TRANSNAV International Journal on Marine Navigation and Safety of Sea Transportation
Volume 4 Number 4 December 2010

Alternative for Kalman Filter – Two Dimension Self-learning Filter with Memory

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ABSTRACT: We propose new solution for idea Prof. Vanicek and Prof. Inzinga. This filter relies basically on the information contained in measurements on the vehicle: position fixes, velocities and their error statistics.

The basic idea behind this new navigation filter is twofold:

1 A cluster of the observed position fixes contains true kinematic information about the vehicle in motion,
2 A motion model of the vehicle associated with the error statistics of the position fixes should be able to get, to a large extent, the information out of the measurements for use.

We base the filter on an analogy. We consider the statistical confidence region of every position fix as "source" tending to "attract" the undetermined trajectory to pass through this region. With these position fixes and their error statistics, a virtual potential field is constructed in which an imaginary mass particle moves. To make the filter flexible and responsive to a changing navigation environment, we leave some parameters free and let the filter determine their values, using a sequence of observations and the criterion of least squares of the observation errors. We show that the trajectory of the imaginary particle can well represent the real track of the vehicle.

In our poster we presents basic idea this filter and numerical method for calculate best position using this filter also we show experiment (with RTK/SPAN technology) that we do for verification presented filter.

Filter function:

$$\phi_{r^0} = \frac{1}{K}\exp\left[-\frac{1}{2}(r - r^0)^T C^{-1}(r - r^0)\right] \quad (1)$$

$r = \begin{bmatrix} x \\ y \end{bmatrix}$ position vector in actual time "t"

$r^0 = \begin{bmatrix} x^0 \\ y^0 \end{bmatrix}$ position vector in time "t_0"

$$K = (2\pi)^{\frac{3}{2}}(detC)^{\frac{1}{2}} \quad (2)$$

Where C is a matrix of covariance

$$C = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} = \begin{bmatrix} D^2X & cov(X,Y) \\ cov(Y,X) & D^2Y \end{bmatrix} \quad (3)$$

The basis for estimation position is potential U_i

$$U_i(t) = G(r - r^0)^T C_i^{-1}(r - r^0)e^{-\alpha(t-t_i)} \quad (4)$$

Next step is conversion U_i when we know "n" position before time "t"

$$U = \sum_{i=1}^{n} U_i = Ge^{-\alpha t}\sum_{i=1}^{n}(r - r^0)^T C_i^{-1}(r - r^0)e^{\alpha t_i} \quad (5)$$

$$U(t) = \sum_{i=1}^{n} U_i(t) = Ge^{-\alpha t}\sum_{i=1}^{n}\left[\frac{(x-x_{0i})^2}{\sigma_{11i}^2} + \frac{(y-y_{0i})^2}{\sigma_{22i}^2}\right]e^{\alpha t_i} \quad (6)$$

where $r = \begin{bmatrix} x \\ y \end{bmatrix}$ $r_{0i} = \begin{bmatrix} x_{0i} \\ y_{0i} \end{bmatrix}$

$$\ddot{r}(t) = e^{-\alpha t}G(Ar - B); \quad t \geq t_n \quad (7)$$

In next step we have:

$$A = 2\sum_{i=1}^{n} e^{\alpha t_i}\, C_i^{-1} \quad \text{matrix (2 x 2)} \tag{8}$$

$$B = 2\sum_{i=1}^{n} e^{\alpha t_i}\, C_i^{-1} r_{0i} \quad \textit{vector} \tag{9}$$

where

$$C^{-1} = \begin{bmatrix} \frac{1}{\sigma_{11}^2} & 0 \\ 0 & \frac{1}{\sigma_{22}^2} \end{bmatrix} = \begin{bmatrix} p_{xi} & 0 \\ 0 & p_{yi} \end{bmatrix} \tag{10}$$

$$\ddot{x}(t) = -G(A_x x - B_x)e^{-\alpha t}; \quad t \geq t_n \tag{11}$$

$$\ddot{y}(t) = -G(A_y y - B_y)e^{-\alpha t}; \quad t \geq t_n \tag{12}$$

$$Ar = (A_x x, A_y y) \; and \; B = (B_x, B_y) \tag{13}$$

$$A_x = 2\sum_{i=1}^{n} e^{\alpha(t_i - t_n)} p_{xi} \tag{14}$$

$$A_y = 2\sum_{i=1}^{n} e^{\alpha(t_i - t_n)} p_{yi} \tag{15}$$

$$B_x = 2\sum_{i=1}^{n} e^{\alpha(t_i - t_n)} p_{xi}\, x_{0i} \tag{16}$$

$$B_y = 2\sum_{i=1}^{n} e^{\alpha(t_i - t_n)} p_{yi}\, x_{0i} \tag{17}$$

Final solution is:

$$\begin{cases} x(t) = \frac{B_x}{A_x} + a_1 J_0\left(\frac{2}{\alpha} e^{-\frac{\alpha}{2}t}\sqrt{GA_x}\right) + a_2 N_0\left(\frac{2}{\alpha} e^{-\frac{\alpha}{2}t}\sqrt{GA_x}\right) \\ y(t) = \frac{B_y}{A_y} + b_1 J_0\left(\frac{2}{\alpha} e^{-\frac{\alpha}{2}t}\sqrt{GA_y}\right) + b_2 N_0\left(\frac{2}{\alpha} e^{-\frac{\alpha}{2}t}\sqrt{GA_y}\right) \end{cases} \tag{18}$$

$$a_1 = -\frac{\pi}{\sigma}\left[\left(x_n - \frac{B_x}{A_x}\right)\sqrt{GA_x} N_1\left(\frac{2}{\alpha}\sqrt{GA_x}\right) - \dot{x}_n N_0\left(\frac{2}{\alpha}\sqrt{GA_x}\right)\right] \tag{19}$$

$$a_2 = -\frac{\pi}{\sigma}\left[\left(x_n - \frac{B_x}{A_x}\right)\sqrt{GA_x} J_1\left(\frac{2}{\alpha}\sqrt{GA_x}\right) - \dot{x}_n J_0\left(\frac{2}{\alpha}\sqrt{GA_x}\right)\right] \tag{20}$$

$$b_1 = -\frac{\pi}{\sigma}\left[\left(y_n - \frac{B_y}{A_y}\right)\sqrt{GA_y} N_1\left(\frac{2}{\alpha}\sqrt{GA_y}\right) - \dot{y}_n N_0\left(\frac{2}{\alpha}\sqrt{GA_y}\right)\right] \tag{21}$$

$$b_2 = -\frac{\pi}{\sigma}\left[\left(y_n - \frac{B_y}{A_y}\right)\sqrt{GA_y} J_1\left(\frac{2}{\alpha}\sqrt{GA_y}\right) - \dot{y}_n J_0\left(\frac{2}{\alpha}\sqrt{GA_y}\right)\right] \tag{22}$$

Our purpose is best estimation G and α from this equation

$$f(\alpha, G) = \sum_{i=1}^{n}\{[x(t_i) - x_{0i}]^2 + [y(t_i) - y_{0i}]^2\} = \textit{minimum} \tag{23}$$

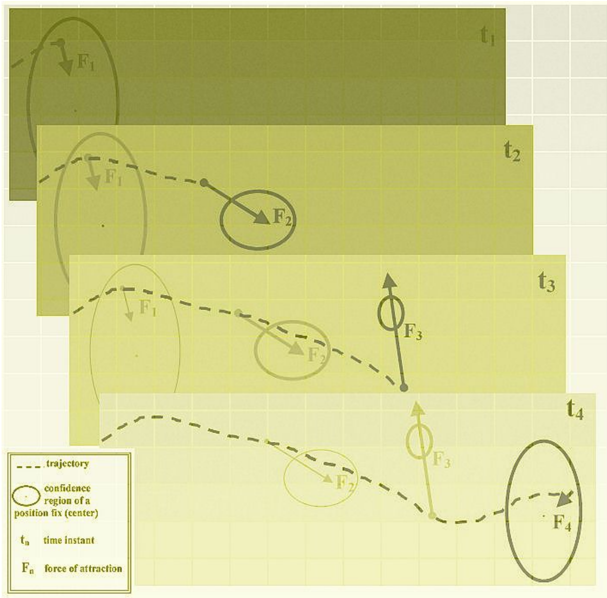

Figure 1. Visualization filter idea.

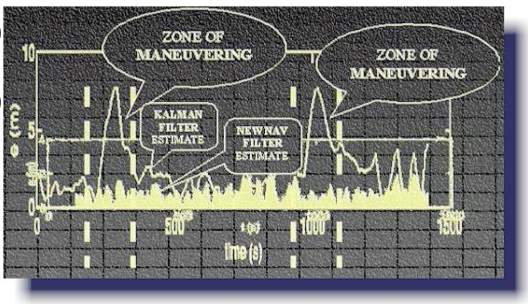

Figure 2. Alternative filter vs Kalman filter.

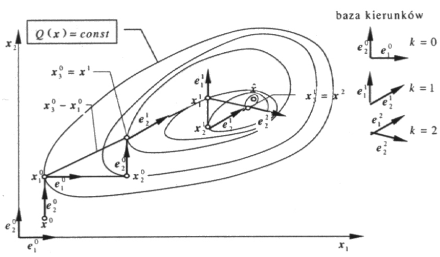

Figure 3. Powell Algorithm

1 TODAY'S NAVIGATION SYSTEMS AND THE REQUIREMENTS PLACED ON THEM

Modern navigation are dominated by satellite systems and assist systems mainly including GPS - NAVSTAR GPS (called the Global Positioning System - Navigation Signal Timing and Ranging), in Europe EGNOS (called European Geostationary Navigation Overlay Service), which de facto is a service for GPS system and Russian GLONASS (called Global Navigation Satellite System, or in Russian Globalnaja Nawigacjonnaja Satelitarnaja Sistemma). Each of these systems offers similar functionality. Let focus on requirements that modern navigation systems should met with reference to existing systems.

Satellite system which can be considered for navigation must ensure:

- Accuracy; GPS does not meet expectations in terms of its accuracy, which is required in aviation - during landing approach. EGNOS is a system that uses GPS position and corrections from ground stations, offering greater level of accuracy than GPS and it is to be used in civil aviation starting 2008, but its accuracy is still between 2-3 meters, which is not fully satisfactory from Air Navigation or even Waterways Navigation (rivers) point of view. GLONASS is a system which is right now exchanging it's satellites constellation, but to date no civilian usage is possible.
- The ability of immediately alert users about system malfunction. A serious issue of GPS is lack of any communication containing information about its credibility (can we use it). Advanced users can view information from the various types of satellites, including healthy/un-healthy status but despite this, users can't obtain data on the state of the entire system. EGNOS in his assumption, as a GPS service was intended to correct its deficiencies, and so is about its ability to provide warnings about improper functioning of the system. EGNOS architecture based on the network of ground stations collecting errors which GPS generates can also determine the quality of the GPS information and instantly send notice to its three geostationary satellites, which will inform the end user about inability to use the EGNOS and in result GPS system.
- Continuity of service. GPS and so as the EGNOS are systems/services which do not meet the desired functionality even because of the fact that GPS is an U.S. property and in any threat situation it can be disabled. EGNOS is in the testing phase and its functionality is not yet complete
- Availability - is a factor expressed in percentage representing the time within the system may be used. The U.S. FAA (Federal Aviation Administration) organization demands availability for air-route navigation, while approaching and landing airports and during aerial surveillance no less than 99,999%. As previously found GPS is disqualified by lack of information about its credibility and availability at less than 99,999%, while the European EGNOS at the moment is in testing phase.

Unfortunately, none of these systems/services offer the level of accuracy of 1 meter without the use of differential techniques. Possible solution for this is usage and development of already existing filters or developing new ones or usage of mathematics and information based on assumptions which will allow individuals to increase the data accuracy regardless of expanding space installations (GPS III and Galileo).

2 EXISTING NAVIGATION FILTERS

Part of the problem is usually solved through a combination of two different types of information, observation and vehicle traffic by creating a model based on the basic rights of physics represented by different equations. Existing filters in navigation have been dominated by the Kalman filter in various forms. Kalman filter will be thoroughly discussed in chapter II. On the basis of experience and many publications related to navigation, especially in areas where the navigation is performed many maneuvers Kalman filter does not meet the requirements of accuracy (positional error has repeatedly been growing in the performance of maneuvers). The basis for conducting further research traffic is a working hypothesis that the existing model navigation filter does not meet the accuracy requirements for the movable object, it is assumed that the acquisition of improvement in this regard will be developed when submission to the new model navigation object memory.

BIBLIOGRAPHY

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