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Evaluation of 3D Image Reconstruction Using Silhouette Algorithm

Norliana Binti Azhar, Wira Hidayat Bin Mohd Saad, Nurulfajar Bin Abd Manap,
Norhashimah Binti Mohd Saad and A.R. Syafeeza
Faculty of Electronic and Computer Engineering,
Universiti Teknikal Malaysia Melaka, Melaka, Malaysia

Abstract: This study presents the approach of 3D image reconstruction using silhouette algorithm applied on the series of images captured surrounding the object. The camera calibration is done in order to recover the extrinsic and intrinsic parameters of camera. Both of this parameter is important for 3D reconstruction using silhouette algorithm. The silhouette-based approach is used in this study for 3D reconstruction from the sequential images captured from several different angle of the object. Visual evaluation is done on the final result of the 3D image produced on several different objects, different camera vertical position set up and different total number of sequence image captured. All factors that affect the final 3D image are evaluated in order to achieve better 3D reconstruction result.

Key words: Reconstration, parameter, angle, camera, Malaysia

INTRODUCTION

Silhouette algorithm for 3D reconstruction always faces with a major problem in producing a good final 3D image. Some of the factors that contribute to this issues are on the techniques of 2D image acquisition such as camera angle, total number of the 2D images sequence, background color and calibration technique (Hernandez *et al*., 2007). Thus, it is important to evaluate these factors to achieve a better 3D reconstruction result on silhouette-based approach.

There are various approaches for 3D image reconstruction such as projective geometry, feature points-based method and multi view geometry. These approaches use different technique of data collection for 3D reconstruction (Fredrikson, 2011). In this study, the multi view geometry method is used. This method use multiple silhouettes to reconstruct the 3D image of the real object (Fredrikson, 2011). Silhouettes are the binary classification of each image for the object and background in order to compute a bounding volume for an object itself. This algorithm enables a user to obtain the rough model of the real object.

The reconstruction of an object can be performed by using volume intersection approach where the volumetric description of an object is recovered through multiple silhouettes (Hendrik, 2003). A region of cone projection form for the volume intersection technique can be obtained by back projecting the slab of volume cube from a view point of the corresponding silhouette for perspective projections through the silhouette for each different camera view (Hendrik, 2003; Lazebnik, 2002). The first region provides an outer bound which has infinite volume for the object's geometry. Thus, the intersection of all those regions form an initial approximation of the real object's shape and can also determine the finite volume bound or also known as visual hull.

MATERIALS AND METHODS

In this study, the methodology done includes the image acquisition, camera calibration and space carving. Image acquisition is an action of retrieving images that usually from hardware-based source. The object is placed on a turntable and an adjustable camera is used to capture the image surrounding the object. During the process, the turn table is rotated while keeping the camera fixed. The image is taken with an equal angle interval in between each sequence.

Camera calibration is an important step in 3D image reconstruction in order to recover camera extrinsic and intrinsic parameters. The image of the checkerboard pattern is taken under a similar position as the object. By using camera calibration toolbox for MATLAB, four

Corresponding Author: Wira Hidayat Bin Mohd Saad, Faculty of Electronic and Computer Engineering,
Universiti Teknikal Malaysia Melaka, Melaka, Malaysia

extreme corners of the calibration grid are manually identified in each image. It is used to identify features that are visible in all images and for which the coordinates are known. The grid corners of the checkerboard images are then extracted and the tool will automatically count the number of square in the pattern. After the corner extraction, main calibration process is done to extract the intrinsic and extrinsic parameters of the camera.

Space carving is a technique to reconstruct the 3D model from multiple images. Space carving process can be summaries by the following steps: load the camera and image data, convert the image into silhouette, create a voxel array and carve the voxels using the camera images.

The camera definition which is camera calibration is loaded along with the image files for each camera position or view. The images in each camera are then converted into binary image or silhouette. In this study, thresholding technique is used to convert from RGB image into binary image. First the RGB image is converted into the HSV color space first in order to make it easy to differentiate the background and the object color. Then, the thresholding technique is used to convert the image into binary by separating it into different regions containing each pixel according to the threshold value. The information in the images is extracted based on their hue level (type of color), saturation and brightness.

Voxel represents a value on a regular grid in 3-dimensional space used to represent the 3D model of an object. The visual hull or silhouette will be projected onto the voxel array. The visual hull produced by intersecting the silhouette cones is the approximation of the real object geometry itself. Any voxels that lie outside the silhouette are carved away. The remaining voxel inside the silhouette is the result of 3D model of the real object.

RESULTS AND DISCUSSION

This study represents the results for 3D image reconstruction of each object. A visual evaluation of 3D reconstruction for different number of sequence and different camera angle is done to relate the factors that influence the result of final 3D image.

The 3d model of different object: The 3D model of object 1-3 are successfully reconstructed by using silhouette algorithm on the series of images captured surrounding those objects. Firstly, the image of the objects are captured under circular motion and converted into binary image as shown in Fig. 1a-f. Silhouette cone is projected into the object’s silhouette from the camera. Figure 2 show the projected silhouette cone and the result after carving by using one and three camera views.

Finally, the intersection of silhouette cones from all camera views will form a visual hull where it will be used as a mask to produce the 3D model of the object. Based on the result of the final 3D image, the geometrical structure of the 3D models are similar to the original object with slight deform in the structure that occur especially on

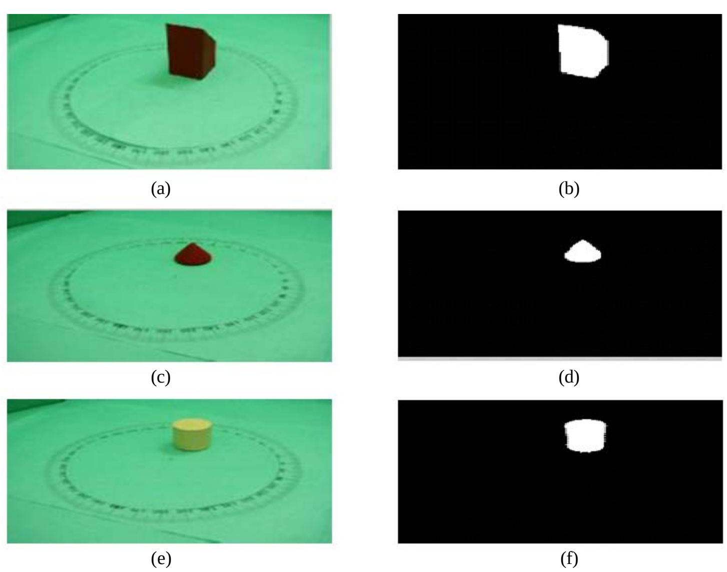

Fig. 1: The image of object 1: a, b) Object 2; c, d) Object 3 and e, f) Object 1-3 are converted from RGB to binary mode (silhouette)

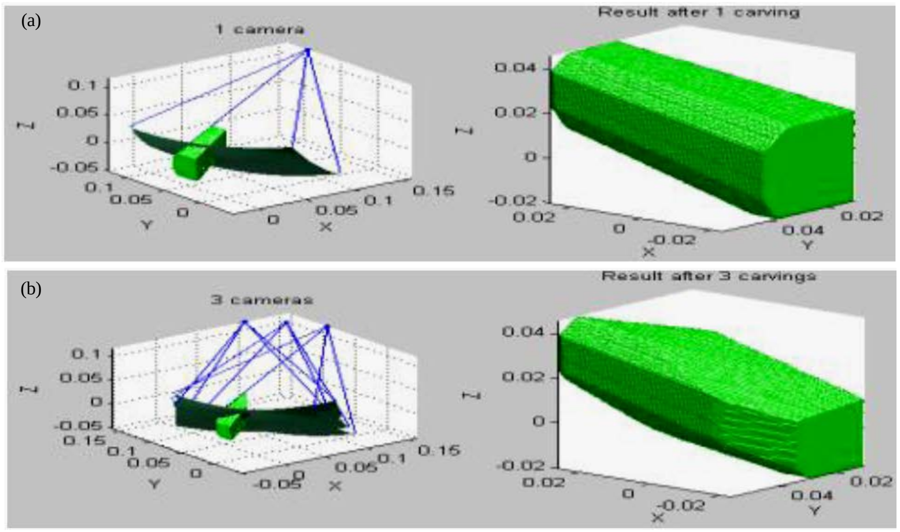

Fig. 2: The projected silhouette cone and the result after carving by using: a) One camera view and b) Three camera view

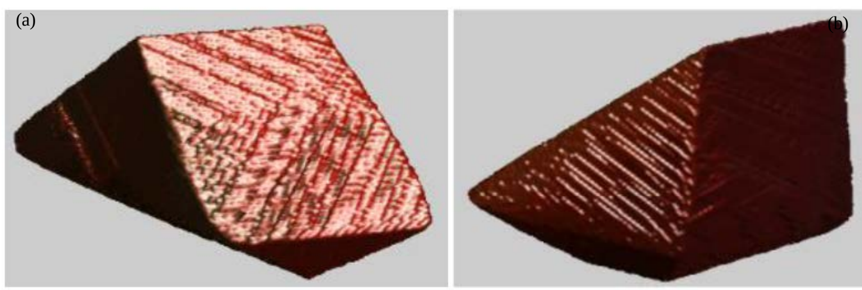

Fig. 3: Final 3D model for: a) The 36 image sequence and b) The 72 image sequence

the top and bottom of the object in the form of cone-shaped. There are many factors that contribute to this problem such as camera angle, total number of the 2D image sequence, background color and also calibration technique (Hernandez *et al*., 2007). The silhouette calculations are relatively sensitive to the errors that can end up giving problems to the intersection of the visual cones ergo result in a poor formation of the final 3D shape.

Different number of image sequence used: The models shown in Fig. 3 are the 3D model for different number of sequence which is 36 image sequence for (a) and 72 image sequence for (b). Since, the image is captured surrounding the object, the degree interval of each image captured are 5° and 10°, respectively. In term of the shape produced, there is not much different with higher or lower number of image use but the surface of the 3D model is smoother by using more sequential image to construct the 3D model. Theoretically as the number of sequence is increased, the 3D model produced is more accurate as the original object. This is due to more camera view that holds the information of the object edge for reconstruction of the 3D model.

Different camera position: In this observation, the location of the camera is placed differently. For Position 1, the camera is placed farther and higher from the center of rotation while for Position 2, the camera is placed nearer and lower to the center of rotation. From the observation on the final 3D image for different camera position, both of the positions still produce a deformation cone like shape on the top and bottom of the 3D model produced. From the result shown in Fig. 4, the size of cone-shaped form is bigger for Position 1 compare to the Position 2. This is due to the reason that, the further and higher the camera position from the object causing the silhouette cones projected through the silhouette of the object is

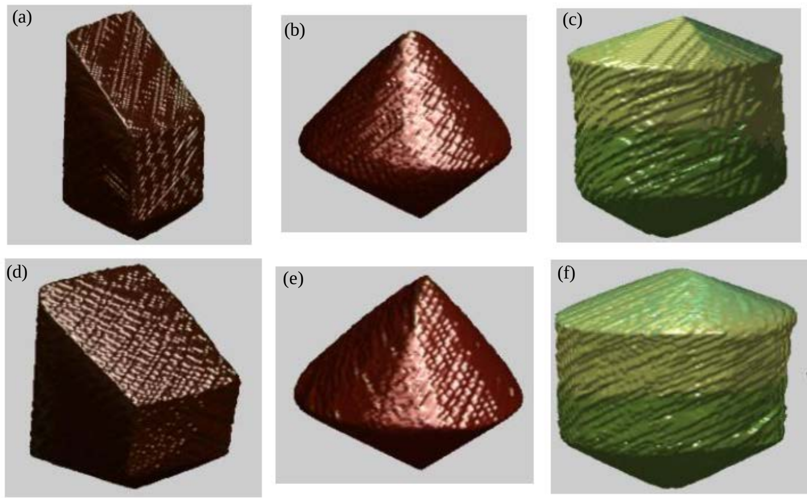

Fig. 4: 3D model for Position 1((a), (b), (c)) and Position 2 ((d), (e), (f))

higher as well. Thus, it will estimate the shape of the parts that hidden from the camera. The intersection of those silhouette cones will result in poor 3D reconstruction model.

CONCLUSION

In summary, for three-dimensional reconstruction for the series of images surrounding the object, the silhouette-based approach has been successfully tested. However, based on the visual observation, the accuracy of the 3D reconstructed model toward the original object is low. This is due to several factors such as camera angle, total number of the 2D image sequence, background color and also calibration technique. The silhouette calculations are relatively sensitive to errors that end up giving a poor intersection of the visual cones that result in a poor reconstruction of final 3D image.

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