Framework for Underwater Positioning with Acoustic Beacons

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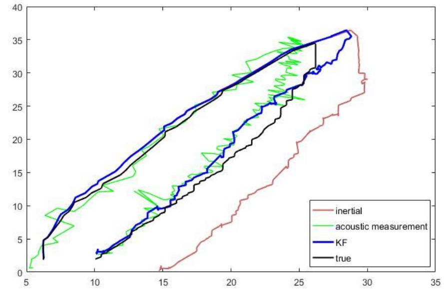
Underwater vehicle localization by using only IMU and odometry has the drawback that its error grows unbounded with time because of the integration of the inertial sensors error as well as the unpredictable external forces, caused typically by water currents, that can be applied on the vehicle along its course. Also, the absorption coefficient of electro-magnetic waves in water makes it impossible to use the GPS reliably.

During this semester project, the goal is to fuse the position estimation made by inertial measurement with another estimate made with acoustic measurements. Using a set of emitters/receivers it is indeed possible to compute the range between the vehicle and a set of beacons with known positions, and from these ranges it is then possible to get an acoustic estimate of the position using methods such as trilateration, single range position update or through the computation of the bearing of the vehicle.

I first characterizing the uncertainty propagation for the trilateration and bearing methods in order to get an idea of the regions were the position uncertainty relatively to measurement uncertainties would be the lowest.

After that I designed a Kalman filter on Matlab to fuse the acoustic estimates with the inertial estimates. This was done using data gathered during experiments done at lake Léman using a surface vehicle.



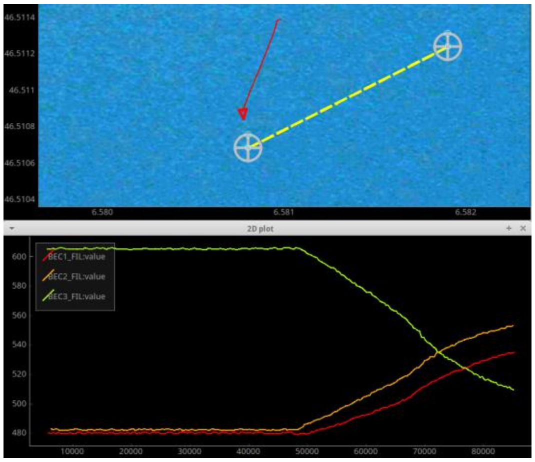
Fusion of acoustic and intertial estimates with Kalman filter

I then implemented the simulation of the acoustics into the surface vehicle simulator.

I implemented the acoustics in a way that reciprocates the real acoustic signal and coded a basic outlier rejection method that only need past range measurements, to reduce processing delay.

Once the acoustics implemented, an acoustic estimation method was coded using a total of three simulated beacons which provided range data not simultaneously, like for the trilateration and bearing methods, but successively, which is a more practical approach considering the hardware at disposition doesn't allow simultaneous time of flights measurements. This acoustic estimate of the position is based on the range coming from one of the receivers (the most recently updated) and the last position update of the vehicle (done by integration).

Once the acoustics implemented and the ranges relatively to each beacons simulated, an acoustic estimate of the position was computed using each range successively then directly fused to the kinematics.



Simulation of the acoustic ranges (bottom) used in the Kalman algorithm, to estimate the position during the navigation among waypoints (top)