Applied Mathematics and Computational Modeling in Engineering

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Abstract - **In many countries of European community, USA, Japan etc., study programs entitled Technomathematik, Applied and computational mathematics, Computational science and engineering, Scientific computing or Mathematical and computational modeling can be studied. All these names try to characterize a connection of applied mathematics, computational modeling and scientific, engineering and/or economic applications. Two years ago, a new study program Mathematical and computational modeling has been launched at the Faculty of Civil Engineering, Slovak University of Technology in Bratislava. The program is currently being prepared also for foreign students and after finishing the transformation it will run in English language. This transformation is supported by European Social Fund and the project called "The complete language transformation and personal providing of a study program Mathematical computing modeling". The goal of the paper is to promote this study program for an international community, present its aims, studied subjects and perspectives of the graduates.**

Index Terms – applied mathematics, applied sciences, mathematical modeling, computational modeling, engineering, labor market, graduate profile, interdisciplinary application, study program, scientific and technical computing, technology, software development.

MOTIVATION

Existence of study programs oriented to applied mathematics and computational modeling in engineering is motivated first of all by rapid development of modern technologies. Real problems arising from an industrial, financial, biological or algorithmic background require good knowledge in modeling, analysis and computation and at the same time they require good orientation in mutually interconnected engineering, natural science or economic applications.

The described study program was designed to be an analogue of programs mentioned above (see Abstract) with some specifics given by the place where it is run. The basic motivation for creating the program has been to offer the students a possibility to study applied mathematics in close connection to computational modeling and modern applications in sciences, engineering and modern technologies as mentioned above. Similarly oriented study program was missing in Slovakia, though there have been some study programs devoted to applied mathematics at universities in Žilina and Trnava. However, these programs are not so deeply oriented on computational modeling in engineering and mostly they cover local country areas. Further study programs with an important role of applied mathematics popular with the students are Economic and financial mathematics and Mathematics and management at the Faculty of mathematics, physics and informatics of the Comenius University or several study programs at the Faculty of Management of the Comenius University in Bratislava. All these programs have been strongly oriented to economical applications, thus the study programs devoted to applications of mathematics in modern technologies were still missing in Slovakia. A natural place for establishing and successful development of such a study program is Slovak University of Technology. It offers strong background for study of real engineering problems either in the framework of the particular subjects or during the work on a thesis. The Departments of mathematics and descriptive geometry of the Faculty of Civil Engineering and Department of mathematics at the Faculty of electronics and informatics which run the program, together with engineering departments of the Slovak University of Technology posses experts in the field of applied mathematics and computational modeling, which are able to offer the students deep background in mathematical and computer oriented subjects with accent to important engineer applications. They are also able to offer modern tools and methods in areas related to scientific computing, numerical and mathematical analysis, probability theory and statistics and computer graphics as arises in various engineering applications, in addition to deep professional view at variety of the engineering problems themselves.

DESCRIPTION OF THE STUDY PROGRAM

To build a bridge between mathematics and engineering the study program is designed to train graduates in various fields of mathematics and computer science as well as in the field of applications. Further emphasis is placed upon software tools related to these fields and to visualization, data analysis and result presentation.

Following figures show the particular subjects and study structure. First, the modeling tools, including mathematical, computational and software tools, are

studied, then they are applied to various engineering subjects. Based on careful study of the mathematical base, the methods of applied mathematics are introduced to the students, see Figure 1, where the basic structure of the mathematical modeling part is presented. Similarly, based on C and C++ computer language study, the students are trained in further computational tools as shown in Figure2.

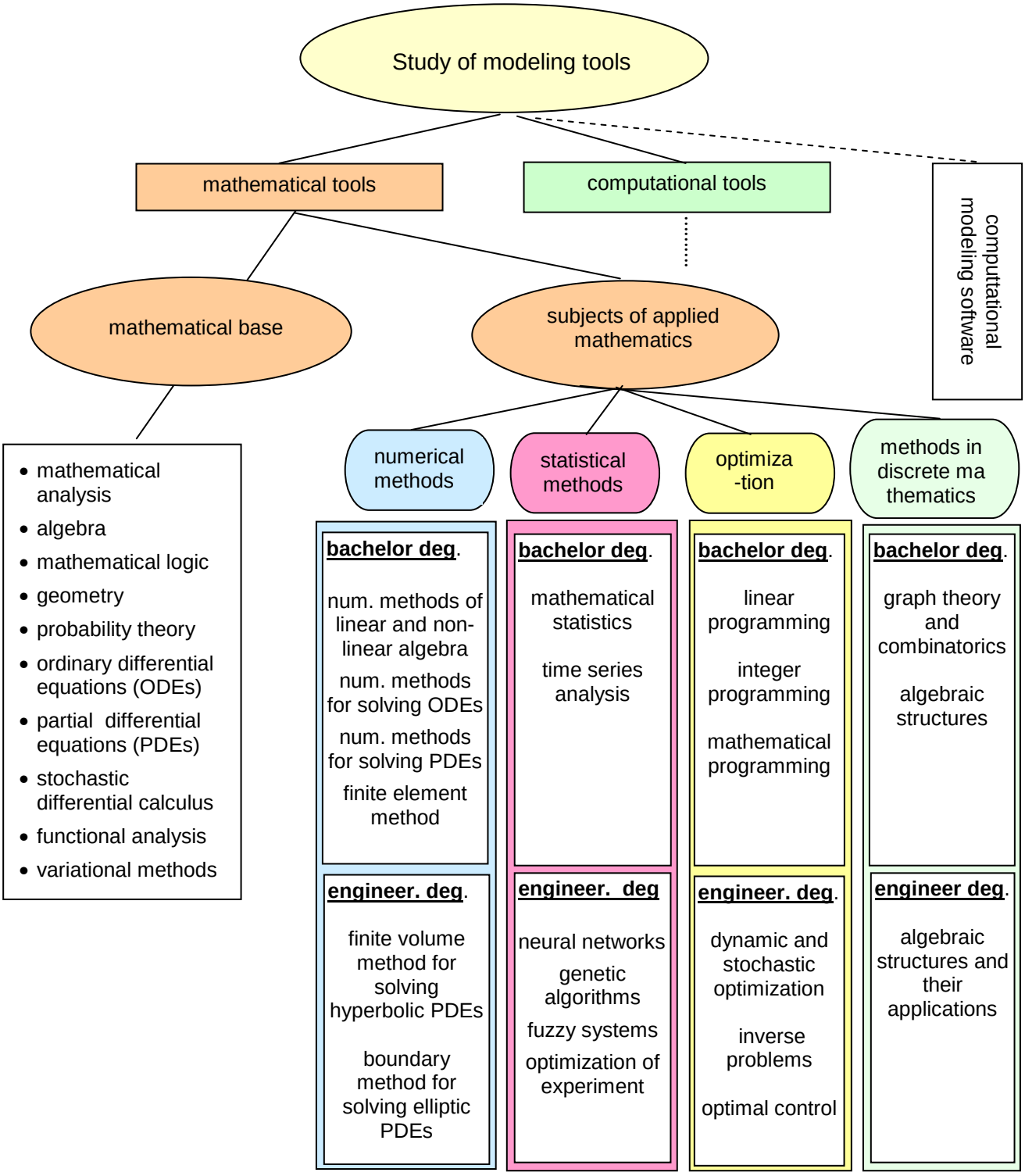

FIGURE 1
THE GENERAL SUBDIVISION OF THE STUDY RPOGRAM
AND SUBJECTS OF THE MATHEMATICAL MODELING.

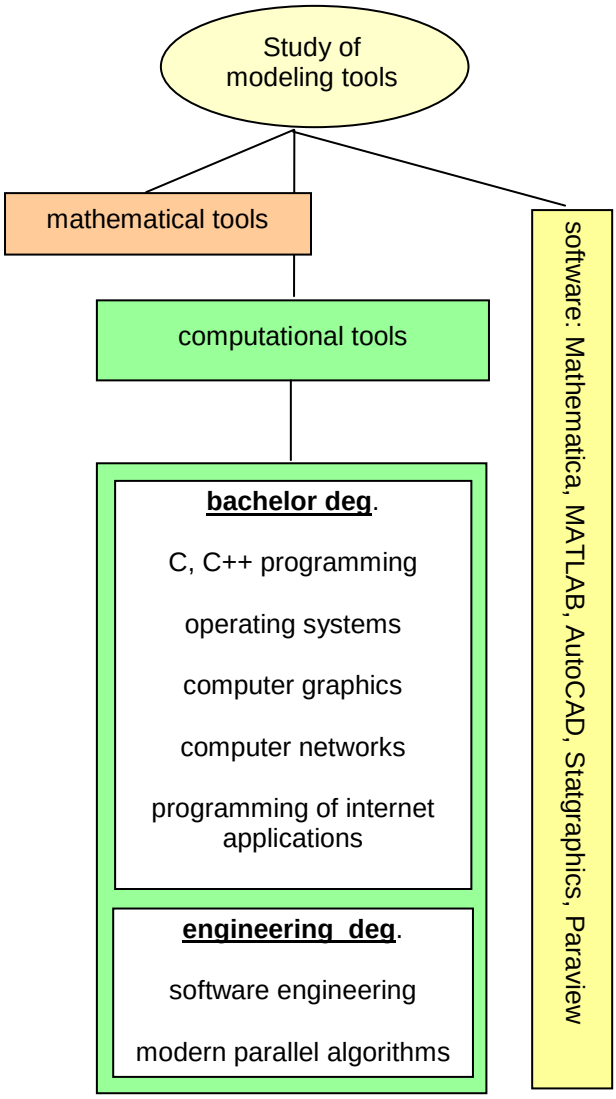

FIGURE 2
SUBJECTS RELATED TO COMPUTATIONAL TOOLS AND SOFTWARE.

Simultaneously with subjects enhancing mathematical and computational abilities, students are educated in related software systems. The following licensed software is included in the study: Mathematica and MATLAB for symbolic and numerical computing in mathematical analysis and algebra, AutoCAD for geometrical modeling and Statgraphics (eventually Excel) for statistics. Later Paraview, Volview and VTK for visualization are added and at the end, software for scientific-technical computations like ANSYS and UG is studied. From the beginning, there is an effort to interconnect the subjects as far as possible, e.g., mathematical analysis ↔ Mathematica software ↔ programming language C ↔ image processing.

As soon as students handle mathematics and computer subjects, applications subjects come with the aim to develop knowledge in particular engineering applications. These subjects are summarized in Figure 3.

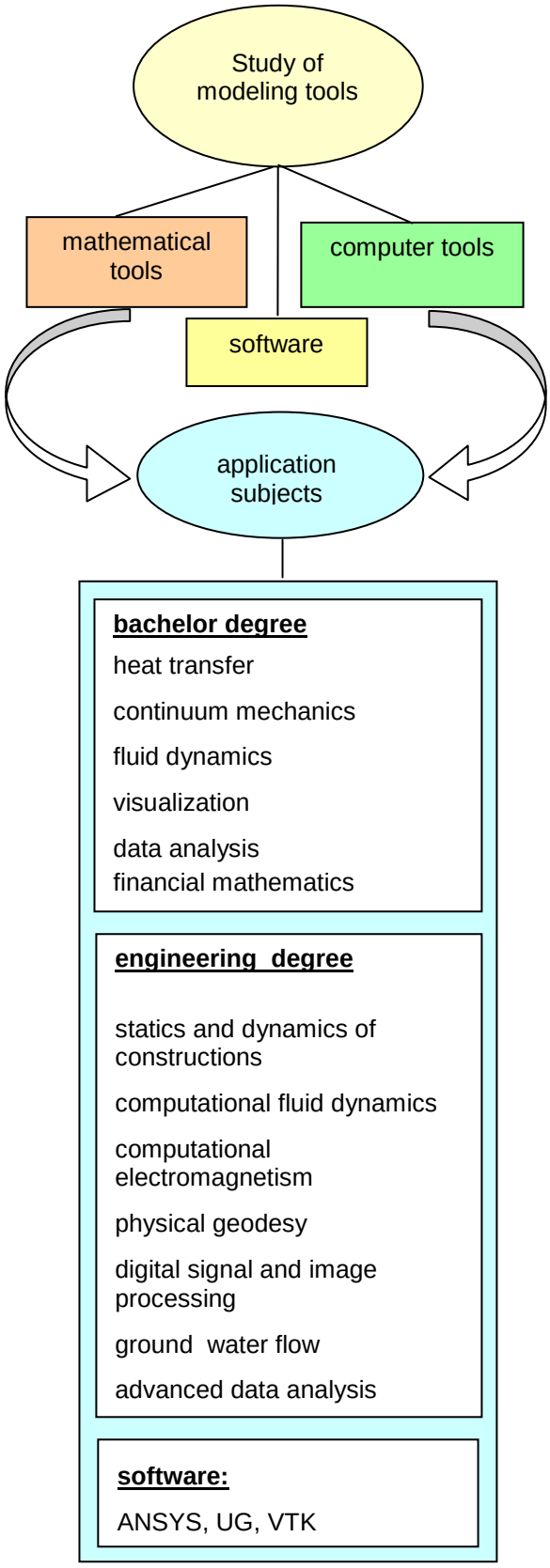

FIGURE 3
SUBJECTS OF ENGINEERING APPLICATIONS STUDY PART.

In the study program there is enough space for electives including also for humanistic and language subjects to allow customization of the program, to complete

knowledge and skills for work on thesis, study of foreign literature, international cooperation and also to meet career needs and personal interests.

GRADUATE PROFILES

Graduate of the bachelor study program

- gains full 1st degree university education in applied mathematics with focus on the mathematical and computational modeling and analysis of the engineering tasks; he/she is prepared either to study to reach the 2nd degree in applied mathematics or to enter the labor market;
- understands the basic methods of applied mathematics (numerical, statistical, optimization methods) and informatics (programming languages, operating systems, computer networks, internet applications, computer graphics) and is familiar with mathematical and computational basis in science and technology;
- is able to use numerical, statistical, visualization and graphics software in modeling and analysis of practical tasks;
- has a large variety of opportunities to find positions in the labor market, mainly in firms oriented to applications of mathematical methods and scientific and technical computing in engineering;
- will have such knowledge of mathematical basis of the applied sciences that will make him/her able to receive new knowledge in future and that enables his/her realization in a long term time horizon.

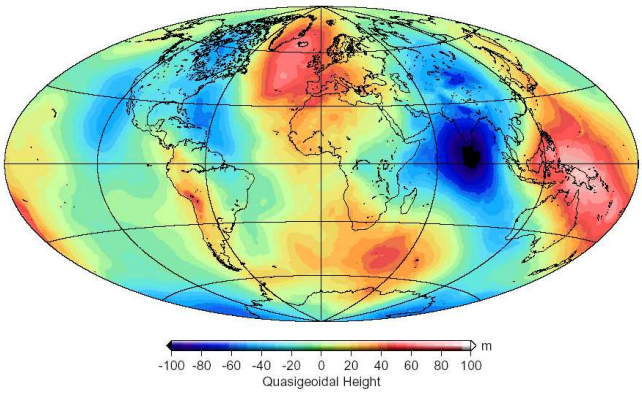

FIGURE 4
DETERMINATION OF QUASIGEOIDAL HEIGHTS. EXAMPLE OF LARGE SCALE PARALLEL SIMULATION IN GEODESY, [2].

Graduate of the engineering study program

- gains full 2nd degree university education in applied mathematics. He will be prepared either to study and reach the 3rd doctoral degree university education or enter the labor market.
- the high-level knowledge of mathematical and computational methods of applied sciences and technology make him/her able not only use them, but also participate at their development. He/she will be able to provide efficient software implementations of these methods on modern (parallel) computer architectures.
- the wide international cooperation of departments providing the study program enables the graduates to achieve experience, contacts and language abilities, which makes them to be well prepared to European labor market.
- the opportunities to find positions in the labor market will be first of all in interdisciplinary teams in firms, enterprises and research institutes oriented to modern technology development, requiring high-level mathematical and computational skills, in firms dealing with development of software for scientific and technical computing, data analysis and statistics, visualization, computer graphics, image processing, etc., and also in consulting companies dealing with mathematical and computational analysis of engineering processes. He/she will be able to work also in the field of civil, electrical, mechanical and material engineering, bio-engineering, geodesy, as well as in some economical and financial applications.

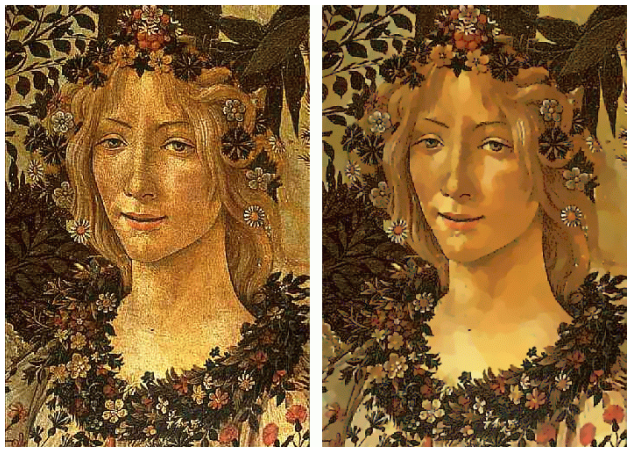

FIGURE 5
FILTERING OF A NOISY COLOR IMAGE, [3]

EXAMPLES

Departments providing the study program have successful cooperation with many universities and research institutes all over the world, the most strength with University of Bologna, University of Heidelberg, CNRS Paris, Czech Technical University in Prague, ICM Warsaw University, Linz University, University of Erlangen-Nurnberg, University of Ghent and University of California at Berkeley. The cooperation has brought many common publications and common scientific national and international (e.g. bilateral, European, NATO) projects devoted to mathematical and computational modeling, mainly in the field of partial differential equations and numerical methods applied in science and engineering. Some results are given in Figures 4-8. The students will be

trained in new emerging areas of mathematical modeling writing their thesis and realizing visits at foreign institutions.

An example of engineering applications is processing and visualization of biological images. The common task is to remove the noise from the images (see Figure 5), to remove the noise from 3D biological data coming e. g. from scanning or microscopy (see Figure 6), to extract the important features and to visualize. Often, new methods and new algorithms are developed and applied. An example of an efficient computation on an adaptive grid is shown in Figure 7. The applied model is based on partial differential equations, and its efficient implementation reflects the features of the data and uses adaptive grids.

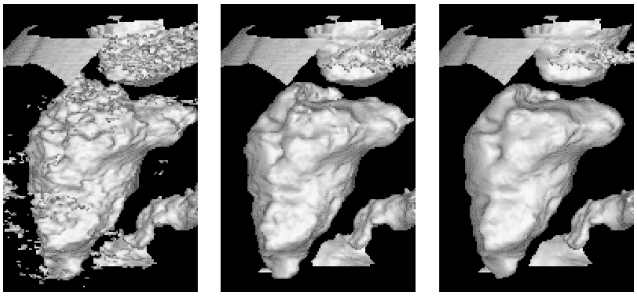

FIGURE 6
VISUALIZATION OF THE HUMAN LEFT VENTRICLE IN THE FIELD OF MEDICAL IMAGING, [5] .

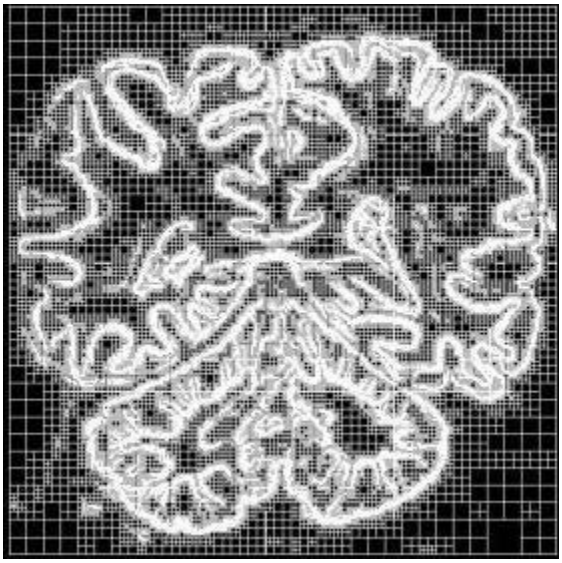

FIGURE 7
EFFICIENT COMPUTATIONS ARE REALIZED ON THE ADAPTIVE GRID, [4] .

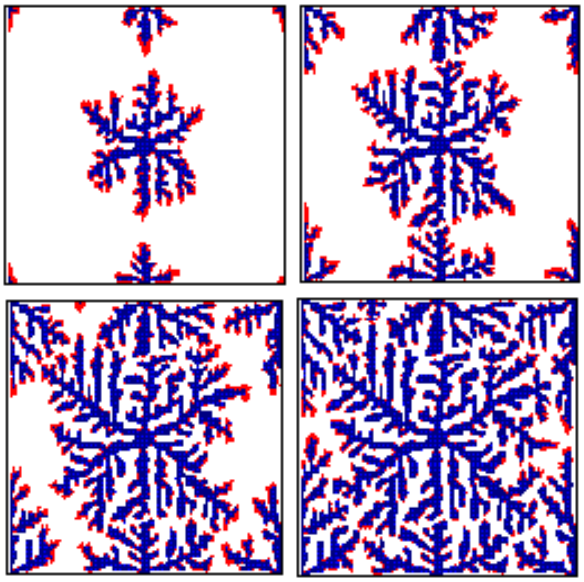

FIGURE 8
CRYSTAL GROWTH MODELED BY PARTIAL DIFFERENTIAL EQUATIONS, [1].

ACKNOWLEDGMENT

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