Proton CT with pencil beam scanning and integrating detectors

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Context

The project is a collaboration between the LMU (Munich), the IPNL (Lyon) and the CREATIS (Lyon), funded by the Franco-Bavarian cooperation center. The master student will realize the collaboration between these institutes with stays in both Lyon and Munich (proportions to be negotiated).

Proton Computed Tomography (pCT) has been proposed at the same time as x-ray CT (xCT). It is based on a measure of the energy loss of protons through matter that can be used to reconstruct the 3D map of the stopping power of the tissues of the scanned object. xCT has rapidly been preferred to pCT because x-ray sources are cheaper and more compact than proton sources. pCT also suffers from a poorer spatial resolution due to continuous deflection from the nuclei of the traversed matter (multiple Coulomb scattering).

Currently, there is a renewed interest in pCT because proton sources are built for treatment and pCT can improve treatment planning compared to xCT. The issue of spatial resolution could be handled by the acquisition of the position and the direction of each proton before and after the object, which can be used to estimate their most likely path [3]. However, the design of such pCT scanners faces technological challenges that have prevented the development of a commercial solution. It would be highly valuable to develop another solution using detectors in an integration mode [1], i.e., that integrate proton information for a substantial number of protons. This for example can be the utilization of the total Bragg curve of a proton pencil beam, instead of using each proton's energy loss.

Objective

The purpose of this master internship is to propose and characterize a scanner that would use detectors that integrate the position and the energy of protons in combination with proton pencil beam scanning (PBS).

Tasks

- Propose and simulate a pCT scanner with detectors that integrate the position and the energy of protons over a substantial number of protons (PB),
- Propose and simulate a scanning scheme that would make efficient use of the PBS,
- Reconstruct pCT images from the simulated data,
- Compare the solution to a simulated pCT scanner with list-mode acquisition and reconstruction [2].

Required skills

- **Education**: master student in image processing, medical physics or particle physics.
- **Scientific interests**: computer sciences (medical image processing), x-ray and particle physics, Monte Carlo simulations.
- **Programming skills**: C++.
- **Languages**: English required, French and German optional.

Practical information

- **Location**: LMU, Munich, Germany and Centre Léon Bérard, Lyon, France.
- **Period**: in 2014 and 2015 (duration negotiable).
- Send CV and a brief statement of interest by email to Georgios Dedes (G.Dedes@physik.uni-muenchen.de) and Simon Rit (simon.rit@creatis.insa-lyon.fr).

References

[1] I. Rinaldi, S. Brons, J. Gordon, R. Panse, B. Voss, O. Jäkel, and K. Parodi. Experimental characterization of a prototype detector system for carbon ion radiography and tomography. *Phys Med Biol*, 58(3):413–427, Feb 2013.

[2] S. Rit, G. Dedes, N. Freud, D. Sarrut, and J.M. Létang. Filtered backprojection proton CT reconstruction along most likely paths. *Med Phys*, 40(3):031103, 2013.

[3] R.W. Schulte, V. Bashkirov, M.C. Loss Klock, T. Li, A.J. Wroe, I. Evseev, D.C. Williams, and T. Satogata. Density resolution of proton computed tomography. *Med Phys*, 32(4):1035–1046, Apr 2005.