Proposal for Earth Magnetic Anomaly Navigation

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1. **Topic and Background**

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| A map of the earth  Description automatically generated |
| **Fig 1: Earth’s Magnetic Field (Wide Perspective)** |

The proposed topic of research is navigation using measurements of Earth’s magnetic anomaly. Magnetic fields are represented by a continuous vector field with magnitude and direction which permeates through free space. Earth’s magnetic field is the field created by the abundant magnetic material within the Earth; this permanent field is perturbed by solar wind and charged particles moving throughout the ionosphere which creates a significant time variation in the field. A magnetic anomaly is a local variation in the Earth's magnetic field caused by geophysical variations present in the Earth’s crust. Magnetic materials occur in varying densities throughout the crust which contribute to the overall magnetic field strength at any point in space. Variations in the field due to these features are orders of magnitude less than the total magnetic field strength which is primarily due to the Earth’s iron core [cite]. The so called core field is on the order of 40,000 nanoteslas (nT) varying slowly around the magnetosphere [cite]. Magnetic anomalies are on the order of 100 (nT) and therefore require more precise instrumentation. A minimum of 10 (nT) of measurement precision is needed to accurately capture the anomaly field. If measurements are made and position-correlated, a map of the magnetic anomaly can be produced. To show just the anomaly affects the core field must be subtracted at every point. The values around the Earth are well modelled by the World Magnetic Model (WMM) [cite]. The measurements must also be corrected for time dependent variations such as those created by charged particles in the ionosphere, solar wind, etc.

If a sufficiently fine map of the magnetic anomaly is available, and precise measurements of the local magnetic field can be made, then the measurements can provide information of the relative position of the sensor. This information can be injected into a position estimation filter in real time or post processed to reconstruct the state. This type of measurement source has a few key advantages over others such as GPS or visual navigation. The magnetic field exists over the entire Earth including over oceans where there are no navigation references. The magnetic field is nearly impossible to interfere with since the power dissipates rather than the square of r as with EM waves. This project will study the prospect of navigation using Earth’s magnetic anomaly [cite].

1. **Data and Methods**

The key data for this project will be the magnetic anomaly map. The minimum information needed is magnetic anomaly field strength and corresponding position over some useful geographic scale. This is generally the toughest part of magnetic navigation since measurement of the field must be made at every position in the field; there is no remote sensing method for collecting this data. Since use for this data are niche (magnetic navigation has not been widely implemented) creating these maps has not been made profitable and so geographic coverage is sparse. Fortunately, the National Oceanic and Atmospheric Administration (NOAA) generates publishes a worldwide map featuring anomaly field strength at sea level and 4 (km) altitude above sea level called the Earth Magnetic Anomaly Grid (EMAG) 2. This map fuses measurements made from satellite, ship, and airborne magnetic measurements [cite] from a variety of data collects. The data is publicly available at this site [cite]. The raw values are plotted below using Matlab.

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| **Fig 2: NOAA EMAG2 Contour Plot** |

This contour plot shows the variation in field over a roughly 10,000 (km2) area around western Virginia at 4 (km) altitude. There are nearly 1000 data points for this area from -200 to 300 (nT). Up sampling using some interpolation scheme should produce data sufficient for regional navigation. This data can at the very least be used to validate methods for use with more detailed maps.

A Kalman Filter can be used to estimate position using a model of the measurement. The measurement model will be created to inject the measurements of position (from simulated magnetometer readings an EMAG2 map) into the filter. There are derivations of this for magnetic navigation studies as well as classical terrain following which uses the same mechanism but with maps of land elevation.

1. **Anticipated Outcome**

The following

**References**

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Government agency reports do not require locations. For reports such as NASA TM-85940, neither insert nor delete dashes; leave them as provided. Place of publication *should* be given, although it is not mandatory, for military and company reports. Always include a city and state for universities. Papers need only the name of the sponsor; neither the sponsor’s location nor the conference name and location is required. *Do not confuse proceedings references with conference papers*.

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*Patents*

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