Image-based Retexturing of Deformed Surfaces from a Single Image

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Abstract

Retexturing is the process of realistically replacing the texture of an object or surface in a given image by a new, synthetic one, such that texture distortion as well as lighting conditions of the original image are preserved. The key challenge is to separate the shading information from the actual local texture and to retrieve the texture distortion from an image without any knowledge of the underlying scene. In this paper, we introduce an approach for automatic retexturing that models an image of a deformed regular texture as a combination of its deformed surface albedo, a shading map and additional high frequency details.

Categories and Subject Descriptors (according to ACM CCS): I.4.8 [Image Processing and Computer Vision]: Scene Analysis—, I.3.8 [Computer Graphics]: Applications—

1. Introduction

Retexturing an arbitrarily deformed surface in an image is a challenging problem which has been addressed in recent years both by the Computer Vision and Graphics communities. The key issue is to estimate texture distortion caused by the shape of the surface as well as shading effects from the original image without knowledge of the underlying geometry. Various texture overlay methods have been proposed for videos [PLF05,HSE10]. These methods estimate surface deformation and shading properties in relation to a given reference frame of the undeformed texture. However, such a reference image is not always available. In this paper, we address the problem of automatically retexturing a deformed surface in a single image. This problem is related to shape-from-shading and shape-from-texture problems which use texture deformation and shading as a strong cue for depth to reconstruct the 3D structure of an object from a single image. Consequently, current methods for single-image retexturing either use shading [JH04,GSPJ08] or texture [LLH04] to estimate the required information. However, [JH04] and [GSPJ08] are restricted to textureless surfaces and [JH04] and [LLH04] need interactive editing by the user.

In this paper, we introduce an approach for automatic retexturing of a deformed surface, e.g. cloth, in a single image. The only assumption we make is that the original texture is of a regular type, which means that it is constructed by regularly tiling the texture space with one texture element, which is the case for many cloth textures. The key idea is to separate the surface albedo (i.e. its underlying local color) from photometric or shading information by estimating the mean appearance of one texture tile and to estimate the texture deformation as a spatial deviation from a synthesized regular texture. Furthermore, we can decompose the texture albedo into a low frequency structure representing the texture itself as well as in a high frequency part representing e.g. the yarn structure of cloth. Finally, these parts are combined with any new texture to generate realistic retexturing results. The composition of high frequency shading effects and yarn structure with the new texture can be manipulated by a user.

2. Texture Analysis and Replacement

In our approach, we model a given image $\mathcal{I}$ of the deformed texture as:

$$\mathcal{I}(\mathbf{x}) = \mathcal{M}_S(\mathbf{x}) \cdot \mathcal{T}(\mathcal{W}(\mathbf{x})) + \alpha \cdot \mathcal{M}_{HF}(\mathbf{x}) \qquad (1)$$

where $\mathbf{x}$ denotes pixel coordinates, $\mathcal{T}$ is the original texture which is deformed by a geometric warp $\mathcal{W}(\mathbf{x})$, $\mathcal{M}_S$ denotes a shading map and $\mathcal{M}_{HF}$ denotes high frequency details on the texture. The idea behind our approach is to decompose an image of a deformed texture into the different components to combine them again with a new texture.

Figure 1: *Upper row: Original texture with estimated deformation grid and texton appearances, estimated shading map, estimated high frequency yarn structure (colors scaled) and retexturing result without applying the high frequency information ($\alpha = 0$). Lower row: Different retexturing results after applying the high frequency information to the new textures ($\alpha = 1$).*

Texton Appearance Estimation: We start by first estimating the mean frontal appearance of one texture tile, called *texton* in the following, and candidate positions of the texton in the image. For this purpose, we generate suitable feature points (using SIFT) on the image and group them using unsupervised clustering. For each cluster a frontal appearance of a texton template is estimated from a mesh model consistent with the geometric relationship between feature points and the assumed texture regularity (note, that there can be more than one *correct* texton).

Texture Decomposition and Distortion Estimation: By exploiting the assumed topology of the texture regularity, we synthesize an image of the undeformed texture from the estimated texture tiles. The estimation of the texture deformation and the shading map is then treated as a geometric and photometric image registration task, solving for a warp that registers the synthesized undeformed texture onto the original image. We jointly estimate a deformation and the shading map (see Figure 1) using an image-based optimization scheme similar to [HSE10] initialized with the estimated texton positions. As the synthetic regular texture is generated from an estimated mean texton, high frequency parts of the original texture, representing e.g. detailed self-shadows of the yarn structure, are not present in the synthetic texture. Thus, the remaining residual between the original image and the registered synthetic texture represents an estimate of these structures (see Figure 1).

Texture Replacement: Having processed the input image, the equation (1) can now be applied to a new synthetic texture. The weight α can be used to modify the influence of the high detail texture structures. Retexturing results achieved with $\alpha = 1$ are presented in the lower row of Figure 1. The addition of the high detail structures significantly increases the realistic perception of the synthetic texture.

3. Conclusions and Future Work

We presented an approach for automatic retexturing of deformed regular textures in a single image without a given reference image of the undeformed texture. We currently estimate a mean texton appearance using SIFT features and unsupervised clustering. However, SIFT fails for strongly foreshortened textons which appear due to perspective distortion. As for the subsequent image-based optimization step a good initialization is needed due to the repetitive texture structure, we will investigate other feature descriptors. Furthermore, self-occlusions due to strong creases and folds lead to discontinuities in the 2D grid structure which have not been handled so far. We are currently working on methods to handle this by approximating the 3D shape from the texture deformation and detecting these discontinuities from depth discontinuities. We are targeting at a method that will use the presented texture decomposition plus approximative 3D geometry estimated from the texture itself.

References

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