Simulating Fuzzy Logic Systems in MATLAB. Application - fuzzy logic washing machine

Objectives: implementing a fuzzy logic system using the Fuzzy Logic Toolbox, analysing various methods for implication and defuzzification.

Note: MATLAB/Simulink is accessed online (https://matlab.mathworks.com/), by logging in with the MS Teams student credentials (surname.name@student.utcluj.ro).

Terms and abbreviations: *fuzzification, defuzzification, implication, centroid, bisector, MOM, SOM, LOM*

○ Process control using fuzzy logic systems

One of the most important practical applications of FLSs is using them as "process control systems". FLSs as control systems rely on a solid theoretical background and are integrated in many commercial applications. The example chosen in this lab aims to show how the washing time of an automatic washing machine can be controlled, using a fuzzy logic system.

When using a washing machine, the user manually sets the washing time, based on the volume of clothes and the type and degree of dirtiness. To automate the washing process, sensors can be used to detect the volume of clothes and their dirtiness. A certain washing time will be chosen, based on this data.

Unfortunately, a precise mathematical relation between the inputs (volume of clothes, dirtiness) and the output (washing time) cannot be defined. Thus, the washing time is manually set by the user, based on previous experience and trials.

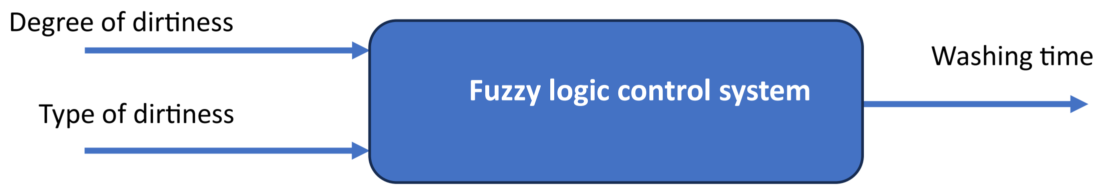
Building a washing machine with automatic washing time determination means building the following two subsystems:

- the sensor system - collects data from the outer environment (the clothes) and send them to the controller
- the controller system - sets the washing time, based on the information received from the sensor system.

Exercise 1
What type of sensors can be used to determine the volume, color, material, degree and type of dirtiness of the clothes?

○ Creating the FLS for the control of the washing time

The goal is to create a fuzzy logic controller for a washing machine, that will compute the appropriate washing time, based on certain information about the clothes. A schematic view of this system is deployed in the figure below:

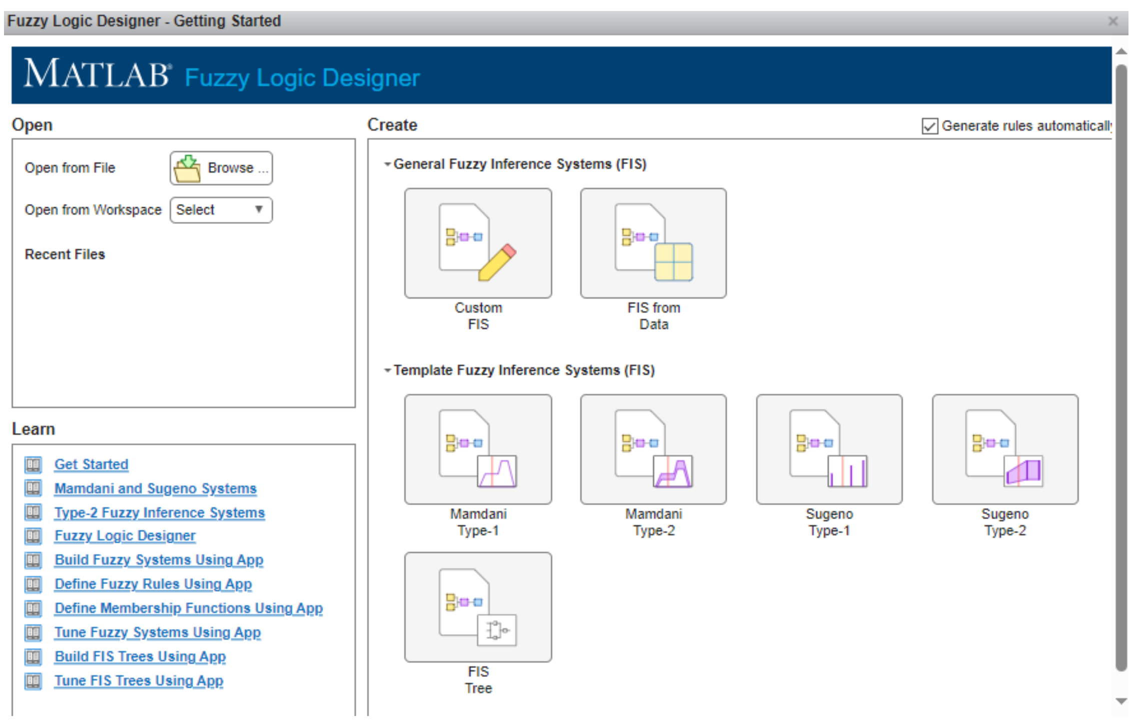


The two inputs of the system are:

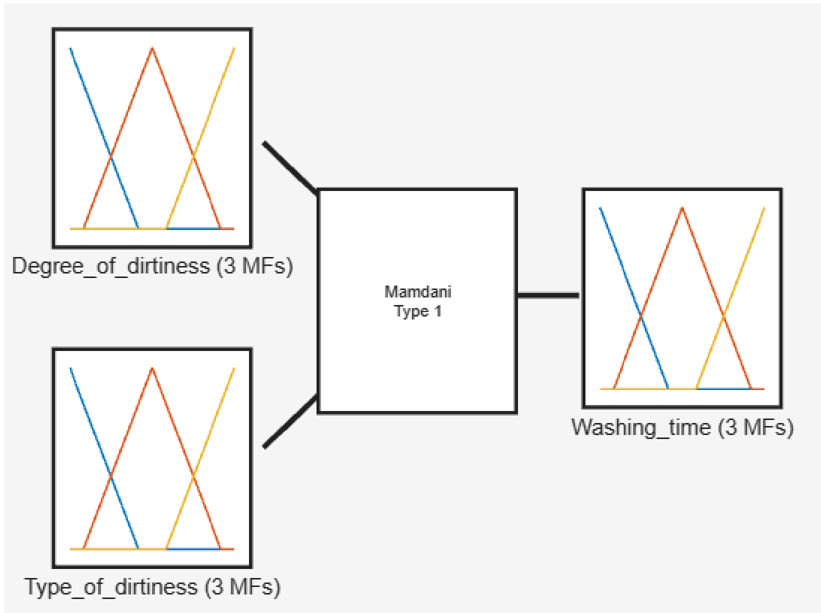
- degree of dirtiness - can be determined by examining the transparency of the water
- type of dirtiness - can be determined by examining the soaking time needed for the water to get to a constant transparency - transparency saturation. For example, for the clothes with fat stains, the time is longer, because the fat dissolves slower in water than other types of dirt.

The FLS is built using *Fuzzy Logic Designer*; to launch the tool, type the following in the command line:

```
FuzzyLogicDesigner
```



Select *Mamdani Type-1* (predefined Mamdani fuzzy system) and set the names for the input and output variables.



The fuzzy sets defined over the three variables have the names, types and parameters in the table below. The fuzzy sets define a fuzzy partition over the universe of discourse, for all three variables.

Variable name	Universe of discourse	Name	Type	Parameters
Degree_of_dirtiness	[0...100] %	*Low* *Medium* *High*	*trimf*	[-40 0 50] [0 50 100] [50 100 140]
Type_of_dirtiness	[0...100] %	*NonFat* *Medium* *Fat*	*trimf*	[-40 0 50] [0 50 100] [50 100 140]
Washing_time	[0...60] minutes	*VeryShort* *Short* *Medium* *Long* *VeryLong*	*trimf*	[0 8 12] [8 12 20] [12 20 40] [20 40 60] [40 60 60]

The rule base of the system is:

Type_of_dirtiness \ *Degree_of_dirtiness*	***Low***	***Medium***	***High***
NonFat	VeryShort	Short	Medium
Medium	Medium	Medium	Long
Fat	Long	Long	VeryLong

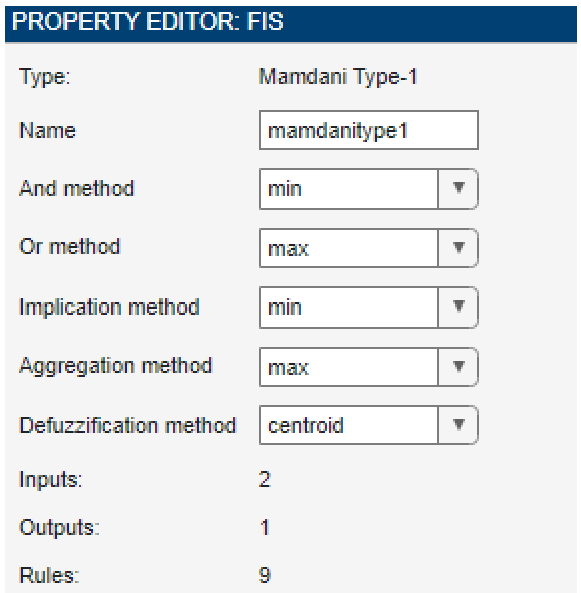
All rules use the AND connector.

Exercise 2
Define the fuzzy sets for all three variables and the rule base, as specified in the previous tables.

The operations of the FLS are:

- fuzzification – turns the crisp input into a *singleton* fuzzy set
- inference - max-min (Mamdani) type
- defuzzification - *centroid* (COA - center of area) defuzzification is used. The output values obtained by using this type of defuzzification guarantee a smooth control surface, which is a very important demand in control processes. The crisp output of a centroid defuzzification is computed using:

$$t_{0-continuous} = \frac{\int_{t=0}^{60} t * \mu_{MFO}(t)}{\int_{t=0}^{60} \mu_{MFO}(t)} \qquad t_{0-discrete} = \frac{\sum_{t=0}^{60} t * \mu_{MFO}(t)}{\sum_{t=0}^{60} \mu_{MFO}(t)}$$



Exercise 3

Analyse the behaviour of the FLS by viewing the control surface and the operations.

Exercise 4

Collect the control surfaces and the crisp output values in a document, for 5 relevant pairs of input values, in the following cases:

- `Implication: min; Defuzzification: centroid`
- `Implication: prod; Defuzzification: centroid`
- `Implication: min; Defuzzification: bisector`
- `Implication: min; Defuzzification: MOM`

Why does the surface of a control system generally need to be as smooth as possible? Which defuzzification method is the best, and which is the worst, for the current application?