**Xiaowei’s Thesis Outline**

**Optimizing Planar Arrays of Magnetic Sensors for Medical Robot Localization**

1. **Introduction**

* Motivation for problem – For minimally invasive medical procedures, there is a need to sense robot position and orientation as well as shape inside the body. (Explain….)
  + Could include graphic of heart with catheter inside….
* Review existing methods for sensing these things (for each, describe method and its pros and cons)
  + External image-based tracking using near-infrared based trackers – limited by line of sight
  + Imaging through tissue: fluoroscopy, ultrasound, MRI, etc.
  + Shape sensing of continuum robots using FBGs
  + Electromagnetic sensors – here is where you set the stage to describe how what you have done is different
    - EM tracking technologies
    - Permanent magnet tracking technologies – here is where you describe most closely related work where sensors are used to track single magnets.
* Describe your contributions here (reword as appropriate):
  + Optimization of sensor array that could be positioned under patient who is lying on OR table
  + Providing design tools for selecting sensors and designing array to enable measurement of specified differential translations and rotations.
  + Algorithm for estimating position and orientation based on sensor measurements.
* Remainder of thesis is arranged as follows. Next chapter describes X. Following chapter covers Y….

1. **Magnet Localization**
   1. **Problem definition**

* Define problem by narrating graphic showing magnet, magnetic field around magnet and sensor array with figure defining all coordinate frames.
* This allows you to define problem as estimating magnet frame from set of all measurements.
  1. **Define governing equations relating magnet position and orientation to sensor measurements**
* Dipole model, representation in appropriate coordinate frames
* Explain how you are going to solve the inverse problem (measurements 🡪 magnet location)
* For inverse problem, you will use differential model: derive that here.
* Explain general approach to solve inverse problem using differential model.

1. **Least Squares Methods for Solving Inverse Problem**

* Standard Method – equations, pros and cons
* Alternative algorithm
* Comparison using grid of sensors (not optimized array)

1. **Sensor Array Optimization**

* Potential criteria for optimization
  + Minimum singular valve – explain potential value mathematically….
  + Reciprocal condition number – explain potential value mathematically
* Minimum Singular Value
  + Challenge of scaling position and orientation
  + Relationship between minimum condition number, sensor noise and minimum resolvable translation and rotation.
* Optimizing with respect to minimum singular value and reciprocal condition number
  + Explain / show plots of numerical experiments that show that an optimized rectangular grid transforms to a circle whose diameter varies along Pareto front.
  + Explain / show numerical experiments that test whether maximizing reciprocal condition number at the expense of reducing minimum condition number do not significantly affect speed of inverse solution.
  + Conclusion is that best sensor array corresponds to circle diameter maximizing minimum singular value.

1. **Experiments**

* Compare unoptimized and optimized grids based on minimum measurable translations and rotations: details of experiments to be determined.

1. **Conclusions**