**Topic 6 Assignment: Fuzzy Logic Models**

This assignment mixes theory and application, in the form of several challenges and problems. Perform the tasks described in each. Note that this (and other) assignments include a few challenging research-related tasks. They are aimed at gradually building your capacity to tackle complex topics, familiarize yourself with academic discourse, and provide context and practice for the skills you will eventually need when working on your capstone thesis or project.

**Part 1 – Theory**

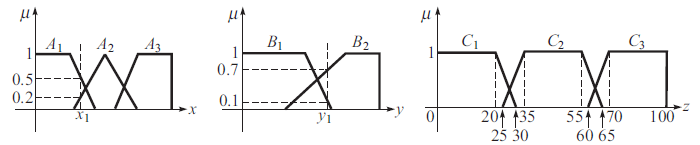
**Task 1**. Consider the following fuzzy model of a system with inputs *x* and *y* and output *z*:

Rule 1: If *x* is *A3* OR *y* is *B1* THEN *z* is *C1*

Rule 2: If *x* is *A2* AND *y* is *B2* THEN *z* is *C2*

Rule 3: If *x* is *A1* THEN *z* is *C3*

The membership functions of the input and output variables are given in the graphs below:



Actual inputs are *x1* and *y1*. Find the output *z* by applying standard fuzzy operation:

*min* for AND

*max* for OR.

Show and explain all your steps.

Part1 - Solution

The membership function graphs reveal the following fuzzified input values

These values are placed into antecedents, and the disjunction and conjunction are evaluated.

Z can be calculated from the analyzing the slope of each Consequent according to the positioning of the Antecedents.

Rule 1:

* If = 0 OR Then z = 29

A picture containing diagram

Description automatically generated

Rule 2:

* If AND Then z = 27, 63

A picture containing graphical user interface

Description automatically generated

Rule 3:

* Then z = 65

Scatter chart

Description automatically generated with medium confidence

**Task 2**. Read “Solving the Ocean Color Inverse Problems by Using Evolutionary Multi-Objective Optimization of Neuro-Fuzzy Systems” from your topic resources.

1. Explain in a short paragraph (10-15 sentences) the application/use of the Takagi-Sugeno fuzzy model in the article.

Delving into the problem of what is known as the Ocean Color Inverse Problem, researchers attempt to utilize SeaWiFS sensors on satellites to derive the concentrations of optically active constituents from the reflective spectrum measurements of the sea’s surface. These measurements are captured into a regression problem where Takagi-Sugeno type fuzzy rule-based systems are applied to form a neural network. This network focuses on optimizing both accuracy and complexity. To reiterate this neural network uses parameters of the Fuzzy Logic system to adjust and tune its model to create multi-objective optimizations. The reasoning why a fuzzy model is selected is because upon analyzing the patterns of sea surface it becomes clear that there is a non-linear relation between reflectance and optically active constituents, resulting in uncertainty in the data. An uncertainty where fuzzy models excel in. This Takagi-Sugeno type fuzzy model or TS-type fuzzy model, is trained from simulated data to form an input-output relation with fuzzy rules that dictate the boundaries of classification. Where antecedent parameters are used to solve for consequent parameters of the TS model.

1. Explain in a short paragraph (10-15 sentences) the application/use of ANFIS.

Adaptive-Network-Based Fuzzy Inference Systems (ANFIS) are used in cases where there is inconsistency of how elements should be treated. The researchers handle the ANFIS model by the tuning of specific grouping of parameters that incorporates a TS-type FRBS modeling. In this situation the input of data challenges a traditional model of ANFIS because of the shear mass of the input that goes through an exponential explosion of the number of rules that guide its boundaries and partitions. That is why they adopted a Multi-Objective Evolutionary algorithm into the ANFIS. Another detail worth noting on the partitions of the ANFIS, is that the TS-type fuzzy rules are what are used to form these partitions. These rules are applied to each layer of variable inputs as the ANFIS computes its membership functions. These membership functions can then be used to measure the weighted output of each rule. The ANFIS they illustrate in the article contains 6 rules that are each interpreted by their layer and weight.

**Part 2 – Fuzzy Models**

Refer to the readings assigned for this topic and provide solutions to the following problems, using Jupyter notebooks. Include formal and detailed explanations to accompany the code.

**Problem 1.** Consider a two-dimensional *sinc* equation defined by:



Training data are sampled uniformly from the input range [–10, 10] × [–10, 10]. With two

symmetric triangular membership functions assigned to each input variable, construct a

Takagi-Sugeno fuzzy model (linear static mappings) for the *sinc* function. Provide defining

equations for determination of the premise and consequent parameters of the model.

* This problem is handled within my GitHub .ipynb.
* <https://github.com/DouglasBui/GCU/tree/main/DSC-540/Assignment6>

**Problem 2.** To identify the non-linear system



Assign two membership functions to each input variable. Training and testing data are

sampled uniformly from the input ranges:

Training data: [1, 6] × [1, 6] × [1, 6]

Testing data: [1.5, 5.5] × [1.5, 5.5] × [1.5, 5.5]

Extract *Takagi-Sugeno fuzzy rules* from the numerical input-output training data that could be employed in an *ANFIS* model.

List and explain all the rules.

* This problem is handled within my GitHub .ipynb.
* <https://github.com/DouglasBui/GCU/tree/main/DSC-540/Assignment6>

Text

Description automatically generated

There are 6 rules that are applied to each antecedent, which is illustrated above in a Takagi-Sugeno type model.

References:

Gafa, C. (2020), Fuzzy Inference System Iimplementation in Python, towards data science, https://towardsdatascience.com/fuzzy-inference-system-implementation-in-python-8af88d1f0a6e