A FLEXIBLE AND AUTOMATIC 3D RECONSTRUCTION METHOD

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ABSTRACT:

This paper proposes a flexible and automatic technique of 3D modeling from images captured by a handheld camera. The camera used here is a metric digital camera. This method is well suited for use without specialized knowledge of 3D geometry or computer vision. The technique only requires the camera to take photos around the object to be measured. The camera can be freely moved. But, the distance of neighboring image station should not be too far. Then the taken photos are processed and the procedure consists of relative orientation and connection of consecutive photos and a rigid bundle adjustment, followed by a robust image matching technique and TIN generation and texture mapping. At this time 3D model is produced. Several sets of real data have been used to test the proposed technique, and very good results have been obtained. Compared with classical techniques which use some special equipment or have some special requirement, the proposed technique is easy to use and flexible, even can be automatic. It advances 3D computer vision one step from laboratory environments to real world use.

1 INTRODUCTION

Obtaining three dimensional (3D) models of scenes from images has been a long lasting research topic in photogrammetry and computer vision. Many applications exist which require these models. In traditionally robotics and inspection applications accuracy was often the main concern. Nowadays however more and more interest comes from the multimedia and computer graphics communities. The evolution of computers is such that today even personal computers can display complex 3D models. Many computer games are located in large 3D worlds. The use of 3D models and environments on the Internet is becoming common practice. This evolution is however slowed down due to the difficulties of generating such 3D models. Although it is easy to generate simple 3D models, complex scenes are requiring a lot of effort. For existing objects or scenes, the effort required to recreate realistic 3D models is often prohibitive and the results are often disappointing.

A growing demand exists for systems which can visualize existing objects or scenes. In this case the requirements are very different from the requirements encountered in previous applications. Most important is the visual quality of the 3D models. In addition, there is an important demand for easy acquisition procedures.

As described above, 3D reconstruction has been a long lasting research topic and its wide application attracted research interest of many researchers and scholars. And many different methods have been developed and used in reconstruction of ancient buildings, preservation of historical relics, medicine reconstruction, industry measurement, human face reconstruction, etc. All these technologies have their own advantages, but requirement of expensive hardware or special environment and control field and profound knowledge of photogrammety and complex operation process limit their wide use. For example, Fabio acquired human body image sequences for reconstruction by using camera and special control field; F. Paul Siebert reconstruct human body and human face by using single baseline stereo and obtained good results, but his method should confine to special shooting environment; Nicola obtained high-accuracy human face model by using special control field; Yongjun Zhang and Ulas Yilmaz measured machine parts and reconstruct common objects' face using rotatory platform and made good results; Carlo carried out experiments on the surface reconstruction of building using expensive laser scanning device and obtained accurate point cloud, but lacks of texture information and other information. There are many other experiments like these, in some of which good results have been made, but simplification, automation and being practical are still urgent problems which need to solve before wide application.

In this paper we present a new 3D technology in which a robust image matching method has been used. Our goal is to automatically reconstruct 3D model of object with image sequence taken by hand-held camera. In this process, only image acquisition process is done by people and all other process is executed by computer automatically until 3D model is produced. The technology applies to surface reconstruction of many objects, no matter large or small, outdoor or indoor. It is simple, fast and automatic. Its detail process is described in following sections.

2 IMAGE ACQUISITION AND CALIBRATION

2.1 Image acquisition

The first step of this 3D reconstruction process is image acquisition. There is no special demand when taking photos and you can do it as you do when you want to get a scene picture. But in order to reduce the difficulty of automatic image matching, the distance between neighbouring image station, that is the baseline, should not be too long. If the baseline is short, the image data amount will be large, but this is not a serious problem because post-processing is done by computers. As shown in Fig. 1, in the measurement process of a coal pile, 83 photos were taken and the distance between neighbouring image station was only about 1-2 meters.

2.2 Calculating of parameters of photos

In this paper, our goal is to visualize existing objects or scenes, not to measure its actual size. So we only need to retrieve objects' shape which has same shape but possible not same size as origin object. Therefore, no any control point is needed and a free network model has been use. In addition, a metric camera is used in this method and its interior parameters are known. And the whole process of obtaining photos' exterior parameter is the same as traditional aerial photogrammetry, including the automatic obtaining of orientation points and tie points (link point), relative orientation in succession, model link, construction of free flight strip and free network adjustment with bundle method. Because we take photos with short baseline, orientation points and tie points can be obtained from automatic matching, and detailed algorithms and formula of model connection and strip construction can be seen in photogrammetry manual. After the process above, photo parameters are obtained in self-define coordinate system. Fig. 1 is the sketch map for all image stations automatically drawn with photo parameters by program after adjusting. The photos just form a circle.

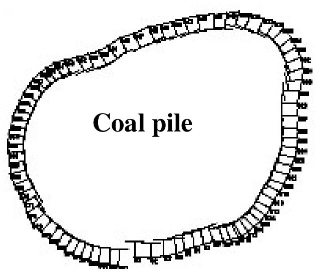

Fig. 1 Orientation of Coal Pile Photos

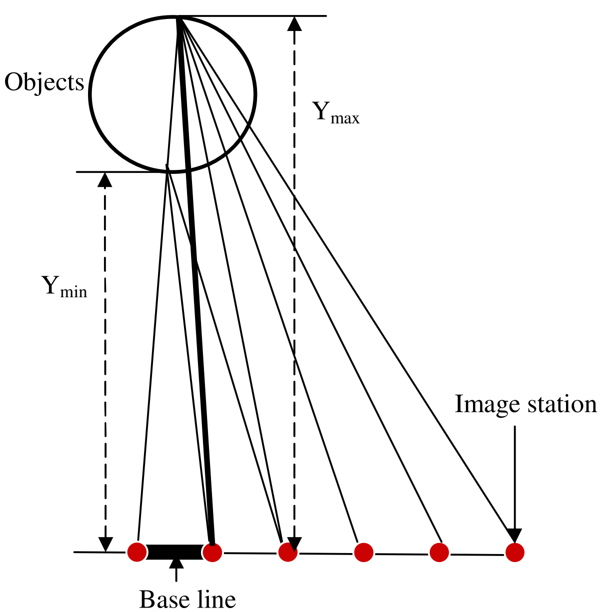

Fig. 2 Images used for matching

3 MULTI-BASELINE STEREO MATCHING AND SURFACE RECONSTRUCTION

3.1 Multi-stereo matching

Image matching is a basic and crucial process for automatic 3D reconstruction. But to get reliable and robust matching results is still very difficult because of following problems existing in images: (1) Radiometric problems: resolution, reflectance, illumination, lab processing noise, digital camera noise; (2) Geometric problems: relief displacement and occluded areas, projective deformation, scale variation; (3) Textural problems: featureless surface, repetitive texture, ambiguous levels such as tree top and ground below them, thin objects.

In this paper, an image matching method based short-baseline and multi-photo has been developed, as shown in Fig. 2. Obviously, the geometry distortion of the objects in images with short-baseline is little. But it is known that the intersection accuracy is low when the baseline is short. So we use multi-photo intersection to maintain the accuracy as shown in Fig. 2.

Because geometry distortion in close-range photography is relatively large, traditional single-stereo matching which uses only two images is very difficult to meet the demand of matching in reliability and accuracy. The multi-stereo matching method which uses multi images and combines with short baseline and multi-photo perfectly solves the image matching and intersection accuracy problem at same time. This method has following characters: on one hand because the baseline between the neighboring photos is relatively short, the geometry distortion of images is relatively little, thus help automatic matching; on the other hand, because baseline is short and multi photos are used, overlap between the neighboring photos is normally very large, we can obtain the corresponding points with multi overlap by matching transit using corresponding points in neighbouring photos. The corresponding points pass constantly through neighboring photos until they can not match, thus each 3D point have multi corresponding 2D image points as shown in Fig. 2. In Fig. 2, it also can be seen that the further the object to be measured, the small the intersection angle, so at this time we use more images to intersect when calculating the 3D space coordinates. The farther the object, the more images are used. Obviously, there are lots of redundant measurement for each group of corresponding points, if obtaining the weights of measurement by iteration method with variable weights and calculating using bundle adjusting, the reliability and accuracy of the coordinates of the model points will improve significantly.

3.2 Surface reconstruction

After image matching, 3D points can be calculated with image matching results and image parameters. Then these 3D points are used to construct triangular network, DEM and contour, then sometimes make epipolar image and orthophoto, finally produce 3D landscape map. Here some questions need us pay more attention when making orthophoto. Because the DEM involves a series of photos, we must correctly choose and resample the appropriate photos to make sure that the orthophoto keep unanimous on color tone.

4 RESULT OF THE EXPERIMENTS

We carried out many experiments to test our 3D reconstruction algorithm. Some test results are shown in Fig. 3. In Fig. 3, (a) is a photo of a plaster statue and (b) (c) are its 3D reconstruction results; (d) a sculpture, (e)(f) its 3D reconstruction results; () a photo of a relief and its 3D reconstruction results in (h); (i) a photo of a coal pile and its 3D reconstruction results in (j) . The plaster statue is relatively small, we took 5 photos; the sculpture is 3 meters wide, 5 meters high, we took 6 photos; the relief is 12 meters wide, 6 meters high, we took 12 photos; the diameter of the coal pile is about 20 meters and the height is about 4 meters, and the shape is very irregular, so we took 83 photos which just form a circle. All photos are taken by hand-held camera and then input into computer and processed by our software and 3D results are produced as shown in Fig. 3. Except taking photos, all other processes are automatically executed by computer. Results show reliability and robustness of our image matching algorithm and convenience and efficiency and automation level of our 3D reconstruction algorithm.

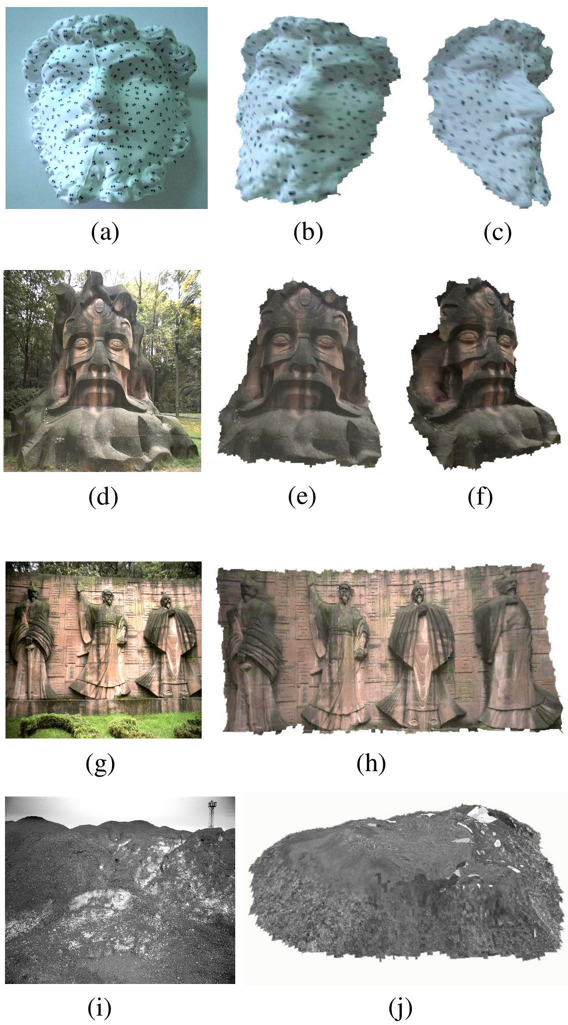

Fig. 3 Images and 3D Models of Reconstruction

5 CONCLUSIONS

This paper proposed a new image matching method which uses short baseline to maintain reliability of matching and uses multi images to maintain intersection accuracy. Based this matching technique, a 3D reconstruction system has been developed which has characteristics of being easy using, fast and automatic and can be widely used in 3D reconstruction of objects. Here a metric camera is used. When using ordinary camera, camera calibration process is essential or self-calibration algorithms should be integrated into current calculation process. All these are our major research subjects.

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