TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

Bayesian Methods for Hybrid Positioning

Henri Nurminen and Simo Ali-Löytty
henri.nurminen@tut.fi and simo.ali-loytty@tut.fi
Tampere University of Technology, Finland, www.tut.fi/posgroup

Bayesian estimation

The Bayes' theorem links the prior distribution $p(\mathbf{x})$ and measurement likelihood $p(\mathbf{y} \mid \mathbf{x})$ with the posterior distribution

$$p(\mathbf{x} \mid \mathbf{y}) \propto p(\mathbf{y} \mid \mathbf{x}) \cdot p(\mathbf{x})$$

(Fig. 1), from which point estimates of $\mathbf{x}$ can be extracted, if needed.

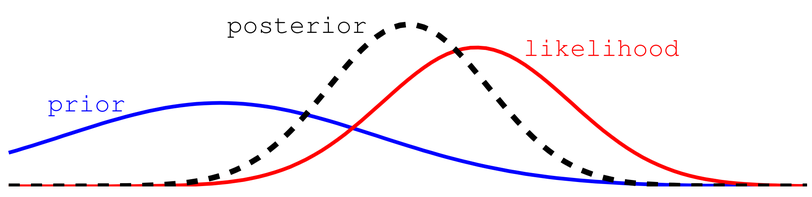

Figure 1: The posterior contains all prior and measurement information.

Statistical path loss models [1]

The real-data tests with existing cell and WLAN infrastructure indicate that especially estimation consistency is improved. Consistency is crucial when different measurements are combined.

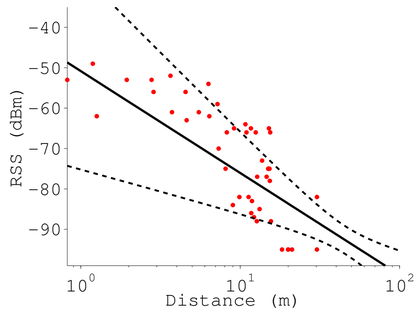

Figure 2: Fitted model with variance induced by unknown PL parameters (dashed curves).

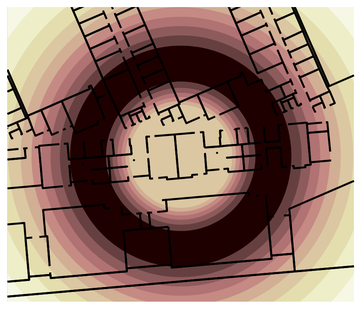

Figure 3: PL model likelihood is omnidirectional.

Gaussian mixture filter [2]

Gaussian mixture filters are an efficient method for hybrid positioning when true posterior is multi-modal.

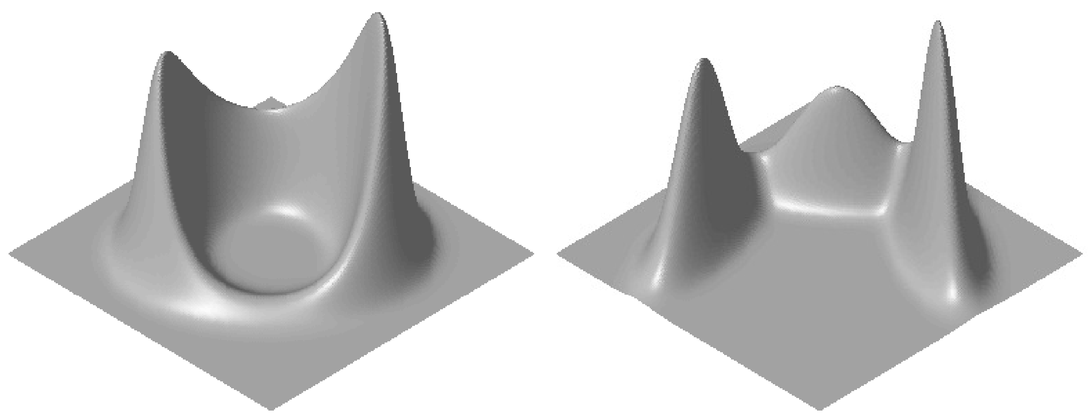

Figure 4: Left: True posterior. Right: posterior approximation using EGMF [2, p. 26].

Kalman-assisted Particle filter [3]

Particle filter (PF) algorithms can be use in indoor localisation with inertial measurement unit (IMU, Fig. 5), barometer, WLAN, and wall constraint information.

Figure 5: Inertial measurements are used for motion modelling.

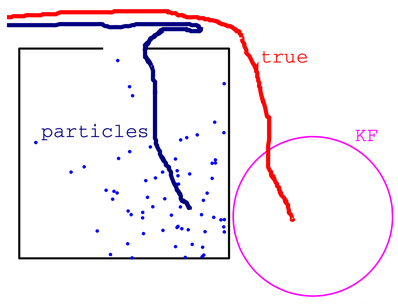

Figure 6: PDR-Kalman filter is the fallback if particles get stuck behind wall constraints.

Map-based motion models [4]

Using a low-quality IMU or no IMU at all makes the wall-collision PF inefficient. A solution is to use map information in the motion and/or proposal model.

Figure 7: Particles move on the links of the graph.

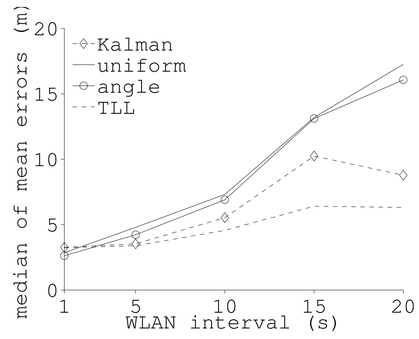

Figure 8: Link transition rule affects performance with large WLAN intervals.

Skew-t variational Bayes filter (STVBF) [5]

STVBF is applied to indoor positioning with ultra-wideband time-of-arrival based distance measurements and inertial measurements. Real-data tests show that the STVBF clearly outperforms the extended Kalman filter (EKF) in positioning accuracy with the computational complexity about three times that of the EKF.

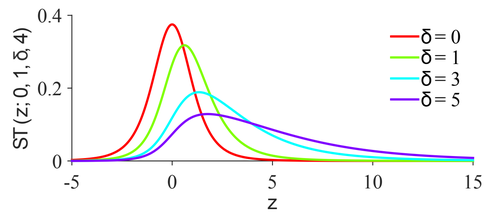

Figure 9: Positive skewness means that most realisations are small negative while some are large positive.

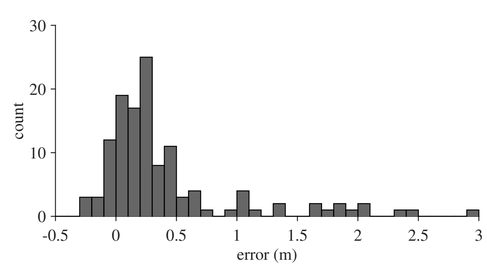

Figure 10: Time-of-arrival ranging has positively skewed errors.

References

[1] Henri Nurminen, Jukka Talvitie, Simo Ali-Löytty, Philipp Müller, Elena-Simona Lohan, Robert Piché, and Markku Renfors. Statistical path loss parameter estimation and positioning using RSS measurements. *Journal of Global Positioning Systems*, 12(1):13–27, 2013.

[2] Simo Ali-Löytty. *Gaussian Mixture Filters in Hybrid Positioning*. PhD thesis, Tampere University of Technology, August 2009.

[3] Henri Nurminen, Anssi Ristimäki, Simo Ali-Löytty, and Robert Piché. Particle filter and smoother for indoor localization. In *2013 International Conference on Indoor Positioning and Indoor Navigation (IPIN2013)*, pages 137–146, October 2013.

[4] Henri Nurminen, Mike Koivisto, Simo Ali-Löytty, and Robert Piché. Motion model for positioning with graph-based indoor map. In *2014 International Conference on Indoor Positioning and Indoor Navigation (IPIN2014)*, 27th–30th October 2014.

[5] Henri Nurminen, Tohid Ardeshiri, Robert Piché, and Fredrik Gustafsson. A NLOS-robust TOA positioning filter based on a skew-t measurement noise model. In *International Conference on Indoor Positioning and Indoor Navigation (IPIN2015)*, October. 2015. in press.

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