ABSTRACT

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Title: Geospatial Process of Airborne Full Waveform Lidar Data.
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This thesis focuses on the comprehensive and thorough studies on the geospatial processing of airborne (full) waveform lidar data, including waveform modeling, waveform decomposition, direct georeferencing, and precise georeferencing with self-calibration.

Both parametric and nonparametric approaches of waveform decomposition are studied in this thesis. The traditional parametric approach assumes that the returned waveforms follow a Gaussian mixture model where each component is a Gaussian. However, many real examples show that the waveform components can be neither Gaussian nor symmetric. To address the problem, this thesis proposes a nonparametric mixture model to represent lidar waveforms without any constraints on the shape of the waveform components. To decompose the waveforms, a fuzzy mean-shift algorithm is then developed. This approach has the following properties: 1) it does not assume that the waveforms follow any parametric or functional distributions; 2) the waveform decomposition is treated as a fuzzy data clustering problem and the number of components is determined during the process of decomposition; 3) neither peak selection nor noise floor filtering prior to the decomposition is needed; and 4) the range measurement is not affected by the process of noise filtering. In addition, the fuzzy mean-shift approach is about three times faster than the conventional expectation-maximization algorithm and tends to lead to fewer artifacts in the resultant digital elevation model.

This thesis also develops a framework of self-calibration that determines the boresight angles and waveform geospatial position at the same time. Besides using the flight trajectory and plane attitude recorded by the onboard GPS receiver and inertial measurement unit, the framework makes use of the publically accessible digital elevation models as control over the study area. Comparing to the conventional calibration and georeferencing method, the new development has

minimum requirement on ground truth or information: no extra ground control, no planner objects, and no overlap flight strips are needed. Furthermore, it can also solve the problem of clock synchronization and boresight calibration when they both exhibit. Through a developed two-stage optimization strategy, the self-calibration approach can resolve both the time synchronization bias and boresight misalignment angles to achieve a stable and correct solution. As a result, a consistency of 0.8662 meter is achieved between the waveform derived digital elevation model and the reference one without any systematic trend. Such experiments demonstrate the developed method is a necessary and more economic alternative to the conventional, high demanding georeferencing and calibration approach, especially when no or limited ground control is available.