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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Svetlana Illarionova

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Deep learning for remote sensing of environment and land cover analysis

Supervisor: Professor Ivan Oseledets

Name of the Reviewer: Mikhail Belyaev

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 18-01-2023**

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

The thesis is a sizeable high-quality work. Within this work, Svetlana created several useful data-science-based tools for remote sensing, which is a significant and timely contribution as the field needs tailored machine learning methods. Although high-level problem statements, e.g., image segmentation, are typical for many other applied domains, Svetlana clearly showed that exploiting domain knowledge is crucial for developing robust, generalizable deep learning models for satellite image analysis.

The overall structure provides a good overview of the achieved results; Svetlana split her works into several sections that roughly form two major groups:

1. Creating models for solving core domain tasks such as forest segmentation and tree counting
2. Exploiting larger unlabelled data sets to create auxiliary models for canopy height estimation and generating near-infrared (NIR) images.

I enjoyed reading the thesis, as every new chapter provides a unique perspective on the thesis goal, creating robust modes for remote sensing:

- In chapter 3, Svetlana showed that object-based augmentation increases robustness when transferring models to unknown terrain.
- Adding height data via a carefully designed hierarchical approach makes models more robust to class imbalance, as shown in chapter 4.
- Chapter 5 demonstrates another approach to battling class imbalance based on the natural idea of creating a "fuzzy" loss function for weakly labelled images.
- Chapter 7 proves that generating NIR images based on large unlabelled datasets not only increases in-domain metrics but also makes models more robust to domain shifts.
- Finally, in chapter 8, Svetlana shows the positive effect of mixing channel augmentation, making models more generalizable.

At the same time, estimating canopy height (Chapter 6) is somewhat disconnected from increasing model robustness, the central message of the thesis. Though it's a reasonable extension of Chapter 4, as adding height data to a model makes it more stable, the majority of experiments for canopy height modelling need to be more directly relevant to the primary goal. However, section 6.3.9 explains how this model can be used in the settings of Chapter 4, so this drawback is a minor one.

A more critical issue is reporting the results of computation experiments. Unfortunately, all individual metrics are shown as average numbers without standard deviation. This information is crucial for the accurate analysis and interpretation of results. For example, if a proposed idea increased F1 score from 0.89 to 0.91, is it because the method works better? Or is it just a random deviation of this metric? Is this difference statistically significant or not? Adding std will give the necessary data for readers to understand the significance of improvement. Hopefully, the majority of metrics for the proposed methods are clearly higher than the baselines, so this reporting drawback doesn't compromise the key results of the work.

Overall, Svetlana demonstrated substantial experience in many modern deep-learning approaches as the spectrum of applied methods varies from networks for segmentation to generative models. The thesis contains an impressive number of data science projects with direct industrial applications. As mentioned above, every new chapter added more and more in-depth details about various aspects of the segmentation problems. I especially like that Svetlana systematically discusses data collection issues, e.g., costs. Without any doubt, she mastered this knowledge domain and created well-tailored deep

learning models for the most acute applied problems. The remote sensing community also recognized the results as Svetlana has published an impressive number of peer-reviewed articles, including seven (!) Q1 journal papers and a workshop paper at a well-established ICCV conference.

Despite a couple of drawbacks, my overall impression is strictly positive. Svetlana has done a tremendous amount of work, demonstrated excellent research skills and succeeded in several applied projects. Without any doubt, Svetlana proved her superior qualification as a mature scientist, and I recommend the highest grade.

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*