Compact, Real-time Localization without Reliance on Infrastructure

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***Abstract*—At Real Earth, we develop state-of-the-art technologies in real-time localization and mapping. Our key motivation is to enable robots to navigate reliably and to separately build accurate three-dimensional representations of the environment. Our methods are suitable for localization applications since we use compact devices that can be easily hand-carried and do not rely on GPS. The Microsoft indoor localization competition provides us an opportunity to demonstrate two of our devices that use cameras, IMUs and laser scanners to produce high-frequency ego-motion estimation along with registered point clouds. We have successfully demonstrated our methods in both indoor and outdoor environments using data collected by us, as well as by others. In the latter case, our method is ranked #1 on the KITTI odometry benchmark[1]. We see an average position error of approximately 0.2% of distance traveled, and we expect a better result in indoor settings.**

Keywords—mobile mapping; real-time; miniature; lidar

I. Technology

Our real-time localization and mapping software combines range data, visually tracked features, and inertial sensing, to estimate the 6-DOF motion. Simultaneously, the system registers lidar points into a coherent point cloud. The novelty of the proposed system is our unique way of solving the state estimation problem—instead of combining data from all sensors in a large, full-blown problem, we parse the problem in to multiple small problems, solve them sequentially in a coarse-to-fine manner, and consequently achieve high-precision [1-2]. Each module in the system couples one or at most a few sensors, generating results for the next module to process. The modules are arranged in an order where processing is carried out at descending frequencies, i.e. modules processed first cover high-frequency motion, handling aggressive maneuvers and ensuring robustness; modules processed last execute at low frequency, fundamentally warranting accuracy of the estimated motion and maps.

The modularized structure further ensures robustness, by selecting "healthy" estimates when forming the final solution. Here, "healthy" means that the sensor data contains sufficient information to carry out state estimation. For example, when a camera is in a low-light or a texture-less environment, the visually tracked features cannot produce useful state estimates. Likewise, in a structure-less environment such as a long and straight corridor, lidar-based methods typically produce poses that "slide" along the corridor, due to insufficient distinction in shape in the direction of the corridor. In these cases, our method is able to determine a degraded subspace in the problem state space. When degradation happens, we solve the problem partially, in the well-conditioned subspace. Finally the "healthy" parts are combined to produce final state estimates and this process repeats several times per second.

II. Devices

Two of our miniature mapping devices are especially suitable for the Microsoft indoor localization competition. The first, named Contour (Fig. 1) is composed of a spinning line scanner, a fisheye camera for ego-motion estimation and point cloud registration, an HD color camera for point cloud colorization, an embedded i7 computer for online data processing, and a touch-screen monitor for real-time display of point clouds. Contour is especially suited for mapping tight and cluttered areas, producing registered point clouds. The second, named Stencil (Fig. 2) contains a 3D lidar, a MEMS inertial sensor, and an i7 processing computer. Stencil has a longer detection range (up to 100+ meters) than contour and is targeted at large and open indoor environments as well as outdoor areas such as urban city streets and residential neighborhoods.

Fig. 1. Real Earth Contour is equipped with a spinning line scanner, a fisheye camera for state estimation, an HD color camera for point cloud colorization, an embedded i7 computer, and a touch-screen monitor.

[1] http://www.cvlibs.net/datasets/kitti/eval_odometry.php

Fig. 2. Real Earth Stencil is composed of a 3D lidar (range up to 100+ meters), a low-grade inertial sensor, and an i7 processor.

III. Example Results

We show a few representative results in this section. The three point clouds in Fig. 3 are generated by an Real Earth Contour (device shown in Fig. 1).

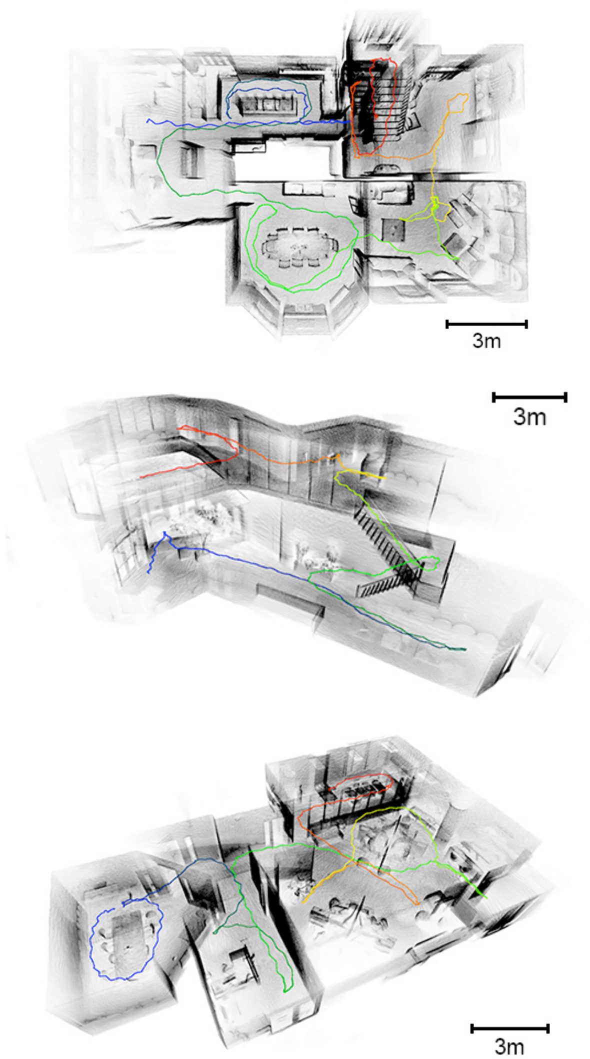

Fig. 3. Results of mapping three indoor areas using Contour (device shown in Fig. 1). The device is hand-carried for approximately three minutes in each case. The colored paths show the sensor motion during mapping.

For each point cloud, Contour is held by an operator walking in the mapped area for about three minutes. The point clouds are generated onboard the device while data is collected, without the need of loop-closure. We show the estimated sensor trajectories in color as well. The sensor starts at the blue end and stops at the red end.

In Fig. 4, we show an example point cloud produced by a Real Earth Stencil (device in Fig. 2). The device is carried by an operator who walks around a residential house for less than five minutes. Again, no loop-closure is involved. Because of the long detection rage (100+ meters), the map covers distanced objects in details.

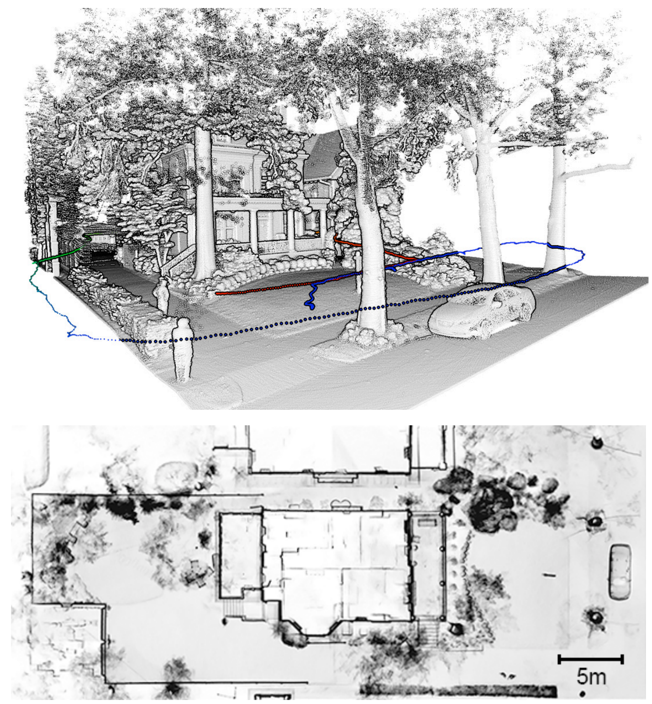

Fig. 4. Results of mapping exterior of a residential house using Stencil (device in Fig. 2). The device is hand-carried while the operator walks around the house for less than five minutes. No separate loop-closure step is needed.

More results at: http://www.realearth.us/-examples.html

IV. Deployment

Both devices can be set up quickly in a few minutes at a new location to produce real-time maps and poses. Based on the guidance provided, we expect to compete in the category of ***Modified Commercial off-the-shelf (COTS) Technologies*** **without reliance on infrastructure**. We expect to report 3D locations (X,Y, Z) of the sensor suite.

V. References

[1] J. Zhang and S. Singh. Visual-lidar Odometry and Mapping: Low-drift, Robust, and Fast. IEEE Intl. Conf. on Robotics and Automation (ICRA). Seattle, WA, May 2015.

[2] J. Zhang and S. Singh. LOAM: Lidar Odometry and Mapping in Real-time. Robotics: Science and Systems Conference (RSS). Berkeley, CA, July 2014.