The Human Visual System in Electronics Engineering Education

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Resumo **- A compreensão do Sistema Visual Humano é fundamental em áreas em que são desenvolvidos métodos e sistemas que produzem imagens destinadas a serem usadas por observadores humanos. Descreve-se brevemente a forma como é ensinado este tópico em disciplinas de opção da Licenciatura em Engenharia Electrónica e de Telecomunicações da Universidade de Aveiro. Apresenta-se também a bibliografia comentada.**

Abstract **- Understanding the Human Visual System is fundamental in certain areas as Digital Image Processing, Computer Graphics, Visualization and Human Computer Interaction, where methods and systems are designed to produce images meant to be viewed by humans. A brief description of the way such a topic is addressed in several elective courses of the last year of the Electronics Engineering degree offered at Universidade de Aveiro is presented. The commented bibliography is also described.**

I. INTRODUCTION

Understanding the Human Visual System (HVS) is fundamental in several areas as, for instance, Digital Image Processing, Computer Graphics, Human Computer Interaction and Visualization, where methods and systems are (often or always) designed to produce images meant to be viewed by humans. Although in Digital Image Processing curricula, teaching HVS as a topic in the fundamentals, is a common practice, in Computer Graphics it is not. This can be inferred from some of the widely used text books in the referred areas; while the texts on Digital Image Processing usually include an independent section on the subject [1,2,3] the ones on Computer Graphics include, at the most, some reference to human vision mechanisms when specifically addressing topics where some knowledge of those mechanisms is essential to their understanding [4,5,6,7] .

In recent areas as Human Computer Interaction and Visualization, it is more difficult to evaluate if educators are commonly including this topic or not.

Consulting the document produced by ACM-SIGCHI [8] which contains recommendations and guidelines for Human Computer Interaction courses, it can be noticed that all four different proposed courses (for different audiences) address the Human Information Processing; however it is not clear if HVS is considered or not. It seems plausible that courses which devote more time (9 hours on a total 42) to this topic will also include an introduction to the HVS. For instance, from two well known books in Human Computer Interaction, one addresses the subject [9] and the other doesn't [10].

Visualization is even more recent as an independent area and, to the best of the author's knowledge, there are not yet text books (at least in the sense as the ones referred for Digital Image Processing and Computer Graphics); however reports on activities concerning the identification of a kernel curriculum in Visualization do include Human Perception Concepts as an independent topic to be addressed [10,11].

The fact the HVS is not usually addressed in Computer Graphics curricula is, in the author's opinion, quite surprising; however the importance of the "human part of the system" seems to have been implicitly recognised by a special IEEE-ACM task force in its document concerning Computing Curricula [12], where Computer Graphics (along with Human Computer Interfaces) was included in the area of Human Computer Communication, one of the nine areas identified as fundamental in Computing as a Science.

Taking into consideration these arguments the author has been spending, on the subject of HVS, 1.5 hour (one lecture) of a 36 hour introductory course on Computer Graphics that she has been offering. This is an elective course of the fifth year of an Electronics Engineering degree at the University of Aveiro, Portugal.

In the next sections some more details concerning the referred lecture about HSV will be presented, namely the type of information that is given to the students and how this is done, as well as the list of commented bibliographic references.

II. TOPICS OF THE HUMAN VISUAL SYSTEM

The main topics addressed in the lecture devoted to the Human Visual System are the following:

I- Definitions

II- Vision according to three points of view:

1- Evolution of Organic Vision

2- Eye and Brain

3- Perception

In part I vision is defined as the complex "process of converting sensory information into knowledge of the objects in the environment"; seeing and perceiving are also defined and the fact that they are different components of vision as well as the fact that the eye is just

a sensor and extracts only a part of the total information available around us are stressed.

Part II starts with a brief overview of the evolution of organic vision so that students gain the perception that organic vision has been evolving along species following mainly two "plans" (each particular solution corresponding to different needs and having different performances). The Human Visual System can thus be viewed as a very sophisticated system developed to solve a very complex "engineering problem".

Under the title "Eye and Brain", one tries to answer the first part of the question "How is the pattern of light energy projected onto the light sensitive cells and transformed into a model of the world?". This is done using low level and high level approaches; thus brief anatomical and physiological descriptions are given, on one hand of what happens when light enters the eye and electrical signals travel to the brain and on the other hand of the high level resulting features. The following important topics are addressed:

- the anatomy of the human eye and some parameters of the HVS that can give an idea of its complexity and performance
- the projection and focus mechanism
- the structure of the retina (layers of cells) and the distribution of rods and cones on it
- the two types of vision (photopic and scotopic): bright adaptation and discrimination
- some very important high level functions: lateral inhibition, stereoscopic vision and feature detection.

These topics have been introduced using different organisations however, at least until this moment, none has stricken the author as being significantly better than the others.

Finally perception is addressed; it is defined as the interpretation of what is seen, stressing the fact that this interpretation is based on past experience. The nature of the "techniques" used by the HVS is explored through the examination of its successes and failures in interpreting natural and contrived images. The following relevant topics are addressed:

- perceiving the real world: recognising patterns (a complex problem that appears to be solved spontaneously, flawlessly and without surprises)
- perceptual organisation (Gestalt laws)
- visual illusions (which provide much information on which theories of the functioning of HVS are based)
- pictural perception and culture

Recently, the author of this work has developed a hypermedia document which could be used to support the study of the Human Visual System and addresses all the referred topics. This document is a web of 18 pages with multiple links between them. Its readability and interest was not yet fully tested, however some preliminary experiments are planned to compare between the performances of students studying the topic supported only by this hypermedia document, only by conventional media (books and notes) and using both.

III. COMMENTED BIBLIOGRAPHY

The structure of the lecture is inspired mainly on one reference [14], which the author considers very interesting, readable and having adequate depth. Brief introductions can be found in the referred text books of Digital Image Processing and Human Computer Interaction [1,2,3,9], which probably are easier to find in technological libraries than the one used.

However many other references can be used by students interested in getting a different approach or a deeper information in specific topics. A few of these references were identified and are given to the students along with a brief overview of their contents, depth and approach. This has the main purpose of providing the students with a small but diversified bibliography that can be useful to them if, in their future research or professional activities, they are confronted with problems involving the need of a more or less deep knowledge of the Human Visual System.

Reading the first reference of the list given bellow is highly recommended to engineering students for its application, up to date and technological oriented approach to the subject. The second reference is, as referred, the one more directly used to support the lecture and can be considered as containing the "minimum" information the student has to acquire. The third and fourth references are more advanced, however still having an approach that can be viewed as "general background" (they are easy to read and appealing to any curious person). The references by Sckuler et al. and Humphreys et al. are important to the student who wants or needs to go much deeper in some topics of perception and visual cognition. These books are not very easy to read and were produced having psychology students in mind, however they can also be useful for the advanced technological student/researcher. Finally, the remaining references are books that deal with specific technological subjects that involve HVS issues and thus contain information that can be relevant for the student/researcher even when working on other subjects that also involve those issues. Also for these people, other obvious sources of much interesting information are proceedings of conferences and journals. The author has recently found interesting information in proceedings of SPIE conferences (e.g. Human Vision Visual Processing and Digital Display and Very High Resolution and Quality Imaging) and SIGGRAPH, as well in the journals Biological Cybernetics, IEEE Transactions on Image Processing, Advanced Imaging, Vision Research, Journal of Optical Society of America A, among others.

- Braham, R., "Toward an Artificial Eye", *Special Report, IEEE Spectrum* , May 1996

A very interesting, up to date and highly readable, selection of papers that describes the fundamentals of the HVS having in perspective the efforts developed toward the construction of artificial visual systems that can be used by impaired humans. It is specially meant to engineering professionals (students) however it seems also general enough to other professionals (students).

- 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. Chapter 8 is completely devoted to the Visual System and is indicated as the main reference.

- Hubel, D., *Eye, Brain and Vision*, Scientific American Library, 1987

It is mainly concerned with how the brain handles visual information and it is meant to be read by people that have scientific training but not in biology. Explores the tasks scientists face in deciphering the workings of human vision and brain.

- Rock, I., *Perception*, Scientific American Library, 1984

The human perception of objects in the world, in art and in visual illusions is addressed. Using ingenious experiments, it is explained how we manage to turn the ambiguous, ever changing, two dimensional images that fall on the eye into the rich, constant three-dimensional world as we see it.

- Sckuler, R., Blake, B., Perception, 3rd ed., McGraw Hill, 1994

The biological bases of vision and the perception of pattern, colour and depth are discussed in detail as well as action and the perception of events. Other senses are also discussed. It is strongly biased toward recent issues, which allow students to appreciate developments at the frontiers of perception. This can be considered a text book for students of perception.

- Humphreys, G., V. Bruce, *Visual Cognition: Computational, Experimental and Neuropsychological Perspectives*, Lawrence Erlbaum Associates, 1991

In the eighties the understanding of visual processing has undergone a rapid change, primarily fostered by the convergence of computational, experimental and neuropsychological work on the topic. This book provides a first major attempt to cover all aspects of this work within a single text and covers: seeing static forms, object recognition, dynamic vision, visual attention and memory as well as visual aspects of reading.

- Grob, M., *Visual Computing*, Springer Verlag, 1994

Addresses topics related to Visual Computing, an emergent discipline which integrates computer graphics techniques, visual perception, digital image processing and technologies. This book presents also the fundamentals of visual perception .

- 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. Tutorial material is introduced where it is necessary to grasp fundamental principles and understand the limitations of both the display device and the perceptual system.

- Kelly, D., (ed.), *Visual Science and Engineering, Models and Applications*, Marcel Dekker, 1994

This book examines, throughout a series of chapters by experts, a broad spectrum of recent topics in visual science, relating basic studies to practical applications and delineating points of intersection among various disciplines that study the mechanisms of vision. It is an interesting resource for imaging scientists and post graduated-level students.

- Landy, M., J. Movshon (eds.), *Computational Models of Visual Processing*, MIT Press, 1991

This book accounts for the enormous progress made in vision sciences in the past decades, in order to answer the question “what has the computational modelling of vision achieved?”, treating vision as an optical instrument upon whose output computations of an experimentally tested nature are performed. It is an important reference to researchers and post-graduate level students interested in using/developing models of the HVS.

IV. CONCLUSIONS

After teaching seven years the subject of Human Visual System, in the referred amount of time, one lecture of 1.5 hours [15], the author considers that, in spite of allowing only a very brief introduction to such a complex subject, it results very useful since it is enough to make the students aware of the importance of the issues concerning the “human part of the system”. It is this awareness, along with the fact that they are introduced to a small but diversified bibliography, which is perhaps the most useful legacy that the students can retain, from such a lecture, for their future professional activities. Moreover, students generally find this subject very interesting, which is perhaps partially due to the used “engineering approach”.

The same approach has also been used in a Digital Image Processing course (for the same engineering students) and it will be used, next year, in a Visualization course.

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