ABSTRACT

Recent advances in web technologies have now created a ubiquitous environment for cross-platform and cross-device multimedia applications. Media files can now be reproduced in a wide range of devices, from mobile phones to desktop computers and web-enabled televisions, using a common infrastructure. This trend towards unifying the technological infrastructure, however, has given rise to a new array of problems resulting from the varying technological capabilities of the different devices and environments. This paper proposes an adaptive streaming framework for the display of 3D models on a wide range of web-enabled devices. The open, XML-based X3D language for 3D graphics is combined with the MPEG-DASH standard for adaptive streaming. The end result is a framework that can adaptively display 3D graphics in the face of network or computational limitations, and dynamically adapt data flow to maximize user Quality of Experience in any situation.

Keywords: Adaptive Streaming, MPEG-DASH, Quality of Experience, Web 3D, X3D

1. INTRODUCTION

Web technologies have been advancing in leaps during the last decades, and we have now reached a stage where a wide range of content types can be displayed on a large variety of devices over the web. Indeed, with the growing ubiquity of HTML5 technologies, a multitude of different devices are now able to process and display multimedia content using a uniform and cross platform infrastructure, regardless of the presence of specific installed software ( codecs, client plugins etc.), needing only an HTML5 compatible browser.

This trend can be seen as a gradual paradigm shift, where a large variety of devices, from
TVs to mobile phones and laptop computers, are all merged in one category, able to execute the same applications and access the same content. However, this does not diminish the inherent differences between the end-system devices, ranging from varying display capabilities, to computational limitations—usually more prominent in mobile devices—and energy consumption considerations. Additionally, since we are discussing Web technologies, there is always a lack of performance guarantees due to throughput limitations which, while not necessarily device-dependent, are definitely variable and dependent on bandwidth availability and congestion. This unavoidable variability in performance brought forth the need for qualitative evaluators of user experience, such as Quality of Experience. The term Quality of Experience encompasses attempts to quantify user perspective on the performance of a system. In the past the term Quality of Service (QoS) had been dominant in multimedia transmission and reproduction, attempting to evaluate network performance by probing delay or jitter. However, it soon became apparent that a more user-centric perspective was needed. Malamos et al. (1999; 2002) had already re-defined QoS as ‘the basic measure of how well the system operates in order to meet the user’s requirements’, and this was indicative of a shift in perspective, which, especially in the face of mobile networks today, has dominated under the umbrella term QoE (Bourdena et al, 2013; Carmona-Murillo et al, 2014; Narayanan, 2014).

With respect to content modalities, it seems reasonable to claim that most typical media types can now be natively reproduced within a browser context, using HTML5 functionalities. However, there still exists a multimedia content type that has been, to an extent, neglected, and whose HTML integration has been slower than the rest: 3D data.

Recently, a radical evolution has taken place in this area, following the advent of WebGL, a JavaScript API based on OpenGL. With WebGL, the HTML Canvas element can display 3D graphics on a browser, using all the processing capabilities of the device, without the need for additional plugins or software. In the past, the Virtual Reality Modeling Language, VRML (ISO 14772:1997, 14772:2004) had been proposed for Web 3D, and its XML-based successor, X3D (ISO 19775:2004, ISO 19776:2005) was an attempt to modernize VRML. However, it was WebGL that essentially opened for the first time the possibility of truly native Web 3D multimedia content, and the X3DOM (Behr et al, 2010) framework soon appeared in order to take advantage of this capability. X3DOM is a JavaScript framework aiming to allow X3D XML code to be embedded directly in web pages, and be directly rendered by the browser. Interactive 3D content can now be displayed directly within web browsers, similar to other information types, such as video and audio.

Essentially Web 3D content can be said to be on par with video with respect to the issues it raises on matters of data size, transmission times and potential delay and computational burden on the end device. A rich, large-scale, high-detail 3D model can consist of up to millions of polygons and be covered with high-resolution texture images. To manage the complexity of 3D models, the concept of Level of Detail (LoD) (Brooks & Tobias, 1996; Luebke, 2003) was proposed, in which a model of the same object can be presented in different models, each of different quality, and thus different computational, storage and bandwidth requirements.

The need to manage the potential complexity of Web 3D material, and provide a smooth user experience, led to increased interest for 3D streaming. 3D streaming, similarly to video and audio streaming—and in some ways image progressive transmission and display—is based on the partial transmission of the multimedia information, in such a manner as to allow users to gradually experience the scene from the moment they request it, at least in some limited way. Within this process, the concept of QoE for 3D graphics is inherently linked to the concept of Level of Detail and the adaptive rendering of graphic models according to network and end-system performance constraints.

However simply progressively streaming 3D data may not be enough. As content is nowadays expected to seamlessly play on a
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