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# Cooperative Localization for a Swarm of AUVs

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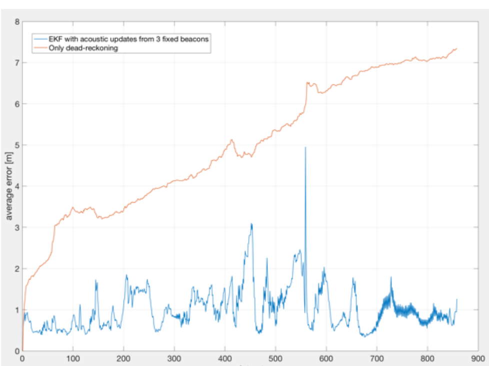
The need for underwater exploration and surveillance have become more and more important. In order to efficiently carry out these tasks we need autonomous swarms of underwater vehicles. These need to know their position under water relative to each other and with respect to their goal. This is not as trivial as above the surface of water since the high absorption coefficient of electromagnetic waves of water prevent the use of GPS and other radio communication. We have to communicate with acoustic waves which are much slower.

The position of the AUV is first estimated only using odometry and the internal accelerometer. This dead-reckoning has an ever-growing error which has to be corrected from time to time. Using the acoustic waves, the AUV can forward its own position estimation to its neighboring AUVs. These measure the time of flight of the acoustic signal and now have the relative distance to one of their neighbors and know his estimated position. The goal of this project is now to fuse this new information from one neighbor with the position estimate of the receiving AUV. The resulting position estimation should be more precise now.




*Growing dead-reckoning error vs error using acoustic updates. Average over 100 simulations*

To begin with the acoustic updates were implemented on Matlab using the data gathered on a field test on the lake. Two fixed beacons broadcasted their position and one vehicle used this information to correct its position estimate. To fuse the data an Extended Kalman Filter (EKF) was used. Simulations with moving beacons and using Covariance Intersection (CI) to fuse the information were also implemented. EKF overestimates the confidence of the position estimate if the information to be fused is correlated. One solution of this problem is using CI.

We cannot implement CI on the AUV since only full state updates are possible. More on the two fusion methods and how they work can be found in the full report. I thus implemented the EKF on the simulator which can then be compiled to be used on the actual AUV.

*Field test; green: boat sender; orange: GPS position; red: estimated position*

The Kalman Filter has then been tested on the lake using radio-controlled boats. We used one ground beacon and a boat to send the acoustic signals. A third boat received these signals and merged the information. The boat was equipped with GPS used as ground truth to evaluate the performance of our position estimation.

The acoustic signals interfered with the engine noise, nether the less the Kalman Filter corrected the position estimate correctly after the engine has been put on idle. This can be seen in the image above. A better noise rejection could solve the problem.

The information fusion with EKF improved the position estimation drastically. As a next step the position updates need to be tested and implemented using multiple boats.