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An efficient Ultra-Wideband TDOA measurement model

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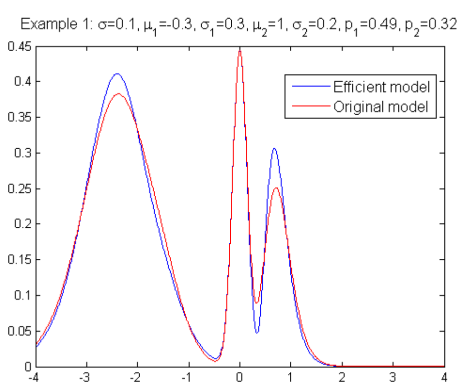
Ultra-Wideband has shown to be a promising technology for indoor localization, since the signals are able to penetrate through various objects. Nevertheless, in such non-line-of-sight (NLOS) conditions, the measurements may be biased. This leads to localization errors, if these biases are not addressed properly.

We consider the problem of localizing a robot with unknown initial conditions using on-board dead-reckoning information and UWB time-difference-of-arrival (TDOA) signals, which the robot receives from a pair of base stations. The standard algorithm employed to solve this problem requires a probabilistic model for the measurement error. We considered the (parametric) UWB TDOA measurement model presented in [1]. It takes explicitly into account NLOS conditions and models the bias using a lognormal distribution. Unfortunately, the resulting probability density of the TDOA measurement error involves e.g. the convolution of a lognormal with a normal density, for which no closed-form expression is known. This leads to difficulties in applying the model in practice, where one first needs to estimate the parameters defining the model using the collected TDOA data.

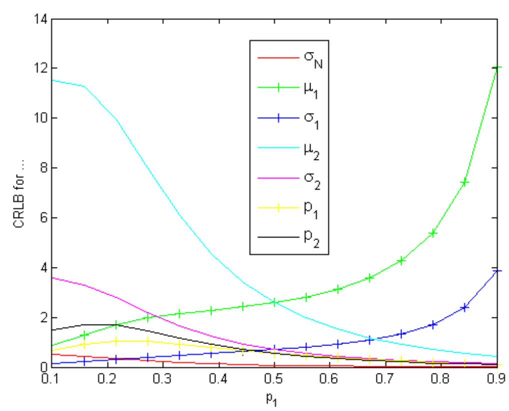


Approximation of model

In this project we were able to simplify the TDOA measurement model using approximations based on real world UWB data. We thereby obtained an efficient, closed-form TDOA measurement model which, for parameters in the range relevant for the problem, is a good approximation of the original model.

Subsequently, we calculated the Cramér-Rao lower bound (CRLB) for the new model, which can be done efficiently. The CRLB provides a useful tool to determine the quality of algorithms estimating the parameters in our model. It also gives insight into the relations between parameter values and estimation accuracy.

Finally, we applied the commonly used Expectation Maximization (EM) algorithm (on- and offline estimation) to the efficient model and show that it takes a very elegant form.



CRLB for estimating the parameters with varying p_1

The model developed in this project is therefore not only a good approximation of the original model, but also very useful in practice. And, as presented in [2], real experiments show that the online EM algorithm for this model leads to excellent localization performance.

References:

[1] A. Prorok, P. Tomé and A. Martinoli: Accommodation of NLOS for Ultra-Wideband TDOA Localization in Single- and Multi-Robot Systems. In *International Conference on Indoor Positioning and Indoor Localization* (IPIN), 2011.

[2] A. Prorok, L. Gonon and A. Martinoli: Online Model Estimation of Ultra-Wideband TDOA Measurements for Mobile Robot Localization. Submitted to *International Conference on Robotics and Automation (ICRA),* 2012.