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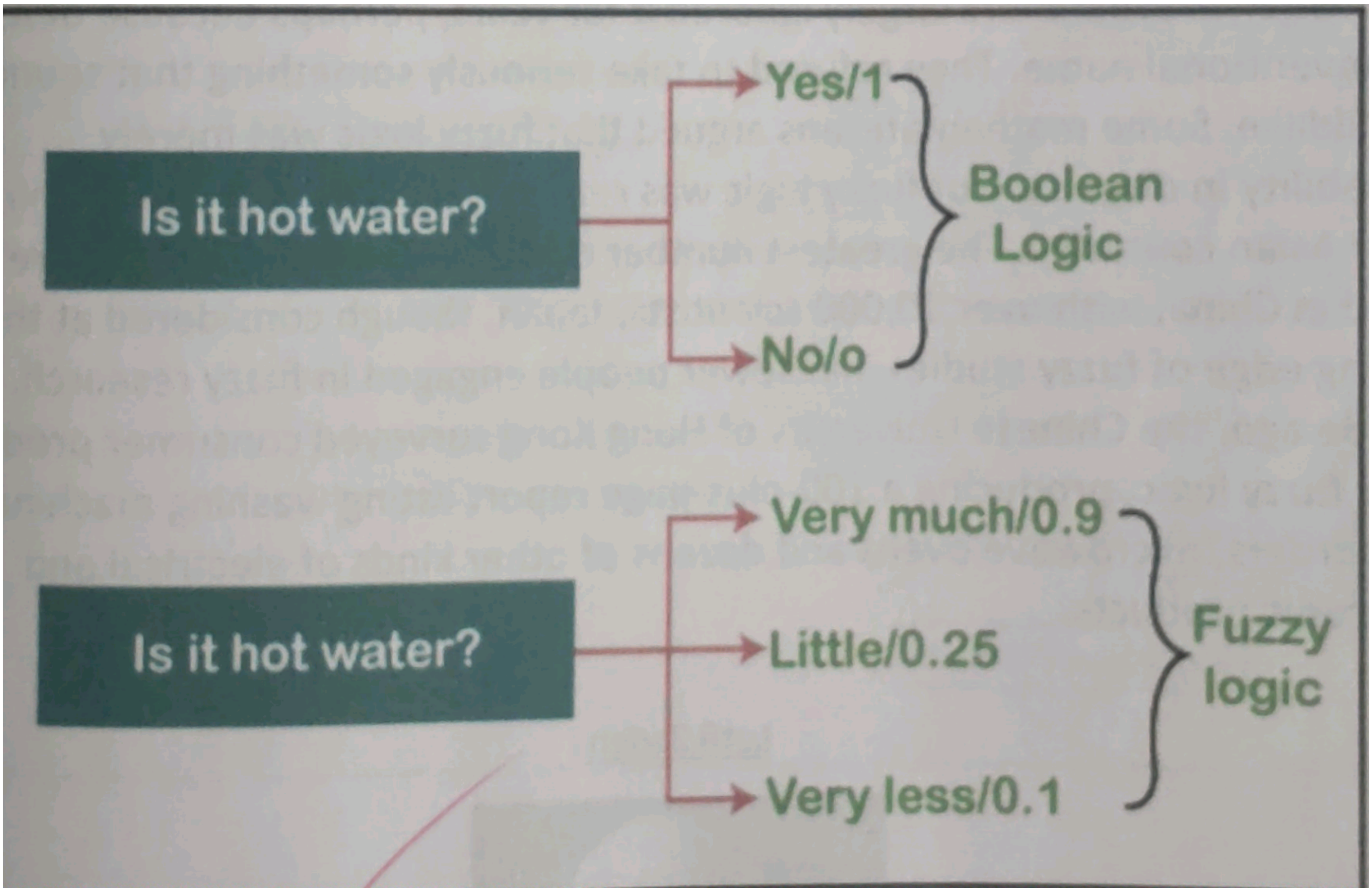

Is it hot water?
Yes/1
No/o
Boolean Logic
Is it hot water?
Very much/0.9
Little/0.25
Very less/0.1
Fuzzy logic

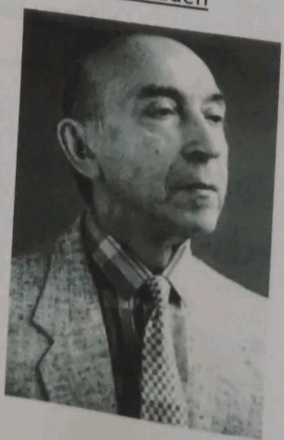
History

The concept of Fuzzy Logic (FL) was introduced by Lotfi Zadeh. He was a professor at the University of California at Berkeley, and it was not presented as a control methodology, but as a way of data processing. According to his observation, unlike other computers, Fuzzy Logic consist a range of possibilities between T or F, in human decisions.

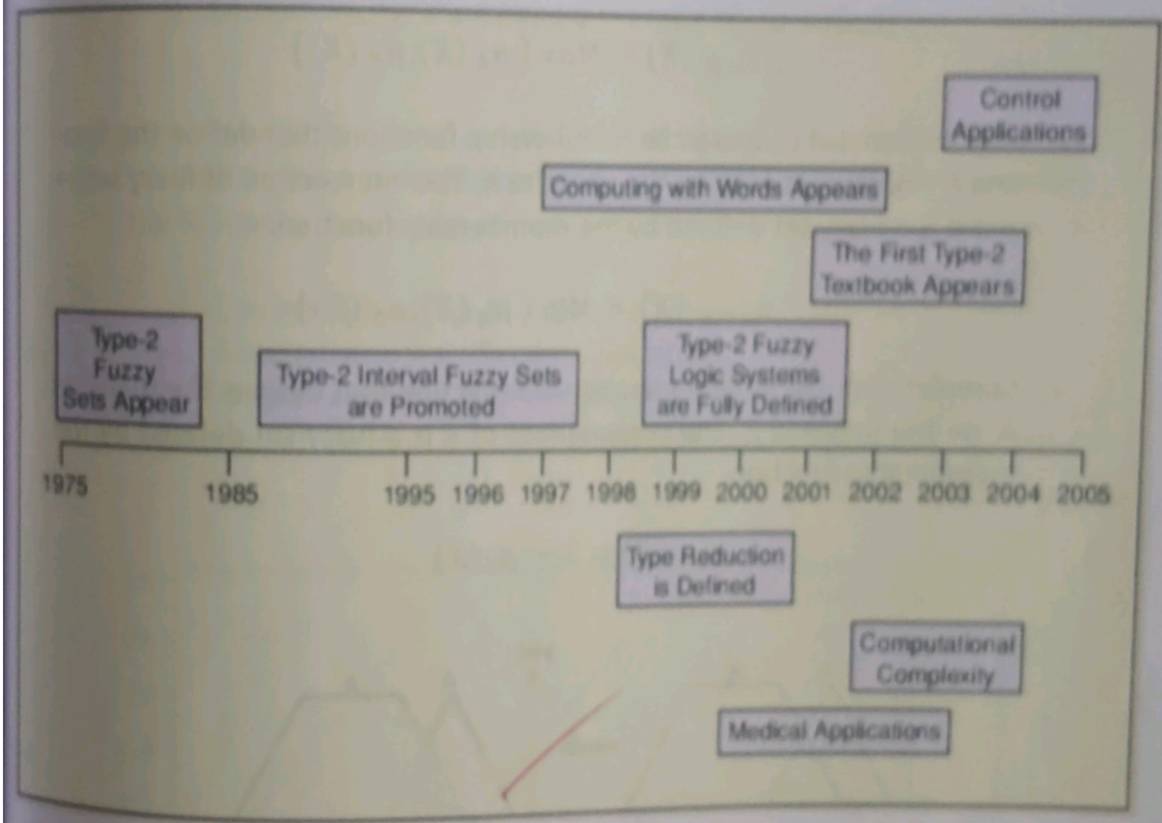
Due to insufficient small-computer capability prior to that time, this approach was not applied until the '70s. Professor Zadeh concluded that people don't require exact numerical information and yet are able to have high adaptive control.

Although, the technology was introduced in the U.S., U.S. and European scientist and researchers largely ignored it for years, perhaps because of its unconventional name. They refused to take seriously something that sounded so childlike. Some mathematicians argued that fuzzy logic was merely probability in disguise. But fuzzy logic was readily accepted in Japan, China and other Asian countries. The greatest number of fuzzy researchers today are found in China, with over 10,000 scientists. Japan, though considered at the leading edge of fuzzy studies, has fewer people engaged in fuzzy research. A decade ago, the Chinese University of Hong Kong surveyed consumer products using fuzzy logic, producing a 100-plus-page report listing washing machines, camcorders, microwave ovens and dozens of other kinds of electrical and electronic products.

Lotfi Zadeh



An Overview



Control Applications
Computing with Words Appears
The First Type-2 Textbook Appears
Type-2 Fuzzy Sets Appear
Type-2 Interval Fuzzy Sets are Promoted
Type-2 Fuzzy Logic Systems are Fully Defined
1975
1985
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Type Reduction is Defined
Computational Complexity
Medical Applications

Operators of Fuzzy Logic

A. Basic Operations:

As in classical logic, in fuzzy logic there are three basic operations on fuzzy sets: union, intersection and complement.

- Union: Let μ_A and μ_B be membership functions that define the fuzzy sets A and B, respectively, on the universe X. The union of fuzzy sets A and B is a fuzzy set defined by the membership function:

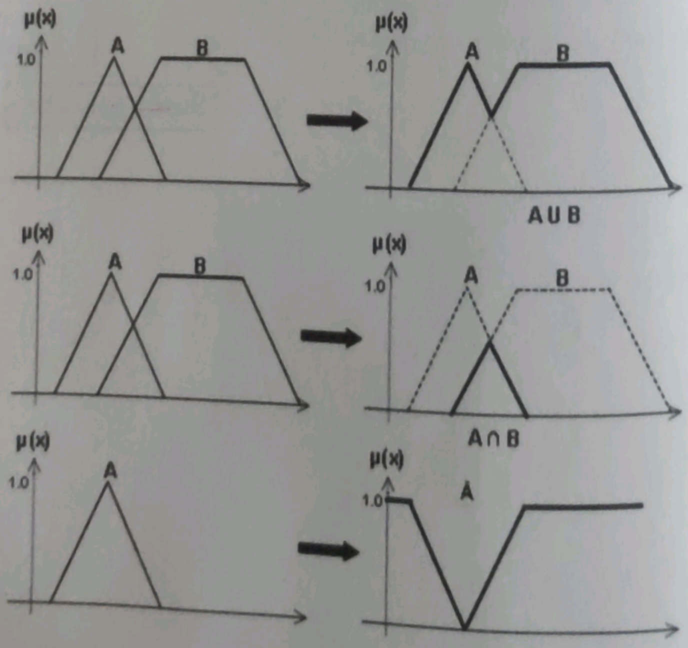
$$\mu_{A \cup B}(X) = Max\left(\mu_A(X), \mu_B(X)\right)$$

- Intersection: Let μ_A and μ_B be membership functions that define the fuzzy sets A y B, respectively, on the universe X. The intersection of fuzzy sets A and B is a fuzzy set defined by the membership function:

$$\mu_{A \cap B}(X) = Min\left(\mu_A(X), \mu_B(X)\right)$$

- Complement: Let μ_A be a membership function that defines the fuzzy set A, on the universe X. The complement of A is a fuzzy set defined by the membership function:

$$\mu_{A^c}(X) = 1 - \mu_A(X)$$

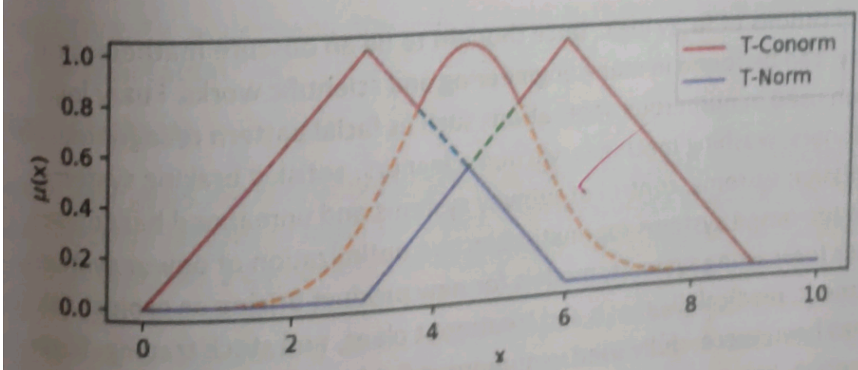


3. t-norms and t-conorms

t-norms and t-conorms are binary operators that generalize intersection and union operations, respectively.

- t-norm: it is a binary operation T: [0,1] x [0,1] → [0,1] which satisfies the following properties:
  - Commutativity: T(a,b) = T(b,a)
  - Associativity: T(a, T(b,c)) = T(T(a,b), c)
  - Identity element: T(a,1) = T(1,a) = a
  - Monotonicity: if a ≤ c and b ≤ d then T(a,b) ≤ T(c,d)

- t-conorm: it is a binary operation S: [0,1] x [0,1] → [0,1] which satisfies the following properties:
  - Commutativity: S(a,b) = S(b,a)
  - Associativity: S(a, S(b,c)) = S(S(a,b), c)
  - Identity element: S(a,0) = S(0,a) = a
  - Monotonicity: if a ≤ c and b ≤ d then S(a,b) ≤ S(c,d)



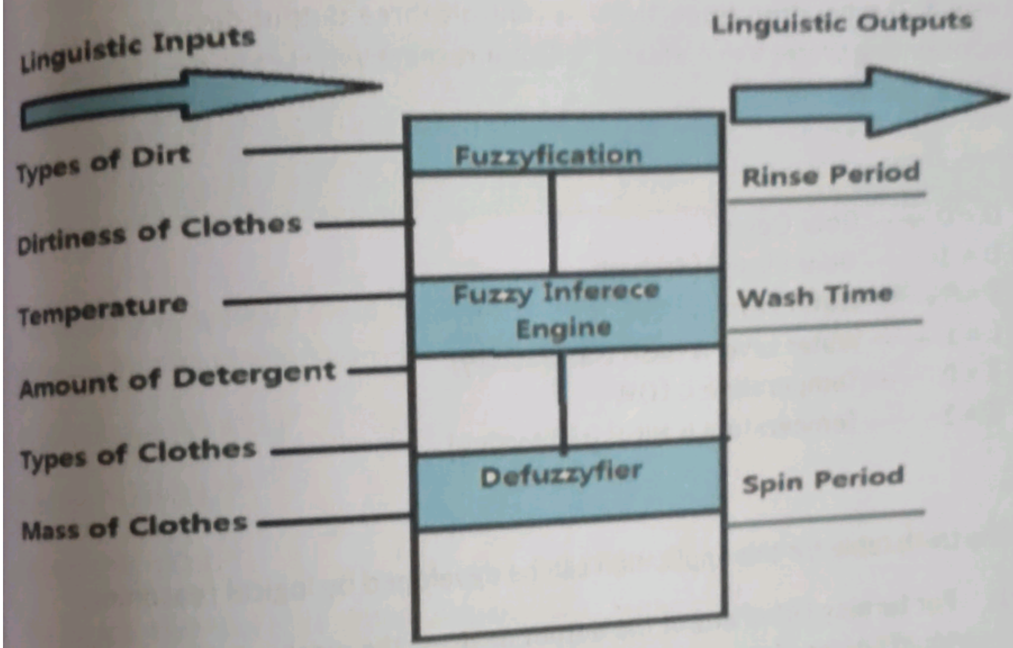
Applications

Fuzzy logic can deal with information arising from computational perception and cognition, that is, uncertain, imprecise, vague, partially true, or without sharp boundaries. Fuzzy logic allows for the inclusion of vague human assessments in computing problems. Also, it provides an effective means for conflict resolution of multiple criteria and better assessment of options. New computing methods based on fuzzy logic can be used in the development of intelligent systems for decision making, identification, pattern recognition, optimization, and control.

Fuzzy logic is extremely useful for many people involved in research and development including engineers (electrical, mechanical, civil, chemical, aerospace, agricultural, biomedical, computer, environmental, geological, industrial, and mechatronics), mathematicians, computer software developers and researchers, natural scientists (biology, chemistry, earth science, and physics), medical researchers, social scientists (economics, management, political science, and psychology), public policy analysts, business analysts, and jurists.

The applications of fuzzy logic, once thought to be an obscure mathematical curiosity, can be found in many engineering and scientific works. Fuzzy logic has been used in numerous applications such as facial pattern recognition, air conditioners, washing machines, vacuum cleaners, antiskid braking systems, transmission systems, control of subway systems and unmanned helicopters, knowledge-based systems for multi-objective optimization of power systems, weather forecasting systems, models for new product pricing or project risk assessment, medical diagnosis and treatment plans, and stock trading. Fuzzy logic has been successfully used in numerous fields such as control systems engineering, image processing, power engineering, industrial automation, robotics, consumer electronics, and optimization. This branch of mathematics has instilled new life into scientific fields that have been dormant for a long time.

Fuzzy Logic in Washing Machines



OBJECTIVE: To understand the use of AND-NOT gates in washing machine control application.

INTRODUCTION

When logic gates are connected together to produce a specific output for certain specific combinations of input variables, with no storage involved, the resulting circuit is called as a *Combinational logic* circuit. The combination of basic gates can be used for variety of applications such as washing machine control, level monitoring and indicating applications in manufacturing processes, elevator control applications, warning indicating applications and binary addition - subtraction and multiplication circuits.

WASHING MACHINE CONTROLLER

Consider a three-sensor based washing machine controller. Let the three sensors be: *Door Sensor, Water Level Sensor and Temperature Sensors* that produce *digital outputs*. Let the controlling action include control of: *Water Valve, Heater and Motor*. All these are digitally controlled devices.

CONCEPT

The motor of the washing machine turns ON when the *right temperature*, the *right water level* and obviously when the *door of the machine is closed*.

The system design involves three inputs: D, L & T representing Door position, Level & Temperature respectively. It controls three output devices: W, H & M representing Water Valve, Heater & Motor respectively. Let us decide the logics behind the system:

D = 0 ------- Door Open;
D = 1-------- Door Closed (desired)
L = 0 --------Water Level is LOW;
L = 1 --------Water Level is HIGH (satisfactory)
T = 0 --------Temperature is LOW
T = 1 --------Temperature is HIGH (right value)

The truth table for this application can be developed by logical reasoning:

1. For turning ON of any of the output devices, *the washing machine door/lid should be closed* at any point of time, so only last four cases of the truth table should to be considered where D takes a value 1.
2. If door is closed & water level is low, the water valve should be turned ON.
3. If door is closed, water level is satisfactory & the temperature is low, the heater should be turned ON.
4. Whereas when the door is closed, water level is satisfactory and the temperature is right, the motor should turn ON.

Door D	Level L	Temperature T	Valve V	Heater H	Motor M
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	0	0	0
0	1	1	0	0	0
1	0	0	1	0	0
1	0	1	1	0	0
1	1	0	0	1	0
1	1	1	0	0	1

Considering only those input conditions that produce a HIGH output, we get the reduced Boolean expressions for controlling as follows:

Water Valve (V) = D.L'

Heater (H) = D.L.T'

Motor (M) = D.L.T

The logical diagram is as shown below.