DFG funded project "Radiography driven deformable image registration in adaptive proton therapy"

2 PhD positions available

The research group of Prof. Marco Riboldi at the Department of Medical Physics, Faculty of Physics of the Ludwig-Maximilians-Universität München (LMU), offers 2 PhD positions to investigate the feasibility of adaptive proton therapy based on proton radiographies. The positions are funded by the German Research Foundation (DFG). The research stems from the outcomes of a previous related project, where a framework for 2D-3D image registration has been developed to adapt the 3D treatment planning CT based on in-room acquired 2D proton images [1, 2].

Project description, tasks & goals

The activities planned in this DFG-funded renewal project are meant to complement the ongoing research efforts toward the development of clinical proton imaging acquisition systems [3]. Alongside the implementation of clinical imaging devices, the existing gaps can be summarized as follows: (1) the absence of integrated methods to concurrently account for anatomical changes uncertainties in the proton range in a daily adaptive plan scenario, (2) the need for a simulation environment where inaccuracies in adaptation are linked to variations in dosimetric outcomes and (3) the lack of accurate anthropomorphic phantoms for experimental validation and quality assurance of adaptive protocols. The proposal aims at the exploitation of the 2D-3D registration framework and the experimental phantom development skills developed throughout the previous DFG project.

The PhD positions will develop original contributions to address the previously mentioned research gaps. The specific tasks for each position can be summarized as follows.

Position A. In this PhD project, we aim to achieve the integration between the available 2D-3D registration framework and online refinement of the calibration between Hounsfield units (HU) and relative stopping power (RSP), as developed in the DFG project HIGH-ART [4]. Once available, the integrated tool will be exploited in simulation to quantify the dosimetric impact of adaptation based on proton radiographies, with a focus on lung cancer cases to account for inter and intra-fractional adaptation. The project entails the following work packages:

1. Integration of 2D-3D registration and calibration refinement
   (a) Selection of the clinical database and data pre-processing
   (b) Implementation and comparison of a sequential/joint optimization model
2. Analyze the impact of proton-radiography based adaptation in dose delivery
   (a) Treatment planning on selected lung 4D-CT
   (b) Evaluation of the uncertainty in tumor tracking based on proton radiographies
   (c) Implementation of plan adaptation and motion correction, with quantification of improvements in dose delivery

Position B In this second PhD project, we will develop a 3D printed multimodal anthropomorphic phantom to test plan adaptation in future studies. The phantom will be designed to meet the specific requirements in proton imaging, and will serve for a possible experimental benchmark of adaptive proton therapy. The project is structured in the following work packages:

1. Development of a 4D multimodal anthropomorphic phantom
   (a) Anatomical segmentation of clinical cases, relying on AI tools
   (b) Overview of the literature and design of the actuation mechanism
   (c) Realization of the thorax structure and of the deformable lung realization
   (d) Assembly and testing of the complete phantom
   (e) Multi-modal imaging characterization
2. Test of combined 2D-3D registration and calibration refinement on phantom images
3. Preparation of phantom construction design for research use (open-source) to be shared with other groups.

Position description and working place

The research project will offer a broad spectrum of tasks for both positions, including the further development of the simulation infrastructure and the realization of physical phantoms. Coordination in the activities for the two advertised positions is envisioned under the guidance of the project PI (Prof. Marco Riboldi). Collaboration with the LMU University Hospital in Großhadern will ensure access to the most advanced imaging technologies and first-class expertise in treatment planning, as required for the project. The salary for both positions will be 75% TV-L E13 for a duration of 36 months.

The working place will be at the Forschungszentrum Garching, which is well connected with public transportation to the city of Munich, including direct connection to the LMU University Hospital. The successful candidate will work in a highly motivated and well established team within a multidisciplinary and international network embedded in a stimulating scientific environment, with a long tradition of collaboration and excellence in biomedical research, with outstanding research and clinical infrastructures. Disabled candidates are preferentially considered in case of equal qualification. Applications from women are highly encouraged. The candidate will be under the academic guidance of Professor Marco Riboldi.

Requirements & Qualifications

- MSc in Physics or Engineering, preferably in Medical Physics or Biomedical Engineering
- Strong academic record
- Medical imaging and / or image processing background
- Fluent English knowledge (spoken and written)
- Basic programming skills in Python, MATLAB or C++
- Technical proficiency, scientific creativity, team working skills
- Solid experimental skills

Application

If you are interested, please send your electronic application (**curriculum vitae, motivational letter, transcript of records and contact information or letters from two references**) **until 28/02/2025** to the following contacts:

Prof. Dr. Marco Riboldi
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Please indicate in the electronic application to which position (**position A** or **position B**) you intend to apply.

References

[1] Palaniappan Prasannakumar et al. "X-ray CT adaptation based on a 2D–3D deformable image registration framework using simulated in-room proton radiographies". In: *Physics in Medicine and Biology* 67.4 (2022), p. 045003.

[2] Palaniappan Prasannakumar et al. "Multi-stage image registration based on list-mode proton radiographies for small animal proton irradiation: A simulation study". In: *Zeitschrift fur medizinische Physik* 34.4 (2024), pp. 521–532.

[3] Robert P Johnson. "Meeting the detector challenges for pre-clinical proton and ion computed tomography". In: *Physics in Medicine and Biology* 69.11 (2024), 11TR02.

[4] Gianoli Chiara et al. "Patient-specific CT calibration based on ion radiography for different detector configurations in 1H, 4He and 12C ion pencil beam scanning". In: *Physics in Medicine and Biology* 65.24 (2020), p. 245014.