WEB-BASED TEACHING AND LEARNING WITH mαth-kit

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ABSTRACT

In this article we present the concepts and first results of mαth-kit, which is being developed at the universities of Bayreuth, Hagen, Hamburg and Paderborn. The research and development is part of the program 'Zukunftsinvestitionsprogramm' sponsored by the German government to introduce new media into university teaching.

mαth-kit is a web-based construction kit, which provides professors and students with multi media support for central topics in undergraduate mathematics. Moreover, its development is intended to close the gaps between the education of mathematics students and the training in technical disciplines such as computer science or mechanical engineering. mαth-kit tools combine mathematical algorithms with examples from other disciplines and vice versa. Furthermore, elements for student motivation, exploration, applications and visualization are contained. With the possibility of combining elements to support different learning objectives, professors are able to employ mαth-kit to compose individual teaching units.

¿From the technical point of view mαth-kit is based on the Sharable Content Object Reference (SCORM) standard and uses XML as the implementation language. The basic elements of mαth-kit are called assets, small highly interactive components like Java applets. Learning units can be built from assets; complete courses consist of different learning units. Further technical highlights of mαth-kit are the accessibility via the web and the possibility of using the computer algebra system MuPAD as the mathematical engine. In contrast to other systems, the elements of mαth-kit cannot only perform numerical computations, but the assistance of MuPAD also makes symbolic computations possible. The mathematical power of MuPAD can be used through the web without forcing the user to learn its complex programming language.

An outline of the system structure and some examples will be given.

1 Introduction

mαth-kit is a web-based consruction kit which is being developed at the universities of Bayreuth, Hagen, Hamburg and Paderborn. The research and development is part of a program called 'Zukunftsinvestitionsprogramm' (Future Investment) sponsored by the German government. Within this program, the German Ministry of Education and Science financially supports 160 projects which develop, integrate and evaluate the use of new media in university teaching [2] with a fundamental capital of 200 million Euro between 2001-2003.

Nowadays most university teachers agree that the use of computers is very helpful in specific learning situations, in particular when teaching mathematics to undergraduates and non-mathematics students. However, the use of computers remains mostly concentrated on isolated laboratory work and is not common in standard lectures. Here most lecturers still prefer traditional teaching methods such as the blackboard or OHP, as the integration of computer-based interactive teaching materials into lectures continues to require a larger degree of technical knowledge and the development of units is time-intensive.

Consequently this is the starting point of the project mαth-kit. In contrast to many existing computer based learning materials mαth-kit is neither a complete learning unit focusing on a specific subject nor a lecture or textbook equipped with hypertext and multi media support. Moreover, it is not intended to replace the human teacher. Instead, mαth-kit is a web based construction kit, which provides professors and students with small, multi media tools for central topics in undergraduate mathematics that can be combined in different ways to create individual learning units.

This project is mainly targeted at university staff who teach mathematics. In general, lecturers are not experts in the use of new media and clearly mαth-kit will only be integrated into individual teaching material if it is easy to use by non-specialists. Therefore a major focus of the project is to develop a technical platform that structures the elements of mαth-kit, and an interface which allows a non-expert to find and combine different elements into learning units. Supporting those who teach will be beneficial for students in the long term.

Another focus of the project is its evaluation. Elements of mαth-kit are currently being implemented used and evaluated at: the University of Bayreuth in lectures for teachers students; at the far distance teaching University of Hagen in courses for beginning mathematics students; at the University of Hamburg in lectures for computer science students and at the University of Paderborn in lectures teaching mathematics to engineering students.

2 Elements of mαth-kit

mαth-kit is designed to support different aspects and different settings of learning. Therefore various categories are distinguished and realized.

2.1 Exploration

In order to apply mathematical methods successfully to a given problem is it not sufficient to know the respective algorithms but to have a deep understanding of the underlying concepts. In this context, successfull learning is often regarded as an active and constructive process rather than a passive storing of information. Therefore, it is crucial to offer resources for self-controlled and explorative learning (see [3] for instance). This concept of learning is therefore a core idea within mαth-kit and reflected in its so-called elements of exploration. These are interactive elements, usually realized as Java Applets, which can be used by students in open learning settings. Often these elements allow and ask for direct as well as indirect manipulation.

2.2 Drills and Exercises

It is crucial for successful learning to give students the resources to practice mathematics and to offer them the opportunity to control their success in understanding. This applies in particular to students in a system of distance education. For this reason, exercises and drills play an important role in mαth-kit, especially when considering that for success in computer-based learning, the emphasis often lies in the necessity of constructive feedback. In this context, the computer has to give the learner as much freedom as possible, allowing them to choose alternatives, make as many attempts as necessary to solve the problem (see [3], [5]) and subsequently see their results. These ideas were taken into account when developing mαth-kit elements for exercises. mαth-kit uses the computer algebra system MuPAD in the background allowing the student to generate as many examples as needed, to receive help and to check the results. A few examples and more details about the implementation of these drills and exercises can be found in [6].

2.3 Application

Another basic principle of mαth-kit is the idea that mathematics should be taught and learned together with its applications. Mathematics is crucial for the understanding of many scientific fields, especially the technical sciences. Therefore, it plays a fundamental role in natural sciences and engineering courses as well as in the studies of computer science. However, the abstraction level of mathematics poses considerable problems for many undergraduate students - applications and connections are not always clear for them. Application elements of mαth-kit are intended to provide this link. 'Real life' problems, for example in connection with electrical circuits or economic models are explained, the hidden mathematics is revealed and it is furthermore shown how mathematics helped to solve the original problem.

Another difficulty facing teachers and learners in higher courses for example system theory in computer science or electrical engineering is that students may not remember the mathematics behind certain applications. With the application elements in mαth-kit, these gaps are intended to be closed.

2.4 Motivation

To a large degree successful teaching depends on the methods employed to motivate students. The already mentioned elements like explorations or applications can be used for motivation. Moreover, special teaching aids for instance videos are classical tools for increasing motivation and will be included in mαth-kit. Furthermore, historical information such as biographies of famous mathematicians or the history of a mathematical problem can serve as motivational tools and are thus a part of mαth-kit.
In addition, we are especially interested in motivating female students to enroll in a technical science and to bring it to a successful end. Examples from the social sciences or art instead of examples of engines or electrical circuits are regarded as useful for addressing women. Therefore we will integrate such applications in mαth-kit.

3 The computer algebra system behind mαth-kit

3.1 Advantages of the use of a computer algebra system

Numerical calculations are widely known and can already be realized on a pocket calculator. The algorithms and their results are interesting in teaching mathematics and can also be easily implemented for use on the web. However, their use is restricted. For learning and teaching mathematics, it is crucial to deal with symbolic computations. A typical example is proving the identity $sin(2x) = 2sin(x)cos(x)$ or to differentiate or integrate functions symbolically. For such functionality, it is nearly impossible to use standard programming languages such as Java, however, so-called computer algebra systems (CAS) give answers to these problems. CAS are powerful software systems that combine numerical and symbolic computations and incorporate algorithms for nearly all kinds of mathematical fields. Within the project mαth-kit, the computer algebra system MuPAD is used. MuPAD is a modern CAS which has its roots at the University of Paderborn [4]. MuPAD is also very useful in generating exercises. In this way, exercises and drills in mαth-kit allow students alternatives to arrive at and enter their solutions. Each student has the possibility to individually make as many attempts as necassary to solve a problem as MuPAD generates as many exercises as needed. As MuPAD can analyze mistakes and assist with problems, it can be used for direct feedback to students (see also [6] for a more detailed discussion of this topic). Hence, the elements of mαth-kit not only combine numerical and symbolic calculations but also use MuPAD as a mathematical expert system in the background. Tools for calculating the row echelon form of an arbitrary matrix, an applet for the calculation of the symbolic and numeric value of an infinite sum or a tool for checking and calculating derivatives already exist [6]; others are about to follow. In these tools the use of the CAS is hidden from the user. Hence, the student does not need to learn the MuPAD language in order to work with mαth-kit. However, if explicitly needed, one can also integrate a complete MuPAD session into mαth-kit elements. This can be very useful when explaining the language and the possibilities of a CAS.

3.2 Computer algebra via the web

Usually computer algebra systems need to be installed on local computers and cannot be accessed through the web. Today concepts for web-based computing with CAS are being developed such that all their functionalities can be used in internet based applications. Integrating this into mαth-kit has the advantage that no local copies of a computer alegebra system must be installed. Hence, all students use the same version of the system without needing to consider installation or local incompatibilties. In mαth-kit we chose MuPAD as the algebra engine behind our applications because the pricing of MuPAD is attractive for universities. The main components of this engine are a Java client applet and a MuPAD Computing Server with JavaScript serving as means of communication between input/output components of the web pages and the client applet. More details are described in [8].

4 Technical outline of the system

4.1 Demands

As already mentioned, the main goal of mαth-kit is to provide multi media support for lecturers. Professors like to use their own notation, have their own structure in their lectures and focus on different aspects in mathematics. Many of them are interested in using multi media tools as long as they are easy to handle and easy to adapt to their own lecture. Therefore, the main design concepts of mαth-kit are the flexibility and adaptibility of elements together with an ease of use and the combination of elements. To achieve these principles, it is necessary to be highly granular and to give the user the possibility to build up learning sequences from small elements. One fundamental element covers only a very specific topic for instance transforming a matrix into row echelon form. This method is one of the basic algorithms in mathematics needed in different fields. The goal of mαth-kit is to make this method available as a web-based tool, to make it easy to use and to integrate it into different lectures. With this flexibility, it is also possible to integrate elements of mαth-kit into different learning contexts and to support different learning objectives.

It is obvious that not all interesting or difficult topics in undergraduate mathematics can be covered within the three year period of the project. Therefore, mαth-kit is being designed to be extendable by authors outside of our group. Guidelines for other developers will be published.

To simplify the publishing of new elements of mαth-kit, we plan to develop an authoring system. Authors are supposed to provide keywords for their elements in order to make all elements of mαth-kit searchable.

4.2 Realization

The structure of all learning units and mαth-kit itself are based on the SCORM (Sharable Content Object Reference Model) standard version 1.2 ([7]), which was proposed by the Advanced Distributed Learning Initiative [1] in 2001. This standard not only guarantees that all elements are searchable but also reflects the fine granularity of the system as well as the possibility to combine different elements. The atomic elements of mαth-kit are small highly interactive components like Java applets called assets. Learning units can be created from assets; complete courses consist of different learning units. XML is the programming language chosen to implement the elements. With XML the content of elements is independent of the representation. It can be translated into any other document format that uses a hierarchical organisation like HTML and PDF. Hence, elements of mαth-kit can be adapted to personal needs or preferences.

5 Summary

In this article we presented the concepts and first results of mαth-kit, which is a highly flexible and adaptable web-based construction kit for multi media support in central topics in undergraduate mathematics. During our presentation several examples will be given. All examples and supplementary material will be published on our web site www.math-kit.de at the beginning of April 2002.

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