Real-time Shape Recovery from Silhouette and Disparity

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1 Introduction

The goal of shape recovery is to derive a 3-D scene description from one or more 2-D images. In computer vision, the techniques to recover shape are called shape-from-X techniques, where X can be shading, motion, texture, silhouette, stereo, etc. We propose a new shape recovery algorithm using silhouette and disparity fields from stereo image sequences.

2 Exposition

A space carving method is very common technique to convert silhouette contours into visual hulls. However, the shape-from-silhouette (SFS) has serious limitations in concave surface regions or multiple, disjoint convex objects. We propose to use both silhouette and disparity information to carve the space by using stereo cameras. We have previously developed real-time segmentation and disparity estimation algorithms [Kim at al. 2004; Kim at al. 2005]. The estimated disparity fields are converted into depth information with camera parameters, and a 3D model of the object is then reconstructed from the silhouette and disparity fields.

All voxels *M(X, Y, X)* in 3D spaces are projected onto multiple images I_n with the following equation, where P_n is a projection matrix of a camera C_n.

$$[u,v,s]^T = P_n[X,Y,Z,1]^T \tag{1}$$

If the projected points of *M* are included in the foreground region of the image, then we check if the voxel places behind the range of depth calculated from disparity. d_{voxel}, a distance from the camera to the point *M*, and d_{surf}, a distance from the camera to the surface, are calculated by Eq. (2) and Eq. (3), respectively, where $[t_x,t_y,t_z]$ is a camera position, $[X_o,Y_o,Z_o]$ a back-projected position of the principal point in 3D space, *f* focal length of the camera, *B* a baseline distance and *d(u,v)* a disparity of the projected point.

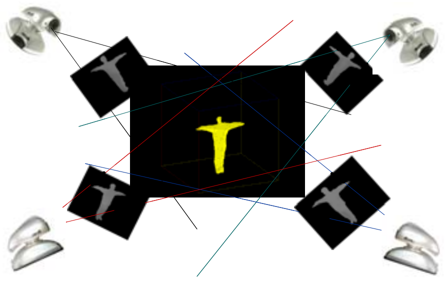

Fig. 1. Proposed shape recovery technique

$$d_{voxel} = \frac{\left\{\begin{array}{l} -(X-X_o)^2-(Y-Y_o)^2-(Z-Z_o)^2 \\ +(X-t_x)^2+(Y-t_y)^2+(Z-t_z)^2 \\ +(X_o-t_x)^2+(Y_o-t_y)^2+(Z_o-t_z)^2 \end{array}\right\}}{2\sqrt{(X_o-t_x)^2+(Y_o-t_y)^2+(Z_o-t_z)^2}} \tag{2}$$

$$d_{surf} = -\frac{fB}{d(u,v)} \tag{3}$$

If all projected points of *M* are included in the foreground region and behind of the distance to surface of multiple images, we select the point as inside voxel of an object. Testing all points in a 3D model is, however, a very time-consuming process. Therefore, we use an octree data structure for modeling. For each voxel of a level, 27 points (i.e., each corner and the centers of edges, faces and a cube) are tested. If all checking points are neither included in nor excluded from an object, the voxel splits into eight sub-voxels and they are tested again at the next level.

Fig. 2 shows models recovered by the SFS algorithm and the proposed method using 4 cameras, respectively. The second model looks more natural and close to real target objects because redundancies in the models by the SFS method are removed by disparity information. The overall speed of full system works in a speed of 16 frames/sec with a common PC.

3 Conclusion

We developed a simple volume carving algorithm using silhouette and disparity with camera parameters at a time that is more robust than conventional SFS algorithms. The algorithm partitions space into an octree and processes it hierarchically so that execution time and space are dramatically reduced. The result is an approximate voxel structure close to the actual surface.

References

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KIM. H., MIN. D., CHOI. S. and SOHN. K. 2005. Real-Time Disparity Estimation using Foreground Segmentation for Stereo Sequences, *Optical Engineering* (submitted).

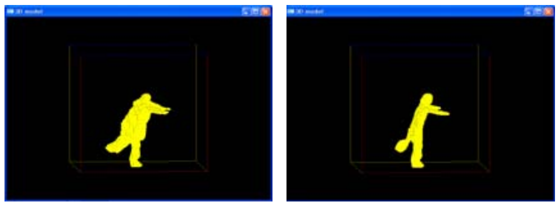

Fig. 2. Simulation results (SFS vs. proposed algorithm)

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