Building 3D model using laser scan data

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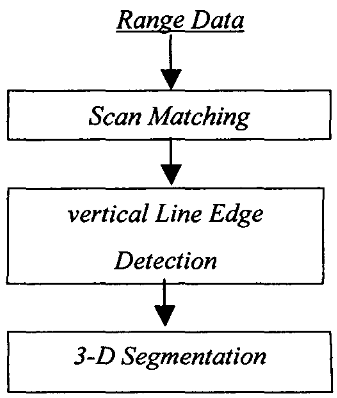
Abstract–**In this paper we describe techniques for the automated creation of geometric correct 3-D models of the building using two 2-D laser scanners. One of the laser scanners is used for position estimation using a scan matching algorithm, while the other is used to build 3-D models of the facade of the buildings. Those models can be used for virtual reality, tele-presence, digital cinematography and urban planning applications. Results are shown for building models in our campus using real data acquired from two sensors.**

1.Introduction

The recovery and representation of 3-D geometric of the real world is one of the most challenging problems in computer vision research[2][3][4]. With this work we would like to address the need for highly realistic geometric models of the world, in particular to create models that represent outdoor urban scenes. Those models may be used in applications such as virtual reality, tele-presence, digital cinematography and urban planning. There exist a variety of approaches to create 3-D models of cities. A broad field of such research is remote sensing, where satellite or aerial images are used to create 3-D models using methods such as stereovision or radar. Although with these methods geometric models can be acquired reasonably quickly, the accuracy of the resulting models is not very high and the lack of detailed information and texture renders them unsuitable for some applications such as virtual walk-through.

Our goal is to create an accurate geometric representation of the scene. The geometry of a scene is captured using range-sensing technology. We have developed a system which, given a set of unregistered depth maps, produces a geometric correct 3-D model representing the scene.

Our system is consisted of two 2-D laser scanners. The system is mounted on moving platform. During moving, data is acquired continuously and then later processed offline. Flowchart 1. describes the data flow of our approach. We start with multiple, unregistered range scans. First, we execute scan matching for deciding vertical scan data's right position of the world coordinates. And then, with those of scan data 3-D lines, the edge is detected by our simple algorithm. The last step is 3-D segmentation. It simplifies the acquired data to enable fast and efficient volumetric set operations for building the 3-D models.



Flow chart 1. System for building geometric model

2.System Constitution

We use a moving platform as our mobile-sensing mounting. The system consists of two parts (e.g., sensor module and a processing unit). The sensor contains two SICK laser scanners mounted at a 90-degree angle towards each other. The processing unit consists of 550MHz processor notebook PC, large hard disk drives and power supply. Both 2-D scanners facing the same side to the building. One is mounted vertically with the scanning plane orthogonal to the moving direction and the other is mounted horizontally with the scanning plane parallel to the ground. The vertical scanner detects the shape of the complete building facades, the horizontal scanner operates in the same plane as the ground and is used for position estimation, which we will describes later.

3.Scan Matching

We execute scan matching for standing in line to Cartesian world coordinate by detecting relative position of vertical data, that is contour of buildings. First we assumed that Cartesian coordainate [x,y,z]. Where x,y is ground and z points into sky. Also we assumed local coordinate [u,v] that is for horizontal scanner of our system. Where u is movement's direction and v is direction to buildings. Assuming that the city streets are flat, the position of the horizontal scanner can be described by the two coordinates x,y and the orientation angle θ of the system coordinate system. The horizontal 2D scans are captured continuously while moving, and as such, successive scans overlap significantly. Taking one scan as reference, we can approximate it with a series of line segments and match the points of a successive scan to these lines.

The displacement $\Delta u, \Delta v$ and rotation $\Delta\phi$ between the two scans in the local coordinate system is estimated by point-to-point matching algorithm. Point to point matching search the nearest point to reference scan and matching two sequential scans. So, By the displacement between horizontal data applied to vertical scan data and we can find right world coordinate's position of next vertical scan data.

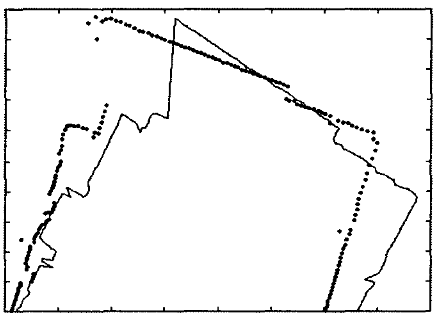
Figure2. shows the scan matching example. The reference scan in line, along with the points of the second scan in point, before and after matching.

For each pair k of successive scans, we apply point-to-point matching algorithm and compute the displacement $\Delta u_k, \Delta v_k$ the rotation $\Delta\phi_k$ in the local coordinate, and we refer to this as a "step k" of scan matching. As an initial guess for the actual world coordinates (x_k, y_k, z_k), we can compute a path of successive positions (x_k', y_k', z_k') in world coordinates as follows

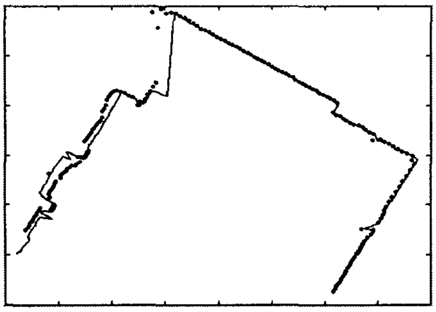
$$\begin{pmatrix} x_{k+1}' \\ y_{k+1}' \end{pmatrix} = \begin{pmatrix} x_k' \\ y_k' \end{pmatrix} + R(\theta_k' + \Delta\phi_k) \cdot \begin{pmatrix} \Delta u_k \\ \Delta v_k \end{pmatrix} \quad (1)$$

$$\theta_{k+1}' = \theta_k' + \Delta\phi_k$$

, where $R(\theta)$ is the 2 x 2 rotation matrix with angle θ.



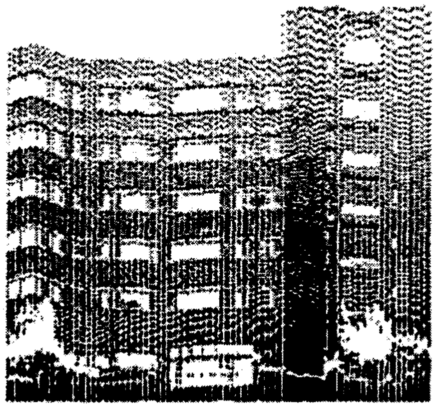
a) Before scan matching



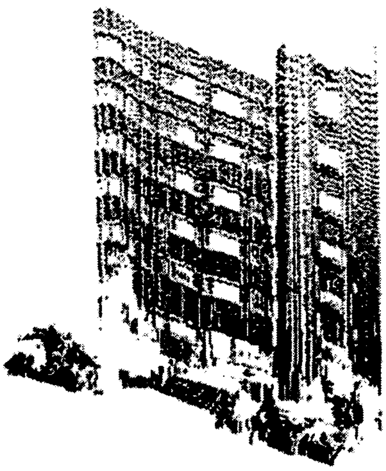
b) After scan matching

Figure2. Scan matching

Fig 3 show building scan data acquired in our campus and each vertical scan line is aligned by scan matching method.



b) Front view



b) 40° view

Fig 4. Building after scan matching

4. 3D line detection

For texture mapping, we need segment some feature something like vertex, line, surface. For simplicity, road is removed. It can be easily detected by height frequency histogram threshold. The adopted scan line approximation algorithm, proposed [5], and splits a scan line into segments, which are approximated by model functions. In our case, building structure is so simple that we detected 3D line candidate points as depth discontinuity. It is scattered order data, so that 3D line fitting is somewhat difficult problem. In general case, Hough Transform is used for line fitting. But the computational complexity and the memory requirements make the HT impractical for our problem. Solution to this problem is lies in the fact that a large number of connected components can be founded in the edge data, which can be used to obtain a coarse segmentation [6]. First, the connected components are detected and initial line is fitted and robust line fitting is performed iteratively. But connected component detection is not easy. Instead of connected components, we performed 2D line extraction from points by scan line discontinuity points. Fig 5. shows edge map where extracted line overlapped as dark line. The line does not mean line in real coordinate, so we should fit it as 3D line based on edge map. It can be done by using the least square line fitting method.

The 3D line can be detected based on scan line edge. But for registration, we need little more feature, so we find vertical 3D line. We project 3D Points to ground plane and make frequency histogram. Fig.6 shows projected view in which gray level (invert image) means frequency in 1cm by 1cm grid. We can find four lines. The lines crossed makes three corner points. It consists infinite vertical line and finite line is selected by near points.

5. Experimental Result

The building after scan matching is shown in Fig 3. we obtained 260 numbers of vertical scan data which has 0.5 degree resolution.

Road was removed. Scan matching is used horizontal line scanner so vertical scan line alignment has some limit that error occurs by rough ground surface or slope road. In our case , we sometimes met locally slope ground surface. Considering road condition, scan match is done satisfactorily.

Candidate points in 361 by 260 grid for 3D line extraction is shown in Fig 5. We set depth difference threshold 5cm. Fig 6 shows frequency image of points projected to ground plane. We detected three conner points, which is 3D line, directed to ground. The scattered candidate points are fitted as 3D line segment and it shown in Fig 7 with three vertical segment line.

6. conclusions

Scan data is somewhat noisy. Though there are some facts about it, Systemic limit in scan matching algorithm in road which is not flat should be improved first of all.

We could acquire depth information on object easily compared to stereovision techniques and extracted feature for registration. But we should improve 3D line detection method. Later, we will fusion the result, depth information with image texture using line segment.

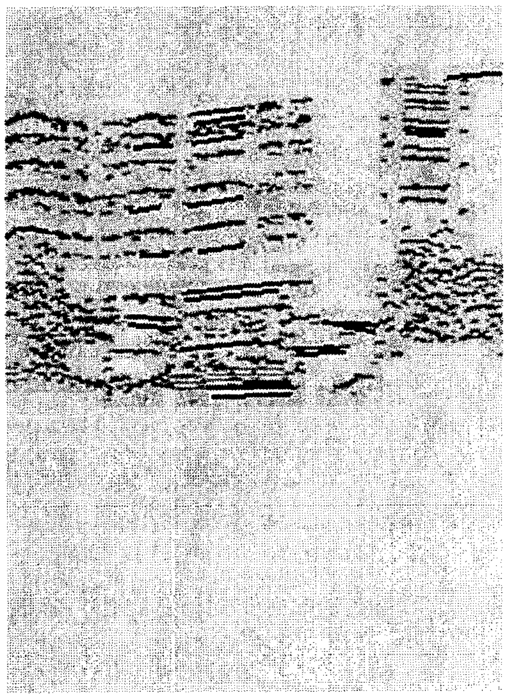


Fig 5. Edge map and 2D line (dark line) for 3D line extraction (361 by 260)

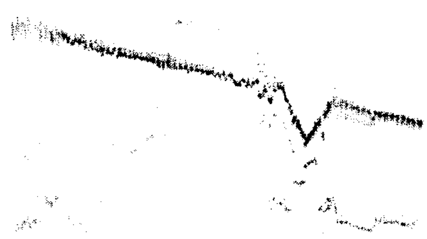


Figure 6. Frequency image of points projected to ground plane (gray level in inverse proportion to frequency)

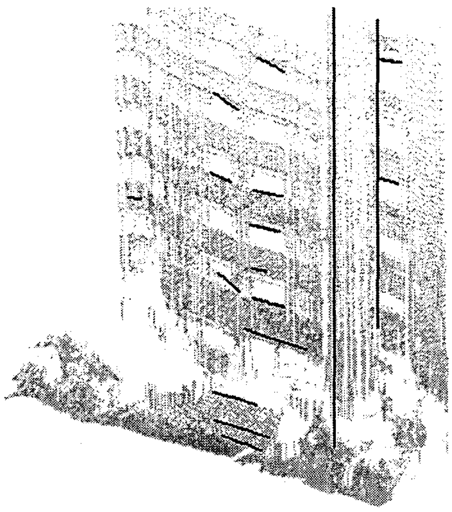


Figure 7. Building scan data and 3D segment line

7. Reference

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