Fuzzy Logic and Neural Networks in CS452

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The AI Problem

- Approximate the real world in software.
- Analogously approximate a function.
- 5 common solutions:
  1. Heuristics
  2. Genetics
  3. Fuzzy Logic
  4. Neural Network
- Worthy mentions:
  1. Distributed (we only have 1 system)
  2. Cooperative (still just 1 system)
  3. Adaptive (I haven't learnt it, but probably very effective)

Heuristics and Genetics

Heuristics:

- Requires accurate modelling
- Difficult to extend
- Cannot learn
- Easiest to inspect and debug

Genetics:

- Learns too slow!

Genetics

- Learns too slow!

Fuzzy vs Neural

	Fuzzy Logic	Neural Networks
Best suited for	Control	Classification
Speed	Fast	Slow
Programming	Manual	Automatic
Learning	No	Yes
Requirements	Rules	Data

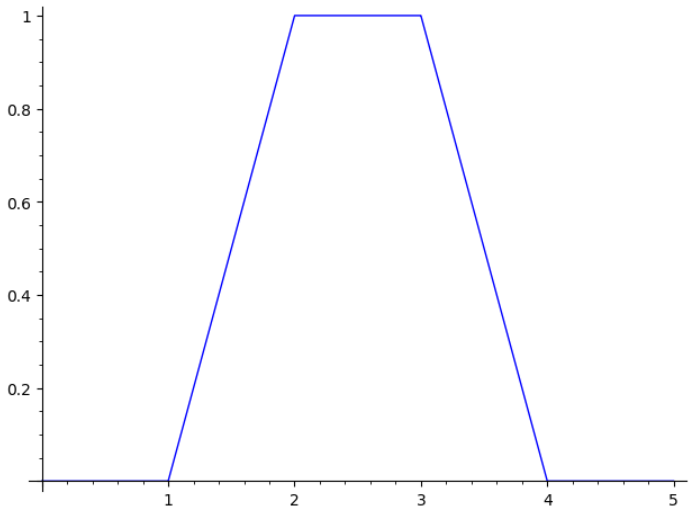
Fuzzy Logic Basics

- First turn inputs into fuzzy variables
- Then do logic with those variables
- Then turn fuzzy variables back to outputs

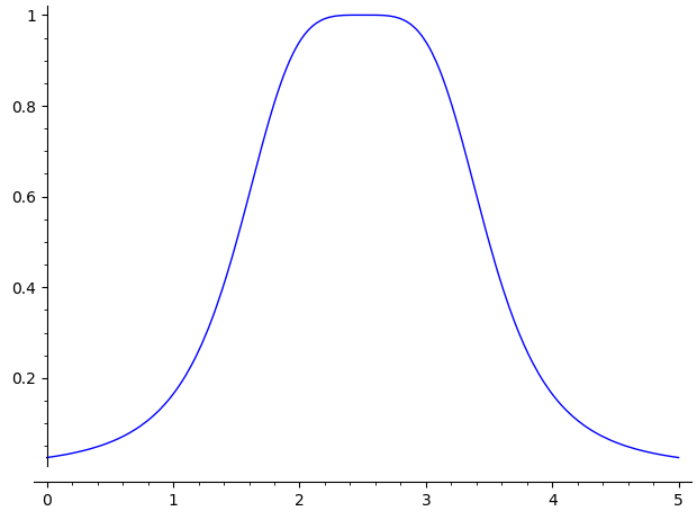
Fuzzification

- Fuzzy sets have non-integer inclusion
- In crisp sets: $x \in S$ is boolean
- In fuzzy sets: $x \in S$ is an element from another set (usually reals)
- Typical membership functions:

Trapezoidal



Bell



Fuzzifier Comparison

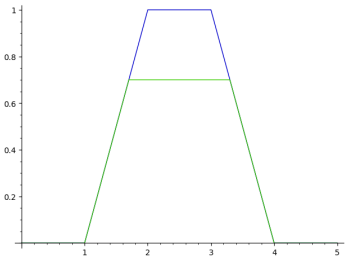
Trapezoidal	Bell
Faster	Slower
Not Differentiable	Differentiable
Less accurate	More accurate

Importance of differentiability is it allows the use of gradient descent algorithms on the membership functions.

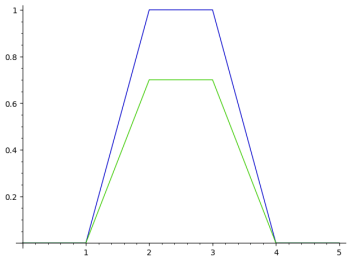
Fuzzy T-norm

- Fuzzy equivalent to AND operation
- Comes with the equivalent S-norm (OR)
- S-norm computed via DeMorgan
- Typical T-norms:

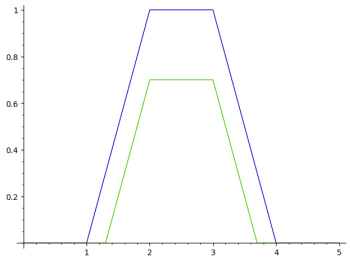
Classical



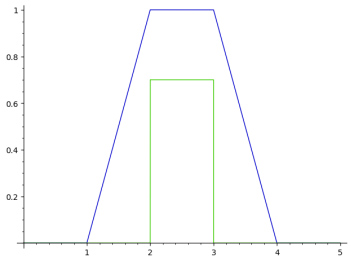
Algebraic



Bounded

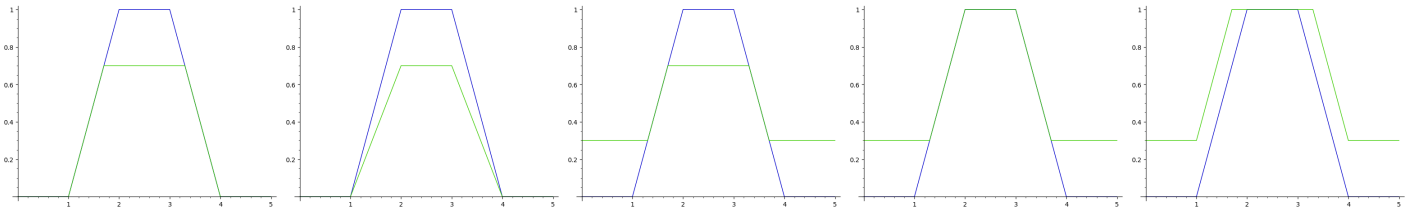


Basic



Fuzzy Implications

Like T-norm, not obvious. Common implication schemes:

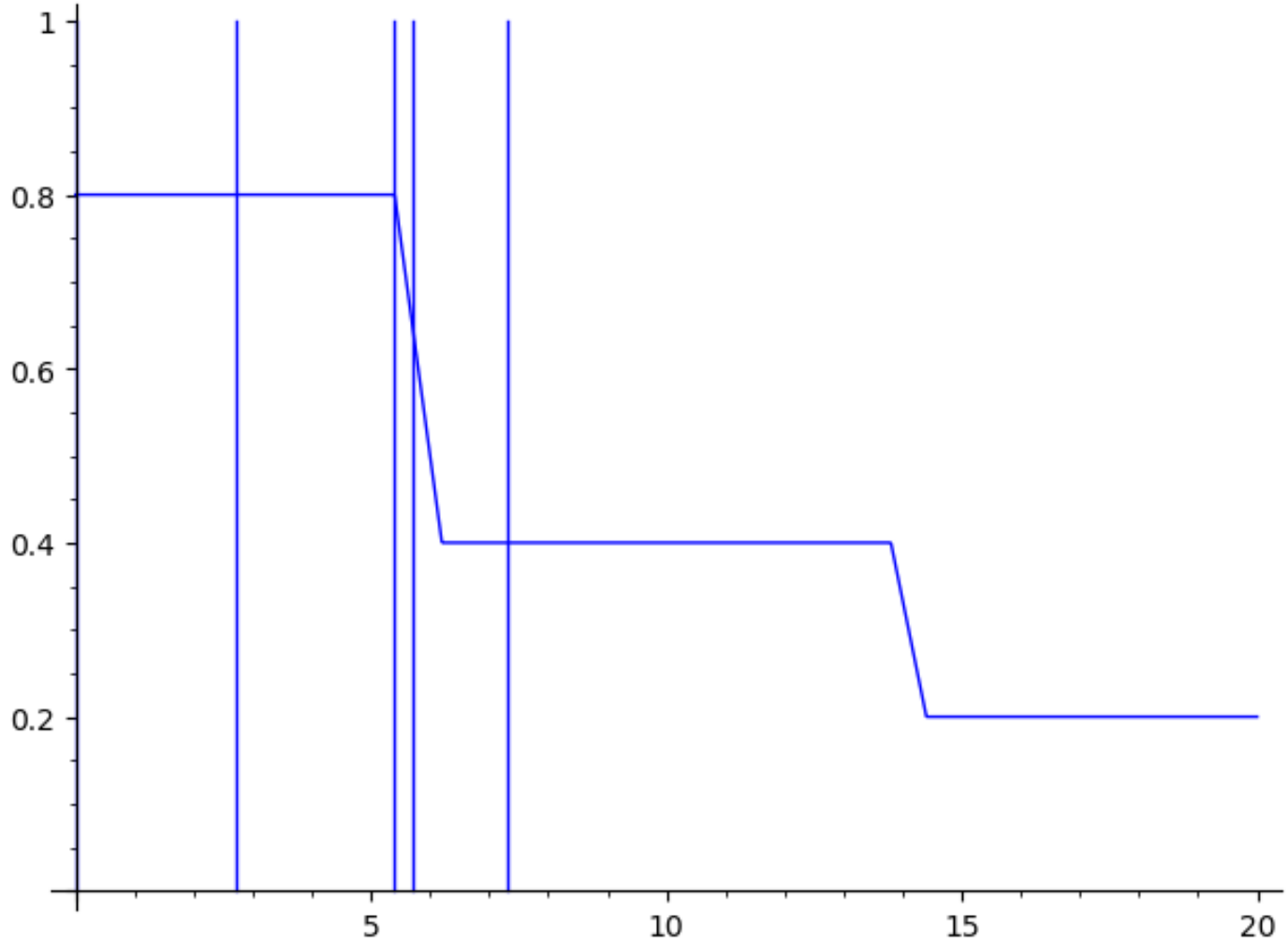


From left to right: Mamdani, Larsen, Zadeh, Dienes-Rascher, Lukasiewicz.

Defuzzification

Last fuzzy operation, turn fuzzy back to non-fuzzy.

Common defuzzification schemes:



From left to right: Min of max (at 0), Mean of max, Max of max, Center of area, Centroid.

Recommendations

- Use a neural network to learn how long it takes a train to get from switch to switch.
- If that is too slow, simply save last switch-to-switch time?
- Take time since last switch, expected switch-to-switch time, speed, etc to fuzzily determine location.
- Definitely look into adaptive algorithms (especially Least-Mean-Squares) to possibly swap out for the neural network.