Detection of Shading for Object–based Coding

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ABSTRACT: *In this paper, a new algorithm for detection of synthesis errors due do object shading under directed illumination for object–based analysis–synthesis coding (OBASC) is presented. The idea of OBASC is to transmit luminances and chrominances only in image regions of model failure. In these regions, synthesis errors are visible between a real image of an image sequence and the decoded image synthesized from formerly transmitted parameters describing object shape, object motion, object colour, and scene illumination. In this contribution, synthesis errors due to object shading are detected by a local analysis of the luminance ratio between real and decoded image based on the model of diffuse reflection. The detected errors are assessed as "non disturbing", thus transmission of luminances and chrominances is avoided for them. This modified OBASC scheme was applied to the test sequence "Claire" (CIF, 10Hz, 50 images). Without degradations in subjective image quality, the data rate is reduced by 9% down to 58kbit/s.*

1. INTRODUCTION

In object–based analysis–synthesis coding (OBASC) [5] based on the source model of moving rigid 3D objects [6], an image sequence is described by a model world consisting of moving 3D model objects. Each model object is defined by three sets of parameters. Colour parameters describe the reflectance of a model object surface. Motion parameters describe 3D rotation and translation. Shape parameters describe the shape by a 3D wireframe. For each image of an image sequence, first motion and shape parameters are automatically estimated, coded and transmitted. Then, a preliminary model image is synthesized using these parameters and previously transmitted motion, shape and colour parameters. The luminance difference between real image and preliminary model image is thresholded to define *regions of synthesis error.* These regions are divided into *regions of geometrical distortions* and *regions of model failure* evaluating size, shape and error signal amplitude of the synthesis error regions. Geometrical distortions are due to small position or shape errors of a model object and are assumed to have no impact on subjective image quality, whereas model failures are assumed to be subjectively visible. In order to reduce data rate, colour parameters are coded and transmitted for model failure regions only. The final model image (decoded image) is synthesized using all transmitted parameters.

In image sequences showing scenes with non–diffuse illumination, reflection effects, i.e. highlights, and illumination effects, i.e. shading and cast shadows, are visible [2]. Highlights occur on smooth object surfaces and do not move together with moving objects. Shading occurs on any concave or convex object. Cast shadows occur if objects or part of objects occlude each other with regard to a light source. Shading and cast shadows lead to temporally varying incident illumination on moving object surfaces. Reflection and illumination effects will cause synthesis errors in an OBASC scheme, if the applied source model can not describe them accurately enough.

To reduce data rate for coding of colour parameters, enhanced subjective visibility criteria for model failure detection have been proposed. In [1], a person's face is detected if possible. Then, synthesis errors inside the facial region are assumed to be more visible than synthesis errors in other image regions. Thus, the threshold for synthesis error detection is set larger outside a face than inside. In [9], synthesis errors due to absence, presence or wrong appearance of highlights are assumed to have no impact on subjective image quality. Such synthesis errors are detected by a method based on the dichromatic reflection model. To reduce data rate, they are not considered as model failures.

In this paper, synthesis errors due to temporal changes of shading are addressed. Such errors stem from the assumption of diffuse and local illumination implicitly used in [6]. They occur in image regions corresponding to rotating real objects under non–diffuse illumination, e.g. a person's face. Even if illumination is assumed to be non–diffuse and modelled for OBASC by a distant point light source and diffuse ambient light as in [10], synthesis errors due to temporal changes of shading occur, because the shape of the model objects is erroneous the illumination model is simple. In this case, such errors can be observed at concave or convex shape details like a person's hair or folded clothes.

In [3], temporal changes of shading are heuristically modelled by an offset applied to the image luminance. In [4] and [10], temporal changes of shading are modelled by a factor applied to the image luminance based on the model of diffuse reflection. The factor varies spatially and is derived from known parameters for object shape, object motion and illumination. It is used for shading compensation. In this contribution, the factor is measured by the luminance ratio between real and preliminary model image. Image regions corresponding to temporal changes of shading will be detected by a spatially homogeneous luminance ratio assuming smooth object shape. This criterion is already used in [7][8] for detection of moving cast shadows on static objects.

In the following sections, the method for detection of synthesis errors due temporal changes of shading will be presented. The method will be used as a subjective visibility criteria for OBASC to assess such errors as "non disturbing". Results for coding efficiency of the modified OBASC scheme will be given.

2. DETECTION OF SYNTHESIS ERRORS DUE TO SHADING

For detection of synthesis errors due to shading, reflection is assumed to be diffuse, illumination is assumed to be non–diffuse. Then, the luminance $s_k(X,Y)$ of a real image k at an image position *(X,Y)* can be described by the product [10] of the reflectance $t_k(X,Y)$ of the corresponding point on the surface of a real object and the incident irradiance $E_k(X,Y)$ (power per area) at this point:

$$s_k(X,Y) = t_k(X,Y) \cdot E_k(X,Y) \qquad k > 0 \,. \tag{1}$$

At the same time instant a model image s_k' can be synthesized from the model world. The luminance $s_k'(X,Y)$ at image position *(X,Y)* is generated from the stored luminance parameter of the surface of an already motion compensated model object at a point on the surface corresponding to image position *(X,Y)*. This luminance parameter was taken from a former image, e.g. the first image *0*. Thus,

$$s'_k(X,Y) = t_0(\tilde{X},\tilde{Y}) \cdot E_0(\tilde{X},\tilde{Y}) \,, \tag{2}$$

with $(\tilde{X},\tilde{Y})$ a position in image *0*. Assuming successful motion compensation, i.e. real and model objects being in a corresponding but rotated position compared to image 0, the reflectances of real and model objects match

$$t_k(X,Y) = t_0(\tilde{X},\tilde{Y}) \,, \tag{3}$$

whereas the irradiance may have changed temporally from $E_0(\tilde{X},\tilde{Y})$ to $E_k(X,Y)$ due to temporal changes in object shading on the concave or convex real rotating object. Assuming the shape of the real objects to be smooth, the incident irradiance $E_k(X,Y)$, $k \geq 0$ does not vary much from pel (picture element) to pel. Then, also the luminance ratio

$$\gamma(X,Y) = \frac{s_k(X,Y)}{s_k'(X,Y)} = \frac{E_k(X,Y)}{E_0(\tilde{X},\tilde{Y})} \tag{4}$$

does not change much from pel to pel. Thus, the variance

$$\sigma_\gamma^2(X,Y) = \frac{\sum_{(x,y)\in A} \left(\gamma(x,y) - m_\gamma(X,Y)\right)^2}{\| A \| - 1}, \tag{5}$$

with $m_\gamma(X,Y)$ the spatial mean of $\gamma(X,Y)$ in the neighbourhood A of size $\| A \|$ of the image position (X,Y), is small. To decide, wether the pel at *(X,Y)* belongs to an area of synthesis error due to temporal changes in shading, the condition

$$k(X,Y) = \sigma_\gamma^2(X,Y) \cdot m(X,Y) \quad \leq th \tag{6}$$

$$\text{with } m(X,Y) = MAX\left\{ m_\gamma(X,Y) \;,\; \frac{1}{m_\gamma(X,Y)} \right\}$$

is evaluated. In Eq. (6), a small variance $\sigma_\gamma^2(X,Y)$ as well as a luminance ratio $\gamma(X,Y)$ being close to one are used heuristically as hints to shading.

The decisions resulting from Eq. (6) are used indirectly to influence model failure detection by OBASC. A modified preliminary model image

$$s_k''(X,Y) = s_k'(X,Y) \cdot \begin{cases} m_\gamma(X,Y) & if \;\; k(X,Y) \leq th \\ 1 & else \end{cases} \tag{7}$$

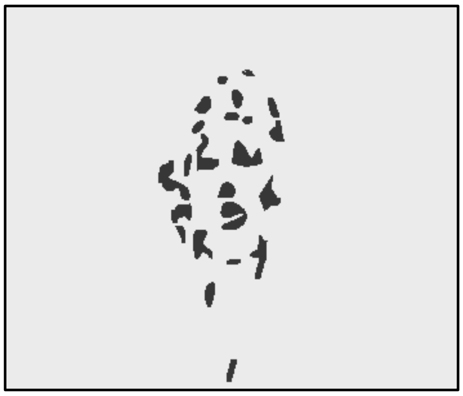
is generated by compensating the temporal changes of shading. The model image $s_k''(X,Y)$ instead of $s_k'(X,Y)$ is then used by OBASC to evaluate the regions of model failures.

The usage of the decisions resulting from Eq. (6) is for two reasons indirect. First, synthesis errors due to temporal changes of shading are not longer considered as model failures, because they can not be any longer detected by OBASC model failure detection. Secondly, by this indirect usage, the decision resulting from Eq. (6) is checked. If for an image region Eq. (6) decides for shading by mistake, the compensation in Eq. (7) will fail for this image region. Thus, $s_k''(X,Y)$ will contain synthesis errors in this region. If these errors are visible, OBASC will detect model failures there.

3. RESULTS

The proposed detection of synthesis errors due to temporal changes of shading was integrated in an OBASC scheme [6] assuming that such synthesis errors have low impact on subjective image quality. The threshold is set to 0.0002 and $\| A \|$ to 9. The OBASC scheme was applied to the the test sequence "Claire" (CIF, 10Hz, 50 images). Using the OBASC scheme without shading detection, results to a data rate of 64kbit/s [6]. Using the OBASC scheme with shading detection reduces the size of model failure regions by 15%. In Fig. 1 an example for reduction of size of model failure regions is shown. This leads to a reduction of data rate by 9% to58 kbit/s without degradations in subjective image quality.

(a)



(b)

(c)

Figure 1: (a) Third image of test sequence "Claire" and detected regions of model failures (b) without and (c) with shading detection. The area of model failures is reduced from (b) to (c).

4. CONCLUSION

In this paper, a new algorithm for detection of synthesis errors due do object shading under directed illumination for object–based analysis–synthesis coding (OBASC) is presented. Such synthesis errors are detected by a local analysis of the luminance ratio between real and decoded image based on the model of diffuse reflection. As a criterion, a spatially homogeneous luminance ratio being close to one is used. These detected errors are assessed as ”non disturbing”, thus transmission of luminances and chrominances is avoided for them. This modified OBASC scheme was applied to the test sequence ”Claire” (CIF, 10Hz, 50 images). Without degradations in subjective image quality, the data rate is reduced by 9% down to 58kbit/s.

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