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


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# An Implantable Wireless Ultrasound Device for Real-Time Diagnosis of Brain Diseases

## Goal: An Implantable Ultrasound Device for Real-Time Diagnosis of Brain Diseases

- Overarching lab goal: To develop the first implantable ultrasound device for long-term post-neurosurgical monitoring in **glioblastoma patients** (prognosis is 14 months post tumor resection surgery)
- CIS II Focus: The primary aim is to develop an app that can monitor the potential regrowth of brain tumor. The app will allow physicians to monitor bleeding, cysts, and growing tumors through images sent from the ultrasound device, impacting over 11 million patients that are affected annually with brain diseases.

# An Implantable Wireless Ultrasound Device for Real-Time Diagnosis of Brain Diseases

## Background

- Currently, the standard of care for patients who have undergone neurosurgery is to get periodic MRI scans (approximately every 3 months)
  - Average cost of the scan is $3000
  - Ultrasound (US) works with a lower resolution but insightful information can be deciphered
  - A cranial implant is needed after neurosurgery and there is precedent for an implantable device with wireless electronics (shunt management system created by Dr. Gordon)
  - An implantable US system would allow for more frequent imaging to determine adverse events in a more expedient time frame (< 1 month)

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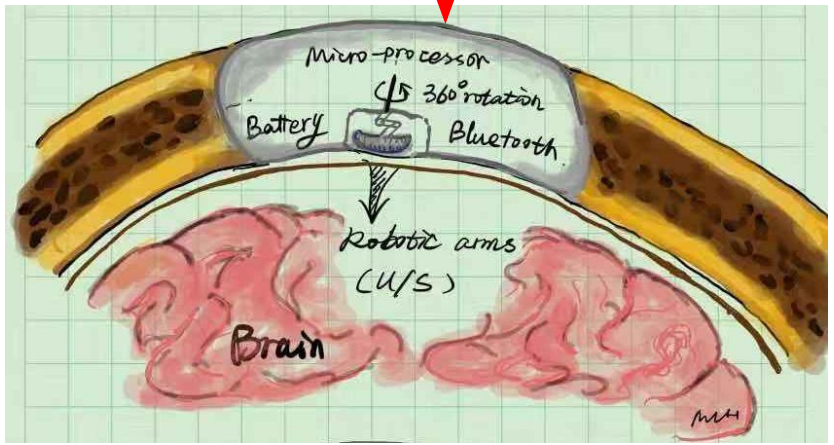
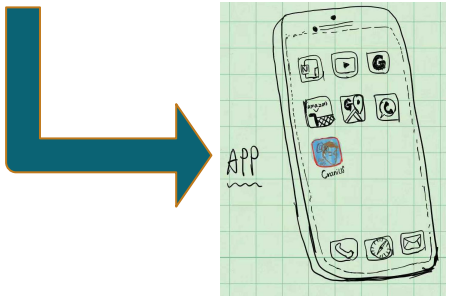
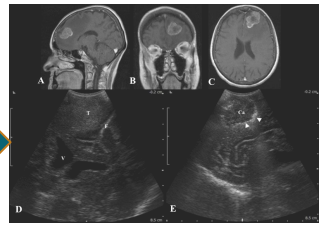
- Ultrasound probe
- Bluetooth
- Battery
- Micro-processor




Coronal view : Diagrammatic drawing



Source: Dr. Ma

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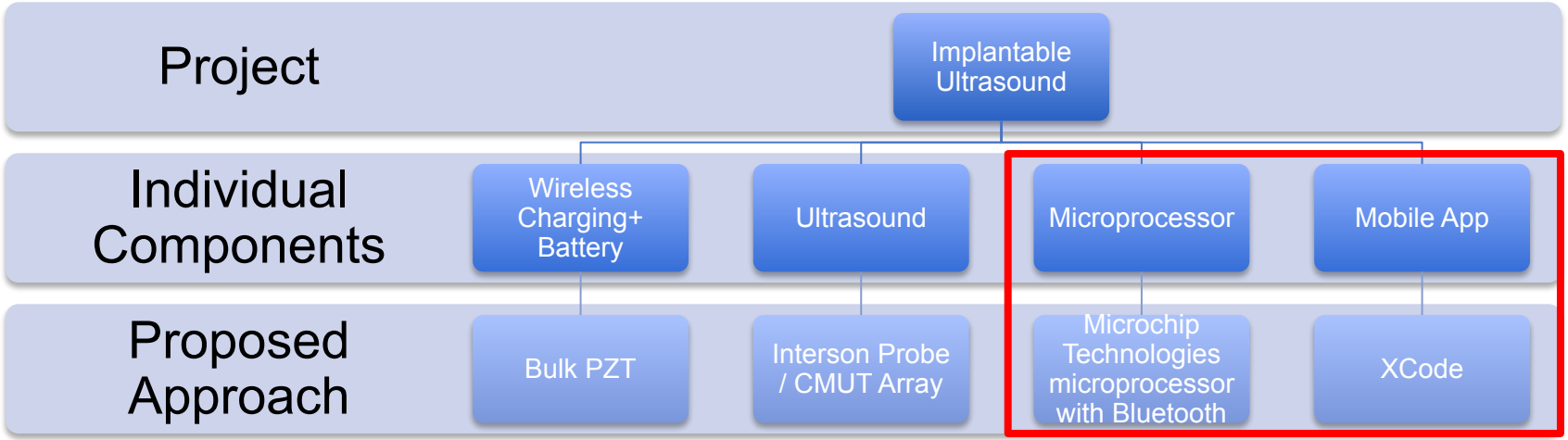
## Overall Project Design Tree




**CIS II Semester**

# An Implantable Wireless Ultrasound Device for Real-Time Diagnosis of Brain Diseases

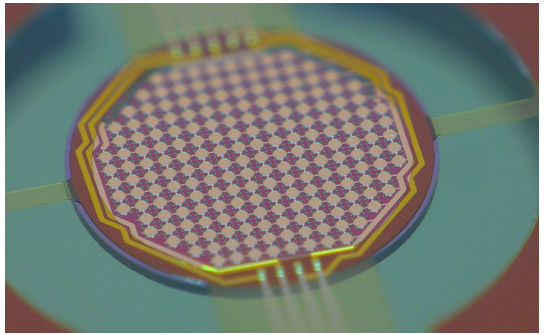
## Proposed Approach: Capacitive Micromachined Ultrasound Transducer

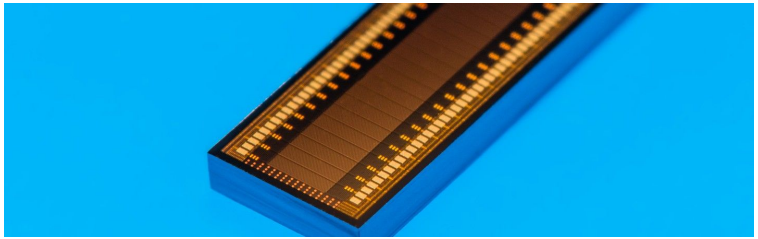
Ultrasound (Traditional)

- produced sound waves by utilizing piezoelectric crystal technology
- high production cost

CMUT

- silicon chips that convert voltage to resonance
- customizable with electronics
- small in size
- can be mass produced
- low cost





Source: Philips,Fraunhofer IPMS

# An Implantable Wireless Ultrasound Device for Real-Time Diagnosis of Brain Diseases

## Miniature ultrasound ring array transducers for transcranial ultrasound neuromodulation of freely-moving small animals

Hyunggug Kim [a], Seongyeon Kim [a], Nam Suk Sim [b], Cristina Pasquinelli [c, d], Axel Thielscher [c, d], Jeong Ho Lee [b], Hyunjoo J. Lee [a, *]

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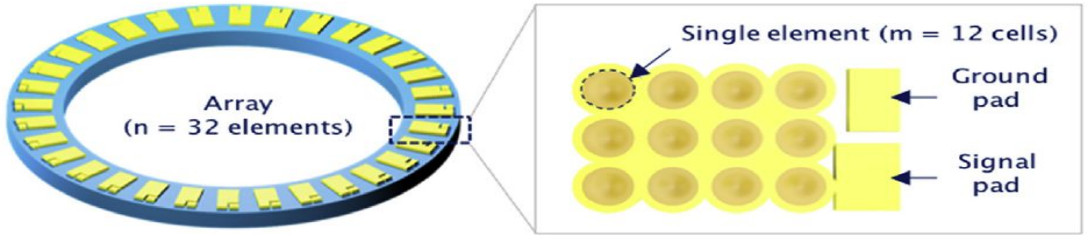
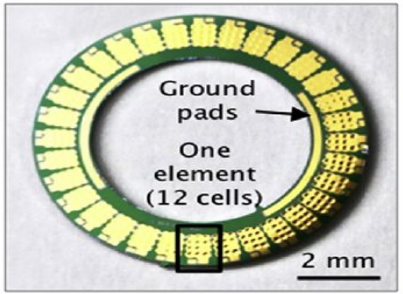
[d] Department of Electrical Engineering, Technical University of Denmark, DK-2800, Kgs. Lyngby, Denmark

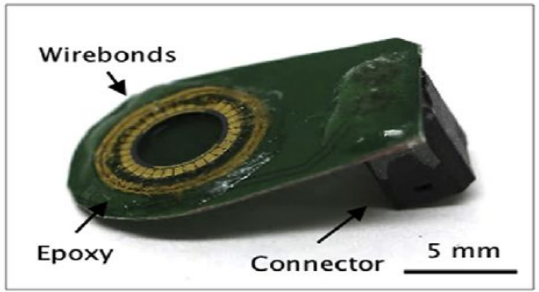
A




B OD: 8.1mm ID: 5.2mm




C




### Materials and methods

We designed and fabricated a ring array with an outer diameter of 8.1 mm and an inner diameter of 5.2 mm to generate a focal point at approximately 2.3 mm from the device with an immersion resonant frequency of 183 kHz (Fig. 1A, B, S1). Ring array was chosen because of the following advantages: natural focus at the center (Figure S2), larger aperture while minimizing localized skull heating, and extra room in the middle for integration with other devices. The ring array is composed of 32 elements, and each element is composed of 12 circular resonating plates (or cells) connected in parallel [24,25]. The weights of the ring array and fully-packaged array with a custom-designed printed circuit board (PCB) were 0.035 g and 0.73 g, respectively (Fig. 1C). For further information, see Supplementary Methods.

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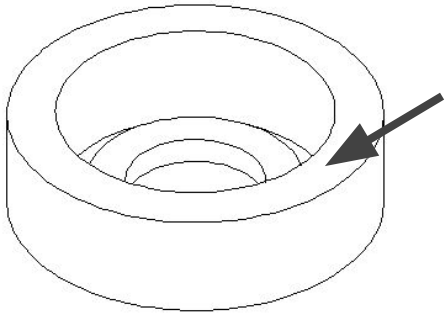
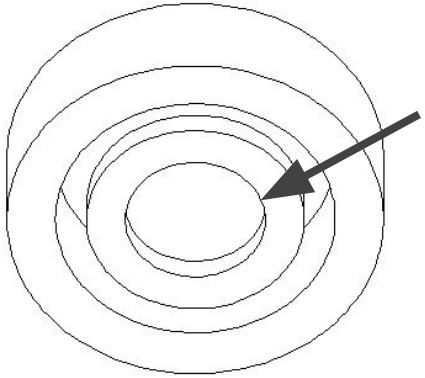
## iUS Device Design in Solidworks

- PMMA is a clear plastic material that is used in neural implants
- Created a preliminary iUS part in Solidworks with the CMUT array produced in the paper
- Shows that it fits very well within the size constraints



PMMA Implant
Depth: 4mm
OD: 14mm
ID: 10.5mm
Edge thickness: 1.75mm



CMUT Array
OD: 81.mm
ID: 5.2mm

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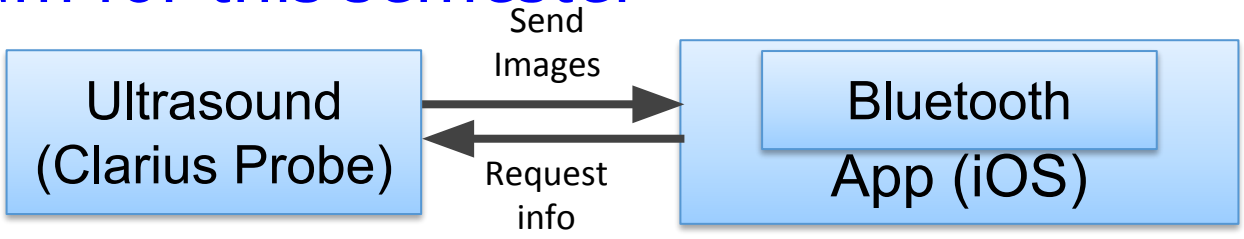
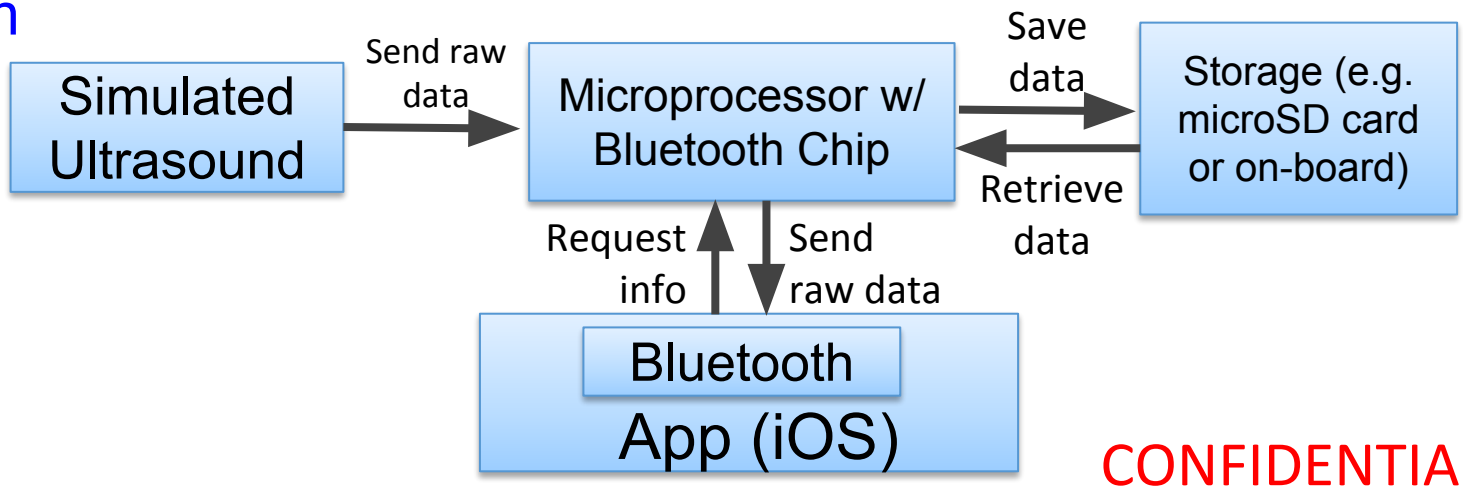
## Block Diagram for this semester

Expected




Maximum



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## Clinical Design Requirements

- Ultrasound device will capture images at some frequency (once a day or once a week) and send the data to a phone for processing within the app
- Surgeons must be able to review images that were taken between appointments to detect tumor regrowth

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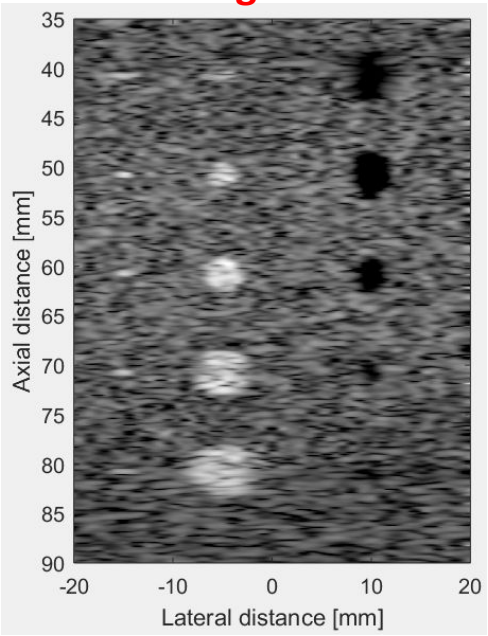
## Image Processing Development

- Implemented code using the Field II  library to simulate a cyst phantom, simulate imaging, save the radiofrequency signals, and reconstruct the image in MATLAB
  - Simulation takes time (~30 min) but creating the image takes seconds
- Implemented code in C based on this image processing MATLAB code because Swift (for app development) interacts well with C, not MATLAB
  - Image reconstruction is noticeably slower than using the MATLAB optimized functions but faster than using the same corresponding functions in MATLAB

**Matlab image**



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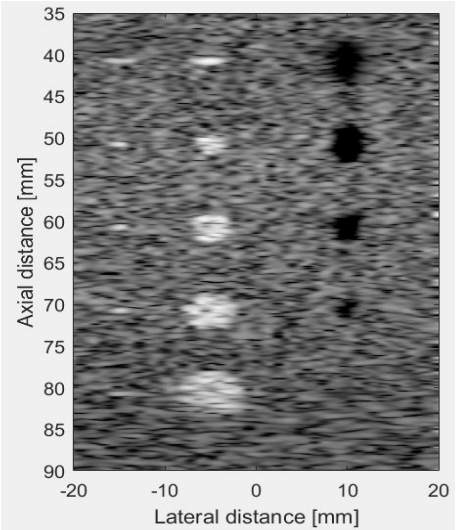
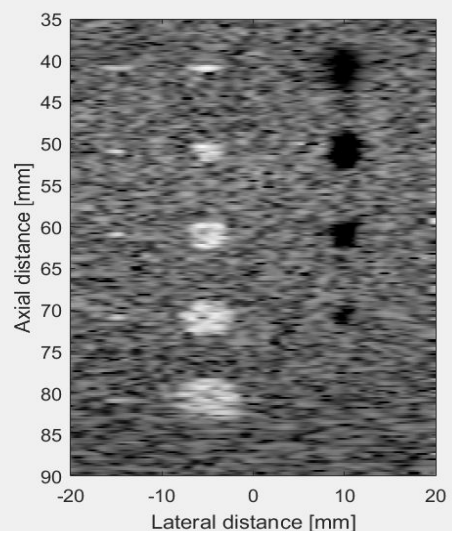
## Image Processing Power Consumption Study

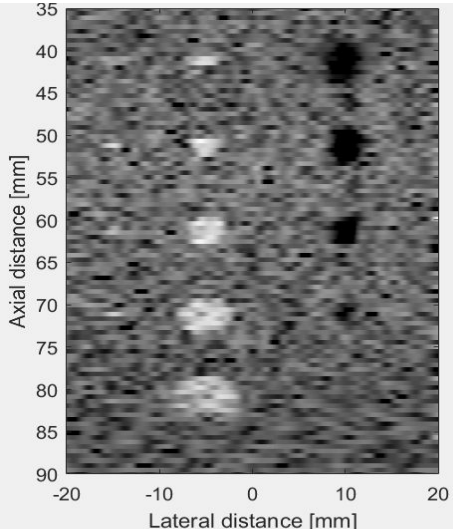
- Changing the **sampling frequency** on the simulation or image processing side affects the image reconstruction time and resolution → would theoretically require less power and save battery for low resolution mode if this frequency is changed in the US device




Original: Sampling freq: 10
Time: 0.741310 s




Sampling freq: 50
Time: 0.223152 seconds




Sampling freq: 70
Time: 0.199255 seconds

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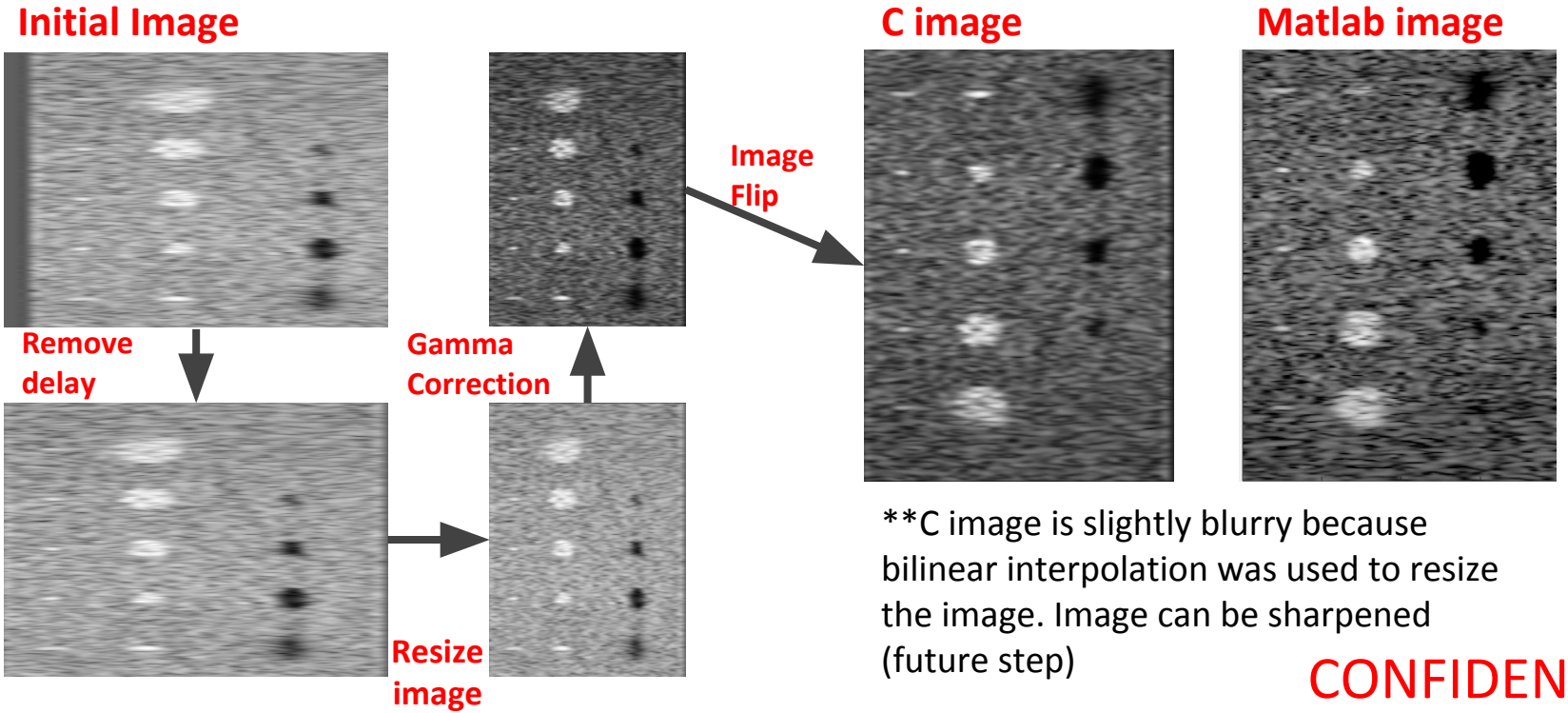
## Image Processing Progress




**C image is slightly blurry because bilinear interpolation was used to resize the image. Image can be sharpened (future step)

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## App Development

- App developed using Swift in XCode
- Deployed the app from XCode to iPhone for testing
- Successfully build the C library in XCode
- Successfully tested local beamforming
- Added activity monitor to show background activity
- Added multiple file selection and image display
- Add gif mode

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## App Demo in XCode Simulator

# An Implantable Wireless Ultrasound Device for Real-Time Diagnosis of Brain Diseases

## Documentation

# An Implantable Wireless Ultrasound Device for Real-Time Diagnosis of Brain Diseases

*Thank you!*