Estimation Methods in a Magnetic Marking System for Cancer Surgery

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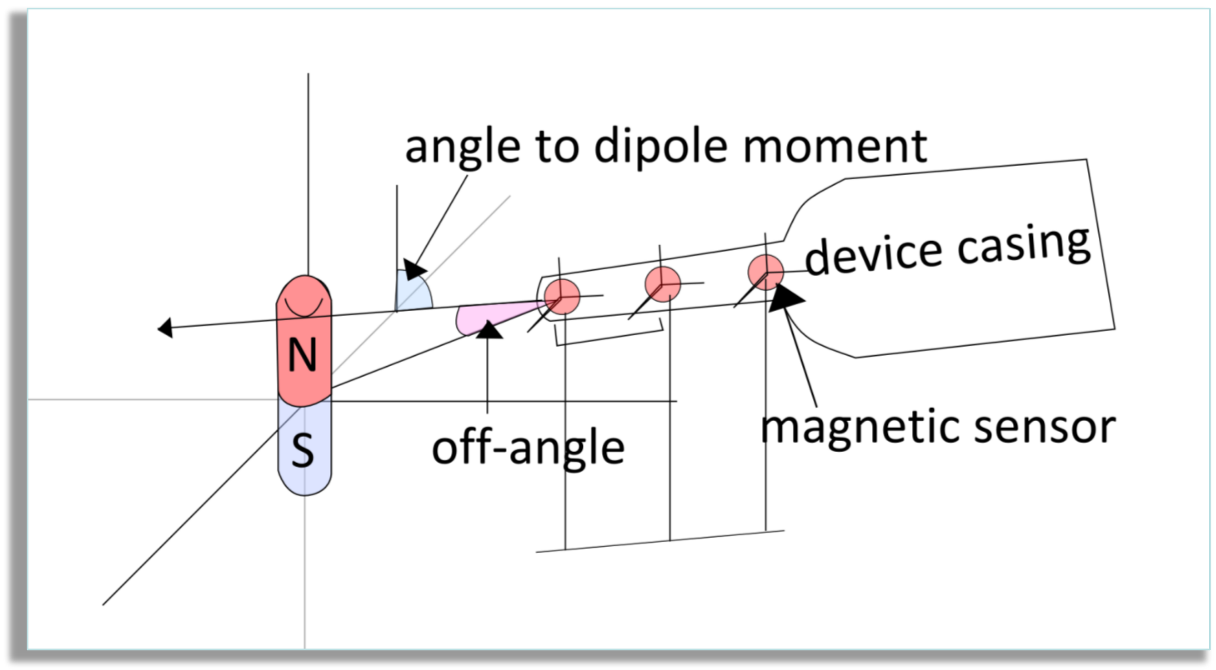
Introduction

Current techniques for performing lumpectomies on breast cancer patients face problems of both accuracy and convenience. To combat these, a device is being developed to use magnetic marking in surgery. In this system, a small permanent magnet is inserted into the affected region before surgery; during surgery, a device using an array of magnetic sensors detects the presence of the magnet and guides the surgeon in locating it. This method can make surgery safer and quicker, but the precision and usefulness of the device need to be improved. This project examines several algorithms for interpreting the sensor data.

An early prototype of the device. The box shows the estimated distance to the magnet and emits beeps of varying frequency, depending on the estimated distance.

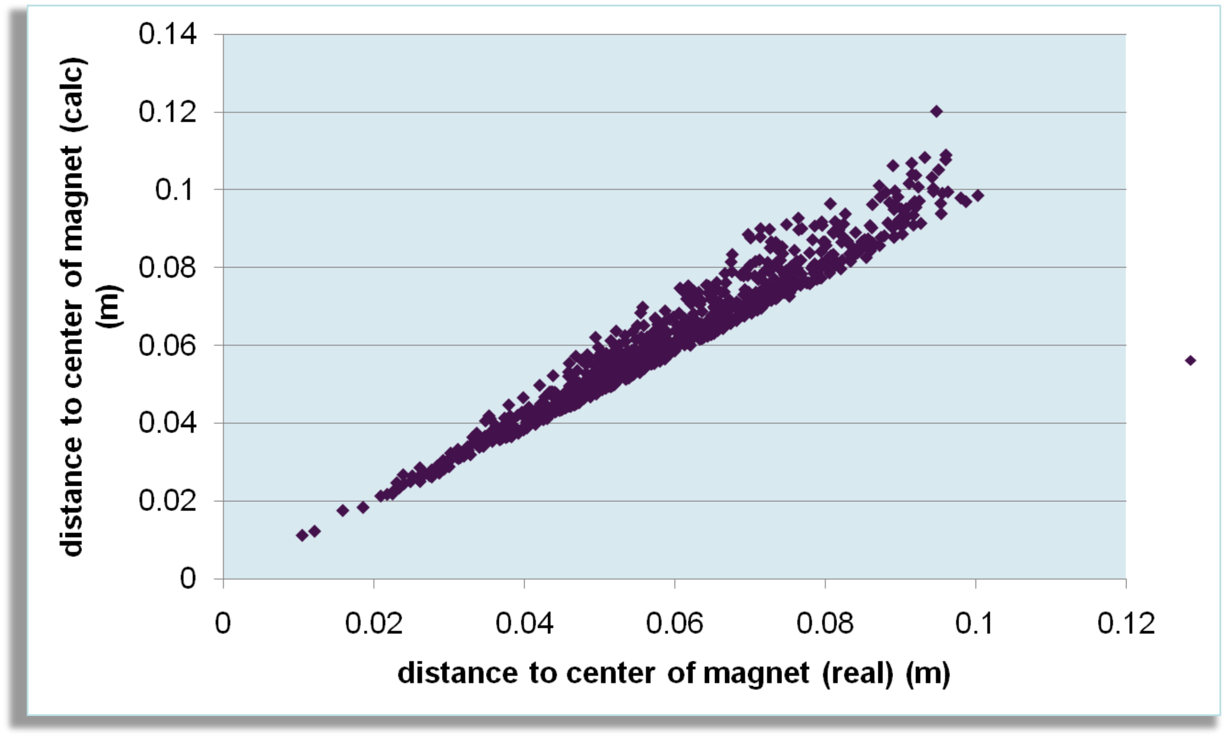


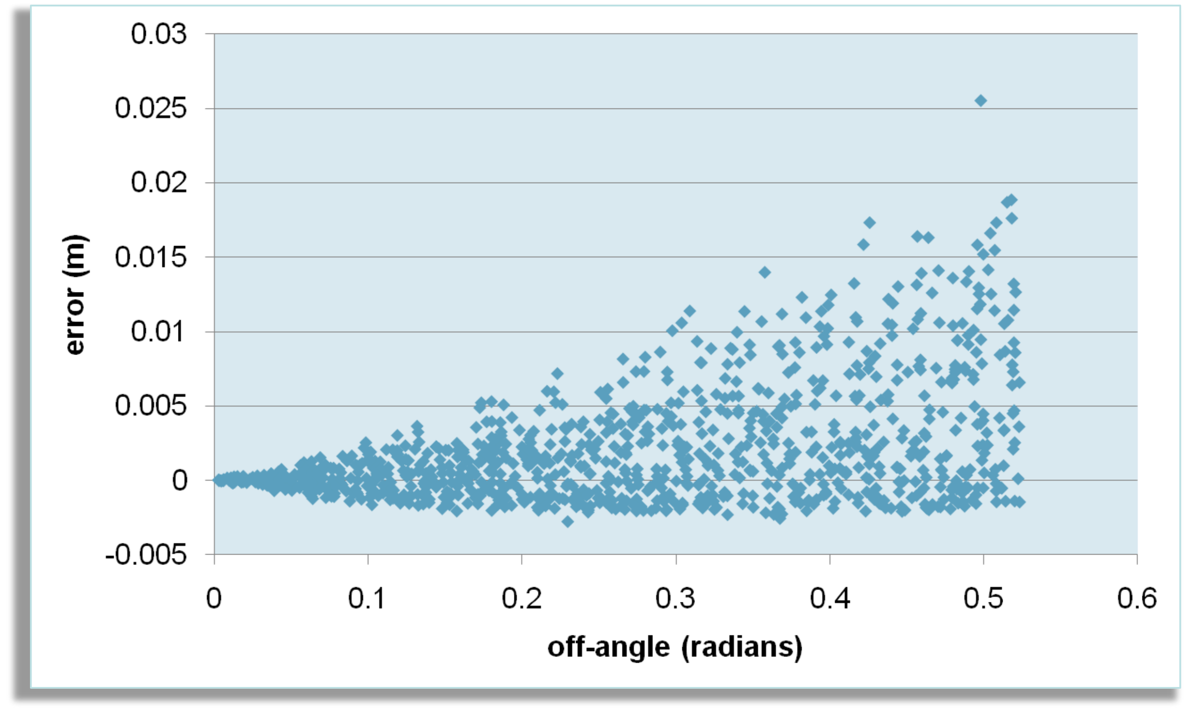
A diagram of the problem setup for the simulations, to clarify terminology. The lines on the sensors represent the axes where the magnetic field is measured,

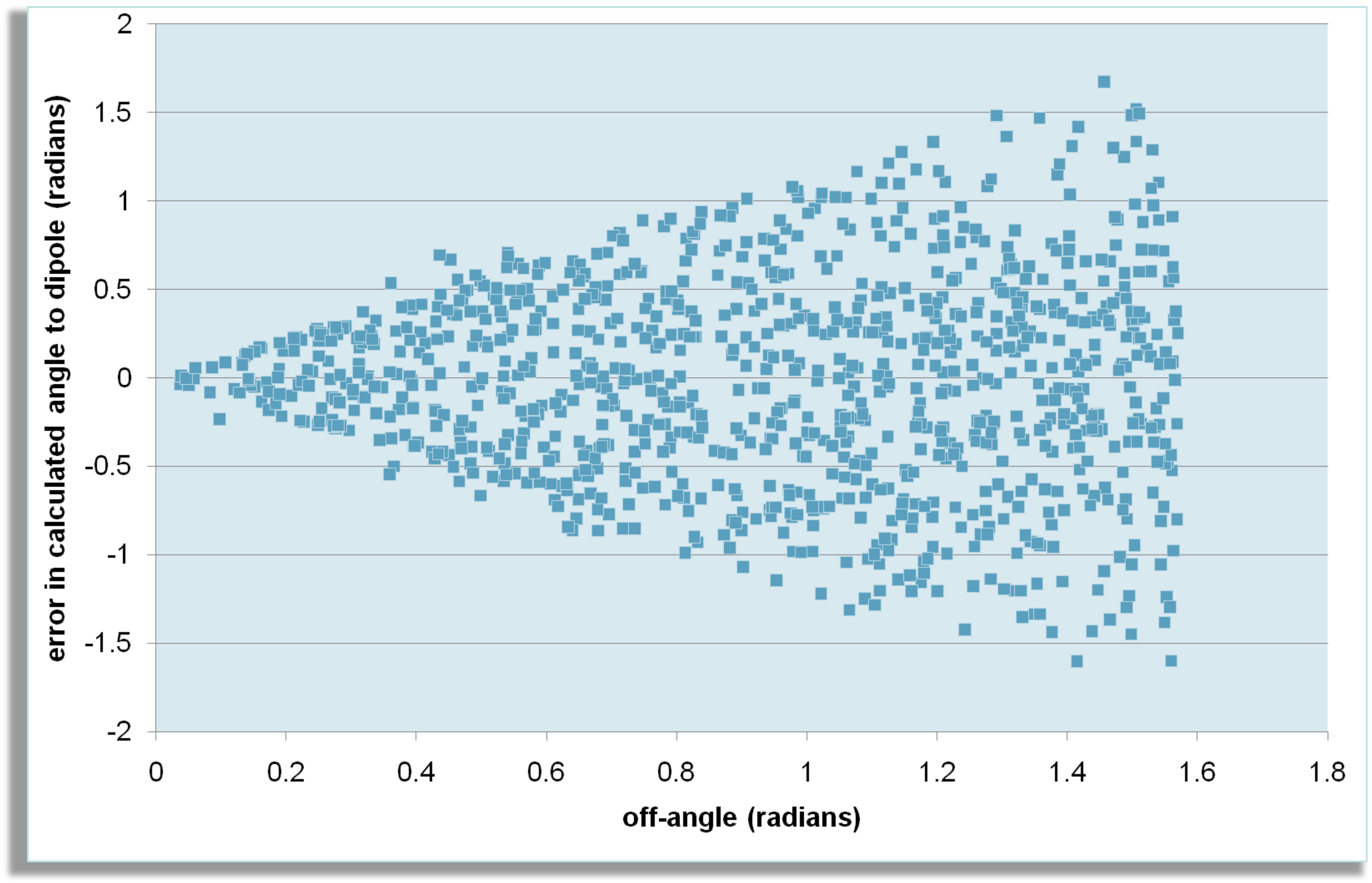
Methods

A simulator for taking data from the three-dimensional magnetic field was developed in C++. The simulated device used three magnetic sensors, each of which was assumed to take measurements on the same x-, y-, and z-axes. Measurements were taken at random points, in random directions, with various conditions and assumptions imposed on their choice.

Several methods for obtaining information about the position of the magnet were tested. These included a simple second-order difference formula for the magnetic field at a point, an iterated formula for the distance to the magnet, and an iterated formula for the angle to the magnet's dipole moment.







Top left: A simulation of the iterated formula for distance, charting the real distance versus the calculated distance, with the condition that the off-angle was less than 30 degrees.

Above: A simulation of the iterated formula for distance, charting the error in the calculated distance vs. the off-angle. As supposed, the maximum error increases with the off-angle.

Left: A simulation of the iterated formula for angle to the dipole axis of the magnet. The maximum error in the calculated angle to the dipole increases as the off-angle increases, in a close-to-1:1 ratio.

Results

The iterated distance formula was very accurate when the detector was close to pointing directly at the magnet, as was the iterated angle formula. The second-order difference formula yielded imprecise results. No simulation provided a clear way to find the off-angle; more study will be needed to obtain accurate confidence estimates for the calculated angle and distance to the magnet.

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