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Class: BE-ITA/B, Semester: VII
Subject: Data Science Lab

Experiment – 2

1. **Aim:** To implement Fuzzy set operation and Fuzzy membership functions and design a Fuzzy Controller

2. **Objectives:** Students should be able to understand basics of Fuzzy Logic

3. **Prerequisite:** Python basics

4. **Requirements:** PC, Python 3.9, Windows 10/ MacOS/ Linux, IDLE IDE

5. **Pre-Experiment Exercise:**
   Theory:
   Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning. The approach of FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO.

   The conventional logic block that a computer can understand takes precise input and produces a definite output as TRUE or FALSE, which is equivalent to human's YES or NO.

   The inventor of fuzzy logic, Lotfi Zadeh, observed that unlike computers, the human decision making includes a range of possibilities between YES and NO, such as −

   CERTAINLY YES
   POSSIBLY YES
   CANNOT SAY
   POSSIBLY NO
   CERTAINLY NO
   The fuzzy logic works on the levels of possibilities of input to achieve the definite output.

   ### Fuzzy Operations:

   Union :

   Consider 2 Fuzzy Sets denoted by A and B, then let's consider Y be the Union of them, then for every member of A and B, Y will be:

   degree_of_membership(Y)= max(degree_of_membership(A), degree_of_membership(B))

   Intersection :

   Consider 2 Fuzzy Sets denoted by A and B, then let's consider Y be the Intersection of them, then for every member of A and B, Y will be:

   degree_of_membership(Y)= min(degree_of_membership(A), degree_of_membership(B))

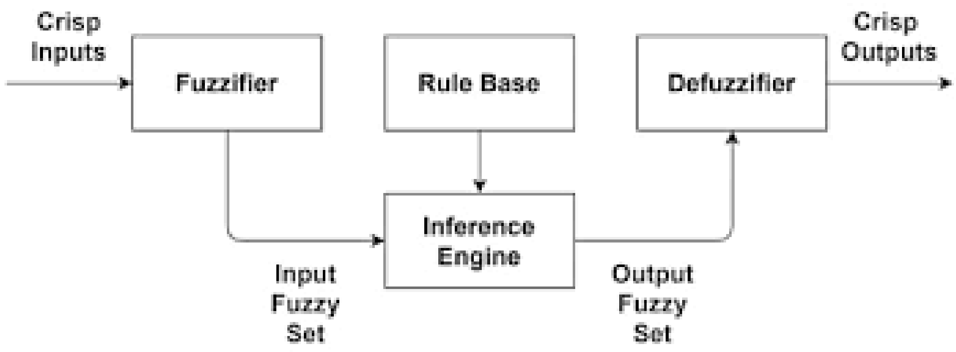
   Complement :

   Consider a Fuzzy Sets denoted by A , then let's consider Y be the Complement of it, then for every member of A , Y will be: degree_of_membership(Y)= 1 - degree_of_membership(A)

Difference :

Consider 2 Fuzzy Sets denoted by A and B, then let's consider Y be the Intersection of them, then for every member of A and B, Y will be:
degree_of_membership(Y)= min(degree_of_membership(A), 1- degree_of_membership(B))

Fuzzy Controller:



6. **Laboratory Exercise**
   A. Procedure
   i. Use google colab for programming.
   ii. Implement following Fuzzy set operations and represent output in graphical format
      - Union
      - Intersection
      - Complement

   b. Implement Fuzzy membership functions
      - Triangular Function
      - Trapezoidal Function
      - Gaussian Function

   c. Design a Fuzzy Controller

7. **Post-Experiments Exercise:**
   A. Extended Theory:
   a. Explain properties of Fuzzy sets.
   b. Write a brief note on Fuzzy Relation.
   c. Solve a problem on Fuzzy composition

   B. Conclusion:

   1. Write what was performed in the program (s) .
   2. What is the significance of program and what Objective is achieved?

   C. References:
[1] https://drive.google.com/file/d/1MVwbyXqlMSeb-25CSQ9WAAxais9LLqhO/view?usp=sharing
[2] S.N. Sivanandam, S.N. Deepa, "Principles of Soft Computing", Wiley Publication.

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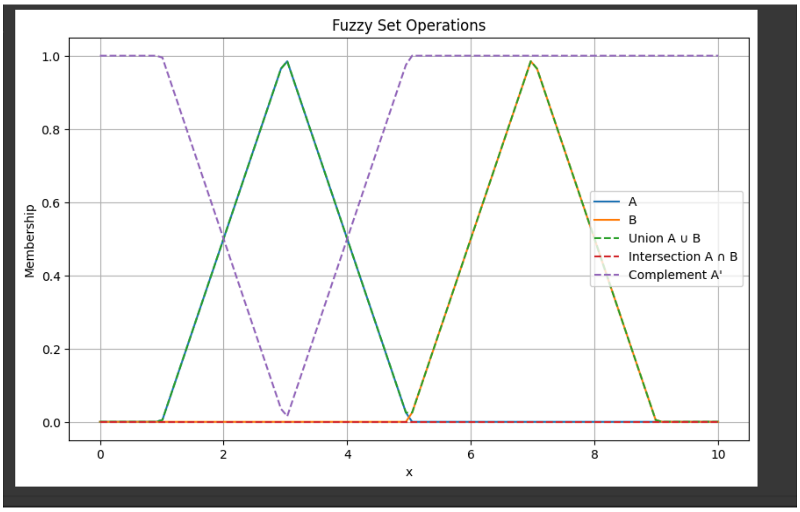
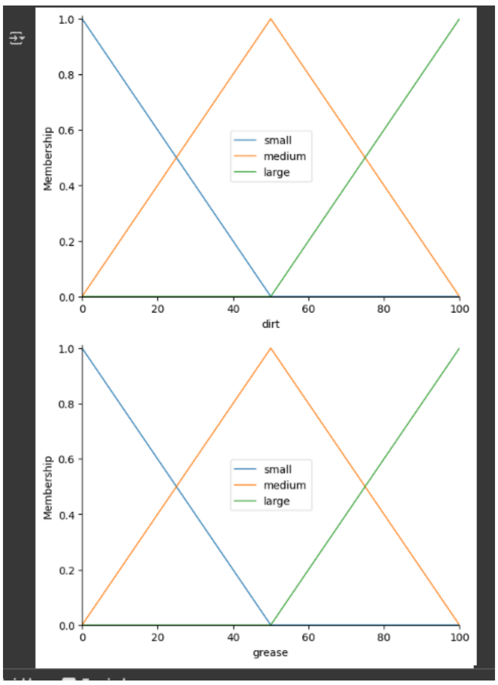
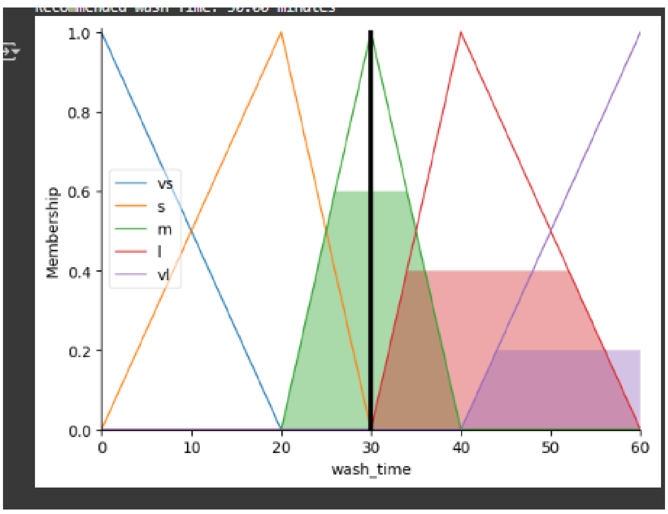
```python
import numpy as np
import matplotlib.pyplot as plt

# Define universe
x = np.linspace(0, 10, 100)

# Define fuzzy sets A and B
A = np.maximum(0, np.minimum(1, 1 - abs(x - 3)/2))
B = np.maximum(0, np.minimum(1, 1 - abs(x - 7)/2))

# Fuzzy Set Operations
union = np.fmax(A, B)
intersection = np.fmin(A, B)
complement_A = 1 - A

# Plotting
plt.figure(figsize=(10, 6))
plt.plot(x, A, label='A')
plt.plot(x, B, label='B')
plt.plot(x, union, label='Union A ∪ B', linestyle='--')
plt.plot(x, intersection, label='Intersection A ∩ B', linestyle='--')
plt.plot(x, complement_A, label='Complement A\'', linestyle='--')
plt.title('Fuzzy Set Operations')
plt.xlabel('x')
plt.ylabel('Membership')
plt.legend()
plt.grid(True)
plt.show()
```




```python
import numpy as np
import pandas as pd

import skfuzzy as fuzz
from skfuzzy import control as ctrl
import matplotlib.pyplot as plt

# Inputs
dirt = ctrl.Antecedent(np.arange(0, 101, 1), 'dirt')
grease = ctrl.Antecedent(np.arange(0, 101, 1), 'grease')

# Output
wash_time = ctrl.Consequent(np.arange(0, 61, 1), 'wash_time', defuzzify_method='mom')

# Membership functions
for var in [dirt, grease]:
    var['small'] = fuzz.trimf(var.universe, [0, 0, 50])
    var['medium'] = fuzz.trimf(var.universe, [0, 50, 100])
    var['large'] = fuzz.trimf(var.universe, [50, 100, 100])

wash_time['vs'] = fuzz.trimf(wash_time.universe, [0, 0, 20])
wash_time['s'] = fuzz.trimf(wash_time.universe, [0, 20, 30])
wash_time['m'] = fuzz.trimf(wash_time.universe, [20, 30, 40])
wash_time['l'] = fuzz.trimf(wash_time.universe, [30, 40, 60])
wash_time['vl'] = fuzz.trimf(wash_time.universe, [40, 60, 60])

# Rules
rules = [
    ctrl.Rule(dirt['small'] & grease['small'], wash_time['vs']),
    ctrl.Rule(dirt['small'] & grease['medium'], wash_time['s']),
    ctrl.Rule(dirt['small'] & grease['large'], wash_time['l']),
    ctrl.Rule(dirt['medium'] & grease['small'], wash_time['s']),
```

```python
]

dirt.view()
grease.view()
wash_time.view()

plt.show()
print("\n Step-2")
# Print all fuzzy rules
data = {
    'Small': ['vs', 's', 'l'],
    'Medium': ['s', 'm', 'l'],
    'Large': ['l', 'l', 'vl']
}
rule_matrix = pd.DataFrame(data, index=['Small', 'Medium', 'Large'])
print("Fuzzy Rule Base Matrix:\n")
print(rule_matrix)

# Control system
wash_ctrl = ctrl.ControlSystem(rules)
wash_sim = ctrl.ControlSystemSimulation(wash_ctrl)

# Input
wash_sim.input['dirt'] = 60
wash_sim.input['grease'] = 70
print("-----------------------------------------------------")
# Compute
wash_sim.compute()
print(f"Recommended Wash Time: {wash_sim.output['wash_time']:.2f} minutes")

# Visualizations

wash_time.view(sim=wash_sim)
```





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