An Introduction to 3D Computer Graphics, Stereoscopic Image, and Animation in OpenGL and C/C++

Fore June

Chapter 1 Introduction

1.1 The Value of Knowledge

Most of us might have heard about the value of knowledge but many of us may overlook the underlying significance of acquiring knowledge in the modern world, not recognizing fully its real value. Though the jobless rate in this nation hovers around 9%, there is a serious shortage of good engineers and scientists. Many large newspapers such as New York Times and Wall Street Journal reported in 2011 that Silicon Valley saw strong hiring demand in the year. In July, 2011, more than 6,500 new jobs were advertised online for IT related openings in the Silicon Valley, up 9% from the same period a year ago. Some claimed that recruiting in Silicon Valley was more competitive and intense and furious than college football recruiting of high school athletes.

In March, 2011, New York Times reported: "As the rest of the country fights stubbornly high unemployment, the shortage of qualified engineers has grown acute in the last six months, tech executives and recruiters say, as the flow of personal or venture capital investing has picked up. In Silicon Valley, along the southern portion of the San Francisco Bay in California, and other tech hubs such as New York, Seattle and Austin, start-ups are sprouting by the dozen, competing with well-established companies for the best engineers, programmers and designers. At the same time, all the companies are seeking ever more specialized skills. Tech recruiters have also expanded their searches. They still scout college campuses, particularly Stanfords computer science department, where this year it was common for seniors to receive half a dozen offers by the end of first quarter. But since college degrees are not mandatory, recruiters are also going to computer coding competitions and parties, in search of talent that is reminiscent of the dot-com mania."

This book is written in the spirit of helping readers acquire a knowledge that will be valuable to their own development. Even though the book presents the materials at an introductory level, some readers may still find some of the materials difficult, depending on their background and willingness of paying efforts in learning. But our knowledge is valuable only if we need to pay effort to gain it. The more effort we pay to acquire knowledge, the wealthier and happier we will be. Topics that are easy to us are also easy to our competitors. In the coming decades, the competition between nations will be a competition of acquiring knowledge. The economic regions that censor information and block the flow of knowledge would eventually fall behind.

Renowned management specialist Peter Drucker (1909 - 2005) had long advocated the emergence of knowledge society and the importance of knowledge workers. The social transformations from an industrial society to a knowledge society would be the most significant event of the century and its lasting legacy. Science and technology have been advancing so rapidly that manufacturing becomes irrelevant in the modern society. A DVD containing certain data that we pay twenty dollars to purchase may just cost a few cents to manufacture. Though it is very rare for the productivity between two labour workers differs by a factor more than two, the productivity of a good knowledge worker can be easily a factor of 100 or higher than that of an average knowledge worker. Nathan Myhrvoid, former Chief Technology Officer at Microsoft Corporation, and a co-founder of Intellectual Ventures, once said the following:

> *The top software developers are more productive than average software developers not by a factor of 10X or*

100X or even 1000X but by 10,000X.

Putting this in another perspective, we see that under an ideal situation (discarding exploition by 'leaders'), if an average engineer earns \$100K a year, a top engineer could earn $10000 \times \$100K = \$1$ billion a year.

To become proficient in a certain field, one must learn with his or her heart, overcoming difficulties, barriers and frustrations. After enduring the hard work, one would enjoy the pleasure of understanding difficult materials and acquiring valuable knowledge. Fauja Singh, the 100-year-old marathoner runner who became the world's oldest person to complete a full-length marathon in October 2011 after crossing the line at the Scotiabank Toronto Waterfront event in eight hours and 25 minutes, said: "Anything worth doing is going to be difficult."

While the position of a labour worker can be easily substituted by another one with little training, it is very difficult to replace a specialist of a field in the knowledge economy, for the new worker must also go through the same learning barriers and hard work to acquire the knowledge.

1.2 The Open Source Movement

In the past few decades, the open source movement may be the most important development in the software industry and in knowledge acquirement. Open source software is made available to anybody to use as its source code can be read by everyone. Open source software promotes learning and understanding, and expedite software development, making software more robust.

Nowadays, open source applications are abundant and they have been propelling the technolgy world moving forward rapidly. This book along with its programs and utilities are 100% written using open source software.

Very often, it takes an abundant amount of computing power to create the stunning visual effects behind blockbuster movies such as King Kong, the Lord of the Rings trilogy and the \$230 million movie *Avatar* produced by James Cameron. The stereoscopic 3D movie *Avatar* of 2009 was exceptionally successful and has set off a phenomenal trend in making 3D films. The movie has also become the top grossing movie of all time, eclipsing James Cameron's former top grossing movie, *Titanic*. Probably the main reason of its huge success is the use of open source technologies to create the fantastic stereoscopic 3D effects. It is interesting to note that Cameron wrote the script for the film more than 15 years ago, but the open source technology was not mature enough to portray his vision of the film, which might be the major cause of the long delay of its production.

While the audience are moved and amazed by the realistic 3D effects, few realise that open source software is the driving force behind the creation of those 3D graphics and animation rendering. Linux has played a silent but an important role in the creation of the movie. Weta Digital, co-founded by Peter Jackson, is a digital visual effects company that gave life to the flora and fauna of Pandora in the movie. It uses Linux and other Linux-based software to achieve all those cutting edge graphics. Weta Digital renders the imaginary landscapes of Middle Earth and Pandora at a campus of studios, production facilities, soundstages and data center consisting of a 40,000 CPU farm. Figure 1-1 below shows some of the high-density server and networking gear inside the Weta Digital data center used to render the animation of the movie *Avatar*. The image was downloaded from the site *http://www.datacenterknowledge.com/archives/2009/12/22/the-data-crunching-powerhouse-behind-avatar/*.

According to an article posted at *http://www.datacenterknowledge.com/* in 2009, the Weta Digital data center got a major hardware refresh and redesign in 2008 and used more than 4,000 HP BL2x220c blades, 10 Gigabit Ethernet networking gear from Foundry and storage from BluArc and NetApp. The system ranked about 195 in the Top 500 list of the most powerful supercomputers. There were more than 90 cameras (configured in a grid) that hang around the perimeter of a sound stage. Later on, a computer replaced the studio walls, the floor and the ceiling with digitally rendered three-dimensional environments and structures.

Figure 1-1 Weta Digital Data Center

Fast-forward to 2011, the year in which open source movement scored a couple of stunning triumps. In February of the year, the whole world was watching with great interest and excitement the human-versus-machine competition on the quiz show *Jeopardy*. On the human side were Brad Butter, the biggest all-time money winner on *Jeopardy*, and Ken Jennings, the record holder for the longest championship streak. On the machine side was an artificial intelligence computer system named *Watson*, which was capable of answering questions posed in natural language, and was developed in IBM's DeepQA project by a research team led by principal investigator David Ferrucci. Watson was named after IBM's first president, Thomas J. Watson. In a two-game, combined-point match, broadcast in three *Jeopardy* episodes, Watson beat both Brad Rutter and Ken Jennings without any connection to the Internet during the game. The audience was much amazed by the intelligence of Watson. However, much of the audience might not know that Watson was actually powered by open source software. IBM did not build Watson from scratch but had leveraged existing open source projects to provide many of the building blocks for the Watson project. Watson's software was written in both Java and C++ and uses Apache Hadoop framework for distributed computing, Apache UIMA (Unstructured Information Management Architecture) framework, IBMs DeepQA software and SUSE Linux Enterprise Server 11 operating system. Watson can run on a few operating systems but to compete on *Jeopardy*, Watson was running SUSE Linux Enterprise Server OS. Just like the human players, Watson had no access to Google or any other outside sources of information during the competition. It played with its own "knowledge".

Another big triump of open source software in 2011 is that Android has become the most popular mobile phone operating system, capturing nearly 50% of smart phone market.

Google first unveiled Android as a Linux-based open-source mobile operating system in late 2007 and it was embraced immediately by many big carriers such as Sprint, T-Mobile, Verizon and AT&T. Since its debut, Android has been gaining market rapidly. Android is an open-source software stack for mobile devices, and the Android project is led by Google. The Android Open Source Project (AOSP) includes individuals working in a variety of roles. Google is responsible for Android product management and the engineering process for the core framework and platform; however, the project considers contributions from any source, not just Google. The Android team created Android in response to their own experiences of launching mobile apps. They wanted to make sure that there was no central point of failure, so that no industry player can restrict or control the innovations of any other. That's why Android was created, and its source code was made open. For details, please refer to the Android official web site at *http://www.android.com/*. It is convenient to develop graphics applications in the Android platform using OpenGL.

1.3 Computer Graphics Applications

The development of computer graphics has made computers easier to interact with, to understand and to interpret different types of data. Developments in computer graphics have made profound impact on many types of media and have revolutionized the film, video game and publishing industries. Beyond these, applications of computer graphics are ubiquitous. The following lists some of the common and important applications.

1. **Computer Graphics and Image Processing**
   The fields of computer graphics and image processing are interwined with each other more and more each year. In general, *computer graphics* applications create pictures and images, synthesizing them using a certain model in a computer. On the other hand, *image processing* is concerned with the analysis and manipulation of images by computer. It improves or alters images that were created elsewhere. Figure 1-2 below shows the segmentation of an image using image processing techniques.

Original Image Segmented Image

Figure 1-2 Image Segmentation

2. **Art, Entertainment, and Publishing**
   Computer graphics have revolutionized movie production, animation, creating special film effects, browsing World Wide Web, producing slides, book publication and magazine design.

3. **Video Games**
   Latest computer graphics technologies are always rapidly incorporated into video game development. Popular video games such as Warcraft, and Halo 3 are created with the state-of-the-art computer graphics technologies.

4. **Monitoring a Process**
   Computer graphics can be used for monitoring, controlling, testing, and acquiring data from an industrial process control system . Figure 1-3 below shows a graphics interface for command and control of real-time system processes. (Image taken from *http://www.genlogic.com/*.)

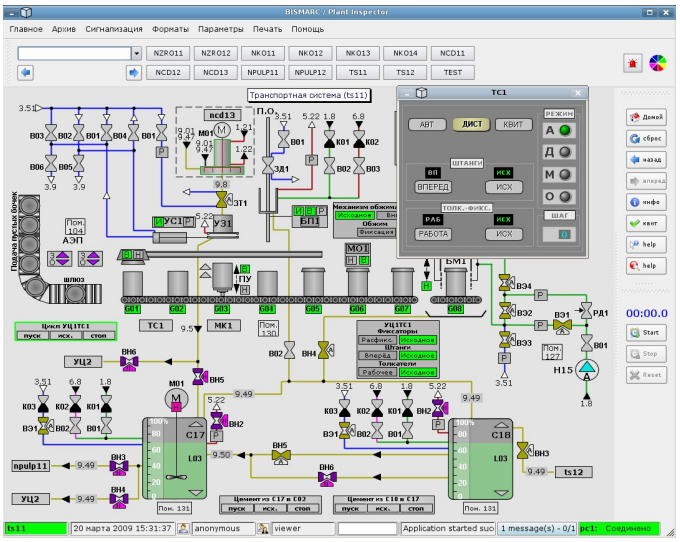


Figure 1-3 Graphics Interface for Command and Control of Processes

5. **Computer-aided Design (CAD)**
   Computer-aided Design makes use of interactive computer graphics to provide the user with input-tools to streamline design processes, drafting, documentation, and manufacturing processes. It is widely used in architectural design, and electrical circuit design.

6. **Displaying Simulations**
   Computer graphics can display simulations generated by software such as the *flight simulator*, which displays objects as if they physically exist, when in reality they are only models inside the computer. Virtual reality (VR) has been a research field as well as a graphics application that empolys computer-simulated environments to simulate physical presence in places in the real world, as well as in imaginary worlds. Most virtual reality environments involve mainly visual experiences; graphics scenes are usually displayed either on a head-mounted computer screen or through special stereoscopic displays. Some simulations may include additional sensory information, such as information from sound coming through speakers or headphones. Some advanced, haptic systems may include tactile information or remote communication environments, which are common in medical and gaming applications. Figure 1-4 below shows a US Navy personnel using a VR parachute training simulator to acquire the skill of using actual parachute. The image was taken from the site

http://en.wikipedia.org/wiki/Virtual_reality.

Figure 1-4 US Navy personnel Using a VR Parachute Trainer

7. **Scientific Analysis and Visualization**
   Graphical presentations of scientific data can help us understand the underlying significance of the data and gain new insights into the investigating process. Figure 1-5 below shows the presentation of data in a 3D graphical view.

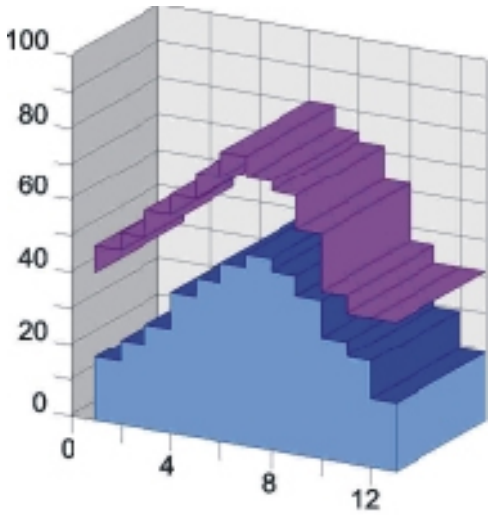
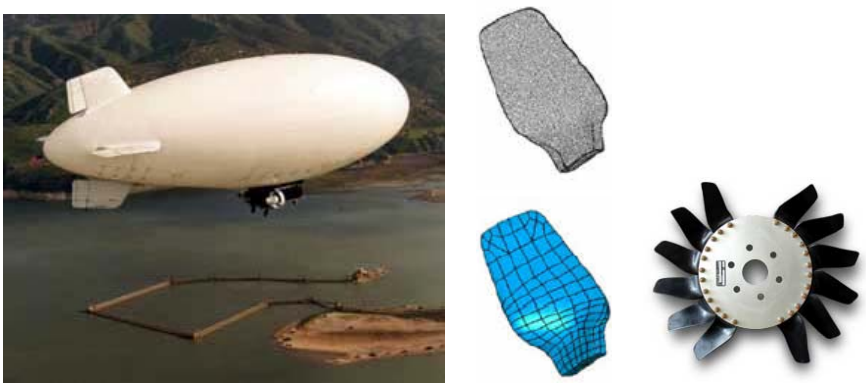


Figure 1-5 3D Graphical Presentation of Data

8. **Digital Shape Sampling and Processing (DSSP)**
   DSSP uses scanning hardware and processing software to digitally capture physical object shapes and forms. It automatically creates accurate 3D models with associated structural properties for design, engineering, inspection and custom manufacturing. What digital signal processing (DSP) is to audio, DSSP is to 3D geometry. Computer graphics is to used to display and model the scanned data. (See for example, *http://www.geomagic.com/en*) Figure 1-6 shows a spaceship engine fan that is rebuilt

using DSSP software; in the figure, (a) shows the spaceship that uses the engine fan, (b) shows a blade of the fan; the upper image shows the actual object and the lower one is the object created by graphics reconstruction, (c) shows the rebuilt fan. The images were downloaded from the site *http://www.geomagic.com*.



(a) (b) (c)

Figure 1-6 DSSP Helps Rebuild Damaged Fan

9. **Video Compression**
   For some video applications where the images do not change abruptly from frame to frame such as news announcement or company meetings, graphics techniques can be used to compress the videos. A graphics model is constructed to represent the largely static features of the scene and a few parameters are transmitted to produce a dynamic scene. Video compression standard MPEG-4 Visual specifies support for animated face and body models. For example, a face model described by Facial Definition Parameters (FDPs) is used to animate a human face using the transmitted Facial Animation Parameters (FAPs) . In a similar way, Body Definition Parameters (BDP) are used to describe a human body and Body Animation Parameters (BAP) are used to animate a human body.

1.4 This Book

This book, *An Introduction to 3D Computer Granphics, Stereoscopic Image, and Animation in OpenGL and C/C++*, is written based on the author's experience of developing stereoscopic video programs to be embedded in some toys. However, to develop the programs one has to learn the basics of graphics programming. So this book is more about basic graphics programming than advanced stereoscopic video development. The materials are discussed at an introductory level and the code is presented in C/C++. The implementations of more advanced topics are not included. The programs presented are mainly for illustrating the principles of graphics and how to implement them; very often error checking and handling are not included. For the purpose of making the materials easy to understand, sometimes the parameters are hard-coded. Nevertheless, the programs can be used as a starting point for further development.

We have to admit that the programs were written over a period of time and thus the notations may not be very consistent. Also, we have not optimized the code for memory

usage or computing time. All the code presented in this book can be found at the site,

http://www.forejune.com/stereo/

and you can download the programs using the password "******". The programs have been compiled and tested in the Linux environment using the Mesa OpenGL Library version 7.0.3 (*http://mesa3d.org/*). The C/C++ programs of this book reside in subdirectories with numbering reflecting the related chapters. For example, the programs discussed in Chapter 8 will be in directory **8/**. If the programs of another chapter need to use the programs developed in Chapter 8, we just need to link their object files in **8/**. We also put most of the sample data files in the directory **data/**.

In our description, when we use the term *into*, we usually refer to a many-to-one mapping such as the mapping of a 3D object to a 2D image. When we say *onto*, we refer to a one-to-one mapping; such a mapping is reversible. In describing a program, we usually express variables in italics.

We hope you enjoy reading this book.

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by *Fore June*

Windws Fan, Linux Fan describes a true story about a spiritual battle between a Linux fan and a Windows fan. You can learn from the successful fan to become a successful Internet Service Provider (ISP) and create your own wealth. See *http://www.forejune.com/*

Second Edition, 2002.
ISBN: 0-595-26355-0 Price: $6.86

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