**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 <https://medicine.yale.edu/pet/>

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.

# Objectives

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

# Qualifications

Programming skill: must be proficient in MATLAB, proficient in C/C++ and/or CUDA/Python is a plus. 2000+ lines minimal coding experience. Computer science- related major is a plus.

Minimal GPA requirement: 3.0/5.0. Note: final evaluation of the candidate will NOT be based on his/her GPA.

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 or neural network is a plus.

English: TOEFL iBT speaking/listening > 22 points or equivalent level is desired but not a must. English communication skill will be assessed during online 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: $600-900 (single room)/month or $1000-$1500 (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. Deep-learning based head motion estimation

Head movement is a major limitation in brain PET imaging, which results in image artifacts and quantification errors. In the past, many methods have been proposed to correct head motion. However, to date, there is no approach that can **track head motion continuously *without* using an external device**. These challenges motivated us to develop an approach that can be used for real-time head motion tracking during PET imaging without the use of external devices, i.e., a data-driven method that only uses PET raw data. We propose to develop a deep learning-based framework capable of real time head motion tracking during brain PET imaging. **The senior project will be focusing on implementing a machine learning/deep learning-based head motion estimation technique using maximum-intensity projection images of a brain for both High Resolution Research Tomograph and Siemens mCT PET scanners.**

# 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. However, head motion during the PET study causes error in tracer uptake quantification 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; however, such approach is too complex for routine clinical use. Recently, Lu et al. 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. 11C-Raclopride.** This study will help the data-driven method to be more widely used in the Yale PET Center and even other institutes.

# Contact information

Please contact Prof. Liya Huang (黄丽亚) at NJUPT for application details. (Huangly@njupt.edu.cn)

Please contact Dr. Yihuan Lu (卢一奂) for project details. (Yihuan.lu@yale.edu)

**Next page lists the students who participated this program. Please feel free to reach out to any of them through their email addresses for any questions.**

# Program Alumni

**2019-2020**

**张家祯** (jiazhen.zhang@yale.edu; jzzhang624@163.com)

南京邮电大学贝尔英才学院16级理工科强化班(信息安全)专业的大四本科生，现在正在耶鲁大学PET中心进行毕业设计项目。在南邮期间, 完成省级大学生创新训练项目并以录用EI会议论文一篇、公开发明专利一项、受理实用新型专利一项成功结项。在耶鲁大学PET中心, 我毕业设计的方向是PET成像中呼吸运动纠正算法的质量评估。我以第一作者提交了题为 “An objective evaluation method for respiratory motion correction in TOF PET”的2020 IEEE-NSS/MIC会议论文一篇。参与利用深度学习生成PET衰减矫正图工, 并以共同作者身份提交一篇2020 IEEE-NSS/MIC会议论文。

**2018-2019**

**孙辰** (c97sun@uwaterloo.ca)

南京邮电大学15级本科生，信息安全方向。在校期间担任数学建模协会会长，曾获得数模美赛M奖。曾于中国普天公司实习，负责C++后端开发。大四期间赴耶鲁大学PET中心完成毕业设计，论文被评为优秀毕业设计。在耶鲁大学毕设期间以第一作者发表2019 IEEE-NSS/MIC会议论文一篇，题为“A data-driven quality control method for head motion tracking in PET”, 录用后论文被选为会议口述报告。现就读于加拿大滑铁卢大学MASc项目，研究兴趣包括机器学习，对抗攻击以及图像压缩等。

**霍南** (nhuo1@jhu.edu)

南京邮电大学15级贝尔英才学院理工科强化2班。在本科期间，曾以第二作者发表两篇会议论文；以第一作者和第二作者发表两篇国内期刊论文。曾获得：贝尔英才学院金质荣誉勋章，南京邮电大学优秀毕业生，南京邮电大学第二届年度人物；贝尔英才院“ 十佳卓越学生 ”，“ 三好学生标兵 ”等；获得校一等奖学金 、二等奖学金若干。参加美国哥伦比亚大学学习营；参加美国加州大学欧文分校暑期学期交换；大四期间前往美国耶鲁大学PET中心完成毕业设计，毕业设计方向为PET成像中基于数据驱动的心脏运动门控优化, 并评为校优秀毕业设计。现就读于美国约翰霍普金斯大学计算机专业。在核医学领域，在卢一奂老师的推荐下我加入了约翰霍普金斯大学核医学实验室，目前在研究SPECT肾脏肿瘤检测。