Development of a High-Accuracy UAV-Photogrammetry Solution for Automated Environmental Modeling

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ABSTRACT

This presentation is an overview of our methodologies and experiments in developing and implementing a UAV-photogrammetry system for accurate three-dimensional (3D) environmental modeling. The most significant components considered in the development of the system include in-house-built software solutions for: camera calibration, platform calibration, system integration, onboard data acquisition, multi-sensor control and flight/control-survey planning. In addition, a specific photogrammetric workflow is developed for 3D reconstruction. The proposed solutions are alternatives to traditional aerial photogrammetry techniques, appropriately adapted to specific characteristics of unmanned, low-altitude imagery. Firstly, a new method is proposed for robust sparse matching and linear estimation of two-view epipolar geometry. The key features of this approach compared to RANASC-like techniques include: evolutionary search instead of random sampling; guided sampling based on the spatial distribution of the matches; inlier classification based on adaptive thresholding. The main achievement of this method was its capacity to handle a high percentage of matching error (outliers among corresponding points) with remarkable computational efficiency (compared to state-of-the-art). Secondly, a successive approach is developed to cluster cameras and refine the connectivity graph based on several internal reconstruction-stability criteria, and to convert two-view parameters of epipolar-geometry first to relative orientation parameters, and then to exterior orientation parameters from which the initial 3D structure can be reconstructed. Then, a bundle block adjustment (BBA) strategy is proposed, mainly based on the integration of the pseudo-observations of camera calibration parameters into a self-calibrating bundle adjustment with Gauss-Helmert model. The principal advantage of this strategy was controlling the adverse effect of the following factors on the accuracy of self-calibration: unstable imaging networks; noisy image observations; and correlations of the unknown parameters. The sparse implementation of this strategy (SBBA) is also performed, which allowed its application to data sets containing millions of tie points. Finally, the concepts of intrinsic curves are revisited for dense stereo matching and 3D point cloud generation. The proposed technique could achieve a high level of accuracy and efficiency by searching only through a small fraction of the whole disparity search space and internally handling occlusions and matching ambiguities. This algorithm was compared to dense-matching state-of-the-art via Middlebury Stereo Benchmark and gained first ranking. The developed system and photogrammetric solutions were extensively tested for surveying and volumetric change detection in an open-pit gravel mine. The environment of the open-pit mine provided a challenging scene for 3D modeling, mainly due to: large scale-variations (causing high geometric distortions); repetitive textures (causing matching errors); long sequences of images (causing high error accumulation); and necessity of high metric accuracy for geological surveying. Achieving absolute 3D dense mapping accuracy of 11±7 mm, as well as sparse reconstruction accuracy of 6±1 mm, illustrated the success of this system for high-precision environment modeling.