18CSE352T-Neuro Fuzzy and Genetic Programming

Case Study Implementation CT3-1

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Year III, B2 section

Topic:

A study on Fuzzy Inference Systems: Fuzzy Lighting Controller System

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INTRODUCTION

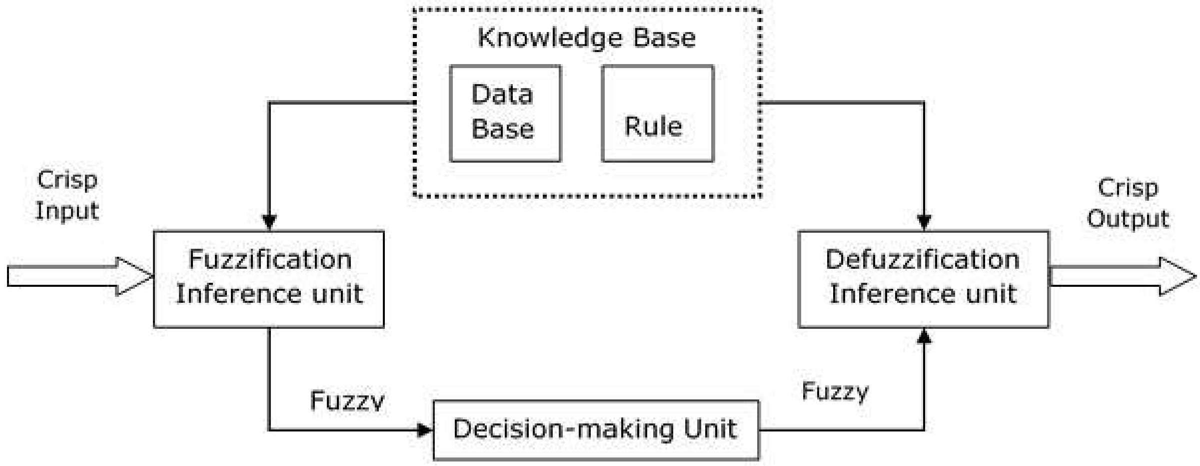
An intelligent system (IS) is a system that emulates some aspects of intelligence exhibited by nature. These include learning, flexibility, robustness across problem domains, enhancing efficiency. Intelligent Systems provide a problem-solving methodology approach to important and fairly complex problems and to achieve consistent and reliable results over time.

A fuzzy inference system may be a computer paradigm supported by fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. A nonlinear mapping that derives its output from fuzzy reasoning and a group of fuzzy if-then rules. The mapping domain and range can be multidimensional spaced fuzzy sets or points. It uses a fuzzy set theory to map inputs to outputs.

Here the input and output are fuzzy meaning they can be a part of a range of values, as opposed to crisp values where output is usually in the form of 0 (false) or true (1).

The fuzzy logic helps in emerging of an inference structure that enables appropriate human reasoning capabilities. Contrary, the conventional binary-set theories depict crisp events, with random probability of occurring

A fuzzy inference system consists of the following basic structure:



The main components include:

- A rule base containing fuzzy rules
- A database (or dictionary), containing the participation functions utilized in the fuzzy rules.
- A reasoning mechanism performing the induction made upon the guidelines and the facts given to infer a reasonable output or conclusion.
- Fuzzification and defuzzification unit to convert crisp values into fuzzy values and vice versa

A fuzzy inference system is used in different fields, for example, information order, choice examination, master system, time arrangement forecasts, advanced mechanics, and example acknowledgment. It is otherwise called a fuzzy rule-based system, fuzzy model, fuzzy logic controller, fuzzy expert system, and fuzzy associative memory.

BACKGROUND

FL is a control system methodology that lends itself to implementation in simple, small, embedded microcontroller to large, networked, multi-channel PC or workstation-based data acquisition and control systems. FL can be developed as a hardware or software solution, or as a combination of both. It offers uncomplicated solution to come to a definite conclusion based upon fuzziness, vague, inexact, noisy, or lacking of input information.

The theory of fuzzy logic is based upon the notion of relative graded membership and so are the functions of mentation and cognitive processes. Fuzzy modelling owns some distinctive advantages, compared to traditional mathematical modelling, such as the mechanism of reasoning in human comprehensible conditions, the capability of captivating linguistic information from human experts and combining it with numerical data and the ability of approximating complex nonlinear functions with simple models. Most real-world problems are characterized by the ability of a representation language (or logic) to process imperfect, inaccurate, unclear or uncertain information. With fuzzy logic, domains are characterized by linguistic terms, rather than by numbers

Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system. The design of fuzzy controllers is one of the largest application areas of fuzzy logic. The first application of fuzzy control comes from the work of Mamdani and Assilian, with their design of a fuzzy controller for a steam engine. Since then, a vast number of fuzzy controllers had been developed for consumer products and industrial processes.

There are three types of fuzzy controllers, table-based, Mamdani and Takagi-Sugeno fuzzy controller. The differences between types of fuzzy controllers are mainly in the implementation of the inference engine and the defuzzifier.

Table Based fuzzy Controller: Table-based controllers are used for a discrete universe where it is possible to calculate all combinations of the system inputs. The relation between all input combinations and their corresponding outputs are then arranged in a table.

Mamdani fuzzy inference: This was first introduced as a method to create a control system by synthesizing a set of linguistic control rules obtained from experienced human operators. In a Mamdani system, the output of each rule is a fuzzy set.

Takagi-Sugeno Control: Takagi and Sugeno suggested an approach to allow for such complex output sets, referred to as Takagi-Sugeno fuzzy controllers. For the Takagi-Sugeno controllers, the fact that the consequent of rules is a mathematical function provides for a more dynamic control. Whereas for the Mamdani controllers, the system is statically described by the rules.

PROBLEM ANALYSIS

Lighting generally consumed 25%-50% of total electricity consumption in a building. Nowadays, the building lighting source is dominated by the use of fluorescent lamps.
Electricity demands are increasing so dramatically and will do so even more in the future. This phenomenon affects research focus of many researchers in order to provide a better solution for energy conservation. Technologies for energy efficient lighting systems have emerged since lighting contributes the highest amount of electricity usage in buildings.
The use of lighting efficiently and effectively can offer major energy and cost saving. Many new technologies have emerged to convey energy efficient lighting by straightforward implementation. However, widening use of a new technology will be hindered if it is complicated to implement or there is uncertainty in the return of investment. The research of energy efficient lighting systems therefore still becomes an open issue till now.

Environmental lighting conditions can vary widely throughout the day due to factors such as daylight, weather changes, and indoor activities. A fuzzy light controller can adapt to these dynamic conditions in real-time, ensuring optimal lighting levels regardless of environmental changes.
Traditional lighting systems often operate at a fixed intensity level, leading to unnecessary energy consumption, especially when natural light is sufficient. A fuzzy light controller can dynamically adjust artificial lighting levels based on ambient

light conditions, leading to significant energy savings by dimming or brightening lights as needed.

Lighting plays a crucial role in creating comfortable and productive indoor environments. By maintaining consistent and appropriate lighting levels, a fuzzy light controller can enhance user comfort, reduce glare, and improve visual clarity, ultimately boosting productivity and well-being.

Constantly running lights at full intensity can lead to premature bulb burnout and increased maintenance costs. By intelligently dimming lights when natural light is abundant, a fuzzy light controller can extend the lifespan of bulbs and reduce the frequency of replacements, resulting in cost savings over time.

Thus the fuzzy lighting control system is a great leap and will be widely helpful in tackling the current overconsumption of electricity and perform a highly automated and intelligent solution.

SOLUTION DEVELOPMENT

The fuzzy lighting controller system is a method to deal with the lighting overconsumption issues through a smart automated system and using the concept of fuzzy inference rules.

The fuzzy control aims at controlling the intensity of the light by dimming the values based on the input values automatically. The input values are based on the environmental surroundings.

Inputs to the system are environmental light (env_light) and rate of change of surrounding environmental light (rate_of change).

Output represents control value to the dimmer.

For example, if outside light is very high with little to no change in lighting, then the light will automatically be dimmed more.

Through this logic, there are 9 inference rules which have been added to this fuzzy lighting controller system.

The controller has been implemented in MATLAB software, using both scripts as well as the available Fuzzy Logic Toolbox.

A two input one output Mamdani was used to show the simulation on Fuzzy Logic Toolbox.

Parameters of the control system:

The following two functions are used to define the different membership functions

trimf(params): triangular membership function

$$f(x; a, b, c) = \max\left(\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right)$$

Trapmf(params): trapezpidal membership function

$$f(x; a, b, c, d) = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right)$$

- Input 1: Environmental light represented by variable "env_light" and ranges between 120 and 220 lumens. It has three values dark, medium and light with the following three trapezoidal membership functions

f(0,120,130,150)= max(min($\frac{x}{120}$,1,$\frac{150-x}{20}$),0) dark

f(130,150,190,210)= max(min($\frac{x-120}{20}$,1,$\frac{210-x}{20}$),0) medium

f(190,210,220,220)= max(min($\frac{x-190}{20}$,1,0),0) low

- Input 2: Rate of change of environmental light represented by variable "rate_of_change" and ranges between -10 and 10.
  It has three values dark, medium and light with the following three triangular membership functions

f(-20,-10,0)= max(min($\frac{x+20}{10}$,0),0)   negative_small

f(-10,0,10)= max(min($\frac{x+10}{10}$,$\frac{210-x}{10}$),0)   zero

f(0,10,20)= max(min($\frac{x}{10}$,$\frac{20-x}{10}$),0)   positive_small

- Output 1: Control Value sent to dimmer represented by variable "dimmer" and ranges between 0 and 10.
  It has four values very small, small, big, very big with the following trapezoidal and triangular membership functions

f(0,0,2,4)= max(min(0,1,$\frac{4-x}{2}$),0)   very_small

f(2,4,6)= max(min($\frac{x-2}{2}$,$\frac{6-x}{2}$),0)   small

f(4,6,8)= max(min($\frac{x-4}{2}$,$\frac{8-x}{2}$),0)   big

f(6 8 10 10)= max(min($\frac{x-6}{2}$,1,$\mathbf{0}$),0)   very_big

The rules of inference are given in the following table

env_light Rate_of_change	dark	medium	light
positive_small	big	small	very_small
zero	big	big	small
negative_small	very_big	big	big

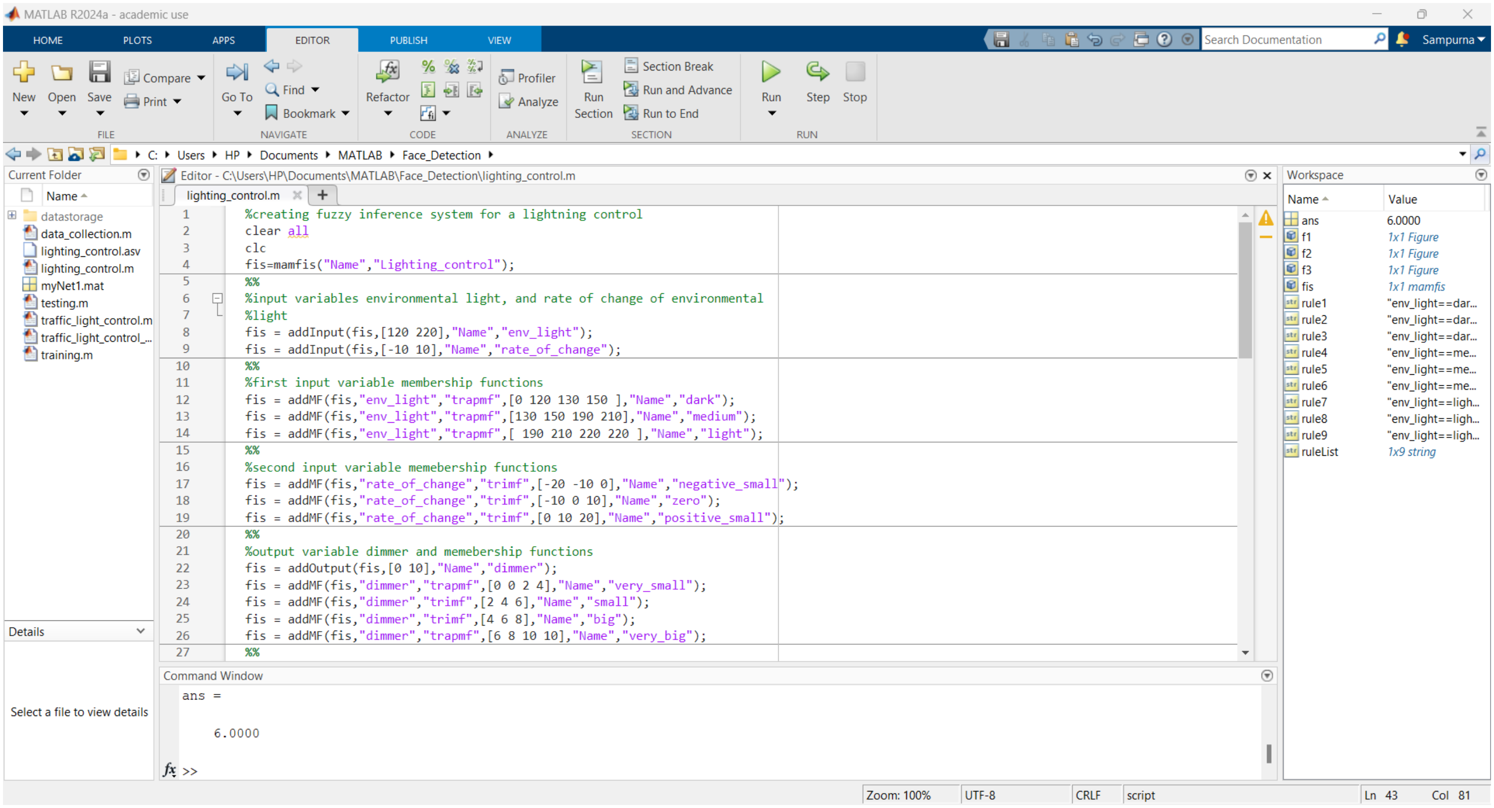
SOURCE CODE

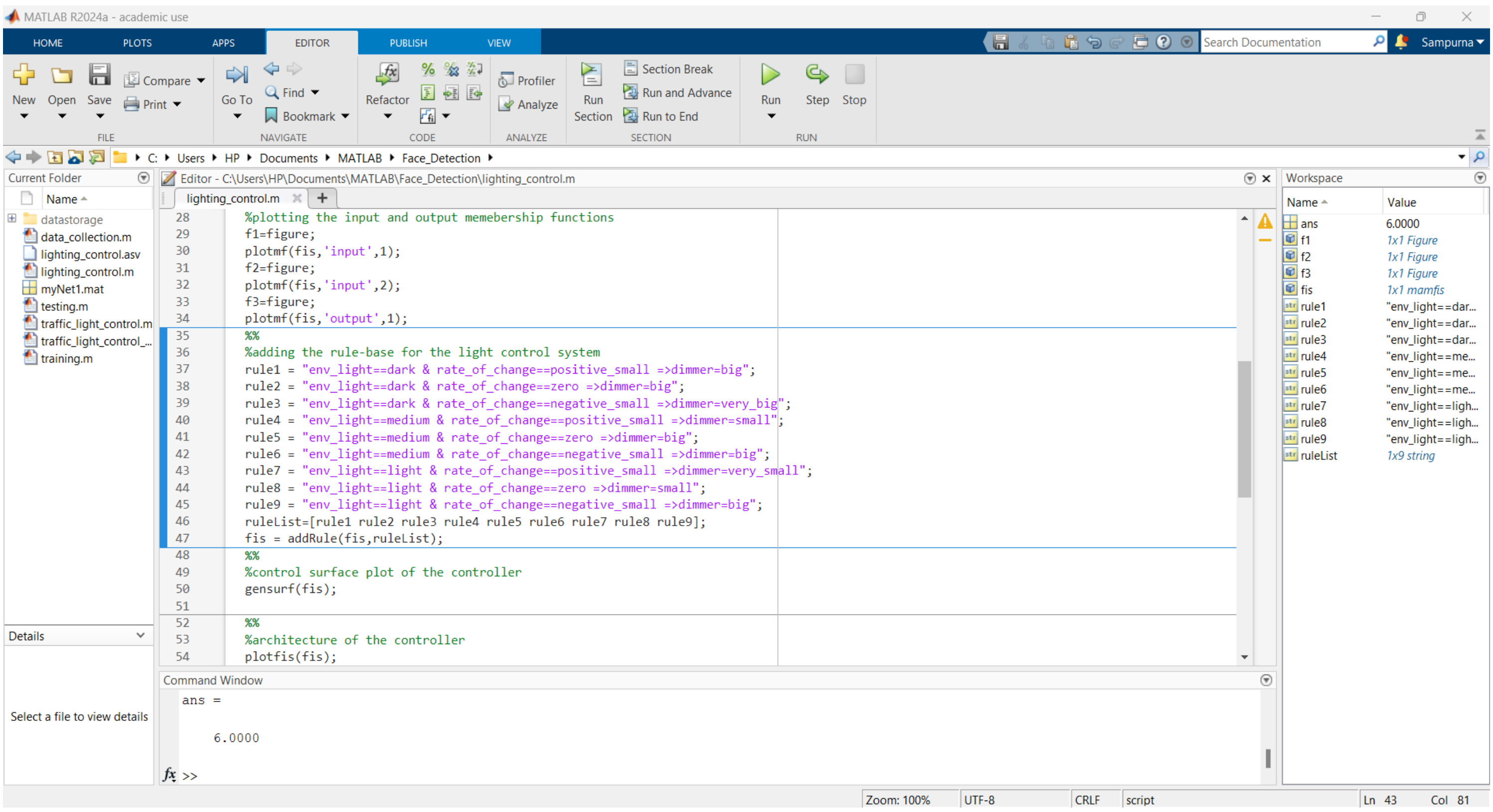
The fuzzy inference system has been implemented manually through the given MATLAB script

```
%creating fuzzy inference system for a lightning control
clear all
clc
fis=mamfis("Name","Lighting_control");

%%
%input variables environmental light, and rate of change of
environmental
%light
fis = addInput(fis,[120 220],"Name","env_light");
fis = addInput(fis,[-10 10],"Name","rate_of_change");

%%
%first input variable membership functions
fis = addMF(fis,"env_light","trapmf",[0 120 130 150
],"Name","dark");
fis = addMF(fis,"env_light","trapmf",[130 150 190
210],"Name","medium");
fis = addMF(fis,"env_light","trapmf",[ 190 210 220 220
],"Name","light");

%%
%second input variable memebership functions
fis = addMF(fis,"rate_of_change","trimf",[-20 -10
0],"Name","negative_small");
fis = addMF(fis,"rate_of_change","trimf",[-10 0 10],"Name","zero");
fis = addMF(fis,"rate_of_change","trimf",[0 10
20],"Name","positive_small");

%%
%output variable dimmer and memebership functions
fis = addOutput(fis,[0 10],"Name","dimmer");
fis = addMF(fis,"dimmer","trapmf",[0 0 2 4],"Name","very_small");
fis = addMF(fis,"dimmer","trimf",[2 4 6],"Name","small");
fis = addMF(fis,"dimmer","trimf",[4 6 8],"Name","big");
fis = addMF(fis,"dimmer","trapmf",[6 8 10 10],"Name","very_big");

%%
%plotting the input and output memebership functions
```

```
f1=figure;
plotmf(fis,'input',1);
f2=figure;
plotmf(fis,'input',2);
f3=figure;
plotmf(fis,'output',1);

%%
%adding the rule-base for the light control system
rule1 = "env_light==dark & rate_of_change==positive_small
=>dimmer=big";
rule2 = "env_light==dark & rate_of_change==zero =>dimmer=big";
rule3 = "env_light==dark & rate_of_change==negative_small
=>dimmer=very_big";
rule4 = "env_light==medium & rate_of_change==positive_small
=>dimmer=small";
rule5 = "env_light==medium & rate_of_change==zero =>dimmer=big";
rule6 = "env_light==medium & rate_of_change==negative_small
=>dimmer=big";
rule7 = "env_light==light & rate_of_change==positive_small
=>dimmer=very_small";
rule8 = "env_light==light & rate_of_change==zero =>dimmer=small";
rule9 = "env_light==light & rate_of_change==negative_small
=>dimmer=big";
ruleList=[rule1 rule2 rule3 rule4 rule5 rule6 rule7 rule8 rule9];
fis = addRule(fis,ruleList);

%%
%control surface plot of the controller
gensurf(fis);

%%
%architecture of the controller
plotfis(fis);

%%
%evaluating the controller by giving crisp input values
evalfis(fis,[165 -6]);
```

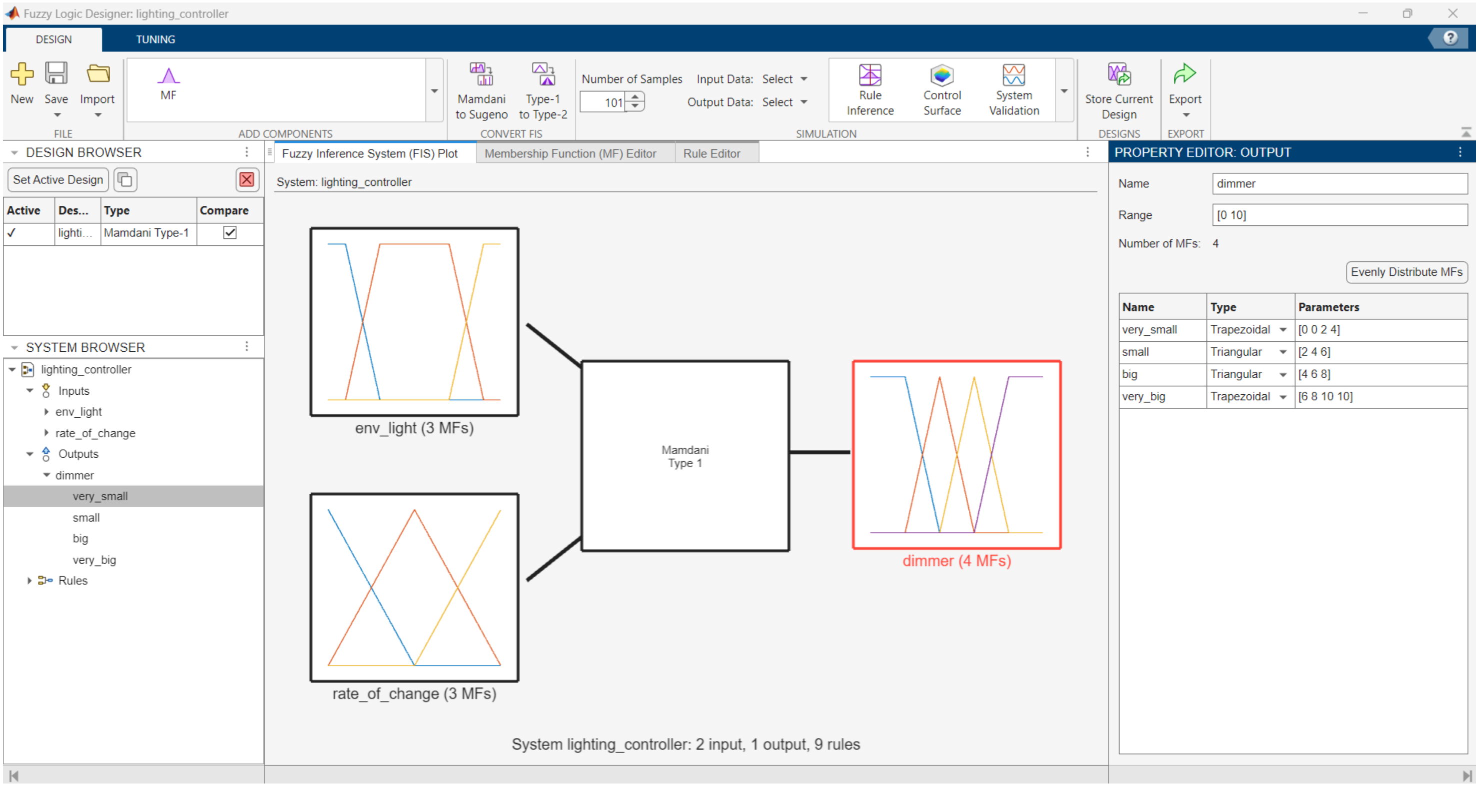
IMPLEMENTATION

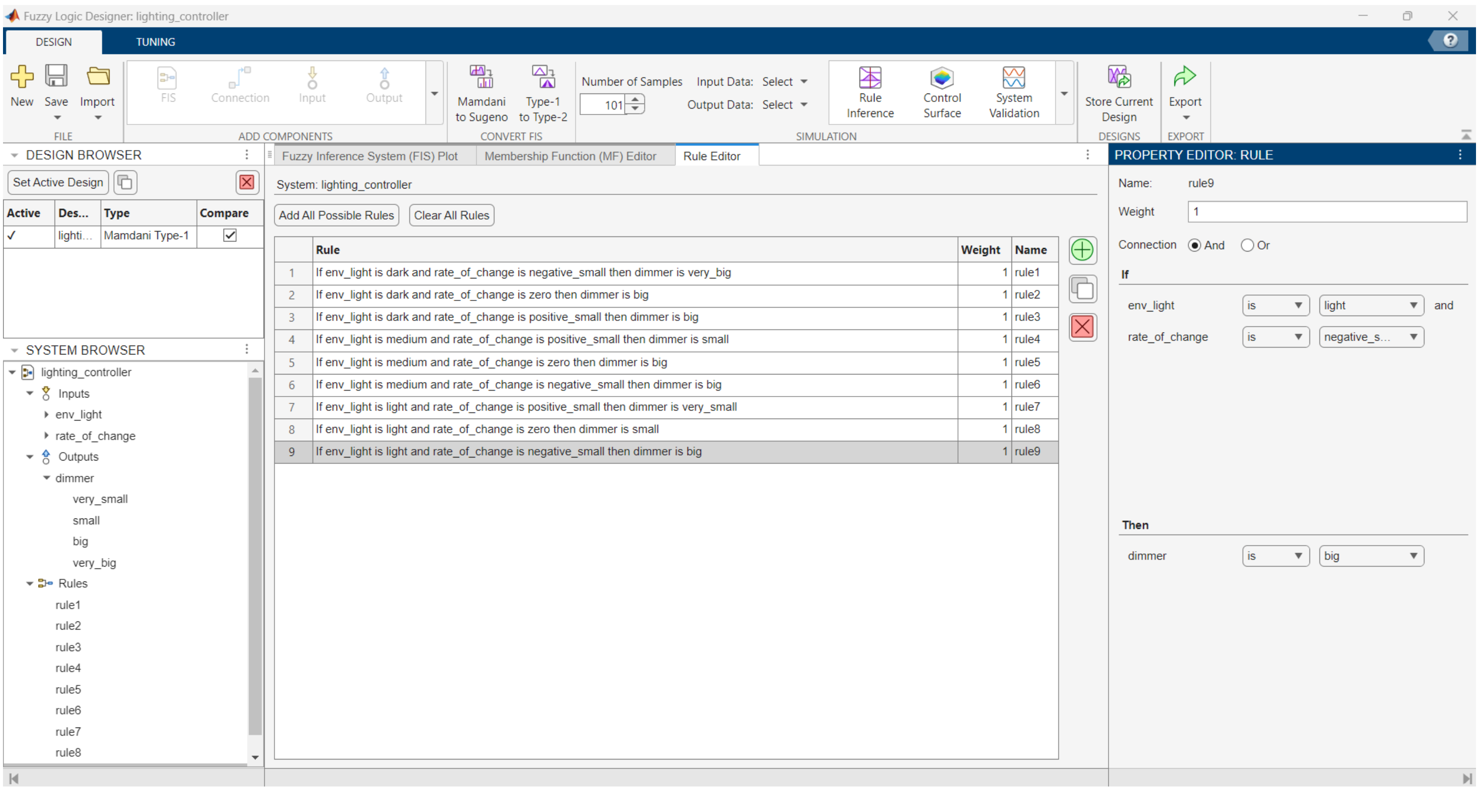




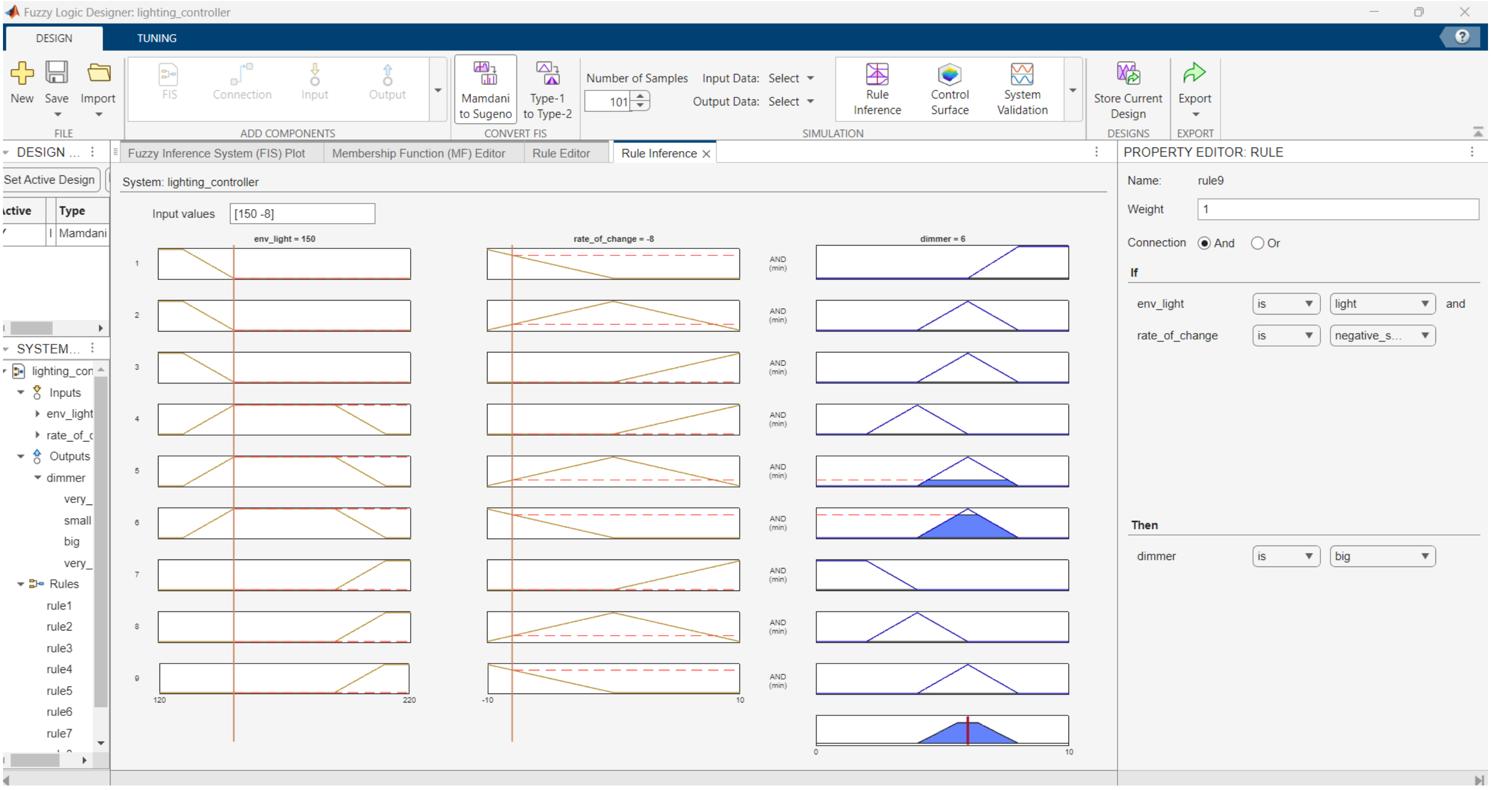
Implementation of script in MATLAB

Implementation using Fuzzy Logic Designer on MATLAB

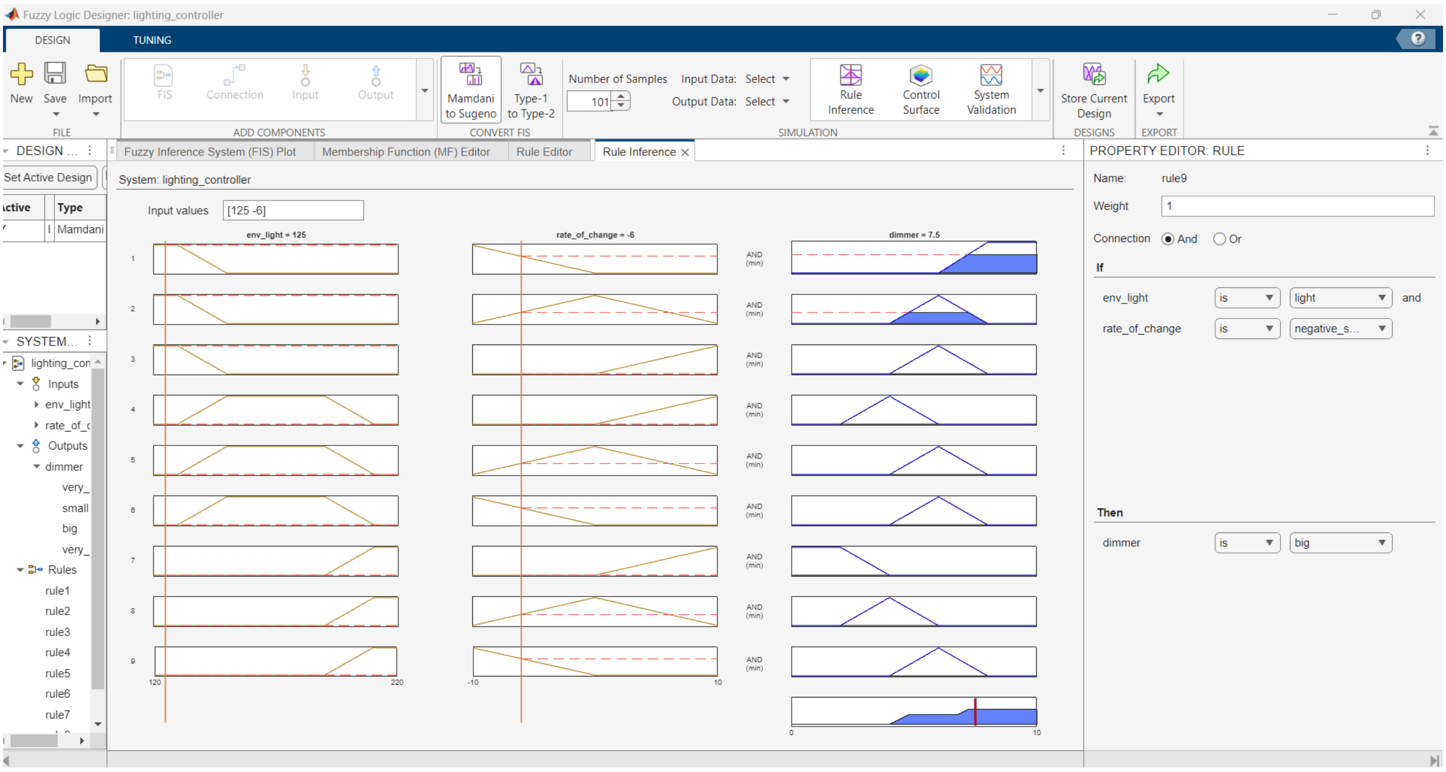




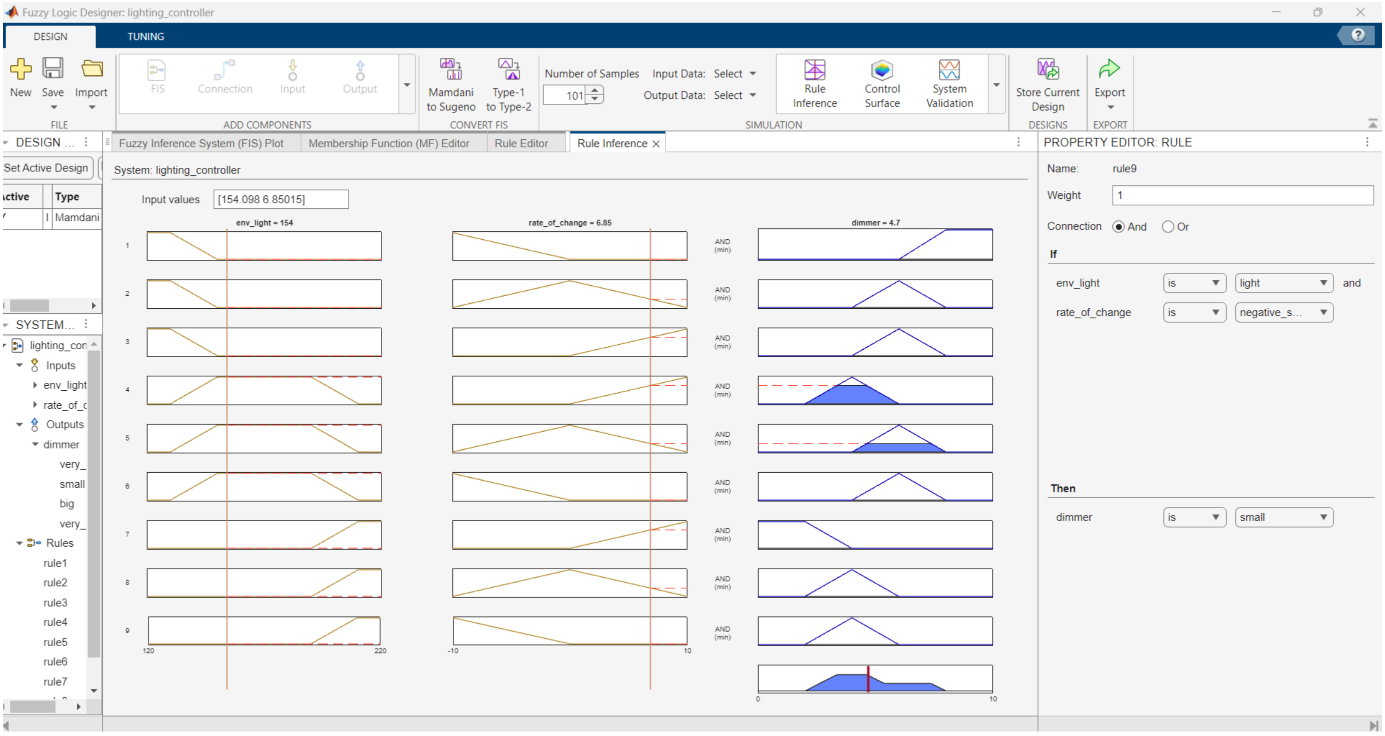
Testing the Inference System



Input values : 150 lumens,-8 rate of change
Output : 6 (control value sent to dimmer)



Input [125-6], Output [7.5]

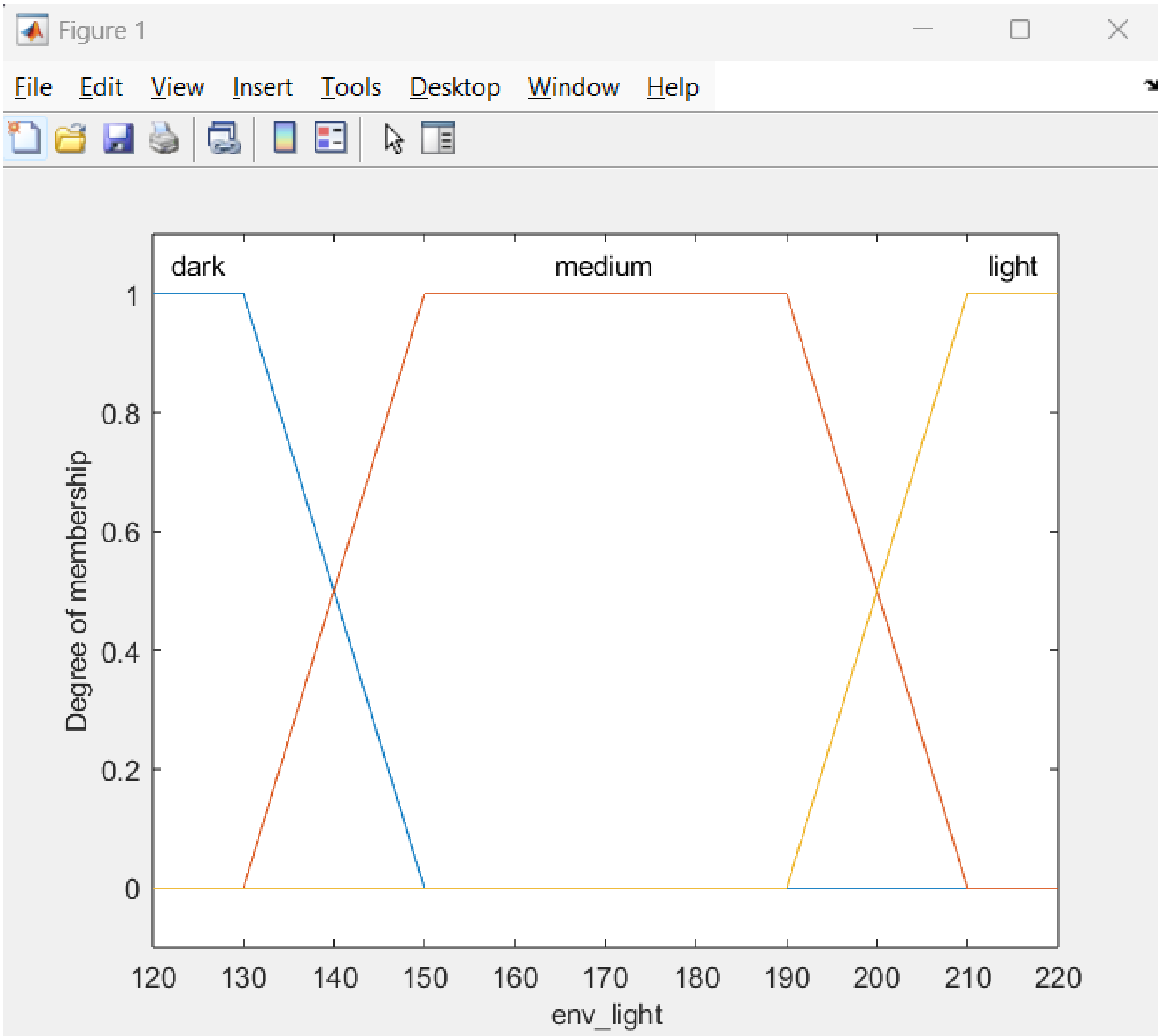


Input: [154.098 6.85015] Output: 4.7

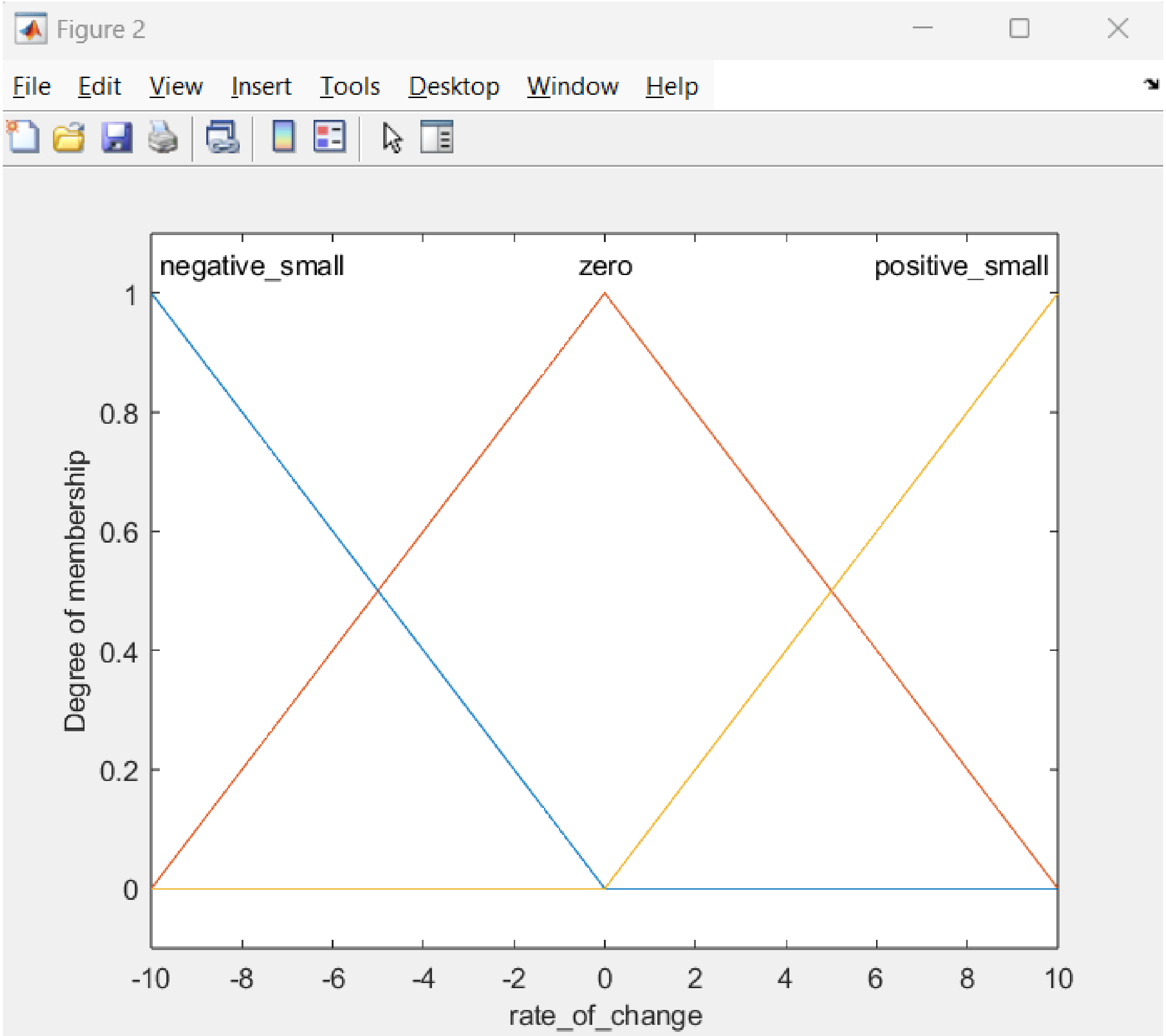
Thus we can see through the Fuzzy Logic Designer we get a simulation of the light controller system and we can analyse and get a large range of values by adjust the input accordingly.

It also provides a highly interactive way to choose input values and also shows clearly which inference rule has the most impact on the output for a certain set of input values as well as how the defuzzification works to produce the crisp output value.

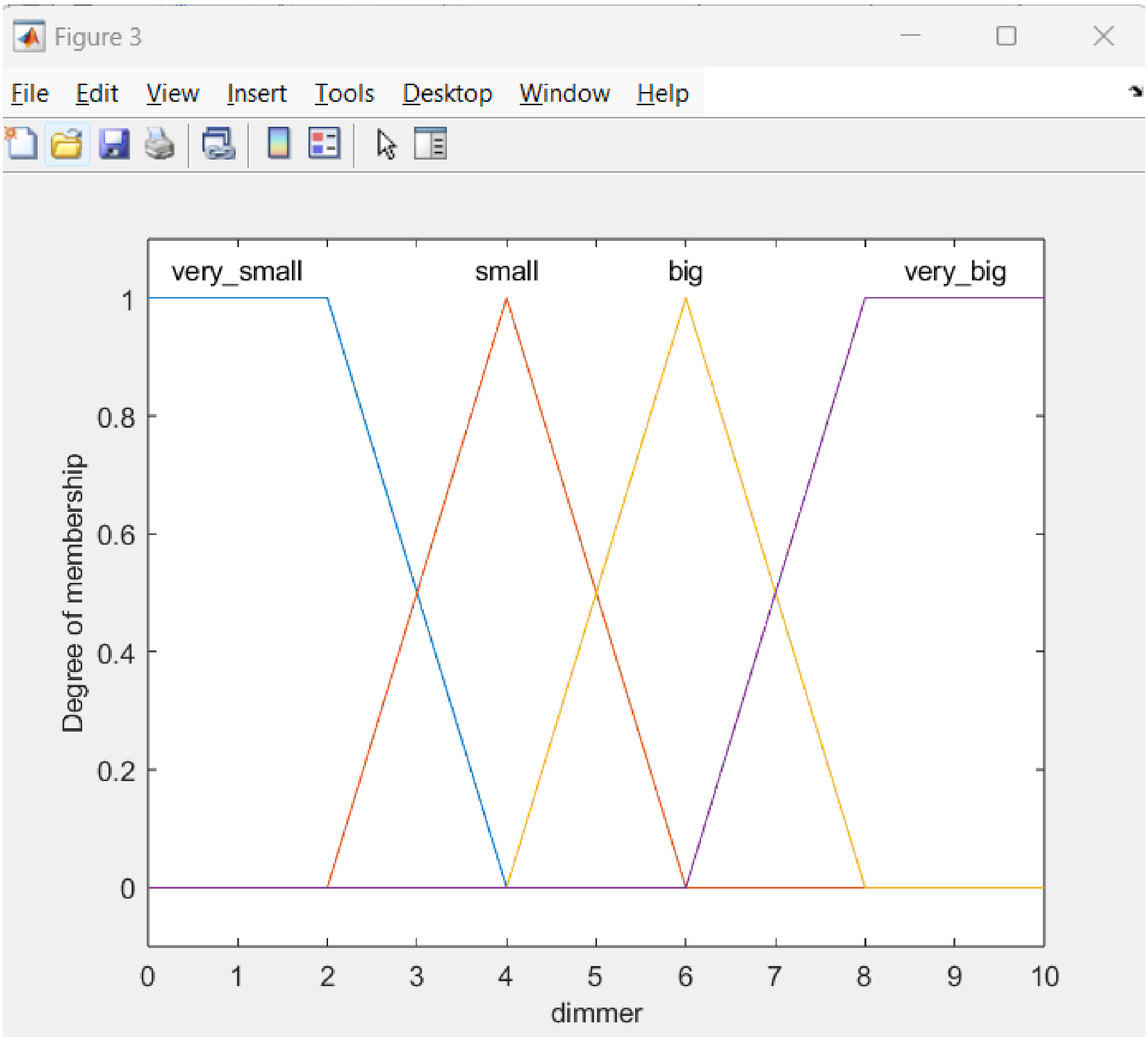
SCREENSHOTS



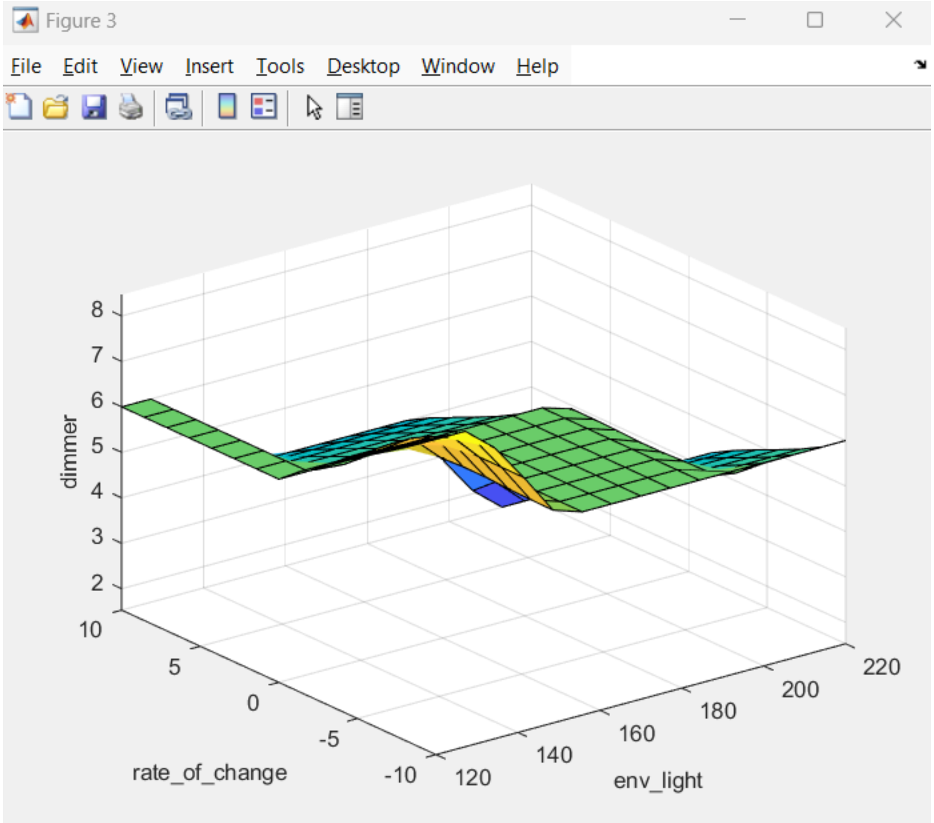
Graphical plot of membership functions of dark, medium, light of input variable “env_light”



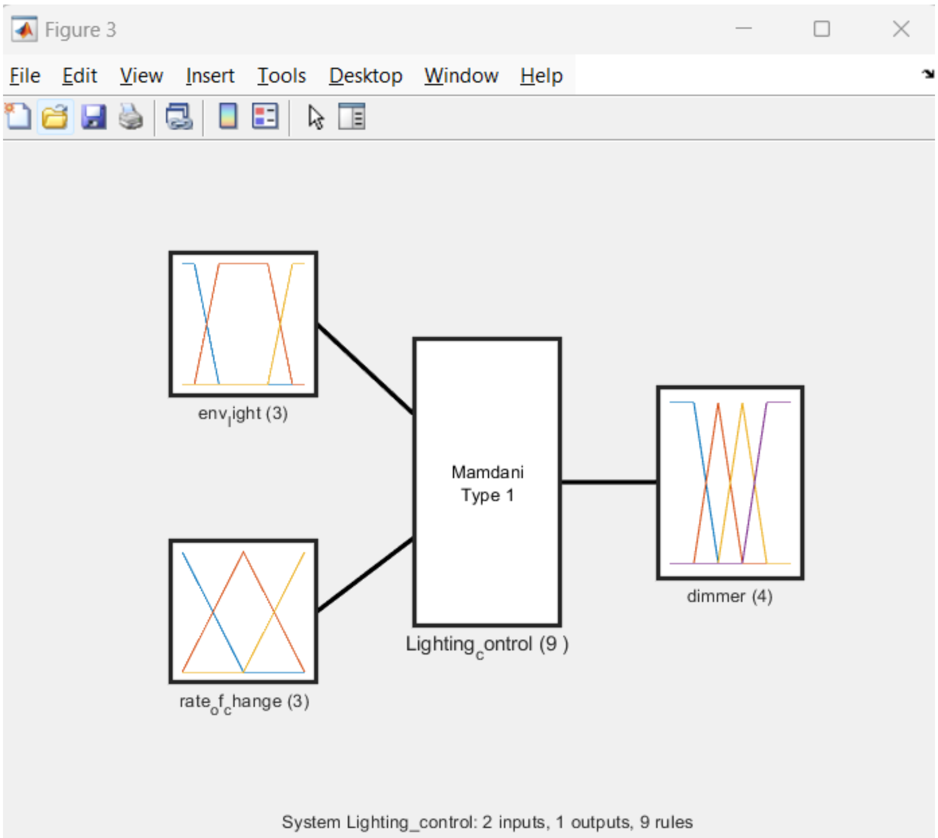
Graphical plot of membership functions of negative_small, zero, positive_small of input variable "rate_of_change"



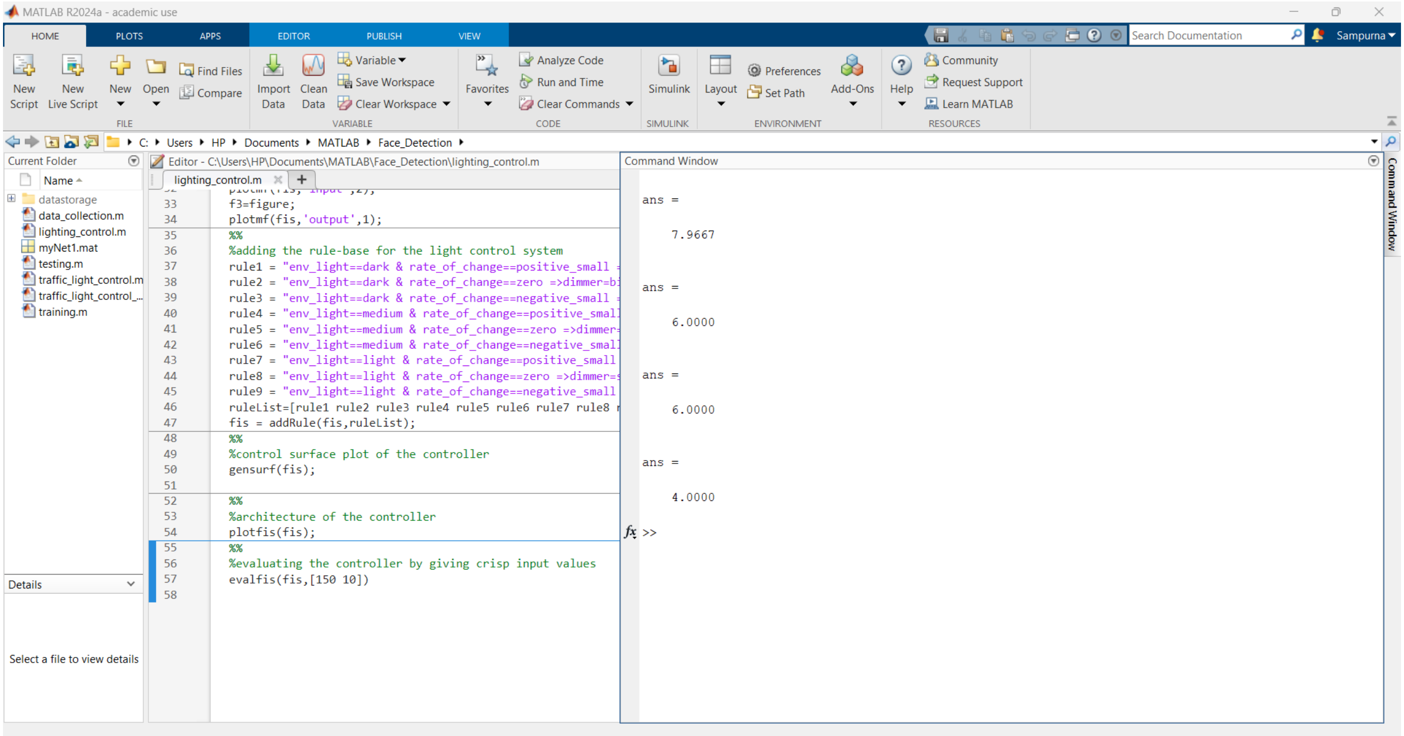
Graphical plot of membership functions of very_small, small, big, very_big of output variable “rate_of_change”



Control Surface plot of the inference system



Mamdani Type 1 Architecture of the Fuzzy Controller



Evaluating different values of the script through evalfis() function

CONCLUSION

The development of a fuzzy controller for light dimming based on environmental light levels and their rates of change addresses the need for adaptive, energy-efficient, and user-centric lighting systems. By intelligently adjusting artificial lighting in response to natural light conditions, the controller enhances both energy efficiency and user comfort, contributing to sustainable and comfortable built environments.

Its ability to consider not only current light levels but also the rate of change in illumination provides a nuanced approach to light control, resulting in enhanced user comfort, productivity, and safety. Moreover the flexibility and adaptability of the fuzzy controller enable it to meet stringent energy efficiency standards and regulatory requirements, making it an indispensable tool for sustainable building design and operation.

This case study shows a simple implementation of a light controller, which forms the framework of much more powerful and advanced fuzzy controller systems. With an increase in the number of input and output parameters, much more intelligent and efficient fuzzy control systems can be designed and made.

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GITHUB LINK

The following case study has been uploaded in GitHub in the following link given below:

https://github.com/sampurna0108/Case-Study-Implementation-RA2111003011044