Topic: Redefining Neuroimaging Standard of Care: An Implantable Ultrasound for Real-Time Diagnosis of Brain Diseases

Goal: To develop a macro size system of the ultrasound-microprocessor-app communication with the ultimate goal of miniaturizing this system to fit in up to 3 14mm holes (holes already drilled for brain surgery).

Team Members: Dante Navarro, Jessica Su, Simon Liu
Mentors: Dr. Chad Gordon, Dr. Liuhong Ma, Dr. Mehran Armand, Dr. Nathan Scott

Relevance/Significance

This project targets patients who have already had neurosurgery. The ultimate goal, this implantable device, is designed to fit in 14mm drilled holes that are already performed during neurosurgery, allowing for this seamless integration. In many of these cases, it is crucial to continuously monitor these patients post surgery. However, due to insurance reasons, the expensive MRI scans are only performed quarterly, every 3 months. In some cases, this length of time may be too long to prevent tumor regrowth. On the other hand, ultrasound imaging is a strong alternative when it comes to brain imaging. Aside from eliminating radiation exposure, high medical costs, ultrasound images have also been proven to allow radiologists to see the same important neurological structures that an MRI would. Our project proposes to use wireless ultrasound imaging to lower these costs significantly, while increasing the rate of imaging and maintaining good quality images as proved in previous publications.

Technical Approach

Our project can be split up into four smaller projects that include the following: an Ultrasound Device, a Microprocessor, Wireless Charging of a Battery and a Phone Application. These stages can be prototyped individually, but the final project relies on the integration of these four parts. We plan on an iterative process that allows for each aspect of the project to be done simultaneously so as to be most efficient with our short time of one semester.

The Ultrasound Device is an aspect of the project that we are not personally fabricating, but we have talked to experts in the field that will allow us to utilize the resources that they have at hand. Currently, we have spoken to Dr. Manbachi (and tentative meetings with Dr. Stoianovici) to utilize some of the ultrasound probes that he already has in his possession. This is for the Expected and possibly Maximum delivery. We have already obtained the stored images for our Minimum deliverable. We hope to open a discussion with Dr. Manbachi in the future about CMUT arrays that seem to be available as a research tool rather than a commercial device. Through discussions with experts in the field, we will begin to understand what data is needed to be transmitted from the ultrasound devices to the Microprocessing unit.

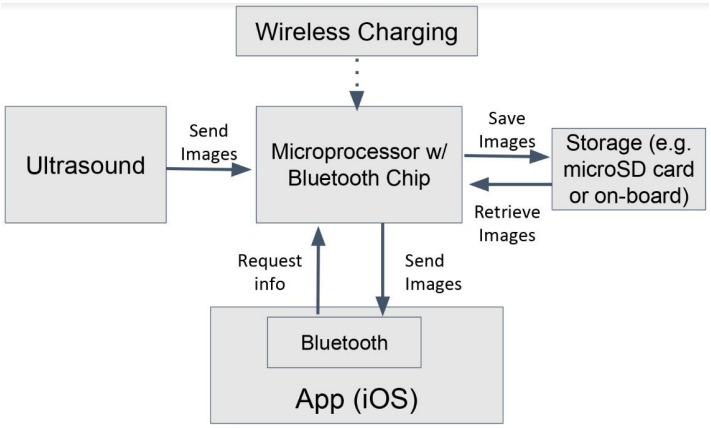
The Microprocessor we acquire must store and send the images from the ultrasound device to the phone application. For the communication, we are going to utilize bluetooth communication to transmit the data that is outputted from the ultrasound device to the phone application. To begin prototyping, an Arduino Uno will be used as the microprocessing unit while the Adafruit Bluefruit LED SPI Friend will begin the

communication to the phone application. To mitigate any data loss during data transmission, we plan to include SD Card storage on the microprocessor. The Microprocessor can be programmed using the Arduino Integrated Development Environment.

We have spoken to a part of our mentor's lab group, the Medicine Delivery Multidisciplinary Team, to obtain the system that they are currently using for Wireless Charging. Once we have obtained this device, the piezoelectric charging system, we then can look at the power consumption of our unit in order to understand the capacity needed for said battery.

The Phone Application must be able to receive the information from the microprocessing unit through bluetooth communication and be able to send and receive data from a bluetooth connection. This application is developed utilizing a software development tool, Xcode, which can develop and deploy iOS applications on real devices and built in simulators.

Because of the iterative process, we will have to work in parallel. Initially, we will start with communication of the Arduino and bluetooth chip to a computer to send and receive simple data between the two devices. In the meantime, a demo application will begin to be developed that can provide a UI for the physician so that we can work with basic user testing studies while communication from the microprocessor to the computer is being set up. Also during this time, communication between the application and a bluetooth will be researched and implemented. With the independent communication systems set up, communication between these devices will be integrated within the system. Once this pipeline has been established, we can begin transmitting data and the stored images between the Microprocessor and the phone application. Next communication between an ultrasound device and the microprocessor is to be established, then the communication to the application is integrated. For our maximum deliverable, we must utilize the CMUT array or a smaller ultrasound device that can fit in the implantable system to replace the larger ultrasound device in the system.



Deliverables

- **Minimum:** Mock ultrasound image communication from an Arduino powered by a battery with stored images to mobile app via Bluetooth.

- **Expected:** Mock ultrasound image communication with macro scale integration (images obtained from an ultrasound system transferred to a microprocessor and then to mobile app via bluetooth) along with rechargeable battery technology.
- **Maximum:** Miniaturized ultrasound device with mobile app communication.

Key Dates

Assigned Responsibilities

- **Jessica:** Ultrasound transmission
- **Simon:** Microprocessor Communication (Arduino)
- **Dante:** App Development
- Note: these are generally the assigned responsibilities due to our backgrounds, however, we'll still be working together for many of these components

Dependencies & Plan for Resolving

Item	Proposed Solution	Alternative	Status
Computer	Use team members' PCs	CS ugrad lab	Resolved
iOS Platform	Use team members' phones	Xcode simulator	Resolved
Data Storage	GitHub	External Hard Drive	Resolved
Workspace	Clark Design Studio	Brody	Resolved

Item	Minimum	Expected	Maximum	Status
Microprocessor	Arduino		Microchip	Resolved
Battery	Li-ion		Develop novel battery technology with Medicine Delivery team	In Progress
Bluetooth	nRF Bluetooth module (ordered)		Microchip	In Progress
Storage Module	SD card module (ordered)		Microchip	In Progress
Ultrasound	Existing ultrasound images (resolved)		CMUT array	In Progress

Management Plan

- Communication with the medicine delivery team regarding bluetooth functionality, and wireless charging via weekly lab meetings and additional meetings as needed
- Weekly lab meetings with Dr. Gordon, Dr. Armand, Dr. Scott, Dr. Ma
- Additional weekly meeting with Dr. Ma
- Meetings once a week (or more if needed) within the team to work together

Reading List

- First-In-Human Experience With Integration of Wireless Intracranial Pressure Monitoring Device Within a Customized Cranial Implant
- First In-Human Experience With Complete Integration of Neuromodulation Device Within a Customized Cranial Implant
- Transcranial MRI-Guided Focused Ultrasound: A Review of the Technologic and Neurologic Applications
- First-in-Human Experience With Integration of a Hydrocephalus Shunt Device Within a Customized Cranial Implant
- Difference-frequency ultrasound imaging with non-linear contrast