ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

DIPLOMA THESIS REVIEW by SUPERVISOR

I. IDENTIFICATION INFORMATION

Thesis title:	Semantic Segmentation of Satellite Images using Deep Learning
Student:	Shivaprakash Muruganandham
Thesis:	Diploma thesis
Faculty/institution:	Faculty of Electrical Engineering (FEL)
Department/institution:	Department of Control Engineering
Supervisor:	Ing. Michal Reinštein, Ph.D.
Supervisor's department:	Department of Cybernetics, FEL, ČVUT

II. EVALUATION CRITERIA

Thesis assignment complexity: rather difficult assignment

Characterize this final thesis in detail and its relationships to previous or current projects. Comment what is difficult about this thesis (in case of a more difficult thesis, you may overlook some shortcomings that you would not in case of an easy assignment, and on the contrary, with an easy assignment those shortcomings should be evaluated more strictly).

The aim of the thesis was to design, implement, and experimentally evaluate a deep neural network for semantic segmentation of urban growth (man-made structures) in satellite images. Beside the deep network, resulting pipeline had to include image pre-processing algorithms to cope with input images of varying quality, resolution, and number of channels as well as environmental effects. State-of-the-art framework from Google, the TensorFlow, was recommended for the actual implementation. Semantic segmentation is one of the more difficult tasks in computer vision and deep learning. Due to very high variance in satellite images and complex theory behind deep neural networks, I consider these thesis aims to be more demanding than common practice.

Fulfilment of the assignment: fulfilled with minor objections

Assess whether the thesis meets the assignment statement. In comments indicate parts of the assignment that have not been fulfilled, completely or partially, or extensions of the thesis beyond the original assignment. If the assignment was not completely fulfilled, try to assess the importance, impact, and possibly also the reason of the insufficiencies.

There were four main points to be considered in the assignment statement:

1. Study the state-of-the-art literature relevant to the thesis (fulfilled fully in chapters 2 and 3).
2. Explore the TensorFlow framework and use it with Python to design, implement and evaluate a deep neural network (fulfilled fully in chapters 6 and 7; two network architectures were implemented in TensorFlow and evaluated).
3. For experimental evaluation use publicly available datasets and compare the final performance to given literature (fulfilled with minor objections in chapter 7; independent testing dataset, including annotations, was created to demonstrate generalization capability of the proposed models to unseen images).
4. Suggested approach: re-implement the VGG architecture into TensorFlow and its fractionally-strided convolution version (the suggested approach was successfully taken, valid conclusions and recommendations were presented).

My first objection concerns the number of instances that were considered for segmentation, i.e. the roads only. With the deep net architectures implemented and thanks to availably of labelled datasets, the task of urban growth could easily be extended to buildings as well. My second objection concerns the actual experimental evaluation. Better performance could be reached by exploiting algorithmic approach to hyper-parameter search (not doing it manually). Furthermore, using larger training dataset (including data augmentation) and letting it train for longer periods could also lead to better results. My third objection concerns the environmental effects, such as presence of clouds, that were not addressed in the thesis at all.

Activity: B - Very good

Assess whether the student was active during the course of the final thesis, whether he met the given deadlines, attended consultations and was adequately prepared for project meetings and reviews. Asses student's ability of individual creative work.

I appreciate the vast amount of literature and state-of-the-art papers the student studied, including the CS231 Open Stanford course on deep learning. The student was very active and creative, always prepared. My only minor objection concerns the underestimation of the time necessary for the actual experimental evaluation, since learning deep networks requires both computation power and sufficient time. This negative affected the achieved performance. Better results could have been achieved if more time was spend for example on implementing algorithm for hyper-parameter tuning and then having sufficient time for executing the experiments.

Factual and logical level of the thesis: B - Very good

Assess whether the thesis is correct as to the facts or if there are factual errors and inaccuracies. Evaluate further the logical structure of the thesis, links among the chapters, and the comprehensibility of the text for a reader.

The thesis is very well structured, well written, easy to follow, and respects the common practice in scientific literature. I appreciate the level of implementation details that can aid the reader to replicate the proposed solution. Also all the metrics used for experimental evaluation respect the recent practice in the state-of-the-art literature. However, there are several minor objections that have to be noted:

1. Some sections in the theoretical part cover unnecessary details that should better be only referenced; theoretical part could hence be shorter.
2. More space should be devoted to the actual experimental evaluation, but the Future work section is very much appreciated.
3. Data review chapter should include only description of the used datasets; any conclusions should be moved into the final chapter.

Formal level of the thesis A - Excellent

Assess the correctness of formalisms used in the thesis, the typographical and linguistic aspects.

The extent of the final thesis is adequate; all the formalities are met, including the abstract, list of figures, list of tables, etc. Some of the references are misplaced after the end of the sentence. I very much appreciate the LaTex template.

Bibliography A - Excellent

Evaluate the student's activity in acquisition and use of studying materials in his thesis. Characterize the choice of the sources. Discuss whether the student used all relevant sources, or whether he tried to solve problems that were already solved. Verify that all elements taken from other sources are properly differentiated from his own results and contributions. Comment if there was a possible violation of the citation ethics and if the bibliographical references are complete and in compliance with citation standards.

The thesis contains 49 references to publically available scientific publications (or other sources); even references to papers published very recently in 2016 are included. However, it has to be noted that due to very rapid development and vast amount of literature being published in the field of deep-learning every month, what is currently in the thesis considered as state-of the-art might very soon become outdated.

Other comments

Assess the level of applicability, technical quality, replicability of the experimental part and publication potential.

The results are pleasing, however, the thesis confirmed that it is very difficult to achieve good generalization capabilities for deep networks when deployed to satellite imagery. This suggests the applicability is rather limited to region specific networks. Due to sufficient technical detail in the thesis, the presented results could easily be replicated. The contribution presented in the thesis does not reach level sufficient for publication.

III. OVERALL EVALUATION

Overall evaluation of the final thesis is B – very good.

Date: 8.9.2016 Signature of the reviewer:

Review report of a final thesis
Czech Technical University in Prague

I. IDENTIFICATION

Thesis title:	Semantic Segmentation of Satellite Images using Deep Learning
Author:	Shivaprakash Muruganandham
Thesis type:	Master thesis
Faculty:	Faculty of Electrical Engineering
Reviewer:	Ing. Jakub Šimánek, Ph.D.
Affiliation of the reviewer:	Spaceknow, Inc.

II. EVALUATION

Difficulty of the assignment

The aim of the master thesis is to design, implement and experimentally evaluate deep learning algorithm, a variation of a neural network, which can label urban areas (man-made structures) in a satellite image. Both the application of deep learning and semantic segmentation of images are highly studied problems in the scientific community. Therefore, the master thesis assignment presents a very relevant topic of interest of adequate difficulty.

Fulfillment of the assignment

The main thesis requirements were fulfilled and the work meets the complexity and quality criteria of a master thesis.

Extent of the thesis

The work addresses the topic very well by studying the required theory and current state of the art solutions, obtaining and preparing the data needed to fulfill the assignment, designing and implementing of several deep learning architectures, and providing sufficient experimental evaluation. Author presents his ability of working with recent findings and research papers in the the presented field and covering all the needed steps in the development of a machine learning algorithm. The implementation is done in Python and an open source library for numerical computation TensorFlow; recently a frequent choice for many machine learning practitioners. Out of the many choices of segmenting regions of man-made structures, author chooses to segment roads in a satellite image. This could be considered as a straightforward task, however, despite the success of applying deep learning in the field, there are still opportunities for further improvement. My only suggestion would be to address better the problem of generalization of the algorithms to unseen data and comment on dealing with environmental effects - one of the main challenges of satellite imagery analysis.

Formal level of the thesis

The thesis is carefully written and generally easy to read. It presents selected research topic in three main chapters further structured into several sections. However, the work the analysis common practice and author's contributions and implementation details is sometimes merged in a less intuitive way. According to my opinion, these should be separated. A few wrongly used citations occur in the text. In few places, the flow of the presented sections and paragraphs could be reorganized.

Review report of a final thesis

Czech Technical University in Prague

III. OVERALL COMMENTS AND QUESTIONS

In overall, the thesis presents very well the topic of analyzing satellite imagery by the deep learning methods. I would like to point out author's ability of working with current scientific results and implementing them in the open source software frameworks.

Previously mentioned shortcomings are definitely not critical for the final outcome of the thesis.

Therefore, I recommend the defense of the thesis and I suggest the grade **B**.

Questions:

1) Environmental effects

Environmental effects in satellite imagery, such as frequent cloud cover, were not addressed in the thesis. What kind of such effects can you expect in satellite imagery and how would you propose to deal with those?

2) Generalization to other data

One of the main goals when designing a machine learning algorithm is how well it generalizes to unseen data. Can you comment on improving the model in order to generalize better to satellite imagery unseen both in spatial and time domain?

Prague, September 8, 2016

Ing. Jakub Šimánek, Ph.D.