the systems of informational transitions.

6.1 Terminological Background

At the beginning of the study, sufficiently precise (remarkable) terminology is important, because it constitutes the conceptual background for the development and decomposition of the characteristically circular transitions and their complex (parallel, serial) linking within a system of social-transition phenomena.

Let us introduce some basic informational entities and their symbols (operands) and operational properties (operand-operator loops):

1. First of the most remarkable phenomenon of new democracies is *nationalism,* marked by the symbol $\mathfrak{n}$. It represents the central point around which other phenomena occur cyclically as it is evident in the next subsection, where the informational graph for a decision-making system is presented.

2. The second most visible phenomenon in postcommunist systems is *corruption,* marked by the symbol $\mathfrak{c}$. Corruption is in the center of some very specific processes, e.g., financial by-passing by firms and banks, budget legalization of criminal-founded business,

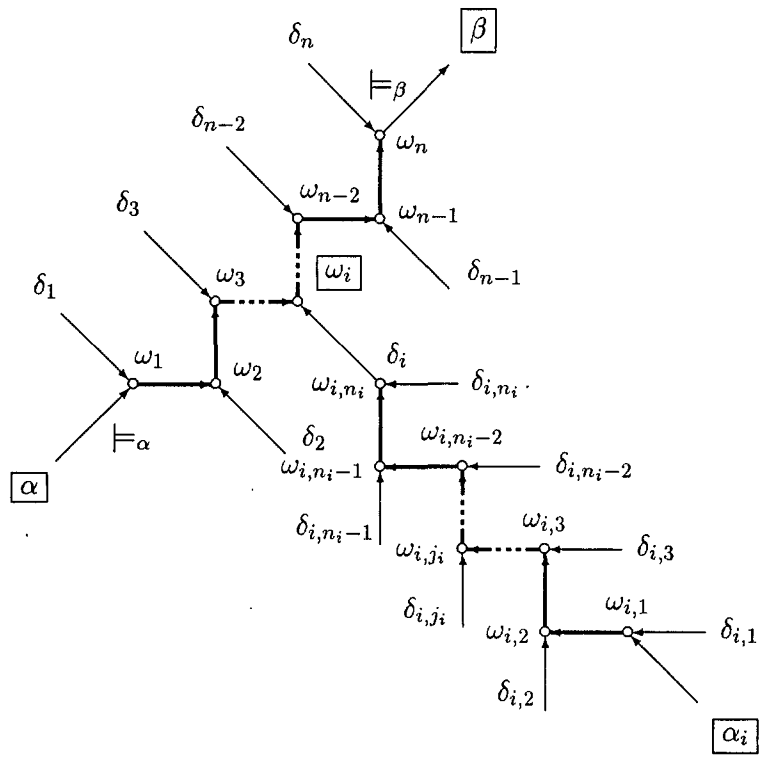


Figure 11: *A graphical interpretation of the composed informational transition $\alpha \models \beta$ divided into the informer part (α with operator $\models_\alpha$), the channel part with its internal informational structure of ω_1, ω_2, $\cdots$, ω_l for the acceptance of the exterior informational disturbers δ_1, δ_2, $\cdots$, δ_n, and the observer part (β with preceding operator $\models_\beta$). In fact, this graphical scheme represent the so-called gestalt of $\alpha \models \beta$, that is, all possible serial parenthesized forms of the length $\ell = n + 1$.*

losses and bankruptcy, privatization, denationalization, defalcation, sanitation of banks, absence of legal legislation, etc. The informational connections will be presented by the mentioned informational graph.

3. The return of nationalized property is accompanied with a sort of moratorium (restriction), $\mathfrak{m}$, called the *moratorium concerning the real-estate return to foreigners.*

4. Another kind of restriction, $\mathfrak{r}_1$, is called the *restriction of the real-estate return to citizens.*

5. The third form of restriction, $\mathfrak{r}_2$, is called the *restriction of investments coming from (particular) foreign countries.*

6. The process of *denationalization,* $\mathfrak{d}$, happens between the most remarkable entities $\mathfrak{c}$ (corruption) and $\mathfrak{n}$ (nationalism) when it is governed (impacted) by $\mathfrak{c}$ and governs (impacts) $\mathfrak{n}$.

7. The government certainly has to improve the market functioning of some firms by the *government (budget) subsidy of inefficient firms,* $\mathfrak{g}$.

8. On the other hand, the *privatization of social firms,* $\mathfrak{p}$, is taking place, with the moratorium of reprivatization of foreigners' property.

9. This process is accompanied by the *defalcation of social property,* $\mathfrak{d}_2$, because of badly (porously) elaborated legislation.

10. To the most important financial phenomena belongs the *improvement (sanitation) of domestic banks in debts and discounts,* $\mathfrak{i}$.

11. One of the significant phenomena is the so-called *partitocratic interest,* $\mathfrak{p}_2$, through which, mainly, the corruption as a social problem is being substantially impacted.

12. The partitocratic interest is fed by the *individual corruption within the ruling political*

parties, $\mathfrak{c}_2$, impacting the partitocratic interest, $\mathfrak{p}_2$, and the government subsidy of inefficient firms, $\mathfrak{g}$.

The enumerated entities of the social transition are in no way the only relevant ones. They constitute an initial model of an inner-politics decision-making system for postcommunist countries.

6.2 A Functional Model of the System

The listed entities can now be put into a circularly perplexed informational graph in Fig. 12. Within

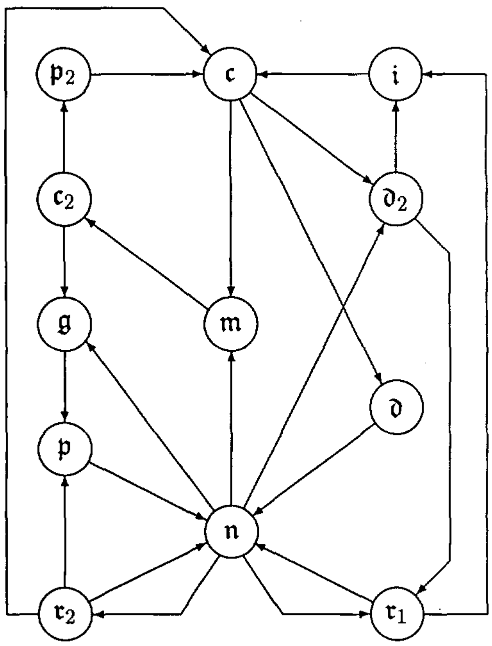


Figure 12: *A graphical interpretation of an inner-politics decision-making system for a postcommunist strategy.*

this graph, by inspection, 16 mutually coupled loops can be identified. As the reader can see, each entity is circularly impacted by the 11 remaining entities. Each loop can be structured in a particular causal form (by occurring parenthesis pairs), or it may happen that even more than one particular circular formula exists for a certain loop of the graph. In an extreme case, the gestalt for a given circular formula can exist, that is, a particular system of causal formulas can inform. On the other hand, the graph can be entirely described by the basic transition parallel circular (loop) system in the form

$$\mathfrak{G}\,(\lambda_{\parallel}^{\circlearrowleft}(\mathfrak{c}, \mathfrak{c}_2, \mathfrak{d}, \mathfrak{d}_2, \mathfrak{g}, \mathfrak{i}, \mathfrak{m}, \mathfrak{n}, \mathfrak{p}, \mathfrak{p}_2, \mathfrak{r}_1, \mathfrak{r}_2)) \rightleftharpoons$$

$$\left(\begin{array}{llll}
\mathfrak{d} \models \mathfrak{n}; & & & \\
\mathfrak{r}_1 \models \mathfrak{i}; & \mathfrak{r}_1 \models \mathfrak{n}; & & \\
\mathfrak{g} \models \mathfrak{p}; & & & \\
\mathfrak{r}_2 \models \mathfrak{n}; & \mathfrak{r}_2 \models \mathfrak{p}; & \mathfrak{r}_2 \models \mathfrak{c}; & \\
\mathfrak{n} \models \mathfrak{r}_1; & \mathfrak{n} \models \mathfrak{g}; & \mathfrak{n} \models \mathfrak{r}_2; & \mathfrak{n} \models \mathfrak{d}_2; \\
 & \mathfrak{n} \models \mathfrak{m}; & & \\
\mathfrak{p} \models \mathfrak{n}; & & & \\
\mathfrak{d}_2 \models \mathfrak{r}_1; & \mathfrak{d}_2 \models \mathfrak{i}; & & \\
\mathfrak{c}_2 \models \mathfrak{g}; & \mathfrak{c}_2 \models \mathfrak{p}_2; & & \\
\mathfrak{i} \models \mathfrak{c}; & & & \\
\mathfrak{m} \models \mathfrak{c}_2; & & & \\
\mathfrak{p}_2 \models \mathfrak{c}; & & & \\
\mathfrak{c} \models \mathfrak{m}; & \mathfrak{c} \models \mathfrak{d}; & \mathfrak{c} \models \mathfrak{d}_2 &
\end{array}\right)$$

This parallel structure of atomic formulas captures the entire circular causal interweavement (all the possibilities) of the system drawn in Fig. 12. On the basis of this formula system the graph in Fig. 12, together with all possible causal situations, is uniquely determined.

If the graph in Fig. 12 is uniquely interpreted by the parallel system of 23 atomic-transition formulas then it implies all possible gestalts Γ of circular formulas (graphical loops) $\lambda_i^{\circlearrowleft}$ belonging to the 16 particular causal loops of the graph $\mathfrak{G}$. Thus,

$$\mathfrak{G}\,(\lambda_{\parallel}^{\circlearrowleft}(\mathfrak{c}, \mathfrak{c}_2, \mathfrak{d}, \mathfrak{d}_2, \mathfrak{g}, \mathfrak{i}, \mathfrak{m}, \mathfrak{n}, \mathfrak{p}, \mathfrak{p}_2, \mathfrak{r}_1, \mathfrak{r}_2)) \Longrightarrow$$

$$\left(\begin{array}{l}
\Gamma(\lambda_1^{\circlearrowleft}(\mathfrak{c}, \mathfrak{d}_2, \mathfrak{i})); \;\; \Gamma(\lambda_2^{\circlearrowleft}(\mathfrak{c}, \mathfrak{d}, \mathfrak{n}, \mathfrak{r}_2)); \\
\Gamma(\lambda_3^{\circlearrowleft}(\mathfrak{c}, \mathfrak{d}_2, \mathfrak{r}_1, \mathfrak{i})); \;\; \Gamma(\lambda_4^{\circlearrowleft}(\mathfrak{c}, \mathfrak{m}, \mathfrak{c}_2, \mathfrak{i})); \\
\Gamma(\lambda_5^{\circlearrowleft}(\mathfrak{c}, \mathfrak{d}, \mathfrak{n}, \mathfrak{r}_1, \mathfrak{i})); \;\; \Gamma(\lambda_6^{\circlearrowleft}(\mathfrak{c}, \mathfrak{d}, \mathfrak{n}, \mathfrak{d}_2, \mathfrak{i})); \\
\Gamma(\lambda_7^{\circlearrowleft}(\mathfrak{c}, \mathfrak{d}, \mathfrak{n}, \mathfrak{m}, \mathfrak{c}_2, \mathfrak{p}_2)); \\
\Gamma(\lambda_8^{\circlearrowleft}(\mathfrak{c}, \mathfrak{d}_2, \mathfrak{r}_1, \mathfrak{n}, \mathfrak{m}, \mathfrak{c}_2, \mathfrak{p}_2)); \\
\Gamma(\lambda_9^{\circlearrowleft}(\mathfrak{c}, \mathfrak{m}, \mathfrak{c}_2, \mathfrak{g}, \mathfrak{p}, \mathfrak{n}, \mathfrak{d}_2, \mathfrak{i})); \\
\Gamma(\lambda_{10}^{\circlearrowleft}(\mathfrak{c}, \mathfrak{m}, \mathfrak{c}_2, \mathfrak{g}, \mathfrak{p}, \mathfrak{n}, \mathfrak{r}_1, \mathfrak{i})); \\
\Gamma(\lambda_{11}^{\circlearrowleft}(\mathfrak{n}, \mathfrak{r}_1)); \;\; \Gamma(\lambda_{12}^{\circlearrowleft}(\mathfrak{n}, \mathfrak{r}_2)); \\
\Gamma(\lambda_{13}^{\circlearrowleft}(\mathfrak{n}, \mathfrak{r}_2, \mathfrak{p})); \;\; \Gamma(\lambda_{14}^{\circlearrowleft}(\mathfrak{n}, \mathfrak{g}, \mathfrak{p})); \\
\Gamma(\lambda_{15}^{\circlearrowleft}(\mathfrak{n}, \mathfrak{d}_2, \mathfrak{r}_1)); \;\; \Gamma(\lambda_{16}^{\circlearrowleft}(\mathfrak{n}, \mathfrak{m}, \mathfrak{c}_2, \mathfrak{g}, \mathfrak{p}))
\end{array}\right)$$

In this system, circular formulas of the form

$$\lambda_i^{\circlearrowleft}(\mathfrak{a}_1, \mathfrak{a}_2, \cdots, \mathfrak{a}_{m_i}); \; i = 1, 2, \cdots, 16$$

have been introduced which mark, in the ordered form, the circles of the circularly involved operands $\mathfrak{a}_1, \mathfrak{a}_2, \cdots, \mathfrak{a}_{m_i}$. One can see that 13 loops concern the operand $\mathfrak{n}$ (nationalism) and 10 of them the operand $\mathfrak{c}$ (corruption).

If we consider that a loop *can begin* at any operand of a loop in the prescribed order, the given initial circular formula constitutes the implication

$$\lambda_i^{\circlearrowleft}(\mathfrak{a}_1, \mathfrak{a}_2, \cdots, \mathfrak{a}_{m_i}) \Longrightarrow \begin{pmatrix} \Gamma(\lambda_i^{\circlearrowleft}(\mathfrak{a}_1, \mathfrak{a}_2, \cdots, \mathfrak{a}_{m_i})); \\ \Gamma(\lambda_i^{\circlearrowleft}(\mathfrak{a}_2, \mathfrak{a}_3, \cdots, \mathfrak{a}_{m_i}, \mathfrak{a}_1)); \\ \vdots \\ \Gamma(\lambda_i^{\circlearrowleft}(\mathfrak{a}_{m_i}, \mathfrak{a}_1, \cdots, \mathfrak{a}_{m_i-1})) \end{pmatrix};$$
$$i = 1, 2, \cdots, 16$$

To study a single i-loop of the system means to have $\frac{m_i}{1+m_i}\binom{2m_i}{m_i}$ causal opportunities for this loop only. Altogether, there are, evidently,

$$N = \prod_{i=1}^{16} \frac{m_i}{1+m_i}\binom{2m_i}{m_i}$$

different possible (to some extent senseful) causal cases. The reader can compute the very large value of N by himself/herself. A parallel informational machine would, corresponding to the graph in Fig. 12, process informationally all these cases and, in accordance to some additional—informational—criteria, show only the (most) relevant (few) ones.

7 Conclusion

The debated analysis and synthesis (the adequate common term for both would be *decomposition*) of informational transition of the form $\alpha \models \beta$ shows the complexity of the question concerning the informing and, in an narrower sense, communication between two or more informational entities in a system. The study shows an unbounded complexity which may emerge in the process of a transition decomposition. Some initially revealed virtualities come to the surface evidently.

The concept and, particularly, formalism of the informational transition satisfy any possible requests regarding to informer-observer situation, that is, observing of informing and observing, operand and operator framing and gestalting [11], and other imaginable concepts within the second-order cybernetics. A social transition, too, can be formalized using this concept of parallel performing transition entities, considering the possibilities of circularly perplexed causalism[7].

References

[1] L. Birnbaum: *Causality and the Theory of Information.* Informatica **18** (1994) 299–304.

[2] E. von Glasersfeld: *Why I Consider Myself a Cybernetician.* Cybernetics & Human Knowing 1 (1992) 1, 22–25.

[3] M. Maruyama: *A Quickly Understandable Notation System of Causal Loops for Strategy Decision Makers.* Cybernetica **36** (1993) No. 1, 37–41.

[4] C. Shannon: *The Mathematical Theory of Communication.* Bell Systems Technical Journal, **27** (1948) 379–423, 623–656.

[5] A.N. Whitehead and B. Russel: *Principia Mathematica,* (in three volumes). Cambridge University Press, Cambridge, 1950.

[6] A.P. Železnikar: *Metaphysicalism of Informing.* Informatica **17** (1993) No. 1, 65–80.

[7] A.P. Železnikar: *Logos of the Informational.* Informatica **17** (1993) No. 3, 245–266.

[8] A.P. Železnikar: *Verbal and Formal Deduction of Informational Axioms.* Cybernetica **37** (1994) No. 1, 5–32.

[9] A.P. Železnikar: *Informational Being-in.* Informatica **18** (1994) No. 2, 149–173.

[10] A.P. Železnikar: *Informational Being-of.* Informatica **18** (1994) No. 3, 277–298.

[11] A.P. Železnikar: *Informational Frames and Gestalts.* Informatica **20** (1996) No. 1, 65–94.

[12] *The Oxford English Dictionary,* Second Edition (on compact disc), Oxford University Press, Oxford, 1992.

[7]Informational causalism will be studied more exhaustively in the paper of the author, entitled *Causality of the Informational,* which will be published as soon as possible.

Another look at computability

Florentin Ipate and Mike Holcombe
Correct Systems Research Group,
Department of Computer Science, University of Sheffield,
Regent Court, 211 Portobello Street,
Sheffield S1 4DP, England, U.K. Email: M.Holcombe@dcs.shef.ac.uk

Keywords: automata, computability, stream X-machine, stack X-machine, partial recursive function, stream function

Edited by: Pavol Návrat
Received: March, 1, 1995 **Revised:** June 2, 1996 **Accepted:** July 3, 1996

1 Introduction

The Turing model [2, 3], has been a cornerstone of the theory of computation for many years and the Chomsky hierarchy of machines a useful mechanism for categorising machines and languages of different capabilities. The theory of X-machines [2, 4], however, offers an alternative approach which has proved valuable and enlightening. For most purposes the Turing model is too restrictive and low-level for serious application as a vehicle for the description and analysis of computational devices. However, the X-machine model offers several important benefits over the Turing model:

1. it is a convenient abstraction that enables different classes of machines to be defined in terms of classes of simple transition functions, thus providing a more unified and coherent approach to the machine hierarchy problem;

2. the data abstraction capabilities of the model make it feasible for use as a basic universal specification and analysis language [4];

3. the approach provides a general framework for the discussion of computational models with greater descriptive power than the Turing model, for example continuous, highly parallel algorithms which are "super-Turing" as in [10];

4. the precision with which the model defines what is practically implementable with current technology allows for the discussion of formal refinement processes and for the verification that implementations satisfy their behavoural requirements as expressed in terms of X-machine specifications [6].

This has some important application potential, also, in the theory of system and software testing where assumptions have to be made about the form of an implementation which must depend on the existence of a feasible computational model as a basis for the representation of this implementation. Previous approaches required the assumption that the implementation was a machine of a particular type, for example a finite state machine, before the question of whether the implementation met its specification could be discussed. Using the X-machine model, such approaches can be enhanced and generalised [9, 8].

We demonstrate some important properties of a natural class of X-machines in terms of their computational capabilities. Thus, for example, the natural classes of X-machines that model computational systems that process a stream of input data into a stream of output data are defined and examined. These, so called, *stream X-machines*, *generalised stream X-machines* and *straight-move stream X-machines* have a number of important properties which relate to other approaches to the modelling of computation.

The principal result is that:

– *2-stack straight move stream X-machines* compute precisely the class of *partial recursive functions.*

2 X-Machines—A General Computational Model

We begin with a number of essential definitions and notational matters.

2.1 The X-Machine Model

The original definition of the X-machine is due to Samuel Eilenberg [2], where it was presented as an alternative to the Finite State Machine, Pushdown Machine, Turing Machine and other standard types of machine. The theory was not developed to any great extent in this source, however. Here we present the definition of an X-machine in its most general form - although not all the features are needed for our purposes.

Definition 2.1.1 *An X-machine is a 10-tuple* $\mathcal{M} = (X, Y, Z, \alpha, \beta, Q, \Phi, F, I, T)$*, where*

1. X *is the* fundamental data set *that the machine operates on.*
2. Y *and* Z *are the* input *and the* output sets, *respectively.*
3. α *and* β *are the* input *and the* output relations *respectively, used to convert the input and the output sets into, and from, the fundamental set, i.e.*

   $\alpha : Y \leftrightarrow X,\ \beta : X \leftrightarrow Z$
4. Q *is the (finite)* set of states.
5. Φ *is the* type *of* $\mathcal{M}$*, a set of relations on* X*, i.e.*

   $$\Phi : \mathcal{P}(X \leftrightarrow X)$$

   where $\mathcal{P}(X \leftrightarrow X)$ *denotes the set of all relations on* X*.*

   The type of the machine is the class of relations (usually partial functions) that constitute the elementary operations that the machine is capable of performing. $\mathcal{P}S$ *denotes the power set of* S*.* Φ *is viewed as an abstract alphabet.* Φ *may be infinite, but only a finite subset* Φ' *of* Φ *is used (*$\mathcal{M}$ *has only a finite number of edges despite the infinite number of labels available, see [2]).*
6. F *is the* 'next state' partial function.

   $$F : Q \rightarrow (\Phi \rightarrow \mathcal{P}Q)$$

   So, for state $q \in Q, F(q) : \Phi \rightarrow \mathcal{P}Q$ *is a partial function. However, when it is convenient,* F *can be treated like a partial function with two arguments, i.e.* $F(q,\varphi) = (F(q))(\varphi)$*.* F *is often described by means of a state-transition diagram.*
7. I *and* T *are the sets of initial and terminal states respectively.*

   $$I \subseteq Q,\ T \subseteq Q$$

□

Before we continue, we make some simple observations. It is sometimes helpful to think of an X-machine as a finite state machine with the arcs labelled by functions from the type Φ. As we shall define formally later, a computation takes the form of a traversal of a path in the state space and the application, in turn, of the path labels (which represent basic processing functions or relations) to an initial value of the data set X. Thus the machine transforms values of its data set according to the relations or functions called during the state space traversal. The role of the input and output encoding relations is not crucial for many situations but it does provide a general interface mechanism that is useful in a number of applications.

Definition 2.1.2 *If* $q, q' \in Q, \varphi \in \Phi$ *and* $q' \in F(q,\varphi)$*, we say that* φ *is the arc from* q *to* q'*, represented thus:*

$$q \xrightarrow{\varphi} q'$$

□

Definition 2.1.3 *If* $q, q' \in Q$ *are such that there exist* $q_1, \ldots, q_n \in Q$ *and* $\varphi_1, \ldots, \varphi_{n+1} \in \Phi$ *with*

$$q \xrightarrow{\varphi_1} q_1 \xrightarrow{\varphi_2} q_2 \ldots \xrightarrow{\varphi_n} q_n \xrightarrow{\varphi_{n+1}} q'$$

then $(\langle q, q_1, \ldots, q_n, q'\rangle, \langle \varphi_1, \ldots, \varphi_{n+1}\rangle)$ *is the* path *from qtoq'. Each path* c *is labelled with* $|c|$*, where*

$$|c| = \varphi_1 \circ \ldots \circ \varphi_{n+1} : X \rightarrow X$$

is the relation computed by the machine when it follows that path. When the state sequence is not *relevant we shall refer to a path as the sequence of relations, i.e.* $c = \varphi_1 \dots \varphi_{n+1}$.

A successful path *is one that starts in an initial state (in I) and ends in a final one (from T).*

A loop *is a path whose initial state is also terminal (i.e. a path from a state to itself).* □

Definition 2.1.4 *The* behaviour *of* $\mathcal{M}$ *is the relation*

$$|\mathcal{M}| : X \to X \text{ defined as } |\mathcal{M}| = \bigcup |c|$$

with the union extending over all the successful paths c in $\mathcal{M}$. □

Given $y \in Y$, the operations of the X-machine $\mathcal{M}$ on Y consist of:

1. Picking a path c, from a start state $q_i (q_i \in I)$, to a final state $q_t (q_t \in T)$.

2. (Optional) Applying α to the input to convert it to the internal type X.

3. Applying $|c|$, if it is defined for $\alpha(y)$. Otherwise, go back to step 1.

4. (Optional) Applying β to get the output.

   Therefore, the operation can be summarised as $\beta(|c|(\alpha(y)))$. Note that the output may be non-deterministic or produce a set of outputs from a given input.

Definition 2.1.5 *The composite relation* $f_{\mathcal{M}}$ *given by*

$$\alpha \circ |\mathcal{M}| \circ \beta : Y \to Z, \text{ i.e.}$$
$$Y \xrightarrow{\alpha} X \xrightarrow{|\mathcal{M}|} X \xrightarrow{\beta} Z$$

is called the relation computed *by* $\mathcal{M}$.

If $\mathcal{M}$ *is a X-machine acceptor (i.e.* $\beta = \emptyset$*), then the relation (partial function) f computed by it will have only one output value, i.e.*

$$f(x) = \begin{cases} d, & \text{if } x \in \text{dom} f \\ \emptyset, & \text{otherwise} \end{cases}$$

where d is an arbitrary constant.

We call $L = \text{dom} f$ *the* language accepted by the machine $\mathcal{M}$. ⌐

Now suppose that X is a fixed data set and Φ, Φ' are types of relations on X such that $\Phi \subseteq \Phi'$ then the class of relations computed by X-machines of type Φ will be contained in the class of relations computed by X-machines of type Φ'. Thus it is conceivable that the study of the relations computed by X-machines of different structures and types provides a mechanism for classifying a wide range of computable relations in a convenient way. For example, we would be interested in defining a class of partial functions that are computable by one class of X-machines and then to use this class of partial functions as the elements of the sets Φ that define a more general class of, say, X′-machines. By carefully defining the classes of machines and the corresponding partial functions computed by them we have the structure for a framework for discussing many types of computational model that extend far beyond traditional Turing-based models.

There are a number of special classes of X-machines that are of interest here. We discuss the relative computational power of these classes of machines both from the point of view of what relations they can compute but also what sort of closure properties they possess—for example if the functions or relations of the type F satisfy some property is this property shared by the functions or relations computed by the machine?

Before proceeding any further we shall describe a general class of X-machines to which we shall be referring in this paper.

We let $Y = \Sigma^*, Z = \Gamma^*$, where Σ (*input alphabet*) and Γ (*output alphabet*) are finite alphabets. Thus relations $f : \Sigma^* \to \Gamma^*$ will be computed. The set X will have the form

$$X = \Gamma^* \times M \times \Sigma^*,$$

where M is a set called *memory.*

In practice M will usually be a product $\Omega_1^* \times \dots \times \Omega_r^*$, where $\Omega_1, \dots, \Omega_r$ are finite alphabets: in this case we shall say that X has $r + 2$ registers of which one (the last one) is the input register, one (the first one) is the output register and the intermediate r registers are memory registers.

For $x \in X, x = (g, m, s)$ the values of output register, input register and memory will be referred to as $s = \text{In}(x), g = \text{Out}(x), m = \text{Mem}(x)$, respectively. Therefore, we have Out : $X \to$

$\Gamma^*, \mathrm{In} : X \to \Sigma^*, \mathrm{Mem} : X \to M, \mathrm{Out}(g,m,s) = g, \mathrm{In}(g,m,s) = s, \mathrm{Mem}(g,m,s) = m, \forall g \in \Gamma^*, s \in \Sigma^*, m \in M$.

This model is sufficiently general to model many common types of machine from finite state machines (where the memory is trivial) to Turing machines (where, as we shall see, the memory is a model of the tape), see [2].

2.2 Deterministic X-Machines

The aim of defining deterministic machines is to compute partial functions rather than relations. In a deterministic X-machine, there is at most one possible transition for any state $q \in Q$ and any $x \in X$.

Definition 2.2.1 *An X-machine $\mathcal{M}$ is called deterministic if:*

1. *α and β are partial functions, not relations:*

$$\alpha : Y \to X,\ \beta : X \to Z$$

2. *Φ contains only partial functions on X rather than relations:*

$$\Phi : \mathcal{P}(X \to X)$$

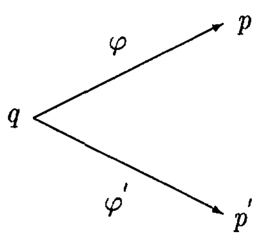
3. *F maps each pair $(q,\varphi) \in Q \times \Phi$ onto at most a single next state:*

$$F : Q \to (\Phi \to Q)$$

A partial function is used because every $\varphi \in \Phi$ will not necessarily be defined as the label to an edge in every state.

4. *I contains only one element (i.e. $I = \{q_0\}$, where $q_0 \in Q$)*

5. *If φ and φ' are distinct arcs emerging from the same state then dom $\varphi \cap$ dom $\varphi' = \emptyset$.*



If we consider F as a function with two arguments, the condition above can be written as:

$\forall q \in Q,\ \varphi, \varphi' \in \Phi, \varphi \neq \varphi'$ if $(q,\varphi),(q,\varphi') \in$ dom F then dom $\varphi \cap$ dom $\varphi' = \emptyset$.

□

These conditions will frequently (but not always) ensure $f = \alpha \circ |\mathcal{M}| \circ \beta$ is a partial function. However, if a deterministic X-machine satisfies an additional condition, it will compute a partial function.

Definition 2.2.2 *A relation $|c| = \varphi_1 \ldots \varphi_{n+1} : X \to X$ defined by a path is called* trivial, *if $\exists x \in$ dom $|c|$ such that $In(|c|(x)) = In(x)$. In other words, a trivial path is one along which the machine does not change the value of the input register for some values of X, while possibly changing the output and memory registers.* □

Then, we have the following straightforward result:

Proposition 2.2.3 [2] If $\mathcal{M}$ is a deterministic X-machine in which no non-trivial path connects two terminal states, then $\mathcal{M}$ computes a partial function. □

Before defining the two X-machine models that we shall be concentrating on in this paper, we introduce some further notations. These allow us to define a number of very simple functions that add and remove, where possible, symbols from either end of a string.

Let Σ an alphabet and let $s \in \Sigma^*$. Then we define (see [2]) the functions

$$L_s, R_s : \Sigma^* \to \Sigma^* \quad \text{by}$$
$$L_s(x) = sx,\ R_s(x) = xs, \forall x \in \Sigma^*$$

and the partial functions

$$L_{-s}, R_{-s} : \Sigma^* \to \Sigma^* \quad \text{by}$$
$$L_{-s}(x) = s^{-1}x$$

(i.e. dom $L_{-s} = \{s\}\Sigma^*$ and $L_{-s}(sx) = x, \forall x \in$ domL_{-s}) and

$$R_{-s}(x) = xs^{-1}$$

(i.e. dom $R_{-s} = \Sigma^*\{s\}$ and $R_{-s}(xs) = x, \forall x \in \text{dom} R_{-s}$).

Note: Here sx is s concatenated to x (or in some notations $s :: x$). Obviously, $L_sL_t = L_{ts}, R_sR_t = R_{st}, L_{-s}L_{-t} = L_{-ts}, R_{-s}R_{-t} = R_{-st}, \forall s,t \in \Sigma^*$. We shall denote by $I : \Sigma^* \to \Sigma^*$ the identity function.

3 Stream X-Machines and Their Generalisations

A number of important classes of X-machines have been identified and studied. Typically the classes are defined by restrictions on the underlying data set X and the type F of the machines. We introduce three such classes.

3.1 (Generalised) stream X-machines; straight move stream X-machines

The main type of X-machines that we consider here are those that process their input streams in a straightforward manner, producing, in turn, a stream of outputs and a regularly updated internal memory state. The power of this subclass of X-machines is considerable and they are able to model many practical computing situations. There are some natural restrictions that must be placed on the form of the processing functions j to ensure that the machines behave in a sensible way.

Definition 3.1.1 *Let Σ and Γ be two finite alphabets, and let $\delta \notin \Sigma \cup \Gamma$ (we call δ the blank or end marker), $\Sigma' = \Sigma \cup \{\delta\}$, $\Gamma' = \Gamma \cup \{\delta\}$.*

Let $(X, Y, Z, \alpha, \beta, Q, \Phi, F, I, T)$ be an X-machine. Suppose that $Y = \Sigma^*$, $Z = \Gamma^*$, $X = \Gamma^* \times M \times \Sigma^*$, $\alpha : Y \to X$ is the natural injection and $\beta : X \to Z$ the natural projection, and $q_0 \in Q$, $m_0 \in M$ then the X-machine, is called a stream X-machine *iff:*

1. The type is defined as

$$\Phi = \{R_\gamma \mid \gamma \in \Gamma\} \times \Phi_M \times \{L_{-\sigma} \mid \sigma \in \Sigma\} \cup \{R_\delta\} \times \Phi_M \times \{L_{-\delta}\},$$

where $\Phi_M = \{\varphi \mid \varphi : M \leftrightarrow M\}$ is a set of relations on M. Therefore, each transition function must remove the head of the input stream and add an element to the rear of the output stream, and, furthermore, no transition is allowed to use information from the tail of the input or any of the output. Additionally, whenever the end marker δ is processed, the output is also δ.

2. The input and output codes

$$\alpha : \Sigma^* \to X,\ \beta : X \to \Gamma^*$$

are defined by

$$\alpha(s) = (1, m_0, R_\delta(s)) \quad \forall s \in \Sigma^*,$$
$$\beta(g, m, s) = \begin{cases} R_{-\delta}(g), & \text{if } s = 1; \\ \emptyset, & \text{otherwise} \end{cases}$$

$\forall g \in \Gamma^*$, where $m_0 \in M$ is called the initial value of the memory and 1 is the empty string.

We denote it by $\mathcal{M} = (Q, \Sigma, \Gamma, M, \alpha, \beta, \Phi, F, q_0, T, m_0)$, (a slightly different notation is used in comparison to the general situation since we wish to highlight the memory, initial state and initial memory value in these machines). □

For any input string $s \in \Sigma^*$ and any corresponding successful path $|c|$, the computation will be:

$$s \xrightarrow{\alpha} s\delta \xrightarrow{|c|} g\delta \xrightarrow{\beta} g$$

with $g \in \Gamma^*$. Therefore the partial function computed by the machine $f = \alpha \circ |\mathcal{M}| \circ \beta$ has type $f : \Sigma^* \to \Gamma^*$ (with no occurrence of δ in the alphabets). The end marker could be totally eliminated and α and β could be defined as:

$$\alpha(s) = (1, m_0, s) \quad \forall s \in \Sigma^*,$$
$$\beta(g, m, s) = \begin{cases} g, & \text{if } s = 1 \\ \emptyset, & \text{otherwise} \end{cases}$$

A stream X-machine without end marker could be easily transformed into one with end marker, but not vice versa.

If the type is $\Phi = \{R_g \mid g \in \Gamma^*\} \times \Phi_M \times \{L_{-\sigma} \mid \sigma \in \Sigma\} \cup \{R_\delta\} \times \Phi_M \times \{L_{-\delta}\}$ then the X-machine is called a generalised stream X-machine. Therefore, the output at each state transition can be a string from Γ^* rather then just a symbol from Γ.

Empty input moves (i.e. moves where the input string remains unchanged) are not allowed in (generalised) stream X-machines. If we accept such moves, we get a more general X-machine model:

Definition 3.1.2 *Let $\Phi_M = \{\varphi \mid \varphi : M \leftrightarrow M\}$ be a set of relations on M and consider the following extensions to the original definition:*

1. *We expand the type Φ by considering $\Phi = \Phi_1 \times \Phi_2 \times \Phi_3 \times \Phi_4$ where:*

$$\Phi_1 = \{R_\gamma \mid \gamma \in \Gamma \cup \{\delta\}\} \times \Phi_M \times \{L_{-\sigma} \mid \sigma \in \Sigma \cup \{\delta\}\},$$

   i.e. $\varphi \in \Phi_1$ reads the head of the input stream (possibly δ) and adds an output character (possibly δ) to the end of the output string;

   $\Phi_2 = \{I\} \times \Phi_M \times \{L_{-\sigma} \mid \sigma \in \Sigma \cup \{\delta\}\}$, i.e. $\varphi \in \Phi_2$ reads the head of the input stream (possibly δ) and leaves the output string unchanged;

   $\Phi_3 = \{R_\gamma \mid \gamma \in \Gamma \cup \{\delta\}\} \times \Phi_M \times \{I\}$, i.e. $\varphi \in \Phi_3$ leaves the input string unchanged while adding an output character (possibly δ) to the end of the output string.

   $\Phi_4 = \{I\} \times \Phi_M \times \{I\}$, i.e. $\varphi \in \Phi_4$ leaves both the input and output strings unchanged.

2. *We further assume that $\forall q \in T, \forall \varphi \in \Phi_3 \cup \Phi_4$ then $(q, \varphi) \in \text{dom}F$. (Therefore, no empty input transition is allowed from a terminal state.)*

3. *Any path p from an initial state to a terminal one (i.e. from q to q' where $q \in I, q' \in T$) has the form $p = \varphi_1 \ldots \varphi_i \ldots \varphi_j \ldots \varphi_n$, for some $i \leq j$, where*

   a. if $i < j, \varphi_i \in (\{R_\gamma \mid \gamma \in \Gamma\} \cup \{I\}) \times \Phi_M \times \{L_{-\sigma}\}$,

   $\varphi_j \in \{R_\delta\} \times \Phi_M \times \{L_{-\sigma} \mid \sigma \in \Sigma\} \cup \{I\})$,

   if $i = j$, then $\varphi_i \in \{R_\delta\} \times \Phi_M \times \{L_{-\delta}\}$.

   b. for $k \in \{1, \ldots, j-1\} - \{i\}$,

   $\varphi_k \in (\{R_\gamma \mid \gamma \in \Gamma\} \cup \{I\}) \times \Phi_M \times (\{L_{-\sigma} \mid \sigma \in \Sigma\} \cup \{I\})$.

   c. for $k \in \{j+1, \ldots, n\}$, $\varphi_k \in \{I\} \times \Phi_M \times (\{L_{-\sigma} \mid \sigma \in \Sigma\} \cup \{I\})$.

   In other words, for any path which starts in an initial state and ends in a terminal one, the machine reads only one blank (δ) and produces only one blank (δ) in this order. Furthermore, no other outputs are produced after the blank (δ) is written at the end the output string.

Then the tuple $\mathcal{M} = (Q, S, \Gamma, M, \alpha, \beta, \Phi, F, Q_0, T, m_0)$, where α and β are defined as above, is called a straight-move stream X-machine.

Φ_1 is called the set of non-empty input and non-empty output operations.

Φ_2 is called the set of non-empty input and empty output operations.

Φ_3 is called the set of empty input and non-empty output operations.

Φ_4 is called the set of empty input and empty output operations. □

A straight-move stream X-machine can process the empty string 1 and can produce 1 as the output. It is fairly clear that a straight move stream X-machine computes a relation $f : \Sigma^* \to \Gamma^*$, where $f = \alpha \circ |\mathcal{M}| \circ \beta$.

Note: The empty string 1 should not be confused with the end marker δ.

Obviously, the straight-move stream X-machine model is more general than the generalised stream X-machine one. Conversely, the generalised stream X-machine is a more efficient or a faster version of the straight move stream X-machine. No empty input moves are allowed in a generalised stream X-machine and the machine reads a character every time a move is performed. Even more importantly, the generalised stream X-machine model ensures that for any input string the machine will stop its computation in a finite time, therefore avoiding the 'halting problem'. For an input string s of length n, the machine will give the result $f(s)$ in at most $n+1$ moves. We formalise this idea in what follows.

Definition 3.1.3 *The type Φ is called* fully computable *if $\forall \varphi \in \Phi$, then there exists an algorithm A such that A computes φ and $\forall x \in X$, x will cause A to stop in a finite time (i.e. $\neg\exists x \in X$ such that A will run forever while computing $\varphi(x)$).* □

Note: We consider an algorithm as being a procedure involving a finite number of basic operations. This notion is in some way ambiguous since it is dependent on the basic operations allowed. This can be addressed, according to Church's thesis, by considering the Turing machine as the general model for an algorithm. Then, for a deterministic X-machine (this is the case we shall be addressing in this paper) our definition of full computability becomes: the type Φ is called *fully* *computable* if $\forall\varphi \in \Phi$, φ is a partial recursive function and dom φ is a recursive set.

However, the more general definition above is sufficient for our purpose at the moment.

Proposition 3.1.4 *Let $\mathcal{M} = (Q, \Sigma, \Gamma, M, \alpha, \beta, \Phi, F, Q_0, T, m_0)$ be a generalised stream X-machine with Φ fully computable. Then, the relation f: $\Sigma^* \longrightarrow \Gamma^*$ computed by $\mathcal{M}$ is fully computable. Hence, the class of fully computable relations is closed under the generalised stream X-machine operator.* □

Proof: We define k = card Φ' where Φ' is the subset of Φ used by M. Let $x = \sigma_1 \dots \sigma_n$, with $\sigma_1, \dots, \sigma_n \in \Sigma$. Hence $\alpha(x) = (1, m_0, \sigma_1 \dots \sigma_n \delta)$. The number of paths determined through the machine by x is $N \leq k^{n+1}$. Therefore, $\varphi(x)$ is determined by applying at most $N(n+1) \leq (n+1)k^{n+1}$ algorithms (i.e. an algorithm for each φ which processes σ_i or δ).

Hence $f = \alpha \circ |\mathcal{M}| \circ \beta$ is fully computable. ◇

Obviously, the proposition above is not true for a straight move stream X-machine since it can contain loops formed only by empty input operations and the machine can run forever following such loops.

3.2 Deterministic (Straight Move) Stream X-Machines

From definition 2.2.1, it follows that a deterministic generalised stream X-machine is one which has only one transition for a certain triplet $(q, m, \sigma) \in Q \times M \times \Sigma'$, i.e. $\forall (q, m, \sigma) \in Q \times M \times \Sigma'$ and $\varphi, \varphi' \in \Phi$, if $\Gamma'^* \times \{m\} \times \{\sigma\}\Sigma'^* \cap$ dom $\varphi \neq \emptyset$ and $\Gamma'^* \times \{m\} \times \{\sigma\}\Sigma'^* \cap$ dom $\varphi' \neq \emptyset$, then either $(q, \varphi) \notin$ dom F or $(q, \varphi') \notin$ dom F. Here Φ is a set of partial functions.

A deterministic straight move stream X-machine will satisfy the following:

1. There is only one possible transition for any triplet $(q, m, \sigma) \in Q \times M \times \Sigma'$, i.e. $\forall (q, m, \sigma) \in Q \times M \times \Sigma'$ and $\varphi, \varphi' \in \Phi_1 \cup \Phi_2$, if $\Gamma'^* \times \{m\} \times \{\sigma\}\Sigma'^* \cap$ dom $\varphi \neq \emptyset$ and $\Gamma'^* \times \{m\} \times \{\sigma\}\Sigma'^* \cap$ dom $\varphi' \neq \emptyset$, then either $(q, \varphi) \notin$ dom F or $(q, \varphi') \notin$ dom F.
2. There is no pair $(q, m) \in Q \times M$ where both a letter $\sigma \in \Sigma'$ and the empty input string 1 can be read, i.e. $\forall (q, m, \sigma) \in Q \times M \times \Sigma'$ and $\varphi \in \Phi_1 \cup \Phi_2$, $\varphi' \in \Phi_3 \cup \Phi_4$, if $\Gamma'^* \times \{m\} \times \{\sigma\}\Sigma'^* \cap$ dom $\varphi \neq \emptyset$ and $\Gamma'^* \times \{m\} \times \Sigma'^* \cap$ dom $\varphi' \neq \emptyset$ then $(q, \varphi) \notin$ dom F or $(q, \varphi') \notin$ dom F.
3. There is no pair $(q, m) \in Q \times M$ where two different empty input transitions are allowed, i.e. $\forall (q, m) \in Q \times M$ and $\varphi, \varphi' \in \Phi_3 \cup \Phi_4$, if $\Gamma'^* \times \{m\} \times \Sigma'^* \cap$ dom $\varphi \neq \emptyset$ and $\Gamma'^* \times \{m\} \times \Sigma'^* \cap$ dom $\varphi' \neq \emptyset$, then $(q, \varphi) \notin$ dom F or $(q, \varphi') \notin$ dom F.

Obviously, no trivial paths exist in a *stream X-machine* or a *generalised stream X-machine* and no trivial paths start from a terminal state in a deterministic *straight move stream X-machine*. Hence:

Proposition 3.2.1 *Any deterministic stream X-machine, generalised stream X-machine or straight move stream X-machine computes a partial function.* □

However, stream X-machines and generalised stream X-machines compute special classes of (partial) functions, as we shall see in the following subsection.

3.3 Stream Functions; Generalised Stream Functions

Each class of machine defines a type of function or relation between input strings and output strings. If there are natural mathematical descriptions of these functions this will be an indication of the extent to which the notions introduced in this paper are natural ones.

Definition 3.3.1 *Let $f : \Sigma^* \longrightarrow \Gamma^*$ be a partial function. Then f is called* segment preserving *if: $\forall s, t \in \Sigma^*$, if $s, st \in$ dom f then $\exists u \in \Gamma^*$ such that $f(st) = f(s)u$.* □

Definition 3.3.2 *Let $f : \Sigma^* \longrightarrow \Gamma^*$ be a partial function. If $|f(s)| = |s|$ $\forall s \in$ dom f then f is called* length preserving. □

Note: $|s|$ denotes the length of the string s.

Definition 3.3.3 *Let f: $\Sigma^* \longrightarrow \Gamma^*$ be a partial function. Then f is called a* partial stream function *if f is both segment preserving and length preserving.* □

If we replace the length preserving condition by a Lipschitz type condition, we get the definition of a partial generalised stream function.

Definition 3.3.4 *Let $f : \Sigma^* \to \Gamma^*$ be a segment preserving partial function. Then f is called a* partial generalised stream function *if:*

$\exists k \in N$ *such that* $\forall s,t \in \Sigma^*$, *if* $s, st \in \text{dom } f$, *then* $||f(st)| - |f(s)|| \leq k|t|$. □

Definition 3.3.5 *A partial (generalised) stream function $f : \Sigma^* \to \Gamma^*$ is* complete *if:*

$\forall s,t \in \Sigma^*$, *if* $st \in \text{dom } f$, *then* $s \in \text{dom } f$. □

We have the following characterisation of deterministic (generalised) stream X-machines:

Proposition 3.3.6 *1. Any deterministic stream X-machine computes a partial stream function.*

2. Any deterministic generalised stream X-machine computes a partial generalised stream function.

3. Any stream X-machine (generalised stream X-machine) without end marker and with all the states terminal ($T = Q$) computes a complete partial stream function (partial generalised stream function). □

Proof: By induction on t it follows that $f(st) = f(s)u \; \forall s,t \in \text{dom } f$.

(2, 3). If the machine is a generalised stream X-machine, then we take $k = \max\{|g| \,|\, (R_g, \phi, L_{-\sigma}) \in \Phi'\}$, where Φ' is the finite set of Φ used to label the arcs of the machine.

3. By induction on t it follows that if $st \in$ dom f, then $s \in$ dom f. ◇

Thus we see the precise connection between the types of machine discussed and the types of function computed.

3.4 Periodic Straight Move Stream X-Machines

It is clear that a straight move stream X-machine does not necessarily compute a partial generalised stream function. However, there is a class of straight move stream X-machines which does.

Definition 3.4.1 *A straight move stream X-machine $\mathcal{M} = (Q, \Sigma, \Gamma, M, \alpha, \beta, \Phi, F, Q_0, T, m_0)$ is called* periodic *if:*

1. *if $p = \varphi_1 \ldots \varphi_n$ is a path with $\varphi_1 \in \{R_\delta\} \times \Phi_M \times (\{L_{-\sigma} \,|\, \sigma \in \Sigma \cup \{\delta\}\} \cup \{I\})$, then $\varphi_i \in (\{R_\delta\} \cup \{I\}) \times \Phi_M \times (\{L_{-\sigma} \,|\, \sigma \in \Sigma \cup \{\delta\}\} \cup \{I\})$ for $i \in \{2, \ldots, n\}$. In other words, the machine cannot produce any output after a blank (δ) has been read except the blank (δ).*
2. *if $p = \varphi_1 \ldots \varphi_n$ is a loop (i.e. a path from a state q to itself) with $\varphi_i \in \Phi_3 \cup \Phi_4$, $i = 1,\ldots,n$, then $\varphi_i \in \Phi_4$, $i = 1,\ldots,n$. Therefore, no loop on empty input operations can produce any output.* □

The periodicity condition does not really affect the computational power of a straight move stream X-machine much since, for example any straight move stream X-machine acceptor (i.e. the output alphabet is $\Gamma = \emptyset$) is periodic. However, it ensures that the function computed is a partial generalised stream function.

Proposition 3.4.2 *Any deterministic periodic straight move stream X-machine computes a partial generalised stream function.* □

Proof: It follows by induction. The first condition ensures that the function is segment preserving, the second one that the Lipschitz condition is satisfied. ◇

4 (Straight-Move) Stream X-Machines with Stacks

In this section we impose a particular structure on the memory of the stream X-machine and explore the consequences.

4.1 k-Stack X-Machines

It is fairly clear that the computational power of the X-machine model will depend on the type F that the machine works on (one could, for example, use non-computable transition functions, but that is neither useful nor desirable in this context). In what follows we shall introduce and examine several X-machine models whose memory structure is a stack or a finite set of stacks. First, the basic operations on stacks will be the usual 'push' and 'pop'. Then we shall use more complex functions on the memory structure, but throughout we restrict ourselves to using those basic functions that can be computed by very simple X-machines.

Definition 4.1.1. *Let* $\mathcal{M} = (Q, \Sigma, \Gamma, M, \alpha, \beta, \Phi, F, Q_0, T, m_0)$ *be an X-machine. If*

1. $M = \Omega_1^* \times \cdots \times \Omega_k^*$ *(hence* $X = \Gamma^* \times \Omega_1^* \times \cdots \times \Omega_k^* \times \Sigma^*$*, where* $\Omega_1, \ldots, \Omega_k$ *are finite alphabets;*

2. $\Phi = \{\varphi = (\phi_\Gamma, \phi_1, \ldots, \phi_k, \phi_\Sigma) \mid \phi_\Gamma : \Gamma^* \to \Gamma^*, \phi_\Sigma : \Sigma^* \to \Sigma^*, \phi_i : \Omega_i^* \to \Omega_i^*$ *are partial functions,* $\phi_i \in \Phi_i\}$*, where* $\Phi_i = \{R_{-u} \mid u \in \Omega_i\} \cup \{R_u \mid u \in \Omega_i\} \cup \{I, E\}, i = 1, \ldots, k$*:*

   then $\mathcal{M}$ *is called a* k-stack X-machine. *The partial function* E*:* $\Sigma^* \to \Sigma^*$ *defined by dom* $E = \{1\}$ *and* $E(1) = 1$ *checks whether the stack is empty or not.* □

From the definition above, it is clear that

1. a *k-stack stream X-machine* has the type:

   $\Phi = \{\mathrm{R}_\gamma \mid \gamma \in \Gamma\} \times \Phi_1 \times \ldots \times \Phi_k \times \{\mathrm{L}_{-\sigma} \mid \sigma \in \Sigma\} \cup \{\mathrm{R}_\delta\} \times \Phi_1 \times \ldots \times \Phi_k \times \{\mathrm{L}_{-\delta}\}$

2. a *k-stack straight move stream X-machine* has the type

   $\Phi = \{\mathrm{R}_y\} \times \Phi_1 \times \ldots \times \Phi_k \times \{\mathrm{L}_{-x}\}$, where $x \in \Sigma' \cup \{1\}$ and $y \in \Gamma' \cup \{1\}$.

Theorem 4.1.2 *Let* Σ *and* Γ *be two alphabets and let* f*:* $\Sigma^* \to \Gamma^*$ *be a partial recursive function, then there exists a deterministic 2-stack straight move stream X-machine* M *which computes* f*.* □

Proof. If f is recursive enumerable, there exists then a Turing machine $\mathcal{T}$ with $Q = \{q_1, \ldots, q_n\}$, the state set (q_1 is the start state), Ω the set of tape symbols ($\Gamma \cup \Sigma \subseteq \Omega$) which computes f. Hence, if t is the initial value of the tape and t' the end one $\mathrm{Rmb}(t') = f(t)$, where Rmb: $\Gamma'^* \to \Gamma^*$ is a function which removes all the occurrences of the blank symbol δ from the tape. Any transition of $\mathcal{T}$ can be described as $(q, a) \to (q', a', d)$, where q is the state $\mathcal{T}$ currently is in, a the character read, q' the next state, a' the replacement character and $d \in \{L, R\}$ is the direction the tape head moves in. We can now simulate the Turing machine $\mathcal{T}$ on the following straight move stream X-machine $\mathcal{M}$:

1. The set of states is $Q' = \{q_1', q_1'', \ldots, q_n', q_n''\} \cup Q''$. The states set of $\mathcal{M}$ is obtained by duplicating each state from Q and adding some extra states. The set Q'' will explicitly follow from the construction of $\mathcal{M}$. $\mathcal{M}$ will be in the state q_i', $i = 1, \ldots, n$ if $\mathcal{T}$ is in the state q_i and it has not read a blank (δ) from the tape (therefore the Turing machine has not finished reading the input sequence); $\mathcal{M}$ will be in the state q_i'', $i = 1, \ldots, n$ if $\mathcal{T}$ is in the state q_i and it has read a blank (δ) from the tape (the Turing machine has read the whole input sequence).

2. The initial state is q_1' and the set $T' = \{q_i'' \mid q_i$ is a halt state of $T\}$.

3. The memory is $M = \Omega'^* \times \Omega'^*$, where $\Omega' = \Omega \cup \{\delta\}$. The values of the two stacks s and s' will hold the tape of the Turing machine up to the rightmost location of the tape that has been read by the tape head, i.e. if $t = a_1 \ldots a_j, (a_1, \ldots, a_j \in \Omega')$, is the tape up to the rightmost location that has been read by the head tape and i is the current position of the tape head, $i \leq j$, then $s = a_1 \ldots a_i$ [illegible] $a_j \ldots a_i$. Hence $t = s\ \mathrm{rev}(s')$, where $\mathrm{rev}(x)$ denotes the reverse of the string x.

The initial value of the memory is $m_0 = (1, 1)$.

4. Φ and F results by the following simulation of $\mathcal{T}$ on $\mathcal{M}$:

a. For a transition $(q, \sigma) \to (p, b, R)$ in $\mathcal{T}$, $\sigma \in \Sigma$, $b \in \Omega'$ the corresponding transitions in $\mathcal{M}$ are:

$F(q', \varphi_1) = p', F(q', \varphi_2) = p', F(q'', \varphi_2) = p''$, where

$\varphi_1 = (I, R_b, E, L_{-\sigma}), \varphi_2 = (I, R_b, R_{-\sigma}, I)$.

Therefore, if $\mathcal{T}$ has not finished reading the input string ($\mathcal{M}$ is in state q') and $s' = 1$ then $\mathcal{M}$ reads a new input character. Otherwise, no input is read and $\mathcal{M}$ only operates on its stacks.

b. For a transition $(q, a) \to (p, b, R)$ in $\mathcal{T}$, $a \in \Omega - \Sigma$, $b \in \Omega'$ the corresponding transition in $\mathcal{M}$ is:

$F(q'', \varphi_3) = p''$, where

$\varphi_3 = (I, R_b, R_{-a}, I)$.

Since a is not an input character, $\mathcal{T}$ has finished reading the input string, therefore $\mathcal{M}$ operates only on its stacks.

c. For a transition $(q, \delta) \to (p, b, R)$ in $\mathcal{T}$, $b \in \Omega'$ the corresponding transitions in $\mathcal{M}$ are:

$F(q', \varphi_4) = p'', F(q'', \varphi_5) = p''$, where

$\varphi_4 = (I, R_b, E, L_{-\delta}), \varphi_5 = (I, R_b, R_{-\delta}, I)$.

Therefore $\mathcal{M}$ can read the end marker of the input string only if a δ has not been read yet.

d. The transitions $(q,\sigma) \rightarrow (p,b,L), (q,a) \rightarrow (p,b,L), (q,\delta) \rightarrow (p,b,L), \sigma \in \Sigma, a \in \Omega - \Sigma, b \in \Omega'$ can be obtained from the ones above by replacing $\varphi_i, i = 1,\ldots,5$ by $\varphi_i' = \varphi_i Tf^2$, where Tf is the function which transfers any character from the first stack to the second one. Such transition can be transformed into a sequence of 3 straight move stream X-machine operations by adding two new states $r, r' \in Q''$ for all a, b. For example $F(q', \varphi_1 Tf^2) = p'$ is equivalent to $F(q', \varphi_1) = r, F(r, \varphi) = r', F(r', \varphi) = p'$, where $\varphi \in \{(I, R_{-a}, R_a, I) \mid a \in \Omega'\}$ (i.e. φ takes all the values of the set $\{(I, R_{-a}, R_a, I) \mid a \in \Omega'\}$).

In order to complete our constructions, we have to deal with the following two problems:

A. $\mathcal{M}$ has to read the entire input sequence even if $\mathcal{T}$ halts earlier. This can be easily addressed by adding one extra state $r_i \in Q''$ for each $i \in \{1,\ldots,n\}$ such that q_i is a halt state of $\mathcal{T}$ and the following transitions: $F(q_i', \varphi) = q_i', F(q_i', \varphi') = r_i, F(r_i, \varphi'') = r_i, F(r_i, \varphi''') = q_i'', i = 1,\ldots,n$, where $\varphi \in \{(I, R_a, R_{-a}, I) \mid a \in \Omega'\}, \varphi' = (I, I, E, I), \varphi'' \in \{(I, R_\sigma, I, R_{-\sigma}) \mid \sigma \in \Sigma\}, \varphi''' \in \{(I, R_\delta, I, R_{-\delta}) \mid \sigma \in \Sigma\}$. Therefore if $\mathcal{T}$ has halted without having finished reading the input string, $\mathcal{M}$ will store the part of the tape already read into the first stack, read the remaining part (until a δ is reached) and store the remaining part of the tape into the first stack. Since no path can leave a halt state in $\mathcal{T}$, $\mathcal{M}$ remains deterministic.

B. So far $\mathcal{M}$ does not produce any outputs. Therefore, any transition of the type $F(q, \varphi) = q_i''$, where $q \in Q'$ (Q' is the state set of $\mathcal{M}$ constructed so far), $q_i'' \in T'$ (i.e. terminal state) has to be replaced by $F(q, \varphi GH) = q_i''$, where G stores s' rev(s) into s', (therefore s' will hold the reverse of the tape value t) where s and s' are the values of the two stacks, and H outputs Rmb(rev(s'))δ (i.e. the string obtained by erasing all the blanks from the tape t followed by a blank). This can be achieved by adding 3 extra states $r_1', r_2', r_3' \in Q''$ for each transition of the type $F(q, \varphi) = q_i''$ and replacing this transition with $F(q, \varphi) = r_1', F(r_1', \varphi_1) = r_1', F(r_1', \varphi_2) = r_2', F(r_2', \varphi_3) = r_2', F(r_2', \varphi_4) = r_2', F(r_2', \varphi_5) = r_3'$, where $\varphi_1 \in \{(I, R_{-a}, R_a, I) \mid a \in \Omega'\}, \varphi_2 = (I, E, I, I), \varphi_3 = (I, I, R_{-\delta}, I), \varphi_4 \in \{(R_\gamma, I, R_{-\gamma}, I) \mid \gamma \in \Gamma\}, \varphi_5 = (R_\delta, I, I, I)$.

From the construction above it is clear that $f = \alpha \circ |\mathcal{M}| \circ \beta$. Therefore $\mathcal{M}$ computes f. ◇

We illustrate the constructions in the following example.

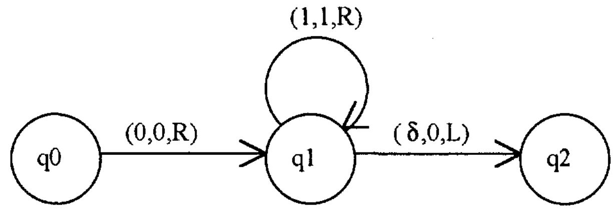


Figure 1:

Example: Let T be the Turing machine described in Fig. 1, where:

$\Sigma = \{0,1\}, \Gamma = \{0,1\}, \Omega = \{0,1\}, q_0$ is the initial state and q_2 the halt state.

By applying the transformations indicated at 4, 5.a and 5.b, T is transformed succesively as described in Figures 2, 3, 4 respectively.

Observations:

1. For the sake of simplicity, we have labelled some arcs with more than one label (i.e. instead of having more than one arc between a pair of states).

2. q_0' is the initial state and q_2'' the final state of the machine.

Since $q_2', q_0'', q_1'', r_3, r_4$ and r_5 are not connected to the initial state q_0', they can be deleted together with the arcs that emerge from them or leave them. Hence, the 2-stack straight-move obtained has the 'initial transition' diagram represented in Fig. 5, where q_0' is the initial state and q_2'' the final state.

Conversely, any simple n-stack straight move stream X-machine can be simulated by a Turing machine. This is achieved by placing the input string, the n stacks and the output string on the Turing machine tape separated by an extra symbol.

Let us denote by $\mathcal{F}_k$ and F_k the class of partial functions computed by k-stack straight move stream X-machines and k-stack generalised stream X-machines respectively and

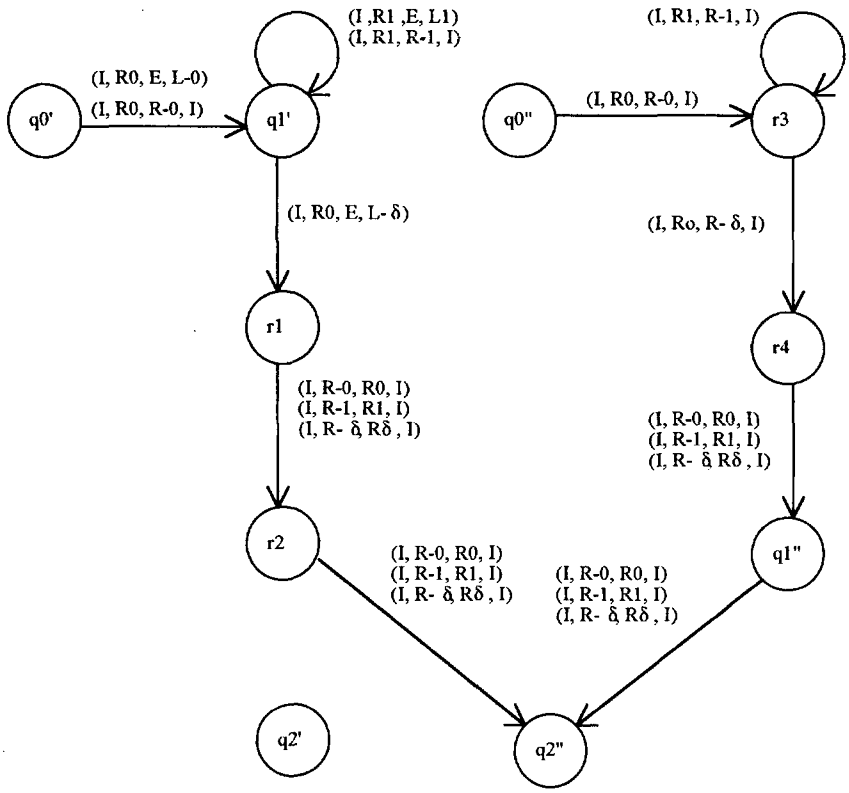


Figure 2:

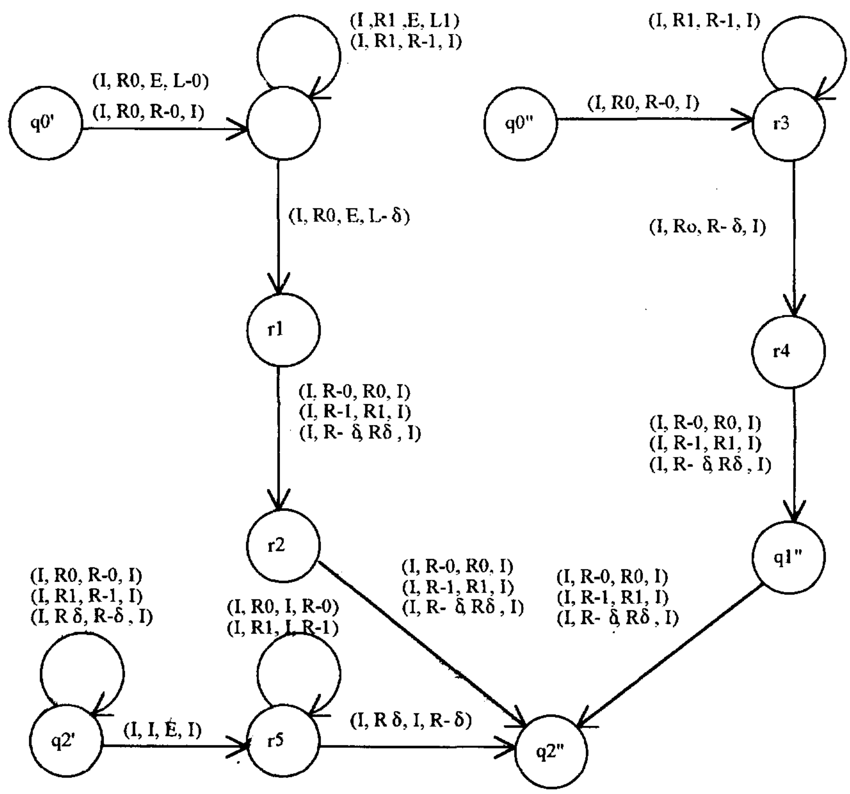


Figure 3:

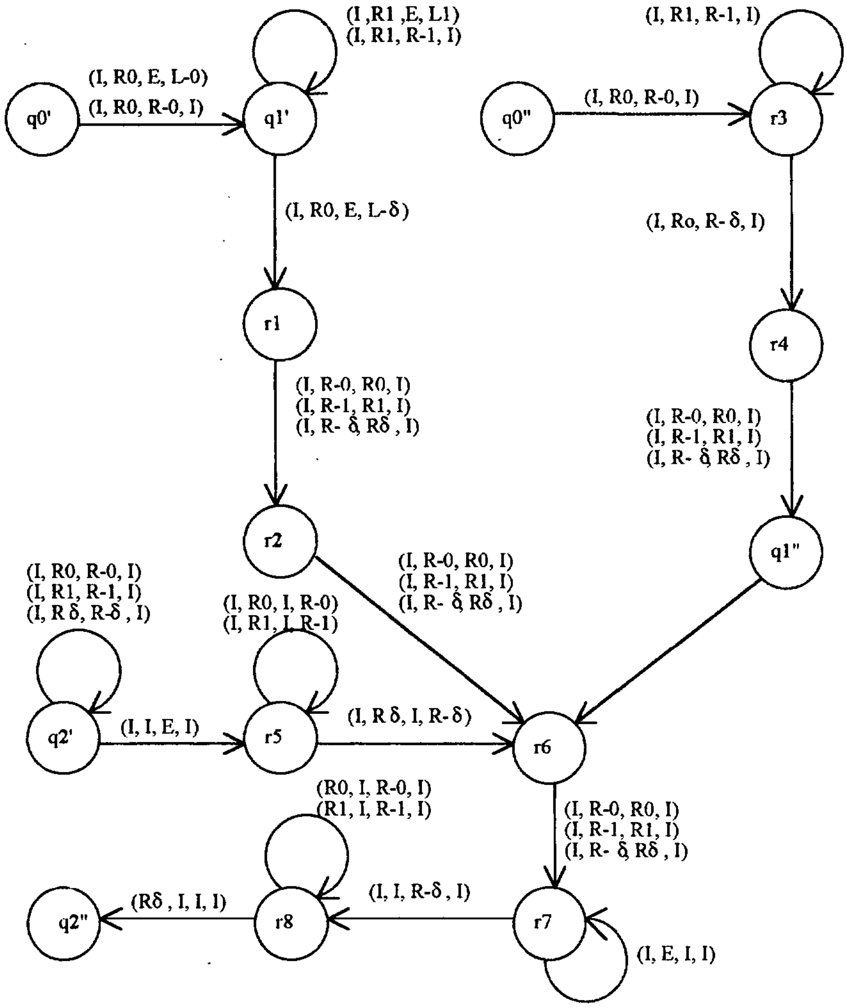

q0'
q1'
q0"
r3
r1
r4
r2
q1"
q2'
r5
r6
r7
r8
q2"
(I, R0, E, L-0)
(I, R0, R-0, I)
(I ,R1 ,E, L1)
(I, R1, R-1, I)
(I, R0, R-0, I)
(I, R1, R-1, I)
(I, R0, E, L-δ)
(I, Ro, R- δ, I)
(I, R-0, R0, I)
(I, R-1, R1, I)
(I, R- δ, Rδ , I)
(I, R0, I, R-0)
(I, R1, I, R-1)
(I, I, E, I)
(I, R δ, I, R-δ)
(R0, I, R-0, I)
(R1, I, R-1, I)
(Rδ , I, I, I)
(I, I, R-δ , I)
(I, E, I, I)
(I, R δ, R-δ , I)

Figure 4:

Informatica **20** (1996) 359–372

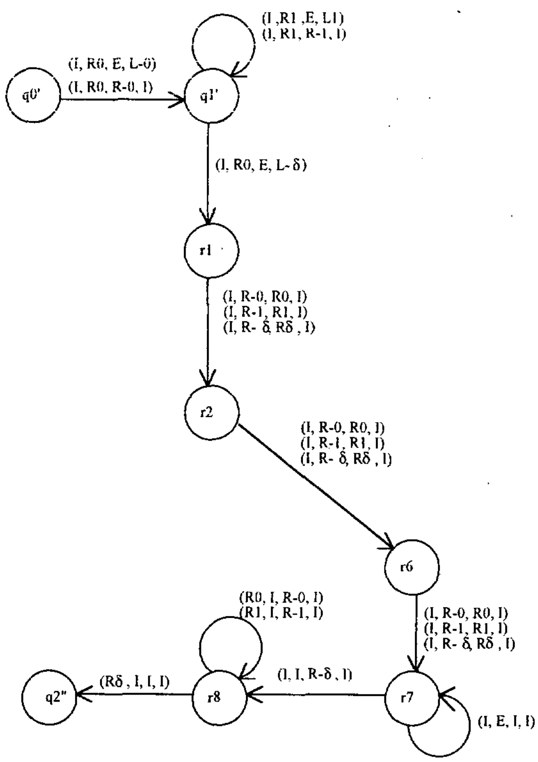


Figure 5:

$$\mathcal{F} = \bigcup_{k=1}^{\infty} \mathcal{F}_k, \; F = \bigcup_{k=1}^{\infty} F_k$$

Then we have:

Corollary 4.1.3 $\mathcal{F}_n = \{f \mid f$ *is a partial recursive function*$\}$ $\forall n \geq 2$. □

Corollary 4.1.4 $\mathcal{F} = \{f \mid f$ *is a partial recursive function*$\}$. □

Therefore, the hierarchy of the sets $\mathcal{F}_n$ stops at 2 and $\mathcal{F}_2$ is the set of all one place partial recursive functions. Obviously, $\mathcal{F}_1 \subset \mathcal{F}_2$, since a straight move stream X-machine acceptor can be shown to be equivalent to a push-down automaton [5].

From proposition 3.1.4, it is clear that a generalised stream X-machine cannot compute an arbitrary partial recursive partial generalised stream function f since the domain of f might not be recursive. Therefore, generally, a 2-stack straight move stream X-machine cannot be converted into a generalised stream X-machine. However, if the machine is a 1-stack straight move stream X-machine, the conversion could be possible since $\forall f \in \mathcal{F}_1$, dom f is a deterministic context-free language. We shall consider the class of periodic 1-stack straight move stream X-machines (since the function computed in this case is necessarily a partial generalised stream function) and we denote by $\mathcal{F}_1^*$ the restriction of $\mathcal{F}_1$ to the class of periodic straight move stream X-machines. The first question which arises is whether a periodic 1-stack straight move stream X-machine can be simulated by a k-stack generalised stream X-machine, with $k > 1$. However, the answer is negative.

Proposition 4.1.5 F_n *and* $\mathcal{F}_1^*$ *are incomparable* $\forall n \in N, n \geq 2$. □

Proof: We prove the proposition for X-machine acceptors (i.e. $\Gamma = \emptyset$).

Let $\Sigma = \{a, b, c\}$ and $L = \{a^n b^n c^n \mid n \in N\}$. Since L is not a context free language, $L \notin \mathcal{F}_1^*$. It can be proved easily that $L \in F_2$.

Conversely, let $L' = \{a^{i_1} b a^{i_2} b \ldots a^{i_r - 1} b a^{i_r} c^s a^{i_r - s + 1} \mid r \geq 1, 1 \leq s \leq r, i_j \geq 1$ for all $1 \leq j \leq r\}$. In [3] it is proven that $L' \in \mathcal{F}_1^*$ and $L' \notin F_n$ $\forall n \in N$. ◇

Hence, the usual push and pop operations are not sufficient for our purpose and therefore we need a more complex basic type Φ. In a future paper [7], we shall present two new types of generalised stream X-machines with stacks and prove that they compute exactly $\mathcal{F}_1^*$. The approach is to consider Φ as a set of partial functions computed by machines which are already well known (for example finite state machines) rather than using simple push and pop operations. This provides us with a new way of building hierarchies of computational models.

5 Conclusions and Further Work

We have defined a number of stream X-machines, generalised stream X-machines and straight move stream X-machines with stacks and investigated their computation capabilities. Further work might involve generalising some of the models presented in this paper (for example a regular stack X-machine or a stack X-machine with markers with a finite number of stacks) and exploring closure properties of classes of the functions computed.

One of the motivations for pursuing this work is to examine more practical alternatives to the Turing model for system specification. The use of stream X-machines has turned out to be a very powerful and easily used fomalism for describing many different types of software systems and hardware devices. Detailed specifications have been developed for several software systems, graphical user interfaces, real-time systems, robot controller devices and parallel processing chips [5]. All have the property that it is possible to determine that the specifications represent computable functions and are thus implementable. The theory of testing that we have developed in [9] builds on this fact. Essentially it compares the formal specification, represented as a stream X-machine with the implementation which can also be interpreted as an X-machine. The construction of functional test sets then reduces to the construction of sets that will determine whether two X-machines have the same behaviour. The process of constructing such test sets has now been fully specified and could be automated. The theory developed here, together with other results, has been crucial for the development of a fully general theory and procedure for system testing.

References

[1] Cole, S.N. 1971. Deterministic Pushdown Store Machines and Real-Time Computation. Journal of the Association for Computing Machinery **18:** 2: 306–328.

[2] Eilenberg, E. 1974. Automata, Languages and Machines. Vol. A. Academic Press.

[3] Harrison, M.A. 1979. Introduction to Formal Language Theory. Addison-Wesley.

[4] Holcombe, M. 1988. X-Machines as a Basis for System Specification. Software Engineering Journal **3:** 2: 69–76.

[5] Holcombe, M. et al. 1992–1995. Various internal reports describing case studies for X-machine specifications. Technical Reports. Department of Computer Science. University of Sheffield.

[6] Ipate, F. 1995. Specification and Testing Based on X-Machines. PhD Thesis. Department of Computer Science. University of Sheffield.

[7] Ipate, F. & Holcombe, M. 1995. X-Machines with Stacks. Technical Report. Department of Computer Science. University of Sheffield.

[8] Ipate, F. & Holcombe, M. 1996. Test Which Are Peoved to Find All Faults. Interantional Journal of Comp. Math. (to appear).

[9] Laycock, G.T. 1992. The Theory and Practice of Specification Based Software Testing. PhD Thesis. Department of Computer Science. University of Sheffield.

[10] Stannett, M. 1990. X-Machines and the Halting Problem—Building a Super-Turing Machine. FACS **2:** 331–341.

Tabular Application Development

Talib Damij and Janez Grad
University of Ljubljana, Faculty of Economics, 1000 Ljubljana, Slovenia

Keywords: MIS, object-oriented methods, systems analysis

Edited by: R. Murn
Received: January 15, 1996 **Revised:** July 18, 1996 **Accepted:** August 22, 1996

The aim of this work is to introduce an effective object-oriented approach which guides the analyst through all phases of the application development and puts the whole process under the complete control of the analyst.
Tabular application development is a method which develops the application by creating several tables. It has four phases and introduces a new idea for developement an application. The first phase defines the problem to be solved. The second phase deals with the analysis of the application. The third phase designs the application in detail, and the fourth phase deals with the implementation of the application.

1 Introduction

This work represents an effective approach called tabular application development (TAD). This approach defines an order in which the whole process of application development is put under the complete control of the analyst. TAD is a new approach, because it introduces a new idea for developing the application by creating several tables. It has four phases. The first phase is the problem definition which identifies the critical success factors, the objectives and the entities of the organization using the factor-objective and entity tables. The second phase is the analysis which defines the actions of the system using the action table, identifies the application's data structures, develops the object model and analyses the outputs of the application. The third phase is the design which uses the information gathered in the factor-objective, action, linkage tables and in the object model to create the application model. This phase also defines the algorithms and generates priority order values. The final phase is implementation which transfers the objects into classes and writes a code according to the algorithms.

The first phase of TAD defines the problem to be solved. The best way to do this is to organize interviews with all users. First we interview the management and then continue with other users. This phase has two steps: the first is to identify the management's critical success factors and objectives, and the second to identify the enteties of the organization.

2 Problem definition

This work will treat a simplified example of a sales organization.

2.1 Critical success factors and objectives

This step tries to identify the critical success factors and the objectives of management. The analyst may start with the second step if it is not possible to perform this stage.

Usually we start the process of interviewing with the top management and continue with the management at lower levels. The purpose of these interviews is to discover the management's expectations and to ensure that each of their requirements and objectives is considered.

The management has to define the critical success factors and the objectives of the organization. The analyst will first ask the top management to determine these factors. In most corporations there are a small number (3-6) of factors which are vital to the success of the organization [Martin, 1982]. When the top management has defined a list of critical success factors and a list of objectives they will be asked to define measurements which enable the application to control these factors and objectives. This means that for each critical success factor or objective the management has to define the information sources and the way in which these sources will be controlled. This process will be repeated with the management at different levels.

The result of these interviews is a list of critical success factors, a list of objectives, their information sources and the ways in which they will be realized. These results will be collected in a table called the factor-objective table.

In the example of a sales organization the following success factors are identified:

1. The organization has to assure a 5% growth per year.
2. The time from the acceptance of an order to the shipment of the ordered products must not be longer than one day.
3. Customers have to complete their payments in eight days.

The management also defines the following three objectives:

1. Permanent profit-making which enables the organization to invest in new technology.
2. Increasing the organization's market.
3. Increasing the organization's export.

These critical success factors and objectives are recorded in Table 1, which shows the factor-objective of the sales organization. An asterisk indicated in any square (i,j) in the factor-objective table means that the source defined in column j must generate information required by the critical success factor or the objective defined in the row i.

2.2 The entities

An entity is any source which is part of the system or is connected with the system by some interaction. So, an entity may be a user or any other source which receives an action (event) from the system or sends an action to the system.

The management helps in identifying the system's entities and creating a plan of inteviews with all users. This plan should be developed in accordance with the hierarchical view of the organization. In this way every user will be consulted and each of his/her requirements or objectives will be registered.

Identifying the entities, their requirements and actions will be achieved by developing a table called the entity table. This table is structured as follows: The rows and also the columns of the table represent the entities of the system. According to this idea every entity occupies one row and one column of the table.

The entity table is developed as a result of the interviews. These interviews should be organized only with the internal users. Internal users inform us about the behaviour of external users and other entities. The internal entity is a part of the system. The external entity is not a part of the system, but it has one or more interactions with the system. To create this table we usually start the process of interviews with the users as they are specified in the rows of the table. So, we start the interviews with the entity defined in the first row, if this entity is an internal user , and then move to the entity defined in the second row. Following this order we continue until we have dealt with all the rows.

Every entity creates a part of the entity table. Let us deal with the entity defined in row i, where i is from 1 up to the number of entities. For this entity we register all actions using the following rules:

1. The name(s) of the action(s) will be written in square (i,i) if the entity in row i creates some action for its use only.
2. The name(s) of the action(s) will be written in square (i,j) if the entity in row i sends this action to the entity defined in column j.

Table 2 illustrates the entities of the sales organization. The analyst identifies five entities. These are Customer, Salesman, Sales Department, Shipping Department and Accounts Department. From the interview with the internal users he found that each Salesman covers a determined number of customers. The Salesman visits his Customers from time to time and collects their orders. The Sales department recei-

Factor,Obj.	Source				Manage ment level	Result
	Order	Shipment	Invoice	Payment		
1. factor	*				Top	Report
2. factor	*	*			Top	Report
3. factor				*	Top	Report
1. objective	*		*	*	Top	Report
2. objective	*				Top	Report
3. objective	*				Top	Report

Table 1: The factor-objective table of the sales organization

ves these orders from Salesmen and sends a copy of these documents to the Shipping Department. For this reason he writes ORDER in the squares (1,2), (2,3) and (3,4). Furthermore, he found that the Shipping Department creates a shipment for every order received. One copy of the shipment is sent to the Customer and an other copy to the Accounts Department. So, he registers SHIPMENT in squares (4,1) and (4,5). Finally he finds that the Accounts Department creates an invoice and sends it to the Customer and then receives a payment from the Customer. For this reason he writes INVOICE in square (5,1) and PAYMENT in square (1,5).

Table 2 also shows that the actions in the entity table are numbered as they happened in the real world.

The result of the problem definition phase is identifying the strategic or business objectives of the management, the critical success factors of the organization, the system's entities and their actions.

3 The analysis

This phase in TAD has five steps. The first step deals with the actions of the entities. The second step defines the data structures of the application. The third step identifies the application's objects and their relationships. The fourth step develops the object model. The last step deals with creating the outputs required by the management.

3.1 The actions

To identify the application's actions let us link every action defined in the entity table with the entities of this table. The best way to do this is by developing a table called the action table. Creating this table leads to discovery of the whole application system, its subsystems and its actions.

The action table is organized as follows: The actions of the system are represented by the rows and the entities are represented by the columns.

To create this table we list the actions in the same order as they occur in the real world. So, the first action occurring (event) will be defined in the first row, second action in the second row and so on. For every action defined in row i, where i is from 1 up to the number of actions, we list the entities in the columns and try to link this action with each of these entities. If any connection exists between action i and entity j, where j is from 1 up to the number of internal entities, then an asterisk is written in square (i,j).

Table 3 shows the action table of the sales organization. From this table we can see that the complete application system is represented by the whole table. Furthermore any column of the table gives a clear picture of the connections of the entity defined in this column and the actions in the rows which are indicated by letters S or T. Letter S indicates a source entity and letter T means a target entity. So, each column represents a determined subsystem. Every subsystem includes one or more actions. On the other hand every row of the table shows exactly what is happening with the action defined in this row.

Hence the Table 3 shows the action table of the sales organization.

3.2 Data structures

The second step of the analysis transforms the user's models into stable data structures. This will be achieved by using the normalization te-

Entity	Customer	Salesman	Sales Department	Shipping Department	Accounts Depatrment
Customer		1 ORDER			4 PAYMENT
Salesman			ORDER		
Sales Department				ORDER	
Shipping Depatrment	2 SHIPMENT				SHIPMENT
Accounts Depatrment	3 INVOICE				

Table 2: The entity table of the sales organization

Action	Customer	Salesman	Sales Department	Shipping Department	Accounts Depatrment
1. Order	S1	T1, S2	T2, S3	T3	
2. Shipment				S	T
3. Invoice	T				S
4. Payment	S				T

Table 3: The action table of the sales organization

chnique. The result of this step is a set of normalized relations. The following relations are the normalized relations of the sale organization.

- Order (Order#, Cust#, Date)
- Shipment (Ship#, Cust#, Order#, Date)
- Invoice (Inv#, Cust#, Ship#, Date, Value)
- Payment(Pay#,Cust#,Inv#,Date,Value)
- Customer (Cust#, Name, Address)
- Product (Product#, description, Price)
- Order-Product (Order#,Product#, Qty)
- Ship-Product (Ship#,Product#, Qty)

3.3 The objects

The process of identifying the objects has two steps. The first step defines different groups of objects and the second step merges these groups together in a unique group.

An object is any thing, real or abstract, about which we store data and those operations that manipulate the data [Martin,1993]. Corresponding to this definition and to the TAD methodology we may conclude that an object is any entity, action and data structure about which the user stores information.

For this reason we define three groups of objects. The first group is obtained by analyzing the entities which are presented in the entity table. If the user collects information about any of these entities then we transform this entity into an object.

In the example of the sales organization we found five entities (Table 2). These are Customer, Salesman, Sales Department, Shipping Department d anthe Accounts Department. Furthermore, the organization stores information about Customers and Salesmen. So, the first group of objects contains the following two objects: Customer, Salesman.

The second group of objects is gained by transforming every action listed in the action table into an object. In our example the action table (Table 3) represents four actions. These actions we transform into objects. For this reason the second group has the following four objects: Order, Shipment, Invoice and Payment.

The third group of objects is found by transforming the data structures into an objects. In our we have eight data structures defined in 3.2. So, in the third group of objects we define eight objects. These are: Order, Shipment, Invoice, Payment, Customer, Product, Order-Product and Ship-Product.

The second step of identifying the objects deals with merging these three groups of objects together. The result of this step is a unique group of objects about which the user wants to store data and operations which manipulate this data.

In the example of the sales organization we merge the above defined three groups to a single group which contains the following objects: Order, Shipment, Invoice, Payment, Customer, Salesman, Product, Order-Product and Ship-Product.

3.4 The object model

From the previous step we obtain a set of objects. To develop the object model we need to identify the attributes of these objects, their associations and their operations. So, the process of creating the object model has three steps.

The first step deals with analyzing every object and identifying its attributes if these attributes have not yet been identified.

In our example we find that the only object which needs further analysis to identifiy its attributes is Salesman. The attributes of other objects were defined in 3.2. From the problem definition phase we find that the organization wants to obtain information about the sales realization of every salesman. Moreover we find that every salesman covers a determined number of customers. This means that every customer has a determined salesman. For this reason we connect the object Salesman with attributes such as Identity number and Name. To link the salesman with his customers we extend the object Customer by one attribute, and this is the identity number of the salesman.

The second step analyses the associations between the objects. The best way to do this is by developing a table called the linkage table. This table is structured as follows: all objects are represented in the rows and also in the columns in the same order. So, every object occupies one row and one column with the same index value. In the linkage table we try to link the objects listed in the rows with the objects listed in the columns. Links existing between objects may be identified successfully by searching for foreign and part keys.

To this purpose we create the linkage table by listing the objects defined in the rows. For every object in the row i, where i is from 1 up to m and m is the number of objects, we list all objects defined in the columns. If object(i) contains a key attribute or part of the key attribute of object(j) in the columns, where j is from 1 up to m, then a letter (K, F or P) will be written in square (i,j).

Letter K (key) means that object(i) and object(j) have a key attribute. Letter F (foreign key) means that object(i) contains a key attribute of object(j). Letter P (part key) means that the key attribute of object(i) is part of the key attribute of object(j).

For these reasons we may say that: letter K indicates an Isa structure, letter F incadites an Is-associated-with structure and letter P indicates an Is-part-of or Is-asociated-with structure.

Table 4 shows the result of implementing this procedure in our example.

The third step uses the information in the linkage table to develop the object model of the application and to identify the operations of each object. To do this we create the following procedure:

```
for every object(i) defined in the rows of the lin-
kage table, where i = 1 to m
  if object(i) is not drawn yet then
    draw object(i), write its attributes and iden-
    tify the operations which manipulate its data.
  for every object(j) in the columns of the linkage
  table, where j = 1 to m
    if object(j) is not drawn yet then
      draw object(j), write its attributes and
      identify the operations which manipulate
      its data.
    if square(i,j) is not empty then
      connect object(i) to object(j)
      add to object(i) the needed operations to
      manipulate the data of object(j).
```

Implementing the above defined procedure results in the object model listed in Figure 1.

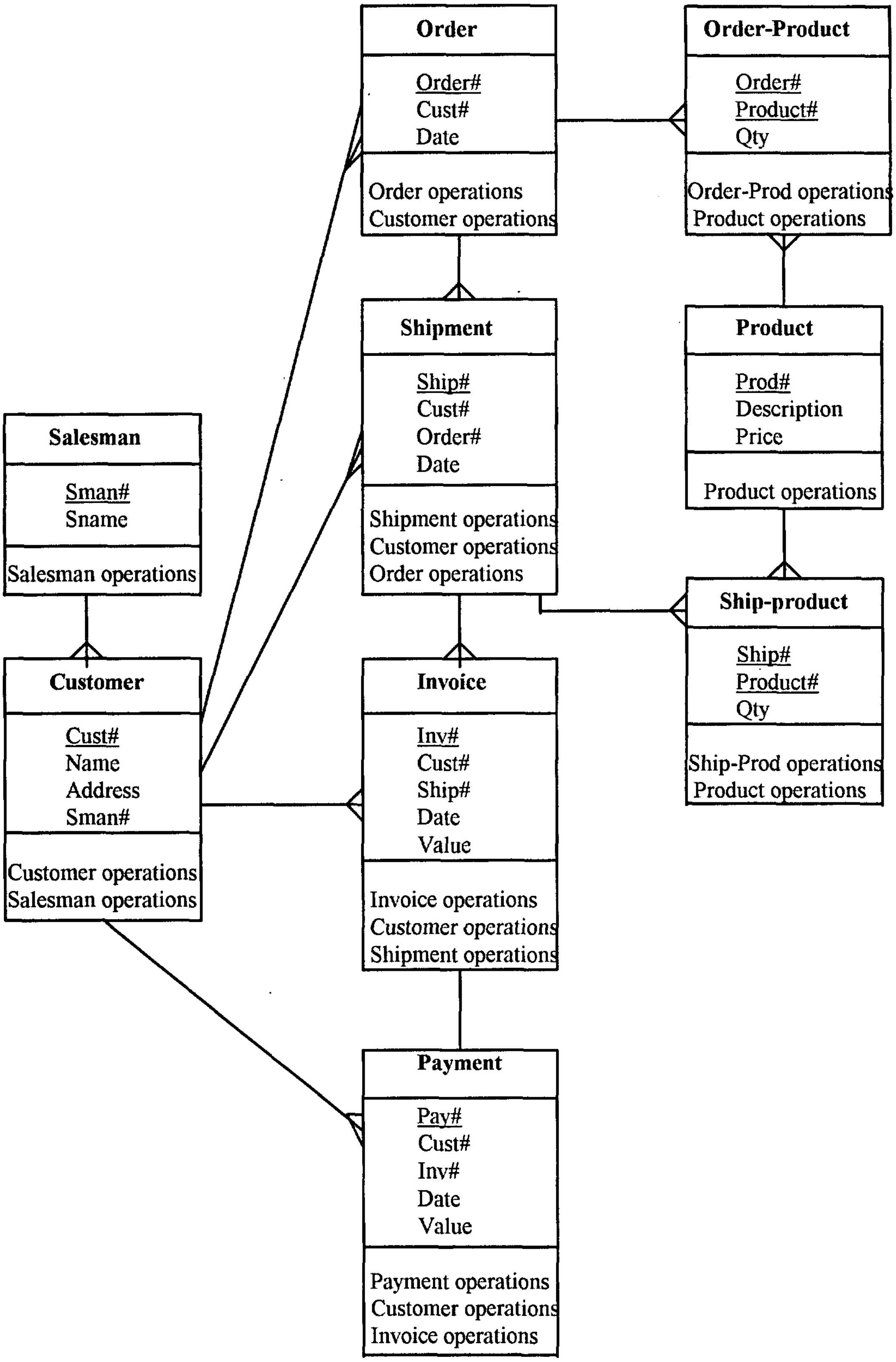


Figure 1: The object model of the sales organization

Object	Order	Shipment	Invoice	Payment	Customer	Salesman	Product	Order-Product	Ship-Product
Order					F			P	
Shipment	F				F				P
Invoice		F			F				
Payment			F		F				
Customer						F			
Salesman									
Product								P	P
Order-Prod									
Ship-Prod									

Table 4: Linkage table of the sales organization

3.5 The outputs

This step deals with analyzing and defining the outputs of the application. We try to find out if the object model defined (Figure 1) enables us to create all the outputs expected by the management and other users.

In this step we consider particularly the outputs which are required by the critical success factors and the objectives defined in the factor-object table.

If one or more outputs cannot be generated from the existing data, then we have to return to the users for more information to eleminate this incompleteness. This means that we have to return to the problem definition phase for greater clarity and accuracy in the definition of the user's requirements.

From this we can conclude that TAD is an iterative process. With every new iteration more problems may be solved and clarification achieved, and the system made more complete.

4 The design

This phase has three steps. The first step develops the application model, the second step writes an algorithm for each action and the third step defines the order of implementation the application model.

4.1 The application model

The first step of the design develops a model of the application using the information existing in the action, and factor-objective tables.

According to the action table we may see that the complete application system is represented by the whole table. Each column of this table is occupied by an entity, which means that every column represents a subsystem. Each subsystem contains one or more actions which are indicated by the asterisks in this column. For this reason we may say that the action table enables us to create the model of the application with all its subsystems and actions.

The action table is very valuable for determining convenient entity access to the data. So, every entity in any column may access those actions (objects) which are indicated by asterisks in that column.

In addition to this, we have to extend the created model of the application by the required outputs. Information about these outputs is contained in the factor-objective table. These outputs are very important to management and may guarantee their support.

Figure 2 shows the application model for the sales organization.

4.2 The algorithm

The second step of the design deals with creating the data flow diagrams and the algorithms of the application. According to the application model the analyst creates a DFD and writes an algorithm for every defined action. To do this we use the information existing in the application model, the object model, the factor-objective table and the action table.

Sales organization	Management	Reports
	Salesman	Sale realizaton
	Sales Department	Reports
		Create Order
	Shipping Department	Reports
		ReadOrder
		Create Shipment
	Accounts Department	Reports
		Read Shipment
		Create Invoice
		Create Payment

Figure 2: The application model of the sales organization

5 The implementation

In this phase the analyst converts the objects into classes and the operations into methods. Furthermore, we generate a code according to the method specifications and to the defined data flow diagrams and algorithms.

The analyst may also define a convenient data access for every user corresponding to information in the action table and to the model of the application.

6 Conclusion

The aim of this work was to introduce an effective object-oriented approach which guides the analyst through all phases of the application development. This approach puts the whole process of application development under the complete control of the analyst. For this reason it is independent of the analyst and his/her experience.

Developing an application using TAD minimizes the time needed to complete this process and puts the application under the full control of the developer the whole time. These characteristics to make this approach very acceptable and useful in practice.

References

[1] T. DAMIJ, An Approach for Information Systems Development. Proceeding of The International Conference on Information Systems Development - ISD '94, Methods & Tools & Theory & Practice, University of Maribor, School of Organizational Scienes, Kranj, 1994, str. 173-182.

[2] T.DAMIJ, Tabular Based Approach for Systems Development. Proceeding of The International Conference on Organization and Information Systems, University of Maribor, School of Organizational Scienes, Kranj, 1995, str. 457-461.

[3] J. MARTIN, Strategic Data-Planning Methodologies. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1982.

[4] J. MARTIN, Principles of Object-Oriented Analysis and Design. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1993.

[5] G. L. SANDERS, Data Modeling. Boyd & Frase Publishing Company, Danvers, 1995.

[6] T.W. OLLE et al., Information Systems Design Methodologies: A Comparative Review. Elsevier Science Publishers B.V., North-Holland, 1982.

[7] J. RUMBAUGH et al., Object-oriented Modeling and Design. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1991.

[8] J. ZUPANCIC, S. WRYCZA, Information Systems Development. ISD '94, Proceedings The Fourth International Conference, University of Maribor, Slovenia, 1994.

Theoretical Foundations of a New Method of Teaching Children Effective Information Processing

Olga S. Fomichova
Studio "Culture, Ecology, and Foreign Languages", Moscow Children and Teenagers Palace for Creative Work
AND
Vladimir A. Fomichov[1]
Department of Information Technologies, K.E. Tsiolkovsky Moscow State Aviation Technology, University, Petrovka street 27, 103767 Moscow, Russia
and Department of Discrete Mathematics, Moscow State University, Vorobyovy Hills, 119899 Moscow, Russia, E-mail: vaf@nw.math.msu.su

Keywords: artificial intelligence, cognitive science, information processing, natural language processing, second language, foreign language, mother tongue, theory of teaching, theory of dynamic conceptual mappings, methods of emotional-imaginative teaching, developing the personality of the child, intelligent tutoring system, cybernetics

Edited by: A.P. Železnikar

Received: June 18, 1996 **Revised:** August 6, 1996 **Accepted:** August 20, 1996

The paper represents a number of key aspects of a new theory of teaching called the Theory of Dynamic Conceptual Mappings (the DCM- theory) and based on it new, highly effective methods of teaching foreign languages and mother tongue to young children (4 - 9 years old) called the methods of Emotional-Imaginative Teaching (the EIT-methods). One part of the paper contributes to explaining the discovery made on the basis of the DCM-theory: how it is possible to teach very young students (from four-and-half to six years old) of usual abilities to read fluently and to discuss complicated texts in a second language (on the example of English).
The other part is language-independent and may be used in teaching both foreign languages and mother tongue to young children. That part describes a new effective, many-component method of developing abstract, symbolic thinking, general associative abilities of young children and, as a consequence, of developing their ability to analyse situations of every-day life. In the paper, three main components of the method are described: (a) teaching young children to carry out diverse inferences proceeding from the read texts and all available background knowledge; (b) how to teach 8-9-year-old students to understand poetical metaphors; (c) teaching to understand information and emotions conveyed by pictures. The component (a) of the method is motivated by ideas of artificial intelligence (AI) theory, first of all, theory of natural-language-processing systems and theory of frames.

1 Introduction

Gams (1995) characterizes the first half of the nineties as a new winter concerning the prevailing attitude to the studies in the Artificial Intelligence (AI) field. This attitude has resulted in cutting down the funds for the development of the field as a long-term trend.[2]

However, it seems that the significance of the

[1]CORRESPONDENCE TO: V. A. Fomichov, the second address

studies on AI for the mankind is tied not only with the construction of more and more perfect applied intelligent systems and is in fact much larger and deeper.

The ideas suggested in the field of AI have caused the birth of a new interdisciplinary approach to investigating phenomena of human reasoning and communication called the *cognitive approach*, contributed to the emergence of Cognitive Linguistics and Cognitive Psychology.

Our analysis and practical experience provide the grounds to conjecture that the ideas of the AI field assimilated and enriched in Cognitive Science may give a powerful impulse to the progress in education and hence have a great social significance.

Problems of education and developing the personality of the child trouble many millions of people being parents or grandmothers or grandfathers or aunts or uncles of children. That is why a lot of specialists in diverse countries looks for new, more effective methods of teaching.

The Theory of Dynamic Conceptual Mappings (the DCM-theory) is a new theory of teaching motivated by ideas of AI, Cognitive Linguistics, and Cognitive Psychology. It has suggested, in particular, highly original and effective ways to teach very young children English as a second language (Fomichov & Fomichova 1993, 1994, 1995a, 1995b, 1996, Fomichova 1995, 1996).

The DCM-theory interprets teaching as a particular case of systematic conveying information from one intelligent system (a teacher or computer tutoring system) to other intelligent systems (learners or a learner). As a consequence, the DCM-theory looks at the problems of teaching in the light of the general theory of communication between intelligent systems.

This generalized look has enabled us to proceed from ideas of AI theory (first of all, of the theory of Natural-Language-Processing Systems), Philosophy of Language, Cognitive Linguistics, and Cognitive Psychology for investigating problems of education and developing the personality of the child. As a result, we've managed to discover the unexpected deep interrelations of seemingly highly different problems and to suggest such effective ways of solving these problems which have much of common.

The central idea underlying this paper is as follows: the essence of many important problems of education is that children are unable to perceive and to process effectively the information of some special sort depending on the problem. For instance, the cause of numerous conflicts between teenagers and adults (parents, teachers) is that teenagers have the inner world's pictures, or conceptual systems (CSs), highly different from CSs of adults.

As a consequence, teenagers can't process effectively the information which seems to be obvious for adults and take false decisions. That is why it would be reasonable to develop in children the abilities to process effectively information of diverse kinds starting to do this when pupils are 4 - 5 years old.

For better understanding of this paper it will be *very important to pay attention* to the following.

We've elaborated a new, highly effective but unexpected way of teaching children to process effectively the information of many important kinds - through the extra-scholastic lessons of second language (SL). The new ideas stated below have been realized in teaching very young children English as a SL. In fact, the described new method of teaching children effective information processing is a main part of our new method of teaching children English as a SL.

But only the first, minor part of the paper (Sections 2 - 4) discusses the subjects being specific for SL lessons. This part describes how it is possible to explain to very young children (the age from four-and-half to six years) by means of thrilling analogies the rules of forming questions in English. The first part is based on the ideas of the DCM-theory set forth in (Fomichov & Fomichova 1993, 1994, 1995b, 1996, Fomichova 1996) and directly extends the description of the EIT-methods given in mentioned papers and in (Fomichov & Fomichova 1995a, Fomichova 1995).

The ideas described in this part of the paper enrich the stock of manners to develop abstract thinking of young children.

We believe that the first part is precious also for making easier the explanation of English grammar to children studying *English as a mother tongue* in primary school.

However, *the second, major part* of the paper is language-independent; its subject is developing general information-processing abilities of young children and, as a result, highly positive developing the personality of the young child.

The connection of two parts is direct but may appear to be highly surprising for the readers of this paper being not acquainted with our previous publications. This connection is given by the fact that the EIT-methods provide the possibility to lead young children during extra-scholastic studies to such a level of mastering English an a SL which *exceeds the average level of mastering mother tongue* by English-speaking young children of the same age. It should be stressed that we mean here the abilities to compose stories, fairy-tales, and poems, to describe landscapes, to take part in discussions of texts expressing the opinions, finding arguments in favour of the own opinion (but not the quantity of the known words designating things surrounding children in every-day life).

That is why the ideas of the second part have a very large sphere of applications, they may be used in preprimary educational system, primary school, and in junior grades of secondary school in diverse countries.

In the nineties, many researchers are looking actively for new theoretical foundations of the AI field (for references see, in particular Mind <> Computer 1995).

Nevertheless, the second part of this paper shows that the creative potential of the ideas suggested yet in 1970's in the works of E. Charniak, M. Minsky, C. Rieger, R. Schank, Y. Wilks, T, Winograd, W. Woods and of some other scientists is far from being exhausted; moreover, the well known ideas of these researchers have influenced highly fruitfully the creation of a new method of teaching children effective information processing.

The method of teaching children set forth in this paper is complicated, many-sided, and pertains to the following different problems of education considered from the uniform standpoint of effective information processing:

- very early teaching children to read fluently in SL, developing the ability of young children to perceive abstract information in the course of explaining to them some rules of English grammar (Sections 2 - 4);

- teaching young children to carry out logical and common-sense reasonings proceeding from situations described in texts (Section 5);

- teaching young children to understand the language of poetry in SL, first of all, to understand metaphors (Section 6);

- teaching young children to understand information conveyed by pictures, developing the feeling of the existence of the narrow ties between different generations of people (Section 7);

- developing the ability to analyse more deeply the facts of every- day life, the interrelations with friends and parents.

The method has been successfully tested by one of the authors in teaching in diverse years more than three hundred children at the age from four-and-half to nine years.

The ideas stated below extend the description of the DCM-theory given in (Fomichov & Fomichova 1993, 1994, 1995b, 1996; Fomichova 1996); in particular, enlarge the collection of basic principles of the DCM-theory (Section 5).

The elaborated method of teaching a FL to young children and developing their abilities to process effectively symbolic information of diverse kinds is discussed in Section 8. Section 9 states a new look at the role of science in the progress of education.

2 The motives of early teaching children to read in a second language

Approximately from the second half of the eighties, the problem of diminishing the starting age for teaching children a second language (SL) has attracted the attention of many specialists in diverse countries. The achieved progress consists usually in shifting the start of SL lessons from the first grade of secondary school to the last grades of primary school; i.e., from the age 11 years to the age 10 and 9 years (Rixon 1992; Fomichov & Fomichova 1994, 1995b). It may be added that the starting age in Austria is 8 years, and one begins to teach children writing when they are approximately 10 years old (Felberbauer 1994).

As concerns children under 7 years, the dominant opinion is that they are psychologically ready only to master separate words and simple phrases pertaining to every-day life, to learn simple poems and songs by heart, to play games in SL (Rixon 1992).

We've discovered that this widely-accepted opinion is a *delusion hampering* (by way of methods of teaching a SL and corresponding text- books) the development of the personality of the child during a highly important, crucial period of his/her life.

Let's analyse more attentively what are the situations when the child wants to communicate with other people. Naturally, the child may say about his/her need: to eat, to go to a zoo, to visit the grandma, etc.; he/she may request also a friend to give a pen or to throw a ball, etc. But the child may want also to tell a friend or parents about joyful or sad events in his/her life, about interesting news, may want to retell a fairy-tell, to tell the topic of an interesting animated cartoon, and may want simply to dream.

Traditional methods of teaching very young children (5-, 6-, 7-year- old) a SL restrict the communication of the child in SL to expressing simple every-day needs and requests, orders to carry out some actions like throwing a ball. Such methods don't provide the child with the means enabling him/her to express the own feelings, emotions, to tell about diverse events, to discuss plans for summer, to retell interesting fairy-tales, etc.

As a result, SL lessons have for the child very little common (practically, nothing) with his/her real life, his/her thoughts and emotions. All this negatively influences the motivation of the child to study a SL and in fact doesn't enable the teacher to use the SL lessons for developing the personality of the child.

We've proceeded from the known fact that the level of intellectual capabilities of a person is determined mainly by the level of his/her intellectual capabilities at the age 5 - 6 years. That is why our *principal idea* has been as follows: to help children to overcome main psychological difficulties in studying SL very early, at the age 5 - 7 years, and thereby to influence highly positively the development of the personality of the child; in particular, to contribute to considerable development of general information processing abilities of the child.

For this, we've suggested an absolutely new conception of teaching young children a SL (on the example of the English language) and of developing the personality of the child (Fomichov & Fomichova 1993, 1994, 1995b, 1996). One of us has tested successfully that conception during 6 years in teaching many children.

The ground of that conception is early teaching children to read in a SL since only the knowledge of written language may enable the child to express in SL his/her rich inner world (Fomichov & Fomichova 1995b, 1996; Fomichova 1996). As for English as a SL , one of the chief and simple arguments is as follows. Children are unable to discuss diverse events of their life without verbs in, e.g., Past Simple. But the verbs in Past Simple very often differ greatly from the same verbs in Present Simple. That is why very young children need some special explanation in order to get accustomed to it (see Fomichov & Fomichova 1995b, 1996, Fomichova 1996, and Section 4 of this paper).

3 A generalized formulation of a new method of teaching children effective information processing

Proceeding from the new conception of teaching young children a SL and from the DCM-theory, we've elaborated the Methods of Emotional- Imaginative Teaching foreign languages (the EIT-methods) described, in particular, in (Fomichov & Fomichova 1993, 1994, 1995b, 1996; Fomichova 1996).

The analysis shows that the main content of the EIT-methods and the main cause of achieved success is highly positive development of the personality of the young child, including development of general information processing abilities of children. The dominant part of ideas may be used both for more effective teaching young children arbitrary foreign languages and for more effective teaching diverse languages as mother tongues (first of all, English as the mother tongue).

That is why we believe that it would be worth to interpret the kernel of EIT-methods as a new method of teaching young children effective information processing. A *generalized formulation* of that new method is given by the following system of goals as concerns extra-scholastic teaching young children:

1. To teach 5-year-old - 6-year-old children to read in a studied SL very early, approximately from the fourth-fifth lesson.

2. To use the lessons destined for explaining the rules of reading words in SL and basic rules of a SL grammar for developing the abstract thinking of children. For this, to establish deep conceptual parallels between the abstract rules to be learned (dealing with symbolic objects like letters of a SL, verbs, nouns, and personal pronouns) and diverse objects, events from the well-known or specially invented stories and fairy-tales being highly interesting, thrilling for young pupils.

3. Proceeding from the ability of children to read in a SL, to teach children to employ actively in oral communication basic grammatical constructions. For instance, to form sentences in Present Simple Tense and Past Simple Tense, questions, and phrases with negation in case the studied SL is English.

4. To teach young children to carry out logical and common-sense reasonings proceeding from situations described in texts (usually, fairy-tales), to explicate a lot of background information implicitly conveyed by texts.

5. Owing to achieving the goals 1 - 4, to awake the fantasy of children, their abilities to retell and compose fairy-tales and to obtain a stable motivation of children to learn a SL, a joyful attitude to the lessons of SL.

6. Beginning from the second year of studying a SL, to teach young children to understand deeply the information and feelings expressed by poetry. For this, to teach children to master the means of SL enabling people to describe the nature and feelings. In particular, it is very important to teach children to understand information and feelings conveyed by poetical metaphors. As a whole, the goal is to teach young children a very beautiful sublanguage of a SL going far beyond the scope of their every-day

7. Owing to achieving the goals 5 and 6, to develop considerably the creative abilities of children and their fantasy, to obtain a very stable and very strong motivation to learn a SL, to awake the "taste" to mastering diverse expressive possibilities of a SL.

8. To teach young children to understand information and feelings conveyed by pictures; for this, to explain systematically the interrelations of symbols used by painters and the meanings of these symbols,

9. As a result of achieving the goals 6 - 8, to develop the feeling of the beauty, the ability to see the beauty of the nature, people, pictures, and poems.

10. After bringing children to a rather high command of the studied SL, to train them for analysing and discussing varied life situations with the aid of SL, for seeing the beauty and value of friendship, love, and mutual aid, to develop the ability to hear and to understand other people - children and adults.

11. As a result of achieving the goals 1–10, to influence positively the *quality* of children's reasoning, reading, and oral communication by means of the *mother tongue*, to overcome the usual primitivism of young children concerning their mother tongue.

12. With the help of developing general information processing abilities of children and a very active attitude to studying a SL, to influence positively the creative abilities of children enabling them to learn successfully in other fields and to develop the ability to work independently with textual, visual, and combined teaching materials, to create the preconditions for effective interaction with intelligent tutoring systems of diverse kinds.

The *integral goal* is as follows: through the successes in studying a SL and other disciplines, to contribute to the development of the confidence of own forces, the ability to understand other people and communicate with them, the feeling of success and the feeling of a leader and, as a consequence, to contribute to the future successes of children in their adults' life.

In comparison with Section 2, the goal 1 is grounded in much more detail in (Fomichov & Fomichova 1995b, 1996; Fomichova 1996). Some important aspects of realizing this goal are described in mentioned papers and in (Fomichov & Fomichova 1993, 1994).

That is why we'll begin to set forth the ways of achieving the enumerated goals of teaching from the goal 2. It should be noted that, describing a way of realizing this goal, we'll extend our previous explanations of the way to achieve the goal 1.

4 Developing abstract thinking of young children by means of explaining to them basic rules of a SL grammar

The inner world's pictures, or conceptual systems (CSs), of very young children (4 - 7-year-old) are highly different from the CSs of adults. The thinking of young children is of very concrete character and is "tied" to the things and events they directly perceive in their every-day life or the ones generated by their imagination proceeding from the heard fairy-tales or from the seen animated cartoons.

As a consequence, it is very difficult, practically impossible for the young child to remember even very simple (from the standpoint of adults) abstract rules. For Russian children, for instance, such is the problem of understanding why the pronunciation of the letter "Y" in some positions is different from the pronunciation of the same letter in other positions.

This peculiarity of very young children's thinking is the principal cause of the mentioned widely-accepted opinion that children under seven are psychologically not ready to learn successfully to read in a SL.

Proceeding from the DCM-theory, we've *discovered* that very young children are able to remember and assimilate *a lot of abstract information.* But for this, each introduced piece of abstract information should be directly and effectively "tied" to some *bright, stable* fragment of the young child's CS.

E.g., the EIT-methods include the explanation of the rule of reading the letter "Y"; it is made with the help of the known fairy-tale about The Wolf and the Seven Little Kids (Fomichov & Fomichova 1993, 1994).

A way (thrilling for very young children) to formulate the rule of using the verb "to be" in Present Simple Tense and combining it with the pronouns "I", "you", "he", "she", "it", "we", "they" may be found in (Fomichov & Fomichova 1995b, 1996; Fomichova 1996).

Let's consider now an original manner to introduce the rule of forming questions in Present Simple Tense. A teacher may explain this rule telling children the following

STORY ABOUT LADY TEACHER AND MR. DO.

You see, children, it's impossible to live without asking questions. So one day Lady Teacher decided to explain to all the verbs how to ask questions. She entered the classroom and began the lesson.

You remember, children, that Lady Teacher is very beautiful and smart. She wears a very nice gown and shoes with high heels. Verbs admired her. The most obedient verbs are the following ones: must, can, may *and, besides, the verb* "to be". *And it doesn't matter what dress* "to be" *is wearing: "are", "is" or "am".*

She explained to the verbs that if they wanted to know anything, they needed to ask. And, burning with curiosity, the verbs ran and occupied the first place in front of all other words. They began to try.

He must go. She can swim. You may go.
Must he go? Can she swim? May you go?

I am kind. He is lazy. She is pretty.
Am I kind? Is he lazy? Is she pretty?

But at the same time all other verbs began to chat and misbehave. Lady Teacher couldn't stand their misbehaviour and left the classroom. You see, children, it's impossible to teach somebody or even to speak with, trying to explain something, if a person doesn't know how to behave in a proper way and doesn't respect other people. I hope, children, you know how to behave in a classroom, for instance.

So Lady Teacher went downstairs to her study. Her study was located just under the classroom. She sat in the cosy armchair and began to speak with her best assistant Mr. Do. Mr. Do is very tall and thin. He wears a top-hat and uses a walking-stick while walking. Suddenly they caught sight of drops of water falling from the ceiling. There was something out-of-the-way in it. Then they realized what it was.

After some time other verbs, disobedient ones, began to understand that they couldn't even live without asking questions from time to time. And discovered that Lady Teacher had left the classroom, and there was nobody who could help them. They began to cry and cry. And after some time they found themselves in pools of tears, and their tears drenched the floor and fell down right on the

Lady Teacher's nice shoes with high heels.

She was shocked and asked Mr. Do for help. She is very strict and couldn't forbid the verbs, but she asked Mr. Do, her assistant, to go upstairs and to make up the situation.

He went upstairs immediately. He decided not to explain anything to the verbs because they were very naughty, but he helped them. As soon as he occupied his place in front of the sentence, the question mark ? took his place in the end of the sentence. Like this: You go to the park. - Do you go to the park?

But when Mr. Do occupied his place before "He", Mr. Do suddenly noticed the poor miserable drenched bow, tied once (as you remember) to the verb. Mr. Do felt sorry for the bow "s" because it was not guilty, and Mr. Do took "s" to his walking-stick "e" in order to dry. Like this:

He runs to the park.
Does he run to the park?

You see, children, you should be careful and try to behave well. Remember that being obedient is smart.

Telling this story, the teacher contributes to (a) creating some bright fragment in the inner world's picture, or conceptual system (CS), of each young student and (b) establishing a dynamic mapping from the set of components of that fragment to the set of components of a rather fuzzy fragment corresponding to the introduced rule of building questions with the aid of the verb "to do".

The scheme represented in Figure 1 illustrates a possible mechanism of establishing such a dynamic conceptual mapping. The schemes of the sort are introduced in (Fomichov& Fomichova 1995b, 1996) and are called Conceptual-Visual Dynamic Schemes (CVD-schemes). The notation of CVD-schemes is an extension of the notation of semantic nets.

In CVD-schemes, *the blocks with single contour* are used for designating: diverse physical objects, situations, processes; sets of objects; concepts qualifying objects, situations, and processes; semantic relations between elements of a text; names of functions, etc. *The blocks with double contour* denote the inner visual images (IVIs) of diverse objects. *Double arrows* designate dynamic conceptual mappings.

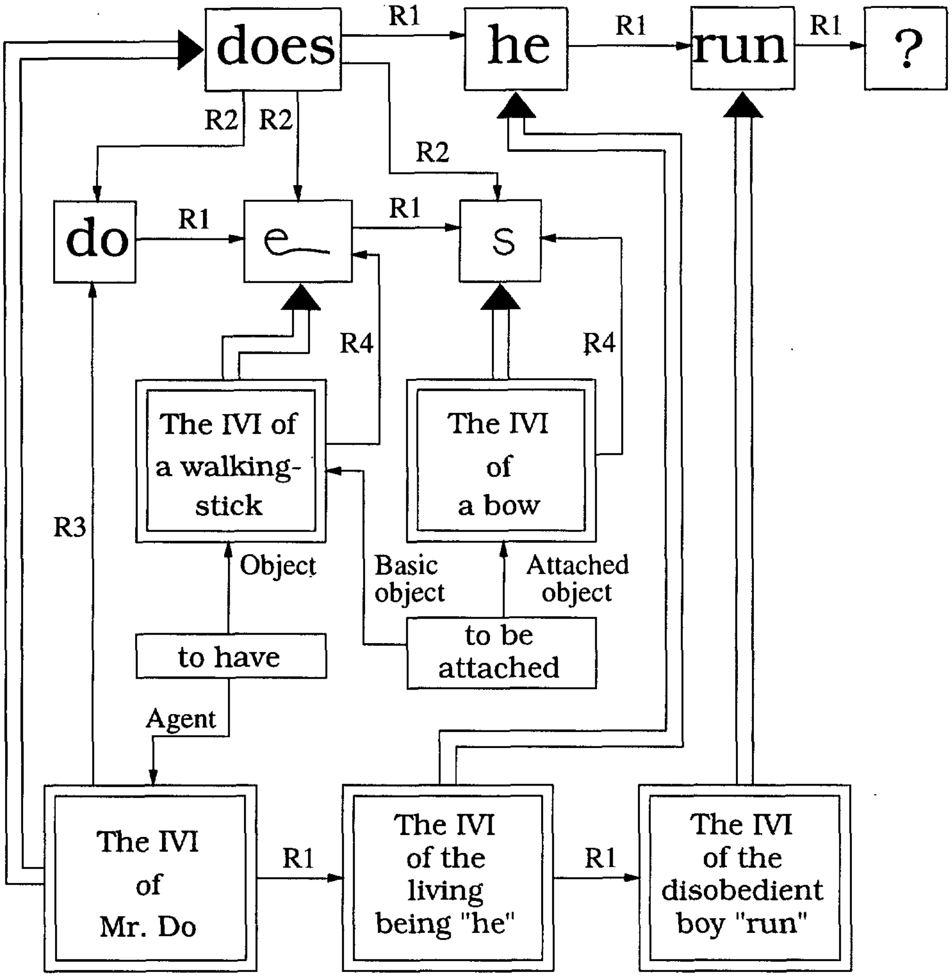
Keeping in mind the story about Lady Teacher and Mr. Do, children simultaneously and unconsciously keep in mind (not for the first time by that moment) that the rules dealing with sequences of symbols may be associated with some thrilling events in the real or imaginary world.

The story about Lady Teacher and Mr. Do is not the only example of establishing a successful analogy between the life of verbs and the life of people. It is wonderful that it has been possible to elaborate a complete thrilling lifestory of verbs: "very young" verbs in prams, their youth, their relations with parents and friends, their school life, the relations between teachers and students; the verbs have their favorite fairy-tales and games, they keep to the conventions in the society, etc.

As a result, it turns out that the everyday experience of the young students is akin to the everyday experience of the verbs. The irony of the situation lies in surprising similarity of two worlds: World of Verbs and World of People.

Consider only one more example. Every person has his or her Past, Present, and Future. And in his/her Past, every person was a baby. The verbs have their Past too, and Lady Teacher has an album with photographs of the verbs in "pram-age". Some of the verbs, like people, have changed greatly (like "went - go"), some of them were plump in childhood and then lost some weight ("cooked - cook"). But when the verbs were babies at so-called "pram-age", they were bald (like babies in prams), and it was impossible to tie the bow "s" - no hair ! That explains the absence of "s" after the verbs in the 3rd Person Singular in the Past Tense.

We agree with the opinion of Scott and Ytreberg (1994) that 5 - 7- year-old children usually don't feel quite well the border between the real and imaginary worlds. Our experience indicates that this peculiarity of the consciousness of very young pupils may be successfully used for explaining to them in specially invented, thrilling forms many basic rules of the SL grammar. Each such explanation (see also Fomichov& Fomichova 1994, 1995b, 1996) contributes to developing abstract, symbolic thinking of very young children.



Denotations: IVI - inner visual image; R1 - the relation "To be located before"; R2 - the relation "Includes-a-part"; R3 - the relation "Name"; R4 - the relation "Similar-to".

Figure 1: A possible conceptual-visual dynamic scheme illustrating the manner to explain the rule of forming questions with the help of the verb "to do".

5 We need to provide support to the general associative engine donated by the nature to young children

5.1 The direction of extending the DCM-theory

Section 4 deepens the understanding of basic principles of the DCM- theory set forth in (Fomichov & Fomichova 1994, 1995a, 1996). It illustrates a manner enabling the teacher to "inscribe" effectively new pieces of studied theoretical materials in the CSs of the young learners. Enriching CSs of the learners, the teacher creates the preconditions for effective perceiving new information.

But all do know quite well that two persons possessing approximately the same background knowledge may draw very different conclusions from the same observed situation or the read information. The reason is that they possess different abilities to process effectively information.

We know also that diverse abilities of people may be considerably developed, especially the abilities of young children. So we add to the set of basic principles of the DCM-theory the following one:

One of the main global aims of teaching young learners (independently on the studied discipline) must be developing abilities of children to process effectively information of a number of kinds depending on the discipline.

We suggest below a very general method of developing the ability of children to process information expressed by means of natural language and, as a consequence, of analysing situations of every-day life. That method contributes also essentially to the development of young children's imagination.

The method is motivated by ideas suggested in the field of AI yet in the beginning of the seventies.

With respect to its extended form, the DCM-theory may be characterized very shortly as a theory of effective enriching conceptual systems of learners, developing their general associative abilities, imagination, and abstract thinking.

5.2 A new method of teaching children to process effectively information conveyed by natural language texts

It is widely known that very young children are usually highly gifted, have a vivid fantasy. It seems that the most important is that very young children have extremely high associative abilities manifesting in various ways. For instance, young children compose fairy-tales and diverse interesting stories, are able to formulate very deep thoughts joining in one phrase seemingly highly remote objects and concepts, can make highly surprising but truthful comparisons of things or situations.

As a rule, young children make such comparisons unconsciously. That is why we may draw the conclusion that the nature donates to practically all young children a very powerful associative engine supported by the subconsciousness of the child.

Regretfully, it is widely known too that the dominant part of children (except of future outstanding poets, writers, scientists, painters, etc.) don't demonstrate such excellent associative abilities even in secondary school to say nothing of the age 19 and more years.

It appears that this situation has common features with the following one. The new-born children are able to swim. But later children lose this ability. That is why adults teach children to swim at a later age supporting in such a manner the innate ability of children. We may say also that adults *explicate* the ability of new-born children to swim.

Several years ago we conjectured that it may be possible to find a way of *explicating* a considerable part of the innate subconsciousness-supported associative abilities of very young children, *to move* a considerable part of such abilities into the sphere of consciousness as a result of systematic studies with young children. We presumed that the realization of this idea may help children to maintain at least a large part of general associative engine at the age 9 - 16 and more years.

We formulated the problem as follows: how to help the child to explicate in his/her consciousness the general subconsciousness- supported associative engine enabling him/her to establish connections between diverse objects, concepts, situations in the framework of his/her inner world's picture, or conceptual system?

The ideas of the AI theory, first of all, theory of Natural-Language-Processing Systems (NLPSs) have allowed us to find an effective solution of this problem.

T. Winograd writes that "in the tradition of artificial intelligence, we project an image of our language activity onto the symbolic manipulations of the machine, then project that back onto the full human mind" (Winograd 1995, p. 457).

We agree with the opinion of T. Winograd that, as a result of carrying out such a double mapping, we may lose from our perspective some essential aspects of processing natural language (NL) by people. However, it is only a possible but not a universal situation. In particular, we've benefited in our study by carrying out a double mapping of the sort.

Winograd (1995) writes that people create their world through language. The studies in the field of NL processing carried out in the end of 1960's - first half of 1970's clarified many aspects of using NL by people.

First, understanding of phrases and discourses is a result of fulfilling diverse logical and commonsense inferences based on the knowledge system of a text's recipient (Charniak 1972; Schank, Goldman, Rieger, & Riesbeck 1975; Wilks 1973; Winograd 1972; Woods & Kaplan 1971).

Second, the knowledge items are concentrated around the representations of concepts. Concepts distinguishing some classes of objects, situations (like "an airplane", "a preparation") are associated with *frames* - structures for representing stereotypic knowledge. The notion of a frame was introduced by M. Minsky in the famous paper (Minsky 1974) and became very popular during 1970's and 1980's. Each frame has several *slots* being structures describing principal characteristics of a class of objects or describing principal participants of situations.

For instance, a frame associated with the concept "a preparation" must indicate that each situation of the type "preparation" is determined by: (a) an event or several events; (b) a person or a group of people who are preparing to that event or events; (c) a set of concrete actions fulfilled by people while preparing to the event (events); (d) a moment of time.

So the frame of the concept "a preparation" has four slots, they may be called EVENT, WHO, ACTIONS, and TIME.

Third, there exists a hierarchy of concepts, and frames of the most part of concepts are usually particular cases of the frames of generalizations of these concepts.

We conjectured that the key to solving the considered problem may be found in the direction of developing general ability of young children to process effectively symbolic representations, to manipulate with symbolic representations, first of all, with words as symbols of NL.

The method of solving the problem suggested and successfully tested by us is many-component and is based on several ideas.

The first idea is to teach children *to reconstruct the complete situation* that is nominated by the word *proceeding from the background frame-like knowledge* represented in the CSs of children. Such reconstruction helps children to feel better the meanings of the words and be ready to see possible consequences, advantages, and disadvantages of this or that situation nominated by the word.

The *integral goal* consists in teaching children to get as much as possible information from books, films, every-day experience in order to gain better understanding between children and grown-ups. Even from the very first fairy-tales children should be taught to get information about the world, relations between people, to analyse what is good and what is bad.

Example 1. The children of the first year of studies read about Snow White. The first sentences of the fairy-tale (it is a script) are:

The Queen's bedroom. The Queen is very ill.

King: *Darling, you are not looking well.*
Queen: *No Sir, I'm very ill. Look at our baby. She is a pretty little girl.*
King: *Yes, darling. She is very pretty.*

Children are asked to begin to retell this fairy-tale and to explain to other children what kind of information they can receive from these sentences. They come to the conclusion that the Queen's bedroom usually is in the palace or in the castle. In the bedroom there should be a bed, a table, a chair, a looking-glass, and a window. Outside it should be a garden or a courtyard or a town. The domes of cathedrals, the spires of the towers may be seen. The weather is gloomy, because the Queen is very ill. The King is very upset, because he loves the Queen. Both of them love the baby. Certainly they are very kind.

With the help of such reconstruction, children make every scene more natural and more clear for them. They become co-authors of the story and enrich their emotional experience and even vocabulary, trying to find proper words to express their attitude. On the other hand, it improves their mental ability to perceive the world.

Example 2. The students of the second year of studies (their age is 6 - 7 years) have the same task. They read "Sleeping Beauty". The beginning of this fairy-tale is as follows:

Once upon a time many years ago there lived a King and a Queen. They had everything they wished for except one thing. They both longed for a baby daughter. One day the Queen went for a stroll through the Palace Gardens. She sat for a while to watch the fishes in the pond. But suddenly, from underneath a lily pad jumped a frog.

Children are asked to tell some words about the Palace, where it was situated, about the King and Queen. They begin to create stories of the following kind:

The Palace was situated on the steep slope leading down to the river. The water in the river *was crystal-clear with silver ripples if the weather was windy. Round the Palace there was a Garden with a pond, a spring, tame squirrels, cunning in their nature ...*

Consider another example. The fairy-tale "Sleeping Beauty" includes the fragment *"There must be celebrations", said the King. "I will tell the Court to prepare the most enormous Christening Party".*

In this context, young students are asked to imagine the events meant by the phrase "There were preparations in the Kingdom". The home compositions of two students learning English during one and half year are given below.

Composition 1 (Polina Rybakova, 8 years old)

A year gone by. Everyone in the Kingdom was awakened by the sounds of the church bells. People began to gather in the streets. Suddenly appeared the Royal Cryer. He went along the streets and announced that the Queen's wish had been granted. The baby-Princess was born that night and great celebrations would take place in the Royal Palace and all over the land.

The birds heard that news and delivered it to everyone in the fields and in the woods. All mice in the fields began to work: they made a beautiful dress decorated with corn-flowers for the Princess. But they were very small and they made a very small dress, so it fitted only Princess' doll. The birds made a little toy bear-cub of the straw. The animals in the woods began to dance and sing merry songs. Even the King and Queen heard those songs.

All the children in the Kingdom in white clothes and white flowers in their hair joined hands and danced around the Palace. The Royal Cookers prepared an enormous cake and decorated it with red roses cream and candles. Every day in the Kingdom was happy.

Composition 2 (Katya Bogomolova, 6 years 10 months old)

A year went by. Everyone in the Kingdom was awakened by the loud sounds of church bells. The church stood in the centre of the town near the palace. The church was very high and beautiful. It looked like the mountain covered with soft white snow. People heard loud sounds of the church bells and began to gather in the streets. Then along came a Town Cryer. He said that their Royal Highnesses, the King and Queen, announced the birth of the daughter, the Princess. The people began to dance and sing. The children sang the beautiful songs in the gardens and churches. These songs were full of heavenly joy and love to God, Jesus and angels up in Heaven above. Beautiful girls brought to the palace nice flowers.

The animals from the nearest wood came to the palace and brought the presents to the King, Queen, and little Princess: tasty mushrooms for the King, beautiful flowers and sweet berries for the Queen, and one little squirrel as a pat for the Princess. The birds began to sing their beautiful songs, and the hares, squirrels and rabbits began to dance. Saint Peter sent the little angel with silver hair down to Earth to help the Princess in her life. Everyone in the Kingdom was very happy.

The personal experience of one of the authors (obtained in teaching in diverse years approximately three hundred young children) says about the high effectiveness of the suggested method. All students of the 2nd year taught English in experimental groups in accordance with the methods of emotional-imaginative teaching (the EIT-methods) make regularly home compositions of the kind.

Our previous publications contain additional examples of home compositions (in particular, examples of fairy-tales, verses, descriptions of landscapes) prepared by many other young learners from experimental groups.

Since the subject of the paper is not numerous details of our new methods, let's mention now only minimal data about the conditions of the carried out experiment. One group consists usually of 10 - 12 young students of average abilities (children were not selected), the duration of one lesson is 40 - 45 minutes. The lessons are twice a week with home tasks, which play an important role in our new approach to early teaching SL. These tasks are being fulfilled by young learners (even by five year olds) very willingly; more information about the reasons of such an unusual attitude of very young children to home tasks may be found in Fomichova(1996).

The method of reconstructing the complete situation proceeding from all available background knowledge develops the ability of the young child to extract as much as possible information from NL-expressions.

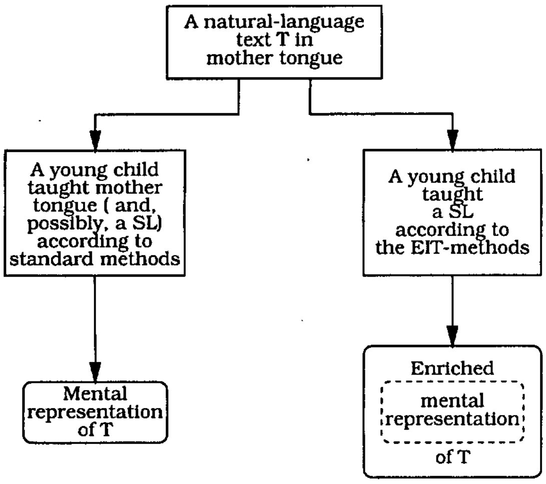


Figure 2: The difference of two mental representations of a natural-language text caused by advantages of the methods of emotional-imaginative teaching.

The obtained data allow us to conjecture that mental representations (MRs) of NL-texts in mother tongue perceived by young students from experimental groups are much larger, richer than MRs of the same texts perceived by other children of the same age 6 - 7 years (see Figure 2).

The experience indicates that this method considerably develops the ability of young children to analyse situations of every-day life and helps children better understand the words of adults. We suppose that our method may be used for more effective teaching mother tongue to young children in primary school and in preprimary educational system.

6 Understanding metaphors as decoding symbolic representations

Young students taught English as a SL in accordance with the EIT- methods during three years achieve such a level of mastering a SL which is unusually high for almost all children of the same age 6 - 8 years. They read and discuss unadapted editions of "Alice's Adventures in Wonder Land" by Lewis Carrol and "Mary Poppins" by Pamela L. Travers, compose fairy-tales (see Fomichov & Fomichova 1994), are able to speculate in SL on arbitrary topics proceeding from the read materials - this applies to speculating both just on the spot and in home compositions in SL.

Students of the 3rd year possess such rich vocabulary and master such rich spectrum of syntactic constructions that they are able to understand deeply the language of describing in SL the nature and feelings in poems. They can also describe and discuss in SL just on the spot the landscapes and seascapes, the feelings evoked by the nature (more information may be found in Fomichov & Fomichova 1993, 1994, 1995b).

The achieved high level of mastering a SL provides the preconditions for the transition to a new stage of developing abstract thinking of children, their abilities to process effectively symbolic representations. During that stage (4th year of extra-scholastic studies) young children are taught to discover the meaning of metaphors, which are considered by us as conditional representations of ideas and feelings coded by the author of the corresponding text by means of words being symbols of NL.

The second basic idea of our new method of teaching children effective information processing is just to teach young students how to decode the meaning of metaphors proceeding from all available initial knowledge about the represented situations.

The goal of this stage is to make a new important step in teaching children to process effectively symbolic information of diverse kinds accumulated by the mankind during many centuries - from painting and sculpture to musics.

The role of this stage in our new approach to developing the personality of the child will become more clear in the context of the next section.

The essence of the considered stage may be explained on the following example. After several preliminary lessons, students of the 4th year are asked to interpret the lines of Boris Pasternak

> "Is it only birds that chatter
> In the blueness of the skies,
> Sipping through the straws of sunrays
> Lemon liturgies on ice?"

In this case we have an image of some concrete situation, emotionally coloured and expressed with the help of symbols. In order to understand these lines, children have to penetrate the essence of the meaning, find possible correlations in meanings of different words, some common features that make it possible to compare different objects or different notions. Having felt these threads, they penetrate the meanings.

So young students (8 - 9 years old) realize that "ice", "blueness of the skies", "sunrays", "birds that chatter" create the atmosphere of the early spring. The word "liturgies" is associated with a church service, which leads them to "lemon" that is a personification of a golden dome soaring in the azure sky.

Children can recall a well-known picture: the pealing of the church-bells summoning people to the church service. The spring sun is shining, reflecting in the golden domes of a church. And the cross above the dome is radiant and from the distance makes an illusion of hardly visible threads of light connecting people with God.

That is the interpretation of the word "sip", not "drink", not "gulp", but "sip" with pleasure and admiration and realizing the enigma of such communication between souls.

The lessons with similar tasks of decoding (being a sort of intellectual puzzles), on the one hand, are very interesting for young students. On the other hand, systematic solving such tasks greatly develops the imagination of the young child, associative thinking, the ability to interpret symbolic (verbal in this case) representations.

As a result, the child paints the world in his/her inner world's picture by means of much more bright, beautiful, various paints. And this brighter, larger vision of the world is reflected in children's home compositions of diverse kinds. Consider only two of them.

We can see the splendor of evening's Petersburg in this picture. The city is twinkling and flaming in the beauty of drawing night. It seems that night comes apace through the cool of the air.

Petersburg is fringed with evening silvery light. Streets look like glistening flood. The moon is glimmering in the dark sky. People and horses move in the shadows near the doorways of the Opera Theatre. Looking at this picture, it seems that splendor of Petersburg is as infinite as sky, which retreated far from the Earth.

It's difficult to conceal my delight from seeing of Petersburg in this picture. (Masha Adabashyan, 9 years old, 4th year of studies).

Oh what an evening! Look, how fair!
Clouds as horses run in the air!
The moon as a glimmering speck in the infinite meadows.
And beautiful people move in the shadows.

(Masha Adabashyan, 9 years old, 4th year of studies).

7 Art as a carrier of selected knowledge: constructive consequences for education

There are two main aspects in the processes of teaching: *how* to transfer knowledge and *what* to transfer. The Theory of Dynamic Conceptual Mappings (the DCM-theory) and Methods of Emotional- Imaginative Teaching (the EIT-methods) deal both with first and second aspects.

The third basic idea of our new, many-component method of teaching children effective information processing is to teach children to understand the language of painting, to interpret elements of pictures as symbols associated with some definite meanings and creating a particular mood.

Proceeding from the DCM-theory, we've created a new, highly effective system of extra-scholastic teaching children foreign languages (in particular, English as a SL and German as a third language) and mother tongue and developing the personality of the child. The system covers the age diapason from four-and-half to sixteen years (see Fomichov & Fomichova 1993, 1994, 1995b, 1996; Fomichova 1996). One of the distinguished features of our new system of language teaching is that it gives an original filling to very many topics traditionally studied at school.

E.g., there are several usual topics for discussion while learning any SL such as weather, nature, seasons, and painting. The traditional approach to studying painting is to discuss the biographies of well-known painters and to enumerate their masterpieces. As for seasons and weather, usually these topics are not discussed in connection with painting at all.

But a particular season and weather framing the season help to reveal the feelings of the artist or a person depicted on the canvas or help to find correlations between the work of art and the state of mind and soul of the observer.

8.2 Interrelations with the "soft" stream in Cybernetics

Itow and Yamakawa (1993) suggested a new philosophy needed for effective management - a philosophy of learning to respect each other. It is based on the soft-cybernetics method going back to the work Maruyama (1963); the main orientation of the method is adaptive self-stabilization and self-organization. According to the new philosophy, "humankind involves the living and non-living in the cosmos. All living and non-living systems cooperate and are interdependent with each other in a global society in the making. This global society consists of a network of all living and non-living systems and a learned respect of the former for both" (Itow & Yamakawa 1993, p. 91).

Our new methods help to teach children to love the nature, to appreciate the beauty in all its manifestations, to understand other people. One can see this, in particular, on home compositions of young students adduced in Section 5. Young children don't imagine the preparations to a celebration without animals in the woods, birds, mice (Composition 1), the animals from the nearest wood, birds, hares, squirrels, rabbits (Composition 2).

The love to the nature, the idea that the child is only a particle of the nature is manifested brightly in compositions of other young students of the 2nd year too. As, for instance, in the following two fragments:

"The carpenter made a cradle. It looked like a dolphin. Gold stars were in eyes. On the tale was a ball" (Nadya Vorobyova, 9 years old);

"All guests, servants, court, birds, animals danced very much" (Olya Dagaeva, 8 years old).

6 - 8 year old students often demonstrate a really global vision of the world as concerns both space and time aspects, as, e.g., in the following fragment:

"Kings and Queens from other countries sent a lot of cards and different gifts. Tulips from Holland, paper fans from Japan. Peter the First sent sables and semi-precious stones" (Polina Rybakova, 8 years old).

Thus, the EIT-methods harmonize quite well with the new philosophy based on the soft-cybernetics method.

8.3 Some interrelations with Cognitive Psychology and Cognitive Linguistics

The analysis indicates that our results are in good correspondence with basic ideas of the famous Russian psychologist Lev Vygotsky (see, in particular, Vygotsky 1962, 1978). In particular, with (a) the idea that the mastering of a written language (learning to read and write) has a profound effect upon the development of abstract thinking, (b) the idea that human consciousness is achieved by the internalization of shared social behaviors Dynamic, intellectually intensive and joyful learning of a FL by young children gives them a unique and highly valuable experience of joint social activity aimed at mastering new knowledge. Both the teacher and parents clearly see how much that interesting joint social activity develops the personality of every child from experimental groups.

As a whole, our study harmonizes quite well with the paradigm of Cognitive Linguistics considering formal structures of NL as reflections of general conceptual organization, categorization principles, processing mechanisms, and experiential and environmental influences, looking at NL as at an instrument for organizing, processing, and conveying information (see, in particular, Fillmore 1985, Geeraerts 1990; Lakoff 1987; Langacker 1990).

Let's note that there is an interesting correlation of the DCM-theory and of the theory of mental spaces suggested in Fauconnier (1985). The essence of that correlation may be explained with the help of the example considered in Section 4.

The rule of forming questions with the verb "to do" corresponds to some mental space Sp1. In order to explain this rule, a teacher tells young pupils the story about Lady Teacher and Mr. Do. As a result, the teacher creates a new, very bright mental space Sp2 in the inner world's picture of each pupil (see Figure 1). From the standpoint of the Fauconnier's theory, the dynamic conceptual mapping from Sp2 to Sp1 may be interpreted as a connector joining Sp2 and Sp1.

8.4 Artificial intelligence community and education

The starting point for our study was mainly the ideas suggested in the field of Artificial Intelligence (AI) more than twenty years ago and considered nowadays as classical. However, our experience shows that the creative potential of these ideas is far from being exhausted, and they've started a new life in the theory of education.

That is why we believe that members of the AI community may make a considerable contribution both to the theory and practice of teaching.

As for the first direction, the specialists on the AI theory may teach future and current teachers how to use the visual means of representing diverse cognitive structures and dynamic conceptual mappings for inventing effective analogies making much easier for children the learning of various theoretical disciplines. Besides, such specialists may invent new methods of developing the abilities of children to process effectively symbolic information of diverse sorts.

Designing Intelligent Tutoring Systems (ITSs) with friendly interfaces (in particular, with NL-interfaces) is an obvious possible direction where the members of the AI community may make a very precious contribution to the practice of teaching.

Studies on constructing ITSs are being carried out in many countries. One of the most large-scale projects of the kind is funded by the National Science Foundation (Wah et al. 1993).

It may be noted that the DCM-theory and EIT-methods open large new prospects for building ITSs destined for teaching (a) FLs, first of all, English, (b) mother tongues (see also Fomichov & Fomichova 1993, 1994). This applies to teaching young children, teenagers, and adults.

9 Conclusions: A new look at the role of science in education

A great number of specialists in diverse spheres have said and written during recent years that science should provide a stimulating help to school education. Usually, one interpret this idea in the following way: scientists should try to make children acquainted (naturally, in accessable forms) with the recent achievements in the corresponding fields.

We believe that this widely accepted interpretation is misleading and doesn't satisfy the real needs of school education. It appears that this situation is to some extent similar to the situation discussed in Subsection 6.1 in connection with the book Scott & Ytreberg (1994): though the authors of the book proceed from a lot of truthful and often subtle observations concerning psychological peculiarities of young children, their conclusions, from the standpoint of our prolongated and various experience, are contrary to the real creative possibilities of young pupils.

We suggest an entirely another interpretation of the possible significance of science for the progress in education.

Keeping in mind the necessity to maintain children's health in a good state, to prevent children from overstraining their forces, it is impossible to increase unlimitedly the number of topics learned on diverse disciplines at school.

We suppose that the principal contribution of science to education is to consist in creating a new philosophy of education and new methods of teaching developing general associative abilities of children, their abilities to carry out various logical and common-sense inferences proceeding from the perceived information and all available background knowledge, the abilities to see clearly causal relationships of diverse events, developing the desire to acquire new knowledge and the ability to extract actively new knowledge from diverse sources, developing the love to the nature, the ability to see the beauty in all its manifestations, and the ability to communicate with other people.

The Theory of Dynamic Conceptual Mappings (the DCM-theory) and the Methods of Emotional-Imaginative Teaching (the EIT-methods) have been elaborated as a result of the emergence of our new look at the role of science in education.

The DCM-theory and EIT-methods focused the achievements of such different fields of studies as AI theory (considered as a part of Computer Science), Cognitive Psychology, Cognitive Linguistics, Philosophy (including Philosophy of Language), Communication Theory, Cybernetics, Mathematical Linguistics, Theory of Translation (see Fomichov & Fomichova 1993, 1994, 1995b, 1996;

Fomichova 1996) on solving the acute problems of education.

To our opinion, just this is the deep cause of unusually high practical effectiveness of the elaborated methods of teaching.

It seems that we've found a way opening thrilling prospects for researchers from diverse fields to contribute to making the learning much more easy, fruitful, and joyful for our children.

References

[1] Charniak, E. (1972). Towards a model of children's story comprehension. AI TR-266, Massachusetts Institute of Technology, Cambridge, Mass.

[2] Fauconnier, G. (1985). Mental Spaces: Aspects of Meaning Construction in Natural Language, Cambridge, MA: Bradford/ MIT Press.

[3] Felberbauer, M. (1994). Fruehes Fremdsprachenlernen an der Grundschule - eine Grundsatzentscheidung, Fremdsprachenunterricht (Berlin), Vol. 47, No. 2, 117-121.

[4] Fillmore, C. (1985). Frames and the semantics of understanding. Quaderni di Semantica, Vol. 6, 222-253.

[5] Fomichov, V.A. & Fomichova, O.S. (1993). The role of the artificial intelligence theory in developing new, highly effective methods of foreign languages teaching. In PEG93: Proc. of the Seventh Intern. PEG Conf. AI Tools and the Classroom: Theory into Practice. Moray House Institute of Education, Heriot-Watt University, Edinburgh, July 2nd-July 4th 1993, 319-329. ISBN 0901580 570.

[6] Fomichov, V.A. & Fomichova, O.S. (1994). The theory of dynamic conceptual mappings and its significance for education, cognitive science, and artificial intelligence, Informatica (Ljubljana, Slovenia), Vol. 18, No. 2, 131-148.

[7] Fomichov, V.A. & Fomichova, O.S. (1995a). From ideas of artificial intelligence and cognitive science to the discovery in the theory and methods of teaching. In Abstracts of Papers. 14th Intern. Congress on Cybernetics. Namur (Belgium), August 21 - 25, 1995. Symposium "From Ideas of Artificial Intelligence and Cognitive Science to New Theories and Methods of Teaching". President- Chairperson: V. Fomichov (Russia). International Association for Cybernetics, Namur, p. 1.

[8] Fomichov, V.A. & Fomichova, O.S. (1995b). The artificial intelligence theory and highly effective methods of teaching young children foreign languages, Cybernetica (Namur, Belgium), Vol. XXXVIII, No. 4, 321-344.

[9] Fomichov, V.A. & Fomichova, O.S. (1996). From ideas of artificial intelligence and cognitive science to the discovery in the theory and methods of teaching. In Proc. of the 14th Intern. Congress on Cybernetics. Namur (Belgium), August 21 - 25, 1995. International Association for Cybernetics, Namur, 731-736.

[10] Fomichova, O.S. (1995). Emotionally-imaginative teaching children foreign languages as a highly effective realization of a general approach to conflicts-free teaching. In Abstracts of Papers. 14th Intern. Congress on Cybernetics. Namur (Belgium), Augu st 21 - 25, 1995. Symposium "From Ideas of Artificial Intelligence and Cognitive Science to New Theories and Methods of Teaching". President-Chairperson: V. Fomichov (Russia). Intern. Association for Cybernetics, Namur, p. 2.

[11] Fomichova, O.S. (1996). Emotionally-imaginative teaching children foreign languages as a highly effective realization of a general approach to conflicts-free teaching. In Proc. of the 14th Intern. Congress on Cybernetics. Namur (Belgium), August 21 - 25, 1995. International Association for Cybernetics, Namur, 743-748.

[12] Gams, M. (1995). Strong vs. Weak AI. In Mind<> Computer 1995, 479-493.

[13] Geeraerts, D. (1990). Editorial Statement. Cognitive Linguistics, Vol. 1, No. 1, 1-3.

[14] Itow, S. & Yamakawa, N. (1993). Self-organizing leadership in Japanese manage-

ment: a view from a soft-cybernetics method. Cybernetica (Namur, Belgium), Vol. XXXVI, No. 2, 85-92.

[15] Lakoff, G. (1987). Women, Fire, and Dangerous Things. What Categories Reveal about the Mind. Chicago: The University of Chicago Press.

[16] Langacker, R.W. (1990). Concept, Image, and Symbol. The Cognitive Basis of Grammar. Berlin, New York: Mouton de Gruyter.

[17] Maruyama, M. (1963). The Second Cybernetics, American Scientist.

[18] Minai, A.T. (1989). Design as Aesthetic Communication. Structuring Random-Order; Deconstruction of Formal Rationalty. New York et al.: Peter Lang Publishing, Inc.

[19] Mind<> Computer (1995). Special Issue of Informatica. An Intern. J. of Computing and Informatics, Vol. 19, No. 4.

[20] Minsky, M. (1974). A Framework for Representing Knowledge. Massachusetts Institute of Technology, Cambridge, Mass.

[21] Rixon, S. (1992). English and other languages for younger children: practice and theory in a rapidly changing world (State of the art article). Language Teaching, Vol. 25, No. 2, 73-93.

[22] Schank, R.C., Goldman, N.M., Rieger, C.J., & Riesbeck, C.K. (1975). Conceptual Information Processing. Amsterdam, Oxford: North-Holland Publ. Company; New York: American Elsevier Publ. Comp., Inc.

[23] Scott, W.A. & Ytreberg, L.H. (1994). Teaching English to Children. Seventh impression. London, New York: Longman Group UK Limited.

[24] Vygotsky, L. (1962). Thought and Language, MIT Press.

[25] Vygotsky, L. (1978). Mind in Society, Harvard Univ. Press.

[26] Wah, B.W. et al. (1993). Report on Workshop on High Performance Computing and Communications for Grand Challenge Applications: Computer Vision, Speech and Natural Language Processing, and Artificial Intelligence. IEEE Trans. on Knowl. and Data Eng., Vol. 5, No. 1, 138-154.

[27] Wilks, Y. (1973). An artificial intelligence approach to machine translation. In Computer Models of Thought and Language, R. Schank and K. Colby (Eds.), San Francisco: Freeman, 114-151.

[28] Winograd, T. (1972). Understanding Natural Language. New York: Academic Press; Edinburgh: Edinburgh Univ. Press.

[29] Winograd, T. (1995). Thinking machines: Can there be ? Are we ? In Mind <> Computer (1995), 443-459.

[30] Woods, W. & Kaplan, R. (1971). The lunar sciences natural language information system. BBN Report, No. 2265, Bolt, Beranek and Newman, Cambridge, Mass.

Journal of Consciousness Studies

controversies in science & the humanities

an international multi-disciplinary journal

STYLE SHEET AND GUIDE TO AUTHORS

A Multi-disciplinary Journal

Journal of Consciousness Studies (*JCS*) is aimed at an educated multi-disciplinary readership. Authors should not assume prior knowledge in a subject specialty and should provide background information for their research. The use of technical terms should be avoided or made explicit. Where technical details are essential (for example in laboratory experiments), include them in footnotes or appendices, leaving the text accessible to the non-specialist reader. The same principle should also apply to non-essential mathematics.

Contributions should be clearly typed in double spacing. Three copies should be submitted and contributors should retain a copy for proofreading purposes. A short 150 word summary should accompany each submission. Articles should not normally exceed 9,000 words (including footnotes). In general authors should adhere to the usages and conventions in Fowler's *Modern English Usage* which should be consulted for all questions not covered in these notes. If you include a copy of your article on disk this will enable us to email it and will speed up review (see below). Please state what machine and wordprocessing program was used to prepare the text.

Footnote numbering should be consecutive superscript throughout the article. References to books and articles should be by way of author (date) or (author, date). Multiple publications from the same year should be labeled (Skinner, 1966a, b, c ...). A single bibliography at the end should be compiled alphabetically observing the following conventions:

1. **References to books** should take the following form:
   Jantsch, Erich (1980), *The Self-Organizing Universe* (Oxford: Pergamon)

2. **Reference to article** should take the following form:
   Black, Antony (1993), 'The juristic origins of social contract theory', *History of Political Thought,* **XIV**, pp. 157–76.

Submission of Manuscripts by Email

Authors are encouraged to email their *wordprocessor files* (retaining italics, accents, superscripts, footnotes etc.) There are two alternative ways to do this: (1) Most email programs have a MIME facility to encode and send binary files, such as 'insert file', or 'transmit from file'. We can handle most standards PC and Mac programs this way; or (2) Save the file as RTF (Rich Text Format) and send this in an ordinary (ascii) email. LaTex documents can also be sent as ascii email. Send all submissions to **jcs@imprint.co.uk**.

Editorial Advisory Board:

Publisher

Keith Sutherland, Imprint Academic, PO Box 1, Thorverton EX5 5YX, UK. Tel: +44 (0)1392 841600; Fax: 841478. Email: keith@imprint.co.uk

Annual Subscription Rates

JCS (ISSN 1355 8250, USPS Reg. No. 012919) is published bi-monthly—six issues per annual volume. Individuals: $40.00 (£25.00), Institutions: $77.00 (£48.00). Back volumes still available. VISA/AMEX/MASTERCARD.

A Look into JCS

Let us make a look into JCS, Vol. 3 (1996) No. 1, dedicated to Explaining Consciousness—The 'Hard Problem' (Part 2) (Edited by J. Shear). Contents of this volume is the following:

Introduction (J. Shear); *Facing Backwards on the Problem of Consciousness* (D.C. Dennett); *The Why of Consciousness* (V. Hardcastle); *The Hardness of the Hard Problem* (W.S. Robinson); *Giving Up on the Hard Problem* (E. Mills); *Solutions of the Hard Problem of Consciousness* (B. Libet); *Conscious Events as Orchestrated Space-Time Selections* (S. Hameroff and R. Penrose); *The Hard Problem: Closing the Empirical Gap* (J. Shear); *The Easy Problems Ain't So Easy* (D. Hodgson); and *Rethinking Nature: AHard Problem Within the Hard Problem* (G.H. Rosenberg). Opinion Piece: *Computers Near the Threshold?* (M. Gardner).

Citations

Let us list some most challenging citations from *JCS* with commentary which characterize the contents of the journal.

Questions concerning consciousness can be the easy, the hard, and the soft ones[1]. The basic and the hardest one may be how does consciousness emerge in human mind, or how does it come into existence through the development of a living being. A more pragmatic point of view (cognitivistic) says that some of us can observe the evident part of conscious events concerning something, and passing from the past now into the future.

[1]The following quotations from JCS will be presented mainly in a commentary style of the undersigned (to avoid the copyright problems).

— **3** (1996) 1, p. 4–6, *D.C. Dennet,* Facing Backwards on the Problems of Consciousness.

[P. 5] What impresses *me* about my own consciousness, as I know it so intimately, is my delight in some features and dismay over others, my distraction and concentration, my unnamable sinking feelings of foreboding and my blithe disregard of some perceptual details, my obsessions and oversights, my ability to conjure up fantasies, my inability to hold more than a few items in consciousness at a time, my ability to be moved to tears by a vivid recollection of the death of a loved one, my inability to catch myself in the act of framing the words I sometimes say to myself, and so forth. □

[P. 6] Further, Dennet discusses Chalmers'[2] recommendation to make experience fundamental in the same sense as mass, charge, and space-time are fundamental in physics. This is a sort of *cutism* where some things are just plain cute, and other are not.

— **3** (1996) 1, p. 7–13, *V.G. Hardcastle,* The Why of Consciousness: A Non-Issue for Materialists.

[P. 7] (COMMENTARY) Today, two sorts of people research the problem of consciousness: naturalists for whom consciousness is a physical phenomenon, and others to whom consciousness is completely mysterious (the *why* of consciousness has made no progress).

Some argue that a scientific theory of consciousness is impossible. For Chalmers[2], consciousness is too bizarre to be real. There is some basic confusion in his philosophy. Where do the points of division lay in playing the game of consciousness?

[P. 8–9] (COMMENTARY) What counts as explanatory? Are causal interactions the end-all and be-all explanations? If many things can be explained in terms of physical causes, qualia may not be. The naturalist might explain merely the *when* of the consciousness (awareness).

Materialists have to believe that consciousness is something physical. They have to isolate components of the brain, its conscious activity. Within the programme of study, Hardcastle advocates an additional option: 'isolate the substrate of experience' and call this component of the brain C.

Why C should be conscious (an identity to intelligible, plausible, reasonable)? What are the most basic, most puzzling, most difficult questions concerning consciousness? Is consciousness just being C (or whatever theory one happens to believe)? Chalmers proposes a dual aspect theory: phenomenal qualities are just part and parcel of information!

However, only few facts we accept are basic (e.g., gravitational attraction, electromagnetic forces, etc. as given elements of the universe).

[P. 12–13] (COMMENTARY) Someday understanding of consciousness will be informationally embedded[3] in a larger mind-brain system. Materialistic explanations of consciousness is social information, determined historically and so remaining within the current scientific realm.

— **3** (1996) 1, p. 14–25, *W.S. Robinson,* The Hardness of the Hard Problem.

[P. 14] (COMMENTARY) The basic question is why the Hard Problem of consciousness cannot be solved within the present conceptual framework. Evidently, conscious experience lacks informational structure and organization.

— **3** (1996) 1, p. 36–53, *S. Hameroff & R. Penrose,* Conscious Events as Orchestrated Space-Time Selections.

[P. 36] (SUMMARY) *Objective reduction* (OR) is introduced as a form of 'quantum gravity' for a

[2] CHALMERS, D. 1995. Facing up to the Problem of consciousness. JCS **2:** 200–219.

[3] A system of understanding with consciousness as its essential component was presented in A.P. ŽELEZNIKAR. 1996. Frames and Gestalts. Informatica **20:** 65–94 (p. 92). This system can become a system of understanding consciousness if in the informational graph (in Fig. 11) instead of input entity β the arrow from operand $\mathfrak{b}_\upsilon$ (consciousness) to operand υ (understanding) is drawn.

description of fundamental processes within quantum/classical physics. Consciousness occurs within OR when a system develops and maintains *quantum coherent superposition* until a threshold related to quantum gravity is reached. The coherent system then self-reduces (OR). As an essential feature of consciousness, this objective *self-collapse* is *non-computable.* The OR process occurs in cytoskeletal microtubules within the brain's neurons.

Tubulins are microtubule subunit proteins in which quantum-superposed states develop and remain coherent until a mass-time-energy threshold is reached and self-collapse or OR *abruptly* occurs. Sequences of OR events constitute a *stream* of consciousness. The OR is self-organized or *orchestrated* (Orch OR) when microtubule proteins tune the quantum oscillations of the quantum superposed states, Orch OR events select in a non-computable manner the microtubule subunit states which regulate synaptic/neural functions. Orch OR offers a completely new view on the hard problem of consciousness.

[P. 37] (COMMENTARY) How to incorporate the phenomenon of consciousness into a scientific world-view? The answer of Chalmers[4,5] is to find scientific explanation of qualia (the subjective experience of mental states).

Panpsychism (Spinoza[6], Rensch[7]), *mentalism* (Leibniz, Whitehead[8,9]), *neutral monism* (Russel[10]), *qualia* (Stubenberg[11]), *monistic idealism* (Goswami[12]), and *information* (Wheeler[13], Železnikar[14,15,16,17]). Chalmers[4,5] proposes a theory in which information is both physical and experiential[18].

[P. 44–50] (SUMMARY) Consciousness might be conditioned by the brain properties as: high prevalence, functional importance, periodic structure, transient isolation from external events, functional coupling, and suitableness for information processing. Cytoskeletal microtubules qualify in all respects.

Neurons are spatially and dynamically organized by *self*-assembling protein networks: the cytoskeleton, which maintains and regulates synaptic connections. Microtubules (MTs) are hollow cylindrical polymers of proteins known as tubulin. MTs are interconnected by proteins to form cytoskeletal lattice network. Information re-

[4]CHALMERS, D. 1995. Facing up to the Problem of Consciousness. JCS **2:** 200–219.

[5]CHALMERS, D. 1996. The Conscious Mind. Oxford University Press. New York.

[6]SPINOZA, B. 1677. Ethica in Opera quotque repeta sunt. J. van Vloten & J.P.N. Land, Eds. Den Haag, the Netherlands.

[7]RENSCH, B. 1960. Evolution Above the Species Level. Columbia University Press. New York.

[8]WHITEHEAD, A.N. 1929. Science and the Modern World. Macmillan, New York.

[9]WHITEHEAD, A.N. 1933. Process and Reality. Macmillan. New York

[10]RUSSEL, B. 1954. The Analysis of Matter. Dover. New York.

[11]STUBENBERG, L. 1996. *In* Toward a Science of Consciousness—The First Tucson Discussiona and Debates. S.R. Hameroff, A. Kaszniak & A.C. Scott, Eds. MIT Press Cambridge, MA.

[12]GOSWAMI, A. 1993. The Self-Aware Universe: How Consciousness Creates the Material World. Tacher/Putnam. New York.

[13]WHEELER, J.A. 1990. Information, Physics, Quantum: The Search for Links. *In* Coplexity, Entropy, and the Physics of Information. W. Zurek, Ed. Addison–Wesley.

[14]ŽELEZNIKAR, A.P. 1987. On the Way to Information. Informatica **11:** 1: 4–18.

[15]ŽELEZNIKAR, A.P. 1988. Principles of Information. Cybernetica **31:** 99–122.

[16]ŽELEZNIKAR, A.P. 1988, 1989. Information Determinations I, II. Cybernetica **31:** 181–213, **32:** 5–44.

[17]ŽELEZNIKAR, A.P. 1990. On the Way to Information. The Slovene Society Informatika. 1–234.

[18]Could this position of Chalmers be called *paninformational*? First attempts in this direction have been made by Železnikar[14] (in a parallel Slovene-English translation, and an abstract in German and Japanese; reprinted in Železnikar[17]).

[P. 5[14]] ...information is not only static, it is a dynamic property, which represents Being as various phenomena in a living and non-living world. This process of information is also informing. ...Thus, the meaning of information also becomes information processing, processing of information, the coming of information into existence, Informing, etc. ...the meaning of information must be extended so that it is active.

[P. 6[14]] What does the notion of information in a broader context of meaning enable? Information, as a form of an information process, is the foundation on which the so-called representations or characteristic representings are possible, e.g. as there exists **mental**, technological, communicational, **physical**, biological, chemical, and almost **all** kinds of phenomena. ...Information, when understood in a broader sense, can be a **universal** foundation for understanding, cognition, representation of the world in a Being, and what is even more important, representation ...outside of a Being. This is also valid in the case of the Being of Information.

presenting, propagating, and processing happens, theoretically, through tubulins interaction within microtubule lattice. MTs are linked to consciousness, as viewed by quantum theorists (e.g., Penrose[19]). In this view, quantum coherence emerges and remains isolated in brain MTs. When differences in mass-energy distribution among superposed tubulin states reach the threshold of instability, the *self*-collapse occurs (OR). Thus, an instantaneous 'now' event is created, and the sequence of them creates a flow of time[20] and consciousness.

Under which physical conditions the (quantum) consciousness could emerge? Formula $T = \frac{\hbar}{E}$ where T is the lifetime for the superposition decay, $\hbar$ Planck's constant, and E the gravitational *self*-energy, is the starting point. If the coherence time $T = 500$ msec is assumed, E can be calculated, and the number of MT tubulins turns out to be about 10^9. To see a bengal tiger might perhaps elicit 10^{12} tubulins or more in 0.5 msec.

(QUOTATION) The Orch OR model thus appears to accommodate some important features of consciousness:

1) control/regulation of neural action
2) pre-conscious to conscious transition
3) non-computability
4) causality
5) binding of various (time scale and spatial) superpositions into instantaneous 'now'
6) a 'flow' of time, and
7) a connection to fundamental space-time geometry in which experience may be based.

— **3** (1996) 1, p. 36–53,
J. Shear, The Hard Problem:
Closing the Empirical Gap.

[19]PENROSE, R. 1994. Shadows of Mind. Oxford University Press. Oxford.

[20]This view of time could be grasped as an informational entity, as described in section 1[14], for instance by the so-called metaphysicalistic approach: Time is the way in which information informs, in which informing is becoming informing, counter-informing *[e.g., collapse]*, and embedding of information. ... time is only another way of stating that information is coming into existence.

[P. 36] (SUMMARY) Systematic scientific investigation of consciousness and of the objective phenomena of matter will bring understanding of the 'hard problem'. A conceptual gap exists between the nature of conscious experience and the nonsubjective (nonconscious) physical objects. While qualia are essential for consciousness, they play no role in science of the physical universe. The panexperientialist postulates experience or qualia as an all-pervasive phenomenon of the physical universe, which is highly counter-intuitive. Chalmers postulation of experience and 'information' as 'fundamental features' points in the same direction. But such counter-intuitiveness is not sufficient reason to reject such theories.

Descartes' thesis of the essentially mathematizable spatiality of objective phenomena continues to dominate in science, and mental contents such as thoughts, hopes, and many others do not belong to the kinds of things (entities) that fall under spatial predicates (see, e.g., McGinn[21]). The gap between the spatial and the non-spatial is so great that non-spatial mind is utterly an incompressible notion. But which aspect of the universe is responsible for the generation of consciousness? Hameroff and Penrose (see ahead) argue that phenomenal aspects of information are a fundamental feature of nature, so we need to go to the deepest stratum of the objective universe. Seager[22] stresses that information itself appears as to be a fundamental property of of quantum dynamics. Clarke[23] attempts to reduce the contrast between ordinary material objects and the non-spatiality of consciousness.

For quite some times, eastern cultures systematically explore the internal phenomena of consciousness. They have developed various methodologies of meditation (Yoga, Vedanta, Buddhism, Taoism, etc.) to steep into deep structures of consciousness. The 'ground' of consciousness is regularly described as the simplest state of awareness, as consciousness devoid of all its activities and contents. The 'pure consciousness' can be experienced only when all discrete fluctuations of mind have 'settled down'. In this state, consciousness

[21]MCGINN, C. 1995. Consciousness and Space. JCS **2:** 220–230.

[22]SEAGER, W. 1995. Consciousness, Information and Panpsychism. JCS **2:** 272–288.

[23]CLARKE, C.J.S. 1995. The Nonlocality of Mind. JCS **2:** 231–240.

is being alone by itself, void, nothingness, pure consciousness[24,25] when all the activities of mind have ceased. Void consciousness removes attention from exterior phenomenal objects.

Foundational knowledge of both matter and consciousness is necessary to tackle the 'hard problem'. This kind of knowledge can play a significant role in 'the more adequate articulation of consciousness' when the unifying theory will link consciousness to the world of matter and space.

— **3** (1996) 1, p. 26–32,
E. Mills, Giving up on the
Hard Problem of Consciousness.

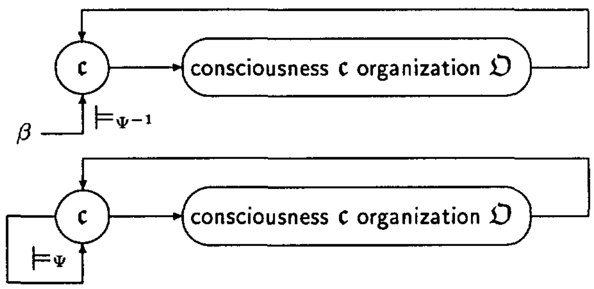
[P. 26] (SUMMARY) Theory of the sort that Chalmers proposes cannot hope to solve the hard problem of consciousness. It takes the relation between physical processes and consciousness as fundamental instead to take the relation as capable of being explained. If the hard problem of consciousness is insoluble it does not mean that naturalistic respectability of consciousness is impugnable.

[P. 28] Chalmers says that information has two basic aspects, a physical aspect and a phenomenal aspect. This sort of double-aspect principle (DAP) offers the best hope of solving the hard problem of consciousness. In every information space, every informational difference corresponds to a phenomenal difference. The Shannonian notion of information space presupposes nothing about mentality. DAP is insufficient in the assertion that informational states—understood in purely physical terms—correspond to phenomenal states, and these correspondences are lawful (causal, computable[26]) rather than accidental (noncomputable, spontaneous-circular, emerging, informationally arising[26]).

The undersigned believes that these short excursions into the contemporary studies of consciousness, principles, and theories will be instructive and helpful for the readers and authors of *Informatica.*

Selected, summarized, and commented
by *A.P. Železnikar*

[24]The question is what within informational theory could be understood as pure consciousness? Informational graph for consciousness concerning β (top graph) and for a pure consciousness would look like



The bottom graph shows the situation for a basic, void consciousness. In the first case, function $\mathfrak{c}(\beta)$ has the meaning

$$\mathfrak{c}(\beta) \rightleftharpoons (\beta \models_{\Psi^{-1}} \mathfrak{c}), \text{ where}$$
$$(\beta \models_{\Psi^{-1}} \mathfrak{c} \rightleftharpoons (\mathfrak{c} \models_{\Psi} \beta)$$

Thus, $\mathfrak{c}(\beta) \rightleftharpoons (\mathfrak{c} \models_{\Psi} \beta)$! So, developmentally (causally in regard to operator $\rightleftharpoons$),

$$\Big(\underbrace{\mathfrak{c}(\beta)}_{\text{as function definition}} \rightleftharpoons (\mathfrak{c} \underbrace{\models_{\Psi}}_{\text{as functional graph requirement}} \beta)\Big) \rightleftharpoons (\beta \underbrace{\models_{\Psi^{-1}}}_{\text{as consequent graph requirement in regard to } \models_{\Psi}} \mathfrak{c})$$

In the bottom case of the figure, the function $\mathfrak{c}(\beta)$ transits into (the senseful) form $\mathfrak{c}(\mathfrak{c})$ where consciousness informs and observes itself (and not any other object), and so transits into the state of void (pure) consciousness. If by $\mathfrak{O}$ the organization of consciousness is marked, the void consciousness is informationally determined by system

$$\mathfrak{c}(\mathfrak{c}) \rightleftharpoons \begin{pmatrix} \mathfrak{c} \models_{\Psi} \mathfrak{c}; \\ (\mathfrak{c} \models \mathfrak{O}) \models \mathfrak{c}; \\ \mathfrak{c} \models (\mathfrak{O} \models \mathfrak{c}) \end{pmatrix}$$

Organization $\mathfrak{O}$ is a coherent parallel-serial informational formula system of various consciousness components.

[25]A metaphysicalistic cognitivistic model of understanding something, in which explicit consciousness components take place, is conceptually and formally presented in ŽELEZNIKAR, A.P. 1966. Informational Frames and Gestalts. Informatica **20**: 65–94. Various informational aspects and psychologic, psychiatric, and understanding models are discussed in ŽELEZNIKAR, A.P. 1966. Organization of Informational Metaphysicalism. Cybernetica **39** (in print).

[26]A comment of the undersigned.

Call for Papers: Consciousness as Informational Phenomenalism

Special Issue of Informatica **21** (1997) No. 3

Informatica, an International Journal for Computing and Informatics, announces the Call for Papers for the issue of an interdisciplinary volume dedicated to the informational problems of consciousness.

The scientific program of the volume includes the following:

1. consciousness as an informationally emerging entity in events, processes and systems of understanding;
2. innovative formal symbolism for study, research and expression of dynamically structured and organized (arising, emerging, generic) events, processes, and systems of consciousness;
3. philosophical (existence, phenomenology), cognitive (intention, qualia, understanding), linguistic (semiotic, pragmatic), psychological (experience, feeling), physiological, neuronal (connectionist), cellular (biological), cybernetic (self-organized) and other views of consciousness as informational phenomenon;
4. physical (space-time, quantum, thermodynamical), chemical (molecular) and other natural models of consciousness as informational phenomena;
5. consciousness as learning, memorizing, associative, concluding, and intelligent processes of behavior;
6. classical, computational and artificial-intelligence approaches (stressing artificialness and constructivism) for understanding and modeling of the consciousness phenomenology;
7. emerging terminology and systematics (structure, organization) of consciousness.

Informatica **21** (1997) No. 3, in an enlarged volume, is fixed as the special issue. The deadline for submitting abstracts via the listed e-mail addresses below is November 15, 1996. The main correspondence with potential authors will be performed electronically (exceptionally by mail).

The deadline for the paper submission in three copies is **April 15, 1997**. International refereeing will be performed according to the standard Informatica procedure. For more instructions see FTP `ftp.arnes.si` with anonymous login or URL: `http://www2.ijs.si/~mezi/informatica.html`.

Correspondence: E-mail addresses: `anton.p.zeleznikar@ijs.si`, `matjaz.gams@ijs.si`, and `mitja.perus@uni-lj.si`.
Printed-paper mail address: M. Gams, Jožef Stefan Institute, Jamova c. 39, SI–1111 Ljubljana, Slovenia.

Call for Papers – Special Issue of Informatica Parallel and Distributed Database Systems

Parallel and distributed database technology is a core of many mission-critical information systems. New challenging problems are posed by the growing demand for large-scale, enterprise-wide, high- performance solutions. Innovative approaches and techniques are necessary to deal with the rapidly expanding expectations with regard to massive data volume processing, performance, availability, and solutions scalability.

The scope of this Special Issue includes all aspects of parallelism and distribution in database systems. The Issue will focus on design, development and evaluation of parallel and distributed database systems for different computing platforms and system architectures.

Original papers are solicited that describe research on various topics in parallel and distributed database systems including, but not limited to, the following areas:

- Distributed database modeling and design techniques
- Parallel and distributed object management
- Interoperability in multidatabase systems
- Parallel on-line transaction processing
- Parallel and distributed query optimization
- Parallel and distributed active databases
- Parallel and distributed real-time databases
- Multimedia and hypermedia databases
- Databases and programming systems
- Mobile computing and databases
- Transactional workflow control
- Parallel and distributed algorithms
- Temporal databases
- Data mining/Knowledge discovery
- Use of distributed database technology in managing engineering, biological, geographic, spatial, scientific, and statistical data
- Scheduling and resource management

Time Table and Contacts

Papers in 5 hard copies should be received by November 1, 1996 at one of the following addresses.

North & South America, Australia:
Bogdan Czejdo czejdo@beta.loyno.edu, Department of Mathematics and Computer Science, Loyola University, 6363 St. Charles Ave., New Orleans, LA 70118, USA

Europe, Africa, Asia:
Tadeusz Morzy morzy@pozn1v.put.poznan.pl, Institute of Computing Science, Poznan University of Technology, Piotrowo 3a, 60-965 Poznan, Poland

Silvio Salza salza@dis.uniroma1.it, Dipartimento di Informatica e Sistemistica, Universita di Roma La Sapienza, Via Salaria 113, I-00198 Roma, Italy

E-mail information about the special issue is available from the above guest editors.

Notification of acceptance will be sent before March 1, 1997. The special issue will be published in the middle of 1997.

Format and Reviewing Process

Papers should not exceed 5,000 words. Each paper will be refereed by at least three anonymous referees.

A Report:
International Conference on

Intelligent Technologies in Human-Related Sciences

July 5 – July 7, 9, 1996

Leon, Spain

ITHURS'96 was the ninth in the series of these conferences, supported by SIGEF, AEDEM, ACODI, MOISIL, BUFSA, AATIF, FLSI and ELITE. There were 188 accepted papers published in the Proceedings by over 300 authors from 36 countries. Majority of participants came from Europe, including Eastern European countries especially those joining European Union. This indicates that integrating forces already play an important role. The number of participants was approximately proportional to the size of the country (our paper Gams, Hribovsek was the only one from Slovenia). Outside Europe, Japanese papers were among the most common.

The conference was oriented towards human-related information research and development. In these domains, exact mathematical models don't work well because of the complexity and especially because humans are involved. Reality and humans are characterised by tolerance, imprecision, uncertainty and partial and subjective truths. Systems have to be tractable, robust and reasonable – meaning that they have to achieve reasonable performance in realistic situations.

Fuzzy logic, advanced modeling and simulations were the most common research methods. Fuzzy techniques were also the most often reported. The honorary chairman of the conference was L. A. Zadeh. Besides fuzzy techniques, other most common methods were neural networks, operation research techniques and genetic algorithms. The scope of the conference was rather broad. An interesting example was a Japanese paper presenting experiments with DNA computing, i.e. computational changes in the process. The idea was to create a DNA chip, a computing chemical device.

The emphasis was on forthcoming application, pure theoretical research was not the mainstream. It was generally agreed that there is a global need to produce more systems that work in practise; on the other hand, as observed by the organisers and participants, successful applications were rare. At the conference, a couple of possibly interesting new products were demonstrated related to simulation and control, e.g., a new bike or an object-sensitive stick for the blind. Most often applications were expert systems and voice recognition systems. Control, systems and signals were the main category often in collaboration with artificial intelligence methods – neural methods, genetic algorithms, language understanding, human intelligence, decision making and support.

In the invited paper "Artificial Sensiology, Artificial Consciousness and the Sensitive Computer", prof. dr. H. N. Teodorescu presented a rather optimistic view that computers will approach new stage in communication with humans when new features will be introduced. Analysing differences in communication between two people and a human and a computer he highlighted several differences. For example, when a human types "Yes" to another human, only a couple of bits of information is communicated. In real life, communicating "Yes" to another person sends millions of bits of information, e.g., body language, voice frequency, altitude etc. Another important difference is in understanding. In human communication, a specific partnership and understanding is quickly obtained – everybody knows or at least assumes goals, motives and general approaches of each other. Natural language should be studied in parallel with this "second-level communicating". Prof. Teodorescu expects that advanced software with the exponential growth of computer power will substantially improve communication in a decade or two. Many participants didn't share his optimism pointing out that the basic problem might be different hardware in computers and humans.

This is the first conference I had visited that a case of scientific fraud was reported. An official public claim was made by an author who submitted a paper to a journal and realised that co-authors had sent the same paper also to the conference but without his name on it. Publish or perish approaching new stages?

By Matjaž Gams

CALL FOR PAPERS

High Performance Algorithms for Structured Linear Systems

edited by: Peter Arbenz, Marcin Paprzycki, Ahmed Sameh

General information

A volume in the series "Advances in the Theory of Computation and Computational Mathematics" (published by ABLEX, Norwood, New Jersey).

In recent years, knowledge about the high performance solution of structured linear systems has grown rapidly. By structured linear systems we mean large sparse systems assembled from relatively small dense or sparse blocks. Examples of such systems abound in many applications; they can be bidiagonal, tridiagonal, banded, block tridiagonal, almost block diagonal, or arrowhead systems. Our understanding of high performance computing is rather broad and includes vector, RISC as well as parallel architectures. Parallel computers considered can be those of shared or distributed memory architectures, or cluster-based that combine characteristics of both.

The volume has three goals. First, it is to summarize the state of the art in the area of high performance solution of structured linear systems. Second, it is supposed to indicate what research directions are perceived as the most important ones for the future. The third and final goal is to provide a collection of algorithms and ideas that may enhance future algorithm development in this area.

In the volume, we hope to cover direct as well as iterative methods. We also hope that a wide spectrum of high performance architectures will be reviewed. It needs to be pointed out that even though we are primarily interested in parallel algorihtms for the solution of structured linear systems, high performance algorithms for a single-processor system (each node of a multiprocessor system) are crucial for realizing high performance on parallel platforms. Thus, we will also accept papers with emphasis on single-processor performance (as related to parallel algorithms).

It is our goal to present the results in a more unified way than merely assembling papers into a collection. This means, among other things, that the authors of accepted papers may be requested to present their experiments on equivalent linear systems and/or using similar performance metrics.

To contribute, please send 6 hard copies of the paper (or PREFERABLY, submit your paper electronically – prepared in plain LaTeX or PostScript) by

August 31st, 1996

to one of the volume editors. The volume is expected to be published in early 1997.

Peter Arbenz, Inst. of Sci. Comp.
ETH Zurich, 8092 Zurich, Switzerland
arbenz@inf.ethz.ch

Marcin Paprzycki, Dept. of Math. & CS
UTPB, Odessa, TX 79762, USA
paprzycki_m@utpb.edu

Ahmed Sameh, Dept. of Comp. Sci.
Univ. of Minnesota, Minneapolis, MN 55455, USA
sameh@cs.umn.edu

Machine Learning List

The Machine Learning List is moderated. Contributions should be relevant to the scientific study of machine learning. Mail contributions to ml@ics.uci.edu. Mail requests to be added or deleted to ml-request@ics.uci.edu. Back issues may be FTP'd from ics.uci.edu in pub/ml-list/V<X>/<N> or N.Z where X and N are the volume and number of the issue; ID: anonymous PASSWORD: <your mail address> URL- http://www.ics.uci.edu/AI/-ML/Machine-Learning.html

CALL FOR PAPERS (New Journal)

Intelligent Data Analysis - An International Journal

An electronic, Web-based journal Published by Elsevier Science

URL: http://www.elsevier.com/locate/ida, http://www.elsevier.nl/locate/ida

Important e-mail addresses:
Editor-in-Chief: A. Famili
(famili@ai.iit.nrc.ca)
Editorial Office: Heather D. Joseph
(h.dalterio@elsevier.com)
Subscription Information:
USDirect@elsevier.com

Introduction

As science and engineering disciplines become more and more computerized, the volume and complexity of the data produced on a day-to-day basis quickly becomes overwhelming. Traditional data analysis approaches have proven limited in their ability to generate useful information. In a wide variety of disciplines (as diverse as financial management, engineering, medical/ pharmaceutical research and manufacturing) researchers are adapting Artificial Intelligence techniques and using them to conduct intelligent data analysis and knowledge discovery in large data sets.

Aims/Scope

The journal of Intelligent Data Analysis will provide a forum for the examination of issues related to the research and applications of Artificial Intelligence techniques in data analysis across a variety of disciplines. These techniques include (but are not limited to): all areas of data visualization, data pre-processing (fusion, editing, transformation, filtering, sampling), data engineering, database mining techniques, tools and applications, use of domain knowledge in data analysis, machine learning, neural nets, fuzzy logic, statistical pattern recognition, knowledge filtering, and post-processing. In particular, we prefer papers that discuss development of new AI architectures, methodologies, and techniques and their applications to the field of data analysis. Papers published in this journal will be geared heavily towards applications, with an anticipated split of 70oriented, and the remaining 30

Editor-in-Chief

Editorial Board

Information for Authors

General

The journal of Intelligent Data Analysis invites submission of research and application papers within the aims and scope of the journal. In particular, we prefer papers that discuss development of new AI architec- tures, methodologies, and techniques and their applications to the field of data analysis.

Manuscript

The manuscript should be in the following format. The first page of the paper should contain the title (preferably less than 10 words), the name(s), address(es), affiliation(s) and e-mail(s) of the author(s). The first page should also contain an abstract of 200-300 words, followed by 3-5 keywords.

Submission

To speed up the production process, authors should submit the text of original papers in PostScript (compressed file), to the Editor-in-Chief (address below). Any graphical or tabular files should be sent in separate files in Encapsulated PostScript or GIF format. The corresponding author will receive an acknowledgement, by e-mail.

The standard format (Times Roman) is preferred. The Manuscript should not exceed 35-40 pages of text (or the compressed/uuencoded PostScript file should not be more than 1.0 Meg).

References

All references in the paper should be listed in alphabetical order under the first author's name and numbered consecutively by arabic numbers. The structure of the references should be in the following format:

(a) Example of journal papers: R.A. Brooks, Intelligence without Representation, Artificial Intelligence, 47 (1) (1991), 139-159.

(b) Example of monographs: A. Basilevsky, Applied Matrix Algebra in the Statistical Sciences, North- Holland, Amsterdam, (1983).

(c) Example of edited volume papers: J. Pan and J. Tenenbaum, An Intelligent Agent Framework for Enterprise Integration, in: A. Famili, D. Nau and S. Kim, eds., Artificial Intelligence Applications in Manufacturing, MIT Press, Cambridge, MA, (1992), 349-383.

(d) Example of conference proceedings papers: R. Sutton, Planning by Incremental Dynamic Programming, in: Proceedings of the 8th International Machine Learning Workshop, Evanston, IL, USA, Morgan Kaufmann, (1991), 353-357.

(e) Example of unpublished papers: C. H. Watkins, Learning from Delayed Rewards, Ph.D. Thesis, Cambridge Uni- versity, Cambridge, England, (1989).

The Review Process

Each paper will be reviewed by at least two reviewers. The authors will receive the results of the review process through e-mail. The authors of conditionally accepted papers are expected to revise their papers within 2-3 months.

Proofreading

Authors will be responsible for proofreading. Final copies of papers will be made available to the author and should be verified by the author within three working days. No new material may be inserted in the text at the time of proofreading.

Final Manuscript

When paper accepted, the publisher requires an electronic copy of the paper in one of the following formats, along with the originals of figures and tables.

Papers can be submitted in any one of the following formats:

- FrameMaker,
- WordPerfect,
- MicroSoft Word or
- Postscript.

Graphical files must be submitted separately, in either PostScript or GIF formats. A paper copy original is also required for any graphical material.

Journal of Intelligent Data Analysis will be a fully electronic, refereed quarterly journal. It will contain a number of innovative features not available in comparable print publications. These features include:

- An alerting service notifying subscribers of new papers in the journal,
- Links to large data collections, including the U.C. Irvine Machine Learning Repository Database,
- Links to secondary collection of data related to material presented in the journal,
- The ability to test new search mechanisms on the collection of journal articles,
- Links to related bibliographic material.

If you are interested in submitting a paper to the Intelligent Data Analysis journal, please contact:

A. Famili, Ph.D. Phone: (613) 993-8554 Editor-in-Chief, Intelligent Data Analysis Fax : (613) 952-7151 Senior Research Scientist email: famili@ai.iit.nrc.ca Institute for Information Technology http://ai.iit.nrc.ca/ fazel National Research Council of Canada, Bldg. M-50, Montreal Rd. Ottawa, Ont. K1A 0R6 Canada

If you are interested in receiving further announcements or subscription information about the upcoming journal, Intelligent Data Analysis, please send e-mail to:

Heather D. Joseph `h.dalterio@elsevier.com`

TIME-97 Fourth International Workshop on Temporal Representation and Reasoning

Daytona Beach, Florida, USA May 10-11, 1997

CALL FOR PAPERS

The purpose of this workshop is to bring together active researchers in the area of temporal representation and reasoning in Artificial Intelligence. Through paper presentations and discussions, the participants will exchange, compare, and contrast results in the area. The workshop is planned as a two day event to immediately precede FLAIRS-97 (Ninth Annual Florida Artificial Intelligence Research Symposium May 10-14; see

http://erau.db.erau.edu/ towhid/workshops-97.html

and the TIME Web page

http://www.cs.uregina.ca/ temporal/index.html

for details), or contact the program chairs at morris,lina@cs.fit.edu. Workshop participants are also encouraged to submit papers to FLAIRS and attend the conference.

TIME-97 will be conducted as a combination of paper presentations, a poster session, invited talks and panel discussions. The format will provide ample time for discussions and exchange of ideas. Submission of high quality papers describing mature results or on-going work are invited for all areas of temporal representation and reasoning, including, but not limited to:

temporal logics and ontologies temporal constraint reasoning temporal languages and architectures continuous versus discrete time point versus interval representations expressive power versus tractability belief and uncertainty in temporal knowledge temporal databases and knowledge bases temporal learning and discovery reasoning about actions and events time and nonmonotonism time and constraints time in problem solving (e.g. diagnosis, qualitative physics,...) multiple agents, communication, and synchronization applications

To maximize interaction among participants, the size of the workshop will be limited. Accepted papers will be invited for full presentation or a poster presentation. All submissions must be received by December 5, 1996. Notification of acceptance or rejection will be sent to the first author (or designated author) by February 19, 1997. Prospective participants should submit 5 copies of a 6-8 page paper (indicating the selected areas) to:

TIME-97 Program Chairs (Robert Morris and Lina Khatib) Computer Science Program Florida Institute of Technology 150 University Blvd. Melbourne, FL 32901 (407) 768-8000, Ext. 7290 morris,lina@cs.fit.edu

Electronic submission is also permitted. Send a postscript file via anonymous ftp to:

ftp://cs.fit.edu/pub/time97

WORKSHOP HIGHLIGHTS

The workshop will be held in world famous Daytona Beach. Warm May Florida breezes will put the participants in the mood for invigorating discussion of issues in temporal reasoning. The technical discussions will be held for two complete days just prior to FLAIRS-97. We are pleased to announce that Mark Boddy and Patrick Hayes will be giving the invited talks for the Workshop.

PUBLICATION OF ARTICLES

All accepted papers will be published in the workshop proceedings, to be published by IEEE Press. As well, a selected subset of the papers will be invited for inclusion (subject to refereeing) in a book or in a special issue of a journal.

ORGANIZATION

GENERAL Chair: Patrick Hayes, University of West Florida

PROGRAM COMMITTEE Chairs: Robert Morris and Lina Khatib, Florida Institute of Technology

PROGRAM COMMITTEE

Frank Anger, University of West Florida, USA Luca Chittaro, Universita' di Udine, Italy Philippe Dague, Universite Paris-Nord, France Jennifer Elgot-Drapkin, Arizona State University, USA Marcelo Finger, Universidade de Sao Paulo, Brasil Michael Fisher, Manchester Metropolitan University, UK Antony Galton, University of Exeter, UK Michael Georgeff, Australian AI Institute, Australia Malik Ghallab, LAAS-CNRS, France Scott Goodwin, University of Regina, CA Hans Werner Guesgen, University of Auckland, NZ Peter Haddawy, University of Wisconsin-Milwaukee, USA Howard Hamilton, University of Regina, CA Lina Khatib (co-chair), Florida Institute of Technology, USA Peter Ladkin, Universitaet Bielefeld, Germany Gerard Ligozat, Universite Paris XI, France Rob Miller, Imperial College of Science, Technology and Medicine, UK Angelo Montanari, Universita' di Udine, Italy Robert Morris (co-chair), Florida Institute of Technology, USA Bernhard Nebel, Albert-Ludwigs University, Germany Han Reichgelt, University of the West Indies, Jamaica Mark Reynolds, Kings College, UK Maarten de Rijke, University of Warwick, UK Abdul Sattar, Griffith University, Australia Erik Sandewall, Linkoping University, Sweden Andre Trudel, Acadia University, Canada Lluis Vila, University of California Irvine, USA

ORGANIZING COMMITTEE

Patrick Hayes General Chair Lina Khatib PC Co-Chair Bob Morris PC Co-Chair Howard Hamilton Treasurer Luca Chittaro Publicity Co-Chair Angelo Montanari Publicity Co-Chair Scott Goodwin Organizing Committee Member Fahiem Bacchus Organizing Committee Member David Leasure Organizing Committee Member

SPONSORING ORGANIZATIONS

Sponsorship for TIME-97 is being sought from the American Association for Artificial Intelligence (AAAI), and the Florida Artificial Intelligence Research Society (FLAIRS).

SUMMARY OF IMPORTANT DATES

December 5, 1996 Submission deadline February 19, 1996 Notification of acceptance April 15, 1997 Camera-ready copy deadline May 10-11, 1997 TIME-97 Workshop May 10-14, 1997 FLAIRS-97 Conference

THE MINISTRY OF SCIENCE AND TECHNOLOGY OF THE REPUBLIC OF SLOVENIA

Address: Slovenska 50, 61000 Ljubljana, Tel.: +386 61 1311 107, Fax: +386 61 1324 140.
WWW:http://www.mzt.si
Minister: Prof. Rado Bohinc, Ph.D.
State Secretary for Int. Coop.: Rado Genorio, Ph.D.
State Secretary for Sci. and Tech.: Ciril Baškovič
Secretary General: Franc Hudej, Ph.D.

The Ministry also includes:
The Standards and Metrology Institute of the Republic of Slovenia
Address: Kotnikova 6, 61000 Ljubljana, Tel.: +386 61 1312 322, Fax: +386 61 314 882., and
The Industrial Property Protection Office of the Republic of Slovenia
Address: Kotnikova 6, 61000 Ljubljana, Tel.: +386 61 1312 322, Fax: +386 61 318 983.

Scientific Research and Development Potential. The statistical data for 1993 showed that there were 180 research and development institutions in Slovenia. Altogether, they employed 10,400 people, of whom 4,900 were researchers and 3,900 expert or technical staff.

In the past ten years, the number of researchers has almost doubled: the number of Ph.D. graduates increased from 1,100 to 1,565, while the number of M.Sc.'s rose from 650 to 1,029. The "Young Researchers" (i.e. postgraduate students) program has greatly helped towards revitalizing research. The average age of researchers has been brought down to 40, with one-fifth of them being younger than 29.

The table below shows the distribution of researchers according to educational level and sectors (in 1993):

Sector	Ph.D.	M.Sc.
Business enterprises	51	196
Government	482	395
Private non-profit organizations	10	12
Higher education organizations	1022	426
Total	1,565	1,029

Financing Research and Development. Statistical estimates indicate that US$ 185 million (1,4% of GDP) was spent on research and development in Slovenia in 1993. More than half of this comes from public expenditure, mainly the state budget. In the last three years, R&D expenditure by business organizations has stagnated, a result of the current economic transition. This transition has led to the financial decline and increased insolvency of firms and companies. These cannot be replaced by the growing number of mainly small businesses. The shortfall was addressed by increased public-sector spending: its share of GDP nearly doubled from the mid-seventies to 0,86% in 1993.

Income of R&D organizations spent on R&D activities in 1993 (in million US$):

Sector	Total	Basic res.	App. res.	Exp. dev.
Business ent.	83,9	4,7	32,6	46,6
Government	58,4	16,1	21,5	20,8
Private non-p.	1,3	0,2	0,6	0,5
Higher edu.	40,9	24,2	8,7	8
Total	184,5	45,2	63,4	75,9

The policy of the Slovene Government is to increase the percentage intended for R&D in its budget. The Science and Technology Council of the Republic of Slovenia is preparing the draft of a national research program (NRP). The government will harmonize the NRP with its general development policy, and submit it first to the parliamentary Committee for Science, Technology and Development and after that to the parliament. The parliament approves the NRP each year, thus setting the basis for deciding the level of public support for R&D.

The Ministry of Science and Technology is mainly a government institution responsible for controlling expenditure of the R&D budget, in compliance with the NRP and the criteria provided by the Law on Research Activities. The Ministry finances research or co- finances development projects through public bidding, partially finances infrastructure research institutions (national institutes), while it directly finances management and top-level science.

The focal points of R&D policy in Slovenia are:

- maintaining the high level and quality of research activities,
- stimulating collaboration between research and industrial institutions,
- (co)financing and tax assistance for companies engaged in technical development and other applied research projects,
- research training and professional development of leading experts,
- close involvement in international research and development projects,
- establishing and operating facilities for the transfer of technology and experience.

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 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 700 staff, has 500 researchers, about 250 of whom are postgraduates, over 200 of whom have doctorates (Ph.D.), and around 150 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 Slovenia (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.

In the last year on the site of the Jožef Stefan Institute, the Technology park "Ljubljana" has been proposed as part of the national strategy for technological development to foster synergies between research and industry, to promote joint ventures between university bodies, research institutes and innovative industry, to act as an incubator for high-tech initiatives and to accelerate the development cycle of innovative products.

At the present time, part of the Institute is being reorganized into several high-tech units supported by and connected within the Technology park at the Jožef Stefan Institute, established as the beginning of a regional Technology park "Ljubljana". The project is being developed at a particularly historical moment, characterized by the process of state reorganisation, privatisation and private initiative. The national Technology Park will take the form of a shareholding company and will host an independent venture-capital institution.

The promoters and operational entities of the project are the Republic of Slovenia, Ministry of 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 Economic Relations and Development, the National Chamber of Economy and the City of Ljubljana.

Jožef Stefan Institute
Jamova 39, 61000 Ljubljana, Slovenia
Tel.:+386 61 1773 900, Fax.:+386 61 219 385
Tlx.:31 296 JOSTIN SI
WWW: http://www.ijs.si
E-mail: matjaz.gams@ijs.si
Contact person for the Park: Iztok Lesjak, M.Sc.
Public relations: Natalija Polenec

INFORMATICA

AN INTERNATIONAL JOURNAL OF COMPUTING AND INFORMATICS

INVITATION, COOPERATION

Submissions and Refereeing

Please submit three copies of the manuscript with good copies of the figures and photographs to one of the editors from the Editorial Board or to the Contact Person. At least two referees outside the author's country will examine it, and they are invited to make as many remarks as possible directly on the manuscript, from typing errors to global philosophical disagreements. The chosen editor will send the author copies with remarks. If the paper is accepted, the editor will also send copies to the Contact Person. The Executive Board will inform the author that the paper has been accepted, in which case it will be published within one year of receipt of e-mails with the text in Informatica LaTeX format and figures in .eps format. The original figures can also be sent on separate sheets. Style and examples of papers can be obtained by e-mail from the Contact Person or from FTP or WWW (see the last page of Informatica).

Opinions, news, calls for conferences, calls for papers, etc. should be sent directly to the Contact Person.

QUESTIONNAIRE

☐ Send Informatica free of charge

☐ Yes, we subscribe

Please, complete the order form and send it to Dr. Rudi Murn, Informatica, Institut Jožef Stefan, Jamova 39, 61111 Ljubljana, Slovenia.

Since 1977, Informatica has been a major Slovenian scientific journal of computing and informatics, including telecommunications, automation and other related areas. In its 16th year (more than two years ago) it became truly international, although it still remains connected to Central Europe. The basic aim of Informatica is to impose intellectual values (science, engineering) in a distributed organisation.

Informatica is a journal primarily covering the European computer science and informatics community - scientific and educational as well as technical, commercial and industrial. Its basic aim is to enhance communications between different European structures on the basis of equal rights and international refereeing. It publishes scientific papers accepted by at least two referees outside the author's country. In addition, it contains information about conferences, opinions, critical examinations of existing publications and news. Finally, major practical achievements and innovations in the computer and information industry are presented through commercial publications as well as through independent evaluations.

Editing and refereeing are distributed. Each editor can conduct the refereeing process by appointing two new referees or referees from the Board of Referees or Editorial Board. Referees should not be from the author's country. If new referees are appointed, their names will appear in the Refereeing Board.

Informatica is free of charge for major scientific, educational and governmental institutions. Others should subscribe (see the last page of Informatica).

ORDER FORM – INFORMATICA

Name: ....

Title and Profession (optional): ....

....

Home Address and Telephone (optional): ....

....

Office Address and Telephone (optional): ....

....

E-mail Address (optional): ....

Signature and Date: ....

Referees:

Witold Abramowicz, David Abramson, Kenneth Aizawa, Alan Aliu, John Anderson, Catriel Beeri, Fevzi Belli, Istvan Berkeley, Azer Bestavros, Balaji Bharadwaj, Jacek Blazewicz, Laszlo Boeszoermenyi, Ivan Bratko, Jerzy Brzezinski, Marian Bubak, Leslie Burkholder, Frada Burstein, Wojciech Buszkowski, Ryszard Choras, Jason Ceddia, Wojciech Chybowski, Andrzej Ciepielewski, Vic Ciesielski, David Cliff, Travis Craig, Tadeusz Czachorski, Milan Češka, Pavol Ďuriš, Sait Dogru, Georg Dorfner, Maciej Drozdowski, Marek Druzdzel, Hesham El-Rewini, Pierre Flener, Terrence Forgarty, Hugo de Garis, Eugeniusz Gatnar, James Geller, Janusz Gorski, Georg Gottlob, David Green, Herbert Groiss, Inman Harvey, Elke Hochmueller, Rod Howell, Tomáš Hruška, Ryszard Jakubowski, Piotr Jedrzejowicz, Eric Johnson, Li-Shan Kang, Roland Kaschek, Jan Kniat, Stavros Kokkotos, Kevin Korb, Gilad Koren, Henryk Krawczyk, Ben Kroese, Zbyszko Krolikowski, Benjamin Kuipers, Matjaž Kukar, Aarre Laakso, Phil Laplante, Bud Lawson, Ulrike Leopold-Wildburger, Joseph Y-T. Leung, Raymond Lister, Doug Locke, Matija Lokar, Jason Lowder, Andrzej Marciniak, Witold Marciszewski, Vladimir Marik, Jacek Martinek, Tomasz Maruszewski, Florian Matthes, Timothy Menzies, Dieter Merkl, Zbigniew Michalewicz, Roland Mittermeir, Madhav Moganti, Tadeusz Morzy, Daniel Mossé, John Mueller, Hari Narayanan, Jerzy Nogieć, Stefano Nolfi, Tadeusz Pankowski, Warren Persons, Niki Pissinou, Gustav Pomberger, James Pomykalski, Gary Preckshot, Cveta Razdevšek Pučko, Ke Qiu, Michael Quinn, Gerald Quirchmayer, Luc de Raedt, Ewaryst Rafajlowicz, Wolf Rauch, Peter Rechenberg, Felix Redmill, David Robertson, Marko Robnik, A.S.M. Sajeev, Bo Sanden, Iztok Savnik, Wolfgang Schreiner, Guenter Schmidt, Heinz Schmidt, William Spears, Hartmut Stadtler, Przemysław Stpiczyński, Maciej Stroinski, Tomasz Szmuc, Jiři Šlechta, Zahir Tari, Jurij Tasič, Piotr Teczynski, Ken Tindell, A Min Tjoa, Wieslaw Traczyk, Marek Tudruj, Andrzej Urbanski, Kanonkluk Vanapipat, Zyunt Vetulani, Olivier de Vel, John Weckert, Gerhard Widmer, Stefan Wrobel, Janusz Zalewski, Yanchun Zhang

EDITORIAL BOARDS, PUBLISHING COUNCIL

Informatica is a journal primarily covering the European computer science and informatics community; scientific and educational as well as technical, commercial and industrial. Its basic aim is to enhance communications between different European structures on the basis of equal rights and international refereeing. It publishes scientific papers accepted by at least two referees outside the author's country. In addition, it contains information about conferences, opinions, critical examinations of existing publications and news. Finally, major practical achievements and innovations in the computer and information industry are presented through commercial publications as well as through independent evaluations.

Editing and refereeing are distributed. Each editor from the Editorial Board can conduct the refereeing process by appointing two new referees or referees from the Board of Referees or Editorial Board. Referees should not be from the author's country. If new referees are appointed, their names will appear in the Refereeing Board. Each paper bears the name of the editor who appointed the referees. Each editor can propose new members for the Editorial Board or Board of Referees. Editors and referees inactive for a longer period can be automatically replaced. Changes in the Editorial Board and Board of Referees are confirmed by the Executive Editors.

The coordination necessary is made through the Executive Editors who examine the reviews, sort the accepted articles and maintain appropriate international distribution. The Executive Board is appointed by the Society Informatika. Informatica is partially supported by the Slovenian Ministry of Science and Technology.

Each author is guaranteed to receive the reviews of his article. When accepted, publication in Informatica is guaranteed in less than one year after the Executive Editors receive the corrected version of the article.

Volume 20 Number 3 September 1996 ISSN 0350-5596

Informatica

An International Journal of Computing and Informatics

Contents: