MSc project: A novel method for PET image reconstruction

Introduction
In vivo molecular imaging is a discipline at the intersection of molecular biology and medical imaging, It is based on the use of biomarkers to probe molecular targets or pathways in living organisms without perturbing them. Essential requirements are the ability to image these biomarkers three- or four-dimensionally, quantitatively, with high spatial resolution, high molecular sensitivity, and high signal specificity.

Imaging of biomarkers radiolabeled with isotopes that decay by positron emission, using an imaging technique called positron emission tomography (PET), provides the best spatial resolution, molecular sensitivity (~10^6 times better than fMRI) and quantitative accuracy available today. PET is based on the detection of the pairs of gamma rays created in the annihilation of positrons with electrons. PET is often combined with CT or MRI to provide anatomical reference for the molecular imaging data.

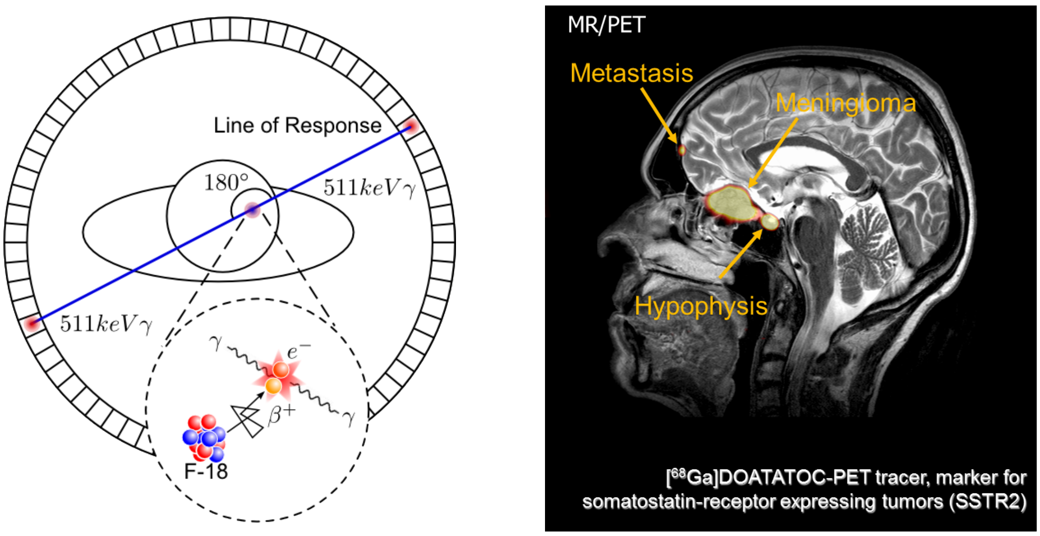

Figure 1. Principle of positron emission tomography (left) and combined PET/MRI image of a patient with a brain tumor.

Project description
PET image reconstruction is practically based on first calculating the 'system matrix' that describes how each single voxel affects the detector response. This makes the problem discrete and can be done by a Monte Carlo code, taking as input the patient geometry and tissue properties (scattering, attenuation). This data, together with the actually measured response, is then used to reconstruct the source (i.e., the radiotracer concentration) in the body through a discrete optimization algorithm. Such iterative reconstruction algorithms are very time-consuming and may take up to several hours to complete.

Here we will investigate a completely new idea for source reconstruction. In this method we view the reconstruction as a continuous optimization problem that can be formulated precisely in terms of the radiation equations (the linear Boltzmann equation) describing the particle behavior from source to detector. This bypasses the necessity of the system matrix completely: after numerical solution of the set of partial differential equations (PDEs), the optimal source distribution is known. It is expected that this can be done in much less time than mentioned before.

The goals of this MSc project are threefold:

- Study and implement an optimization strategy around our existing Boltzmann solvers
- Construct detector response from a known source in model geometries and attempt study reconstruction quality
- Deliver a proof of principle of the method for real-life problems

We are looking for
an enthusiastic student who likes mathematical modeling and development of simulation tools with a purpose of practical application.

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