SYNTHESIZED TEXTURES IN MPEG-4

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ABSTRACT

SynthesizedTextures represent continuous-tone images with a small set of vectors and color profiles. This representation is not only efficient in terms of compression ratio but also serve as the basis of photo-realistic animations in AFX.
Unlike standard synthetic texture techniques, the SynthesizedTexture imaging starts with analysis of photo-realistic images or video sequences and conversion to their vector representation. This 3D representation is decoded at the player and rendered to reproduce the original image.

1. INTRODUCTION

The Synthesized Texture imaging technology represents animated photo-realistic textures using vector graphics approach to describe color and geometric information. These vector based parameters can be animated over time, producing very low-bit-rate movies suitable for terminals and networks with limited resources and narrow bandwidth. The technology is known as VIM – VectorIMaging by Vimatix [1].

2. SYNTHESIZED TEXTURE ELEMENTS

The **SynthesizedTexture** node in MPEG-4 BIFS is similar to **CompositeTexture2D** and reuse the same fields and semantic. All synthesized textures are made of 3 base elements and 3 animation enabling elements[2],[3]:

SynthesizedTexture Base Elements:

- ***Characteristic Curves*** are made of **SynthesizedTextureCurve** nodes and **Color Profile** nodes. A color profile is associated with each segment of the curves and could be *Edge* or *Ridge* type.
- ***Patches*** are defined as elements of few pixels long whose color is significantly different from their surrounding. They are represented by **Ellipse** nodes colored with **GradientRadial** nodes.
- ***Area Color Points*** describe the low-scale (background) color changes in the areas between Characteristic curves and are represented by BIFS **PointSet** nodes.

SynthesizedTexture Animation enabling elements:

- ***Sub-textures*** define a high-level structure enclosing entire regions of the texture.
- ***Skeletons*** are invisible curves that affect the animation of *sub-textures*. They can be transformed directly or by external skeletons like Skin&Bones (Bone Based Animation) or by BIFS interpolators.
- ***Objects*** (layers) are an aggregation of *sub-textures* that are subject to animation. Rigid transformations applied to an Object result in transforming of all its sub-textures.

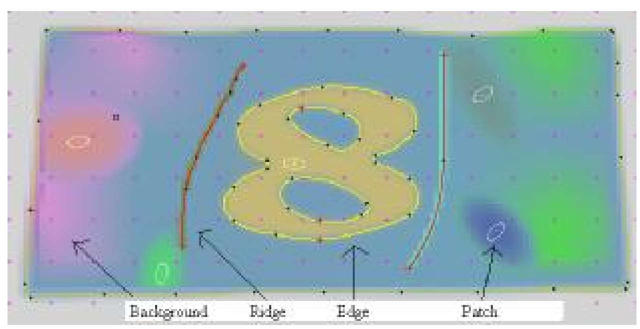

Figure 1. SynthesizedTexture sample - enlarged with overlaying base elements indicators

Figure 2. SynthesizedTexture sample – actual size after rendering

3. SYNTHESIZED TEXTURE RENDERING

It is important to note that although the result is a 2D image, the Synthesized Texture scene is described using 3D elements. The third dimension is used to define layering information that a content creator can use for creation of overlapping sub-textures. The color information associated with curves is applied after projection of the SynthesizedTexture elements to the 2D image plane.

The synthesized Texture decoder uses the combination of the three Base elements mentioned above to produce the image. Color is interpolated along the SynthesizedTexture curves and the result is interpolated with the color of the patches and the background. Signal expansion, sub-division of the imaging plane and layering techniques are used for reproducing the color.

Note that unlike MPEG-4 BIFS' **CompositeTexture2D** the SynthesizedTexture elements are not just drawn on the screen . They are first rendered in compressed form to solve visibility and animation issues, then pixels are produced accumulated in an off-screen buffer.

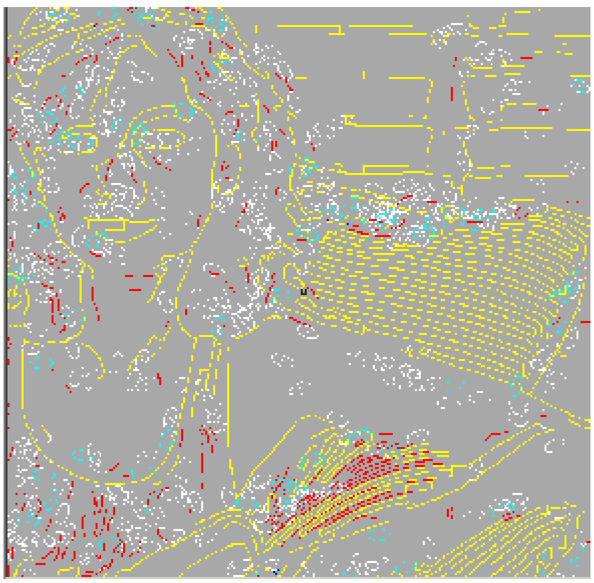

Figure 3. Vector representation of a photo-realistic image showing in figure 4b. Edges show in yellow, Ridges in red, Patches in white and green.

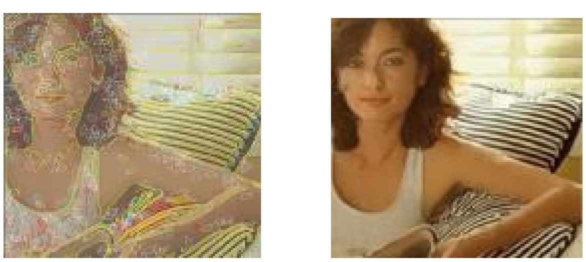

Figure 4a: Vectors overlaying the semi-transparent reconstructed image. Figure 4b: the reconstructed photo-realistic image

3. COMPRESSION RATIO STATISTICS

The vector representation of images is usually more compact than other image compression techniques. For example, the original size of the image in Figure 3 is 185Kbyte as BMP; JPEG compressed file size of this image is 27Kbyte. When vectorized, this image occupies only 13Kbytes.

4. COLOR PROFILES

In VRML and BIFS, lines and curves can have a single color. In synthesized textures, a curve's color information covers not only the curve itself, but also its vicinity. Color is also interpolated along the curve. For this purpose **ColorProfile** nodes are introduced in BIFS.

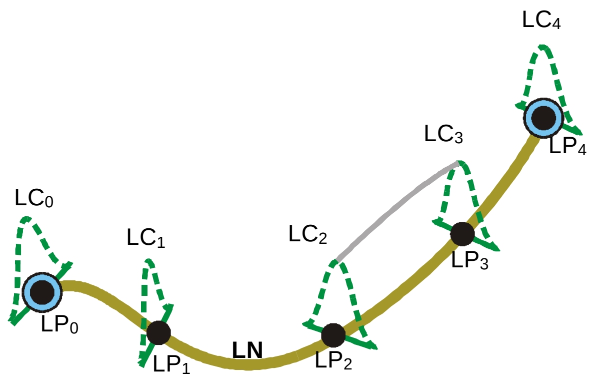

Figure 5. SynthesizedTextureCurve with associated ColorProfiles

Each control point along the **SynthesizedTextureCurve** LN in Figure 5 has its own **ColorProfile**. The height of the profile represents its brightness. When two adjacent color profiles have the same brightness, for example LP_2 and LP_3, the color between the two points is the same. In other cases, the color should be interpolated along the curve by the decoder.

There are two types of color profiles: Edges and Ridges. Normally all profiles along a **SynthesizedTextureCurve** are of the same type.

5. EDGE COLOR PROFILES

Edge color profiles of SynthesizedTextures describe borders between adjacent areas of different color.

In Figure 6. LB2 and RB2 are the colors at the two sides of the Edge. They are clearly different. The LB1 and RB1 brightness values are served to reproduce the background color. The center of the profile is aligned with the carrying **SynthesizedTextureCurve**. The left and rights widths of the profile, WL and WR respectively are normally between 1/16 of a pixel to 8 pixels in size.

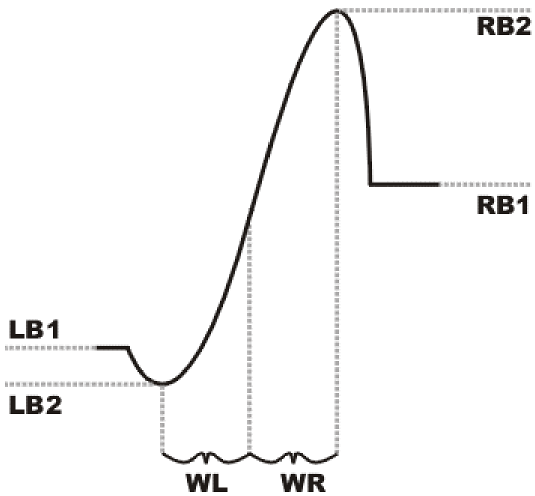

Figure 6. SynthesizedTexture Edge ColorProfile

6. RIDGE COLOR PROFILES

Ridge color profiles in SynthesizedTextures may separate between two zones with a close color tone or describe a brightness spikes on top of a uniform background color zone. Their Central Brightness (CB) describe the color on the center of the SynthesizedTextureCurve (Figure 7); LB2, RB2 values describe respectively the left and right brightness of the curve; LB1 and RB1 describe the left and right background brightness respectively; WL and WR describe the left and right widths of the Ridge color profile. In general, the width is in the range of 1/16 of a pixel to 16 pixels.

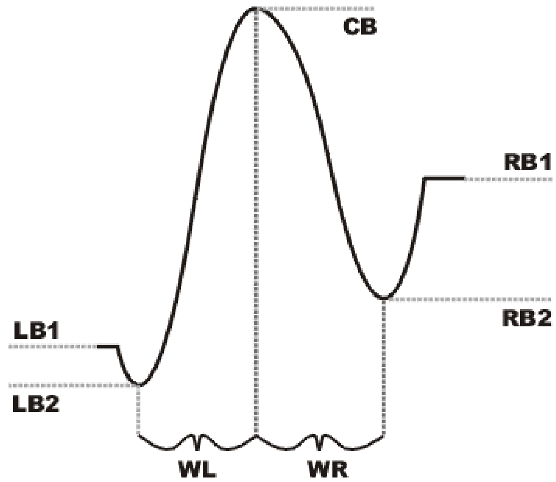

Figure 7. SynthesizedTexture Ridge ColorProfile

7. VECTORIZATION OF DIGITAL IMAGES

The analysis procedures described below are not part of the MPEG-4 specifications and are provided to complete the previous description of the decoding process. More on the vectorization process can be found at [1].

High-resolution images of real world origin present such a variety of local visual patterns and structures that their representation by a small number of vector elements cannot be easy. Vimatix solved this problem by combining several methods:

1. Color Profiles allow for vector elements to faithfully represent their visual vicinity.
2. Multi-scale and multi-order image analysis methods are combined to yield very high level of accuracy
3. Relations between the adjacent vector elements are identified and used at later stages

The vectorization algorithm is computationally simple, local and completely automatic. It is based on a multi-order and multi-scale analysis of the brightness function of the image. For each pixel the best approximation of second and third degree polynomials of the brightness function are computed on the 3x3 and 5x5 pixel areas, centered at the very pixel.

Subsequent analysis of these polynomials first produces (near the considered pixel) the rough estimates of the local Edge or Ridge elements, with their positions and directions, and finally, an accurate estimate of these parameters, as well as the brightness profile.

The rough estimates use only the zero and the first order of information (which is relatively stable to the noise). According to the results of the first order analysis, the second order information is used in such a way that the derived noise of the second order is eliminated. In the next step the third order corrections are computed. This allows using in a stable way highly unstable, but very accurate, third order polynomial approximations of the noisy brightness function.

The above procedure produces a 0.1 pixel geometric accuracy and an accuracy of a couple of gray levels in a color profile capturing.

After local Edge or Ridge elements have been identified, the vectorization proceeds as follows:

1. Adjacency relations between the local Edge or Ridge elements, captured on step 3, are detected, still on the same local information, as above.
2. The chains of the local Edge or Ridge elements are constructed, representing actual Edges and Ridges, approximated by splines. Their profiles and the adjacency relations between them are stored.
3. The background is subdivided according to the structure of the edges, and a low-degree polynomial approximation of the brightness function on a certain grid in each background region is obtained.

If necessary, the resulting parameters of the basic vectorization process can be further quantized, according to their psycho-visual significance, and a lossless statistical compression can be applied to the resulting files.

10. SUMMARY

We have introduced the vector imaging technology for image representation and compression. It serves as a very efficient way to store, transmit and reproduce photo-realistic images and movie clips. The technology is incorporated in MPEG-4 BIFS as SynthesizedTexture nodes and is part of the Animation Framework eXtension (AFX).

11. REFERENCES

[1] M. Briskin, Y. Elichai, Y. Yomdin, “How can Singularity Theory help in Image Processing?”, In “Pattern Formation in Biology, Vision and Dynamics”, A. Carbone, M. Gromov and P. Prusinkiewitcz, Editors, World Scientific Publishers, 1999., pp. 392 – 423.

[2] Yosef Yomdin, Yoram Elichai, Ehud Spiegel, “Synthetic Video and Photo-Realistic 2D Animation”, ISO/IEC JTC 1/SC 29/WG 11 MPEG2001/**m7313** proposal, Sydney, July 2001.

[3] Yosef Yomdin, Ehud Spiegel, Shlomo Birman, “VIM Texture Integration in MPEG-4”, ISO/IEC JTC 1/SC 29/WG 11 MPEG2001/**m7574** proposal, Pattaya, December 2001.