LABORATORY FOR Computational Sensing + Robotics THE JOHNS HOPKINS UNIVERSITY

ERC | CISST

MUSiiC Research Laboratory

Ultrasound Imaging of Brain Shunts

Team 1

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Mentors: Dr. E. Boctor, Dr. R. Taylor, Dr. J.Kang

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Overview

- Background
- Motivation
- Technical Approach
- Deliverables
- Timeline
- Management Plan
- Dependencies
- Reading list and Reference

Background1

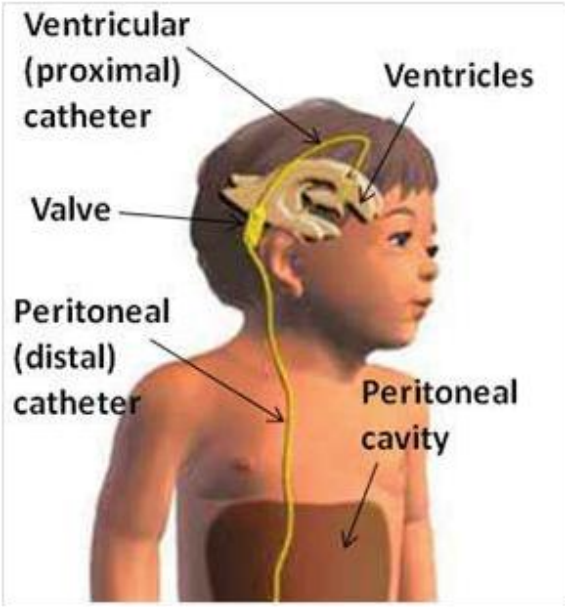
- **Hydrocephalus:** Excessive cerebrospinal fluid (CSF) accumulates in the ventricular space, creating increased pressure on the brain

- **The most common treatment:** placement of a CSF shunt to divert excess CSF to a re-absorption site and regulate intracranial pressure

Background1

Neurosurgeons place shunts by

- Making scalp incision and drilling hole in the skull
- Passing a small catheter (1.5mm inner dia.) through the brain into a ventricle (often 3rd ventricle)
- Distal catheter placed under skin to peritoneum



40,000 shunt-related operations performed annually in US

Motivation

CSF shunts have an unacceptably high incidence of occlusions from in-grown tissues that block CSF flow

- Failure rates are estimated to be ~40% in the first year and ~80% within 10 years
- Currently, the only accepted clinical solution for resolving obstructions is either shunt replacement or revision

Motivation

Challenge: Can we develop a system for minimally invasive clearing of brain shunts to regain patency without shunt replacement?

- The company itself is in charge of developing an in-patient brain shunt clearing stem

Goal: Use external US probe, together with photoacoustic excitation to image occlusions and brain shunts inside the skull.

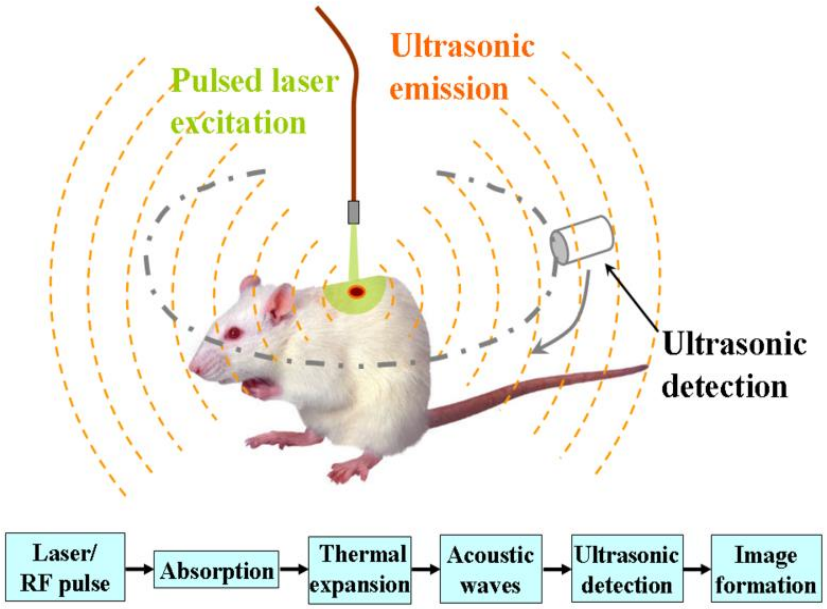
Background2

Photoacoustic imaging, which is based on the photoacoustic effect, has developed extensively over the last decade.

- Discovered by Alexander Graham Bell in 1880.
- Possessing many attractive characteristics such as the use of nonionizing electromagnetic waves, good resolution and contrast, portable instrumentation, and the ability to partially quantitate the signal.

Background2

- High frequency pulses of light are absorbed by medium, causing its energy converted into heat, which leads to thermal expansion.
- Pressure variations caused by radiation of the heat will propagate as ultrasound waves in the medium.
- Ultrasound waves can be detected by acoustic devices such as an US probe.



Technical Approach 1

- Design and build, (borrow / buy) a brain phantom that will be used for the ultrasound imaging. The shunt will be placed at a typical surgery position in this phantom and the tissue-like material will be placed in the shunt.

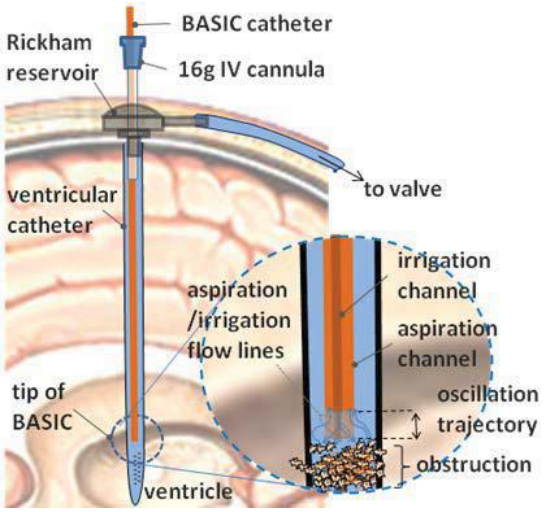


Image from: http://sidschwab.blogspot.com/2012/01/theyre-all-insane-scary-insane.html

Technical Approach 1

- A pulse laser system will be used to project on the tissue-like material without the brain phantom. The data will be detected and collected by using the ultrasound system.
- After the ultrasound coordinates were obtained, sensitive analysis will be conducted to demonstrate the validation of the algorithm and the system works properly.
- Specifically, the laser source will be placed at a position we measured accurately, and the data will be collected, processed and compared with the measured data.

Technique Approach 1

- A same procedure will be done on the phantom without the skull. Also, a sensitive analysis will be done (to find whether the phantom will affect the accuracy).
- The image process will be done to achieve visualization.
- Offline approach.

Technique Approach 2.

- A phantom brain with skull will be used this time.
- Different levels of occlusion (tissue-like material) will be used to for the imaging.
- Certain technique (like time inverse image) will be used to solve the problem of defocused.
- Offline approach.

Technical Approach 3.

- Collect the data from different materials to visualize the shape of the shunt, the obstacles and the clearing device.
- Then algorithms will be used for fast data processing. Integrate monitor screen and the CW laser source to achieve the visualization in real time.

Deliverables

- Minimum – without skull
  - Design and build a ultrasound friendly brain phantom and insert the shunts.
  - Preliminary test of US probe for reflected PA signal detection
  - Collect and process the data of the occlusion with brain phantom into delayed image

Deliverables

- Expected – with skull
  - Collect and process the data of the occlusion into delayed image
  - Capability to distinguish shunts, tissues and fluids
  - Demonstrate PA imaging of shunts with different levels of occlusion

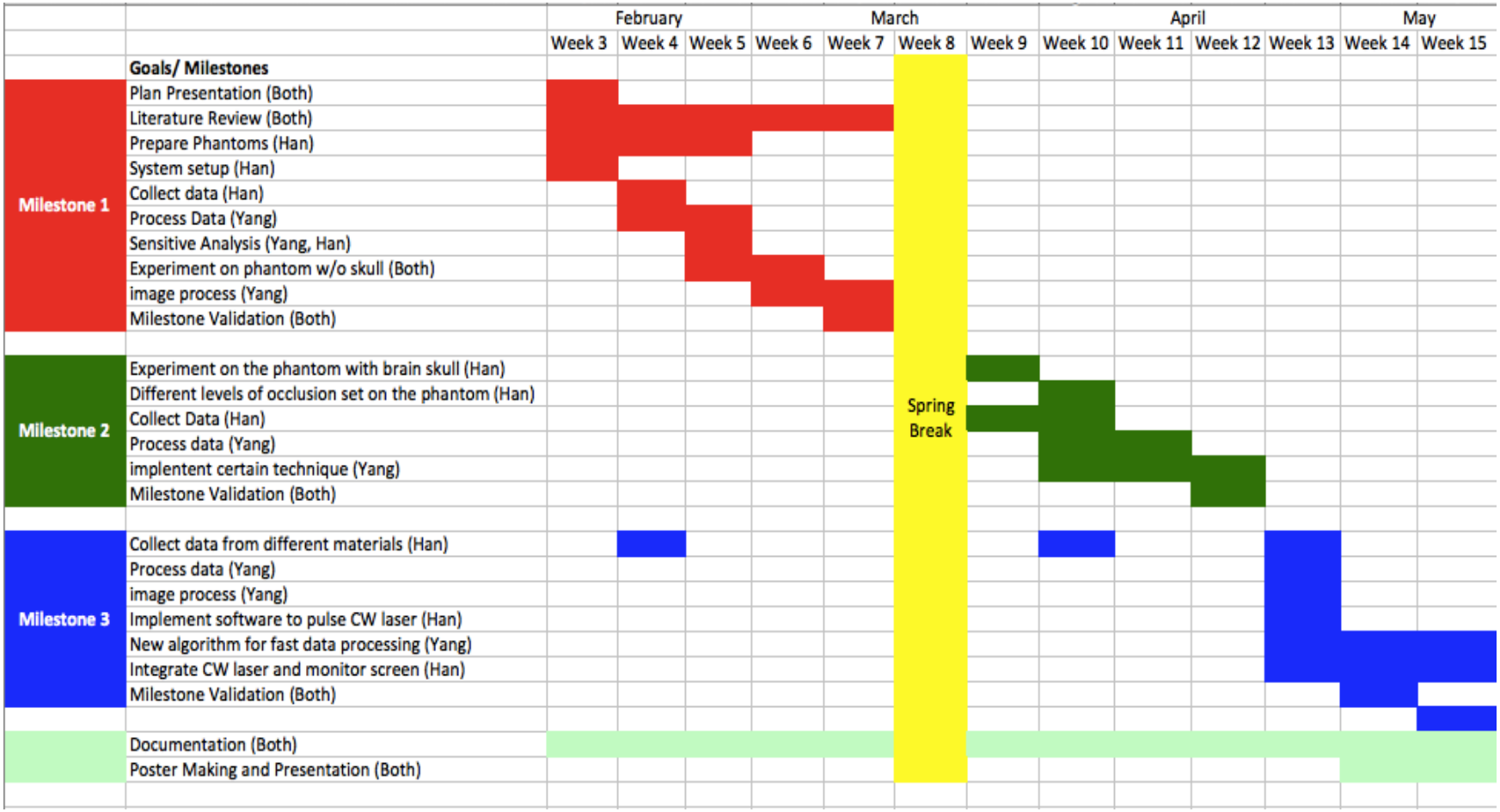
Deliverables

- Maximum
  - Demonstrate realtime PA imaging through the skull of shunts with different levels of occlusion
  - Monitor clearing of the shunt

Milestone Validations

- Phantom construction
  - Complete by Febuary 28
- Preliminary test with occlusion material
  - Complete by Febuary 28
- Visualization of occlusion in shunts without skull
  - Complete by March 18
- Visualization of occlusion and clearing stem in shunts with skull
  - Complete by April 15
- Realtime imaging of occlusion and shunts with skull
  - Complete by May 10

Timeline


February
March
April
May
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Goals/ Milestones
Milestone 1
Plan Presentation (Both)
Literature Review (Both)
Prepare Phantoms (Han)
System setup (Han)
Collect data (Han)
Process Data (Yang)
Sensitive Analysis (Yang, Han)
Experiment on phantom w/o skull (Both)
image process (Yang)
Milestone Validation (Both)
Milestone 2
Experiment on the phantom with brain skull (Han)
Different levels of occlusion set on the phantom (Han)
Collect Data (Han)
Process data (Yang)
implentent certain technique (Yang)
Milestone Validation (Both)
Spring Break
Milestone 3
Collect data from different materials (Han)
Process data (Yang)
image process (Yang)
Implement software to pulse CW laser (Han)
New algorithm for fast data processing (Yang)
Integrate CW laser and monitor screen (Han)
Milestone Validation (Both)
Documentation (Both)
Poster Making and Presentation (Both)

Management Plan

- Weekly meetings with Dr. Emad Boctor at either Homewood Campus or JHMI
- Team meetings every Monday, Friday at 7p.m for sharing updates and discussing further plans
- Work and responsibilities will be split according to the following criterion:
  - Rongguang Han: Phantom construction, data collection
  - Yang Hong: data collection, signal processing
- Keep Dr. Russell updated weekly by email, or schedule appointments as appropriate
- The plan will be updated online when changes are made. Throughout the semester. Mentors will be notified accordingly.

Dependencies (1)

- **Dependency:** Access to Dr. Boctor's lab and equipment
  - **Resolution Plan:** Dr. Boctor has informed his postdoc to provide the equipment
  - **Resolve By:** 2/22/2013
  - **Resolved:** No.
  - **Fallback Plan:** N/A
  - **Affects:** All subsequent milestones
- **Dependency:** Get the brain phantoms
  - **Resolution Plan:** Do research on material suitable for ultrasound and learn how to build the brain phantoms/ Also search on the internet for the cheap brain models
  - **Resolve By:** 2/22/2013
  - **Resolved:** No
  - **Fallback Plan:** Beg Dr. Taylor for money to buy a professional model from elsewhere
  - **Affects:** Milestone 1
- **Dependency:** Learning how to collect the data using external probe
  - **Resolution Plan:** Dr. Boctor has informed his PHD to help us
  - **Resolve By:** 2/22/2013
  - **Resolved:** No.
  - **Fallback Plan:** N/A
  - **Affects:** Milestone 1

Dependencies (2)

- **Dependency:** Learn how to connect new software to the device
  - **Resolution Plan:** Dr. Boctor has offered his PhD students to help us
  - **Resolve By:** 5/1/2013
  - **Resolved:** No
  - **Fallback Plan:** give up the maximum deliverables
  - **Affects:** Maximum Deliverables
- **Dependency:** Monitor the realtime clearing of brain shunts
  - **Resolution Plan:** the clearing stem is built by the company
  - **Resolve By:** 5/1/2013
  - **Resolved:** No
  - **Fallback Plan:** give up the second maximum deliverable
  - **Affects:** Maximum Deliverables

Reading list

- Szabo, Thomas L. , "Diagnostic ultrasound imaging: inside out", Amsterdam: Elsevier Academic Press, 2004.
- Limng Nie, Xin Cai, Konstantin Maslov, Alejandro Garcia-Uribe, Mark A. Anastasio, Lihong V. Wang, "Photoacoustic tomography through a whole adult human skull with a photon recycler", Washington University, Department of Biomedical Engineering, St. Louis, Missouri 63130.
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- Xueding Wang, Yongjiang Pang, Geng Ku, George Stoica and Lihong V. Wang, "Three-dimensional laser-induced photoacoustic tomography of mouse brain with the skin and skull intact", 10/1/ 2003, Vol.28, No.19, Optics Letters.
- Medical Imaging Signals and Systems, J. L. Prince and J. M. Links, (Pearson Prentice Hall, Upper Saddle River, NJ), 2006.
- The Essential Physics of Medical Imaging, J.T. Bushberg, J.A. Seibert, E. M. Leidholdt and J. M. Boone, (Lippincott Williams & Wikins, Philadelphia, PA), 2001.
- Physical Principals of Medical Ultrasonics, C.R. Hill, J.C. Bamberand G.R. ter Haar, (John Wiley & Sons Ltd) 2004.

Thank you !

Questions ?