Tracking Multiple Ground Targets with Emitted Power Density

Umut Orguner and Fredrik Gustafsson

AUTOMATIC CONTROL
REGLERTEKNIK
LINKÖPINGS UNIVERSITET

Introduction

- Tracking of ground targets using acoustic power measurements from several microphones is a challenging problem.
- Most of earlier work has concentrated on bearing only (direction of arrival) measurements based on techniques like beamforming.
- Acoustic power is much easier to compute.

Ground Target Scenario

- N_T targets (number is unknown) on a road segment with states $x_k^j \triangleq \left[\mathsf{p}_k^j \; \mathsf{v}_k^j\right]^{\mathrm{T}}$ satisfying a nearly constant velocity model.
- N_S microphones located around the road segment which measures acoustic power modeled by

$$y_k^m = \sum_{j=1}^{N_T} \frac{\Psi^j}{\|\vec{r}_k^{m,j}\|^\alpha} + v_k^m.$$

  - y_k^m is the acoustic power measured from the mth microphone at time k;
  - Ψ^j is the unknown (assumed constant) acoustic power emitted by the jth target;
  - α is the (assumed known) path loss exponent;
  - $\vec{r}_k^{m,j}$ denotes the range vectors from the mth microphone to the jth target;
  - $v_k^m \sim \mathcal{N}(v_k^m; 0, r)$ is the measurement noise.

The aim is to estimate both the number and the states of the targets based on the acoustic power measurement obtained from the microphones.

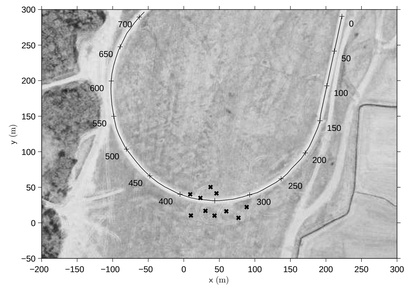

Figure 1: The map of the area, road segment, microphones.

Multiple Target Tracking

- The conventional MTT uses data association which is irrelevant because the sensor is superpositional.
- Bayesian estimation for a single target calculates $p(x_k|y_{0:k}^{1:N_S})$ which satisfies

$$p(x_k|y_{0:k}^{1:N_S}) = \int \delta_{x_k}(x) p(x|y_{0:k}^{1:N_S}) \, \mathrm{d}x \triangleq E\left[\delta_{x_k}(x) \,\middle|\, y_{0:k}^{1:N_S}\right].$$

- Recently developed Bayesian multiple target tracking (PHD-filter) calculates

$$\mathrm{PHD}_{k|k}(x) \triangleq E\left[\sum_{j=1}^{N_T} \delta_{x_k^j}(x) \,\middle|\, y_{0:k}^{1:N_S}\right].$$

- We here define

$$\mathrm{EPD}_k(x) \triangleq \sum_{j=1}^{N_T} \Psi^j \delta_{x_k^j}(x)$$

and find estimates of EPD as

$$\mathrm{EPD}_{k|k}(x) \triangleq E\left[\mathrm{EPD}_k(x) \,\middle|\, y_{0:k}^{1:N_S}\right]$$

using the measurement equation

$$y_k^m = \int h^m(x) \, \mathrm{EPD}_k(x) \, \mathrm{d}x + v_k^m$$

where $h^m(x) = \|\vec{r}^m(x)\|^{-\alpha}$ represents a range related function.

- We find recursions for the EPD and develop a filter (EPD-filter) making use of
  - Gaussian processes;
  - Position discretization on the road segment.
- Estimates are obtained by searching the local peaks of $\mathrm{EPD}_{k|k}(x)$ which exceeds a pre-defined threshold depending on the expected target sound level.
  - The number of detected peaks gives the estimated number of targets.
  - Peak locations in the state space give the target state estimates.

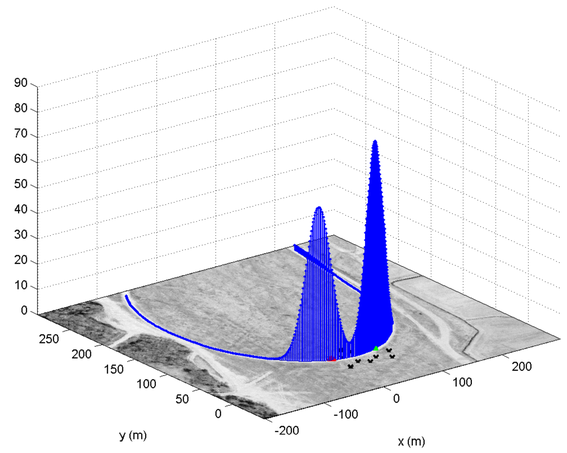

Figure 2: How $\mathrm{EPD}_{k|k}(x)$ (expected EPD) looks like.

Example

- Field experiments near Skövde by FOI;
- 2 targets: A car (green) and a motorcycle (red);
- 10 microphones.

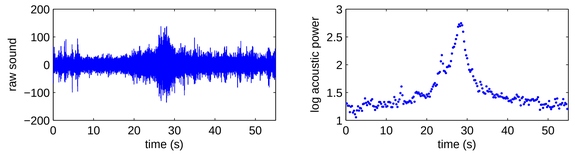

Figure 3: The raw sound data and the acoustic power measurements for the microphone located at [46m, 41.3m].

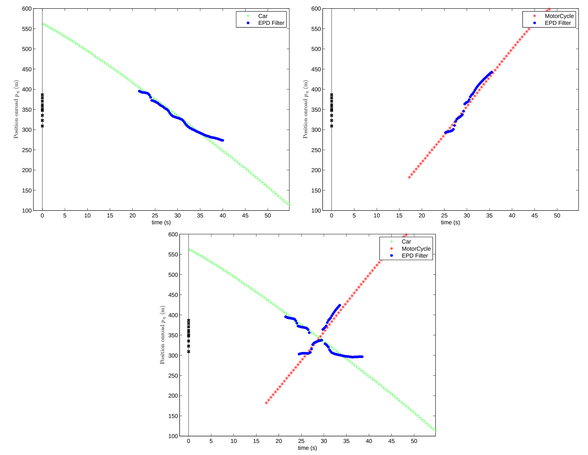

Figure 4: The position estimates of the EPD-filter with single target and two target data sets.

Conclusions

- A novel methodology with superpositional sensors.
- Quite efficient method compared to direction of arrival based trackers.
- Discretization is limiting. Particle based representations must be investigated.

Acknowledgments

The authors would like to thank FOI (Swedish Defense Research Agency) for the data used in the example.

References

[1] U. Orguner and F. Gustafsson, "Multi target tracking with acoustic power measurements using emitted power density," Department of Electrical Engineering, Linköping University, Tech. Rep. LiTH-ISY-R-2947, Apr. 2010.

[2] ——, "Multi target tracking with acoustic power measurements using emitted power density," Accepted to the 13th International Conference on Information Fusion, 2010.