Resources for CG Courses

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Abstract

This paper briefly describes three different Computer Graphics (CG) modules along with some considerations about the resources used in teaching them. This provides a basis for some general thoughts about the provision of resources for CG modules, which then leads to a loose categorisation of types of resources into *raw materials* and *perspectives.* Examples of each are listed. Finally, recommendations are given for future resource generation.

1. Introduction

The library of Alexandria (see http://pharos.bu.edu/Egypt/Alexandria/links.html) was filled with collections of papyrus scrolls and provided a great resource for researchers. Now libraries proliferate. But what of future libraries or resource bases? Change. Brought about by perhaps the greatest and worst library of them all - the WWW. Panacea? No. Much of the information on the WWW is not good quality. We need to separate out the existing quality material and to develop new quality material. We also need examples of how to use this.

Consider the following scenario: You have just been given the syllabus for the CG module you will be teaching: 15 week semester - 10 weeks teaching, 2 weeks reading/revision, 3 weeks exams. You thus have 30 contact hours (say 20 lectures and 10 tutorials) to enlighten. You need resources and your students need resources. Of course the type of resource depends on the style of teaching to be used on the module (and the size of the class). It could be self-study or a traditional lecture series or, more probably, a mix. And the resources to be used could be books, journal papers, magazine articles, conference proceedings, slide sets, software (e.g. POV-Ray), lecture notes, images, CG company literature, videos, WWW sites, Usenet newsgroups, etc. What is available and how do you decide what to use? Are current FAQs useful? How do you make use of what there is? And what would you like to be available? The rest of this paper attempts to consider some of these questions. It will concentrate mainly on the teaching angle, but many of the suggestions are equally valid for a research resource base.

First, three different CG modules will be described along with considerations about what resources could be used in teaching them. This will be drawn from experiences on modules that used to be available in the Dept. Comp. Sci, Univ. Sheffield. This will provide a source for some general themes about the provision of resources. From this a loose categorisation of types of resources into *raw materials* and *perspectives*, along with examples, will be given. Finally, some recommendations for future resource generation will be suggested.

2. Resources for a module

We shall consider three types of graphics module. CG I is an introduction to computer graphics concentrating mainly on 2D, but discussing extensions into 3D where appropriate. CG II is a first module on 3D CG looking mainly at rendering techniques. CG III is an advanced module looking at modelling techniques, animation and scientific visualisation.

At Sheffield, each Computer Science undergraduate student on a 3 year degree programme takes six modules (they are actually half-modules but we shall refer to them as modules) per semester and there are two semesters of 15 weeks in each academic year. Each semester is split into 12 weeks teaching time and 3 weeks of exams. Each module involves 30 hours contact time. None of the CG modules are compulsory. They are chosen in competition with other modules.

The three CG modules we will look at will be used as tangible examples to demonstrate how an existing resource base can be used to provide supporting material for teaching. In each case, we start with the syllabus, aims and objectives being given and a decision having been made that each module will have an assignment and an examination.

Perhaps the first decision made is what angle/perspective an individual lecturer would put on the particular module. In the case of the following three modules, each was taught in a different way and, to a certain extent, different resources were needed.

2.1 CG I: Introduction to CG

This module covers a range of introductory CG topics (see Figure 2.1), and the recommended text books are FOLE90, FOLE94 and HILL90. The module is mainly populated by second year undergraduates, however there are also some dual honours students (mainly Maths/Computer Science) in their third year and some MSc students (on a one year course) who are allowed to choose it as one of their options. Many of the MSc students are overseas students, who are a few years older than the undergraduates and this adds to the richness of the group. In 93/94, there were 41 second year Single Honours undergraduates, 11 third year Dual Honours undergraduates and 24 mature, overseas MSc students.

Graphics environments: components of current systems; input/output devices; graphics standards and languages;
Basic two-dimensional techniques: linear transforms; coordinate systems; the two-dimensional viewing pipeline; clipping; interactive techniques - pick-and-drag, rubberbanding; raster techniques - line drawing, region filling, halftoning;
Applications of two-dimensional graphics: image processing; computer-aided design (CAD) - parametric curves; modelling natural phenomena - fractals, L-systems; animation - interpolation, morphing; scientific illustration and simple visualisation.

Figure 2.1 Outline of CG I syllabus

The assignment for CG I involves teams of students developing CAL systems (using Asymetrix Toolbook) on particular topic areas related to the module. These separate systems are chosen to match the topics (or chapters) of the module lecture notes and together form the chapters of a CAL 'book'.

The aim of the module is to use CAL as the catalyst for involving students in their courses more. The premise is that a rewarding, active learning experience can be achieved when students develop their own personal CAL workbook for the module they are actually taking. Such students have to (i) assimilate information and then structure it for others, (ii) devise assessments and thus learn how to assess others, and (iii) work in teams and thus foster management skills (see MADD94 and MADD95 for more details). The final aim was to combine the chapters to make graphiCAL, the complete CAL book. The students are thus a bootstrapping resource for the following year's module.

For this module both the lecturer and the students need images to illustrate their lecture and their CAL workbooks respectively along with a good library resource for other material. However, the use of images is perhaps different. The lecturer can freely photocopy illustrations or images (if he can find them) for use in lectures. However the student cannot do the same for a CAL workbook. There are copyright issues to address. For this exercise many of the students initially ignored these issues. Thus a useful resource for a module such as this one would be a free image bank.

The idea of students as multimedia composers could be extended. For instance, a(n inter)national competition could be sponsored which required students to develop WWW materials for particular CG topics.

2.2 CG II

This module is constructed around Watt's book [WATT93] on 3D CG and focuses mainly on rendering techniques (see Figure 2.2). The (approx. 25) students thus have a good set of notes. To a certain extent, this gives more freedom in course delivery. It allows a style to be adopted which uses a wide range of material to complement and contrast with Watt's viewpoints. For instance a useful resource was an art&design book on drawing perspectives and shadows. However, as with CG I, a main concern is finding the right illustrations for particular topics which involves much legwork in the library searching through books and journals. A particularly useful resource here was the Shutterbug sequence in Foley et al. [FOLE90] which was used as the basis for a lecture introducing the complete module.

Basic three-dimensional theory: transformations; polygon mesh models and wireframe representation; other modelling techniques; viewing systems;
Reflection models - Phong, Cook and Torrance, illumination models;
Shading and rendering techniques- Gouraud, Phong, HSR, Z-buffer;
Anti-aliasing techniques;
Realism: shadows; texturing;
Ray tracing;
Radiosity.

Figure 2.2 Outline of CG II contents

This course also introduces fairly detailed programming techniques to the students. The assignment uses in-house software (written in Modula-2) called MRender which is a Z-buffer-based renderer that handles polygon mesh models and uses Gouraud interpolative shading. The students have to enhance this program by first adding Phong interpolative shading and then choosing from a range of alternatives, e.g. implementing procedural texturing, implementing a shadow technique, investigating alternative viewing systems, investigating alternative illumination models.

2.3 CG III

(For 1995/96 CG II and CG III have been collapsed into a single module.)

Figure 2.3 gives an initial plan that was produced for this module. It shows the emphasis on modelling and animation techniques that was the particular individualism placed on the initial syllabus. With a fairly small class of approx. 25 students, an approach involving more discussion of topics could be attempted.

The module used a wide range of resources including a seminar by a PhD student and a demonstration of software produced by a previous undergraduate student. It was also possible to hold a number of discussions around particular research papers. And of course the subject material lent itself to using video clips as illustrations.

For the assignment the students were given the choice of implementing a simple animation tool for designing fly-bys of simple wireframe objects or developing a Toolbook-based teaching tool for one of the topics on the module.

Week 1
Notes: 13. Geometric Modelling ([SNYD92], chapter 1)
Notes: 14. Parametric Representation (chapter 6 of [WATT93], ch. 6 of [WATT89], ch. 3 of [WATT92])
Lecture 1. Shape Representation
Lecture 2. Bezier patches
Tutorial: Review of semester 1 project

Week 2
3. B-Splines versus Bezier patches, polygons versus Bezier patches
4. Free-Form Deformations (FFDs) (see [SEDE86], ch. 6 of [WATT93], ch. 17 of [WATT92])
Tutorial: (i) comparison of modelling techniques (ii) introduce assignment, group assignment, choice of projects: Toolbook on modelling techniques or tool for designing animation fly-bys of simple 3D objects.

Week 3
Notes: 15. Natural Phenomena (ch. 12 of [WATT93], ch. 11 of [WATT89], ch. 7 of [WATT92])
5. Procedural modelling, terrain, plants and trees; Video: William Latham's work
6. Fournier's taxonomy (see [FOUR89])
Tutorial: discussion of Fournier's taxonomy

Week 4
Notes: 16. 3D Animation; Low-level motion control (ch. 13 of [WATT93], ch. 13 of [WATT89], ch. 15 of [WATT92])
Notes: 17. Articulated Structures (ch. 16 of [WATT92])
7. Low-level control methods; Video: TV logo sequences and fly-throughs.
8. Articulated Structures; Video: walking human figures; Software demonstration: robokit (undergrad project)
Tutorial: logo sequences and TV programmes

Week 5
Notes: 18. Animating Deformations (ch. 17 of [WATT92])
9 Scripting FFDs, Facial Modelling. Video: PDI locomotive
10. Implicit Surfaces - seminar by Agata Opalach
Tutorial: Assignment

Week 6
Notes: 19. Procedural Animation (ch. 18 of [WATT92], ch. 12 of [WATT93], ch. 11 of [WATT89])
11. Waves, cloth - use in fashion industry, bring in texture mapping material from semester 1
12. Particle systems and flocking models. Videos: eurythmy, particle dreams
Tutorial: Identification of animation techniques used in a selection of short animation pieces - use PIXAR video.

Week 7
Notes: 20 Colour (ch. 14 of [WATT93], ch. 14 of [WATT89])
13. Colour in computer graphics - AGOCG slides
14. Colour spaces and standards
Tutorial: Assignment

Week 8
Notes: 21. Visualisation in Scientific Computing (ViSC) (ch. 9 of [WATT93], ch. 13 of [WATT92])
15. Visualisation; Video: fluid dynamics example
16. Volume rendering
Tutorial: Surfaces and volumes - pixels and voxels

Week 9
17. Marching cubes
18. Visualisation systems, applications. Video: visualisation 'glitz'.
Tutorial: Visualising data sets.

Week 10
19. Spare lecture
20 and tutorial. Review semester 1 and semester 2 work. Video: SIGGRAPH 93.

Figure 2.3 Initial plan for CG III

3. General themes

A general theme which emerges from the previous section is that materials need to be flexible so that a lecturer can individualise a module, i.e. he can stamp his own identity on it. Of course a 'rigid' resource such as a broadcast video lecture could still be used flexibly by using it as the basis for a small class discussion. The emphasis is on the lecturer individualising the material as he puts his perspective on it. The resource base needs to provide materials that make it easy for a lecturer to do this.

The main practical resource that is needed is an image bank. This raw material would support both lecturers and students. Of course, it would need structuring and an indexing system or search engine would need to accompany it. Such an image bank would support the 'standard' lecture which has a place in any course as it gets a lot of material over to a large audience quickly, as well as offering a demonstration of (an expert's) scientific thinking as it shows the distillation process undertaken by the teacher. The image bank offers a raw resource that a lecturer can use as a building block when preparing a lecture.

Another resource is the set of basic notes for a student. This could be in the form of a book (a good example is [WATT93]), the lecturer's own notes or an on-line set of material, e.g. a CD-ROM based system such as HyperGraph [OWEN92]. Added to this would be advanced material which could be used for self-study or as the basis for a class discussion, e.g. Fournier's taxonomy for modelling natural phenomena [FOUR89]. We need to be careful about producing material on CD-ROM though. A book is still preferable to passive on-line reading. The CD-ROM must offer what it is best at, namely-interactivity.

Given the basic notes and accompanying images, another useful resource is demonstration software which can again be used for self-study or in lectures. A demonstration of an algorithm (e.g. see [SCHW92]) is often better than an image and an explanation.

The general conclusion is that quality building blocks are needed (such as image banks) along with self-contained material (such as commentaries on benchmark papers by leading teachers/researchers) offering particular perspectives to agree with or to contrast with other material.

4. Types of resources

We can loosely identify two types of resource: *raw materials* (e.g. an image bank) and *perspectives* (e.g. self-contained sequence of images on a particular CG topic). The raw materials are used as building blocks in constructing perspectives. A perspective is a particular viewpoint on a CG topic. The perspective offers both the viewpoint and implicitly a 'record' of scientific method and the creative thinking of an individual. The following lists present examples of each:

Raw materials

- an image bank;
- sets of multiple choice questions on topics - WWW form-based;

- brief descriptions of all CG teaching/courses in the UK and contact e-mail addresses/WWW links;
- list of CG exam questions;
- book reviews;
- brief description of current CG or CG-related research groups around the UK, with contact e-mail address or WWW link;
- s list of major CG groups in Europe (and the rest of the world) and contact e-mail addresses. This would be useful for trying to set up European projects;
- diary of CG events in the year;
- pointers to other contact lists, e.g. Alan Chalmers at Bristol (alan@cs.bris.ac.uk) keeps an Eastern Europe contacts directory for CG;
- list of CG companies; Perhaps a section for companies to advertise their CG products for which they could be charged. These could include short demos of software;
- list of all CG PhD projects being undertaken/successfully completed in the UK;
- list of Grants, etc. available for CG work or for conferences, etc;
- descriptions of useful (free) software that could be obtained via ftp. Need to keep a ‘best of’ list as there is too much in current CG FAQs.

Perspectives

- linked, sequence of slides with minimal text on a particular topic, e.g. rendering (perhaps by A.Watt), texturing (perhaps by J.Blinn); An alternative is a matrix of images to illustrate parameter changes within an algorithm, e.g. the 20 spheres examples (see WATT93];
- (inter)national competition (AGOCG-sponsored) amongst students (groups) to develop best n-page WWW materials on a particular CG topic;
- a (virtual) CG museum - historical & contemporary exhibits (use WWW&VRML);
- commentaries on books;
- commentaries on benchmark papers;
- articles on graphics teaching in different countries;
- controversial essay on a topic.

WWW-based demonstration software for particular CG topics and algorithms could be considered as raw material. This could be combined with a commentary on a book chapter to create a particular perspective. In addition, we can see that perspectives themselves can become raw materials to be used in creating other perspectives.

There also has to be something that structures or binds these materials together. This could be done via the WWW (AGOCG has already begun a site that describes their activities and gives links to other material), or using a CD-ROM based system such as HyperGraph. But perhaps the issue of CD-ROM or WWW is not really an issue as a student could download WWW material to a local hard disc on portable PC. Or, alternatively, the two could be combined: the raw materials could be recorded on a CD-ROM and this could then be used like a local cache - the WWW material would address the CD-ROM locally.

5. Recommendations

We can break the recommendations down into three areas: raw materials, perspectives and a uniting structure.

First, existing quality raw materials should be identified and collected; then new raw materials should be developed. An immediate example would be the creation of a WWW-based image bank supported by an indexing structure and a search engine. A lecturer could then order or download copies of images or, alternatively, buy the collection on CD-ROM. A suggestion for the population of this image bank would be every figure and colour image from every SIGGRAPH proceedings and from every major CG book for the last five years (although there are obvious copyright problems with this!!).

Secondly new perspectives should be developed. An immediate example could be the commissioning of sets of slides (again to be WWW-based) on particular topics. These would be based around illustrations with minimal text. For instance Watt could be asked to do a set on rendering techniques and Blinn could be asked to do a set on texturing methods. Another example would be commentaries on benchmark papers for particular topics.

Thirdly, a structure needs to be developed to bind it all together. For example the AGOCG WWW site could be developed further or a second generation HyperGraph could be developed. Whichever approach is adopted, the creation of a WWW virtual library/museum of quality resources can only benefit the CG community.

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