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Utilizing the Iterative Closest Point (ICP) algorithm for enhanced registration of high resolution surface models – more than a simple black-box application

Claudia Stöcker (1,2) and Anette Eltner (1)

(1) Faculty of Geo-Information Science and Earth Observation, University of Twente, Enschede, The Netherlands (claudia.stoecker@mail.de), (2) Institute of Photogrammetry and Remote Sensing, Technische Universität Dresden, Dresden, Germany

Advances in computer vision and digital photogrammetry (i.e. structure from motion) allow for fast and flexible high resolution data supply. Within geoscience applications and especially in the field of small surface topography, high resolution digital terrain models and dense 3D point clouds are valuable data sources to capture actual states as well as for multi-temporal studies. However, there are still some limitations regarding robust registration and accuracy demands (e.g. systematic positional errors) which impede the comparison and/or combination of multi-sensor data products. Therefore, post-processing of 3D point clouds can heavily enhance data quality. In this matter the Iterative Closest Point (ICP) algorithm represents an alignment tool which iteratively minimizes distances of corresponding points within two datasets. Even though tool is widely used; it is often applied as a black-box application within 3D data post-processing for surface reconstruction.

Aiming for precise and accurate combination of multi-sensor data sets, this study looks closely at different variants of the ICP algorithm including sub-steps of point selection, point matching, weighting, rejection, error metric and minimization. Therefore, an agricultural utilized field was investigated simultaneously by terrestrial laser scanning (TLS) and unmanned aerial vehicle (UAV) sensors two times (once covered with sparse vegetation and once bare soil). Due to different perspectives both data sets show diverse consistency in terms of shadowed areas and thus gaps so that data merging would provide consistent surface reconstruction. Although photogrammetric processing already included sub-cm accurate ground control surveys, UAV point cloud exhibits an offset towards TLS point cloud. In order to achieve the transformation matrix for fine registration of UAV point clouds, different ICP variants were tested. Statistical analyses of the results show that final success of registration and therefore data quality depends particularly on parameterization and choice of error metric, especially for erroneous data sets as in the case of sparse vegetation cover. At this, the point-to-point metric is more sensitive to data "noise" than the point-to-plane metric which results in considerably higher cloud-to-cloud distances. Concluding, in order to comply with accuracy demands of high resolution surface reconstruction and the aspect that ground control surveys can reach their limits both in time exposure and terrain accessibility ICP algorithm represents a great tool to refine rough initial alignment. Here different variants of registration modules allow for individual application according to the quality of the input data.