Fuzzy Logic : Introduction

Lecture 1

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The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1978

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Lecture Outline

- Statement from *Lotfi Zadeh*
- Man Machine Interface
- Partial Truth and Fuzziness
- Crisp Set and Fuzzy Set

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Lotfi Zadeh

As the complexity of a system increases, our ability to make precise and yet significant statements about its behaviour diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics

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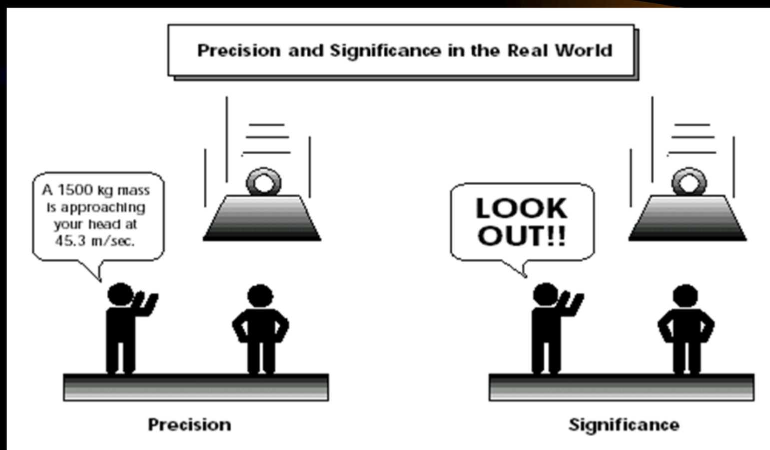

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Man-Machine Interface

- Is it possible to command a robot: ***Turn left a little bit, then slowly speed up ?***
- Is it also possible to get a response from the robot such as ***The obstacles looks like a cat sleeping on the floor?***

Key element of Communication- The ability to address uncertainties that can be understood mutually

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Partial Truth and Fuzziness

- A bat's hearing is better than dog's.
- An owl can see better than a mouse
- A man in front of radar screen can predict an approaching hurricane better than a man watching the sky

Examples indicate measurement capability (or quality) is relative

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Some more examples –within proximity of the absolute truth

- A glass is never completely full or empty in reality.
- The temperature of a liquid in a container is never exactly what the thermometer indicates.

Most uncertainties are tolerable, manageable, or negligible.

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F S Marvin's Quote

"The essence of science is to discover identity in difference"

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How do you define Fuzziness?

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Fuzziness

- Describes uncertainty or partial truth
- Has number of related concepts mostly derived from daily language
  - Randomness
  - Chaos
  - Ambiguity
  - Vagueness
  - Undecidedness
  - Inaccuracy
  - Imprecision

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Randomness

- Occurrence of an event without any recognizable pattern.
- A random noise can be a contributing factor to partial truth.

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Chaos

- Highly complex iteration of order in which the principles of its evolution cannot be justified through repeated observations.
- Known as **nonlinear phenomena**
- Can be disruptive factor in the perception of absolute truth

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Ambiguity

- Multiplicity in the perception of truth → leads to partial truth → **Fuzziness**

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Vagueness

- **Mild** form of ambiguity
- **Strong** form of imprecision
- Such that a statement can be either depending upon context.
- Like ambiguity, vagueness defines the state of an expression in describing truth.

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Undecidedness

- **Very close** ☺ to its meaning in daily language
- Defines the collision point of two or more equally justifiable decisions.
- In the ocean of possibilities, an undecided state of affairs may be rare event, yet it somewhat implies fuzziness.

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Inaccuracy

- Measure of distance between absolute truth and perceived truth caused by **sheer lack of knowledge**
- Directly related to fuzziness

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Imprecision

- Measure of distance between absolute truth and measure truth caused by the limitations of the measurement vehicle.
- Directly related to Fuzziness

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Fuzzy Developments

1965 Seminal Paper "Fuzzy Logic" by Prof. Lotfi Zadeh, Faculty in Electrical Engineering, U.C. Berkeley, Sets the Foundation of the "Fuzzy Set Theory"

1970 First Application of Fuzzy Logic in Control Engineering (Europe)

1975 Introduction of Fuzzy Logic in Japan

1980 Empirical Verification of Fuzzy Logic in Europe

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Fuzzy Developments

1985 Broad Application of Fuzzy Logic in Japan

1990 Broad Application of Fuzzy Logic in Europe

1995 Broad Application of Fuzzy Logic in the U.S.

2000 Fuzzy Logic Becomes a Standard Technology and Is Also Applied in Data and Sensor Signal Analysis. Application of Fuzzy Logic in Business and Finance.

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Some Successful Fuzzy Systems at Work

Example	Product
Cement kiln control (Denmark)	Industrial
Blast furnace control (NKK Fuoyama, Japan)	Industrial
Automatic train operation (Sedai subway system, Japan)	Industrial
Nuclear reactor control (Art Fugen, Japan)	Industrial
Home air conditioners (Mitsubishi Heavy Industries, Japan)	Commercial
Washer machine (Matshushita Electrical Industrial, Japan	Commercial
Home Heating system (Viessmann-INFORM, Germany)	Commercial
Helicopter control (LIFE, Japan)	Research
Fuzzy autofocus still camera (Sanyo, Japan)	Commercial

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Some Successful Fuzzy Systems at Work

Example	Product
Photocopy machine (Sanyo, Japan)	Commercial
Fingerprint classification (NIST, USA)	Research
Smart sensors (Fisher-Rosemount, USA)	Commercial
Speech recognizer (NTT Communications, Japan)	Research
Fire detector (Cerberus, Switzerland)	Industrial
Health management (OMRON, Japan-USA)	Commercial
Fuzzy Medical expert systems	Research
Autonomous robot control, (SRI International, USA)	Research
Camera tracking (NASA, USA)	Industrial

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Some Successful Fuzzy Systems at Work

Example	Product
Water treatment system(Fuji Electric, Japan)	Industrial
Target tracker in Patriot Missile	Industrial
Used car selection (A used car center in Kansai, Japan)	Research

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Important Characteristics of Fuzzy Technology

- Simple in terms of their objective and structure
- Employs solutions articulated in daily language by means of fuzzy IF-THEN rules.
- Meets its anticipated advantages regardless of the problem type.

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Fuzzy Logic

Consider the following rule:

If the patient has *high* fever
and he is shivering *a lot*
then influenza is *highly likely*

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Fuzzy Rule

The words shown in *italics* are imprecise terms. These are called *fuzzy predicates.*

Such a rule is termed as a *fuzzy rule.*

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Examples of Fuzzy Logic

- Air traffic Controllers are trained in identifying differences between various types of aircrafts, e.g. missile, fighter and civil airliner.
- They do this by identifying patterns in the images received by laser TV systems. These images are imprecise and so fuzzy logic techniques can be quite useful.

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Question yet to be answered

- How does a basic problem become fuzzy basic problem?

e.g. How does control or pattern recognition become fuzzy control or fuzzy pattern recognition problem?

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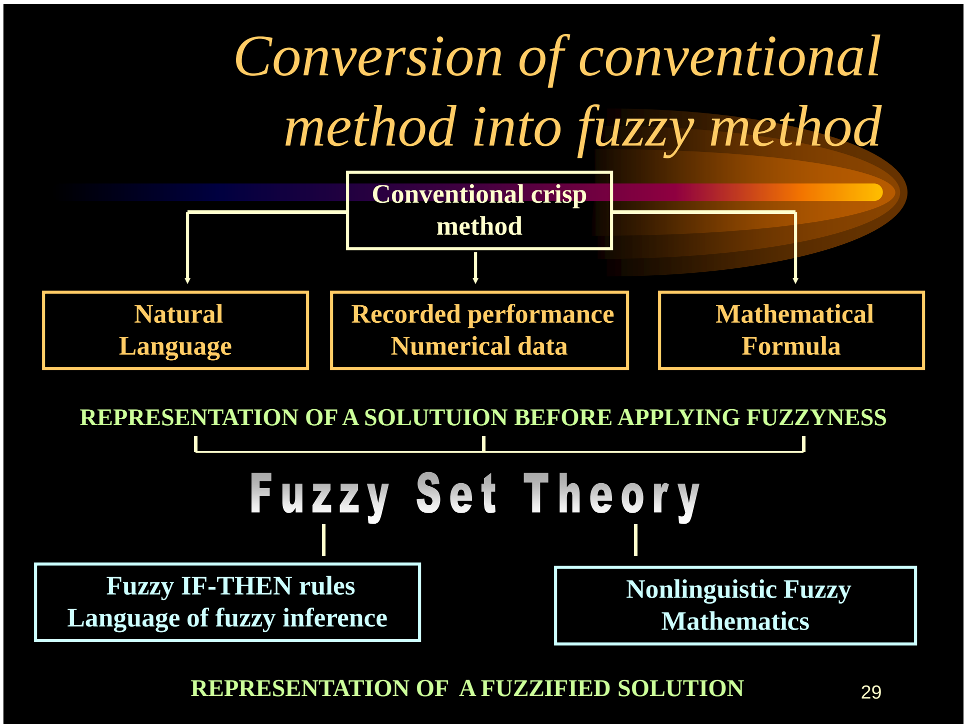
Conversion of conventional method into fuzzy method
Conventional crisp method
Natural Language
Recorded performance Numerical data
Mathematical Formula
REPRESENTATION OF A SOLUTUION BEFORE APPLYING FUZZYNESS
Fuzzy Set Theory
Fuzzy IF-THEN rules Language of fuzzy inference
Nonlinguistic Fuzzy Mathematics
REPRESENTATION OF A FUZZIFIED SOLUTION
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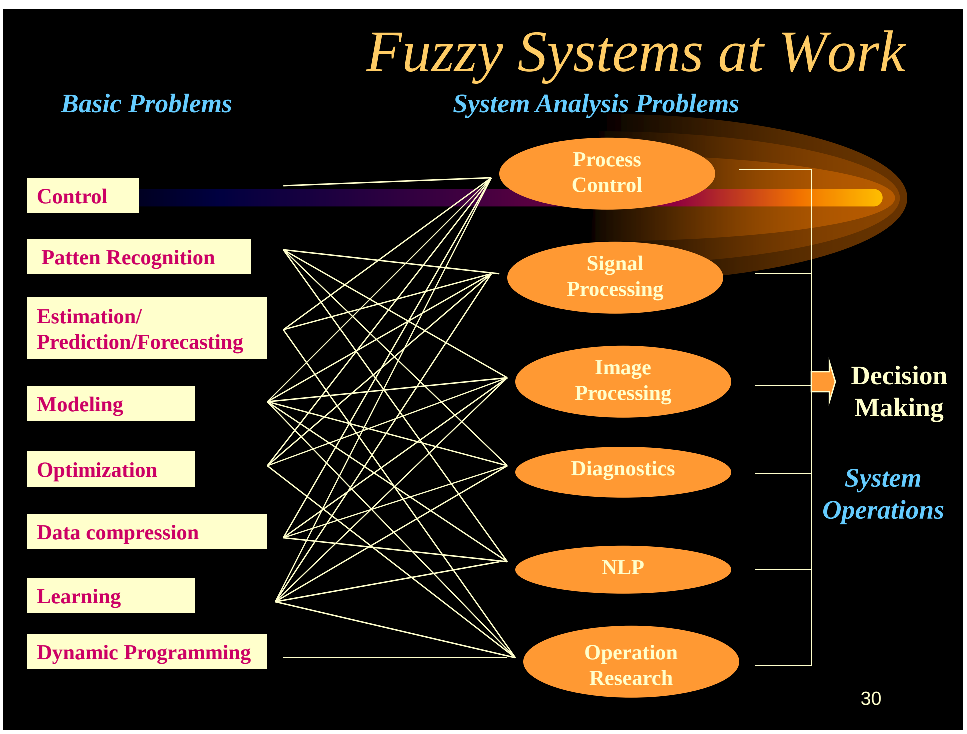
Fuzzy Systems at Work
Basic Problems
System Analysis Problems
Control
Patten Recognition
Estimation/ Prediction/Forecasting
Modeling
Optimization
Data compression
Learning
Dynamic Programming
Process Control
Signal Processing
Image Processing
Diagnostics
NLP
Operation Research
Decision Making
System Operations
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Ordinary (Crisp) Sets to Fuzzy Sets

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World of Difference

- **Crisp Set:** To dichotomize the individuals in some given universe of discourse into two groups: members (those that certainly belong in the set) and non members (those that certainly do not).

- **Fuzzy Set:** mathematically by assigning to each possible individual in the universe of discourse a value representing its grade of membership in the fuzzy set

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Examples

Crisp Set Theory:

38°C 38.7°C

40.1°C 41.4°C

42°C

39.3°C

"Strong Fever"

37.2°C

Fuzzy Set Theory:

38°C 38.7°C

40.1°C 41.4°C

42°C

39.3°C

"Strong Fever"

37.2°C

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Crisp Sets: An Overview

- Z = {….,-2,-1,0,1,2,….} – The set of all integers
- N = {1,2,3,…. } – The set of all positive integers or natural numbers
- N_0 ={0,1,2,….} – The set of all non-negative integers
- N_n ={1,2,…,n}
- $N_{0,n}$ ={0,1,2,….,n}
- R: The set of all real numbers
- R^+ : The set of all nonnegative real numbers

Cont…

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Crisp Sets: An Overview

- [a, b], (a, b], [a, b), (a,b): Closed, left-open, right open, open interval or real numbers between a and b, respectively.
- $<x_1, x_2, \ldots..x_n>$: ordered n-tuple of elements $x_1, x_2, \ldots..x_n$

Cont…

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Crisp Sets: An Overview

- Three basic Methods to define set within a given universal set X
- List Method: for finite sets

  $A = \{a_1, a_2, \ldots.., a_n\}$
- Rule Method: for property based sets

  $A = \{x \mid P(x)\}$

  P(x) is true or false and $x \in X$

Cont…

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Crisp Sets: An Overview

- Characteristic Function : declares which elements of X are members of the set and which are not.
- Set A is defined by its characteristic function χ_A, as follows:

$$\chi_A(X) = \begin{cases} 1 \text{ for } x \in A \\ 0 \text{ for } x \notin A \end{cases} \qquad \chi_A : X \rightarrow \{0,1\}$$

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Fundamental Properties of Crisp set Operation

- Involution $\overline{\overline{A}} = A$
- Commutative $A \cup B = B \cup A$, $A \cap B = B \cap A$
- Associativity $(A \cup B) \cup C = A \cup (B \cup C)$
  $(A \cap B) \cap C = A \cap (B \cap C)$
- Distributivity $A \cap (B \cup C) = (A \cap B) \cup (A \cap C)$
  $A \cup (B \cap C) = (A \cup B) \cap (A \cup C)$
- ……

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Crisp Sets: An Overview

Homework : General background from recommended text book of ***Klir and Yuan***

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Fuzzy Sets : Basic Types

- The characteristic function of crisp set assigns value of either 1 or 0 to each individual in the universal set.
- Two distinct notations are most commonly used to denote membership functions

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Fuzzy Sets : Basic Types

Membership function of a fuzzy set A is denoted by μ_A; that is

$\mu_A : X \rightarrow [0,1]$

The function is denoted by A and has the same form:

$A : X \rightarrow [0,1]$

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"The motherboard must be acting up."

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