Heikki Hyyti*, Juha Mäkelä, Antero Kukko, Harri Kaartinen

An integrated positioning and mapping sensor for forest machinery

Keywords: rotating multi-beam lidar, inertial measurements, sensor fusion, calibration, point cloud, forestry

Extended abstract. Mobile mapping is a promising technology for collect-ing single-tree level inventory data for precision forestry [1, 2, 3]. Forest machinery could be used as a platform for a mobile mapping system. The same instrument could also give forest machinery an ability to perceive forests for automating their operation. For these purposes, a ro-bust and low-cost prototype of a rotating multi-beam li-dar (RMBL) sensor with an integrated inertial measure-ment unit (IMU) is proposed (see Figure 1).

The prototype increases the field of view (FOV) of a Velodyne multi-beam lidar sensor by operating it on a rotating mounting at a configurable fixed inclination. In addition to the Velodyne lidar [4], the prototype is constructed from a motor operated rotating platform, an angular position sensor [5], an inertial measurement unit (IMU) [6], and a computer [7] for real-time processing. The configured FOV of the sensor is 360° × 110°.

As the construction is complex, there are many parameters in the setup which need to be estimated to measure accurate point clouds. The calibration parameters for the prototype sensor are estimated using a data-based calibration procedure which minimizes errors by fitting planes into the lidar point cloud which is collected during a full revolution of the rotating platform. The error minimization is performed for data collected inside a building which has floors and walls that can be assumed planar.

The IMU, on the other hand, is temperature stabilized to a fixed temperature (40°C) and gyroscope and accelerometer biases and gains are estimated for the fixed temperature by a computational parameter estimation method used in [8].

In the paper, we show how to build and calibrate the RMBL sensor and how to calibrate it together with an IMU for future development of omni-directional lidar-inertial odometry. Our calibration method has minimal amount of parameters, the method is simple to use, and it is able to calibrate major part of the parameters in the setup with only a small amount of manual work.

When the sensor is fitted on top of the forest machine cabin (as in Figure 2) it may be used to detect ground level, tree trunks, crowns, and tops (see example data in Figure 3), which are required for many forest inventory pur-poses (see e.g. [1, 2, 3]). The sensor is also able to see the forestry crane constantly which may allow crane and tool positioning in the future [9].

Figure 1: A close up of the integrated positioning and mapping sensor

***Corresponding author: Heikki Hyyti,** Finnish Geospatial Research Institute (FGI), National Land Survey of Finland (NLS) and Department of Electrical Engineering and Automation, Aalto University, E-mail: heikki.hyyti@iki.fi
Juha Mäkelä, Häme Vocational Institute, Häme University of Applied Sciences
Antero Kukko, FGI, NLS and Department of Built Environment, Aalto University
Harri Kaartinen, FGI, NLS and Department of Geography and Geology, University of Turku

Figure 2: A forest machine and the proposed sensor installed on top of the machine cabin at Evo, Häme Vocational Institute. The corresponding author stands next to the cabin.

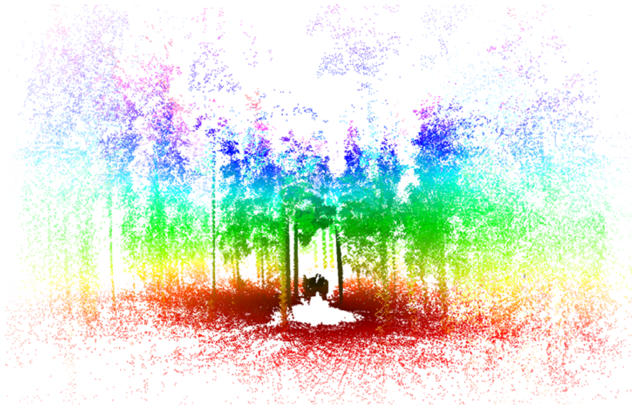

Figure 3: A forest machine inside a forest as viewed by the proposed sensor mounted on top of the cabin. The collected point cloud is colorized by the height as hue and point range as value in a hue-saturation-value (HSV) color space.

Acknowledgments

Strategic Research Council at the Academy of Finland is acknowledged for financial support of project "Competence-Based Growth Through Integrated Disruptive Technologies of 3D Digitalization, Robotics, Geospatial Information and Image Processing/Computing – Point Cloud Ecosystem" (project decision number 293389 / 314312).

References

[1] Hyyppä J, Yu X, Kaartinen H, Kukko A, Jaakkola A, Liang X, Wang Y, Holopainen M, Vastaranta M, Hyyppä H. Forest Inventory Using Laser Scanning. In: *Topographic Laser Ranging and Scanning*, pp. 379–412. Taylor & Francis. 2018;.

[2] Holopainen M, Vastaranta M, Hyyppä J. Outlook for the next generation's precision forestry in Finland. *Forests*. 2014; 5(7):1682–1694.

[3] Vastaranta M, Saarinen N, Kankare V, Holopainen M, Kaartinen H, Hyyppä J, Hyyppä H. Multisource single-tree inventory in the prediction of tree quality variables and logging recoveries. *Remote Sensing*. 2014;6(4):3475–3491.

[4] Velodyne LiDAR. *Puck LITE: Light weight real-time 3D LiDAR sensor*. 2018. Datasheet 63-9286 Rev-H. URL https://velodynelidar.com/docs/datasheet/63-9286_Rev-H_Puck%20LITE_Datasheet_Web.pdf

[5] ASM GmbH. *POSIMAG® - PMIS3/PMIS4: Magnetic Scale Position Sensors*. 2017. Installation and operation manual, MAN-PM-E-17. URL https://www.asm-sensor.com/en/downloads.html?file=files/asmTheme/pdf/pm_man_en.pdf

[6] InvenSense. *MPU-9250 Product Specification Revision 1.1*. 2016. Datasheet PS-MPU-9250A-01 v1.1. URL http://www.invensense.com/wp-content/uploads/2015/02/PS-MPU-9250A-01-v1.1.pdf

[7] Intel. *Intel® NUC Board NUC7i5BNB and Intel® NUC Board NUC7i7BNB*. 2018. Tech. prod. spec., J59951-008. URL https://www.intel.com/content/dam/support/us/en/documents/boardsandkits/NUC7i5BN_NUC7i7BN_TechProdSpec.pdf

[8] Hyyti H, Visala A. A DCM based attitude estimation algorithm for low-cost MEMS IMUs. *International Journal of Navigation and Observation*. 2015;2015:18.

[9] Lindroos O, Ringdahl O, La Hera P, Hohnloser P, Hellström TH. Estimating the position of the harvester head–a key step towards the precision forestry of the future? *Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering*. 2015;36(2):147–164.