Vertigo

UNIVERSITY OF Southampton

THE INSTITUTE for RESEARCH in Schools

Investigating the dynamics of theme park rides

What is Vertigo?

Vertigo is an inertial data logger, which measures its acceleration in orthogonal IMUs (Inertial Measurement Units), its position in GPS, ie. polar coordinates and its rate of rotation in degrees per second. What makes Vertigo interesting is that it constantly checks for North using the Earth's magnetic field and Down using gravity allowing to convert what it detects into a world frame.

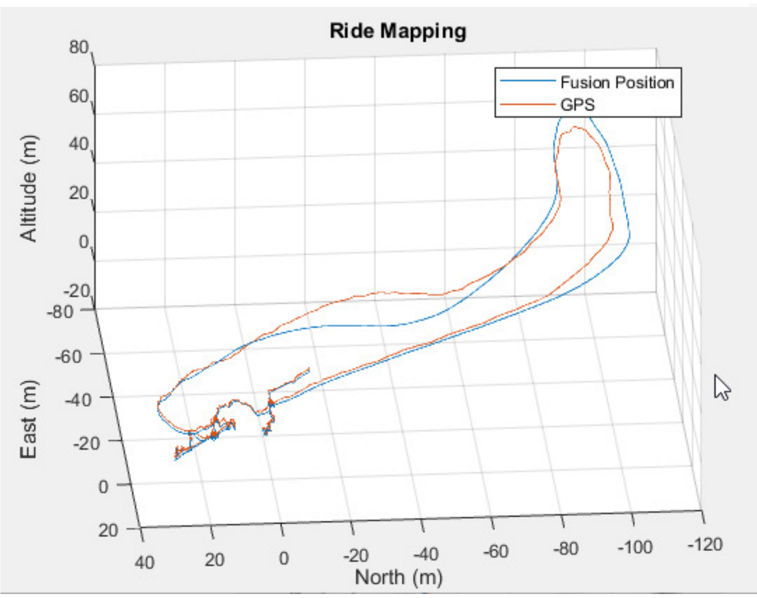
Aim

Our aim was to quantify what we experience on a roller coaster. So, for example, a rush of blood or being pushed into your seat could be measured by G-Force and a feeling of dizziness could be quantified by angular velocity. We wanted to be able to compare rides, as well as evaluate the safety of the rides.

Mapping

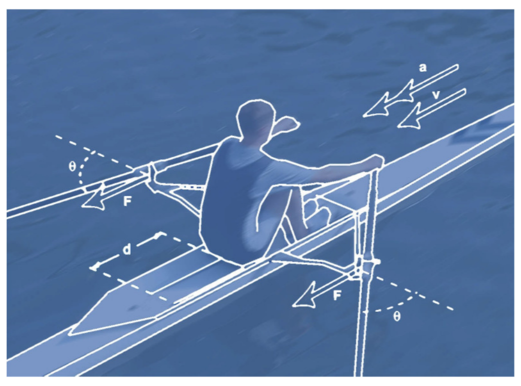
Vertigo measures its position by GPS but it also measures its acceleration, which can be integrated twice to work out the distance moved. Doing this, we now had two sets of values for position, both with a known uncertainty. Therefore, we decided to use a Kalman filter. This works by predicting the next position including associated uncertainty using the defined variables that account for noise. It then updates the position variable and the uncertainty variables with the predicted values and the cycle repeats. It also calculates based on velocity and altitude, how reliable each of the data sets are and how heavily to weight the bias onto GPS or onto the IMU data.

As shown, using a Kalman filter instead of a single data set creates a better path estimation and allows us to accurately map using Vertigo. The height of Stealth is 62m which corresponds to almost exactly the altitude we obtained using the Kalman filter.



Further Applications

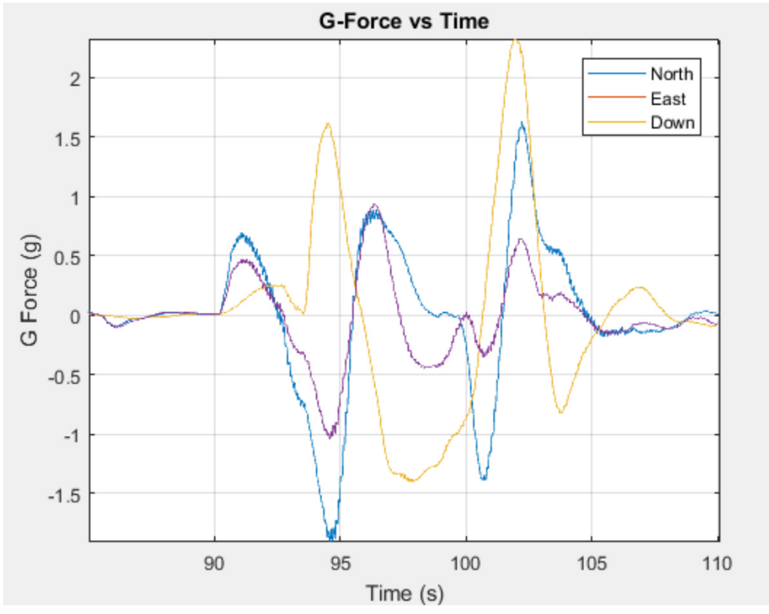
We can apply our method to any other situation where having access to accurate data is useful. For instance, we are working in conjunction with the University of Southampton on improving performance by looking at angle of attack on a wingsuit glider, where over or under-rotating could lead to death.

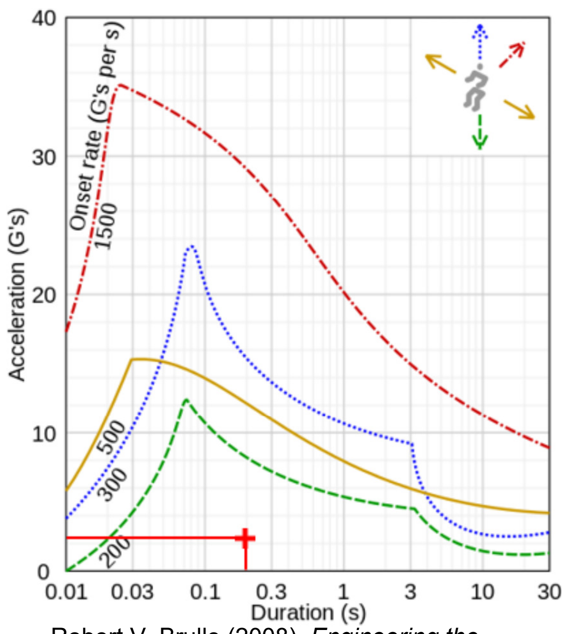


Vertigo also has applications in rowing where you can see how synchronised the members of a team row, or the angle and rotation of oars.

Analysis

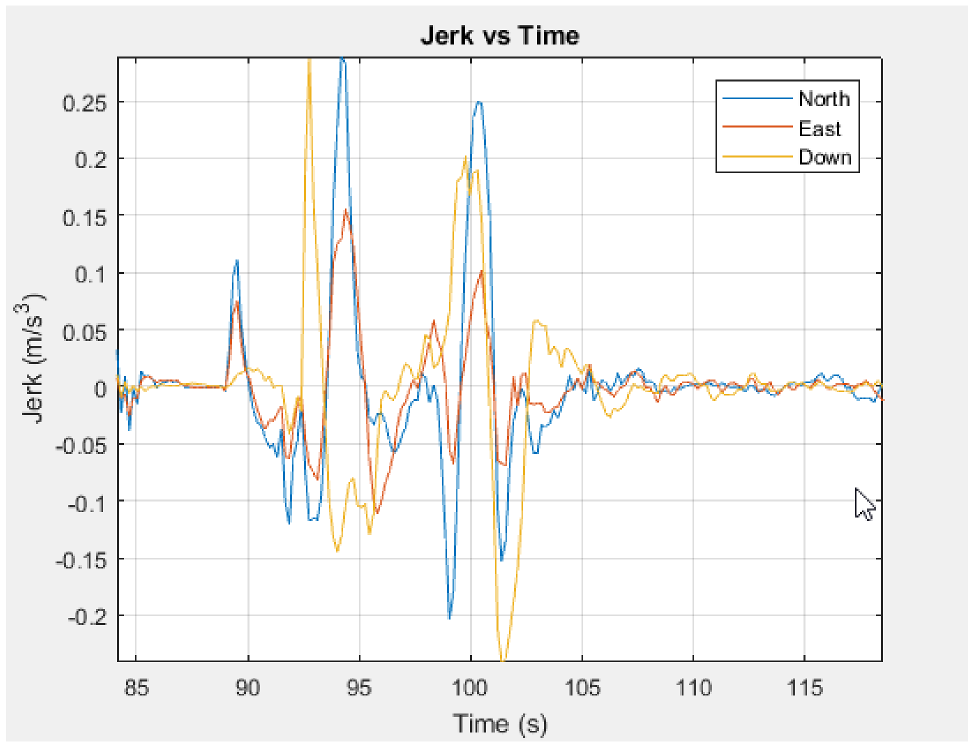
To measure safety, we decided to compare the experienced G-Force with an existing study on the human body's tolerance to linear acceleration.



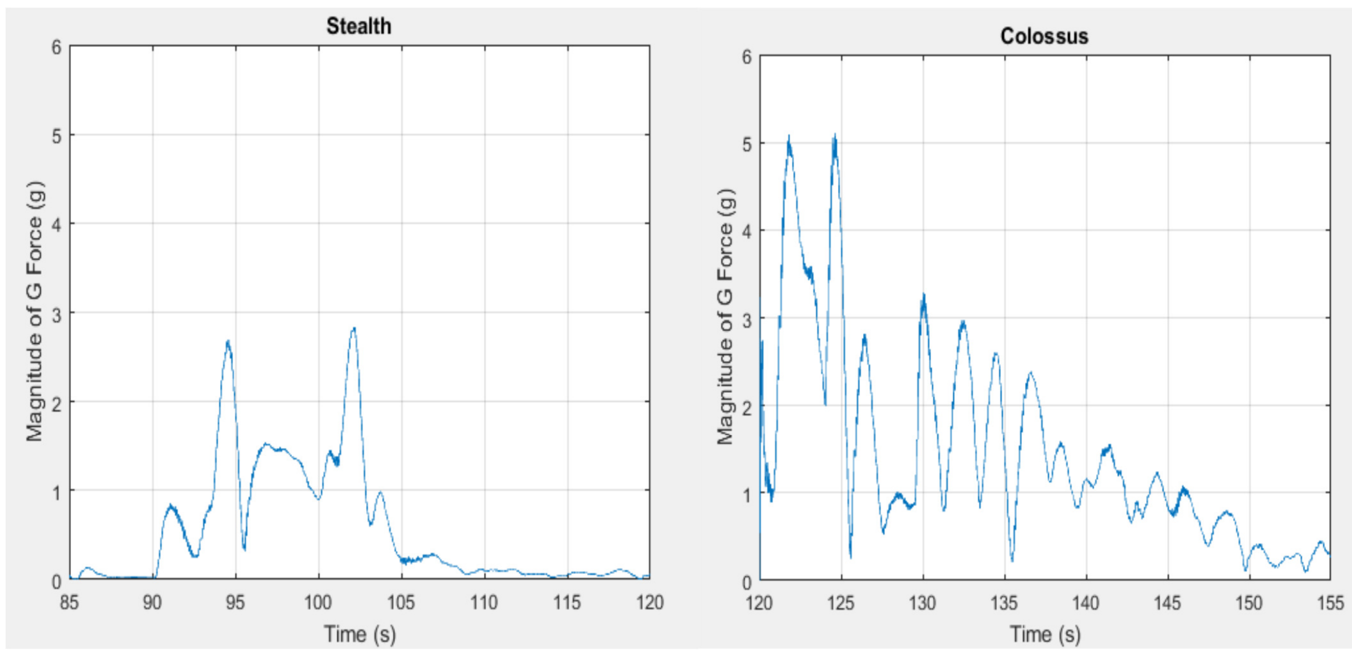


Robert V. Brulle (2008). *Engineering the Space Age: A Rocket Scientist Remem-*

We did this by looking at the acceleration in three orthogonal axes, North, East and Down on Stealth, a ride at Thorpe Park.. The maximum G-Force in any direction is 2.3G for 0.2 seconds. As shown, the experienced G-Force is well within the human body's limits, marked by the red cross.



In addition, we also looked at jerk as it must be minimised to reduce uneven forces which can lead to back pains as well as cause the structural integrity of a ride to deteriorate more quickly. As shown the jerk is always between 0 and 0.25 ms^{-3} which suggests that it is safe. Therefore based on our analysis, we would conclude that it is safe based on physical experience.



We calculated the magnitude by using Pythagoras on the three orthogonal vectors. One interesting thing to notice is that at the start of Stealth, Thorpe Park claim you accelerate from 0 to 83mph in 1.1 seconds, and yet the magnitude of G-Force experienced is small compared the G-Force produced by rotation. Colossus has lots of loops which explains why it has a high G-Force and why the graph looks sinusoidal. The decrease in G-Force at the peaks is representative of the fact that energy is lost throughout the ride.