An Introductory Course on Visualization: a proposal

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Resumo **- Apresenta-se uma proposta para o curriculum de uma disciplina de Visualização a oferecer ao Mestrado em Electrónica e Telecomunicações da Universidade de Aveiro. Inclui-se também a bibliografia comentada.**

Abstract **- A Visualization course designed to be offered as an elective in the MSc degree on Electronics and Telecommunications at the University of Aveiro is proposed. Its curriculum and bibliography are presented.**

I. INTRODUCTION

The ever increasing power of computers and other information sources, enabling the generation and processing of vast amounts of data, creates the imperative need for techniques that allow easy exploration, analysis and communication of those data. This need is being answered by using the capability of computers to present data in graphical form, facilitated by advances of technology which have brought low cost displays, better software and multimedia to the desktop [1,2].

Graphics have the power to present large amounts of numerical information in an efficient and effective way so that we can gain insight into numbers, which is, according to the much cited Hamming[1], the purpose of computation. The goal of the so called Scientific Visualization, or simply Visualization, is to promote a deeper level of understanding of the data under investigation and to foster new insight into the underlying processes, relying on the powerful human ability to visualize. To achieve this goal, aspects of the areas of computer graphics, human-computer interaction, image processing, system design, cognitive science and signal processing are used. Formerly these were independent fields, however convergence is being brought about by the use of analogous techniques in the different areas. Visualization is thus an additional tool for research in science and technology [3].

According to Brown et al. [1], the general interest of Visualization to scientists and engineers can be summarised as the following four items:

- Exploratory graphics enable a scientist/engineer to gain more knowledge (e.g. visualizations can suggest hypothesis for further investigations and experiments)
- Peer graphics enable scientists/engineers to show information to their colleagues and to more easily collaborate with other scientists/engineers
- Presentation graphics allow to communicate the information and results that are already well understood
- Publication of the visualization, as well as the data sets, make easier to other scientists/engineers the use of the data for their own purposes.

Taking into consideration all these aspects, an introductory course on Vizualization seems to be a valid contribution to the curriculum of any post-graduation in science or technology and thus it seems adequate to the curriculum of the MSc in Electronics and Telecommunications offered at the University of Aveiro. This post-graduation aims to be a large spectrum degree encompassing mainly four areas of Electrical Engineering (Electronics, Telecommunications, Signal Analysis and Processing and Computer Science), which means that it can give formation either to future consumers or facilitators of visualization techniques and systems. This is the context where the proposed introductory course is meant to exist and thus its general objectives should be, as for other similar courses, to introduce the students to a new area which evolves rapidly, addressing the fundamental concepts, providing a basic foundation, good enough to allow and encourage them to apply or proceed work in that area. Stating these general objectives more specifically, this course should introduce the students to what Visualization is and can do, as well as it should make them appreciate its benefits and how current tools can be exploited in many application areas. This course intends to give a consumer's perspective as well as a facilitator's perspective. However the later should be stronger to some of the students having the adequate background[2].

In the following sections a brief description of the general contents and bibliography of the proposed introductory course on Visualization will be presented.

II. GENERAL CONTENTS OF THE CURRICULUM

This course was designed to have 36 hours spread along the 12 weeks of a semester which are devoted to leactures.

Nine topics should be addressed:

[1] "the purpose of computing is insight not numbers" by R. W. Hamming in "Numerical Methods for Scientists and Engineers", McGrawHill, 1962

[2] which can be obtained at graduate level, in the so called "enabling technologies" of Visualization (areas as Computer Graphics, Digital Image and Signal Processing and Human Computer Interface)

1- Introduction: definitions, history, goals and principles of Visualization
2- Overview of Visualization applications
3- Human Visual and Information Processing Systems
4- Framework
5- Visualization Techniques
6- Data Characteristics
7- Interaction Issues
8- Visualization Products
9- Reports from the Front Line: Case Studies and Applications

In the first lectures, corresponding to topic n.1, a general introduction to the area should be made. Besides presenting the definitions and goals of Visualization, the fact that it is not new in concept should be stressed; most principles that have been used to produce good maps, scientific drawings and data plots apply to computer visualization.

Topic n.2, is meant to give an idea of the large quantity of applications that Visualization finds in a great diversity of scientific and engineering disciplines. This should make the students aware of the importance and usefulness of Visualization, as well as allow them to better understand all the other topics of the course. This overview could consist in presenting a large collection of visualization images, describing generically the techniques used to construct images in a variety of disciplines and emphasising the kinds of information revealed rather than the details of the visualization techniques.

The third topic is concerned with the “human part” of the visualization process, which is essential. The capabilities and limitations of the human visual and information processing systems should be briefly described, stressing that they have important implications for design and that users, in spite of sharing common capabilities and limitations, are individuals with differences which should not be ignored.

Topic n.4 should present a framework model describing Visualization systems in abstract terms and which will be used to present techniques, data characteristics, products and applications in the remaining lectures. As an introduction to this topic, models of scientific investigation and visualization process should be addressed.

The concept of visualization technique, introduced in the previous topic, as the responsible for generating and manipulating a graphic representation from a set of data and allowing investigation through user interaction, should be developed in topic n.5. A range of techniques, generic in nature and which can be tailored to different applications, should be introduced.

Topic n.6 is concerned with data. A classification suitable for describing the different types of data flow identified within the used reference model should be presented as well as data formats and data compression techniques.

Topic n.7 deals with Human-Computer Interface issues in relation with visualization, which should be introduced using the information about Human Visual and Information Processing Systems provided in the corresponding topic.

A Visualization system should be presented, ideally, as an integrated whole providing means to support the effective exploration of complex data. Topic n.8 should present a classification of visualization software and a variety of existing software products.

The last topic covers recent visualization case studies in a variety of application areas. With the purpose of illustrating the general benefits users can obtain from Visualization, it should be important to stress why each visualization was performed in that way and what its users were able to learn from it.

This is the general contents of the curriculum for the proposed course as it is to be applied in the academic year of 1997/98; however it is expected to evolve, according to the experience obtained, each time it will be taught. This evolution is expected to occur in the specific way each topic is addressed, bibliography, sequence or duration of different topics, rather than on the overall structure since it seems to follow, in essence, what have been done by the community of Visualization educators [4,5,6].

III. BIBLIOGRAPHY

Knowing how to search for and use bibliography is an important part of any course, however at MSc level it is fundamental. At this level lectures are mainly meant to give the basic underlying theory and point out important issues, not to present them in detail; for these reasons a good bibliography is in fact fundamental.

Due to the fact that Visualization is a relatively new discipline, no text books seem to be available (at least in the sense as they exist in other longer established disciplines as Computer Graphics or Digital Image Processing). To overcome this type of difficulty usually two alternatives exist: use several books and papers or write some notes to support the course. Since the author has never lectured a course on Visualization, the second alternative does not seem to make sense at this moment and so the book by Brodlie et al. [3] was used as general support for the course. Some other more detailed or more up to dated references were used as support for several topics. Attempting also to provide the students with a bibliography that can be useful in their future activities, the author selected a small set of bibliographic references. In the next sections the general usage of these bibliographic references is described and a commented bibliography is provided.

A. General usage of bibliography

The first bibliographic reference (of the list presented in the next section) is, as already mentioned, the one that will provide general guidance for the course; however it

does not deal with the subjects in detail and in some of them is not up to dated.

The following five references of the same list can also be used as support for several topics, as definition and goals of Visualization, overview of visualization applications, techniques, data characteristics, visualization products and case studies.

The most interesting reference by Tufte could support the study of the history and principles of Visualization.

The next five references can all be considered as text books of so called enabling technologies of Visualization: Computer Graphics, Human Computer Interaction and Digital Image Processing; thus they can be used by the students to obtain a background on those technologies.

The reference by Travis is very useful as a support for a difficult problem: the use of colour.

Finally, the last reference can be used to support the introduction to the Human Visual System.

B. Commented bibliography

The list of all referred bibliographic references is presented, along with some comments.

Brodlie, K., L. Carpenter, R. Earnshaw, J. Gallop, R. Hubbold, A. Mumford, C. Osland, P. Quarendon, *Scientific Visualization, Techniques and Applications*, Springer Verlag, 1992
This book was written to be a reference guide for the Visualization community on the technical aspects. A framework is described and used to present techniques, data characteristics, products and applications.

Brown, J., R. Earnshaw, M. Jern, J. Vince, *Visualization, Using Computer Graphics to Explore Data and Present Information*, John Wiley, 1995
Provides a brief background on the field of visualization giving an overview of design issues, visualization market and various visualization products. It illustrates a wide variety of real-world applications through case studies.

Keller, P., M. Keller, *Visual Cues*, IEEE Computer Society Press, 1993
It is intended to people confronted with the problem of discovering the meaning of their data sets. Using practical examples from many disciplines, it illustrates visualization techniques, tips and rules of thumb, that help to produce informative images.

Rosenblum, L., R. Earnshaw, J. Encarnação, H. Hagen, A. Kaufman, S. Klimenko, G. Nielson, F. Post, D. Thalmannn, *Scientific Visualization*, Advances and Challenges, IEEE Computer Society Press, Academic Press, 1994
It presents current trends, issues and practice of Scientific Visualization at publishing time. Written for computer and computational scientists, it addresses topics as volume visualization, interface technology and perception, foundations and systems and presents in-depth case studies in practical daily use.

Earnshaw, R., N. Wiseman, *An Introductory Guide to Scientific Visualization*, Springer Verlag, 1992
It is intended for readers new to the field who need a quick easy-to-read introduction to what Scientific Visualization is and can do.

Scott Owen, G. et al., *HiperVis-Teaching Scientific Visualization Using Hypermedia*, ACM SIGGRAPH Education Committee, http://www.education.siggraph.org, 1996
It is a hypermedia document under development which addresses the fundamental topics of Scientific Visualisation.

E. Tufte, *The Visual Display of Quantitative Information*, Graphics Press, 1983
It is concerned with the design of statistical graphics as well as with how to communicate information through the simultaneous presentation of words, numbers and pictures. It reviews the graphical practice in the last two centuries and seeks to account for the differences in quality of graphical designs.

Foley, J., A. van Dam, S. Feiner, J, Hughes, *Computer Graphics: Principles and Practice*, 2nd ed., 1990
This is considered the standard reference in Computer Graphics. It deals with the fundamental topics of this area in adequate depth, as well as with many others.

Hearn, D., M. Pauline Baker, *Computer Graphics*, 2nd ed., Prentice Hall, 1994
This second edition is greatly improved when compared to the first one. It addresses the fundamental topics of Computer Graphics and may be considered as text book for that area.

Mayhew, D., *Principle and Guidelines in Software User Interface Design*, Addison Wesley, 1992
It is a practical text which provides principles and guidelines for the design of user interfaces, without disregarding the fundamental concepts.

Dix, A., J. Finlay, G. Abowd, B. Russell, *Human Computer Interaction*, Prentice Hall, 1993
It is a text book in its area, providing a multidisciplinary perspective of the subject. It covers the basic psychology and computer technology involved and the interface between them, as well as usability and advanced topics.

Gonzalez, R. C., R. E. Woods, *Digital Image Processing*, Addison Wesley, 1992
It is commonly used as a text book in its area; it covers the fundamental concepts and methodologies for Digital Image Processing.

Travis, D., *Effective Color Displays: Theory and Practice*, Academic Press, 1991
The aim of this book is to synthesise the knowledge needed and specify guidelines so that programmers, engineers and psychologists can use colour effectively.

Fishler, M., O. Firschein, *Intelligence, The Eye, the Brain and the Computer*, Addison Wesley, 1987
Uses an integrated approach on human and machine intelligence, using knowledge from several areas as computer science, cognitive science, linguistics, biology anthropology and psychology.

IV. CONCLUSIONS

A curriculum and bibliography of an introductory course on Visualization, designed to be an elective course for the MSc on Electronics and Telecommunications of the University of Aveiro, was proposed. This course will be offered for the first time during the academic year of 1997/98 and will have 36h of lectures. The proposed curriculum is based on the curricula of similar courses offered in several European and American Universities and thus it is expected to evolve in the specific way each topic is addressed, bibliography, sequence or duration of different topics, rather than on its overall structure.

REFERENCES

[1] Brown, J., R. Earnshaw, M. Jern, J. Vince, *Visualization, Using Computer Graphics to Explore Data and Present Information*, John Wiley, 1995

[2] Rosenblum, L., R. Earnshaw, J. Encarnação, H. Hagen, A. Kaufman, S. Klimenko, G. Nielson, F. Post, D. Thalmannn, *Scientific Visualization, Advances and Challenges*, IEEE Computer Society Press, Academic Press, 1994

[3] Brodlie, K., L. Carpenter, R. Earnshaw, J. Gallop, R. Hubbold, A. Mumford, C. Osland, P. Quarendon, *Scientific Visualization, Techniques and Applications*, Springer Verlag, 1992

[4] Domik, G.,"Education for Visualization - Activities of the ACM-SIGGRAPH Education Committee*", Proceedings of the Third Eurographics Workshop on Graphics and Visualization*, Maastricht, August, 1995

[5] Scott Owen, G. S., M. Bailey, K. Brodlie, G. Domik, "Issues in Education for Visualization", *Proceedings of IEEE Visualization 95*, Atlanta, October, November, 1995, pp. 427-430

[6] Scott Owen, G. et al., *HiperVis*, ACM SIGGRAPH Education Committee, http://www.education. siggraph.org, 1996

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