Automatic 3D model generation from 2D X-ray images

Minh Tuan Le*, Hae-Kwang Kim**
*, ** Dept of Software Engineering, Sejong University, Seoul, 143-747, Korea
Tel : +82-02-498-2966 E-mail: tuanlm@cdit.com.vn
Tel : +82-011-381-3757 E-mail: hkkim@sejong.ac.kr
*Center for Development of Information Technology, Posts and Telecommunications Institute of Technology, Hanoi, Vietnam.

Abstract:

This paper describes an automatic 3D models generation algorithm based on 2D silhouette images, using X-ray camera without camera parameters. The algorithm takes a multi steps process approach. First, a series of 2D silhouette images is captured from different directions of object and then converted to binary images. An octree data structure is constructed for voxel-based representation of object. An estimate 3D volume of object can be reconstructed by intersecting voxels and the 2D silhouettes. The marching cube algorithm is applied to get triangle mesh representing of the obtained 3D model for rendering.

Keywords: Keywords: 3D modeling, X-ray, shape from silhouettes, visual hull.

1. INTRODUCTION

Recently, 3D computer graphics domain has become increasingly important in 3D game, virtual reality, visual inspection, CAD/CAM. It refers to the creation, storage and processing of 3D models of objects. Normally, a real object is 3D modeled by designers and this work is difficult and takes time.

A variety of algorithms have been proposed that try to overcome the problem, automatic generation 3D models of real object from different viewpoints [1], [2], [3], [4]. From object's silhouettes, an estimate volume of real object is reconstructed that called visual hull [5] (Fig. 1). The shape of reconstructed model depends on the number of input silhouettes and their position.

In the work, the real object is an old knife that is placed inside of a cover (Fig.3). Our goal acquires 3D shape information from the knife without removing the cover. We use an X-ray camera (Fig. 2) to look into the cover and capture the knife's silhouettes from different direction. Then using shape from silhouettes techniques to render the knife in 3D space. In the other work [3], before starting the image acquisition, the system must be calibrated to achieve camera parameters. Our work does not use any camera parameters. The input information for 3D reconstruction is 2D silhouette images and silhouette's position.

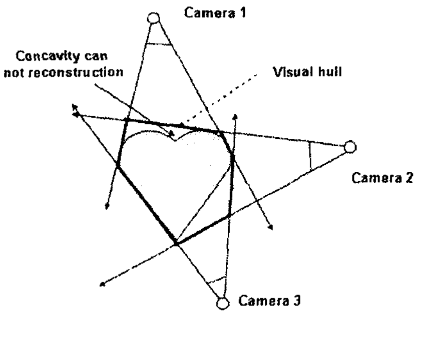

Fig. 1. Visual hull of real object

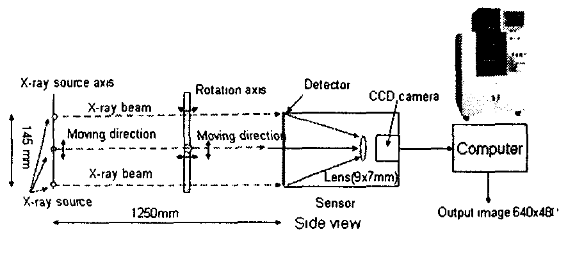

Fig. 2. X-ray system

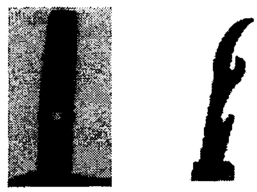

Fig. 3. A old knife is placed inside of a cover and its silhouette

The remaining sections of this paper are organized as follows. In section 2, describes the steps required to reconstruct a 3D model from 2D X-ray images. Results are showed in section 3. Finally, the conclusion is summarized in section 4.

2. AUTOMATIC 3D MODEL GENERATION

. Reconstruction 3D model of a real object from their silhouettes involves acquisition images of the object from different direction, extraction silhouettes from acquired images and volumetric intersection (Fig. 4). A triangle mesh of reconstructed model can be obtained by applying marching cube algorithm [6].

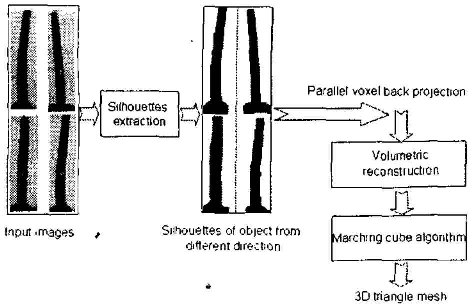

Fig. 4. Steps of 3D model generation from silhouette images

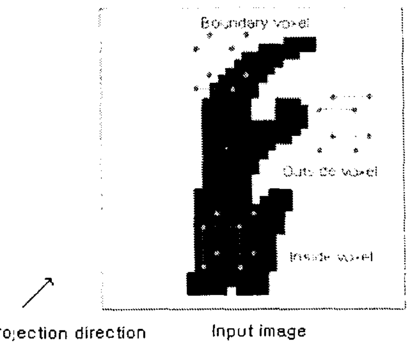

Fig.6. Outside voxel, inside voxel and boundary voxel

2.1. Acquisition X-ray system

There are several kinds of X-ray systems. The typical cases are parallel projection type and fan-beam projection type [7]. The X-ray system, shown in Fig. 2, is parallel projection type consists of a turntable rotation, a detector system with CCD camera, an X-ray source and a computer with display. The object is placed on the turntable that is between the X-ray source and the detector system. The X-ray source generates an X-ray beam that has intensity. The intensity can be controlled by the voltage. The detector system can measure attenuation of X-ray beams that depend on the material and the depth of object. X-ray source and detector system are connected to a computer so that X-ray images collected can be correlated to the position of the object.

2.2. Silhouette extraction

In the X-ray system, background brightness is uniform so only apply an adjustable threshold on X-ray images to extract silhouette of the knife (Fig. 5).

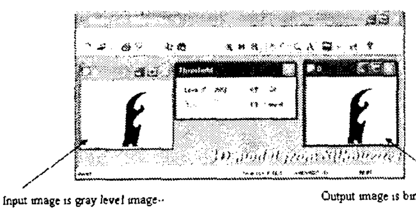

Fig. 5. Extraction object's silhouette from X-ray image

2.3. Volumetric intersection

An octree data structure is created for 3D volumetric representation of the old knife. Each voxel of octree is parallel back projected to input images. There are three kinds of voxel, boundary voxel, outside voxel and interior voxel that is classified by intersecting position between back projected voxel and the silhouette. As described in [8], a voxel is marked as boundary voxel if its shadow partly lay inside and partly lay outside the silhouette. Outside voxel and inside voxel are opposite, outside voxel has corners that belong to background and inside voxel's corners belong to silhouette (Fig.6).

The old knife can be approximated in 3D space by keeping only useful voxels and removing the others. The following example will describe how to approximate 3D volume of an object by parallel back projection voxels on object's silhouettes.

Let's assume that we have two input silhouette images. A voxel-based space that contains 3D volume of an object is created. All voxels in the space are putted in a queue. A 3D volume of object can be obtained from images by removing unneeded voxels in the queue.

- First, all voxel in the space are back projected on the first image (Fig.7) and then only outside voxels are removed from queue.

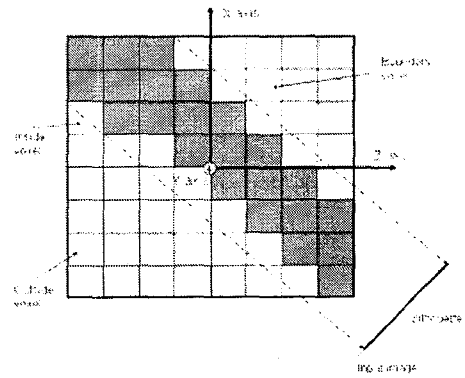

Fig. 7. Back projection voxels on silhouette image (top view)

- Second, back project the remaining voxels in the queue on the second image. Only boundary voxels are kept in the queue, it represents 3D volume of object (Fig. 8).

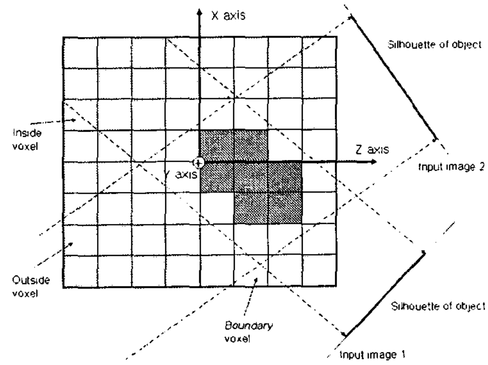

Fig. 8. Volumetric representation of object (topview)

- A smooth volume of object can be gained by dividing all boundary voxels in the queue into eight child sub-voxels. All child sub-voxels in the queue are back projected on silhouette images as the first and the second step (Fig. 9). Only boundary child sub-voxels in the queue are kept to represent a smooth volume of object.

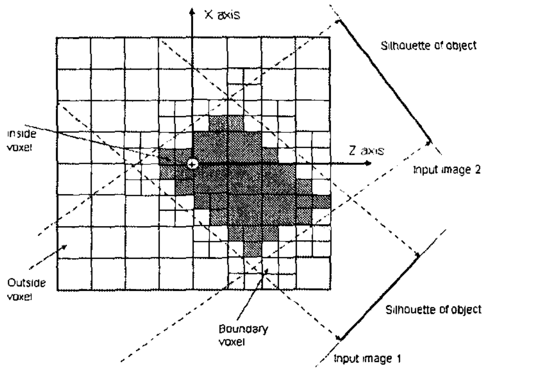

Fig. 9. A smooth volumetric representation of object (top view)

2.4. Triangle mesh representation

Triangle mesh is a collection of triangles that stitching together to form a surface of object. VRML, an ISO standard, is the most popular format for describing 3D content that save 3D model as triangle mesh. By applying the Marching cube algorithm [6], the reconstructed object is saved as VRML format.

3. RESULT

Fig. 10 shows the architecture of our implemented 3D model generation from 2D X-ray images software. Input is X-ray images that were taken from different direction and its position as angles.

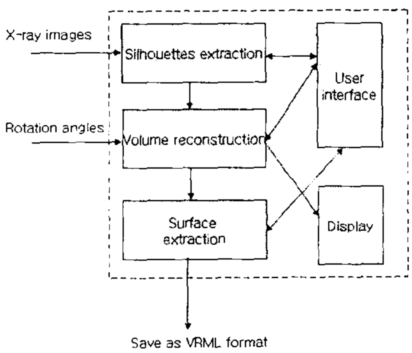

Fig. 10. Architecture of implemented software

For tests with real object we reconstructed an old knife (Fig. 3) that is captured at different angles as 0, 30, 60, 90 and 130 degrees (Fig. 11). The test was done on a Pentium 4(1.6 Ghz) machine with 128 Mb of RAM, OpenGL is used for rendering the 3D knife.

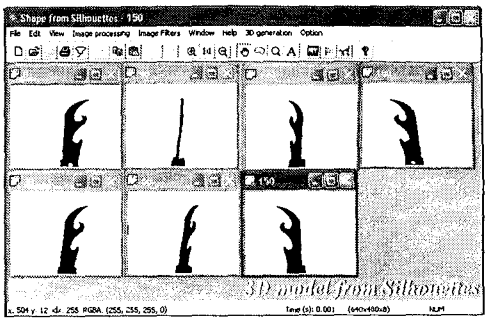

Fig. 11. The old knife's silhouettes from different direction

The top image in Fig. 12 shows 3D volumetric representation of the old knife with voxel resolution set to 5 pixels. The middle image of the reconstructed knife is obtained with voxel resolution set to 2 pixels. The bottom image of Fig. 12 shows the reconstructed knife with voxel resolution set to 1 pixel. The program takes 72 seconds, 107 seconds and 375 seconds for processing each case.

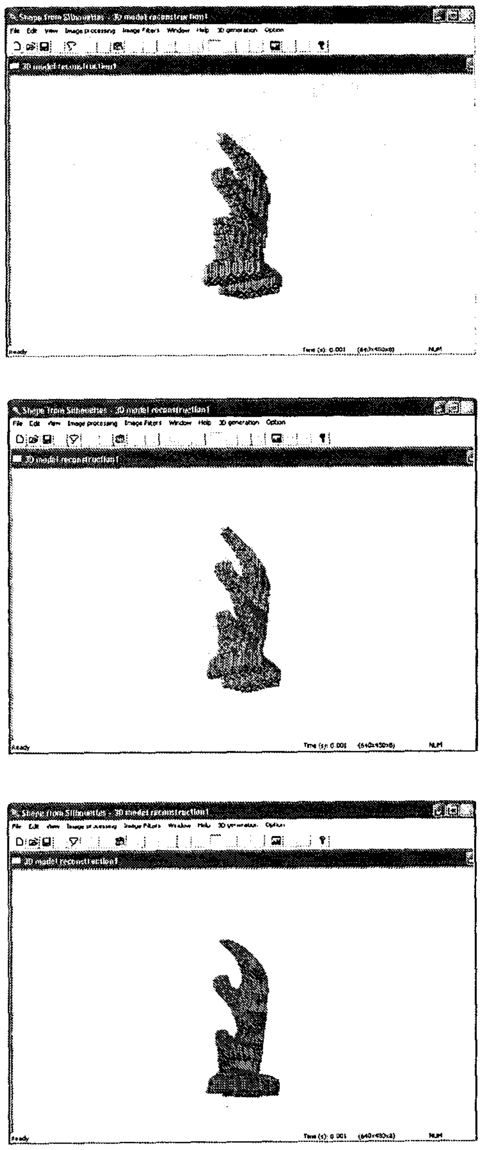

Fig. 12. 3D volume of knife with voxel resolution set to 5 pixels, 2 pixels and 1 pixel

Fig.13 shows the reconstructed old knife model in VRML format at different views point.

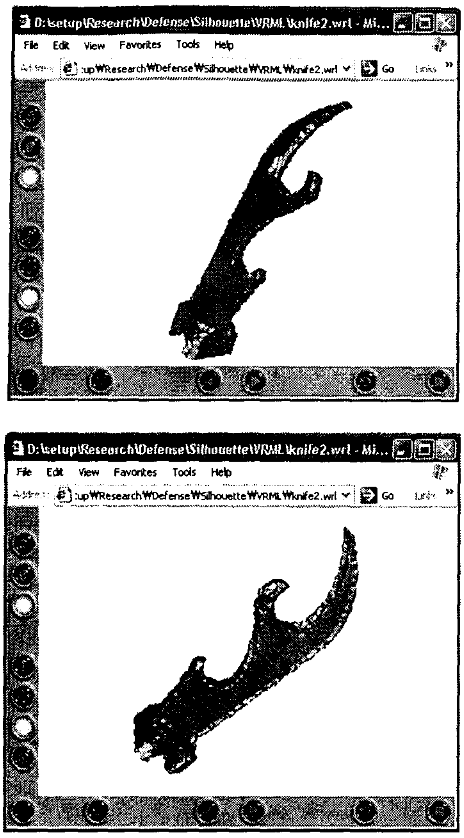

Fig. 13. 3D knife in VRML format is displayed via Internet Explorer at different viewpoints

4. CONCLUSION

In this paper, we exploit the advantages of the X-ray camera and shape from silhouettes algorithm. Thus, an old knife that is placed inside of a cover can be reconstructed. The limitation of this approach is concavities of object can not be reconstructed from input images and their position. Quality of 3D reconstructed model depends on number of input images and their position. In future work, how to select the best number and position of input images is a problem should be solving.

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