The South African Institute for Computer Scientists and Information Technologists

ANNUAL RESEARCH AND DEVELOPMENT SYMPOSIUM

23-24 NOVEMBER 1998
CAPE TOWN
Van Riebeeck hotel in Gordons Bay

Hosted by the University of Cape Town in association with the CSSA, Potchefstroom University for CHE and The University of Natal

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SYMPOSIUM THEME:
Development of a quality academic CS/IS infrastructure in South Africa

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FOREWORD

The South African Institute for Computer Scientists and Information Technologists (SAICSIT) promotes the cooperation of academics and industry in the area of research and development in Computer Science, Information Systems and Technology and Software Engineering. The culmination of its activities throughout the year is the annual research symposium. This book is a collection of papers presented at the 1998 such event taking place on the 23rd and 24th of November in Gordons Bay, Cape Town. The Conference is hosted by the Department of Information Systems, University of Cape Town in cooperation with the Department of Computer Science, Potchefstroom University for CHE and and Department of Computer Science and Information Systems of the University of Natal, Pietermaritzburg.

There are a total of 46 papers. The speakers represent practitioners and academics from all the major Universities and Technikons in the country. The number of industry based authors has increased compared to previous years.

We would like to express our gratitude to the referees and the paper contributors for their hard work on the papers included in this volume. The Organising and Programme Committees would like to thank the keynote speaker, Prof M.C Jackson, Dean, University of Lincolnshire and Humberside, United Kingdom, President of the International Federation for Systems Research as well as the Computer Society of South Africa and The University of Cape Town for the cooperation as well as the management and staff of the Potchefstroom University for CHE and the University of Natal for their support and for making this event a success.

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ELECTRONIC LECTURES FOR THE MATHEMATICAL SUBJECTS IN COMPUTER SCIENCE

Y. Velinov
Department of Computer Science and Information Systems
University of Natal, PMB
yuri@cs.unp.ac.za

Abstract

In this paper we share our experience in the design of electronic lectures for theoretical subjects. The basis for our discussion are experiments for designing electronic lectures in Set Theory using the potential of contemporary computers and multimedia. The motivation for initiating such a project was the fact that teaching abstract subjects is always problematic and that the arising problems are much more serious in the new South African environment. We expect that electronic lectures can make the abstract subjects alive, touchable and more immediate. In addition they can support self-study and distance education. At first sight it might seem that in essence an electronic presentation cannot change the exposition of a formal theoretical subject significantly. We will analyse a typical mathematical text, reveal its different structural levels and show on this basis the benefits of its electronic presentation. The applicability of the multimedia techniques will also be discussed. A demonstration of real software will support the presented ideas.

Introduction

A high level of abstract and formal thinking is not only an indispensable part of science but also a key to any contemporary scientific achievement. Computer Science from the very beginning was a science based on formal models and as close to mathematics as, say, Physics. It was driven by mathematics and influenced the development of mathematics itself. For example, Theory of Computation originated as a purely mathematical discipline but is now a fundamental discipline in Computer Science. The methods of Set Theory, Algebra, Analytic Geometry, Mathematical Logic, Graph Theory are not only widely used, but also unavoidable at the modern level. A new discipline – Discrete Mathematics - was created to serve the specific needs of Computer Science. Notice that a programming language is precisely a formal system in a mathematical sense. The development of the methods for designing programming languages, at the syntactical level, gave rise to the Theory of Formal Grammars. Associating meaning with the phrases of a programming language lead to the methods of Axiomatic Semantics, Fixed Points Semantics, Algebraic Semantics or Categorical Semantics. Some programming languages like LISP or PROLOG are based on ideas developed initially in mathematics. The problem of program correctness evolved into Formal Methods – a technique strongly advocated by the leading researchers in Computer Science as a necessary subject at tertiary level (see [2]).

On the other hand it is not a secret to anybody with some teaching experience in the field that a large proportion of the population has serious difficulties with the assimilation of subjects which involve formalism. Teaching such subjects has been a challenge to the contemporary large-scale educational system. It is not hard to notice that the achievements of the educational institutions are lagging far behind the advances of science and technology. The weakness of the educational system created unhealthy social distortions. Opposite to the bright expectations at the beginning of the century, only a relatively small number of advanced scientists and researchers have developed a real understanding of the scientific methods and subjects. Ordinary people just accept the presence of science as a reality and since it seems to be human nature to distrust what you do not understand, bad feelings towards science are widely spread.
The appearance and the development of computer technology opened the door for new approaches in education. The influence of computers in education has been debated for a long time and lately one can feel a disappointment in the obtained results. However, if the impact of computers in education is negligible; then it is the educational system which is to blame for not using their enormous potential appropriately. Part of the reasons for the existing frustration are the unrealistic promises and expectations supported unfortunately even by the professionals in Computer Science. Computers were and still are considered as the "magic contraption" of the century, which once appropriately used, will solve effortlessly our intellectual problems. In particular, the myth that education will change into some kind of entertainment enterprise is quite popular. Once the populistic illusions that computers can relieve the students from the hard efforts of studying and can transform the process of studying into a joyful game are abandoned, computers show themselves as an extremely useful educational tool, capable of supporting faster and deeper understanding of the theoretical subjects.

Electronic lecturing

One of the possible ways of applying computers in education is by electronic lecturing. If compared with the traditional approaches, electronic lectures, using the multimedia capabilities of the contemporary technology, have numerous advantages. To mention some of them:

- Ability to collect large amounts of information on a small carrier.
- Ability to better structure a text and display/hide its components according to the accepted structure. A subject can be presented on different levels of difficulty and depth.
- Fast and convenient search mechanisms.
- Hypertext reference mechanisms.
- Ability for illustrations and animations.
- A great variety of possibilities to increase the readability of teaching material by its artistic appearance.
- Ability to incorporate interactive tests and quizzes in the exposition of teaching material.
- Ability for easy reproduction and correction.
-Ability for fast transmission over long distances.

On the negative side are the facts that:

- Electronic lectures require appropriate electronic devices for display, which still does not make the process of reading as comfortable as it is with ordinary books.
- Creation of electronic lectures is a difficult, labour consuming task, which requires from an author not only deep knowledge of the subject but also artistic skills and taste.

Similar to books electronic lectures are tools for self-study. Users can advance at their own speed and if necessary return back to the previously studied material. Moreover, keeping to a great extent the benefits of the alive-lecturer presentations, electronic lecturing relieves the reader from any psychological discomfort from contact with a live person. Losing a chess game to a computer, one may feel annoyed, may be frustrated, but never feel stupid. A computer can be asked "stupid questions" without fearing the impression it might leave if asked of another human. On the other hand, exactly as it is with the books while self-studying, electronic lectures require self-discipline in the reader.

Structure of the electronic lectures for mathematical subjects

The specifics of the methods of the formal disciplines lead to a noticeable distance between them and the surrounding perceptible environment. From this point of view the usefulness of some of the above mentioned advantages of the electronic lectures seems questionable. Let us consider to what extent the potential of the electronic media can be used for exposition of subjects where the material for direct natural illustrations seems to be quite limited.

The analysis of typical texts (see [3, 4, 5, 6, 7, 8, 9]) reveals that any theoretical exposition is a balance of two opposite tendencies: to make it as deep, precise and complete as possible, or to make it as easy and as comprehensive as possible.
A precise and complete text gives a full and persuasive exposition of the subject. It is very convenient for references and as a basis for further research. On the other hand it contains too many results and "dry" definitions where every word has indispensable importance and might be left unnoticed while reading. The hierarchy of the result's importance is not clear enough. The large amount of concepts and facts presented in a continuous flow hides to a great extent their significance for the further development of the subject or for its practical use.

Typically in an easy to comprehend or a popular text the definitions and the results are not expressed in a precise manner. Sometimes, they are not even well distinguished as such in the text flow. Usually, many additional explanations and illustrative examples follow them and are supposed to compensate for the lack of precision. Such a text is readable, but the inherent ambiguity which is present leads to permanent misunderstanding. It is not easy to find the essence in the bulk of explanations, comments and examples. Texts of this kind can by no means be used as a basis for referencing, research or practical developments because of their incompleteness and imprecision.

A general problem in either of the two cases is the cross-referencing - a source of jokes and frustration from the side of the reader.

![Figure 1. Structure of an electronic exposition.](image-url)
sequentially presented and their presence cannot be hidden. Still this idea can be used as a leading thread for the electronic design.

All considered above attempts of the authors to improve the exposition of a text can be implemented much better on electronic media. Moreover, every theoretical text, regardless of the style, is highly structured. Typically it contains as almost independent units definitions, comments, explanations, statements, proofs, references, historical remarks, which in the framework of the logic of the subject are loosely connected (in an ordinary text they are situated as it comes or according to the taste of the author). Electronic media have the potential to reflect this structure and combine completely the independence of the units with their connectivity.

The above observations reveal the first possible steps of the design of electronic lectures which on the basis of the potential of the electronic media promise considerable improvement of the exposition of a mathematical or any other theoretical subject:

- Split the material into two or more streams, each one presenting it at different depth, which can interface each other at appropriate places.
- In each stream reveal the logically dependent modules and organize their consecutive access in a linear or tree form.
- Within a module abandon the linear style of exposition and on the basis of the natural structure of the material split it into separate units. Organize proper interaction between the units or with the units of the other streams.

A possible structure of electronic lectures based on these ideas is shown in Fig. 1. We find it useful for presenting material on Set Theory. The overview stream presents the material on a very intuitive and superficial level. It does not contain definitions or proofs but mainly explanations of the ideas. The main stream is the core of the exposition. It is divided into modules which follow one after the other (a tree scheme of accessibility is also possible). Each module contains precise definitions, explanations and statements of the main most significant results. The necessary proofs and the examples are hidden and are displayed on request from the reader. From each separate module one may also display its extensions which contain more results, proofs and explanations.

**Technique of exposition**

As can be seen in the previous sections we limit our considerations to the “informatory” or “instructional” models of exposition [1]. The technique for presentation of visual information in the framework of these approaches was discussed in many papers and many general recommendations have been outlined (see for example [1,10]. As a whole they are valid in our case but the specifics of the theoretical subjects require additional analysis for their appropriate interpretation.

Following and understanding proofs has been one of the most difficult tasks while studying a mathematical subject. In general each proof consists of a series of steps together with justification of those steps which the author does not consider as obvious. The concept of “obvious” differs significantly from author to author. Most rigorous proofs can be given on the basis of formal logic. Such proofs are typically very lengthy and not easy to follow. Even when it is expressed in a conventional mathematical language, a thorough proof contains too many details which hide its main ideas. Skipping some steps or explanations can help in revealing the general structure of a proof and its main idea, but creates problems with justification or restoring the missing steps (typically left to the ingenuity of the reader). Even an experienced reader must spend time restoring the missing details. Electronic presentations can relieve and improve the situation by hiding some details or justifications and displaying them on request. For example, if a proof consists of a chain of equations the justification of each equation can be displayed by clicking on the equation sign. In this case the way the equation sign is displayed must inform the reader that such a possibility exists. Another approach is to introduce a universal “question button” somewhere on the display and trigger the display of information by dragging it on those parts which need justification or additional explanations. In this case the places which have such a supplement must be properly indicated by color or additional markers.

Proofs can also be presented dynamically by unfolding them step by step. Such an approach has the advantage of imposing a discipline of correct scanning on the reader, preventing him or her from jumping
between the steps and missing some of them. On the other hand since a bird’s eye view of a proof can also be useful, such an approach must be made optional.

Appropriate colors or font-styles can be used to distinguish or stress the different items displayed on a page. On the other hand, authors must restrain from color or style overloading of a page since this may lead to a complete loss of the sensitivity of the reader.

Illustrations from the directly observable alive surrounding which are appropriate for the mathematical subjects can be found only in occasional cases. Moreover, except for the purpose of applied interpretations, their usefulness is questionable since their nature contrasts with the formal nature of the subject. On the other hand, many abstract structures have adequate geometric interpretations and can be illustrated by geometric figures and their relations. In addition, the mathematical language is rich in diagrams and graphs. Illustrations of such a nature can be widely used in electronic expositions. They also allow animation in the form of figure-transformations, movement of simple geometric forms, tracing paths in a graph, and so on. Another possibility for animation is to show the evaluation process of a formula or the evolution of some key values computed by an algorithm.

![Figure 2. Title page of the electronic lectures on Set Theory.](image)

Altogether, the considerations above demonstrate that electronic media are a rich environment holding considerable potential for designing expositions on mathematical subjects.

Experiments

The ideas shared in the previous sections were experimented with the design of electronic lectures on Set Theory, which is one of the main modeling environments for Computer Science (Fig. 2). The textbook [11] was used as a source. The lectures use about 30-Mb of files and were designed using
Toolbook™ authoring software. Although it is popular nowadays to consider Internet publishing as a main option it is clear that such an amount of information is not appropriate for Internet online presentation. We found that the potential of Toolbook™ for design is considerably better (to mention some advantages: communications with the final product are much faster; lectures always appear in the same prescribed, during the design, format; rich collection of tools and techniques for structuring a text, animation or and association with sound). In addition most of the design can be exported in the appropriate form for Internet. The lectures at the present stage of their development, cover the following topics:

- The concept of a set;
- Operations on sets;
- Correspondences and Relations.

The electronic lectures are organized according to the diagram in Fig. 1. They contain an overview stream, main stream, extensions and are rich in historical material. More material will be added in the future.

Conclusions

We believe that electronic lecturing is the future of the education and that in the next 15 years the electronic lectures in their different forms will develop as a powerful substitute for books. Together with electronic simulators (see [12] for an example) and the electronic systems for testing and examination electronic lectures will completely change the process of education where the role of the present lecturers will be (as it had been once in ancient Greece) a role of constructive study and research guides and advisors.

References

3. Halmos, P.R. Naive Set Theory; Springer-Verlag, New York; 1974.