CIS II Project Proposal

Project Title:

18. Ultrasound Needle Guidance for Hydrogel Injection During Cervical Cancer Brachytherapy

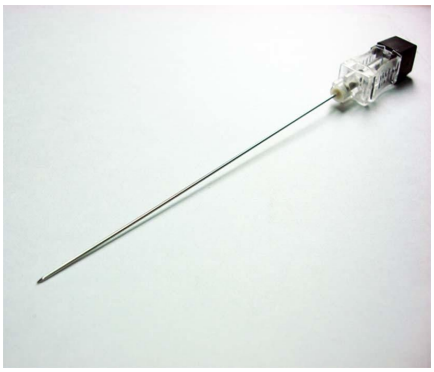
Mentor(s):

Carmen Kut, Dr. Emad Boctor, Dr. Akila Viswanathan, and Younsu Kim

Team Member(s): Tracy Kao

Objective

The objective of this project is to develop a needle prototype for hydrogel injection during a brachytherapy procedure that is compatible with existing ultrasound systems for improved visualization.

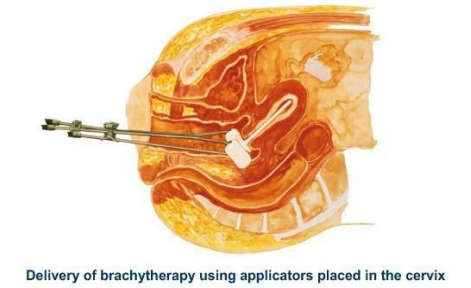


Skills

This project will mainly require familiarity with manipulating electronics and hardware.

Clinical Need

Cervical cancer is the third most common cancer among women worldwide, with an annual incidence of 530,000 cases and 250,000 deaths yearly. Unlike early-stage disease, locally advanced cervical cancer has finite survival times and cannot be cured by surgery alone (with a high relapse rate at 30%).



Delivery of brachytherapy using applicators placed in the cervix

In the developing world, it is even the second leading cause of cancer. Recent data have repeatedly and consistently shown the benefit of administering brachytherapy, the insertion of a radiation source directly into the cancerous tissue, following external beam radiotherapy (EBRT) to prolong survival and to improve patient outcomes (when coupled with chemotherapy). There is a clear need to differentiate the cervical tumor mass from surrounding normal tissues e.g. the rectovaginal septum during brachytherapy.

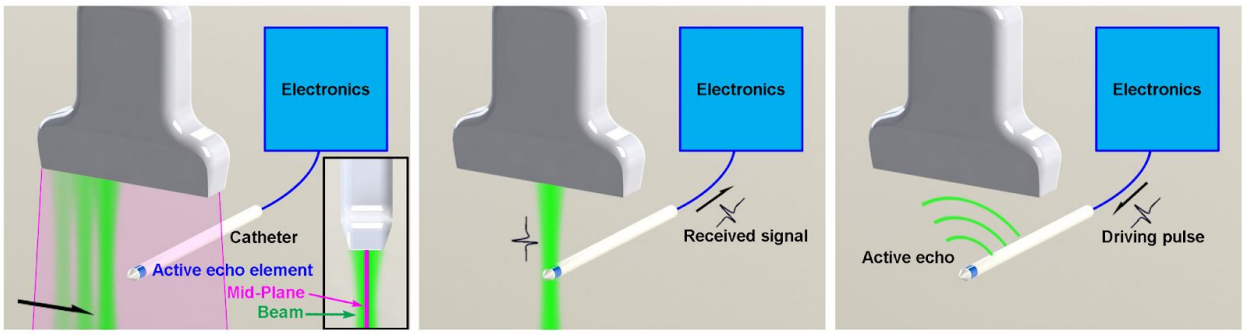
In brachytherapy planning, it is routine practice to inject a hydrogel spacer to minimize radiation dose to normal anatomical structures. However, this is a challenging procedure, and inaccurate needle placement can lead to complications such as accidental perforation of the bowel and rectum. In this project, we want to develop a method for more precise localization and/or visualization of the needle for hydrogel injection under ultrasound image guidance during preparation of the cervical cancer patient for a brachytherapy procedure.

To develop this project, there is a team of mentors who have agreed to provide assistance and know-how. Carmen Kut is the main mentor for this project. Dr. Viswanathan is our clinical

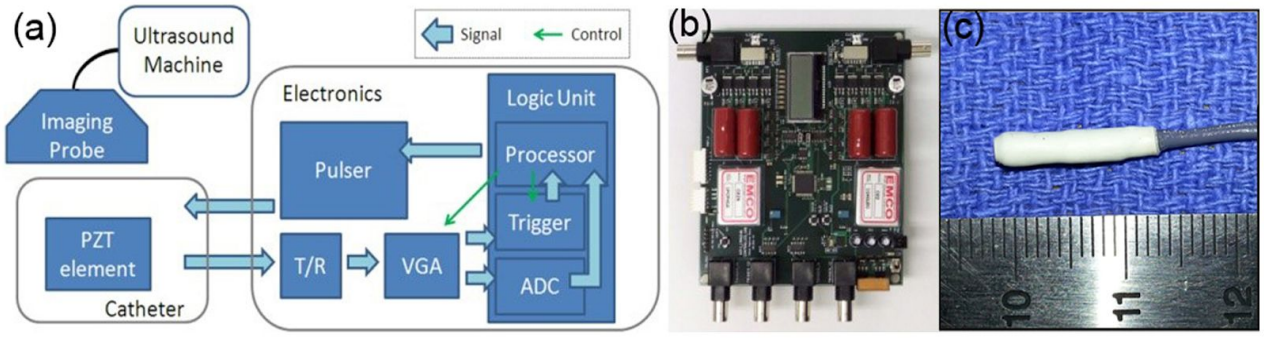
consultant. Dr. Boctor is our technical consultant, whose lab has worked with many ultrasound technologies, and finally Younsu Kim of the Medical UltraSound Imaging and Intervention Collaboration Lab has provided a number of technical resources for this project.

Technical Approach

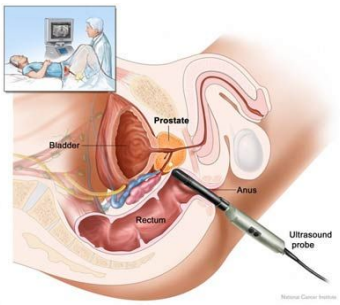
In order to design a fitting hydrogel injection for the ultrasound context, this project will adapt the electronic layout and algorithmic technology developed in the Adapt Active Ultrasound Pattern Injection System (AUSPIS). Under this ultrasound-based tool tracking paradigm, bi-directional ultrasound communication is enabled between the interventional tool and ultrasound imaging machine within the tissue. The secondary, interventional tool generates an active ultrasound field counter the original imaging signals. Control of timing and amplitude allows a virtual pattern to be displayed on the ultrasound image.



The electronics that make it possible, as utilized in the AUSPIS system and published in their corresponding paper, are shown below. Attachment of a piezoelectric element onto the needle tip allows for the needle to generate the secondary field in active response to the primary transducer.



Additionally, in order to maximize the resolution of the ultrasound in the rectal region, a Endo-Rectal Ultrasound System (ERUS) [also known as Trans-Rectal Ultrasound System (TRUS)] will be used. Currently, it's often used in conjunction with brachytherapy for prostate cancer.



Deliverables

Below are the classification of minimum, expected, and maximum deliverables as well as their due dates.

Minimum: (Expected by for part I:3/6/3018, for part II: 4/5/2018)

- Choice of a relevant, existing ultrasound system.
- Documentation of specifications and initial design concepts.
- Denoted in green.

Expected: (Expected by 3/29/2018)

- Development of a hydrogel injection needle prototype adapted for ultrasound compatibility.
- Needle interfaces with existing electronics and research-use ultrasound system.
- Documentation of working prototype design and process.
- Denoted in blue.

Maximum: (Expected by 5/10/2018)

- Selection of appropriate phantom(s) for testing and evaluating the prototype.
- Construction of the phantom.
- Documentation of phantom design, construction, and resulting test data.
- Denoted in orange.

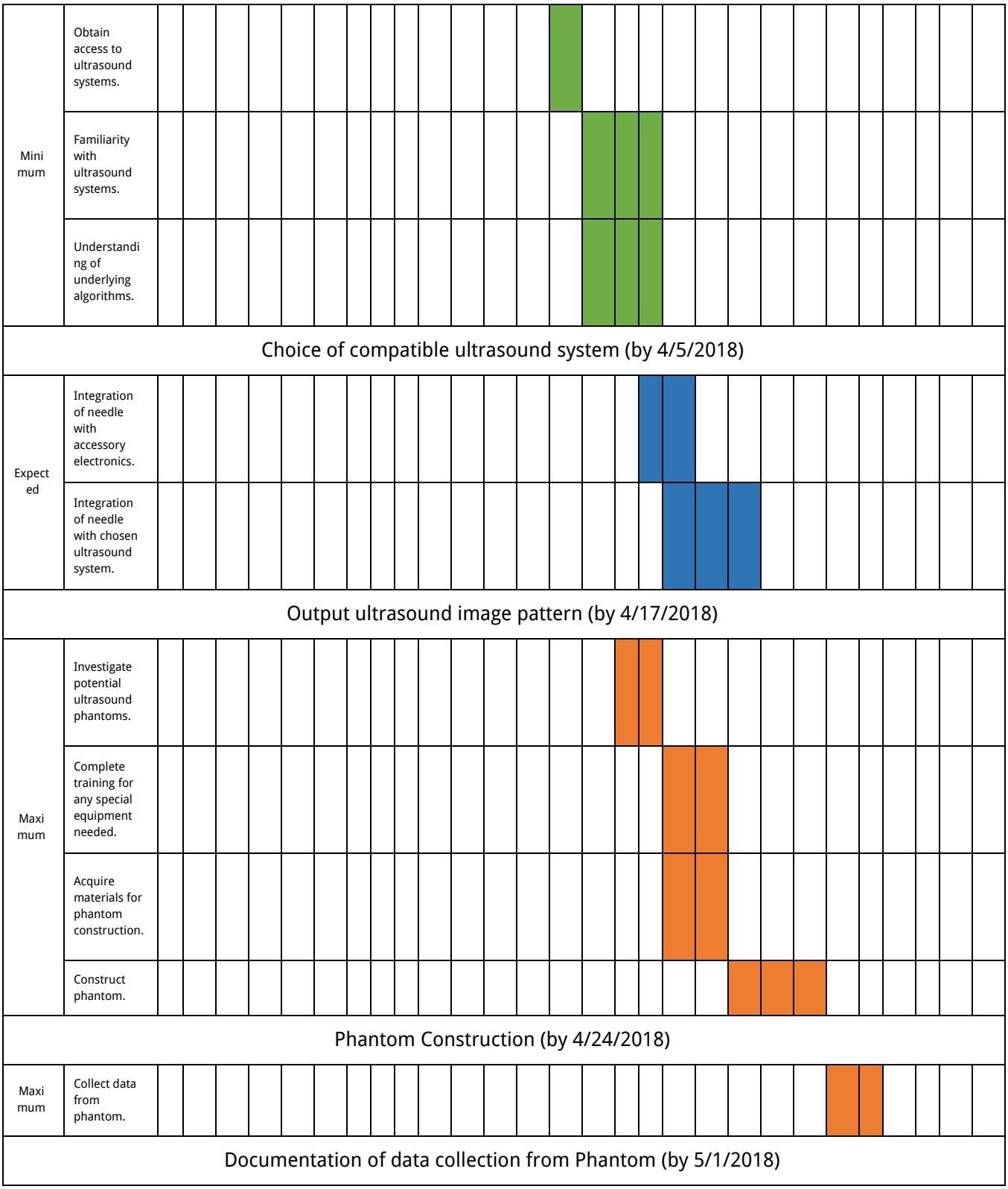
Milestones

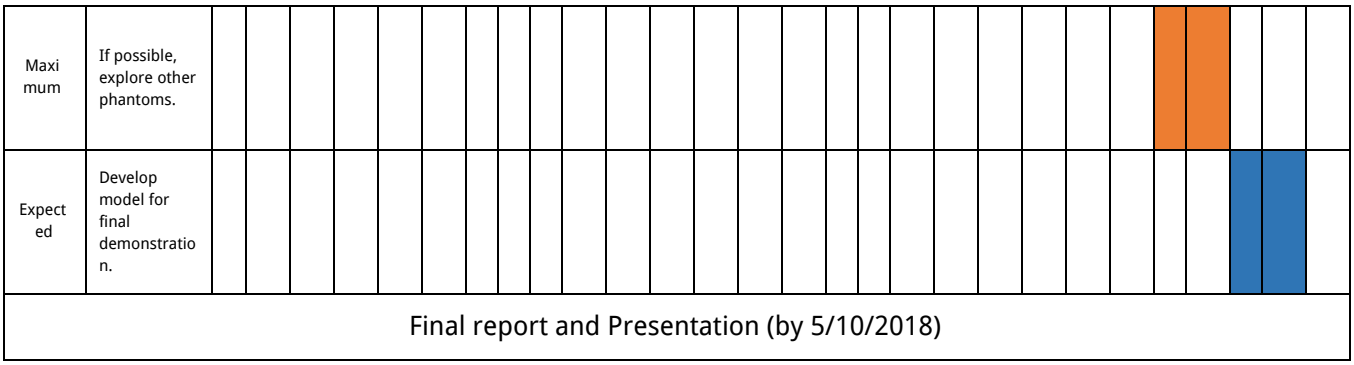
To produce the above deliverables, these milestones I'd like to reach by certain dates.

- Clinical Observation & Clinical Need Evaluation (3/1/2018)
- Initial Design Sketch (3/6/3018)
- Documentation of Specifications and Conceptual Design (3/8/2018)
- Working prototype that meets specified specifications (3/27/2018)
- Documentation of working prototype (3/29/2018)
- Choice of compatible ultrasound system (4/5/2018)
- Output ultrasound image pattern (4/17/2018)
- Phantom Construction (4/24/2018)
- Documentation of Phantom Data (5/1/2018)
- Final Report and Presentation (5/10/2018)

Timeline

Deliverable Classification	Item	FEB						MAR									APR								MAY				
		8	10	13	15	20	22	1	6	8	13	15	20	22	27	29	3	5	10	12	17	19	24	26	1	3	8	10	11
Minimum	Select and confirm project choice.																												
	Initial Meeting with mentors.																												
	Shadow the procedure.																												
	Read relevant papers.																												
Clinical Observation & Clinical Need Evaluation (3/1/2018)																													
Minimum	Consult design options (papers).																												
	Budget Estimate																												
Initial Design Sketch (by 3/6/2018)																													
Expected	Confirm access to lab space.																												
	Confirm access to prototyping materials.																												
	Put in orders for components.																												
	Documentation of Specifications and Conceptual Design (by 3/8/2018)																												
Expected	Construct prototype.																												
	Preliminary testing on oscilloscope.																												
Working prototype that meets previously proposed design specifications (by 3/27/2018)																													
Documentation of working prototype (by 3/29/2018)																													


Minimum
Obtain access to ultrasound systems.
Familiarity with ultrasound systems.
Understanding of underlying algorithms.
Choice of compatible ultrasound system (by 4/5/2018)
Expected
Integration of needle with accessory electronics.
Integration of needle with chosen ultrasound system.
Output ultrasound image pattern (by 4/17/2018)
Maximum
Investigate potential ultrasound phantoms.
Complete training for any special equipment needed.
Acquire materials for phantom construction.
Construct phantom.
Phantom Construction (by 4/24/2018)
Maximum
Collect data from phantom.
Documentation of data collection from Phantom (by 5/1/2018)



Dependencies

Level of Deliverable Affected	Dependency	Proposed Solution	Important Dates	Alternatives	Status
Expected	Hydrogel needle	Acquire from Clinical Consultant	Need by 3/8/2018	Use other needle.	RESOLVED as of 2/14/2018
Expected	Electronic Components	Provision by MUSiiC Lab.	Need by 3/8/2018	Place order in accordance with budget constraints	PARTIALLY RESOLVED as of 2/22/2018
Expected	Electronic Interface from AUSPIS	Provision by MUSiiC Lab.	Need by 4/5/2018	Build it myself.	Access confirmed as of 2/22/2018
Expected	Access to Lab environment for prototype development	Provision by MUSiiC Lab.	Need by 3/8/2018	Use currently available lab space.	Access confirmed as of 2/22/2018
Minimum	Ultrasound System and Compatible Algorithm	Provision by MUSiiC Lab. TRUS, in particular.	Need by 4/5/2018	Look for non-research abdominal probes with Radiation Oncology and Hopkins Simulation Center.	Access confirmed as of 2/22/2018
Maximum	Phantom Construction Materials	Purchase with budget.	Need by 4/12/2018	Purchase with own money. Or borrow from MUSiiC Lab	Not yet resolved.
Maximum	Phantom Construction Machinery/ Equipment	Provision by MUSiiC Lab, BME Design Studio, or Wyman Equipment after proper training.	Need by 4/12/2018	Make do with freely available equipment.	Currently doing training on multiple equipment.
Minimum	Mentorship	Weekly meetings if possible; otherwise, availability upon need.	Need by 2/21/2018	Rely on papers.	Have met with all mentors by 2/21/2018, confirming their roles in this project.
Expected	Financial Resources	Come up with budget at beginning of project, and attempt to get it processed through the mentors.	Need by 3/6/3018	Pay personally.	As of 2/20/2018.

Management Plan

To manage the project, I will keep in e-mail communication with all mentors. Mentors have demonstrated their availability upon need. Additionally, I will also be in weekly meeting with my Main Mentor (Carmen). I will also update all mentors when milestones are reached.

Reading List

Bair, R. J., Bair, E., & Viswanathan, A. N. (2015). A radiopaque polymer hydrogel used as a fiducial marker in gynecologic-cancer patients receiving brachytherapy. *Brachytherapy, 14*(6), 876-880.

Banerjee, R., & Kamrava, M. (2014). Brachytherapy in the treatment of cervical cancer: a review. *International journal of women's health, 6,* 555.

Bell, M. A. L., Kuo, N. P., Song, D. Y., Kang, J. U., & Boctor, E. M. (2014). In vivo visualization of prostate brachytherapy seeds with photoacoustic imaging. *Journal of biomedical optics, 19*(12), 126011.

Guo, X., Kang, H. J., Etienne-Cummings, R., & Boctor, E. M. (2014). Active ultrasound pattern injection system (AUSPIS) for interventional tool guidance. PloS one, 9(10), e104262. Viswanathan, A. N., Damato, A. L., & Nguyen, P. L. (2013). Novel use of a hydrogel spacer permits reirradiation in otherwise incurable recurrent gynecologic cancers. *Journal of Clinical Oncology, 31*(34), e446-e447.

Zhang, H. K., Lin, M., Kim, Y., Paredes, M., Kannan, K., Patel, N., ... & Boctor, E. M. (2017, March). Toward dynamic lumbar punctures guidance based on single element synthetic tracked aperture ultrasound imaging. In *Medical Imaging 2017: Image-Guided Procedures, Robotic Interventions, and Modeling* (Vol. 10135, p. 101350J). International Society for Optics and Photonics.