Comparison of scanning strategies for the Small Mobile Mapping System

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In this paper two scanning strategies (stop-scan, continuous scanning) of Small Mobile Mapping System (SMMS) are discussed. SMMS registers 3D scans to provide accurate metric maps. This strategies have been implemented and evaluated in INDOOR environment. First is stop-scan fashion – SMMS stops, acquires data and moves forward to next position. The second approach is scan acquisition during motion. The data acquired in these approaches are registered using GPGPU ICP algorithm. As a result the comparison of the two registered point clouds with ground truth data is demonstrated.

Key words: 3D scan matching, GPGPU ICP algorithm, Mobile Mapping System

Introduction

Mobile Mapping Systems [1] are very promising technologies. MMS can be used in many applications such as Urban Search And Rescue (USAR), spatial design, map services etc. Current MMSs are manned surface, aerial or ground vehicles. It is difficult to replace the human operator by an autonomous system. The Small Mobile Mapping System (SMMS) can be deployed and controlled by one operator. It can perform simple tasks autonomously, but the autonomous behaviour is not a main topic of this paper. We are focused on comparison of two scanning strategies for SMMS. To compare these strategies we used data from two experiments and matched them using GPGPU ICP [2] – General Purpose Computing on Graphics Processing Units implementation of Iterative Closest Point algorithm introduced by Besl and McKay in [3]. GPGPU ICP uses regular grid decomposition and parallel computation to decrease computation time of Nearest Neighbour Search (NNS) with minimal lost of accuracy. NNS procedure takes the most of computation time as shown in[4]. Another approach is to use kd-tree [5] or octree based NNS [6]. In [7] a comparison of point cloud matching strategies is presented.

In section "Scanning strategies" we describe the two strategies compared in this paper. Section "Motion model" shows the way of creating point clouds while SMMS is moving. We have shown evaluation of scanning strategies in section "Experiments". Final observations and remarks are denoted in section "Conclusions".

Scanning strategies

In this paper we are focused on comparison of two scanning strategies for the SMMS. The first one is stop-scan strategy – the mapping system moves forward e.g. 1m, then system stops and makes a full scan. Scanner field of view is 270° vertical and 360° horizontal. Full scan takes approximately 1-2 minutes. After scanning robot moves to the next location and performs the measurement again. This cycle is repeated until operator stops mapping. The second is continuous scanning strategy – the mapping system moves forward with a speed set by the operator and acquires the 3D data. Each profile from the scanner is transformed to local coordinates and every 180° point cloud is saved with current platform odometry.

Motion model

We assume that the Small Mobile Mapping System (SMMS – fig. 1.) is moving straight forward. SMMS consists of several components: mobile platform (MobileRobots Pioneer 3-AT), IMU XSENS MTI-G, 3D Laser Measurement System based on SICK LMS100 scanner presented in [8]. IMU is mounted with offset in x axis (fig. 1. - second coordinate system) to the platform's coordinate system. 3D Laser Measurement System is installed on the top of the platform (third coordinate system on fig. 1.) with offset in y axis.

When SMMS is performing the scan 3D scanner is rotating around the y axis. The coordinates of the point P_i coordinates in local coordinate system are transformed into IMU coordinates system – translation $T_3=\{0, offset_Y, 0\}$, and rotation $R_{pitch}=\{0,0,\kappa\}$, and $R_{roll}=\{\omega,0,0\}$. Next step is to transform the point cloud to the global coordinates system. Every point is moved along x axis – $T_2=\{offset_x,0,0\}$. Finally all points from 3D scan are saved with odometry information ($R=\{0,\varphi,0\}$ and $T=\{x,0,z\}$) separately (data is

Fig. 1. Small Mobile Mapping System with three coordinate systems: 1) mobile robot odometry – global, 2) IMU, 3) 3D laser scanner

not transformed into the global coordinates system) in order to align the data using GPGPU ICP algorithm. Data from one 3D scan are transformed using equation (1) – the origin (0,0,0) of local coordinate system is in the end of the measurement.

$$P'_i = (P_i - P_n) \cdot \mathbf{R}_i \qquad (1)$$

P_n – odometry at the end of the measurement,
P_i – odometry of i-th profile,
P'_i – new odometry of i-th profile,
$\mathbf{R}_i$ – rotation matrix – around y axis by $\varphi - \varphi$ - difference between i-th platform angle and n-th angle.

Experiments

Small Mobile Mapping System was tested in two INDOOR experiments. First one is production hall – approximately 50 meters long (fig. 2), and the second one is 80 meters long corridor (fig. 4). Fig. 2c shows point clouds from two strategies aligned with GPGPU ICP algorithm. The alignment error in this case is small, but if we consider more scans the error is bigger and increases with number of scans. There is 1 meter error after 40 meters of scanning.

If the mapping system is moving slowly we can have more accurate metric maps. Especially when its speed is reduced to zero (stop-scan) – there is no odometry error in a single 3D scan. If we have an error in each point cloud be-

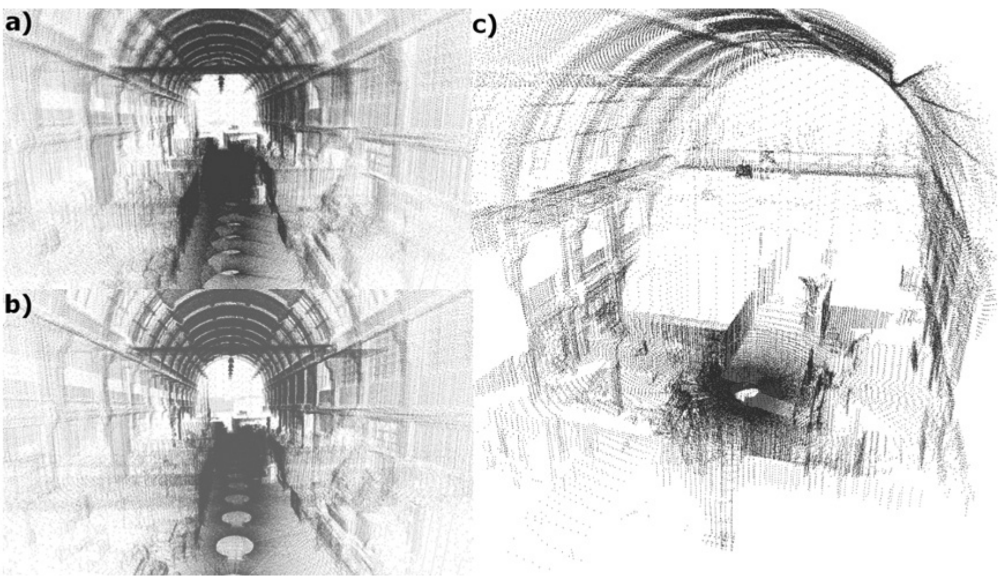

Fig. 2. Point clouds acquired in the first experiment using a) continuous scanning strategy (25 scans), b) stop-scan strategy (18 scans), c) one cloud from each strategy aligned with GPGPU ICP algorithm

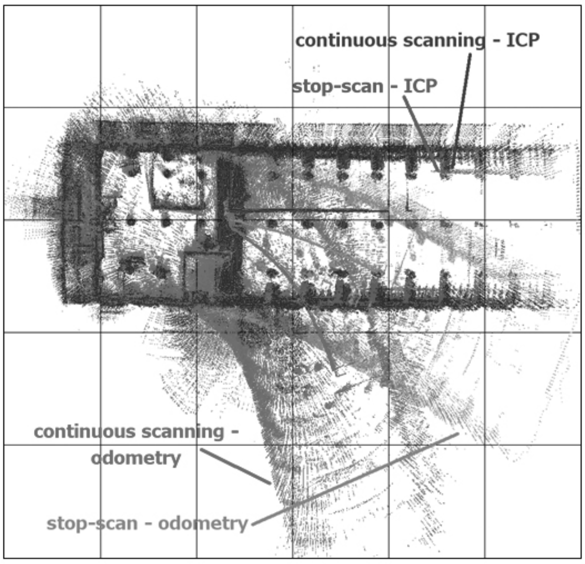

Fig. 3. Point clouds from stop-scan and continuous scanning with odometry and after registration using GPGPU ICP; top view, grid 10m x 10m

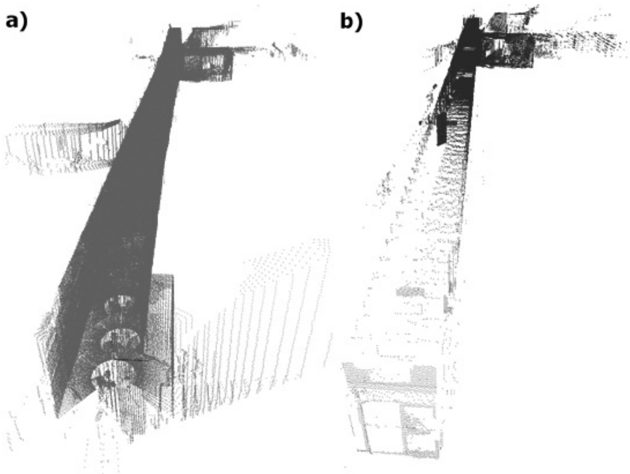

Fig. 4. Point clouds acquired in the second experiment; a) stop-scan strategy (45 scans), b) ground truth data from ZF 5010 laser scanner

fore registration, we cannot correct it. Reducing the speed of the mapping system movement we can increase its accuracy, but it extends scanning time.

In the second experiment two scanning strategies are compared to ground truth data from ZF 5010 scanner. The scanner has 187.3m range and 0.1mm resolution with 320°×360° field of view. The corridor was mapped using 3D Laser Measurement System with LMS100 and ZF 5010 scanner (fig. 4). Using the stop-scan and continuous scanning strategy 45 and 109 point clouds has been acquired accordingly. In fig. 5. the comparison of maps created in experiment is shown. Point clouds were aligned using 100 iterations of GPGPU ICP algorithm with same parameters. The stop-scan map is more accurate – there is few meters error at 80m distance after aligning compared to ground truth data.

The first experiment was done in a complex environment, where many structured elements are distributed around. This environment is better than an almost empty corridor, where algorithm may have problems to align clouds correctly along the corridor – there is no plane, except the end of the corridor, orthogonal to the direction of motion. In the first experiment the stop-scan strategy provides a better odometry than continuous scanning one, but in the second experiment both paths are similar. This may be caused by gyroscope mounted in the platform – in production hall (first experiment) the floor was made of metal and there were many running machines generating strong magnetic fields.

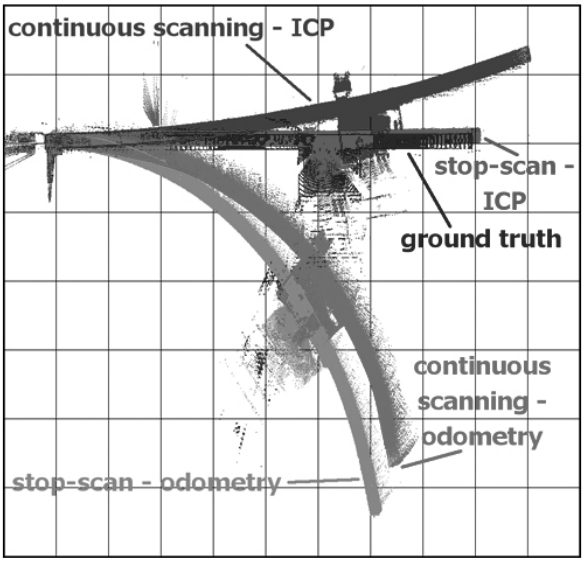

Fig. 5. Point clouds from stop-scan and continuous scanning with odometry and after registration; top view, grid 10m x 10m

Conclusions

In this paper two scanning strategies of Small Mobile Mapping System are discussed. Stop-scan strategy provides more accurate metric maps after alignment using GPGPU ICP algorithm. Continuous scanning strategy is faster than stop-scan and provides more data at the same distance. Using GPGPU ICP algorithm we can build accurate 3D maps. Continuous scanning can provide maps from the moving platform with minimal loss of accuracy. It is possible to build SMMS which can create maps from 3D data while it moves.

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