Application of Acceleration Data to Inertial Navigation

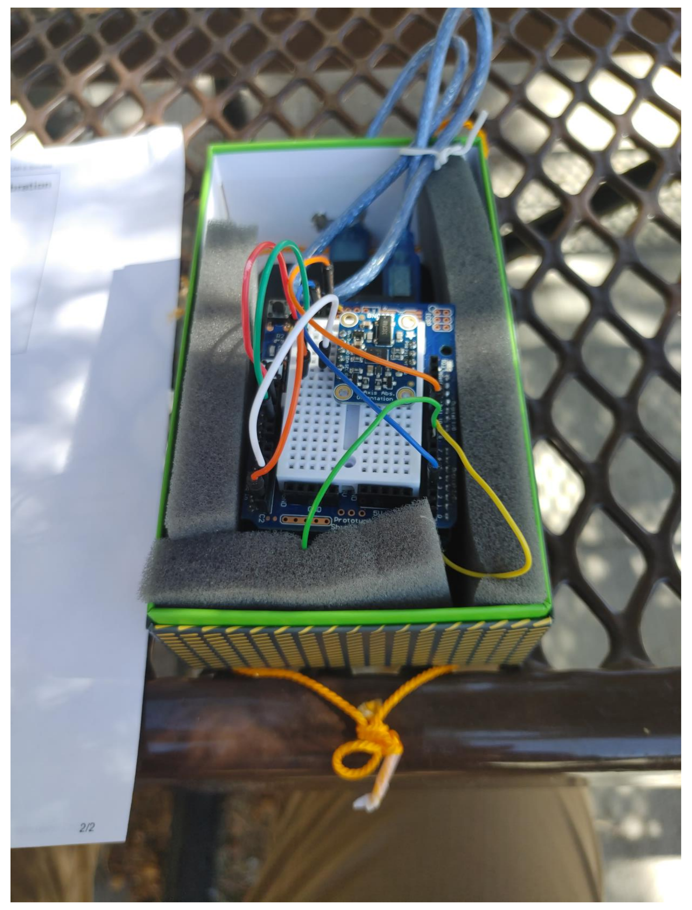
Eric Eastham
Utah State University

Donald Rice
Utah State University

Introduction

Inertial Navigation is the method of using measured acceleration and rotation values over a period of time to calculate velocity and position over the same length of time. This data is then translated to an inertial reference frame from a frame that rotates with the sensor, and then integrated using numerical methods to determine the position.

This position can either be calculated as from the initial starting point, or can also be used to determine an object's position in space from a particular reference point



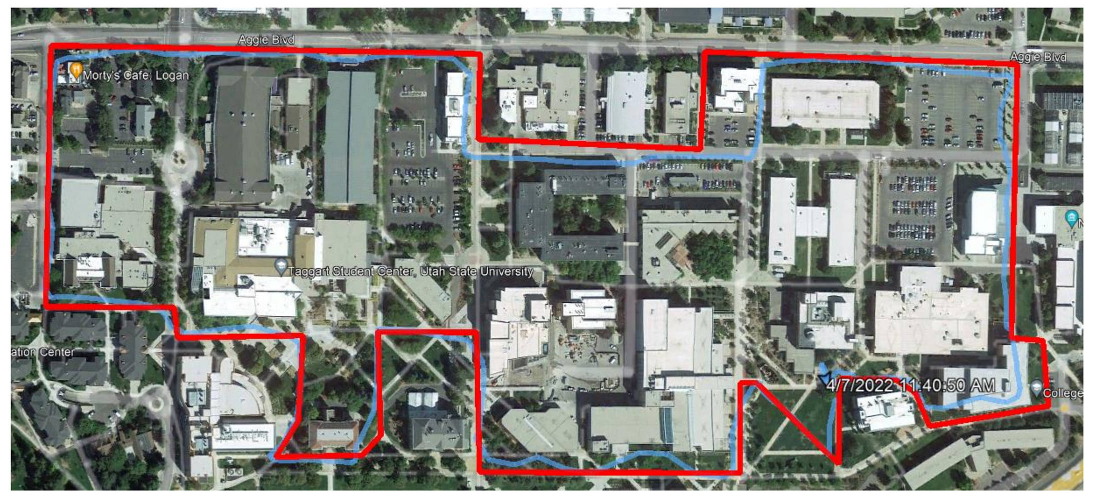
Left: Image of the 9-axis IMU (Inertial Measuring Unit) used to measure the accelerations and rotational angles for this experiment. The device is constructed from the accelerometer, an Arduino, and a power supply

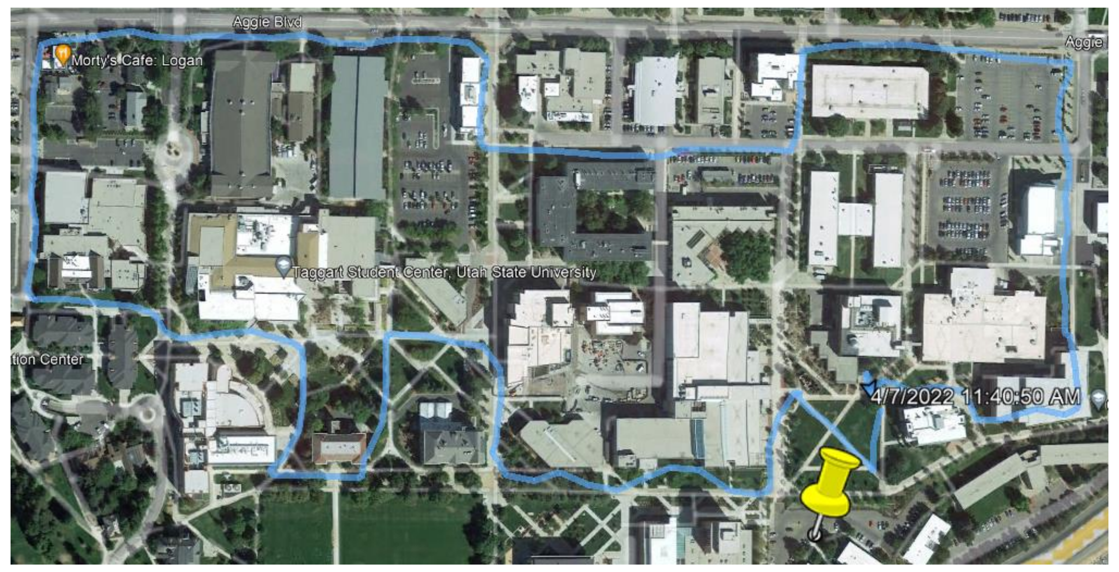
Methods

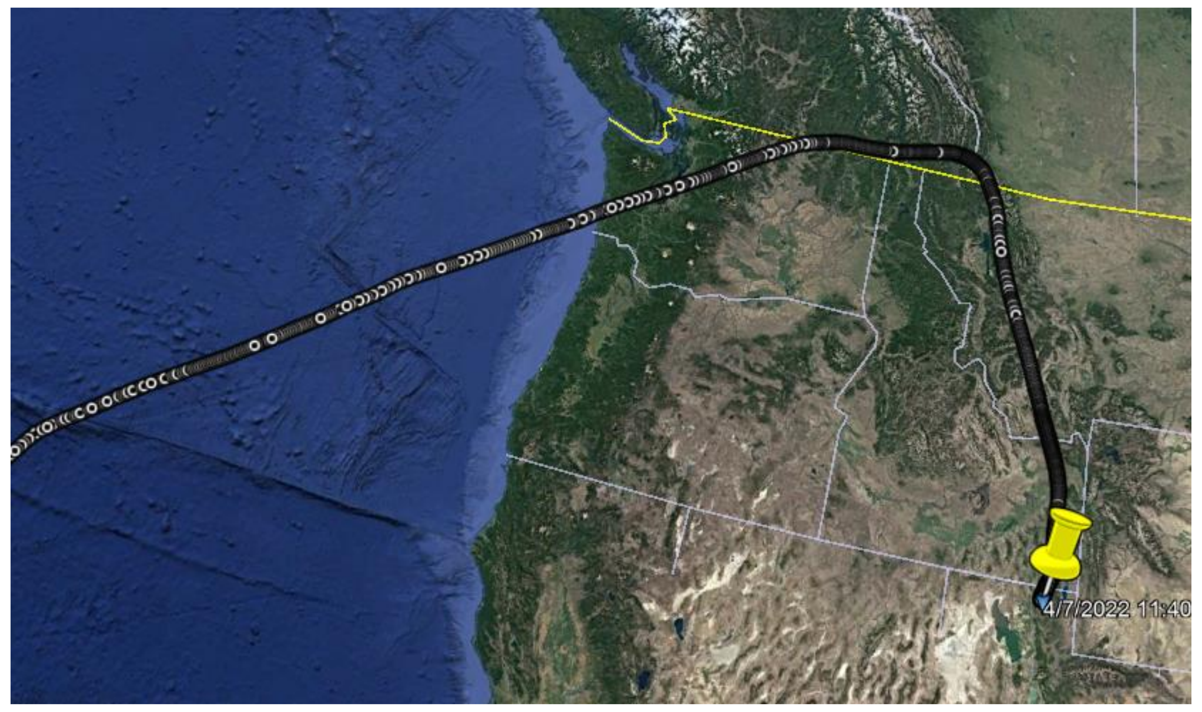
First, a theoretical framework was constructed using Euler Angles and acceleration values to convert the non-inertial sensor reference frame to an inertial sensor centered reference frame. These values can then be integrated using the Trapezoidal Rule from numerical methods to first calculate velocity, and then repeated to calculate position. A conversion factor can then be used to determine GPS coordinates

GPS Tracks

Top Left: Track recorded by commercial GPS unit(shown in blue) compared to planned track (shown in red).
Bottom Left: First calculated gps position (shown by the pin), against the commercial gps unit track (shown in blue).
Right: First section of the calculated gps track over the Northwestern US, with the first calculated gps position again marked with a pin.







Results

Initial calculated positions match closely with what would be expected with the actual path that was taken to record the measurements, staying within about 1000 feet during the first part of the experiment. The GPS conversion method however produces very inaccurate results, quickly diverging from the given path and ending halfway around the world in the first 30 minutes.

Conclusion

This method has shown to be a fantastic method of measuring acceleration and rotation. The measurement unit, once calibrated, will align the rotation readings to be against magnetic north, allowing for simple conversion to inertial measurements.

The integration method for calculating position also appears to be sound, producing reasonable velocity and position calculations, or at least those within human abilities.

Issues encountered included calculating uncertainty. The methods used, propagated over the simulation, resulted in uncertainty values that overflowed the variables used to store them. The gps conversion also appears to be highly sensitive to variations in recorded data. Issues with programming may have also resulted in incorrect values.

https://carnegiescience.edu/news/how-does-earth-sustain-its-magnetic-field