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A MATLAB PROGRAM FOR CONTROL OF TIME-DELAY SYSTEMS USING MODIFIED SMITH PREDICTORS

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Abstract: *The contribution presents a Matlab program for control of time-delay systems using three various modifications of Smith predictor, namely the modification for unstable and integrating processes, PI-PD modification for systems with long dead time, and modification applying control design by Coefficient Diagram Method (CDM). This freely downloadable software offers relevant computational and simulation facilities via simple Graphical User Interface (GUI).*
Key words: *Time-Delay Systems, Modified Smith Predictor, Matlab, Graphical User Interface*

1. INTRODUCTION

Presence of time-delay always means serious complications in process control and therefore this phenomenon has been widely studied (Richard, 2003). The relatively effective tool for compensation of time-delay term represents the classical Smith predictor which has been known to automation community since 1959 (Smith). On the other hand, this control structure has also its disadvantages and limitations.

Naturally, some of drawbacks have been eliminated by improving the idea and creating many modifications of Smith predictor (Watanabe & Ito, 1981); (Åström *et al.*, 1994); (Mataušek & Micić, 1996); (Majhi & Atherton, 1998); (Kaya & Atherton, 1999); (Hamamci *et al.*, 2001). Furthermore, several of them have been applied also to other problems, e.g. to control of systems with time-varying delay (Matušů & Prokop, 2010a); (Matušů & Prokop, 2011).

This contribution describes facilities of a Matlab environment for control of time-delay systems using three selected modifications of Smith Predictor (Matušů & Prokop, 2010b). The program is a translated version of the one created under the scope of the Master's Theses (Matušů, 2002).

2. THEORETICAL BACKGROUND

As it has been outlined above, three modifications of classical Smith predictor have been studied and implemented into the software support. More specifically it covers:

- Modified Smith predictor for unstable and integrating processes (Majhi & Atherton, 1998).
- Modified PI-PD Smith predictor for systems with long dead time (Kaya & Atherton, 1999).
- Modified Smith predictor design by CDM (Hamamci *et al.*, 2001).

All three incorporated methods have improved the Smith predictor loop using more sophisticated and complicated structure with additional controllers. An example of such embellishment is depicted in fig. 1, which shows the modified Smith predictor structure for CDM with trio of controllers $G_{c1}(s)$, $G_{c2}(s)$ and $G_{c3}(s)$ (Hamamci *et al.*, 2001). Due to the limited space, other structures can be found in respective literature or in the program itself (Matušů & Prokop, 2010b).

Anyway, all the methods use mathematical model of really controlled plant including time-delay term in the inner loop. Moreover, this model is assumed also during design of controllers as a nominal system.

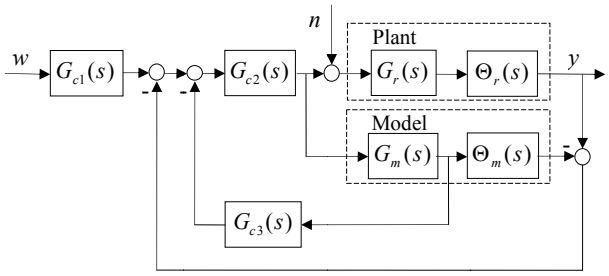

Fig. 1. Example of modified Smith predictor structure

The controller synthesis itself is based on various approaches and techniques according to the applied modification. For example the standard forms for obtaining the optimal closed-loop transfer function parameters in the meaning of integral squared time error (ISTE) criterion; a simple algebraic approach to control system design; coefficient diagram; modification of Kessler standard form; or Lipatov stability analysis have been utilized (Mataušek & Micić, 1996); (Majhi & Atherton, 1998); (Manabe, 1998); (Kaya & Atherton, 1999); (Hamamci *et al.*, 2001); (Hamamci & Ucar, 2002); etc. The final relations for controller design have been usually pre-derived for first and second order time-delay plants.

3. PROGRAM DESCRIPTION

The software package with basic instructions can be freely downloaded from the web page (Matušů & Prokop, 2010b). The main window of the program GUI (fig. 2) allows selecting the modification which should be used for a whole control experiment.

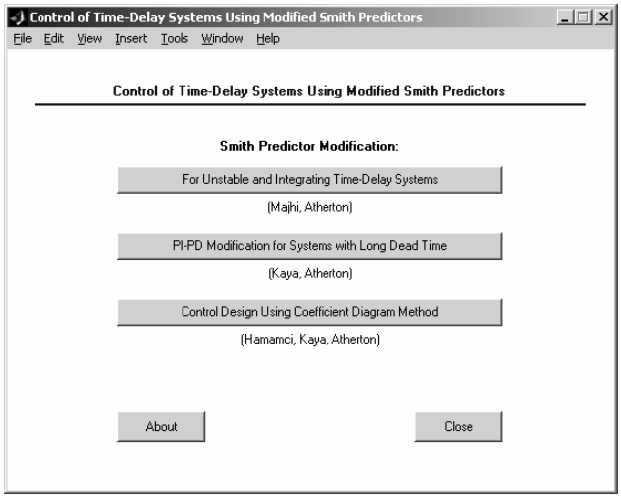

Fig. 2. Initial window of the program

Subsequently, sort of controlled system (e.g. first order, second order or integrating plant as a special type) can be chosen together with fundamental properties of the experiment (simulation time, reference signal, disturbances) – see fig. 3.

In the next step, coefficients of the controlled system of specific type and possibly some other additional parameters depending on the used method can be set as illustrated in fig. 4. However, the program permits not only adjustment of nominal system (considered as a model for control design and in control loop – fig. 1), but also of the perturbed system (used as a really controlled plant) with potentially different coefficients.

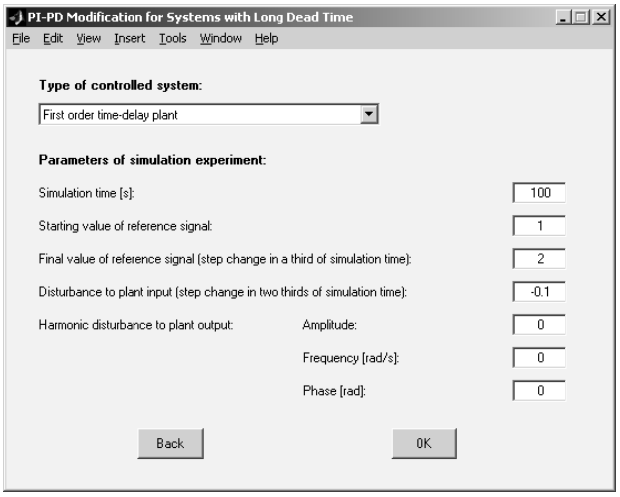

Fig. 3. Basic properties of control experiment

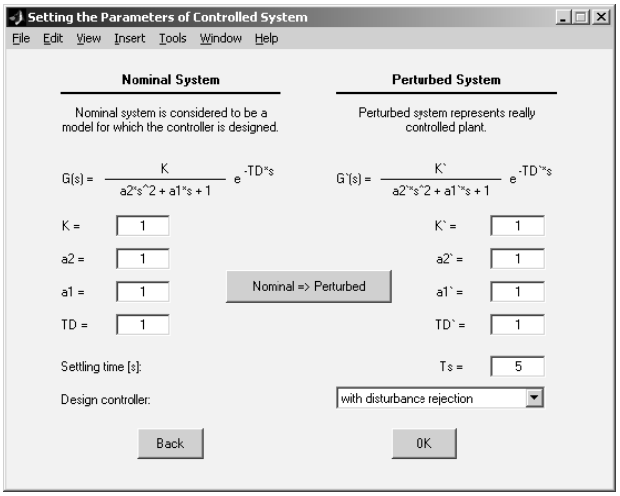

Fig. 4. Definition of parameters for nominal and perturbed system

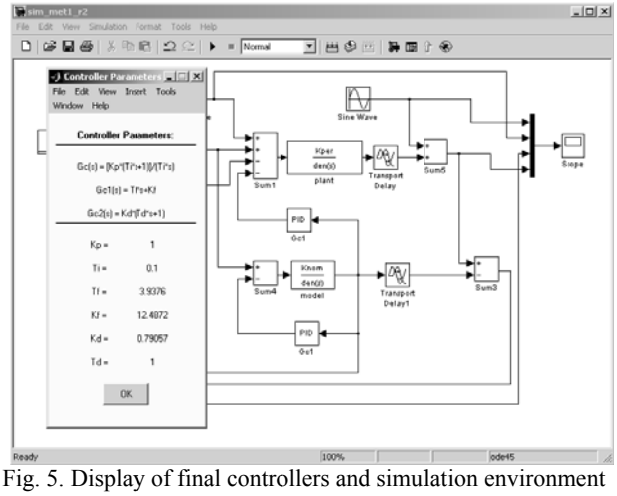

Fig. 5. Display of final controllers and simulation environment

Finally, the program computes the controllers and opens the Simulink scheme where control behaviour with the preset values can be simulated. An example is shown in fig. 5.

4. CONCLUSION

The paper has been focused on description of the program for control of time-delay systems using modified Smith predictor for unstable and integrating processes, modified PI-PD Smith predictor for systems with long dead time, and modified Smith predictor design by CDM. The software has been created in Matlab R13 but tested also under several newer versions.

5. ACKNOWLEDGEMENTS

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