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Review of the Dissertation Thesis *Trénovatelné metody pro automatické zpracování biomedicínských obrazů* (Trainable Methods for Automatic Biomedical Image Processing) **submitted by Ing. Václav Uher**

Thesis Assessment

This thesis investigates possibilities of productive segmentation of biomedical images. In computer vision and digital image processing, image segmentation is the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into a form that is more meaningful and easier to analyse. The success of image analysis in biomedical domains depends on reliability of segmentation, accuracy of partitioning, and speed of processing (real- or nearly real-time processing response) that generally involves very challenging problems promoting research of a lot of research and development projects. This type of research is aligned with the effort addressing automated machine learning that represents a fundamental shift in the way organizations of all sizes approach machine learning and data science. Research activities along this line are welcomed. Therefore, **the subject of the thesis is extremely relevant to the need of scientific community and several modern application domains and aligned with the current world-wide top-level research.**

The author of this thesis was invited to participate in the workshop addressing this topic at the Massachusetts Institute of Technology.

The introductory part briefly outlines the motivation and context for this research and characterizes the contents of the 5 involved chapters. The author could built up his research on experience gained from the development of the public domain tool IMMI (Image Mining) at the Department of Telecommunications.

Chapter 1 provides, in the first part, a brief overview of medical imaging methods and classical segmentation algorithms, and then the basic background to deep learning and segmentation. Several models of segmentation networks are introduced and compared. This investigation involves the U-net network that is an important input for the kernel research focus described in the later thesis parts. Further, methods for the training set extension and evaluation of results precision are discussed.
Though the thesis aims at providing contribution to automatic segmentation, the state of the art in automated machine learning that, among others, involves splitting machine-learning processes in pipelines is not discussed.
It would be useful to outline the trajectory of the development of the segmentation methods, both traditional and associated deep learning ones, show positioning of the research conducted in the thesis in this "big picture", and propose the future work. Unfortunately, no future work is mentioned.

There are several formal and structural bugs in Chapter 1. Most of them are enumerated below.

- Page 15: Figure 1.2 is not referred; PD is used but not explained; T1 and T2 are called "specific times" in one place and "specific sequences" in another place;
- Chapter is not well structured (its hierarchy is not appropriately chosen), e.g.; there is a very week relation of 1.2.3 to 1.2.2; 1.2.4 is quite isolated;
- Page 21: Sentence "Deep learning ovlivnilo prakticky vsechny oblasti, kde sa pouziva DL" is not logical;
- Figure 1.7 is not explained – therefore, its inclusion in the text was not neccessary (it brings no information value);
- Several figures are far away from the text places, where they are referred to;
- The work consists of 5 chapters (the highest structural level). The author names lower hierarchical levels, like sections and subsections, as chapters too (e.g., he writes "v kapitole 1.3.2");
- Figure 1.6 is not appropriately explained; the author did not apply an appropriate abstraction level for description:
- In Figure 11, there are explicit references to 11.a and 11.c in the text; however, no reference to 11.b.;
- Figure 1.20: tranlace → translace.

Chapter 2 enumerates a list of objectives that drive the research conducted in the thesis. This goal specification is based on the background and useful comparative studies provided by Chapter 1.

Chapter 3 describes the kernel contributions of the thesis that meet the objectives specified in Chapter 1: the proposal and realization of a universal method for

automatic segmentation of 3D medical data. The method is based on the U-Net network and optimizes the whole process of training and application of the model. It is possible to use it as a general segmentation algorithm for biomedical data. The whole solution including network model, development environment, and output optimization is described in detail. Finally, the whole algorithm is expressed formally by a pseudo-code.
It seems that the "one-shot design" method was used. The result of the design is only presented. How the design decisions were taken? Were other variants considered or even tested (simulated)?

Chapter 4 presents utilization of the developed solution in 2 use cases, segmentation of neuron cells and brain tissue, from the biomedical domain. This research part was conducted in an impressive way and presented using the following scheme: description of input data (Unfortunately, the origin of the data is not mentioned. Was it taken from a hospital, the Internet, etc?), original solution, results achieved by the 3D deep learning method proposed (Here, the influence of various options/parameters is systematically investigated and discussed.). Comparisons with other published work are presented too.

The thesis investigated the application of the solution developed to only two use cases. What about its portability to other use cases? Would it be possible to upgrade the solution to a generic framework involving software, application methodology (guideline), demonstrating use cases, and provide it as a Cloud service?

Publication activity and scientific competence of the author

The author has an impressive publication record (3 publication in journals with impact factors, 1 in a journal without impact factor, 20 in conference proceedings, 3 book chapters).
To sum up, it is possible to state that the Ph.D. candidate conducted a very good scientific work during his Ph. D. study and brought original contributions to data science and biomedicine.

Questions to the Ph.D. candidate

1. Is performance of the hardware and software environment a relevant issue?
2. What is the origin of the input data you used in experiments?
3. What about utilization in other scientific domains?
4. Do you see any rationales to upgrade the results to the tele-medicine sphere?

Conclusion

The author of the thesis proved to have an ability to perform research and to achieve relevant scientific results. I do recommend the thesis for presentation at the defence with the aim of receiving a Ph.D. degree. Due to my opinion, it fulfils recognized requirements for awarding of doctoral degree.

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Peter Brezany

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