Internal Model Control

Seminar Project Report

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Brief Introduction

The internal Model Control philosophy relies on the Internal Model Principle, which states that control can be achieved only if the control system encapsulates, either implicitly or explicitly, some representation of the process to be controlled. In particular, if the control scheme has been developed based on an exact model of the process, then perfect control is theoretically possible.

It means that if we have complete knowledge about the process (as encapsulated in the process model) being controlled, we can achieve perfect control. It also tells us that feedback control is necessary only when knowledge about the process is inaccurate or incomplete.

The detailed overview of the topic and the Matlab simulations done in the 1st semester were noted in the previous report, and hence are not included in this report.

Practical design of IMC

Given a model of the process, , first it is factorized into ‘invertible’ and ‘non-invertible’ components.

The non-invertible component contains terms which if inverted, will lead to instability and realisability problems, e.g. terms containing positive zeros and time-delays.

Next, and then , where is a low-pass function of appropriate order.

Implementing the IMC within a conventional PID framework

The IMC philosophy can also be used to generate settings for conventional PID controllers.

Note that the previously used IMC block diagram (Figure 1) can be reduced to a conventional closed loop structure by first re-arranging to the form shown in Figure 2, and then reduced to the form shown in Figure 3.

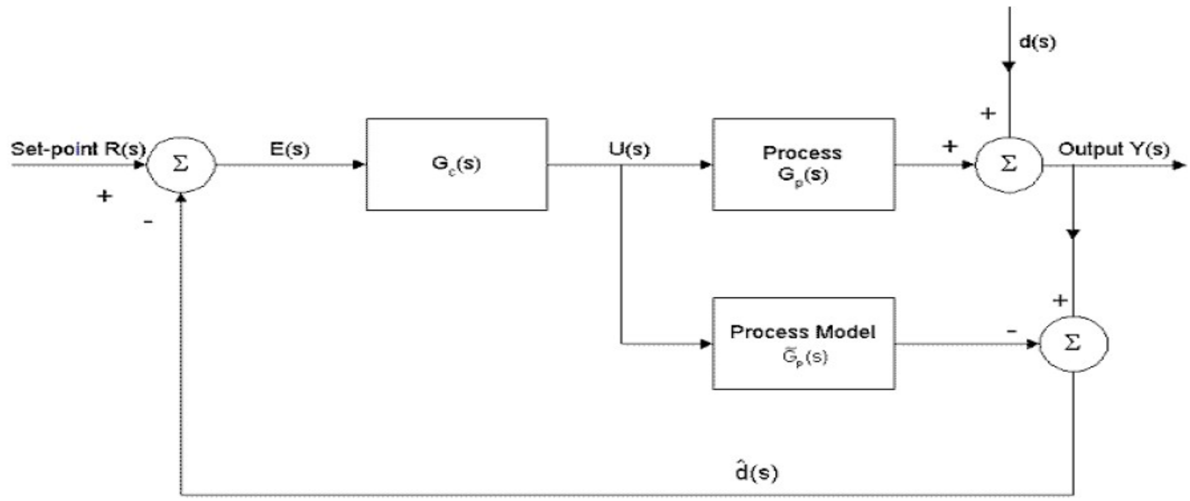

Figure 1

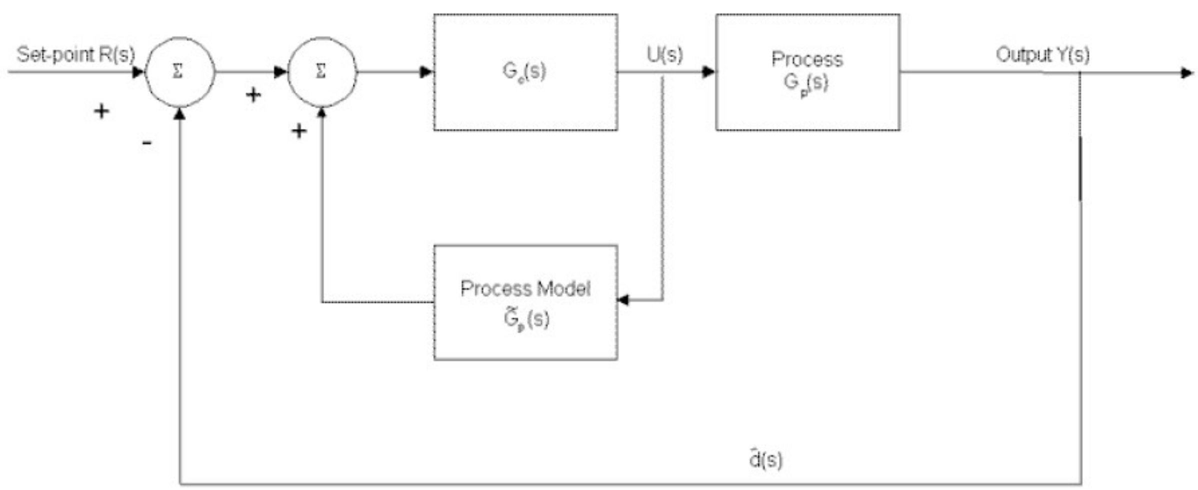

Figure 2

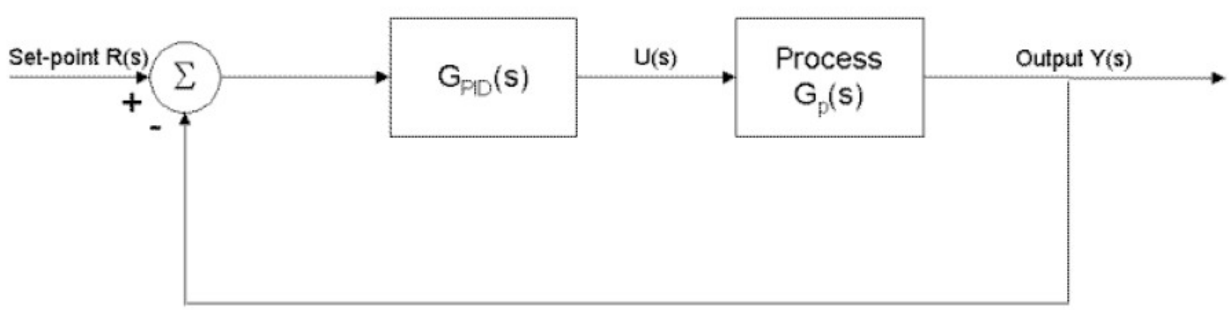

Figure 3

Thus

Assuming that the process is a first-order process with time-delay, its model has the following general form:

Using Padé approximation for the time-delay, ,

we get

with and

Thus

[since,]

Simplifying, we obtain

Again, by comparing this against the ideal PID controller,

, we get

SIMULATIONS

Comparison of PID tuning (IMC vs. Z-N)

Matlab simulations were carried out to compare the performances of the two PID tuning methods (IMC scheme vs. Ziegler–Nichols) for a particular process.

A first order process (with time-delay) was considered for simulation.

Transfer function:

The required values for PID tuning (K_p, T_i & T_d) obtained by the two methods are tabulated below.

	Z-N	**IMC**
K_p	3.695	1.778
T_i	3.62 s	8 s
T_d	0.905 s	0.875 s

Figure 4 & 5 show the unit step response of the Ziegler-Nichols tuning method & Internal Model Control tuning method respectively (without noise).

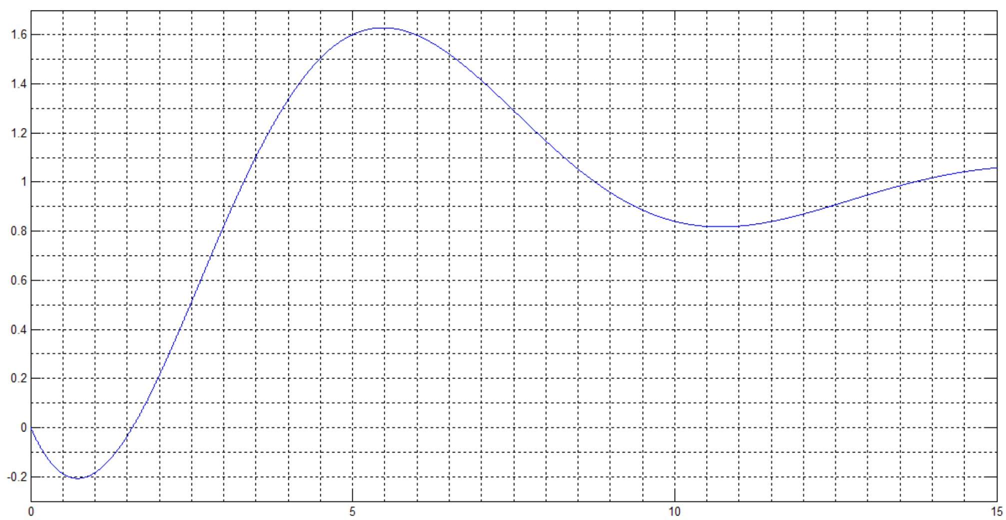

Figure 4

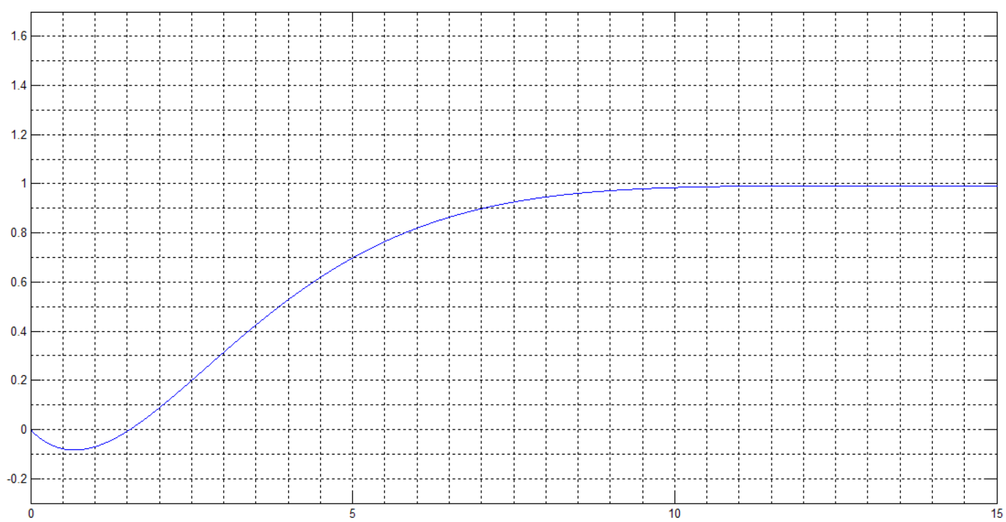

Figure 5

Figure 6 & 7 show the unit step response of the Ziegler-Nichols tuning method & Internal Model Control tuning method respectively (with noise).

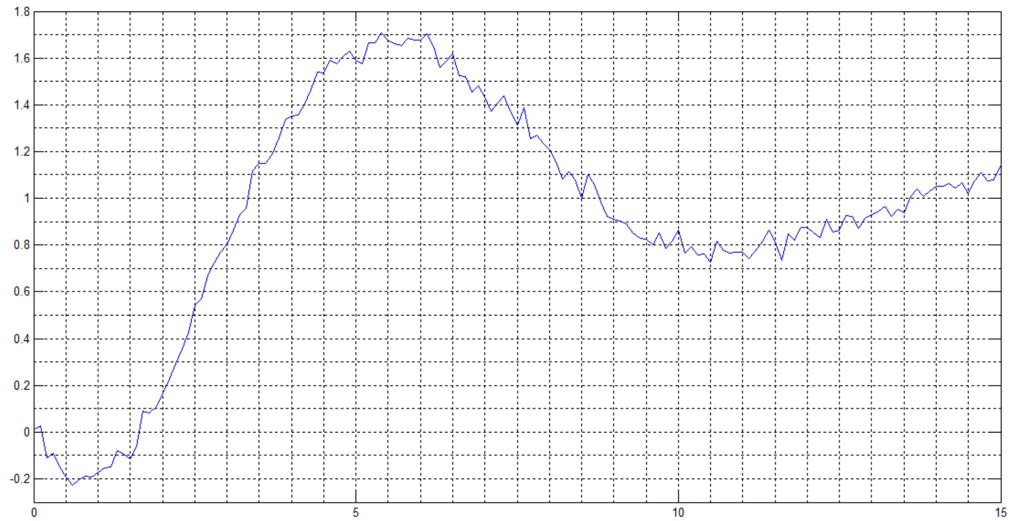

Figure 6

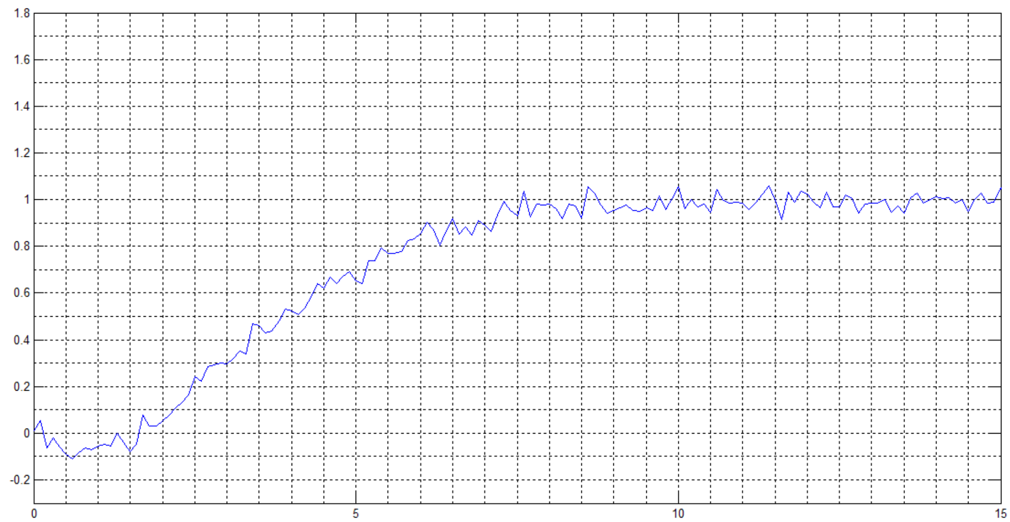

Figure 7

It can be seen that IMC method eliminates overshoots completely, has lower negative excursion and has somewhat better noise immunity.

The performance parameters of the two methods are tabulated below.

	Z-N	**IMC**
Settling time	12.5 s	7 s
Rise-time	3.5 s	7 s

It should be noted that the rise time is comparatively higher in IMC method of PID tuning.

Yet another Matlab simulation was done to investigate the capability of IMC method (of PID tuning) in handling higher-order processes [since the IMC tuning scheme was derived assuming a first-order process]

For this, a second-order process (one dominant & one non-dominant pole) with time-delay was considered for simulation.

Transfer function:

Figure 8 shows the unit step response of the Internal Model Control tuning method (PID tuning values were obtained by ignoring the non-dominant pole)

From the figure, it is inferred that IMC method of tuning can be extended to higher-order systems (by ignoring non-dominant poles) with somewhat satisfactory results.

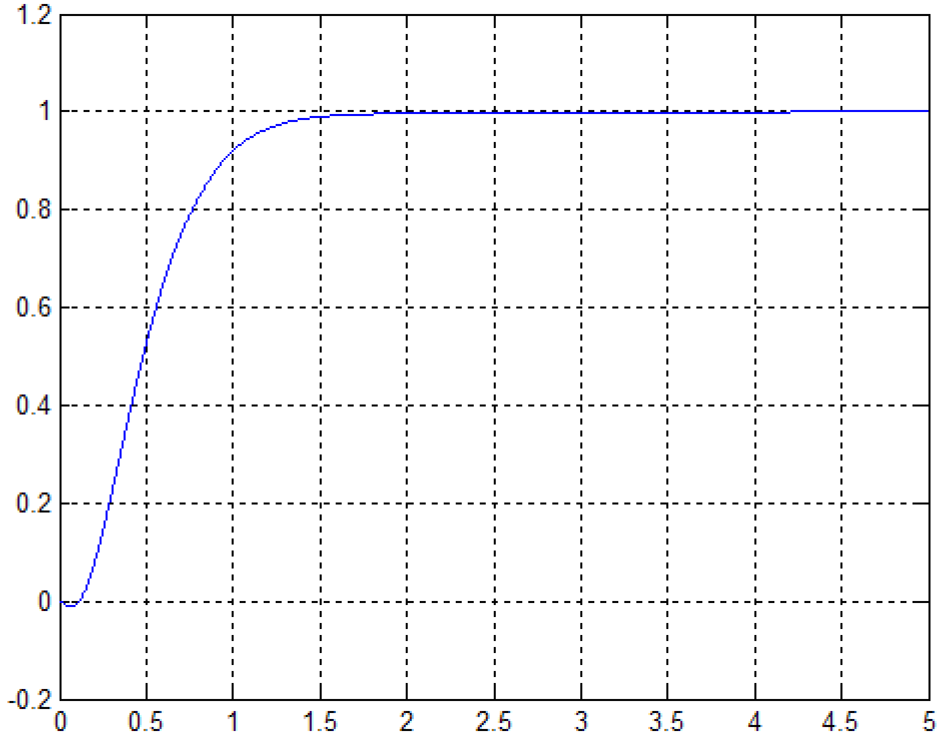

Figure 8

Conclusion: Identifying suitable areas of application for IMC

Observing the results obtained from the various simulations, we conclude that Internal Model Control yields quite satisfactory performance with one distinct characteristic – overshoots are eliminated at the cost of increasing rise-time.

Hence, Internal Model Control is suitable for use in slow processes(where low rise-time is not necessary) and where overshoots are not desirable (i.e. where “less aggressive” methods are preferred)

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