Proceedings of the World Congress on Engineering 2009 Vol I
WCE 2009, July 1 - 3, 2009, London, U.K.

An Adaptive Multimedia System for Teaching Fundamentals of Finite Element Method Using the Case-based Content Sequencing

Haris Supic, *Member, IAENG*

***Abstract*— This paper describes an adaptive multimedia system for teaching fundamentals of finite element method (STFFEM) using a case-based content sequencing. The finite element method is a method for solving partial differential equations. The method is applicable to a wide range of physical and engineering problems that can be mathematically described by partial differential equations. The STFFEM's learning material organization has a hierarchical structure with four levels. The STFFEM is able to utilize the specific knowledge of previously experienced, concrete content sequencing situations (cases). A new content sequencing problem (a new case) is solved by finding a similar past case, and reusing it in the new content sequence problem situation.**

***Index Terms* — multimedia teaching systems, finite element method, case-based content sequencing.**

I. Introduction

Multimedia teaching systems combine texts, graphics, sound and animation. A well designed multimedia teaching system should enhance the communication of ideas. The main goal of communication is to direct the learner's attention to more important information on the screen. The interaction is one of the most important constituent of computer-based teaching and learning. Interactive learning is a key mechanism for the development of cognitive skills. If a computer interaction system contains well designed examples, simulations, and animations then it can be used to stimulate cognition and learning. Techniques and examples of simulations allows a student to experiment with phenomena which are too complex or to expensive to be reproduced in a lab, but which can be modeled using computer environments. One of the main challenges when developing multimedia teaching systems is the capability to adapt the learning experience to different users. The design of adaptive multimedia teaching systems requires significant effort, since dependencies between educational characteristics of learning resources and learner characteristics are too complex to exhaust all possible combinations [1]. Karampiperis and Sampson address the design problem of the adaptation model proposing an alternative sequencing method that instead of generating the learning path by populating a concept sequence with available learning resources based on adaptation rules, it first generates all possible sequences that match the learning goal in hand and then adaptively selects the desired sequence, based on the use of a decision model that estimates the suitability of learning resources for a targeted learner [2, 3]. Adaptability requires an appropriate scheme for sequencing the learning material to different students. The learning objects presuppose the existence of an environment with the capacity to decide which object is to be presented next. To accomplish adaptation of the educational content to the particular needs of every learner it is necessary, however, for content to be described appropriately and in enough detail for a system to be able to automatically and dynamically establish the most appropriate sequencing of the learning objects for each learner [4].

This paper describes a system for teaching finite element method (STFFEM) using a case-based content sequencing. The finite element method is a method for solving partial differential equations [5, 6, 7]. The method is applicable to a wide range of physical and engineering problems that can be mathematically described by partial differential equations. An approach to the finite element method applied to the solution of stationary electromagnetic problems is presented. This method is suitable for teaching electrical engineering students at the undergraduate level.

Manuscript received March 23, 2009. This work was supported in part by the Canton Sarajevo, Ministry of education and science under Grant 11-14-20308.1/07.

Haris Supic is with the Department of Computer Science, Faculty of Electrical Engineering, University of Sarajevo, Bosnia and Herzegovina, Zmaja od Bosne bb, phone: +(387) 33 250 736; fax: +(387) 33 250 725; e-mail: haris.supic@ etf.unsa.ba.

II. The main features of the STFFEM

The main features of the STFFEM are:

- the STFFEM is able to adapt its content sequencing to different contexts;
- the STFFEM includes multimedia learning objects that represent concrete authentic experiences that provide a richer and therefore more memorable and accessible representation than do abstract principles;
- the STFFEM is able to utilize the specific knowledge of previously experienced, concrete content sequencing situations (cases). A new content sequencing problem (a new case) is solved by finding a similar past case, and reusing it in the new problem situation;
- the STFFEM can be viewed as continuous knowledge acquisition and learning system. Iterative cycles of explanations, exercises, assessments, interpreting feedbacks, and updating case-based memory provides a model for promoting learning.

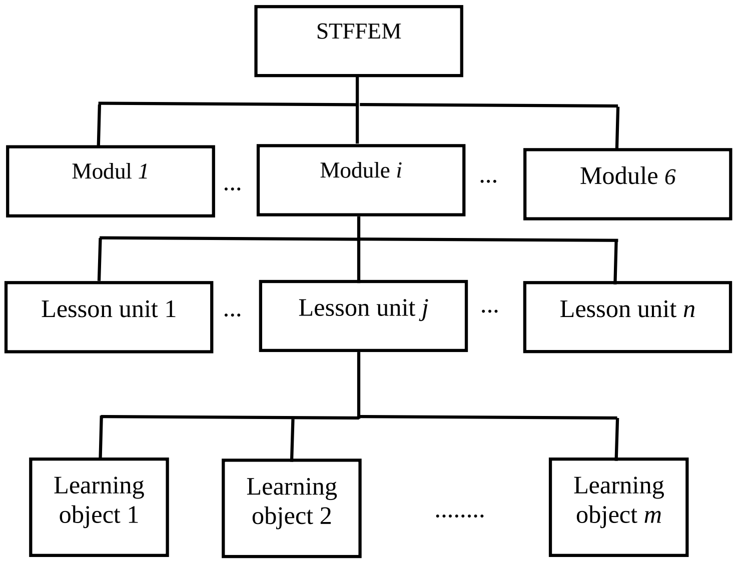


Fig. 1. The STFFEM's hierarchical organization

The STFFEM is given the following kinds of knowledge:

- a model of educational outcomes to be achieved;
- a set of attributes to describe new content sequence problems;
- an initial casebase of content sequence cases that may be initially applied to achieve educational outcomes.

III. The STFFEM's Learning Objects

The STFFEM's learning material organization has a hierarchical structure with four levels (see Fig. 1). The highest level corresponds to the whole system, which is composed of modules, which in turn are composed of lesson units. Finally, the lesson units are composed of multimedia learning objects at the lowest level in the hierarchy. Multimedia learning objects are learning resources designed

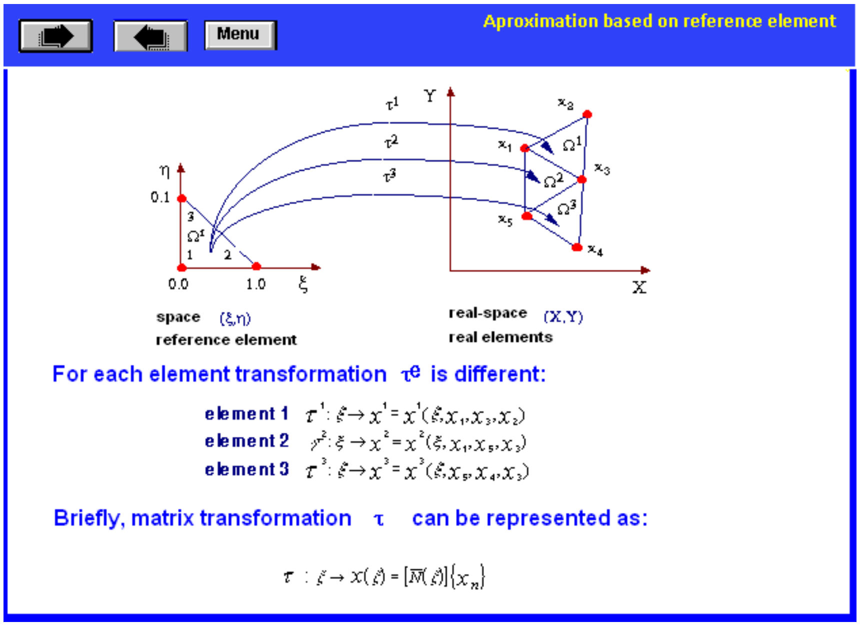


Fig. 2. An example of explanation learning object

as elements of instruction that can be used and reused in different contexts. They can be combined with other learning objects to form larger units of instruction. Multimedia learning objects and information needed for the domain knowledge representation are represented by text, images, animations and interactive 2D models. Images and animations are used to complement textual and audio explanations. The STFFEM distinguishes three different classes of multimedia learning objects: explanations, exercises, and assessments. Learning objects are organized in this order inside each lesson unit.

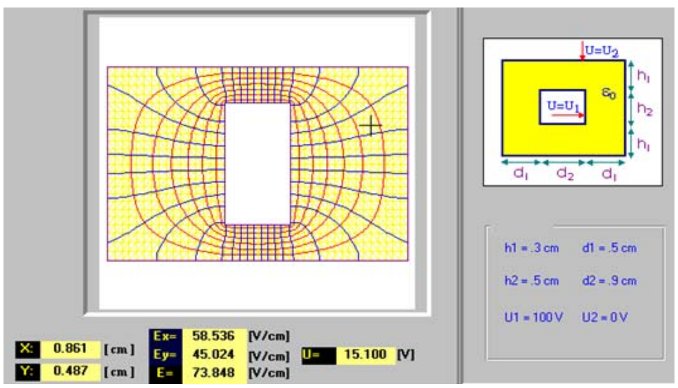
The main menu consists of six menu groups (modules):

- Introduction to FEM;
- Finite element approximation;
- Integral equations and discretization;
- Numerical methods;
- Techniques of programming;
- Examples of FEM applications.

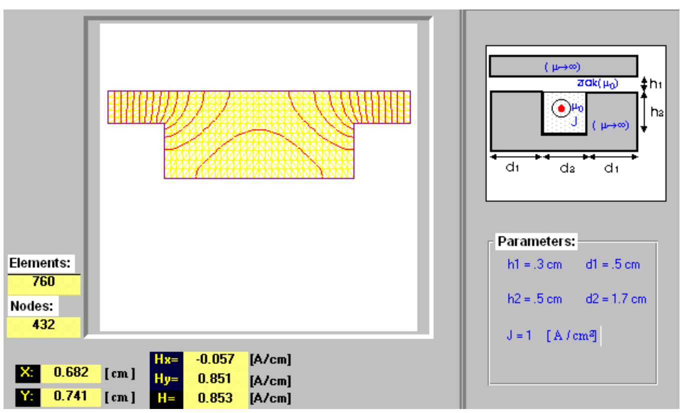
Each menu group represents a module within the system. There is a module menu for each of the six modules. Modules are hierarchically structured into smaller lesson units, and each lesson unit can be displayed as a set of multimedia objects on the same screen. Each lesson unit begins with explanations, continues with exercises and ends with an assessment. A lesson unit's assessment tests the acquired knowledge by the student.

The main menu is the screen from which all of the modules can be accessed. Module 1 provides an introduction to finite element method. This method is presented as a numerical method that is used to solve problems described by a partial differential equation and a set of boundary conditions. Modules 2, 3, 4, and 5 build on the foundations established in the module 1. These modules develop deeper mathematical background to provide a more complete finite element method description. Techniques of understanding the fundamentals of the method and using numerical methods to develop a mathematical description are emphasized. All modules are complemented by a series of examples and exercises demonstrating practical applications of finite element method to solve the different electrostatic potential problems defined by Poisson equation.

Fig. 2 shows an illustration of the STFFEM's explanation learning object. Different strategies such as the use of color, use of animations and font style changes helps to make the system more effective. The STFFEM's explanation learning objects are integrated with simulation examples to focus on learning outcomes. Learning outcomes are statements that specify what learners will know or be able to do as a result of a learning activity. Outcomes are usually expressed as knowledge, skills, or attitudes.



(a)



(b)

Fig. 3. Examples of the STFFEM's learning objects for exploring electrostatic forces and fields in different types of geometrical configurations

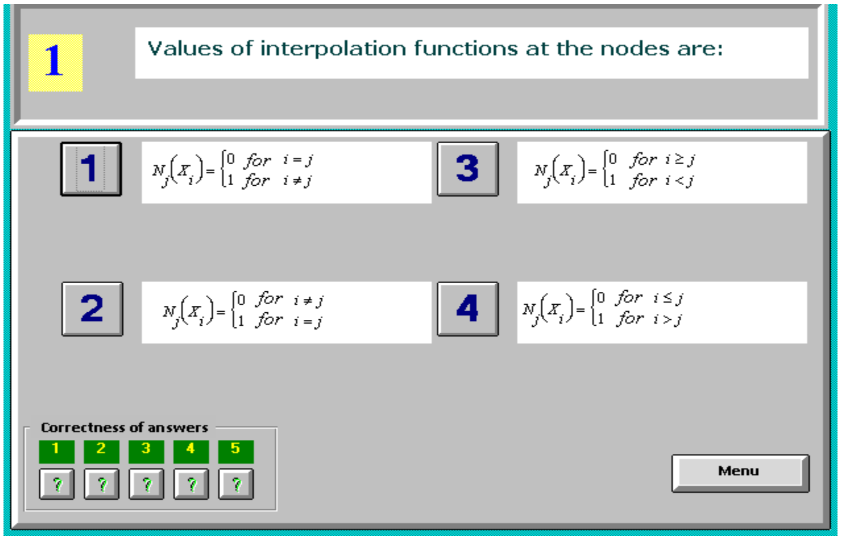


Fig. 4. An example of assessment learning object

Fig. 3 shows an illustration of the STFFEM's learning objects for exploring electrostatic forces and fields in different types of geometrical configurations. This kind of learning objects allow students to explore electrostatic forces and fields, learn about the concept of electric potential, and understand the nature of electric flux. A student can select different geometrical configurations and different interaction options in order to get authentic experiences that provide more memorable representations.

Fig. 4 shows an illustration of the STFFEM's assessment learning object. The assessment learning objects are designed with the aim of evaluating learning outcomes.

IV. ADAPTIVE CASE-BASED CONTENT SEQUENCING

Content sequencing is a crucial part of any learning activity. There is a wide variety of sequencing strategies. Some systems sequence the content based on a previously created plan. This plan usually includes a set of rules to allow transitions among stages depending on the fulfillment of one or more objectives. These plans may allow dynamic decisions. Another type of sequencing is based on a collection of strategies for each learning object. Depending on how the student performs on previous modules, a strategy is selected for a new module. The STFFEM can deliver the same learning objects conforming a lesson in two different ways: a fixed sequence, predefined by the course author, and a sequence dynamically determined by using case-based reasoning. As a result of case-based reasoning processes the STFFEM selects an appropriate content sequence (Fig. 5).

Case-based reasoning (CBR) is a type of reasoning based on the reused past experiences called cases. Solving a new problem by CBR involves obtaining a new problem description, measuring the similarity of the new problem to old problems stored in a casebase with their solutions, retrieving similar previously experienced cases, and reusing

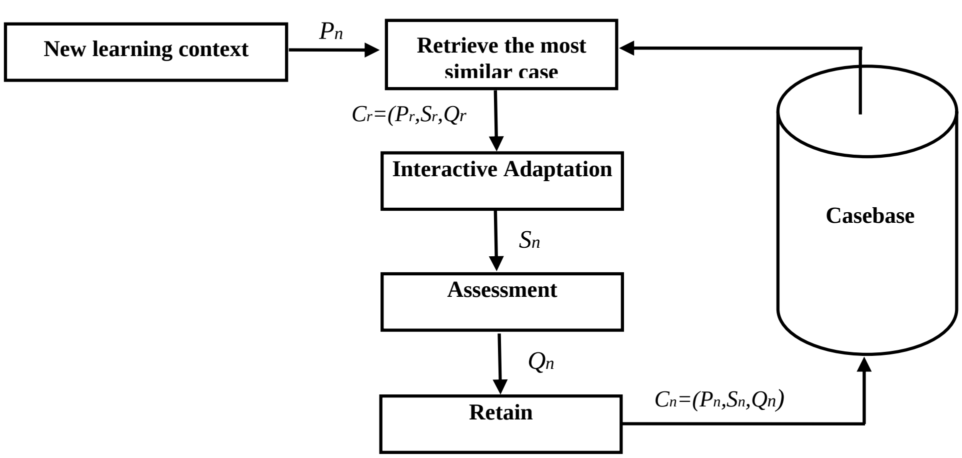


Fig. 5. Case-based reasoning for new content sequence

the solution of one of the retrieved cases [8].

Case representation is generally regarded as one of the most important problems and is crucial to success of the STFFEM. The case representation problem is primarily the problem of deciding what to store in a case, and finding an appropriate structure for describing case contents. In general, a case consists of a problem description component and a solution component [9, 10]. In the STFFEM, cases C are represented as two-tuples:

$$C=(P, S, Q)$$

where:

- P is a problem description component that describes different learning contexts;
- S is a solution component that represents a content sequence, $S=(lo1, lo2,\dots lon)$ where loi denotes learning object $i, i=1,2,\dots n$;
- Q is an outcome component that represents assessment results.

The CBR module of the STFFEM compares the similarity of the description component Pn of the new case and previously stored description components $Pi,\ i=1,2,...|CB|$, of cases in the casebase CB. The Euclidean distance between two description components $d(Pn,Pi),\ i=1,2,...|CB|$, provides a measure of similarity between the new case Cn and previously stored cases $Ci, i=1,2,...|CB|$. By using the criterion of similarity based on Euclidean distance, CBR module determines and retrieves the most similar case $Cr=(Pr,Sr,Qr)$ in the casebase. The solution component Sr of the retrieved case Cr represents the content sequence that will be interactively adapted to new learning context. The adapted content sequence proposed by the user is then evaluated by using the assessment learning object. Through adaptation, the student is given the right type of material in the right order to maximize the efficiency of the learning experience. The new problem description (new learning context) Pn, its solution (content sequence) Sn, and the outcome component Qn can then be retained as a new case $Cn=(Pn,Sn,Qn)$, and the system has learned to solve a new problem.

The STFFEM has some important limitations:

1. the method of adaptation is interactive;
2. learning objects can be recombined only within a lesson unit.

We plan overcome all these limitations in the near future. We plan to develop automatic case adaptation strategies. Also, we are interesting in development of algorithms for more efficient case retrieval from the casebase.

V. Conclusions and Future Work

In this paper, we describe an adaptive system for teaching fundamentals of finite element method (STFFEM) using a case-based content sequencing. Currently, the STFFEM can take the same learning objects conforming a lesson and deliver them in two different ways: a predefined fixed sequence, and a sequence dynamically determined by using case-based reasoning. We have not yet compared the effectiveness of the STFFEM sequencing method to fixed sequencing method. Analysis of the preliminary results showed very strong support and positive perception by students, but more research is needed to show whether the STFFEM's content sequencing method is effective in teaching the fundamentals of finite element method. Because the STFFEM is only as good as the starting case library and because the STFFEM is still in an exploratory, acquiring a diverse set of cases is challenging. The next phases of this work are the development of a case library which covers more diverse learning strategies and development of automatic case adaptation.

Acknowledgment

The author is grateful for the support by the Ministry of education and science, Canton Sarajevo, B&H.

References

[1] P. De Bra, L. Aroyo, and A. Cristea, "Adaptive Web-based Educational Hypermedia". In Levene, M. & Poulovassilis, A. (Eds.), Web Dynamics, Adaptive to Change in Content, Size, Topology and Use, Heidelberg, Germany: Springer, 2004, pp. 387-410.

[2] P. Karampiperis, and D. Sampson, "Adaptive Learning Resources Sequencing in Educational Hypermedia Systems", Educational Technology & Society, 8 (4), 2005, pp. 128-147.

[3] P. Karampiperis, and D.G. Sampson, "Adaptive Learning Objects Sequencing for Competence-Based Learning", Proceedings of the 6th IEEE International Conference on Advanced Learning Technologies (ICALT 2006), 2006, pp. 136-138.

[4] R. Morales, and A.S. Agüera, "Dynamic Sequencing of Learning Objects", Proceedings of IEEE International Conference on Advanced Learning Technologies (ICALT 2002), 2002, pp. 502-506.

[5] O.C. Zienkiewicz, and R.L. Taylor, *Finite Element Method*: Volumes 1, 2 & 3., 5th Edition Butterworth Heinemann, 2000.

[6] J.E. Akin, *Finite elements for analysis and design*, 4th Printing, Academic Press, 2000.

[7] S.C. Brenner, and L.R. Scott, *The Mathematical Theory of Finite Element Methods*, Series: Texts in Applied Mathematics , ISBN: 978-0-387-75933-3, Vol. 15 3rd ed., 2008.

[8] L. Mantaras, et al., "Retrieval, Reuse, Revision, and Retention in CBR". Knowledge Engineering Review, 20(3), 2005, pp. 215-240.

[9] A. Aamodt, and E. Plaza, "Case-Based Reasoning: Foundational Issues, Methodological Variations and System Approaches", in AICOM, vol 7(1), 1994, pp. 39-59.

[10] J.L. Kolodner, *Case–Based Reasoning*, Morgan Kaufmann Publishers, Inc., San Mateo, CA, 1993.