Estimation of Nonuniform Irradiance for Object–Oriented Coding Based on 3D Objects

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Abstract

Nonuniform irradiance is estimated from a monocular image sequence. Image analysis uses the source model "3D rigid object with 3D motion and local illumination" allowing for 3D motion and nonuniform colour. The irradiance is modelled by a reflection map. First experimental results of estimating and compensating nonuniform irradiance using a synthesized image sequence are given.

1 Introduction

In object–oriented analysis–synthesis coding [5][6] three dimensional information has to be extracted from two dimensional projections of a real 3D scene containing moving 3D objects. Working on a monocular image sequence, a 3D model based image analysis algorithm was presented [2]. The images are segmented into static background and moving objects. Each moving real object is modelled by a 3D model object. A model object is defined by its shape, motion and colour. The shape is rigid and represented by control points connected by a mesh of triangles, the motion is represented by six 3D motion parameters for rotation and translation, the colour is represented by texture mapped on each triangle. For every real image of the image sequence a model image is synthesized by projection of the model objects into a model image plane. Based on the source model the 3D image analysis estimates and improves the 3D model object parameters by analyzing the differences between real and model image. In [2] reflection was assumed to be diffuse, illumination to be diffuse, white and local. Local illumination assumes spatially constant irrradiation in the 3D scene, no multiple reflections, and no shadows. If one of the above assumptions does not hold in the real 3D scene, as may happen in video telephony, model failures occur, i.e. regions of a real image differ significantly from the model image.

To estimate illumination or reflectance a lot of work has been done in case of uniformly coloured and still objects. Only a few references can be found on estimation or compensation of illumination or reflectance taking into account motion and nonuniform colour [3][4][7]. This contribution is based on 3D image analysis [2], allowing for 3D motion and nonuniform colour. The assumption of diffuse illumination is rejected expanding the source model to "3D rigid object with 3D motion and local illumination".

2 Modelling nonuniform irradiance

Assuming local, white and time–invariant illumination, diffuse reflection, and time–invariant viewing direction, the radiance L_r reflected from an object surface depends on the incident irradiance E_i and the object surface reflectance R:

$$L_r(N,\lambda) = R(\lambda)\ E_i(N) \tag{2.1}$$

with N the surface normal and λ the wave length. Neglecting optical blurr and deviations of the image formation due to perspective projection from that of orthogonal projection the image plane irradiance E_{image} incident on the image plane is proportional to the radiance L_r reflected by an object surface patch. A reflectance map M(i,j) of I×I fields is defined here as samples of the luminance of E_{image} of a white matt ball providing uniform reflectance $R(\lambda) = R_0$ all over its surface:

$$M(i,j) := c\ R_0\ E_i(\sigma^{(i)},\tau^{(j)}) \qquad c = const. \quad i,j \in\ [0;I\text{–}1] \qquad I \in N \tag{2.2}$$

$\sigma^{(i)}$ and $\tau^{(j)}$ are the in $[-\frac{\pi}{2},\frac{\pi}{2}]$ uniformly quantized polar and azimuth angles σ and τ of a Gaussian sphere, i and j are the corresponding indices of the reflectance map.

3 Estimation of the reflectance map

To estimate the reflectance map $M(i,j)$ the model object is assumed to be correctly motion compensated leading to the basic idea that the remaining differences between real image and current model image are due to nonuniform irradiance only. For a model object triangle moved from position 0 to position 1 corresponding to (σ_0, τ_0) to (σ_1, τ_1) in the Gaussian sphere, a local luminance ratio of the averaged luminances $\langle Y_{image,1} \rangle$ and $\langle Y_{image,0} \rangle$ of real and model image respectively is evaluated, taking into account only image points belonging to the triangle. This ratio is a hint to the irradiance change of that triangle due to its motion. Attaching the ratio to the corresponding fields of the reflectance map leads to:

$$M(i_1, j_1) - \frac{\langle Y_{image,1} \rangle}{\langle Y_{image,0} \rangle} M(i_0, j_0) = 0 \tag{3.1}$$

The indices i_0, j_0, i_1, j_1 correspond to $\sigma_0, \tau_0, \sigma_1, \tau_1$ respectively. Collecting all existing dependencies (3.1) between fields of the reflectance map, a linear homogeneous equation system arises:

$$M(i,j) - a_{ijkl} M(k,l) = 0 \qquad a_{ijij} = 0 \qquad i,j,k,l \in [0, I-1] \tag{3.2}$$

Eqs. (3.2) is weighted by an accuracy measure derived from the number of image points involved. Grouped to clusters of equations joining the same unknowns, they are solved for least error using side conditions. The clusters are adjusted to each other and undefined fields are interpolated.

During every reflectance map estimation new dependencies like eq. (3.1) occur or old ones are updated by averaging former $\langle Y_{image,0} \rangle$ and $\langle Y_{image,1} \rangle$ with currently measured image luminances. Collecting and updating dependencies a memory is built accumulating knowledge about the irradiance distribution over the Gaussian sphere.

4 Experimental results

As input to the image anlysis a synthetic image sequence of 90 images was generated showing a textured rigid head and shoulder object, illuminated by one Lambertian distant point light source. Motion was applied varying the models position by rotation up to 15 degrees away from its inital position tributing to typical video telephone scenes.

For this first experiment, shape, colour and motion of the object were assumed to be known. For each image a reflectance map of 45×45 fields was estimated, the object was motion and irradiance compensated using Gouraud shading[1]. The remaining mean square synthesis error was measured and averaged over the image sequence. Without irradiance compensation the peak SNR turned out to be 43.69 dB due to object rotation up to 15 degrees. With compensation using current estimated reflectance map it is 50.46 dB and using ideal reflectance map it is 51.59 dB. Due to limited spatial resolution of the reflectance map, texture interpolation and Gouraud shading the error cannot reach zero.

5 References

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