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A robust method for 3D mapping by multi-sensor fusion

Masahiko Nagai[1]; Ryosuke Shibasaki[1]

[1] none

Three dimensional data is in great demand for the various applications such as 3D GIS, car navigation, pedestrian navigation, digital archive, simulation, computer games, and so on. In addition, targets of 3D data acquisition are now spreading to the 3D modeling of moving objects. In order to represent 3D space and moving objects in details, it is indispensable to acquire precise trajectory of sensors efficiently. However, there still lacks a reliable, quick, cheap and handy method of acquiring trajectory at high frequency and accuracy in outdoor and moving environments. In this research, we propose a combination of a CCD images and inexpensive IMU and GPS for robust trajectory tracking of sensors. After acquisition of the accurate trajectory tracking with precise attitude changes, 3D modeling is conducted by automatic stereo image matching and direct geo-referencing of laser range data.

While measuring, the sensors are continuously changing its position and attitude with respect time. In this research, GPS and IMU are combined by Kalman filter to acquire high frequency trajectory data. Through Kalman filter operation, an optimal estimate of the sensor position and attitude are determined by very high frequency which is frequency of IMU. And also its accuracy depends on GPS accuracy. However, IMU and GPS have a rising quality, but it is still affected by systematic errors, such as miss alignment, drift error, or effect of PDOP. It is not enough accuracy for 3D modeling by direct geo-referencing.

Meanwhile, CCD images are acquired from CCD sensor such as a digital camera. Their orientations of continual CCD images are determined by bundle adjustment. Bundle adjustment is a non linear least squares optimization method using tie-points of inside block. CCD images are taken every 10 second and its orientation is computed by bundle adjustment that the result shows very accurate trajectory, even though frequency is very low. GPS and IMU allow automatic setting of tie-points for bundle adjustment and they reduce the number of tie-points and searching time of tie-points by the limitation of searching area. Image orientation is achieved automatically using all the sensors without any ground control points.

Finally, the results of the image orientation get feedback to trajectory tracking. Bundle adjustment and Kalman filter are combined to acquire high accuracy and frequency trajectory data. That is to say, the result of bundle adjustment aids Kalman filter. In this research, the result of bundle adjustment is treated as a true trajectory, and then IMU and GPS are initialized for Kalman filter using the result of bundle adjustment. That is, after the every bundle adjustment which is every 10 second, GPS and IMU and their errors are complemented. As a result, this precise trajectory is utilized for 3D modeling which accuracy depends on the accuracy of trajectory such as stereo image matching and geo-referencing of laser range data. Therefore, direct geo-referencing is done very accurately without any control points.

In conclusion, the robust method for 3D mapping is developed by closely combining CCD images and laser scanner with GPS and IMU. This is the way of rendering objects with rich shape and detailed texture automatically. This mapping system is mounted on an unmanned helicopter. The measurement is carried from the sky, and the data of the site can be easily acquired collectively with safety and mobility.