LAISSZ-FAIRE ANTICIPATORY FUZZY CONTROL

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ABSTRACT

Anticipatory fuzzy control combines traditional fuzzy logic with feedback concepts and prediction of system behavior. Fuzzy rules in the system can be 'nested' so that it is not necessary to evaluate all rules at each time step if some smaller subset of rules will produce acceptable system behavior. A special case of anticipatory fuzzy control, the Laissez-Faire controller anticipates the unforced movement of the system, and if the system will move to decrease error, applies a control value of "0." The somewhat whimsical name "Laissez-Faire" comes from the well-known political doctrine of "that government is best which governs least," i.e., anticipatory fuzzy rules are applied to generate a nonzero control value only when the anticipated behavior of the unforced system is unacceptable. This approach significantly decreases control energy necessary to control system performance, as well as processing time (as when the predicted unforced system behavior is acceptable, no further fuzzy rules must be computed to determine the desired control value). Results are given comparing the response of the system as controlled by the Laissez-Faire Anticipatory Fuzzy Controller, a standard fuzzy logic controller, anticipatory fuzzy control, and a linear quadratic regulator.

INTRODUCTION

Anticipatory fuzzy control combines traditional fuzzy logic with prediction of system behavior. This allows the designer to fully utilize all available control expertise for the system, while enabling the system to automatically eliminate control values which would have an undesirable effect on system performance. This controller demonstrates desirable robustness properties when compared to standard control techniques [1]. Laissez-Faire Anticipatory Fuzzy Control retains many of the benefits of anticipatory control, while significantly decreasing control cost.

The example system to which the method is applied in this study is control of the Control Structures Interaction Suitcase Demonstrator developed at NASA's Marshall Space Flight Center. The CSI Suitcase Demonstrator is a flexible beam, mounted at one end with springs and bearings, and with a single actuator capable of rotating the beam about a pin at the fixed end. The control objective is to return the tip of the free end to a zero error position (from a nonzero initial condition). Anticipatory fuzzy logic control has been demonstrated to successfully control the system and to exhibit desirable robustness properties compared to conventional control [1].

ANTICIPATORY FUZZY LOGIC CONTROL

Anticipatory fuzzy logic control differs from traditional fuzzy control in that once fuzzy rules have been used to generate a control value (as in standard fuzzy logic), a predictive routine built into the controller is called to anticipate the effect of the proposed control on the system output. If using the current control value will result in system behavior which is in some way unacceptable, additional rules are called. This method may be used to nest as many sets of rules as desired. Advantages of this approach are first, that testing rules allows use of only as many rules as are necessary to achieve desired system performance, resulting in savings in computer run time; and second, by predicting system performance, controls which would result in unstable or otherwise unacceptable system performance can be eliminated before they are sent to the system.

This method essentially adds feedback to the fuzzy system, but it is feedback based on the predicted future performance of the system rather than being based on past system states or outputs.

The anticipatory method described here contains, as part of the controller, a mathematical simulation of the system to be controlled. This simulation performs the prediction function necessary for the anticipatory feature of the control.

This system has been shown to possess many desirable qualities, such as resilience to noise and modeling errors [1]. This will be illustrated in the Results section of the paper.

ANTICIPATORY LAISSEZ-FAIRE FUZZY CONTROL

While anticipatory fuzzy control has been shown to have many desirable properties such as resilience to noise and modeling errors, it is not always optimum in terms of control cost or processing required [1]. A special case of anticipatory fuzzy control, the Laissez-Faire controller anticipates the unforced movement of the system, and if the system will move to decrease error, applies a control value of "0." The somewhat
whimsical name "Laissez-Faire" comes from the well-known political doctrine of "that government is best which governs least," i.e., anticipatory fuzzy rules are applied to generate a nonzero control value only when the anticipated behavior of the unforced system is unacceptable. That this approach significantly decreases control energy necessary to control system performance will be demonstrated in the Results section of this paper. This method can also decrease required processing time: the Laissez-Faire rule judging the predicted unforced system behavior of the system is the first rule to be evaluated, so when the unforced response is acceptable, no further fuzzy rules must be computed to determine the correct control value. "Acceptable" unforced system response is defined in this case as the system tending to zero error without a nonzero control value being applied at the current time step.

RESULTS

All computer simulations in this study were performed on an IBM-compatible 486 PC equipped with MATLAB. Performance of the system with no forcing function exhibits sustained oscillation and constant offset in the system response. The output of the system when controlled with a standard fuzzy controller, with an anticipatory fuzzy controller, with a linear quadratic regulator (chosen by the NASA sponsors of the original project as the benchmark for comparison purposes), and the Laissez-Faire Controller (LFC) is shown in Figure 1. Each of the candidate controllers drives the system response to zero in approximately the same amount of time. The standard fuzzy controller exhibits considerable overshoot and some oscillation, while the output of the other controlled systems is much smoother. The LQR response contains almost no overshoot, while the Laissez-Faire Controller has slightly more overshoot than the anticipatory fuzzy controller. If driving the system to zero smoothly were the only consideration, one might choose the LQR as the best candidate; however, one advantage of the Laissez-Faire controller becomes clear when control energy is considered (Figure 2). The measure used for control energy was unnormalized: the simple square of the control was used, so no units are given. The total control energies for the controllers were 2261.3 for the LQR, 2959.2 for the standard fuzzy controller, 207.9 for the anticipatory fuzzy controller, and 121.6 for the Laissez-Faire Controller. Thus while the Laissez-Faire Controller has more overshoot than the anticipatory fuzzy and LQR controllers, the necessary control energy for the LFC is only 58.5% of the energy required for full anticipatory fuzzy logic control and 5.38% of that required by the LQR. Furthermore, in the given example, in 47.15% of the timesteps the Laissez-Faire controller judged that the unforced system response was acceptable, since in these cases only a single anticipatory fuzzy rule was evaluated, savings in computation were also significant.

The resilience of fuzzy systems to error also gives the fuzzy systems the potential to outperform standard control methods such as LQR (to which exact values are more critical) when noise is present. As will be shown in the presentation, the anticipatory fuzzy and Laissez-Faire fuzzy systems can still control the system effectively when noise is present, while the LQR becomes markedly unstable.

CONCLUSIONS

Fuzzy control methods have been shown to adequately control the CSI Suitcase Demonstrator. A new type of anticipatory Laissez-Faire fuzzy controller has been developed, and has been shown to exhibit desirable resilience to noise, while significantly decreasing control cost and computation time. This new controller shows promise for application to systems which can be effectively controlled by anticipatory fuzzy logic control, with its desirable robustness properties, but in which control costs and computation costs are a consideration. This makes Laissez-Faire fuzzy control a promising candidate for many future applications in the real world.

REFERENCE

[1] C. L. McCullough, "An Anticipatory Fuzzy Logic Controller Utilizing Neural Net Prediction," Simulation, Vol. 58, No. 5, May 1992.

Figure 1. LOS Error for the System Controlled by Linear Quadratic Regulator ("--"), Plain Fuzzy Controller ("-"), Anticipatory Fuzzy Controller ("- -") and Laissez-Faire Controller ("_ _"),

Figure 2. Total Control Energy Required for Each Controller

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