

# MMT - A Web Environment for Education in Mathematical Modelling and Simulation

Andreas Körner, Irene Hafner, Martin Bicher,  
Stefanie Winkler, Felix Breitenecker  
akoerner@asc.tuwien.ac.at, irene.hafner@tuwien.ac.at, martin.bicher@tuwien.ac.at,  
stefanie.winkler@tuwien.ac.at, felix.breitenecker@tuwien.ac.at  
Institute for Analysis and Scientific Computing, Vienna University of Technology,  
Wiedner Hauptstraße 8-10, 1040 Vienna, Austria

## Abstract

The MMT- web server constitutes a surface to enable students to get in touch with simulation and modelling in a fundamental and user-friendly way. Simulation and modelling have become elementary skills for various fields of study in the recent decades.

To help students to strengthen their first modelling experience, examples concerning linear algebra and analysis are provided by the MMT server. Students of electrical engineering and geodesy and geomatics engineering are able to train their just gained skills in basic mathematics by solving given problems and comparing their results to the output of the example on the MMT server. Students in higher semesters of technical mathematics or computer sciences with deep going mathematical foundation can concentrate on high-level models based on differential equations or econometrics.

Most examples on the MMT server are implemented in MATLAB. The user has permission to gain every source code and download it to be able to follow the mathematical background and assembling of the given problem and possibly adapt and extend the program on his computer. On the server itself one can adjust most of the parameters of an example so effects of small data modification can easily be observed.

Besides training modelling skills, the MMT server can also be used in exams by testing the student's ability to follow the consequences of data modification on the model.

In addition to examples implemented in standard MATLAB code, models based on the MATLAB toolbox Simulink will soon be installed at the MMT server. Using Simulink, even more sophisticated models and simulations based on complex physical coherences can be provided.

Contrary to the given impression, the MMT server does not depend on MATLAB itself. Programs in other languages like octave can be linked just as well and after successfully integrating Simulink, it won't take long until Simscape, MATLAB's physical modelling toolbox, as well as Java applets are embedded into the MMT server.

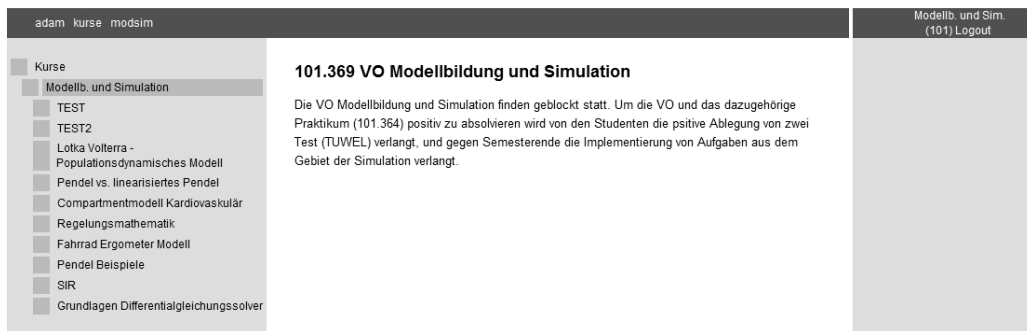
# 1 Introduction

A part of the Institute of Analysis and Scientific Computing of Vienna University of Technology works a lot with simulation and modelling. Thus this institute offers many different courses on the subject of simulation in addition to the courses for mathematic 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 relationship between these dynamical models and the reality is also a very important goal of the MMT system [1].

To become acquainted with the surface of the new MMT system, see Fig.1:

## Math Playground



**Figure 1:** overview of the new MMT surface - chapter

In the very left column you see a tree with a content overview. This tree easily allows switching between the different compartments.

The middle column contains a short description of the current section as in Fig.1 or, as in Fig. 2, a description of the current example and fields for parameter setting.

Additional files can be attached and further downloaded from the very right column, as you can see in Fig. 2.

## Math Playground

The screenshot shows the MMT server interface for a pendulum simulation. On the left is a navigation menu with various models. The main content area is titled "Mathematisches Pendel" and contains a description of the classical pendulum equation: 
$$ml\ddot{\varphi}(t) = -mgsin(\varphi(t)) - ld\dot{\varphi}(t)$$
 Below the equation, there is a text description in German and a parameter input section. The parameters are: Länge (10), Startwinkel in rad (0.7854), Startgeschwindigkeit (0), and Dämpfungskonstante (0.2). An "OK" button is present. On the right, there is a "view m-file" button and a "Logout" link.

Figure 2: overview of the new MMT surface – example: pendulum

Let's use Fig.2 to demonstrate the procedure of running examples on the MMT server. As mentioned before, one gets a short overview of the example's background in the first lines of the middle column. Beneath this description, the example's parameters can be set. By pressing 'OK', the example starts to run on the MMT server. The example's output is now shown beneath the parameter section, see Fig. 3.

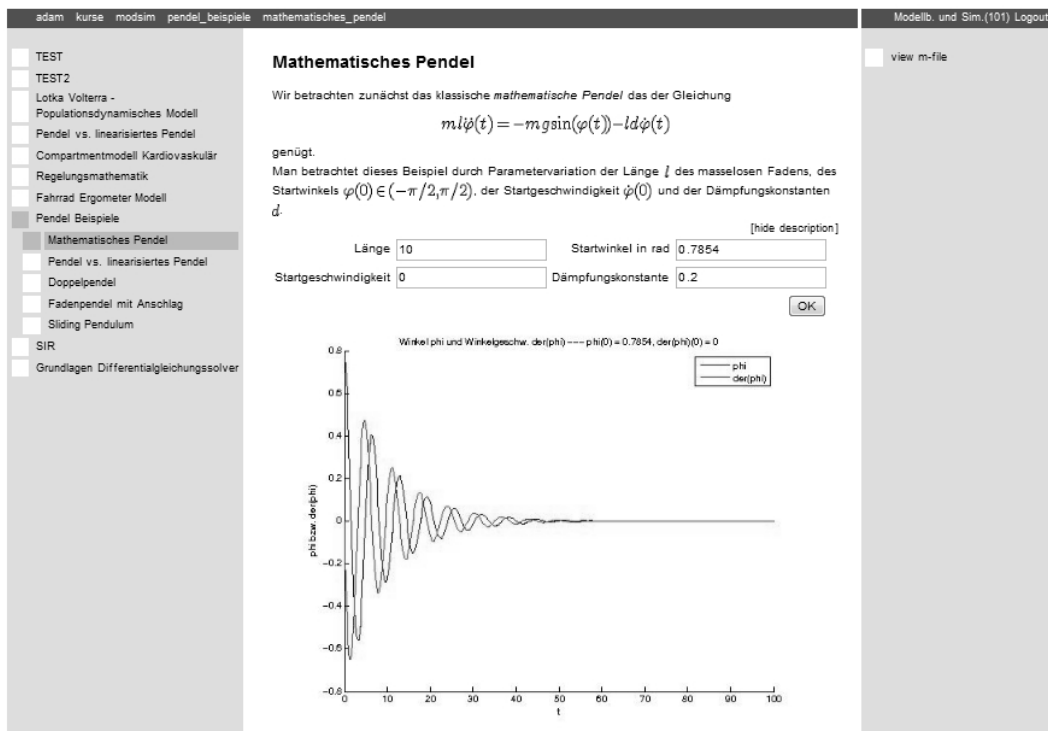


Figure 3: example: pendulum on the MMT server

In addition to observing an example's reaction to data modification, one can also download the complete MATLAB file by clicking 'view m-file'.

That way a student can locally alter the given MATLAB code on his computer and create a slightly modified example.

To enable further understanding for the given problem and provide additional information, PDF or similar files can also be attached to an example. These files will then be shown next to the 'view m-file' option.

## **2 Examples**

All examples currently existing on the MMT server are implemented in MATLAB. Nevertheless the MMT system does not depend on MATLAB but can also handle examples implemented in Octave and can easily be adapted to enable accurate embedding of other languages.

Anyhow, in this paper we will keep our focus on MATLAB based examples.

Creating a MMT compatible MATLAB example is based on programming a common MATLAB function. To create an example the MMT server can deal with, a special standardised header - clearly distinguished by leading and finishing comment lines - is inserted directly beneath the usual MATLAB function header.

This special header includes a short description of the given example to enable a quick overview and basic understanding of the problem.

In the next section the inputs given by the parameters selected on the MMT server are converted from strings into numericals so they can be used by the MATLAB program itself.

After initialising possibly necessary constant variables, the common MATLAB function is run.

The following lines create the desired output on the MMT server, e.g. graphs, error plots or simple output data.

To conclude, it is possible to add further function calls before the now MMT compatible m-file is finished.

## **3 Exams**

Whereas the MMT server basically constitutes a surface to practice and train gained simulation and modelling skills, it can also be used as an auxiliary tool for exams in modelling and simulation lectures.

Via a surface not depending on the MMT server, the examples on the MMT server can be used to check the students' improvement during the semester.

In this surface (e.g. TUWEL, see Fig. 4) questions concerning examples on the MMT server can be asked and validated without directly accessing the MMT server. Figure 4

shows a question concerning different ODE solvers where the student has to adapt the step size to reach a certain maximum error.

2 Experimente am MMT-Server  
 Punkte: 3 <http://www.adamriese.at/adam/kurse/modsim/TEST2>

Der MMT Modul ODE Solver vergleicht Euler-Verfahren, Heun-Verfahren und RK4 Verfahren bei der Lösung der linearen Schwingungsgleichung (Lösung ist gedämpfte Cosinus - Funktion). Neben den Lösungen zu den Zeitpunkten  $t(i)$  wird auch der jeweilige absolute Fehler dargestellt. Bestimmen sie geeignete Schrittweiten abhängig von qualitativen und quantitativen Genauigkeitsvorgaben durch Experimente mit dem Modul am MMT-Server (ODE-Solver)

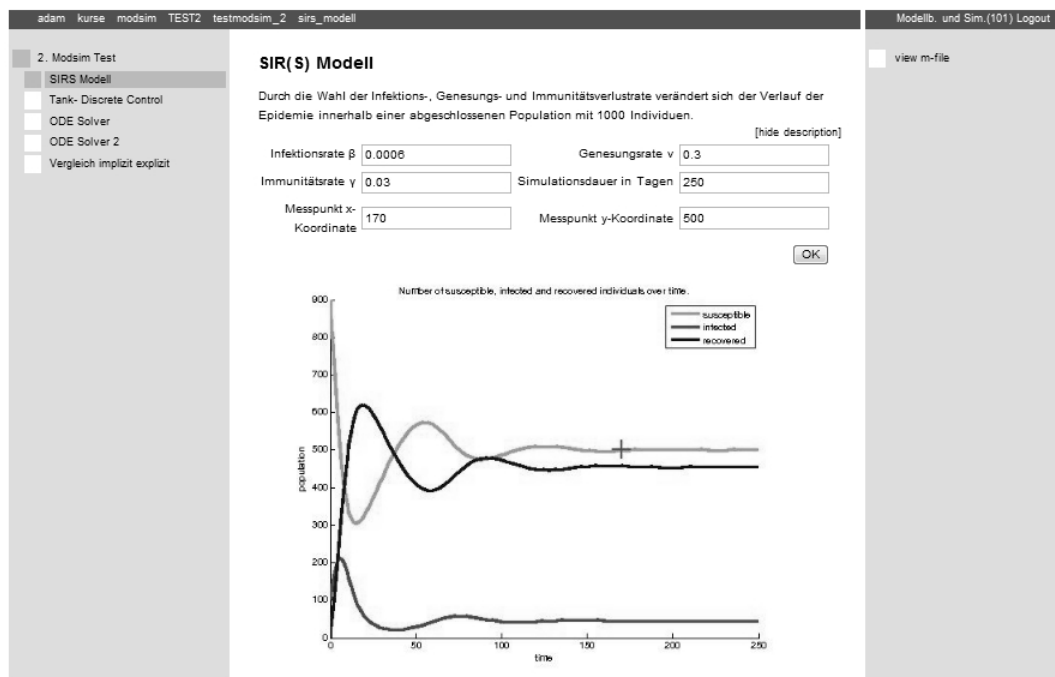
---

Frage:  
 Bestimmen Sie die maximale Schrittweite, bei der das Euler-Verfahren einen maximalen absoluten Fehler von 0.2 aufweist!

Antwort:

**Figure 4:** question concerning an example on the MMT server at a test via TUWEL

For some kinds of questions, MMT examples are modified so a checkpoint can be set additionally to the common parameters in the output graph to enable exact reading of the output data as shown in Fig. 5:



**Figure 5:** question concerning an example on the MMT server at a test via TUWEL

## 4 Outlook

Nowadays physical modelling has become one of the most important and upcoming fields in modern simulation. This kind of modelling requires software exceeding the potential of MATLAB itself.

Therefore, to provide access to more demanding simulation models, our developers are currently working on integrating the MATLAB toolboxes Simulink and Simscape into the MMT server. These simulation environments which have been developed in the recent decade enable modelling and simulation on a way higher level.

Physical processes described by differential equation systems one could barely ever set up in the traditional way can be created within a few mouse clicks via Simulink and Simscape. In this way the MMT server can be used to convey very deep going modelling skills and understanding of complex coherences. Models implemented with Simulink and Simscape throughout exercises or bachelor theses in modelling and simulation will then be additionally put on the MMT server. As all currently existing examples on the MMT server have been developed by students or assistants and professors of the Vienna University of Technology, this method of enlarging the range of MMT examples has already proved itself with common MATLAB examples.

## 5 References

- [1] *Stefanie Winkler, Andreas Körner, Irene Hafner*: MMT – A web-based e-learning System for Mathematics, Modeling and Simulation using MATLAB. 7<sup>th</sup> EUROSIM Congress on Modelling and Simulation, paper 231 ,Prag, 2010
- [2] *Andreas Körner, Günther Zauner, Günther Schneckenreither*: Ein e-learning System für MMT – Mathematik, Modellbildung und Tools, Systemerweiterung und Einbindung von graphischer Modellbildung. 20<sup>th</sup> Symposium Simulation Techniques, pages 87–94, Cottbus, 2009