

Master of Technology

Computational Intelligence II

Introduction to Fuzzy Logic

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Objectives

- To provide an introduction to fuzzy logic and fuzzy systems.

Fuzzy Logic 101 Videos

An Egg-Boiling Fuzzy Logic Robot

https://www.youtube.com/watch?v=J_Q5X0nTmrA

Fuzzy Logic: An Introduction

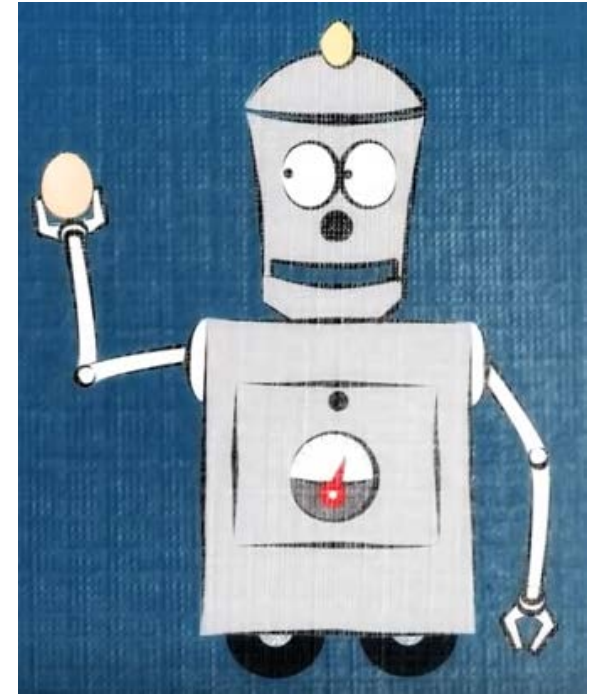
<https://www.youtube.com/watch?v=P8wY6mi1vV8>

What is Fuzzy Logic? - Professor Bob John

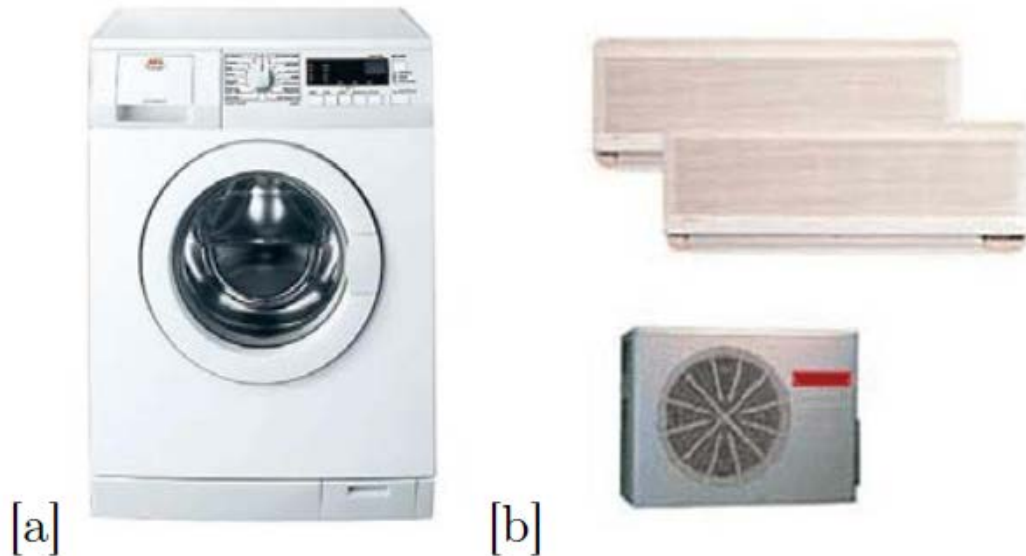
<https://www.youtube.com/watch?v=T-kdIrRfM9k>

Real-Time Fuzzy Logic Control of an Inverted Pendulum

<https://novom.ru/en/watch/rTrxLqSk0Kc>



Fuzzy Systems at Home



Adaptive Non-singleton Type-2 Fuzzy Logic Systems: A Way Forward for Handling Numerical Uncertainties in Real World Applications

Author(s): N. Sahab, H. Hagra

A practical application of fuzzy control for an air-conditioning system

Author(s): ToshikazuTobi,
ToshiharuHanafusa

Figure 1 shows two examples of fuzzy logic usage in domestic appliances which are the AEG washing machine [8] (shown in Figure 1a) and the Hitachi air conditioner [9] (shown in Figure 1b). According to the John Lewis website about a top brand washing machine from AEG and reporting about the fuzzy logic washing machine, the website mentions "fuzzy logic circuit detects when the laundry is out of balance and re-jig it accordingly, ensuring minimum wear and tear to the drum bearings. The fuzzy logic also detects half loads, if too much detergent has been added and adds extra rinses if required" [8]. Hence, for the past thirty years fuzzy logic and its applications became embedded in our everyday environments.

More Fuzzy Systems

Fuzzy Logic in Intelligent System Design Theory and Applications

Fuzzy Logic in Medicine

An Expert System Based on Fuzzy Bayesian Network for Heart Disease Diagnosis	191
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M.H. Fazel Zarandi, A. Seifi, M.M. Ershadi, and H. Esmaeeli

A Hybrid Intelligent System Model for Hypertension Risk Diagnosis	202
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Ivette Miramontes, Gabriela Martínez, Patricia Melin, and German Prado-Arechiga

Applications of Fuzzy Logic

Two Hybrid Expert System for Diagnosis Air Quality Index (AQI)	315
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Leila Abdolkarimzadeh, Milad Azadpour, and M.H. Fazel Zarandi

Fuzzy Rule Based Expert System to Diagnose Chronic Kidney Disease	323
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M.H. Fazel Zarandi and Mona Abdolkarimzadeh

A Theory of Event Possibility with Application to Vehicle Waypoint Navigation	329
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Daniel G. Schwartz

Advances in Intelligent Systems and Computing 648

Patricia Melin
Oscar Castillo
Janusz Kacprzyk
Marek Reformat
William Melek *Editors*

Fuzzy Logic in Intelligent System Design

Theory and Applications

 Springer

Deep Learning Fuzzy Hybrid System

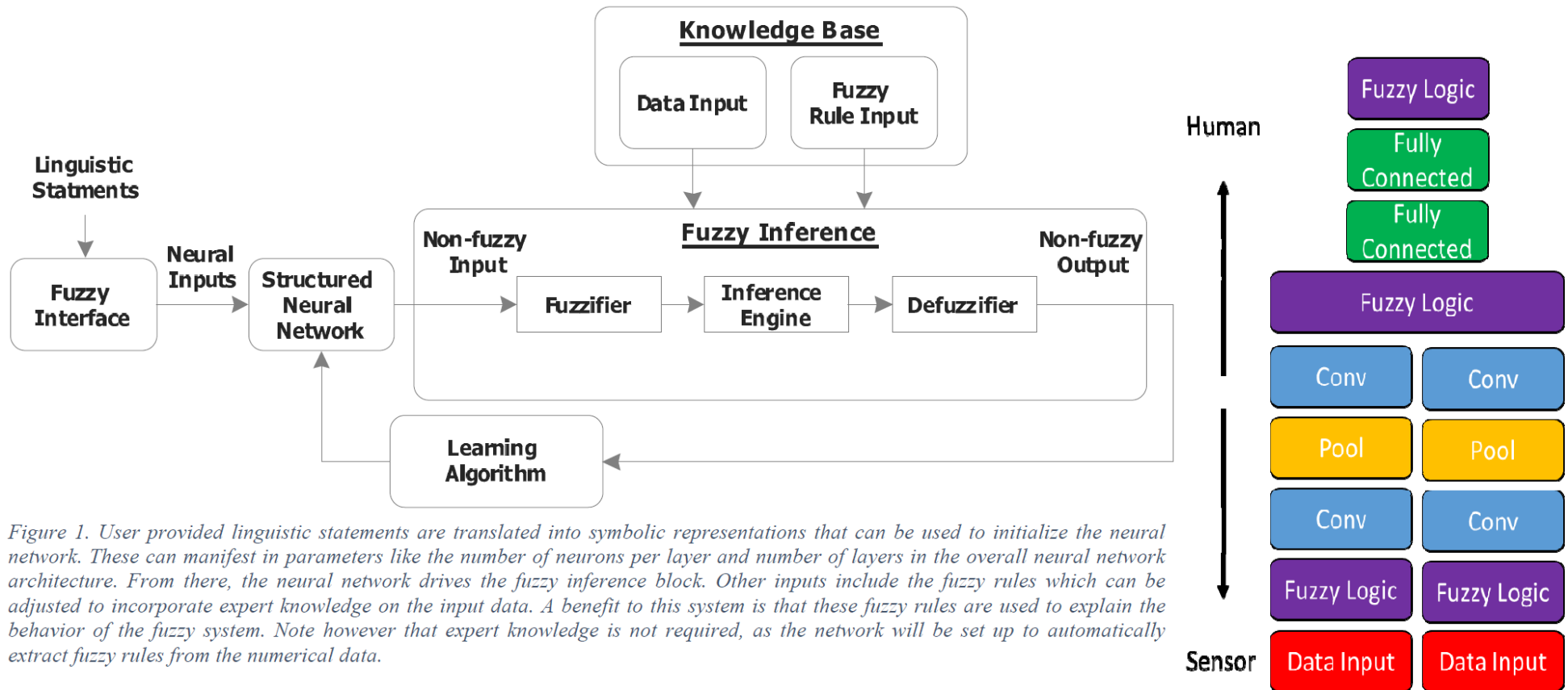


Figure 1. User provided linguistic statements are translated into symbolic representations that can be used to initialize the neural network. These can manifest in parameters like the number of neurons per layer and number of layers in the overall neural network architecture. From there, the neural network drives the fuzzy inference block. Other inputs include the fuzzy rules which can be adjusted to incorporate expert knowledge on the input data. A benefit to this system is that these fuzzy rules are used to explain the behavior of the fuzzy system. Note however that expert knowledge is not required, as the network will be set up to automatically extract fuzzy rules from the numerical data.

An approach to explainable deep learning using fuzzy inference

Author(s): [David Bonanno](#), Kristen Nock, [Leslie Smith](#), Paul Elmore, Fred Petry

Machine Learning Algorithmic Trading GA-Fuzzy Hybrid System

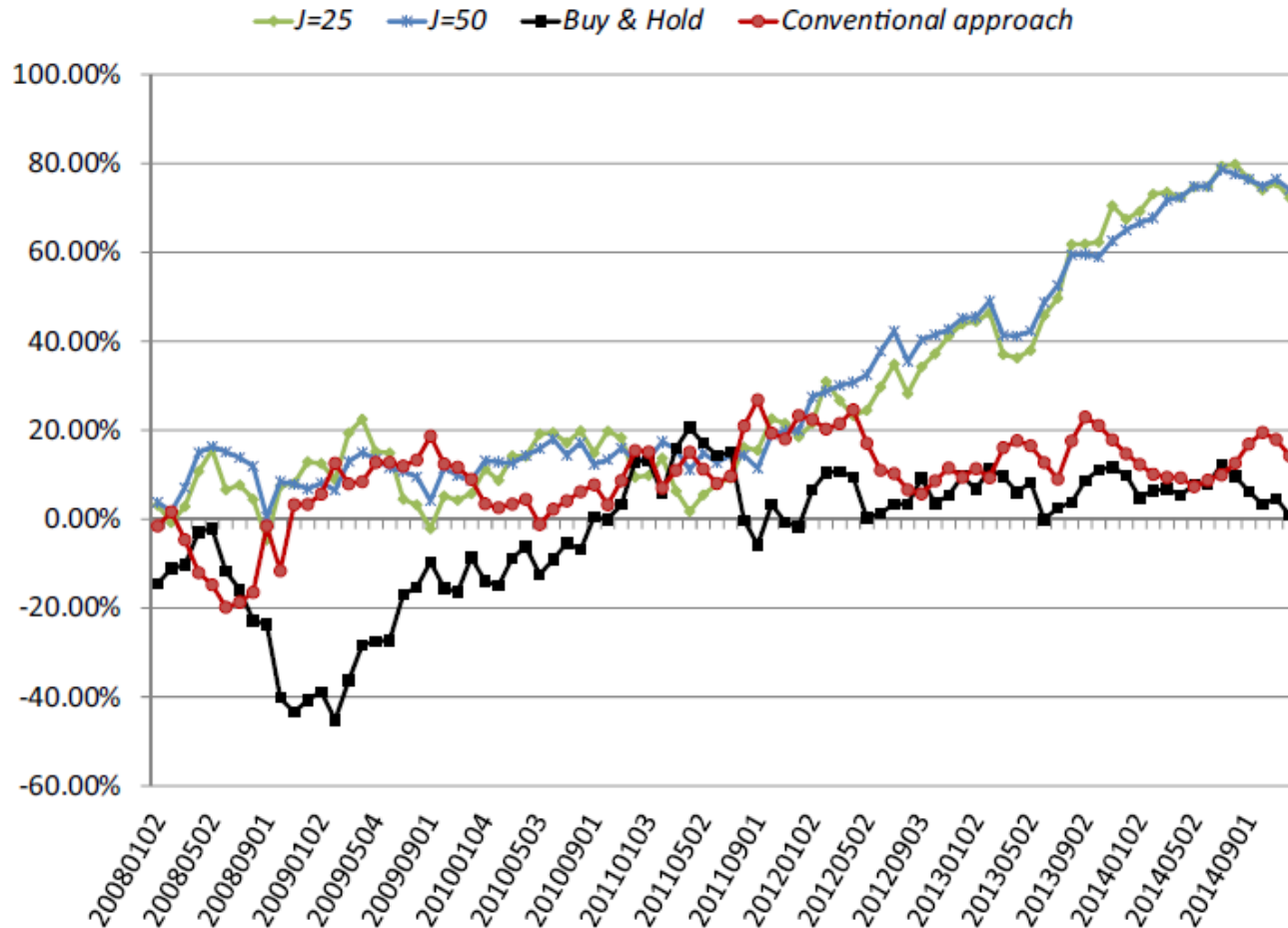


Fig. 6. Cumulative return for the rule discovery mechanism using a 6 month training period.

An intelligent hybrid trading system for discovering trading rules for the futures market using rough sets and genetic algorithms

Author(s):

[YoungminKim^a](#)

[WonbinAhn^b](#)

[Kyong JooOh^b](#)

[DavidEnke^c](#)

Knowledge Engineering

- Knowledge engineering (KE) comprises
 - » Methodologies, techniques, and practical approaches for the successful development of knowledge-based systems (KBS) — intelligent systems in broad sense.
- *Knowledge imperfection*
 - » An important issue in the design of KBS is how to equip human knowledge that often appears to be uncertain, imprecise, and incomplete to some degree.
 - » Traditional AI (symbolic AI) theory does not accept knowledge imperfection

Human Concepts & Mathematical Models

- Most human concepts lack a rigorous definition.
 - » We apprehend the inner and the outer world by vague feelings which become progressively more precise.
- Mathematical models are built for some of them
 - » but, unfortunately, *the more rigorous the model, the less similar to reality.*
 - » The subtle behaviour of the natural world (as we perceive it) cannot be modelled by rigid axioms.

Lack of Definition or Lack of Information

- The theory of fuzziness is to build models for entities which lack a rigorous definition.
 - » The concept of "graded membership" belongs to a class which *lacks a rigorous definition*.
 - » It is not compatible with a concept suitable for the *lack of information*, which is with probability.

Imprecision of Knowledge in Real World


- *Fuzzy concepts*
 - » The girl is *very tall*.
 - » This student is *good* in Math.
 - » It is *very hot* today.
- Recognition using fuzzy concept:
 - Did you see an *old* and *short* woman
- Decision of action (control) by rules with fuzzy concepts:
 - IF temperature is *high* THEN set the aircon *strong*
 -
 - IF the clothes is *dirty* THEN wash *long* time
 -

Imprecision of Knowledge in Real World (cont.)

- *Fuzzy number*

- » Many quantifiable phenomena do not lend themselves to being characterised in terms of absolutely precise numbers
 - ◆ e.g. an invitation to dinner at “around six-thirty”
 - ◆ e.g. a cake weighs “approximately 2 pounds”
- A fuzzy number is usually described in terms of
 - » a number word and a linguistic modifier, such as *approximately, nearly, around*, etc.

A Brief History

- 1965 Fuzzy Set Theory was introduced by Prof. Lotfi A. Zadeh (UC Berkeley, USA)


Professor L.A. Zadeh,
the father of fuzzy logic
picture: Wikipedia
- 1974 Late Prof. Ebrahim Mamdani (Queen Mary College in London, England) successfully applied the Fuzzy IF-THEN rule reasoning for automatic operation of a steam engine and that was the beginning of fuzzy control application
- 1980 The industrial application report of a fuzzy controlled automatic operation system in a cement factory in Denmark was published
- 1985 The first International Fuzzy System Association (IFSA) World Congress was held

A Brief History (cont.)

- 1987 Many applications of fuzzy control were published
- 1989 The application of fuzzy logic to home electronics in Japan made a “fuzzy boom”
- 1990s The fuzzy boom in Japan had a strong impact on Korea and the United States.
- 2000s School of neuro-fuzzy hybrid systems
- 2010s School of deep learning fuzzy hybrid systems

Today much research is carried out in world wide.

Find out more from NUS Library

Fuzzy Logic is not Fuzzy

- Fuzzy logic is a precise logic of imprecision and approximate reasoning. (alike human reasoning)
- Fuzzy logic is much more than a logical system.
 - » It has many facets. The principal facets are
 - ♦ logical,
 - ♦ fuzzy-set-theoretic,
 - ♦ epistemic, and
 - ♦ relational
- Fuzzy logic system is a form of cognitive system & natural language processing system, which can handle linguistic elements.

Fuzzy Logic is not Fuzzy (cont.)

- Most of the applications of fuzzy logic involve the concept of a *linguistic variable* and the machinery of fuzzy if-then rules.
 - » The formalism of linguistic variables and fuzzy if-then rules is associated with the relational facet.
- The cornerstones of fuzzy logic are *graduation*, *granulation*, *precisiation* and the concept of a *generalized constraint*.
 - » Graduation should be understood as an association of a *concept* with *grades* or *degrees*, e.g.
Temperature/Coldness: *seriously* cold, *very* cold, *rather* cold, *pretty* cold, and so on...

Some Quotes on Fuzzy Logic

- All traditional logic habitually assumes that precise symbols are being employed. It is therefore not applicable to this terrestrial life but only to an imagined celestial existence”
— philosopher B. Russell (1923)
- “Everything is vague to a degree you do not realize until you have tried to make it precise”
— B. Russell (1956)
- “Tyranny is one choice. Binary is next with two choices. Fuzzy gives a whole spectrum of choices.”
— Bart Kosko
- “As the complexity of a system increases, our ability to make precise and yet significant statements about its behavior diminishes until a threshold is reached beyond which precision and significance/ relevance become almost mutually exclusive characteristics”
---- Lotfi Zadeh (1973)

Fuzzy Logic: Broad Sense and Narrow Sense

- The term *fuzzy logic* has been used in the literature in two different senses
 - » Broad sense
 - ◆ is viewed as a system of concepts, principles, and methods for dealing with modes of reasoning that are approximate rather than exact.
 - » Narrow sense
 - ◆ is viewed as a generalization of the various multivalued logics, which have been studied in the area of symbolic logic since the beginning of last century

Fuzzy Logic: Terms with “Fuzzy”

- *Fuzzy Set (Fuzzy Set Theory)*
 - » the early development of fuzzy theory
 - » an extension (generalization) of set theory
 - » the foundation of fuzzy mathematics
- *Fuzzy Logic* (narrow sense)
 - » an extension (generalization) of binary logic
 - » mainly refer to approximate reasoning
 - » for knowledge representation and inference with imprecise, incomplete, uncertain or partially true information
- *Fuzzy Mathematics*
 - » refer to the research efforts related to fuzzy theory (in mathematical aspects) and also applications

Fuzzy Logic: Terms with “Fuzzy” (cont.)

- *Fuzzy Engineering*
 - » refer to the research and development activities, achievements related to fuzzy theory and applications in wide areas
- *Fuzzy Technology (Fuzzy Systems)*
 - » widely used now, refer to all the achievements related to “fuzzy” approaches, “fuzzy” methods, and their applications
- *Fuzzy Logic* (broad sense)
 - » the latest definition by Zadeh, includes all the efforts mentioned above

What FL Comprises: **from KE point of view**

- Representation of imprecise and vague knowledge
- Reasoning with imperfect knowledge
- Information processing with imprecision and uncertainty
- Application of fuzzy logic in Knowledge Based Systems
 - » Greatly extends the ability of the traditional rule-based systems by fuzzy granulation

Types of Uncertainty

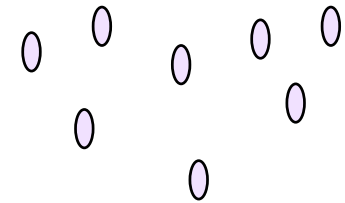
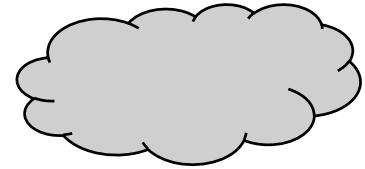
- *Fuzziness* and *randomness* deal with different types of uncertainty in our life

Is it going to rain tomorrow?

- ◆ The event may or may not happen
- ◆ It is objective (determined by natural law)
- ◆ Uncertainty of occurrence

Is it a raining day today?

- ◆ To describe some existing situation
- ◆ It is more subjective
(different people may have different ideas)
- ◆ Uncertainty of classification



Fuzzy Logic and Probability

- Probability describes randomness
 - » is time-dependent
 - ◆ when the die lands on the table top and stops rolling, the face is determined
 - *all probability is gone*
 - ◆ “there is 50% chance of rain tomorrow”, if we wait until tomorrow it will rain or it will not
 - *the uncertainty disappears.*

Fuzzy Logic and Probability (cont.)

- Fuzzy logic handles fuzziness
 - » concerns the ambiguity associated with the actual description of an event
 - » is a calculus of compatibility
 - » much of the descriptive power of fuzzy logic comes from the fact that these *semantic partitions can overlap*
 - ♦ E.g.: *very-small, small, big, very-big*

Why & Where Fuzzy Systems

- Large, complex, non-linear systems without proper mathematical models, or with complex mathematical models
- The systems which need huge computing time for their mathematical models
- The systems which deal with uncertain or incomplete information
- The systems which need to use human experience described by natural languages
- Representatives of fuzzy systems
 - » Fuzzy control systems, fuzzy expert systems, fuzzy optimization, fuzzy clustering, fuzzy-rule-based classification and prediction, ...

Fuzzy Systems: **successful applications**

Fuzzy Automation for Subway Train Operation

- Advantages
 - » fewer break notch (more comfortable)
 - » smaller stop error (stop in correct position)
 - » energy saving

Quay Crane Fuzzy Control Model

- Using fuzzy rules in the form of
 - » IF angle(*large*) THEN move(*fast*)
 - » IF distance(*large*) THEN move(*fast*)to achieve faster stop (time and cost saving)

Fuzzy Systems: **successful applications** (cont.)

Automatic (fuzzy) Washing Machine

- Using fuzzy rules in the form of
 - » IF *few* clothes and they are *soft*
THEN *gentle* flow and *short* washing timewhere *few*, *soft*, ... are based on measure from sensor,
gentle, *short*, ... are fuzzy concepts for control



Fuzzy Cleaner

- Fuzzy control of absorbing power based on the *material* & the *dirty degree* of the floor
 - » if the power is too strong, the nozzle will be absorbed on floor (difficult to operate); if too weak, the dust cannot be absorbed well.

Fuzzy Systems: **successful applications** (cont.)

Human Face Retrieval

- Using the *language impression* for input human face
 - » to make possible retrieval of human face presented by linguistic expression (size, length, figure, colour, ...) from image data: *In a police station, a victim described that the suspect had short black hair, big head, thick eyebrow... and very talkative with pervasive fuzzy logic knowledge...*

Elevator Group Management

- Using fuzzy rules in the form of
 - » IF (there is a calling from upstairs) and
((the elevator(s) are moving up) and
(response of (X) will not cause a *long-waiting*))
THEN (select elevator (X))

to reduce overall waiting time

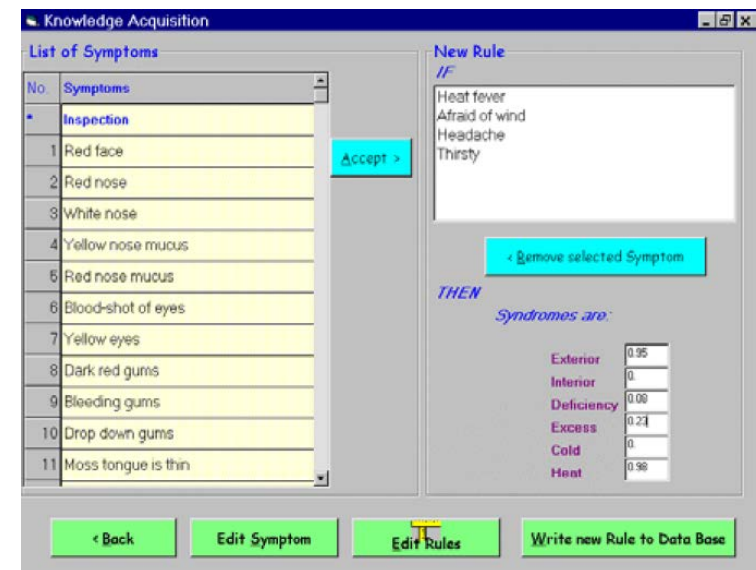
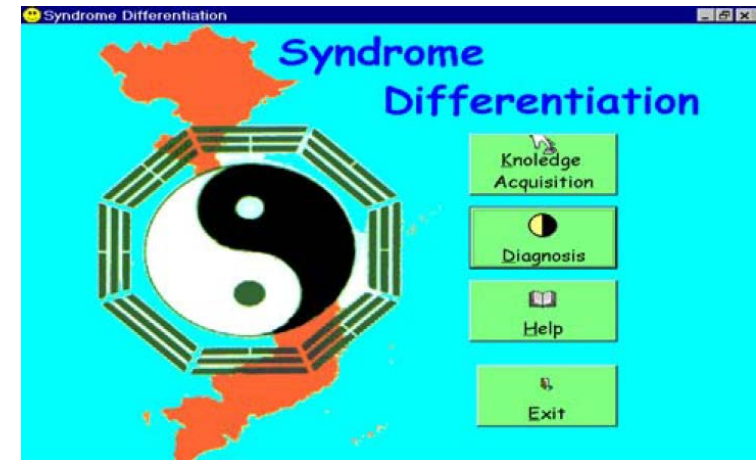
Fuzzy Systems: successful applications (cont.)

Eastern Medical Systems

- Take into consideration of the imperfection of domain knowledge
 - » represent experts' knowledge in fuzzy rules
 - » allow the inputs represented in fuzzy terms
 - » apply fuzzy inference for consultation
 - » possible learning / modifying of fuzzy rules

Building a fuzzy expert system for syndrome differentiation in the oriental traditional medicine

Author(s): PHUONG, NGUYEN HOANG



Impact of Fuzzy Logic

Area

Chem. Tech
Computer Tech.
Entertainment indust.
Household appliances
Industrial plants
Medicine
Optical equipment
Physics
Pollution control
Robotics
Stock market
Food Industry

Improved products

Polymer production,
Fuzzy Neural Networks
TVs, Camcorders
Cookers, Dishwashers, Wash machines
Blast furnaces, Cement Kilns
Disease diagnosis, Pacemakers
Cameras, light sensors
Fuzzy Chaos, fuzzy simulation
Oil spill monitors
Process controllers, Cranes
Fund mgmt., trend prediction
Electronic Nose non-destructive detector

Impact of Fuzzy Logic (cont.)

Transportation	Cars, Buses, Trains
Mathematics	Fuzzy Integral, Fuzzy Metric Spaces
Operations Research	Fuzzy Optimization, Fuzzy Games
Economics	Fuzzy Supply-fuzzy Demand models
Social sciences	Modeling Fuzzy behaviors
Management	Fuzzy Decision Making models
Statistics	Fuzzy Cluster Analysis, Fuzzy Regression Analysis
Financial Engineering	Modeling fuzzy behavior of customers
Reliability Engineering	Fuzzy Reliability Analysis
Nuclear Science/Engg.	Fuzzy Safety Analysis of Nuclear Reactors
Data Mining	Fuzzy Data Mining

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