TAMPERE UNIVERSITY OF TECHNOLOGY
Mathematics

Personal Positioning Algorithms

Prof. Robert Piché

Niilo Sirola
researcher, M.Sc.

Kari Heine
researcher, Lic.

Simo Ali-Löytty
researcher, M.Sc.

Henri Pesonen
researcher, M.Sc.

Tommi Perälä
research assistant

Tuomi Mäki-Marttunen
research assistant

Matti Raitoharju
research assistant

Personal positioning

for example, a mobile handset

sources of positioning information:

- navigation equipment: GPS, IMU
- cellular network, WLAN, Bluetooth, . . .
- digital compass, step counter, barometer
- aiding data (altitude, cell sector, . . .)
- digital maps
- etc.

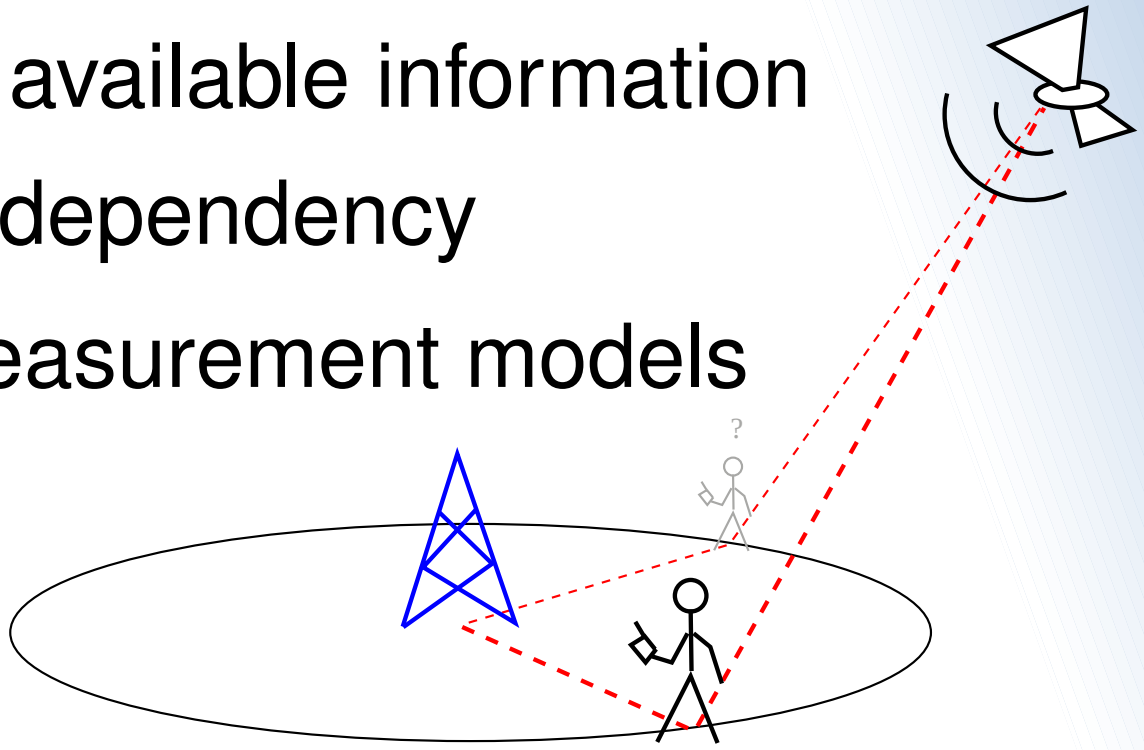
Challenges

- large linearization errors
- scarce measurements – underdetermined
- non-normal noise structure

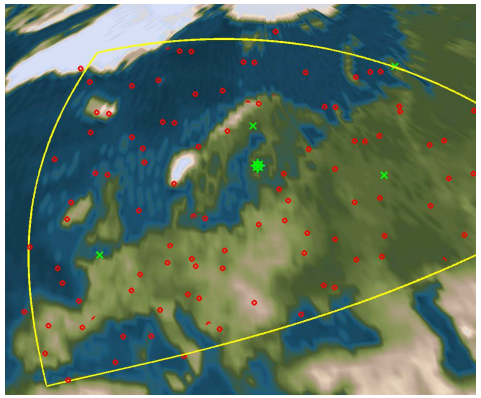
$\longrightarrow$ make use of **all** available information

$\longrightarrow$ exploit the time dependency

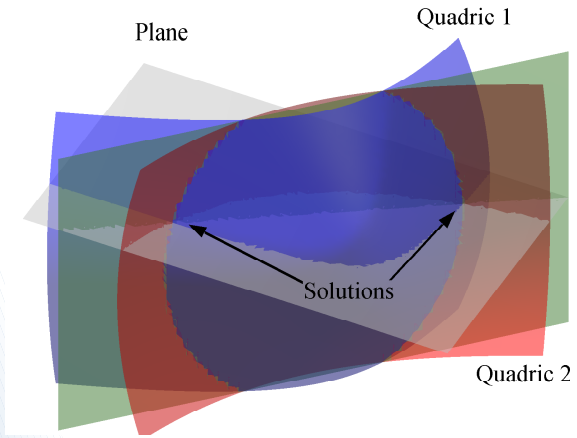
$\longrightarrow$ allow flexible measurement models



Research highlights

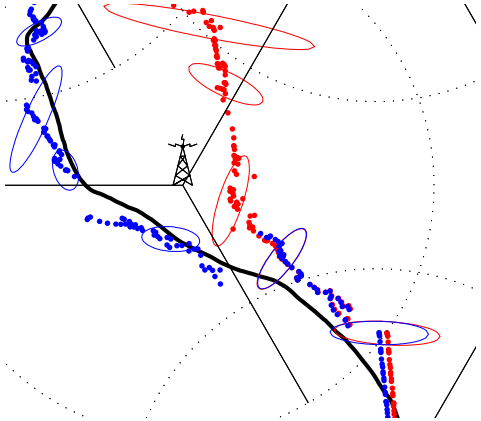


Solving position and time from GPS code phase measurements without the navigation data (2001)

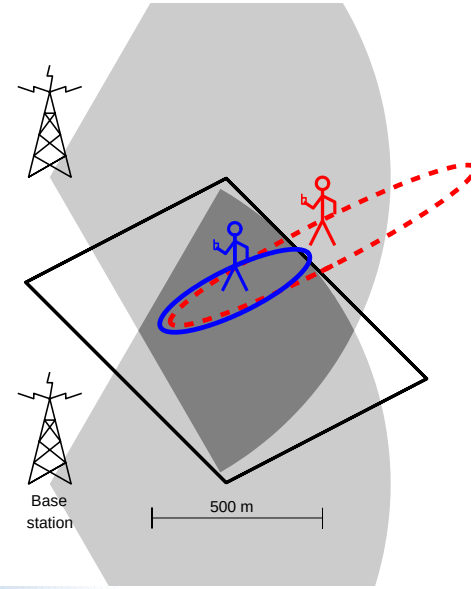


Versatile closed form solutions for hybrid positioning (2004)

Research highlights



Inconsistency of EKF with nonlinear measurements (2005)

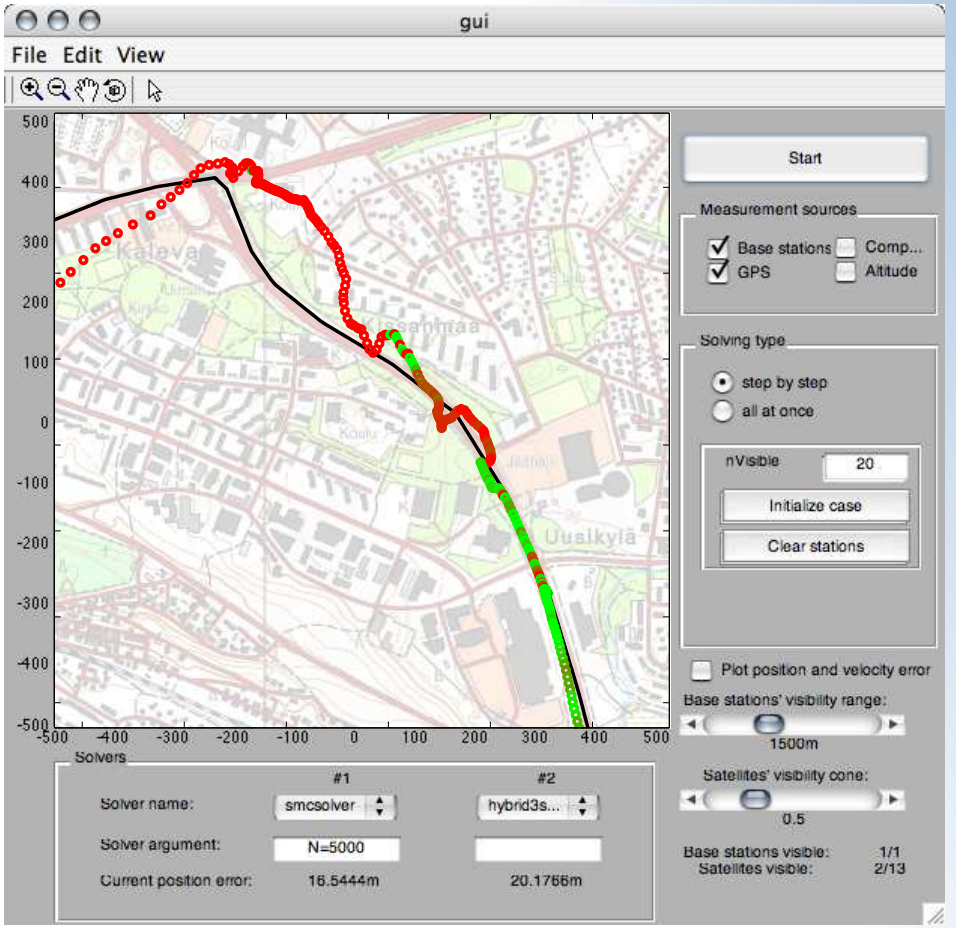


Modified EKF that uses restrictive information (2006)

Research highlights

Simulation/real data test bench and visualization tools in Matlab

- EKF, 2nd order
  EKF, unscented KF
- Gaussian mixture
- particle filters
- point-mass & grid filters
- batch processing
- smoothing



Discrete nonlinear filtering problem

Distribution of initial state x_0 given.

Motion model:

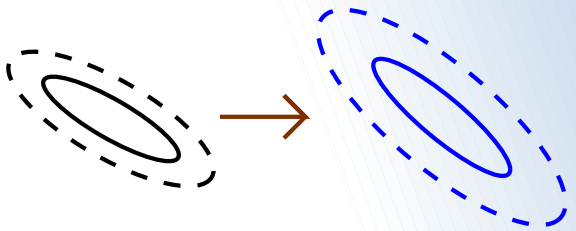
$$x_{k+1} = f_k(x_k) + w_k$$

Measurement model:

$$y_k = h_k(x_k) + v_k$$

Optimal solution: recursive Bayesian filter

Recursive Bayesian filter

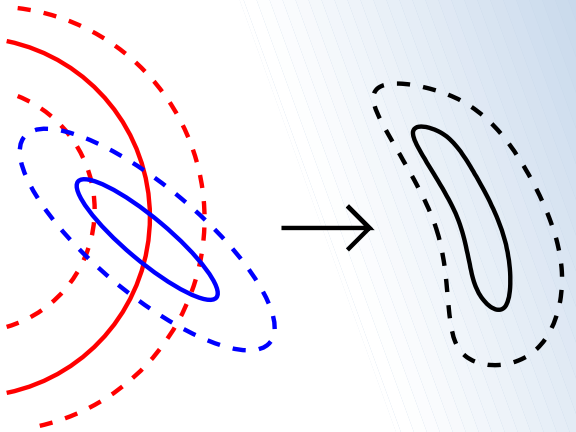


Prediction step:

$$p(x_k \mid Y_{k-1}) = \int_{\mathbb{R}^d} \underbrace{p(x_k \mid x_{k-1})}_{\text{motion model}} \underbrace{p(x_{k-1} \mid Y_{k-1})}_{\text{previous}} dx_{k-1}$$

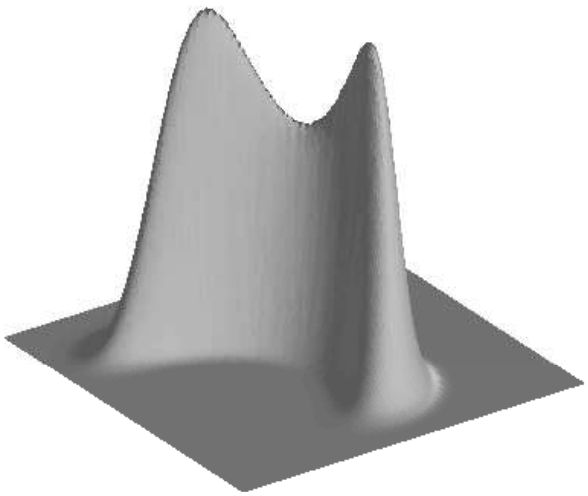
Update step:

$$p(x_k \mid Y_k) \propto \underbrace{p(y_k \mid x_k)}_{\text{measurement}} p(x_k \mid Y_{k-1})$$

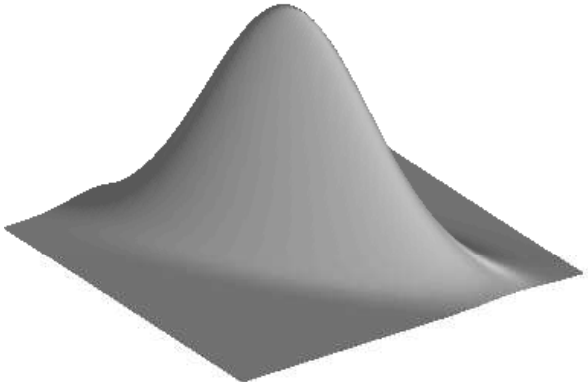


In general, exact solution requires infinite time and memory!

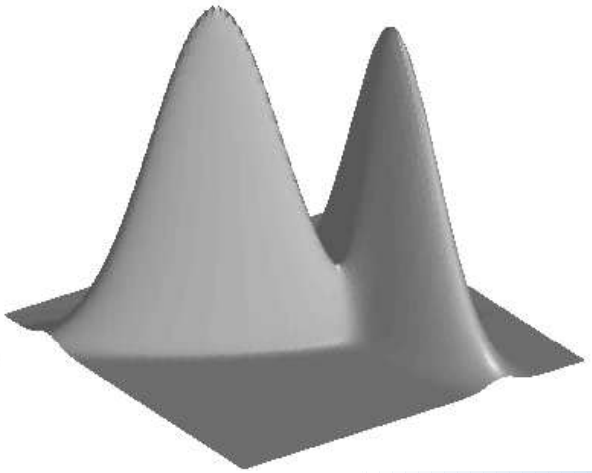
Numerical pdf approximations



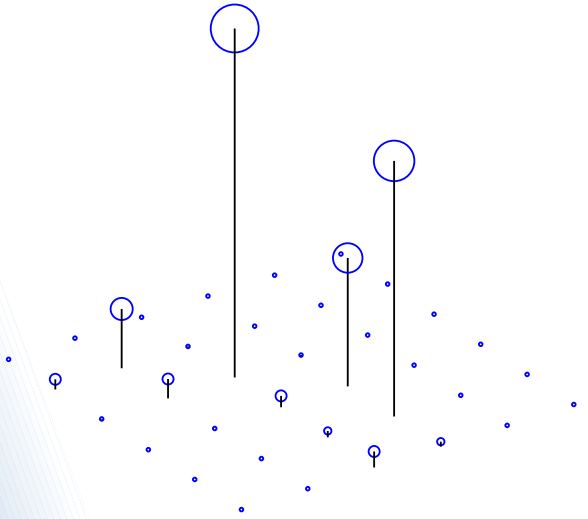
true pdf



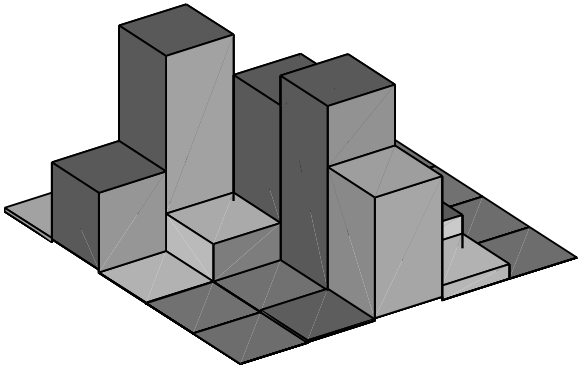
Gaussian



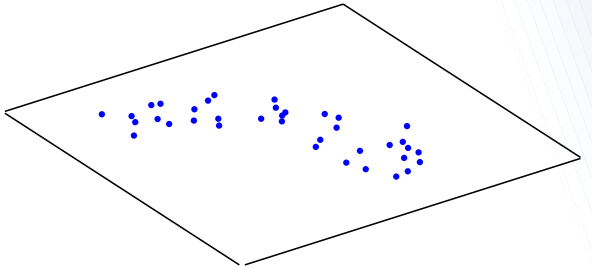
Gaussian Mixture



point mass



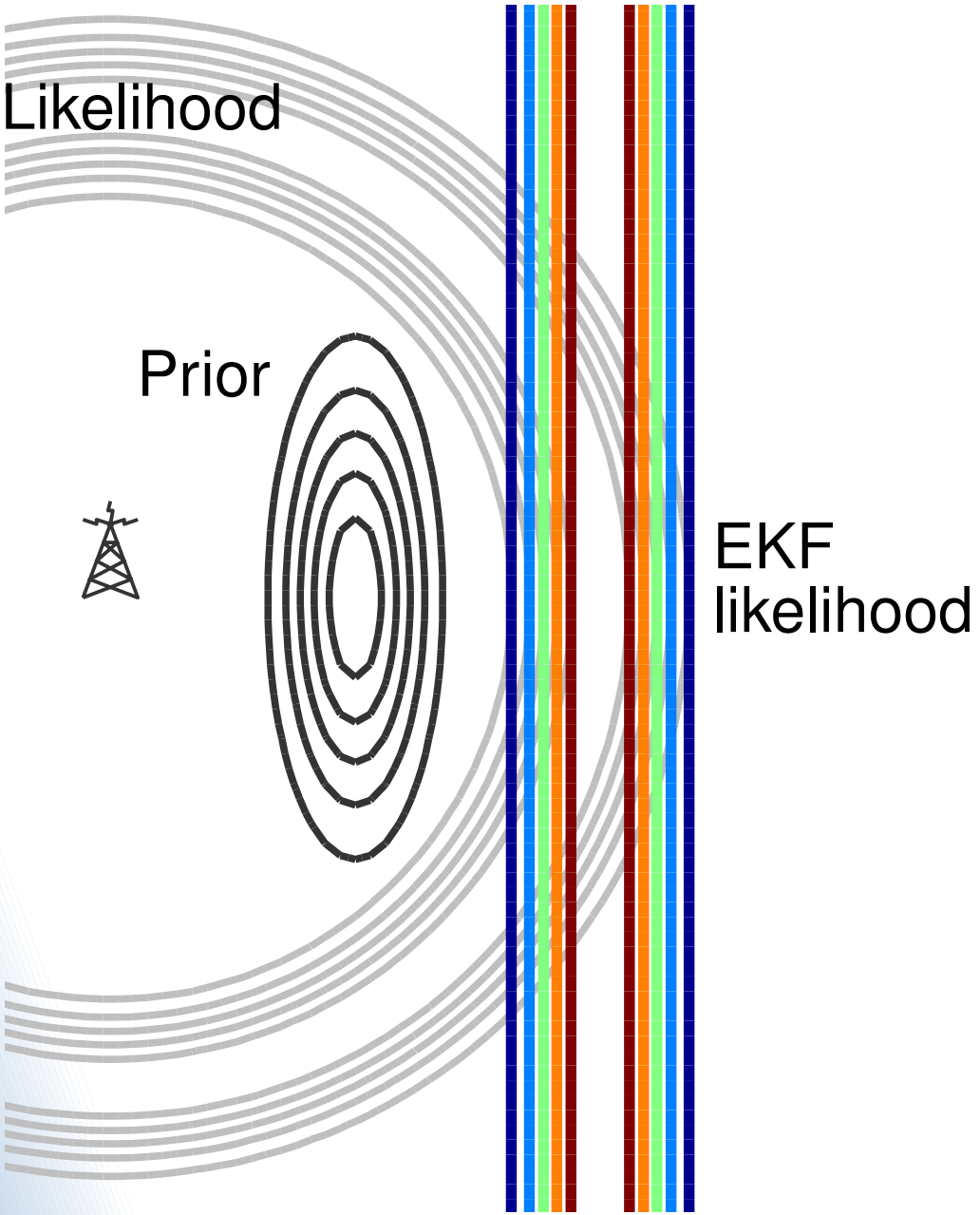
grid mass

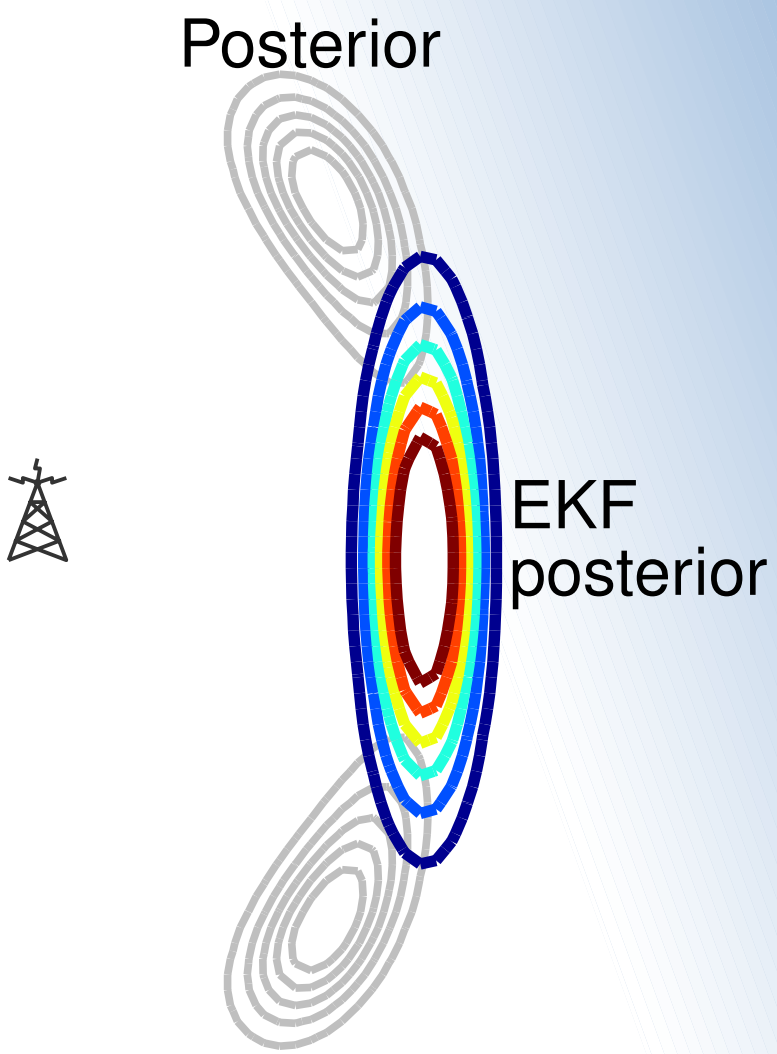


Monte Carlo

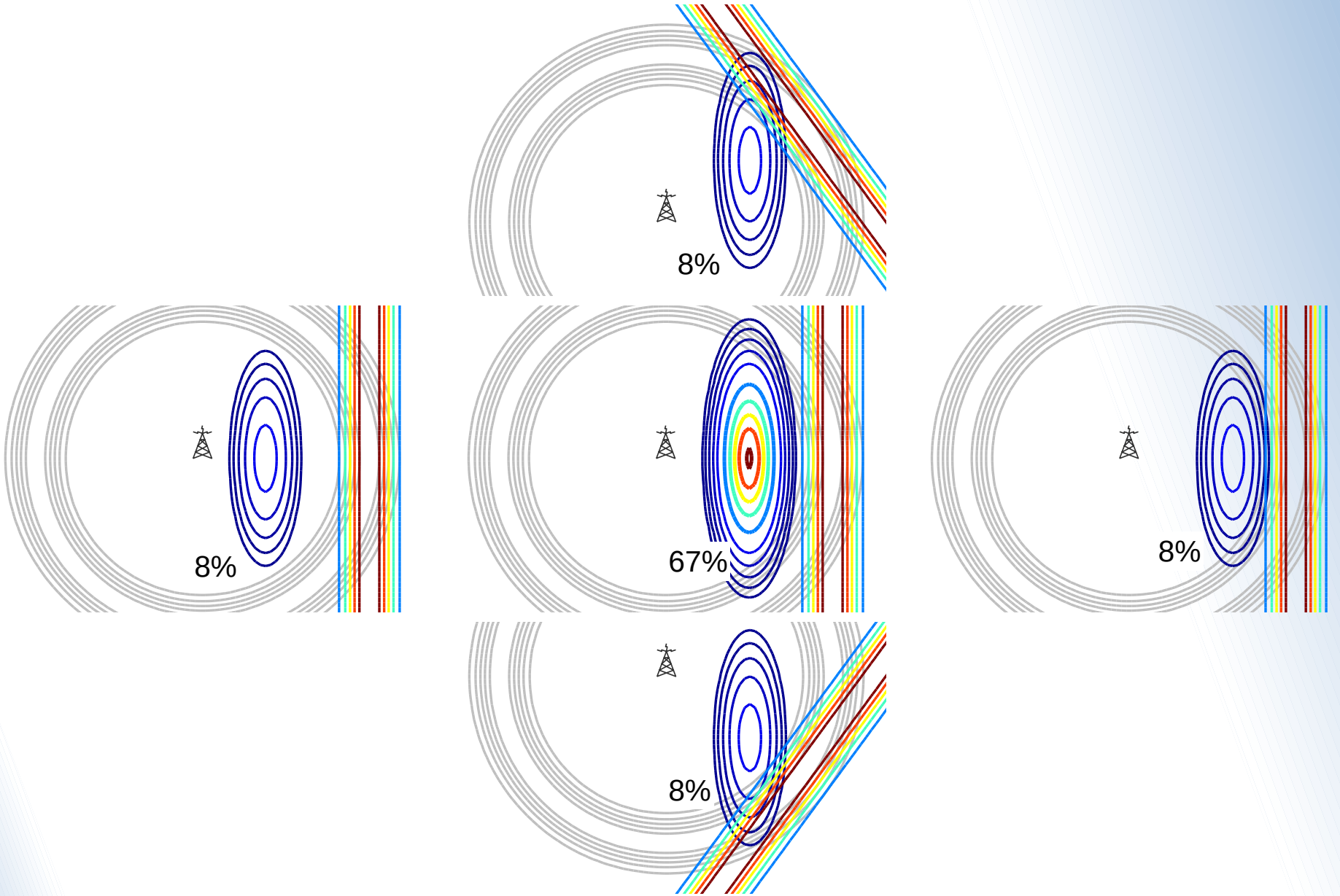
Examples

Problem: linearization (EKF) does not work

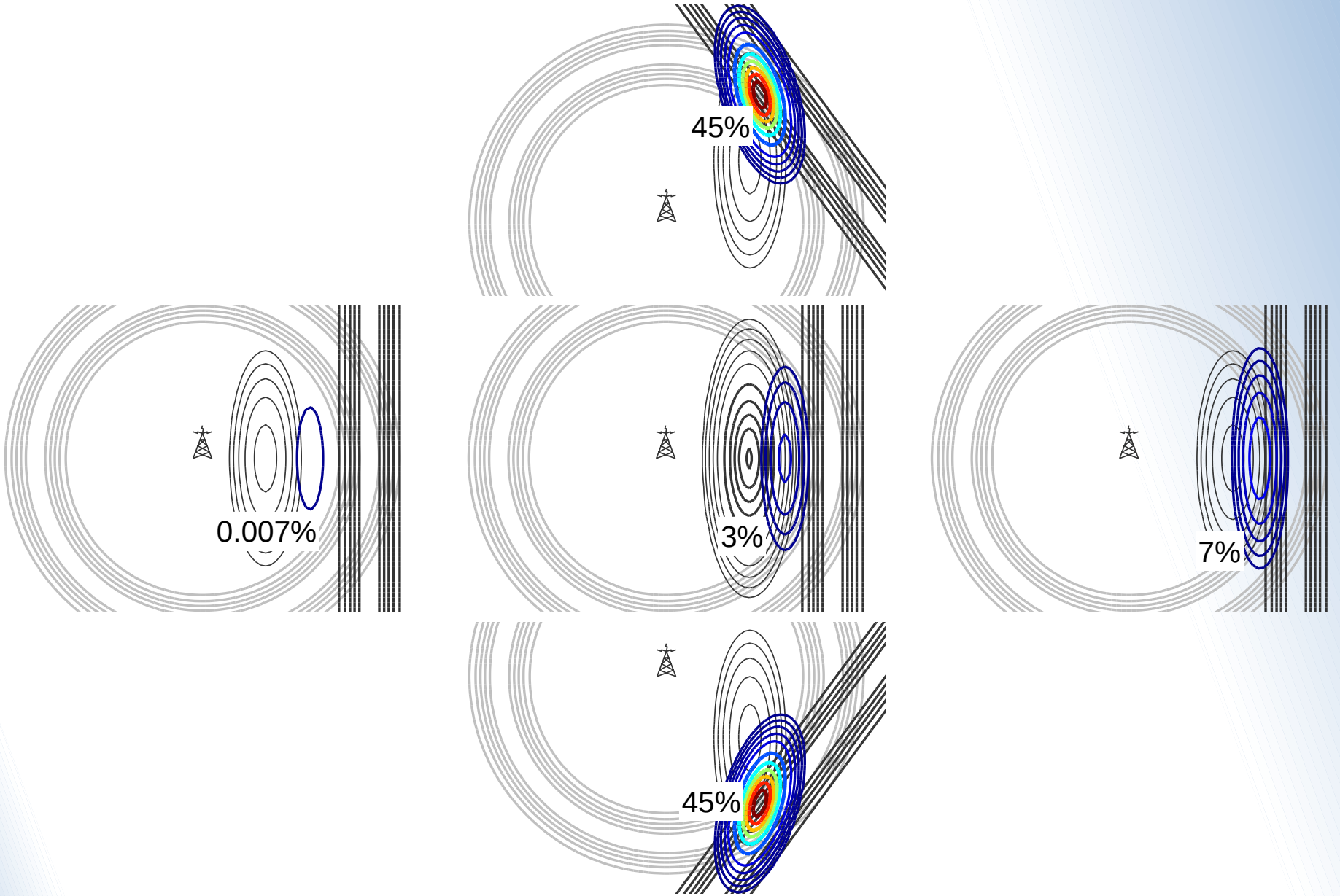




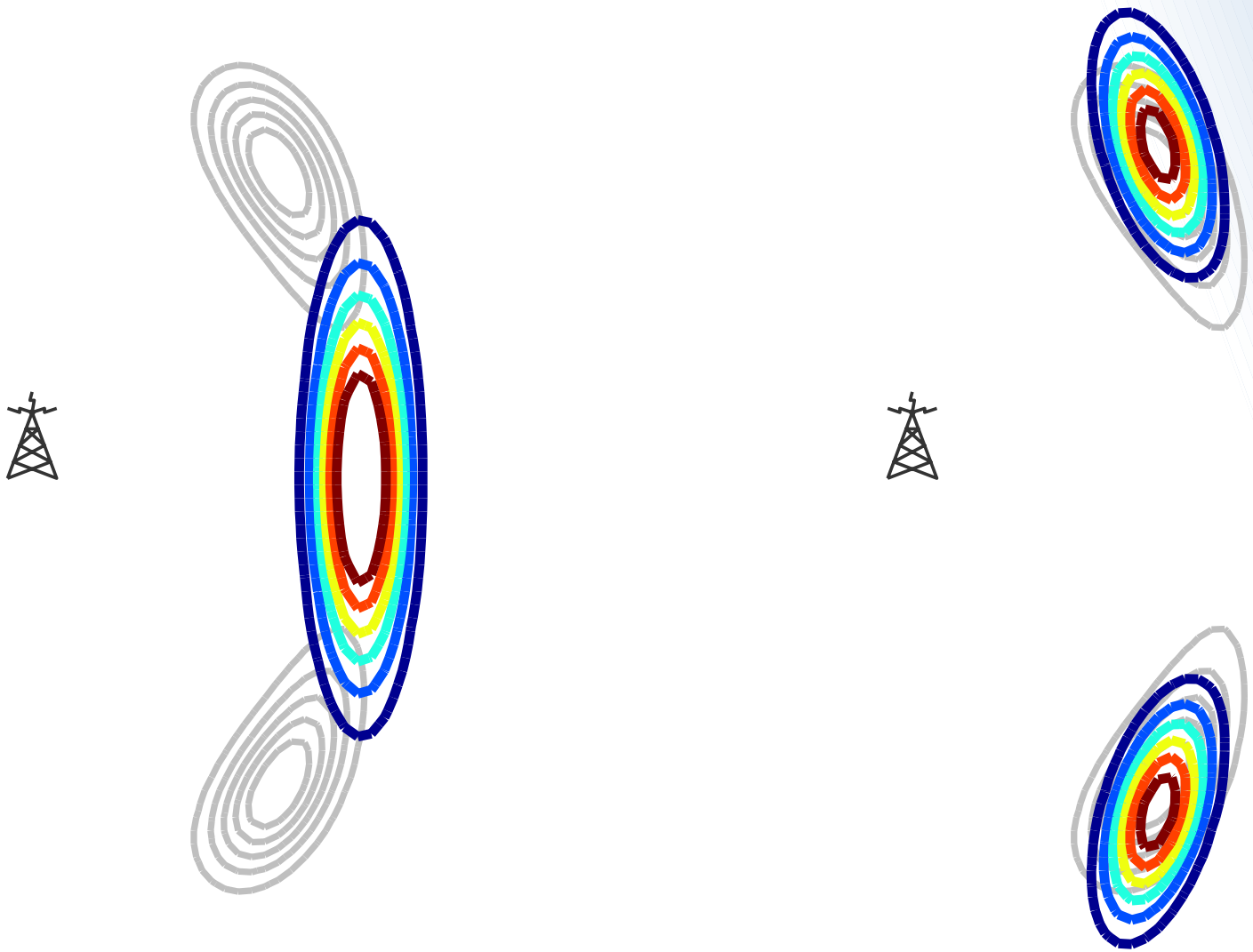
Solution: Splitting prior into a Gaussian Mixture



Posterior is also Gaussian Mixture



EKF and GMF posteriors vs. correct posterior



GPS + simulated BS range meas.