3D Modeling of Wide Area Outdoor Environments by Integrating Omnidirectional Range and Color Images

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Abstract

This paper describes a method for modeling wide area outdoor environments by integrating omnidirectional range and color images. The proposed method effectively reconstructs the 3D models of outdoor environments by using omnidirectional laser rangefinder and omnidirectional multi-camera system (OMS). In this paper, we also give experimental results of 3D wide area reconstruction using the data acquired at 50 points in our campus.

1. Introduction

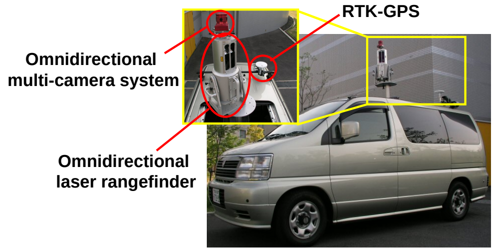
3D models of outdoor environments can be used in a number of applications such as navigation and virtual walkthrough. However, such 3D models are often made manually with high costs, so recently automatic 3D modeling has been widely investigated; for example measuring outdoor environments by a laser rangefinder [1] and 3D shape estimation from an image sequence [2]. This paper proposes a 3D reconstruction method for wide area outdoor environments. By using an omnidirectional laser rangefinder and an omnidirectional multi-camera system (OMS) which can capture a wide-angle high-resolution image, the 3D outdoor environment model is effectively generated.

2. 3D Modeling of Outdoor Environments

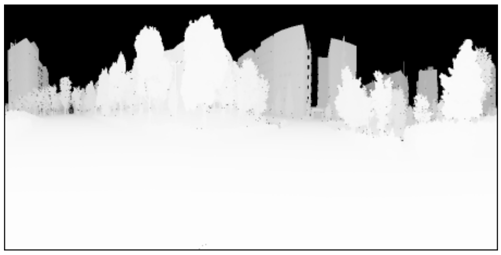
2.1. Data Acquisition

Fig. 1(a) illustrates the sensor system mounted on a vehicle. The system equips an omnidirectional laser rangefinder (Riegl, LMS-Z360), an OMS (Point Grey Research, Ladybug), and an RTK-GPS. Geometrical relationships among these sensor coordinate systems are fixed, therefore the alignment between sensor coordinate systems are required only once.

Fig. 1(b) shows an acquired omnidirectional range image in which the distance from the rangefinder is coded in intensity. Note that the maximum measurable range of rangefinder is about 200m and its measurement accuracy is within 12mm. The OMS consists of six cameras in order to acquire high-resolution omnidirectional color images and is calibrated geometrically and photometrically in advance[3]. The RTK-GPS is used to measure the position of the sensor system and its measurement accuracy is about 3cm.



(a) The sensor system



(b) An omnidirectional range image

(c) An omnidirectional color image

Fig.1 Sensors and acquired data.

2.2. Registration of Range Images

The position of the range data is acquired by the RTK-GPS. The orientation of the range data is calculated by applying the Iterative Closest Point (ICP) algorithm [4] to range data. In the conventional ICP algorithm, the distance between points in paired range data is defined as an error, and the rotation matrix is calculated so that the errors converge. The present rangefinder measures the distance by rotating the laser scan, thus the spatial density of data points depends on the distance; that is, close objects are measured densely and far objects are measured sparsely. This causes a problem in registering range data obtained at different positions. In order to overcome this problem, we define an error by computing the distance between a point in one data set and a plane determined by adjacent points in the other data set. Whole model is generated by sequentially registering a pair of range data whose acquired positions adjoin each other.

2.3. Integrating Range and Color Images

The 3D shape obtained in the previous section is texture-mapped by omnidirectional color images. The position and orientation of OMS are also simultaneously estimated by registering range images because geometrical relationship between the rangefinder and the OMS is fixed and aligned.

Each triangular patch on the 3D shape is colored by the texture from the image which gives the highest resolution. However, this strategy fails when an occlusion occurs. The occlusion is detected when the whole 3D shape intersects with a triangular pyramid determined by triangular patch vertexes and the projection center of camera. In such a case, the second highest resolution image is selected.

3. Experiments

We have carried out experiments of reconstructing our campus. In experiments, the range and color images are acquired at 50 points in our campus (about 200m x 300m). The resolution of each range image is 904 x 450. The transformation matrix between rangefinder and OMS coordinates is estimated by pairing corresponding points in a range and a color image manually. The antenna of the RTK-GPS is installed in a site measurable from the rangefinder.

The number of polygons of the generated 3D model is 2,930,462. Fig. 2 illustrates a 2D CAD data of our campus with the generated model data. We confirm that the generated model has no large distortion.

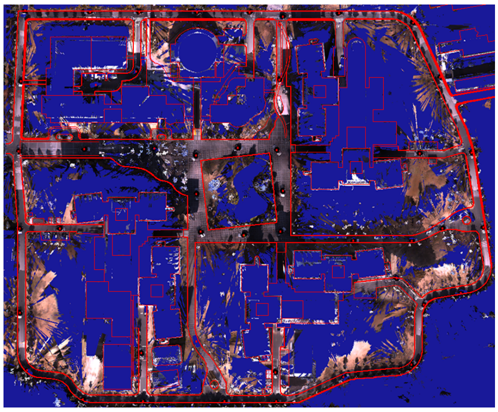


Fig.2 2D CAD data and a generated model

Examples of rendering the generated model are shown in Fig. 3.

4. Conclusion

This paper has proposed a 3D modeling method which is based on integrating omnidirectional range and color images for wide area outdoor environments. In experiments, a 3D model is actually generated from omnidirectional range and color images acquired at 50 points in our campus. Moreover, we can move viewpoint and look around the model freely.

Reference

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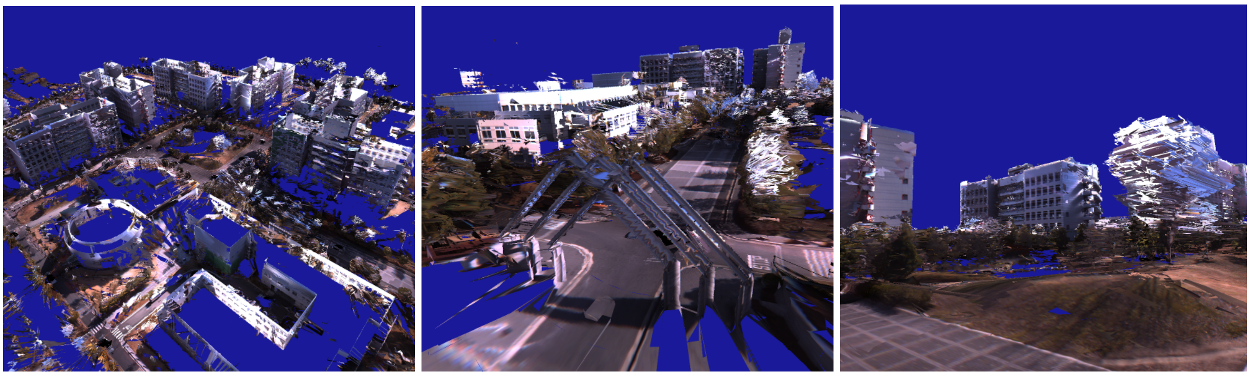

Fig. 3 Generated 3D model