

A Web-based Platform for E-Learning and Blended Learning in Modelling and Simulation

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Abstract. The Mathematics Modelling and Tools (MMT) e-learning system is a platform used for supporting lectures and tutoring at the Vienna University and Technology. Additionally to traditional e-learning properties like up- and download of lecture notes, videos and slides the MMT system provides the surface for a virtual modelling and simulation laboratory. Very powerful calculation software like MATLAB, Java or Octave, running in behind, allows experimenting with targeted modelling and simulation examples prepared and developed by experts. These are first of all used to support the presentation directly at the lecture and can afterwards be accessed by students given a password at home. As especially MATLAB also allows development of suitable examples dealing with mathematics, so far about ten percent of all examples treat this specific topic and are used in math lectures. It showed that especially the live experience fiddling on pre-implemented examples poses a big improvement for lectures.

1 Motivation

To guarantee a modern university education well prepared lectures, good didactics and consequent tutoring is essential but nowadays usually not sufficient anymore. More and more the support of e-learning features has become a necessity in order to first of all reduce organisational efforts for students and also to support and simplify their studying at home. Thus so called e-learning platforms are used nowadays fulfilling one the hand side organisational needs of students (like timetables, internal communication systems etc) and on the other hand provide download of teaching material within a password secured area.

Observations during the last decades investigating modelling and simulation lectures very often showed that these e-learning possibilities are not sufficient in order to fascinate students by the great variety and flexibility of the science. On the one hand developing theoretical models is an essential part of modelling and simulation education. On the other hand students usually lack of necessary prerequisites like general knowledge in physics, math and informatics due to their specification within their own field of study. Especially programming skills are very often to low to develop (serious) own models and experiment with them.

To make it at least possible for students to experiment on prepared models in 2006 a cooperation of the dwh Simulation Services Vienna and the AMSDM group, a subgroup of the Institute of Analysis and Scientific Computing mainly responsible for all modelling and simulation lectures at the Vienna University of Technology, decided to develop an own virtual modelling and simulation laboratory in form of a course-based e-learning system. The MMT system, abbreviation for Mathematics Modelling and Tools, was developed and installed at a server which is still maintained by dwh[1].

2 Basic Usage of the MMT System

Although the interface and handling of the server have changed several times during the last years the basic ideas of the laboratory have remained valid until now:

- Experts develop and implement didactically professional models.
- The models are uploaded to the server. The developer chooses specific model parameters which can be modified by the user.
- Students login via a mask and are faced a user-friendly e-learning system containing example models. Each example is properly described and documented. After choosing a parameter setting the simulation can be performed by the student – without knowledge regarding implementation and mathematics of the model!
- Additionally the fully commented source code is available for download encouraging the student to deal with the implementation of the model as well.
- If the student is furthermore interested and technically advances within this topic the advanced student might be given access to develop models for the server as well. The advanced student is furthermore encouraged producing something sustainable for the future.

So far about 550 different examples are uploaded to the MMT system dealing with different topics. Most of them pose for more or less sophisticated mathematical simulations, usually assembled in courses with increasing difficulty for didactical reasons. About ten percent of the examples are dealing with basic and extended math in order to support corresponding lectures for surveying students. Additionally the system is used in tests for modelling and simulation lectures as well[2].

3 Interfaces

Basically the online user interface of the MMT system can be split up into two web-pages. The first of the two, called the “front-end”, is mainly used by students - the consumers of the platform - accessing to experiment with the models and to download teaching material. The second page is traditionally called “back-end” and is used by the developers of the examples. Upload of files is also performed there.

3.1 With the Eyes of a Student

The so called front-end poses the user interface of the system. Accessed via a classic login-mask the user is first of all faced a sketch of Adam Ries, a German Mathematician of the 15th century, who inspired naming the web-page (www.adamriese.at). This first window is shown in Fig. 1.

Math Playground



Fig. 1 Image of Adam-Ries shown after the first login at the MMT front-end system.

At the left hand side of the window the node-tree can be found used to navigate through the user specified course. Which examples the user is allowed to work with depend on which examples suit to the course the user is attending.

Currently there are about 20 different courses which can each be accessed via different users. The corresponding topics spread from basic and extended Maths for Geodesy students, basic Modelling and Simulation for Electrical Engineering students, Mathematicians, Business Informatics students or Computer Engineering students, Cardiology for Health Technology Assessment lectures to finally architectural Airport and Hospital planning for qualification seminars. Depending on the usage they are either developed in English, German or both. For external representation of the system also a so called "visitor-course" was designed containing samples of all features of the MMT system. If interested admission can be granted by contacting one of the authors.

Fig. 2 shows what a visitor is to see if navigating to the basic-math example in the visitor course. The area at the left hand side of the screen shows the hierarchical structured navigation-tree and is used to browse through the course. The area in the middle is reserved for description of examples and performing experiments. As seen in Fig. 2 the optical representation of the description can be improved using formulas (LaTeX) and extended textual formatting like tables (HTML). Finally parameters of the models can be chosen by the user typing them into the HTML text-boxes. Pressing the "OK" button starts the simulation. In this case, the MATLAB engine is activated. Files offered for download can be found at the right hand area (in Fig. 2, the code of the MATLAB file can be accessed clicking "view m-file")

Math Playground

adam kurse visitor basic_math gibbs_phenomenon TU Editor(4) Logout

view m-file

Gibbs Phenomenon

Given an unsteady signal function s

$$sig(t) = \begin{cases} 1, & t \in (2k, 2k+1), k \in \mathbb{N} \\ -1, & t \in (2k+1, 2k+2), k \in \mathbb{N} \\ 0, & t \equiv 0(2) \end{cases}$$

which can alternatively be calculated by $s(t) = \text{sign}(\sin(x\pi))$. Gibbs discovered that Fourier series, for wavelength 2 here given by the formula

$$\mathfrak{F}(t) = a_0 + \sum_{n \geq 1} a_n \cos(n t \pi + \phi) + b_n \sin(n t \pi + \phi),$$

do not converge correctly at points of unsteadiness. So interesting behaviour of the Fourier approximation is expected for the chosen signal function s at $t = 0, 1$ and 2 . This effect is shown below as the order (between 80 and 120) of the Fourier approximation can be chosen as input parameter.

Plot 1 shows the input function as well as the Fourier approximation. The Gibbs effect can be observed as there are high peaks of the approximation next to 0, 1 and 2.

Plot 2 shows the error, caused by the approximation.

Plot 3 shows the amplitude spectrum of the Fourier polynomial. It can be observed, that every second value is equal to zero.

[hide description]

Order 100 OK

Fig. 2 Image of the description of the MMT example “Gibbs Phenomenon”. This basic math example deals with a phenomenon emerging by approximating an unsteady function by its Fourier-series.

The “Gibbs Phenomenon” focussed in this example is named after Josiah William Gibbs [3] was found at the end of the 19th century and emerges if an unsteady signal is approximated by its Fourier-series. It can be proven that the Fourier-series does not converge correctly at the points of unsteadiness of the signal – no matter how many elements of the series are calculated.

In the context of this example the Fourier series of a periodic rectangular signal is calculated up to a user specified order. The resulting series is finally compared optically with the input signal. The resulting plot can be seen in Fig. 3. The “Gibbs Phenomenon” can be seen very obvious. The result-plot(s) usually appears directly below the description. For space reasons the description can be hidden by a simple mouse-click onto “hide description”.

Math Playground

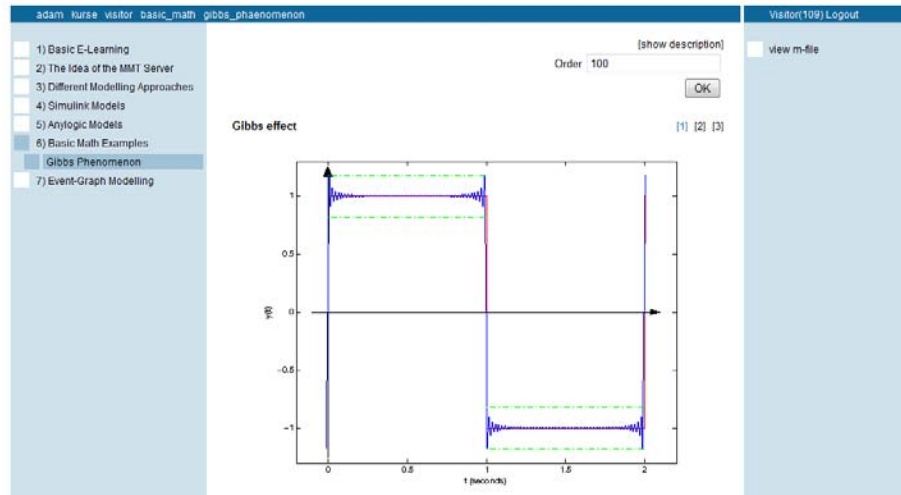


Fig. 3 Picture of the output of the MMT example “Gibbs Phenomenon”. It is clearly seen that the series does not converge at the unsteady points of the signal.

3.2 With the Eyes of the developer

The so called MMT back-end, seen in Fig. 4, is used to upload and calibrate the prepared examples and develop descriptions for the models. At the left hand side of the screen, the node-tree is seen. Based on the principle “What You See is What You Get”, modifications of the tree in the back-end directly change the appearance of the tree in the front-end. The area in the middle is used to modify single nodes. Hereby not only description but also permissions, attached files and, in case of MATLAB examples, also parameters can be modified.

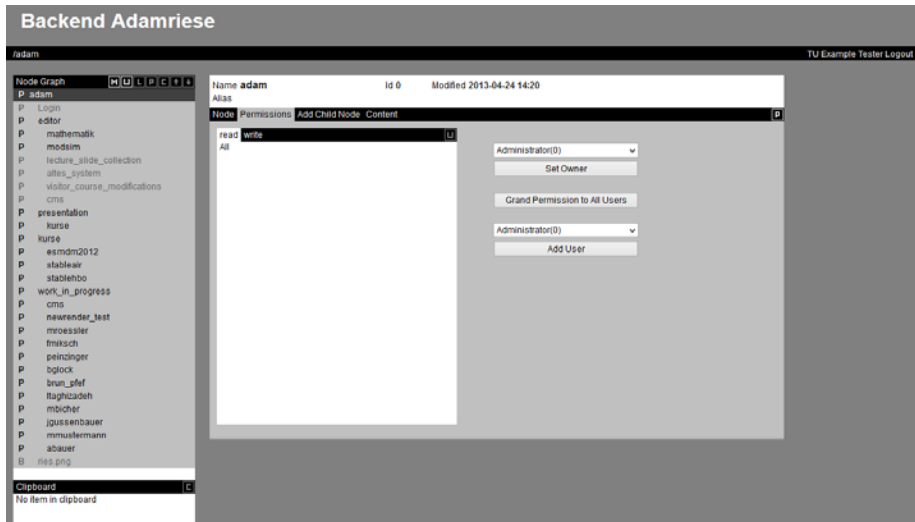


Fig. 4 Figure showing the MMT back-end. Note that the structure is similar to the front-end.

If given permission via a login mask the back-end system allows connection to and modification of the content of the so called Content Management System (CMS), posing the base of the MMT system.

Different to a Windows-typical folder-based storage system, uploaded files are first of all stored basically unstructured. Any uploaded file is given a unique identification number and can afterwards only be accessed and used if linked to a node. The nodes itself are structured hierarchically and thus pretend a hierarchically structured storage system. This leads to a lot of advantages:

- If something goes wrong with the node system, the files remain unharmed.
- Files can be linked to any number of nodes without causing additional space requirements and unhandy linkages.
- Nobody needs to care about the original place of storage of a file as it is inaccessible. A file is finally deleted by deleting the last node linked to it.
- The properties of the node can be fitted to the linked file by choosing between different node-types (page node, example node, data-node)

This idea is graphically indicated in Fig. 5.

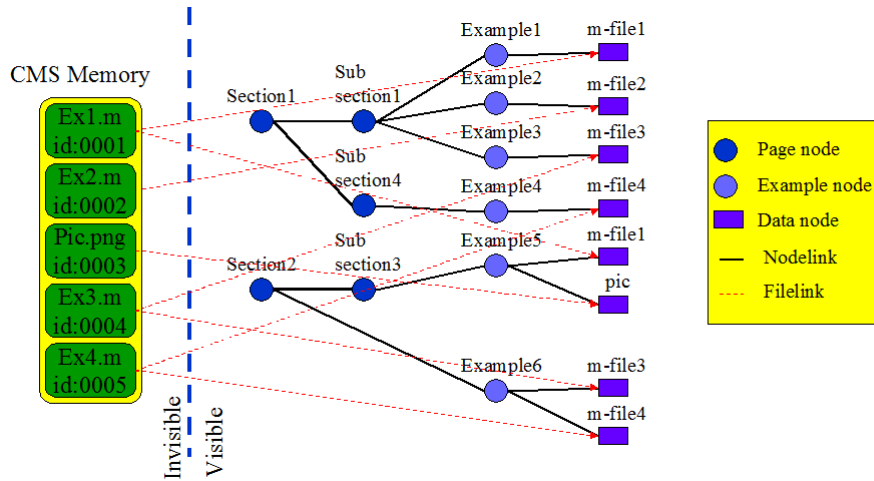


Fig. 5 Management of files in the CMS system by nodes and links.

4 Support of Software

As nowadays basic knowledge about the numerical programming language MATLAB is still very often a prerequisite for finding industrial professions after graduation, the first version of the MMT system was developed supporting only examples implemented in this language. So on the one hand for historical reasons and on the other hand due to a lack of serious alternatives most of the models (about 450) are still implemented in MATLAB. As a MATLAB version is installed at the server which is used for all calculations, it is not necessary to have MATLAB locally installed in order to experiment at the server. The communication between the server-version and the web-page is done via HTML forms and self written PHP-tools. The MATLAB output is usually stored in form of static images (PNG- format), static text and animated output (animated GIF figures) at a temporal folder accessed by the browser after the simulation has stopped. Of course the simulator Simulink is also supported by the MMT system.

As most of modern simulators or simulation environments provide the export of a built model to Java also an up-to-date Java-version was installed on the server. So far models previously developed in AnyLogic and Netlogo were exported and uploaded to the MMT system posing a big improve of quality especially with respect to the representation of animated simulation output.

An example exported from AnyLogic is shown in Fig. 6. It deals with the famous problem of two cohabitating species, a predator species and a prey species. Here the problem is solved using a model based on the famous Lotka-Volterra Differential equations [4]. To improve the visualization of the model the equations were implemented graphically using the modelling method System-Dynamics.

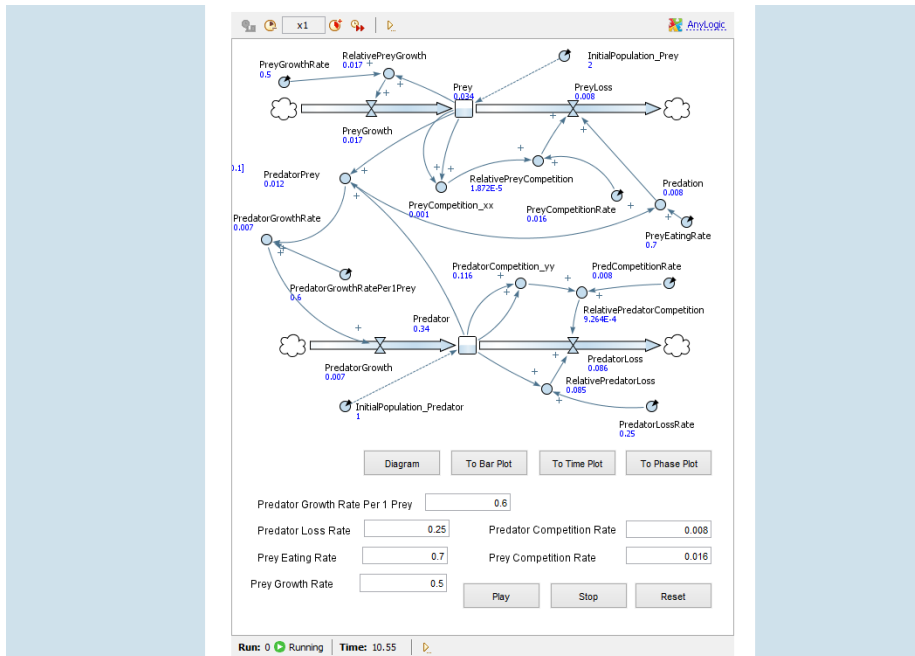


Fig. 6 Implementation of a Predator-Prey model using System Dynamics.

5 Recent Developments and Outlook

During the last months especially the expansion of the collection of AnyLogic examples was focused but also new MATLAB toolboxes and libraries were developed. In cooperation with the University of Ljubljana a special designed Petri-net[5] and Event-graph library[6] was developed to simplify the development new models using these techniques. In addition to MATLAB also Octave was installed to the server and the statistical programming language “R” is planned to be installed too.

References

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