Dipl.-Ing. Yasemin Kuzu
Dipl.-Inform. Volker Rodehorst

Technical University of Berlin
Photogrammetry and Cartography

Volumetric Modeling Using Shape from Silhouette

1. Introduction

This work describes an efficient image-based approach to compute volume models from silhouette images in a low cost measuring environment. First, the contours of a real object must be extracted from a sequence of images.

In a second step, a bounding pyramid is constructed using the projection center and the silhouette. The intersection of all bounding pyramids defines an approximate geometric representation for the object, called visual hull.

Silhouette based reconstruction methods have the principal inability to detect object concavities. We present some new results to minimize the modeling error on critical areas using a block matching approach.

2. System Configuration

Definitions:

- $\vec{a}$: Unit vector along optical axis
- C : Vector to the focal center
- $\vec{h}'$: Horizontal unit vector
- O : Projection center
- P : Real-world point in WCS
- P': Image point in ICS
- $\vec{v}'$: Vertical unit vector

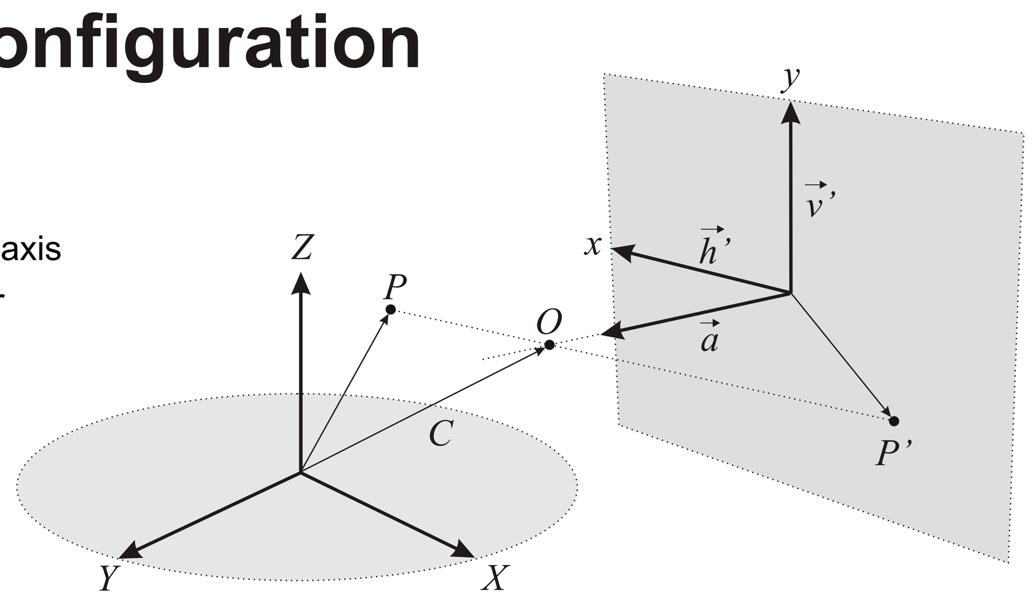

Figure 1: Mathematical camera model for central projection.

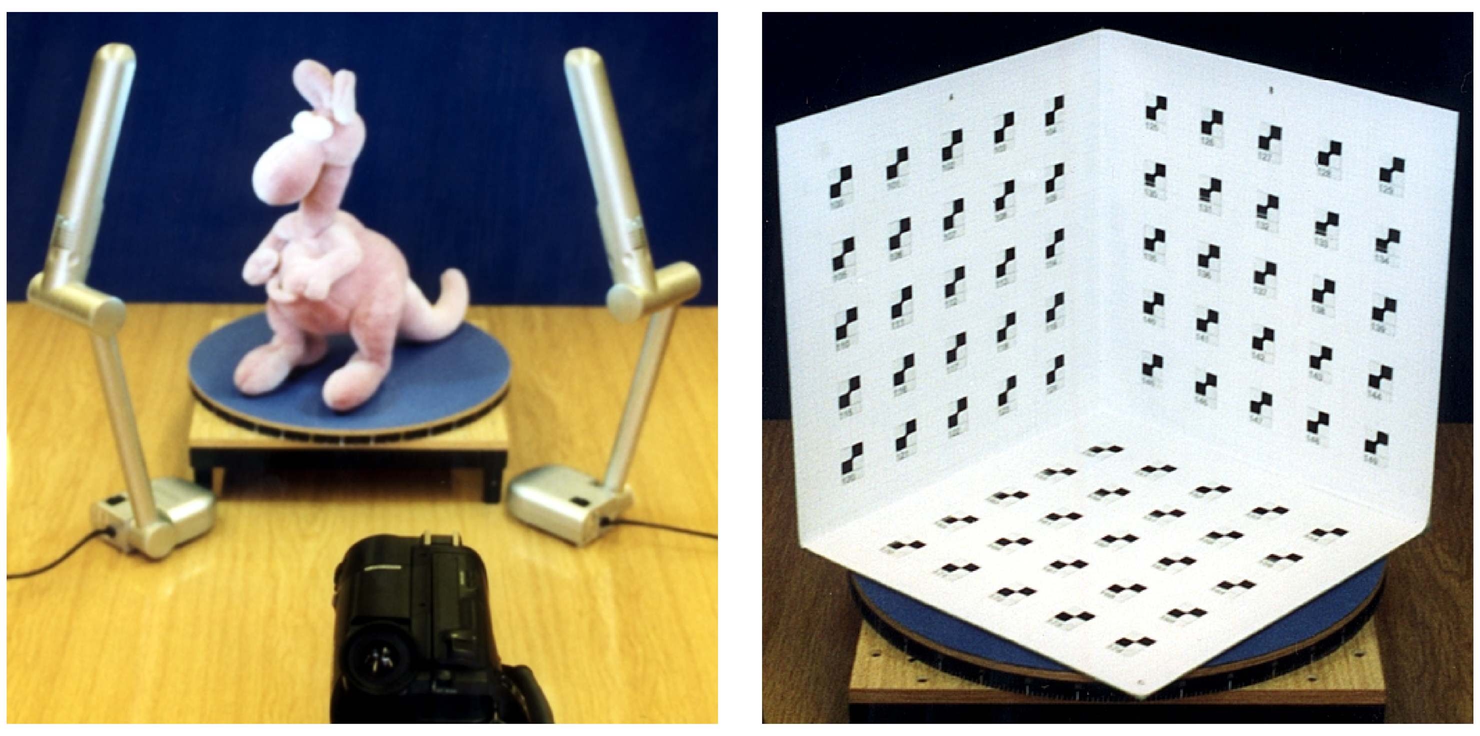

Figure 2: Experimental setup using a turntable (left) and a calibration object (right) in front of a monoscopic camera.

3. Automatic Image Segmentation

Figure 3: Background estimation using an IHS color space histogram (left) and the resulting silhouette extraction (right).

4. Shape Modeling Using Voxel Carving

$$P'_x \quad \frac{(P \quad C)\ \vec{h}}{(P \quad C)\ \vec{a}} \qquad P'_y \quad \frac{(P \quad C)\ \vec{v}}{(P \quad C)\ \vec{a}} \qquad \vec{h} \quad f\ \vec{h}'\ \vec{a}\ x_h \qquad \vec{v} \quad f\ \vec{v}'\ \vec{a}\ y_h$$

Equation 1: Projection formula for the transformation of a real-world point P (WCS) to the image point P' (ICS) using the image center (x_h, y_h) and the focal length f.

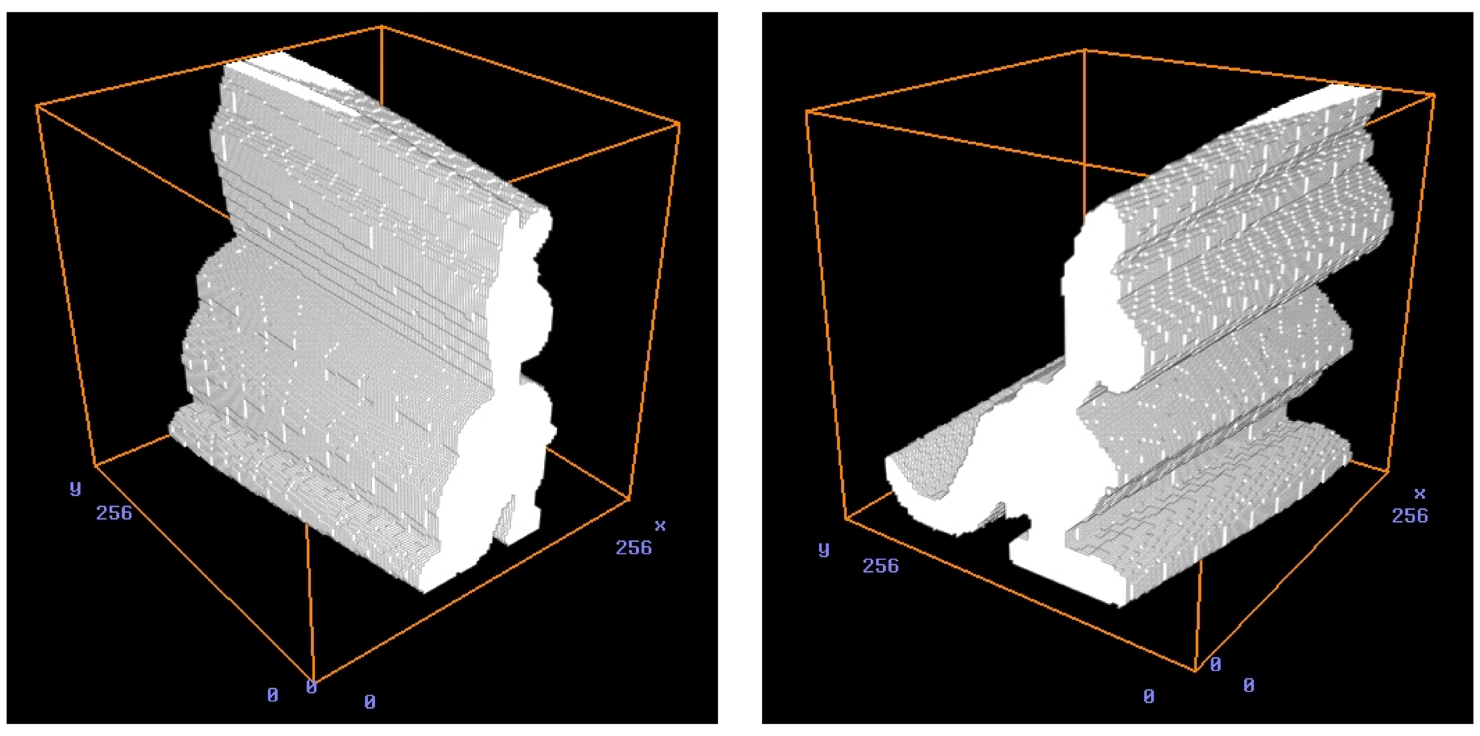

Figure 4: Voting-based carving of a voxel cube using various silhouettes under central projection.

5. Experimental Results for the Visual Hull

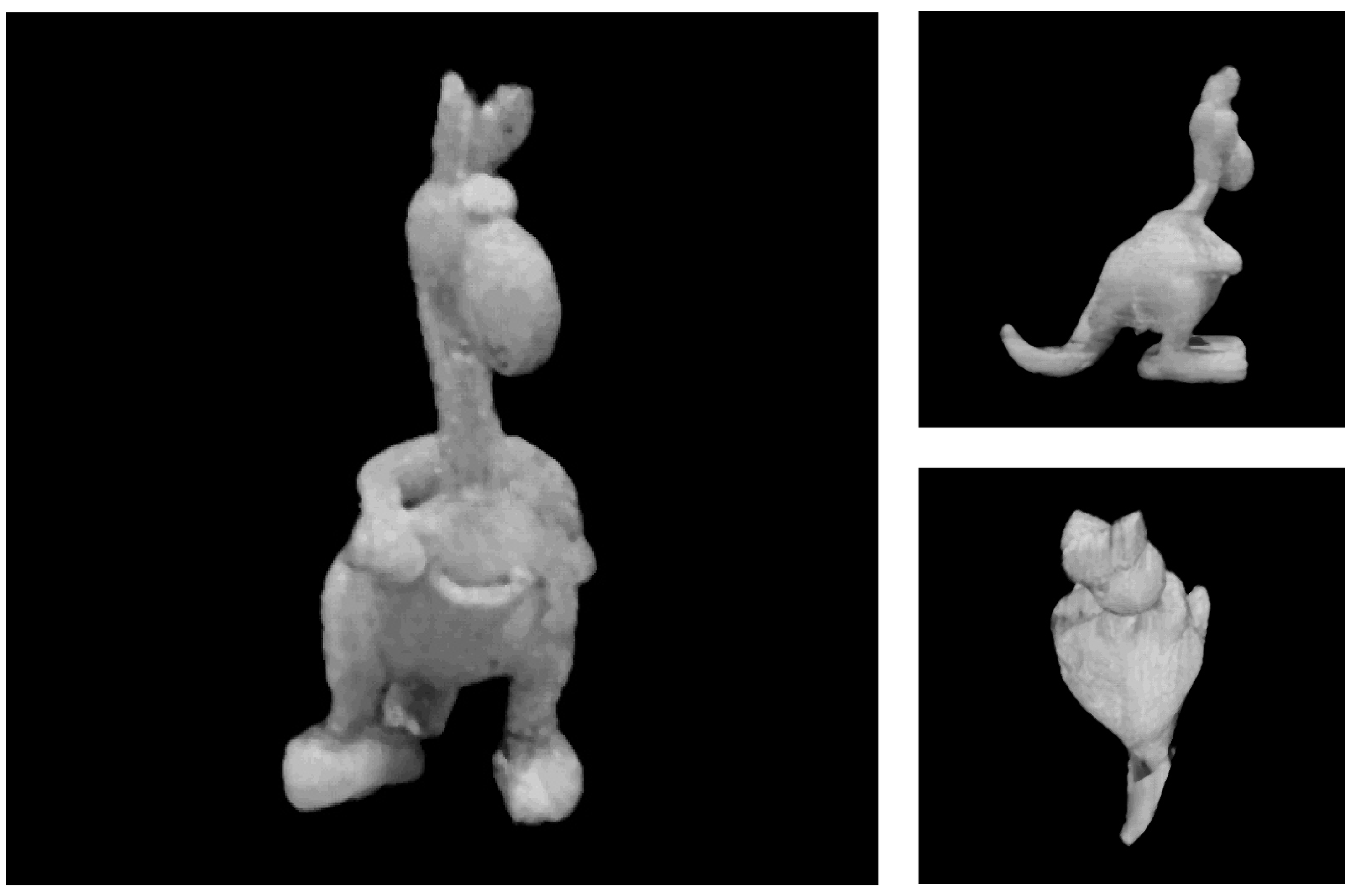

Figure 5: Voxel model of the 3-D shape reconstruction using 60 images and 256^3 voxels with texture mapping.

6. Hierarchical Processing Using Octrees

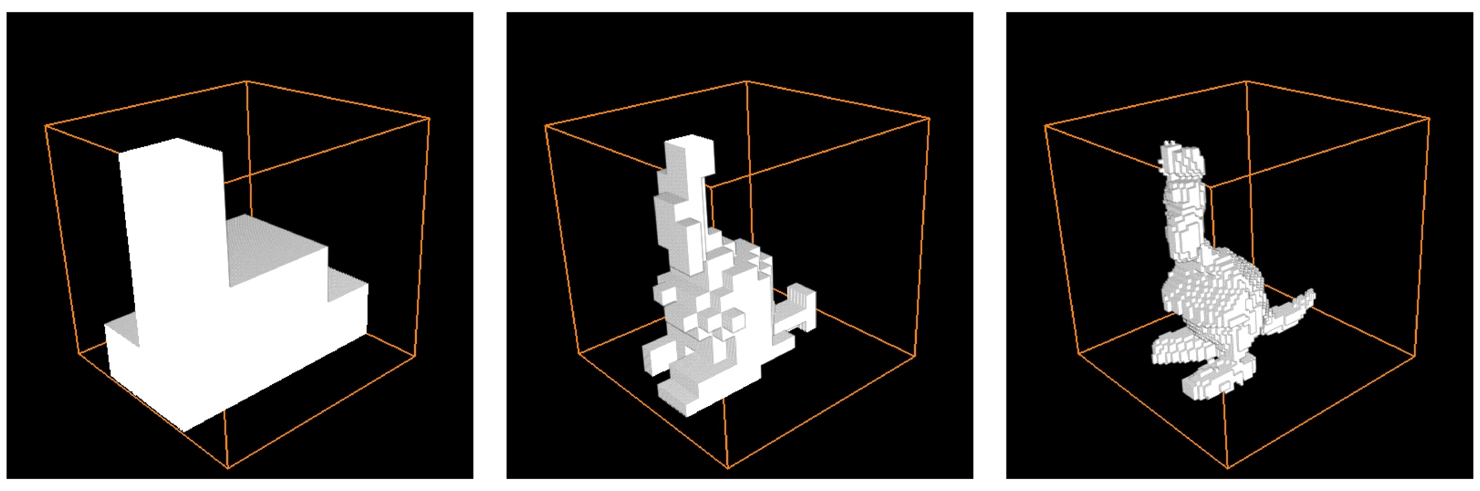

Figure 6: Iterative generation of an octree model using 4^3, 16^3, and 64^3 voxels.

Level	Intel PIII	SGI R12k
1	39:00	12:40
2	7:01	2:21
3	3:05	1:03
5	2:26	0:51
7	2:16	0:48

Computation time (in min.)

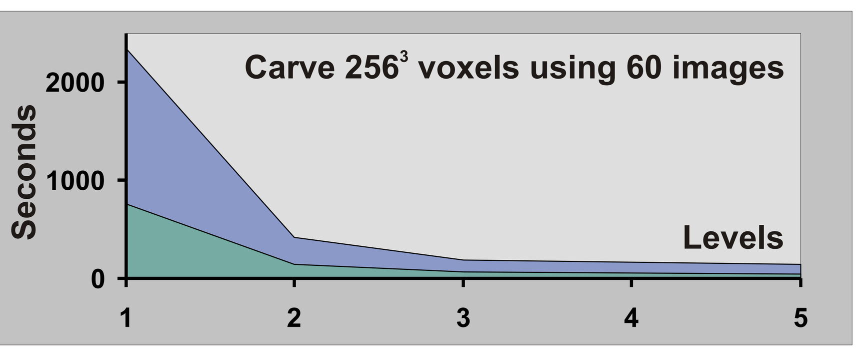

Table 1: Speed optimization using hierarchical processing.

7. Stereo Analysis Using Block-Matching

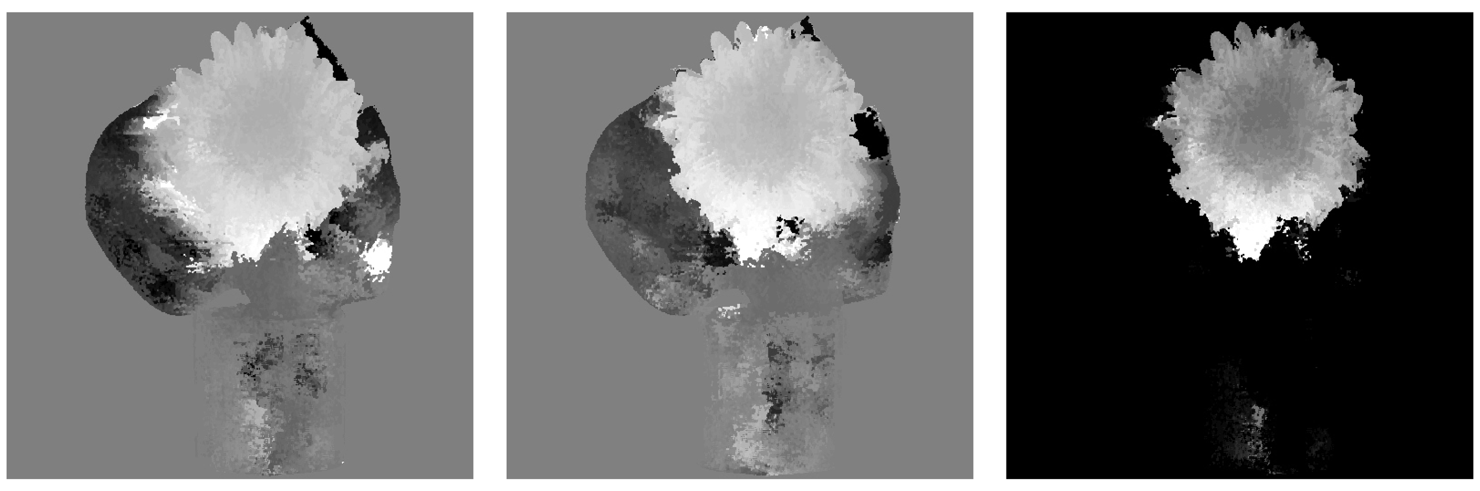

Figure 7: Computed stereo depth maps (left, middle) and the combination of three neighboured views (right).

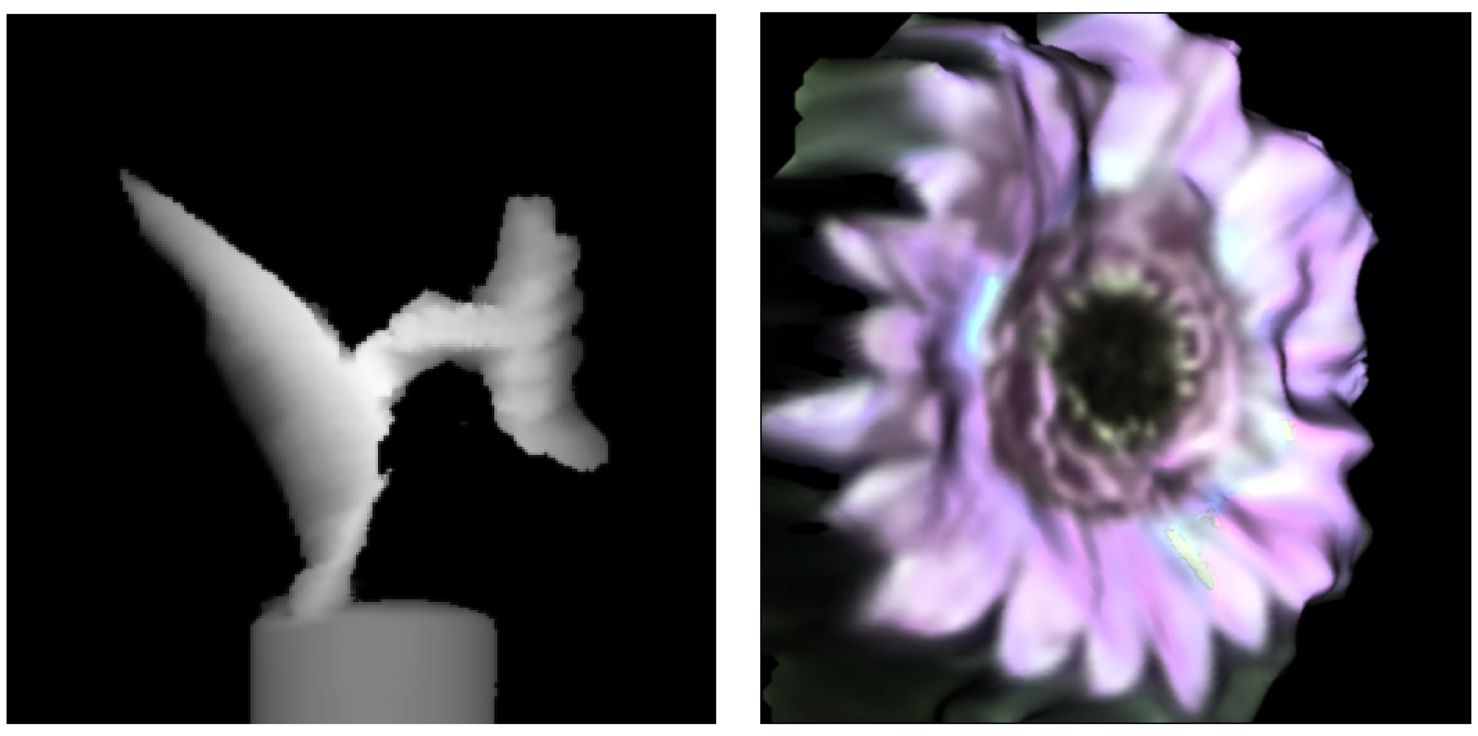

Figure 8: Voxel model of the flower (left) and the enhanced concave head using block matching (right).

8. Summary and Future Work

We presented an approach to construct 3-D models of real-world objects using silhouette data in a controlled environment. The system requirements are simple and therefore attractive for many applications.

The silhouette extraction method using histogram information in the IHS color space works robust. The hierarchical processing reduces the computation time significantly. The combination with the block matching technique to handle concavities still suffers from a lack in accuracy, but further improvements are in progress. The future work will concentrate on auto calibration, error estimation and color texture mapping.

Straße des 17. Juni 135, Sekr. EB 9, D-10623 Berlin ☎ (030) 314-24987 (030) 314-21104 Kuzu@fpk.tu-berlin.de