



3D MODEL RECONSTRUCTION FROM MULTIPLE VIEWS USING OPEN SOURCE TOOLS

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Abstract-

The development of 3D model reconstruction has grown rapidly for applications such as computer vision, object recognition, pose estimation, reverse engineering, 3D printing, augmented reality and virtual reality etc. This work presents a novel technique for 3D model reconstruction from multiple views by combining the ideas from structuring and modeling. Our approach to 3D model reconstruction consists of three major phases viz object image acquisition, 3D object point cloud generation and mesh model creation from point cloud. It is demonstrated that by integrating the functionalities from open source tools like VisualSFM and MeshLab, it is possible to reconstruct 3D model of an object very effectively and efficiently.

Keywords: 3D Reconstruction, Point cloud, Mesh model, Multiple Views, Open Source Tools.

INTRODUCTION

The development of 3D model reconstruction has grown rapidly for applications such as computer vision, computer graphics, object recognition, object pose estimation, reverse engineering, augmented reality and virtual reality etc. This work presents a novel technique for 3D model reconstruction from multiple views by combining the ideas from structuring and modeling. Our approach to 3D model reconstruction consists of three major phases viz object image acquisition, point cloud generation and 3D object mesh model creation from point cloud.

Object images can be acquired through imaging sensors, cameras and scanners to obtain 3D model of the acquired object. Either multiple views from same camera or stereo images from multiple cameras can be used to generate 3D models. In case of multiple-views-single-camera applications, to obtain multiple views of the same object, either the camera is rotated keeping the object stationary or the object is rotated keeping the camera stationary. The images so acquired are next transformed into point clouds.

VisualSFM is an open source application for 3D reconstruction using structure from motion (SFM). It exploits multicore parallelism for feature detection, feature matching, and bundle adjustment. It can be used to generate point clouds from acquired images.

Point clouds are used to create 3D meshes used in 3D modeling for various domains including medical imaging, architecture, 3D printing, computer-aided manufacturing, 3D gaming and virtual reality applications. A point cloud is a collection of data points defined by a given coordinates system. In a 3D coordinates system, a point cloud may define the shape of some real or created physical system. In addition, point clouds have applications in robot navigation and perception, depth estimation, stereo vision and visual registration.

MeshLab is an open source, portable, and extensible system for the processing and editing of unconstructed 3D triangular meshes. It takes point clouds as input to create 3D meshes.

This work presents a novel technique for 3D model reconstruction using single-camera-multiple-views method for image acquisition followed by point cloud generation and mesh model creation, thus reconstructing a 3D model. It is demonstrated that by integrating the functionalities from open source tools like VisualSFM and MeshLab, it is possible to reconstruct 3D model of an object very inexpensively, effectively and efficiently.

RELATED WORK

The reconstruction of 3D model from different perspectives by the arrangement of 2D images is an important issue being considered for quite a long time in the region of object identification, object pose estimation and computer vision. Several researchers have attempted to address the issue with possible solutions. Some of the major issues related to 3D model reconstruction from multiple views can be summarized as follows. (i) the number of views in the acquired input 2D images; (ii) the complexity of the acquired scenes (iii) the representation of the 3D output model [1].

Active research has been conducted related to 3D image reconstruction from multiple views. Nevertheless, all the outcomes acquired still have chances of improvement and also be used to any other suitable applications. Some salient parts of the research literature are briefed here.

Motomura et al. [2] have investigated for probability and possibility to create tomographic 3D imaging using single and multiple camera units set up are tested. The strength is highlighted where γ -ray source distribution is able to obtain in multiple directions of projection just by using a fixed-angle imaging with only a single Compton camera unit [2].

Mai and Hung [3] have described reconstruction of 3D curves by exploitation of point along curves method. Multiple 2D images are taken by few uncalibrated cameras because the reconstruction does not require any 2D or 3D parameter and also additional information of point features. Further, it is able to handle images with occluded and/or partially visible curves and can reconstruct both planar and non-planar type of curves [3].

Lee et al. [4] devised a system based on scene geometry by structure from motion (SfM) method to reconstruct 3D model. A single uncalibrated camera was used to capture multiple 2D images of model object for data acquisition. Iterative closest point algorithm helps register two target postures of the model object captured by patch-based multiple views stereopsis in order to acquire information on dense 3D point clouds [4].

Radwan et al. [5] proposed an automatic approach to reconstruct 3D poses from a single 2D image. The algorithm is based on imposing both orientation and kinematic constraints in order to reduce ambiguity on motion and shading which is evaluated on different scenario of human poses and available datasets from public [5].

With the development of Open Source application packages there has begun a new trend to perform multi-view alignment and dense 3D point cloud calculation at the client side. This paper proposes a simple camera positioning architecture with the utilization of open source software to make a 3D digital model inexpensive, effective and efficient. The only problem is that of the computational speed, which depends on the selection of the clients' computer.

3D MODEL RECONSTRUCTION

There are few important steps that are followed for 3D reconstruction from multiple views of images, in which a sequence of images is shot on the target object in different orientations or projections. It is normal to set specific angle for each orientation. Then, suitable and matching algorithms designated for chosen approach are applied on the acquired 2D images to extract, match up, and estimate correspondence feature points. The feature points compose a 3D point cloud that contains information on 3D geometries and spatial location. The area of the surface and detail appearance remains unknown but only shows approximate shape of the object. This issue is resolved by creating 3D meshes, which are composed of connecting triangles from 3D point clouds. The triangulation procedure is used to construct surface in 3D space [6-8].

Our approach to 3D model reconstruction consists of three major phases that can be summarized as follows (Figure 1).

- i. 2D Image Acquisition
- ii. 3D Point Cloud Generation
- iii. 3D Mesh Model Creation

The novelty of design approach lies in carrying out the steps for aforementioned phases for the construction of 3D model. It is demonstrated that by integrating the functionalities from open source tools like VisualSfM and MeshLab, it is possible to reconstruct 3D model of an object very effectively, efficiently and inexpensively.

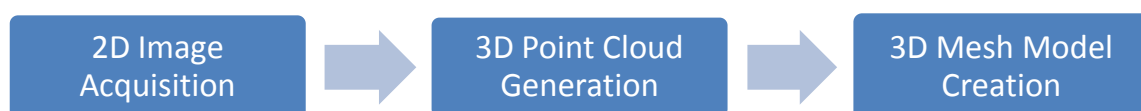


Figure 1. 3D Model Reconstruction Process

2D Image Acquisition: The images of the object of interest are acquired through single camera. Neither any camera calibration is required nor the camera should have any specific resolution. Commonly available camera or even the cell phone based imaging camera can be utilized. Further, the object is kept stationary and camera positions are changed to acquire multiple views. Total number of captured images of the object may range from 50 to 100 covering almost all the views from six sides. Multiple view images so acquired are stored in color image format.

3D Point Cloud Generation: The multiple views of the object are input to this phase. This phase is mainly responsible for creating Structure from Motion (SfM). SfM is a photogrammetric range imaging technique for estimating three-dimensional structures from two-dimensional image sequences that may be coupled with local motion signals. VisualSfM is employed for point-cloud reconstruction from multiple view images. The output of this phase is a 3D point cloud generated from the 2D images [9].

The SfM pipeline allows the reconstruction of three-dimensional structures starting from a series of images acquired from different observation points. The complete flow of incremental SfM pipeline operations is shown in Figure 2.

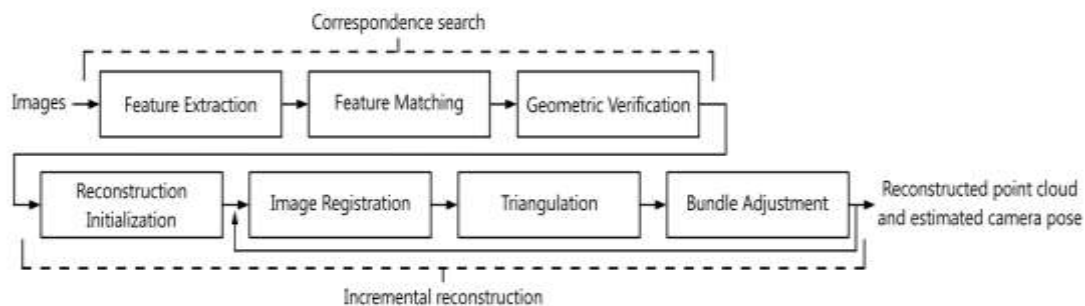


Figure 2. Incremental Structure from Motion pipeline.

In particular, incremental SfM is a sequential pipeline that consists of a first phase of correspondences search between images and a second phase of iterative incremental reconstruction. The correspondence search phase is composed of three sequential steps: Feature Extraction, Feature Matching and Geometric Verification. This phase takes as input the image set and generates as output the so called View Graph that represents relations between geometrically verified images. The iterative reconstruction phase is composed of an initialization step followed by three reconstruction steps: Image Registration, Triangulation and Bundle Adjustment. Using the scene graph, it generates an estimation of the camera pose for each image and a 3D reconstruction as a sparse point cloud.

Mesh Model Creation from Point Cloud: This phase filters the point-cloud 3D object into a clear noise free mesh model [10]. MeshLab is an open source, portable, and extensible system for the processing and editing of unconstructed 3D triangular meshes. It takes point clouds as input to create 3D meshes. The MeshLab is utilized for conversion of 3D noisy point cloud to cleaner 3D model of the object.

RESULTS AND DISCUSSION

Experimental Setup:

High Resolution Camera is used for image acquisition.

Core i5 processor with 2.5-3.1 GHz of clock frequency is used for processing and storing the multiple view images.

VisualSfM is employed for point-cloud reconstruction from multiple view images.

MeshLab is utilized for conversion of point cloud to cleaner 3D model of the object.

The entire process only takes around ten to fifteen minutes, starting from image acquisition to the 3D model reconstruction output and analysis. The device used for the reconstruction process is a laptop with Windows 10 operating system, 2.5-3.1 GHz Intel Core i5 processor including memory of 4GB RAM.

Figure 1 shows the images of the real models. The results of 3D point clouds and 3D meshes are shown in Figure 2 and Figure 3 respectively. The 3D meshes are constructed by computing the triangulation together with 3D point cloud algorithm inbuilt with MeshLab. From the images shown it can be clearly seen that the reconstruction of the 3D models is done successfully.

The advantage of this proposed study is that it can be done with simple experimental setup, as the devices used are usually owned by most people and easily can be found. It does not require any sophisticated mechanical scanning system, which may be hard to handle and is slow. The time consumption to reconstruct 3D surface from the 2D images acquired is less than five minutes

since the images taken are from an uncalibrated camera and thus there are no complicated problems otherwise arising out from the camera parameters.

Dense reconstruction of 3D Point cloud from 2D Images:

If a 3D model of the object is not available, it needs to be created by taking multiple views photographs of the object. The photographs are taken from various angles, without changing the position of object so as to achieve proper reconstruction. Figure 3 depicts an example dataset we used for reconstructing the 3D model.



Around 50-200 images could be used to create 3D point-cloud with good reconstruction; in our case we used 52 images.

Figure 3. Bottle Dataset used for exemplary reconstruction

VisualSFM is used for the reconstruction of 3D model from 2D images supplied as a point-cloud data (Figure 4). The feature matching as well as the dense reconstruction is obtained in 1570 seconds.



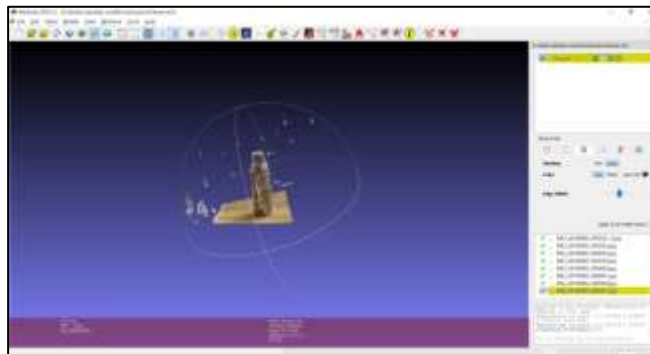
Figure 4. Point-cloud reconstruction from bottle dataset

Mesh and 3D object Construction from Point cloud data:

In MeshLab, the following steps are followed to generate the 3D Object [10-11]:

- The point cloud data is sub-sampled using Poisson Disk Sampling.
- The normals are constructed by computing the normals point set.
- For surface reconstruction, Cube Marching technique is used.
- The mesh is converted into 3D object with Per-Triangle filter.
- Vertex color to texture conversion is done.

The total reconstruction took less than 180 seconds in our case. The last step, vertex color to texture conversion is done (Figure 5) which may be utilized further in another open source tool like OpenCV for the



pose estimation of the object..

Figure 5. Mesh converted from point-cloud

It has been observed that processing time required by VisualSFM and MeshLab using a Core i5 processor with 2.5-3.1 GHz clock frequency comes out to be approximately five minutes. Thus, it is possible to extend the proposed technique to real time applications. Hence, another area of application for the proposed technique could be in the field of real time surveillance.

CONCLUSION

This work has presented a novel technique for 3D image reconstruction by combining the ideas from structuring, modeling and computer vision. It is demonstrated that by integrating the functionalities from open source tools like VisualSFM and MeshLab, it is possible to reconstruct 3D model of an object very inexpensively, effectively and efficiently.

From the experimental results, it is found that the 3D object can be reconstructed simply by using the 2D models and available open source tools. It is also observed that the proposed technique requires less computational power as well as it can be implemented in real time.

Another novelty of the proposed technique is that it is scalable to any number of objects. The 3D image reconstruction or the 2D image acquisition does not require any camera calibration. A corollary to this feature is that the 2D image acquisition using same single camera with multiple angle views is object independent, thereby maintaining the confidentiality required in any surveillance application.

Because of the facts that the 2D image acquisition, 3D point cloud generation and the 3D image reconstruction are object-independent requiring no camera calibration, the technique is scalable. The future scope of the work includes seamless extension of the technique to the real time pose estimation of objects by utilizing the open source tools like OpenCV. Hence, another area of application for the proposed technique could be in the field of real time surveillance.

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