Review of the Dissertation Thesis

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Title of the Thesis: **Numerical and machine learning methods for medical image processing**

The thesis revolves around mathematical modelling in medical image processing. Namely, it focuses on three main problems: medical image registration, image deblurring, and estimation of the parameter T1 based on image data.

For medical image registration, there are proposed and derived two approaches. The first one is applied to register myocardium from a very challenging MOLLI image series. The approach consists of the segmentation of the object by the level set method, its representation by the signed-distance function, and determining the optical flow based on these functions. In the second, mechanics-based, approach, the registered object is discretized using an independent mesh, and the displacement is then calculated for each point of this mesh. In practical numerical experiments it is used for determination of the torsion of the left ventricle from MRI images series.

The second studied problem is image deblurring. It is formulated as a PDE constrained minimization problem, with the adjoint problem used in the minimization. It is solved iteratively by the gradient descent method with the primary and adjoint problem being solved in each iteration. The use of the method is tested on several images with different levels of added blur. The obtained results confirm the correctness of the proposed approach.

The last problem is the estimation of T1 relaxation time based on the MOLLI image series, where the model parameters are optimized to minimize the difference between the signal measured by MRI and generated using the model. The parameter optimization is done by the neural network and numerical optimization. The method is tested on the synthetic, phantom, and in vivo data, and discussion about the obtained results is rich and very detailed.

This aims of the PhD thesis were clearly fulfilled. The proposed approaches and methods with obtained results were published in renowned mathematical journals (Discrete and Continuous Dynamical System – Series S, IF = 2.425; Computers and Mathematics with Applications, IF = 3.476), medical journal (Pediatric Cardiology, IF = 1.838) as well as in the book series: Modeling Biomaterials. All these publications confirm the topicality and original contribution of the presented thesis to mathematics and medicine, as well as correctness of developed approaches. Moreover, from this publishing activity it is evident that the author successfully cooperated with many

researchers from other institutions, such as IKEM, INRIA, École Polytechnique, which is very interesting at such a young age and testifies to the quality of the student. The topicality of the thesis is also obvious from the very rich list of used sources, including many from the last decade. The student in the thesis demonstrated very good knowledge of methods of numerical mathematics as well as programming skills and ability to use many diverse software. Methods which were used are appropriate and author needed to cover various topics at a high level of expertise. The processing of the dissertation topic is at a high formal and content level, written in a very high level of English language. I appreciate that the author clearly states own contribution at the end of each chapter.

Conclusion:

I evaluate the thesis positively and I clearly recommend it to be accepted for the defence and to award the title PhD. to Ing. Kateřina Škardová afterwards.

Question for discussion:

You compare the quality of your results with the results obtained using standard methods. Could it be possible to do this comparison also with respect to the computational time?

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