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The *Electrotechnics, Electronics, Automatic Control and Computer Science* series of the Scientific and Technical Bulletin of the „Aurel Vlaicu” University of Arad will devote it self to the dissemination of the original research results, technical advances and new items in Electrical and Computers Engineering and in Knowledge Engineering.

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FROM SEARCH ENGINES TO QUESTION-ANSWERING SYSTEMS – THE PROBLEMS OF WORLD KNOWLEDGE, RELEVANCE, DEDUCTION AND PRECISIATION

*Note: The paper was presented as Invited Conference to the
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Arad – Romania*

CURRICULUM VITAE

Lotfi A. Zadeh

Lotfi A. Zadeh joined the Department of Electrical Engineering at the University of California, Berkeley, in 1959, and served as its chairman from 1963 to 1968. Earlier, he was a member of the electrical engineering faculty at Columbia University. In 1956, he was a visiting member of the Institute for Advanced Study in Princeton, New Jersey. In addition, he held a number of other visiting appointments, among them a visiting professorship in Electrical Engineering at MIT in 1962 and 1968; a visiting scientist appointment at IBM Research Laboratory, San Jose, CA, in 1968, 1973, and 1977; and visiting scholar appointments at the AI Center, SRI International, in 1981, and at the Center for the Study of Language and Information, Stanford University, in 1987-1988. Currently he is a Professor in the Graduate School, and is serving as the Director of BISC (Berkeley Initiative in Soft Computing).

Until 1965, Dr. Zadeh's work had been centered on system theory and decision analysis. Since then, his research interests have shifted to the theory of fuzzy sets and its applications to artificial intelligence, linguistics, logic, decision analysis, control theory, expert systems and neural networks. Currently, his research is focused on fuzzy logic, soft computing, computing with words, and the newly developed computational theory of perceptions and precisiated natural language.

An alumnus of the University of Tehran, MIT, and Columbia University, Dr. Zadeh is a fellow of the IEEE, AAAS, ACM, AAAI and IFSA, and a member of the National Academy of Engineering. He held NSF Senior Postdoctoral Fellowships in 1956-57 and 1962-63, and was a Guggenheim Foundation Fellow in 1968. Dr. Zadeh was the recipient of the IEEE Education Medal in 1973 and a recipient of the IEEE Centennial Medal in 1984. In 1989, Dr. Zadeh was awarded the Honda Prize

by the Honda Foundation, and in 1991 received the Berkeley Citation, University of California.

In 1992, Dr. Zadeh was awarded the IEEE Richard W. Hamming Medal "For seminal contributions to information science and systems, including the conceptualization of fuzzy sets." He became a Foreign Member of the Russian Academy of Natural Sciences (Computer Sciences and Cybernetics Section) in 1992, and received the Certificate of Commendation for AI Special Contributions Award from the International Foundation for Artificial Intelligence. Also in 1992, he was awarded the Kampe de Fieriet Prize and became an Honorary Member of the Austrian Society of Cybernetic Studies.

In 1993, Dr. Zadeh received the Rufus Oldenburger Medal from the American Society of Mechanical Engineers "For seminal contributions in system theory, decision analysis, and theory of fuzzy sets and its applications to AI, linguistics, logic, expert systems and neural networks." He was also awarded the Grigore Moisil Prize for Fundamental Researches, and the Premier Best Paper Award by the Second International Conference on Fuzzy Theory and Technology. In 1995, Dr. Zadeh was awarded the IEEE Medal of Honor "For pioneering development of fuzzy logic and its many diverse applications." In 1996, Dr. Zadeh was awarded the Okawa Prize "For outstanding contribution to information science through the development of fuzzy logic and its applications."

In 1997, Dr. Zadeh was awarded the B. Bolzano Medal by the Academy of Sciences of the Czech Republic "For outstanding achievements in fuzzy mathematics." He also received the J.P. Wohl Career Achievement Award of the IEEE Systems, Science and Cybernetics Society. He served as a Lee Kuan Yew Distinguished Visitor, lecturing at the National University of Singapore and the Nanyang Technological University in Singapore, and as the Gulbenkian Foundation Visiting Professor at the New University of Lisbon in Portugal. In 1998, Dr. Zadeh was awarded the Edward Feigenbaum Medal by the International Society for Intelligent Systems and the

Richard E. Bellman Control Heritage Award by the American Council on Automatic Control. In addition, he received the Information Science Award from the Association for Intelligent Machinery and the SOFT Scientific Contribution Memorial Award from the Society for Fuzzy Theory in Japan. In 1999, he was elected to membership in Berkeley Fellows and received the Certificate of Merit from IFSA (International Fuzzy Systems Association). In 2000, he received the IEEE Millennium Medal; the IEEE Pioneer Award in Fuzzy Systems; the ASPIH 2000 Lifetime Distinguished Achievement Award; and the ACIDCA 2000 Award for the paper, "From Computing with Numbers to Computing with Words – From Manipulation of Measurements to Manipulation of Perceptions." In addition, he received the Chaos Award from the Center of Hyperincursion and Anticipation in Ordered Systems for his outstanding scientific work on foundations of fuzzy logic, soft computing, computing with words and the computational theory of perceptions. In 2001, Dr. Zadeh received the ACM 2000 Allen Newell Award for seminal contributions to AI through his development of fuzzy logic. In addition, he received a Special Award from the Committee for Automation and Robotics of the Polish Academy of Sciences for his significant contributions to systems and information science, development of fuzzy sets theory, fuzzy logic control, possibility theory, soft computing, computing with words and computational theory of perceptions. In 2003, Dr. Zadeh was elected as a foreign member of the Finnish Academy of Sciences, and received the Norbert Wiener Award of the IEEE Society of Systems, Man and Cybernetics "For pioneering contributions to the development of system theory, fuzzy logic and soft computing." In 2004, Dr. Zadeh was awarded Civitate Honoris Causa by Budapest Tech (BT) Polytechnical Institution, Budapest, Hungary. Also in 2004, he was awarded the V. Kaufmann Prize, International Association for Fuzzy-Set Management and Economy (SIGEF).

Dr. Zadeh is a recipient of twenty-three honorary doctorates from: Paul-Sabatier University, Toulouse, France;

State University of New York, Binghamton, NY; University of Dortmund, Dortmund, Germany; University of Oviedo, Oviedo, Spain; University of Granada, Granada, Spain; Lakehead University, Canada; University of Louisville, KY; Baku State University, Azerbaijan; the Silesian Technical University, Gliwice, Poland; the University of Toronto, Toronto, Canada; the University of Ostrava, the Czech Republic; the University of Central Florida, Orlando, FL; the University of Hamburg, Hamburg, Germany; the University of Paris(6), Paris, France; Johannes Kepler University, Linz, Austria; University of Waterloo, Canada; and the University of Aurel Vlaicu, Arad, Romania; Lappeenranta University of Technology, Lappeenranta, Finland; Muroran Institute of Technology, Muroran, Japan; Hong Kong Baptist University, Hong Kong, China.

Dr. Zadeh has single-authored over two hundred papers and serves on the editorial boards of over fifty journals. He is a member of the Advisory Committee, Center for Education and Research in Fuzzy Systems and Artificial Intelligence, Iasi, Romania; Senior Advisory Board, International Institute for General Systems Studies; the Board of Governors, International Neural Networks Society; and is the Honorary President of the Biomedical Fuzzy Systems Association of Japan and the Spanish Association for Fuzzy Logic and Technologies. In addition, he is a member of the Advisory Board of the National Institute of Informatics, Tokyo; a member of the Governing Board, Knowledge Systems Institute, Skokie, IL; and an honorary member of the Academic Council of NAISO-IAAC.

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Abstract

FROM SEARCH ENGINES TO QUESTION-ANSWERING SYSTEMS – THE PROBLEMS OF WORLD KNOWLEDGE, RELEVANCE, DEDUCTION AND PRECISIATION

Lotfi A. Zadeh^{*}

Existing search engines, with Google at the top, have many truly remarkable capabilities. Furthermore, constant progress is being made in improving their performance. But what is not widely recognized is that there is a basic capability which existing search engines do not have: deduction capability – the capability to synthesize an answer to a query by drawing on bodies of information which reside in various parts of the knowledge base. By definition, a question-answering system, or a Q/A system for short, is a system which has deduction capability. Can a search engine be upgraded to a question-answering system through the use of existing tools – tools which are based on bivalent logic and probability theory? A view which is articulated in the following is that the answer is: No.

The first obstacle is world knowledge – the knowledge which humans acquire through experience, communication and education. Simple examples are: “Icy roads are slippery,” “Princeton usually means Princeton University,” “Paris is the capital of France,” and “There are no honest politicians.” World knowledge plays a central role in search, assessment of relevance

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and deduction. The problem with world knowledge is that it is, for the most part, perception-based. Perceptions—and especially perceptions of probabilities—are intrinsically imprecise, reflecting the fact that human sensory organs, and ultimately the brain, have a bounded ability to resolve detail and store information. Imprecision of perceptions stands in the way of using conventional techniques – techniques which are based on bivalent logic and probability theory – to deal with perception-based information. A further complication is that much of world knowledge is negative knowledge in the sense that it relates to what is impossible and/or non-existent. For example, “A person cannot have two fathers,” and “Netherlands has no mountains.”

The second obstacle centers on the concept of relevance. There is an extensive literature on relevance, and every search engine deals with relevance in its own way, some at a high level of sophistication. But what is quite obvious is that the problem of assessment of relevance is quite complex and far from solution.

There are two kinds of relevance: (a) question relevance and (b) topic relevance. Both are matters of degree. For example, on a very basic level, if the question is q : “Number of cars in California?” and the available information is p : “Population of California is 37,000,000,” then what is the degree of relevance of p to q ? Another example: To what degree is a paper entitled “A New Approach to Natural Language Understanding” of relevance to the topic of machine translation.

Basically, there are two ways of approaching assessment of relevance: (a) semantic; and (b) statistical. To illustrate, in the number of cars example, relevance of p to q is a matter of semantics and world knowledge. In existing search engines, relevance is largely a matter of statistics, involving counts of links and words, with little if any consideration of semantics. Assessment of semantic relevance presents difficult problems whose solutions lie beyond the reach of bivalent logic and probability theory. What should be noted is that assessment of topic relevance is more amendable to the use of statistical techniques, which explains why existing search engines are

much better at assessment of topic relevance than question relevance.

The third obstacle is deduction from perception-based information. As a basic example, assume that the question is q : What is the average height of Swedes?, and the available information is p : Most adult Swedes are tall. Another example is: Usually Robert returns from work at about 6 pm. What is the probability that Robert is at home at 6:15 pm? Neither bivalent logic nor probability theory provide effective tools for dealing with problems of this type. The difficulty is centered on deduction from premises which are both uncertain and imprecise.

Underlying the problems of world knowledge, relevance and deduction is a very basic problem – the problem of natural language understanding. Much of world knowledge and web knowledge is expressed in a natural language. A natural language is basically a system for describing perceptions. Since perceptions are intrinsically imprecise, so are natural languages.

A prerequisite to mechanization of question-answering is mechanization of natural language understanding, and a prerequisite to mechanization of natural language understanding is precisiation of meaning of concepts and proposition drawn from a natural language. To deal effectively with world knowledge, relevance, deduction and precisiation, new tools are needed. The principal new tools are: Precisiated Natural Language (PNL); Protoform Theory (PFT); and the Generalized Theory of Uncertainty (GTU). These tools are drawn from fuzzy logic—a logic in which everything is, or is allowed to be, a matter of degree.

The centerpiece of the new tools is the concept of a generalized constraint. The importance of the concept of a generalized constraint derives from the fact that in PNL and GTU it serves as a basis for generalizing the universally accepted view that information is statistical in nature. More specifically, the point of departure in PNL and GTU is the fundamental premise that, in general, information is representable as a system

of generalized constraints, with statistical information constituting a special case. This, much more general, view of information is needed to deal effectively with world knowledge, relevance, deduction, precisiation and related problems.

In summary, the principal objectives of this paper are: (a) to make a case for the view that a quantum jump in search engine IQ cannot be achieved through the use of methods based on bivalent logic and probability theory; and (b) to introduce and outline a collection of non-standard concepts, ideas and tools which are needed to achieve a quantum jump in search engine IQ.

***From Search Engines to Question-
Answering Systems—The Problems of
World Knowledge, Relevance, Deduction
and Precisation***

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BACKDROP



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KEY ISSUE—DEDUCTION CAPABILITY

Existing search engines, with Google at the top, have many truly remarkable capabilities. Furthermore, constant progress is being made in improving their performance. But what should be realized is that existing search engines do not have an important capability—deduction capability—the capability to synthesize an answer to a query by drawing on bodies of information which reside in various parts of the knowledge base.

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CONTINUED

- ***What should be noted, however, is that there are many widely used special purpose question-answering systems which have limited deduction capability. Examples of such systems are driving direction systems, reservation systems, diagnostic systems and specialized expert systems, especially in the domain of medicine.***

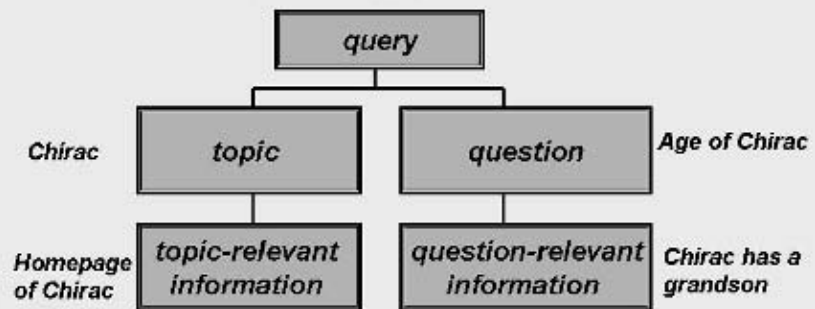
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SEARCH VS. QUESTION-ANSWERING

- **A question-answering system may be viewed as a system which mechanizes question-answering**
- **A search engine in a system which partially mechanizes question-answering**

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PARTIAL MECHANIZATION



- **A search engine is primarily a provider of topic-relevant information**
- **User of a search engine exploits this capability to derive an answer to a question**

6

COMPLEXITY OF UPGRADING

- *Addition of deduction capability to a search engine is a highly complex problem—a problem which is a major challenge to computer scientists and logicians*
- *A view which is articulated in the following is that the challenge cannot be met through the use of existing methods—methods which are based on bivalent logic and probability theory*
- *To add deduction capability to a search engine it is necessary to (a) generalize bivalent logic; (b) generalize probability theory*

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HISTORICAL NOTE

- *1970-1980 was a period of intense interest in question-answering and expert systems*
- *There was no discussion of search engines*
Example: L.S. Coles, "Techniques for Information Retrieval Using an Inferential Question-Answering System with Natural Language Input," SRI Report, 1972
- *M. Nagao, J. Tsujii: Mechanism of Deduction in a Question-Answering System with Natural Language Inputd. IJCAI 1973: 285-290.*
- *J. R. McSkimin, J. Minker: The Use of a Semantic Network in a Deductive Question- Answering System. IJCAI 1977: 50-58.*
- *A. R. Aronson, B. E. Jacobs, J. Minker: A Note on Fuzzy Deduction. J. ACM 27(4): 599-603 (1980)*
- *W.J.H.J. Bronnenberg, H.C. Bunt, S.P.J. Lendsbergen, R.J.H. Scha, W.J. Schoenmakers and E.P.C. van Utteren. The Question Answering System PHLQA1. In L. Bolc (editor), Natural Language Question Answering Systems. Macmillan, 1980.*

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TEST QUERIES: GOOGLE

t: precisiation

q: What is precisiation?

r:

[UAI] The concept of cointensive precisiation

... from data expressed in a natural language is precisiation of meaning. ...

In this perspective, the problem of precisiation is that of picking a ...

AI Magazine: Precisiated natural language

... The Concepts of Precisiability and

Precisiation Language ... p is precisiable

if it can be translated into what may be called a precisiation language, ...

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SIMPLE EXAMPLES OF DEDUCTION INCAPABILITY

q: What is precisiation?

r: same as for t

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CONTINUED

q₁: What is the capital of New York?

q₂: What is the population of the capital of New York?

r₁:

Web definitions for capital of new york Albany: state capital of New York; located in eastern New York State on the west bank of the Hudson river

News results for what is the capital of New York - View today's top stories After the twin-tower nightmare, New York is back on form, says ... - Economist - 3 hours ago
The New Raiders - BusinessWeek - 14 hours ago
Brascan acquires New York-based Hyperion Capital for \$50M US

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CONTINUED

q₂: What is the population of the capital of New York?

r₂:

News results for population of New York - View today's top stories After the twin-tower nightmare, New York is back on form, says ...

UN: World's population is aging rapidly - New, deadly threat from AIDS virus

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CONTINUED

**q: What is the distance between the largest city in Spain
and the largest city in Portugal?**

r:

[Porto - Oporto - Portugal Travel Planner](#)

[Munich Germany Travel Planner - Hotels Restaurants
Language ...](#)



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CONTINUED

q: Age of Chirac

r:

Jacques Chirac

Date of Birth: 29 November 1932



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CONTINUED

q: Age of son of Chirac

r:

*... Albert, their only son, becomes Monaco's de facto ruler
until a formal investiture*

*... French President Jacques Chirac hailed the prince's
"courage and ...*



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CONTINUED

**q: How many Ph.D. degrees in mathematics were granted
by European Universities in 1986?**

r:

A History of the University of Podlasie

Annual Report 1996

A Brief Report on Mathematics in Iran



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UPGRADING

- *There are three major problems in upgrading a search engine to a question-answering system*
 - *World knowledge*
 - *Relevance*
 - *Deduction*
 - *Precisiation*

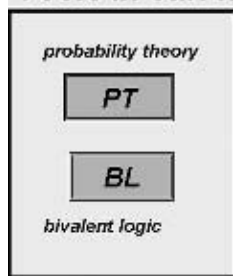
- *These problems are beyond the reach of existing methods based on bivalent logic and probability theory*

- *A basic underlying problem is mechanization of natural language understanding. A prerequisite to mechanization of natural language understanding is precisiation of meaning*

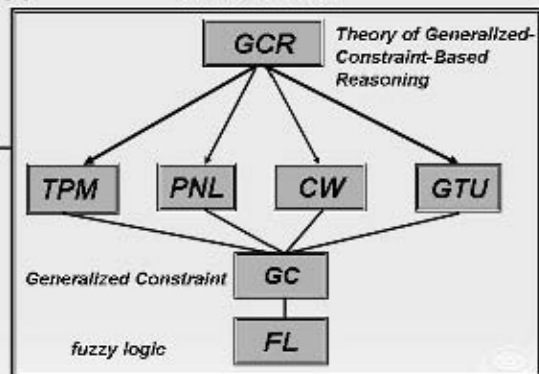
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NEED FOR NEW TOOLS

Tools in current use



New Tools



PT: standard bivalent-logic-based probability theory
TPM: Theory of Precision of Meaning
PNL: Precisiated Natural Language
CW: Computing with Words
GTU: Generalized Theory of Uncertainty
GCR: Theory of Generalized-Constraint-Based Reasoning

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KEY CONCEPT

- *The concept of a generalized constraint is the centerpiece of new tools—the tools that are needed to upgrade a search engine to a question-answering system*
 - *The concept of a generalized constraint serves as a bridge between linguistics and mathematics by providing a means of precisiation of propositions and concepts drawn from a natural language*
- *Information = generalized constraint*

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WORLD KNOWLEDGE

- *World knowledge is the knowledge acquired through experience, education and communication*
 - *Few professors are rich*
 - *There are no honest politicians*
 - *It is not likely to rain in San Francisco in midsummer*
 - *Most Swedes are tall*
 - *There are no mountains in Holland*
 - *Usually Princeton means Princeton University*
 - *A person can have only one father*

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A QUICK EXAMPLE OF LACK OF WORLD KNOWLEDGE

Query: *number of fathers of Bush*

Google:

Results 1 - 10 of about 803,000 for number of fathers of Bush. (0.20 seconds)

- Sins of the Fathers -- In These Times
American Dynasty impressively describes an America where a small number of key ... Phillips traces the origins of the Bush Dynasty to two of Dubya's great ...
www.inthesetimes.com/site/main/article/142/
- George Bush Jr. And the Number 13
George Bush Jr. And The Number 13. by Robert Howard ... We have President George Bush Jr. who is 13th cousin of Britain's Queen Mother, and of her daughter ...
www.theforbiddenknowledge.com/hardtruth/george_bushjr_13.htm

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COMPONENTS OF WORLD KNOWLEDGE

- **Propositional**
 - *Paris is the capital of France*
- **Conceptual**
 - *Climate*
- **Ontological**
 - *Rainfall is related to climate*
- **Existential**
 - *A person cannot have more than one father*
- **Contextual**
 - *Tall*

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CONTINUED

- ***Much of world knowledge is perception-based***
 - ***Most Swedes are tall***
 - ***Most Swedes are much taller than most Italians***
 - ***Usually a large house costs more than a small house***
- ***Much of world knowledge is negative, i.e., relates to impossibility or nonexistence***
 - ***A person cannot have more than one father***
 - ***There are no honest politicians***
- ***Much of world knowledge is expressed in a natural language***

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PROBLEM

- ***Existing methods cannot deal with deduction from perception-based knowledge***
 - ***Most Swedes are tall***
What is the average height of Swedes?
How many are not tall?
How many are short?
 - ***A box contains about 20 black and white balls. Most are black. There are several times as many black balls as white balls.***
How many balls are white?

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THE PROBLEM OF DEDUCTION

- p_1 : usually temperature is not very low
 p_2 : usually temperature is not very high
?average value of temperature
- most students are young
most young students are single
?students are young and single
- Brian is much older than most of his close friends
How old is Brian?

25

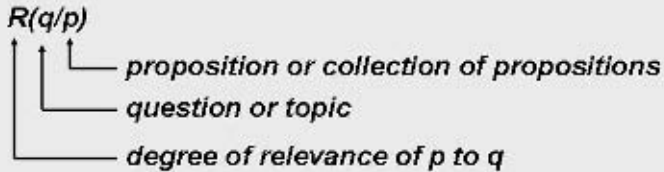
THE PROBLEM OF RELEVANCE

- A major obstacle to upgrading is the concept of relevance. There is an extensive literature on relevance, and every search engine deals with relevance in its own way, some at a high level of sophistication. But what is quite obvious is that the problem of assessment of relevance is very complex and far from solution
- What is relevance?
- Relevance is not bivalent
- Relevance is a matter of degree, i.e., is a fuzzy concept
- There is no cointensive definition of relevance in the literature

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CONTINUED

Definition of relevance function



q : number of cars in California?

p : population of California is 37,000,000

To what degree is p relevant to q ?

- assessment of degree of relevance requires world knowledge

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A SERIOUS COMPLICATION— NONCOMPOSITIONALITY

- $R(q/p, r) = ?$
- $R(q/p) = 0; R(q/r) = 0; R(q/p, r) \neq 0$

Example

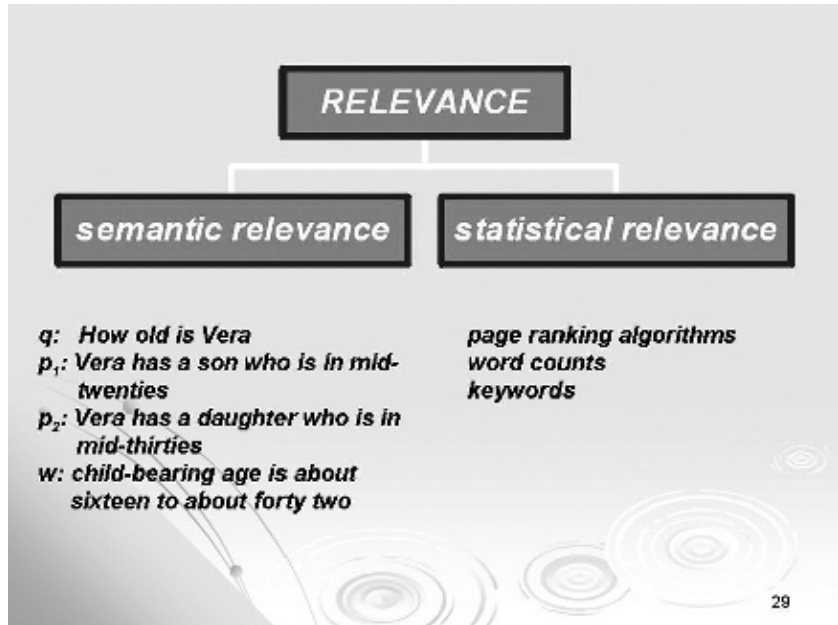
q : How old is Mary?

p : Mary's age is the same as Carol's age

r : Carol is 32 $R(q/p) = 0; R(q/r) = 0; R(q/p, r) = 1$

- Conclusion: relevance cannot be assessed in isolation
- Definition
- p is i -relevant to q if p is relevant to q in isolation
- p is i -irrelevant to q if p is not relevant to q in isolation

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MECHANIZATION OF QUESTION ANSWERING

- *Much of world knowledge and web knowledge is expressed in a natural language*
- *Natural language understanding is a prerequisite to question-answering*
- *Precisiation of meaning is a prerequisite to mechanization of natural language understanding*
- *Human natural language understanding is a prerequisite to precisiation*
- *Machines do not have the human ability to understand what has imprecise meaning*

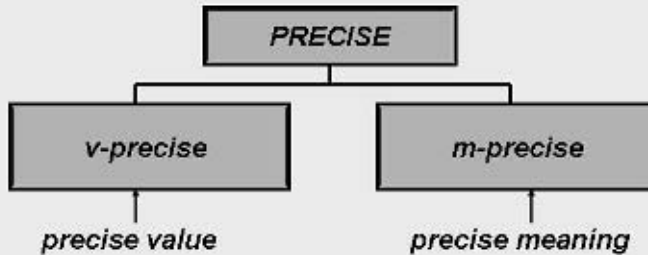
Example: Take a few steps

30

THE CONCEPTS OF PRECISIATION AND COINTENSIVE PRECISIATION

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WHAT IS PRECISE?



- p : X is a Gaussian random variable with mean m and variance σ^2 . m and σ^2 are precisely defined real numbers

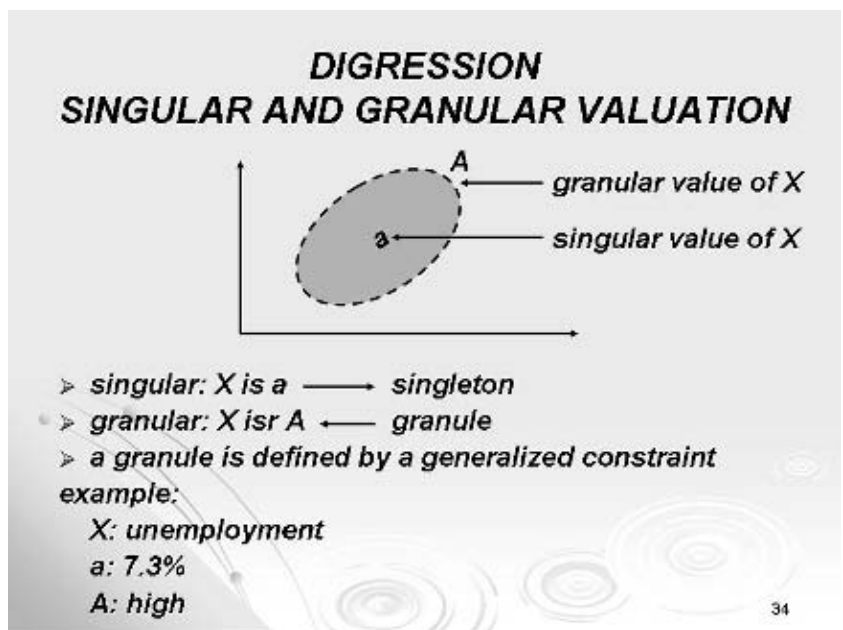
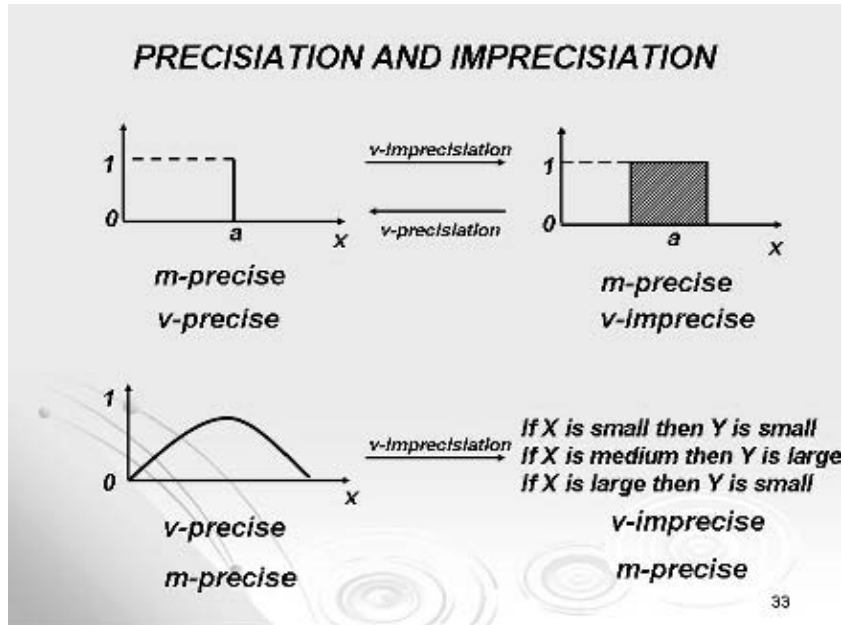
- p is v -imprecise and m -precise

- p : X is in the interval $[a, b]$. a and b are precisely defined real numbers

- p is v -imprecise and m -precise

m -precise = mathematically well-defined

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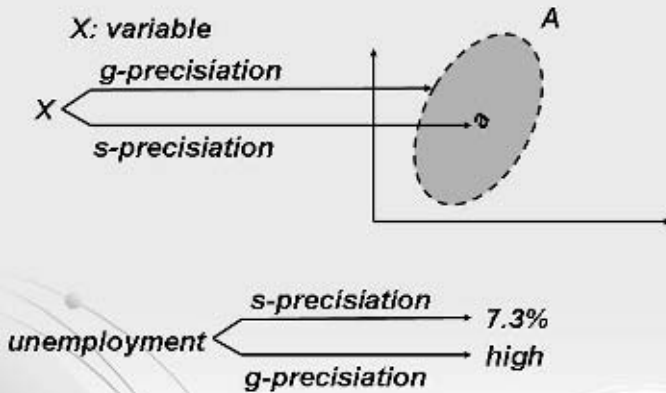


ATTRIBUTES OF A GRANULE

- *Probability measure*
- *Possibility measure*
- *Verity measure*
- ...

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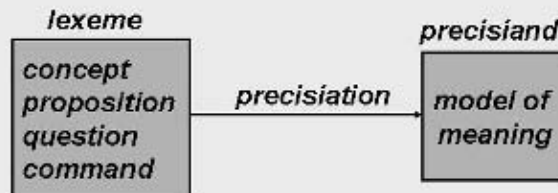
V-PRECISIATION



- *s-precision is used routinely in scientific theories and especially in probability theory*

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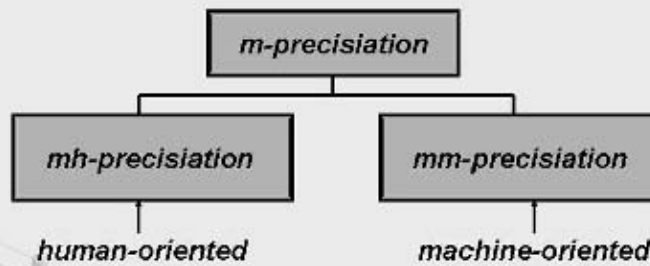
m-PRECISIATION AND COINTENSIVE PRECISIATION



- To be useful, precisiation must be cointensive
- Cointension = goodness of model of meaning

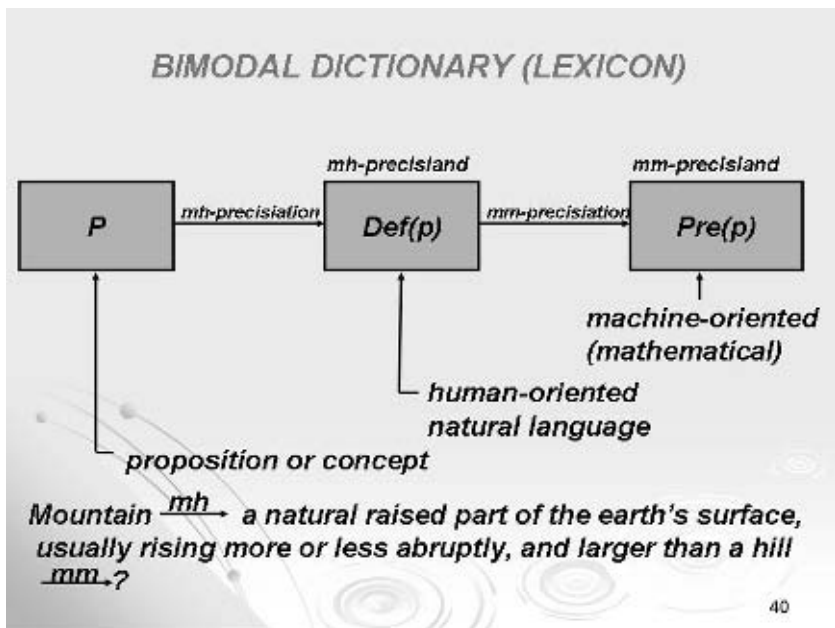
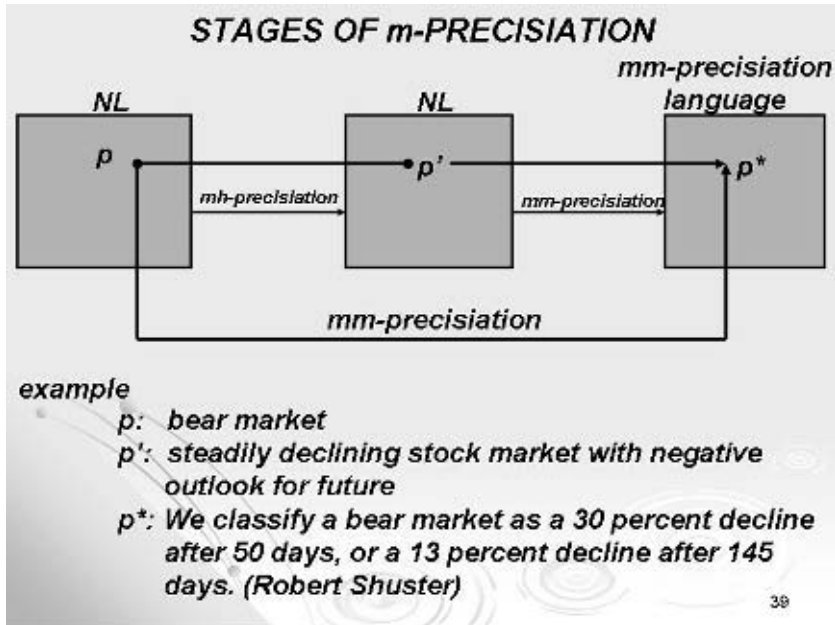
37

MODALITIES OF *m*-PRECISIATION



$p \xrightarrow{m\text{-precisiation}} \text{precisiand of } p \text{ (Pre}(p))$

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RATIONALE FOR IMPRECISIATION IMPRECISIATION PRINCIPLE

$p: X \text{ is } V$
└─ value of X
└─ variable

X : real-valued variable

X : (X_1, \dots, X_n)

X : function

X : relation

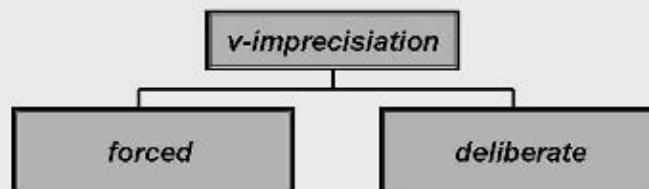
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V is v -precise if V is a singleton (singular)

v -imprecisiation: singular \longrightarrow granular

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v -IMPRECISIATION



forced: V is not known precisely

deliberate: V need not be known precisely

v -imprecisiation principle: Precision carries a cost. If there is a tolerance for imprecision, exploit it by employing v -imprecisiation to achieve lower cost, robustness, tractability, decision-relevance and higher level of confidence

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CONFIDENCE

$p = X \text{ is } V$
 ↳ value of X is uncertain

$Con(p) = \text{Prob that } (X \text{ is } V) \text{ is true}$

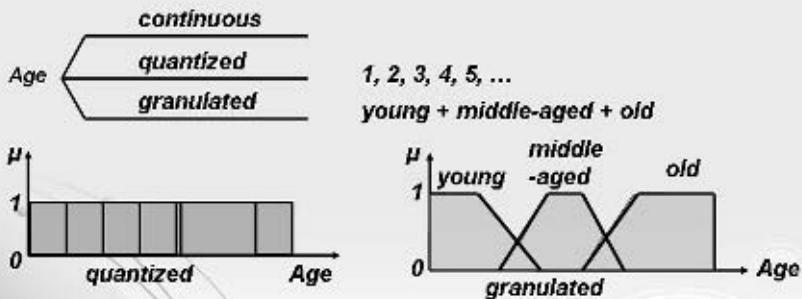
➤ Generally, v -imprecisiation of V serves to increase $Con(p)$

$Con(\text{Carol is young}) > Con(\text{Carol is 23})$
 lower specificity → higher confidence

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GRANULATION REVISITED

➤ Granulation is a derivative of v -imprecisiation principle



granulation = v -imprecisiation / m -precisiation

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KEY POINT

- *Granulation plays a key role in human cognition*
- *In human cognition, v-impreciation is followed by mh-preciation. Granulation is mh-preciation-based*
- *In fuzzy logic, v-impreciation is followed by mm-preciation. Granulation is mm-preciation-based*

- *mm-preciation-based granulation is a major contribution of fuzzy logic. No other logical system offers this capability*

KEY IDEAS

- *In TPM, a proposition, p , is preciated by representing its meaning as a generalized constraint, $GC(p)$*

- *In TPM,*

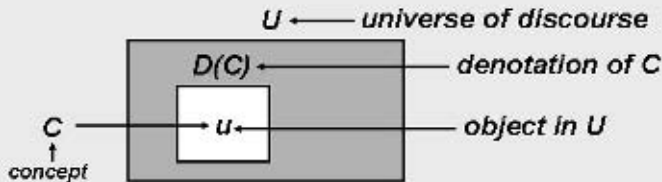
preciation = m-preciation

- *preciation of meaning does not imply preciation of value*

- *A desideratum of preciation is cointension*

- *Informally, p and q are cointensive if the intension (attribute-based-meaning) of p is approximately the same as the intension (attribute-based-meaning) of q*

DIGRESSION: EXTENSION VS. INTENSION



- $D(C)$ = set of all u 's which fit C
- Extensional definition of $D(C)$: instance-based, surface-structure-based
- Intensional definition of $D(C)$: attribute-based, deep-structure-based
- Extension of $C = D(C)$ if $D(C)$ is defined extensionally
- Intension of C : intensional definition of $D(C)$

Example:

young	{	$u = \text{Robert}$ $u = \text{Robert}$	extensional, Robert is young intensional, young \leftrightarrow Age < 25 Robert is 23 \rightarrow Robert is young
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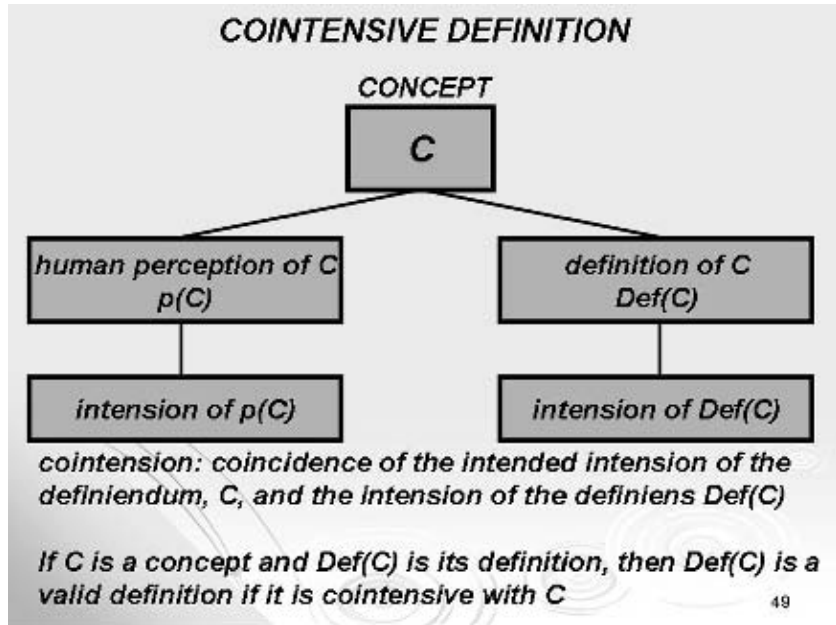
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KEY POINT

- Precision is necessary but not sufficient
- To serve its purpose, precision must be cointensive

Cointensive precision is a key to mechanization of natural language understanding

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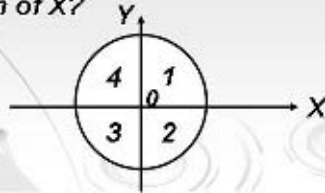


AN IMPORTANT IMPLICATION FOR SCIENCE

- *It is a deep-seated tradition in science to employ the conceptual structure of bivalent logic and probability theory as a basis for formulation of definitions of concepts. What is widely unrecognized is that, in reality, most concepts are fuzzy rather than bivalent, and that, in general, it is not possible to formulate a cointensive definition of a fuzzy concept within the conceptual structure of bivalent logic and probability theory.*

TEST PROBLEMS (PROBABILITY THEORY)

- X is a real-valued random variable. What is known about X is: a (usually X is much larger than approximately a); b (usually X is much smaller than approximately b), where a and b are real numbers with $a < b$. What is the expected value of X ?
- X and Y are random variables. (X, Y) takes values in the unit circle. $\text{Prob}(1)$ is approximately 0.1; $\text{Prob}(2)$ is approximately 0.2; $\text{Prob}(3)$ is approximately 0.3; $\text{Prob}(4)$ is approximately 0.4. What is the marginal distribution of X ?



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EXAMPLES OF FUZZY CONCEPTS WHOSE STANDARD, BIVALENT-LOGIC-BASED DEFINITIONS ARE NOT COINTENSIVE

- *stability*
- *causality*
- *relevance*
- *bear market*
- *recession*
- *mountain*
- *independence*
- *stationarity*
- *cluster*

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EXAMPLE OF A BIVALENT DEFINITION OF A FUZZY CONCEPT

Robert Shuster

(Ned Davis Research)

We classify a bear market as a 30 percent decline after 50 days, or a 13 percent decline after 145 days.

- *A problem with this definition of bear market is that it is not cointensive*

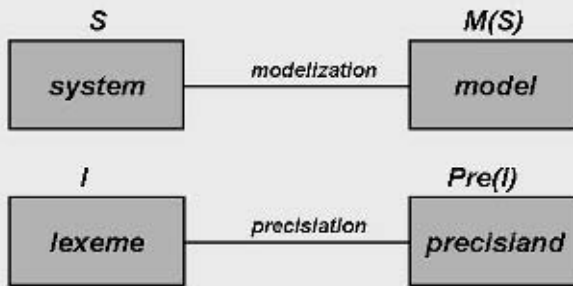
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COINTENSION

- *In general, a cointensive definition of a fuzzy concept cannot be formulated within the conceptual structure of bivalent logic and probability theory*
- *To understand the meaning of this cointension, an analogy is helpful*

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ANALOGY

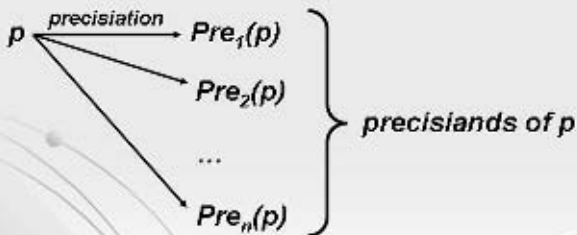


- *input-output relation* \longrightarrow *intension (test-score function)*
- *system analysis* \longrightarrow *semantical analysis (Frege's Principle of Compositionality)*
- *degree of match between M(S) and S* \longrightarrow *cointension*
- *In general, it is not possible to construct a cointensive model of a nonlinear system from linear components*

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PRECISIATION OF MEANING BASIC POINT

- *The meaning of a proposition, p, may be precisiated in many different ways*



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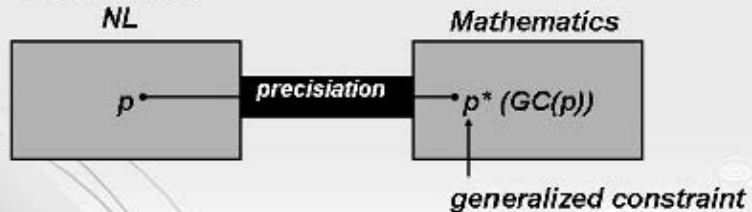
CHOICE OF PRECISIANDS

- In TPM, $Pre(p)$ is equated to $GC(p)$
- The concept of a generalized constraint opens the door to an unlimited enlargement of the number of ways in which a proposition may be precisiated
- An optimal choice is one which achieves a compromise between complexity and cointension

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THE KEY IDEA

- In TPM, a proposition, p , is precisiated by expressing its meaning as a generalized constraint. In this sense, the concept of a generalized constraint serves as a bridge from natural languages to mathematics.



- The concept of a generalized constraint is the centerpiece of TPM

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THE CONCEPT OF A GENERALIZED CONSTRAINT



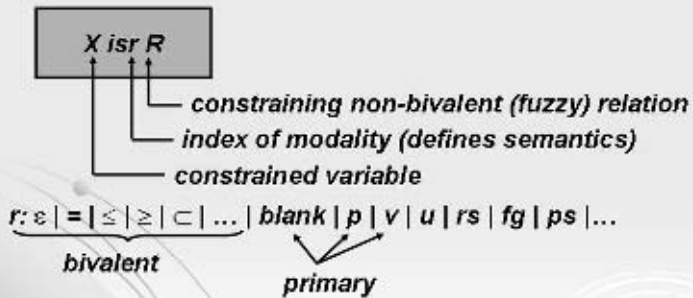
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GENERALIZED CONSTRAINT (Zadeh 1986)

- Bivalent constraint (hard, inelastic, categorical):

$X \in C$ — constraining bivalent relation

- Generalized constraint:



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CONTINUED

• *constrained variable*

- *X is an n-ary variable, $X = (X_1, \dots, X_n)$*
- *X is a proposition, e.g., Leslie is tall*
- *X is a function of another variable: $X = f(Y)$*
- *X is conditioned on another variable, X/Y*
- *X has a structure, e.g., $X = \text{Location}(\text{Residence}(\text{Carol}))$*
- *X is a generalized constraint, $X: Y \text{ is } R$*
- *X is a group variable. In this case, there is a group, $G[A]: (\text{Name}_1, \dots, \text{Name}_n)$, with each member of the group, $\text{Name}_i, i = 1, \dots, n$, associated with an attribute-value, A_i . A_i may be vector-valued. Symbolically*

$$G[A]: (\text{Name}_1/A_1 + \dots + \text{Name}_n/A_n)$$

Basically, *X* is a relation

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SIMPLE EXAMPLES

- *“Check-out time is 1 pm,” is an instance of a generalized constraint on check-out time*
- *“Speed limit is 100km/h” is an instance of a generalized constraint on speed*
- *“Vera is a divorcee with two young children,” is an instance of a generalized constraint on Vera’s age*

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GENERALIZED CONSTRAINT—MODALITY r

$$X \text{ is }_r R$$

- $r: =$ equality constraint; $X=R$ is abbreviation of $X \text{ is }=R$
 $r: \leq$ inequality constraint; $X \leq R$
 $r: \subset$ subethood constraint; $X \subset R$
 $r: \text{ blank}$ possibilistic constraint; $X \text{ is } R$; R is the possibility distribution of X
 $r: v$ veristic constraint; $X \text{ is }_v R$; R is the verity distribution of X
 $r: p$ probabilistic constraint; $X \text{ is }_p R$; R is the probability distribution of X
Standard constraints: bivalent possibilistic, bivalent veristic and probabilistic

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CONTINUED

- $r: bm$ bimodal constraint; X is a random variable; R is a bimodal distribution
 $r: rs$ random set constraint; $X \text{ is }_rs R$; R is the set-valued probability distribution of X
 $r: fg$ fuzzy graph constraint; $X \text{ is }_fg R$; X is a function and R is its fuzzy graph
 $r: u$ usuality constraint; $X \text{ is }_u R$ means usually ($X \text{ is } R$)
 $r: g$ group constraint; $X \text{ is }_g R$ means that R constrains the attribute-values of the group

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PRIMARY GENERALIZED CONSTRAINTS

- **Possibilistic: $X \text{ is } R$**
- **Probabilistic: $X \text{ isp } R$**
- **Veristic: $X \text{ isv } R$**

- **Primary constraints are formalizations of three basic perceptions: (a) perception of possibility; (b) perception of likelihood; and (c) perception of truth**

- **In this perspective, probability may be viewed as an attribute of perception of likelihood**

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DIGRESSION—FOUNDATIONS OF SCIENTIFIC THEORIES

- **Scientific theories have their origins in perceptions**
- **A scientific theory may be viewed as a formalization of perceptions**

Basic perceptions and their formalizations

- **Likelihood —→ probability theory , probability is an attribute of likelihood**
- **Possibility —→ possibility theory**
- **Truth and consequence —→ logic**
- **Similarity —→ classification theory**
- **Causality —→ theory of causality**

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EXAMPLES: VERISTIC

- **Robert is half German, quarter French and quarter Italian**
Ethnicity (Robert) isv $(0.5|German + 0.25|French + 0.25|Italian)$
- **Robert resided in London from 1985 to 1990**
Reside (Robert, London) isv $[1985, 1990]$

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STANDARD CONSTRAINTS

- **Bivalent possibilistic: $X \varepsilon C$ (crisp set)**
- **Bivalent veristic: $Ver(p)$ is true or false**
- **Probabilistic: X isp R**
- **Standard constraints are instances of generalized constraints which underlie methods based on bivalent logic and probability theory**

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GENERALIZED CONSTRAINT—SEMANTICS

A *generalized constraint, GC*, is associated with a *test-score function, $ts(u)$* , which associates with each object, u , to which the constraint is applicable, the degree to which u satisfies the constraint. Usually, $ts(u)$ is a point in the unit interval. However, if necessary, it may be an element of a semi-ring, a lattice, or more generally, a partially ordered set, or a bimodal distribution.

example: *possibilistic constraint, X is R*

$$X \text{ is } R \longrightarrow \text{Poss}(X=u) = \mu_R(u)$$

$$ts(u) = \mu_R(u)$$

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TEST-SCORE FUNCTION

- $GC(X)$: *generalized constraint on X*
- X takes values in $U = \{u\}$
- *test-score function $ts(u)$: degree to which u satisfies GC*
- $ts(u)$ may be defined (a) *directly (extensionally) as a function of u* ; or *indirectly (intensionally) as a function of attributes of u*

intensional definition=attribute-based definition

- *example (a) Andrea is tall 0.9*
(b) *Andrea's height is 175cm; $\mu_{\text{tall}}(175)=0.9$;
Andrea is 0.9 tall*

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CONSTRAINT QUALIFICATION

➤ $p \text{ isr } R$ means r -value of p is R

in particular

$p \text{ isp } R \longrightarrow \text{Prob}(p) \text{ is } R$ (probability qualification)

$p \text{ isv } R \longrightarrow \text{Tr}(p) \text{ is } R$ (truth (verity) qualification)

$p \text{ is } R \longrightarrow \text{Poss}(p) \text{ is } R$ (possibility qualification)

examples

$(X \text{ is small}) \text{ isp likely} \longrightarrow \text{Prob}\{X \text{ is small}\} \text{ is likely}$

$(X \text{ is small}) \text{ isv very true} \longrightarrow \text{Ver}\{X \text{ is small}\} \text{ is very true}$

$(X \text{ is } R) \longrightarrow \text{Prob}\{X \text{ is } R\} \text{ is usually}$

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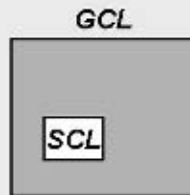
GENERALIZED CONSTRAINT LANGUAGE (GCL)

- GCL is an abstract language
 - GCL is generated by combination, qualification and propagation of generalized constraints
 - examples of elements of GCL
 - $(X \text{ isp } R)$ and $(X, Y) \text{ is } S$
 - $(X \text{ isr } R)$ is unlikely) and $(X \text{ iss } S)$ is likely
 - If X is A then Y is B
 - the language of fuzzy if-then rules is a sublanguage of GCL
- deduction= generalized constraint propagation
- the language of fuzzy if-then rules is a sublanguage of GCL

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STANDARD CONSTRAINT LANGUAGE (SCL)

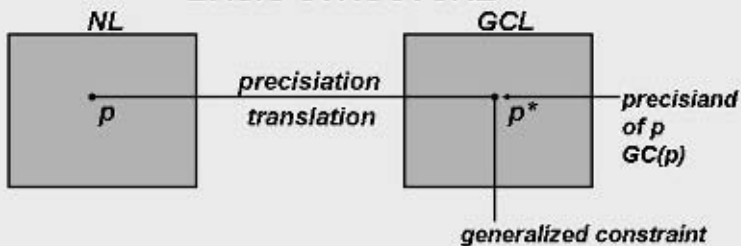
- SCL is a sublanguage of GCL



- SCL is generated by combination, qualification and propagation of standard constraints
- The language of differential equations is a sublanguage of SCL

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PRECISIATION = TRANSLATION INTO GCL BASIC STRUCTURE



annotation

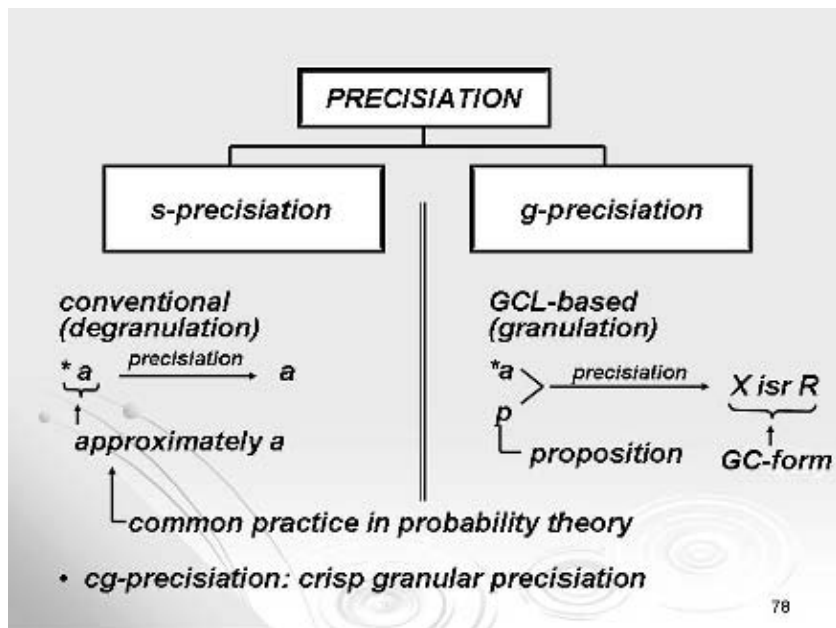
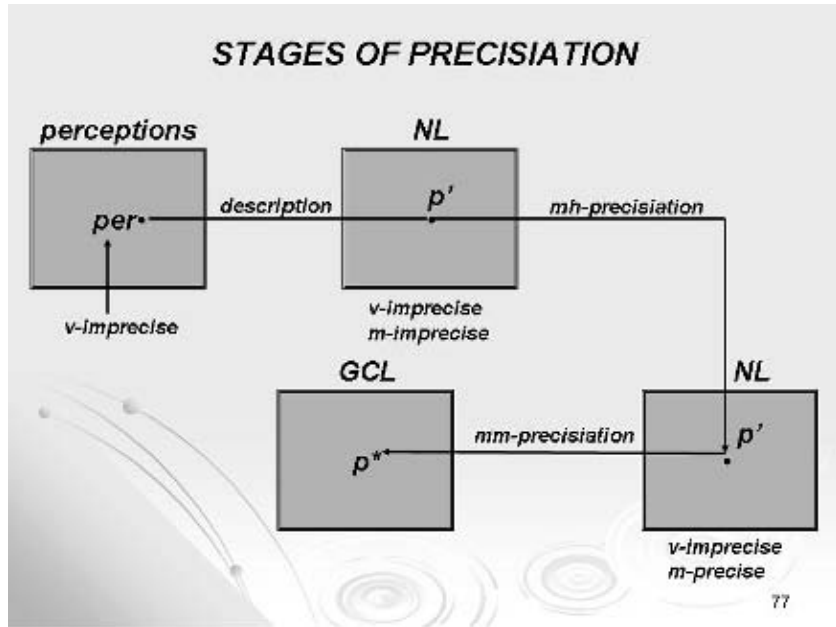
$p \rightarrow X/A \text{ is } R/B \leftarrow \text{GC-form of } p$

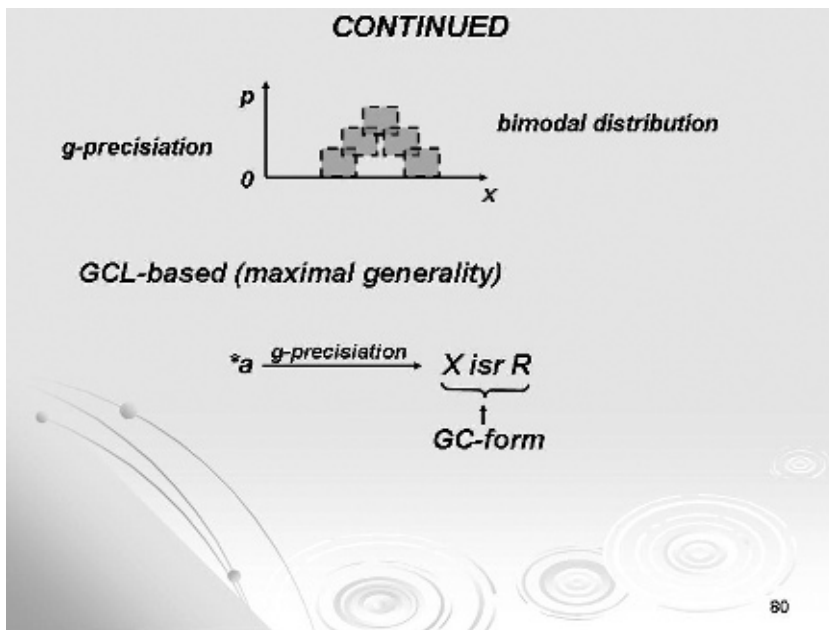
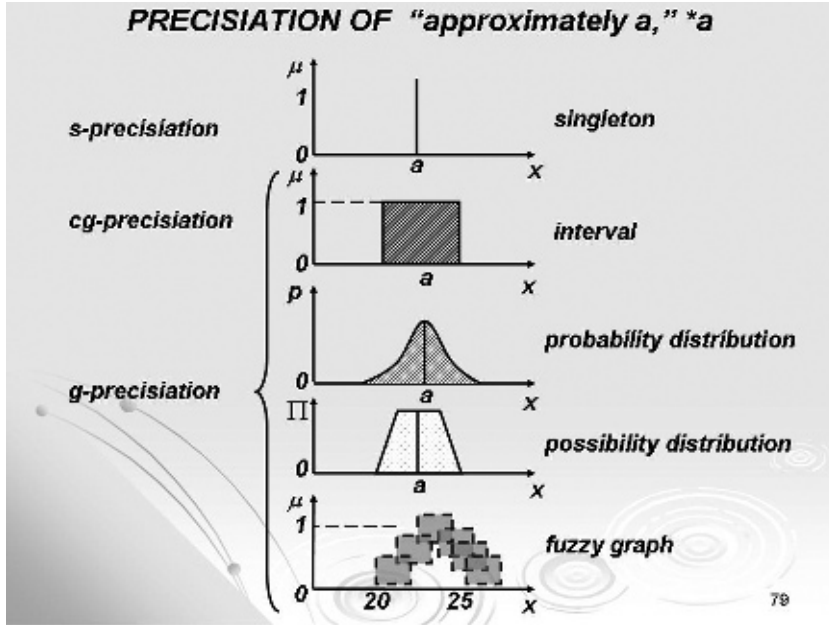
example

p : Carol lives in a small city near San Francisco

$X/\text{Location}(\text{Residence}(\text{Carol})) \text{ is } R/\text{NEAR}[\text{City}] \wedge \text{SMALL}[\text{City}]$

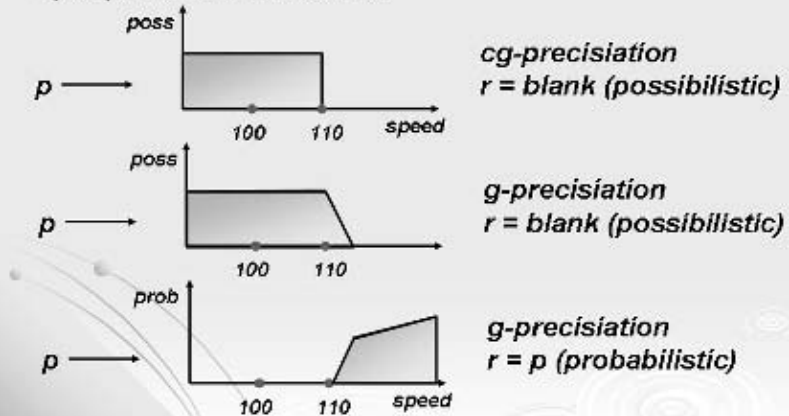
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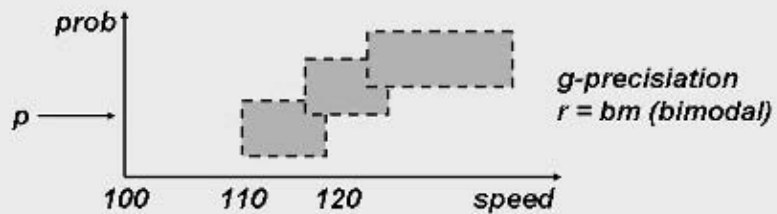
EXAMPLE

- p : Speed limit is 100 km/h



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CONTINUED



If Speed is less than *110, Prob(Ticket) is low

If Speed is between *110 and *120, Prob(Ticket) is medium

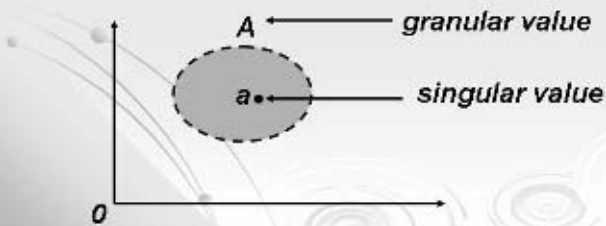
If Speed is greater than *120, Prob(Ticket) is high

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THE CONCEPT OF GRANULAR VALUE

X is a ← **singular value**
↳ *singleton*

X is A ← **granular value**
↳ *granule*

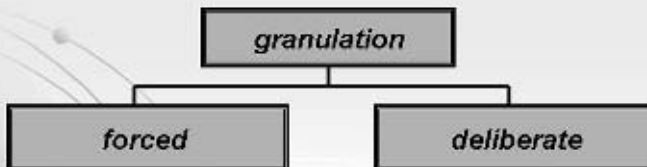


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CONTINUED

➤ A is defined as a generalized constraint
example

X is *small* ← **granular value**
↳ *fuzzy set*



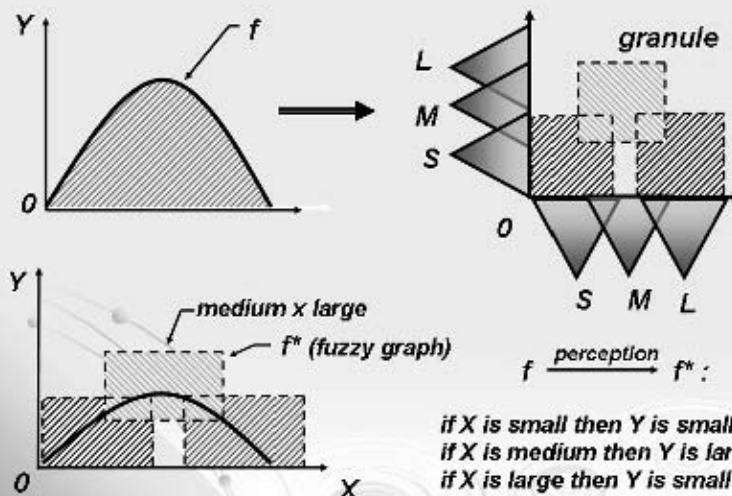
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GRANULAR COMPUTING (GrC)

- *The objects of computation in granular computing are granular values of variables and parameters*
- *Granular computing has a position of centrality in fuzzy logic*
- *Granular computing plays a key role in precisiation and deduction*

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GRANULAR DEFINITION OF A FUNCTION



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PRECISIATION AND DEDUCTION

- *p*: most Swedes are tall
*p**: $\Sigma \text{Count}(\text{tall.Swedes}/\text{Swedes})$ is most

further precisiation

h(u): height density function
h(u)du: fraction of Swedes whose height is in $[u, u+du]$, $a \leq u \leq b$

$$\int_a^b h(u)du = 1$$

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CONTINUED

- $\Sigma \text{Count}(\text{tall.Swedes}/\text{Swedes}) = \int_a^b h(u)\mu_{\text{tall}}(u)du$

➤ *constraint on h*

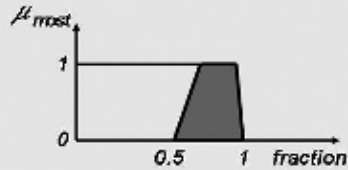
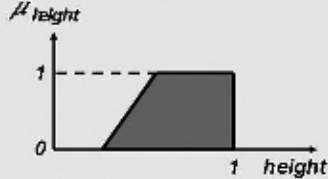
$$\int_a^b h(u)\mu_{\text{tall}}(u)du \text{ is most}$$

$$\pi(h) = \mu_{\text{most}} \left(\int_a^b h(u)\mu_{\text{tall}}(u)du \right)$$

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CALIBRATION / PRECISIATION

- calibration



- precision

most Swedes are tall $\longrightarrow \pi(h) = \mu_{most}(\int_a^b h(u)\mu_{tall}(u)du)$

h : count density function

- Frege principle of compositionality—precisiated version
- precision of a proposition requires precisiations (calibrations) of its constituents

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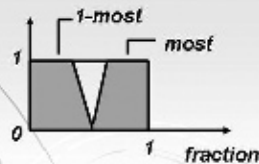
DEDUCTION

q : How many Swedes are not tall

q^* : $\int_a^b h(u)\mu_{not.tall}(u)du$ is ? Q

solution: $\int_a^b h(u)(1 - \mu_{tall}(u))du =$

$$\int_a^b h(u)du - \int_a^b h(u)\mu_{tall}(u)du = 1 - most$$



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DEDUCTION

q: How many Swedes are short

q:* $\int_a^b h(u)\mu_{short}(u)du$ is ? Q

solution: $\int_a^b h(u)\mu_{tall}(u)du$ is most

$\int_a^b h(u)\mu_{short}(u)du$ is ? Q

extension principle

$$\mu_Q(v) = \sup_u (\mu_{most}(\int_a^b h(u)\mu_{tall}(u)du))$$

subject to

$$v = \int_a^b h(u)\mu_{short}(u)du$$

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CONTINUED

q: What is the average height of Swedes?

q:* $\int_a^b h(u)udu$ is ? Q

solution: $\int_a^b h(u)\mu_{tall}(u)du$ is most

$\int_a^b h(u)udu$ is ? Q

extension principle

$$\mu_Q(v) = \sup_h (\mu_{most}(\int_a^b h(u)\mu_{tall}(u)du))$$

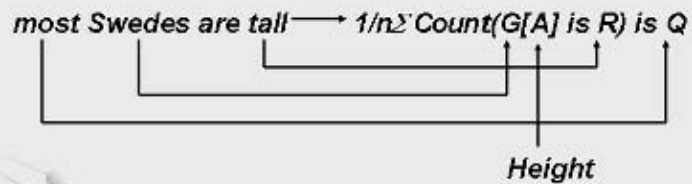
subject to

$$v = \int_a^b h(u)udu$$

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PROTOFORMAL DEDUCTION

Example:



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PROTOFORMAL DEDUCTION RULE

$$\frac{1/n \sum \text{Count}(G[A] \text{ is } R) \text{ is } Q}{1/n \sum \text{Count}(G[A] \text{ is } S) \text{ is } T}$$

$$\frac{\sum \mu_R(A) \text{ is } Q}{\sum \mu_S(A) \text{ is } T}$$

$$\mu_T(v) = \sup_{A_1, \dots, A_n} (\mu_Q(\sum_i \mu_R(A_i)))$$

subject to

$$v = \sum \mu_S(A)$$

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PROTOFORM LANGUAGE AND PROTOFORMAL DEDUCTION

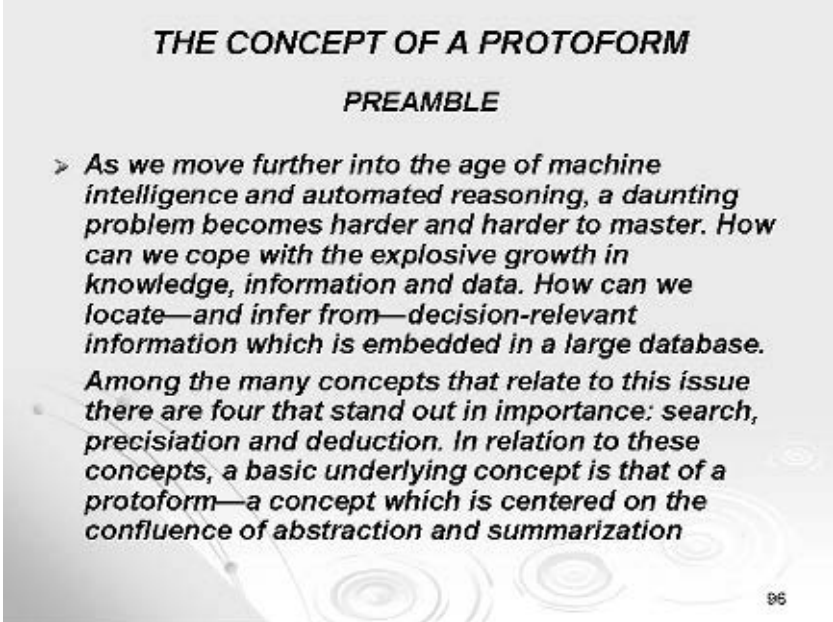
PFL



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THE CONCEPT OF A PROTOFORM

PREAMBLE

- *As we move further into the age of machine intelligence and automated reasoning, a daunting problem becomes harder and harder to master. How can we cope with the explosive growth in knowledge, information and data. How can we locate—and infer from—decision-relevant information which is embedded in a large database. Among the many concepts that relate to this issue there are four that stand out in importance: search, precisiation and deduction. In relation to these concepts, a basic underlying concept is that of a protoform—a concept which is centered on the confluence of abstraction and summarization*
- 

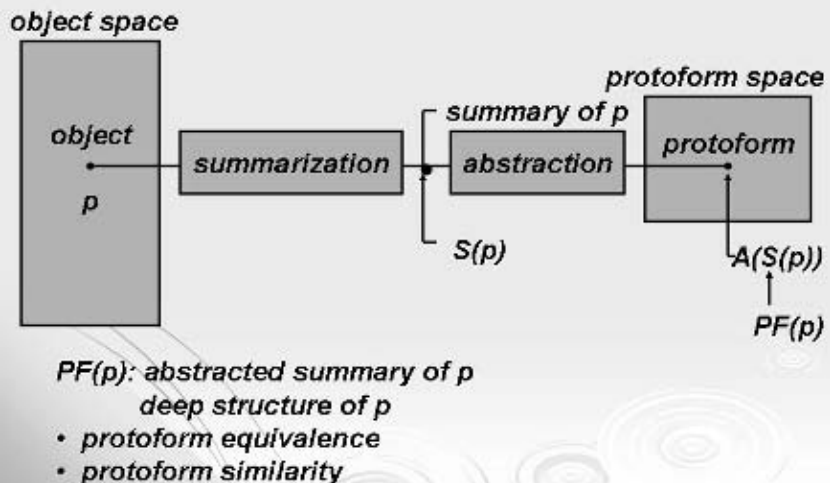
96

WHAT IS A PROTOFORM?

- *protoform = abbreviation of prototypical form*
- *informally, a protoform, A , of an object, B , written as $A=PF(B)$, is an abstracted summary of B*
- *usually, B is lexical entity such as proposition, question, command, scenario, decision problem, etc*
- *more generally, B may be a relation, system, geometrical form or an object of arbitrary complexity*
- *usually, A is a symbolic expression, but, like B , it may be a complex object*
- *the primary function of $PF(B)$ is to place in evidence the deep semantic structure of B*

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CONTINUED



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PROTOFORMS

object space

protoform space

PF-equivalence class {

- at a given level of abstraction and summarization, objects p and q are PF-equivalent if $PF(p)=PF(q)$

example

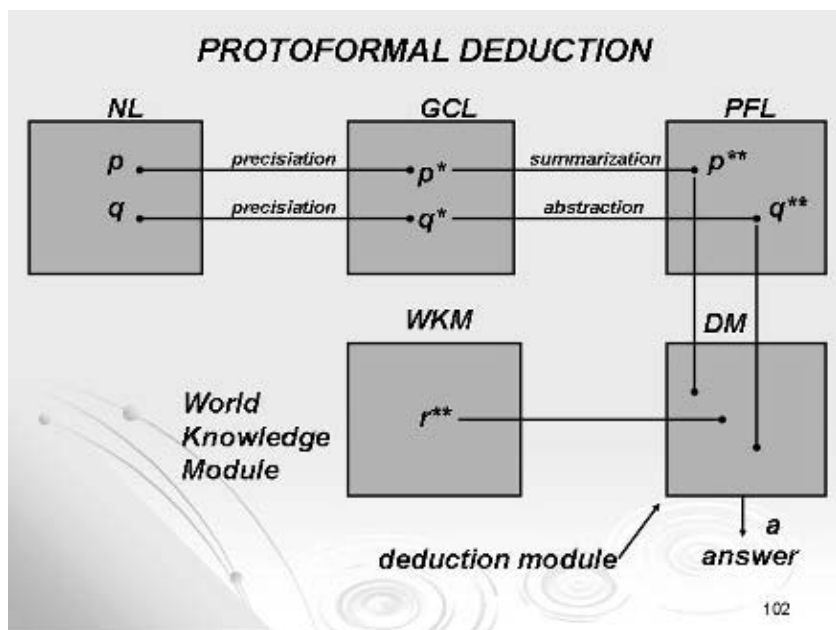
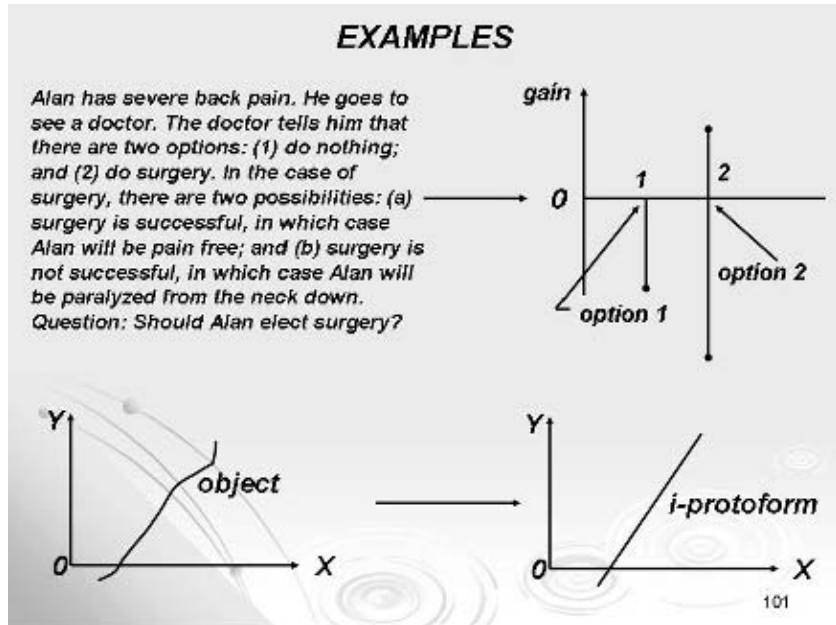
p : Most Swedes are tall	Count (A/B) is Q
q : Few professors are rich	Count (A/B) is Q

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EXAMPLES

- *Monika is young* → *Age(Monika) is young* → *A(B) is C*
 - Instantiation (bracketed above the arrow from *Age(Monika) is young* to *A(B) is C*)
 - abstraction (bracketed below the arrow from *A(B) is C* to *Age(Monika) is young*)
- *Monika is much younger than Robert* → *(Age(Monika), Age(Robert) is much.younger* → *D(A(B), A(C)) is E*
- *Usually Robert returns from work at about 6:15pm* → *Prob{Time(Return(Robert)) is 6:15*} is usually* → *Prob{A(B) is C} is D*
 - usually (bracketed above the arrow from *6:15** to *usually*)
 - Time (bracketed below the arrow from *Time* to *Return(Robert)*)

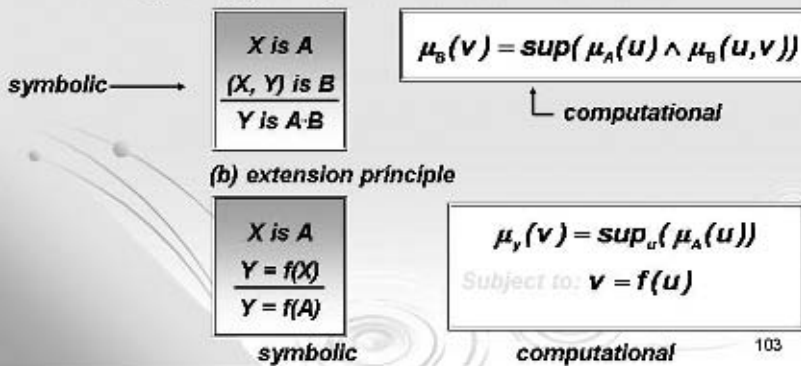
100



PROTOFORMAL DEDUCTION

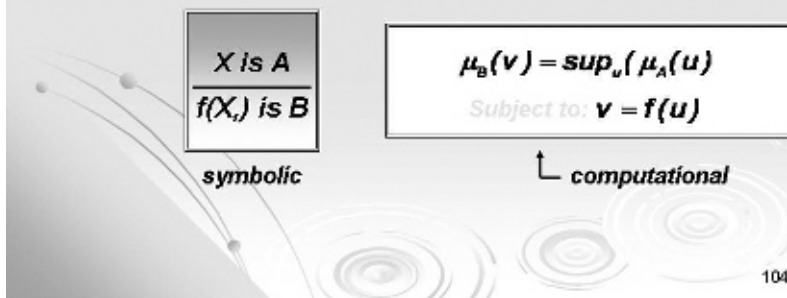
- Rules of deduction in the Deduction Database (DDB) are protoformal

examples: (a) compositional rule of inference



RULES OF DEDUCTION

- Rules of deduction are basically rules governing generalized constraint propagation
- The principal rule of deduction is the extension principle



GENERALIZATIONS OF THE EXTENSION PRINCIPLE

information = constraint on a variable

$f(X) \text{ is } A$	← <i>given information about X</i>
$g(X) \text{ is } B$	← <i>inferred information about X</i>

$$\mu_B(\mathbf{v}) = \sup_u (\mu_A(f(u)))$$

subject to: $\mathbf{v} = g(u)$

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CONTINUED

$f(X_1, \dots, X_n) \text{ is } A$
$g(X_1, \dots, X_n) \text{ is } B$

$\mu_B(\mathbf{v}) = \sup_u (\mu_A(f(u)))$
Subject to: $\mathbf{v} = g(u)$

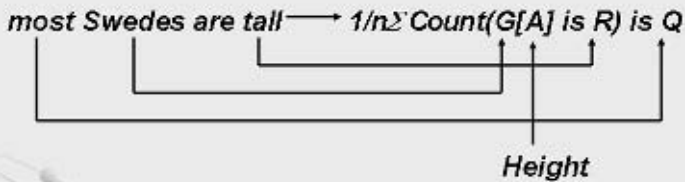
$(X_1, \dots, X_n) \text{ is } A$
$g_j(X_1, \dots, X_n) \text{ is } Y_j, j=1, \dots, n$
$(Y_1, \dots, Y_n) \text{ is } B$

$\mu_B(\mathbf{v}) = \sup_u (\mu_A(f(u)))$
Subject to: $\mathbf{v} = g(u)$
$j = 1, \dots, n$

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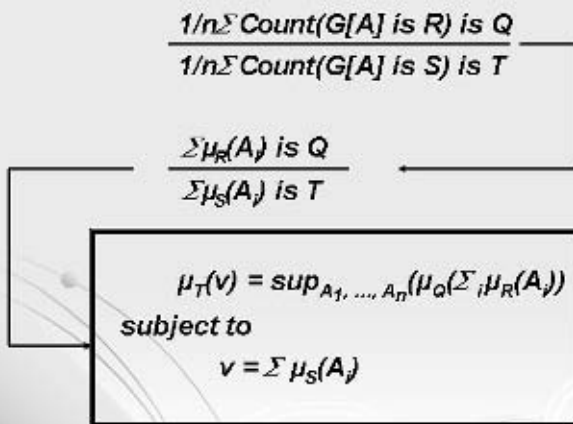
PROTOFORMAL DEDUCTION

Example:



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PROTOFORMAL DEDUCTION RULE



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EXAMPLE OF DEDUCTION

p: Most Swedes are much taller than most Italians

q: What is the difference in the average height of Swedes and Italians?

TPM-based solution

Step 1. *precision*: translation of *p* into GCL

$S = \{S_1, \dots, S_n\}$: population of Swedes

$I = \{I_1, \dots, I_n\}$: population of Italians

$g_i = \text{height of } S_i$, $g = (g_1, \dots, g_n)$

$h_j = \text{height of } I_j$, $h = (h_1, \dots, h_n)$

$\mu_{ij} = \mu_{\text{much.taller}}(g_i, h_j) = \text{degree to which } S_i \text{ is much taller than } I_j$

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CONTINUED

$r_i = \frac{1}{n} \sum_j \mu_{ij}$ = Relative Σ Count of Italians in relation to whom S_i is much taller

$t_i = \mu_{\text{most}}(r_i)$ = degree to which S_i is much taller than most Italians

$v = \frac{1}{m} \sum_i t_i$ = Relative Σ Count of Swedes who are much taller than most Italians

$ts(g, h) = \mu_{\text{most}}(v)$

p \rightarrow generalized constraint on *S* and *I*

q: $d = \frac{1}{m} \sum_i g_i - \frac{1}{n} \sum_j h_j$

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CONTINUED

Step 2. Deduction via extension principle

$$\mu_q(d) = \sup_{g,h} ts(g,h)$$

subject to

$$d = \frac{1}{m} \sum_i g_i - \frac{1}{n} \sum_j h_j$$

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DEDUCTION PRINCIPLE

- Point of departure: question, q
- Data: $D = (X_1/u_1, \dots, X_n/u_n)$

u_i is a generic value of X_i

- Ans(q): answer to q
- If we knew the values of the X_1, u_1, \dots, u_n , we could express Ans(q) as a function of the u_i

$$\text{Ans}(q) = g(u_1, \dots, u_n) \quad u = (u_1, \dots, u_n)$$

- Our information about the u_i , $i(u_1, \dots, u_n)$ is a generalized constraint on the u_i . The constraint is defined by its test-score function

$$f(u) = f(u_1, \dots, u_n)$$

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CONTINUED

➤ Use the extension principle

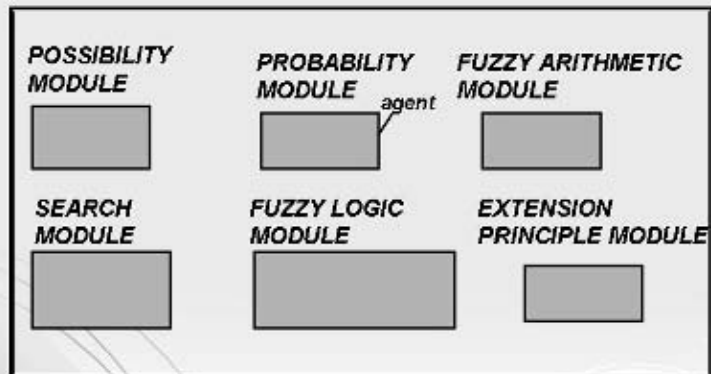
$$\mu_{Ans(q)}(v) = \sup_u (ts(u))$$

subject to

$$v = g(u)$$

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MODULAR DEDUCTION DATABASE



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PROBABILITY MODULE

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THE CONCEPT OF BIMODAL DISTRIBUTION (ZADEH 1979)

X isbm R

└─ bimodal distribution
└─ random variable

- A bimodal distribution is a collection of ordered pairs of the form

$$R: \{(P_1, A_1), \dots, (P_n, A_n)\}$$

- or equivalently

$$\sum_i (P_i | A_i) \quad , \quad i=1, \dots, n$$

where the P_i are fuzzy probabilities and the A_i are fuzzy sets

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CONTINUED

Special cases:

1. *The P_i are crisp; the A_i are fuzzy*
2. *The P_i are fuzzy; the A_i are crisp*
3. *The P_i are crisp; the A_i are crisp*

➤ *The Dempster-Shafer theory of evidence is basically a theory of crisp bimodal distributions*

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EXAMPLE: FORD STOCK

➤ *I am considering buying Ford stock. I ask my stockbroker, "What is your perception of the near-term prospects for Ford stock?" He tells me, "A moderate decline is very likely; a steep decline is unlikely; and a moderate gain is not likely." My question is: What is the probability of a large gain?*

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CONTINUED

- *Information provided by my stockbroker may be represented as a collection of ordered pairs:*

*Price: ((unlikely, steep.decline),
(very.likely, moderate.decline),
(not.likely, moderate.gain))*

In this collection, the second element of an ordered pair is a fuzzy event or, equivalently, a possibility distribution, and the first element is a fuzzy probability.

- *The importance of the concept of a bimodal distribution derives from the fact that in the context of human-centric systems, most probability distributions are bimodal*

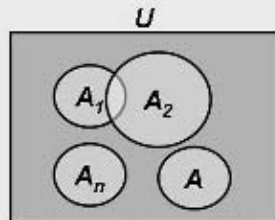
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BIMODAL DISTRIBUTIONS

- *Bimodal distributions can assume a variety of forms. The principal types are Type 1, Type 2 and Type 3. Type 1, 2 and 3 bimodal distributions have a common framework but differ in important detail*

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BIMODAL DISTRIBUTIONS (Type 1, 2, 3)



- **Type 1 (default):** X is a random variable taking values in U
 A_1, \dots, A_n, A are events (fuzzy sets)
 $p_i = \text{Prob}(X \text{ is } A_i)$, $i = 1, \dots, n$
 $\sum p_i$ is unconstrained
 p_i is P_i (granular probability)

BMD: bimodal distribution: $((P_1, A_1), \dots, (P_n, A_n))$
 $X \text{ isbm } (P_1 \setminus A_1 + \dots + P_n \setminus A_n)$

Problem: What is the probability, p , of A ? In general, this probability is fuzzy-set-valued, that is, granular

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CONTINUED

- **Type 2 (fuzzy random set):** X is a fuzzy-set-valued random variable with values A_1, \dots, A_n (fuzzy sets)
 $p_i = \text{Prob}(X = A_i)$, $i = 1, \dots, n$

BMD: $X \text{ isrs } (p_1 \setminus A_1 + \dots + p_n \setminus A_n)$
 $\sum p_i = 1$

Problem: What is the probability, p , of A ? p is not definable. What are definable are (a) the expected value of the conditional possibility of A given BMD, and (b) the expected value of the conditional necessity of A given BMD

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CONTINUED

➤ **Type 3 (augmented random set; Dempster-Shafer):**

X is a set-valued random variable taking the values X_1, \dots, X_n with respective probabilities p_1, \dots, p_n

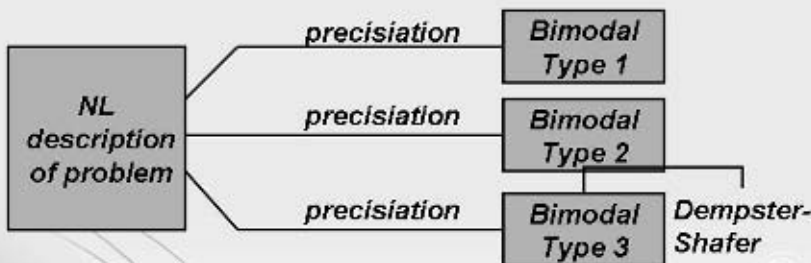
- Y_i is a random variable taking values in $A_i, i = 1, \dots, n$
- Probability distribution of Y_i in $A_i, i = 1, \dots, n$, is not specified
- X is $p_1 \setminus X_1 + \dots + p_n \setminus X_n$

Problem: What is the probability, p , that Y_1 or $Y_2 \dots$ or Y_n is in A ? Because probability distributions of the Y_i in the A_i are not specified, p is interval-valued. What is important to note is that the concepts of upper and lower probabilities break down when the A_i are fuzzy sets

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IS DEMPSTER SHAFER COINTENSIVE?

- In applying Dempster Shafer theory, it is important to check on whether the data fit Type 3 model.

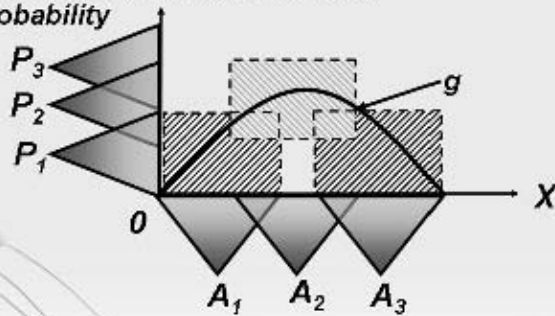


- **Caveat:** In many cases the cointensive (well-fitting) precisand (model) of a problem statement is bimodal distribution of Type 1 rather than Type 3 (Dempster-Shafer)

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**BASIC BIMODAL DISTRIBUTION (BMD) (Type 1)
(PERCEPTION-BASED PROBABILITY DISTRIBUTION)**

X is a real-valued random variable
probability



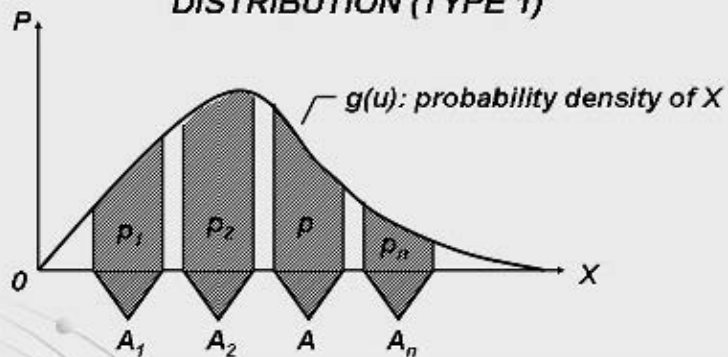
$$\text{BMD: } P(X) = P_{i(1)} \setminus A_1 + P_{i(2)} \setminus A_2 + P_{i(3)} \setminus A_3$$

Prob (X is A_i) is $P_{i(0)}$

$$P(X) = \text{low} \setminus \text{small} + \text{high} \setminus \text{medium} + \text{low} \setminus \text{large}$$

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INTERPOLATION OF A BASIC BIMODAL DISTRIBUTION (TYPE 1)



p_i is P_i : granular value of p_i , $i=1, \dots, n$

(P_i, A_j) , $i=1, \dots, n$ are given

A is given

$(?P, A)$

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INTERPOLATION MODULE AND PROBABILITY MODULE

$\text{Prob}\{X \text{ is } A_i\} \text{ is } P_i, \quad i = 1, \dots, n$

$\text{Prob}\{X \text{ is } A\} \text{ is } Q$

$$\mu_Q(v) = \sup_g (\mu_{P_1}(\int_U \mu_{A_1}(u)g(u)du) \wedge \dots \wedge$$

$$\mu_{P_n}(\int_U \mu_{A_n}(u)g(u)du))$$

subject to

$$U = \int_U \mu_A(u)g(u)du$$

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OPERATIONS ON BIMODAL DISTRIBUTIONS

$P(X)$ defines possibility distribution of g

$$\pi(g) = \mu_{P_1}(\int_U \mu_{A_1}(u)g(u)du) \wedge \dots \wedge \mu_{P_n}(\int_U \mu_{A_n}(u)g(u)du)$$

problem

a) what is the expected value of X

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EXPECTED VALUE OF A BIMODAL DISTRIBUTION

$$E(P^*) = \int_U ug(u)du = f(g)$$

Extension Principle

$$\mu_{E(P^*)}(v) = \sup_g (\mu_{P_1}(\int_U \mu_{A_1}(u)g(u)du) \wedge \dots \wedge \mu_{P_n}(\int_U \mu_{A_n}(u)g(u)du))$$

subject to: $v = \int_U ug(u)du$

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SUMMATION

- *addition of significant question-answering capability to search engines is a complex, open-ended problem*
- *incremental progress, but not much more, is achievable through the use of bivalent-logic-based methods*
- *to achieve significant progress, it is imperative to develop and employ new methods based on computing with words, protoform theory, precisiated natural language and computational theory of precisiation of meaning*
- *The centerpiece of new methods is the concept of a generalized constraint*

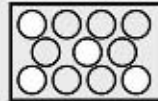
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APPENDIX

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DEDUCTION THE BALLS-IN-BOX PROBLEM

Version 1. Measurement-based



A flat box contains a layer of black and white balls. You can see the balls and are allowed as much time as you need to count them

- ***q_1 : What is the number of white balls?***
- ***q_2 : What is the probability that a ball drawn at random is white?***
- ***q_1 and q_2 remain the same in the next version***

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DEDUCTION

Version 2. Perception-based

You are allowed n seconds to look at the box. n seconds is not enough to allow you to count the balls

You describe your perceptions in a natural language

p_1 : there are about 20 balls

p_2 : most are black

p_3 : there are several times as many black balls as white balls

PT's solution?

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MEASUREMENT-BASED

version 1

- a box contains 20 black and white balls
- over seventy percent are black
- there are three times as many black balls as white balls
- what is the number of white balls?
- what is the probability that a ball picked at random is white?

PERCEPTION-BASED

version 2

- a box contains about 20 black and white balls
- most are black
- there are several times as many black balls as white balls
- what is the number of white balls?
- what is the probability that a ball drawn at random is white?

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COMPUTATION (version 2)

➤ *measurement-based*

X = number of black balls

Y_2 number of white balls

$$X \geq 0.7 \cdot 20 = 14$$

$$X + Y = 20$$

$$X = 3Y$$

$$X = 15 \quad ; \quad Y = 5$$

$$p = 5/20 = .25$$

➤ *perception-based*

X = number of black balls

Y = number of white balls

$$X = \text{most} \times 20^*$$

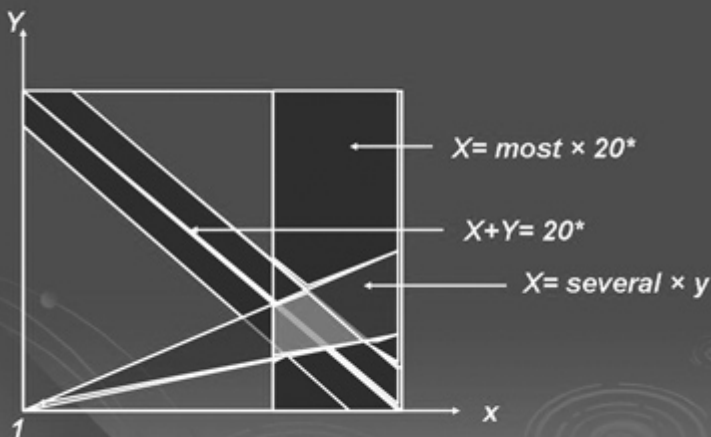
$$X = \text{several} \times Y$$

$$X + Y = 20^*$$

$$P = Y/N$$

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FUZZY INTEGER PROGRAMMING



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RELEVANCE, REDUNDANCE AND DELETABILITY

DECISION TABLE

Name	A_1	A_j	A_n	D
Name ₁	a_{11}	a_{1j}	a_{1n}	d_1
.
Name _k	a_{k1}	a_{kj}	a_{kn}	d_1
Name _{k+1}	$a_{k+1, 1}$	$a_{k+1, j}$	$a_{k+1, n}$	d_2
.
Name _i	a_{i1}	a_{ij}	a_{in}	d_i
.
Name _n	a_{n1}	a_{nj}	a_{nn}	d_r

A_j : j th symptom

a_y : value of j th symptom of Name

D : diagnosis

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REDUNDANCE → DELETABILITY

Name	A_1	A_j	A_n	D
.
Name _r	a_{r1}	*	a_{rn}	d_2
.

A_j is conditionally redundant for Name_r, A_1 is a_{r1} , A_n is a_{rn}
if D is d_2 for all possible values of A_j in *

A_j is redundant if it is conditionally redundant for all values of Name

• compactification algorithm (Zadeh, 1976); Quine-McCluskey algorithm

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RELEVANCE

D is ? d if A_j is a_{rj}

constraint on A_j induces a constraint on D
 example: (blood pressure is high) constrains D
 $(A_j \text{ is } a_{rj})$ is uninformative if D is unconstrained

A_j is irrelevant if it A_j is uninformative for all a_{rj}

irrelevance \rightarrow deletability

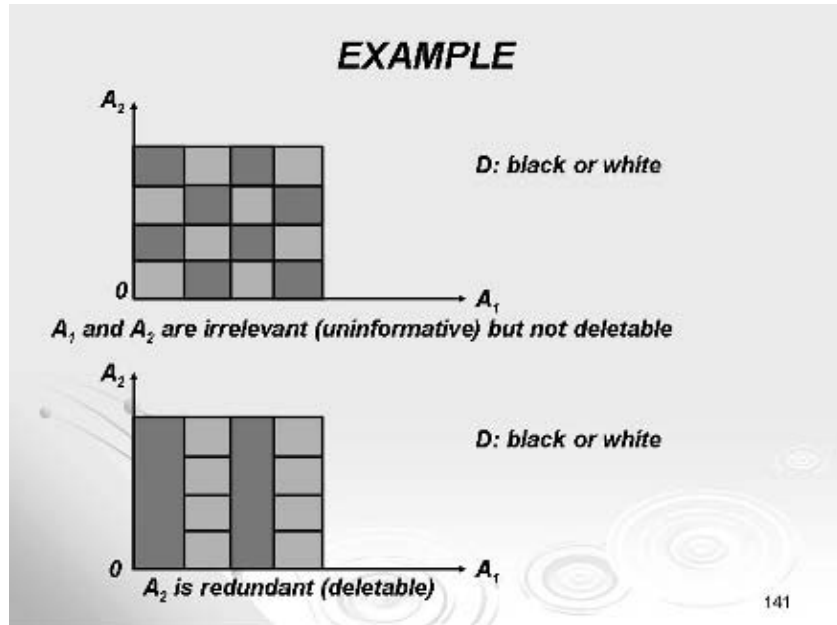
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IRRELEVANCE (UNINFORMATIVENESS)

Name	A_1	A_j	A_n	D
Name	.	a_{ij}	.	d_1
r	.	a_{ij}	.	d_1
Name	.	a_{ij}	.	d_2
$l+s$.	a_{ij}	.	d_2

$(A_j \text{ is } a_{ij})$ is irrelevant
(uninformative)

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KEY POINT—THE ROLE OF FUZZY LOGIC

- Existing approaches to the enhancement of web intelligence are based on classical, Aristotelian, bivalent logic and bivalent-logic-based probability theory. In our approach, bivalence is abandoned. What is employed instead is fuzzy logic—a logical system which subsumes bivalent logic as a special case.
- Fuzzy logic is not fuzzy
- Fuzzy logic is a precise logic of fuzziness and imprecision
- The centerpiece of fuzzy logic is the concept of a generalized constraint.

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- *In bivalent logic, BL, truth is bivalent, implying that every proposition, p , is either true or false, with no degrees of truth allowed*

- *In multivalent logic, ML, truth is a matter of degree*

- *In fuzzy logic, FL:*
 - *everything is, or is allowed to be, to be partial, i.e., a matter of degree*
 - *everything is, or is allowed to be, imprecise (approximate)*
 - *everything is, or is allowed to be, granular (linguistic)*
 - *everything is, or is allowed to be, perception based*

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CONTINUED

- *The generality of fuzzy logic is needed to cope with the great complexity of problems related to search and question-answering in the context of world knowledge; to deal computationally with perception-based information and natural languages; and to provide a foundation for management of uncertainty and decision analysis in realistic settings*

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January 26, 2005

Factual Information About the Impact of Fuzzy Logic

PATENTS

- **Number of fuzzy-logic-related patents applied for in Japan: 17,740**
- **Number of fuzzy-logic-related patents issued in Japan: 4,801**
- **Number of fuzzy-logic-related patents issued in the US: around 1,700**

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PUBLICATIONS

Count of papers containing the word "fuzzy" in title, as cited in INSPEC and MATH.SCI.NET databases.

Compiled by Camille Wanat, Head, Engineering Library, UC Berkeley, December 22, 2004

Number of papers in INSPEC and MathSciNet which have "fuzzy" in their titles:

INSPEC - "fuzzy" in the title

1970-1979: 569

1980-1989: 2,404

1990-1999: 23,207

2000-present: 14,172

Total: 40,352

MathSciNet - "fuzzy" in the title

1970-1979: 443

1980-1989: 2,465

1990-1999: 5,483

2000-present: 3,960

Total: 12,351

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JOURNALS ("fuzzy" or "soft computing" in title)

1. **Fuzzy Sets and Systems**
2. **IEEE Transactions on Fuzzy Systems**
3. **Fuzzy Optimization and Decision Making**
4. **Journal of Intelligent & Fuzzy Systems**
5. **Fuzzy Economic Review**
6. **International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems**
7. **Journal of Japan Society for Fuzzy Theory and Systems**
8. **International Journal of Fuzzy Systems**
9. **Soft Computing**
10. **International Journal of Approximate Reasoning--Soft Computing in Recognition and Search**
11. **Intelligent Automation and Soft Computing**
12. **Journal of Multiple-Valued Logic and Soft Computing**
13. **Mathware and Soft Computing**
14. **Biomedical Soft Computing and Human Sciences**
15. **Applied Soft Computing**

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APPLICATIONS

The range of application-areas of fuzzy logic is too wide for exhaustive listing. Following is a partial list of existing application-areas in which there is a record of substantial activity.

- | | |
|---|--|
| 1. Industrial control | 19. Financial engineering |
| 2. Quality control | 20. Assessment of credit-worthiness |
| 3. Elevator control and scheduling | 21. Fraud detection |
| 4. Train control | 22. Mine detection |
| 5. Traffic control | 23. Pattern classification |
| 6. Loading crane control | 24. Oil exploration |
| 7. Reactor control | 25. Geology |
| 8. Automobile transmissions | 26. Civil Engineering |
| 9. Automobile climate control | 27. Chemistry |
| 10. Automobile body painting control | 28. Mathematics |
| 11. Automobile engine control | 29. Medicine |
| 12. Paper manufacturing | 30. Biomedical instrumentation |
| 13. Steel manufacturing | 31. Health-care products |
| 14. Power distribution control | 32. Economics |
| 15. Software engineering | 33. Social Sciences |
| 16. Expert systems | 34. Internet |
| 17. Operation research | 35. Library and Information Science |
| 18. Decision analysis | |

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Product Information Addendum 1

This addendum relates to information about products which employ fuzzy logic singly or in combination. The information which is presented came from SIEMENS and OMRON. It is fragmentary and far from complete. Such addenda will be sent to the Group from time to time.

SIEMENS:

- * washing machines, 2 million units sold
- * fuzzy guidance for navigation systems (Opel, Porsche)
- * OCS: Occupant Classification System (to determine, if a place in a car is occupied by a person or something else; to control the airbag as well as the intensity of the airbag). Here FL is used in the product as well as in the design process (optimization of parameters).
- * fuzzy automobile transmission (Porsche, Peugeot, Hyundai)

OMRON:

- * fuzzy logic blood pressure meter, 7.4 million units sold, approximate retail value \$740 million dollars

Note: If you have any information about products and or manufacturing which may be of relevance please communicate it to Dr. Vesa Niskanen vesa.niskanen@helsinki.fi and Masoud Nikravesh nikravesh@cs.berkeley.edu.

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Product Information Addendum 2

This addendum relates to information about products which employ fuzzy logic singly or in combination. The information which is presented came from Professor Hideyuki Takagi, Kyushu University, Fukuoka, Japan. Professor Takagi is the co-inventor of neurofuzzy systems. Such addenda will be sent to the Group from time to time.

Facts on FL-based systems in Japan (as of 2/06/2004)

1. Sony's FL camcorders

Total amount of camcorder production of all companies in 1995-1998 times Sony's market share is the following: Fuzzy logic is used in all Sony's camcorders at least in these four years, i.e. total production of Sony's FL-based camcorders is 2.4 millions products in these four years.

1,228K units X 49% in 1995
1,315K units X 52% in 1996
1,381K units X 50% in 1997
1,416K units X 51% in 1998

2. FL control at Idemitsu oil factories

Fuzzy logic control is running at more than 10 places at 4 oil factories of Idemitsu Kosan Co. Ltd including not only pure FL control but also the combination of FL and conventional control.

They estimate that the effect of their FL control is more than 200 million YEN per year and it saves more than 4,000 hours per year.

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3. Canon

Canon used (uses) FL in their cameras, camcorders, copy machine, and stepper alignment equipment for semiconductor production. But, they have a rule not to announce their production and sales data to public.

Canon holds 31 and 31 established FL patents in Japan and US, respectively.

4. Minolta cameras

Minolta has a rule not to announce their production and sales data to public, too.

whose name in US market was Maxxum 7xi. It used six FL systems in a camera and was put on the market in 1991 with 98,000 YEN (body price without lenses). It was produced 30,000 per month in 1991. Its sister cameras, alpha-9xi, alpha-5xi, and their successors used FL systems, too. But, total number of production is confidential.

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5. FL plant controllers of Yamatake Corporation

Yamatake-Honeywell (Yamatake's former name) put FUZZICS, fuzzy software package for plant operation, on the market in 1992. It has been used at the plants of oil, oil chemical, chemical, pulp, and other industries where it is hard for conventional PID controllers to describe the plant process for these more than 10 years.

They planed to sell the FUZZICS 20 - 30 per year and total 200 million YEN.

As this software runs on Yamatake's own control systems, the software package itself is not expensive comparative to the hardware control systems.

6. Others

Names of 225 FL systems and products picked up from news articles in 1987 - 1996 are listed at http://www.adwin.com/elec/fuzzy/note_10.html in Japanese.)

Note: If you have any information about products and or manufacturing which may be of relevance please communicate it to Dr. Vesa Niskanen vesa.niskanen@helsinki.fi and Masoud Nikravesh Nikravesh@cs.berkeley.edu, with cc to me.

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**THE OPERATING
CHARACTERISTICS OF THE
ASYNCHRONOUS MOTOR AT THE
ROTORICAL PARAMETERS
VARIATION IN COMPARISON
WITH THE FREQUENCY**

Abstract:

In this paper are analyzed the operating characteristics at the rotorical parameters variation in comparison with the charge and in that conditions when rotorical parameters (R_2', X_2') are constant.

Keywords:

asynchronous motor, characteristics.

1. INTRODUCTION

The equations for the asynchronous motor with cage rotor in permanent regime of working, are [1], [2]:

$$\begin{cases} \underline{U}_1 = \underline{Z}_1 \underline{I}_1 - \underline{U}_{e1} \\ 0 = -\underline{Z}'_2 \underline{I}'_2 + \underline{U}_{e1} \\ \underline{I}_{01} = \underline{I}_1 + \underline{I}'_2 \\ \underline{U}_{e1} = -\underline{Z}'_{1m} \underline{I}_{01} \end{cases} \quad (1)$$

where:

$\underline{Z}_1 = R_1 + jX_1$ - statorical winding impedance;

$\underline{Z}'_{1m} = R_{1m} + jX_{1m}$ - magnetizing impedance;

$\underline{Z}'_2 = C_R \frac{R'_2}{s} + jC_x X'_2$ - rotorical impedance in comparison

with rotorical frequency.

$$C_r = \frac{\left[R'_2 R_{1m} \left(\frac{f_2}{50} \right) + X'_2 X_{1m} \left(\frac{f_2}{50} \right)^2 \right] \left[R'_2 + R_{1m} \left(\frac{f_2}{50} \right) \right] + \left[R'_2 X_{1m} \left(\frac{f_2}{50} \right) + X'_2 R_{1m} \left(\frac{f_2}{50} \right)^2 \right] \left[X'_2 \left(\frac{f_2}{50} \right) + X_{1m} \left(\frac{f_2}{50} \right) \right]}{R'_2 \left\{ \left[R'_2 + R_{1m} \left(\frac{f_2}{50} \right) \right]^2 + \left[X'_2 \left(\frac{f_2}{50} \right) + X_{1m} \left(\frac{f_2}{50} \right) \right]^2 \right\}} \quad (2)$$

$$C_x = \frac{\left[R'_2 X_{1m} \left(\frac{f_2}{50} \right) + X'_2 R_{1m} \left(\frac{f_2}{50} \right)^2 \right] \left[R'_2 + R_{1m} \left(\frac{f_2}{50} \right) \right] - \left[R'_2 R_{1m} \left(\frac{f_2}{50} \right) - X'_2 X_{1m} \left(\frac{f_2}{50} \right)^2 \right] \left[X'_2 \left(\frac{f_2}{50} \right) + X_{1m} \left(\frac{f_2}{50} \right) \right]}{X'_2 \left(\frac{f_2}{50} \right) \left\{ \left[R'_2 + R_{1m} \left(\frac{f_2}{50} \right) \right]^2 + \left[X'_2 \left(\frac{f_2}{50} \right) + X_{1m} \left(\frac{f_2}{50} \right) \right]^2 \right\}} \quad (3)$$

Knowing the electrical parameters:

$R_1, R'_2, R_{1m}, X_1, X'_2$ and X_{1m} at a nominal frequency ($f=50$ Hz) and the supply, we can find-out the current in the stator winding and in the rotor winding.

$$\underline{I}'_1 = \frac{C_2 \underline{U}_1}{\underline{Z}_1 + C_1 \underline{Z}'_2}; \quad \underline{I}'_2 = -\frac{\underline{Z}'_2 \underline{U}_1}{\underline{Z}_1 + C_1 \underline{Z}'_2} \quad (4)$$

where:

$$\underline{C}_1 = 1 + \frac{\underline{Z}_1}{\underline{Z}_{1m}}; \quad \underline{C}_1 = 1 + \frac{\underline{Z}_1}{\underline{Z}_{1m}} \quad (5)$$

Equivalent impedance of the motor is:

$$\underline{Z}_e = \underline{Z}_1 + \frac{\underline{Z}_{1m}\underline{Z}'_2}{\underline{Z}_{1m} + \underline{Z}'_2} \quad (6)$$

from where we can determine the power factor:

$$\cos \varphi_1 = \frac{R_e(\underline{Z}_e)}{|\underline{Z}_e|} \quad (7)$$

The electromagnetic torque and the efficiency of the machine will be determined with the relations:

$$M = \frac{pm_1}{\omega_1} \cdot \frac{R'_2}{s} I_2'^2 \quad (8)$$

$$\eta = \frac{M \frac{2\pi f_1}{p} (1-s)}{3U_1 I_1 \cos \varphi_1} \quad (9)$$

Using the relations (4), (5), (8) and (9) we can sketch the operating characteristics of the asynchronous motor in comparison with the charge, taken into account the rotorial parameters variation in comparison with the rotorial frequency f_2 .

2. PRACTICAL PARAGRAPH

We consider a triphases asynchronous motor, with a nominal power $P_N=4$ KW at 1500 rot/min, supplies by a nominal voltage $U_1=220$ V.

In figure 1 it is shown the working characteristics: $I_1=f(s)$; $I_2'=f(s)$; $\cos\varphi_1=f(s)$; $M=f(s)$.

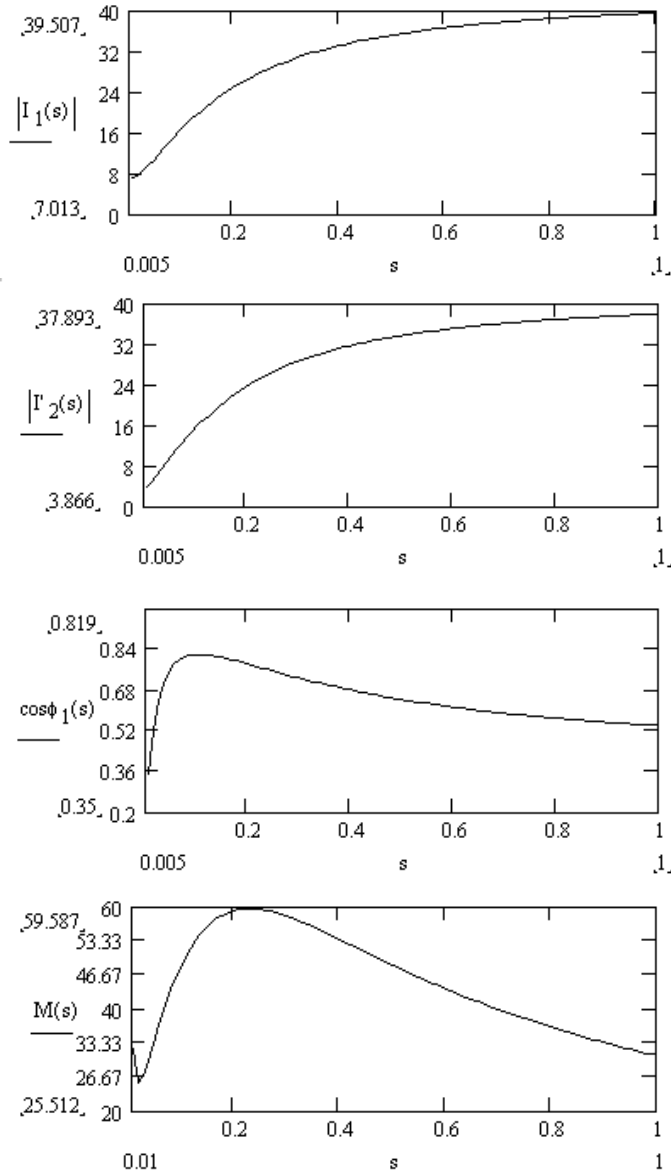


Fig.1. The working characteristics to the rotorical parameters modification in comparison with the frequency.

3. CONCLUSIONS

From mechanical characteristic $M=f(s)$, at discharge regime ($s=0$), appear an increase of the electromagnetic torque due to the increase of the dispersion reactance of the rotor coefficient C_x .

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**THE VARIATION OF THE
ROTORICAL PARAMETERS IN
COMPARISON WITH THE
FREQUENCY AT THE INDUCTIVE
(ELECTRIC) MOTOR**

Abstract:

In this paper it is shown the variation of the rotor resistance R_2' and the dispersion reactance X_2' , magnitudes reduced at the stator in comparison with the charge.

Keywords:

asynchronous motor, rotorical parameters, frequency.

1. INTRODUCTION

The determination of the charging work characteristics is done, if we know all the parameters from the equivalent scheme in „T”, for the inductive (electric) motor, shown in figure 1.

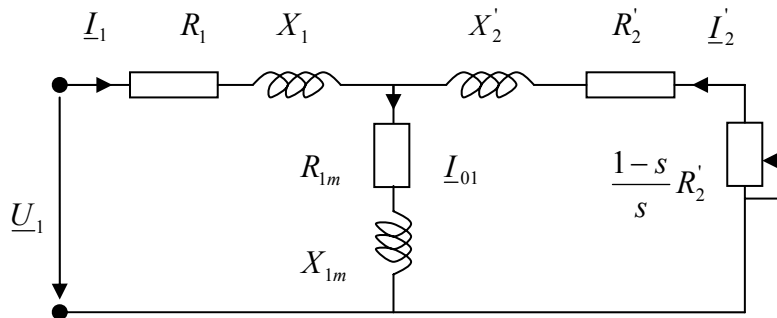


Fig. 1 Equivalent scheme in „T” for the inductive electric motor

The parameters for the sketch below are:

R_1 – the resistance of the statorical phase winding;

X_1 – dispersion reactance of the statorical phase;

R_{1m} – magnetizing rezistance;

X_{1m} – magnetizing reactance;

R_2' – the resistance of the rotor winding, reduced at the stator;

X_2' – the dispersion reactance of the rotor winding, reduced at the stator.

In many simulations, the parameters are treated like to be steady at a frequency of $f_1=50$ Hz.

These suppositions make that the final results given by the machine model, in a certain regime, clear-away from reality.

To take into account the influence of the rotorical frequency f_2 , on the rotorical parameters, improve the machine model, based on the equivalent scheme in „T”. We try to improve a new modality to find out which of the rotorical

parameters are implicit functions to the rotorical frequency. These determinations are made on the short-circuit evidence at a variable frequency [1], [2].

In the mathematical relations of the resistance and reactance we introduce the corrective coefficients:

$$R_2'(f) = C_R R_2' \quad (1)$$

$$X_2'(f) = C_X X_2' \quad (2)$$

where:

$$C_R = \frac{A_1 S_r + B S_x}{R_2' (S_r^2 + S_x^2)} \quad (3)$$

$$C_X = \frac{B S_r - A_2 S_x}{X_2' \left(\frac{f}{50} \right) (S_r^2 + S_x^2)} \quad (4)$$

$$A_1 = R_2' R_{1m} \left(\frac{f}{50} \right) + X_2' X_{1m} \left(\frac{f}{50} \right)^2 \quad (5)$$

$$A_2 = R_2' R_{1m} \left(\frac{f}{50} \right) - X_2' X_{1m} \left(\frac{f}{50} \right)^2 \quad (6)$$

$$B = R_2' X_{1m} \left(\frac{f}{50} \right) + X_2' R_{1m} \left(\frac{f}{50} \right)^2 \quad (7)$$

$$S_r = R_2' + R_{1m} \left(\frac{f}{50} \right) \quad (8)$$

$$S_x = X_2' \left(\frac{f}{50} \right) + X_{1m} \left(\frac{f}{50} \right) \quad (9)$$

In this relations R_2' , R_{1m} , X_{1m} , X_2' are corresponding to a nominal frequency ($f_1=50$ Hz).

2. EXPERIMENTAL PARAGRAPH

We consider a triphases asynchronous motor, with a nominal power $P_N=4$ KW at 1500 rot/min, supplies by a nominal voltage $U_1=220$ V.

The electrical parameters found-out on the schort-circuit evidence and discharge working regime at a frequency of 50 Hz are next:

$$R_1 = 1,694\Omega ; R_2' = 1,124\Omega ; R_{1m} = 3,690\Omega ;$$

$$X_1 = 2,323\Omega ; X_2' = 2,529\Omega ; X_{1m} = 59,410\Omega .$$

In figure 2 it is shown the variation of C_R and C_X coefficients in comparison with the rotorical frequency.

In figure 3 it is shown the rotorical impedance deviation, to rotorical impedance at a frequency of 50 Hz.

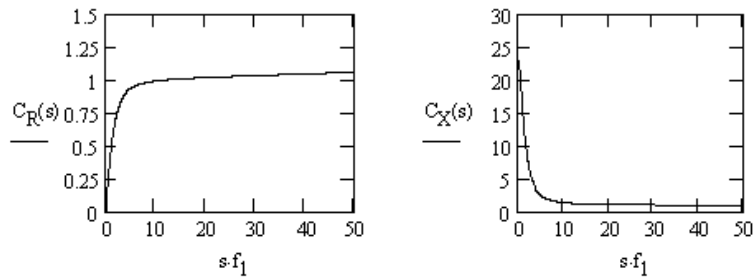


Fig.2. The variation of C_R and C_X coefficients.

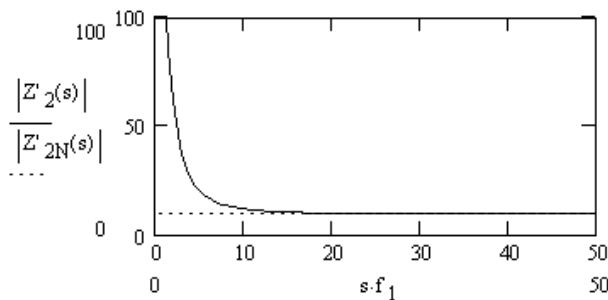


Fig.3. The rotorical impedance, to frequency.

3. CONCLUSIONS

The corrective coefficients C_R and C_X that we introduce in the relations (1) and (2) have major variations, from 0÷10 Hz.

In figure 3 Z'_{2N} is the value of the rotorical impedance is calculated at the nominal frequency.

As we have already expected important variations of the rotative impedance are at low frequency from 0÷10 Hz.

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**A HYBRID METHOD, COMBINING
HIERARCHIC AND COGNITIVE
MODELS, FOR THE MODELING
AND SIMULATION OF COMPLEX
SYSTEMS**

Abstract

Complex decision making in a complex, dynamic environment is often a very difficult task. Investigation into huge amount of multivariate data is needed to extract and manipulate information distributed within, so that decision making can be soundly sustained.

Keywords:

cognitive models, hierarchical structure, fuzzy numbers, cognitive map.

1. INTRODUCTION

Decision support systems built for this purpose should have advanced features such as:

- Good explanation facilities, preferably presenting the decision rules used;
- Dealing with vague, fuzzy information, as well, as with crisp information;
- Dealing with contradictory knowledge, e.g. when two experts predict different trends in the stock market;
- Dealing with large data bases with a lot of redundant information, or coping with lack of data.
- Hierarchical organization, i.e., they can involve different levels of processing, comparing different possible solutions, using alternatives, sometimes in a recurrent way.

Techniques of computational intelligence, such as artificial neural networks, fuzzy logic systems, genetic algorithms, advanced statistical methods, along with traditional statistical and financial analysis methods, have been widely applied on various problems in finance and economics. First of all, it must be noticed, that in the field, like economics, the expert's knowledge is always used. This expert's knowledge is the basis of each economic decision support system. Rule-based system and fuzzy rule-based system in particular have been used in financial and economic decision making. The main advantage of rule-based systems is that their functioning is based on expert rules. The main disadvantage is that these systems are not flexible enough to react to changes in the data. It is proposed to decompose the data domain involved into two parts: the fuzzy hierarchy of the purposes and tasks, which is changed only in a crisis situation, and a cognitive map of the situation, which is changed at each receipt of new information in the system.

2. THE HYBRID METHOD

The structure of the hierarchy of the purposes and tasks holds the main factors of the involved data domain and the links between these factors, which stay invariant. This hierarchical structure is determined by the experts of this domain. Only in the crises situations this structure can be changed, but these changes must be controlled by the expert's rules. The development of the hierarchy is made by the experts, they select the main factors and determine they levels and the links between them. The meta-levels of the structure are the following: first level is the level of the global aim; the others are levels of the criteria, which determine the global aim. The last level is the level of factors with a set of values. The links in the hierarchy define the dependency between the upper level element's realization and the corresponding underlying level element's realization.

After hierarchy construction, the elementary estimations should be made by experts. The elementary estimation consists on the getting for certain vertex $i \in V_m$ paired estimations $r_{jk}^{(i)}$ of the arcs weights $(i, j) \in W$, $j \in \Gamma_i = \{k \mid (i, k) \in W\}$. Paired estimations show, in how many times the contribution of the object j is more than the contribution of the object k in the achievement of the object i aim; $j, k \in \Gamma_i$. The proposed method of the hierarchy analysis allows to get the experts estimations as exact ($r_{jk}^{(i)} \in R_+$ - nonnegative numbers), interval ($r_{jk}^{(i)} = [a_{jk}^{(i)}, b_{jk}^{(i)}] \subset R$ - intervals) or fuzzy numbers ($r_{jk}^{(i)} = \{(t, \mu_{jk}^{(i)}(t)) \mid t \in R_+\}$ - closed convex fuzzy sets on R_+). The last case includes the linguistic estimates and two previous cases. Thereby, we get as a result of an elementary estimation a binary relation $R^{(i)} = \{(j, k), r_{jk}^{(i)} \mid j, k \in \Gamma_i\}$ on the objects set Γ_i , which gives the intensity of the objects superiority. After

getting the estimations, we must average them. In each of the elementary estimations may participate several experts, so for some pairs (j, k) of the objects $j, k \in \Gamma_i$ different experts s can assign different estimations $r_{jk}^{(i)s}$ (s – expert’s number). The procedure of the expert estimation averaging consists in the determination of the mean geometric estimation. The result of the pairs estimations average in the i elementary estimation – exact, interval or fuzzy relation $R_{(i)}$ – is used in the determination of the weights $y_{i,j}$, of all the arcs $(i, j) \in W$, coming out of the vertex i. The arcs weights satisfy the following condition:

$$\sum_{j \in \Gamma_i} y_{ij} = 1; \quad y_{ij} \geq 0, \quad \forall i \in \Gamma_i$$

If there are several objects on the first level y_1 , then the “zero” elementary estimation is made, it means, that the pair comparison of the objects importance coefficients must be made. As a result of the “zero” estimation, the importance coefficients of the first level objects are determined. After the elementary estimations results processing, the importance coefficients z_j of the objects $j \in V_1$ of the first level of the hierarchic structure are determined. And also the weights y_{ji} of all the arcs $(i, j) \in W$ are determined (the coefficients of the relative importance of the vertex $Y_{ji}^{(s)}$ for the vertex $Y_i^{(s-1)}$ of the nearest upper level, where s – is a level number. The weights of the underlying level objects are determined by the recurrence from top to bottom recalculation of the objects weights (objects importance coefficients):

$$z_i = \sum_{j \in \Gamma_i^{-1}} y_{ji} z_j, \quad i \in V_2,$$

.....

$$z_i = \sum_{j \in \Gamma_i^{-1}} y_{ji} z_j, i \in V_M$$

$$(\Gamma_i^{-1} = \{j \mid (j, i) \in W\}).$$

Directly influenced factors are situated on the hierarchy last level. The realization of these factors (they represent the factors with a set of taken values), spreading upwards on consecutively located levels of the factors hierarchical structure, will bring into the realization of all above located factors and, finally, - to the achievement of the global aims of the considered complex object development. Last level's factors are also independent and have no links between each other. Obviously, in reality, the actions have the links between each other. That why, the hierarchic model is insufficient. To allow this contradiction, we will use the cognitive model.

The cognitive model allows analyzing the currant situation state. The current situation state model is presented by the graph, which is called a cognitive map. To each node of the map corresponds a function f_i , which is called a factor. In each moment of time a factor takes on a value from a linear ordered set. These sets are called scales. The factor's value is also called factor's expression rate. If these values are measurable in impartial scores, then they form a quantitative scale. But, more typical for the natural systems is the case, where factor's expression rate can not be measured directly and can only be estimated by the expert as a linguistic value. The set of these values must be also ordered and forms a linguistic scale. Hereinafter f_i will denote the name of the factor i . Its value in the moment of time t will be denoted as $x_i(t)$. The vector $X(t) = (x_1(t), x_2(t), \dots, x_n(t))$ of all the factors values in the moment t forms a situation state at the moment t .

The variable w_{ij} , assigned to the branches (f_i, f_j) , is numerical and can take on all real values. It is called link's weight (f_i, f_j) and characterizes the intensity of the influence of the factor f_i on the factor f_j . The variables w_{ij} whole is given by the contiguity

matrix of the graph $W = ||w_{ij}||$. Variable value w_{ij} , i.e. the influence intensity f_i on f_j generally depends on the factor f_i value. But, practically, the branches weights are changed seldom, that why they can be considered as constant. A cognitive model is established, if

- Set of situation factors $F=\{f_i\}$; is established
- Linguistic (Z_i) and numerical (X_i) scales are established and also the reflection $Z_i \rightarrow X_i$ is given
- Established cause-and-effect relations between factors, which are given by the contiguity matrix of the oriented graph $W=|w_{ij}|$.
- The initial incremental vector of the situation factors $P(t) = (p_1(t), p_2(t), \dots, p_n(t))$ is defined.

The task is to find the incremental vector of the situation factors $P(t), P(t+1), \dots, P(t+n)$ and the situation states $X(t), X(t+1), \dots, X(t+n)$ in successive discrete moments of time $t, t+1, \dots, t+n$.

This task is accomplished with the aid of some matrix algorithms (for example, the algorithm of the transitive closure).

The factors of both models represent the same situation in the involved data domain, but their sense differs. The factors in the hierarchy represent the main aim to reach and the criteria of the general aim realization. The last hierarchy level contains the concrete actions, which can confront with the factors in the cognitive model. The cognitive model's factors represent the concrete actions and the links between them. But, we can simply take the factors from the last hierarchical level and consider them as cognitive factors. The factors on the last level are the concrete actions which exert influence on the upper factors. And the cognitive model gives all the actions of the situation. It exist a univocal correspondence between a subset of cognitive factors and the set of the last level's hierarchical factors. Each factor in the cognitive has its value, which is defined in each moment of time from the cognitive map. Each factor in the hierarchy has only the importance coefficient, which shows the contribution of this factor in the realization of the global aim, but doesn't have the concrete

quantitative value. The synthesis of both models occurs independently from each other, for their synthesis different expert estimations are required. After this synthesis, we need to compare the corresponding factors. To construct the correspondence between the factors it is proposed to use the expert's rule-based algorithm.

3. CONCLUSION

The situation modeling in the fuzzy environment, like sociology, economics etc requires first of all the expert's knowledge. All the fuzzy data domain modeling systems are built with the expert's participation. The proposed method gives the possibility to distinguish the global aims and the backbone factors of the situation. Also the method allows to follow up the situation state and to have the values of the situation factors in each moment of time.

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