SELF-TUNING CONTROLLER TOOLBOX

Josef Böhm[*], *Vladimír Bobál*[**]
[*] Ústav teorie informace a automatizace AV R,
[**] Katedra automatizace a řídící techniky , fakulta technologická

Abstract: Self-tuning controller toolbox offers means to design and simulate wide variety of adaptive PID and LQ controllers.

1 Introduction

Self tuning controllers represent an interesting branch of control theory and applications because they cope with the basic problem of almost any control task, the lack of suitable model of a system to be controlled. Their algorithms solves this situation in a consistent way by realizing identification and controller design in a unified algorithm.

The complexity of the task almost prevent the strict mathematical analysis. In such case the simulation becomes effective tool of the controller design, study of its properties and a verification of the behaviour with the simulated system. Presented toolbox offers the possibility to make these tasks efficiently.

2 Theoretical background

The model of a system is assumed in the form of a regression model

$$y(k) = -\sum_{i=1}^{n} a_i y(k-i) + \sum_{i=0}^{n} b_i u(k-i) + e_k + \sum_{i=1}^{n} d_i v(k-i) + K \tag{1}$$

The order of the model is supposed to be known or can be deduced from the requirements of the controller design. The parameters of the model 1 are estimated by a recursive version of the least squares. The certainty equivalence principle is used in the controller synthesis, i.e. the estimated parameters are used as true ones.

The controller design covers several techniques of the design of PID parameters and a general controller synthesis based on the minimization of a quadratic criterion

$$J = \sum_{i=k+1}^{k+T} [q_y(w(i) - y(i))^2 + q_u(u(i) - u0(i))^2]. \tag{2}$$

The criterion has generally finite horizon T, but a control strategy is applied that asymptotically converge to a infinite horizon criterion.

3 Toolbox description.

The toolbox has two different forms. It can be considered as a Simulink block library of adaptive controllers. In this case it is a completely open system based on Simulink features. The second form is a closed one, controlled by a GUI. Here all actions are guided by prepared graphical windows that checks any action and leads the user step by step to correct settings. This version is typically efficient in education.

These two versions differ in the upper level appearance, however, use the same or slightly different lower level functions.

3.1 The GUI form of the toolbox

The GUI form of the toolbox supports the following actions:

1. Simulation of controlled process in the form of a
   - continuous transfer function
   - discrete transfer function
2. Disturbances are considered in the form of
   - deterministic disturbance
   - stochastic disturbance
3. On-line identification of a discrete regression model of specific structure corresponding to different method of controller synthesis can use
   - exponential forgetting
   - directional forgetting
4. The PID controller is designed by
   - Banyasz-Keviczky method
   - Dahling method
   - several modification of Ziegler- Nichols method
   - four types of pole placement method
   - minimum variance controller

The toolbox is used in the following way. The toolbox is started by the command initstc and the following menu appears.

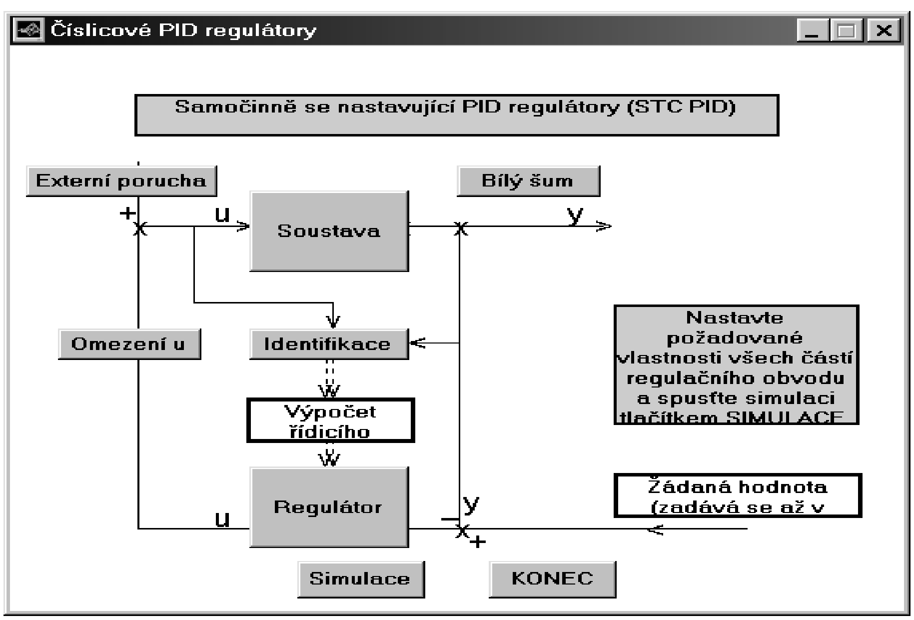

Figure 1: Initial menu

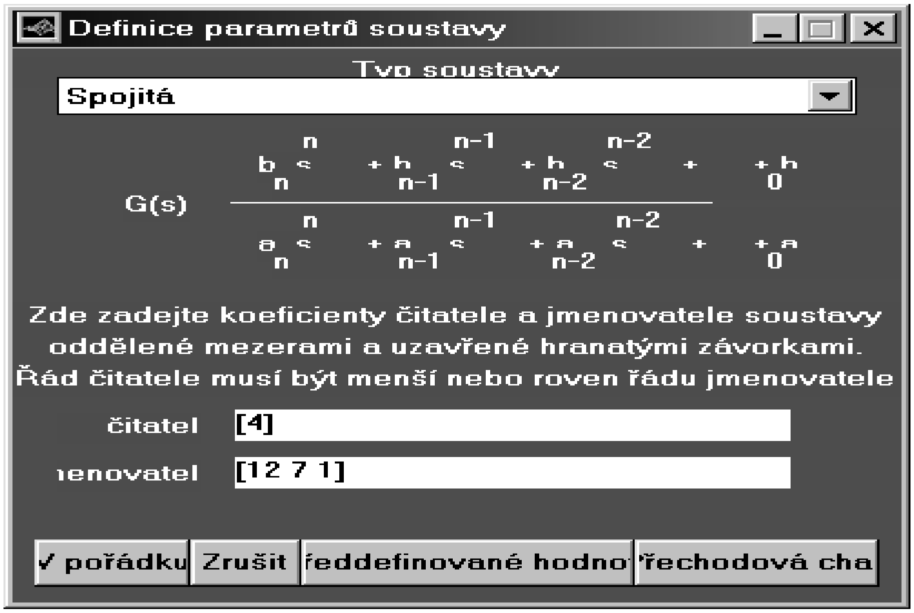

Figure 2: System definition

and then is guided through all actions by menus and buttons. Typical setting of a system has a form

The simulation uses Simulink schemes simulated from the command line. Parameters of the simulation are set by the following menu

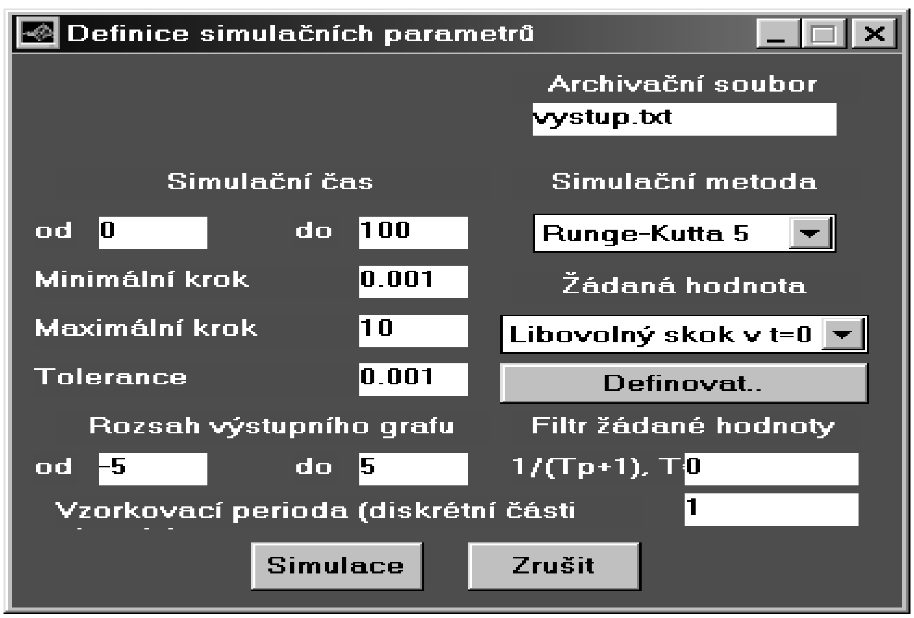

Figure 3: Simulation setup

The results are presented in the following form

3.2 The Simulink oriented form

The Simulink oriented form of the toolbox is formed by three levels of functions.

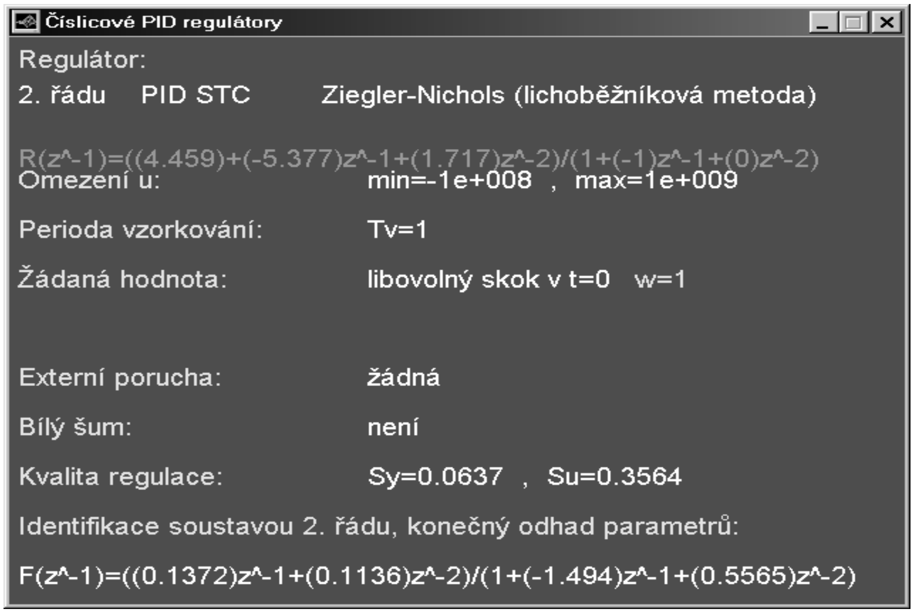

Figure 4: Presentation of the results

To the highest level belong several Simulink schemes containing specific type of adaptive controller as a Simulink block. The scheme shows typical environment where the controller is used and how it is connected to a system.

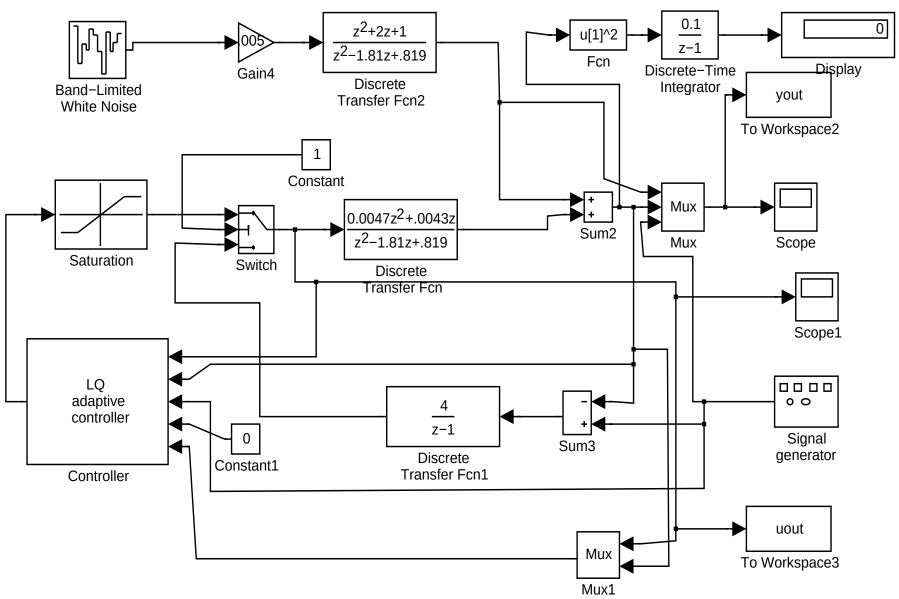

Figure 5: Typical Simulink scheme of adaptive controller

The schemes serve as a source of adaptive controllers to be used in specific user created schemes. The adaptive controller is a grouped masked block.

When ungrouped, the detailed structure of adaptive controller is obtained. These blocks belong to a mean level functions. Mean level functions are typically M-file S-functions for identification, controller synthesis and the controller itself and some other auxiliary functions.

These mean level functions use inside several specific lower level functions realizing

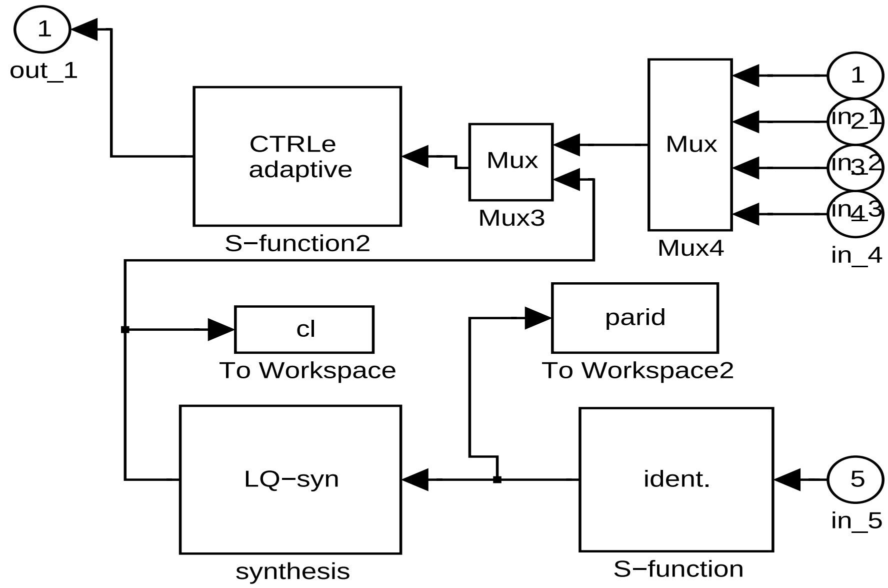

Figure 6: Internal scheme of adaptive controller (unmasked ungrouped)

specialized mathematical operations in LQ design. These are written in C and are present as MEX files. They ensure fast, efficient and reliable calculations in LQ design.

Such a structure can address wide variety of users from those who want only passively use prepared controllers over those who are capable of creating its own modifications at the mean level (e.g. by adding some filters to existing controller structure) until the most skilled users that are capable to do its own specializations of LQ controllers (e. g. multivariable ones)

4 conclusion

Both forms of presented toolbox are available for Matlab 4.2, the Simulinkg part is available for Matlab 5.

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Addresses:
Ústav teorie informace a automatizace AV R,
Pod vodárenskou věží 4, 183 08 Praha 8
tel. ++420 2 66052337
E-mail: bohm@utia.cas.cz
Katedra automatizace a řídící techniky, Fakulta technologická Zlín, VUT Brno, Nám. TGM 275, 762 72 Zlín
tel., fax: ++420 67 7211521
E-mail: bobal@zlin.vutbr.cz