Final Year B. Tech (EE)

Semester: I **Subject: Artificial Intelligence and Machine Learning**

Name: Shreerang Mhatre **Class: TY**

Roll No: 52 **Batch: A3**

Experiment No: 08

Name of the Experiment: **Implement** FIS with Mamdani Interfacing Mechanism Functions

Performed on: 30/10/2023

Submitted on: 4/11/2023

Marks	Teacher's Signature with date

Aim: To implement FIS with mamdani inferencing mechanism using MATLAB/Python code.

Prerequisite: Knowledge of fuzzy sets, membership functions.

Objective:

To implement various fuzzy membership functions using Python code.

Components and Equipment required:

Python software, NumPy and Panda Libraries, MATLAB with Fuzzy toolbox

Theory:

The Mamdani fuzzy inference system is proposed as a first attempt to control a food quality and service by a set of linguistic control rules. To use fuzzy toolbox to model tips value that is given after a dinner based on quality of food (poor, average or good) and service (poor, average or good) and the tip value is decided accordingly in the range from 0 to 25 % of bill value.

As an illustration model we would consider an example in which two input linguistic variables Quality of food and Service provided are considered with poor, average or good membership functions.

Procedure:

INPUTS:

Quality**:** {Poor, Average, Good}

Service: {Poor, Average, Good}

OUTPUT:

Tips**:** Tip value ranging from 0-25 % of bill amount

Use Fuzzy Inference System (FIS) Editor and perform the following

1. Go to command window in Matlab and type fuzzy.
2. New Fuzzy Logic Designer window will be opened.
3. Give Input / Output Variable.
    a. Go to Edit Window and click Add variable
    b. As per our requirements create two input variables namely quality and service

       Quality**:** {Poor, Average, Good}

       Service: {Poor, Average, Good}
    c. Similarly, one output variable as tip value ranges from 0 to 25%.
4. The values for Quality and Service variables are selected for their respective ranges.

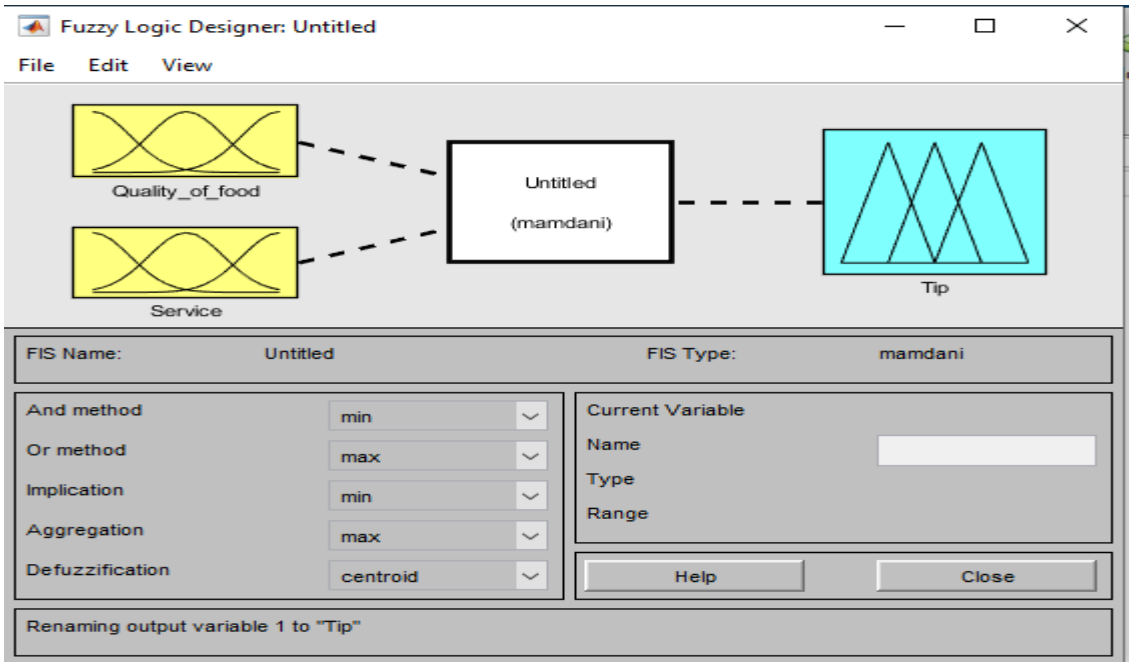
5. Quality:
    a. Double click the Quality input variable.
    b. New window will be opened and remove all the Membership Functions.
    c. Go to Edit and Click Add MFs and select the 4 Parameters for Quality table.

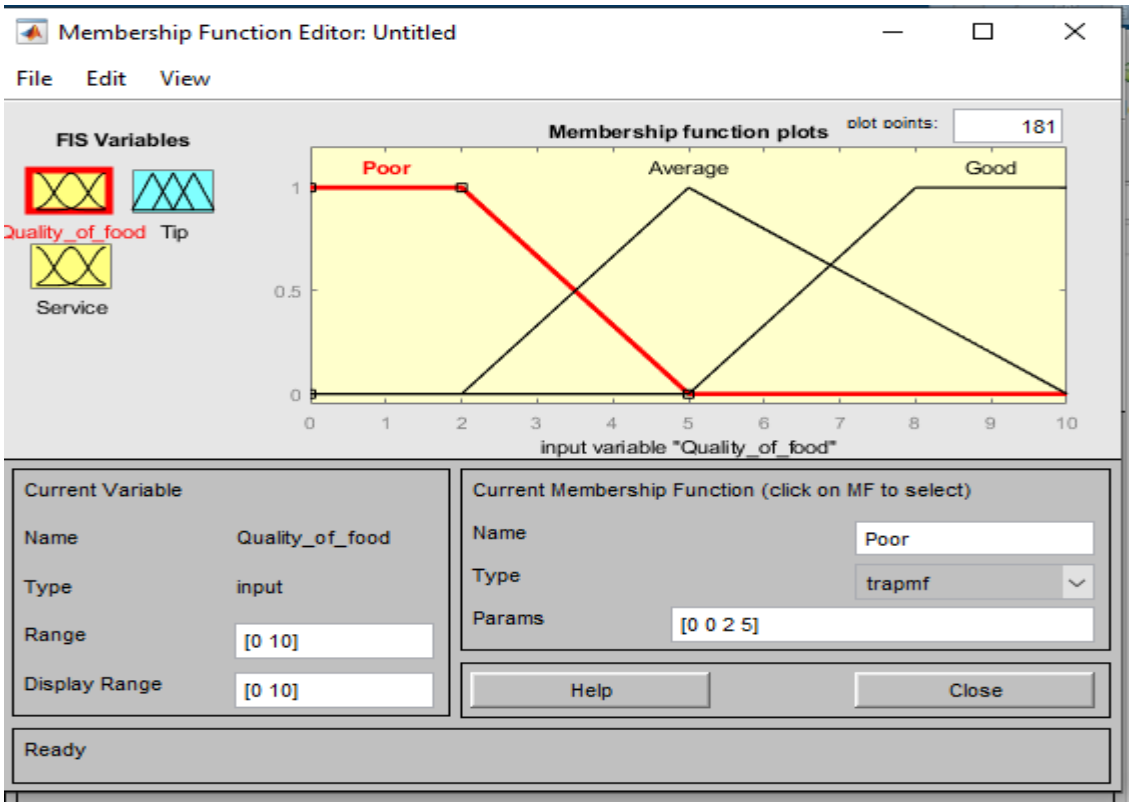
Change the following fields as per the table given below.

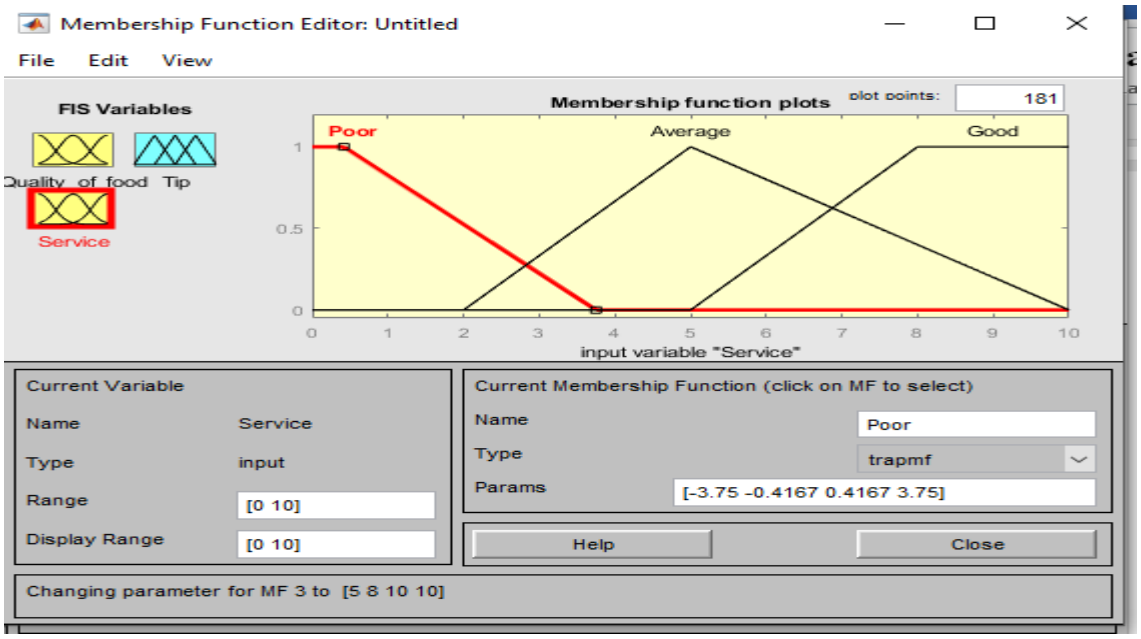
MF1: Range: [0 1 10] Name: Poor Type: trapmf Parameter [0 0 2 5]	MF2: Range: [0 1 10] Name: Average Type: trimf Parameter [2 5 10]	MF3: Range: [0 1 10] Name: Good Type: trapmf Parameter [5 7 10 10]

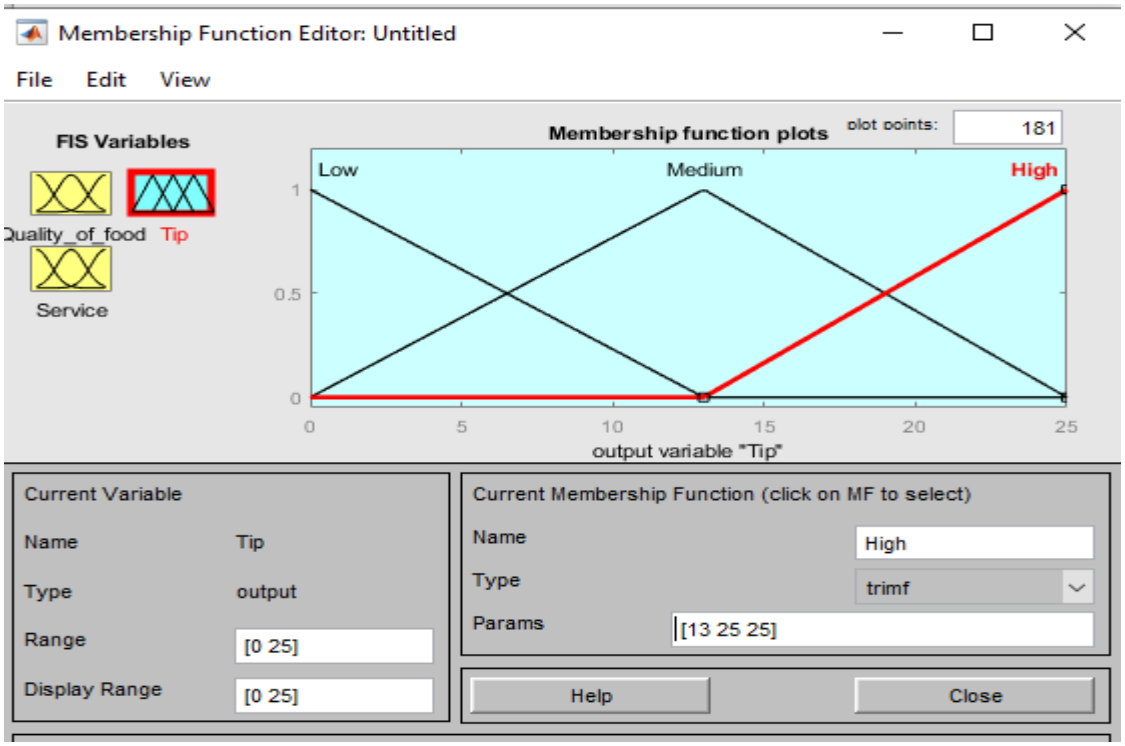
6. Similarly add the data to service and tips variables.
7. Go to Rules: Edit → Rules
8. Add the Rules
9. Go to view → Rules
10. Exit

Sample Input and Output:

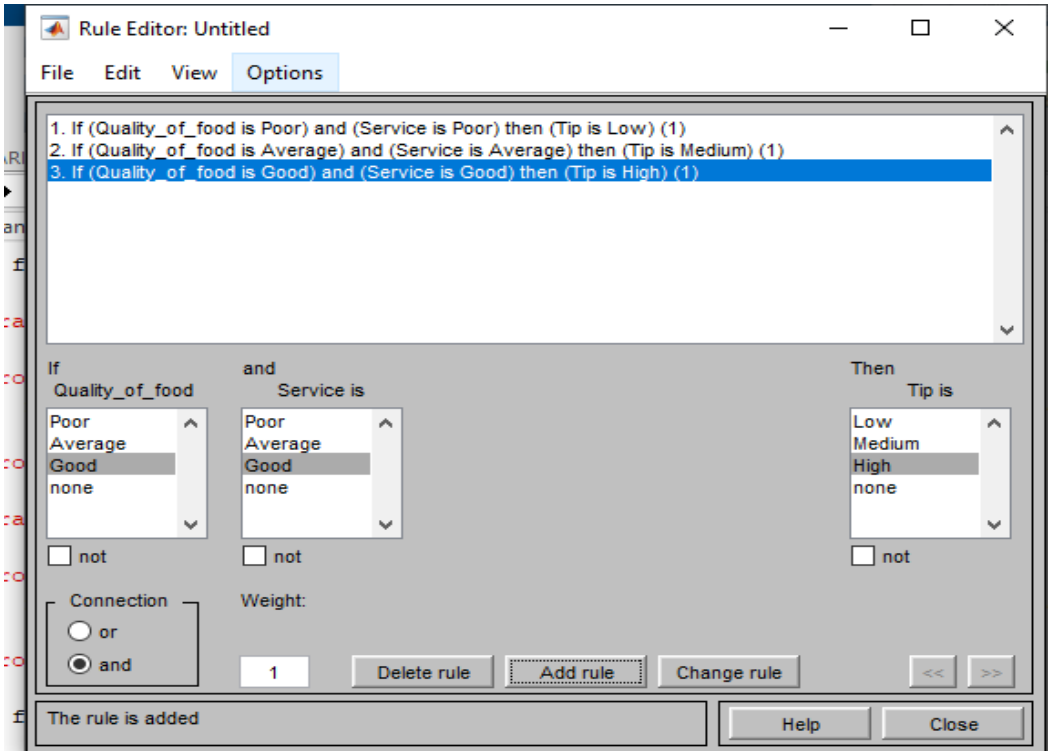



Membership Function Editor: Untitled
File Edit View
FIS Variables
Quality_of_food
Tip
Service
Membership function plots
plot points:
181
Poor
Average
Good
input variable "Quality_of_food"
Current Variable
Name
Quality_of_food
Type
input
Range
[0 10]
Display Range
[0 10]
Current Membership Function (click on MF to select)
Name
Poor
Type
trapmf
Params
[0 0 2 5]
Help
Close
Ready

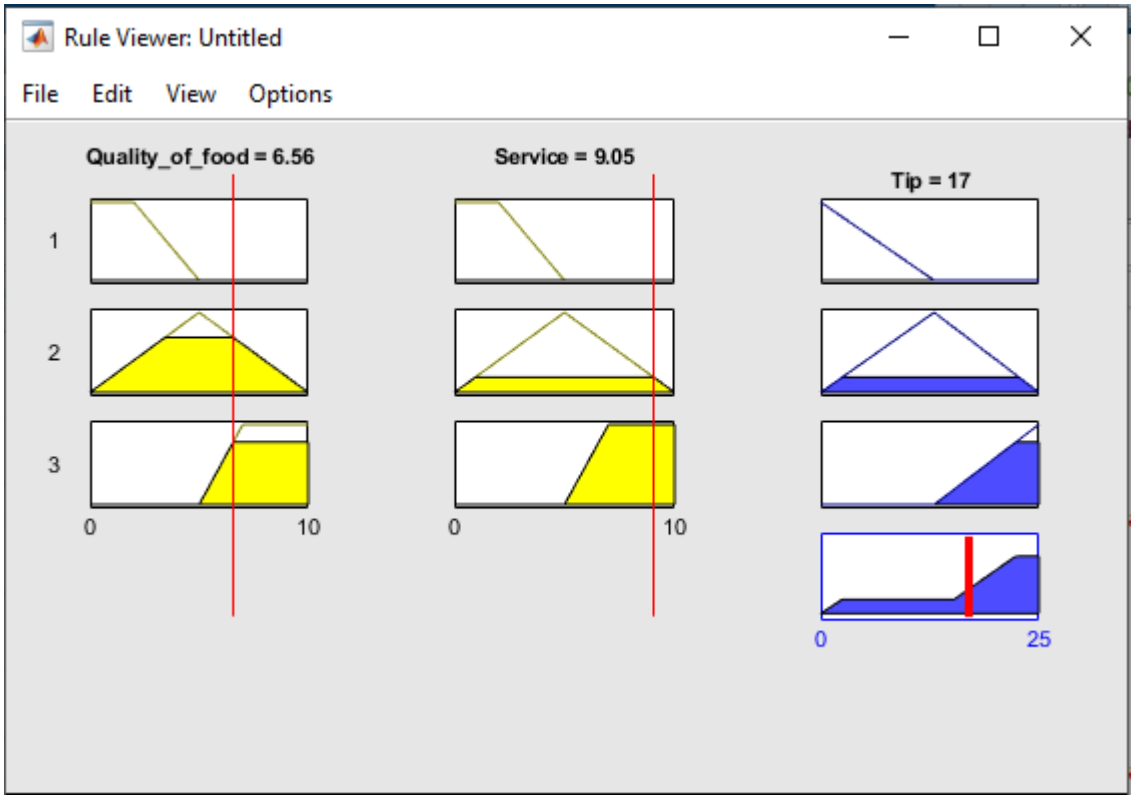

Membership Function Editor: Untitled
File Edit View
FIS Variables
Quality_of_food
Tip
Service
Membership function plots
plot points:
181
Poor
Average
Good
input variable "Service"
Current Variable
Name
Service
Type
input
Range
[0 10]
Display Range
[0 10]
Current Membership Function (click on MF to select)
Name
Poor
Type
trapmf
Params
[-3.75 -0.4167 0.4167 3.75]
Help
Close
Changing parameter for MF 3 to [5 8 10 10]

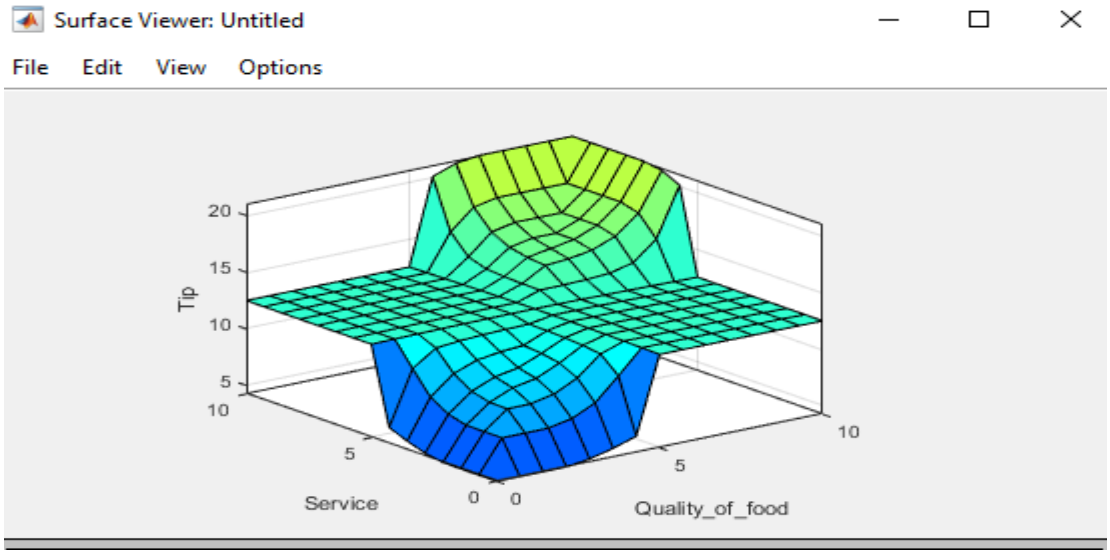


Created Rules:



Output Obtained:





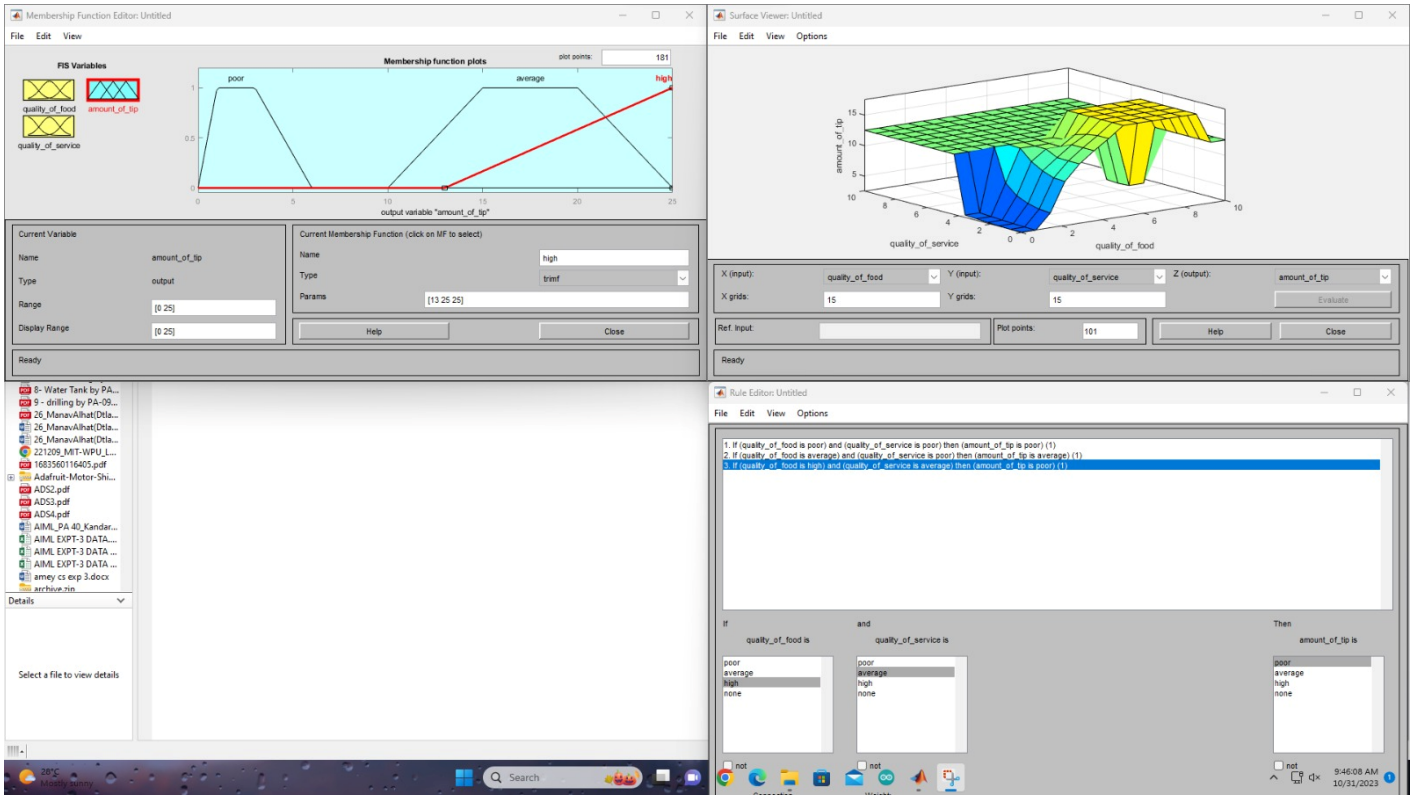
Python Code:

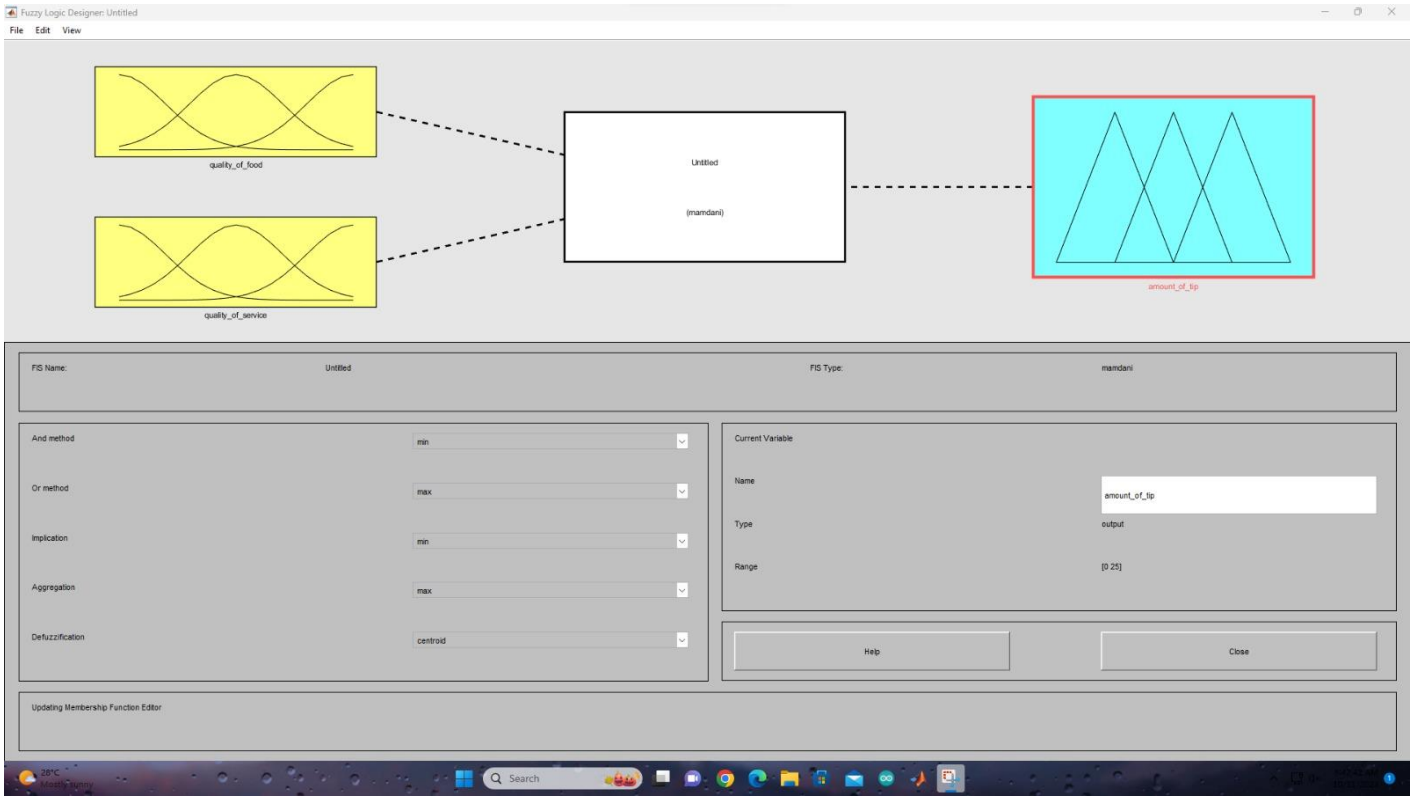
```
import numpy as np
import skfuzzy as fuzz
from skfuzzy import control as ctrl
quality = ctrl.Antecedent (np.arange(0, 11, 1), 'quality')
service = ctrl.Antecedent (np.arange(0, 11, 1), 'service')
tip = ctrl.Consequent (np.arange(0, 26, 1), 'tip'
service.automf()
quality.automf(3)
tip ['low'] = fuzz.trimf(tip.universe, [0, 0, 13])
tip ['medium'] = fuzz.trimf(tip.universe, [0, 13, 25])
tip ['high'] = fuzz.trimf(tip.universe, [13, 25, 25])
quality['average'].view()
service.view()
tip.view()
rule1 = ctrl.Rule(quality['poor'] & service['poor'], tip['low'])
rule1.view()
rule2 = ctrl.Rule(quality['average'] & service['average'], tip['medium'])
rule3 = ctrl.Rule(quality['good'] & service['good'], tip['high'])
tipping_ctrl = ctrl.ControlSystem([rule1, rule2, rule3])
tipping = ctrl.ControlSystemSimulation(tipping_ctrl)
tipping.input['quality'] = 8.5
tipping.input['service'] = 9.5
tipping.compute()
print(tipping.output['tip'])
tip.view(sim=tipping)
```

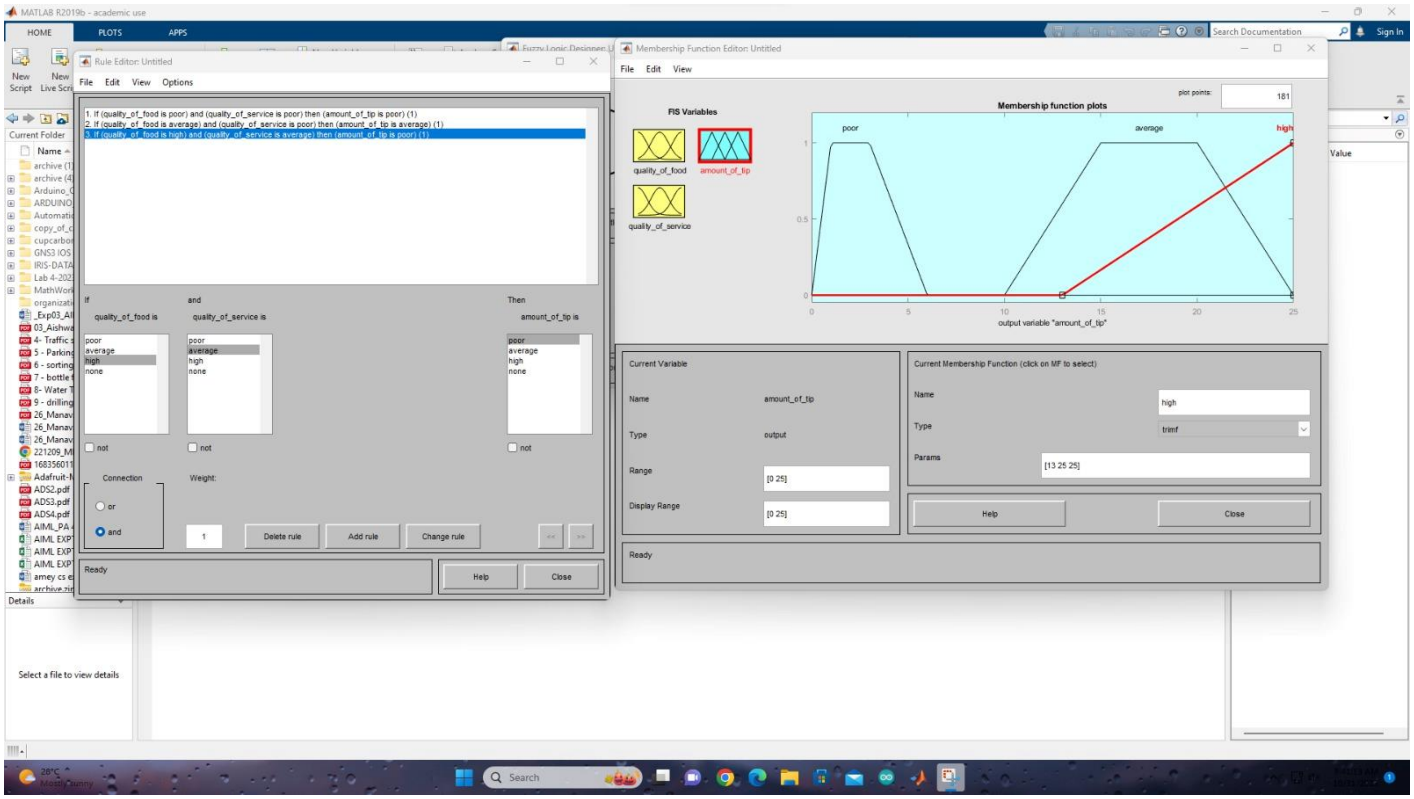
Conclusion:

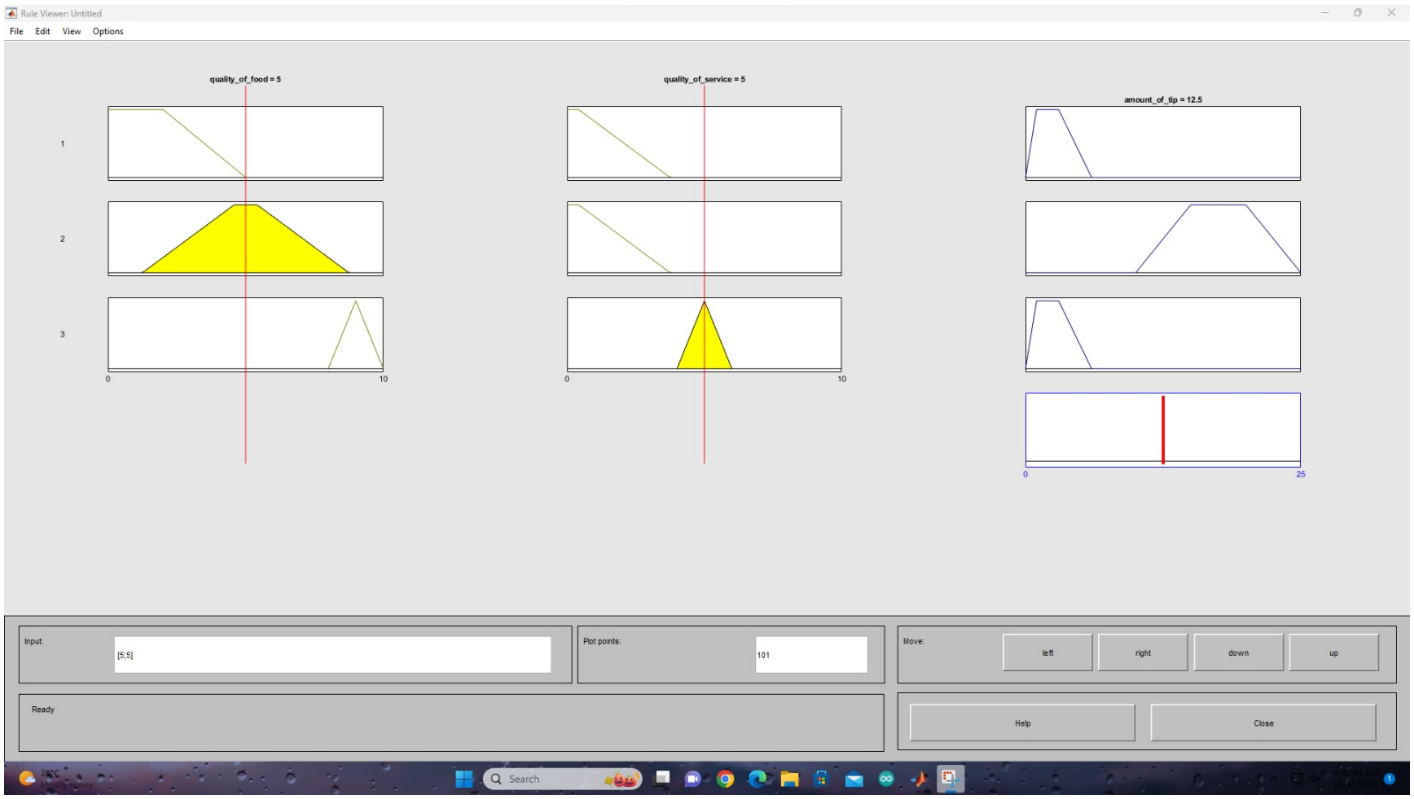
Post Lab Questions:

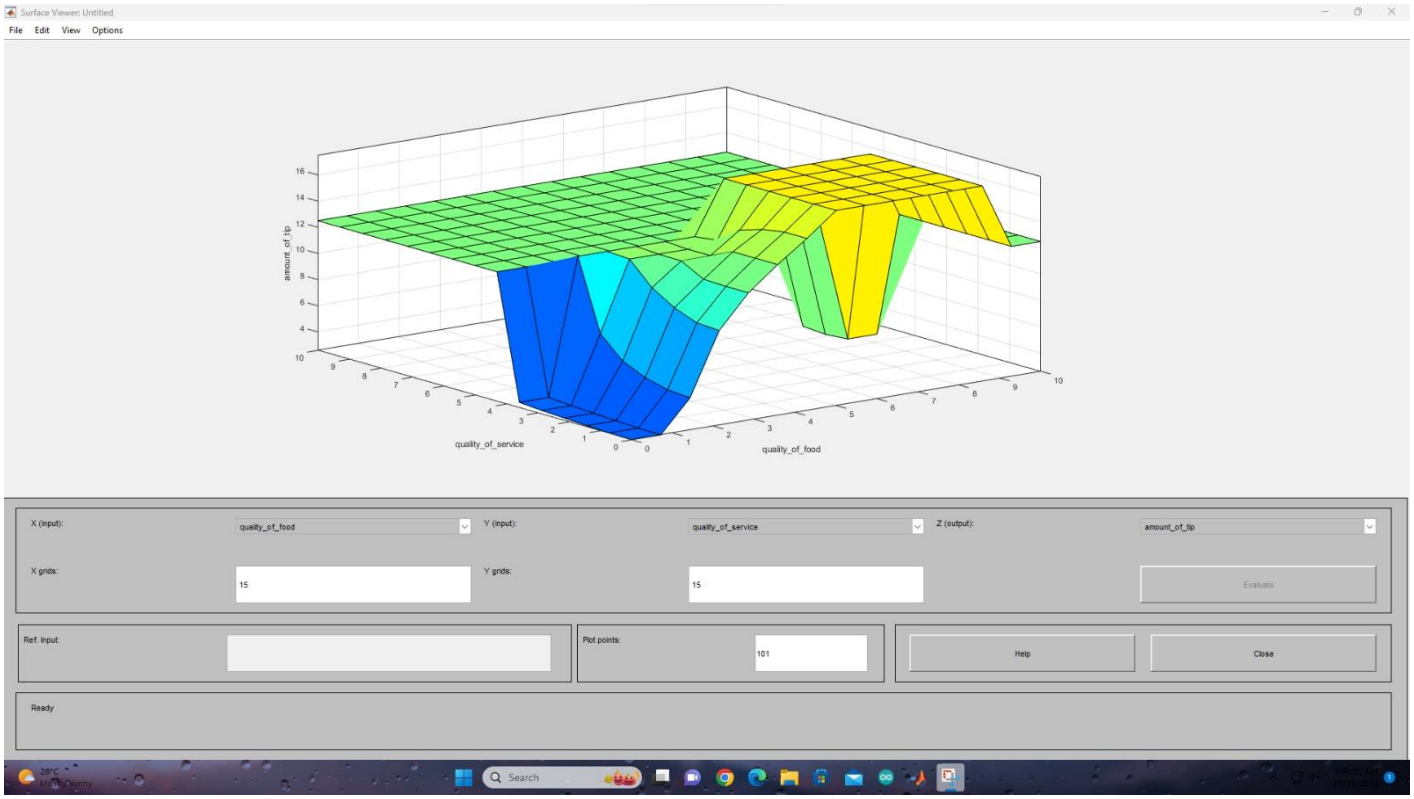
1. Define fuzzy set and crisp set.
2. What are the various operations on fuzzy set?
3. What are the set operations which are violated in fuzzy set theory?
4. Explain FIS in detail.


Membership Function Editor: Untitled
File Edit View
FIS Variables
quality_of_food
amount_of_tip
quality_of_service
Membership function plots
plot points: 181
poor
average
high
output variable "amount_of_tip"
Current Variable
Name amount_of_tip
Type output
Range [0 25]
Display Range [0 25]
Current Membership Function (click on MF to select)
Name high
Type trimf
Params [13.25 25]
Help
Close
Ready
Surface Viewer: Untitled
File Edit View Options
amount_of_tip
quality_of_service
quality_of_food
X (input): quality_of_food
Y (input): quality_of_service
Z (output): amount_of_tip
X grids: 15
Y grids: 15
Evaluate
Ref. Input:
Plot points: 101
Help
Close
Ready
Rule Editor: Untitled
File Edit View Options
1. If (quality_of_food is poor) and (quality_of_service is poor) then (amount_of_tip is poor) (1)
2. If (quality_of_food is average) and (quality_of_service is poor) then (amount_of_tip is average) (1)
3. If (quality_of_food is high) and (quality_of_service is average) then (amount_of_tip is poor) (1)
If
and
Then
quality_of_food is
quality_of_service is
amount_of_tip is
poor
average
high
none
not
Details
Select a file to view details
Search
9:46:08 AM
10/31/2023


Fuzzy Logic Designer: Untitled
File Edit View
quality_of_food
quality_of_service
Untitled
(mamdani)
amount_of_tip
FIS Name: Untitled
FIS Type: mamdani
And method min
Or method max
Implication min
Aggregation max
Defuzzification centroid
Current Variable
Name amount_of_tip
Type output
Range [0 25]
Help
Close
Updating Membership Function Editor
Search


MATLAB R2019b - academic use
HOME
PLOTS
APPS
Rule Editor: Untitled
File Edit View Options
1. If (quality_of_food is poor) and (quality_of_service is poor) then (amount_of_tip is poor) (1)
2. If (quality_of_food is average) and (quality_of_service is poor) then (amount_of_tip is average) (1)
3. If (quality_of_food is high) and (quality_of_service is average) then (amount_of_tip is poor) (1)
If
quality_of_food is
and
quality_of_service is
Then
amount_of_tip is
poor
average
high
none
not
Connection
or
and
Weight:
1
Delete rule
Add rule
Change rule
Ready
Help
Close
Membership Function Editor: Untitled
File Edit View
FIS Variables
quality_of_food
amount_of_tip
quality_of_service
plot points:
181
Membership function plots
poor
average
high
output variable "amount_of_tip"
Current Variable
Name
amount_of_tip
Type
output
Range
[0 25]
Display Range
[0 25]
Current Membership Function (click on MF to select)
Name
high
Type
trimf
Params
[13 25 25]
Help
Close
Ready
Details
Select a file to view details
Value


Rule Viewer: Untitled
File Edit View Options
quality_of_food = 5
quality_of_service = 5
amount_of_tip = 12.5
1
2
3
0
10
0
10
0
25
Input:
[5.5]
Plot points:
101
Move:
left
right
down
up
Ready
Help
Close


Surface Viewer: Untitled
File Edit View Options
amount_of_tip
quality_of_service
quality_of_food
X (input):
quality_of_food
Y (input):
quality_of_service
Z (output):
amount_of_tip
X grids:
15
Y grids:
15
Evaluate
Ref. Input:
Plot points:
101
Help
Close
Ready
Search

Exp 8

FIS with Mamdani Interfacing Mechanism Functions

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* Post Lab Questions:

① ~~A fuzzy set is a~~
② Define fuzzy set & crisp set

→① Fuzzy set -

A fuzzy set is a mathematical concept that generalizes the idea of a traditional, or "crisp", set by allowing elements to belong to the set to varying degrees.

In a fuzzy set, each element is associated with a membership function that assigns a value between 0 & 1, indicating the degree to which the element belongs to the set.

② Crisp set -

A crisp set, in contrast to a fuzzy set, is a traditional set in which elements are either members or non-members with no intermediate states.

Crisp sets are used in classical set theory and are suitable for modelling well-defined, discrete, and non-ambiguous concepts. They do not accomodate uncertainty or gradual membership.

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Q2) What are the various operations on fuzzy set?

→ Various operations on fuzzy set are.

① Membership Function -
The membership fonction of a fuzzy set defines the degree of membership of each element in the universal set.

② Union (Fuzzy Union) -
The union of two fuzzy sets A & B is a fuzzy set denoted by A∪B.

③ Intersection (Fuzzy Intersection) -
The intersection of two fuzzy set denoted by A∩B

④ Complement (Fuzzy complement) -
The complement of a fuzzy set A is the fuzzy set denoted by A'.

⑤ De Morgan's law -
Fuzzy sets obey De Morgan's laws which relate union and intersection operations for complements.

→

Q3) What are the set operations which are violated in fuzzy set theory?

-> Set operations -

① Commutative law of union -
In classical set theory, the union operation is commutative, meaning that $A \cup B$ is the same as $B \cup A$. But, in fuzzy set theory the commutative law of union is violated.

② Commutative law of intersection -
Similar to the union operation, the commutative law of intersection is violated in fuzzy set theory

③ Idepotent law -
The idepotent law states that $A \cup A$ and $A \cap A$ is equal to A

④ Distributive law -
The distributive law for classical set theory $(A \cup (B \cap C) = (A \cup B) \cap (A \cup C))$ is also violated in fuzzy set theory.

⑤ Absorption law -
The absorption law in classical set theory $(A \cup (A \cap B) = A$ & $A \cap (A \cup B) = A)$ is also violated in fuzzy set theory.

Q4) Explain FIS in detail

→ ① A Fuzzy Inference System (FIS) is a computational framework rooted in fuzzy logic, designed to handle uncertainty and vagueness in data & and decision-making.

② It comprises several key components fuzzification, where crisp data is transformed into fuzzy sets with linguistic terms; a rule base that defines the relationships between input and output fuzzy sets using conditional statements.

③ An inference engine that evaluates rules based on current input values and determines the strength of each rule's conclusion.

④ FIS finds applications in a wide range of fields, including control systems, decision support, pattern recognition, and human-machine interaction, where it excels at handling imprecise & vague information