Localisation of magnetic material in cancerous tissue during breast cancer surgery using a handheld magnetic probe

Piramol Krishnan
Imperial College London

Masaki Sekino
Sekino Lab, Department of Electrical Engineering
Graduate School of Engineering

Introduction

The primary focus of this research project is to enable the productization of a magnetic probe that aids in the localization of cancerous breast tissue during biopsies and related surgeries. Currently, when lesions are removed from breast tissue during surgery, the localization of said tissue is done via a visual examination. As such, there is no quantitative means of determining the location of the tissue that is meant to be removed. Therefore, an accurate dataset of its usage must be produced along with supporting devices to enable its transition into the operating room.

Partial Mastectomy Using a Hookwire

First, an X-ray is taken of the breast tissue to identify tumors/lesions. A cutting margin—the area of tissue meant to be removed—is thus determined. The hookworm is inserted into the tissue and the cutting margin is confirmed by the surgeon through a hand and visual evaluation with the use of the hookwire. Once confirmed, the incision is made and the tissue is removed and sent for another X-ray to determine if the cutting margin was satisfied. If the amount of tissue is less than intended, another surgery must take place.

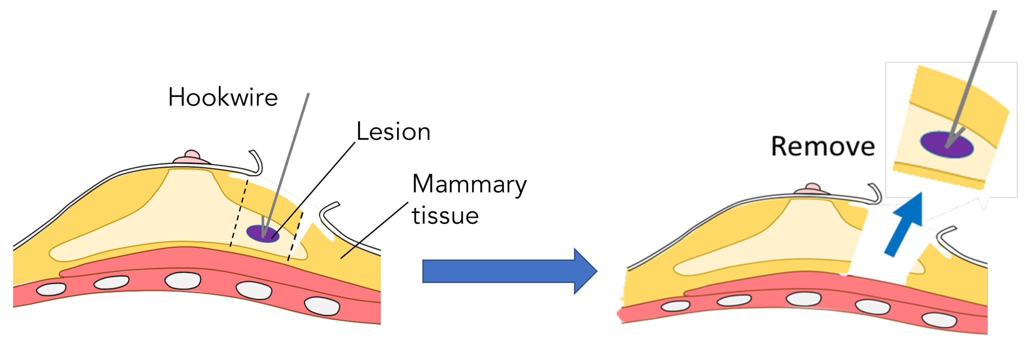


Figure 1: Hookwire in use

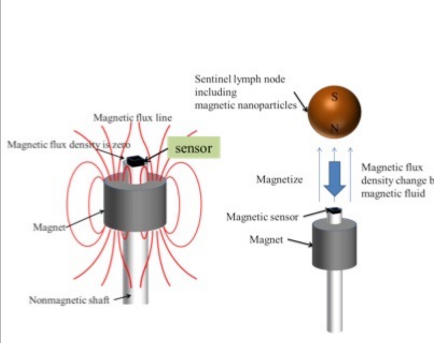
Aims and Objectives

Aim 1: Produce a 3D magnetic sensitivity map to numerically locate magnetic material

Aim 2: Design and develop a device to support the usage of the magnetic probe in the operating room.

Aim 3: Using the sensitivity map developed, develop an algorithm to numerically locate the magnetic material

Magnetic Probe



The probe is typically used in conjunction with magnetic nanoparticles that are injected into the tissue. The tip of the probe has a magnetic sensor that induces a magnetic field in the nanoparticles and the sensor detects the change in magnetic flux density.

Materials and Methods

Computer Aided Design with Autodesk Fusion

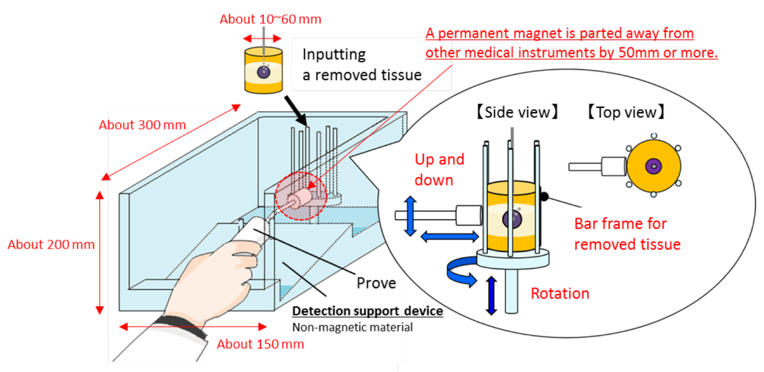


Figure 2: Idea of probe box

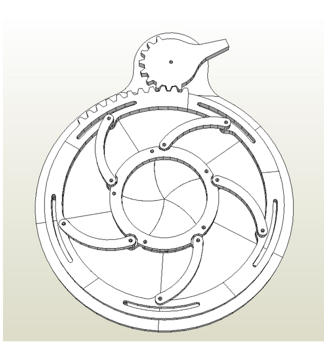


Figure 3: Mechanical Iris

The Probe Box helps facilitate the use of the magnetic probe in the operating room. Once the affected tissue has been removed, the probe box can be used in examining the tissue by placing it on the platform. The various motions aid in the localisation of magnetic material within the tissue and can instantaneously determine if the cutting margin was met, thereby bypassing the need for an X-ray. In order to prevent the influence of the magnet of the probe on other medical equipment, the box must accommodate a minimum spherical volume of 10cm or more in diameter.

Design requirements
1) Central platform: Lateral Motion
2) Central platform: Rotational Motion
3) Probe platform: Relative Vertical Motion
4) Central platform: Bar frame with adjustable radius
   - This was achieved by modelling after a mechanical iris that allows for great control over the degree of motion.
5) Materials used must not be magnetic.
   - Fabrication of the probe box was achieved through laser cutting of acrylic and using plastic gears and belt.

Materials and Methods

Figure 4: actuator system

Equipment:
3 Linear Actuators,
1 Rotational Actuator

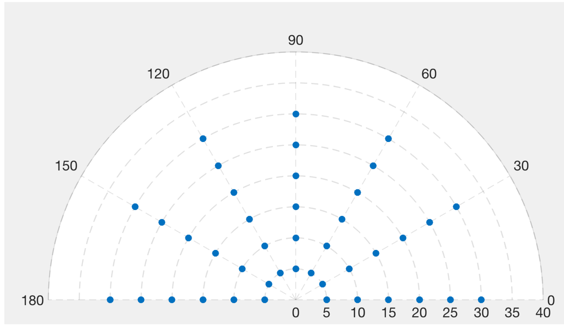


Figure 5: Data point locations

Programming in Igor

Flow of program

1) The starting point of the actuators is at the 5mm radius from the origin to account for the space taken up by a sample. The origin is located along the centreline of the Z axis and directly above the centre of the rational axis.
2) The actuator then moves to the background position, 40 mm from the origin along that slice to collect data accounting for the background magnetic field.
3) After collecting the background data it will return to the 5mm position to collect data for that point.
4) It will then collect the background data for the next position, 10mm before moving back to collect data for that point. The cycle repeats in 5mm increments until 30mm. The actuator will then rotate by 30° to the next slice.
5) After all the slices are down for that z-value, the Z-actuator will increment 5mm upwards. Each Z-increment is 5mm and increments until 30mm.

Results and Discussion

Probe Box

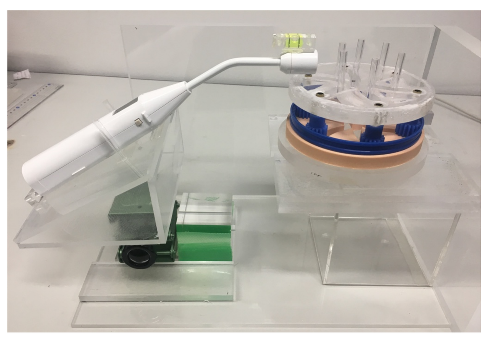


Figure 6: Fabricated probe box

The fabricated probe box met all the outlined design requirements. There is full 360° rotational motion of the platform and lateral motion for both the probe platform and sample platform. However, the adjustable diameter range is 20-59 mm instead of the intended 10-60 mm. The platform for the probe was fitted with a jack with a knob to adjust the height relative to the platform with a range of about 70mm.

Sensitivity Map

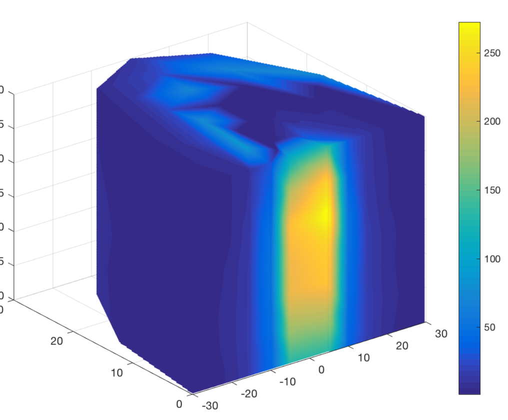


Figure 7: 3D Sensitivity Map

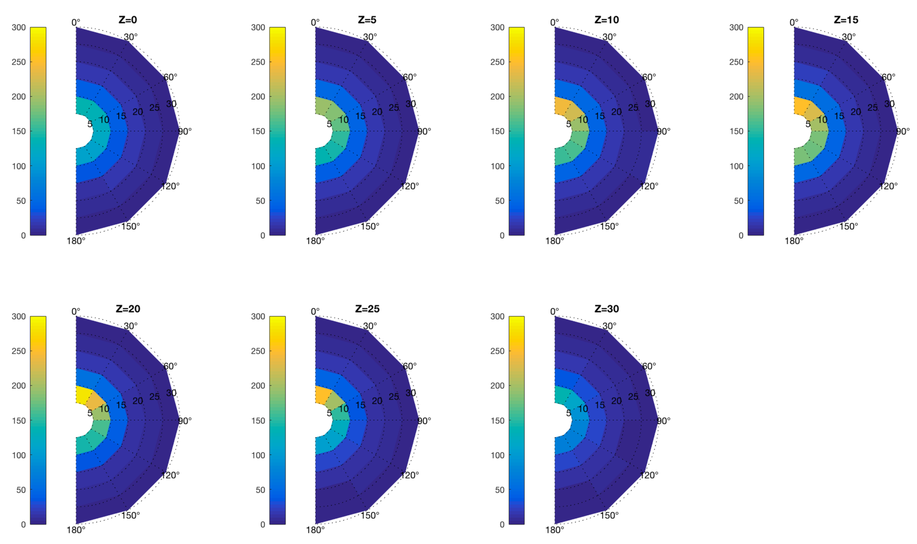


Figure 8: 2D Sensitivity Maps Slices at different Z positions

A control experiment was conducted where the sensitivity map was collected when no sample was used. From this map, the margin of error for collected values is taken to be ± 1μT. In Figure 7, the peak intensity occurs in the innermost centre of the figure between 15-20 mm on the z-axis. This corresponds to the geometry of the hookwire in which the wing is between that range. The wing itself would induce a greater change in magnetic flux density when faced head on to the probe which occurs at the angles 0 and 180. From Figure 8, it can be confirmed that the peak intensity is at the z-value of 20mm and around 0°.
The location of the magnetic material corresponds to the areas of high intensity (yellow). Using the 3D map allows for visualisation in space and the 2D map provides guidance on the coordinates of peak intensity and so magnetic material.

Conclusions

While the fabrication process was successful overall, some aspects of the design could be improved such as the range of adjustable radius for the bar frames. While the sensitivity maps can estimate the location of the magnetic material, the resolution could be improved to be more precise in the estimation which could be the focus for future projects.

Perspective

The Amgen Scholars Program was challenging, exhilarating and incredibly insightful. Not only was I given insight into the realities of research on a graduate level, i learnt a great deal about myself in the process. Throughout the program, I constantly had my ideas and preconceptions challenged. While daunting at times, those moments of question truly stretched my capabilities and reaffirmed my love for design and biomedical engineering. I have walked away with greater faith in myself and a stronger belief in myself to realise my aspirations to effect positive change in myself. I also have much higher regard for and interest in research now, in particular product development, which will guide my future career aspirations.

Acknowledgment : Thank you for the financial support provided through the Amgen Scholars Program.

Amgen Scholars Japan Program
AMGEN Foundation
Amgen Scholars Program