Traditional (crisp) logic

In 300 B.C. Aristotle formulated the law of the excluded middle, which is now the principle foundation of mathematics.

$$A \bigcup \overline{A} = X$$

X must be in a set of A or in a set of not A.

Traditional (crisp) logic

A rose is either RED

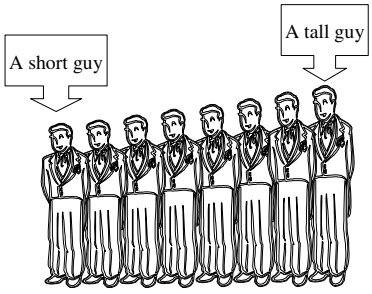
or not RED.

Traditional (crisp) logic

What about this rose?

What color is this leopard?

Is this glass full or empty?



At what point short people become tall?

What is fuzzy logic?

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth – the truth values between "completely true" and "completely false".

* http://www.cs.tamu.edu/research/CFL/fuzzy.html

What is fuzzy logic?

A type of logic that recognizes more than simple true and false values. With fuzzy logic, propositions can be represented with degrees of truthfulness and falsehood. For example, the statement, today is sunny, might be 100% true if there are no clouds, 80% true if there are a few clouds, 50% true if it's hazy and 0% true if it rains all day.

*http://webopedia.internet.com/TERM/f/fuzzy_logic.html

What is fuzzy logic?

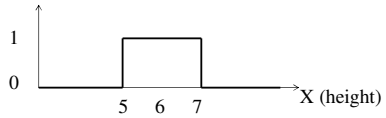
" A form of knowledge representation suitable for notions that cannot be defined precisely, but which depend upon their context. It enables computerized devices to reason more like humans"

* http://www.fuzzylogic.co.uk/

Classical vs. fuzzy logic

Crisp set: membership of element X of set A is defined by

$$\mu_A(x) = \begin{cases} 0, \text{ if } x \notin A, \\ 1, \text{ if } x \in A. \end{cases}$$

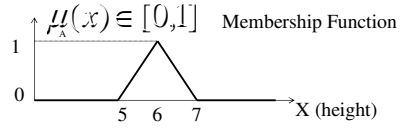


Example: Set of heights from 5 to 7 feet

Classical vs. fuzzy logic

Fuzzy set: Contain objects that satisfy imprecise properties of membership

Example : The set of heights in the region around 6 feet

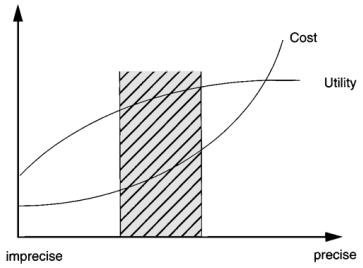


Fuzzy Logic: Motivations

- **Alleviate difficulties in developing and analyzing complex systems encountered by conventional mathematical tools.**
- **Observing that human reasoning can utilize concepts and knowledge that do not have well-defined, sharp boundaries.**

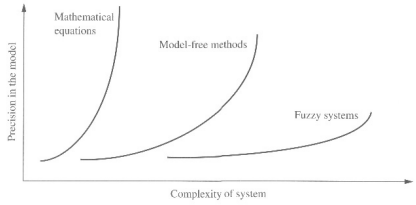
*Fuzzy Logic: Intelligence, Control, and Information - J. Yen and R. Langari, Prentice Hall 1999

Fuzzy Logic: Motivations



*Fuzzy Logic: Intelligence, Control, and Information - J. Yen and R. Langari, Prentice Hall 1999

Fuzzy Logic: Motivations



Complexity of a system versus precision in the model of the system.

*Fuzzy Logic with Engineering Applications, Timothy J. Ross, Prentice Hall 1995

Fuzzy Logic: Motivations

Fuzziness is beneficial for:

- **Complex systems that are difficult or impossible to model**
- **Systems controlled by human experts or systems that use human observations as inputs**
- **Systems that naturally vague (behavioral and social sciences)**

*Fuzzy Logic with Engineering Applications, Timothy J. Ross, Prentice Hall 1995

History of Fuzzy Logic

1964: Lotfi A. Zadeh, UC Berkeley, introduced the paper on fuzzy sets.

- **Idea of grade of membership was born**
- **Sharp criticism from academic community**
  - **Name!**
  - **Theory's emphasis on imprecision**
- **Waste of government funds!**

*Fuzzy Logic: Intelligence, Control, and Information - J. Yen and R. Langari, Prentice Hall 1999

History of Fuzzy Logic

1965-1975: Zadeh continued to broaden the foundation of fuzzy set theory

- **Fuzzy multistage decision-making**
- **Fuzzy similarity relations**
- **Fuzzy restrictions**
- **Linguistic hedges**

1970s: research groups were formed in Japan

*Fuzzy Logic: Intelligence, Control, and Information - J. Yen and R. Langari, Prentice Hall 1999

History of Fuzzy Logic

1974: Mamdani, United Kingdom, developed the first fuzzy logic controller (steam engine control)

1982: First commercial control system using fuzzy logic (cement kiln, Holmblad and Ostergaard)

*Fuzzy Logic: Intelligence, Control, and Information - J. Yen and R. Langari, Prentice Hall 1999

History of Fuzzy Logic

1976-1987: Industrial application of fuzzy logic in Japan and Europe

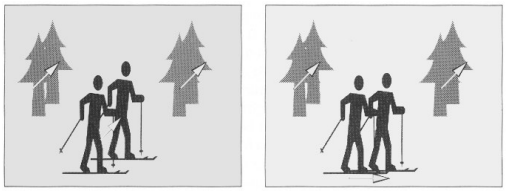
1987- Present: Fuzzy Boom

2003: First class on fuzzy logic is held at Clarkson University

*Fuzzy Logic: Intelligence, Control, and Information - J. Yen and R. Langari, Prentice Hall 1999

Fuzzy Logic Applications

Image Stabilization



"**If all motion vectors are almost parallel and their time differential is small, then the hand jittering is detected and the direction of the hand movement is in the direction of the moving vectors".**

*Fuzzy Logic: Intelligence, Control, and Information - J. Yen and R. Langari, Prentice Hall 1999

Fuzzy Logic Applications

Aerospace
- **Altitude control of spacecraft, satellite altitude control, flow and mixture regulation in aircraft deicing vehicles.**

Automotive
- **Trainable fuzzy systems for idle speed control, shift scheduling method for automatic transmission, intelligent highway systems, traffic control, improving efficiency of automatic transmissions**

Fuzzy Logic Applications

Business
- **Decision-making support systems, personnel evaluation in a large company**
- **Data mining systems**

Chemical Industry
- **Control of pH, drying, chemical distillation processes, polymer extrusion production, a coke oven gas cooling plant**

Fuzzy Logic Applications

Defense
- **Underwater target recognition, automatic target recognition of thermal infrared images, naval decision support aids, control of a hypervelocity interceptor, fuzzy set modeling of NATO decision making.**

Electronics
- **Control of automatic exposure in video cameras, humidity in a clean room, air conditioning systems, washing machine timing, microwave ovens, vacuum cleaners.**

Fuzzy Logic Applications

Financial
- **Banknote transfer control, fund management, stock market predictions.**

Industrial
- **Cement kiln controls (dating back to 1982), heat exchanger control, activated sludge wastewater treatment process control, water purification plant control, quantitative pattern analysis for industrial quality assurance, control of constraint satisfaction problems in structural design, control of water purification plants**

Fuzzy Logic Applications

Marine

- Autopilot for ships, optimal route selection, control of autonomous underwater vehicles, ship steering.

Medical

- Medical diagnostic support system, control of arterial pressure during anesthesia, multivariable control of anesthesia, modeling of neuropathological findings in Alzheimer's patients, radiology diagnoses, fuzzy inference diagnosis of diabetes and prostate cancer.

Fuzzy Logic Applications

Mining and Metal Processing

- Sinter plant control, decision making in metal forming.

Robotics

- Fuzzy control for flexible-link manipulators, robot arm control.

Securities

- Decision systems for securities trading.

Fuzzy Logic Applications

Signal Processing and Telecommunications

- Adaptive filter for nonlinear channel equalization control of broadband noise

Transportation

- Automatic underground train operation, train schedule control, railway acceleration, braking, and stopping