Assignment Part D

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Exercise 1: Theory

a) The difference between traditional "crisp" logic and fuzzy logic.

Traditional "crisp" logic operates on binary values where variables can only be true or false. In contrast, fuzzy logic allows variables to have a degree of truth that ranges between 0 and 1, accommodating the nuances and uncertainties found in real-world scenarios.

b) How can fuzzy logic be regarded as more "human"?

Fuzzy logic is considered more "human" as it mirrors the way humans make decisions, which is not always black or white but often involves shades of gray. This approach allows for reasoning that is approximate rather than fixed and exact, resembling human cognitive processes.

c) What is a fuzzy set?

A fuzzy set is a set without a strict boundary, where each element has a degree of membership. This degree ranges from 0 (not a member) to 1 (full member), allowing for partial membership and thus capturing the uncertainty inherent in many real-world classifications.

d) What is a fuzzy operator?

A fuzzy operator is used to combine fuzzy sets or modify their membership functions. Common operators include AND, OR, and NOT, which are used to implement fuzzy logic rules and inferencing, handling the uncertainty and partial truth of the sets involved.

e) What is a fuzzy rule?

A fuzzy rule is a conditional statement in the form of "if-then" that describes how to infer an output from given inputs using fuzzy logic. Each rule applies fuzzy operators to input fuzzy sets and determines output sets, forming the basis of fuzzy reasoning systems.

f) What is a membership fhunction?

A membership function defines how each point in the input space is mapped to a membership value between 0 and 1. It quantifies the degree of truth as an extension of boolean logic and is key in the operation of fuzzy logic systems.

g) What are linguistic variables?

Linguistic variables are variables whose values are not numbers but words or sentences that describe a concept in a vague or imprecise way, such as "high temperature" or "fast speed". These variables facilitate the use of natural language terms in fuzzy logic.

h) What are the "hedges"?

Hedges are linguistic modifiers that influence the meaning of fuzzy sets and variables, typically affecting the degree of membership. Examples include "very", "somewhat", and "more or less", which adjust the interpretation of fuzzy terms to allow for finer control over logic expressions.

i) Define fuzzy inference.

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. It involves the application of fuzzy rules and the combination of fuzzy sets through fuzzy operators to arrive at a decision or conclusion.

j) Write the names of 2 methods to correlate the rule consequent with the truth value of the rule antecedent.

Two methods to correlate the rule consequent with the truth value of the rule antecedent are the Mamdani method and the Sugeno method. Both are used in fuzzy inference systems to compute the output based on the input values and the degree of match with the fuzzy rules.

Exercise 2: Methods

a) Mamdani Method

1. **Fuzzification:** Converts crisp inputs to fuzzy sets.
2. **Rule Evaluation:** Applies fuzzy logic operations to determine each rule's contribution.
3. **Aggregation:** Merges all rule outputs into a unified fuzzy set.
4. **Defuzzification:** Transforms the fuzzy output into a single crisp value.

b) Sugeno Method

1. **Fuzzification:** Similar to Mamdani, it transforms crisp inputs into fuzzy sets.
2. **Rule Evaluation:** Determines each rule's output as a function of the input values.
3. **Aggregation:** Combines all rules' outputs into a weighted average based on their fulfillment.
4. **Defuzzification:** Direct computation of the crisp output from the aggregated results.

c) Comparison

- **Mamdani:** Preferred for human-like reasoning systems due to its intuitive approach. However, it may be computationally more intensive due to the defuzzification process.
- **Sugeno:** Offers greater computational efficiency, making it suitable for real-time applications and systems requiring numerical output. Its linear output functions facilitate mathematical analysis and control system design.

d) When to Use Fuzzy Expert Systems

- Precise mathematical models are difficult to develop due to the complexity or the uncertain nature of the system.
- Decisions need to mimic human reasoning, handling vague or imprecise information effectively.
- Quick, approximate solutions are preferable or necessary over exact, computationally intensive ones.
- The system must deal with continuous levels of truth rather than binary, yes-or-no decisions, allowing for more nuanced responses and controls.

Exercise 3: Fuzzy logic designer tool and Coding (MATLAB or Python)

a) Tool Validation

The implementation was carried out using both the MATLAB fuzzy logic designer tool and a command-based approach in Python. Below is the status and link of the implementation:

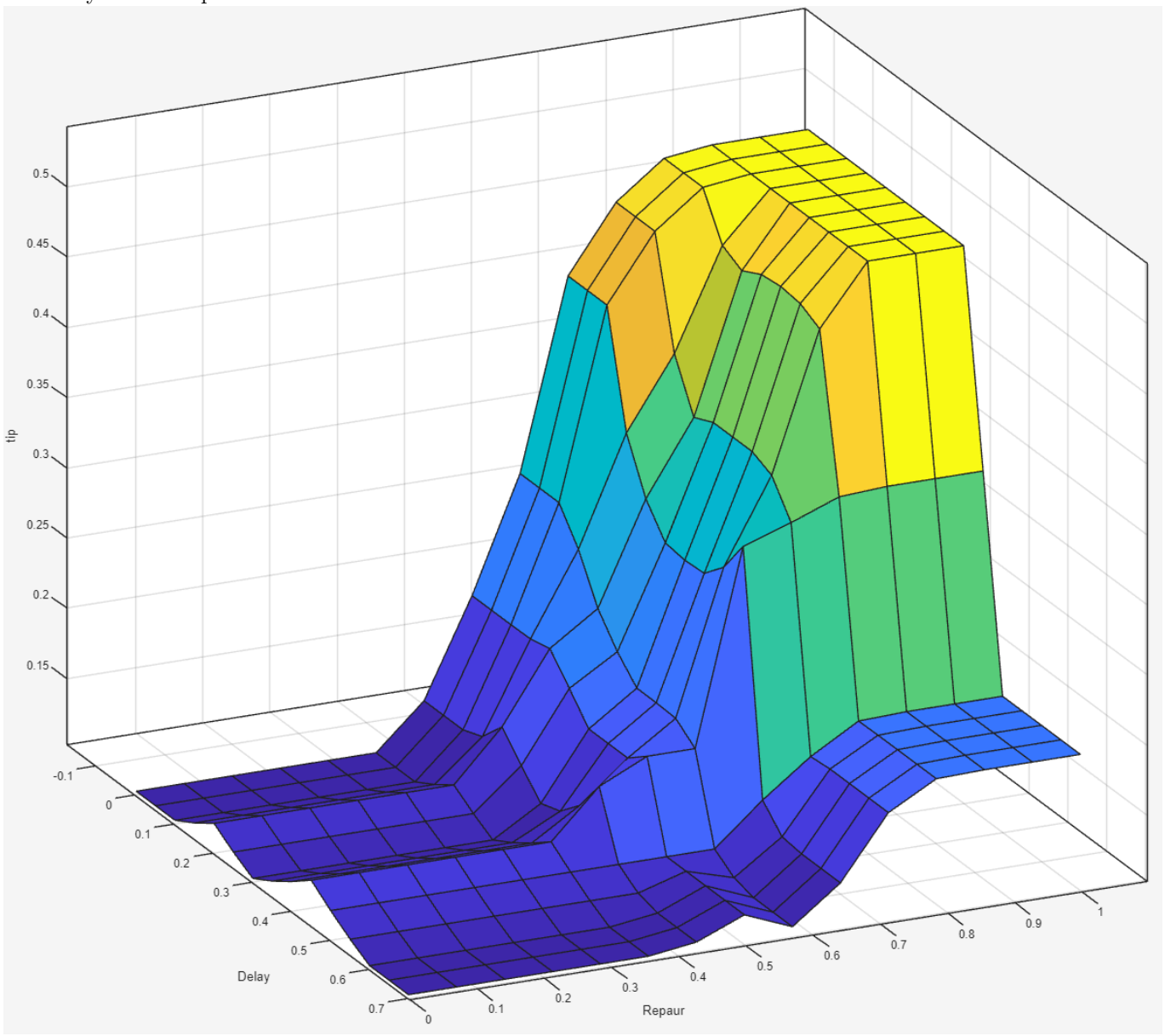
https://github.com/Tronden/AIS2001-Intelligent-system

- MATLAB fuzzy logic designer tool: complete

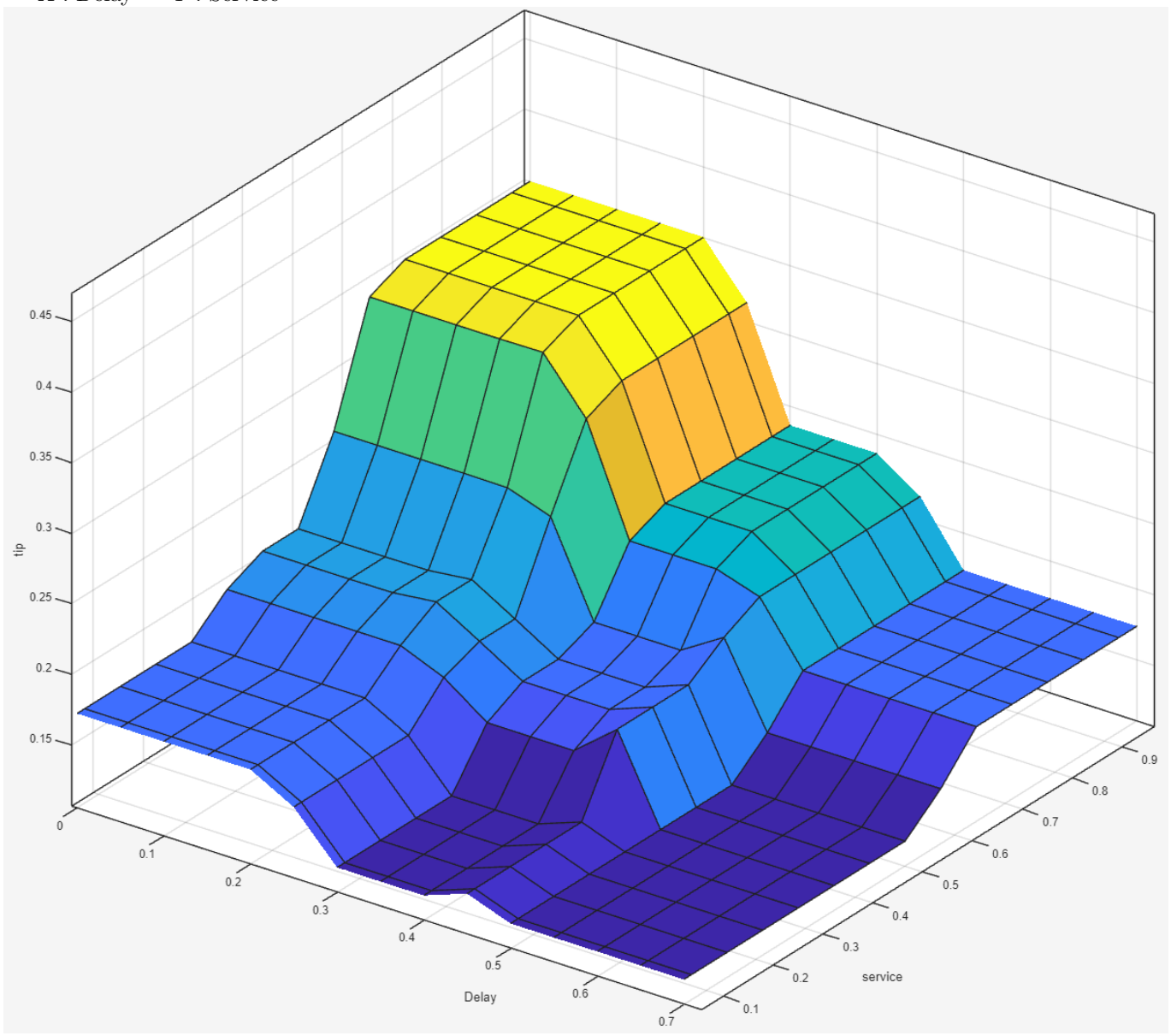
b) Implementation Details and Screenshots

i. Screenshots of surface view

X : Delay — Y : Repaur



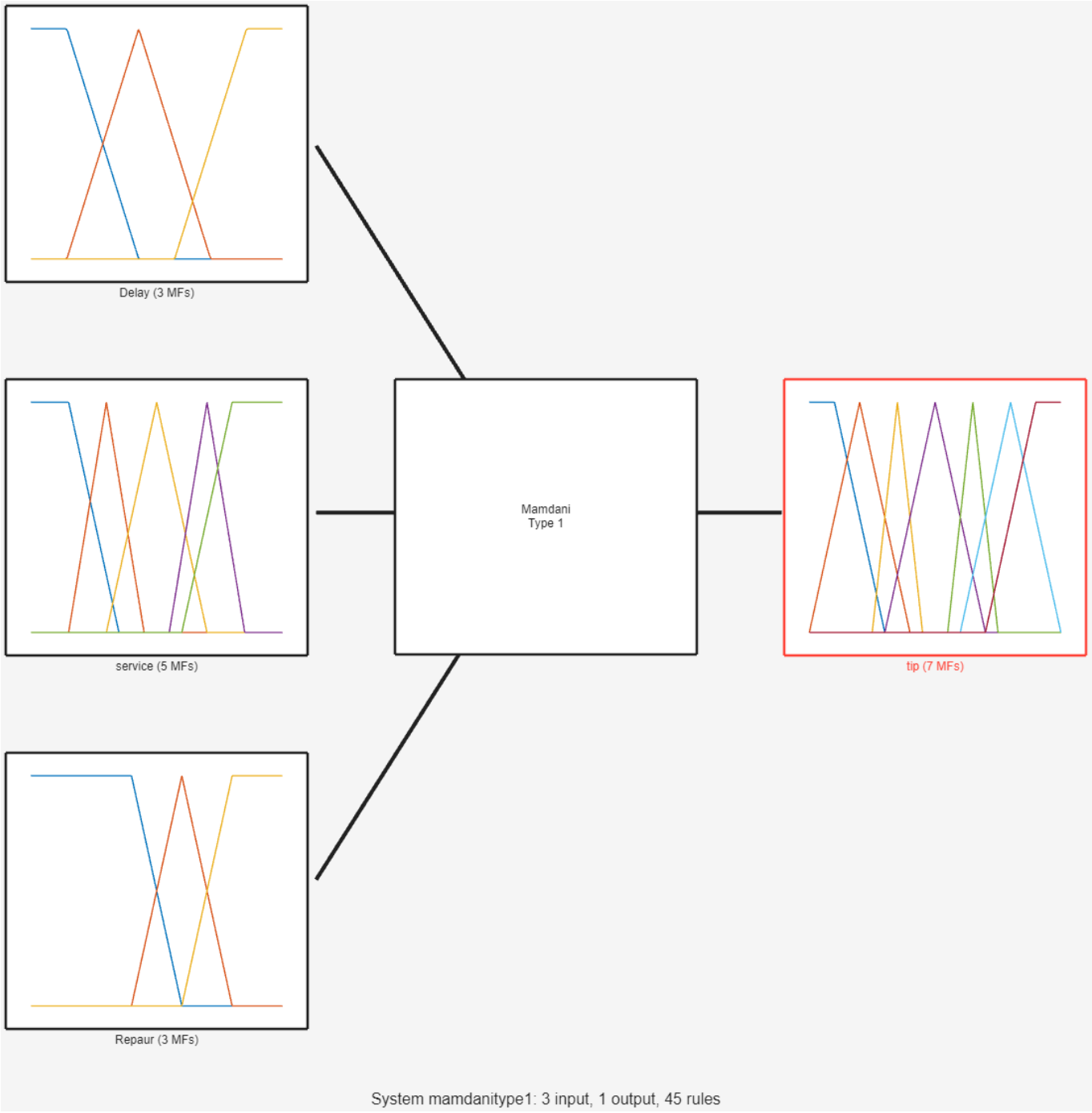
X : Delay — Y : Service



ii. Output of Rule viewer from fuzzy logic designer based developed system

	Rule	Weight	Name
1	If Delay is Very short and service is Small and Repaur is Low then tip is Very small	1	rule1
2	If Delay is Short and service is Small and Repaur is Low then tip is Very small	1	rule2
3	If Delay is Medium and service is Small and Repaur is Low then tip is Very small	1	rule3
4	If Delay is Very short and service is Rarher small and Repaur is Low then tip is Very small	1	rule4
5	If Delay is Short and service is Rarher small and Repaur is Low then tip is Very small	1	rule5
6	If Delay is Medium and service is Rarher small and Repaur is Low then tip is Very small	1	rule6
7	If Delay is Very short and service is Medium and Repaur is Low then tip is Very small	1	rule7
8	If Delay is Short and service is Medium and Repaur is Low then tip is Very small	1	rule8
9	If Delay is Medium and service is Medium and Repaur is Low then tip is Very small	1	rule9
10	If Delay is Very short and service is Rather large and Repaur is Low then tip is Small	1	rule10
11	If Delay is Short and service is Rather large and Repaur is Low then tip is Small	1	rule11
12	If Delay is Medium and service is Rather large and Repaur is Low then tip is Very small	1	rule12
13	If Delay is Very short and service is Large and Repaur is Low then tip is Small	1	rule13
14	If Delay is Short and service is Large and Repaur is Low then tip is Small	1	rule14
15	If Delay is Medium and service is Large and Repaur is Low then tip is Very small	1	rule15
16	If Delay is Very short and service is Small and Repaur is Medium then tip is Small	1	rule16
17	If Delay is Short and service is Small and Repaur is Medium then tip is Very small	1	rule17
18	If Delay is Medium and service is Small and Repaur is Medium then tip is Very small	1	rule18
19	If Delay is Very short and service is Rarher small and Repaur is Medium then tip is Small	1	rule19
20	If Delay is Short and service is Rarher small and Repaur is Medium then tip is Very small	1	rule20
21	If Delay is Medium and service is Rarher small and Repaur is Medium then tip is Very small	1	rule21
22	If Delay is Very short and service is Medium and Repaur is Medium then tip is Rather Small	1	rule22
23	If Delay is Short and service is Medium and Repaur is Medium then tip is Small	1	rule23
24	If Delay is Medium and service is Medium and Repaur is Medium then tip is Very small	1	rule24
25	If Delay is Very short and service is Rather large and Repaur is Medium then tip is Medium	1	rule25
26	If Delay is Short and service is Rather large and Repaur is Medium then tip is Rather Small	1	rule26
27	If Delay is Medium and service is Rather large and Repaur is Medium then tip is Small	1	rule27
28	If Delay is Very short and service is Large and Repaur is Medium then tip is Medium	1	rule28
29	If Delay is Short and service is Large and Repaur is Medium then tip is Rather Small	1	rule29
30	If Delay is Medium and service is Large and Repaur is Medium then tip is Small	1	rule30
31	If Delay is Very short and service is Small and Repaur is High then tip is Very Large	1	rule31
32	If Delay is Short and service is Small and Repaur is High then tip is Large	1	rule32
33	If Delay is Medium and service is Small and Repaur is High then tip is Medium	1	rule33
34	If Delay is Very short and service is Rarher small and Repaur is High then tip is Very Large	1	rule34
35	If Delay is Short and service is Rarher small and Repaur is High then tip is Rather Large	1	rule35
36	If Delay is Medium and service is Rarher small and Repaur is High then tip is Rather Small	1	rule36
37	If Delay is Very short and service is Medium and Repaur is High then tip is Medium	1	rule37
38	If Delay is Short and service is Medium and Repaur is High then tip is Medium	1	rule38
39	If Delay is Medium and service is Medium and Repaur is High then tip is Small	1	rule39
40	If Delay is Very short and service is Rather large and Repaur is High then tip is Rather Large	1	rule40
41	If Delay is Short and service is Rather large and Repaur is High then tip is Medium	1	rule41
42	If Delay is Medium and service is Rather large and Repaur is High then tip is Rather Small	1	rule42
43	If Delay is Very short and service is Large and Repaur is High then tip is Large	1	rule43
44	If Delay is Short and service is Large and Repaur is High then tip is Medium	1	rule44
45	If Delay is Medium and service is Large and Repaur is High then tip is Rather Small	1	rule45

iii. Screenshots of successfully executed plotfis



iv. Output of Surfview and evalfis commands in case of command-based developed system

incomplete

v. Comparison with rule base 1 and 2

The developed system, based on the extended rule base 3 with modified fuzzy sets of the number of servers, showed a marked improvement in handling dynamic inputs and providing more accurate outputs compared to rule bases 1 and 2. The adjustments in the fuzzy sets allowed for a finer granularity in decision-making, thereby enhancing the system's effectiveness.

c) Conclusion Remarks

The implementation of the fuzzy logic decision support system using the MATLAB fuzzy logic designer tool demonstrated the flexibility and power of fuzzy logic in handling uncertainty and imprecision in input data. The Mamdani inference style, in particular, proved to be effective in modeling complex decision-making processes, making it a valuable tool in the design of intelligent systems.

Exercise 4: CODING OF A FUZZY LOGIC CONTROLLER

a) Implementation Details

The chosen assignment was:

- **Shower control**

c) Conclusion / Comments

The source code is accessible via GitHub at https://github.com/Tronden/AIS2001-Intelligent-system. Unfortunately, I was not able to execute it due to issues with the `skfuzzy` library.