AC 2003-438: SKETCH OF AN ADVANCED COURSE IN COMPUTER GRAPHIC APPLICATIONS IN CONSTRUCTION

Russell Walters, Iowa State University

Zhili (Jerry) Gao, North Dakota State University

A New Sketch of an Advanced Course in Computer Graphic Applications in Construction

Russell Walters, Zhili Gao
Department of Civil and Construction Engineering, Iowa State University

Abstract

This paper presents the sketch of a graduate-level course being designed in the construction engineering and management program to teach students advanced computer-graphic based knowledge and applications. Students in the course will use OpenGL, MicroStation, ShockWave, 3D Studio, Cyclone, and Object Oriented CAD (OO-CAD) to integrate design and construction processes, enhance construction operations, reduce construction operation and management efforts, and solve real world construction problems of increasing complexity. OpenGL and related computer language basics allows students to learn the theories and tools to develop and apply various CAD packages in architectural and construction area. MicroStation allows student to apply or develop 2D and/or 3D drawings as the base to perform construction engineering data extraction, storage, and calculations. ShockWave and 3D studio provide the tools to develop 2D and 3D animation of transition from design to construction process. Cyclone allows students to perform laser scanning operations for existing projects or current construction sites and gather as-built graphical data to help the design process and construction management. OO-CAD together with other tools is used to develop graphic specifications and guidelines for the construction process. After students obtain these computer-graphic based skills, they will be able to graphically simulate and the operate construction process in a simple, accurate, safe, and effective way. Also, more advanced construction simulation and integration concepts could be created from this knowledge. The prerequisite knowledge for this course and the way to bring industry practice into this course is discussed as well.

Introduction

Computer graphics and its applications are becoming increasingly important for construction practice due to the increasing availability of applications and the evolution of computer technologies. This is because computer-graphics enables an easy, visible, efficient, and integrated way to improve the performance of construction activities. The applications of computer graphics can, in return, change the way computers and computer graphics are used in the construction industry. The advantages of computer graphics technologies can be easily applied to construction workers, including those without advanced computer skills.

The advanced course described in this paper is being designed for a graduate level course in

construction engineering. This course provides graduate students the opportunity to become familiar with new computer technologies and to recognize the application of computer graphics in construction.

Course Components

The prime objective of the course is to expose students to the basic concepts and practices involved in applying and using computer graphics and applications to construction activities such as planning, designing, and simulation. The proposed course includes three major components:

- Part I – Basic Computer Graphics: This review allows students to review the basic theories about computer graphics and learn the potential benefits for construction.
- Part II – Applications in Construction: This part focuses on using available software packages based on computer graphics and their applications in construction. These include Computer Aided Design (CAD), animation, simulation, and integration.
- Part III – Advanced Technologies: This part introduces new technologies related to computer graphics in construction, including graphical construction data capture and design. Recent applications such as laser scanning and object-oriented visualization will be included.

Different teaching strategies should be applied in each of the parts above, including formal lecture, lab practice, and real projects. Some of the main software packages will be explained in the following details.

Upon completion of the course, the students will be able to:

- Understand the basic concept of computer graphics and its capability to meet some construction needs.
- Recognize new developments in computer graphics related to architectural and construction.
- Recognize the scope of construction activities for which computer graphics are applicable.
- Independently select appropriate packages and design uncomplicated systems for applying computer graphics knowledge to improve construction performance.
- Design complicated systems after self-study and advice from experienced engineers.
- Locate the future research direction if more research work is needed for this area.

In one word, students should know how to analyze and design construction operations using computer graphics knowledge to simplify and improve the critical construction process.

Basic Computer Graphics

This is the first topic, which allows the students to learn two major concepts: one is about computer graphics; the other is about computer languages for computer graphics. The reason for

including those concepts in this course is straightforward. Students need a solid computer graphics background to learn and develop graphic based applications. However, the course is significantly different from any computer graphics or programming classes in computer science or engineering area.

The purpose is to review and enhance students' background to meet architectural and construction activities requirements. It is intended for students to apply the basic principles and techniques of the computer graphics field to write substantial graphics applications for construction activities with an emphasis upon 3D environment. It includes translating a particular design task into its underlying geometric components, finding a suitable mathematical representation, and translating this representation into suitable algorithms and program codes. The related computer programming languages and library include, for example, C++, OpenGL, and Visual Basic.

C++ Programming Language

Although many computer programming languages are available for computer graphics, the most powerful, highly flexible, adaptable, popular, and probably easiest programming language is C++. It allows users to organize and process information quickly and effectively. In addition, it can be written in object-oriented style and easily call functions from a computer graphics programming library. Therefore, it is appropriate to adopt C++ as the main programming language for this course.

C++ was first developed by Bjarne Stroustrup in 1980, which based on C language (Oualline, 1997). The important reason of its popularity is portability (Gaddis 2001). A graphics program written in C++ can run on many types of computer systems with little or no changes. This is important for the construction industry where there is a variety of computer systems from personal computers to UNIX systems.

In this course, as a review, students will be asked to program a simple code to graphically simulate a building or highway bridge. Besides the basic requirements, students can freely add more components such as crane operations, form set-up, and more complicate construction site. The purpose of this project is to allow students to refresh their memory about C++ syntax, coding standards and style, creation and use of object classes, templates, debugging, and optimization.

3D Graphics Interface OpenGL

OpenGL is a hardware-independent software interface that can be implemented on many different hardware platforms (Woo et al. 1999). It consists of about 250 distinct commands needed to produce interactive three dimensional (3D) applications. The software runtime library ships with all Windows, MacOS, Linux and other Unix systems. The following features of OpenGL are very useful to make computer graphics simulation of construction operations:

- Fast and complete 3D hardware acceleration: massive amounts of data of construction activities can be manipulated in real-time by using OpenGL hardware accelerated geometry and rendering.
- Possible real-time 3D effects: openGL provides special effects to images without compromising performance. These effects include, for examples, real-time fog, anti-aliasing, volume shadows, bump mapping, motion blur, transparency, reflections, and 3D textures. This can make construction simulations closer to the real world and allow computer graphics become meaningful application in the construction industry.
- Compatibility on every platform: since OpenGL is fully platform independent, the application can be easily communicated among Windows, Unix, Linux, and MacOS. This means all sizes of construction companies can use the same software with their own system.

An OpenGL project is the combination of C++, OpenGL, and basic computer graphics concepts. The OpenGL Utility Library (GLU) provides many of the modeling features, such as quadric surfaces, which make it easier to simulate the construction scene and activities. The class project could be similar to the image shown in Figure 1 (modified from www.3dnature.com, Mike Mundy). The construction process of the highway construction should be simulated graphically in this project. Through this project, students are able to be familiar with the process to apply computer graphics using OpenGL for construction activities.

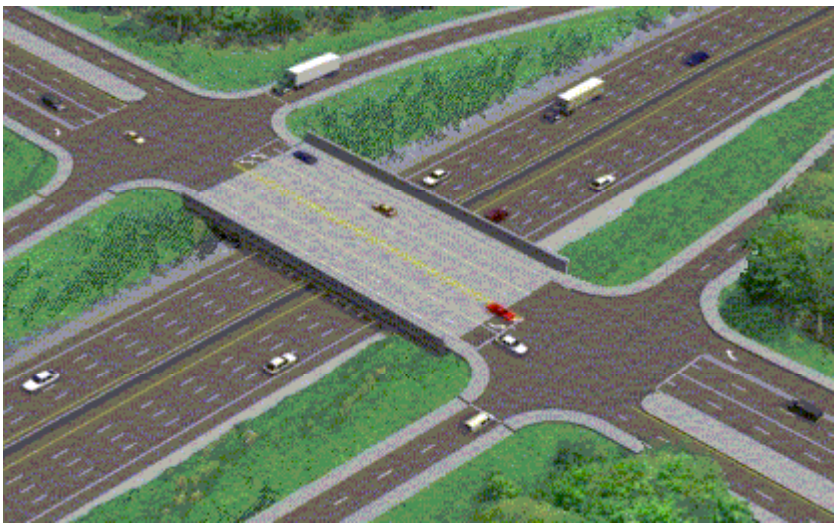

Figure 1. OpenGL class project

Current Applications

Although the tools introduced in the first part can develop the graphics of construction process, it is time consuming and needs solid programming skills. This limits the applications of computer graphics in construction industry. Fortunately, many CAD packages are available on the market that allows construction people to develop construction models with minimal programming. The

second course topic allows the students to recognize the most popular and useful software packages that can be used to apply computer graphics benefits to improve the efficiency of construction process.

The purpose of this part is to help students develop the ability to select software packages for future specific construction applications. The course will summarize the available software packages and then select a few critical packages for students to practice by doing class projects. The applicable software packages can be categorized into four groups. The first group includes CAD packages such as AutoCAD and MicroStation. Construction engineers need to use these packages to view, modify or develop 2D and 3D architectural and construction drawings. Since many formal and informal courses are available for construction students, this course will only introduce MicroStation. Another reason is that MicroStation provides powerful 3D and an object-oriented environment. The second group includes animation packages such as Macromedia Flash, Director (Shockwave), and 3D Studio Max. These packages provide construction engineers the tools to develop 2D and 3D animation of the construction process. This is especially useful for web-based applications. The third group includes multi-graphics/drawings viewers or converters. This is very useful for the real world construction because different graphics or drawings always exist. The last group includes graphical construction simulation tools that combine graphics with construction management activities such as construction planning and scheduling, cost estimation, and database management.

MicroStation

MicroStation is Bentley System's key CAD package for building, civil engineering, transportation, process plants, discrete manufacturing facilities, utilities and telecommunication networks. MicroStation allows users to create 3D models. From design and engineering through construction and operation, CAD models can contain all information about the design, simplifying project management and making the operation of the facility more efficient and cost-effective (Bentley, 2003).

MicroStation is an important application taught in this course, because it is an example of a CAD package that can communicate design files with graphical construction systems and process design. It also fully supports DWG (AutoCAD's format) files. A brief history and major features of MicroStation will be reviewed in this class. The class will also teach ways to make a design using MicroStation; however, the course assumes that students know how to create a drawing with some basic operations and will focus on 3D design and image rendering. This will save time and bring MicroStation to the next level of application, i.e., topics in advanced technologies section.

The lectures and class projects will focus on the following features of latest version of MicroStation that:

- Allows project managers to create new efficiencies for mixed design software environments. Since one construction project may have more than one drawing file

source, it is an incredibly important feature of MicroStation's new paradigm, which allows the cross-use of AutoCAD and MicroStation files without loss of data or functionality. The class will set up a project for students to test an AutoCAD example with standard setting by opening in both MicroSattion V8 and AutoCAD 2002.

- Allows project managers to manage the changes within the shop drawing files and contribute to the project scheduling and estimating update. One of the class projects will simulate a real world construction project by setting up the changes and maintaining an as-built record. The purpose of the project is to learn that change management capability in MicroStation V8 can (1) track individual contributions; (2) undo work that has been integrated into the whole; (3) backtrack to the last approved version; (4) tell changes incompatibilities; and (5) track the time sequence of additions and changes.

The successful application of this powerful graphic tool can potentially save an enormous amount of time and money in the event that rework is needed.

Macromedia Flash and Shockwave

Both Flash and Shockwave are products of Macromedia, Inc. (Macromedia, 2003). Macromedia Flash creates lightweight Web content including designs, animations and application user interfaces for immediate deployment across all browsers and platforms. Macromedia Shockwave creates highly extensible multimedia content including advanced 3D applications and learning applications deployable across multiple mediums. To simulate the construction process, the Shockwave is more applicable because of its 3D nature.

One class project is to use Shockwave and Flash to develop Web-accessed files for the graphics and drawings developed in previous projects.

Advanced Technologies

After the computer graphics basic and current applications sections are taught, some advanced technologies are ready to be introduced into class. Laser scanning allows users to graphically catch existing projects or current construction sites and gather as-built graphical data to help the design process and construction management. Object-oriented CAD together with tools taught in the previous sections is used to develop graphical documentation and guidelines for the construction process. Construction simulation systems such as STROBOSCOPE (State and Resource Based Simulation of Construction Processes) (Martinez 1996) is to allow students graphically simulate the construction process before the actual activities happen in the real world. The reason to bring STROBOSCOPE to the class is that it can be used to model extremely complex operations by using more advanced features

One example of laser scanning, Cyrax 3D Laser Scanning System (Cyra 2003), consists of a Cyrax scanner, a laptop computer, and Cyclone Software. The Cyrax system captures 3D surface

geometry of complex structures and sites with an unprecedented combination of completeness, speed, accuracy, and safety. Complete surface geometry of exposed surfaces is remotely captured in minutes in the form of dense, accurate "3D point clouds", ready for immediate use. The scanner can be rotated or moved around the site to capture entire scenes. As soon as Cyrax has scanned a structure or site, Cyra's suite of Cyclone software lets users use the 3D point clouds for a wide variety of applications, including those that require export to MicroStation. MicroStation users can work efficiently with large point clouds directly using MicroStation tools and commands. The 2D and 3D drawings of existing and new designed projects can be created within MicroStattion.

After graphics and drawings are developed, object-oriented concept and tools within MicroStation can associate the specifications and other documentation with specific components on the drawings. This can significantly reduce the time for construction managers to manage construction activities.

Through the exposure to these advanced technologies, the students will gain the solid ability to apply computer graphics to the construction process. The benefits for their future career are expectable at this stage.

Involving Construction Industry in Class

The construction process is complex and fragmented. As new technology is developed and implemented, the industry is in a constant state of change (Abudayyeh et al 2000). It is valuable and beneficial to bring construction professionals to the classroom as guest lecturers. It is important to bring student to the construction site to visit the applications of those technologies.

Conclusion

The course sketch described in this paper features an integrated and incremental exposure to the advanced features of computer graphics and its applications. It gives graduate construction engineering and management students to learn and practice computer graphics technology. The knowledge and skills gained in the class will help students graphically simulate and operate construction process in a simple, accurate, safe, and effective way. The practice of class projects give students the encouragement to pursuit the research related to computer graphics. Also, more advanced construction simulation and integration concepts might be created with the solid foundation developed in this course.

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Author Biographies

RUSSELL WALTERS
Dr. Walters is an Assistant Professor at the Department of Civil and Construction Engineering. His major research interests are in computer integrated construction. He can be reached at the Department of Civil and Construction Engineering, Town Engineering Building, Ames, Iowa 50011-3232, 515-294-2171, rwalters@iastate.edu, http://erl.cce.iastate.edu.

ZHILI GAO
Zhili Gao is a Ph.D. Candidate at the Department of Civil and Construction Engineering at Iowa State University. He can be reached at the Department of Civil and Construction Engineering, Town Engineering Building, Ames, Iowa 50011-3232, 515-294-8553, zlgao@iastate.edu.