Dismounted Soldier Positioning in GNSS-Denied Environments Using Magnetic Fields

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Figure 1: Wooden Rig

Introduction

Situational awareness provided by robust and resilient positioning systems is mission-critical for many military applications and emergency services. Global Navigation Satellite Systems (GNSS) receivers are ubiquitous. However, GNSS signals can be denied, degraded or otherwise unavailable in many operational environments, necessitating one or more additional positioning navigation and timing (PNT) technologies to be available to the user. No single PNT technology, including GNSS, is sufficient in all operational environments[1]. Therefore, a multisensor integrated system using a system of subsystems is required[2].

This PhD project focuses on dismounted soldier positioning based on subsystems derived from inertial and magnetic measurement units (IMMU). Inertial navigation is well-researched for pedestrians; however, map matching derived positioning using magnetometers is under-researched, particularly the effect of different environments on performance. This magnetic-derived subsystem does not require new sensors but complements the commonly used IMMU system.

Building Type and Height of Sensor

This project has investigated how the characteristics of magnetic fields, that could be used for magnetic map matching, vary across different types of buildings. Some of these environments differ significantly from the university buildings typically used by other researchers. These characteristics of magnetic flux density (MFD) measurements have been analysed across various environment types, where specific characteristics for each environment are identified.

This includes five indoor environments as defined by ISO/IEC 18305[3] and one outdoor location:

- Single-family House
- Concrete Office Building
- Warehouse/Factory
- High-rise Steel Structure
- Subterranean Structure
- Rural Outdoors

This spatial database of measured MFD will become open access, providing contextual data for each environment, including 3D models and 360° photos.

Analysis of this database proves that MFD measurement characteristics vary by environment type. In the future, the knowledge of these characteristics can be used to tailor MFD positioning algorithms per environmental type, benefiting from these unique characteristics.

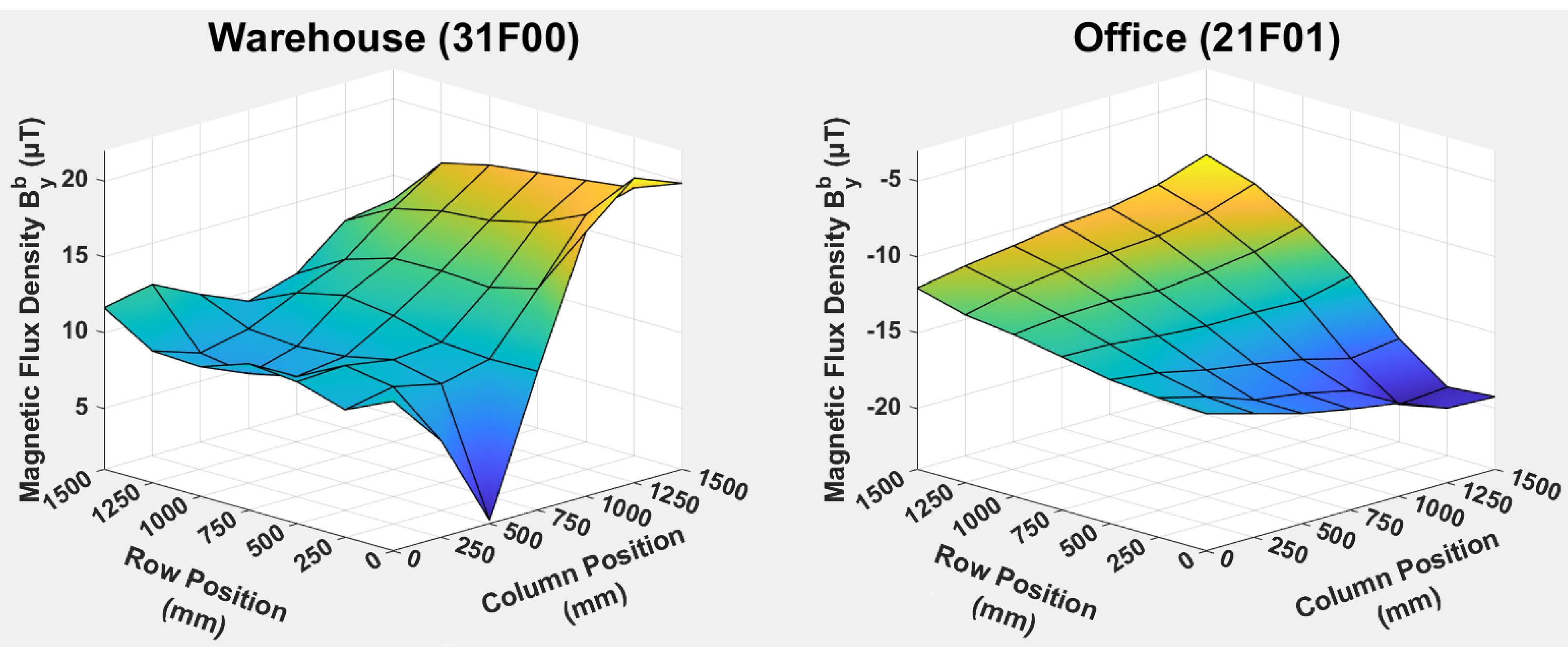


Figure 2: MFD (B_y^b) in the Warehouse and the Office Environment

Depending on the environment, the measured MFD varies with height above ground, making the height of the sensor on the user critical. In some indoor environments, foot-level sensors show larger MFD variation across a horizontal grid than sensors placed higher on the body. Thus, it is recommended that the height placement of IMMUs on dismounted soldiers be tailored to the type of indoor environment.

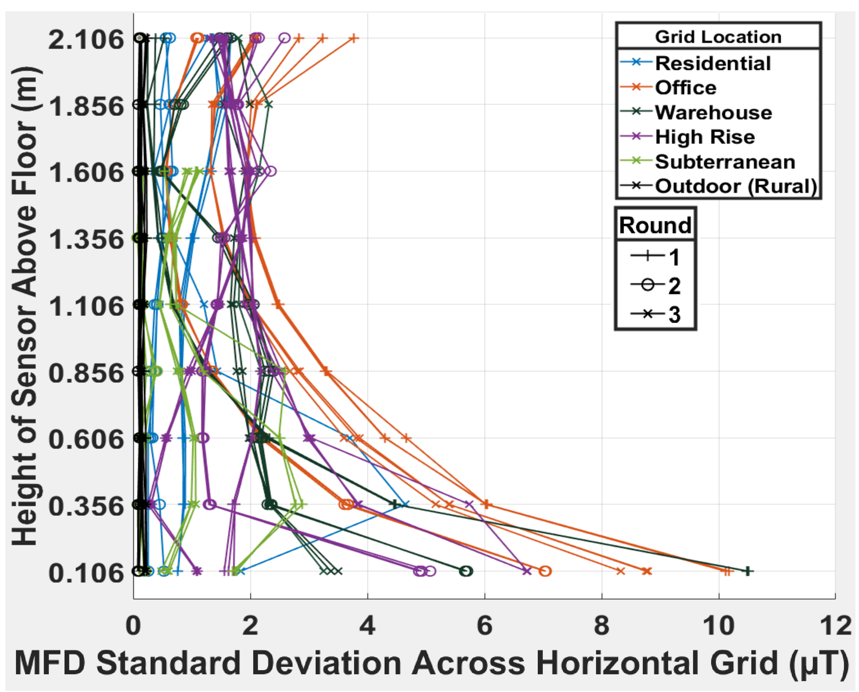
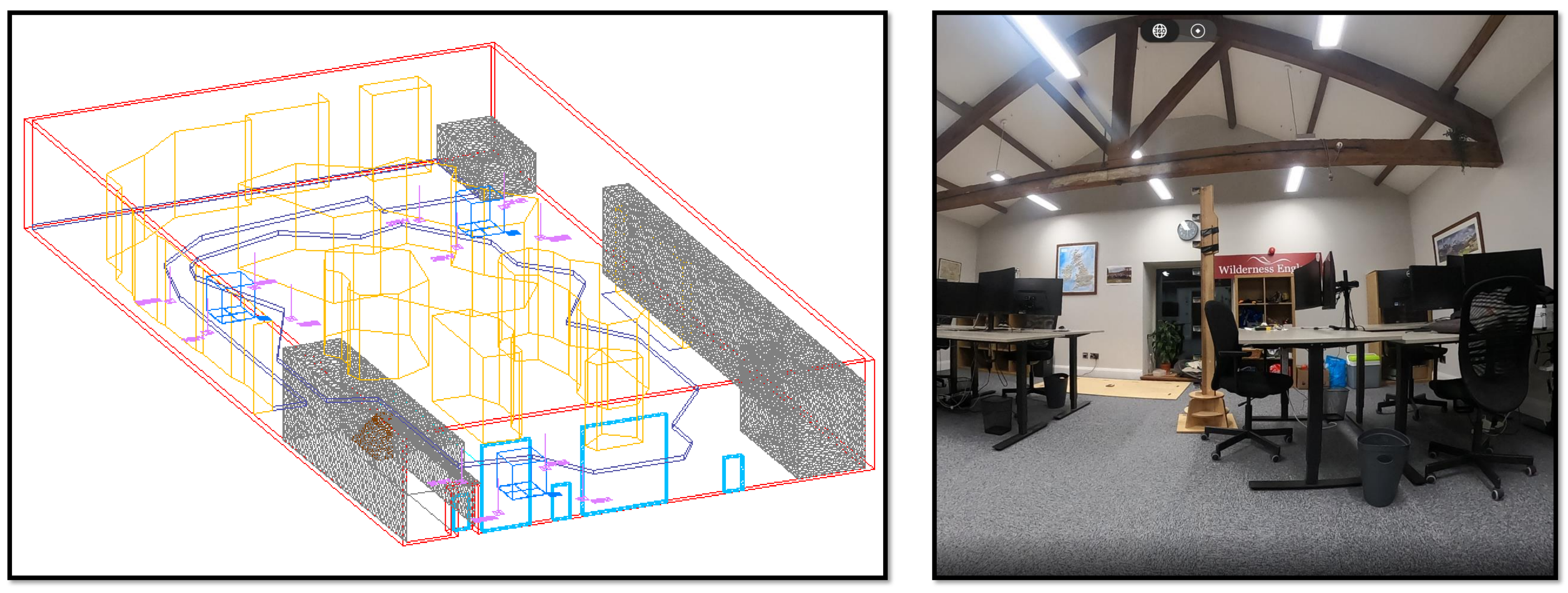


Figure 3: Standard Deviation of MFD (B_z^b) across a Horizontal Grid at each Height above Ground (m) in each Environment Type (μT)



(a) Warehouse)

(b) Office

Figure 4: Contextual Building Models (a) and 360° Photos (b)

MFD Source: AC Electrical Cable[4]

Unpredictable temporal variations in MFD could severely disrupt magnetic map matching. A significant source of these is electrical power cables; research on how underfloor cabling affect magnetometer measurements has been conducted. The variables examined include the magnetometer type, the alternating current (AC) electrical power transmitted through the cable, the cable type, and the distance from the cable.

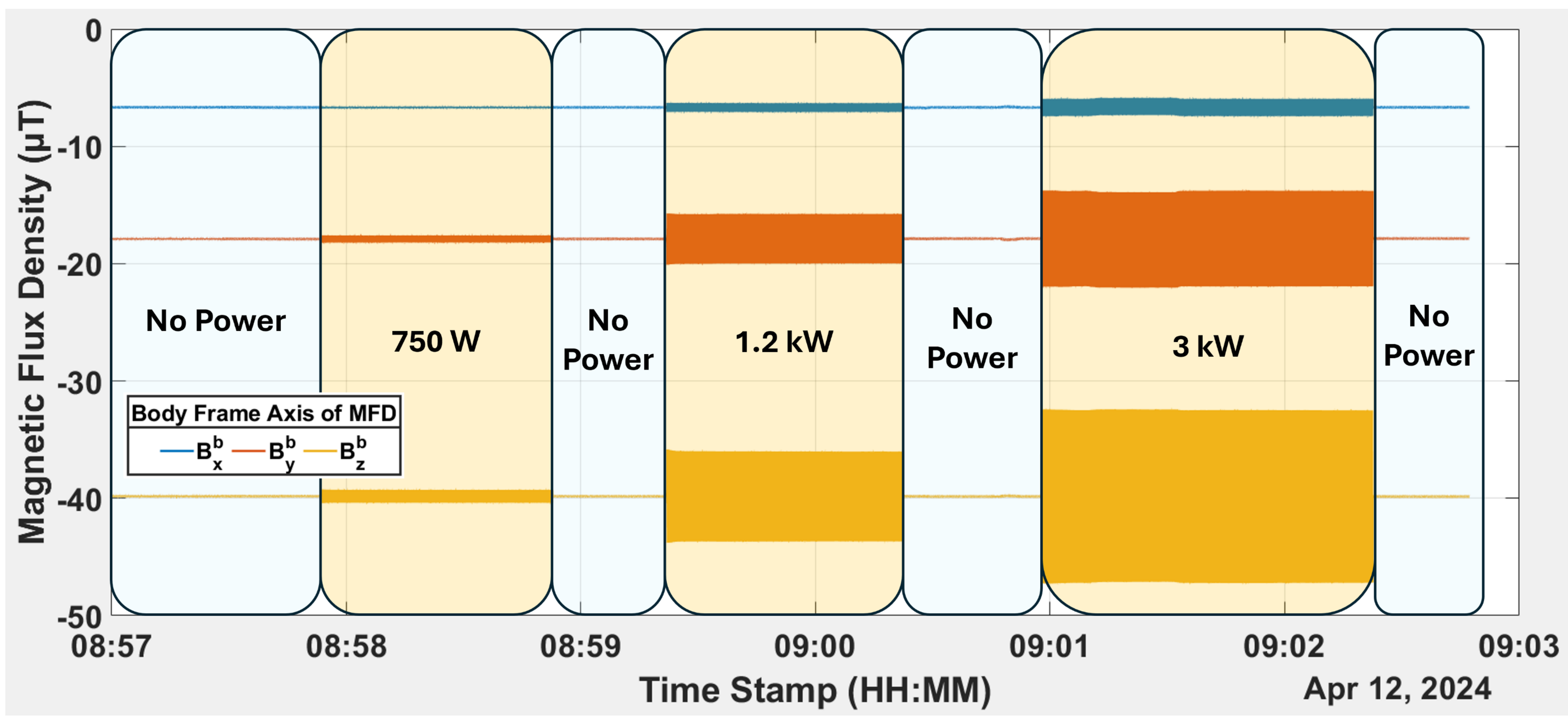


Figure 5: Time Series on MFD with a Range of AC Power with an Unshielded Cable

A significant amount of building electrical power is alternating current (AC). Due to this, the AC-sourced magnetic fields can be separated using frequency-domain filtering, which requires high-bandwidth magnetometers. This filtering can improve the performance of a magnetic-derived positioning subsystem, improving the overall multisensor integrated positioning system. Therefore, it is recommended that dismounted soldiers use magnetometers with bandwidth high enough to isolate AC sources of MFD.

References

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