Detection of Highlights for Object–Based Analysis–Synthesis Coding

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Abstract

A new detection method for model failures in an Object–based Analysis–synthesis Coding (OBASC) scheme is proposed. It allows synthesis errors due to highlights assuming that presence, absence or shape of a highlight is subjectively irrelevant to an observer. Highlights are detected by identification of object and illumination colour using the dichromatic reflection model. First results applying the image analysis of an OBASC scheme to a real video telephone sequence show a slight reduction of model failures in the facial area of 1.5% of the facial area without loss of subjective image quality. The proposed model failure detection can be applied to any type of low bitrate image coding as supplement to a subjective image quality criterion.

Introduction

For moving image transmission at low bit rates OBASC [4] has been proposed. For each image of a real image sequence, the real objects are described by model objects defined by their shape, motion and colour parameters. The colour parameters include luminance and chrominance. In this contribution Ostermann's source model of ”moving flexible 3D objects” [6][7] is applied. For each image, first the shape and motion parameters are estimated by image analysis, transmitted and stored at the transmitter and receiver in a parameter memory. This memory also contains shape, motion and colour parameters from formerly transmitted images. Using the stored parameters a preliminary image is synthesized. A quality criterion decides in which image areas the synthesized image differs significantly from the real image. These areas are called model failures. Only for them, colour parameters are transmitted to the receiver. After colour parameter transmission, a final image is synthesized.

Transmitting colour parameters is expensive in terms of bit rate. Therefore the detection of model failures is a critical part of an OBASC scheme. In [6], the model failure detection evaluates the frame to frame difference between the preliminary synthesized image and the real image using a threshold decision. The resulting binary mask of synthesis errors is further processed according to a receiver model. This model assumes that synthesis errors due to geometrical distortions (i.e. slightly wrong object position or object shape) are subjectively irrelevant to an observer. Therefore the synthesis error mask is median filtered and small regions are removed. The remaining regions are declared to be model failures.

Specular reflections on object surfaces, called highlights, is another reason for synthesis errors beside geometrical distortions. They occur on smooth surfaces, where the assumption of diffuse reflection does not hold. If a highlight appears in a real image, it will not appear in the synthesized image properly, because a highlight does not move together with an object. To save bit rate for complex moving image transmission, an extended receiver model is proposed in this contribution. It assumes that the presence, absence or shape of a highlight is subjectively irrelevant to an observer.

Model failure detection

For application of the extended receiver model to model failure detection, highlights have to be detected. For detection, a photometric model instead of a geometric model is sufficient. This is important, because for geometric modelling [1][5] exact geometric information like local object surface normals, object surface roughness, viewing and illumination directions is necessary that is not available in an OBASC scheme today.

Klinker, Shafer and Kanade [2] proposed a method for highlight analysis using the dichromatic reflection model [8]. This model describes the colour of reflected light from a highlight as a superposition of diffuse light of object colour and directed light of illumination colour. Projected by a RGB camera into an image plane, both colours can be found clustered around two segments in the RGB colour space. These segments, called matt and highlight segments, are together T–shaped (see Fig. 1). The highlight segment contains those picture elements (pels) of an image region belonging to the highlight, whereas neighbouring pels in the image plane belong to the matt segment. The segments are found by linear regression knowing about the T–shape and that the darkest point belongs to the matt segment and the brightest to the highlight segment. The method assumes uniformly coloured objects, absence of shadows and an object presenting a large surface area with different local surface normals. It allows for arbitrarily shaped monochromatic light sources and, to a certain extent, takes into account multiple reflections.

In this contribution a new model failure detection method based on the extended receiver model is proposed. It combines a modified version of the highlight analysis of Klinker, Shafer and Kanade with Ostermann's model failure detection method [6]. It is applied to YUV images (amplitude range 0..255) and consists of four steps.

In a **first step**, Ostermann's model failure detection method [6] is applied to the real and synthesized image. In the areas of detected model failures both images are segmented into regions of uniform luminance. It is assumed that different colours exhibit different luminances. For each region, it is assumed that a uniformly coloured part of an object surface corresponds to it. The applied segmentation technique is based on a minimum spanning tree (MST) representation of an image with the luminances as weights [3].

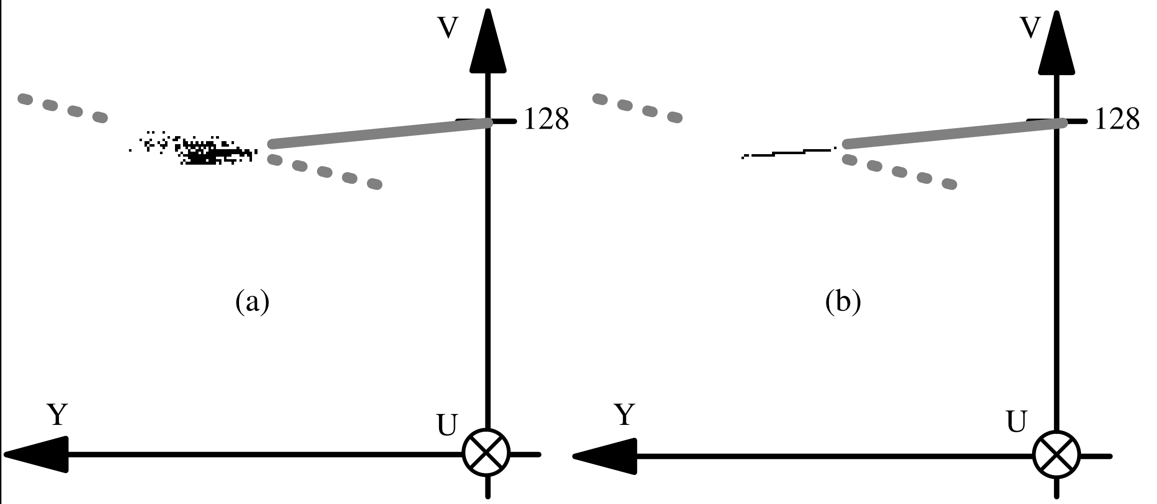

Figure 1: A sample highlight region in YUV space at second (a) and third (b) step of model failure detection; matt (▬) and highlight (• •) segments are shown

In a **second step**, the regions in each image are classified into highlights and other regions. For each region first, the matt and highlight segments are searched assuming a highlight. Knowing the segments, it is decided, whether the assumption is valid or not.

(i) **Finding the segments:** The segments are found by a modified version of Klinker's, Shafer's and Kanade's highlight analysis: The size of the regions depend on the texture of the surface of the objects, but they are usually small compared to the size of the image area corresponding to an object. The object surface normals do not vary much over a small region. If such a region contains a highlight, nearly all pels are clustered around the highlight segment in YUV space. Thus finding the matt segment usually fails. If no multiple reflection is assumed, the zero point (0,128,128) in YUV space belongs to the matt segment. Using this knowledge, the method of Klinker, Shafer and Kanade performs well to find matt and highlight segments. For further processing, the pels in YUV space are represented in a new coordinate system (x,y,z) with x and y parallel to the matt and highlight segments, respectively, and $z = x \times y$. Fig. 1 (a) shows a sample highlight region and its segments in YUV space.

(ii) **Deciding on highlight:** Knowing the segments, a two step criterion is used to decide, whether the highlight assumption is valid or not. First, an Euclidian distance measure using a noise adapted threshold decides, whether the pels in YUV space match the segments or not. If yes, the region is said to be a highlight candidate. A second step eliminates two–coloured regions with only a slight difference between the two colours. Such regions can not be discriminated from highlights in YUV space. But in the image plane they can be identified using second order statistics, if the two colours exhibit a pattern. Therefore the mean absolute difference of the highlight segment components of the pels to their neighbours in the image plane is required to be lower than a certain threshold. If so, the region is accepted as a highlight.

In a **third step**, the illumination colour is eliminated in highlight regions. Therefore the highlight segment components of the pels in a highlight region are set to zero. Fig. 1 (b) shows a sample highlight region with eliminated illumination colour. This is done with the real and the synthesized image resulting in a pair of images free of highlights.

Finally in a **fourth step**, Ostermann's model failure detection method [6] is applied to the this pair of modified images. If the first three steps work properly, synthesis errors only due to highlights on uniformly coloured object surfaces are no longer detected as model failures. In case of second or third step failure even without notice never more model failures are detected than by Ostermann's method.

Results

Using the proposed model failure detection method in Ostermann's OBASC scheme [7] experiments were carried out analyzing 25 images of the real image sequence "Erik". The filmed scene shows Erik talking using a lot of facial expression. The scene is illuminated by diffuse and directed light, self shadowing and highlights are present.

In Fig. 2 the facial area of a sample image of the image sequence "Erik" is shown. For this image the result of the highlight detection (see second step), as well as the results of Ostermann's and the new proposed model failure detection method are given as an example. Knowing the illumination and object colour by manual investigations, most of the detected highlights were found to be true ones, although barily visible in the sample image.

For the image sequence "Erik", 31.3% of the facial area were detected by Ostermann's model failure detection method. 2.9% of the facial area were detected as highlights inside Ostermann's model failures. Half of this highlight area, 1.5% of the facial area, was not any longer detected by the proposed model failure detection method. The other half remain model failure because the third step fails. This happens, because either the segments are not found properly (second step failure) or these regions do not correspond to uniformly coloured object surfaces (first step failure). The proposed model failure detection method causes no visible degradation of subjective image quality.

Conclusion

To save bitrate in colour parameter transmission, a new detection method for model failures in an OBASC scheme has been proposed. It allows synthesis errors due to highlights. Highlights are detected in regions of synthesis error by analysis of object and illumination colour based on the dichromatic reflection model. First results applying the image analysis of an OBASC scheme to a real video telephone sequence show a reduction of model failures in the facial area of 1.5% of the facial area without loss of subjective image quality. The proposed model failure detection can be applied to any type of low bitrate image coding as supplement to a subjective image quality criterion. In future synthesis errors due to nonuniform illumination [9] may be detected and allowed too.

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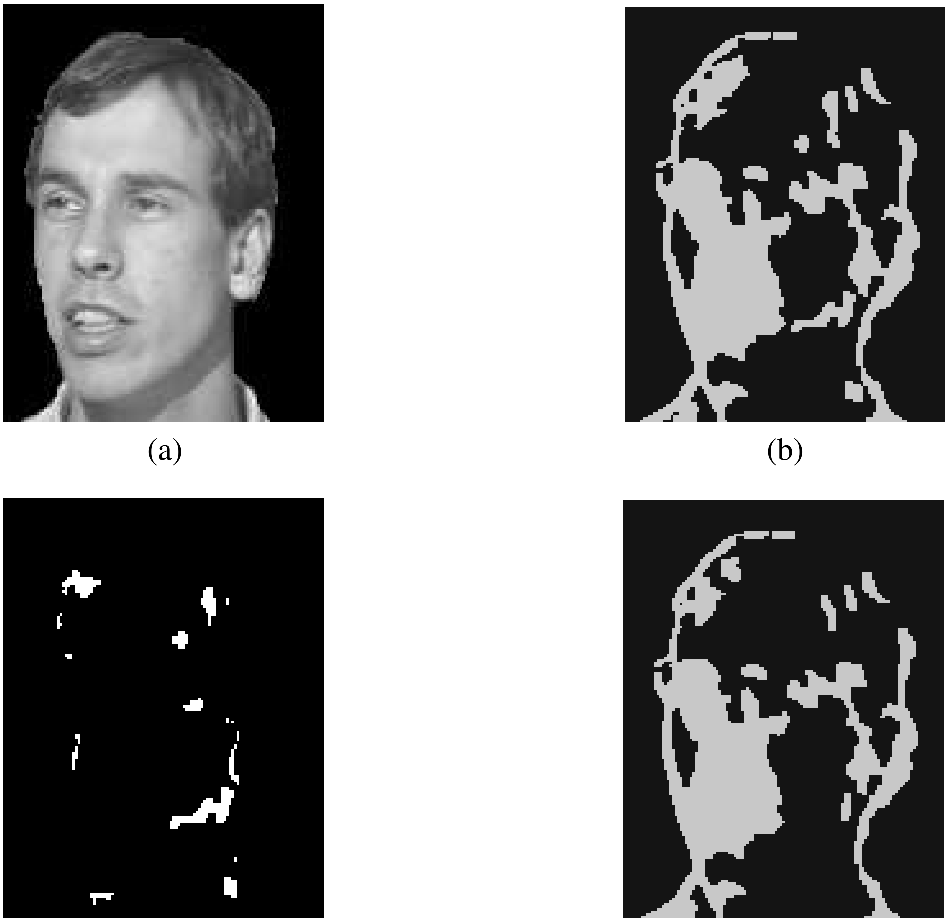

(a) (b)

(c) (d)

Figure 2: Reduction of model failures: Facial area of real image 21 of the image sequence ”Erik” (a), model failures found by Ostermann's detection method (b), highlight regions inside Ostermann's model failures detected in real image (c) and model failures found by the proposed detection method (d)