Fuzzy Logic

CS4881 Ariticial Intelligence
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Outline

- Learning agents
- Inductive learning
- Decision tree learning

Fuzzy Logic

- Derived from *fuzzy set* theory
- Fuzzy set theory deals with *degrees of truth*
- Reasoning that is *approximate* rather than precise like predicate logic
- Apply fuzzy set theory to world expert values for complex problems.

Fuzzy Logic

- Introduced by Lofti Zadeh in 1965, UC Berkley.
- Also called Possiblity Theory.

Reference:
Zadeh, Lotfi, "Fuzzy Sets as the Basis for a Theory of Possibility", *Fuzzy Sets and Systems* 1:3 28, 1978. (Reprinted in *Fuzzy Sets and Systems* 100 (Supplement): 9 34, 1999.)

Degrees of Truth

- Degrees of truth are often confused with probabilities.
- Degrees of truth represent membership in vaguely defined sets.
- Probability deals with the likelihood of some event of condition.

Degrees of Truth, examples

- As you enter class and pass through the doorway from the hall and enter our class room, are you in the hall or the classroom?
- As you eat an apple, when does the apple become an apple core or stem?

- Quantifying partial states yeilds a fuzzy set membership.
- Fuzzy sets are based on vague definitions of sets, not randomness

Fuzzy Set Membership

- Fuzzy set theory allows partial set membership.
- Set membership values range between 0 and 1 inclusively.
- In its linguistic form, it allows imprecise concepts like “slightly”, “very”, etc.

Fuzzy Controversy

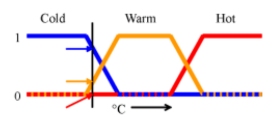
- Fuzzy logic has a broad track record of successful applications, though it is somewhat controversial.
- Control engineers reject it for validation reasons.
- Statisticians reject its lack of mathematical rigor relative to probability theory.
- Mathematicians argue that it cannot be a superset of oridnary set theory since membership functions are defined in terms of convential sets.

Applications

- Automobile and other vehicle subsystems, such as ABS and cruise control (e.g. Tokyo monorail)
- Air conditioners
- Cameras
- Digital image processing, such as edge detection
- Rice cookers
- Dishwashers
- Elevators
- Washing machines and other home appliances
- Pattern recognition in Remote Sensing
- Fuzzy logic has also been incorporated into some microcontrollers and microprocessors, for instance, the Freescale 68HC12.

Typical Application

- Characterize subranges of a continuous variable, e.g., temperature measurement for antilock brakes.
- Each function maps the same temperature value to a truth value in the 0 to 1 range.
- These truth values can then be used to determine how the brakes should be controlled.
- Cold, warm, and hot are functions mapping a temp to a scale.
- A point has three “truth values” – one for each of the three functions.



How fuzzy logic is applied

Fuzzy Set Theory defines Fuzzy Operators on Fuzzy Sets.

Problem in applying this is that the appropriate Fuzzy Operator may not be known.

Fuzzy logic usually uses IF/THEN rules, or constructs that are equivalent such as fuzzy associative matrices.

For example, a simple temperature regulator that uses a fan might look like this:
IF temperature IS very cold THEN stop fan
IF temperature IS cold THEN turn down fan
IF temperature IS normal THEN maintain level
IF temperature IS hot THEN speed up fan

Note: there is no "ELSE". All rules are evaluated, because the temp might be "cold" and "normal" at the same time to differing degrees.

Fuzzy Logic Operators

- AND, OR, and NOT operators of boolean logic exist in fuzzy logic, usually defined as the minimum, maximum, and complement;
- So for the fuzzy variables x and y:
  - NOT x = (1 - truth(x))
  - x AND y = minimum(truth(x), truth(y))
  - x OR y = maximum(truth(x), truth(y))
- Other operators are more linguistic in nature, called *hedges* that can be applied.
- These are generally adverbs such as "very", or "somewhat", which modify the meaning of a set using a mathematical formula.

A more detailed example

- If a man is 1.8 meters, consider him as tall:
  - IF male IS true AND height >= 1.8 THEN is_tall IS true; is_short IS false
- The fuzzy rules do not make the sharp distinction between tall and short, that is not so realistic:
  - IF height <= medium male THEN is_short IS agree somewhat
    IF height >= medium male THEN is_tall IS agree somewhat

A more detailed example

- In the fuzzy case, there are no such heights like 1.83 meters, but there are fuzzy values, like the following assignments:
  - dwarf male = [0, 1.3] m
    short male = (1.3, 1.5]
    medium male = (1.5, 1.8]
    tall male = (1.8, 2.0]
    giant male > 2.0 m
- For the consequent, there are also not only two values, but five, say:
  - agree not = 0
    agree little = 1
    agree somewhat = 2
    agree a lot = 3
    agree fully = 4

Summary

- Based on fuzzy set theory and concepts of possibility theory.
- Most applications are in control.
- Not as mathematically rigourous as probability theory and other mathematical frameworks.
- Same/better results with probability densifty functions and finer granularity of rules.