# Framework for acoustic localization for AUVs

Ahmed Saadallah

Professor : Alcherio Martinoli
Assistant(s) : Anwar Quraishi

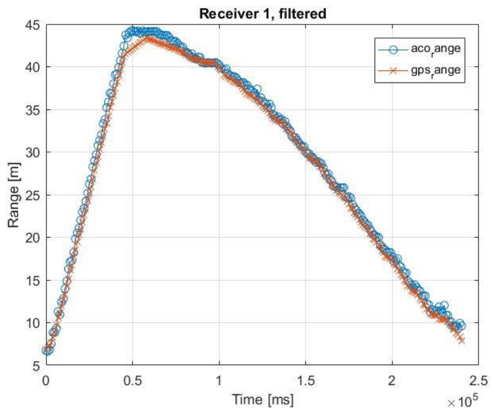
The purpose of this project is to develop a positioning system that can be used to localize AUVs underwater.

The focus is to use acoustic trilateration to aid the inertial navigation system to improve the localization and navigation estimation. Knowing the time of flight between a transmitter and a receiver, we can compute the range and therefore, using multiple beacons allows to find the position of the vehicle.

This project involved also tweaking the ground control software to visualize the acoustic ranges and bringing some modifications on the architecture of the code.

Although the positioning system that is being developed is intended to be used to localize AUVs, we used autonomous surface vehicles ASVs instead to be able to compare the acoustic ranges with GPS.

The first step was to acquire one range measurements between a hydrophone at a fixed position and a transmitter mounted on the boat and dipped in water. To extract the time of flight both the transmitter and the receiver clocks had to be synchronized using the PPS signal from GPS. The clocks speeds are adjusted in a way that a full second in each coincides with the PPS signal.

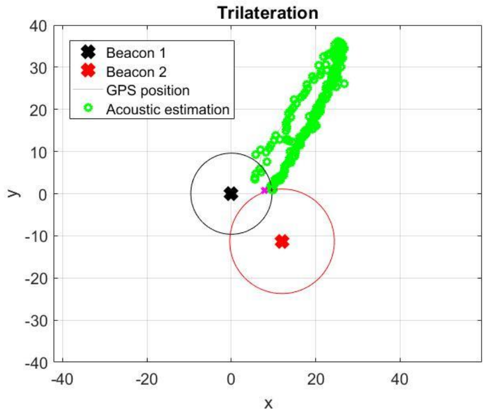



*Filtered Acoustic signal vs GPS*

As expected the acoustic signal is noisy. This might be explained by the shallow water depth where experiments took place This increases significantly multi-path as the lake floor and water surface are close to the transmitter. Wave scattering can also corrupt the transmission since suspended particles exist in the water. Based on measurements, the noise distribution contains a non-gaussian component. Noisy data was approximated using a white noise component, a random walk component and 3 gauss-markov components.

The measurement then had to be filtered to remove outliers. A hampel filter was implemented to reject samples that do not fall close to the mean of a surrounding window of samples.

Then we performed experiments using 2 receivers where each records a timestamp for every ping. The measurements were then used to draw circles with radiuses equal to both ranges and intersect them to find the acoustic position estimation. After comparing with the GPS, over 772 samples, the mean error for the position is 1.8 m and the standard deviation is 1.27 m. Even though we used GPS data as the ground truth, we observed some noise in the GPS position of the static receiver that goes up to 3 meters in each direction.




*Acoustic Trilateration*

The acoustic position estimation is incorporated in a Kalman Filter to correct the IMU integration that drifts in time. A particle filter with a gaussian kernel yielded better results with 0.25 m mean error in the x direction and 2.04 m in the y direction over 2700 samples. If the triangle formed by the beacons and the vehicle to be localized is obtuse, a small error in range translates in a relatively big error in the position estimate.

Another approach for navigation was to use the range measurements sequentially one after the other. This would be the case if the hydrophone is mounted on the vehicle to pick up the acoustic wave. A Kalman Filter and a particle filter were implemented where the state is the range between the beacon and the vehicle.