COMP4660/8420 Fuzzy Logic

Part 1: Theory

1. Why is Fuzzy Logic considered bio-inspired?

Designed to represent human discourse

1. What might a real world application of Fuzzy Logic be? How would this scenario benefit from the use of Fuzzy Logic as opposed to Boolean Logic?

Describing heights of people, speeds, temperature — all use a sliding scale rather than sharp decision boundaries.

1. Define the set of natural numbers near 4 using a fuzzy set.

Examples:

Fuzzy set: [0.1/2, {0.5/3}, {1.0/4}, {0.5/5}, {0.1/6}]

Or use a triangular fuzzy set: Fuzzy trapezoid = [1 4 4 7]

1. Give several examples of fuzzy rules. Label the linguistic variables, values, antecedents, and the consequents.

Fuzzy rule:

IF x is A

THEN y is B

x, y are linguistic variables and A, B are linguistic values e.g. x, y can take values "fan\_speed" and "room\_temperature" respectively and A, B can take values "high" and "cool"

1. Consider the following fuzzy sets:

A = {0.2/a, 0.4/b, 1/c, 0.8/d, 0/e}

B = {0/a, 0.9/b, 0.3/c, 0.4/d, 0.1/e}

Calculate:

1. The height, Support, Core, Cardinality, Complement for both A and B.

height(A) = 1, height(B) = 0.9

Supp(A) = {a, b, c, d)

Supp(B) = {b, c, d, e}

Core(A) = {c}

Core(B) = {}

Card(A) = 0.2 + 0.4 + 1 + 0.8 + 0 = 2.4

Card(B) = 0 + 0.9 + 0.3 + 0.4 + 0.1 = 1.7

Comp(A) = {0.8/a, 0.6/b, 0/c, 0.2/d, 1/e}

Comp(B) = {1/a, 0.1/b, 0.7/c, 0.6/d, 0.9/e}

1. The alpha-cut and strong alpha-cut for both sets of
2. Calculate the Union and Intersection of A and B

Union (take the max) = {0.2/a, 0.9/b, 1/c, 0.8/d, 0.1/e}

Intersection (take the min) = {0/a, 0.4/b, 0.3/c, 0.4/d, 0/e)

1. What is a fuzzy inference (rule based) system?

A fuzzy inference system (FIS) is a system that uses fuzzy set theory to map inputs to outputs (classes in the case of fuzzy classification).

1. What are the four steps performed in fuzzy inference systems? Briefly describe each step.
   1. Fuzzification of inputs: Get membership values for each fuzzy set.
   2. Rule evaluation (inference): Calculate antecedent truth values and scale/cut consequent fuzzy sets.
   3. Aggregation (composition): Combine consequent fuzzy sets from every rule.
   4. Defuzzification: Compute the (weighted) average value.
2. What is the difference between Mamdani and Sugeno inference systems?

The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant.

1. What is the difference between Fuzzy C-Means clustering and k-means clustering?

Fuzzy c-means (FCM) is a clustering method that allows each data point to belong to multiple clusters with varying degrees of membership.

1. Discuss the differences between sparse hierarchical fuzzy systems and fuzzy signatures. How do they each achieve the goal of reducing the number of rules needed?

Hierarchical systems make use of interpolation to handle inputs for which no rule exists. Fuzzy signatures apply aggregation to tree-like structured inputs to reduce the size and complexity of the structure.

Part 2: Introduction to the Scikit Fuzzy

Now it’s time to apply the concepts to some examples using a Python package called scikit-fuzzy. Working through these practical examples will help to develop your understanding.

Your first task is to build a Mamdani style inference system. You may find this link (<https://pythonhosted.org/scikit-fuzzy/auto_examples/plot_tipping_problem.html>) to be helpful for you understanding scikit-fuzzy. To get started, please run

*pip install scikit-fuzzy*

to install scikit-fuzzy on your machine.

Task 1: Fuzzy Inference System for a Temperature Control

1. What are the linguistic variables and the universe of discourse of each variable?

Temperature – 0 to 45

Power – 0 to 10

1. What are the fuzzy sets?

For temperature the fuzzy sets are Cold, Pleasant and Hot. For Power the fuzzy sets are Low. Medium and High

1. What are the fuzzy rules?

[Rules]

If (Temp is Cold) then (Power is Low)

If (Temp is Pleasant) then (Power is Med)

If (Temp is Hot) then (Power is High)

1. What is the defuzzification method?

Centroid.

Refer back to the lecture notes on Fuzzy Rule Based Systems to read through the Air Conditioner example. Change the fuzzy sets for the Temperature variable to be the same as in the lecture notes. Then change the fuzzy sets for the Power variable to be the same as the Speed Fuzzy sets in the lectures. Now modify the fuzzy rules to be the same as in the lecture notes. Now evaluate the FIS with the same inputs used in step 4.

#### What results do you get now? Do you think the modified FIS more accurately portrays the problem space? Why?

#### Do you agree with the range of the universe of discourse and the linguistic variable used? Are there any factors that you think have been overlooked and would be useful in altering the speed of the air conditioner?

#### The universe of discourse for temperature could be expanded to include some negative values and some temperatures greater than 45. The fuzzy set for hot should be non-decreasing. Some additional variables may be considered, e.g. humidity.

Play around with FIS settings and comment on how it changes the FIS mode. You may like to experiment with different membership functions, more variables, different defuzzification methods etc.