Raspberry Pi Foundation

esa

ASTRO PI
MISSION SPACE LAB

Team name: HHorizon

Chosen theme: Life in Space

Organisation name: Heckmondwike Grammar School

Country: England (United Kingdom)

1. Introduction

The aim of our investigation was to build a model which allowed the magnetic field strength (MFS) of the Earth to be mapped to its longitude and latitude. From this, we believed that we could use the model to analyse the MFS of exoplanets from a distance. This would be invaluable as planets with a similar MFS to Earth's have a similar core composition which would further make it suitable for lifeforms to evolve. In short, the Astro Pi would allow us to see which planets have a MFS similar to Earth's and are thus able to potentially support life.

We expected to find that the Earth's MFS varied in a repeating sinusoidal pattern as MFS is strongest at the poles and weakens the further away from the poles the ISS gets. We then posed that, if the Earth's MFS was periodic we could use this model to test potential Goldilocks planets to see if they have a stable MFS. This could be used to assess exoplanets on whether lifeforms similar to those on Earth could reside on them.

2. Method

Using the magnetometer and accelerometer, we measured magnetic field strength and acceleration every tenth of a second. With our aim to find a relationship between the position of the ISS and the Earth's magnetic field strength in mind, we calculated the displacement of the ISS between each data reading, and hence its distance travelled. We additionally recorded both the longitude and latitude of the ISS, to validate our magnetometer data.

All data, including calculated values, were compiled into a csv file during the 3-hour runtime, to then be used for analysis once it was broadcasted back to Earth.

$$a = \frac{\Delta v}{\Delta t}$$
$$\Delta v = a\Delta t$$
$$v_{n-1} - v_{n-2} = \frac{1}{2}(a_{n-1} + a_{n-2})(t_{n-1} - t_{n-2})$$
$$v_{n-1} = \frac{1}{2}(a_{n-1} + a_{n-2})(t_{n-1} - t_{n-2}) + v_{n-2}$$

$$v = \frac{\Delta x}{\Delta t}$$
$$\Delta x = v\Delta t$$
$$x_n - x_{n-1} = \frac{1}{2}(v_n + v_{n-1})(t_n - t_{n-1})$$
$$x_n - x_{n-1} = \frac{1}{2}\left(\frac{1}{2}(a_n + a_{n-1})(t_n - t_{n-1}) + v_{n-1} + v_{n-1}\right)(t_n - t_{n-1})$$
$$x_n = \frac{1}{4}(a_n + a_{n-1})(t_n - t_{n-1})^2 + v_{n-1}(t_n - t_{n-1}) + x_{n-1}$$

Figure 1: Derivations of the two formulae used

We calculated displacement using an iterative formula, requiring previous values of acceleration, velocity, the previous displacement, and time between data readings to find the overall displacement between the current reading and the previous.

$$x_n = \frac{1}{4}(a_n + a_{n-1}){t_\alpha}^2 + v_{n-1}t_\alpha + x_{n-1}$$

Note: t_α is the time between recording a_n and a_{n-1}

However, to use the above equation, velocity must be calculated using previous data sets, so we used the following formula involving acceleration from two previous data sets, and velocity from the data set before the previous:

$$v_{n-1} = \frac{1}{2}(a_{n-1} + a_{n-2})t_\beta + v_{n-2}$$

Note: t_β is the time between recording a_{n-1} and a_{n-2}

Back on Earth, we planned to use graphing software to plot graphs of magnetic field strength against distance travelled and latitude.

3. Experiment results

We received the data and discovered that our displacement formula did not produce the data expected. Upon further analysis, the accelerometer values were too low to produce accurate values. If the Astro Pi was in orbit by itself, then our formula would likely work. We then moved to our back-up plan, which was the ISS position data, recorded at each sensor reading.

We plotted magnetic field strength against latitude and the graph (shown in Figure 2, overleaf) did not show what we expected. However, this is due to the Earth not having a uniform magnetic field strength, which we unearthed upon overlaying ISS position data over the WMM (World Magnetic Model) map, shown in Figure 3. It shows that our results seem valid.

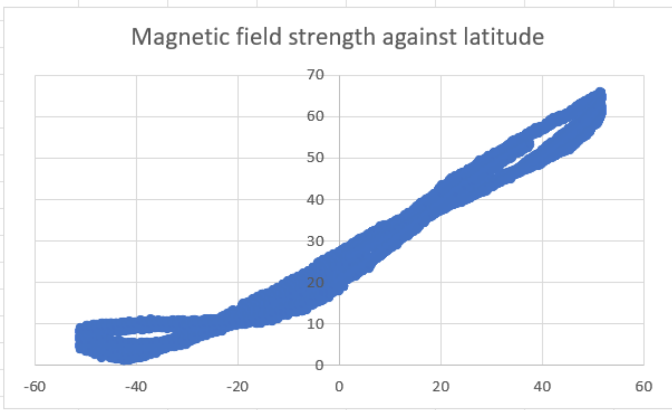

Figure 2 - Graph of Magnetic Field Strength in T against latitude

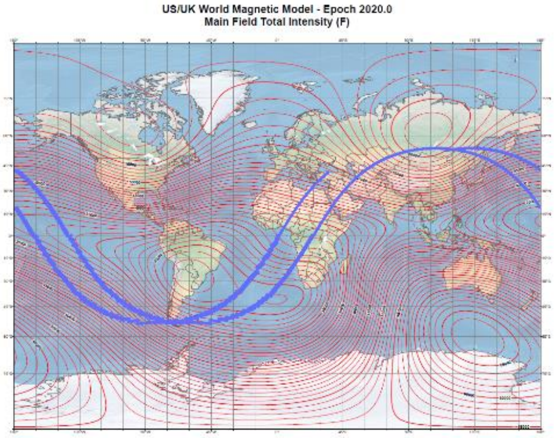

Figure 3 - ISS Location data overlaid on WMM map

To overcome this, we plotted magnetic field strength against distance travelled by the ISS, and it shows a periodic pattern. To remove the noise in the data, we used an algorithm to produce a line of best fit to our data, which uses a piecewise polynomial function. From this function, we took equally spaced values from 0 and 182 and then we used the Levenberg-Marquardt algorithm to find the coefficients of the polynomial equation until the R^2 value is closest to 1. We used this algorithm due to it using the principle of least squares, which will give us the best fit. The link to the graph is on the GitHub repository and shown in Figure 4, and our equation has a R^2 value of 0.9987 to 4 decimal places.

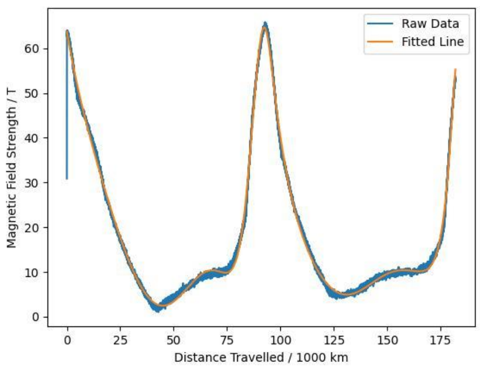

Figure 4 - Graph of Fitted line on top of raw data

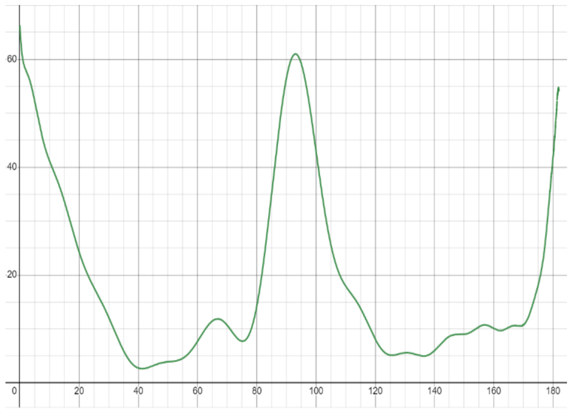

Figure 5 - Desmos Plot of the polynomial equation produced

4. Learnings

In achieving organisation, we ensured all contributions made by members were in one folder. This proved extremely important to us. Using Microsoft Teams and OneNote, the team were able to discuss changes made to the code in real time and arrange in person meetings.

Collaboration and teamwork were successfully achieved by each of us specialising in different subtasks of the project. Moreover, the team members communicated their opinions openly if they believed someone could have taken a different approach in their designated task which elevated the overall strength of the project.

Tasks including dividing the project into subtasks and assigning them to members could have been better. Furthermore, our group consisted of six members meaning each person had less workload however there was added complication of conflicting opinions. Improvement in our teamwork has been made as we are now more aware of each other's strengths and weaknesses as well as improving in assigning work meaning everyone could stay on top of their section.

If we were to do this process again, we think we should be more considerate about our team members' opinions as communication was occasionally lost.

5. Conclusion

Although our original plan didn't quite work out the way we wanted, we managed to use our backup plan to successfully achieve our aim of mapping the magnetic field strength of the earth and produce an equation which could be used in the discovery of habitable planets in other galaxies.

With more time to run the experiment, we could orbit the Earth more times and improve the accuracy of our results. We could also improve our formulae of calculating distance travelled with low acceleration being measured and utilise it in another mission. We could also improve our code's efficiency to take more measurements per second, therefore improving our results overall.

We aim to simulate an experiment with the Astro Pi on top of a remote-controlled car (orbit) and the magnet (planet) in the middle of different strengths. We could then create a program that will compare the two datasets and give a reading of whether it has a similar magnetic field to Earth's.

GitHub Repository - https://github.com/HHorizon2023/Report

We would also like to thank the Maths, Computer Science, Design Technology and Physics departments for their time and use of their equipment for our project.