Multimodal Imaging: Correlating Spectral Photon-Counting CBCT with in-beam PET for Quantitative Tissue Characterization

Multimodal imaging offers the possibility of combining complementary information about physiology, tissue composition and function. In proton therapy research, accurate tissue characterization is particularly important for treatment planning and range verification. While computed tomography (CT) provides anatomical information and allows the estimation of the relative stopping power (RSP), in-beam positron emission tomography (PET) provides range verification as well as functional and molecular information through the detection of positron-emitting isotopes.

Spectral photon-counting CT additionally resolves the energy dependence of X-ray attenuation. Through material decomposition, it provides quantitative information on tissue composition and can improve RSP estimation. In a complementary way, the dynamic analysis of in-beam PET data, i.e. of the time evolution of the signal from positron emitters with different half-lives (e.g. 11C and 15O), also carries information on the elemental composition of the irradiated tissue.

The general goal of this project is to investigate the relationship between material-decomposed spectral photon-counting cone-beam CT (PC-CBCT) images and co-registered in-beam PET images. By combining the complementary information from both modalities, the project aims to explore whether material-specific information obtained from spectral CBCT can be correlated with the spatial distribution and isotope composition measured by PET in-beam. This provides an opportunity to investigate the physical relationship between X-ray attenuation, material composition and isotope distributions, both in phantoms and potentially in vivo, and to assess the potential of multimodal imaging for improved tissue characterization.

The student will work with experimental spectral PC-CBCT and PET datasets, perform image reconstruction and material decomposition, and refine image co-registration between the two modalities. Different reconstruction and image-processing approaches will be investigated to optimize image quality and quantitative accuracy. Based on the resulting multimodal datasets, correlations between spectral imaging parameters and PET-derived isotope distributions will be evaluated.

The project is carried out at the Chair of Medical Physics of LMU Munich and is embedded in three ongoing projects at the Chair, SIRMIO, MCQST and ACACIA (PI: Prof. Dr. Katia Parodi). It will draw on the expertise available in these projects in photon-

counting detector technology, spectral imaging, PET imaging, image reconstruction and radiation physics.

The ideal candidate has:

- A strong interest in medical imaging and its underlying physical principles
- Interest in multimodal imaging and quantitative image analysis
- Experience in programming with Python, C/C++
- Basic knowledge of image reconstruction and image processing
- Interest in radiation physics, detector physics and material interactions
- Independent working style, scientific curiosity and analytical thinking
- Ability to work in an interdisciplinary team
- Good English knowledge (spoken and written)

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