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%).

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, an 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 (3/6/2018)
- 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

<table>
<thead>
<tr>
<th>Deliverable Classification</th>
<th>Item</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>Select and confirm project choice.</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>15</td>
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<tr>
<td></td>
<td>Initial Meeting with mentors.</td>
<td>22</td>
<td>1</td>
<td>6</td>
<td>8</td>
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<td></td>
<td>Shadow the procedure.</td>
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<td>Read relevant papers.</td>
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<td></td>
<td>Budget Estimate</td>
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<tr>
<td>Initial Design Sketch (by 3/6/2018)</td>
<td>Confirm access to lab space.</td>
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<td>Confirm access to prototyping materials.</td>
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<td>Put in orders for components.</td>
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<td>Preliminary testing on oscilloscope.</td>
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<tr>
<td>Working prototype that meets previously proposed design specifications (by 3/27/2018)</td>
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<tr>
<td>Documentation of working prototype (by 3/29/2018)</td>
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### 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)
If possible, explore other phantoms.

Develop model for final demonstration.

**Final report and Presentation (by 5/10/2018)**

## Dependencies

<table>
<thead>
<tr>
<th>Level of Deliverable Affected</th>
<th>Dependency</th>
<th>Proposed Solution</th>
<th>Important Dates</th>
<th>Alternatives</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected</td>
<td>Hydrogel needle</td>
<td>Acquire from Clinical Consultant</td>
<td>Need by 3/8/2018</td>
<td>Use other needle.</td>
<td>RESOLVED as of 2/22/2018</td>
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<tr>
<td>Expected</td>
<td>Electronic Components</td>
<td>Provision by MUSiC Lab.</td>
<td>Need by 3/8/2018</td>
<td>Place order in accordance with budget constraints</td>
<td>PARTIALLY RESOLVED as of 2/22/2018</td>
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<tr>
<td>Expected</td>
<td>Electronic Interface from ASUSP</td>
<td>Provision by MUSiC Lab.</td>
<td>Need by 4/5/2018</td>
<td>Build it myself.</td>
<td>Access confirmed as of 2/22/2018</td>
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<td>Expected</td>
<td>Access to lab environment for prototype development</td>
<td>Provision by MUSiC Lab.</td>
<td>Need by 3/8/2018</td>
<td>Use currently available lab space.</td>
<td>Access confirmed as of 2/22/2018</td>
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<td>Minimum</td>
<td>Ultrasound System and Compatible Algorithm</td>
<td>Provision by MUSiC Lab. TRUS, in particular.</td>
<td>Need by 4/5/2018</td>
<td>Look for non-research abdominal probes with Radiation Oncology and Hopkins Simulation Center.</td>
<td>Access confirmed as of 2/22/2018</td>
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<td>Maximum</td>
<td>Phantom Construction Machinery/Equipment</td>
<td>Provision by MUSiC Lab, BME Design Studio, or Wyman Equipment after proper training.</td>
<td>Need by 4/12/2018</td>
<td>Make do with freely available equipment.</td>
<td>Currently doing training on multiple equipment.</td>
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<td>Minimum</td>
<td>Mentorship</td>
<td>Weekly meetings if possible; otherwise, availability upon need.</td>
<td>Need by 2/21/2018</td>
<td>Rely on papers.</td>
<td>Have met with all mentors by 2/21/2018, confirming their roles in this project.</td>
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<tr>
<td>Expected</td>
<td>Financial Resources</td>
<td>Come up with budget at beginning of project, and attempt to get it processed through the mentors.</td>
<td>Need by 3/6/2018</td>
<td>Pay personally.</td>
<td>As of 2/20/2018.</td>
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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


