SHAPE FROM TWO IMAGES UNDER POINT LIGHT SOURCE ILLUMINATION AND PERSPECTIVE PROJECTION

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Abstract

This paper introduces one of the advanced researches of the research project 53-(b) in Information Science Research Institute, Chubu University. As a method to recover 3-D shape from shading images, Light Fall-off Stereo (LFS) has been proposed using the inverse square law for illuminance with point light source illumination. This paper extends the principle of light fall-off stereo and proposes a new approach under the assumption of both point light source illumination and perspective projection using two images with the different size of target object. The proposed approach is demonstrated through computer simulation and real experiment.

1. INTRODUCTION

Endoscopy allows medical practioners to observe the interior of hollow organs and other body cavities in a minimally invasive way. Sometimes, diagnosis requires assessment of the 3-D shape of the observed tissue. Specialized endoscopes with a laser light beam head or with two cameras mounted in the head have been developed.

Here, the general endoscope is assumed to recover the 3-D shape for the medical application. The approach uses the geometrical calculation for the corresponding points and uses the interpolation for remained points of the object. While Light Fall-off Stereo (LFS) approach [1] uses the inverse square law for illuminance to compute the depth of each point of the target image. This approach still uses the condition that only the light source moves while the camera is fixed.

This paper extends LFS approach with two images taken under the condition that both point light source and camera are moved with the perspective projection of the endoscope environment.

2. PREVIOUS LIGHT FALL-OFF STEREO

The Light Fall-off Stereo is an approach that recovers an image's depth-map from the light source using two images. The inverse square law for illuminance is used to determine the distance between the light source and the object. This law is defined as

$$I(p) = \frac{k_p}{r_p^2} \tag{1}$$

where k_p represents a constant related to the intensity of the light source as well as the reflectance and orientation of the surface point p, while r_p represents the distance between the light source and surface point p. This results in the following Eq.(2) using two image with the change of position of point light source.

$$\frac{I'_p}{I_p} = \frac{r_p^2}{{r'}_p^2} \tag{2}$$

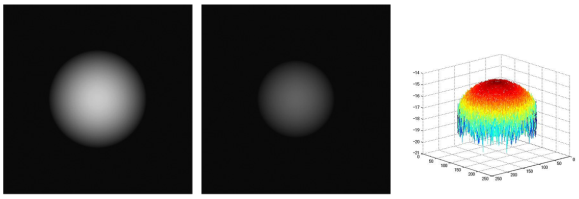
The depth r_p is computed using the following equation.

$$r_p = \frac{\Delta r}{\sqrt{\frac{I_p}{I'_p}} - 1} \tag{3}$$

where $\Delta r = r'_p - r_p$ represents the distance between two light source positions, and I and I' represent the intensities of at any point p of the two images.

3. EXTENTION TO ENDOSCOPE IMAGES

In the endoscope, the light source and the camera are fixed as the same position and moved together, and as the endoscope progresses in a human body. Under the perspective projection, the positions of corresponding points change between image frames and determination of the corresponding points becomes necessary to recover the depth map. Since the corresponding points change between two images in the movement of endoscope, SIFT [2] is used to detemine the corresponding points between two images. Staining liquid is sometimes used in the observation of the medical endoscope



(a) 20mm (b) 25mm (c) 3-D Shape

Fig. 1. Simulation Example

and this image with staining liquid is assumed to be used as the target. This can increase the corresponding points between frames but some miscorresponding points should be removed from the pairs obtained through SIFT as follows. **1) Removal of some specular reflectance points, 2) Removal of some points using distance information from Epipolar line, 3) Removal of some points using corresponding vector at the surrounding points.** These procedures can leave the correct corresponding points between images.

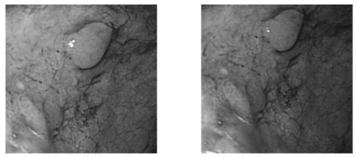
After determining corresponding points, the region of the target object is adusted to the same size for the adaptation of LFS. It consists of the following steps. **1) Delaunay triangulation is generated from the corresponding points. 2) Another point is added to the Delaunay triangulation and quadrangle tetragon is generated. 3) Perspective projection matrix is calculated for each quadrangle (tetragon). 4) The image region is resized for each Delaunay triangulation.** Thus, the object target is resized using the transformation of perspective projection. In the implementation, the depth r_p is recovered using the K neighboring points for the interesting point p for the improvement of the result.

$$r_p = \frac{\Delta r}{\sqrt{(\sum_{i=1}^{K} I(p_K)/\sum_{i=1}^{K} I'(p_K))} - 1} \quad (4)$$

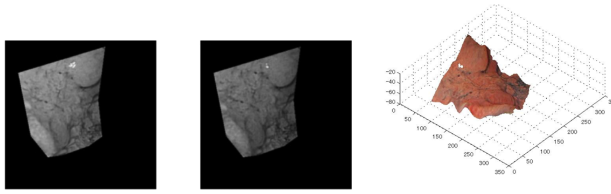
4. EXPERIMENTS

Computer simulation demonstrates the recovery of 3-D shape using two images with the distance between object and camera of 20mm and 25mm, respectively. It is also assumed that the endoscope moves along only the Z direction and no movement along X or Y directions. Two images of a Lambertian sphere with the diameter 20mm are shown in Fig.1(a) and (b) with the respective distance apart from the camera. and the recovered result is shown in Fig.1(c). The mean error to the true depth map was 0.320mm with high accuracy.

The real experiment was done for the endoscope images are shown in Fig.2. The recovered result is shown



(a) Reference Image (b) Another Image before Resizing



(c) Recovered Region for (a) (d) Another Image after Resizing (e) Recovered Shape

Fig. 2. Real Experimental Example

in Fig.2-(e). These results suggest that the polyp shape is recovered with the bulge by the proposed approach which is extended the endoscope images under the perspective projection and inverse square law for illuminance.

5. CONCLUSION

This paper proposed a new approach to extend the previous Light Fall-off Stereo approach to the conditions of both point light source illumination and perspective projection. The proposed approach gives the robust result for the endoscope environment where the distance between light source and object surface is near. The extension for the assumption of movement restriction of endoscope is remained as the futher subject.

6. REFERENCES

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