Yale-NJUPT Senior Project

Yale PET Center

Yale Positron Emission Tomography (PET) Research Center is dedicated to providing the highest quality of nuclear imaging research. PET is a non-invasive diagnostic scanning technique that provides researchers and clinicians with quantitative visual images of organ function. PET scans can detect biochemical changes in body tissues before structural changes occur from disease. This information allows clinicians to be proactive in their treatments and enables researchers to develop early biomarkers of disease that can aid diagnosis and advance drug development. Please see details at http://petcenter.yale.edu/.

Our research projects focus on 1) New algorithms for image reconstruction for PET, 2) Development of new image processing methodologies to improve the quality and quantitative accuracy of PET, 3) creation of mathematical models for novel radiopharmaceuticals to produce images of physiological parameters, and 4) application of PET tracers in clinical and preclinical populations for the study of disease mechanisms and treatment outcomes. Yale students and many international students in biomedical engineering and other disciplines participate in cutting-edge research in these areas.

Objective

The senior-year student is expected to perform his/her senior project which is closely related/in parallel to on-going cutting-edge researches under the guidance of mentor(s) at Yale University. He/she will receive intensive training in terms of research methodology, research-article reading skills, English oral-presentation skills and English writing skills. The final project report is expected be in both Chinese and English. Potential publication opportunities regarding the project depend on the quality of the study.

Mentors at Yale

Dr. Richard E. Carson (Professor of Biomedical Engineering & Radiology and Biomedical Imaging; Director of the Yale PET Center; Director of Graduate Studies in Biomedical Engineering)

Dr. Chi Liu (Associate Professor of Biomedical Engineering & Radiology and Biomedical Imaging)

Dr. Yihuan Lu (Associate Research Scientist of Radiology and Biomedical Imaging)

Qualifications

Knowledge: good understanding of Signal Processing and Signal & System; proficient in vector/matrix mathematical expressions (linear algebra); basic knowledge of statistics. Any knowledge of image processing/analysis is a plus.

Desired personality: skeptical, self-motivated, passionate and dedicated.

Programming: experience with MATLAB and C/C++.

English: TOEFL iBT speaking/listening > 22 points or equivalent level is desired but not a must. English communication skill will be assessed during Skype interview.

Desirable qualifications: knowledge of optimization theory; experience in mathematical modeling; participation of any scientific project in one lab.

Project Duration and Cost

Six to ten months depending on the circumstances.

No tuition cost at Yale side. Living expenses and traveling medical insurances must be self-supported or supported by NJUPT. No school dormitory is provided but housing advice will be given. Living cost estimate: $600-800 (single room)/month or $900-$1400 (studio or one-bedroom apartment), and $300-600/month on food.

Academic Environment

The student will have free access to Yale University resources, such as Sterling Memorial Library (http://web.library.yale.edu/building/sterling-library), Yale Peabody Museum of Natural History (http://peabody.yale.edu), Yale University Art Gallery (http://artgallery.yale.edu), etc.

The student will have access to varieties of extramural activities organized by Yale Office of International Students and Scholars (http://oiss.yale.edu/calendar).

The student is encouraged to attend the seminars at Yale School of Medicine, such as weekly Yale PET center seminar (https://tauruspet.med.yale.edu/wiki/index.php/PET_Imaging_Lab_meeting) lead by Dr. Richard Carson, weekly Medical Grand Rounds (https://tools.medicine.yale.edu/calendar/) given by established researchers or clinicians, etc.

The student is encouraged to join other research group meetings, such as monthly Project Discussion meeting, weekly Deep Learning, etc. The student is also encouraged to communicate with all other researchers and staff members at the PET Center regarding not only research questions, but also studying and career plans.

Topics for Senior Project

Project 1. Automated data-driven approach for body motion detection in PET

Voluntary body motion is a source of error in PET imaging (Figure 1 A), particularly for dynamic studies with long scan durations which collect a series of images over time ("frames"). Current motion correction approaches include software-based image-to-image registration and hardware-based external motion tracking. Both approaches have limitations, i.e. the former method does not correct for intra-frame motion whereas the latter is too complex for routine clinical use. Lu et al. [1] at the Yale PET Center has developed a new data-driven motion detection approach followed by event-by-event motion correction (Figure 1 B). Data-driven means that the PET data themselves are used to deduce when body motion occurs. Initial success is to be published [1]; however, **automated motion detection, based on count statistics, has not yet been established. The senior project will be focusing on this study, using simulated and actual patient data.** We expect that the testing of this approach with more data will lead to **highly robust motion detection performance.**

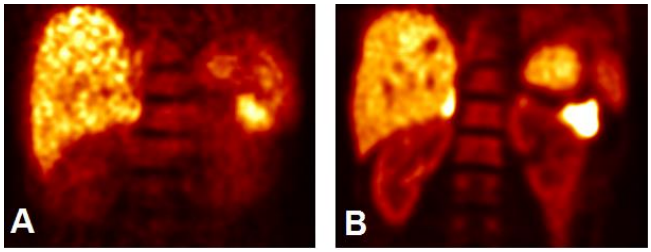

Figure 1. A) Lower abdominal imaging PET image without body motion correction. All the organs are completely blurred and image cannot be used for further analysis. B) With body motion correction [1], blurring and tracer concentration is largely restored.

Project 2. Data-driven head motion correction with the aid of machine learning/deep learning-based image denoising technique for PET

There is a growing research interest in brain disease, e.g. Alzheimer, depression, and Parkinson's. PET brain imaging provides in-vivo images which help researchers/doctors to understand or stage the disease [2]. However, head motion during the PET study causes error in tracer uptake quantification (Figure 2 A) and even incorrect diagnosis of the disease. The Yale PET Center has been using hardware-based external motion tracking, i.e. Vicra system, which accurately detects/corrects head motion for the Siemens HRRT PET scanner (Figure 2 B); however, such approach is too complex for routine clinical use. Recently, Lu et al. [3] has established a data-driven head motion correction technique, however, such

approach requires broad-distributed tracer to be robust in motion estimation using the image registration technique. **The senior project will be focusing on implementing a machine learning/deep learning-based image denoising technique to improve the robustness of motion estimation for other more challenging tracers, e.g. ^{11}C-Raclopride.** This study will help the data-driven method to be more widely used in the Yale PET Center and even other institutes.

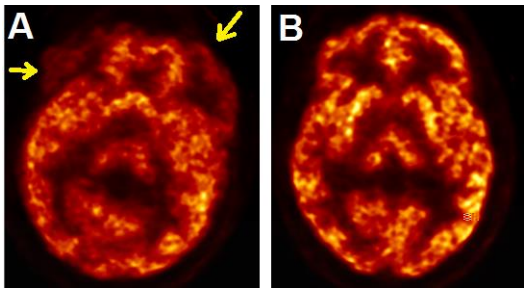

Figure 2. A) Reconstructed brain image without motion correction. Observable image blurring is shown (arrows). B) With event-by-event motion correction [3], the blurring is recovered.

Project 3. Improved Respiratory Motion Correction in PET/CT – Respiratory motion model exploration

Respiratory motion degrades the image quality of PET images by introducing blurring (Figure 3 A). Recently, the Yale PET Center has implemented a state-of-art technique, INTernal-EXternal (INTEX), to event-by-event correct respiratory motion during the image reconstruction [4-7] (Figure 3 B). However, INTEX in [4-7] assumed a fixed linear relationship between the 1-D external signal and the internal organ's movement. Such assumption has been shown to be not accurate for certain population [8]. **The senior project will be focusing on exploring new respiratory motion models to improve the accuracy of INTEX for real patient data**. This study will help the respiratory motion correction technique to be highly personalizable for each individual patient.

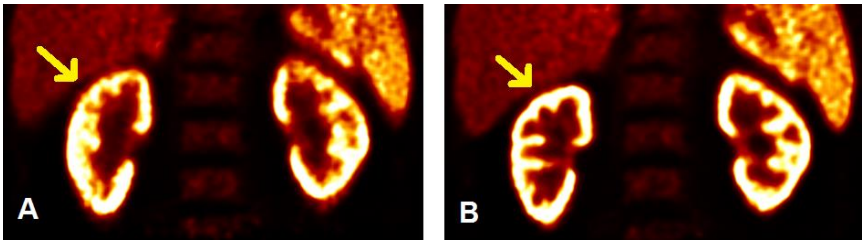

Figure 3. A) Lower abdominal imaging PET image without respiratory motion correction. B) With respiratory motion correction found in [7]. Arrows point at the left kidney. With respiratory motion correction, the contrast and kidney cortex fine structure are recovered.

Contact information

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Please contact Dr. Yihuan Lu for project details. (Yihuan.lu@yale.edu)

Reference

[1] Y. Lu, S. Ren, *et al.*, "Non-rigid event-by-event body motion correction with automated data-driven motion detection for static and dynamic PET," *European Journal of Nuclear Medicine and Molecular Imaging,* vol. (Submitted), 2018.
[2] S. J. Finnema, N. B. Nabulsi, *et al.*, "Imaging synaptic density in the living human brain," *Science Translational Medicine,* vol. 8, pp. 348ra96-348ra96, 2016.
[3] Y. Lu, M. Naganawa, *et al.*, "Data-driven motion detection and event-by-event correction for brain PET: Comparison with Vicra for dynamic studies", *Journal of Nuclear Medicine,* vol. (Submitted), 2018.
[4] X. Jin, C. Chan, *et al.*, "List-mode reconstruction for the Biograph mCT with physics modeling and event-by-event motion correction," *Physics in Medicine and Biology,* vol. 58, pp. 5567-5591, Aug 21 2013.
[5] Y. Yu, C. Chan, *et al.*, "Event-by-Event Continuous Respiratory Motion Correction for Dynamic PET Imaging," *Journal of Nuclear Medicine,* Feb 23 2016.
[6] C. Chan, J. Onofrey, *et al.*, "Non-rigid Event-by-event Continuous Respiratory Motion Compensated Listmode Reconstruction for PET," *IEEE Trans of Medical Imaging*, 2018.
[7] Y. Lu, K. Fontaine, *et al.*, "Non-Rigid Event-by-event Respiratory Motion Compensation for PET/CT with Motion Information Derived from Matched Attenuation Corrected Gated PET Data," *Journal of nuclear Medicine,* 2018.
[8] Y. Lu, K. Fontaine, *et al.*, " Accounting for Breathing Pattern Variability and Baseline Shift in Event-by-Event Respiratory Motion Correction in PET Using Dynamic Internal-External Motion Correlation," *IEEE MIC,* 2017.