Chapter XXXIII
3–D Visualization on Mobile Devices

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ABSTRACT

Recent improvements in technology of last generation mobile devices (smartphones, Personal Digital Assistants, Ultra-Mobile PCs) have opened up challenging new scenarios in 3-D ubiquitous visualization. Entertainment, cultural heritage, telemedicine, and distance learning are only a few of the disciplines that can take advantage of 3-D model visualization on mobile and hand-held devices. This chapter investigates the main methodologies used to display and navigate complex scenes and heavy datasets on mobile devices. Both local and remote rendering software techniques are considered with respect to solutions based on hardware acceleration. Moreover, issues related to the design of suitable graphics user interfaces are tackled. Finally, a solution for high performance visualization based on the remote rendering approach and enabling interactive manipulation of 3-D scenes composed by millions of polygons at 30 frames per second even on 50 Kbit/s wireless communication channels is presented.

INTRODUCTION

The advent of large-bandwidth wireless networks and improvements in graphics hardware have opened up exciting and intriguing new scenarios concerning ubiquitous visualization on mobile devices. Mobile phones and personal digital assistants (PDAs) are now able to display 3-D graphics contents and the demand for visualization applications is rapidly increasing.

In the past years, reduced hardware resources, limited bandwidth communication channels and inadequate graphics users interfaces (GUIs) strongly limited the use of mobile devices for 3-D graphics. Nowadays, mobile phones (often named smartphones), PDAs, and tablet PCs are able to
connect to the Internet via high-speed networks (like for example IEEE 802.11 and UMTS) and high-performance CPUs, able to provide a support for multimedia applications, are becoming available. Several solutions integrating a CPU and a GPU (graphics processing unit) have also been developed (it is worth observing that a spread diffusion of graphics applications for desktop PCs began when accelerated graphics adapters appeared on the market). Moreover, hand-held devices can be equipped with a wide range of accessories allowing researchers to design and implement a complete and effective set of multimodal interfaces.

All these technological advances make ubiquitous graphics a new and challenging field of research. Today mobile devices are able to locally manage and display several thousands of polygons per second, as well as play high-resolution video streams in real time. Additionally, frameworks for managing mobile interactive visualization of highly complex datasets composed of millions of polygons/voxels have been developed. This means that ubiquitous 3-D visualization can now be performed in an efficient and effective way, thus helping scientists and doctors to achieve a clearer understanding of the nature of data under investigation, and supporting the entertainment market. Many fields of research and applications can take advantage of ubiquitous 3-D visualization: education, art, advertising, medicine, entertainment, and so on.

In order to provide an overall view on the state of the art of 3-D visualization on mobile devices, the chapter starts following a scheme based on the device workload. Thus, local visualization is considered first in the following Section. In this technique, the entire visualization process (geometry management, rendering, and display) is performed exploiting exclusively the computational resources of a mobile device often named fat client. An entire Section is then devoted to remote visualization. Here, a remote server is in charge of processing the geometry and rendering the scene. The mobile device, also called thin client, only has to display a set of still images or a video stream. Remarks concerning the design and the development of mobile GUIs for 3-D are then presented. Finally, the design and experimental results of a framework for high-performance 3-D visualization on mobile devices based on the remote rendering approach are presented.

**LOCAL COMPUTATION**

The term local computation refers to a situation where the entire geometry of the model can be stored on the mobile device and locally available computational resources are sufficient to render and display the scene (Zhou, 2006). The adjective sufficient can take different meanings according to the application fields being considered: a few frames per second can be considered sufficient when a limited interaction is required, but 30 frames per second, or more, can be necessary for video games or other “real-time” applications.

It is worth stressing that local computation requires data to be stored in the memory of the mobile device; beyond implications related to hardware resources, a problem of security can arise. Sometimes, it is preferred not to move visualization datasets outside “secure” environments, because data can contain reserved and/or highly confidential information. On the other hand, limited network resources are not involved in the visualization process, at least for single-user applications. Thus, visualization performances do not depend on network coverage and bandwidth.

From the software point of view, several solutions have been proposed to design and implement 3-D rendering engines for mobile devices. MiniGL (2006) and PocketGL (2006) were two of the first examples; they consist of a 3-D toolkit exporting a large number of utility functions needed to manipulate 3-D objects. They exhibit several similarities with OpenGL (Woo, Neider, Davis, & Shreiner, 1999). In fact, OpenGL code and tutorials can be used as a starting point to implement MiniGL- and PocketGL-based applications.

Another set of APIs named OpenGL ES, similar to OpenGL but specifically tailored for mobile devices, has been recently proposed (OpenGL ES, 2006). It is worth observing that the acronym ES means embedded system in order to outline
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