TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Umweltwissenschaften – Fachrichtung Geowissenschaften
Institut für Photogrammetrie und Fernerkundung

Technische Universität Dresden, D-01062 Dresden

Prof. Dr. sc. techn. habil.
Hans-Gerd Maas

Tel.: +49 - 351 - 463-32859
Fax: +49 - 351 - 463-37266
E-Mail: hans-gerd.maas@tu-dresden.de

Review on the doctoral thesis of Agata Walicka

"Application of terrestrial laser scanning for the monitoring of changes in the mountain river bed"

Agata Walicka develops a comprehensive geodetic-photogrammetric technique for monitoring sediment transport in streams based on terrestrial laser scanner data, which offers a number of advantages over established measurement techniques in that field and is complementary to those in several aspects. Her method is able to deliver a number of parameters especially concerning long-term movements, which cannot be obtained with other techniques under realistic effort. The core contribution of her work is to go beyond multi-temporal digital elevation models, which are primarily suited for the height component and do not deliver hypothesis-free information on lateral movement. Instead, her approach of 3D-tracking individual objects in laser scanner point clouds allows to determine time-resolved 3D translation and rotation parameters. Challenges herein are in the segmentation of data, in the reliable matching of objects in multi-temporal datasets and in the precise determination of motion parameters. Actually, the title of the thesis ‚application of terrestrial laser scanning …' is a bit misleading (and too modest) in the sense that the thesis is going clearly beyond the pure application of an existing measurement technique and has its focus on the development, application and validation of a complete laser scanner data processing chain in a demanding application field.

The cumulative thesis consists of five publications, including three articles published in peer-reviewed ISI-ranked journals and two conference papers, which also went through a review process and were published in ISI-ranked conference proceedings series. The candidate is first author (and main contributor) of all five articles. The publications are properly integrated into an extended framework consisting of an introduction, a general theory chapter and a conclusion.

The thesis starts with a motivation chapter briefly introducing into the task of riverbed sediment transport monitoring and reviewing established measurement techniques in this field. The chapter formulates four research hypotheses forming the guidelines for the thesis. Chapter 2 provides the relevant theoretical background on distance metrics, neighbourhood definitions, geometric feature description, clustering, segmentation, classification point cloud matching on 24 pages. The chapter is clearly structured and well embedded in the

literature, and it confirms the strong theoretical background of the candidate in her research field. It is rather generic and has a great value also beyond this thesis. Only in a few passages, the reviewer would have appreciated a deeper discussion of the advantages of chosen approaches over alternative techniques with respect to the tasks treated in the further chapters.

In the following chapter, the five articles forming the core part of the thesis are mapped into the structure of three major work packages (manual approach / segmentation / tracking) defined in the introductory part of the thesis. The individual publications are briefly summarized and set into an overarching content frame.

- The first article takes the consequent step from multiple digital riverbed elevation models to tracking individual objects as a basis for the determination of horizontal movements, thus going beyond the analysis of pure height changes. Herein a manual approach is chosen to track grains in the multi-temporal datasets. This manual data processing approach by itself would probably not qualify as a doctoral thesis topic, but it is important as an entry point into the thesis and a reference for the next chapters. The accuracy of manual grain displacement measurement is specified with 4 cm, which probably does not fully exhaust the potential of the technique yet.
- Article 2 takes a logical next step by developing an approach to automatically segment individual grains in the point clouds. The author uses an existing classification algorithm here. This is absolutely justified, but some explanation on why this algorithm was chosen would have been useful here. Concerning the results, the reviewer would have expected a somewhat better classification success ratio than the obtained ca. 70-80% – but that may also have to be attributed to the complexity of the scanned scene.
- The third (and longest) article is closely related to this, presenting an improved segmentation scheme on 22 journal pages. The approach is based on a Random Forest algorithm using various features derived from the point cloud coordinates, embedded in a pre-processing and rejection stage. The obtained results (in the order of 85% correct segmentation) seem to be a bit better than those reported in the previous article, but the reviewer is missing a direct comparison of results of the two approaches here. The analysis of segmentation success rate vs. rock size is rather valuable, but the fact that only 76% of the rock with 25 – 50 cm diameter were detected gives the impression that there is still room for improvement.
- Article 4 establishes correspondences between objects segmented in consecutive point clouds. The author employs the well-known ICP algorithm here, combined with a sophisticated technique to provide the necessary approximate values. Detailed results are not shown here.
- As a continuation of the work presented in article 4, article 5 presents an improved 3D object tracking approach. The method requires successful segmentation in only one time step now, performing a match of the segmented portion of the point cloud into the next (or previous) time step dataset. The author seems to favour this approach, but a clear motivation is not provided. The validation has its main focus on the detectability of rock

motion, resulting in a minimum detectable movement of 2 cm. However, the reviewer found it a bit difficult to retrieve generalized statements on the actual accuracy potential concerning the translation and rotation parameters from the article.

In the opinion of the reviewer, the largest contribution is given by the 3rd article, followed by the 5th. Overall, beyond answering the initial research hypothesis on the general feasibility of terrestrial laser scanner point cloud data based riverbed motion monitoring, the thesis delivers a complete workflow for task-specific terrestrial laser scanner data processing, implemented and validated on various challenging datasets. The thesis thus provides an original solution of a challenging scientific problem, together with valuable general knowledge on the topic, and it is definitely of scientific significance in the wide field of environmental monitoring. It does contain some open ends – that is not forbidden in research, but the open ends might have been addressed more specifically in the conclusion, directing into more detailed future work suggestions. In some cases, the rationale for choosing a certain approach might have been motivated in more detail. The thesis is well written in rather routinely English and well illustrated, and it is based on a thorough literature review. The candidate shows deep general theoretical knowledge in the field of geodesy as well as good skills in the design and conduction of practical experiments and in software implementation of complex algorithms.

The reviewers final conclusion is positive, as the doctoral dissertation clearly fulfils the requirements for a doctoral degree under *Article 13 of the Act of March 14, 2003 Ustawa o stopniach naukowych i tytule naukowym oraz o stopniach i tytule w zakresie sztuki (Dz.U. 2003 Nr 65 poz. 595 z p6zn. zm.)*. The reviewer therefore recommends acceptance of the doctoral thesis to the Faculty of Environmental Engineering and Geodesy.

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