A modified Kalman filter for hybrid positioning

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This paper presents a new hybrid positioning algorithm whereby restrictive information such as base station sector and maximum range can be used in a Kalman-type filter. This new algorithm is fast to compute and gives almost the same accuracy as the particle filter with millions of particles. Simulations show that in some cases restrictive information such as mobile phone network sector and maximum range information dramatically improve filter accuracy. Mathematical paper presents a fast way to approximate integrals

$$\int_{Ax \leq a} x p(x)\, dx \quad \text{and} \quad \int_{Ax \leq a} (x-\mu)(x-\mu)^T p(x)\, dx,$$

where $p(x)$ is multinormal density function.

Hybrid positioning means that measurements used in positioning come from many different sources, e.g. Global Navigation Satellite System (GNSS), Inertial Measurement Unit (IMU), or local wireless networks such as a cellular network, WLAN, or Bluetooth. Range, pseudorange, deltarange, altitude, and compass measurements are examples of typical measurements in hybrid positioning. In hybrid positioning, there is lot of other measurements such as restrictive information, which can be used in positioning. Restrictive information tells that state e.g. position, is inside some area. In the simplest case, the area is a half-space. For example, base station sector and maximum range information (Cell ID) are restrictive information.

Positioning filters are used to compute an estimate of the state using current and past measurement data. Filters also give an approximation of the error covariance matrix, which tells how accurate state estimation is. Kalman type filters approximate distribution of the state as a Gaussian or as a mixture of Gaussians. Extended Kalman Filter (EKF), Second Order Extended Kalman Filter (EKF2) and Gaussian Mixture Filter (GMF) are examples of Kalman type filters. Maybe the most popular example is EKF, which is very commonly used in satellite based positioning and has also been applied to hybrid positioning. Unfortunately, EKF has serious consistency problem in highly nonlinear situations, which means that EKF does not work correctly. Contrary to satellite based positioning, highly nonlinear situations are common in hybrid positioning. Because of this, many applications use general nonlinear Bayesian filter, which is usually implemented as a particle filter or a point mass based filter. These filters usually work correctly and give good positioning accuracy but require much computation time.

We show in this paper that in some cases the new hybrid positioning algorithm gives almost the same accuracy than a particle filter. In addition, the new algorithm avoids most of the consistency problems that exist with traditional EKF. Maybe the biggest advantage of the new algorithm is that it needs notably less computation time than a particle filter and because of this, it is conceivable that the algorithm can be implement in a mobile device such as a mobile phone.