Computer Graphics and Multimedia: Course Design for an E-Learning Platform

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Summary

Work practices have changed as a result of the use of information and communication technology. Students and faculty need to be prepared for this new contingency in the work environment. Universities have to adapt their curricula to supply employers' demands for skilled graduates.

We must rethink university education in general and course design in particular in light of the new work practices. I integrate recent findings in pedagogy, in computer graphics research and information and communication technology to offer a novel way of teaching. In my thesis, I present a computer graphics and multimedia course based on leading-edge technology.

I review some innovative ways to teach in the computer graphics field and elsewhere. There is a tendency among educators to have students take an active role in learning and even in assessment. Students are encouraged to take a deep approach to learning. As a result, the roles of teachers are changing from people who transfer their knowledge to students to managers, mentors and facilitators of learning.

The field of computer graphics is a discipline that is used extensively in a lot of computer science areas. It is viewed as an integral part of every computing curriculum. The multimedia applications in conjunction with the Web are increasingly becoming part of the field.

The possibilities in computer graphics are advancing rapidly as new application areas emerge and more computing resources become available. More bandwidth, wireless devices, and faster graphics chips make the progress tremendous. Students need to acquire and grasp the basic concepts behind computer graphics to understand their more advanced applications.

Most e-learning will take place over the Internet, using Web technologies. E-learning will be deployed company-wide in intranets, or with extranets where external partners and suppliers have access to learning resources. Internet technology is involved in all these scenarios.

The key to success for e-learning on the Web is to provide interoperability and therefore conform to set standards. In doing so, universities will be able to exchange learning objects and process them automatically. Portals that integrate data from different sources are easily deployable through the use of metadata.

The course presented consists of a lecture part, tutorials, and projects. A review cycle is established and the students present their projects' results. They can collaborate with their peers accompanied by a Web application. Students and faculty

can continually update the materials. Furthermore, students can use the materials on the site to start carrying out their own research.

The course presented in this thesis combines leading-edge technology with the latest findings in pedagogy. In my thesis, I have tried to put together the various pieces needed for designing and implementing an electronically supported course about computer graphics. This and other issues that go along with e-learning were put into broader perspective.

Für meine Eltern

Contents

Preface

This thesis started with my visit at the Centro Polytechnico Superior at the University of Zaragoza, Spain under the auspices of the Erasmus program. Besides learning about the principles of computer graphics at the GIGA group of the CPS, I had the chance to learn a lot about Spanish language and culture. My stay in Zaragoza was a valuable experience, and after three months under the Spanish sun I even gained some color.

I will always remember the hospitality of the people from the Iberian Peninsula. I will never forget the folks I was living with in a piso and am grateful for the great farewell party. I owe a lot to the international crowd who made the stay so pleasant and interesting. I especially enjoyed the long and thoughtful runs with Julia that helped me build up endurance and brought some ideas on how to carry out teaching,

Back in Würzburg, I needed some time to make the transition back to Germany. After that, I continued to write the thesis and to implement the prototype I present in this thesis. Time passed quickly, and now the fruits of the last months' work are in evidence. A lot of people supported me during the last few months while I was working on this thesis.

First of all, I'd like to thank my advisers, Prof. Bernd Breutmann and Prof. Dr. Pedro Latorre Andrés for making this thesis possible, their patience, and valuable ideas and insights.

Thanks go to Dominik for providing his LaTeX template. Thomas also provided a template, and quick and valuable support in my struggle with LaTeX. His emails were great and I hope we stay in contact even when he's gone to California. Furthermore, I am in debt to Mike for his offer to host my application on his DSL server and suggestions on the software and the text, and to Casey for last-minute suggestions on a draft of this document.

The remainder of the document is organized as follows:

Chapter One aims to answer why learning matters in the new economic climate and how enterprises tackle the challenge to manage knowledge acquisition and dissemination. This has an impact on university teaching.

Chapter Two outlines how teaching and assessment can be carried out. Students should acquire new knowledge based on their previous experience and also develop teamwork skills.

Chapter Three gives an overview of state-of-the-art computer graphics technologies. It presents and defines major standards, software packages and applications of today's computer graphics technology.

Chapter Four looks into the technology side of e-learning. E-learning is closely tied to Web technologies because most e-learning courses are deployed via intranets or the Internet.

Chapter Five presents the material of the course including projects, a proposed schedule, and a shared workspace application to manage all the course-related materials.

Chapter Six summarizes the thesis and a gives short outlook into possible future areas of interest.

This document was written in XML and converted afterwards to LaTeX. It is available online through my web page at http://harth.org/andreas/thesis/ in both PDF and HTML format.

A.H.

Würzburg, January 2003

Chapter 1

Does Learning Matter?

1.1 The Virtual University

Businesses have already adjusted to the new realities of the information economy. Now universities have to make a transition and offer innovative curricula. They have to adapt to the changing needs and demands of the marketplace for skilled workers. The change impacts not only the teaching process but also students' learning.

Universities should teach not only knowledge relevant to the respective field, but also generic skills (Chung, Harmon, and Baker [22], Glaser and Baxter [26], Hamid [27], Luca et al [37]). Mastery of technical content is no longer sufficient. Students need to "learn how to learn" in order to be prepared for the new realities of the workplace. They need courses that reflect the new requirements of learning in the information economy. Students have to work in teams and must actively pursue their learning. New course formats may cause anxiety and frustration for the students at the beginning as they have to get acquainted with new learning methods.

Arnal et al [9] have argued this point in the context of work practices. "Like many other types of innovation, changes in work practices do not bring about their results immediately. Both employers and employees need to learn how the new practices can be used effectively. As a consequence, it is perfectly possible that their introduction will reduce the level of productivity in the short run". They found evidence that use of technology and new work practices complement each other. Highest productivity gains were visible in countries where both were combined and implemented as bundle — and not separately.

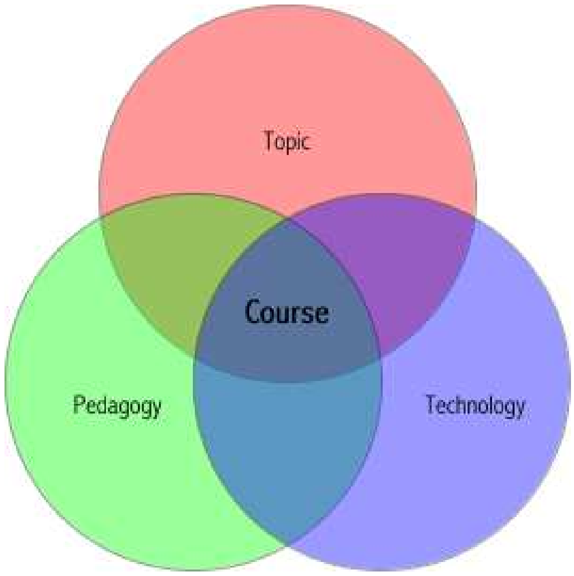

Figure 1.1: An e-learning course is the overlap between topic, pedagogy, and technology

The above insights have implications for the design of university courses. Course designers cannot view technology or pedagogy in an isolated way. These disciplines must be combined to maximize the learning outcome for the participants of a lecture. The dimensions that influence the course design are the topic, accompanying pedagogy, and technology (Figure 1.1). Consequently, this document consists of three building blocks: pedagogy and teaming issues, computer graphics as the content, and technology that supplies students with means of communication and helps them acquire hands-on experience in the graphics field.

1.2 Knowledge Management

Knowledge management's goal is to provide employees with the knowledge they need, just in time, at their fingertips. Learning is important for every worker and should influence the culture of the whole organization. The willingness and the ability of the employees to share their knowledge, ideas, and experience also matters a great deal.

Organizations need to be geared toward learning as it becomes an ultimate prerequisite for the individual worker. Companies want to leverage their knowledge and the wisdom of their workforce by means of knowledge management.

There are two knowledge management cultures: IT-based and communication-based. Hansen et al [28] identified two distinct strategies either based on informa-

CODIFICATION	**PERSONALIZATION**
Provide high-quality, reliable, and fast information-systems implementation by reusing codified knowledge	Provide creative, analytically rigorous advice on high-level strategic problems by channeling individual experience.
People-to-documents: Develop an electronic document system that codifies, stores, disseminates, and allows reuse of knowledge.	Person-to-person: Develop networks for linking people so that tacit knowledge can be shared.
Invest heavily in IT; the goal is to connect people with reusable codified knowledge.	Invest moderately in IT; the goal is to facilitate conversations and the exchange of tacit knowledge.

Table 1.1: Strategies for consulting firms to manage their knowledge (adapted from Hansen et al)

tion technology (codification) or communication (personalization). In the former approach, knowledge in the form of best-practice documents is codified and stored in databases, where it can be accessed and used by anyone in the company. The latter approach sees knowledge as closely tied to the person who developed it. It is mostly shared through person-to-person contacts. The intent of this strategy is to foster and stimulate communication in the company. Technology's role here is limited to helping employees communicate with and locate co-workers that have knowledge in a specific area (Table 1.1).

Learning organizations pay attention not only to the learning of one single employee. They try to understand the connections and implications of learning for the organization as a whole. Individual knowledge and group knowledge are important and need to be increased and retained.

Bartell [10] compiled a learning organization checklist for enterprises that engage in knowledge-intensive work. The company culture of learning organizations should be influenced by the following values:

- Learning is incorporated into everything people do.
- Learning for learning's sake is encouraged and rewarded.
- The organization supports teamwork, creativity, empowerment and quality.
- Employees are trusted and encouraged to choose courses that they need.

- People with different job titles from different departments learn together.
- The organization promotes mentoring relationships to enhance learning.
- Learning is an integral part of meetings, group work, and work processes.
- Everyone in the organization has equal access to learning.
- Mistakes are learning opportunities.
- The organization encourages cross-training and rewards employees that learn a broad range of job skills

The way workers learn, collaborate, and communicate has changed. Virtual teams are part of the new work realities. This kind of collaboration has become critical for companies' survival, partly because of the trend towards corporate restructuring. Virtual teams consist of "people who share a common purpose or goal and interact interdependently within a larger organizational setting. Unlike their conventional counterparts, virtual teams can be dispersed across organizational, space, and/or time boundaries" (Lurey [38]).

Learner communities do have similar characteristics. Today learners meet at a particular place at a particular time to work on their assignments or prepare for examinations. New ways of teaching can help students prepare for this type of collaboration. Workers need to acquire these skills either as students during their university education or later as graduates at work.

1.3 Learning in the Future

Technology is becoming an integral part of labor and can also be used to enhance learning. There are visionary people that advocate carrying out learning in a completely technolgoy-based manner. As a result they want to make instructors and faculty obsolete and replace them with computers.

Bork [16] tries to project future environments for learning with the aid of science fiction. He describes scenarios from four science-fiction books on how learning could take place in the years to come. In all the scenarios he describes students interact with computers via natural language. They speak with their learning program and it continuously adapts to their needs, offering a unique learning path for each person. Students can ask questions with no restrictions on the form of the reply. Instructors or fellow learners are not needed any more in this "brave new learning environment".

To be sure, education should prepare for work. When you consider the realities of today's jobs with the increased emphasis on team culture, these scenarios really are science fiction. Learning needs to be balanced, using technology, but not solely relying on it. Still technology must be an essential part of learning because it is impacting the way people work.

Arnal et al [9] suggest that there are different requirements for workers in the knowledge-driven economy. A new type of skill set is required with the increasingly complex and interconnected economy. Workers need the ability to handle complexity. They must manage functioning on their teams.

Workers need the ability to acquire new knowledge when needed. With this comes the requirement to forget old, unused knowledge in order to provide space for the new knowledge. It is hard for people to replace something that is already there with some new learning. Nevertheless this processes will play an important role in the future of labor as learning becomes an indispensable skill in the knowledge economy.

Conclusion

Work practices have changed as a result of the use of information and communication technology. Students and faculty need to be prepared for this new contingency in the work environment. Universities have to adapt their curricula to supply employers' demands for skilled graduates. Management must also be concerned with the new shape of work culture. The further learning of employees who work in knowledge intensive areas has to be facilitated, managed, and fostered to help companies gain a competitive edge.

We must rethink university education in general and course design in particular in light of the new work practices. I integrate recent findings in pedagogy, in computer graphics research, and information and communication technology to offer a novel way of teaching. I present a computer graphics and multimedia course based on leading edge technology and on an approach to peer learning for students of computer science.

Chapter 2

Knowledge and Learning

Introduction

Schein [23] argues that every time learning takes place an outside motive is responsible for the learning event. According to his theory there are two ways to increase people's ability to learn: either by threatening them or by creating a safer environment for unlearning and new learning.

Learning and the change that accompanies it is often more a "source of frustration than achievement". Guilt and anxiety are associated with radical relearning. Schein draws some parallels between learning and brainwashing because indoctrination is involved in both of them: "Depending on the content of the messages, you called it brainwashing and deplored it — or you called it learning and approved of it" (Schein [23]).

The design of the learning facilities — schools, universities and corporate training centers — clearly reveals Schein's notion. Teachers have the power to create pressure to learn by grading, yet they try to motivate students by other means as well. Nevertheless, students often dislike lectures because they feel the material is either outdated or not relevant to their field. They are limited to the given range of topics and have little opportunity to influence what is taught, let alone how grading or assessment is carried out.

Universities should strive to become as student-friendly as possible. A positive environment for learning increases students' willingness to learn. Awarding students more freedom is a risky approach, but this method provides an opportunity to yield higher results.

2.1 Taxonomies of Knowledge

We need to look at the existing types of knowledge to understand how teaching can be carried out effectively. There are different views on how knowledge can be categorized. When we know what different types of knowledge exist, we can select what students should learn and align the goals and the design of the course accordingly.

2.1.1 Tacit vs. Explicit Knowledge

Organizational researchers identify two primary types of knowledge: tacit and explicit. Explicit knowledge can be captured and expressed, for example, in a document. Tacit knowledge is typically acquired through experience. The concept of tacit knowledge is closely related to the concept of skills. It is something you can do but the process of which you cannot describe. You can recognize a familiar face but are hardly able to describe how it is done (Seuber [51]).

These knowledge types apply to individuals, but tacit knowledge also exists on the group level. In the area of group knowledge there is a distinction between individual tacit knowledge and group tacit knowledge. Group or team-based tacit knowledge is stored in something similar to a "collective mind". Basically, group tacit knowledge is acquired through the experience a group of people gains when working together. The team acquires that kind of knowledge through practice and experience. The team members need a chance to mutually adjust to work together without significant errors (Berman et al [12]).

Tacit knowledge is by definition an unobservable resource and therefore cannot be measured directly. "Indeed [...] if tacit knowledge could be measured directly, it could also be codified and, thus, it would no longer be tacit" (Berman et al [12]). Researchers use proxy data to measure group tacit knowledge indirectly. For example, in the area of sports such data can consist of win sets and detailed team data.

The notion of implicit knowledge supplements the original classification of tacit knowledge. This type of knowledge is something that cannot be stated, but can be inferred from explicit knowledge (Nickols [44]).

Evaluation	Judging the value of material or ideas
Synthesis	Building a structure from diverse elements
Analysis	Separates concepts into parts for better understanding
Application	Apply knowledge to new situations
Comprehension	Understanding information
Knowledge	Recall of data

Table 2.1: Taxonomy of the Cognitive Domain (Bloom)

Internalizing values	Has a value system controlling behavior
Organization	Acts consistently according to own values
Valuing	The values a person attaches to something
Responding to phenomena	Takes an active part in learning
Receiving phenomena	Willingness to listen

Table 2.2: Taxonomy of the Affective Domain (Bloom)

2.1.2 Bloom's Taxonomy

There are views on classifying knowledge from educational psychologists as well. A group of educational researchers classified teaching objectives in the 1950s. They created a taxonomy of educational objectives similar to the biological taxonomy of plants and animals. They identified three learning domains: cognitive (knowledge), affective (attitude), and psychomotor (skills).

The cognitive domain includes the objectives that deal with the recall or recognition of knowledge and the development of intellectual abilities and skills (Bloom [14]). Recall of data is on the lower end, while judging the value of ideas represents high-order knowledge. See Table 2.1 for an overview of the categories in this domain.

The affective domain addresses a learner's emotions towards learning. It describes the learner's motivation and changes in interest, attitudes, and values. Table 2.2 gives a short overview of this domain (Bloom [15]).

The psychomotor domain refers to the use of basic motor skills, coordination, and physical movement. Bloom's research group identified this domain but did not provide detailed categories for it.

	Structure of knowledge		
Cognitive activity	**Fragmented**	⟷	**Meaningfully organized**
Problem representation	Surface features and shallow understanding	⟷	Underlying principles and relevant concepts
Strategy use	Undirected trial-and-error problem solving	⟷	Efficient, informative, and goal-oriented
Self-monitoring	Minimal and sporadic	⟷	Ongoing and flexible
Explanation	Single statement of fact or description of superficial factors	⟷	Principled and coherent

Table 2.3: Cognitive activity and structure of knowledge (adapted from Glaser)

2.2 Teaching, Study and Learning

These categories of knowledge are interesting when it comes to learning. Certainly students should have the opportunity to acquire higher order skills in a university course. In addition to this, communication and teamwork skills are increasingly a requirement for graduates.

Educators try to achieve such goals with new methods of teaching. A modern approach is employed with the CRESST model of learning objectives based on content understanding, problem solving, collaboration, communication, and self-regulation (Table 2.3). Students should seek a deep approach to learning.

2.2.1 Lecture-based Teaching

The prevailing teaching concept is the lecture-based approach. This requires students to pay the least amount of attention. To circumvent this problem often additional teaching methods are used to get students more involved in the learning process.

Klein and Hanisch [30] describe a combined approach for teaching visualization and interaction in the context of computer graphics. They developed an extensive modular Web-based course for computer graphics. It consists of five components:

- the instruction manual and editorial of the course itself
- the course text (script)

- an index of all available applets — interactive examples — and the application interface (API)
- the programming exercises and
- links to external documentation and sources.

A common interface integrating lectures, programs, programming exercises, user support, and related literature increased the learning success of their students.

"A drawback of the current situation is that a single applet provides too much functionality. [...] Instead of being focused to the basis (sic) functions the student is distracted by that functionality of the applet which is irrelevant in the current context" (Klein and Hanisch [30]).

Spalter and Simpson [52] used an interactive computer program to let students explore different filters for scaling an image. They received positive responses from students who were using the applet. Still they shifted towards a "fine-grained" approach with specialized components to avoid a lack of structure in the applets or the text pages that may have an impact on students learning. This eliminated much of the complexity associated with developing larger software as an added bonus.

The teaching in a course was enhanced with the use of new material in the MEIIGA project at the CPS (Latorre [33]). Computer graphics related concepts were taught using interactive examples and simulations. The applets were used in class and students had the chance to learn with them at home. The students attending the lecture were surveyed anonymously about their satisfaction with the new course format (Table 2.4). The responses were positive that the use of the new material improved teaching compared to the traditional approach.

Problems with the poor visibility of the image generated by the LCD projector while presenting the material in class was of concern in the comments. The interactive examples in both the presentation and in the module received the highest ratings for overall satisfaction and improvement.

2.2.2 Project-based Studying

Some educators employ a "learning by doing" teaching approach. Their courses are either completely based on projects or supported by them. The projects can be either carried out individually or in groups.

Student survey (44 Responses)	**Mean**	**S.D.**
Interface		
Presentation in general	1,57	0,82
Navigation (ease of understanding)	1,82	0,79
Typography (clearness, visibility)	-0,66	1,61
Interactive examples (usability)	2,41	0,82
Geometric Transformations Module		
Textual presentation (explanations)	0,68	1,23
Interactive examples	2,50	0,66
Benefit from the application		
Support for teaching during class	1,50	1,07
Support for self-study at home	2,28	0,93

Table 2.4: Improvement of a lecture using electronic means (Latorre)

Cunningham [24] "describes a set of projects for a computer graphics programming course, with a particular focus on projects whose content is in the area of visualization in the science".

He proposes five programming projects with increasing complexity for a half-year course. The result of a project is used as the basis for subsequent projects. Implementation is done by using a graphics API such as OpenGL. Although the goal of this course is to teach students how to program using OpenGL, the projects are designed so that any API can be used.

The five assignments are:

- Project 1: Identify some appropriate geometry to be displayed using the API that supports the course.
- Project 2: Use the same or different geometry, but increase the sophistication of the rendering by adding shaping and lights to the scene.
- Project 3: Use the same or different geometry, but focus on simple interaction with the scene, adding keyboard, menu, and mouse callbacks and controls for the scene.
- Project 4: Use the same or different geometry and add more features of modeling and/or rendering.

- Project 5: A more advanced, 'capstone' project would ask the student to use additional techniques noted in Project 4 that were not used there, as well as other new techniques

Other courses include team work and let student groups carry out projects. Maddock [39] presents a series of three computer graphics modules. He describes some considerations about the resources used in teaching them.

The first course is mainly taught to second-year undergraduate students. The course covers the fundamental introductory CG topics. Additionally, there is an assignment that involves teams of students developing electronic modules for a topic of the course. "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".

The second course involves as an assignment the programming and enhancement of a Modula-2 renderer developed at the University of Sheffield. The assignment of the third part is either programming a simple animation tool or developing a Toolbook-based teaching tool for one of the topics of the module.

2.2.3 Peer Learning

In most projects, students carry out their project without gaining insight into the work of their peers. A peer is defined as a student with the same academic background, including knowledge maturity and expertise (Tsai et al [54]). Peers can be either other individuals or a team in the same course.

Peers can learn from each other. Students can learn from the experience they have gained while working on their teams or can gain wisdom from situations in other teams. Peer learning can take place when students have full exposure both to their own projects and to those of the other people or teams (Cardozo et al [21]).

Social interaction and communication with peers is an important part of every learning experience (Garrison [25]). Generic skills such as team work or presentation experience are important in today's economy. You learn best through experience. Therefore, the best way to acquire generic skills is to interact with people.

There are courses that are student-centered and focus on self-regulation and team work. Some approaches work their way from a specific case to a more generalized view. "Instead of providing students with all necessary background before exposing them to recent research, students start with the latest SIGGRAPH proceedings and discover what topics they need to learn to understand them" (Novins [45]).

The students choose two papers from each conference session in a selection process. Then they summarize the papers and vote to determine which papers should be worked on. The selected papers are then given over to group work. Each group has to give an overview of their papers and write their topics and the foundations relevant to their topics. The other participants use the work of their peers to prepare for the final written examination at the end of the course. As a consequence, each student is able to benefit from their peers' research.

2.3 Assessment and Grading

Assessment is central to university education. "Instructors assess textbooks and students. Students assess courses and instructors. Instructors assess peers striving for tenure. Institutions assess programs and curriculum. Regents and legislature assess institutions" (Kwok et al [31]).

Usually, assessment is carried out at the end of the course with a final exam and the awarding of grades. Some institutions even establish an evaluation process spanning the complete life cycle of a course to observe the performance of instructors and learners continually (McCarthy-McGee [42]). This is in line with the principles of total quality management that sees quality as the result of regular inspection throughout the production process (Rovai [50]). Other approaches try to weave assessment into the overall course process and make it an integral part of the course.

Assessment tries to measure how much knowledge a student has acquired during a course. Measuring the learning outcome and awarding grades are closely related activities.

2.3.1 Assessment of Students

Multiple-choice tests and oral or written answers to open-ended questions are quite common in traditional classroom teaching environments.

One characteristic of traditional assessment is that all learners are tested in the same location at the same time. All students face the same conditions with a standardized procedure. This makes the tests reliable and the performance of students comparable. General assessment principles, however, change in an online environment. Multiple-choice tests are often used in e-learning systems because they can be easily automated (Rovai [50]).

The combination of simulation-based learning and online assessment makes new applications thinkable. "The use of modern assessment techniques is consistent with recent calls to use methods beyond course evaluation and student attitude surveys" (Chung et al [22]). They describe a complex simulation for conducting a hazardous waste site investigation and the evaluation process. They used an online knowledge-mapping system to measure students' learning.

Students maps were scored automatically against a knowledge map crafted by an expert. Some students created knowledge maps that were correct but not in line with the expert map. This finding suggests that automatic scoring and grading of more complex assessment types are hard to carry out online. Another drawback with online assessment is that academic honesty cannot be easily enforced.

The types of assessment described are suitable for assessing individual performance. Group assessment has different requirements.

2.3.2 Peer Assessment

Assessment is not only a way to assign grades. Instructors face new challenges with grading in collaborative and projects-based courses. They realize that assessment embedded into the learning process can improve the overall learning experience.

Peer learning and assessment have drawbacks, however. Students are graded by the outcome of the work of their teams, regardless of the amount of work carried out by the individual student. It is in the interest of the instructor that the workload among the team members is distributed evenly. The members of a team need to carry out their share of work to ensure a good working climate.

One possible solution might be to put the power of grading into the hands of the students. They learn the important skill of how to grade and judge peers with this method. This model can help students understand the difficulties and problems of grading. When embarking on a peer review model, they have the chance to improve their work based on their peers' feedback.

Kwok et al [31] describe a collaborative teaching assessment approach. They present a complex method using a group support system. Various input parameters and assessment criteria from both students and teachers are combined and processed by a system based on fuzzy theory. The system then calculates the students' learning outcome on a fuzzy grading scale.

Giving students a voice in the grading process is an interesting approach even though objectivity must be ensured. The processes must ensure that students judge their peers for no other reason than the quality of work. This is difficult when each student or student group knows what topic their peers are working on.

Tsai et al [54] try to solve these problems by using a networked peer assessment model. It consists of the following steps:

- Teacher and students discuss the project
- The project result is uploaded to the system
- The system randomly assigns reviewers
- Reviewers comment on the project
- The teacher grades each student's homework
- Students are notified by the system of their grades and comments
- They must modify their material based on the comments
- Steps 2 to 7 are repeated once or twice
- The teacher performs a final assessment

Conclusion

This chapter reviewed some innovative ways to teach in the computer graphics field and elsewhere. There is a tendency among educators to have students take an active role in learning and even in assessment. Students are encouraged to take a deep approach to learning. As a result, the roles of teachers are changing from people who transfer their knowledge to students to managers, mentors and facilitators for learning.

Chapter 3

Computer Graphics and Multimedia

Introduction

The field of computer graphics has come a long way since its beginnings in the late 1960s when the term computer graphics was first coined. The field arrived in the mainstream when Apple and Microsoft introduced graphical user interfaces in the 1980s. The 1990s brought the first full-length computer animated film Toy Story. Exponential increases in hardware capabilities went along with improvements in algorithm research and the development of advanced programming interfaces. Games like Quake and Doom based on three-dimensional graphics have been a huge success. The World Wide Web and its multimedia aspects have contributed to the widespread use of computer graphics.

Computer graphics have found their way into the mainstream of society. The field constitutes a powerful medium to communicate information and knowledge. Technology in this area is improving and new applications are being found. New scales of quality and speed are being achieved with increased computing power. All applications are based on fundamentals mainly from the sciences of geometry and physics.

3.1 Theory and Foundations

The science of computer graphics draws from many disciplines. It borrows illumination models and the rules of force and gravitation from physics. Geometry provides matrix mathematics and things such as transformation and rotation of objects. Psychology is the basis for the field of human computer interaction.

Topic	**Time**
Geometric algorithms (AL10)	2 hours
Building a simple graphical user interface (HC2)	2 core hours
Human-centered software evaluation (HC3)	2 hours
Human-centered software development (HC4)	2 hours
Graphical user-interface design (HC5)	5 hours
Graphical user-interface programming (HC6)	5 hours
Fundamental techniques in graphics (GV1)	2 core hours
Graphic systems (GV2)	1 core hour
Graphic communication (GV3)	2 hours
Geometric modeling (GV4)	3 hours
Basic rendering (GV5)	3 hours
Computer animation (GV8)	2 hours
Virtual reality (GV10)	2 hours
Multimedia information and systems (IM13)	4 hours
Using APIs (SE2)	2 core hours (of 5)
Elective topics	1 hour

Table 3.1: Suggested content of IEEE's Computer Graphics and Multimedia course (IEEE Computing Curricula)

A course in computer graphics is an integral part of every computer science curriculum. A joint task force from the leading engineering and computer science organizations — ACM and IEEE — developed curricular guidelines for undergraduate programs in computing. They constructed a complete modular computer science curriculum, including a course for computer graphics.

The course CS255 entitled "Computer Graphics and Multimedia" identifies topics for a computer graphics lecture from the modules Algorithms and Complexity, Human Computer Interaction, Graphics and Visual Computing, Information Management, and Software Engineering (see Table 3.1). Prerequisites for the course that are targeted at second-year students are a course on Introduction to Computer Science, Discrete Structures and Linear Algebra. The purpose of the course is to investigate the principles, techniques, and tools that have enabled the advances in computer graphics, particularly in association with the multimedia aspects of the World Wide Web (ACM/IEEE Model Curriculum for Computing [47]).

Topic	Number of Curricula
Viewing transformations/camera	19
Hardware/terminology	15
Lightning models	15
3D transformations	14
User interaction	14
Object representation	11
Shading models	11
Color/color models	10
Curves	10
Hidden-surface removal	10

Table 3.2: Major topics in Computer Graphics courses (adapted from Wolfe)

Another compilation of teaching topics relevant to computer graphics was done by Wolfe [55]. She presents a survey of 20 syllabi from various educational institutions. Prerequisites for the introductory computer graphics courses were mostly courses in Algorithms and Data Structures, and Linear Algebra. The vast majority of the surveyed teachers used OpenGL in their courses for demonstration and programming. You can find a list with the top ten topics in the curricula surveyed in Table 3.2.

The ACM/IEEE model curriculum and Wolfe agree that geometric modeling is an integral part of a computer graphics course. The fundamentals are covered in both publications and seem to represent the state of the art in computer graphics education. ACM/IEEE added aspects of human computer interaction and multimedia to their course.

To learn about these foundations and to understand the basics, I programmed a viewer for three-dimensional objects in Java (Figure 3.1). The basic geometric transformations can be demonstrated with this application. The mouse can be used to rotate a wire-frame model of a cube. The viewpoint can be changed, and a transformation matrix can be applied.

The students should acquire a sound understanding of the basic concepts in every computer graphics course. These concepts can be taught in traditional lectures with support from simulations and applets.

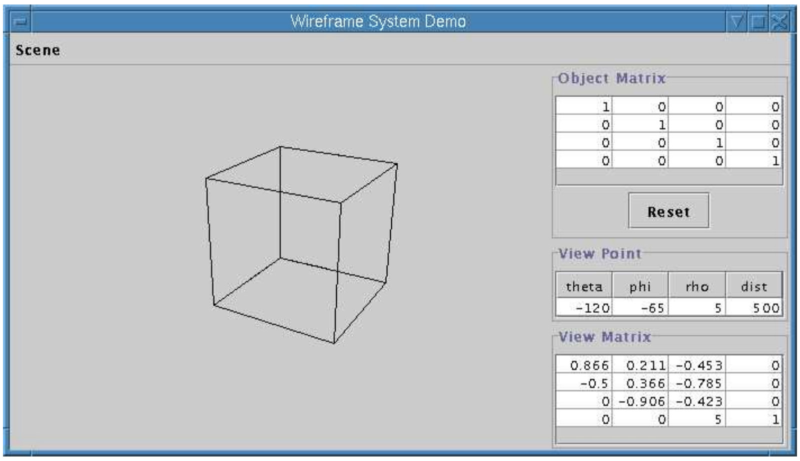

Figure 3.1: Wire-frame viewer demonstrating transformation and rotation

3.2 Application Scenarios

Computer graphics are used in a variety of scenarios. Some today's application scenarios are the topic of the following sections. Almost every computer program uses some graphics for either user interaction or presenting content. Some parts of computer graphics involve creativity and lean towards art, while others focus on clever use of technology.

Computer graphics are used today in many different areas: industry, business, government, education, and entertainment. The following describes some representative uses for computer graphics.

3.2.1 World Wide Web

The Web brings many new applications to the desk of the end user. Streaming video, for example, allows new means of communication. Video-conferencing can be carried out based on this technology. Web sites are spiced up with two-dimensional animations and interactive elements. The flexible architecture of URLs makes addressing and integrating every type of content possible, such as audio, video, and three-dimensional virtual worlds.

New standards are being developed and existing ones improved. The W3C's Scalable Vector Graphics (SVG) format is for deploying two-dimensional vector graphics onto the Web. The Web3D Consortium has developed an XML-based language to encode and deliver three-dimensional worlds to the Internet. The Synchronized Mul-

Figure 3.2: Characters from Monsters, Inc. created with RenderMan

timedia Integration Language (SMIL) of the W3C aims to integrate all kinds of data formats such as audio, video, and text into unified presentations.

3.2.2 Movies and Computer Games

The entertainment industry is the area of computer graphics application with the largest audience. Whole movies can now be created on the computer and consist only of synthetic characters. Pixar's RenderMan suite is often used to model synthetic characters in movies (Figure 3.2). The quality of such animations is advancing quickly as more computing power becomes available.

Another application in the entertainment sector are computer games. The leader in the field is id Software with its Quake and Doom series that regularly employ breakthrough three-dimensional graphics and effects.

The core of these games often consists in very sophisticated game engines that adhere to basic physical principles. They compute illumination effects to make scenes more realistic. The gravitation and deformation of objects are computed in real time. The images are rendered and displayed using the high-performance OpenGL API. Multi-player functionality built into game engines allows groups of people to meet in cyberspace and play together. Even tournaments are carried out virtually.

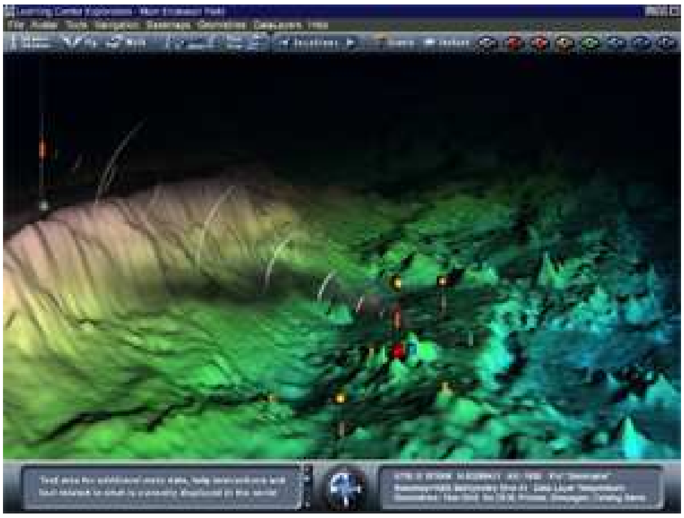

Figure 3.3: Big Beef Creek Neptune Exploration

3.2.3 Simulation, Training, Education

Methods of computer graphics can be used to support learning by means of animations and simulations. Animations are used to show simple concepts, while simulations are employed to demonstrate more complicated matters.

Lowe [35] investigates the use of animations "that are meant to represent dynamic subject matter" in electronic learning material. Animations are supposed to be superior to static graphics as a tool of learning because of their entertainment value and high motivation possibilities. He points out that the danger with animations for educational purpose is that the learner "selectively attends to only certain aspects of the animation but neglects others".

There are other applications that are more complex than simple animations. Campbell et al [20] describe how they deliver three-dimensional collaborative virtual environments to online audiences. The users of this service can navigate through a representation of the Big Beef Creek near Seattle, WA. The simulation gives users a better sense of the overall surroundings before they actually go out there. Moreover, students can use this application to learn about ocean sciences such as marine biology.

The developers of the system store geo-data and related information obtained through fieldwork in a relational database system. Figure 3.3 shows the user interface used to display the data. They programmed an application using the Java 3D framework because there are limitations to deploying virtual worlds on the Web.

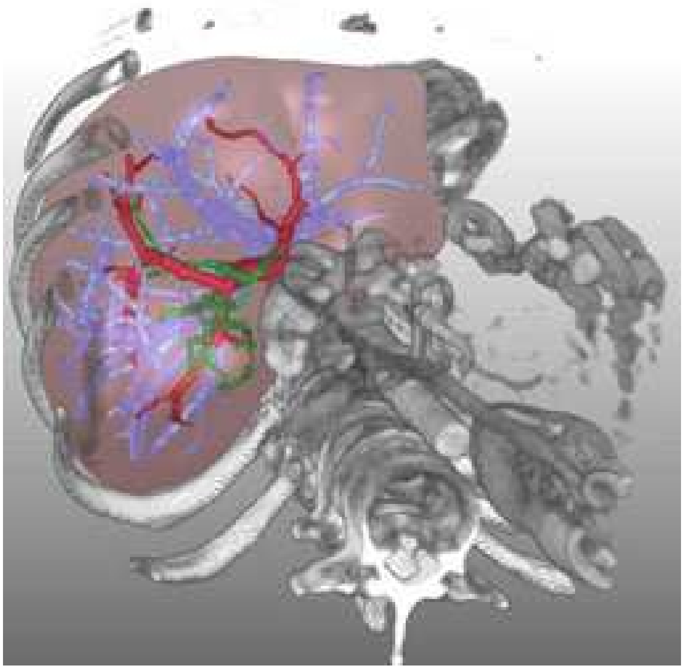

Figure 3.4: Surface rendering of the liver with vessels and bone structure

However, conversion for displaying on the Web is possible because it is stored in a VRML-compliant format.

3.2.4 Medical Imaging

Modern medicine is unthinkable without computer graphics and relies heavily on it. X-Ray images are displayed and delivered electronically, and new technologies and procedures such as computed tomography have evolved.

Computer graphics are applied in the area of medical diagnosis and surgery. Prein et al [49] present a system that supports the planning of soft tissue operations, for example, in liver surgery. Currently such treatment is planned with two-dimensional computer tomography images. This is problematic because volume, distance, and regions involved in the surgery are difficult to judge from these images.

They process the original computer tomography slices into three-dimensional representations that can be displayed using SGI's Open Inventor. The surgeon can then navigate the organ in three dimensions. The doctors can add annotations to objects, for example, the estimated volume of tumors. They can use "erasers" to cut

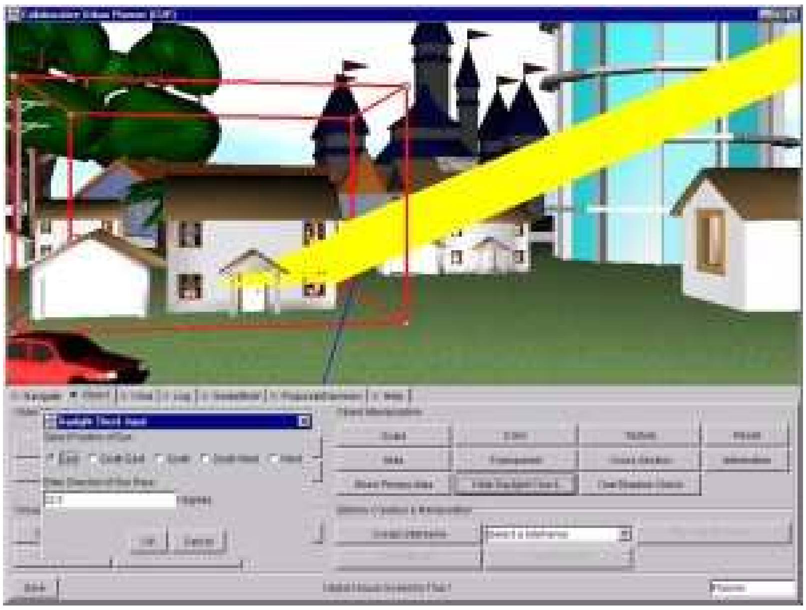

Figure 3.5: Daylight and sunlight analysis with CUP

out objects and judge the intended outcome of the surgery. This can greatly help surgeons and radiologists with preoperative planning.

There are commercial medical imaging systems that integrate all common medical imaging tasks and applications on the market. One example for such a solution is syngo (Siemens [2]). This system embeds medical imaging solutions into a working environment for all clinical applications. Images from x-ray and computed tomography can be electronically browsed and delivered via networks. The documentation and storage of related data, such as patients' medical histories, are also carried out digitally with this system.

3.2.5 Architecture, Environmental Protection

Computer graphics are used in architecture for displaying planned buildings and in the area of environmental protection to judge the impact of buildings and construction on the surrounding area.

Manoharan et al [40] present CUP, a collaborative virtual environment system. Its aim is to improve the productivity and quality of urban planning, and to achieve more transparency in the planning process. Information technology can help planners, architects or engineers in assessing proposals and discussing possible alterations of designs. Sharing an image of a planned building in its original surroundings can improve the collaboration of all stakeholders involved in the planning process.

The Java 3D framework for visualization of architectural data is used in the CUP prototype system. It incorporates interactive change of fog density and illumination. Daylight and sunlight analysis can be performed (Figure 3.5). The system supports animated fly- and walk-throughs and can be delivered via the Internet.

3.3 Standards and Tools

A lot of the described applications build upon industry standards. The following sections investigate some of these standards in detail.

3.3.1 OpenGL

APIs that provide high-level interfaces to low-level functionality facilitate the programming of computer graphics systems. These APIs, namely Java3D, OpenGL, and Direct3D, are all based upon the fundamental principles of geometry, and the internals are quite similar. OpenGL is discussed here because it is platform independent and widely used in teaching.

OpenGL is a software interface to graphics hardware for programming real-time three-dimensional applications. The interface provides about 250 distinct commandos. The specification is independent of the operating system and the windowing system. User input and the performance of windowing tasks are not covered by the standard and must be programmed manually. Several commercial and open source implementations are available. Some graphics cards have OpenGL drivers that are able to use hardware acceleration (Woo [56]).

OpenGL lets the programmer build complex models from a small set of geometric primitives: points, lines, and polygons. The API provides a set of commands that allow the specification of geometric objects in two or three dimensions. The interface offers commands that control how these objects are rendered into the frame buffer.

Animation is supported with double-buffering either in hardware or software. The next frame for the animation is drawn in a invisible buffer while the current frame is displayed. Then, the two buffers are swapped. This technique allows for smooth animations that are rendered in real-time.

Figure 3.6 shows a scene from the upcoming Doom III computer game. The scenes in the game are rendered in real time using OpenGL.

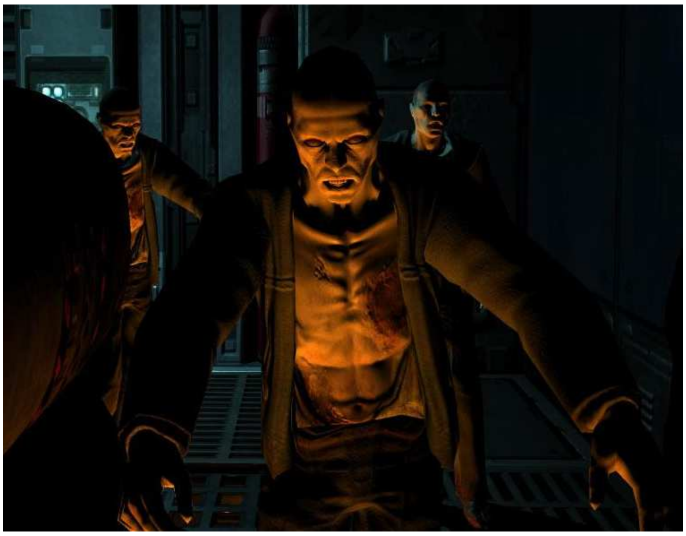

Figure 3.6: Screen Image from Doom III which uses OpenGL for image generation

3.3.2 Extensible 3D (X3D)

VRML and its successor Extensible 3D (X3D) are software standards for deploying three-dimensional worlds. VRML models are stored in ASCII text files while the newer X3D is based on XML. Extensible 3D aims to define interactive web-based 3D content integrated with multimedia. The standard is modular and builds on a component-based architecture (X3D Standard [5]). It includes hyper-linking capabilities and can be processed and searched with standard XML tools. It integrates seamlessly with other Web technologies.

X3D worlds consist of simple graphic primitives such as lines, polygons, spheres, and cones. There are several viewers to browse and display the virtual worlds; most of them are plug-ins for Web browsers. VRML is often used as a format for the exchange of data between software applications because the majority of them provide VRML export and import capabilities.

3.3.3 Scalable Vector Graphics (SVG)

The Scalable Vector Graphics (SVG) format is an XML-based language to represent two-dimensional graphics. It was developed and standardized by the World Wide Web Consortium (W3C) with authors from companies such as Adobe, Microsoft, IBM, and Sun contributing to this standard.

The imaging model of SVG is similar to PDF and Postscript. SVG allows three types of graphics objects: vector graphics shapes, images, and text. Vector graphics

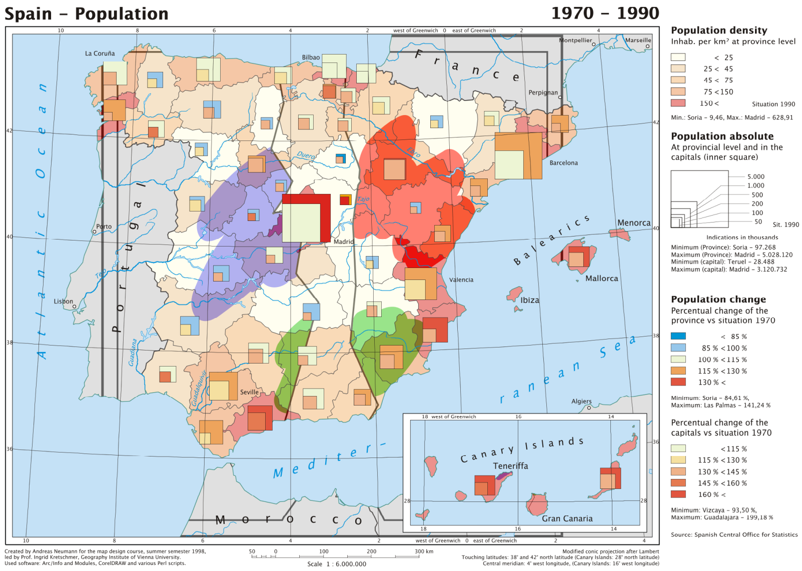

Figure 3.7: Map of Spain in the SVG format

shapes include basic objects such as circles and rectangles as well as more complex shapes such as Bezier paths. The feature set includes complex gradient fill patterns, clipping, and object transparency. Bitmap images can be included into an SVG drawing. There are also powerful text manipulation commands available (Ferraiolo [17]).

A broad range of uses for high-quality drawings on the Web can be imagined: illustrations, animations, diagrams, and maps (Figure 3.7). These can be viewed either with browser plug-ins or stand-alone applications such as Apache's Batik (Batik [6]).

3.3.4 Synchronized Multimedia Integration Language (SMIL)

The World Wide Web Consortium's Synchronized Multimedia Integration Language (SMIL; pronounced "smile") is a format for encoding multimedia presentations for delivery via the Web (Bulterman [19]). SMIL is XML-based. It is used to describe the temporal and spatial coordination of one or more media objects. SMIL lets users define how independent media objects should be integrated during a presentation's lifetime. Media objects can be text, video, audio, or a set of images.

The core of the specification is the timing and synchronization grouping. The SMIL 2.0 W3C recommendation is divided into the following components.

- Timing and synchronization: an extensive collection of modules detailing the SMIL timing model's elements, attributes, and behavior.

- Time manipulation: a collection of modules that define how to manipulate time within a presentation.

- Media objects: a collection of modules that define the elements and attributes associated with the definition and inclusion of media elements into a presentation.

- Layout: a collection of modules used to explicitly manage a presentation's rendering space and audio-visual resources.

- Animation: a collection of modules used to define time-varying values to elements and attributes within the containing document.

- Content control: a collection of modules used to conditionally include media items in a presentation based on various system- and user-defined test attributes.

- Linking: a collection of modules that define and manage both SMIL temporal and HTML-like links.

- Meta-information: a module, compatible with the Dublin Core, for encoding meta-information on an entire presentation or any subpart of that presentation.

- Structure: a collection of modules that define the basic structure of native SMIL documents.

- Transitions: a collection of modules that add visual transitions to a presentation.

The language can be used to integrate different media objects into a coherent presentation. It can be delivered via streaming servers or viewed locally. Users can view the presentations in compatible web browsers or SMIL players. MS Internet Explorer 5.5 supports the SMIL 1.0 standard. New players are being developed for next-generation wireless devices such as cell phones and hand-held computers.

Conclusion

The field of computer graphics is a discipline that is used extensively in a lot of computer science areas. It is viewed as an integral part of every computing curriculum. The multimedia applications in conjunction with the Web are increasingly becoming part of the field.

The possiblities in computer graphics are advancing rapidly as new application areas emerge and more computing resources are available. More bandwidth, wireless devices, and faster graphics chips make the progress tremendous. Students need to acquire and grasp the basic concepts behind computer graphics to understand their more advanced applications.

Chapter 4

Web Technology

Introduction

"The introduction of computers into education has been in progress for at least 20 years". Merrill [43] wrote this in 1982. And it is still true: the introduction of computers into education is still in progress, but today it has been so for at least 40 years. Twenty years ago he classified the field into three major categories: computer-assisted instruction, simulation, and artificial intelligence.

Communication and collaboration were of no concern at that time. Computers were mainly used in isolation. The Internet and electronic communications media were just being developed and were only used by a few researchers. Today's hype towards e-learning is closely tied to the success of the Internet and the Web.

The Web creates new opportunities to support learning, mainly by integrating documents from different sources and connecting people. It is a great resource for publishing documents and provides library-style functionality. The Internet adds new means of communication.

E-learning courses use hypertext and Internet technologies to encode and transfer information. Hypertext is more expressive than plain text for knowledge representation. Today, only little of the power is leveraged. University web pages contain scripts and maybe a course schedule. They just deliver content and do not help much in the courses themselves.

Other educators can hardly draw upon the material for their teaching. It cannot be machine processed, thus limiting easy reuse. In addition, much of the information in such systems is not publicly available. Access to the knowledge buried in course material is either restricted or impossible due to lack of structure.

4.1 Knowledge Representation

The basic form of knowledge representation is language in the form of speech and text. From a technical standpoint these formats are problematic. The structure of language in the form of grammar is complex and ambiguous. Machine-processing of this kind of information is not feasible. Nuggets of information are often buried in a mountain of related but superfluous data. Data-mining technologies try to glean valuable information from the vast data available, but the results are meager compared to the cost of deploying them.

There are several models and approaches for representing knowledge in a structured manner. Several disciplines are concerned with the challenge of capturing the complexity of the real world. "In computer science, the issue of knowledge representation arises when data structures and the structure of records and files in databases are to be decided. In linguistics, the problem of knowledge representation arises when dealing with the syntactic and semantic structure of natural language. Artificial intelligence is concerned with the creation of a knowledge base which, when programmed, results in machine-based intelligence. In psychology, the representation system of cognitive theory and models of human memory are very much concerned with the issues of knowledge representation" (Binwal [13]).

One of the more prominent approaches to codifying knowledge is the application of semantic networks. A semantic network represents knowledge as a pattern of interconnected arcs and nodes. The nodes represent concepts and the arcs link the nodes and show the relationships between them. Important links structures include is-a, has, and part-of. These links add important information to the overall representation. The information implicitly contained in links can be used by algorithms to recognize relationships between concepts.

Hypertext employs a similar concept by adding links to documents. The Web can be seen as a large semantic network, with the documents representing the nodes and hyperlinks the arcs. Links are an important way for measuring the relevance of documents. Search engines measure the popularity of a site by counting the links that point to it. The more links point to a document, the more important the document should be considered for a given search term. Search engines that make use of this discovery work considerably well (Brin and Page [18]).

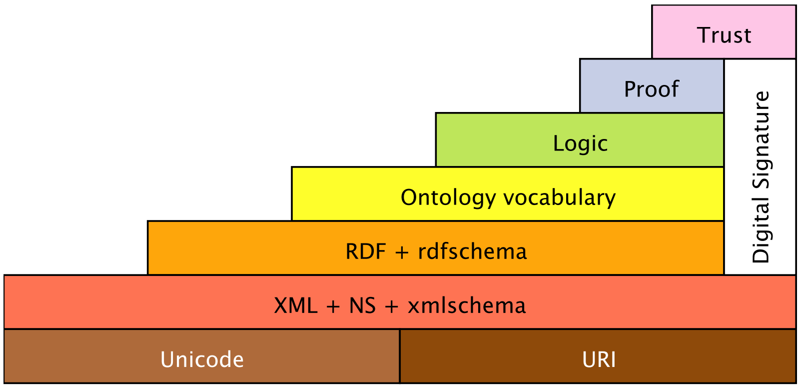

Figure 4.1: Layer architecture of the semantic web

4.2 Semantic Web

The W3C and researchers worldwide are part of an effort to build the second generation Web called Semantic Web. The Semantic Web consists of several layers (Figure 4.1). Unicode and the URI concept, and the Extensible Markup Language (XML) provide the foundation on that more sophisticated technologies are based. I will discuss RDF and ontologies in the following sections. Concepts such as logic, proof, and trust will be an issue when the underlying layers are deployed in a few years.

4.2.1 Metadata

"The World Wide Web was originally built for human consumption, and although everything on it is machine-readable, this data is not machine-understandable. It is very hard to automate anything on the Web" (Lassila and Swick [32]). It is impossible to manually manage the vast amount of documents and information that are available on the Web.

Language is the prevailing medium for humans expression and communication. They use sentences, which are, in their most basic form, subject-predicate-object constructs.

So why not codify machine-interpretable information in a similar format? The Resource Description Framework (RDF) is a machine-readable language. You can use this format to make statements about objects. The structure of RDF is simple. Basically, it consists of three parts:

- the subject: a thing, identified by its URL

Subject	**Predicate**	**Object**
Andreas Harth	created	thesis

Table 4.1: Triples of a sample rdf sentence

Figure 4.2: Graph of an RDF statement

- the predicate: the type of metadata, also identified by a URL
- the object: the value of this type of metadata

You can model the statement "Andreas Harth created this thesis" with the triples ['Andreas Harth', 'created', 'thesis'] (Table 4.1). The concept "created" is ambiguous and some other users may prefer to refer to the same concept as "authored", "wrote" etc. URLs are unambiguous, so you can replace the predicate "created" by an URL with a defined meaning.

For larger models — even models from different content sources — to make sense when combined, it is beneficial to use the same predicates in all models. The Dublin Core Initiative, for example, provides a vocabulary for some basic metadata predicates. The predicate with the meaning "created" would resolve to the URL http://purl.org/dc/elements/1.1/creator.

Metadata vocabularies for virtually every area are emerging. Major news sites like Wired or Slashdot already use RDF Site Summary (RSS) for syndicating news items (Beged-Dov [11]). In the learning arena the Learning Objects Metadata (LOM) standard emerges (Hodgins [29]). LOM defines a vocabulary to mark up learning objects with additional information.

Metadata — "data about data" — helps to navigate great quantities of data. The distinction between data and metadata is sometimes artificial and blurry. It is often influenced by technical criteria. Besides RDF there are TopicMaps that use a similar concept to represent metadata (Pepper and Moore [48]).

RDF statements can also be represented as graphs. Nodes of the graph depict the subject or object, and arcs are used for predicates. See Figure 4.2 for a graph of our example with all the elements resolved into URLs.

With more information available in this format, new possibilities for merging and querying information from diverse data sources will develop. Machine processing of data that is available on the Web will become an easy task.

4.2.2 Ontologies

An ontology consists of machine-readable bits of information for a specific field. "An ontology defines a common vocabulary for researchers who need to share information in a domain. It includes machine-interpretable definitions of basic concepts in the domain and relations among them" (Noy and McGuinness [46]). Ontologies have become common on the World Wide Web, although they are seldom identified in this way. The ontologies on the Web range from large taxonomies categorizing Web sites (such as on yahoo.com) to categorizations of products for sale and their features (such as froogle.com).

Some of the reasons for developing an ontology are (Noy and McGuinness [46])

- To share common understanding of the structure of information among people or software agents
- To enable reuse of domain knowledge
- To make domain assumptions explicit
- To separate domain knowledge from operational knowledge
- To analyze domain knowledge

Several technologies to model an ontology have been developed. To model knowledge you need to represent the properties of objects and their interactions. These are as follows (Binwal [13]):

- Naming (proper nouns)
- Describing (adjectives)
- Organizing (categorization and possession)
- Relative (transitive verbs and relationship nouns)
- Constraining (conditions)

The DAML (DARPA Agent Markup Language) project incorporates these building blocks into their DAML+OIL language. With DAML+OIL and its W3C cousin WebOnt it is possible to model complex objects and their relationships. The language is based on frame-based logic and supports classes and restrictions among other features.

You can let programs reason with these ontologies and try to find information that is modeled implicitly. For example, if you model the relationship "dog is-a mammal", and "mammal is-a animal", then you (or better, the computer) can reason that a "dog is-a animal". This is a very simple example, but one can just imagine an information universe as huge as the Web of today. You can check data models for integrity or make implicit knowledge embedded in models explicit. The goal is to have most of the world modeled and described in machine-interpretable form to pave the way for "intelligent" applications.

4.2.3 Tools and APIs

The Semantic Web is an area of very active research and development. A lot of tools for working with RDF are being developed. Some of them have reached a stage where they can be used in production environments, others should be considered work in progress. In the following I present some tools that were useful for me in handling RDF and DAML+OIL, namely OilEd, the Jena API, Versa, and cwm.

OilEd is a powerful ontology editor developed by the University of Manchester. It is a Java application that processes ontologies in RDF and DAML+OIL. Ontologies can be developed using a graphical interface. A screen shot is shown in Figure 3.4. The models can be checked by a reasoner for validity, contradicting statements, and consistency.

Jena is an API from Hewlett Packard's Bristol Labs for manipulating RDF from Java programs (McBride et al [41]). It provides commands for reading and writing RDF and DAML+OIL. Models can be stored either in flat files or relational databases. It provides RDQL, a rudimentary query language with a syntax similar to SQL.

Versa is a language for querying and addressing in an RDF model. It is written in Python and is part of the RDF suite 4RDF. It has XPath-style grammar and is clean, intuitive, and easy to learn. Results are returned in XML and therefore can be easily processed with standard XML tools.

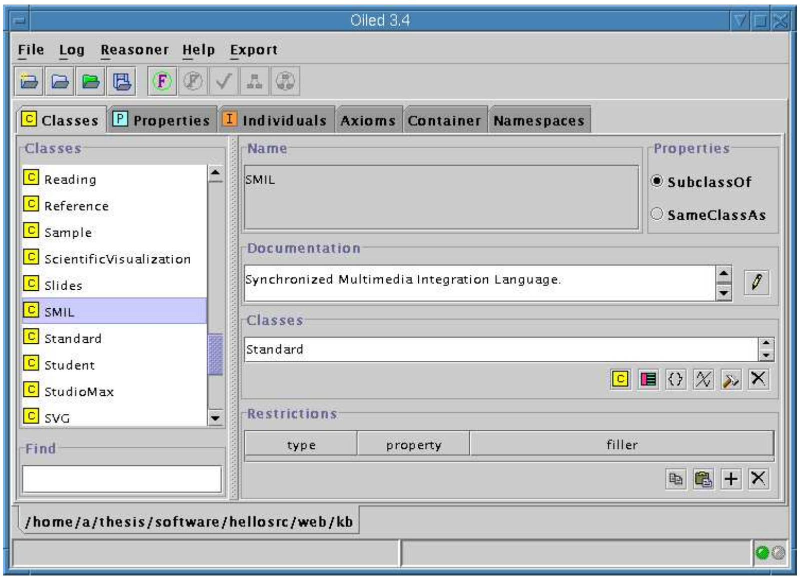

Figure 4.3: Screen shot of OilEd

Cwm — Closed World Machine — is the Swiss army knife for processing RDF written in Python. It can be used to merge, process, query, convert, and transform RDF models from the command line. Cwm consists of a parser, query engine, interference engine, and various other components. There are more sophisticated applications that build on cwm's functionality.

Conclusion

Most e-learning will take place over the Internet, using Web technologies. E-learning will be deployed company-wide in intranets, or with extranets where external partners and suppliers have access to learning resources. Internet technology is involved in all these scenarios.

The key to success for e-learning on the Web is to provide interoperability and therefore conform to standards. In doing so, universities will be able to exchange learning objects and process them automatically. Portals that integrate data from different sources are easily deployable through the use of metadata.

Chapter 5

Course Material and Implementation

Introduction

"An essential requirement of any computer science degree is that it should enable graduates to cope with — and even benefit from — the rapid change that is a continuing feature of the computing field. But how does one achieve this goal in practice? At one level, the pace of change represents a challenge to academic staff who must continually update courses and equipment. At another level, however, it suggests a shift in pedagogy away from the transmission of specific material, which will quickly become dated, toward modes of instruction that encourage students to acquire knowledge and skills on their own" (ACM/IEEE Joint Task Force on CC2001 [47]).

This chapter presents all material necessary to carry out a course in the spirit described above. The presented course is intended for implementation in a traditional university setting, with electronic support. It is a 12-week course with a traditional lecturing block at the beginning to lay foundations, some hands-on tutorials in the middle, and projects with a peer review cycle towards the end.

All necessary information is codified in a machine-interpretable ontology. This approach allows for transparency, because both faculty and students have access to all the relevant information. Exchange of the materials and deployment on other platforms is enabled through this approach. The model can be easily kept up to date, both faculty and students can make modifications and additions to the model.

5.1 Goals

After taking the course, students should be able to:

- describe the principles of computer graphics and give an overview of the field
- understand basic algorithms concerning two- and three-dimensional representations of geometric objects
- apply their computer graphics knowledge to related problems and other areas of their work
- plan, schedule, carry out, monitor, and control project work
- receive and incorporate feedback into their own projects, and give feedback on others' work
- navigate information and contribute to a shared model of knowledge

5.2 Course Format

The course is a mixture between traditional lectures and project-based study. Peer learning is facilitated by incorporating projects and peer reviews of the project presentations. Students can communicate and collaborate with both faculty and one another with a Web application. The course content in these formats is easily expandable and reusable in other contexts.

The topics of the projects are taken from the area of standards and application scenarios of computer graphics. Students can either choose to prepare presentations about the uses of computer graphics in science, the Web, gaming, movies, medicine, or review and present standards such as SMIL, SVG, Web3D, OpenGL, or Java3D. Starting points for own research and links to resources about these topics are provided in the ontology.

The participants are encouraged to add the outcome of their own projects and edit the shared material to the website. The Web application provides an online space to add, edit and categorize the material of the course. This makes the course material constantly a work-in-progress. Students can draw upon the work of prior participants.

Faculty can retrieve information about how to carry out the course from the ontology. Every time the course is held they can improve it by adding new experiences and updating existing materials. Hints for assessment and sample exams are also provided. The instructor can choose between different instruction and assessment methods based on which one suits the current situation best.

Teachers can use all or parts of the materials in their courses. The topic can be presented in different ways. The information in the ontology is encoded in a flexible manner. This facilitates tailoring the course to the requirements of the instructor. The whole course is highly adaptable, but, on the other hand, also structured because the course content is stored in the RDF format.

5.3 Content Covered

The core categories of the content are

- Introduction (Samples)
- Foundations of Computer Graphics (Theory)
- Programs and Tools (Hands-On)
- Representative Uses (Projects)
- Standards (Projects)

I withdrew from the idea of creating my own computer graphics related materials. There is already tons of quality material about computer graphics available: in books, magazines, and documents on the Web. Using these sources to write a script would be tantamount to reinventing the wheel.

I chose a different approach. I compiled a taxonomy with categories for all content relevant to the course. Various materials — the learning objects — were stored according to the hierarchy. The combined materials represent a framework that can be used to carry out a leading-edge computer graphics course.

The learning objects are either Web resources or parts of written material. Online resources consist of slides from other courses, online articles, and sample images and videos. Tutorials available online build the foundation for the hands-on training part. Pointers to books were added for reference and to enable students to research a topic in greater detail. The ontology is a repository for all relevant materials about computer graphics.

The ontology is stored in machine-interpretable format, so it can be transformed into different representations. The Web page is one way to present the hierarchy.

There are other ways to represent the information model, for example, graphs. You can find a machine-generated graph overview from this data in Figure 5.1.

5.4 Schedule

The course is divided into three parts. The first part spans four weeks and is carried out like a lecture course. Then, the learned principles are applied in tutorials on the computer for two weeks. The next six weeks are for carrying out the projects, including a peer review cycle and the final exam.

A detailed plan with the content of the lecture part can be found in Table 5.1. Part two offers tutorial work and hands-on experience with major tools and applications (Table 5.2). Table 5.3 shows the schedule for the project and collaboration part.

Although there are efforts underway to make process descriptions available in XML (Lubell [36]), there is no accepted format for representing this. The way implemented here is to link the various learning objects via a linked list. The schedule tables were extracted form the ontology with the Versa query language.

5.5 Information and Communication Technology

The course's Web application enables students to collaborate and contribute to a collection of shared information. Access to the application is possible through standard Internet browsers like Internet Explorer and Netscape Navigator and through command line tools such as the Lynx browser. The underlying information is stored in the ontology, making reuse in other contexts possible.

Information from the course site can easily be integrated into other sites and pages. Other pages can refer to parts of the course with the use of meaningful URLs. The use of metadata facilitates the exchange of learning objects with other organizations.

5.5.1 Course Ontology

The ontology editor OilEd was used to create a class hierarchy. Figure 5.2 shows the ontology in which the course is modeled. The major classes are

- Topic: Everything you need to know about Computer Graphics.

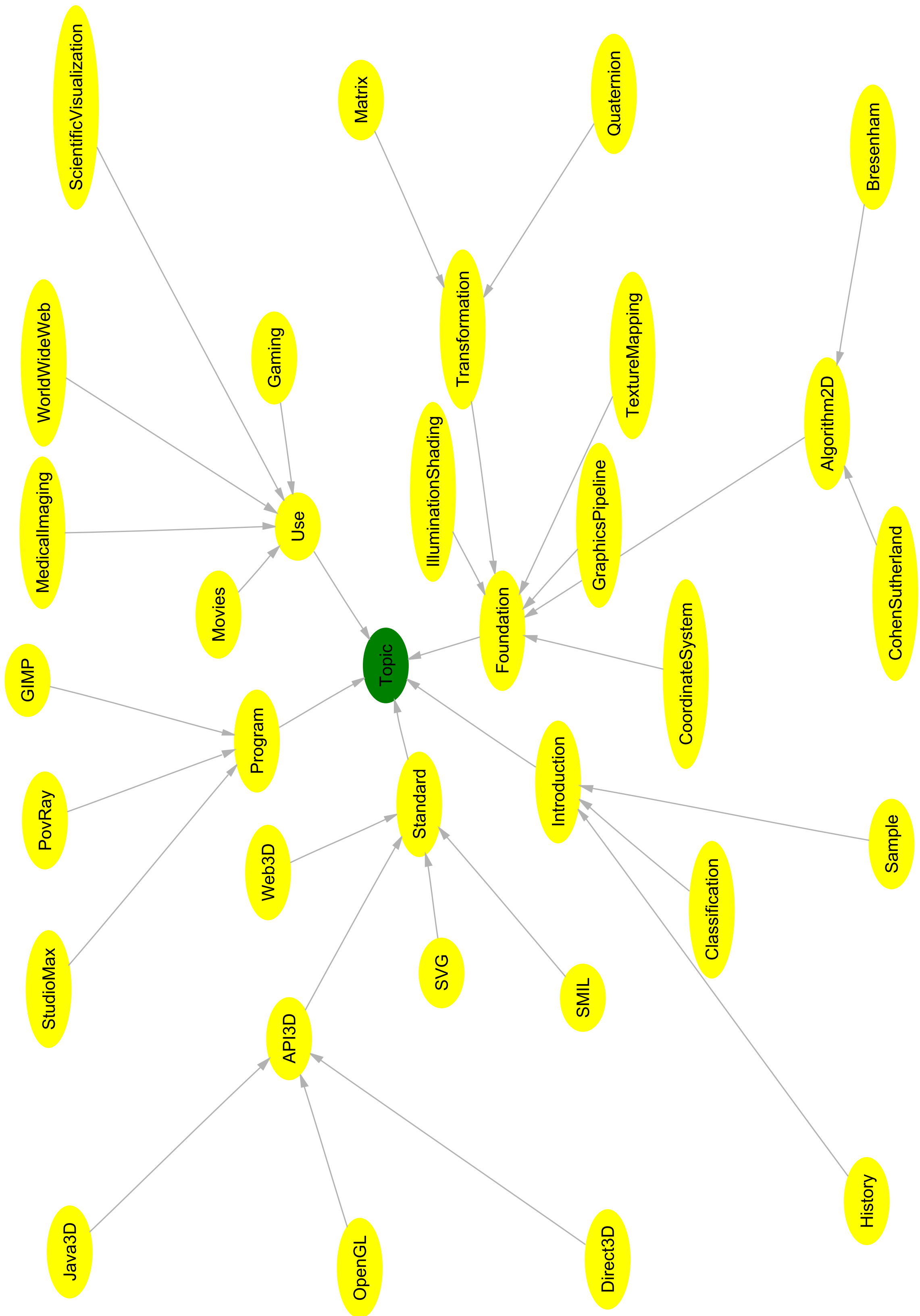

Figure 5.1: Course topic hierarchy

Duration	**Topic**	**Type**
	Week 1	Week
5min	Geri's game	Animation
10min	Sample synthetic images and videos	Sample
5min	Kurze Geschichte der Computergrafik	History
10min	A (Spotty) History and Who's Who of Computer Graphics	History
10min	Grundbegriffe	Classification
5min	vector graphics	Classification
30min	Explain Course Format and Schedule	Lecture
45min	Presentation of Project Topics	Lecture
60min	Building Teams	Process
	Week 2	Week
45min	The Bresenham Line-Drawing Algorithm	Bresenham
30min	Cohen-Sutherland Line Clipping Algorithm	CohenSutherland
5min	3D-Koordinatensystem	CoordinateSystem
5min	Cartesian coordinate system 3D	CoordinateSystem
15min	Wie funktioniert 3D Grafik	GraphicsPipeline
10min	A 3-D Graphics Pipeline	GraphicsPipeline
5min	Modern Graphics Pipeline	GraphicsPipeline
30min	3D Transformation	Transformation
	Week 3	Week
90min	The Mathematics of the 3D Rotation Matrix	Transformation
90min	Geometric Transformation Foley	Book
	Week 4	Week
20min	Licht und Farbe	IlluminationShading
10min	The RGB (CMY) Color Model	IlluminationShading
20min	Texture Mapping as a Fundamental Drawing Primitive	TextureMapping
40min	Raytracing Fundamentals	Fact
15min	POV-Ray - The Persistence of Vision Raytracer	Fact

Table 5.1: Course schedule part one

Duration	**Topic**	**Type**
	Week 5	Week
90min	GIMP Tutorials	GIMP
90min	PovRay - Beginning Tutorial	HandsOn
	Week 6	Week
90min	3D Studio Max Tutorials	HandsOn
90min	Creating Low Polygon Characters	HandsOn

Table 5.2: Course schedule part two

Duration	**Topic**	**Type**
	Week 7	Week
180min	Prepare Projects - No Lecture	Collaboration
	Week 8	Week
180min	Peer Reviews of Project Outcome	Online
	Week 9	Week
180min	Present Project Outcomes	Presentation
	Week 10	Week
180min	Repeat and Wrap Up of Content	Lecture
	Week 11	Week
90min	Question and Answer Session	Lecture
45min	Peer Assessment	Assessment
	Week 12	Week
90min	Final Exam	Assessment

Table 5.3: Course schedule part three

- Activity: Piece of work that takes amount of time.
- Actor: Everybody at whom this course is targeted and who is involved.
- Goal: That is why an activity is carried out.
- Document: A document can be a book or html, doc, ppt
- Location: Where an activity is carried out.
- Time: For the schedule.

The combination of the class hierarchy model and the instance data — the learning objects — forms the ontology that contains all the necessary information. The information embedded in the ontology is the source for all the graphs and tables in this chapter and for the HTML pages on the course website. The data is pulled out of the model with the help of online services or query languages. It can be automatically processed and transformed to HTML pages, graphs, and tables.

AT&T's GraphViz was used for generating the graphs. DFKI's RDFSViz web service extracted the class hierarchy information out of the model. 4Front's Versa query language pulled the schedule tables out of the RDF model. Tim Berner-Lee's cwm joined the different RDF files.

Metadata to every learning object is encoded in vocabularies from IEEE's LOM standard and the Dublin Core Metadata standard (IEEE LOM [29], Dublin Core [7]). I used my own vocabulary for the parts where no standard was available, for instance to encode the schedule information. New vocabularies can be easily plugged into the RDF model when they emerge.

5.5.2 Web Application

I used the Apache Tomcat 4 application server to deploy the application on the Web. Tomcat is a servlet container similar to IBM's WebSphere. It is used by the official Reference Implementation for Sun's Java Servlet and Java Server Pages technologies.

The RDF files are loaded using HP's Jena API. They are converted to XML and then put through a stylesheet processor using XSLT. The result is HTML pages that are sent via http to the browser of the user (Figure 5.3).

I included the Google search engine that makes its functionality available through their web services API. It demonstrates how integration of web services works and

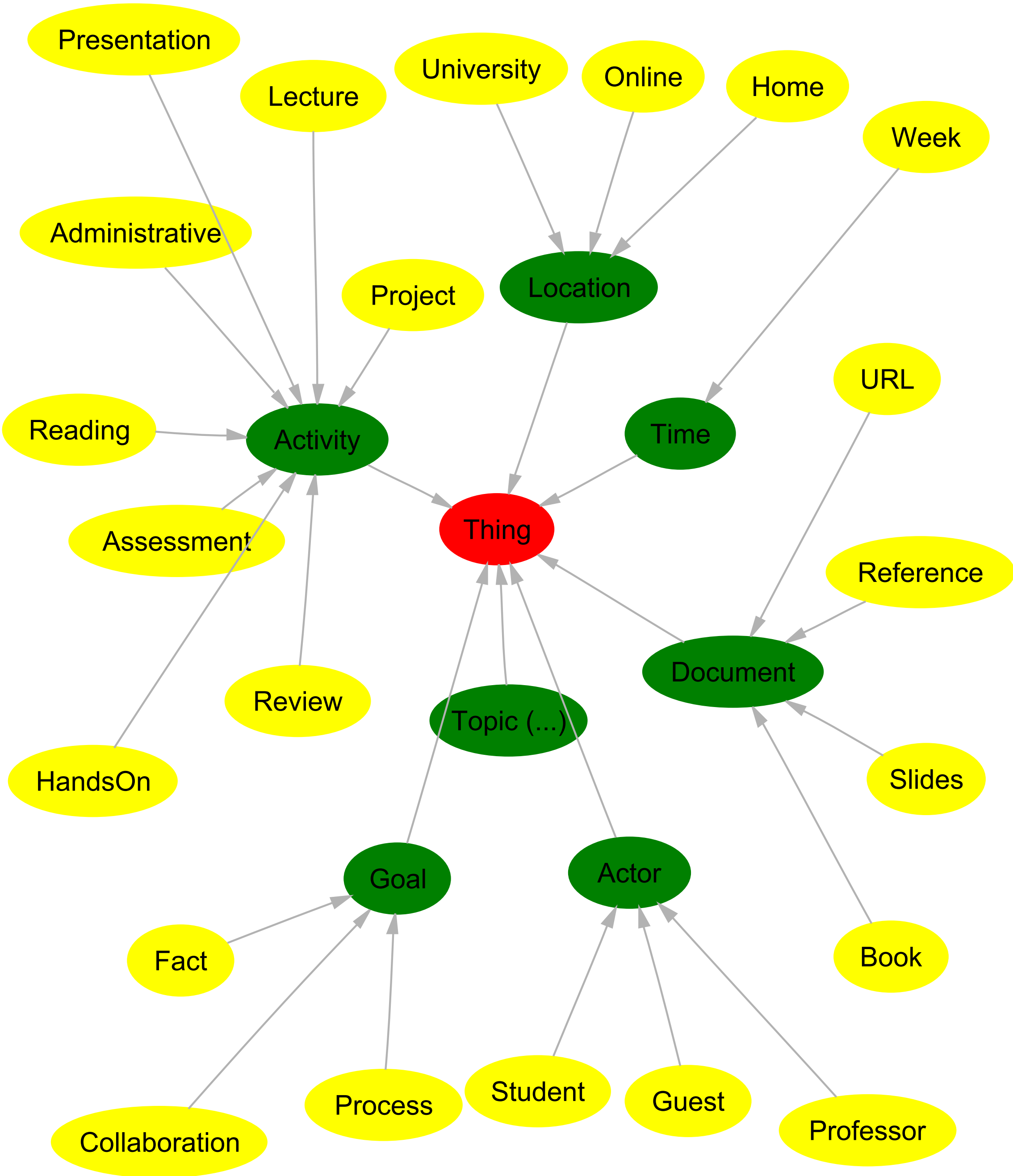

Figure 5.2: The complete class hierarchy for the course.

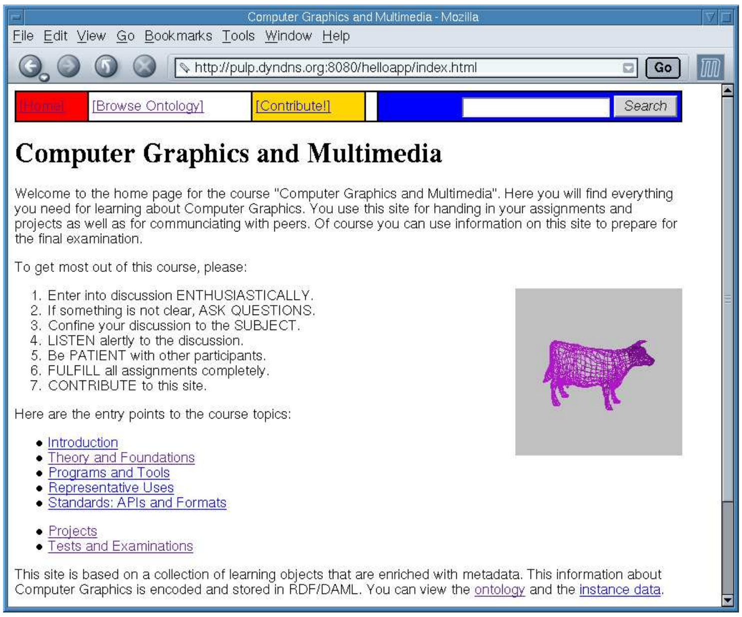

Figure 5.3: Screen Shot of the Web Application

encourages students to explore the field themselves. In addition, the analysis of the search terms can bring valuable insight into topics that students are interested in.

5.5.3 Collaboration Features

Students and teachers can annotate the learning objects with the Web application. The users also have also the chance to add their own instance data. They can use tools to create RDF information bits and upload them into the application. The new information is then automatically merged into the course material. This enhances the quality of the ontology and makes it even more useful.

This mechanism can also be employed to link project presentations into the ontology. Peers can then add comments to the material and give feedback on the website.

Email — the prevalent communication medium on the Internet — can also be integrated. Mailing lists can be generated with all participants modeled and included in the application. It is possible to offer a mailing list for all participants of a particular team and for all students of the course.

Altough the exchange of data with platforms is enabled by adhering to widely accepted metadata standards, some information may get lost when the course model is deployed in other environments since these environments may not support some of the constructs used in the model that go beyond the standard vocabulary. This is just from minor concern since most RDF applications are very tolerant when importing information. Missing or additional data is just not displayed.

Conclusion

The course presented in this chapter consists of a lecture part, tutorials, and projects. A review cycle is established and the students present the outcome of their project. They can collaborate with their peers with the Web application. Students and faculty can continually update the materials. Furthermore, students can use the materials on the site to carry out their own research.

The course materials are encoded in RDF using recent technologies. As a result, the material can be utilized in and exchanged with future learning platforms. Learning objects from different sources are included. The materials are intended to serve as a foundation and provide groundwork for others' own implementation of courses.

Chapter 6

Summary and Outlook

Introduction

The course presented in this thesis combines leading-edge technology with the latest findings in pedagogy. In my thesis, I have tried to put together the various pieces needed for designing and implementing an electronically supported course about computer graphics. This and other issues that go along with e-learning were put into broader perspective.

Semantic Web technology is used to codify all relevant information needed to carry out the course. Students can use the ontology to learn about the course content, project work, and the processes involved in the course. It integrates multiple sources of information and forms a new whole. This approach makes the material available for all participants in a structured and transparent manner. It allows for easy exchange of all knowledge relevant to the course.

I developed a frame into which all graphics related material from various resources are fit. The ontology contains the required information from the computer graphics area. High quality information bits that are available on the Web are integrated in a concise manner. The Web application that displays the content acts as a shared workspace. This makes it easy for students to add their own material and for faculty to keep the content up-to-date to keep abreast with the latest developments in the fast-moving computer graphics arena.

The ontology also contains a framework for carrying out the course based on a peer learning approach. The fundamental processes are described. It is possible to modify and refine them every time the course is held. Educators can add new experiences to the ontology. Furthermore, the open approach facilitates the collaboration

Attribution.	**Noncommercial.**	**No Derivative Works.**	**Share Alike.**
You let others copy, distribute, display, and perform your copyrighted work — and derivative works based upon it — but only if they give you credit.	You let others copy, distribute, display, and perform your work — and derivative works based upon it — but for noncommercial purposes only.	You let others copy, distribute, display, and perform only verbatim copies of your work, not derivative works based upon it.	You allow others to distribute derivative works only under a license identical to the license that governs your work.

Table 6.1: Creative Commons license types (Creative Commons)

and exchange of content across educational institutions presuming they adhere to a "share what you know — learn what you don't" culture.

6.1 Intellectual Property Rights

A lot of content providers fear that others will copy their work and data. Plagiarism poses a great danger with the new type of linking and integration possibilities. Companies from the software and entertainment industry already have problems with copyright abuse. The question arises as to how handle the intellectual property of course objects. Who has the control, who owns the material, and who has the rights to the intellectual property? (Syed [53]).

New types of licenses are emerging to address these problems. There is a catalog of licenses for people who want to publish their material online (Creative Commons [8]). The Creative Commons licenses allow individuals and organizations to release all kinds of information — texts, photos, art, audio, video — under different conditions. They can choose between four basic types of licenses that are described in Table 6.1. These licenses can become for a variety of material what the GNU Public License is for software.

The new licensing model can also affect how content is being developed. The Massachusetts Institute of Technology started its OpenCourseWare initiative to make all their course material publicly accessible by 2007 (OpenCourseWare [4]). The material can be enhanced by people dispersed among various organizations. Others build upon the initial work of content providers and material improves over time, similar to the Open Source software development process.

6.2 Market for Adult Training

It is unlikely that everybody will supply free access to their content due to the cost associated with creating high-quality content (Klein and Hanisch [30]). Content developers want to protect their investments.

However, partnerships between universities and other educational organizations may evolve. In such partnerships, the organizations involved connect their programs, and curricula and tie them together. This enables synergies because of economies of scale. Organizations can bundle their resources not only by co-developing material but also by providing student support and tutoring across organizational boundaries. Institutions around the globe can provide their students with high-quality courses developed by specialists in the field.

Businesses might also be part of such alliances. They can provide financial aid and practical insights into industry projects via case studies. In exchange for that, they can use results from research and include courses about current research issues into training plans for their employees. This leads to a well-educated workforce that can keep abreast of the latest developments in their respective fields.

Issues may arise concerning cultural and regional differences and language barriers. In the European Union, language barriers pose a particularly big problem, which will get even worse when the new candidate countries join. Translation of the material to all of the various languages adds immense cost to development of such programs.

Businesses have also realized the need to develop content for training their workforce. Training can become another enterprise application. Big enterprise software vendors like SAP and PeopleSoft are working on solutions to satisfy this demand.

E-learning can be also targeted at customers. Nokia needs to train its customers because of the increased complexity of their cellular phones. They deploy e-learning to help customers handle their products (eLearningForum [3]).

Clearly, there is a need and a market for adult training. Material developed at universities can be used in various different application scenarios. Whether universities satisfy that demand or private enterprises offer solutions for it remains to be seen. There is a good chance that a combination of both will happen.

6.3 Government Efforts

Governments have realized that learning has become the ultimate competitive advantage in our dynamic, knowledge-based world. Adults should be provided with (e-)learning opportunities to acquire key skills needed in the knowledge society. Key skills include digital literacy and higher-order skills such as teamwork, problem solving and project management. Some countries are further than others in their distance education efforts. Countries that span huge distances are traditionally strong in this area, such as Australia.

There are also e-learning initiatives fo other reasons. The World Bank's African Virtual University was launched in 1997. Its aim is to bring knowledge to an underdeveloped and undereducated continent. The lectures are delivered in the form of video broadcast via satellite to African students. The lessons are taught by European and American faculty and transmitted to 22 universities in Africa. One of the keys to success is feedback loops. Students are given homework assignments, which are then reviewed by the professors. The program has been quite successful. It is currently being continued although the programs' cost is a big issue (Light [34]).

The European Union is trying to transform its economy into a "knowledge" or "information economy" as well. The eLearning initiative there is trying to establish an infrastructure for an economy based on exchange of information. "The eLearning initiative of the European Commission seeks to mobilise the educational and cultural communities, as well as the economic and social players in Europe, in order to speed up changes in the education and training systems for Europe's move to a knowledge-based society [...] It is providing opportunities for [...] helping the workforce to acquire the skills needed in a knowledge-driven economy" (eEurope [1]).

The Commission of the European Communities has assembled an action plan to help Europe effect the transition into a knowledge-based society. Its eEurope initiative states that Europe should have the following by 2005:

- modern online public services: e-government, e-learning services, e-health services
- a dynamic e-business environment

These goals should be made possible by developing widespread availability of broadband access at competitive prices and a secure information infrastructure.

A target for 2002 was to provide all schools with Internet access. The next step is to provide schools, teachers and students with convenient access to multimedia resources. By the end of 2003 there will be Europe-wide networks and platforms. By 2005 member states should ensure that all universities offer online access for students to maximize the quality and efficiency of their learning processes and activities. The Commission intends to propose a specific eLearning program for 2004-2006. Networks and platforms made possible by this program will allow the sharing and exchange of learning resources across Europe.

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Erklärung

Hiermit versichere ich, daß die vorgelegte Diplomarbeit selbständig verfaßt und noch nicht anderweitig zu Prüfungszwecken vorgelegt wurde.
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