Development of Attitude determination and control algorithm

Mohamed Ahmed Hassan Ahmed

Author Note

This work is presented to fulfill the take-home exam requirement set by the Egyptian Space Agency for the position of AOCS Engineer.

Abstract

In the following pages, I aim to provide a concise overview of my advancements in the required take-home exam. Initially, I constructed a simulation of a satellite orbiting the Earth. Subsequently, I implemented the International Geomagnetic Reference Field (IGRF) Model. Following this, I designed a simplified version of a Magnetometer and a Gyroscope to initiate work with filtering algorithms. I proceeded to implement the error state extended Kalman filter, as proposed in the provided Diploma Thesis. Additionally, I developed a model for three reaction wheels and successfully implemented a basic PID controller to manage the satellite's angular rates.

You can review my code which is compressed as (.zip) file attached. Run the code by executing the $main.m$ routine.

The documentation may not meet the desired standards, and I acknowledge this shortfall. However, the constraints of limited time compelled me to prioritize the fulfillment of task requirements, impacting the overall quality of the documentation.

Future work

I had hoped to incorporate a control technique learned in a non-linear control course, time permitting. In summary, I apply state feedback linearization to transform a non-linear state space into a linear one, subsequently utilizing it in a linear quadratic regulator. I successfully implemented this controller in a quadrotor, serving as the final project for the nonlinear control course.

Simulation of Satellite Orbiting Earth

A simulation base on 6DOF rigid body motion was developed using numerical integration Runge-Kutte4. This state vector for this simulation is as following:

$$x = [x, y, z, \dot{x}, \dot{y}, \dot{z}, q_1, q_2, q_3, q_4, p, q, r, \omega_{rw1}, \omega_{rw2}, \omega_{rw3}]$$

It consists of inertial position and velocity, rotation represented on quaternion, angler rates in satellite body frame and reaction wheel angler rates about reaction wheel frame.

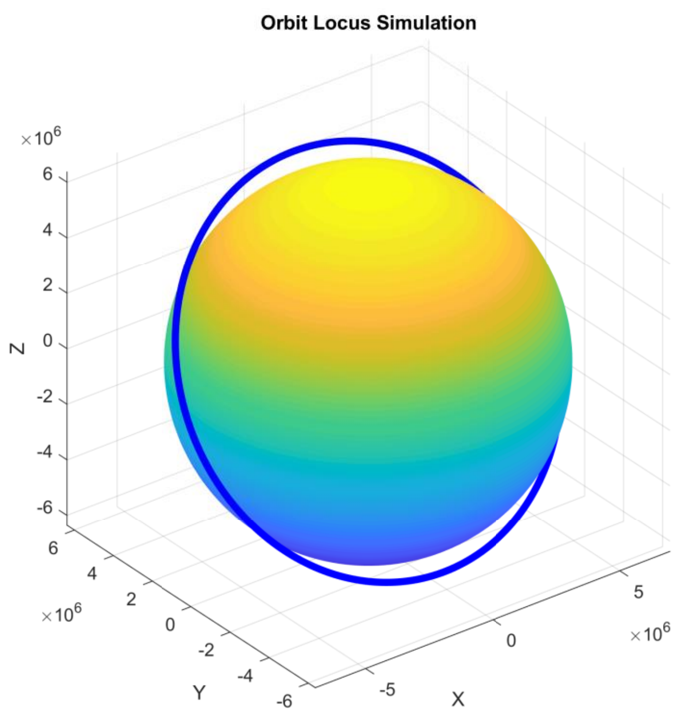
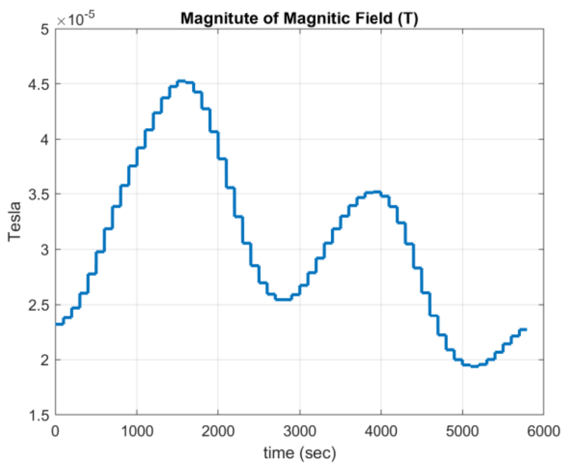
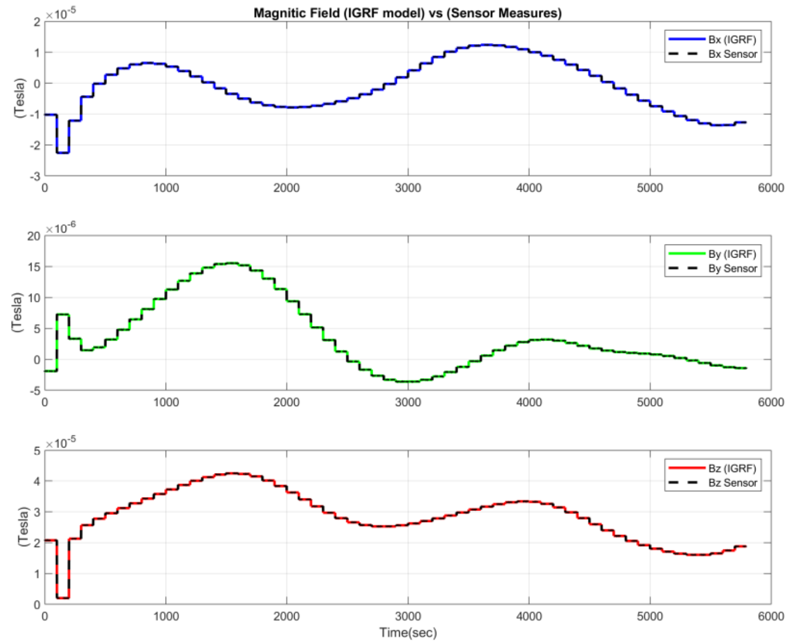


Figure 1. Satellite orbiting Earth

IGRF Model





Attitude Determination

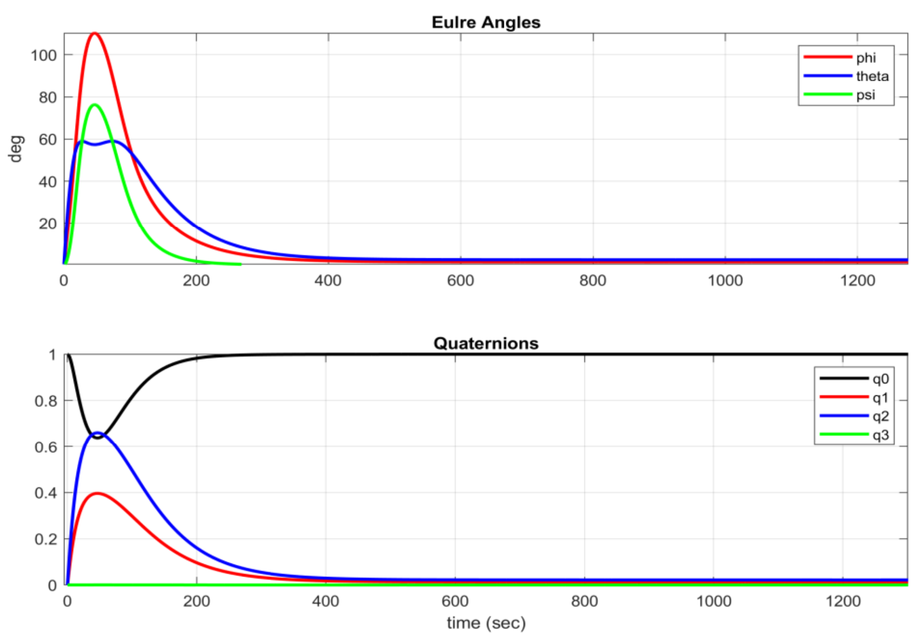


Figure 2. Euler angles and Quaternion representation

Attitude Determination (Filtering) and Control

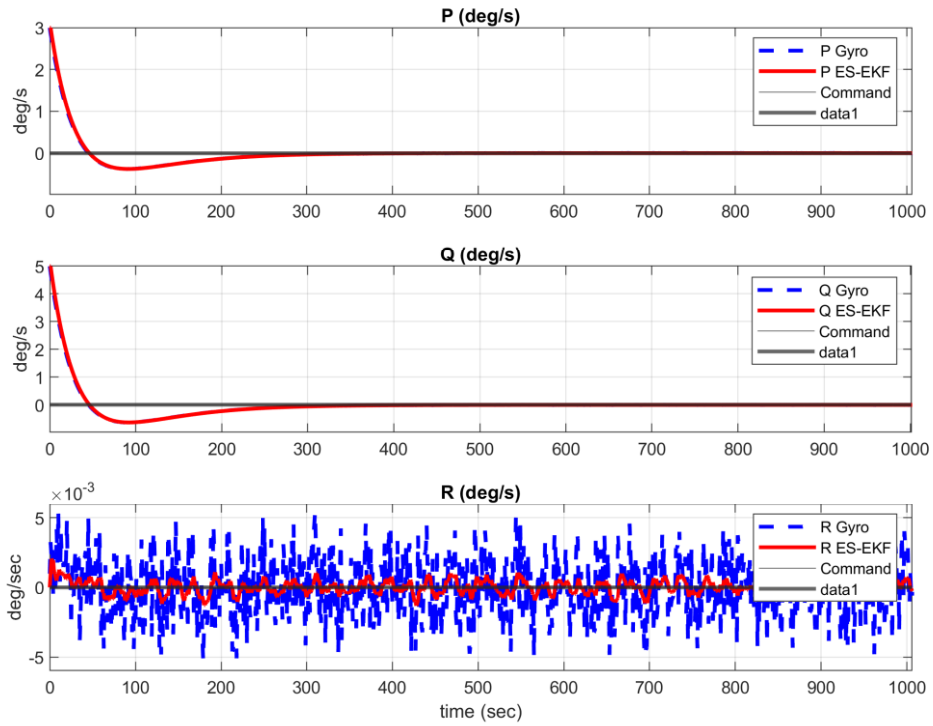


Figure 3. angular rates due to zero control input

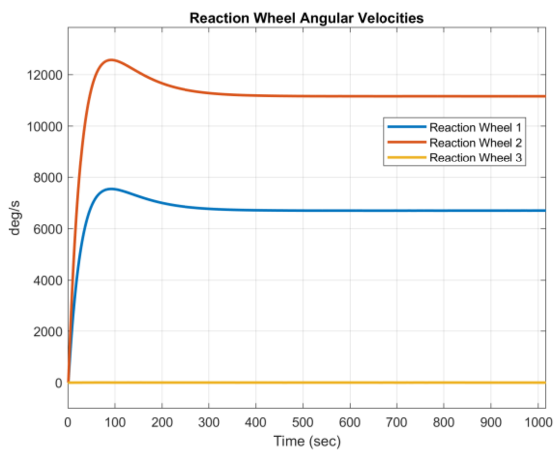


Figure 4. Reaction Wheels Angular Velocities

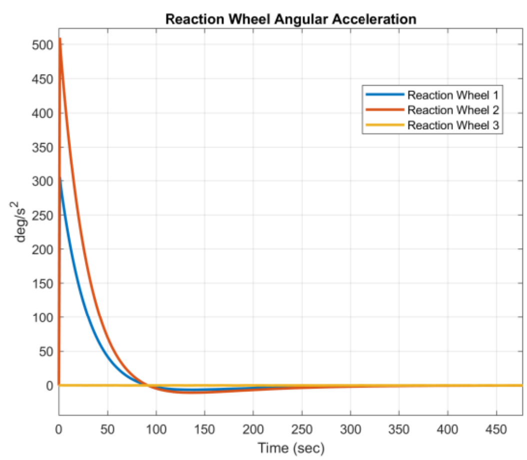


Figure 5. Reaction Wheels Angular Acce.

I did not have the time to implement a Magnetic Coils so that I can help controlling the attitude and also could help bringing the reaction wheel to stationary state again unlike the results show above which illustrate that the reaction wheels will continue to run a constant speed.

References

German Aerospace Center (DLR). Development of algorithms for attitude determination and control of the asteroidfinder Satellite.

Carlos Jos´e Montalvo. Aerospace Mechanics and Controls, University of South Alabama

Autopilot Undergraduate Project (Cairo University, Aerospace Engineering Department)