3D Graphics Standardization in MPEG-4

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INTRODUCTION

Computer graphics is currently the spine of several industries of information technology. From computer aided design of almost all objects surrounding us, through virtualization of 3D environments such as Google Earth, to video games, 3D graphics becomes a valuable media with a similar impact as the one of video, image and audio. Such digital assets should be exchanged between producers, service providers, network providers and device manufacturers. Supporting large-scale interoperability needs the development and deployment of open standards. ISO[a], as a major international standardization organization, anticipated this issue and proposed in the last decade several standards addressing 3D graphics assets exchange. VRML (ISO, 1997) (Virtual Reality Modeling Language), published in 1997, provides basic geometry primitives, appearance models and animation mechanisms for representing 3D objects and scenes. Built on top of VRML, the first version of MPEG-4 (ISO, 1998) supports tools for the compression and streaming of graphics assets. Since then, MPEG improved the 3D graphics compression technologies and published the MPEG-4 Part 16 (ISO, 2004) in order to address theses issues within a unified and generic framework.

This chapter is dedicated to professionals of 3D graphics industry, solution providers for on-line systems involving 3D content (games, persistent universes, virtual spaces with graphical representation), students and professors in digital sciences.

The first section aims at presenting the background of the compression for multimedia signals. The second section presents the latest developments in MPEG-4 with respect to the compression and streaming of 3D graphics objects and scenes. The MPEG-4 tools, categorized into geometry, appearance and animation, are introduced. While MPEG standards specify only the bit-stream syntax and the architecture of the decoder, scheme for encoders' implementation are presented in this section.

In the third section we describe a recently adopted MPEG model for 3D graphics consisting in opening the representation of graphics primitives to any XML-based format and completing it with binarization and compression layers. This shift in the manner of using MPEG-4 for 3D graphics is concretized in Part 25 of MPEG-4 (Preda, Jovanova, Arsov& Prêteux, 2007).

BACKGROUND

A generic compression schema aims at eliminating redundancy in the data representation. Additionally when dealing with lossy compression, it makes also possible to identify

Figure 1. Generic signal compression schema

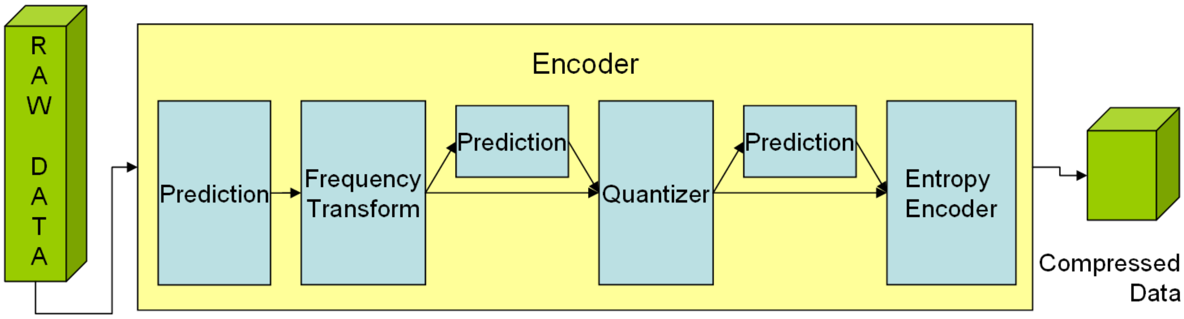

Table 1. MPEG-4 tools for 3D graphics compression

Compression Tool	Type
3D Mesh Compression	Geometry
Wavelet Subdivision Surface	Geometry
Coordinate, Orientation and Position Interpolator	Animation
Bone-based Animation	Animation
Frame-based Animated Mesh Compression	Animation
Octree Compression for Depth Image-based Representation	Appearance
Point Texture	Appearance

the attributes for which a less precise reconstruction results in an acceptable signal distortion for human observers. As example, image and video encoders exploits the way that humans perceive the colors. In general, a compression schema is based on prediction, frequency transform, quantization, and entropy encoder as illustrated in Figure 1.

Compression is necessary when data should be transmitted over the networks or to optimize the data storage. Nowadays, it is used in many applications of the real life: photo cameras, digital television, DVDs, video servers on the Internet (like Youtube) and so forth. Forecasting the importance of the compression for the development of multimedia applications, the MPEG consortium initiated in 1998 an international standardization project for specifying bit-stream syntax for audio and visual information. The first product, called MPEG-1 was designed for compressing video and audio at low bit-rates. A world-wide recognized part of MPEG-1 is the MP3format, used for compressing music data. The second product, MPEG-2 was designed for compressing video and audio in high-quality. The technical performances of MPEG-2 explain the success of applications such as DVD[b] (used by the movie industry) and DVB[c] (used in television). MPEG-4 completes the compression solutions provided by the MPEG consortium and is the main focus of the current chapter.

MAIN FOCUS OF THE CHAPTER: MPEG-4 TOOLS FOR 3D GRAPHICS COMPRESSION

A major advancement of MPEG-4 over its predecessors, MPEG-1 and MPEG-2, is the extension of data types to rich media, offering the possibility to handle, in a unique format, pixel-based image representation, 2D scalable vector graphics and 3D graphics. On top of these representations, the MPEG consortium developed generic and data-specific compression tools. In order to handle the composition and presentation of various media elements in the scene as well as the user interactivity, MPEG-4 introduced the concept of scene graph by adopting the VRML specifications and adapting it to specific requirements of streaming. A first tool responding to such adaptation is BIFS[d] (ISO, 2005), a binary encoded version of an extended set of VRML. Designed as a generic tool, BIFS attempts to balance the compression performances with the extensibility, ease of parsing and simple bit-stream syntax. It includes the traditional modules such as prediction, quantization and entropy coding, without pushing them to extreme complexity. With respect to the textual description of the same data, BIFS may compress by a factor up to 15:1, depending on quantization step. However, for 3D graphics primitives and for animation, BIFS does not fully exploit the spatial and respectively, temporal correlation of (animated) 3D objects. To overcome this limitation, MPEG defined specific tools in Part 16 of the MPEG-4 standard.

For compressing 3D graphics assets, MPEG-4 offers a rich set of tools classified with respect to the data type, namely geometry, appearance and animation (Table 1).

The following sections describe the key elements for geometry and animation compression tools.

3D Mesh Compression (3DMC)

3DMC, initially published in 1999 (ISO, 1999) and extended in 2007 (ISO, 2007) is based on the Topological Surgery (TS) representation (Taubin & Rossignac, 1998). It applies to 3D meshes defined as an indexed list of polygons and consists of geometry, topology and properties (e.g., color, normal, texture coordinate, and other attributes).

The connectivity information is encoded loss-less, whereas the other information could be quantized before compression. In order to maintain the congruence of the system, geometry and properties information are encoded in a similar fashion. 3DMC supports three modes of compressing the mesh: single resolution, when the entire mesh is encoded as indivisible data, incremental representation, when data is interleaved such as each triangle may be rendered immediately after decoding, and the hierarchical mode, when an initial approximation of the mesh is improved by additional decoding of the details. 3DMC supports error resilience and computational graceful degradation. The extension published

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