ABSTRACT

The ever-increasing demand for highly detailed mapping solutions has resulted in a surge of small footprint mapping platforms. Among these mobile mapping systems (MMSs), those used outdoors typically contain an integrated global navigation satellite system/inertial navigation system (GNSS/INS) to directly georeference cameras and light detection and ranging (LiDAR) sensors. Ideally, under open sky conditions, these systems are highly effective in generating high-accuracy geospatial information. However, there are applications where GNSS reception vary from intermittent access to complete outage. Such scenarios impact platform localization, often lowering the quality of the resulting mapping products. Currently, there is a lack of comprehensive investigation into the influence of GNSS availability on system development, system calibration process, quality of acquired multi-modal (say, image and LiDAR) data, as well as remedies to address any mapping challenges related to these factors. To demonstrate these challenging matters, this dissertation examines three distinct application areas – resource inventory, agriculture, and forestry, each representing a unique spectrum of environmental complexity and GNSS availability. For these applications, the study explores how GNSS reception issues will affect the selection and integration of sensors, their system calibration, and the quality of sensor-derived data. The mapping products generated in these three applications include stockpile volume estimates, individually segmented plants within agricultural fields, and individually segmented forest trees with associated biometrics such as location, height, and diameter at breast height (DBH). In essence, the dissertation develops wide-ranging mapping strategies to deliver high-precision geospatial data. Thus, the contributions of this dissertation include: (1) application-oriented mapping system development, considering cost and complexity of the platform, ease of data acquisition, and crew safety, all within the environment-imposed constraints; and (2) in-situ geospatial data enhancement, where multi-modal sensor data play a key role in providing useful features necessary for various optimizations (in system calibration, platform localization, and mapping). The developed mapping systems are evaluated though extensive field trials and data processing, leading to hardware–software design iterations as required. Finally, the findings from these experiments are reported on the basis of various evaluation metrics, including quality of individual features, multi-modal and multi-temporal feature alignment, and consistency between sensor-derived mapping products and reference measurements (such as volume estimates obtained

from a conventional mapping system and tree DBH obtained from field measurement). Among the most severe cases of data inconsistency, the developed approach reduced multi-modal (image–LiDAR) feature misalignments from over 2 m to under few centimeters. Furthermore, analyses of mapping products across the three application areas validate the results to have under ±2–3% error relative to the reference. In summary, this dissertation builds a comprehensive framework for mapping diverse environments under conditions of limited or no GNSS/INS availability, while ensuring effective delivery of high-precision mapping products across various domains.