Development of a Gyroscope-Free Inertial Navigation System

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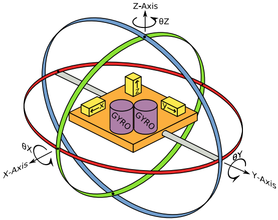
Problem Overview

Inertial Navigation System

A navigation system that uses sensors to determine and track a vehicle's position and attitude without any external references.

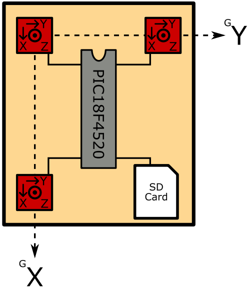
- Used in guided missiles, aircraft, and spacecraft.
- Traditionally use a mechanical gimbal system to maintain a reference orientation.
- GPS can be used to eliminate long-term drift.
- MEMS gryos are relatively expensive ($30+ per axis) compared to MEMS accelerometers ($6 for 3-axis part).
- Is it possible to track position and orientation with nothing but accelerometers?



A gimbal platform

Approach

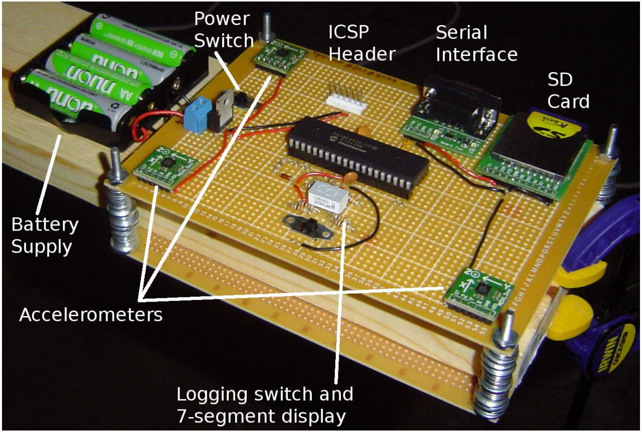
- MEMS accelerometers carefully arranged.
- Digitize and record 50 samples per second.
- Store data to SD card.
- Prototyping board provides rigid mounting.
- Characterize each of the sensors with controlled accelerations.
- Matlab software to perform numeric integration and recover position data.



Board Layout

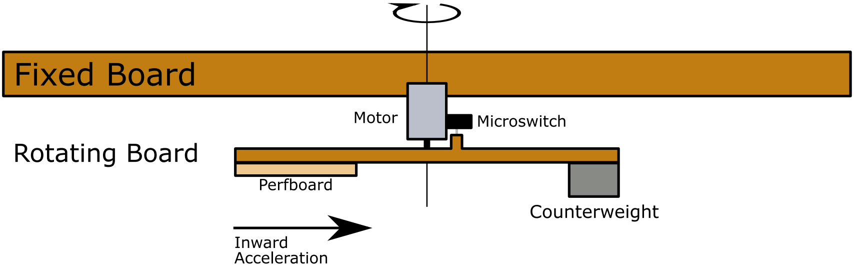
Project Progress, I: Hardware Construction

- Picture of protoboard construction.
- User interface: Switches for main power and "Enable logging"
- Added 7-segment display to provide state feedback.

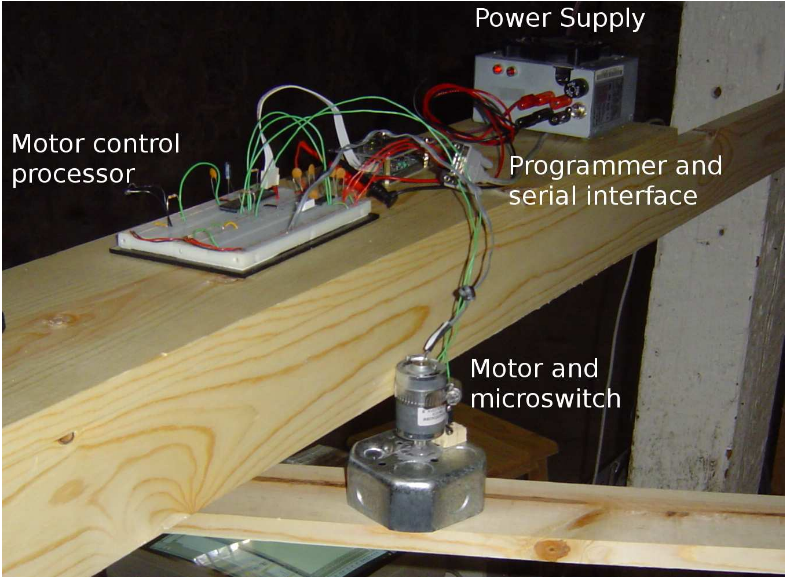


Project Progress, II: Turntable Construction

- Sensors output an analog value, proportional to acceleration.
- Need to find $0g$ value, and conversion ratio to convert between offset from $0g$ reading and the actual acceleration.
- Created a rotating assembly to apply a controlled and calculable acceleration to sensors.

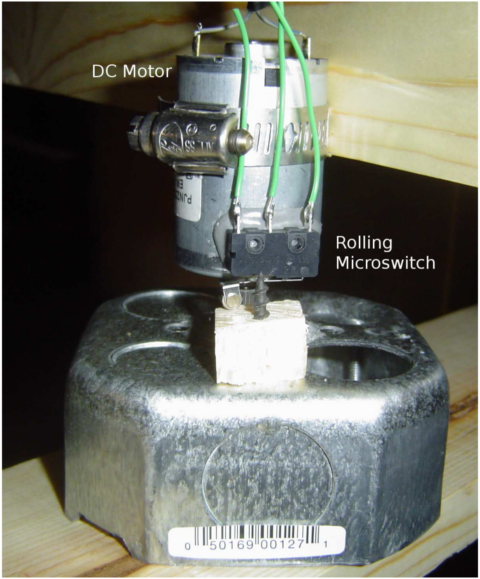


Project Progress, II: Turntable Construction Pictures

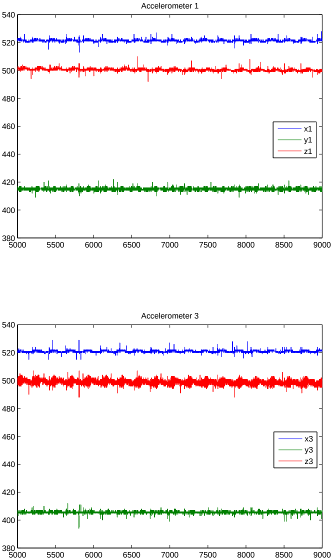


Project Progress, II: Turntable Construction Pictures

- To calculate acceleration, we need an accurate measure of angular velocity.
- A rolling microswitch was attached to the stationary motor, and triggered once per revolution.
- PIC processor used to measure rotation time, and report it over serial connection.



Project Progress, III: Sensor Characterization



Project Progress, III: Sensor Characterization Results

- Values in table are:

$$\frac{ADCvalue}{\left(\frac{m}{s^2}\right)}$$

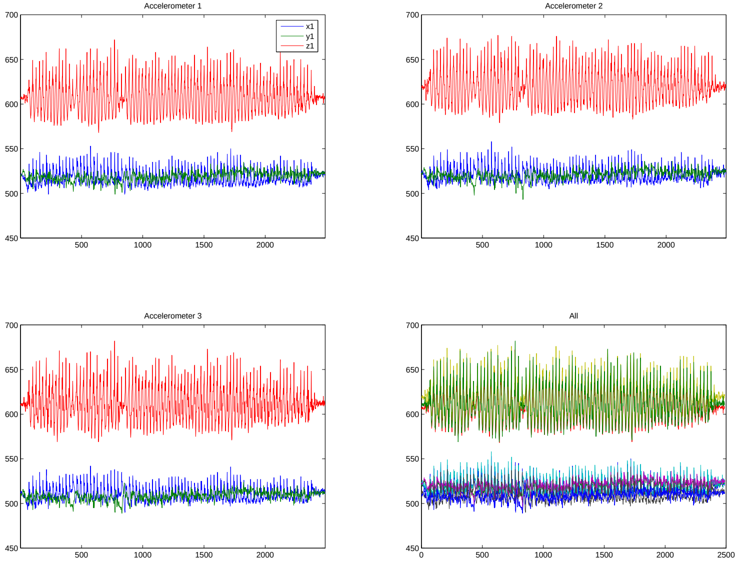
- $0g$ value used to compute offset.
- 10.6 means $\alpha = 1\frac{m}{s^2}$ produces a reading of 10.6 away from the $0g$ reading.

CALIBRATION OF Y-AXIS SENSORS

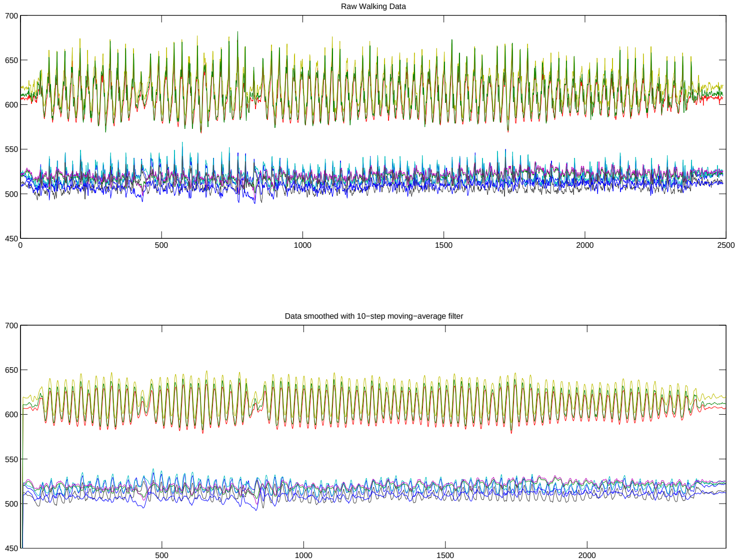
	Y1 (522)	**Y2 (523)**	**Y3 (511)**
$\omega = 1.62\frac{rad}{s}$	10.5953	10.6742	10.5657
$\alpha_{in} = 0.13g$	10.5600	10.6180	10.4809
$\alpha_{out} = 0.16g$	10.6112	10.6856	10.5772
	10.6388	10.7126	10.5902
	10.6094	10.6795	10.5273
$\omega = 2.92\frac{rad}{s}$	10.6818	10.7425	10.6412
$\alpha_{in} = 0.43g$	10.6818	10.7761	10.7137
$\alpha_{out} = 0.53g$	10.7569	10.8094	10.7287
	10.7003	10.7333	10.6531
	10.7396	10.7952	10.6967
$\alpha = 1g$	10.8577	10.9682	10.7078
Mean	10.6757	10.7450	10.6257
StdDev	0.0862	0.0936	0.0831

Project Progress, IV: Real-life Accelerations

This is the raw sensor data when I walked around my house.



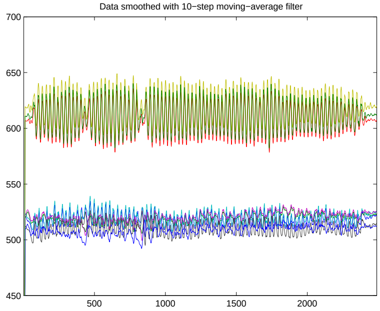
We can use a filter to clean up the raw data (top) to get a smoother plot.



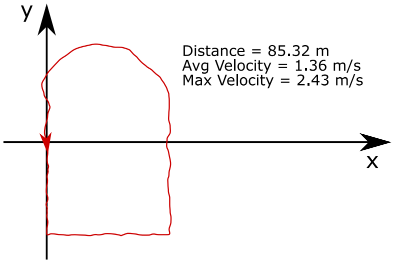
Further Work

- Finish the MATLAB code to analyze recorded accelerations.
- Develop a decent way to visualize three-dimensional movement over time.

Current Results



Desired Results



Lessons Learned

- Everything takes longer than estimated.
- Accurate estimation is hard.
- Don't be afraid to ask for help.
- Building things in the real world is much more difficult than simulation!
- Accomplish something worthwhile every day.

Acknowledgements / Questions

Many thanks to:

- Project Advisor Professor Charles Rennolet
- ECE Department

Any Questions?