Skoltech

Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Emre Ozdemir

PhD Program: Engineering Systems

Title of Thesis: Geospatial point cloud classification

Supervisor: Associate Professor Alessandro Golkar

Co-supervisor: Dr. Fabio Remondino, Bruno Kessler Foundation

Name of the Reviewer: A/Prof. Dr. techn. Franz Rottensteiner, Leibniz Universität Hannover, Germany

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 03-11-2021**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications
- The summary of issues to be addressed before/during the thesis defense

Evaluation of the thesis quality and overall structure

In his thesis, Mr. Özdemir deals with a problem of high scientific and practical relevance. Deep learning methods have become increasingly important for automatic information extraction from remote sensing data. In this context, the classification of point clouds acquired by laser scanning or by stereo matching is considered to be more problematic than the classification of image data because of the irregular structure of point clouds, which inhibits the straight-forward application of convolutional neural networks. Mr. Özdemir presents a method for point cloud classification which relies on the combination of hand-crafted features and artificial neural networks (ANN). Every point of a point cloud is classified individually using an ANN, the input of which consists of the point's coordinates and a series of features extracted from a local neighbourhood. In this way, the network depth and, thus, the number of parameters to be determined can be limited, leading to a reduction of the memory consumption and the requirements with respect to the availability of training samples compared to other methods. In order to speed up the classification process for very large datasets, Mr. Özdemir proposes a method for thinning the point cloud before classification. Finally, a method for post-processing is presented; its goal is the identification of individual buildings based on the classified point cloud.

Mr. Özdemir presents a very thorough evaluation of his methods for classification based on five datasets acquired using different types of sensors and having different characteristics. He assesses the impact of his most important hyperparameter, which is related to the density of the thinned-out point cloud, and compares two different variants of his method with each other and to a baseline. A comparison to state-of-the-art methods reveals that the method performs on par if slightly worse, but requires far less computation time and computer memory. Further tests indicate that the loss of classification accuracy to be expected if a classifier is to be applied to another dataset than the one used for training is limited.

The quality of the scientific work conducted by Mr. Özdemir is high, and his results seem to be thorough. The advantage of his method is that it can process large point clouds in less time than existing ones; thus, an explicit goal of Mr. Özdemir is fulfilled by his thesis. From a structural perspective, his thesis is good, but there are a few aspects that could have been dealt with in a better way. The description of the fundamentals is too broad in scope (e.g. containing completely irrelevant aspects of terrestrial or GNSS survey) but a bit superficial w.r.t. the actual topics of the thesis (ANN and point clouds). The literature review is also a bit too broad. It is largely a description of what other authors have done, but an explicit critical analysis of the cited references with respect to the goals of the thesis is missing. The description of the methodology is understandable in general, but Mr. Özdemir could have made better and more frequent use of formal mathematical definitions. The only aspect that is not really comprehensible is the way in which the input for the 3D CNN ANN is generated. The method for post-processing is a bit of an appendix; as it is not evaluated quantitatively, its scientific value is not really shown in the thesis. The conducted experiments seem to be thorough, but the presentation of the results suffers from the fact that the experimental setup is not described precisely. For instance, it is not quite clear which points are used for evaluation. At some (very late) stage the author says that the classification results achieved for the thinned-out point cloud are transferred to the original one and that the latter is used for evaluation; however, he fails to describe how this transfer is achieved. It is also a bit unfortunate that hardly any information about the training procedure is given. Of course, the training procedure is not the focus of this thesis, but it is nevertheless relevant for being able to reproduce its results. It is also a bit unfortunate that the presentation and the analysis of the results are separated; the analysis itself is relatively short and could have been expanded.

It has to be noted that all of the mentioned problems are minor; none of them is so severe that it could impede the acceptance of the thesis.

Consistency between the thesis topic and its actual content

The contents of the thesis are largely consistent with the topic. The title is a bit too broad, but Mr. Özdemir narrows down the topic in section 1, anyway. It could be considered a minor critical aspect that the

analysis of the results is very short – the reader is somewhat left alone with the interpretation of the tables. Mr Özdemir has achieved the goals he defines in section 1, but the fact that they are fulfilled is sometimes only established implicitly. The method for instance segmentation is nor evaluated in a quantitative sense and it is also a bit out of scope of the overall topic of the thesis. This reviewer would not have missed it if it had been omitted.

Relevancy of the methods used in the thesis research

As pointed out earlier, this is a very relevant topic. The methods proposed in this thesis are a step forward towards the applicability of modern deep learning methods for very large datasets such as those used by national mapping agencies.

Scientific value of the results obtained and their conformity to the international standard and current state of the art

Mr. Özdemir has presented an innovative method that renders possible the application of deep learning for very large point clouds. This is certainly a step forward, beyond the current state of the art, and a very relevant contribution worth to be investigated in the context of a PhD thesis. In general, Mr. Özdemir has embedded his thesis well in the current state of the art, but the presentation of the way in which this embedding is achieved could have been better. As far as methodology is concerned, the research gap left open by existing work and to be closed by Mr. Özdemir's thesis is only identified implicitly.

Usability of the obtained results in applications (if relevant)

As pointed out earlier, the results are highly relevant for practical application. This is actually one of the major strengths of Mr. Özdemir's thesis.

Quality of the publications

Mr. Özdemir lists nine scientific papers to which he has contributed. Four of them have appeared in scientific journals, the others in non-peer-reviewed conference proceedings. As far as the journal papers are concerned, Mr. Özdemir is the main author of only one of them (Özdemir et al., Remote Sensing, 2021), and this paper also seems to be the one most closely related to the contents of the thesis. The list of publications is certainly acceptable for a PhD thesis.

Summary of the items to be addressed before/during the PhD thesis defence

There is nothing critical that needs to be addressed before the PhD defence; if a new version of the PhD work were produced, the very minor issues mentioned above could be fixed.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*