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Project Summary

Embedded avionics and attitude estimation for a spherical autonomous robot

Marc Schönenberger

Professor : *Alcherio Martinoli, Joel W. Burdick*
Assistant(s) : *Duarte Dias, Matthew R. Burkhardt*

Moball is an innovative spherical autonomous mobile robot project capable to harvest energy from the wind and is designed to operate in areas where solar energy is not a reliable source for energy harvesting, such as in the Arctic. It is the result of a combined effort between the Jet Propulsion Laboratory and Caltech.

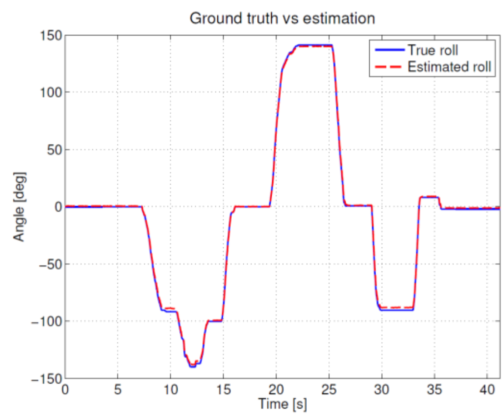
In this project, the goals were to set up an embedded computer system in the robot whose tasks are to give an attitude estimate of the robot as well as the ability to communicate with sensors and other boards if needed. Some tools for visualization and simulation in the future of the project were also to be considered.

A low cost Arduino Due board has been chosen as the electronic basis because of its strong input-output and computational capabilities. A low cost MARG sensor has been used to get an attitude estimate. Using a novel gradient based filter, the system can deliver an estimated attitude in the form of a quaternion.

The magnetometer and accelerometer have been calibrated with a simple 2 steps procedure which can be done by hand.

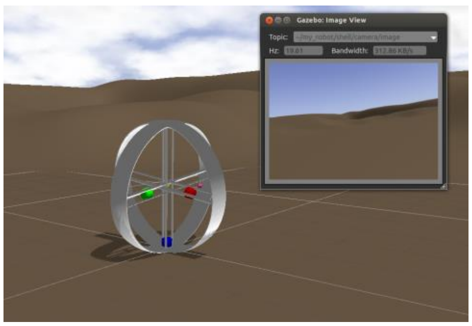
The attitude estimation has been tested both in simulation and in a real experiment. The simulation allowed some comparisons with the standard EKF approach. The gradient descent showed very similar performance to the quaternion based EKF designed. The real experiments showed an RMSE below 2° on the roll and pitch axis.

The update rate was measured at 77Hz for the complete gradient descent using all sensors from the MARG and at 500 Hz for the simple gradient descent using only accelerometers and gyroscopes. It includes retrieval of the sensor raw output, use of calibration data to get corrected output and then sensory fusion with the gradient filter. No particular software optimization were made.



Real experiment of the roll axis estimation with gradient descent method

The bases for simple simulations in the Gazebo robot simulator have also been laid down which include an arbitrary landscape with wind, 3 constrained masses sliding inside the spherical robot, a camera feed from a camera inside the robot as well as an IMU at the center.



Simulated Moball system in Gazebo with camera feed. 3 masses can slide freely or be actuated inside the robot.