EE682
HW2 - MFLC Design

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Contents

1 Introduction

The task was to design a Multi-criteria Fuzzy Logic Controller (MFLC) for the system given in HW1. Source code implementing both the controller and the system was handed out. The output response should be tuned following the user-preference for multi-criteria which includes rise time (T_r), percentage of overshoot ($\%OS$) and settling time (T_s). Finally, the characteristics of the MFLC should be described.

2 Framework

Similar to the previous homework, a MATLAB file called *plotting.m* was created in order to both plot the different step-responses of the MFLC and display the step-response characteristics. In order to display the characteristics, the MATLAB-function *stepinfo()* was used. To make it easier to both compile and run the *c*- and MATLAB-code, the bash script *run.sh* was created. In order to obtain the output from the MFLC with different configurations, selected parts of the source code were commented out and uncommented in.

3 Step response of MFLC

It was specified that the gain parameters from HW1 should be used for the MFLC. However, the FLC from HW1 was not optimally tuned and as a result the parameters for the MFLC were poorly chosen. The gain parameters from HW1, which was chosen for the MFLC, are shown in table 1.

Table 1: Gain parameters for MFLC

Parameters	**Value**
K_e	1.6
K_{ce}	1.2
K_u	3.6

Further, the MFLC was designed with three criteria where each criterion represented rise time T_r, overshoot percentage $\%OS$ and settling time T_s, respectively. The MFLC was tested out with both $\xi = 0.9$ and $\xi = 0.1$ which corresponds to plausibility measure and belief measure, respectively. For each type of fuzzy measure, different weights for the criteria was set. The response of the MFLC using plausibility measure is shown in fig. 1, while the response using belief measure is shown in fig. 2. As can be seen, both the responses are oscillatory which is a consequence of the chosen gain parameters. In order to obtain a better performance, the gain parameters should be tuned for the MFLC.

4 MFLC characteristics

The MFLC can be regarded as an augmented FLC. Instead of calculating an output solely based on the rule base, the output of the MFLC is also influenced by a set of criteria. Each criterion has its own weight representing how much that criterion is considered. A higher weight corresponds to a more considered criterion. To every rule, a global score is calculated using fuzzy integrals. This global score is based on partial scores which again depends on the weighted criteria. In our case, three attributes can be tuned for each fuzzy rule. These attributes corresponds to how much T_r, OS and T_s are considered, respectively. Once the global scores have been computed, they can be used to rank the outputs or select an output that best satisfies the given criteria.

Together with the weighting of criteria, the output of the MFLC is also affected by the choice of fuzzy measure. Fuzzy measure signifies to what degree an element belongs in a crisp set. This is done by assigning a value to each possible crisp set the element might belong to. Further, fuzzy measure is useful for mathematically representing the interactions among criteria, where the measure allows to define a weight on a subset of criteria. Plausibility measure will inflict a negative interaction between two criteria, which acts as a counterweight to positive correlated criteria. Belief measure, on the other hand, will inflict a positive interaction between two criteria, which will balance out negative correlated criteria.

Table 2: Characteristics of MFCL step response with $\xi = 0.9$

Metric	Preference $\{T_r{:}OS{:}T_s\}$		
	$\{1:10:2\}$	$\{2:1:10\}$	$\{10:2:1\}$
T_r	20.8068	20.7425	20.5259
$\%OS$	2.9230	3.8380	4.7890
T_s	179.1898	160.5594	192.8116

The effect of applying different weighted criteria and different types of fuzzy measure is reflected by the characteristics of the step response of the MFLC. The characteristics while using plausibility measure is shown in table 2. From the table, the effects of changing the preferences for the attributes are clearly shown. For instance, favouring settling time results in a significant decrease in the metric. On the contrary, putting less consideration into settling time will make it increase. The same pattern can be seen for the other two metrics as well. This is in compliance with how the MFLC works, where the controller will choose an output which favours the most considered criteria.

However, by comparing column two and three of table 2 it is seen that the overshoot percentages increases in the third column, even though the criterion has a higher consideration compared to column two. A reason for this could be

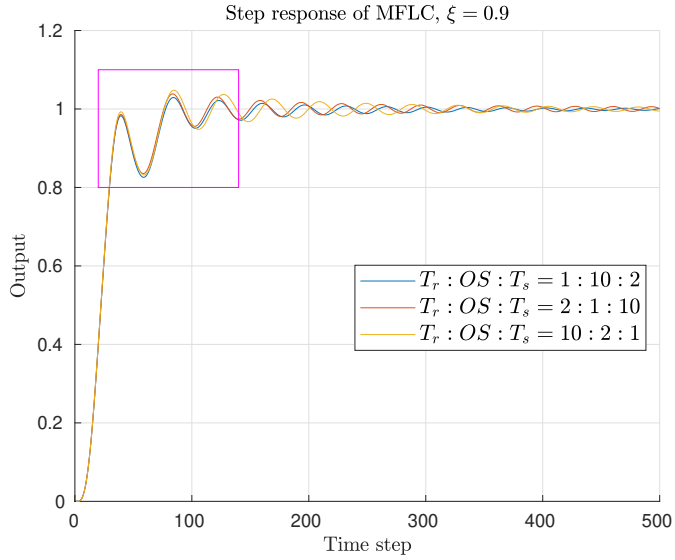
the high consideration of the T_r criterion. The controller may conclude that the only way to decrease the rise time is to allow a higher overshoot Effectively, the rise time criterion trumps the overshoot criterion.

Table 3: Characteristics of MFCL step response with $\xi = 0.1$

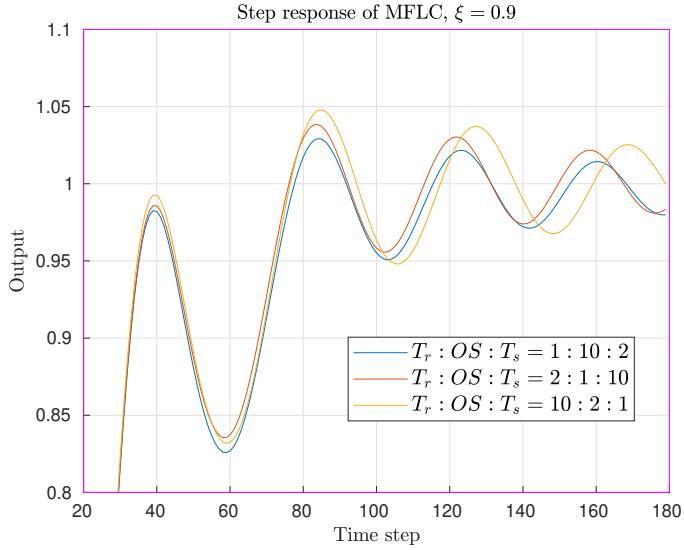
Metric	Preference $\{T_r{:}OS{:}T_s\}$		
	$\{1:10:2\}$	$\{2:1:10\}$	$\{10:2:1\}$
T_r	19.9187	19.9205	20.7235
$\%OS$	2.2610	5.0220	8.6550
T_s	152.9354	173.3107	156.0065

The characteristics of the step response while using belief measure is shown in table 2. By looking at table 3, it is possible to notice a somewhat strange pattern. Focusing on column two and three, the pattern shows that a higher criterion consideration results in an increase in the metric, and not a decrease as expected. It looks as the considerations of the criteria are flipped. Higher consideration results in worse performance, while lower consideration gives better performance. The explanation could be the applied fuzzy measure, where belief measure will work as a counterweight for negative correlated criteria. However, the criteria implemented in the MFLC are not necessarily negative correlated. For instance, an improvement in rise time could likely result in a lower settling time, if the overshoot is held roughly constant. This is an example of positive correlated criteria, which is better represented by plausibility measure. Ultimately, the criteria would be poorly represented by the chosen fuzzy measure, and resulting in some counter-intuitive relationship between the considerations and the criteria.

Compared to using plausibility measure for the MFLC, belief measure gives a more aggressive response. By comparing table 2 and table 3, the rise- and settling time for the belief measure are generally smaller. On the other hand, the overshoot is significantly smaller for the plausibility measure.

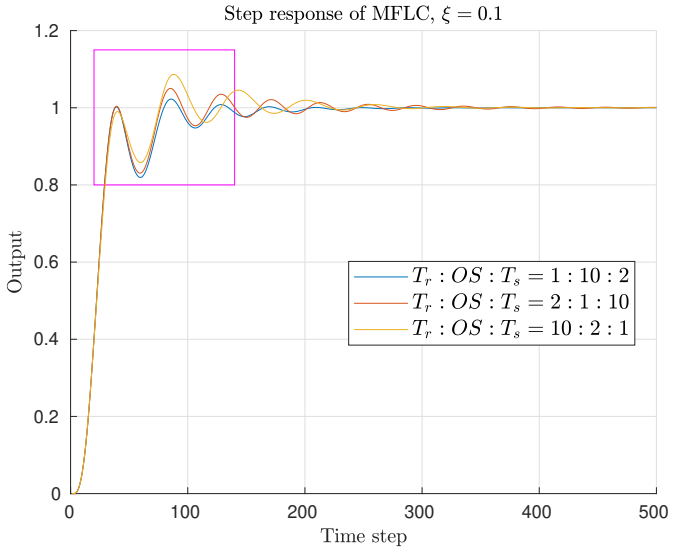


(a) Response with different criteria consideration

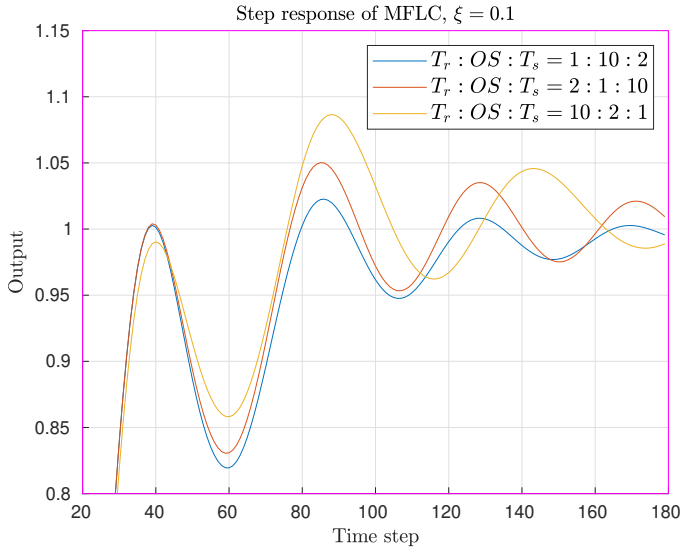


(b) Zoomed in plot

Figure 1: Response of MFLC with plausibility measure, $\xi = 0.9$



(a) Response with different criteria consideration



(b) Zoomed in plot

Figure 2: Response of MFLC with belief measure, $\xi = 0.1$