CAT: Computer Assisted Teaching in magnetics

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Abstract **— Starting with the 3rd academic year the students taking electrical energy as their major subject at the K.U.Leuven are following theoretical lectures and laboratory sessions supporting the basic knowledge on the finite element method (FEM). The numerical sessions take place in front of workstations. The students have to work with commercial FEM program packages and the numerical parts are always followed by a practical laboratory session. Here, the students have to measure the beforehand computed results such as currents, induced voltage and inductances of simple magnetic circuits. In the following 4th academic year more complex tasks are demanded such as computations of dc machines or induction machines. For a better inside of the physical behavior and to make the field solutions of induction machines understandable a multimedia software program is available to the students and distributed via the Internet. The methodology of the step by step approach of computer assisted teaching, performed at the K.U.Leuven, to transfer the knowledge of the complex numerical field computation techniques are discussed.**

INTRODUCTION

The well known abbreviation CAE (computer aided engineering) is regularly used to describe engineering techniques aided by digital computers. Thus, activities of industrial or university engineers to solve design problems or calculate and predict the behavior of physical technical products such as electromechanical energy converters are part of this definition. Due to constantly decreasing prices of standard computer hardware and software, powerful PC's now can be found in nearly every student-household. The possibilities to easily access information at anytime from nearly every place in the world via the internet are increasing as well. As a reaction and to ensure the equal opportunities the Katholieke Universiteit Leuven is renting students hard and software by a subsidized fee. As a consequence, the university teaching staff includes computer-aid tools into the lectures and laboratory sessions. Therefore, the new abbreviation CAT can now be used for Computer Assisted Teaching.

A STEP BY STEP APPROACH

The authors think of the discussed methodology in teaching as a step by step approach. The complex knowledge of numerical techniques is transferred on different difficulty levels. A split up between high level, the knowledge on matrix level, intermediate and basic skills, understanding of the functionalities of the method, must be made to reach and succeed in teaching different target groups. Students of the different fields of engineering science and engineers already working in industry are the target groups that have to be reached.

In general, universities have a threefold duty:

- transfer of knowledge to the society
- placing scientific service at the society's disposal
- academic and applied research

All the mentioned points are linked to teaching. The transfer of knowledge is mainly done by instructing students from undergraduate to the doctorate level. The training of engineers from industry by giving annual short courses can be linked to the first two points of the list. Research finally influences the content of the teaching material and contributes to the first point as well. To fulfill the threefold duty, it is necessary to split the knowledge to be transferred into three difficulty levels in a didactically straight forward way (Fig. 1).

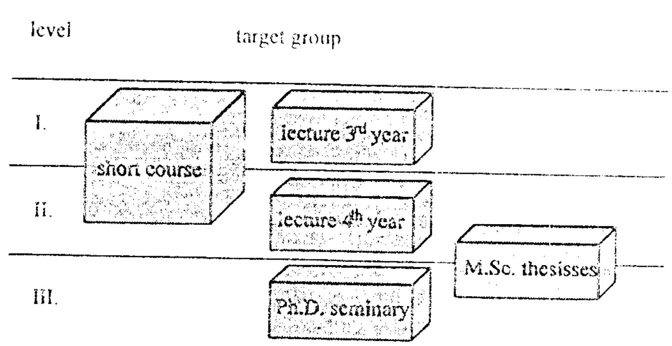
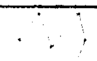
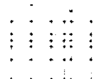
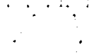
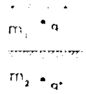


Fig. 1: Target groups and related levels in teaching.

TABLE I: Aims and steps in teaching computational magnetics.

level		target group	aim
I	a)	undergraduates 3rd year	• basic theoretical knowledge of numerical field computation methods
	b)	engineers out of industry	• capability to solve simple standard electromagnetic static and time-harmonic field problems in 2D
II	c)	undergraduates 4th year	• advanced theoretical knowledge of numerical field computation already on matrix level
	d)	(partly) engineers out of industry	• numerical optimization algorithms
			• design theories and methodologies
			• capability to solve more complex field simulation tasks in 2D and simple problems in 3D
III	e)	Ph.D. students	• extended theoretical knowledge on matrix and program level
	f)	programme developer	• knowledge of data structures
			• capability of handling data to obtain own solution algorithms
			• programming own software routines
			• capability to solve advanced 3D problems

TABLE II: Field computation methods[1].

method	principle of discretization	geometry approximation	non-linearities	computational costs
FEM		extremely flexible	possible	high
FDM		inflexible	possible	high
BEM		extremely flexible	troublesome	high
MEC		specific geometries	possible	very low
PMM		simple geometries	by constant factors	low

(1) FEM - finite element method, FDM - finite difference method, BEM - boundary element method, MEC - magnetic equivalent circuit, PMM - point matching method.

The aims of the three level structure used at the K.U.Leuven, with other words the three steps in teaching students in magnetics, are collected in Table I. A short course in 'CAD in magnetics' is given annually to interested engineers from industry and other universities.

Level I

In a first step to enter the level I, the target group has to be prepared. Here, it is explained where the numerical field computation has its place. Therefore, advantages and disadvantages of classical analytical models of the field approximation have to be treated, as well as the various pure numerical methods (Table II). This step is accompanied by studying the working principles of electromechanical energy converters to transfer a feeling to the students of how a field behaves and of the order of magnitude of the various quantities. Along with the lectures on electrical machines, the students can work at a computer with a multimedia tool to understand the operating principles of an induction machine before they start to solve its associated field problems. The multimedia software tool is developed by the group at the K.U.Leuven and distributed via the Internet and can be downloaded by the students at any time [1]. A secondary effect is obtained by distributing the software in this way and letting the undergraduates work with it. Even nowadays, there are students not used to work with a computer and they are loosing in this way the uncertainty with this device.

To support the understanding of the physical behavior of the technical devices treated in the lecture and the methods to calculate them, practical CAD sessions at the computer are obligatory. Here, simple 2D computations are performed using the FEM. Examples are chosen to point out the connection between analytical, numerical and measurements in particular.

Level II

After the entry level, a basic understanding of the physical device and its numerical treatment can be assumed. Now the numerical problems and all neglections assumed are part of the lecture. More and more numerical details are illuminated. Simple 3D computations are performed in the CAD sessions to demonstrate the differences with the 2D approximation. Other methods combined with the FEM such as optimization algorithms are introduced as well.

Level III

The last step of this 4 year program is reserved for the doctorate level. The theory of the method is presented on the matrix and program organization level. Here, special problems such as error estimation, mesh adaptation techniques, solver strategies etc. are treated. The capabilities in coding specific parts in field computation programs are trained.

CONCLUSIONS

A CAT program is described which, always carefully updated, successfully runs for a couple of years already.

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[1] INDUCTUTOR: http://www.esat.kuleuven.ac.be/elen/elen.html, K.U.Leuven, ESAT / ELEN, multimedia tool, 1995.