The Influences of AD and DA Converters Complexity upon a Minimal Fuzzy Controller Performances

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Abstract- Most existing control schemes developed with fuzzy logic are using extensive memory and processing power. Motivated by the need for computationally efficient controllers, the structure with two uniformly distributed membership functions is considered. The control algorithm is designed with minimal fuzzification features in case of a linear dynamic process control. The goal of this work is to emphasize the influences of ADC and DAC converters used at the interface level with the real process onto the overall controller performances. The study is made using computer simulation in LabView environment.

I. Introduction

The growing interest of the academic communities in fuzzy control applications is explained by the advantages of the incorporated approximate reasoning theory [1] and also by the fast development in modern computing technology affording a real support for some straightforward implementations. There has been an explosion in the development of the theory and application of fuzzy logic to control systems, significant research work being done for the development of new and efficient fuzzy controllers. Such a work was reported in [3], where a minimal fuzzification technique in the control algorithm has been explored and tested on a linear process control problem. Results obtained in [3] and [4] proved that the proposed control strategy is able to achieve the goals in a simple manner with respect to the control algorithm dimensionality and computational effort. The advantages of this control algorithm are the reduced computational effort and memory requirements, making it suitable for real-time implementations in dedicated hardware.

However, a satisfactory outcome could not be reached without precise real-time measurements due to necessary accurate feedback information. Being the major components linking the analogue world of sensors and actuators to the digital core of the control instrument, AD and DA converters are used in all contemporary measuring devices. It is expecting this conversion to influence the quality of the control action on both ways [2]. The need to create highly complex, fast and yet low cost systems, with reduced consumption, is leading further to the possibility of using 8-bit converters in both controller-process interfaces: data acquisition and command generation interface. This paper focuses on the influences of these low cost converters onto the time domain performances of the fuzzy controller.

II. Structure of the fuzzy control system

The electric drives control is a typical example for the specific purpose. It was considered the position control problem of a servomotor based on a DC motor with separated excitation. In realized simulations the process is modelled by a third order linear time-invariant transfer function. After discretization with a sampling period T, the obtained recursive model is used in a basic closed loop structure. The architecture of the fuzzy logic controller is a Mamdani-type that represents a PID action in a nonlinear form. The application belongs to the class of two-input fuzzy PID type.

The control algorithm on trial is a fuzzy PD simple structure designed in a minimal manner. On the fuzzification level, where each of the input variables must first be mapped to a degree of membership in their respective fuzzy sets, the control algorithm synthesis deal with an amount of design parameters. In order to avoid this inconvenience, the structure of the control algorithm is based on a simple fuzzification technique. Consequently, the rule base is considerably reduced. The infer method is min-max and defuzzification method is center-of-gravity. This structure has been proved a great potential of the simplified controller. The study is done by expressing system response in terms of time domain specifications on the closed loop unit-step response.

A. Minimal fuzzification

Owing to the great number of parameters to be tuned on the fuzzification level in a traditional fuzzy control structure, the membership functions number is reduced here to unconventional minima: onto a normalized universe of discourse two monotonic fuzzy sets are assigned for every variable (Fig. 1).
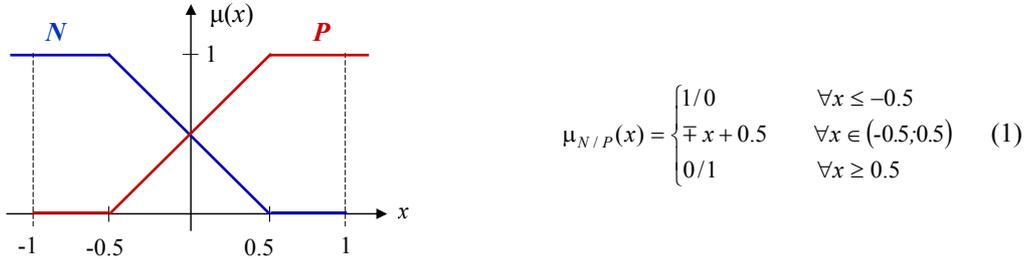
$$\mu_{N/P}(x) = \begin{cases} 1/0 & \forall x \leq -0.5 \\ \mp x + 0.5 & \forall x \in (-0.5;0.5) \\ 0/1 & \forall x \geq 0.5 \end{cases} \quad (1)$$

Figure 1. Fuzzy sets both for inputs and output.

The membership functions are likely the simplest possible functions to use for this purpose, monotonic, represented by negative and positive linguistic values. In the same manner is treated the control output variable, despite of general approach in three linguistic values [4], [5], with a central one. The defined fuzzy sets are described by correspondingly membership functions given in (1).

B. Fuzzy concepts implementation

LabView graphical programming environment has been proved to ensure the proper transfer support for such technology demands owing to modular methodology feature of the used library [6] because of its simplicity in design and robustness.

The schematic structure of the control system used in simulations is presented in Figure 2, where the most important components of the system are emphasized. Decisions are computed based on input error signal and its changing trend. In the condition interface, mapping the range of the values of the controller input/output variables to a pre-defined universe of discourse requires scaling factors. The choice of scaling factors has a significant effect on the controller performances. All other structure parameters being settled, the design task is consists only in the optimal selection of the three scaling factors meaning the universe of discourse for error, error change and control variables.
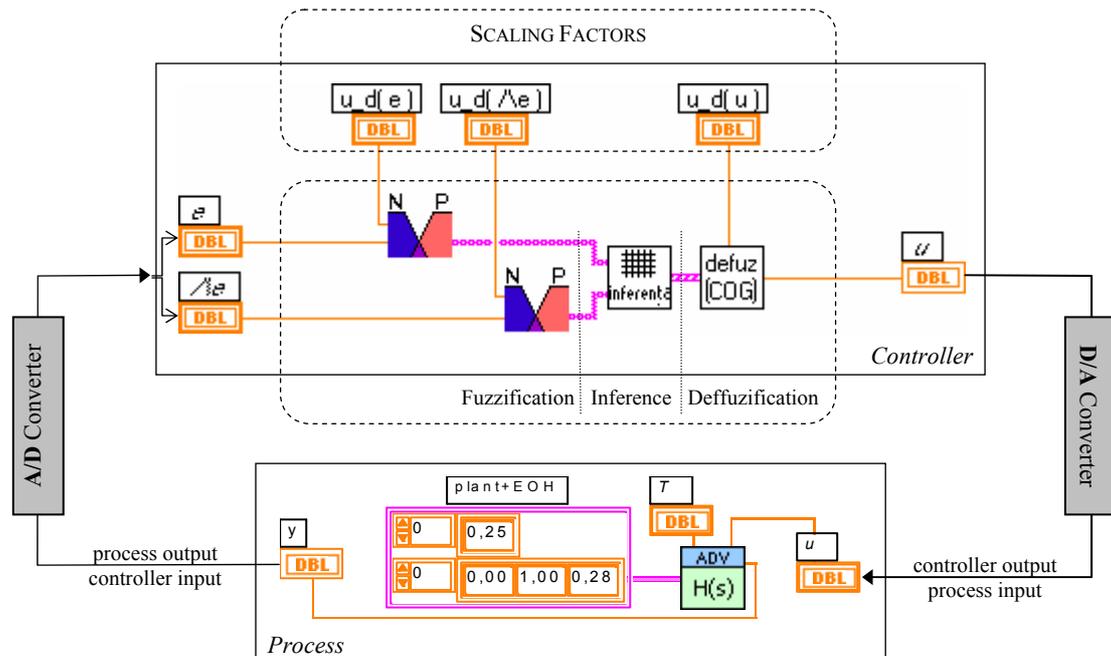
Figure 2. Control loop implementation in LabView environment

At the fuzzification interface level, every measure of input variable is transformed into degrees of membership for all fuzzy sets defined on its universe of discourse. The instrument that performs the above fuzzification technique is presented below in Figure 3.
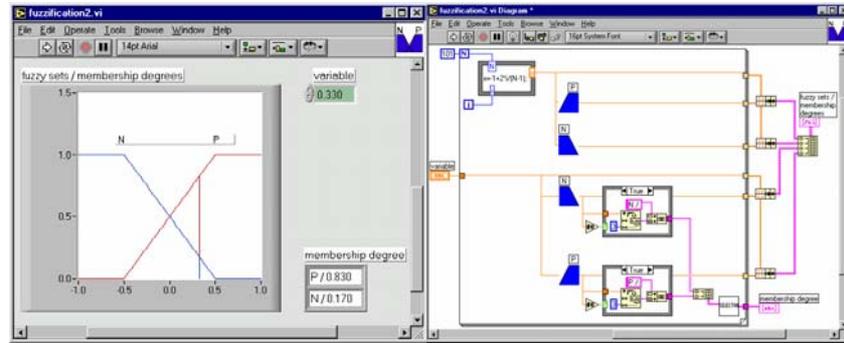

Figure 3. Minimal fuzzification in LabView environment

The heart of the fuzzy controller consists in the inference engine: the firing rules code the dynamics as they determine the output fuzzy value. This "core unit" together with COG deffuzification strategy are implemented as it can be seen in Figure 4. The inferring process is illustrated in the instrument block diagram in the specific dataflow programming manner, and the result consisting in the output fuzzy value is depicted in "*control fuzzy value*" graphical indicator on its front panel.
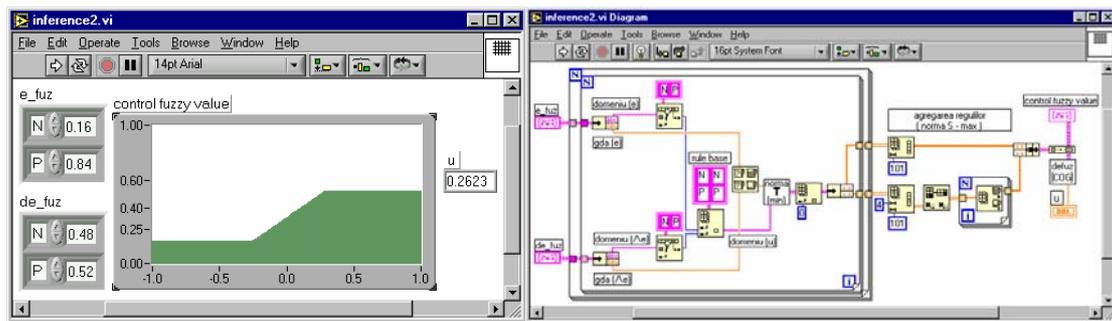

Figure 4. Inference *min-max* policy for two fuzzy sets in LabView

III. Simulation results

Both the system response and the command signal are considered as resulting from an 8 bits ADC and DAC respectively. The system behaviour is studied in terms of time domain performances eq. overshoot and settling time. The simulation results are presented in Figures 5, representing system output and system output error.
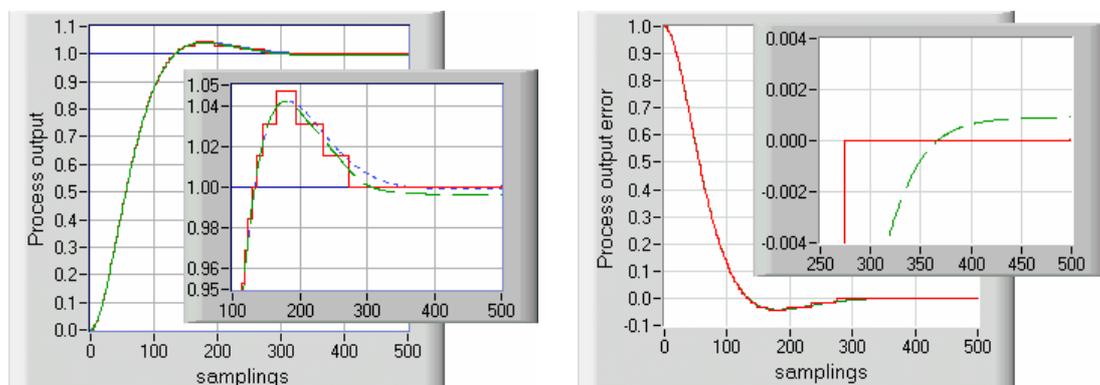

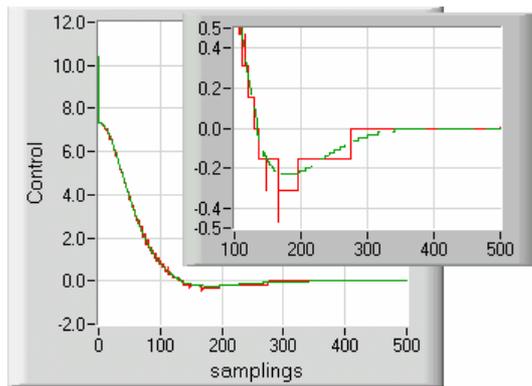Figure 5. Simulated system output and system output error

Figure 6. D/A converter output

Curves depicted in Figure 5 and Figure 6 are representing the system response, the output error and the controller output as follows:

- evaluated response for double precision representation (dotted line)
- 8 bits ADC reported response (continuous line)
- 16 bits ADC reported response (dashed line)

It can be observed that the low cost converters are introducing a supplementary static error, but its level is less than 0.5%. This supplementary error is due to the fact that the output error computed with variables represented in double precision (Figure 5, dotted line) is less than the quantisation error of the AD converter. As consequence the fuzzy controller input is reported to be null (Figure 5, continuous line) which is equivalent with apparent steady state accomplishment.

IV. Conclusions

Many successful applications of fuzzy logic in control demonstrate that a number of substantial benefits were achieved through the use of this computational tool. LabView graphical programming environment was considered for the implementation of the necessary fuzzy tools and an algorithm with minimal fuzzification features was tested in such an environment in relation with some conversion issues.

The simulation results have demonstrated that the proposed control strategy is able to achieve the goals in a simple manner with respect to the control algorithm dimensionality and computational effort. The presence of the low cost 8 bits AD and DA converters in the real process communication interfaces is introducing only around 0.5% supplementary steady state error.

Acknowledgments

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