Fuzzy Systems

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1. Fuzzy Systems - Overview

- Fuzzy Systems
- Fuzzy Logic
- A Little History
- Fuzzy Sets
- Fuzzy Sets Operations
- Fuzzy Rules
- Fuzzy Applications
- Fuzzy Logic Control
- References
1.1 Fuzzy Systems

- Based on Human Thought Processes
- Systems that use objective and subjective knowledge of a problem
- Objective knowledge – mathematical models
- Subjective knowledge – linguistic information
1.2 Fuzzy Logic

Fuzzy logic provides a method to formalize reasoning when dealing with vague terms.

Traditional computing requires finite precision which is not always possible in real world scenarios. Not every decision is either true or false, or as with Boolean logic either 0 or 1.

Fuzzy logic allows for membership functions, or degrees of truthfulness and falsehoods. Or as with Boolean logic, not only 0 and 1 but all the numbers that fall
in between.
1.3 A little History

The idea behind fuzzy logic dates back to Plato, who recognized the logic system of true and false, and also an undetermined area – the uncertain.

In the 1960’s Lotfi A. Zadeh Ph.D., University of California, Berkeley, published an obscure paper on fuzzy sets that allowed for approximate information and uncertainty when generating complex solutions; a process that previously did not exist.

Fuzzy Logic has been around since the mid 60’s but was not readily accepted until the 80’s and
90’s. Although now prevalent throughout much of the world, China, Japan and Korea were the early adopters.
1.4 Fuzzy Set

- Classical ("crisp") sets:
  - Membership in a set is all or nothing
  - Membership function \( c_S: \text{Universe} \rightarrow \{0, 1\} \)
  - \( c_S(x) = 1 \) iff \( x \in S \)

- Fuzzy sets:
  - Membership in a set is a degree
    - membership function \( c_S: \text{Universe} \rightarrow [0, 1] \)
Linguistic Characterizations of Degree of Membership

- Consider the set of “hot” days in Chennai in 2007.
- Was July 17 “hot”? It might have been called one of:
  - “very hot”
  - “sort of hot”
  - “not hot”
- The answer depends on the observer,
time, etc.
Sounds similar to probability, but isn’t

- Probability deals with uncertainty, likelihood
- Fuzzy logic deals with ambiguity, vagueness
Fuzzy Sets

Sets with fuzzy boundaries

A = Set of tall people

Crisp set A  Fuzzy set A

Membership function
1.5 Fuzzy-Set Operations expressed using membership functions

Fuzzy OR (union)

\[ c_{A \cup B}(x) = \max(c_A(x), c_B(x)) \]

Fuzzy AND (intersection)

\[ c_{A \cap B}(x) = \min(c_A(x), c_B(x)) \]
Fuzzy Complement (not the only possible model)

\[ c_{A'}(x) = 1 - c_A(x). \]
Fuzzy Anomaly?

The intersection of a set with its complement is not necessarily empty.

\[ c_{A'}(x) = 1 - c_A(x). \]
1.6 Fuzzy Rules

“If our distance to the car in front is small, and the distance is decreasing slowly, then decelerate quite hard”

- Fuzzy variables in blue
- Fuzzy sets in red
- Conditions are on membership in fuzzy sets
- Actions place an output variable (decelerate) in a fuzzy set (the quite hard deceleration set)

- We have a certain belief in the truth of the condition, and hence a certain strength of desire for the outcome

- Multiple rules may match to some degree, so we require a means to arbitrate and choose a particular goal - defuzzification
1.7 General Fuzzified Applications

- Quality Assurance
- Error Diagnostics
- Control Theory
- Pattern Recognition
Specific Fuzzified Applications

- Otis Elevators
- Vacuum Cleaners
- Hair Dryers
- Air Control in Soft Drink Production
- Noise Detection on Compact Disks
- Cranes
- Electric Razors
- Camcorders
- Television Sets
- Showers
Expert Fuzzified Systems

- Medical Diagnosis
- Legal
- Stock Analysis
- Mineral Prospecting
- Weather Forecasting
- Economics
- Politics
1.8 Fuzzy Control System
1.9 References

- Kartalopoulos, S.V., Understanding Neural Networks and Fuzzy Logic, IEEE Press,
New York, 1996.