Realistic 3D Projection Mapping using Polynomial Texture Maps

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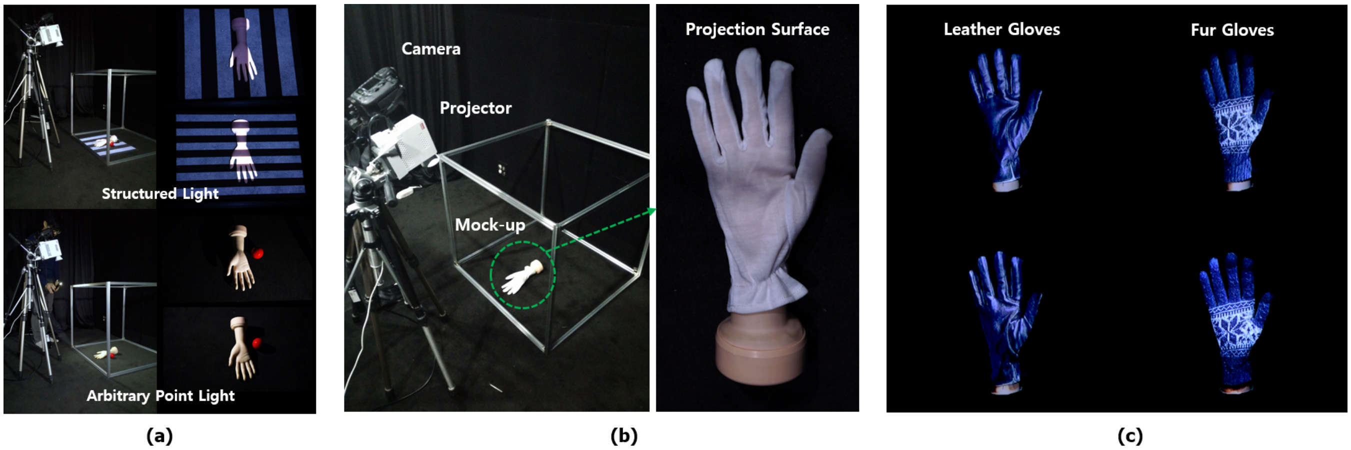

Figure 1: *Realistic 3D Projection mapping: (a) The measurement system, (b) The system configuration, and (c) Results of the projection mapping on a white-cloth glove.*

INTRODUCTION

Projection mapping has been widely used to efficiently visualize real world objects in various areas such as exhibitions, advertisements, and theatrical performances. To represent the projected content in a realistic manner, the appearance of an object should be taken into consideration. Although there have been various attempts to realistically represent the appearance through digital modeling of appearance materials in computer graphics, it is difficult to combine it with the projection mapping because it takes huge amount of time and requires large space for the measurement. To counteract these challenges of time and space, [Malzbender et al. 2001] present polynomial texture maps (PTM) that can represent the reflectance properties of the surface such as diffuse and shadow artifacts by relighting of the 3D objects according to varying light direction around the object. PTM does not have temporal or spatial constraints requiring only several tens of images of different light directions so that it makes it possible to easily produce an appealing appearance.

Keywords: spatial augmented reality, projection mapping, relighting, polynomial texture maps

Concepts: •**Computing methodologies** → **Mixed / augmented reality;**

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In this paper, we propose a realistic projection mapping method combined with the PTM technology. In order to accurately align the relighting texture with the object, we first reconstruct the projection view using the structured light patterns. The relighting texture is generated by the PTM. The intensity of each pixel in the projection view is interpolated using PTM samples and transformed into the projection image plane. Our method can accurately project more realistic texture onto the three dimensional projection surface with varying appearance that contains different texture patterns. The final results demonstrate excellent 3D effects with realism.

THE PROPOSED METHOD

The projector-camera system is used to define the correspondence between the projection image plane and the camera image plane as shown in Figure 1-a (top). The projection image plane is segmented into a set of patches based on [Lee et al. 2015]. We define the transformation function of the quadratic form for each patch as follows.

$$X_i = A_j \hat{X_m} \;\; where \;\; \hat{X_m} = [{x_m}^2, {y_m}^2, x_m y_m, x_m, y_m, 1]^T \\ and \; X_i = [x_i, y_i]^T$$

Here, (x_i, y_i) is a pixel in the projector image and (x_m, y_m) is a pixel in the camera image. And A_j is mapping coefficient matrices for each pixel.

We capture PTM samples illuminated under a moving single light source as shown in Figure 1-a (bottom). Then we can estimate coefficients of the polynomial function at each pixel using the least squares method.

$$L(u,v,l_u,l_v) = a_0(u,v)\cdot {l_u}^2 + a_1(u,v)\cdot {l_v}^2 + a_2(u,v)\cdot l_u l_v + \\ a_3(u,v)\cdot l_u + a_4(u,v)\cdot l_v + a_5(u,v)$$

Here, $(a_o \sim a_5)$ are coefficients of the polynomial function, (l_u, l_v) is the light direction estimated by using a reflective ball and L is the luminance value of the pixel using the coefficients of the PTM. Finally we can generate a realistic rendered image under user-defined arbitrary light directions.

Estimated PTM coefficient at each pixel is generated on the camera image plane. Therefore, stored coefficients of the PTM at each pixel in the camera image plane need to be transferred to the projector image plane using the transformation function estimated between the projector and camera. Through this process we can accurately project realistic texture onto the three-dimensional mockup without geometric distortion.
The system configuration is shown in Figure 1-b. We use a static projector-camera system and a texture-less physical mockup. Using this system, the user can create a promising rendered result that contains reflectance effects which offer more realistic and immersive experience. In this paper, we choose leather and fur gloves for the measurement of PTM data and the results are projected on a white-cloth glove. The results exhibit realistic rendering effects according to the different light direction as shown in Figure 1-c.

Conclusion & Future Work

In this paper, we developed a realistic 3D projection mapping system using the reconstruction of the projector view based on the projector-camera correspondences and polynomial texture maps that can provide effective visualization. The proposed system is expected to be applied to a variety of applications that need immersive contents. We plan to extend our method by applying it to a variety of materials such as highly specular and heterogeneous materials and also using other material appearance reflectance function method such as BTF and SVBRDF.

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