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FA/MA: Mutual Information Neural Estimation for multilateration localization systems

Description: Multilateration is a common and popular localization approach that can be realized with different kinds of sensors and references points. The accuracy of such systems is highly dependent on the placement of the reference points that are used for localization.
A common objective to optimize such reference point placements is the Geometric Dilution of Precision (GDOP). However, GDOP makes strong assumptions (e.g. linear measurement model, independent measurements for the references, Gaussian noise etc.).

A better metric than GDOP is mutual information (MI), which makes no such assumptions. However, computing and therefore optimizing MI is prohibitively expensive. Therefore, such approaches have currently only been investigated using heuristical pruning or subspace transforms in combination with MI approximation algorithms.
Recently, a new class of neural MI estimators have been proposed, which show faster convergence and better approximation quality than previous non-neural MI estimators.
This thesis shall investigate the application of an algorithm called Mutual Information Neural Estimation (MINE) for the optimization of reference point placements for multilateration systems in scenarios with limited visibility (including shadowing and restricted sensing range) of the references. An existing simulation- and optimization framework in Python shall be used for this, where different objectives (not including MI) for such scenarios can already be optimized using particle swarm optimization (PSO).

Work package:

- Literature study of multilateration systems.
- Literature study for the optimization of reference point layouts for such systems using GDOP and MI / cond. Entropy.
- Investigation of the behavior of MINE for multilateration reference point placement optimization. This includes different neural network architectures (MLPs, CNNs, ...), the convergence behaviour of the algorithm, effects of noise and the relationship between GDOP and estimated MI.
- Investigation of the achieved positioning accuracy using GDOP- and MI-optimized reference point layouts using a common multilateration algorithm (e.g. iterative least-squares, SVD or similar).

Prerequisites:

- Interest in the topic and ability to work indepedently
- Advanced mathematics, especially probability and information theory, e.g. our AM lecture or information theory by INUE
- Programming experience, ideally Python (keras, tensorflow, pytorch, jax, numpy ... or similar)
- Deep Learning lecture and ideally also DL lab participation