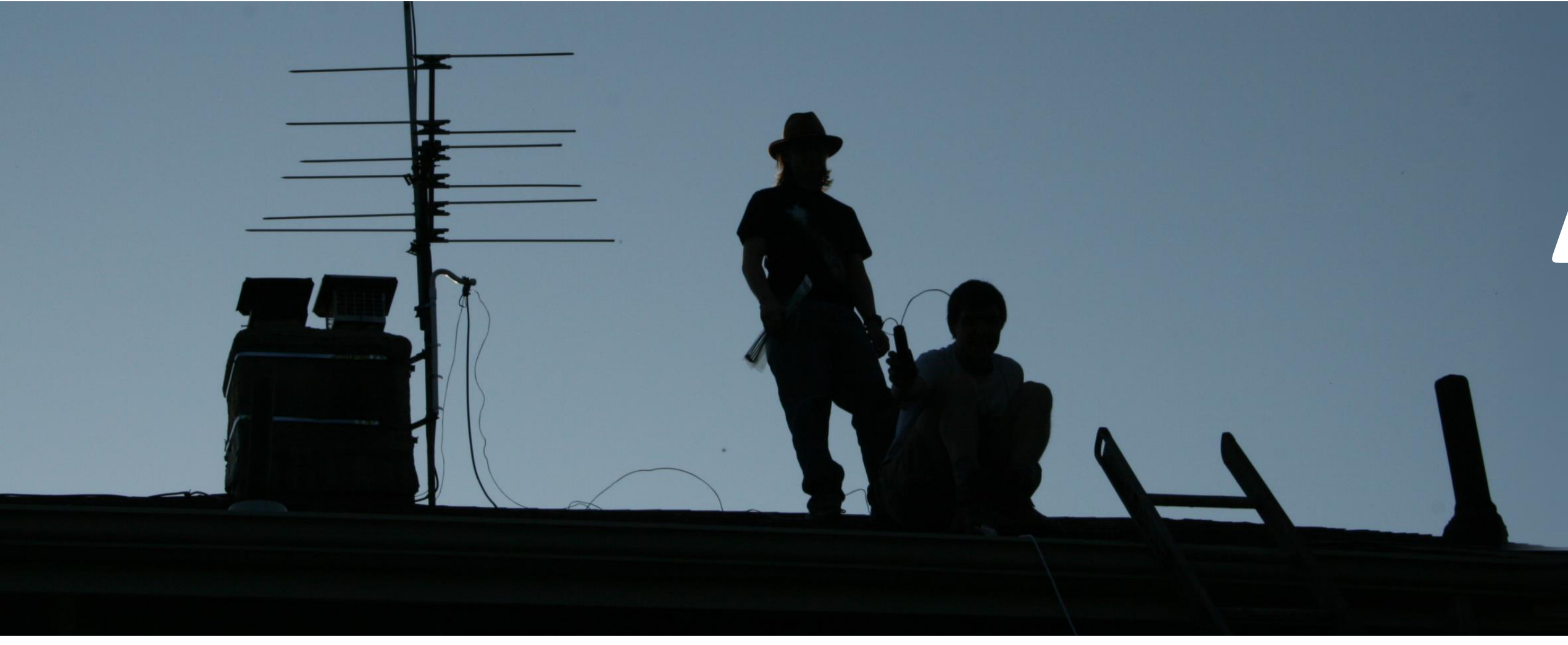

A Real-Time Web Dashboard for Measuring Earth’s Magnetic Field

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Abstract

Recent events, such as the 2024 Gannon solar storms, have prompted much closer investigation into how various kinds of interactions with the Earth’s magnetosphere affect it. Such measurements of Earth’s magnetic field are observed by devices known as magnetometers. Existing research in this area has produced a cost-efficient solution for amateur radio enthusiasts and interested researchers to set up their own magnetometers within the confines of their homes (Kim et al. 2024). However, the current resources that exist for interpreting these measurements are limited and insufficient for the average researcher. We present a prototype of a web application that visualizes both real-time and historical readings from our existing magnetometer system.

Introduction

A magnetometer is a device that measures the movement of the Earth’s magnetic field. Their most common use is detecting magnetic anomalies and other geophysical applications. The 2024 Gannon solar storms, brought greater attention to these fronts both from a public perspective and a research perspective. Historically, laboratory-grade magnetometers have been inaccessible to larger crowds due to their high shelf prices. Fortunately, research by Kim et al. in 2024 successfully produced a ground magnetometer system of commercial-grade quality at a fraction of the price. The intentions of this specific research project are to extend upon the existing low-cost system by creating better tools for effective visualizations with an emphasis on real-time data analytics. There are two primary motivations for pursuing these ideas:

1. The current tooling and software for visualizing magnetometer time lapses requires a background in programming, which not everyone has.
2. Allowing for real-time data visualizations enables researchers to see live changes in the magnetic field as they happen. This quality would be of particular importance during solar storms.

In this research, we present a prototype of a web-based “magnetometer dashboard” with real-time plotting capabilities and historical data viewing.

Requirements

Since this dashboard is intended to be used by researchers and other interested parties, it should have some basic requirements in terms of functionality and accessibility. On the functional side, it must support data visualizations from both real-time hosts and historical data. For accessibility, the dashboard should be intuitive and easy for researchers to use. Data visuals should be clearly readable with their significance self-evident. Furthermore, the dashboard should adhere to sound web design practices to ensure a positive user experience.

Architecture

The previous research by Kim et al. (2024) produced a system consisting of a magnetometer connected to a Raspberry Pi that ran a software known as runMag. In contrast, we present a system that utilizes a Linux computer with a new USB-C-to-I^{2}C adapter called the Pi Eliminator Board. This new system is running a new software called Mag-USB, which is equivalent in function to the previous system, but easier to extend upon.

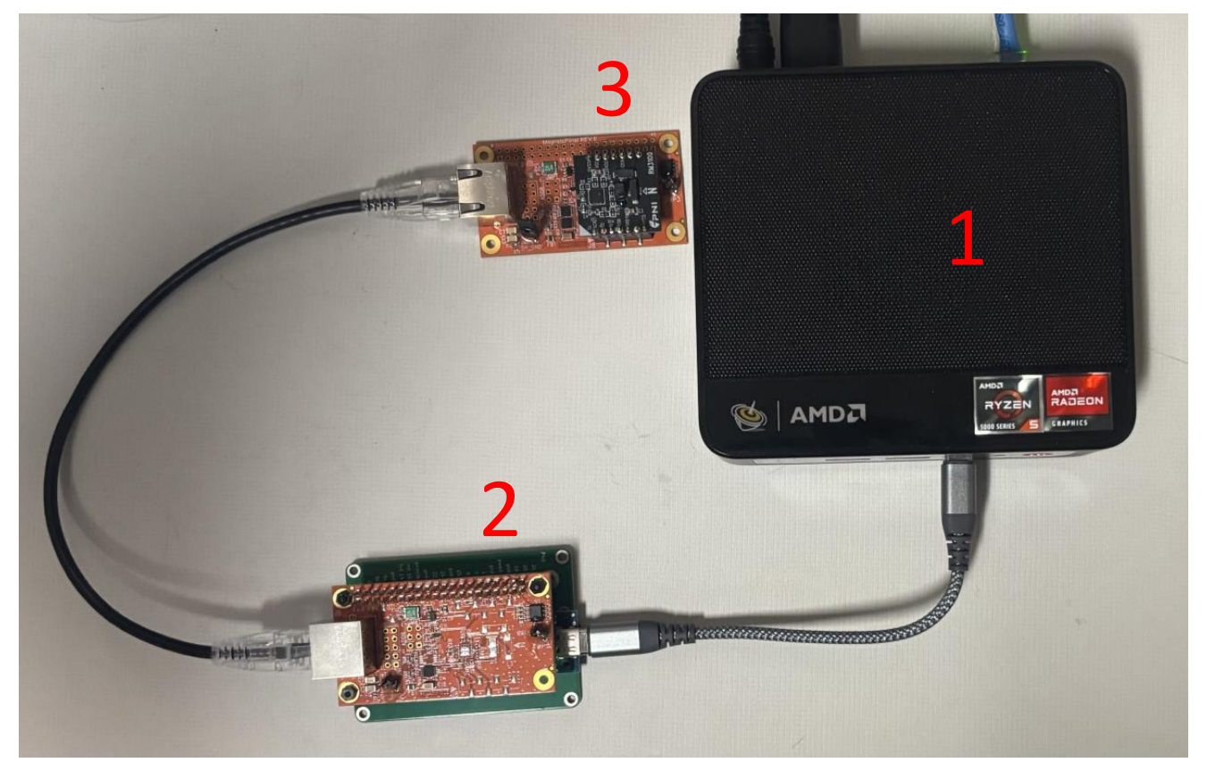

Fig. 1: Setup of a BeeLink (1), Pi Eliminator (2), and RM3100 (3)

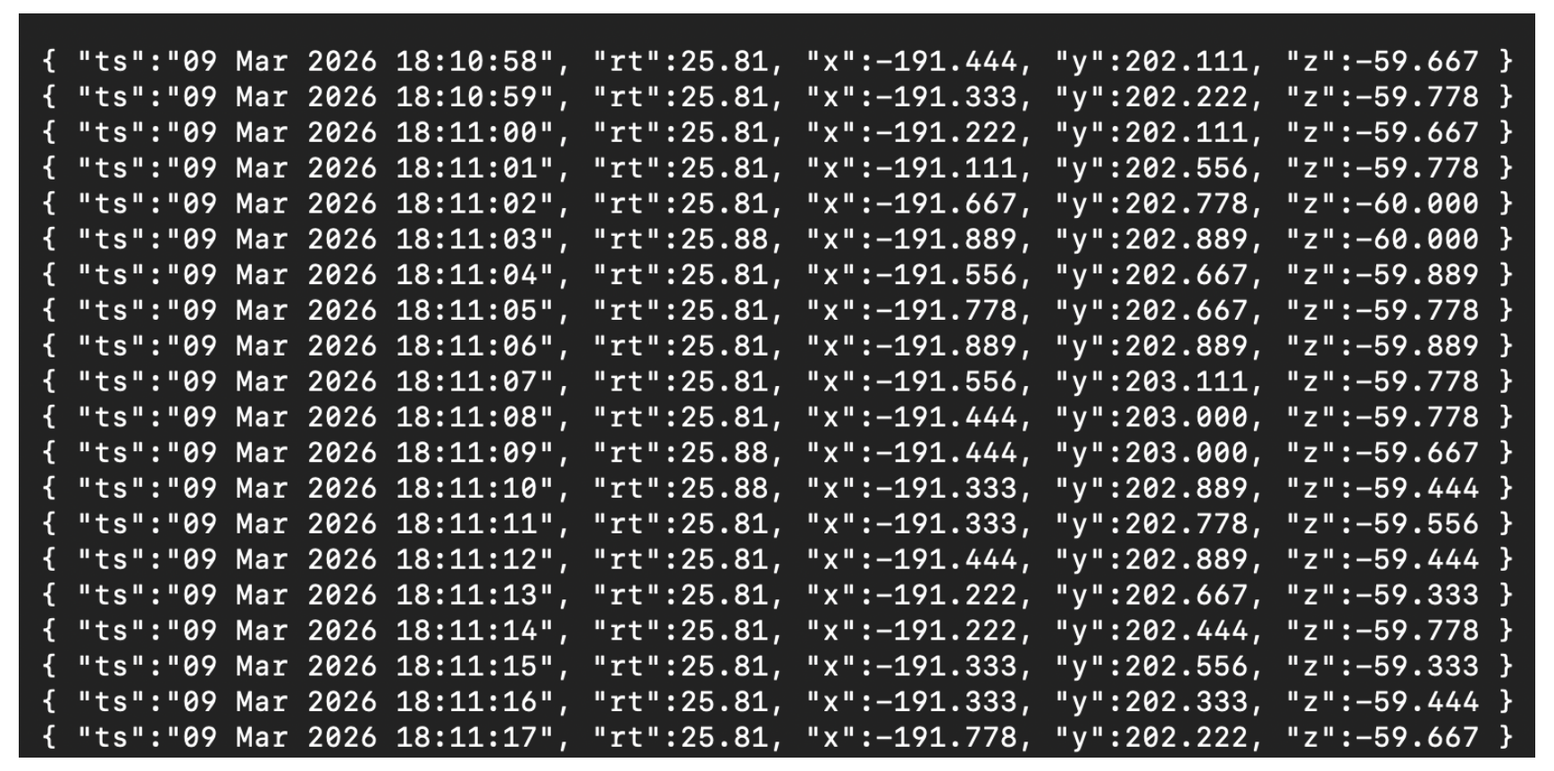

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Fig. 2: Sample Mag-USB output. The data is formatted as JSONL

Mag-USB measures the magnetic field in nanoteslas (nT) and interprets the result as an XYZ vector, along with reporting a separate remote temperature. The data reported by Mag-USB is formatted as JSON Lines (JSONL) for ease of translation by connected clients. The dashboard runs on a Deno backend and is responsible for connecting to Mag-USB via WebSocket, post-processing, and data visualization. The dashboard’s frontend is programmed in JavaScript and uses Plotly for data visuals.

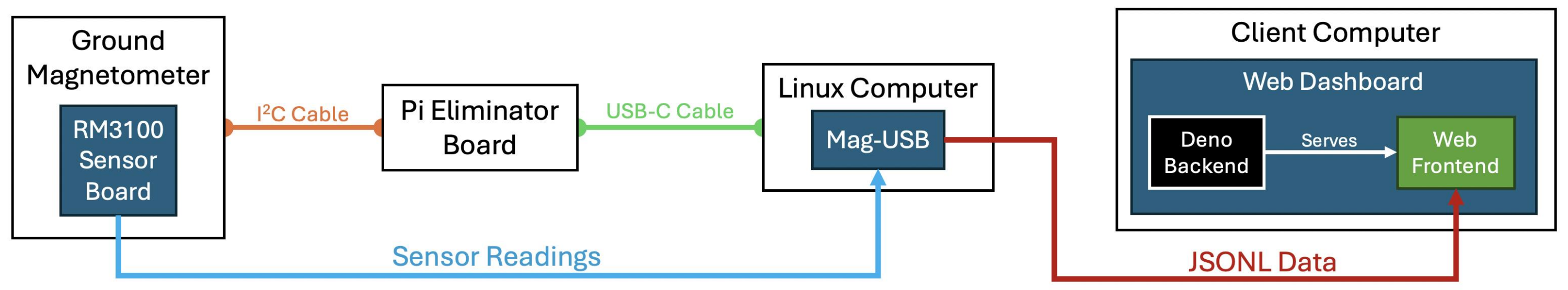


Fig. 3: Magnetometer system architecture and data flow diagram

Data Handling & Visualization

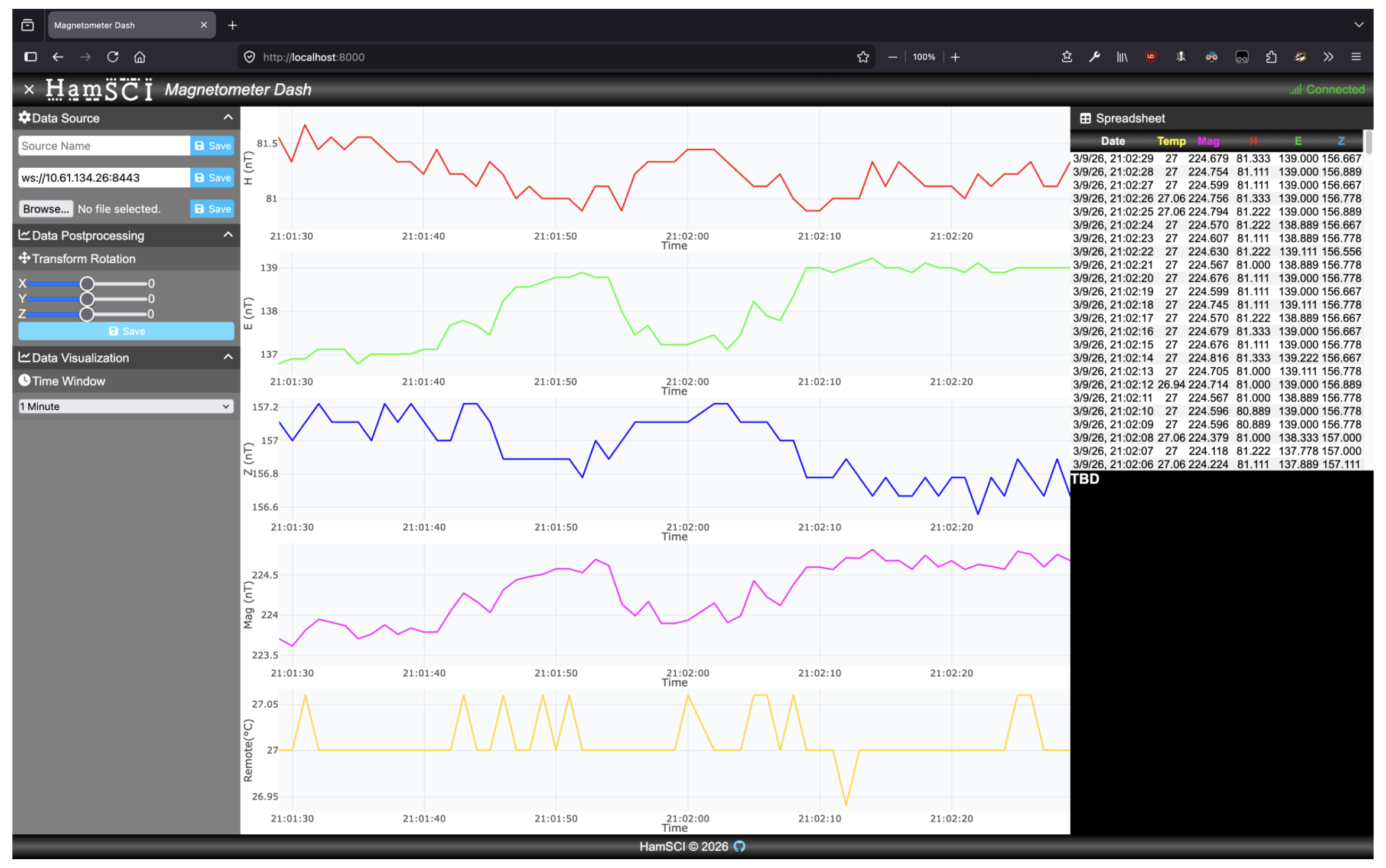
In post-processing, the dashboard transforms the XYZ vector of each measurement to its equivalent HEZ vector, where $H = -Z$, $E = Y$, and $Z = X$. The data is displayed in a series of five plots that update every second. In order, these plots are the H, E, and Z components, the field magnitude, defined as $\sqrt{H^2 + E^2 + Z^2}$, and the remote temperature. The plots can be constrained to different time windows (e.g. 1 minute, 15 minutes, 1 hour, etc.). The dashboard also displays the transformed data in tabular format for ease of viewing purely numerical data.

Future Plans

The roadmap for the project is not set in stone and plans are subject to change depending on feedback. Priorities as of current are focusing on historical data review and general improvements to user experience. However, we are looking at implementing other features pertinent to data analysis such as baseline variations and greater control over data visuals. A current limitation of our proposed system is that it only supports connecting to one magnetometer at a time. However, it may be desirable to modify the current implementation to allow users to connect to multiple magnetometers at once for comparing readings at different locations.

Conclusion

Although this current iteration of the magnetometer dashboard is only a prototype, we believe that the real-time capabilities of the dashboard will make it an asset to researchers and ham radio operators alike. The overall intent of this project is to make researching Earth’s magnetic field accessible to everyone from various backgrounds.



Date	Temp	Mag	H	E	Z
3/9/26, 21:02:29	27	224.679	81.333	139.000	156.667
3/9/26, 21:02:28	27	224.754	81.111	139.000	156.889
3/9/26, 21:02:27	27	224.599	81.111	139.000	156.667
3/9/26, 21:02:26	27.06	224.756	81.333	139.000	156.778
3/9/26, 21:02:25	27.06	224.794	81.222	139.000	156.889
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3/9/26, 21:02:22	27	224.630	81.222	139.111	156.556
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3/9/26, 21:02:15	27	224.676	81.111	139.000	156.778
3/9/26, 21:02:14	27	224.816	81.333	139.222	156.667
3/9/26, 21:02:13	27	224.705	81.000	139.111	156.778
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3/9/26, 21:02:10	27	224.596	80.889	139.000	156.778
3/9/26, 21:02:09	27	224.596	80.889	139.000	156.778
3/9/26, 21:02:08	27.06	224.379	81.000	138.333	157.000
3/9/26, 21:02:07	27	224.118	81.222	137.778	157.000
3/9/26, 21:02:06	27.06	224.224	81.111	137.889	157.111

Fig. 4: A prototype of the magnetometer dashboard. The data plots are displayed in a 1-minute timeframe

References

Kim et al. (2024). *Citizen science: Development of a low-cost magnetometer system for a coordinated space weather monitoring*. HardwareX, vol. 20 https://doi.org/10.1016/j.ohx.2024.e00580.

https://github.com/HamSCI/gmag_webui/blob/main/docs/REQUIREMENTS.md.

Acknowledgements

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