Cloud and Mobile Web–Based Graphics and Visualization

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1. INTRODUCTION

Cloud computing will be the most prevailing computing platform in the near future. The World-Wide Web has progressed from an electronic bulletin board (with hyperlinking) to a nearly complete application platform. Mobile+Cloud, the combination of mobile- and cloud computing, is changing how developers produce, and how users consume computing resources. Visual computing is going through this same revolution.

The recent introduction of HTML5, related graphics technologies, and their rapid penetration have made high-quality, browser-based interactive graphics a reality. For lightning-fast interactivity, client-side rendering technologies, such as SVG, Canvas, and WebGL can be employed. For graphical "heavy lifting" or if client devices are too slow, rendering can take place on the server side.

We envision that Mobile+Cloud will become the most common platform for computer graphics and visualization soon. Furthermore, it will democratize the use of advanced graphics and visualization, and it stands to revolutionize mainstream data analysis using interactive visualization.

Our goals in this article are to make the reader familiar with the underlying technologies that enable computer graphics implementation on the Mobile+Cloud platform.

2. BACKGROUND

The first computers were extremely large, with limited access, and less computing power than today's smartphones. The personal computer "democratized" computing by offering affordable desktop – then briefcase – access to all. The Internet connected these computers, and the World-Wide Web ("The Web") made that connectivity user-friendly and expanded the Internet's user base beyond the realm of techies. Recent mobile devices, such as smartphones and tablets, have extended the reach of the Web to people who never imagined they would become computer users.

Visual computing (the aggregate of computer graphics, computer vision, image processing, and data visualization) has followed a parallel path. Although graphics hardware has become more powerful, less costly, and more portable, graphics software has not enjoyed the same reach as Web pages in general until very recently. New technologies, such as HTML5 and cloud computing, have created a new computing environment that makes it feasible to build interactive graphics applications which, for example, allow users to view and interact with huge quantities of data in visual form, and control the process from a mobile device.

3. A BRIEF HISTORY OF COMPUTER GRAPHICS AND THE WORLD-WIDE WEB

We start with a brief (and incomplete) history of Computer Graphics and the World-Wide Web. For more details, see, e.g., (Foley, van Dam, Feiner, & Hughes, 1990; Shoaff, 2000; Chapman, 2009; Berners-Lee, 2000)

3.1 The Early Days: The Birth of Computer Graphics

Early computers only recognized and displayed alphanumeric text. Ivan Sutherland invented interactive computer graphics in his 1963 MIT Ph.D. dissertation, Sketchpad (Sutherland, 1963). Sutherland's system used a light-pen to provide input to an interactive vector-graphics display. Into the 1970s, several developments progressed the state-of-the-art of interactive computer graphics. Bresenham (1965; 1977) introduced algorithms to draw line segments, circles, and other primitives efficiently on raster displays. Coons (1966a; 1966b; 1968; 1977) and Bezier (Rogers, 2001) developed parametric surface representations and created the foundations of computer-aided geometric design. Appel (1967; 1968) and Crow (1977) developed hidden-surface removal and shadowing. Engelbart invented the mouse. Evans & Sutherland built flight simulators utilizing raster graphics. Gouraud (1971) and Phong (1975) introduced new rendering and reflection models. A paint program was developed at Xerox PARC. Catmull (1974) gave light to parametric patch rendering, the z-buffer algorithm, and texture mapping. Recursive ray-tracing (Whitted, 1980) became the standard for photorealistic rendering. Apple launched the personal computer age with its first computer. The first SIGGRAPH conference offered a meeting place to discuss and exchange ideas about new developments in interactive computer graphics, animation, and related visual computing innovations.

3.2 The 1980s: CG in Film, the PC, the GUI, Desktop Publishing, Pixar, GL, Shaders

The 1980s gave rise to fractals (Fournier, Fussell, & Carpenter, 1982) and Adobe Systems with its Postscript page layout language and Photoshop. Computer animation was launched. Video arcades became an attraction. Disney released TRON, which had more than 20 minutes of computer-generated animation. IBM introduced the PC. Raiders of the Lost Ark won an Oscar for computer generated visual effects. ILM's Genesis Effect in Startrek II revolutionized computer-animated special effects for film.

Pixar was founded as a special-purpose graphics hardware maker, then evolvied into a software producer, and finally into a production house. It produced Toy Story, the first completely computer-animated film. In 1988 Pixar also offered the "RenderMan Interface Specification" to the graphics world (Upstill, 1990). That specification introduced *shaders,* which became – and remain– the prevailing way to implement the *graphics pipeline.*

The 1984 launch of Apple's Macintosh opened a new era by popularizing the Graphical User Interface (GUI), which made computers much more accessible to lay people. This also launched the desktop publishing revolution. (By some estimates, close to 90% of all compute cycles in the world are dedicated to handling GUI-related tasks.) In 1989 the World-Wide Web was invented with Tim Berner-Lee's development of the HTTP protocol and the HTML markup language and the introduction of the first server and browser (Berners-Lee, 2000). Silicon Graphics, Inc. (SGI) introduced the graphics pipeline in hardware and the graphics library GL, which lead to OpenGL, OpenGL ES, and WebGL.

3.3 The 1990s: The WWW, More Powerful Graphic Displays

In the 1990s more advanced graphics found its way into more films. Standard graphics hardware provided 24-bit raster displays and much more graphics support. Mosaic, the first widely-available graphical Web browser, really launched the Web era by bringing the Web to wider populations.

3.4 The 2000s: Interactive CG Popularized, the Growing and Maturing WWW

During the 2000s graphics capabilities trickled down from special purpose equipment to consumer-level PCs, becoming more capable at the same time. A wide variety of input/output devices became standard equipment in almost every office and household. The performance and accuracy of three-dimensional modeling surpassed previous capabilities.

Since the mid 1990s, when the Web expanded beyond the academic and military world, it has gone through a progressive transformation from an electronic bulletin board to a full application development platform.

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