Effects of Sampling Rate and Pose Error on Volume Reconstruction by Space Carving

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Abstract. Effects of sampling rate and pose error on silhouette-based volume reconstruction are addressed in this paper. An account of importance of choosing silhouette samples (viewpoint distribution) is given. A new viewpoint distribution method is introduced and its performance is compared to a traditional method empirically. We also investigate effects of sampling rate variation and different levels of pose error on silhouette-based reconstruction quality. We observed that in presence of considerable pose error, increase of sampling rate cannot enhance reconstruction quality. We also observed that reconstruction process in higher sampling rates is more sensitive to pose error.

1 Introduction

Reconstruction of a three-dimensional (3-D) object from monocular video (frames are images of the object taken from different viewpoints), requires: (1) Estimation of the viewpoint for (or pose of the object in) each image. (2) Fusion of those images into a 3-D model. The quality of reconstruction in this paradigm depends on several factors, namely:

1. Pose error.
2. Volume quantization.
3. Image quantization.
4. Spatial sampling rate.
5. Choice of viewpoints.
6. Object concavity.

The system we proposed for 3-D information retrieval from monocular video [1], uses a pose estimator and a silhouette-based volume reconstruction method. For quality assessment of reconstructed 3-D models, in this paper we address sensitivity of this volume reconstruction method to choice of viewpoints, spatial sampling rate and pose error.

Some of the factors given above are discussed in the literature. Recent studies on sampling requirements of the Light Field Rendering [2], a method for fusion of images into a 3-D profile of the object, is given in [3] and [4]. To the
best of authors’ knowledge there is no similar work for sampling requirement of silhouette-based volume reconstruction method, although a class of studies (e.g. [5]) address the problem of camera viewpoint control for optimization of some local quality criterion.

Object concavities are a source of reconstruction error, since silhouette-based reconstruction methods are inherently able to make a model of the object up to the visual hull of the object only [6].

Our literature search for other issues of reconstruction quality assessment failed to produce any result. From the above mentioned issues of silhouette-based volume reconstruction quality analysis, we will explore effect of pose error, spatial sampling rate and viewpoint selection/distribution in this paper.

To this aim, we first introduce a new uniform viewpoint distribution scheme and demonstrate its good functionality by few experiments with different sampling rates. We then investigate variation of reconstruction quality with changes in spatial sampling rate and levels of pose error. We show that in presence of considerable pose error, sampling rate increase can result in inferior reconstruction quality. In the last section we mention a number of concluding remarks and some ways to extend this work.

2 Viewpoint Distribution

The capture phase of 3-D volume reconstruction consists of taking images of the subject from different viewpoints. In this section we introduce a new uniform distribution of viewpoints for 3-D volume reconstruction and compare it to traditional viewpoints distribution through an experiment.

Consider the object is located at the center of a large sphere. And each viewpoint is corresponding to a point on that sphere. We call this sphere the “focal sphere”. Note that for each viewpoint on focal sphere, there is another viewpoint so that the segment connecting these two viewpoints is a diameter of the focal sphere. Assuming orthographic projection, the silhouette of the object is the same from these two viewpoints, i.e. one of these viewpoints is redundant as long as silhouette-based volume reconstruction is concerned. So all of the information of object’s silhouette can be captured from viewpoints located on only half of the focal sphere, which we call “focal hemisphere”.

In previous works ([7] and [8]), the object is placed on a turn table. While the table is turning, images are taken by a stationary camera. Changes in camera elevation result in viewpoint distribution depicted in Fig. 1 (left). Note that this sampling scheme is denser near the pole of the focal hemisphere, so it is not uniform.

To distribute the viewpoints evenly, one should have the same density of viewpoints on different spots of the focal hemisphere. To this aim, we first flattened a differential surface element of the focal hemisphere. Viewpoints are taken as nodes of a grid projected onto the flattened hemisphere. In other words, the angular distance of neighboring viewpoints should be scaled by 1/ cos x; x denotes the latitude on which the viewpoints are placed. Thus less number of viewpoints