

DEVELOPMENT OF A WEB BASED TRAINING SYSTEM AND COURSEWARE FOR ADVANCED COMPUTER GRAPHICS COURSES ENHANCED BY INTERACTIVE JAVA APPLETS

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ABSTRACT

We propose a web-based training system and courseware for advanced computer graphics for undergraduate students. By using the system, the students have no temporal and spatial limitations for learning computer graphics technologies. Once they can connect to the Internet, they can study for as much time as they wish and in any place. We have designed more than 50 Java applets from the educational viewpoint, and developed them to enable complicated computer graphics algorithms to be comprehensibly understood. All of the applets have been developed by using pure Java programming language because of its hardware-neutral features and wide availability on many hardware platforms. Hence, the students can use any Java enabled browser on any kind of platform to study interactively computer graphics technologies via the system.

Key words: computer graphics, Java applet, web-based training

1. INTRODUCTION

The technologies of computer graphics have become more and more important, since there are more and more people wanting to use them to create more imaginative contents. How, when and where one can study these useful technologies are good questions for many people, because not everyone majors in computer graphics. With the rapid growth of the Internet, we propose a web-based training (WBT) system and courseware for advanced computer graphics for undergraduate students. By using the WBT system, the students have no temporal and spatial limitations for studying computer graphics technologies. Once they are able to connect to the Internet, they can study as much as they wish and in any place.

We have designed more than 50 Java applets for the educational purposes, and developed them so that complicated computer graphics algorithms can be comprehensibly understood through interactive and intuitive operations in the WBT system. These include 2D/3D geometrical transformation, digital image processing, z-buffer algorithm, smooth shading, lighting models, material, texture-mapping, rendering, animation, etc. Besides the Java applets, we have also provided an on-line textbook written in HTML (Hypertext Markup Language), so that the students can still get support from a textbook as before. From the educational viewpoint, communication between advisors and the students is also important, therefore an on-line FAQ whiteboard is also provided to answer all the questions from the students.

There are several advantages for the WBT system: (1) the students could plan their own study schedule and arrange their leisure time for studying; (2) the students could study the multimedia materials interactively since we use web technologies, like HTML and Java, to design them; (3) because all of the computer graphics algorithms in the system have been implemented by using Java, the students could study them by controlling all the parameters via friendly graphical user interface; (4) the students' studying statuses have been recorded by the system so that to monitor the statuses is possible; (5) an on-line teacher mechanism is also provided to check the homework and mini-tests of the students.

Finally, the contents have been designed to produce two three-month distance learning courses, which have been evaluated in Japan by the Computer Graphics Arts Society (CG-ARTS) since November 10th, 2000. From April, 2002, the distance learning system has been improved and renamed the "e-Learning CG Technique Master Courses".

2. RELATED WORK

The traditional CG learning methods are introduced first, and then previous Internet distance CG learning methods are described.

2.1 Trends and Categories in Computer Graphics Learning

The methods of teaching computer graphics can be classified into three categories (Suzuki et al., 1993). The first category is to do the programming tasks to understand the algorithms, which is called programming learning. The second one is to do the programming tasks from given programs of some basic algorithms, which is called semi-programming learning. The last one is to use some commercial products or applications for studying, which is called ready-program learning.

Suzuki et al. (1992) provided several programming assignments on the set operation algorithm, which is the foundation of solid modeling. These assignments included drawing a curved surface and some Pascal programming exercises (Suzuki, 1999). For Kondo and Ogata's (1993) example, they used the exercises for geometrical transformation and projection which are basic computer graphics technologies (Kondo, 2001). Mende and Fuchigami (1993) instructed students majoring in design, to do programming tasks to introduce their work, and hoped that this would allow them to understand the rules or sequences of a natural model for developing good design systems. Besides these, Suzuki (2001), Tsutsumi (2001), and Yamaguchi (2001) also provided some examples for teaching computer graphics.

For these examples, although it is necessary to provide other programming courses and the students should also spend some time for debugging, to develop some new computer graphics technologies, this kind of learning for fundamental algorithms is very important.

2.2 Computer Graphics Learning via the Internet

Via the Internet, teachers can not only use textbooks but also show slides, data sheets, pictures of real objects, or other media to the students. Moreover, since some programming languages, like Java, are designed for the Internet and enable users to use interactively, the courseware for computer graphics learning could be provided all over the world. For example, in the educational homepages provided by Nishita¹ (Nishita, T., 1998) and Kondo², there are some course notes, a computer generated image gallery, and links toward other related societies and researchers. Since they have some program examples, these homepages are similar to the semi-programming category. However, there are also some more complex exercises without any simple examples; this is more like the programming category.

Takahashi et al. (1996, 1997) created a homepage for computer graphics learning using HTML files, Java applets, example programs, and data. This course page can realize distance learning by using active courseware and can be executed on almost any kind of computer. Nagae and Iida (1997, 1998) proposed a project for learning descriptive geometry from the Internet. Lieu (1999) and Tan et al. (2001) also have reported on education for engineering graphics via the Internet. Chen et al. (1998) used VRML (Virtual Reality Modeling Language) models to demonstrate the process of model generation. Araki (1996) showed the results of CAD (Computer Aided Design) education for several universities via the Internet.

However, to date, there is no project or system that enables computer graphics technologies to be learnt efficiently and systematically using Java applets that can be used to understand algorithms for self-study via the Internet.

3. FEATURES OF JAVA COURSEWARE

The Java courseware has the following features:

- 1) By using Java applets, distance learning courses can be realized for interactive studying.
- 2) Students can control several parameters interactively by themselves, so that they can learn what they really want, in their own way. The system can give the students hints in the teaching material to match the study schedule by ranking their study progression automatically, so that the individual differences between the students can be decreased.
- 3) Since the Java applets can be executed on any Java enabled web browser, no extra special software is needed. Therefore, the students can not only study in the classroom but also by using a computer at home.

By utilizing 3D technologies, multi-dimensional information can be deeply understood, since the courses can be taught by using 2D and 3D technologies, static images, and interactive animation.

By using the WBT system, there are no temporal and spatial limitations for studying, once the students are able to connect to the Internet, they can study as much as they wish in their own time. The teaching material is developed by utilizing the Java applets and information technology (IT) according to their interactive involvement, so the students are able to get extra useful help for studying rather than being only able to use books, as before.

4. INTERNET DISTANCE LEARNING

4.1 Study Target

"Internet Correspondence Courseware for CG Standard Courses" is designed for teaching the required knowledge and technologies equivalent to the second level of "The Certification Test of Com-

¹ <http://nis-lab.is.s.u-tokyo.ac.jp/~nis/>

² <http://www.ke.ics.saitama-u.ac.jp/kondo/>

puter Graphics”, which is authorized by the Ministry of Education, Culture, Science, Sports, and Technology of the Japanese government. Therefore, helping the students to fully understand the contents of the main textbook, “Standard CG Textbook: Theory and Algorithm Version”, is the main target of the courseware development. To reach this target, we developed web teaching materials, using Java applets for the main part, to help students to study the high-tech contents easily. Hence, we focus on undergraduates and technical college students who wish to study more high-end computer graphics technologies.

4.2 Courseware Organization

The contents in part 1 of the courseware are “Computer Graphics and its Applications”, “Rendering”, “Digital Image Representations”, and “Image Processing”, and part 2 includes “2D Image Generation”, “3D Geometrical Transformation”, “Modeling”, “Computer Animation”, “Digital Image and Modeling”, “System”, and “History of Computer Graphics”.

4.3 Courseware Advantages

The advantages of our distance learning courseware are listed as the follows:

1) Web Based Training

- The students can plan their own study schedule and arrange their leisure time to enable them to study from anywhere via the Internet.
- The students can study the multimedia teaching material interactively since we use web technologies, i.e. HTML and Java, to design them.

2) Java Courseware

- Since a lot of interactive computer graphics courseware has been developed by Java programming language, by studying with these Java applets interactively, complex computer graphics algorithms can be easily understood. This will be described in the next section.

3) Rich in Study Support Mechanisms

- Each student’s studying status is controlled by the system, so that the mechanism to re-open the lesson where the student stopped last time, the mini-tests mechanism designed for checking the student’s level, and the monitoring mechanism for the students’ progression are offered. Moreover, the mechanism to send mail automatically to students to encourage them to study harder is also implemented.
- Since the students study by themselves via distance learning courseware, we also offer the following mechanisms: (1) useful FAQ (Frequently Asked Questions) pages to help the

students find solutions easily; (2) several on-line teachers to answer questions from the students and also check their homework and mini-tests; (3) the status of the students’ answers to the questions are also monitored by the system.

4) Course Notes

- The contents of the “Standard CG Textbook: Theory and Algorithm Version” are described by using only two dimensional representations just like other textbooks, which for some people makes the more difficult parts hard to understand. In the course notes (Computer Graphics Arts Society, 1999), much additional material are also provided, such as: (1) detailed descriptions and the derivation of the formulas; (2) the algorithms are explained by flowcharts; (3) the difficult contents are described more clearly by using several comparison tables, figures, and flowcharts.
- While reading the course notes, the students can use the Java teaching material to verify what they have learned through the results. This is a new method of learning by which we want to teach them.

4.4 Learning Sequence

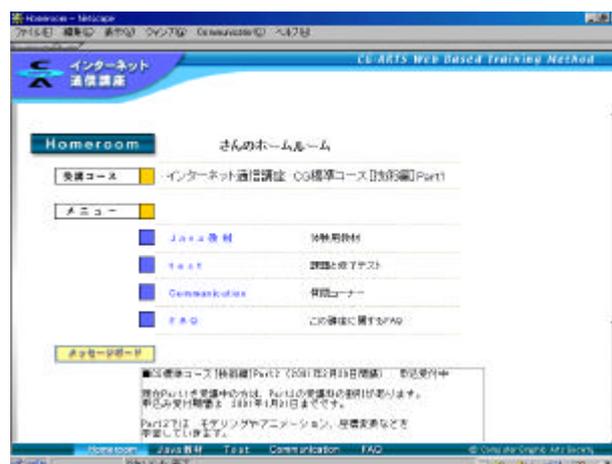


Figure 1: top page.

The “homeroom” page, shown in Figure 1, is the top page of the system and displayed every time the student enters the system. From the menu, the student can select “Java Courseware”, “Test”, “Communication”, or “FAQ” as he or she needs. The main part of our system, Java Courseware, will be described in the next section; other components are as follows:

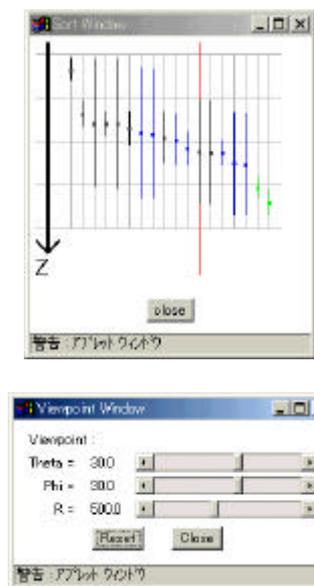
- 1) **Homework** – for checking the study schedule and understanding, there are three parts to the homework in our system. This homework is referenced from the “Computer Graphics License Examination” and formed as mini-tests; the students can check their own problems or misunderstandings through this.
- 2) **Question** – if the student has some questions while studying,

he or she can find the proper answers from the “FAQ” page. If he or she is unable to find the proper answers from there or wishes to know more details about the questions, he or she can use the mailing mechanism on the “Communication” page and the questions will be answered by the on-line teachers.

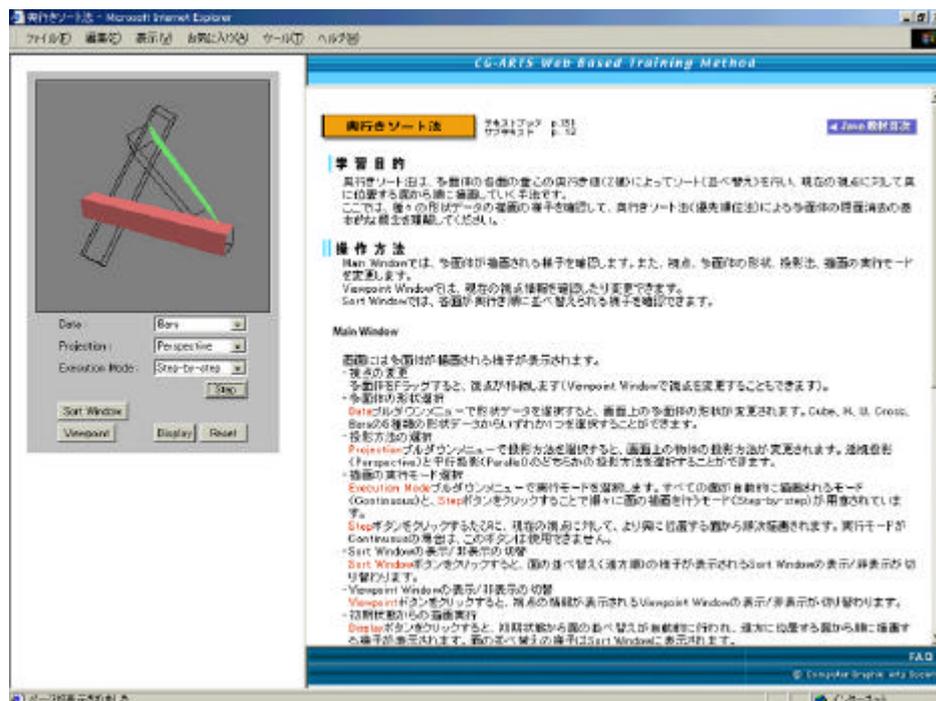
- 3) **Final Exam** – when the student, after finishing the curriculum, has passed all three mini-tests, he or she is able to attend the final exam. If the student also passes this exam, he or she will get a certification.

5. JAVA COURSEWARE DEVELOPMENT

We have developed about 54 Java applets, which include ray-tracing, fractal, Bezier surface, radiosity, etc., as listed in the



(a)



(b)

Figure 2: (a) control windows and (b) main window.

Figure 2 is the page for learning the depth-sort algorithm, which is also called the painter’s algorithm. The polygons in Figure 2 (b) are converted into several vertical line-segments as shown in the upper window of Figure 2 (a), which shows the position of each polygon in the z axis. When the user moves the viewpoint, the length of the line-segment is changed and the line-segments are re-arranged automatically. The color (blue, green, and black) of the line-segment represents the rendered face (blue), the face that is going to be rendered (green), and the face that has no need to be rendered (black). Figure 2 (a) are the control windows of the Java applet in Figure 2 (b) for helping to show the information or control the parameters of the main window when needed.

Figure 3 shows an example of the page for image processing, which contains the sampling and quantization courses. For a

appendix. To make the system easy to use for the students, the system development is described in the following sections.

5.1 Layout Design

The main window layout, which is shown in Figure 2 (b), has two parts: the left frame is a Java applet, and the right frame is the introduction and course manual. All of the courses in the system follow the same layout rules, so that the student can read and use these pages uniformly. The window size of the Java applets is fixed and uniform so that it is not necessary for the students to use the scrollbar. However, in the page for image processing, shown in Figure 3, since we wish to compare the original image with the processed one on the same page, the size of the frame which contains the Java applet is set to be twice the width of one image.

given image, by changing the level of quantization or the interval of sampling interactively, the basic algorithms of image processing can be easily understood.

5.2 Design to Improve Understanding

We developed the interactive Java courseware by utilizing the features of Java applets, and designed the system to enable the students to understand the contents easily and quickly. In this section, we use the example shown in Figure 2 to describe how it is used.



Figure 3: the applet for image processing.

For example, if a student wants to move the viewpoint, he or she can (1) use the mouse to drag the object in the main window interactively, or (2) use the scrollbar in the lower window of Figure 2 (a) to change the position of the viewpoint, or (3) enter the exact position of the viewpoint directly. Therefore, the user has many choices to control the Java applet to study.

For understanding the complex computer graphics algorithm, we develop the Java applets as following:

- 1) For the Java course example in Figure 2 for learning the depth-sort algorithm, there is a “step-by-step” mode. When the user sets the “step-by-step” mode “on”, the system pauses after rendering one polygon when processing the algorithm. Hence, the user is able to see the algorithm progressively and understand it more easily.
- 2) To enable the student to understand the depth-sort algorithm easily, we use the “sort window”, which is shown in the upper part of Figure 2 (a), to show steps in the algorithm processes. Each line-segment in the window represents a polygon in the main window, and the position of the polygon in the z axis sorts the line-segment from left to right. The length of the line-segment represents the range in the z axis in which the polygon exists. When the user moves the viewpoint, the length of the line-segment is changed and the line-segments are re-arranged automatically. The color (blue, green, and black) of the line-segment represents the rendered face (blue), the face that is going to be rendered (green), and the face which has no need to be rendered (black).

5.3 Lifting Windows

The windows shown in Figure 2 (a) are the “lifting windows” which are used to help the students understand computer graphics algorithms and display some useful information to them. These lifting windows are popped by the main window when necessary. If the student is using a computer with low screen resolution, the lifting windows might be hidden by the main window. Therefore, when the main window has finished the process, the open lifting

windows are re-popped again to make them shown.

5.4 CD-ROM Version

To enable the students to study off-line, we also deliver the CD-ROM version of the Java courseware to the students. Figure 4 is the applet for radiosity in the CD-ROM version of the Java courseware. Therefore, our system does not only teach the basic algorithms, but also some advanced computer graphics technologies.



Figure 4: the applet for radiosity in the CD-ROM version.

6. CONCLUSION

We have proposed a web-based training system and courseware for advanced computer graphics. All the contents have been designed to be included in two three-month distance learning courses, which have been evaluated and have served in Japan from November 10th, 2000. Since we published the courses on the Internet, more than 250 students have registered and studied, and we have also got many good responses and suggestions from other teachers and students all over the country. These have enabled us to improve the WBT system to provide more useful courses and to satisfy the students' wishes.

From the experimental development of this WBT system, we hope to build a more efficient educational system for students. The responses from the students are also valuable for our analysis of the learning system and to help us improve the Java courseware to provide a more powerful system in the near future.

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APPENDIX

The prepared Java applets in the system are divided into 8 chapters, the followings are the list.

- 1) **Rendering** - painter's algorithm, z-buffer algorithm, scan-line algorithm, ray-tracing, ambient light, diffuse reflection, specular reflection, transparency/refraction, radiosity, Gouraud shading, Phong shading, shadows of parallel or point light source, texture mapping, solid texturing, bump mapping, and environment mapping.
- 2) **Digital Image Representations** - sampling, quantization, Additive color mixing, and Subtractive color mixing
- 3) **Image Processing** - contrast transformation, gamma correction, segmentation, halftone approximation, smoothing, mask, overlay, chroma key, hi-contrast effect, posterization, nega effect, solarization, emboss, mosaic, and blur.
- 4) **2D Image Generation** - 2D geometrical transformation, line drawing, painting, and antialiasing.
- 5) **3D Coordinate Transformation** - 3D geometrical transformation, projection, and coordinate system.
- 6) **Modeling** - CSG (constructive solid geometry), sweep, curved surface, parametric curve, parametric surface, fractal, and meta-ball.
- 7) **Computer Animation** ? display objects and viewpoint, key-frame, morphing, dynamics, and FFD (free-form deformation).
- 8) **Digital Image and Modeling** - design and mathematical expressions

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