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Education

The development of a digital library to support the teaching of computer graphics and visualization

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Abstract

The ACM SIGGRAPH Education Committee web site is being evolved into a Digital Library that will be a worldwide resource for Graphics and Visualization Education. We discuss the history of the website, including a long-standing partnership with the National Science Foundation, and the current work to evolve it into a Digital Library. Finally, we discuss a proposed vision of the future of the Digital Library and how we are working to achieve that vision. © 2000 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The National Science Foundation (NSF) in the United States, in conjunction with other federal agencies, has a major research initiative on the design and creation of Digital Libraries. As part of this initiative, the NSF Division of Undergraduate Education (DUE) has a vision of a Digital Library to support education in Science, Mathematics, Engineering, and Technology (SMET). The goal is to leverage previously funded NSF projects that have developed curriculum materials, and to combine the results of these projects, as well as future such projects, with research into Digital Libraries to develop useful Digital Libraries to support education in SMET. Since these Digital Libraries will be based on the World Wide Web (WWW), they will be international in nature.

This paper addresses the effort to create and enhance a Digital Library to support education in Computer Graphics and Visualization. This is a joint effort between the NSF and the ACM SIGGRAPH Education Committee. As part of the SIGGRAPH Education Committee web site (www.education.siggraph.org) we have had a Computer Graphics Courseware Repository (CGCR) for several years. This has now been extended to Visualization, becoming the Computer Graphics and Visualization Courseware Repository (CGVCR). The CGVCR is being enhanced and is evolving into the SIGGRAPH Education Committee Digital Library (SECDL). This work builds on previous cooperative work between the NSF and the Education Committee.

There has also been a long history of cooperation between the Education Committee and the Eurographics Working Group on Education. At the Graphics and Visualization '99 Conference, held in Coimbra, Portugal in June 1999, it was agreed that there would be a joint effort between the two groups to produce, evaluate, and disseminate educational materials. Thus, the envisioned SECDL would also be a Eurographics DL.

There are two main tasks involved in the creation of a Digital Library to support education. The first is the assembling and/or production of relevant high-quality educational materials and placing them onto a web site. The second task is the evolution of this web site into a Digital Library.

2. Digital Libraries

A Digital Library differs from a database, web site, or online repository in the way it is structured and the way that users can find, access, and retrieve the information. As the amount of materials increases, the ability to locate

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needed materials, or even to browse the information, becomes more difficult. New and innovative methods of navigation are needed. In addition, the materials should be flexible enough to be reused or repurposed, i.e., reconfigured and easily delivered in different sized "chunks" of information. Finally, there should be a sense of community among the developers and users of the materials. The vision of a Digital Library is that of a repository of materials wherein all of this is possible.

Now let us apply this vision to graphics and visualization educators. A professor teaching a course in global illumination wants to find material on ray-tracing caustics. She goes to the SECDL, does a search, and retrieves teaching materials consisting of text, images, and videos illustrating the principles. She also finds relevant portions of SIGGRAPH Conference Course notes and links to original research papers that are housed at the main ACM SIGGRAPH site (www.siggraph.org). She decides to visit the SEC World (see later discussion) to see who might be around. There, she meets an art professor who, as she discusses her work, decides that he is also interested in the same topic, but from an art perspective. He goes to the SECDL and retrieves a set of materials that also cover caustics, but that are suitable for his art classes.

Another professor teaching visualization wants to find images of all visualization techniques that produce images that have an appearance similar to streamlines. So, he performs a query by image content and finds a set of images, ranked in similarity order.

Finally, a professor teaching human modeling techniques wants to illustrate proper and realistic poses, but is unsure of just how to do it. She goes to the CGVCR and finds a section on Contrapposto with images comparing Egyptian and Greek sculpture, as well as some by Donatello.

The common thread in all of the above is that the professor may have an exact idea of what he wants, or only a vague idea and may just be browsing. In all cases the SECDL is able to support their needs.

Computer Graphics and Visualization are unique in that they are of interest to a wide variety of disciplines, e.g., engineers, mathematicians, computer scientists, natural and physical scientists, artists, graphics designers, animators, etc. Thus, educators from all of these disciplines need to have access to materials to teach their own view of these topics. Ideally, the materials could be reused and tailored to the different views.

3. Previous and current efforts on increasing the materials in the CGVCR

Previous efforts were focused on building up the amount of educational materials available on the Education Committee web site. The Education Committee and the NSF have collaborated on several previous projects to provide faculty enhancement workshops in Computer Graphics (1990 (NSF USE-8954402), 1993, and 1994 (NSF DUE-9255489), and Scientific Visualization 1996 and 1997 (NSF DUE-9554692). While the primary thrust of these projects was the faculty workshops, some educational materials were created and placed on the SECDL (HyperGraph and HyperVis). In addition, there has been some donation of materials from other sources.

We have intensified our efforts to gather and/or produce educational materials to place on the SECDL. A recent effort, funded by the NSF (DUE-9752398), has been a project to develop instructional materials to teach concepts of Visualization. These materials are being developed in conjunction and accord with the recommendations of the Education Committee *Committee on Education for Visualization*, Chaired by Gitta Domik, University of Paderborn, Germany. In June 1996, The UK Advisory Group on Computer Graphics (AGOCG) held a workshop on computer graphics and visualization education. Several of the recommendations of that workshop are being implemented in this project. In addition, Ken Brodlie, University of Leeds, was funded by AGOCG to develop a web site on Visualization Techniques, which has been added to the SECDL.

We are incorporating materials from the annual SIGGRAPH Conference into the SECDL, e.g., Educational Slide sets, and some SIGGRAPH Conference Course notes. We plan to put papers from the Educators program on the site. We also plan to place some digitized versions of SIGGRAPH Video Reviews on the SECDL. Of course, all of the above depends upon getting proper copyright permission from the original authors. We also have been in contact with the organizers of the annual IEEE Visualization conference and will try to place some of these tutorials, etc. on the SECDL.

In summary, the SECDL has a rich set of high-quality multimedia learning materials. However, the very richness and size of the SECDL, and the different viewpoints and needs of the educators that want to access it, makes the material not as accessible and flexible as desired, which is the motivation for these projects.

4. Digital Library project

We have begun another set of projects, in collaboration with the NSF to evolve the CGVCR into the ACM SIGGRAPH Education Committee Digital Library (SECDL). As discussed above, this means improving the navigation and retrieval capabilities and the flexibility of the materials.

4.1. Database-related projects

These projects, supported by NSF (DUE-9816443), involve improving the navigation and information

retrieval aspects of the SECDL using database related technology. We are approaching this in several ways. We have implemented a conventional search engine (InfoSeek). However, this type of technology is limited so we are performing research on two other types of navigation and retrieval.

It is the opinion of many people that database technology will play a critical role in Digital Libraries. However, there is one important difference between the information available on the Web and the information usually stored in a traditional database: the lack of "structure" in the Web information and the strong "structure" to the information stored in a database. Recently, the term "semi-structured" data has been coined to refer to the data and information such as those stored on the Web. The SECDL falls under this category of "semi-structured" information. We are using two different data base systems that deal with semi-structured data on the Web to provide ad hoc querying and search capabilities for the SECDL.

One system is Lightweight Object Repository (Lore), developed at Stanford University, and designed to support storage and queries of semi-structured data. In Lore, data is self-describing, so it does not need to adhere to a schema fixed in advance. Lore is particularly well suited for document data, including HTML documents available on the World Wide Web. Lore uses XML for its data definitions. We have developed a prototype system using the SPACE Slides portion of the SECDL. The user can enter queries and the Lore system returns information about the different slides.

The second approach is Virtual database technology, a radically different approach to manage and query semi-structured data on the Web. In this approach, textual data is converted to structured relational database data and queries are performed on the relational database. All this is transparent to the user who is interacting with a Web agent that receives search and query requests and processes them by invoking data converter modules (adaptors) and then querying a relational database.

Virtual database technology transforms the Web into a database, using adapters that analyze the HTML from Web sites to present them as relational data sources. The limited descriptive capability of HTML necessitates manual analysis for the creation of adapters. However, with XML the creation of these adaptors can be automated.

We are also investigating Visual Information Retrieval techniques, such as the Query by Image Content (QBIC) system from IBM and the Oracle-based VIR system. These systems will allow users to use graphical queries, e.g., either start with an existing image or sketch a new image and request similar images. We have implemented the QBIC system on the SECDL and queries are now possible over all images in the system.

4.2. XML-related projects

These projects are supported by the NSF Digital Libraries Initiative (IIS-9980130). They extend the above efforts to increase the navigation and information retrieval aspects of the SECDL and directly address the reusability issue. They also include the creation of SEC World. These projects involve XML and its associated technologies.

The eXtensible Markup Language (XML) (see, for example, [1]) is a markup language for documents containing structured information, i.e., information that contains both content (words, pictures, etc.) and some indication of what role that content plays. The XML specification defines a standard way to add markup to documents. Unlike HTML, XML is extensible, i.e., you can create your own tags. XML can be applied to any application area by creating a Document Type Definition (DTD) for that topic. The DTD is the set of XML tags for the particular area and is specific to that area. DTDs are the technology that allow standard XML tags to be defined, and that permit different platforms and machines to understand XML descriptions and applications. DTDs for specific disciplines have been previously created, e.g., for mathematics [2], chemistry [3], and biology [4].

4.2.1. Material reuse

For this project we are creating a DTD for computer graphics and visualization. This DTD is based on the results of the SIGGRAPH Education Committee Graphics Taxonomy Project, led by Jacquelyn Ford Morie. The goals of the Taxonomy Project are to create a complete Taxonomy for Computer Graphics and Visualization and to have educators from different disciplines create different curricular views of the topics. This DTD will allow us to semantically markup any document in these areas.

Another important part of XML technology is the eXtensible Style Language (XSL). An XSL style sheet is an XML document containing a set of template rules. These template rules describe how the original XML element node is converted into an XSL element node that can be formatted, styled, and displayed. By having different XSL style sheets, a set of XML documents can be tailored to different views. We will create different XSL style sheets in our project that correspond to the different curricular views of educators wanting to use the resources in the SECDL.

Even though the Taxonomy Project will not be completed until August 2000, we have begun to develop and test prototype DTDs based on the current version of the Taxonomy Project. We have taken part of the section on Rendering (Lighting Models and Texture Mapping) and created a prototype DTD from this. We have found that this is a straightforward process, enough to give us the

confidence that, given the final, full Taxonomy, we will be able to create a full DTD.

4.2.2. 3D navigation of the information space

Navigation in a complex 3D space is a difficult problem. The user needs to be able to have an overview of the complete space and be able to dive down into the details of a particular subspace. The user should also have a trail and know which parts of the space they have already visited. This is now possible with the 3D Graphics technologies associated with XML, especially the eXtensible 3D (X3D) project [5]. The goal of the X3D effort is to express the geometry and behavior capabilities of VRML in XML. There has been a draft DTD created for VRML created by Bullard [6]. Lipkin [7] discusses the use of XSL Stylesheets to dynamically generate VRML worlds to display the results of database queries. Ancona [8] discusses 3DXML as a way of describing websites and other structured information spaces in XML and publishing them in VRML. This would allow for 3D navigation of the information space.

The objective of this portion of our project is to generate a 3D VRML world that represents the particular view of the information space generated in the first part of the project. Assume a user in computer science has requested a particular view of a topic area. From the first part of the project, this query will have generated a set of XML/HTML pages and associated materials. This query will also generate a 3D VRML representation of all of the materials in the form of a hierarchical graph structure.

In this VRML world each node might be a sphere that could contain a sub-graph structure. Sub topic areas could be represented as translucent spheres that the user could move into as they traveled. There would be a nested graph structure that could represent an information space of considerable complexity. For example, a top-level node might be *Rendering*. This might then contain a sub-graph with one of the nodes being *Lighting Models*. This could contain another sub-graph with nodes representing *Local Illumination* and *Global Illumination* models, each with additional sub-graphs. The user can navigate in this VRML world to find the different types of materials. The user can pull back and look at the entire space or traverse along the links to look at different volumes of the space. When the user visits a portion of the space that node/sphere would be marked, e.g., a color change, as having been visited. Since a user can have more than one instance of a VRML browser, they could simultaneously have multiple views of the information space world.

4.2.3. Sense of community

Developing a sense of community among Digital Library users and developers was one of the important issues identified at the NSF January, 1999 workshop on Digital Library research. There are several ways we have addressed this in the SECDL. The first is a simple listserve that is used for announcements and has some discussion. But a listserve or web discussion page is asynchronous and not real time. A real-time chat room engenders more sense of community, but is text based and not visual. We are developing a 3D virtual world that will be more attractive to our community.

Imagine the existence of a fully 3D interactive virtual world (SEC World) and the following possible scenarios:

A computer science professor from Darmstadt, Germany logs in to SEC World. As she wanders around she encounters another avatar who is an art professor from Ohio, USA and also a professor from the University of Leeds, UK, who teaches visualization. They engage in a three-way discussion about the possibilities of incorporating aspects of each other's disciplines into their own courses. The art professor mentions a book on drawing that illustrates how certain techniques can help a person focus in on what is important in an image and the Leeds professor decides he will look at it and incorporate parts of it into his class. After further discussion the three of them decide to get together later and submit proposals to their respective Universities for interdisciplinary courses that they will jointly develop.

An engineering professor from Colorado, USA enters SEC World for the first time. He is just beginning to teach courses on Engineering Graphics and he is not sure what he is looking for and would like to find out what all this is about. He sees an avatar with a baseball cap that identifies her as an SEC World Guide and goes and asks her some questions. He knows that she is a guide because the Student Volunteers at the annual SIGGRAPH Conference wear baseball caps to identify them. She informs him of who else is currently in the SEC World and where they are located. She also gives him brief descriptions of the parts of SEC World and answers some of his questions. He thanks her and goes to another room where another engineer is talking with some artists.

The people in the above cases might not be faculty but could just as easily be students who are looking for some interdisciplinary help that might not be readily available at their own institution.

The above is possible by the use of Multiple User Shared Environment (MUSE) worlds. SEC World could be created and downloaded the first time from the central SECDL. After that, the users could invoke this world and enter it without downloading a large amount of information. A complex world needs a powerful processor and graphics card, but these are becoming very inexpensive. The required bandwidth is low since the only information that is being transmitted is the changing coordinates of the avatars and the text chat. If the users use microphones, then the bandwidth requirements are only slightly higher. For example, current commercial MUSE worlds are designed for users who communicate to the Internet via 28/56K modems.

Users could choose an avatar in the database or design a new one and upload it to the server. The special guide mentioned above would not be a person but an intelligent agent with a specific knowledge base who would have access to a large amount of information about the SEC World as well as the SECDL. We are not proposing a full natural language discourse but only a subset.

We have begun working with the DeepMatrix [9] VRML server/client system. This is an opensource system written in Java. We have installed the system and are currently modifying it for our project. The primary modification is to allow the system to use locally stored worlds, solving the bandwidth problems discussed above, and use network connections for changes, avatar updates, and text/speech.

4.2.4. EduCause IMS

A final proposed project relates again to navigation and retrieval issues. We have been in contact with the developers of the EduCause Instructional Management System (IMS), an XML-based system of metadata for general instructional navigation and retrieval. EduCause is proposing that IMS become a standard for all educational sites. We are planning on using the SECDL to act as a multimedia testbed for IMS in version 1.0. We will extend the general IMS metadata to be more specific for topics in graphics and visualization. This project is a collateral project with those discussed above and has also been submitted to NSF as part of a consortium effort led by the Collegis Research Institute.

5. Conclusion

The evolution of the current CGVCR into a full Digital Library, the SECDL, will provide much greater functionality for graphics and visualization educators. Using new XML related technologies; we plan on increasing the flexibility and navigation capabilities of the SECDL and enhancing the sense of community among its users. The SECDL has the potential to be an international resource that can service educators worldwide. There are many research problems that must be investigated and overcome before the ideal can be realized, however once achieved, the SECDL will provide a prototype of the educational Digital Library of tomorrow.

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