

Review Statement for Ondřej Klíma's Doctoral Thesis

“Model-based 2D-3D registration methods for analysis of conventional radiographs”

July 10, 2022

As the reviewer nominated by Brno University of Technology, I respectfully make the following statement concerning the doctoral thesis of Mr. Ondřej Klíma, submitted for the fulfillment of the requirements of the PhD degree in Computer Science and Engineering. I consider the following details of the thesis: the position in the research field, originality, and contributions, including also the candidate's publications.

This thesis investigates the 3D analysis of conventional radiographs based on the registration of digital models into pairs of calibrated X-ray images. The goal is using intensity-based non-overlapping information to improve the current state-of-the-art methods to obtain computationally more efficient solutions with better accuracy. The proposed methods are applied for the reconstruction of complete intact models of long bones which suffer displaced diaphyseal fractures. Medical image processing is one of the main application areas of Computer Vision. Thus, the topic of the thesis is very well motivated. The main contributions are the intensity-based revision of non-overlapping area registration and the density-based registration pipeline for patient-specific bone models. The candidate motivates the proposed methods by describing shortcomings of current approaches and shows experimentally that the approach is computationally efficient and more accurate as compared to the existing solutions.

As a conclusion, the topic is appropriate to the particular area of the dissertation, and it is up-to-date from the viewpoint of the present level of knowledge.

The thesis consists of eleven chapters. In Chapter 1, the research field is shortly introduced, the focus of the work is defined, and the structure of the thesis is shown. The chapter is rather concise. The objectives should have been presented more clearly either as explicit research questions or as listed specific objectives, preferably with a illustrating figure. Chapters 2 and 3 cover computer-assisted methods in radiographs analysis. The candidate introduces methodological challenges, needed experimental setups, and compares available practical solutions. CT imaging is time-consuming, expensive, and radiation-intensive so the goal is to build a simpler yet robust system for preoperative planning using pairs of radiographs. The interest to focus especially on long bones could have been motivated more.

Chapters 4-9 contain the research contributions of the candidate. First, the main research question has been set: “It is possible to design a method performing reconstruction producing models with accurate shape and length that overcomes the capabilities of the state-of-the-art reconstruction methods.” Then, the corresponding publications as the reply to the research question have been presented, each chapter containing one publication, including the following novel scientific contributions: the intensity-based non-overlapping area 2D-3D registration considering also drop-outs for patient-specific bone models (Chapter 5), the reconstruction of uninjured patient-

specific bone models using density-based 2D-3D reconstruction of statistical shape and intensity models including the Levenberg-Marquardt optimization (Chapter 6), the computationally robust atlas-based 2D-3D reconstruction as compared to evolution strategies (Chapter 7), lossy compression of 3D statistical shape and intensity models for femoral bones to reduce storage space requirements (Chapter 8), and the design and evaluation of the 2D-3D reconstruction approach for long bones suffering diaphyseal injuries (Chapter 9). The methods could have been presented as algorithms to make them easier to understand and to reproduce. Moreover, the main pipeline could have been illustrated as a figure/flow chart.

Discussion and conclusions are given in Chapters 10 and 11. The contributions could have been summarized as a compact list.

Based on the considered matters, the work is original and contains a sufficient contribution to the area.

Related to the thesis, the candidate has published one journal article in Journal of Healthcare Engineering, four conference papers, and three extended conference abstracts. The journal is an internationally recognized journal with an impact factor, and most of the conferences are well-known international conferences. The candidate has written several joint publications with other researchers, and thus, the candidate has proven to be able to co-operate efficiently with other scientists. The candidate is the first author in all the publications. However, the role of each author could have been explained better in the thesis. According to Google Scholar, the candidate's h-index is 4 and there are 67 citations to the candidate's research work, showing that his publications have attracted other researchers.

As a conclusion, the doctoral thesis has been published at an appropriate level and the candidate has published actively showing the scientific quality.

Besides the clear merits of the thesis, there are also presentation shortcomings, including minor mistyping and misspelling, especially "the" missing in case of nouns. For pleasant readability, a figure should be presented after it has been mentioned in the text, not before. This problem is enhanced when the chronological order of citations is missing, for example, when the figure numbering does not match to the citation order. This is a problem especially in the chapters which are directly based on the candidate's publications, making the thesis challenging to read. Moreover, in Chapter 5 there seems to be citations to wrong figures and tables which are actually presented in Chapter 9. Since Chapters 5-9 are directly from the publications the corresponding copyrights should have been mentioned in the beginning of each chapter. Moreover, it should have been mentioned that the appendices presented in these chapters are not the part of the original publications. However, these appendices are very useful to understand the experimental setups. Despite these presentation problems, in general, the candidate has written a well-structured thesis which is comfortable to read.

The candidate has shown a good understanding of the key issues in the research field. The thesis clearly contains contribution to knowledge in the field of computer science and engineering. There are many references to related work, the research problems are

considered properly, and there are several scientific papers published based on the results of the thesis.

Based on the considerations presented in this review statement I conclude that the doctoral thesis meets the requirements of the proceedings leading to the PhD title conferment.

Professor Heikki Kälviäinen
Lappeenranta-Lahti University of Technology LUT
Finland