

ON-LINE MATLAB-BASED EDUCATIONAL TOOLS FOR PROCESS CONTROL RELATED COURSES

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Abstract

In this paper we show a new approach of MATLAB Web tools development. The on-line tools are aimed at education in automatic control related courses, and they are based on HTTP Socket server. The server is emulated in base MATLAB runtime environment and it provides all MATLAB supported features over Internet. Server can handle user requests, sent from classic HTML Web pages and process them using predefined M-file algorithms, returning generated Web pages containing requested results. Tools provide several automation topic related features like matrix and polynomial operations, transfer function algebra, generating of system responses plots and model-based process control simulations.

1 Introduction

The significant part of modern engineering education is highly dependent on methods of computer aided learning. This trend puts high requirements on educational software engineers, forces them to develop new solutions and tools to keep quality of modern teaching and learning trends.

In engineering associated science and education we often meet methods based on use of computational and simulation software tools and environments like MATLAB, GNU Octave, LabVIEW, Scilab and SciPy. Due to the functional capacity and development support, MATLAB is one of best choices for scientific and teaching purposes in fields of automatic control, electrical engineering, signal processing, advanced mathematics, and others. MATLAB itself provides several possibilities of Web applications deployment like MATLAB Web Server (MWS), MATLAB Compiler and its extensions.

Available literature provides a lot of examples of on-line tools and laboratories based on various software technologies and development approaches. MWS is software tool, provided by MathWorks Inc., designed for front-end MATLAB based Web application development. In [1] the MWS based electrical engineering laboratory is introduced. The control of direct-current motor through MWS is shown in [2]. The interesting MWS solution of physics experimental data handling and processing is given in [3]. In [4] the authors show the MWS on-line laboratory for simulation of antenna radio-wave propagation. As shown in mentioned papers, the computational potential of MATLAB is useful in many topics. Despite the fact that MWS is one of most used MATLAB deployment Web tools even today, the technology itself is outdated and no longer supported by MathWorks. MWS was discontinued from version of 2006b.

MATLAB Compiler is wide functional source code compiler from native M-file functions and scripts to standalone executable C/C++ programs and shared libraries. As compiler's extensions the source builders for Java, .NET and Excel are available. These are also often used for on-line tools development. In [5] the authors have developed effective Web-based environment for analysis of power systems and load flow studies, using builder for Java. Another similar approach is shown in [6], where builder for Java is used for on-line tools development in pathology image analysis. The solutions based on MATLAB and .NET are also available in literature. The author of [7] uses

builder for .NET to develop Web services providing numerical modeling of evolutionary systems. The interesting overviews of MATLAB-to-Web possibilities and solutions are shown in [8, 9].

We have been using MATLAB at our institute as the main computational software for many years now. The most of practical courses aimed on control education are based on it, not only for control in-topic tasks, but also as tool for various task of optimization, programming and application deployment.

In the past, we have developed the package of on-line tools for automatic control courses [10], designed for at-home and in-class exercising. The main idea was to bring features of MATLAB environment to students through the Internet, to provide them with opportunity of independent work not only from classrooms or only in school hours. During the whole period of on-line tools development we were trying to keep abreast of technological progress in MATLAB deployment and also to provide always up-to-date solutions.

The first technology used for this purpose was MWS. The developed tools are designed for various control related computational tasks and system simulations [11]. The provided features are: transfer function algebra; mathematical operations with polynomials; polynomial roots finding; matrix mathematical operations and solutions of matrix equations; pole-zero maps, step and impulse responses of LTI models; and model-based open-loop and closed-loop control simulations.

These tools were later rebuilt on technologies provided by MATLAB Compiler, specifically on Java and C/C++ executables [12], but due to the issues with unsupported functionalities, shown in next section, we were forced to look for alternative technology to rebuild our on-line tools and set them up-to-date.

In this paper we show our new approach based on HTTP Socket server that can easily handle all past features of computational and simulation on-line tools, and simultaneously have much easier implementation and lower development requirements.

2 HTTP Socket server and comparison with other used deployment approaches

The HTTP Socket server is built on independent open-source project *Web Server*, developed and published by Dirk-Jan Kroon that is free available at [13]. The principle of server is based on execution of native MATLAB code over the Web. The server side service is emulated in by Java package classes *java.net.** which are designed for I/O network communication handling. The service is set up to process common HTTP requests for GET and POST methods sent from client side Web pages. The source code of server consist of M-file executable scripts and functions containing base methods for handling HTTP request/response model and methods for local execution of server side processing scripts.

When HTTP Socket server is initialized in MATLAB environment, the HTTP services are published on specific port of server machine IP address. The server side file structure contains M-file functions that can be addressed through server's IP and provide processing of requests in similar way as other server side scripting languages. The M-file function scripts collect inputs from request posted data and perform defined procedure of computation. The results are returned in the form of regular generated Web page to client's Web browser.

The comparison of HTTP Socket server to MWS, Java-based and C/C++/CGI-based approach is shown in Table 1.

Focusing on MWS, we can say, that it has low requirements on implementation and run,

and provides all MATLAB features on the side of server. MWS also provides wide support for OS platform containing MS Windows, UNIX and Linux. Even though that this deployment technology is very popular and easy to implement, the absence of development support makes it out-of-date and unsuitable for modern use. Another significant disadvantage is the fact that new types of MATLAB licences are incompatible with MWS, so developers using MWS are forced to use older versions of MATLAB to run it.

The deployment approaches based on Compiler builders are more suitable for MATLAB-to-Web development than MWS, but also have several issues, which limits developers to incorporate all necessary features of MATLAB environment to their Web applications. The main issue of compiled sources is the absence of Simulink support and also support of some toolboxes.

Using the HTTP Socket server, we can evade all mentioned problems of other deployment technologies and focus our attention on tools development itself.

Table 1: COMPARISON OF DIFFERENT APPROACHES USED FOR ON-LINE TOOLS DEVELOPMENT

<i>Approach</i>	<i>Requirements to deploy</i>	<i>Requirements to run</i>	<i>Implementation difficulty / type of source</i>	<i>Platform dependency</i>	<i>Supported resources</i>	<i>Not supported resources</i>	<i>Other issues</i>
MATLAB Web Server	• MATLAB	• MATLAB • HTTP server	easy / interpreted	• MS Windows • UNIX (Solaris) • Linux	all included MATLAB resources	none	• discontinued from v. 2006b • incompatible with new licences • separate licence
MATLAB/JAVA (JSP)	• MATLAB • MATLAB Compiler	• JAVA server	difficult / compiled	independent	base MATLAB resources	• Simulink • some toolboxes	none
MATLAB/C++ (HTML/CGI)	• MATLAB • MATLAB Compiler	• HTTP server (CGI support)	medium / compiled	dependent on compiler's platform	base MATLAB resources	• Simulink • some toolboxes	none
MATLAB HTTP Socket server	• MATLAB	• MATLAB (act as server)	easy / interpreted	independent	all included MATLAB resources	none	none

3 Tools overview

The computational and simulation tools based on MATLAB Socket server are embedded in regular Web pages, divided by topics of course tasks. Every Web page contains written task and input form where students fill in parameters for problem definition (Fig. 1). These are sent to server-side M-file script and are processed by it. For example, when student uses the tool for computation of polynomial roots, the input form requires its definition in standard MATLAB form (e.g. [1 4 1 -6]). After request with this data is sent to server, it is processed by M-file, including script `output = roots(input)`, where `input` is sent polynomial and `output` is result that will be printed into layout of Web page, returned to student.

Tools containing simulation features call Simulink, to run predefined model schemes at server side MATLAB environment. All these tools provide also graphical outputs (Fig. 2). After simulation is over, collected data are used to generate figures in PNG file format, which are stored in directory with temporary content. During the generating of output Web page, these are referenced to its layout.

Another useful feature of simulation tools is possibility of data download. All collected data from Simulink model can be stored in data file. Students can choose between two types of files, the text format ASCII encoded DAT file and/or binary MAT file.

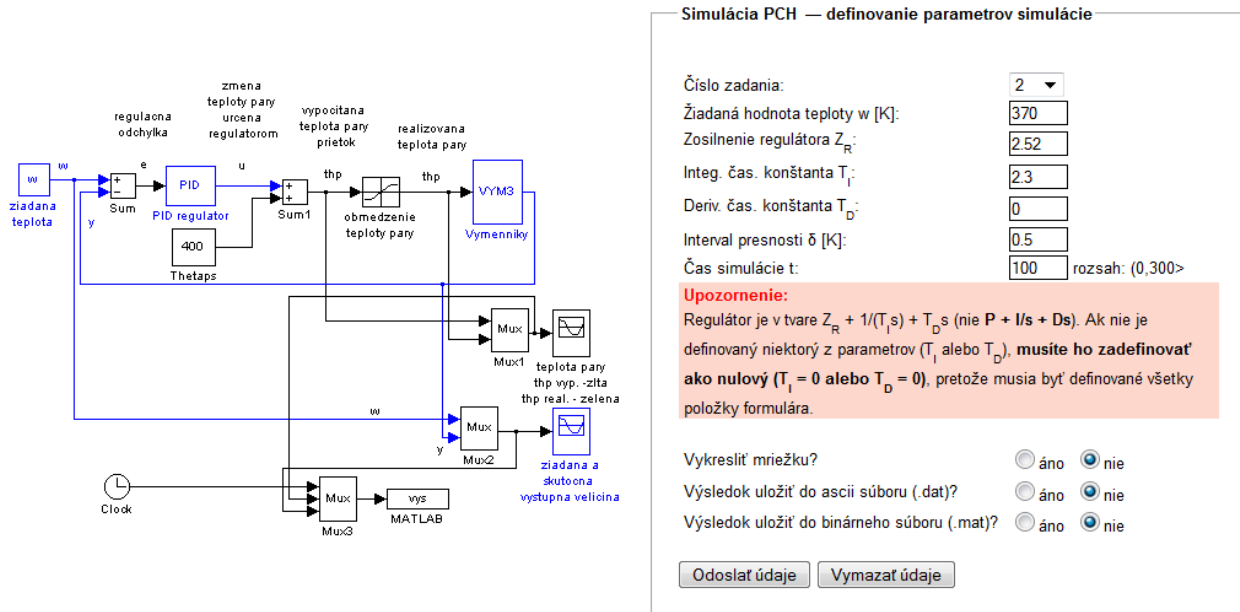


Figure 1: Heat exchangers control: setting up simulation parameters

Simulácia riadenia výmenníkov tepla

Číslo zadania: 2
 Žiadaná hodnota teploty w [K]: 370
 Zosilnenie regulátora Z_R : 2.52
 Integ. čas. konštanta T_I : 2.3
 Deriv. čas. konštanta T_D : 0
 Interval presnosti δ [K]: 0.5
 Čas simulácie t: 100
 Údaje PCH v dátovom súbore: [data_tp315844.dat](#)
 Údaje PCH v binárnom súbore: [data_tp315844.mat](#)
 Legenda k obrázku: — Priebeh teploty
 — Žiadaná hodnota teploty
 — δ okolie žiadanej teploty

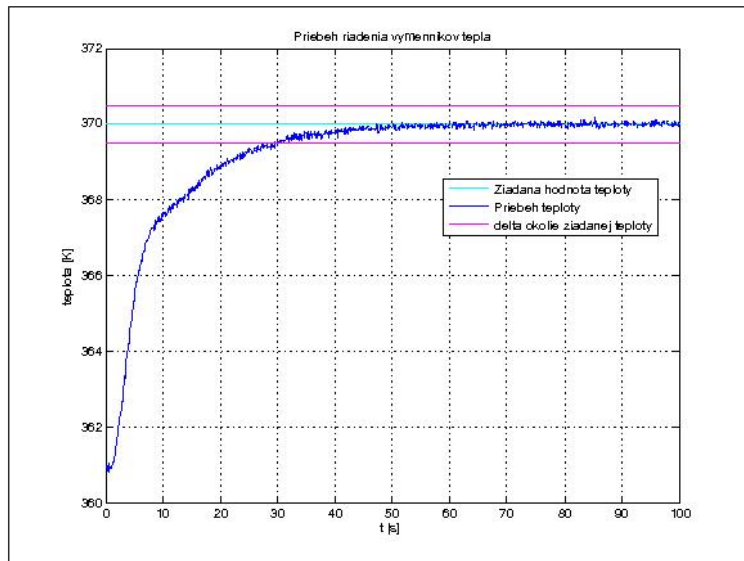


Figure 2: Heat exchangers control: generated Web page with results and graph

4 Conclusion

In this paper we have introduced our newest approach in the development of on-line tools for students participating in automation and process control related courses. By the comparison, we have shown that educational tools built on HTTP Socked server can easily handle all necessary features of MATLAB-to-Web applications and substitute outdated and functionally limited deployment technologies used in past.

The use in practice proved that solution based on MATLAB HTTP Socket server is effective and very stable, providing all MATLAB resources and possibility of future extension without undesirable restrictions.

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