MMT – Mathematics, Modelling and Tools: An E-Learning Environment for Modelling and Simulation

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Abstract. This contribution presents MMT, an e-learning system used in mathematical based courses at Vienna University of Technology. The MMT system makes use of computer numeric systems like MATLAB and R and offers experiments via web server technology. The online tool MMT on the one side enables students to increase their skills in mathematics and modelling, and on the other side to train implementation of models in the computer numeric system used. Developments are planned as well on example libraries as well as functionality.

Introduction

This contribution deals with an e-learning system called MMT- Mathematics, Modelling and Tools. It is constituted to help students of the Vienna University of Technology to increase their abilities on both, basic mathematics on the one hand and modelling and simulation on the other hand.

This e-learning system is based on the MATLAB Web Server Technology. Initially the MATLAB Server of version 2006 was used. As this product has been discontinued MMT has been using a self-made server containing the MATLAB of version 2009a. This fact supports us to update our examples for the students or create examples containing the actual tools of MATLAB, for instance SIMULINK.

Currently there are generated examples which integrate the tools of MATLAB/SIMULINK. These programs are suitable especially for students because it is easy to get the connection to modelling and simulation by watching animated simulations and well-structured program files. They can download these files and edit it by themselves to learn more about MATLAB.

At the moment there is a modification at the system. The improvement of using a Content Management System (CMS) should be realised. This system supports and organizes the shareable creation and adaptation of text- and multimedia-files. The CMS will provide the means to develop and maintain the MMT examples without the need of HTML knowledge.

1 Use of MMT system

The students of Vienna University of Technology are the main target of the creation of this e-learning system. There are many different courses, which deal with simulation and modelling. It is difficult to teach simulation and modelling without any modern facilities. MMT allows students of different fields like mathematics, geodesy and geomatics engineering, computer science, engineering and electrical engineering to use the provided examples for better understanding of modelling and simulation principles [1].

Beside the modelling and simulation part there are also examples, which help to understand mathematical basics and the influence of parameter variation. By studying the MATLAB file, which is available for each example on the MMT, the student gains insight into MATLAB and its usage. There is the possibility to download these files and edit them. The main part of the visitors of these different lessons, where the Web server application is used, has already attended courses about programming. Therefore they are familiar with reading MATLAB code.

A part of the department of the institute for analysis and scientific computing of Vienna University of Technology works a lot with simulation and modelling. Thus this institute offers many different courses about simulation in addition to the courses for mathematical basics for several studies.

In these lessons the MMT system is used to present different simulation models and explain the main aspects of modelling. This 'learning by doing' process is supported by the availability of these examples via a web interface for advanced learning at home. The rela-

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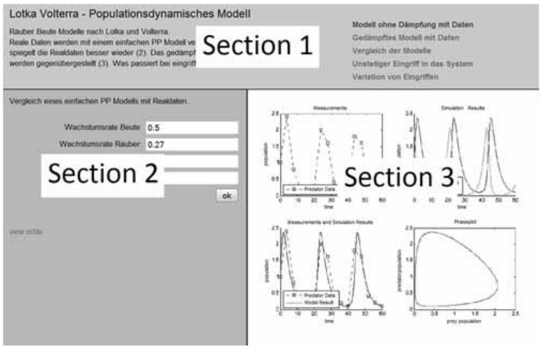


Figure 1. Current layout of the examples.

Figure 2. Designed layout in the CMS with the help of another homepage of our workgroup.

tionship between these dynamical models and the reality is also a very important goal of the MMT system [2].

To assure the comprehensibility of the examples and the MATLAB codes, they underlie a certain structure. This well defined structure supports an easy implementation and illustrates special contents of teaching.

Fig.1 shows the current layout of the examples. It is separated in 3 parts. There is the header (section 1) which contains the name of the example the main content the example deals with and on the right there are similar examples. The left block offers the opportunity to choose certain variables which are defined in the text above. There is also a short description of the model. Section 3 is white at the beginning. If the parameters are chosen the student confirms his choice and receives an output-image there. That was the layout used until now.

Figure 2 shows the approximately layout of the MMT e-learning system. In the section 1 the student chooses the right lecture and will get a list of all the examples convenient to this lecture. In section 3 on the right side there will resides the button 'view m-file' and the SIMULNIK block model, if the example is implemented in SIMULINK. It is also possible to upload other important files for every example, for instance fitting pdf-documents or pictures. In the middle section number 2 there the description of the example, the input fields and the output window are arranged.

In our case the interface, used for input and output representation, is defined by standard HTML frames. These files interact with MATLAB directly via the web server so the system becomes more stable. After defining the structure once, it is possible to adapt examples and add new ones without any code writing in PHP of HTML.

2 Further Improvements

2.1 CMS – Content Management System

Another development, beside new and revised examples, is the modification of MMT using a Content Management System (CMS). This system supports and organizes the shareable creation and adaptation of text and multimedia-files. The CMS will provide the means to develop and maintain the MMT examples without the need of HTML knowledge. This CMS is already used in combination with another e-learning system. The difference is that, there the CMS is only used for preparation of information and administration.

In this context the CMS is used to integrate the examples directly on the website without a link and the use of a password to open the link. In CMS it is possible to connect to another system, in case of Technical University of Vienna the TUWEL system (TU Vienna e-learning system). If the student attends a certain lecture the system shows automatically all subscribed courses and the adapted examples. So the CMS facilitates the handling of MMT for students as well as for the administrators.

2.2 MATLAB Tools

Currently there are generated examples which integrate MATLAB and the tool of MATLAB/SIMULINK. There are very different MATLAB examples, easier ones for the basic mathematical lectures and other ones for courses about modelling and simulation. The student can study the MATLAB code-file which contains the main instructions for building such models. In addition the student has the opportunity to download the MATLAB file to edit and to test this file and learn more about programming.

SIMULINK In contrast SIMULINK provides a set of blocks presenting data in- and output, mathematical and logical operations. Connectors stand for the flow of data between the separate blocks. In SIMULINK equations can be implemented combining these blocks. To look ahead there will be more examples generated containing SIMULINK models.

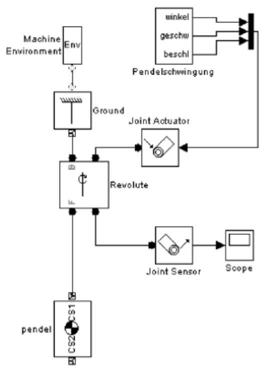


Figure 3. The bar pendulum modelled with SIMSCAPE.

SIMSCAPE Another innovation will be the embedding of examples working with other MATLAB tools, for instance SIMSCAPE. SIMSCAPE is another block-structured simulation tool of MATLAB. This tool simplifies representing physical structures because it is not necessary to formulate the based mathematical equations. It has also a block library and the examples are developed by combining these blocks. But the blocks differ from the ones of the SIMULINK library. Below there is shown a model in SIMSCAPE which describes the movement of a pendulum without a free fall. Comparing Fig.3 and Fig.7 the difference between SIMULINK and SIMSCAPE becomes clear. [5]

The model consists of much less blocks and the blocks differ from the SIMULINK ones. There is a ground connected to a revolute-block and the body. The axis of rotation is set within the revolute-block. In the bodyblock the coordinates of the position are set. The, so called, joint actuator block is necessary for the damping, in other words the revolution is influenced by the incoming differential equation of the pendulum. In SIMCAPE there is also the possibility to take a look at a three-dimensional animation of the model, which is very useful to spark the student´s interest in simulation.

3 Examples

In the following paragraph explains some examples contained in the MMT e-learning system, based on MATLAB and the MATLAB-tool SIMULINK. The advantage of SIMULINK is the clear block structure. The program code of these examples consists of many small mathematic blocks which describe every single step of the based equations. It is also possible to take a look at the based MATLAB code.

3.1 Interpolation with Splines

The first example shows an interpolation problem. It is implemented in MATLAB. The topic is the interpolation of a function which describes an increase in trapeze form by using 4 different variants.

As shown in Fig.4 the different coloured lines characterises the different ways of interpolation. The green line describes the piecewise hermit-interpolation. This interpolation takes care of the derivations of the function which has to be approximated. The dashed red line shows the interpolation with splines. Splines are defined piecewise with the additional condition that the meeting point of two polynomial pieces has to be differentiable.

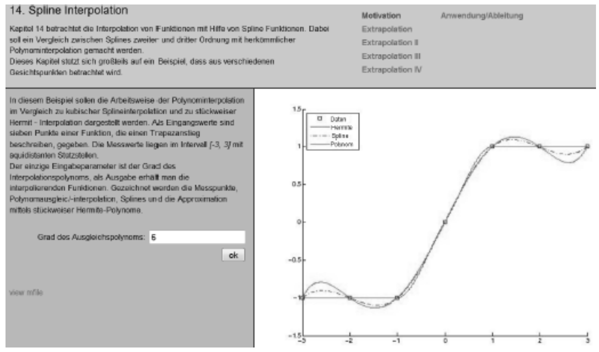


Figure 4. An example of the basic mathematical course-spline-interpolation

The used splines in this example are cubical which means that the meeting point has to be two times differentiable. The pink line describes a normal polynomial-interpolation. There is only one selectable parameter which describes the degree of the interpolation-polynomials.

Figure 5 shows the influence of the chosen degree for the interpolation-polynomials.

3.2 Discrete Controller

In this subsection a water level regulator is considered with draft from [4]. In modeling and simulation the control theory is an important field. This theory is easy to learn by typical examples like this water level regulator, so it is reasonable that the MMT e-learning system contains some applications in control theory.

The principle of the water level regulator is shown in Fig. 6. It consists of a water supply, a float lever and a tap. The requirement of the controller is to adjust the water inflow.

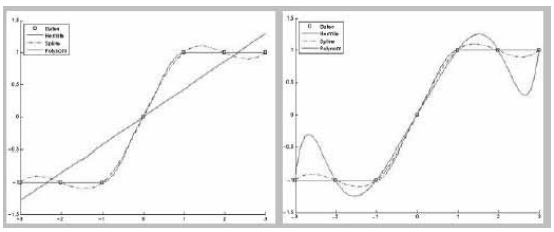


Figure 5. Influence of different chosen degrees of the interpolation polynomial.

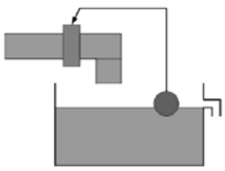


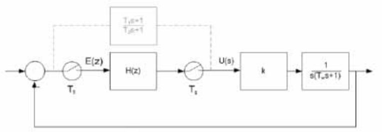
Figure 6. Sketch of a water level regulator.

The adequate continuous controller for this requirement is a PDT1-controller. When $U(s)$ describes the control deviation and $E(s)$ the actuating variable, for given $T_1, T_2 \in R$ the equation in Laplace-region is given by

$$U(s) = \frac{T_1 s + 1}{T_2 s + 1} \cdot E(s) \qquad (1)$$

In Figure 7 the control circuit is figured. The objective is, to design a discrete controller. For this problem the discrete controller is abstract characterized in the z-domain as

$$U(z) = H(z) \cdot E(z) = \frac{a_0 - a_1 z^{-1}}{1 - b_1 z^{-1}} \cdot E(z) \qquad (2)$$



with $a_0, a_1, b_1 \in \mathbb{R}$. The discrete controller works with the sampling time T_s and the coefficients calculate to

$$a_0 = \frac{T_1}{T_2} \mathrm{e}^{-T_s\left(\frac{1}{T_2} - \frac{1}{T_1}\right)}, \quad a_1 = \frac{T_1}{T_2} \mathrm{e}^{-\frac{T_s}{T_2}}, \quad b_1 = \mathrm{e}^{-\frac{T_s}{T_2}} \qquad (3)$$

This both control strategies, the continuous and the discrete controller is implemented and compared in SIMULINK, see Fig. 7.

The scopes of the model in Fig.7, allow the students to view the results of the simulation. They can observe the influence of the sampling time Ts on the performance of the discrete controller. Another aspect is the real technical implementation of the discrete controller. In technical systems they are realized via a micro controller and it is possible that a failure occurs. This time lag causes a failure in the behaviour of the controller. For the observation of this influence a MATLAB-function is provided on MMT e-learning system. The system differentiates between a failure, when the micro

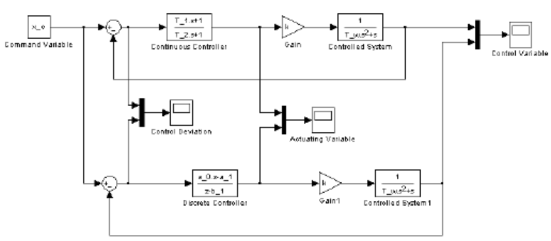


Figure 7. Control circuit with continuous and discrete controller implemented in SIMULINK

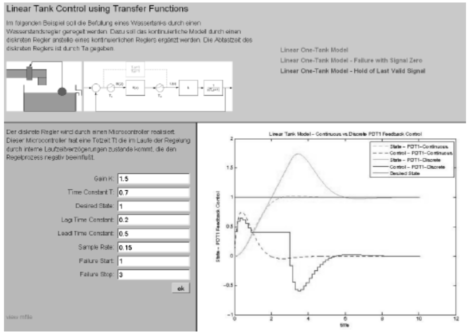


Figure 8. Discrete controller with failure

controller stores the last valid actuating variable longer than scheduled or the micro controller produces a zero signal at the output. In Figure 8 the case of storing the last valid actuating variable is shown.

4 Conclusion

The main aspect of the MMT-system is to give the students the possibility to get a connection to the modelling and simulation. On the one hand there are many examples which help the students to test different parameters and their impact on the other hand there are shown different ways to implement examples of modelling and simulation, like MATLAB and SIMULINK. They get to know a lot of connected fields and applications of modelling like control theory and simulation as shown in the pendulum example. The pendulum especially also shows how to connect to different models, which is also a very important part of simulation.

Additionally there is the background part. The conversion to CMS helps the lecturer and his assistants to coordinate the examples to the right lectures. There is also the permission point which is controlled by the web system as well.

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