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Report on the bachelor thesis

Deep Learning for Tree Line Ecotone Mapping from Remote Sensing Data

submitted by

Jakub Dvořák

for the Bachelor in Physical Geography and Geoinformatics

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The thesis submitted by Mr Jakub Dvořák deals with automatic classification (through deep learning) of high-resolution optical remote sensing data for tree mapping. The manuscript of 76 pages is well-organized and is composed of 7 sections, a list of 117 references and 3 appendices. The scientific developments and discussions are easy to follow thanks to a good writing style, and the manuscript comes with the appropriate number and quality of illustrations. The main contributions of the thesis are a comparative assessment of existing classifiers on a specific remote sensing mapping problem and study site, and the improvement of a well-known deep network (U-Net) based on some adaptations proposed in the literature, leading to a novel network called KrakonosNet.

After a short introduction (section 1), main principles of deep learning are recalled (section 2), with a focus on networks tailored for semantic segmentation (especially the U-Net model that will be experimentally assessed in this study). Some applications of deep learning to remote sensing data are reviewed. Interestingly, the author proposes a critical discussion of the deep learning features available in the main geospatial software solutions. While it is not possible to offer a full coverage of deep learning methods and applications in remote sensing, an in-depth analysis of related works on tree mapping would have been useful to better underline the novelty and innovative material brought by this study. The section 3 is dedicated to the presentation of the dataset, containing mainly airborne images of the Krkonoše mountains in Czech Republic, but also elevation models that will be used only to generate automatically some reference data (these elevation models could have been used to feed the deep networks, at least for the sake of comparison). The section 4 aims to present the methods used in the study, from the class definition, the data pre-processing step (including the automatic annotation), the classifiers, the data partitioning and the evaluation metrics. More precisely, the author proposes to bring some adaptations to U-Net, through reducing the number of feature maps (and thus network parameters), batch normalization after each convolution, dropout, and parametric ReLU. The results are presented in section 5 and focus on the outcomes of the automatic annotation procedure, as well as the effects of using different splits between training and validation (but one can wonder how many runs were made when reporting the results, and if cross-validation was involved). The author then provides an insightful discussion that illustrates his scientific maturity, before concluding the study.

The experimental comparison includes some standard classifiers (MLC, SVM, RF) and two deep networks (U-Net and the proposed KrakonosNet). The input features are the pixel spectra in RGB and color IR images. The choices made by the author are well-explained but call for a number of comments. First, the standard classifiers are not fed with spatial features (only spectral signatures) and thus lack of information w.r.t. convolutional neural networks. It is not surprising to observe poorer performances of these standard classifiers if the spatial correlation that does exists in mapping trees is not taken into account. Furthermore, it seems that the samples provided to each classifier might vary (overlapping tiles for deep networks, less samples for training the SVM, etc). In this context, it is hard to report a fair comparison. The evaluation is conducted with pixelwise accuracy metrics while the trees to be mapped could be considered as objects given the image resolution, and thus it would have been interesting to also use object-based metrics such as IoU. As far as deep networks are concerned, one can wonder why a multi-modal network e.g. (Audebert et al., 2018) has not been used since it would allow to cope with both RBG and Color IR images. It seems that a single network taking 6 bands as input is used instead. This does not allow to initialize the network through fine-tuning e.g. from ImageNet. Another issue is related to the automatic annotation process that brought some salt and pepper noise and is thus far from perfect. In this context, the reliability of classification scores is probably weakened due to the errors in the reference data. These remarks can be considered as suggestions to further improve the quality of the study.

To conclude, the bachelor thesis presented by Jakub Dvořák is a well-written manuscript introducing some solid scientific work, with extensive experiments and critical discussions. I judge the quality of this bachelor thesis as **1 – excellent**.

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