2006-01-01

Latency compensation control of computer based control systems

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Latentcy Compensation Control of Networked Computer Based Control Systems

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Abstract

This paper discusses the use of a modified Smith predictor for latentcy (i.e. time delay) compensation, to assist in the implementation of network computer based control systems. Such systems typically have a variable time delay associated with the transfer of information; the modified Smith predictor is robust to time delay variations.

1. Introduction

In building industrial control systems, it is increasingly common to use more sensors, actuators and microprocessor based controllers, to implement an intelligent digital system solution. As the number of devices grows, they need to exchange increasing amounts of data by means of various serial communications networks. Such networks (or fieldbuses) include Controller Area Networks (CAN), Profibus and Foundation Fieldbus. A practical problem with a networked control system is the time delay (or *latentcy*) associated with information transfer. This time delay may be deterministic, though it typically has a variable component (called *jitter*) [1], [2].

Networked control systems with such time delays may be compensated by using proportional integral derivative (PID) controllers, as reported previously [3]. Recently, the use of a dedicated time delay compensator, the Smith predictor, which is well known in the process control community, has been suggested for the application [4]-[6]. The motivation of this paper is to introduce the Smith predictor to the wider information technology and telecommunications community, and to introduce a modified Smith predictor, developed by the author, which allows a further improvement in performance.

2. The Smith Predictor

The design of controllers for processes with long time delays has been of interest to academics and practitioners for several decades. In a seminal contribution, Smith [7] proposed a technique that reduces the dominance of the delay term; a 'primary' controller, typically in PID form, may then be easily designed for the non-dominant delay process. This method, called the Smith predictor, has been the subject of numerous experimental and theoretical studies. A block diagram of the Smith predictor is provided in Figure 1 [8]. The *process* is the communications network. A mathematical process model is clearly required.

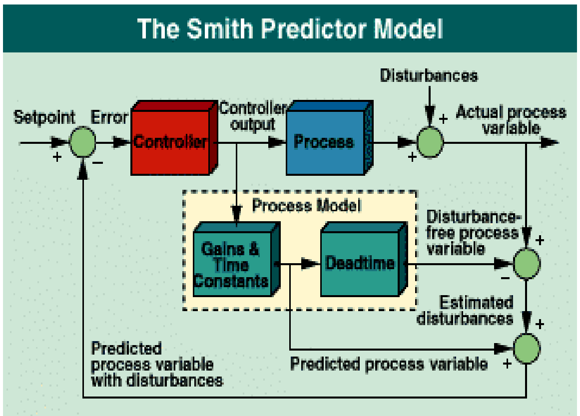

Figure 1. The Smith predictor.

3. The Modified Smith Predictor

When the primary controller is appropriately specified, the Smith predictor gives excellent response to setpoint variations. However, good response to disturbances (e.g. in link capacity) is important in the application. The author has developed a modified Smith predictor to improve the disturbance response by including an extra dynamic term in the outer feedback loop of the Smith predictor. The parameters of this term are functions of the process model parameters.

Simulation results showing the operation of the method are given in Figures 2 to 4 The nominal process (G_p) is $2e^{-s}/1+8.5s+22.5s^2+18s^3$. The process model is specified using an appropriate identification method [9]. The process parameter values are allowed to vary between upper and lower limits; a $\pm 30\%$ variation in process time delay (latentcy) is allowed, with a similar variation in the other non-gain process parameters; a $\pm 40\%$ variation in the gain is permitted. The PI primary controller is specified using standard design techniques.

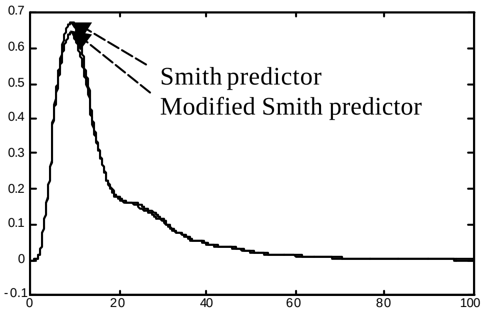

Figure 2. $G_p = 1.2e^{-0.7s}/1+5.9s+15.7s^2+12.6s^3$

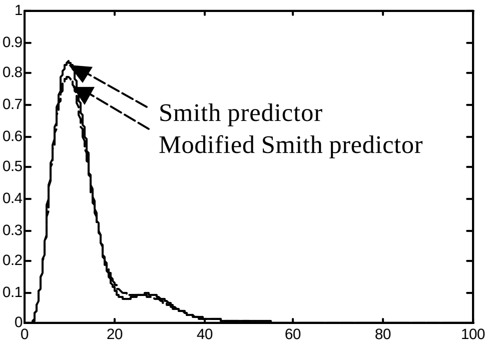

Figure 3. $G_p = 2e^{-s}/1+8.5s+22.5s^2+18s^3$

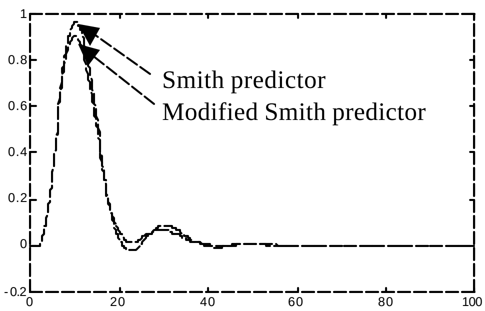

Figure 4. $G_p = 2.8e^{-1.3s}/1+11s+29.3s^2+23.4s^3$

The results show that the modified Smith predictor facilitates a modest improvement in disturbance responses.

4. Conclusions

The Smith predictor and its modifications may be readily applied to the control of networked systems. These compensators are more complex than the standard PID control solution; however, their performance tends to be better than that achievable with the PID controller, particularly if the latentcy is large.

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