COMP4660/8420 INTRODUCTION TO FUZZY LOGIC
PART 1: ANSWERS

Part 1: Tutorial on Fuzzy Logic

1. Why is Fuzzy Logic considered bio-inspired?

   Designed to represent human discourse

2. 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.

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

   Examples:

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

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

4. 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"

5. 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:

   a. 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, 0/e}

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

b. The alpha-cut and strong alpha-cut for both sets of $\alpha = 0.4$

$A_{0.4}$ = {b, c, d}
$A_{\overline{0.4}}$ = {c, d}
$B_{0.4}$ = {b, d}
$B_{\overline{0.4}}$ = {b}

c. Calculate the Union and Intersection of A and B

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

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

6. 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).

7. What are the four steps performed in fuzzy inference systems? Briefly describe each step.

i. Fuzzification of inputs
ii. Rule evaluation (inference)
iii. Aggregation (composition)
iv. Defuzzification

8. 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.

9. 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.

Part 2: Introduction to the Matlab Fuzzy Logic Toolbox

Now it's time to apply the concepts to some examples using Matlab. Working through these practical examples will help to develop your understanding.

Task 1: Fuzzy Inference System for a Temperature Control System

Goal: Understand and implement a basic inference system in Matlab.

Your first task is to build a Mamdani style inference system. First work through the Matlab tipper example that was briefly discussed in the lectures:
http://au.mathworks.com/help/fuzzy/working-from-the-command-line.html

You can also refer to the functions:

http://au.mathworks.com/help/fuzzy/mamdani-fuzzy-inference-systems.html

We will work through another example which is a basic temperature control system that was discussed in the lectures. Download the *tempControl.fis* file from Wattle and open this file in a text editor and investigate the contents.

Q1. What are the linguistic variables and the universe of discourse of each variable?

Temperature – 0 to 45

Power – 0 to 10

Q2. 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

Q3. What are the fuzzy rules?

[Rules]

1, 1 (1) : 1

2, 2 (1) : 1

3, 3 (1) : 1

Q4. What is the defuzzification method?

centroid

1. Read the fis file into Matlab
2. Plot the fuzzy inference system

3. Generate plots of the membership functions.
4. Evaluate the FIS with various input values.
5. 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.

Q5. What results do you get now? Do you think the modified FIS more accurately portrays the problem space? Why?

Q6. Do you agree with the range of the universe of discourse and the linguistic variables used? Are there any factors that you think have been overlooked and would be useful in altering the speed of the air conditioner?

6. 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.

Task 2: Fuzzy clustering

Goal: Implement and compare Fuzzy c-means and k-means to appreciate the difference.

We will now investigate Fuzzy C-means clustering of the iris dataset that we have used throughout the neural networks labs.

1. Open the fuzzy c-means demo and play around with difference datasets and numbers of clusters.

   ```
   >> fcmdemo
   ```

2. Go to the Help button and navigate to Documentation → Fuzzy Logic Toolbox → Data Clustering
3. Under "Examples and How To" and work through examples in the "Data clustering using the Clustering Tool" link.
4. Go back to the Data Clustering page and click on the "fcm" link under "Functions" and work through the example.
5. Now it is your turn to cluster some data. Begin by working through the example of k-means clustering of the iris data set: http://au.mathworks.com/help/stats/kmeans.html?refresh=true
   Focus on the "Partition data into two clusters" section where you will generate a data set randomly. Cluster the data set using k-means and then apply you knowledge of fuzzy c-means to cluster the data set.

Q7. Try a few different randomly generated data sets. Are there some sets where one technique gives more appropriate looking answers than the other? Why?