

Report of the CGE 06 Computer Graphics Education Workshop

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Executive Summary

In order to include computer graphics in European university programmes in computer science, the computer graphics curriculum must be organised along lines that satisfy the Bologna requirements for cross-university transfers. This workshop suggests ways to organise courses so that a computer graphics programme can be as comprehensive in its scope as fits any particular university, have its curriculum be easily understood by others, and allow simple transferring into and out of its programme. The structure developed by this workshop is still in outline form, but it serves as a framework from which actual courses and textbooks can be developed to fill out a comprehensive Bachelors and Masters computer graphics curriculum.

Workshop organization

The 2006 Computer Graphics Education Workshop was held on September 9, 2006 at the Technische Universität Wien, immediately following the Eurographics 2006 conference. The goal of the workshop was to define an international curriculum in Computer Graphics studies in a computer science or informatics programme that respects the Bologna requirements of the EU and reflects the international nature of the computer graphics education workshops to date.

This was the fourth in a series of workshops held with the sponsorship of Eurographics and ACM SIGGRAPH. The previous workshops were held in 1999 in Coimbra, Portugal; 2002 in Bristol, England; and 2004 in Hangzhou, China. The reports on these previous workshops may be found in the references for this report. The particular findings of these workshops that were key to the 2006 workshop were the discussion of the beginning course in all of them and the discussion of advanced courses in the Bristol workshop.

The 2006 workshop was invitational, based on submitted and reviewed position papers. Additional invitations were extended to authors of papers on computer graphics teaching in computer science in the EG06 Education Programme, to members of the Eurographics Education Board, and to the ACM SIGGRAPH Director for Education. In all, 23 persons participated in the workshop. A list of participants is included below.

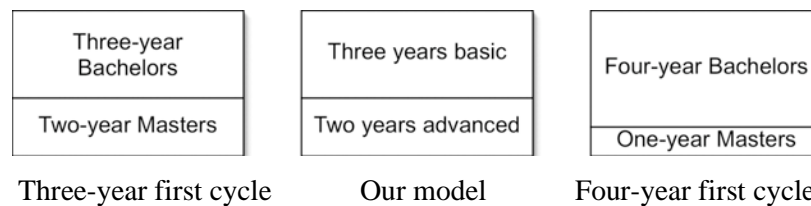
The Bologna requirements

The focus of the workshop was to make recommendations about computer graphics in the computer science/informatics area that meet the Bologna education conditions in Europe. Some of these that were important to the workshop discussions may be summarized as:

- Universities are expected to develop a system in which degrees and courses are easy to read and compare.
- Students and teachers are expected to be able to be mobile, moving between universities freely, and students are expected to be able to complete their studies without taking any extra time because of this mobility. This is facilitated by the ECTS (European Credit Transfer System) standardised credits (one ECTS unit is defined as content requiring 30 hours of student work).
- Universities are expected to have a first cycle (first degree, or Bachelors) of at least three years, with the student having skills for employment after the first cycle; a second cycle may be offered (second degree, or Masters) to complete five years of study.
- Universities are expected to cooperate to assure quality assurance in their courses and programmes.

For additional information on the Bologna process, see the article by Fuller et al. in the references.

One condition on any curriculum recommendations quickly became apparent. European universities differ in the way their Bachelors (first cycle) and Masters (second cycle) programmes are organised. In some universities, the Bachelors is three years and can be followed by a two-year masters programme; in some universities the Bachelors is four years and can be followed by a one-year masters programme. We thus decided to focus our discussions on an approach that can accommodate both arrangements: a three-year “basic” studies area and a two-year “advanced” studies area, as illustrated in the figure below. In the case of a four-year Bachelors degree, we assume that some of the “advanced” area work will be available within the four-year programme.



The workshop opened with a discussion of previous workshops and of the Bologna education requirements. Participants then discussed both basic and advanced topics, creating a list of courses without providing particular details about any of them. After lunch, we continued discussing the nature of the European university systems and decided that we should focus on topics for the basic courses. The discussions finally concluded with some work to create topics lists for courses. With the limit of the one-day schedule, we believe that the workshop made a good start on outlining a curriculum that is appropriate for the first and second pre-research cycles, that is comprehensive in the topics that can be covered at these levels, and that gives students a sound background for either graphics-related employment or doctoral studies.

The workshop's findings

General concepts:

In order for different universities to compare courses, a standard course length must be adopted for course definitions. This workshop chose to consider courses of 5 ECTS size, realizing that some universities may be organised in ways that will need other sizes. It is important to note that the topics listed in the courses below are somewhat preliminary, and experience is needed to determine just what can appropriately be covered in a single 5-ECTS course. We expect that the breadth and depth of these courses will evolve over the next few years. We look forward to graphics faculty publishing their courses in these areas and perhaps to considering the details of these courses at a future computer graphics education workshop.

The beginning course:

The workshop affirmed the recommendations of the previous workshops on the beginning graphics course and urged that Eurographics and ACM SIGGRAPH jointly develop and formally support a recommendation that at least one course in computer graphics should be included in every Bachelors computer science programme, and that serious consideration should be given by each programme to making that course a requirement for graduation. This is based on the recognition that while many parts of computer science involve only machine internals such as operating systems, data communication, and databases, whenever a computer communicates with a person it is likely that it will use graphical techniques. Thus students need to be prepared to be productive in graphical techniques.

The workshop also recognized that the beginning course can serve as an important source of learning and experience in communication from the computer to the user, and hence suggests that the recommendations from the 2004 workshop be extended so that the course should include an emphasis on visual communication. In some cases the emphasis on visual communication could lead to greater acceptance of this course across the university, and in those cases the workshop suggests that it could be helpful if the term “visual communication” is part of the course title.

Other background:

There are several areas in which students should have studies that support their work in computer graphics. These include communication skills (writing, presentation, graphical), programming, mathematics, and some physics. Some of these will naturally be part of the student’s supporting studies in or for computer science, but some will not. The academic programme must be sure to let students know of the need for these studies and create appropriate formal requirements in these areas.

Basic courses:

Basic courses are defined as those that a student can take in the first three years of undergraduate studies following the beginning computer graphics course. These courses will develop the student’s graphics knowledge and skills, and are preparation both for further study and for careers that will use graphics. The beginning course is expected to be taken in the second year of study, so basic courses are expected to begin in the third year.

A list of the basic courses is given here, with a set of topics that are expected in each. The topics have not been fully developed or prioritized because there is not yet a well-agreed curriculum for each topic, but we anticipate that this workshop report will encourage the development of these curricula. Depending on the exact coverage in the beginning graphics course, some of the topics included in the Basic courses may have already been covered in a beginning course. General categories of these courses include graphics techniques beyond the beginning course (Modeling, Rendering, Animation), applications (Visualization, Interaction), and graphics systems (GPU Programming).

Rendering I:

The rendering equation; spectral colour; realism and visual perception; visibility: scanline, Z-buffer, ray-tracing; local lighting; shading models; texturing and texture synthesis; bump mapping; anti-aliasing.

Modeling I

Geometry and topology fundamentals; standard representations such as boundary representations (B-Rep) or constructive solid geometry (CSG); procedural and parametric modeling; NURBS curves and surfaces; meshes; subdivision surfaces; level of detail; implicit surfaces; application areas: architectural and CAD modeling, design.

Animation I

Review of mathematics and physics; interpolation: keyframing, path animation, deformation, morphing; procedural animation; navigation; rigid body motion; collision detection; soft objects; particle systems; motion of natural phenomena such as water, air, clouds, fire.

Visualization I

Perception and visual communication; colour ramps and other synthetic colour schemes; geometrization and other techniques for scientific or information visualization; considerations for accessibility for persons with limited perceptual skills; modeling techniques for theoretical or measured data; techniques for information visualization; high-performance computing.

GPU Programming

Architecture of GPUs; shader languages; geometry shaders, vertex shaders, and fragment shaders; noise; shader techniques; high dynamic range; applications in volume rendering, medical visualization, or games; topics in rendering; GPGPU.

Interaction

Interactive devices, haptic techniques, human perception, VR/AR techniques, human-computer interface topics, game interfaces.

Advanced courses:

Advanced courses need more background than beginning courses and would normally be expected to be taken in the fourth or fifth year of studies. These will need one or more basic courses as prerequisite and may need more experience or maturity than would be expected of a student through the first three years of study. They may also require more study in mathematics or the sciences than a basic course. Again, the topics and sequence listed is preliminary and concrete curriculum experience is needed before these can be made firm.

Rendering II

Global illumination: radiosity, photon mapping; camera models; anisotropic reflectance and BRDF; advanced shadows; volume rendering; non-photorealistic rendering; image-based rendering; advanced anti-aliasing; reflectance measurement; high dynamic range displays.

Modeling II

Advanced geometric modeling, differential geometry, volume modeling, minimal surfaces, collision detection and avoidance, point-based modeling, special kinds of models including particle systems and generation models (e.g. fractals).

Animation II

Modeling and motion of articulated figures: hierarchical modeling, forward kinematics, inverse kinematics, muscle models, facial animation; cloth modeling; motion capture; animation using implicit surfaces.

Visualization II

Networked graphics; VR environments; coordination with sound, haptic, or other modalities; application-based techniques.

Real-time Graphics

Simulation, games, ...

Additional findings:

There are some topics that are very closely allied to computer graphics but are not strictly within the field. These topics, in particular HCI and image processing, should be included in the overall computer science curriculum. Computer graphics students should be encouraged—perhaps even strongly encouraged or required—to study these topics. We do not list them here, however.

Part of the Bologna conditions are that courses should be easy to read and compare, and that students are expected to be able to move between universities freely. However, at the current time it is possible for a student to present several courses that have very similar content and request credit for all of them in the university to which he or she transfers. The workshop suggests that this problem could be reduced by all European universities using the names as given above for their computer graphics courses so that everyone would understand the general content of each.

Followup:

The workshop participants realized that one day was not enough to develop a curriculum for computer graphics, and additional email discussions after the workshop have gone into creating this report. However, a genuine curriculum needs course outlines, textbooks, and good sets of projects that were not discussed at the workshop and, in some cases, are not generally available at all. The organisers encourage individuals to create courses and develop textbooks along the lines of the courses described here, and we recommend that a follow-up workshop should be considered that would bring together persons doing this work to share their course development and build a concrete graphics curriculum.

Summary:

The workshop recommends several steps in establishing computer graphics curricula within a computer science programme.

1. We recommend that universities use “visual communication” in the catalog description and content of the beginning computer graphics course to make it clear that the course includes more than just technical content. We also suggest that as appropriate the term be used in the course title because we believe this inclusion would help universities recognize the broad value of the beginning course.
2. We recognise the differing structure of the first and second cycles of European curricula and so we categorise courses as “basic” or “advanced,” depending on whether the course is intended to be used in the first three years or the last two years of a five-year programme.
3. We recommend that a computer science programme organise its basic computer graphics courses from the set of courses described above, with the expectation that a student would normally not take more than two basic computer graphics courses beyond the beginning course in the first three years of study.
4. We recommend that the computer science curriculum include at least a core set of advanced computer graphics courses and that they be organised as electives so that a student can take at least one sequence of a basic and advanced course in a single graphics subject. Thus we recommend that a programme offer both Rendering I and Rendering II, or Modeling I and Modeling II, or Animation I and Animation II. This will allow a student to have a solid depth in at least one area of the field.
5. We recommend that universities adopt a uniform naming policy for courses as above so that the course content is clear from the course title. This will allow universities to be more accurate in assessing a transfer student’s computer graphics experience and avoid both giving students credits for overlapping content and allowing students to take courses for which they do not have the correct preparation.

The workshop’s limitations

It is important to realize that the workshop focused very strongly on the Bologna requirements and their impact on how curricula can be organised to coordinate many programmes in widely-differing universities. These requirements may not be present in universities outside Europe, and there it may be desirable to use the workshop’s recommendations in different ways. Some discussions with computer graphics faculty in Latin America, for example, suggest that rather than develop the course structure above, it may be more useful for them to select from the topics in the listed basic and advanced courses to create more general advanced undergraduate courses. This would also seem to be more compatible with the usual practice in the United States and Canada. Thus the reader outside

Europe should not feel constrained to follow all the detailed recommendations above. Rather, we suggest that the following guidelines should be considered:

- include visual communication in the content of the beginning course and include the term in the course's title,
- coordinate studies in computer graphics with studies in image processing and HCI,
- select topics from the Basic courses for at least one course beyond the beginning course (a "second" graphics course), and
- consider carefully whether to select additional topics from Basic courses to develop additional graphics courses (more of a "breadth" approach), or whether to select topics from the Advanced courses to further develop the material from the second graphics course (more of a "depth" approach).

The workshop participants

The workshop participants are shown in the photo and are listed below. The organisers would like to acknowledge the help of the Eurographics 2006 organisers in developing the local arrangements for the workshop and in providing support for publicity and registration for the workshop.



Mike Bailey, Oregon State University, USA
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Vincent Boyer, University of Paris 8, France
Judy Brown, University of Iowa (retired), USA
Colleen Case, Schoolcraft College, USA
Steve Cunningham (workshop co-chair), Grinnell College, USA
Gitta Domik, University of Paderborn, Germany
Marta Fairen (workshop co-chair), Polytechnic University of Catalunya, Spain

Mario Rui Gomes, IST/INESC, Portugal
Werner Hansmann, University of Hamburg, Germany
Hannes Kaufmann, Technical University of Vienna, Austria
Lars Kjell Dahl, Royal Institute of Technology, Sweden
Cecilia Sik Lanyi, University of Pannonia, Veszprém, Hungary
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Zhicong Pan, Zhejiang University, China
Ken Perlin, New York University, USA

References:

- 1999 Coimbra: <http://education.siggraph.org/conferences/eurographics/gve-99/reports/papers/gve-fullreport.pdf>
2002 Bristol: <http://education.siggraph.org/conferences/eurographics/cge-02/report>
2004 Hangzhou: <http://education.siggraph.org/conferences/eurographics/cge-04/Rep2004CGEworkshop.pdf>
2006 SIGGRAPH knowledge base: <http://education.siggraph.org/curriculum/knowledge-base/report>
Fuller, Ursula et al., "A computing perspective on the Bologna process," SIGCSE Bulletin (38, 4), December 2006, pp. 115 - 131