Group 6:

Topic: Thermal Imaging

Goal: Design and evaluate a deep learning network that uses channel data from HIFU ultrasound signal as input and generate accurate temperature image of the tissue.

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Mentor: Dr. Emad Boctor, Younsu Kim

Background statement：

When patients have tumor in their body, doctors usually perform a surgery. They cut into body and excise the tumor. However, such a surgery will leave a permanent scar and great pain on patient. Nowadays, new technology HIFU (High Intensity Focused Ultrasound) system helps to relieve the pain. The machine is placed at the bottom of a patient and it send ultrasound focused on the tissue to increase the temperature. With the doctors' operation, the machine ablates different small areas in the tissue and finally ablate all of them. MRI image is used to monitor the temperature in the body. The machine looks like below.

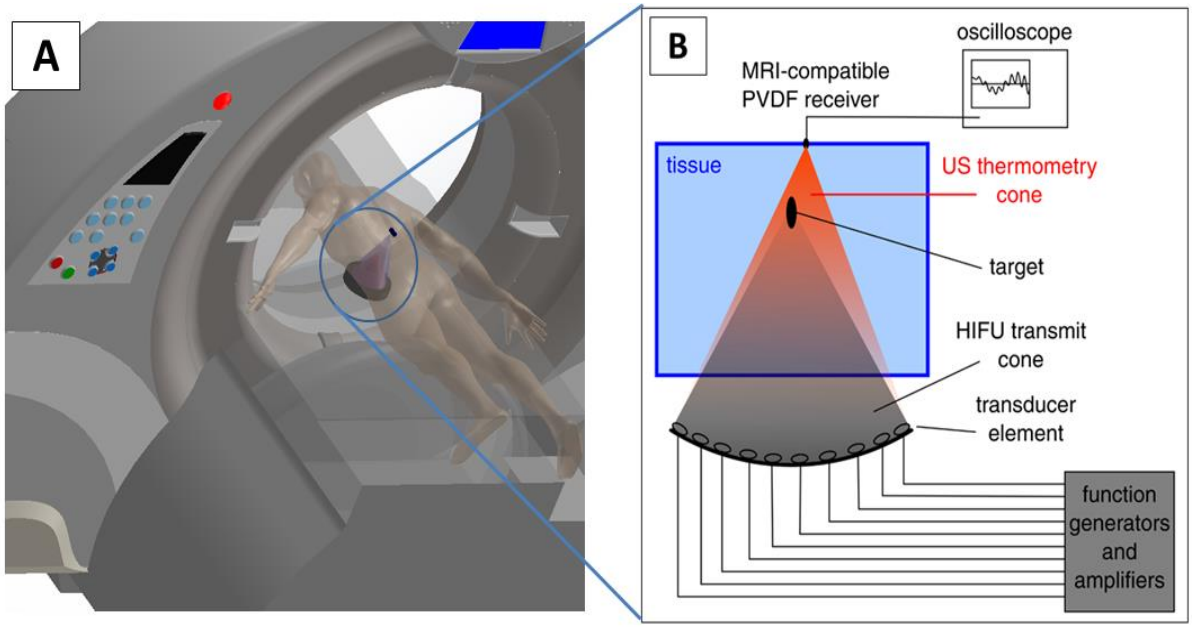

Figure.1 HIFU System

However, MRI machine is expensive and not portable. Our goal is to design a machine which is portable, low-cost so that every hospital can afford that. Easy to use so that doctors put more attention on ablating the tissue instead of operating the machine. Also, the image should be high quality and accurate. Thus, we plan to use the signals received from HIFU to generate temperature image with deep learning network and determine whether the cell is alive or not. Experiments are needed to collect data from the system.

Technical Approach:

Here is how our experimental setup looks like. We have a HIFU at the bottom which conduct two different

phases. Specifically, the first one is to send high intensity ultrasound to ablate the tissue. The second one is to send signals which is received by US probe in order to monitor the temperature in the phantom. The top one is US probe which has 128 elements which means we can receive signals from 128 places to get more information.

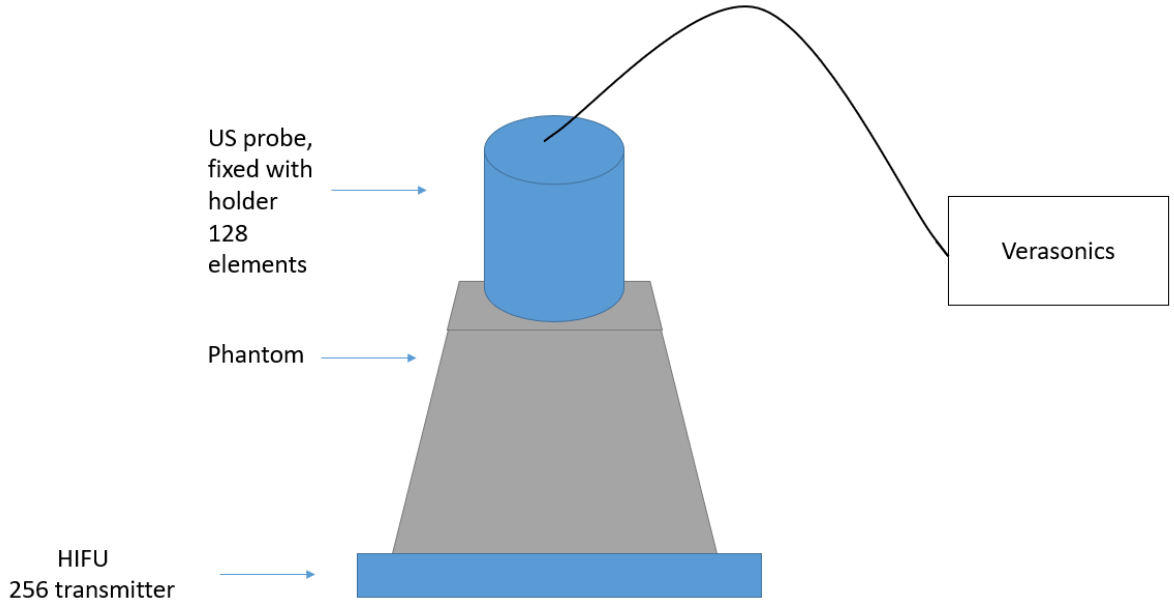

Figure.2 Experiment setup to collect channel data

The signal received is relevant to temperature based on the fact that speed of sound and attenuation ratio of signal will change as temperature changes. The curve looks like below.

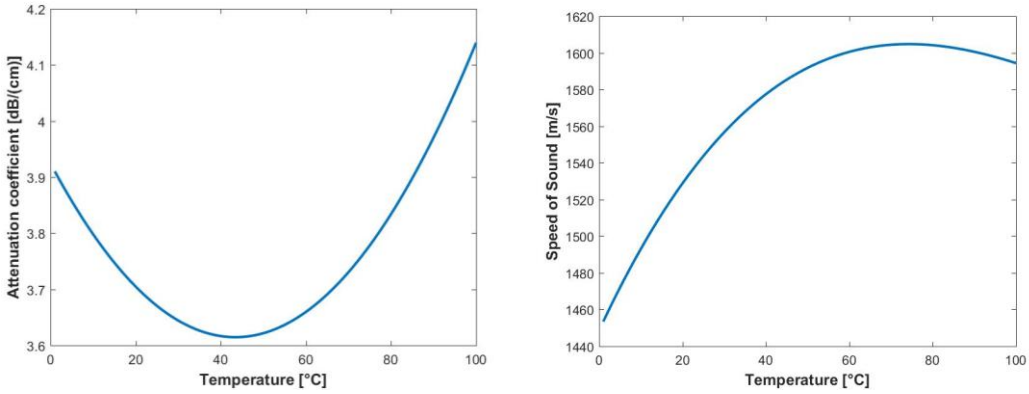

Figure.3 Speed of Sound and Attenuation coefficient change with temperature

We plan to design different networks to generate the temperature image and choose best of them as final version. Below are four different structures we plan to use and validate. With the help of CNN we can extract features in the signals like attenuation rate and change of Time of Flight. By using LSTM, we take information in previous stages as reference to help predict current temperature image. Since we have both axial image and coronal image as ground truth, we use both of them as targets to improve performance.

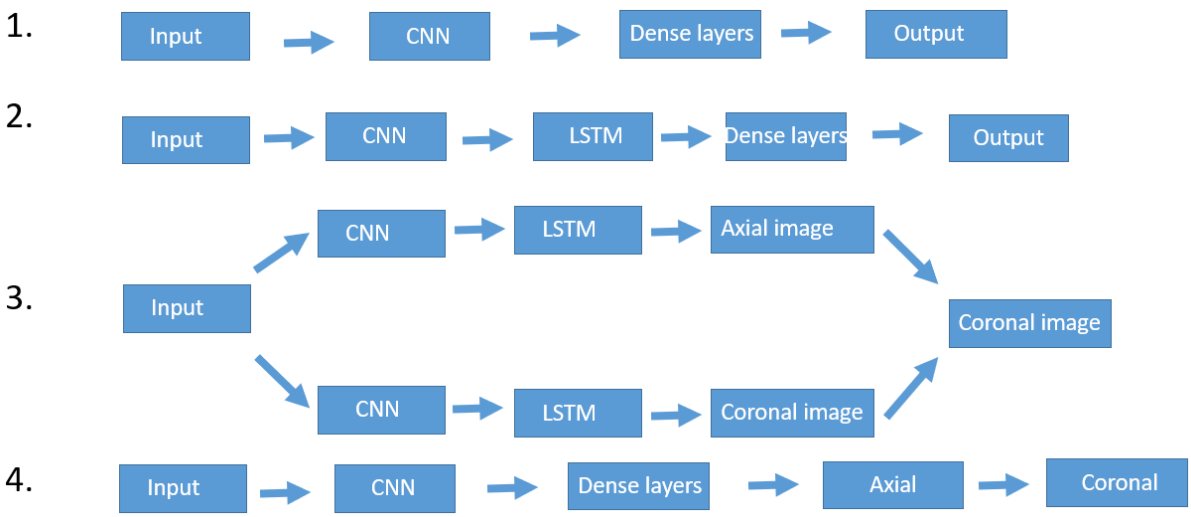

Figure.4 Four different deep learning network

After that, simulation of HIFU system will be conducted to validate and increase data. Finally, with accurate measurement of temperature, we will conduct animal experiments.

Timeline

	February				March				April				May
	5~11	12~18	19~25	26~4	5~11	12~18	19~25	26~4	5~11	12~18	19~25	26~4	7~13
Improve CNN network with part of data													
Read half of reading list													
Minium Deliverable													
Read all reading list													
Design network with the help coronal and axiel image													
Conduct experiment to collect more data													
Data processing													
Develop and test algorithms on simulation framework													
Expected Deliverable													
Extract TOF from raw data with little noise													
Design network with TOF and compare													
Maximum Deliverable													
conduct animal experiment													

Deliverables:

- Minimum:

Video of comparison between prediction and ground truth

Well-documented code written in Python which generate temperature image from channel data

Report on how different parameters and 4 different structures affect performance

- Expected:

Report of 7 experiments of HIFU experiments

Written report of difference between performance of TOF and channel data

- Maximum:

Written report on vivo experiments

Dependency:s

Dependency	Solution	Alternative	Status
GPU	Thin6	MARCC	Solved
Machine Learning and data processing packages and Matlab	Open source Acquire Matlab with Hopkins ID	Open source Acquire Matlab with Hopkins ID	Solved
HIFU	Make appoint with hospital to use Sonalleve HIFU	Borrow HIFU from Dr. Boctor	Solved
MRI Room	Make appoint with hospital and ask Xiaoyang to conduct	Make appoint with hospital and ask Xiaoyang to conduct	Solved
Degaser	Borrow from hospital	Borrow from hospital	Solved
US Probe Verasonics	Borrow from Dr.Boctor		Solved
Phantom	Ask Younsu for help	Contact Dr. Boctor to buy one	Due Mar 14th
3D Printer	Use the one in Wyman Park	Buy one online	Due Mar 14th
Animals	Ask Dr. Boctor for in vivo pig	ex vivo tissue	Due May 7th

Management Plan:

Meeting:
Lab meeting: Once a week with Dr. Boctor's lab on Monday or Wednesday
Personal meeting: Meeting with Younsu when needed and follow schedule
Data and code:
JH Box
MRI help:
Xiaoyang Liu, Parag Karmarkar

Milestone:

March 11th: Design network with help of coronal and axial image and do documentation
March 26th: Conduct 4 more experiments to collect more data

April 26th: Design network with TOF and finish report of difference
May 13th: Conduct animal experiment
May 13th: Final report written and video taken

Reading List:

[1] Kim Y, Audigier C, Ziegle J, et al. Ultrasound thermal monitoring with an external ultrasound source for customized bipolar RF ablation shapes[J]. International journal of computer assisted radiology and surgery, 2018, 13(6): 815-826.
[2] Kim Y, Audigier C, Ellens N, et al. A novel 3D ultrasound thermometry method for HIFU ablation using an ultrasound element[C]//2017 IEEE international ultrasonics symposium (IUS). IEEE, 2017: 1-4.
[3] Audigier C, Kim Y, Ellens N, et al. Physics-based simulation to enable ultrasound monitoring of hifu ablation: An mri validation[C]//International Conference on Medical Image Computing and Computer-Assisted Intervention. Springer, Cham, 2018: 89-97.
[4] Audigier C, Kim Y, Boctor E. A Novel Ultrasound Imaging Method for 2D Temperature Monitoring of Thermal Ablation[M]//Imaging for Patient-Customized Simulations and Systems for Point-of-Care Ultrasound. Springer, Cham, 2017: 154-162.
[5] Kim Y, Audigier C, Ellens N, et al. Low-Cost Ultrasound Thermometry for HIFU Therapy Using CNN[C]//2018 IEEE International Ultrasonics Symposium (IUS). IEEE, 2018: 1-9.
[6] Gers F A, Schmidhuber J, Cummins F. Learning to forget: Continual prediction with LSTM[J]. 1999.
[7] Eilertsen G, Kronander J, Denes G, et al. HDR image reconstruction from a single exposure using deep CNNs[J]. ACM Transactions on Graphics (TOG), 2017, 36(6): 178.