Developing ACM Computing Curriculum Courseware on Graphics & Visual Computing

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Abstract

We combine previously unrelated requirements and approaches for an online support of classes for graphics and vision. ACM Computing Curriculum provides the contents guidelines, TU Graz fundamental lecture on Graphics and Visual Computing implements the lecture notes, with frequent hyperlinks into the slides. Awarded applets at pg.netgraphics.sk *offer the interactive experience. Algorithm animation, open problems and knowledge tests enhance the topics understanding and feedback. All the abovementioned main components represent the layers of a long term educational project. All the features will be presented or exemplified to the workshop audience either online or using videos. Besides addressing ethical issues in computer graphics curricula in the sense by Bannatyne et al., use of VR techniques and constructivistic approach by Wen-Tsai Su, we discuss the teaching experience from Japan, Slovakia, and Austria within the framework of global online set of refereed resources, as proposed in SIGCSE 2002 BOF on Computer Graphics by Steve Cunningham.*

Keywords

ACM Computing Curriculum, graphics and visual computing, education, courseware.

1. INTRODUCTION AND MOTIVATION

The paradoxical situations with multiple development of frequently overlapping global or international curricula and standards are depicted and discussed in another CGE02 paper [Ferko02b]. Here we assume that after the below described intervention [Skala01] the ACM Computing Curriculum core and elective content for graphics and vision has been developed using clever data mining and qualified interpretation and discussion. In other words, that the future direction towards our part of semantic web [Berners-Lee01] is clearly given and we have only to discuss the implementation of global online set of refereed resources, as proposed in SIGCSE 2002 BOF on Computer Graphics by Steve Cunningham [Cunningham01].

The Online Refereed Resources for Computer Graphics Instruction initiative we understand as graphics education community part of globalisation, in the good sense of the word.

But what are the resources? The relatively exhausting list of ***resource types*** can be found at [Sears01] (SIGCHI official web page). We have grouped similar items, numbered them and shortened a little bit.

1. course outlines, project ideas, degree outlines, concentration outlines, etc., accompanied with success evaluation; is financial assistance needed to help develop the course/concentration/degree and get it started?
2. good books;
3. A list of reports on HCI Curricula (SIGCHI etc.);
4. Web pages with partial or full course content online, including student exercises;
5. A list of good published papers that cover various topics;
6. A list of all relevant journals & conference proceedings available, especially those available on the internet, that could be accessed by students;
7. A list of all relevant professional societies/ chapters;
8. A list of all Conferences in the field;

9. A list of all Web pages devoted to HCI that would be useful for teachers, and those for students;
10. A list of listservs & usenet groups related to the topic
11. A list of online job-listings (to ensure students would be getting the required training);
12. A list of existing standards;
13. A list of prototyping tools, and user-skill requirements for each; A list of various usability testing tools;
14. A set of "design dilemmas" that can be used in the course (interactively);
15. A set of bad-design examples and a set of good-design examples;
16. Design rational artifacts from real projects in industry;
17. A comprehensive list of videotapes covering various topics;
18. A listing of available student internships in industry; A list of available student scholarships, awards, example syllabi, example tests, tool evaluations, outlines of alternative approaches for fitting HCI into existing courses; corporate connections to help find 'real' projects, hardware to support the courses, software to support the courses.

Obviously, some of those resource types should not be developed locally. There are global prominent conference calendars by ACM SIGGRAPH, IEEE, TechExpo, Eurographics (Helwig´s Conference Calendar) [Hauser02], and Upcoming Computer Vision Conferences [Sablatnig02]. For Central Europe area we maintain the specialised one at [Baja02]. So, there arise two questions for discussion in one. Which resource types and how deep content are worth to develop as an online refereed set?

In the following, we will discuss a few types of resources not mentioned above. First, there are included no collections of solved problems (nice examples are [Plastock86], [Strasser85]), no algorithm animations and no open problems. We will not deal with this issue in detail. In Central Europe we have a unique student seminar, Cental European Seminar on Computer Graphics CESCG [Theussl02] which we understand as an invaluable, competition-based educational resource.

We are distant of distant learning. Our intention is not the distant learning, e-teaching or so. It is our strong belief that the essence of the university is the authentic human communication among students and teachers. We would like to support the true classes by advanced additional courseware: interactive applets and animated algorithms and asking more inspiring questions. This is why we can directly start to implement the arising standard body of knowledge: the vividly discussed **ACM Computing Curriculum**. The document known as the Strawman report [Strawmann00] that time, appeared about eleven months before WSCG 2001 conference. The later Ironman Report [Ironman01a], appeared in February 1, 2001. The detailed description of the courses is at [Ironman01b]. Probably the first European discussion on the curriculum was held at the WSCG 2001 in the same February 2001. The disputes, obviously, discussed the previous (Strawman) version. The updated version and the appendix on **CS Body of Knowledge** are in the Steelman Report [Steelman01]. The discussions continue at the ACM Computing Curricula website, as well. Let us quote from the discussion the – evidently, although partially, accepted - opinion of Vaclav Skala [Skala01]: „*Geometric Modeling GV4 and Computer Vision GV11 should be in the CORE, while GV3 Graphic Communication I would see as an elective… Reason: Geometric Modeling GV4 - gives methods, algorithms and data structures, which can be, used also in others fields. Computer Vision GV11 - gives long term knowledge based on math*.“ Indeed, graphics, visualization and multimedia were originally **<u>not included</u>** into the core CS body of knowledge in [Strawman00]. Regardless, the motivation for teaching the graphics and visual computing is obvious.

On the other hand, ACM Computing Curriculum can be discussed, but up to now this is the leading global current CS education standard, maybe under the further development, converging, eventually, to the future „formal“ standard. For the education of computer graphics there are two most relevant units **CS250 Human-Computer Interaction, and CS255 Computer Graphics** (CS stands for Computer Science). Up to now, there are the “official” SIGGRAPH course notes, slides, and other educational tools in the Education part of the webpage, including the computer graphics taxonomy and the slide sets. No respect to Curriculum up to now. Probably the most popular web page on image processing is the Hypermedia Image Processing Reference (HIPR) [Fisher00]. There are at least three huge graphics and vision books available online – by Dave Mount, David Forsyth & Jean Ponce, and Steve Cunningham. None of them reflects the ACM CC structure up to now.

The paper is organized as follows. We discuss the courseware contents (Section 2) and form (Section 3). We review the methodology of the used presentation technologies, giving by the way the incomplete selection of prospective recent projects (Sections 4, 5, 6). Many other educational URLs are provided at [Štugel01], evaluated by the speed of downloading, extent of the material presented and other criteria. Section 7 is a Conclusion.

2. GRAPHICS AND VISUAL COMPUTING

Primarily, the courseware content is given by the contents of classes. Note that there is the usual and frequent practice to teach certain parts of methodology and technology separately, although they may have many common points, like computer graphics and vision. Recent books [Scherer01] and [Leonardis01] make explicit the Common Points or Confluence of Computer Vision and Computer

Graphics. The first Visual Computing book has been written by Markus Gross [Gross94]. At the Institut für Maschinelles Sehen and Darstellen (the original German name) there is taught the rare combination of computer graphics and vision for many years. This has been influenced by many practical TU Graz projects, mainly creating virtual cities in former years, including the record speed modeling French village in the Alps within two days [Leberl96] for the simulation of a rescue action in one of the wars in Yugoslavia. The web notes and slide shows are available for students at [Leberl01], designed and maintained by Markus Grabner.

Noticeably, the early motivation for interactive computer graphics was a simple ***architectonic application*** example in the very first edition of the fundamental textbook by Jim Foley & Andy Van Dam. The motivation example with many open problems formulated for Graz lecture is the ***cybercity technology***, graphics and vision for the common goal. Jed Lengyel …

The efficiency of the fruitful combining Graphics and Vision is obvious when teaching, e. g. fill area procedures along with the border and skeleton algorithms or explaining geometric transformations applied in graphics and vision, as well. This is in contrast with the approach at the Japan and Slovak universities.

2.1 Case Study 1 - University of Aizu, Japan

The University of Aizu Computer Graphics courses start with an undergraduate ***Computer Graphics***.

Lessons are based mainly on well-known book by Foley et al. Van Dam, Computer Graphics, Principles and Practices, Second Edition in C +, additional materials from SIGGRAPH papers and tutorials.

Recitations. Student task is to create a software product for manipulation with 2D images. This product should be similar as for example Adobe Photoshop with the basic functional properties for image processing and manipulation.

The next part of the education is ***Functionally based Shape Modeling***. Shape modeling paradigm based on real functions of several variables is presented. The function representation (or F-rep) defines a geometric object by a single real continuous function of several variables as F(X) >= 0. It combines many different models like classic "implicits", skeleton based "implicits", set-theoretic solids, sweeps, volumetric objects, parametric models, procedural models. Details are given for objects, operations and relations description.

Course Objectives. At the end of the course students should be familiar with the existing types of F-rep primitives, operations and relations. Also students should be able to specify complex 3D objects using F-rep and implement it in C code.

Graduate Computer Animation. In this course, is studied both theory and applications of modern computer animation. It starts from 2D techniques such as keyframe animation and image morphing. Then it proceeds with theoretical foundations of motion control, kinematics and dynamics, procedural, behavioral and cognitive animation. Finally, it provides some examples of application of these tools to fluid dynamics and animal animation. Recitations mean an animation project. At the end of the course students should be able to:

- Understand the basic theory of the motion control, kinematics and dynamics;
- Explain ideas of modern techniques like procedural and behavioral animation;
- Understand research issues of human body and facial animation;
- Design algorithms for basic animation problems.

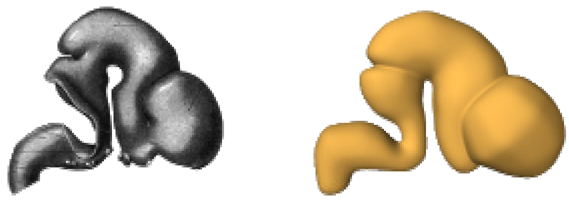

Fig. 1: An example of Undergraduate project. Human Brain Growth Modeling authored by Hirofumu Inoue, advised by Silvester Czanner.

In order to understand human development, realistic models are necessary; one particular model is the human embryo brain. The goal of this project is to create realistic 3D models from artistic drawing as shown in Figure and render animation. Until now, polygonal models were often used to make medical models, but it was difficult to create smooth shape and the animation needed complex key framing when polygon representation is used. Here we propose to use the convolution surfaces to make the brain model and explain our modeling experiences. The advantage of this approach is the smoother shape when compared to polygon model representation and easier key framing by a simple animation of the skeleton of convolution surface.

Note, that the content role of vision in this educational approach is minor. Having strong modeling research lab, the Aizu students are oriented into this direction.

2.2 Case 2 – Comenius University, Slovakia

Although the department name includes computer graphics and image processing, this was inspired by the name of ISO/IEC JTC1/SC24 Computer Graphics and Image Processing. The first Slovak textbook [Ružický95] is entitled identically. The block study program lasts for 3 years, 6 semesters. Together with the teachers from the Department of Geometry and with many external teachers there is the offer of about 30 lectures. The mandatory ones cover ***geometric modeling, computer graphics, ISO***

standards, computational geometry, CAD theory and practice. The elective part offers i. e. OpenGL programming, multidimensional visualization, photorealism, multimedia, fractals, medical applications, DTP, web graphics, data compression, image processing – and computer vision. There is more than 30 very diverse diploma projects a year. One part of them deals with educational support.

Using the language of the standard textbooks, some students keep in touch with the fundamental book [Gonzales93] – if only they elect one class on image processing. The elective vision class is in the same position. The proportion of vision technology is marginal. We have tried to enrich the computer graphics classes by image processing methods, but this was no systematic. Some digressions only.

2.3 Case Study 3 – TU Graz, Austria

The combining of graphics and vision at Graz University of Technology appears surprisingly compatible with the currently proposed curriculum substructure:

Graphics and Visual Computing (GV):

- GV1. Fundamental techniques in graphics [core],
- GV2. Graphic systems [core],
- GV3. Graphic communication [core],
- GV4. Geometric modeling [elective],
- GV5. Basic rendering [elective],
- GV6. Advanced rendering [elective],
- GV7. Advanced techniques [elective],
- GV8. Computer animation [elective],
- GV9. Visualization [elective],
- GV10. Virtual reality [elective],
- GV11. Computer vision [elective].

We took this from the Ironman Report because the link with the Strawman Report does not work… The „core“ and „elective“ markers identify the mandatory and optional parts of educational contents. Two examples follow. Part GV1. **Fundamental techniques in graphics** includes ***Halftoning, Font generation, Representation of polyhedral objects, Scan conversion of 2D primitive, forward differencing, Tesselation of curved surfaces, Homogenous coordinates, Affine transformations, Viewing transformation, Clipping, Hidden surface removal methods, Z-buffer and frame buffer, color channels***. Part GV5. **Basic rendering** includes ***Color models, Light source properties, Phong reflection model, Rendering and shading of a polygonal surface, Texture mapping, Ray tracing, Image synthesis, sampling techniques, and anti-aliasing***. It can be easily seen that there is a significant overlap with the fundamental educational material in [Foley00] and [Gonzales93], which are the key references for the TU Graz Graphics and Vision approach. We can conclude that Austrian students in Graz study the theory and practice from both fundamental books in graphics and vision.

2.4 Curriculum Content Revisited

The educational methodology can be, roughly speaking, based on success or knowledge. Success-based approach gives at the beginning of each class the list of short time goals and at the end there comes – “coming soon” - a guaranteed happyend. This is impossible, for instance, when building the serious theory behind the fractal geometry. The dilemma seems to be bridged by hardening and widening the computer graphics. What approach should dominate the refereed resources?

The increasing power and comfort of the hardware and software tools made possible that Steve Cunningham and other teachers can harden computer graphics, even the introductory course. From the workflow geometry-rendering-display to data-geometrizing-rendering-display-informatin&insight-new data, with possible loops.

This process of empowering the educational environment has both hardware and software drives. Free Maya Personal Learning Edition, AMAYA with other tools from Web3D Consortium and the new generation of hardware accelerators have an impact on content taught. David Salomon excluded from his recent book the **visibility algorithms** and at Aizu University the **rasterisation** went out from the fundamentals.

Mark Bannatyne with co-authors [Bannatyne01] mean that the computer graphics curriculum should address **ethical issues**. Graphics & vision professionals are the speakers of our image creating and consuming world. And some tools are really used for questionable purposes.

On the other hand, student life has the ironic layer based on game (ludus) which system of values is **fundamentally immoral**. The role of jokes and alternative culture in education cannot be formally addressed in the curriculum but the academic life should cultivate and tolerate acceptable forms in support of creativity. The popular videos created by students for the Spring Conference on Computer Graphics annually, the Master Edi Groeller tradition in Vienna and the Videa conference story give three examples how computer graphics and vision academic people can be creative, so to say, out of everyday banality. Should the educational content ignore this layer of reality? The HCI people have at the official SIGCHI page the part dedicated to stupid designs…

The content question can be discussed from many aspects. As we said earlier, we will not deal with this. The current contents of ACM CC gives the advantage to synchronize the global efforts. This value, at the moment, is more important than any neverending discussions.

3. ONLINE COURSEWARE FORM

Evidently, the crystallization of fundamental graphics and vision educational material is completed, at the curriculum level, at least. Right time to prepare the appropriate courseware for computer science students. Note that the "standard" content can be seen as stabilized in many other older books: [Hearn90], [Szirmay-Kalos95], [Watt92], [Watt95], [Hill90]… and [Watt00].

There arises the question of the form of the courseware. Dave Mount at http://www.cs.umd.edu/~mount/427/ offers online a printable book. Remarkably, the text contains recommendations to read another books, namely and mainly by Hill [Hill90]. This is evidently not a form of online solution, but a distribution method. Some professors publish high-quality slide shows, e. g. Nicolas Holzschuch [Holzschuch97]. The SIGGRAPH Visualization Curriculum by Gita Domik offers all the sources. Ken Joy at Davis has popular Geometric Modeling Notes.

There are at least two very successful approaches, which we can characterize as **interactive webtextbooks**. (We measure the success by the response of our students.) One of them is the slideshow [Leberl01] containing more than 1000 slides, connected directly via hypertext with the English text. Another approach shows the Slovak text illustrated by interactive applets [Štugel01]. The project originated as the diploma work by Juraj Štugel at the Comenius University, supervised by Andrej Ferko. The teacher or the student can change the input or display, e. g. Bézier knots positions or the size of pixels.

We see the improved possibility to combine both successful and extend them by the knowledge tests and the algorithm animations. We cannot accept two very different approaches. There is a very interesting solution using Virtual Reality by Wen-Tsai Sung at National Central University, Taiwan. At the site [Sung00] there is the project WebDeGrator, a constructivism based educational VR tool. In general, the VR hardware is not frequently available; therefore we opt for the standard PC platform. The constructivistic educational paradigm is both very suitable for VR and interesting educational approach, too. The second approach we do not adopt is simply to tape the lecture of the professor and put it on the web. Even, we are not satisfied by a quality of communication with lectures of famous professors broadcast on TV or Internet. We have taped excellent speakers and offered the tapes to students… And there are taped vision tutorials – in the library, on the shelf.

Our experienceleads to the following combination of approaches. The detailed specifications for each subtopic (e.g. GV2. Graphic systems) should follow the identical scheme. Each subtopic is rigorously defined, the method is explained by text and image, the static or dynamic example is provided, the tests of the knowledge are done and evaluated (in Slovak, German, or English). If available, the links to other web sources are given. If possible, the algorithm animation will be created and provided.

4. COMPUTER GRAPHICS APPLETS

The top prominent web page on graphics education should be the SIGGRAPH page, including the HyperGraph educational project and a selection of SIGGRAPH course notes. Patrick Min at Princeton University has developed two groups of applets - JAR versions (for Netscape 4 and up: ***Bézier applet, 2D Transforms applet, 3D Viewing applet, Cohen-Sutherland clipping applet, and Lighting applet***) and in separate class files (for Netscape 3: ***Bézier applet, 2D Transforms applet, 3D Viewing applet, Cohen-Sutherland clipping applet, and Lighting applet***). Last modified on Feb 9, 2001. The ten applets are at the ACM education web page [Min99]. They illustrate five parts of the graphics computing.

Tens of applets are at [Štugel01], based on [Ružický95] the first Slovak book on computer graphics and image processing. These interactive applets were awarded in the international SUN Company competition and in fact they recorded many visits after being published. Their interactivity is highly appreciated by frequent visitors. Juraj Štugel at Comenius University developed the interactive page, which currently became very probably the most popular page among Slovak and Czech students of graphics. To our best knowledge, his is the largest group of computer graphics education applets. E. g., there are 15 applets for raster conversions: ***point drawing, DDA algorithm slope value, DDA algorithm increments, DDA algorithm slopes, Bresenham algorithm with zoom, Bresenham algorithm for moving endpoint, circle drawing and rasterizations by four methods, ellipse drawing, pixel neighborhoods, fill area, scan line demonstration, and scan line algorithm***. There are 7 applets for clipping, 10 applets for various curves, 4 applets for surfaces, 10 applets for elementary image processing, 10 applets for transformations, 5 applets for projections, 3 applets for solid modeling, 5 visibility applets, 14 applets for color and illumination, 3 texturing applets and several fractal applets. This applet set rapidly grows. Recently, Pavol Kovac has appended the fractal geometry applets. Boris Burger prepares the real-time rendering page. Tens of very remarkable applets are at the courseware pages of Andy Van Dam, Brown University [VanDam01] and Tomoyuki Nishita, Tokyo University [Nishita01]. Our courseware should provide links to graphics and vision applets worldwide.

The try to provide more links applies for any resource types, not only for applets.

5. ALGORITHM ANIMATION

Marc Brown at Brown University wrote his classical book [Brow87] in 1987 and Alejo Hausner and David P. Dobkin give the recent informed representative survey [Hausner99] - Making Geometry Visible: An Introduction to the Animation of Geometric Algorithms. Regardless, there are the well done and well working principles and some excellent projects, even there is a remarkably ambitious try to make algorithm animation automatically. However, the use of algorithm animations in education is rare up to now. Instead, the animations showing the algorithm results are widely used. The example for this approach is the HyperGraph, on-line educational project [Owen01], at ACM SIGGRAPH page. The essence of methodology introduced by Marc Brown is to show the algorithm in both static and dynamic forms, using multiple windows for simultaneously viewed algorithm work. The audience shares code or pseudocode, history of main data structures, input, processing, and output. The experience with animated algorithms shows the superiority of this way of teaching. By the way, the teacher in the class animates somehow the algorithm explained. Markus Grabner at TU Graz has created the scenario [Grabner01] for animation of the Phong illumination model and Phong shading by visualizing all the input parameters using advanced visualization techniques. The key idea is to show the audience the difference between illumination model and shading. The explanation will be based on [Hearn90] and other books. At Comenius, there were completed several diploma projects in algorithm animation – 2D graphics, visibility algorithms, routing algorithms, radiosity in flatland, among others. The algorithm animations by Zuzana Cerneková [Cerneková99] are routinely used in the classes. Note that the approach is not suitable for graphics only, [Crescenzi98] reports on a „Multi-Platform Collaborative Tool for Teaching Graph Algorithms“, but graphics, unlike other disciplines, provides itself the appropriate tools for animation. The movie means usually fun. Our intent is not to make show but to teach ideas for image synthesis and analysis. This position holds for more than animations. The fundamental role of each form of courseware is to support the true classes.

6. WEB LINKS, OPEN PROBLEMS AND TESTS

We recommend following strategy of [Štugel01] to introduce the page content by providing as many as possible pointers to other similarly oriented or concurrent pages. In addition, to any topics should be added the list of open problems. They inspire the best students, some of graphics ones can be found in [Chazelle96], [Goodman97]. The courseware should contain the updated collection of open problems. Maybe, even including the eight millennial open problems in mathematics donated by the eight millions dollar rewards. At least one of them, the famous P=NP open problem could belong to the far horizon of challenges known to graphics and vision students and graduate students worldwide.

The knowledge tests are very suitable, even unavoidable, tools for providing the feedback by simple fill-ins or more intriguing questionnaires. The success-based learning [Ericson98] requires the immediate feedback. (Werner Purgathofer gave to his students not only graphics problems, just for keeping them fresh and open minded. For instance, give the next number in this sequence: 10000, 121, 100, 31, 24, 22, 20, 17, 16, 15, 14, 13, 12, 11, 10. The answer is based on expressing the decimal number 16 in different number systems.) While open problems stimulate the far future professional orientation and the touch with the emerging inherent problems of the field, the immediate knowledge tests support the short time progress self-evaluation of the webtextbook visitors.

7. CONCLUSION

The unlimited creativity of students seems to be the most valuable advantage of academic institutions over the industrial ones. The creation of courseware under the supervision of the ACM SIGGRAPH and Eurographics referees may be targeted to feel students free to create for students, for themselves and for their younger colleagues. The up to now developed components of the interactive courseware inclining to the open source „bazaar“ international project could fit with the recent curriculum initiatives.

From the point of view of efficiency, our up to now efforts focused – in paralel - to the common initiative by ACM SIGGRAPH and Eurographics to contribute to the semantic web and know-how quality by the online refereed resources for computer graphics and vision instruction. The growing international team can consist of students and advisors. The work can be done in a highly parallel mode. The bazaar approach and the open source license policy will be applied [Raym01]. All the slide shows, applets, animations and other courseware materials will be available in the languages provided by the authors. The implication of the bazaar development is that there is no rigorous scheduling of the project. In the future, we will focus to particular parts and modalities of the courseware.

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