Cooperative Localization for a Swarm of AUVs

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This work demonstrates an adaptation on existing algorithms for cooperative localization in a swarm of AUVs. By incorporating the covariances of the transmitting AUV, the covariance and position of the receiving AUV can be enhanced whenever an acoustic range measurement is received. The algorithms were implemented into the current framework by maintaining the same structure as the previous estimation filter. For comparative reasons, both an augmented extended Kalman Filter and an augmented Particle Filter were implemented. Experiments on the lake of Geneva were performed to gather new datasets with the required data for the new algorithms. The algorithms were assessed in post processing, analysed and compared to the previous implementation where it was shown that the error as well as the covariances are in reasonable bounds.

After an extensive literature review, an EKF and Particle Filter were implemented which include the covariance of the transmitting AUV so as to assess the importance of an acoustic range measurement. By incorporating the covariance, a fully cooperative localization could be performed. This has a tremendous benefit since additional expensive equipment for localization is no longer needed and the AUVs can be deployed relatively quickly.

The acoustic range measurements are based on clock synchronization between all the AUVs. When a AUV broadcasts its position estimate, a timestamp is included which can then be used the calculate the one-way travel time between the transmitter and the receiver. Since no response is needed, this information can be used by any AUV of the swarm who receives it.

The range measurement is then used to calculate the measurement update step in an EKF and a PF. In the case of the EKF, the state space is increased to temporarily also host the state of the transmitting AUV which includes its covariance. Therefore allowing to assess its uncertainty in the estimate. In case of the PF, the transmitting covariance is truncated into a single value by taking the square norm of it. This value is then used to calculate the weights of the particles following a students'T distribution. The students'T distribution is chosen, because the noise of the acoustic range measurements does not correspond to Gaussian noise and has been found to be better modelled with a students'T distribution due to its flat tails. Furthermore, the PF seems to be more adequate for the task since the system has a non-linear behaviour. The time update step in the filters is calculate based on the odometry of the AUV.

Several experiments with 2 ASVs and a fixed beacon were performed in the lake of Geneva and the results are evaluated for two cases:

1. A has perfect position information (from GNSS), B depends on A for localization using ground truth (GNSS) range measurements, including the estimated covariance of A

2. A has perfect position information (from GNSS), B depends on A for localization using acoustic range measurements, including the estimated covariance of A

The comparison of the filters was done with the RMSE and can be seen in the following Figure 1. The increase in error for the augmented PF could be due to a higher respond to uncertainty in the transmitted estimate, which was constantly increasing over the trial runs.

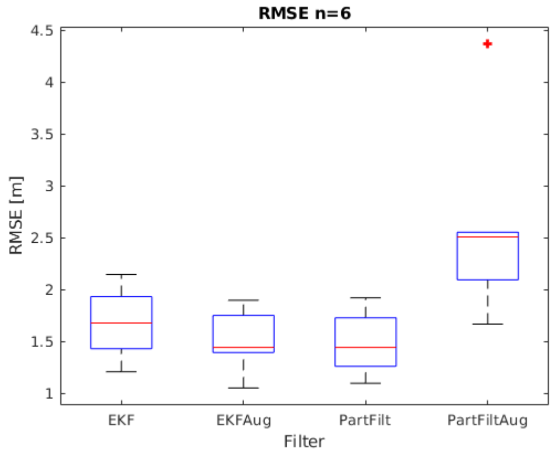

Figure 1: RMSE over 6 different experiment runs

The proposed algorithms solve the cooperative localization task, but further experiments are needed since the analysis was performed in post processing and online localization is still to be confirmed. For this, the hardware on the ASVs has to be adapted and improved since the acoustic range measurements were not reliable in the conducted experiments. Therefore the ground truth ranges had to be used in the analysis.