Small Animal Neurodegenerative Phantom Toolkit for Semiconductor PET

J. Kroeger[1] , A. Groll[1], J. Smith[1], Ling-Jian Meng[1,2]
[1]Department of Nuclear, Plasma, and Radiological Engineering, [2] Beckman Institute, University of Illinois at Urbana-Champaign

INTRODUCTION

The need for development of high resolution imaging (sub-millimeter) increases as more and more people get neurodegenerative diseases. The current use of positron emission tomography (PET) may be improved upon for application in neurodegenerative imaging.

Improvements in PET system performance can be achieved through the revision of the detector technology. Updating to a pixelated semiconductor detector made from CdTe that have the potential to image down to the pixel in an area of 350 µm x 350 µm pixels. However, implementing a spatial resolution by means of semiconductor detectors produces challenges with sensitivity as well as a high chance coincidence rate due to the intrinsic physics of the system.

Using the Allen Mouse Brain Atlas, a 3D printable phantom is currently being developed toward the objective of eventually creating phenotype and timeline similar animal models for Alzheimer's Disease (AD) and AD related diseases. This toolkit would allow phantom based preclinical performance assessment of emerging PET systems.

AIM

- Understanding a key biology of interest
- Developing a means to utilize the Allen Mouse Brain Atlas for 3D printers
- Printing and testing disease like animal phantoms
- Evaluating the phantom in a CdTe PET imaging system
- Determining noise degradation elements and how to optimize such elements
- Determine sensitivity potential for animal model imaging

METHOD

Alzheimer's Literature Review

Alzheimer's is a neurodegenerative disease, meaning that as the brain further progresses in the disease the brain functions deteriorate. Causes like B-amyloid plaques and neurofibrillary tangles increase in quantity as the disease evolves. The causes are a way to track the progression as seen in figure 1.

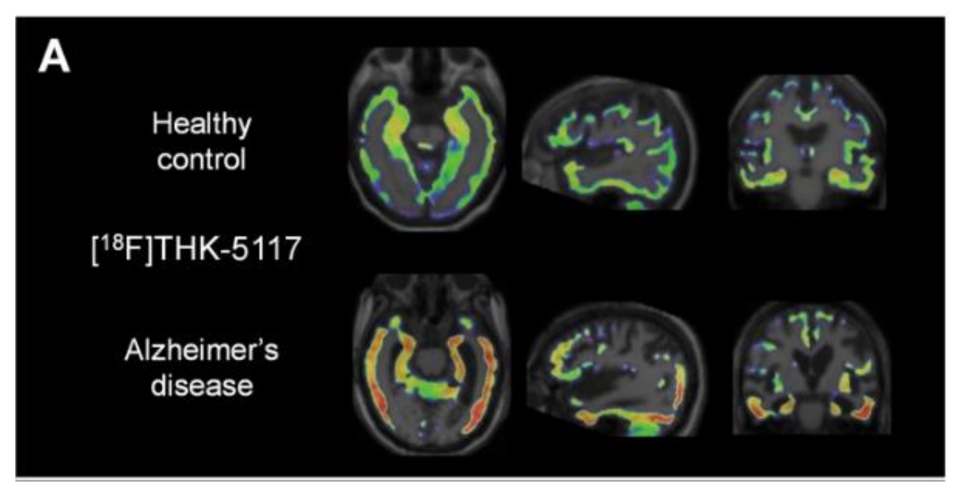

Fig. 1: Comparison of [18F]THK-5117 PET images (after partial volume correction) in a healthy control subject (73 years old, MMSE score 30) and in a patient with Alzheimer's disease

Atlas Mouse Brain Atlas

Atlas mouse brain atlas is a useful tool, because it allows for the user to interactively explore a mouse brain as seen in figure 2. Additionally, the atlas lets people use the data inside Matlab. Matlab allows visualization of slices of the brain.

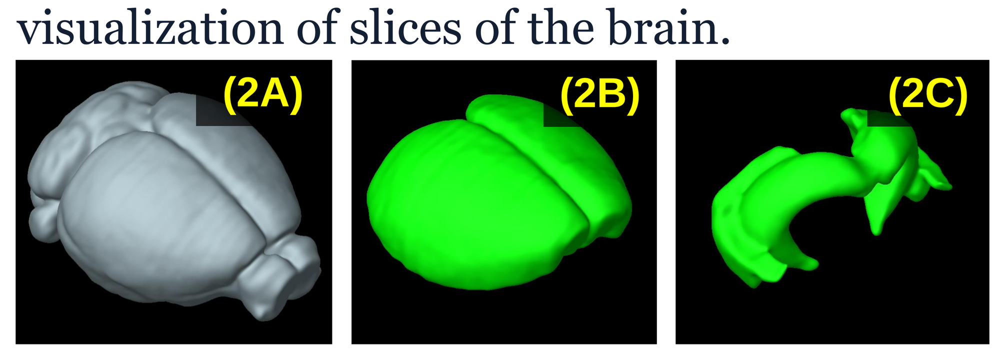

*Fig. 2: **(A)** Full Atlas mouse Brain with all regions present in model. **(B)** The first criteria of the APP/PS1 model is the isolation of the cortex which shows earliest deposition of the Aβ at 6 weeks of age. **(C)** The hippocampal formation shows later deposition of the Aβ at 3-4 months [1].*

Matlab Framework

The information from the above described processes was used to develop a phantom toolkit. This toolkit intends to select various anatomical features associated with a disease of interest for the purpose of developing a 3D printable medical imaging phantom. The phantoms from this toolkit will assist in the assessment of PET systems.

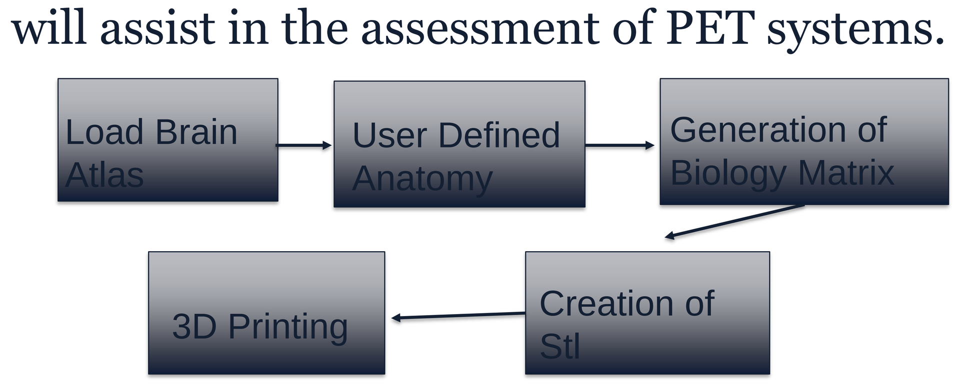

Fig. 3: Structure of the matlab program flow chart

Experimental Setup

PET System

A dual detector coincidence system was designed for PET imaging applications. The unique detectors utilize semiconductor material with a highly pixelated anode which intends to improve the overall imaging performance of PET modalities. Each detector was 2 mm thick with 2048 pixels of 350 um x 350 um in size.

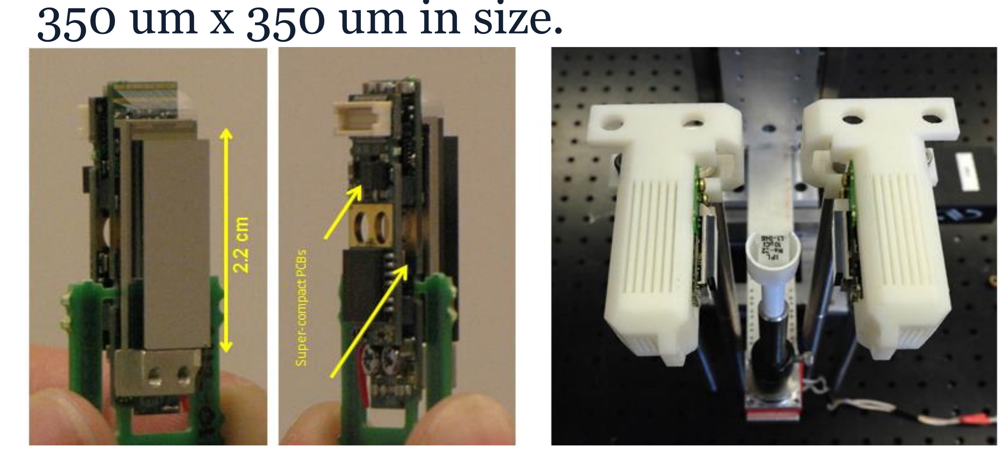

Fig. 4: (Left) A compact ERPC CdTe detector (Right) A dual-detector coincidence setup for preliminary PET imaging studies Detector thickness: 2mm Detector-Detector distance: about 5cm Waveform sampling acquired with external ADC @ 200MHz

RESULTS

Graphical User Toolkit

- Fully incorporated Allen Mouse Brain Atlas
- 3D matrix generation for anatomical feature selection
- Stl file generation for 3D printing

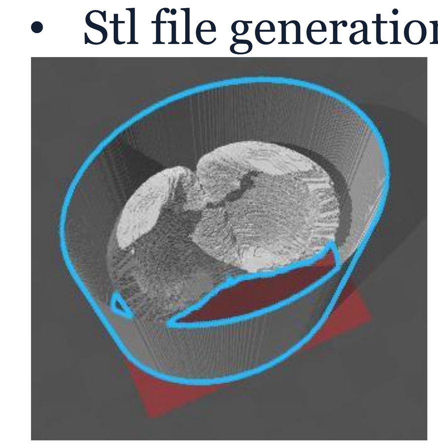

Fig. 5: Filled Cylinder with mouse brain unfilled in the middle

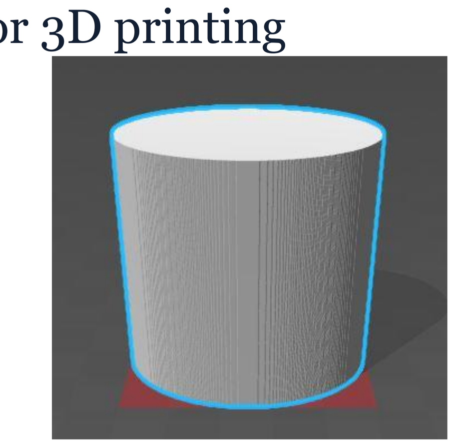

Fig. 6: Mouse brain that is located in the cylinder

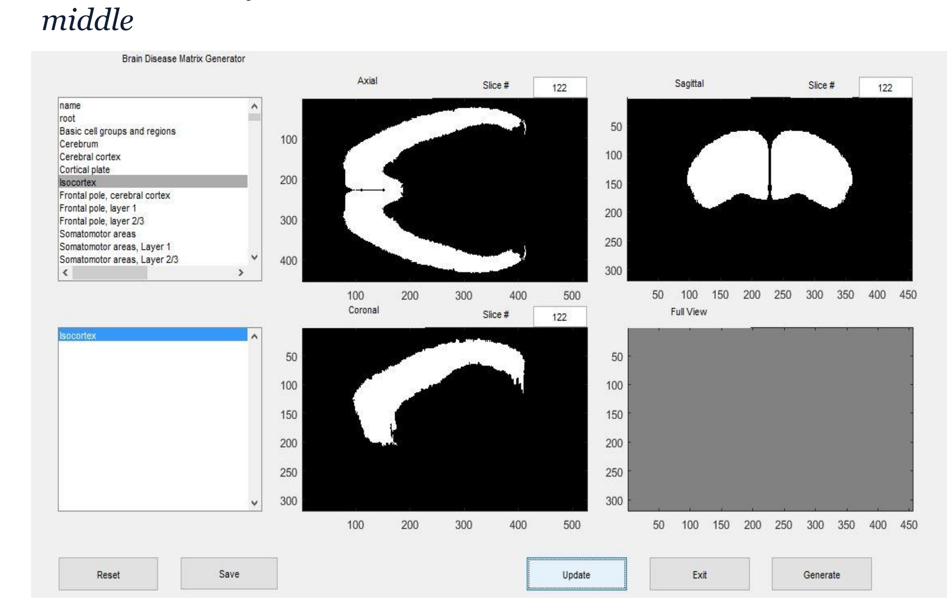

Fig. 7: Generated mouse brain and looking at slices of the brain from different views

FUTURE

- Finding articles that specify specific parts of the brain that signs of Alzheimer's can be found
- Print 3D Phantom and test it with CdTe PET
- Add more diseases that effect the brain to the toolkit
- Create manageable data sizes for printing capatability

CONCLUSIONS

The toolkit performed with the expected results after tweaking different parts of the program. Phantoms for future use will be easily made and can give a good substitute to the biological aspect. However, further work can still be done to the program by adding more diseases as specified in the future work.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Allen Mouse Brain Atlas Lein, E.S. et al. (2007) Genome-wide atlas of gene expression in the adult mouse brain, Nature 445: 168-176. doi: 10.1038/nature05453