Restructuring Comp u ter Graphics and Visualisation Curricula at IST

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Abstract

This paper addresses the restructuring of the undergraduate and graduate programs in Computer Graphics, Visualisation and Multimedia that was recently carried out at Instituto Superior Técnico. The paper details the rationale for the changes in both curricula and course content and describes the new structure. The result is a coherent and complete series of courses spanning the undergraduate and M.Sc. degrees in Informatics Engineering. It further discusses the structure of the basic course on Computer Graphics within this context and draws conclusions to contribute to the ongoing discussion on Computer Graphics, Visualisation and Multimedia curricula.
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1. Introduction

The Informatics and Computer Science undergraduate program at Instituto Superior Técnico (IST) started in the academic year of 1989/90 under the aegis of three departments, Electrical Engineering, Mathematics and Mechanical Engineering, which shared the co-ordination of the new degree program. Roughly at the same time the M.Sc. program in Electrical Engineering and Computers offered a specialisation in Computing. Courses on Computer Graphics were taught within the undergraduate and graduate programs.

This scenario lasted until 1998 when IST decided to create a new department, the Department of Informatics Engineering (DEI). The decision was taken given the need for better co-ordination of the undergraduate program which had come of age and the number of teaching staff and undergraduate students involved. The new department was officially established September 1st, 1998.

DEI´s creation started a new and extremely dynamic process. The novel Department's professors engaged in an overall revision of the department's teaching activities with three purposes in mind. First, previous experience had shown an effective need for adjustments in the undergraduate program syllabi. Second, the new department needed to assess in detail and demonstrate its requirements in terms of teaching staff. Finally, the revision was necessary because of the continued changes in Information Technology.

At the same time this dynamic process had implications in the graduate curricula. The result was the decision to create a new autonomous M.Sc. program addressing the needs of graduate student in the scientific area of the new department and related areas.

By and large, this constituted a unique opportunity to address all these matters from a global perspective. Instead of taking the classical approach and address undergraduate and graduate levels separately, this was the time when the two programs could be changed together to make the graduate program the logical sequence of the undergraduate program.

The outcome was the adoption of a model currently adopted in other universities, notably in the United States. This model allows undergraduate students intending to continue their studies through the graduate program to take advanced courses from the M.Sc. program while in their senior year. This concept became the Integrated M.Sc. Program.

After restructuring the undergraduate program, all scientific areas in the Department of Informatics Engineering were asked to set-up their particular graduate (M.Sc.) curricula. Later on, the integrated undergraduate-graduate scenario was finally revised and approved. In this process the Computer Graphics and Multimedia professors of DEI took the opportunity to assess and reprogram all courses within their responsibility.

This paper reports the results of that work. Section 2 lists the objectives set at the beginning while section 3 presents the rationale and describes the new program structure for the area of Computer Graphics and Multimedia. Section 4 addresses in detail one of the basic components of the program, the Computer Graphics course. The final section presents some remarks and general conclusions.

2. Objectives

In Portugal, as in most other countries, the supply of information engineering professionals has not kept pace with job market needs. Besides the hiring frenzy driven by the arrival of the Euro and Y2K endeavours, many new Portuguese companies have been created in recent years, with some of them involved in international activities such as ParaRede and EasySoft, to name a few. This shows clearly that there is a need for new and highly qualified professionals at all levels. Furthermore, the continuous development of information related technologies, of which the WWW is a good example, requires professional skills that were not taught a few years back. Furthermore, currently employed professionals are required to continuous update their qualifications in order to be on par with technological development.

Therefore, the first goal of the new curricular structure was to produce an undergraduate program that would satisfy the above needs. The second goal was to create a specialisation area in Interactive Systems and Multimedia suited to the needs of future professionals. Another important goal was to set the groundwork for a doctoral program in Interactive Systems and Multimedia.

Since the topics to cover are interrelated, we decided to develop an integrated approach spanning both undergraduate and graduate programs, in order to:

- offer students a coherent global program in Computer Graphics, Visualisation, Multimedia and Interactive Systems.
- establish a complete and logical sequence of subjects and courses extending from early undergraduate to advanced graduate studies.
- allow students intending to obtain a M.Sc. degree to proceed smoothly and quickly to graduate studies by shortening the intermediate steps required.
- empower students not intending to pursue graduate studies to achieve a high degree of proficiency.
- enable students from other undergraduate programs to enrol in our graduate program.

3. The M.Sc. Program in Interactive Systems and Multimedia

This section presents the Master's program in Interactive Systems and Multimedia, its guidelines and structure, together with the outline of each course's syllabus.

3.1. Rationale

This following addresses the general guidelines for the new program organisation. We will discuss the requirements at undergraduate level before moving on to the graduate program in Interactive Systems and Multimedia.

All undergraduate students must become familiar with the basic principles of Computer Graphics. These minimum requirements comprehend both two-, three-dimensional, surface and hierarchic modelling and use of colour. Furthermore, most undergraduate students will take courses on Computer Aided Design and Human-Computer Interaction. These complete the knowledge requirements at the undergraduate level and are the basis for graduate level studies. Any student applying to the master's program must have the above basic Computer Graphics background. If not, they will have to complete it before moving to the master program by taking the missing courses.

Students at the end of the fourth year of graduation may elect to proceed directly to the master's program. Instead of moving on to the fifth and final year of the undergraduate degree, they can take advanced courses from the master's program first year.

The master's curriculum in Interactive Systems and Multimedia includes courses from two major areas, Computer Graphics and Information Systems. Students intending to specialise on the design, implementation and use of Computer Graphics Systems opt for a major on Computer Graphics and a minor on Information Systems. Conversely, students whose interest lies on Interactive Systems can opt for a major in Information Systems and a minor in Computer Graphics.

Students earn credits from courses in these two areas. Each major begins with a fundamental course offered during the first semester of graduate studies. After that students must take at least four courses in their major area. Of these four courses, two intermediate curses on the second semester are required studies for the two advanced courses on the third semester.

A master's thesis to be done during the second year completes the graduate master program. The thesis must be supervised by a professor of DEI's Computer Graphics & Multimedia scientific area.

Students choosing a major in Computer Graphics Systems must take the Three-dimensional Modelling and Visualisation course in the first semester. During the second semester, students will take two more specialised courses, one on Visualisation and the other on Modelling.

Students choosing a major in Interactive Systems must take the course on Human-Computer Interaction in the first semester. These students will then have to take the two more specialised courses on Hypermedia and Intelligent Interfaces in the second semester.

In the third semester, students can choose two courses from the five advanced courses available. These are Visual Languages, Virtual Reality, Scientific Visualisation, Geographic Information Systems and Advanced Topics on Computer Graphics and Multimedia.

3.2. Program Structure

The courses in the new structure were classified into four categories: G, L, M and A.

G courses are typical undergraduate courses and constitute pre-requisites for enrolling into the master program. The Computer Graphics course is part of the Informatics and Computer Science undergraduate program. Other related undergraduate programs have the option for the Computational Graphics Methods course, which is a version of the Computer Graphics course adapted to such other undergraduate programs.
L courses are offered both as part of the undergraduate program, and of the first semester of the graduate master program

M courses take place in the second semester and are typical master program courses. Completion of the corresponding L courses is necessary to take any M type course. M courses are pre-requisites for all A type courses.

Type A courses are final master's program courses addressing advanced topics and take place during the third semester.

Figure 1 presents a diagram showing the courses and their pre-requisites. Table 1 lists the undergraduate and graduate courses according to type, curricular semester and year.

3.3. Syllabi

This section presents the abridged syllabi of the courses listed above. The **Computer Graphics** course is presented in more detail in the next section. The reason for this is the fact that this course is the introductory fundamental course for the whole area of Computer Graphics and, therefore, deserves special attention.

The first semester course on **Three-dimensional Modelling and Visualisation** aims at teaching students how to create and use different 3D representation models, model scenes and animate objects. The curriculum also addresses visualisation techniques to cope with specific requirements like games. This course is project oriented.

Course Designation	Type	Yr.	Sem.
Computer Graphics	G	2	2
Computational Graphics Methods	G	5	1
3-D Modelling and Visualisation	L	5	1
Human-Computer Interfaces	L	4	1
Intelligent Interfaces	M		2
Hypermedia	M		2
Graphical Modelling Complements	M		2
Visualisation Complements	M		2
Visual Languages	A		2
Virtual Reality	A		3
Scientific Visualisation	A		3
Graphical Information Systems	A		3
Adv. Topics in CG and Multimedia	A		3

Table 1. Undergraduate and graduate courses according to type, curricular semester and year.

The course on **Human Computer Interaction** (first semester) is intended to teach students how to create and evaluate user interfaces. To achieve these goals, students learn the concepts of Human Factors (cognitive and motor-sensorial), and Usability and how to use and apply different software methodologies and tools for interface creation. This course is project oriented.

The second semester course on **Intelligent Interfaces** explores new paradigms in user interaction that will replace present-day approaches based on direct manipulation and the desktop metaphor. The course discusses multimedia input analysis; recognition of speech, gestures, gaze and calligraphic sketches; synergetic combination of multiple interaction modalities; the architecture and construction of novel user interfaces; presentation of multimedia information; agent-based interfaces and natural language.

The course on **Graphical Modelling Complements** course (2^{nd} semester) addresses a large set of topics related to the design and implementation of generic geometric algorithms in both 2D and 3D. Starting with a comparative study of several solutions to some classical and elementary geometric problems, it then progresses to the description of more complex geometric modelling techniques. The course then presents suggestions for the application of those results to solving practical problems in different domains such

as Virtual Reality, Computer Aided Design, Computer Vision, Robotics, etc.

The second semester course in **Visualisation Complements** is an exposition of state of the art techniques in 3D rendering such as antialiasing theory, texture mapping, ray-tracing advanced strategies, radiosity methods or volume rendering. The motivation of this course is to explain the many techniques that have evolved, with sufficient theoretical rigour and in enough detail to enable their use in a project on realistic image synthesis.

In the third semester, the course on **Visual Languages** focuses on a class of formal languages based on the non-linear organisation of information. The relevance of such languages is reflected on the proliferation of systems such as spreadsheets, CAD and GIS systems, which structure information in an essentially visual manner. The course establishes the connection and contrasts visual to conventional formal languages, balancing a discussion of theory with the study of practical applications.

The objective of the third semester **Virtual Reality** course is to provide a comprehensive technical review of the engineering details underlying the development of virtual environment displays. Students should not only become familiar with concepts like immersion and stereo rendering but also understand existing virtual reality systems and their associated technologies. Special focus is given to the Web visualisation. Students will then explore this topic through a project where they must apply VRML and Java technologies.

The advanced course on **Scientific Visualisation** (third semester) addresses the architectural solutions found in such systems and the means and ways of achieving realistic scientific data visualisation applied by both traditional and immersive visualisation systems, including real-time visualisation and user interaction. This course is project oriented.

In third semester advanced course on **Geographic Information Systems** the students will apply previous knowledge on Organisation Models, Information Systems, Interactive Systems and Computer Graphics to study not only the technology (information access, information publication, specific methodologies) but also to study the impact of technology on organisations. Case studies will be used.

The third semester advanced course on **Advanced Topics on Computer Graphics & Multimedia** program will be defined each year and will include the latest scientific subjects in the field.

4. The Basic Course: Computer Graphics

The **Computer Graphics** course is the entry point to the Computer Graphics world to most students enrolled in the Informatics and Computer Science undergraduate program. For this reason, this paper addresses it in more detail in the following.

Note that the **Computational Graphics Methods** course, that is offered at IST to students enrolled in the Electronics and Computer Engineering and Applied Mathematics undergraduate programs, runs parallel to the Computer Graphics course and addresses roughly the same subjects. However, it follows a more traditional pedagogical approach with adaptations to those programs and in line with those programs' nature.

4.1. Objectives and Guidelines

The Computer Graphics course is the basic course at undergraduate level in its scientific area. After this course, students are expected to understand and apply the fundamentals and algorithms in Computer Graphics.

At the same time, this course plays the very important role of attracting students to the area of Computer Graphics. Students are familiar with the latest advances in the area since they have most certainly experienced it in computer games and while browsing the World Wide Web (e.g., VRML). Moreover, what used to be expensive hardware and heavy applications can be found today in multimedia PCs at a low cost. Most basic algorithms come already embedded in low cost hardware.

From the above, it is evident that the traditional pedagogical approach to a basic course in Computer Graphics is no longer on par with the today's reality and can be a negative factor in keeping students interested in the subject. This is why we decided to follow a different pedagogical approach that looks at Computer Graphics from a global structured perspective using today's typical applications and then proceed to more detailed levels.

4.2. Course Contents

A typical semester consists of thirteen weeks with three hours of lecture time per week at IST. In line with was previously said we propose to develop the course curriculum of the introductory Computer Graphics course as in the following course outline (the numbers in parentheses indicate the number of classes dedicated to each subject).

1. Introduction and General Concepts [2]
2. Geometric Transformations [3]
3. 3D Visualisation [7]
   3.1. Projections and the Rendering Pipeline
   3.2. Geometric Modelling and Object Hierarchy
   3.3. Visualisation Algorithms
   3.4. Clipping, Scan Conversion, Hidden Line and Surface Removal
4. Parametric Surfaces [2]
   4.1. Representation
   4.2. Tessellation
5. Colour models, halftoning, reproduction [2]
6. Shading and Illumination [2]
7. Ray-Tracing and Radiosity [2]
8. Animation [2]

We will use the classic textbook "Computer Graphics and Applications" by Foley et. al.[1]. This comprehensive classical textbook has been traditionally used at IST although it leaves much to be desired from the pedagogical point of view. We are currently looking for alternatives.

4.3. Other Features of the Curriculum

The practical pragmatic aspects of programming and algorithm implementation are relegated to the weekly laboratory and practice classes (two hours per week) instead of recitation sessions.

The study and description of 2D windowing systems and raster primitive operations, already reduced in previous editions of the course, disappears as autonomous curriculum item. The discussion of two-dimensional primitives appears at its logical place in the discussion of the visualisation pipeline, i.e., after the discussion of the scan-line algorithm conversion.

We introduce students to modelling languages such as VRML to construct a fairly complex scene as their first assignment. The second laboratory project focuses on the study, implementation and experimentation of three-dimensional visualisation algorithms, building on the enthusiasm students traditionally vow to such activities.

5. Conclusion and Final Notes

This paper presented the new program structure in Computer Graphics and Multimedia of the integrated undergraduate and graduate (M.Sc.) programs in Informatics and Computer Science at Instituto Superior Técnico, Technical University of Lisbon. We addressed the aims of the novel integrated program and described the curricula of both programs' courses, paying special attention to the introductory course in Computer Graphics.

The new curricula are the outcome of collaboration work carried out by the professors of the DEI's Computer Graphics and Multimedia scientific area and follow the experience gained by similar initiatives already in place in other countries, especially in the United States. In our view, the program and curricula proposed here constitute a well balanced and comprehensive set, covering both the fundamentals and advanced topics in this scientific area in a progressive manner. Furthermore, the advanced topics proposed are well in line with current research trends in our field.

The proposed program is also clearly in tune with modern requirements for competent Computer Graphics professionals at both undergraduate and graduate (M.Sc.) levels. Moreover, the program ensures a smooth transition from undergraduate to graduate level with minimum delay.

The program will be set in place at the beginning of the 1999/2000 academic year and is expected to be in full operation by the year 2001.

References

[1] J. D. Foley, A. van Dam, S. K. Feiner, J. F. Hughes, *Computer Graphics, Principles and Practice*, 2nd. Edition, Addison-Wesley, 1990.

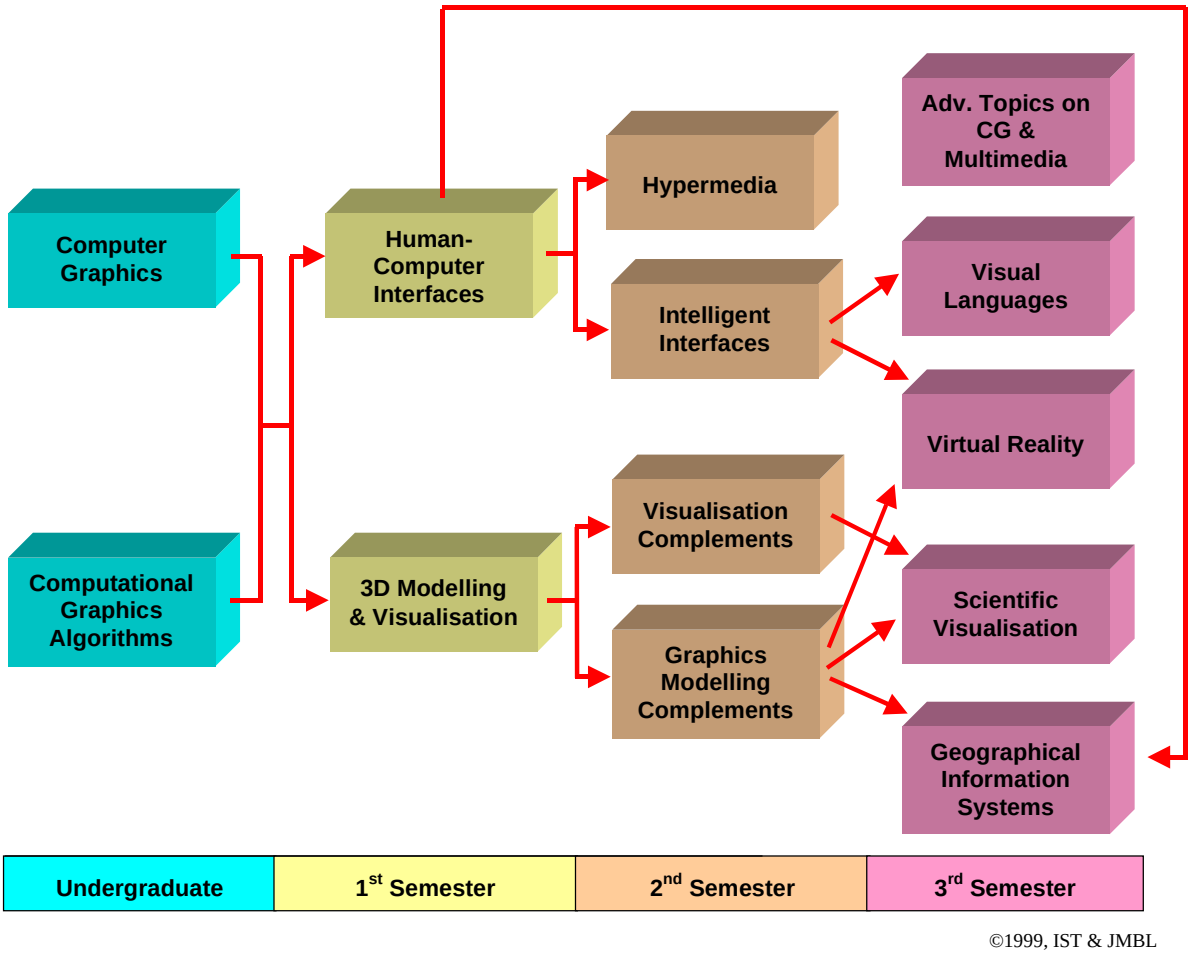

Figure 1. Course diagram showing course dependencies.