EE682
HW3 - IT2 FLC Design

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Contents

1 Introduction

The task was to compare the performance of Type-1 FLC and Type-2 FLC for the control of the system used in the previous homework. Source code, which included an implementation of a Type-2 FLC, was handed out.

2 Tuning of controllers

Using the out-handed source code, a file named *control.hpp* was created. The file uses the Type-2 FLC and the Type-1 FLC to control the system given the previous homework, respectively. In order to implement a Type-1 FLC, the source code was modified to where the Field of Uncertainty (FOU) of the Type-2 FLC was set to zero.

The source code included a rule base for the controllers. However, the chosen rules gave a poor performance, and a new set of rules were therefore chosen. By implementing one rule at the time and checking the corresponding step response of the system, the rules where implemented iteratively. The final choice of rules can be seen in *fuzzy_rules.h*.

The step responses of the controllers are shown in fig. 1. Looking at fig. 1, it can be concluded that the controllers are not optimally tuned. For instance, the Type-1 FLC has an oscillatory response which imposes a long settling time. The response could be further improved by either optimizing the rule base, tuning the FLC parameters K_e, K_{ce} and K_u, or optimizing the membership functions given in *fuzzy_param.h*. Further, the function *inf_defuzz(...)* in the file *IT2FLS_HW.cpp* returns a default value of -0.6 if no matching rule is found, due to the default value of the out-indices. By giving the out-indices a default value of 2, the function would instead return zero as a default value. This could maybe simplify the tuning process and improve the performance. However, the response is sufficiently good to show the difference in performance between the two types of FLC.

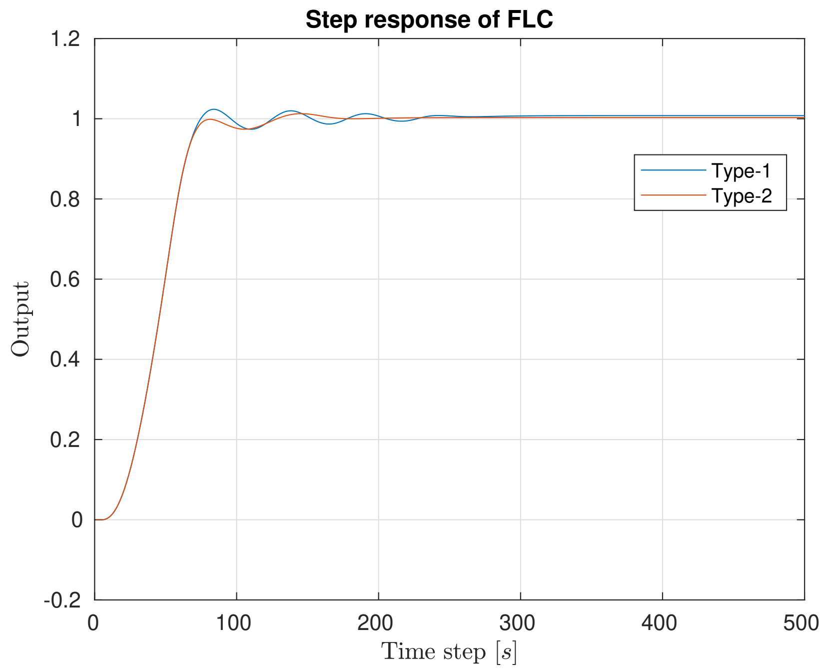

Figure 1: Step response of motor system with Type-2 and Type-1 FLC

3 Comparison of performance

The task specified to taint the output of the plant model with a ±10% uniform random noise. This amount of noise gave a distorted output from the controllers and it was difficult to extract any information from the plots. In order for the controllers to handle this amount of noise, they should be better tuned. Hence, the output of the model was instead tainted with a ±1% uniform random noise. The outcome is shown in fig. 2.

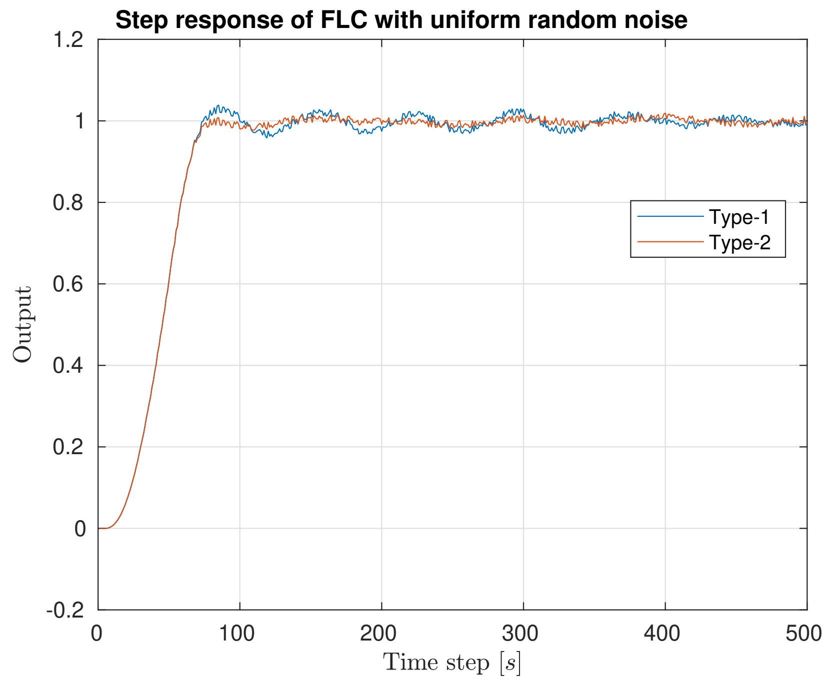

Figure 2: Step response of motor system with Type-2 and Type-1 FLC where model output is tainted with ±1% uniform random noise

Comparing fig. 1 with fig. 2, the strength of the Type-2 FLC is clearly shown. While the noise imposes more oscillations to the response of the Type-1 FLC, the Type-2 FLC looks unaffected by the noise. With almost no oscillations, it manages to hold its steady-state value. The reason behind this is the design of the Type-2 FLC. The Type-1 FLC, on one hand, has its limitations in modelling uncertainties due to its membership grades being crisp values. The Type-2 FLC, however, has membership functions which are fuzzy themselves. This enables the ability to model and minimize the effect of uncertainties to a greater extent.

The controllers were also tested with Gaussian random noise, where $\mu = 0$ and $\sigma = 0.01$. The result is shown in fig. 3. In this scenario, the Type-2 FLC still outperforms the Type-1 FLC, but to a smaller extent compared to the scenario with uniform random noise. The Type-2 FLC has smaller oscillations compared to the Type-1 and is able to hold its steady-state value better. The difference in performance between the two controllers would be more clear if the controllers were better tuned.

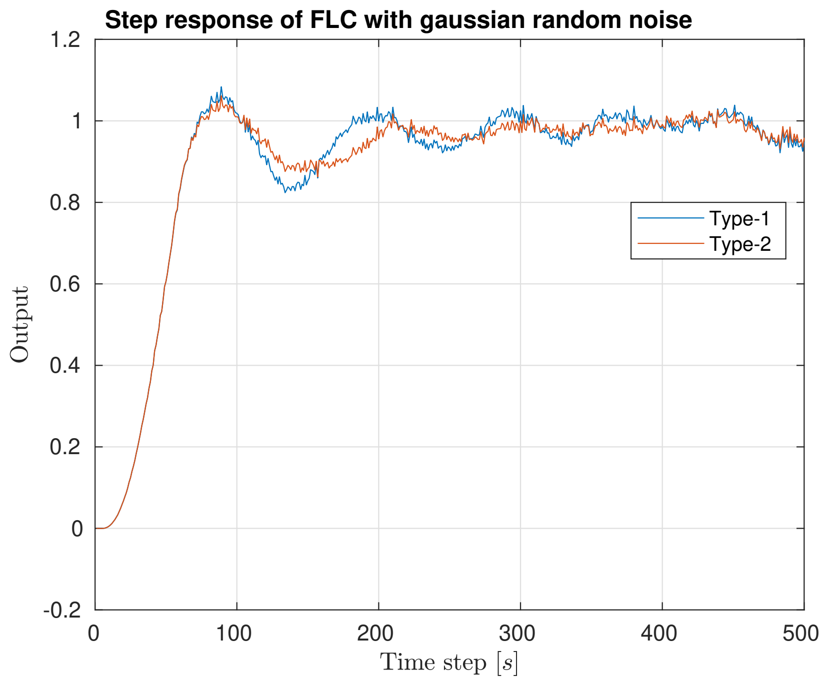

Figure 3: Step response of motor system with Type-2 and Type-1 FLC where model output is tainted with Gaussian random noise, $\mu = 0$ and $\sigma = 0.01$

Finally, it was tested out to add only $\pm 1\%$ uniform random noise to the model parameters. This resulted in the unstable system shown in fig. 4. The system could probably be made stable by doing some tuning, but this was not tested out.

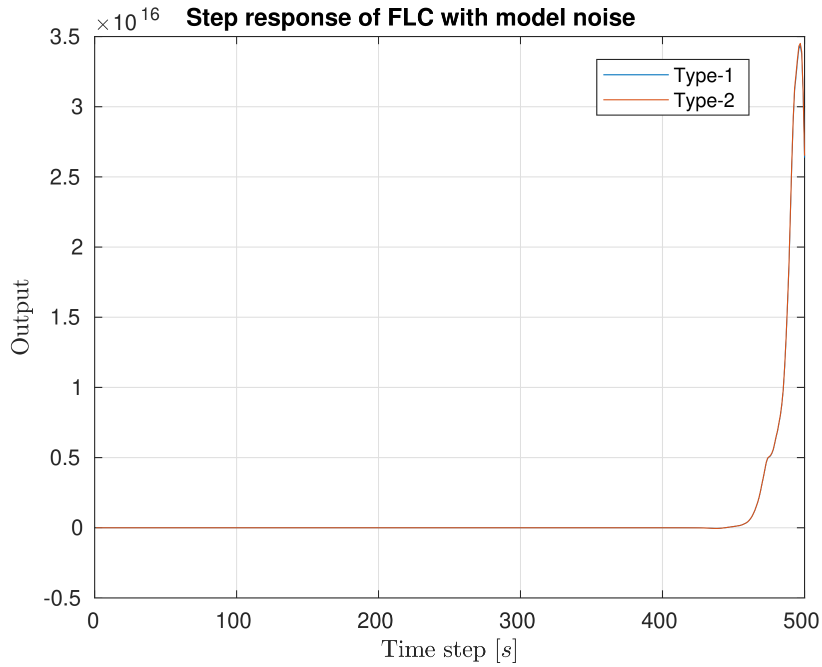

Figure 4: Step response of motor system with Type-2 and Type-1 FLC where model parameters are tainted with $\pm 1\%$ uniform random noise

4 Conclusion

The Type-2 FLC is able to handle uncertainties better compared to the Type-1 FLC. This is due to the Type-2 FLC making its memberships functions fuzzy themselves, which enables the ability to model and minimize the effect of uncertainties. The two controllers were tested out to handle both uniform and Gaussian noise. The Type-2 FLC perfomed better in both cases. The difference in performance would have been clearer if the controllers were better tuned. Finally, the controllers were tested out to handle uncertainties in the parameters governing the plant dynamics. Due to sub-optimal tuning of the controllers, this resulted in an unstable system.