AI based image enhancement for reduced radiation exposure in CT imaging

Type: Postdoc or PhD

Principal Investigators

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Background

Previously, several authors demonstrated that algorithms based on deep neural networks can be used for the enhancement of low-quality medical images [1–4]. The authors proposed certain types of network architectures that can be trained for the reduction of image artifacts and noise in low-dose CT images. For the patient, this means a lower exposure to ionizing radiation, while maintaining the same diagnostic significance of the CT image. The U.S. Food and Drug Administration (FDA) already cleared one such product for PET imaging (SubtlePET, Subtle Medical, USA).

However, algorithms like this carry a certain risk. The enhancement of the image quality with the help of AI based algorithms could suggest a high image quality to the doctor, despite a potential loss of important anatomical detail during the optimization process. E.g. it was shown for AI based algorithms for image reconstruction, that there is "a variety in the failure of recovering structural changes […], ranging from complete removal of details to more subtle distortions and blurring of the features." [5]. To ensure safe diagnostics for the patient, it is essential to explore the limits of such algorithms and to define the necessary requirements.

Project Aim, Objectives and Program

In this project, the suitability of AI based algorithms (in particular deep neural networks) for image optimization in CT imaging will be investigated. Special attention will be paid on the development of test criteria aimed on assessment of robustness of such algorithms (based on methods as described in [5]) which can be used later to increase the confidence in such algorithms and thus accelerate the broad application of AI driven algorithms in hospitals.

The first objective is to identify high-risk algorithms (especially these based on generative adversarial networks, GANs) for image enhancement literature and to establish a database of test-cases. These test-cases do not necessarily include patient data alone, but in addition synthetic test-data obtained from already established Monte Carlo methods and phantom measurements at the departments CT-scanner. As a second objective, the identified algorithms will be implemented and trained on publicly available patient data (cf. available data). The limitations of the algorithms will be examined by application of objective measures for image quality like observer models [6].

Ultimately, the final objective is to derive criteria reflecting the robustness of the implemented algorithms.

Available data

Several databases for medical images are freely available (visceral, LCTSC, Open-Access Medical Image Repositories) and are currently used for training of U-Net based algorithms in our project on automatic image segmentation. In addition, our department maintains contact with various partners such as the German Cancer Research Center (DKFZ).

We provide several facilities like a CT-scanner and several X-ray tubes on site. These facilities can be used for the creation of synthetic data. Also, synthetic data will be generated within the framework of this project using Monte Carlo methods for radiation transport (EGSnrc), that are already established at our department. For this, we provide detailed photon spectra of the source of the departments CT-scanner as well as a ready to use procedure for accessing the corresponding bow-tie filtration [7].

Collaboration

- Heidelberg University, Medical Faculty
- German Cancer Research Center (DKFZ) (current collaborations on AI based segmentation of CT datasets and AI based dose calculation for personalized medicine)
- Technical University of Dortmund, Department of Physics (current collaborations on AI based segmentation of CT datasets and AI based dose calculation for personalized medicine)
- Städtisches Klinikum Braunschweig (collaboration within a research project to unify dose parameters in CT and CBCT)

Candidate Requirements

- MSc. in physics, medical physics or similar
- Affinity to software development
- Basic knowledge in Python, preferably experience with TensorFlow/Keras
- Knowledge of Monte-Carlo software packages like EGSnrc or Geant4 are advantageous

References

[1] Umehara K, Ota J and Ishida T 2018 Application of Super-Resolution Convolutional Neural Network for Enhancing Image Resolution in Chest CT *J. Digit. Imaging* **31** 441–50

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[3] Zhang Y, Yue N, Su M, Liu B, Ding Y, Zhou Y, Wang H, Kuang Y and Nie K 2020 Improving CBCT Quality to CT Level using Deep-Learning with Generative Adversarial Network *Med. Phys.* mp.14624

[4] Yuan N, Zhou J and Qi J 2020 Half2Half: deep neural network based CT image denoising without independent reference data *Phys. Med. Biol.* **65** 215020

[5] Antun V, Renna F, Poon C, Adcock B and Hansen A C 2020 On instabilities of deep learning in image reconstruction and the potential costs of AI *Proc. Natl. Acad. Sci.* **117** 30088–95

[6] Barrett H H, Yao J, Rolland J P and Myers K J 1993 Model observers for assessment of image quality *Proc. Natl. Acad. Sci. U. S. A.* **90** 9758–65

[7] Rosendahl S, Büermann L, Borowski M, Kortesniemi M, Sundell V M, Kosunen A and Siiskonen T 2019 CT beam dosimetric characterization procedure for personalized dosimetry *Phys. Med. Biol.* **64**