Computer-based study material in mathematics: planning principles and realization

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Abstract. The development of software and network technology has given enormous possibilities to teaching and learning. At least, it is widely believed that there is a great potential. In practice, it is not so clear how these possibilities should be used.

An experiment in the field of mathematics at university level is reported: philosophy, planning principles, realization, future. The core of the experiment is a study package based on hypertext, web browsers and computer algebra systems.

1 Background

The mathematical knowledge and ability of the new students at a university of technology — in Finland, but probably also in any other country — is not so firm as would be expected. Some revision of the school level mathematics is needed before the actual university studies. Here, computer-based study material could be a solution. Except at universities, the material could also be used at polytechnics and as additional reference at mathematically oriented schools.

This situation has been the starting point of a research project at the Helsinki University of Technology. The project is called *MatTa*, in Finnish ***Mat****ematiikkaa* ***t****ietokone****a****vusteisesti*, roughly in English *Computer aided mathematics teaching* [1].

The objectives of the project are

- to develop computer-based mathematical study material of various kinds,
- to investigate the necessary software technologies,
- to study what kind of learning process should be supported and
- how the material should be planned.

A study package for revising and slightly enlarging the school level mathematics will be produced. (This will be in Finnish with the name $\mathfrak{M}$ *niinkuin matematiikka* [2].) At the moment, the main components are already completed. A test of the package is planned for August 1999, when some new students of the Helsinki University of Technology will use the package during one week before beginning their university courses. The use at upper secondary schools and in distance education systems is also planned.

2 Philosophy

The student will be given an open study environment: This consists of information about mathematics, problems to be solved, computational tools, guidance, general help (both technical and mathematical).

The student may study what he/she feels the most interesting. He/she must begin to do his/her own research, to create a view on mathematics. Thus, the view on the learning process is constructivist.

In principle, the criterion of the learning is the ability to solve the given problems. On the other hand, the students are not graded. The purpose is only to give them a study environment that will be interesting enough to make them study mathematics at their own pace.

3 Planning principles

The planning principles for the study package are set as follows:

- The study package consists of the following components:
  - a hypertext based mathematical encyclopedia with visualizations, animations etc.;

  - a collection of often application oriented problems with hints on several levels and a summary of the solution;
  - some mathematical program as the computational tool in addition to a calculator (on the screen or on the table);
  - demonstration sheets as documents of the mathematical program;
  - help systems.

- Because (school and university basic course level) mathematics is much more invariant than software systems, all the material must be written in such a form that it will be possible to convert it to any new software system or platform that will be available in the near future — if possible.
- The hypertext links are generated as automatically as possible.
- The mathematical formulae and expressions must be written as beautifully as possible.
- In the first stage, the use of the material should be possible in the network environment (WWW), locally in the user's own machine and in the university's workstations.
- It must be possible to put the system to collecting data (activated interactions, time stamps) about the work and behaviour of the student. This is used for analyzing the learning process the package supports, not for grading the student.
- The distribution of the most important parts of the material must be free, if possible. If licensed programs are needed, there must be possible to use different alternatives.

If the material should be free, the project must have the funding from public sources. During the last year, the situation has been good.

4 Structure and technical solutions

At the moment, the technical solutions used in the package are as follows:

- The mathematical encyclopedia consists of more than 400 pages (screens). The source text is written in LaTeX [3] and converted to pdf form. Acrobat Reader [12] is used for reading.

- Hypertext links are defined in the LaTeX code, where the additional package `hyperref` is used [4]. The author of the text has to mark the anchor of the link and the name of the target (in mathematical terms); the position(s) of the target is/are detected by a special program.

- The encyclopedia contains a lot of pictures in PostScript form. They may be made in any program able to print in an eps file. Most of the mathematical pictures are made in Mathematica [7] or Matlab [10].

- The encyclopedia may also contain animations and interactive visualizations. Some experiments are made, but the distribution version does not yet contain any of them.

- The problem collection contains more than 100 problems with hints and a survey of the solution. The material is written in LaTeX [3] and converted to html form with the program `latex2html` [6]. WWW browsers are used for reading. (Earlier, the authoring system MetaCard [13] was used, but now it is replaced by WWW browsers.)

- The computer algebra system Mathematica [7] has been used as the computing tool; short beginner's guide is available. Any other mathematical software can be easily installed instead. Also, a simple screen calculator is available.

- The whole package may be used in the web. For reading the encylopedia, Acrobat Reader [12] must be installed as a plugin of the browser. The user must have his/her own copy of Mathematica [7] (or any other computer algebra system like Maple [8], Mathcad [11], Derive [9], etc.).

  As an alternative, the user may copy the material to his/her own machine. In this case, too, he/she must have his/her own copy of the computational tool.

5 Features to be developed

The development of the package will continue. The following new features are planned:

- There must be more animations and visualizations. They may be in different forms: computer algebra system based, VRML [14], series of gif pictures, Java based. It is rather easy to animate many mathematical phenomena, but to find animations really useful for learning is not so simple.

- When the package is used through the web, the user (student) could send his/her answers of the problems to the server. Here, the answers are checked, some feedback is given and a statistics is collected. Thus, it would be possible to give the student a survey of the work done during several sessions (which of the problems are solved, how many correct and wrong answer are given, etc.) It must be emphasized that the idea is not to grade the student, but to give some feedback for self-evaluation. On the other hand, the data collected in this way can be used for developing the system further.

- The conversion of LaTeX code to html form is not optimal: at the moment, the mathematical formulae will be transformed to very many gif pictures. In the near future, there will be — hopefully — better solutions. If the mathematical markup language MathML [5] will be the solution for publishing mathematics in the web, it will be appropriate also for study packages. In this case, both the encyclopedia and the problem collection will be converted in the MathML form. Of course, software for doing the conversion is needed.

- Another interesting environment for the whole package is Mathematica [7]: hypertext links are supported, typesetting of formulae is (almost?) possible, pictures and animations can be easily included and, of course, computations can be done in the same system. The main disadvantage is that then the package is bound to Mathematica and Mathematica is rather expensive. Also, software for transforming the LaTeX [3] code with hypertext links to Mathematica notebook form would be needed.

- Very often, computer and network based study packages are produced, but when they are finished, they are already old-fashioned. As a consequence, they will never be thoroughly tested: What kind of learning process are they really supporting? Is anything learnt better compared to books? The aim is to develop a system for collecting the data about the students work, integrate it into the package and analyze the data. The details are considered by Riikka Nurmiainen [15].

6 Acknowledgements

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[5] Mathematical Markup Language MathML:
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