Integration of GPS and MEMS inertial sensor

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Abstract

Recent technological advances in both Global Positioning System (GPS) and low cost MEMS based inertial sensors enabled monitoring the location of moving platforms for numerous positioning and navigation applications. When miniaturized inside any moving platforms, MEMS based inertial navigation system (INS) can be incorporated with GPS and enhance the performance in denied GPS environments (like in urban canyons). GPS/INS integration is motivated by the complementary characteristics of the two systems: INS slow drifts are compensated by GPS long term accuracy whereas INS can coast during GPS outages. The coupling between GPS and INS is classically performed by means of a hybridization filter that fuses information from both navigation systems to compute the correct data's. The integration helps to limit the INS derived Position, Velocity and Attitude errors by using GPS measurements as update to the position and velocity whenever it is available. The combination of the two systems, traditionally performed by Kalman filtering (KF), but KF has limited capabilities in providing accurate positioning especially when the system is highly non-linear and the noise is Non-Gaussian. Particle filtering (PF) was suggested to accommodate for arbitrary inertial sensor characteristics, motion dynamics and noise distributions. Particle filters (PFs) are good candidates to solve the estimation problem associated to INS/GPS hybridization, because of the nonlinear measurement equation. PFs belong to the class of Sequential Monte Carlo methods, which provide a set of powerful algorithms for handling the nonlinear and non-Gaussian state space models.

Aircraft Navigation Systems

- Determination of position of an aircraft is a challenging task in Aerospace field.
- In the beginning of aircraft history mechanical system is used to find the position of an aircraft.
- Nowadays mechanical systems is replaced by electronics systems (Avionics Systems) like GPS, INS, etc..,
- The purpose of this replacement is provide the accrued information, secure and safe flight.

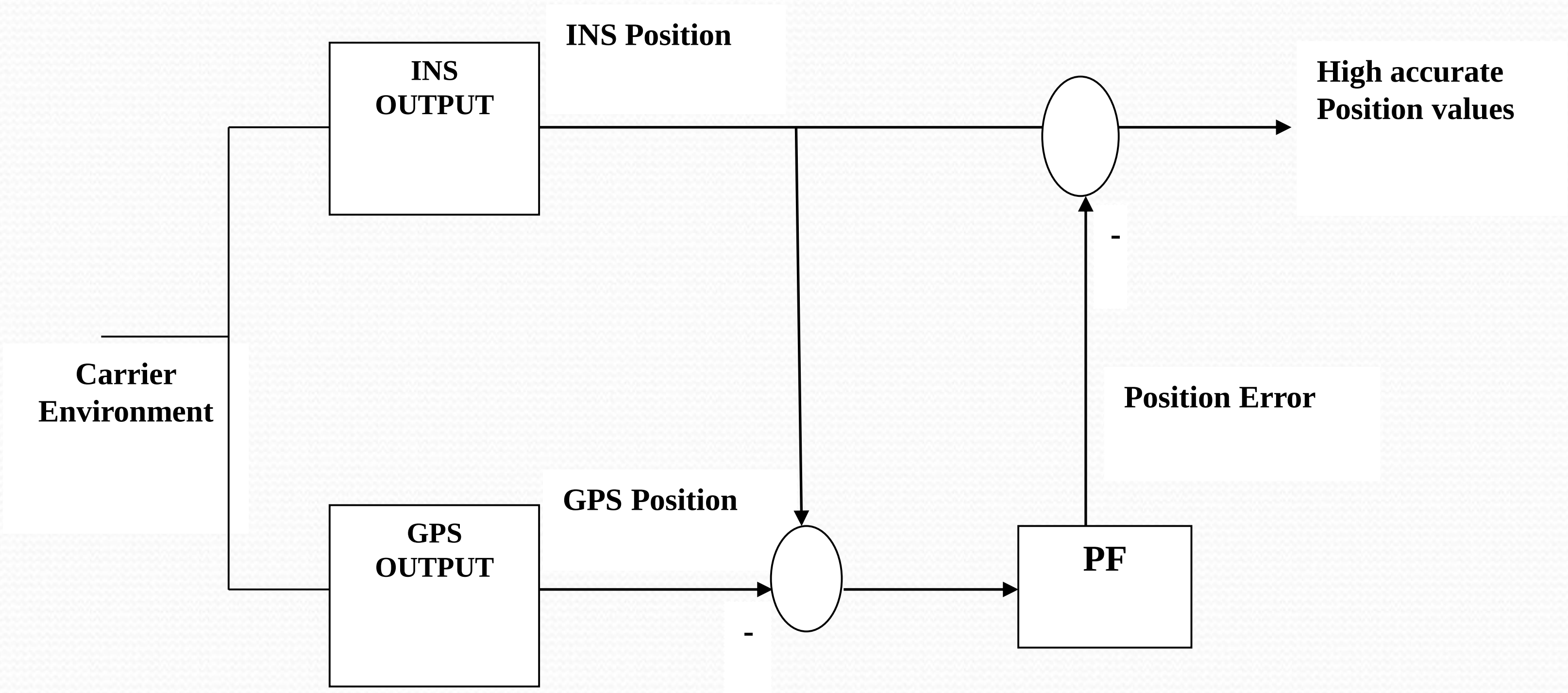
Disadvantages in Navigation systems (GPS, INS)

- Low data rate
- Susceptible to Jamming
- Unbound errors as time increases
- High cost for the quality

Solution technique (GPS/INS)

- For an aircraft or other autonomous vehicles, navigation is most important one. Various systems are used in navigation of aircraft, like inertial navigation systems (INS), global positioning systems (GPS), air-data dead reckoning systems, Radio Navigation Systems (RNS), Doppler heading reference systems, etc.
- Our interest lies in integrating any two systems and to find the position of the object with the help of that new modified system, here this project deals with the integration of INS and the GPS to provide the best possible estimate of the aircraft position in terms of the latitude, longitude and height above the surface of the earth.

Project Concept



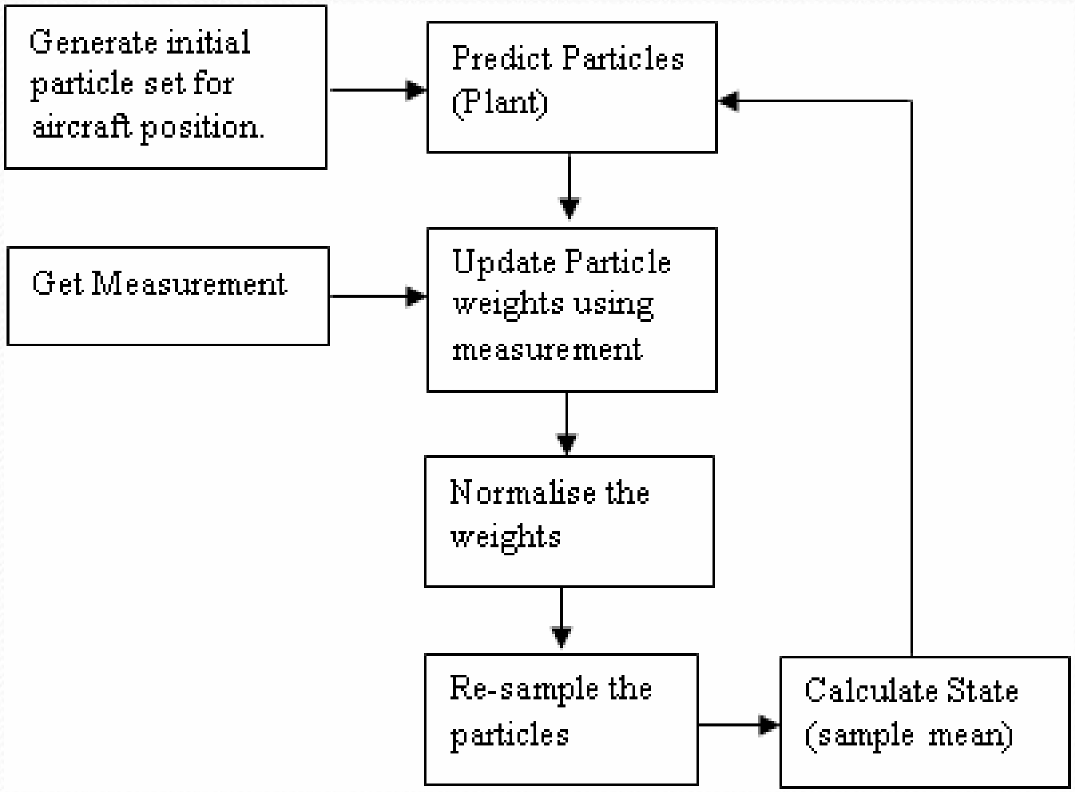
Advantages Of GPS/INS Integration

- It autonomous and does not rely on any other external aids or on visibility conditions and maintains the availability of navigation solution during GPS outages due to interference, jamming, etc.
- Optimal mixing of the INS and the GPS information reduces the effect of GPS errors. Therefore GPS-only accuracy is improved on by the integrated solution.
- The INS provides the full navigation (6 degrees of freedom) state without differentiation. The 6 degrees of freedom refer to 3 translational and 3 rotational degrees of freedom. GPS signals could be used to determine accelerations by differentiation or attitude by techniques.
- The INS provides the navigation solution in real time (i.e. without latency) at rates higher than may be achievable from a GPS receiver.

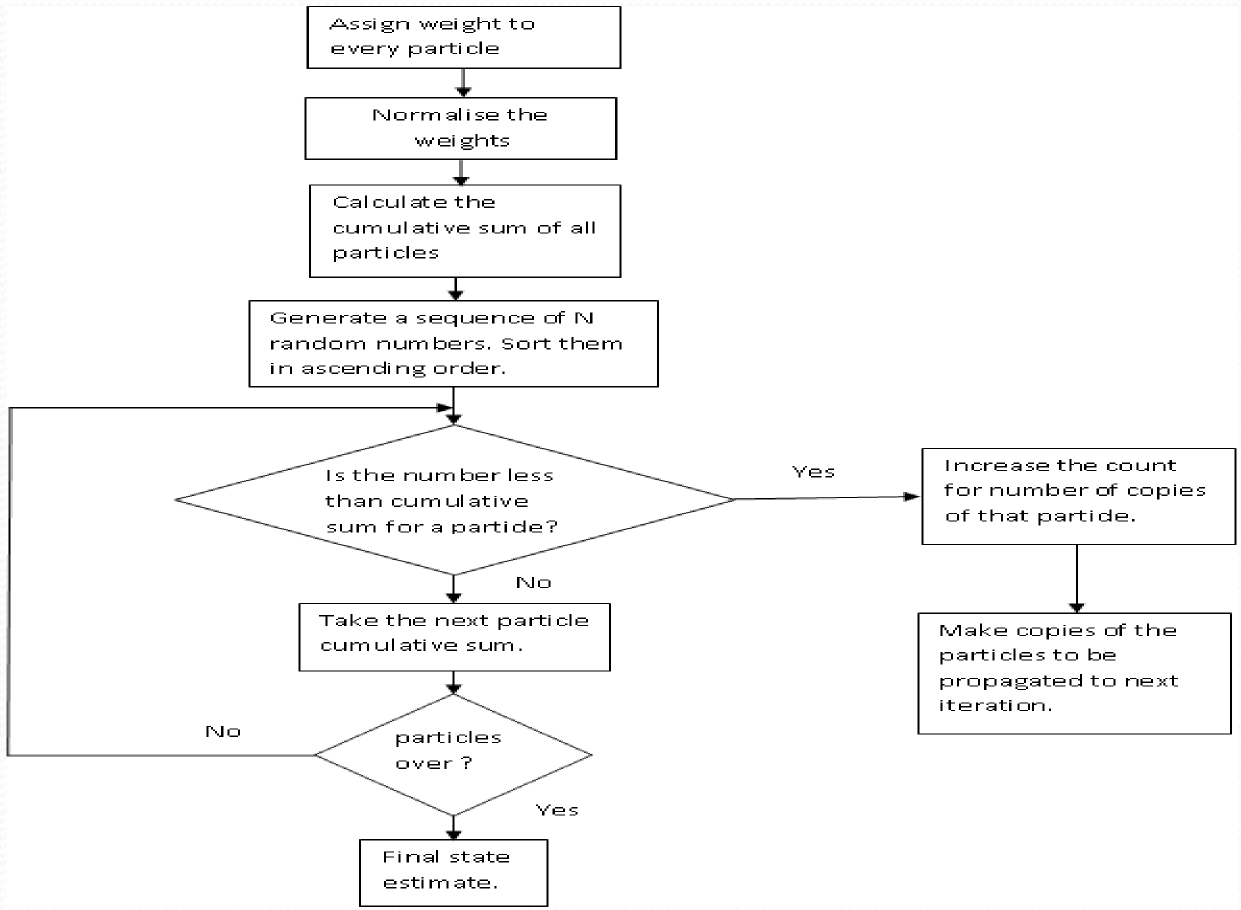
Approach used to solve problem:

- The combination of the two systems, traditionally performed by Kalman filtering (KF), due to the inherent errors of MEMS inertial sensors and the relatively high noise levels associated with their measurements.
- KF has limited capabilities in providing accurate positioning especially when the system is highly non-linear and the noise is Non-Gaussian.
- Particle filtering (PF) was suggested to accommodate for arbitrary inertial sensor characteristics, motion dynamics and noise distributions.
- Particle filters (PFs) are good candidates to solve the estimation problem associated to INS/GPS hybridization, because of the nonlinear measurement equation.
- PFs belong to the class of Sequential Monte Carlo methods, which provide a set of powerful algorithms for handling the nonlinear and non-Gaussian state space

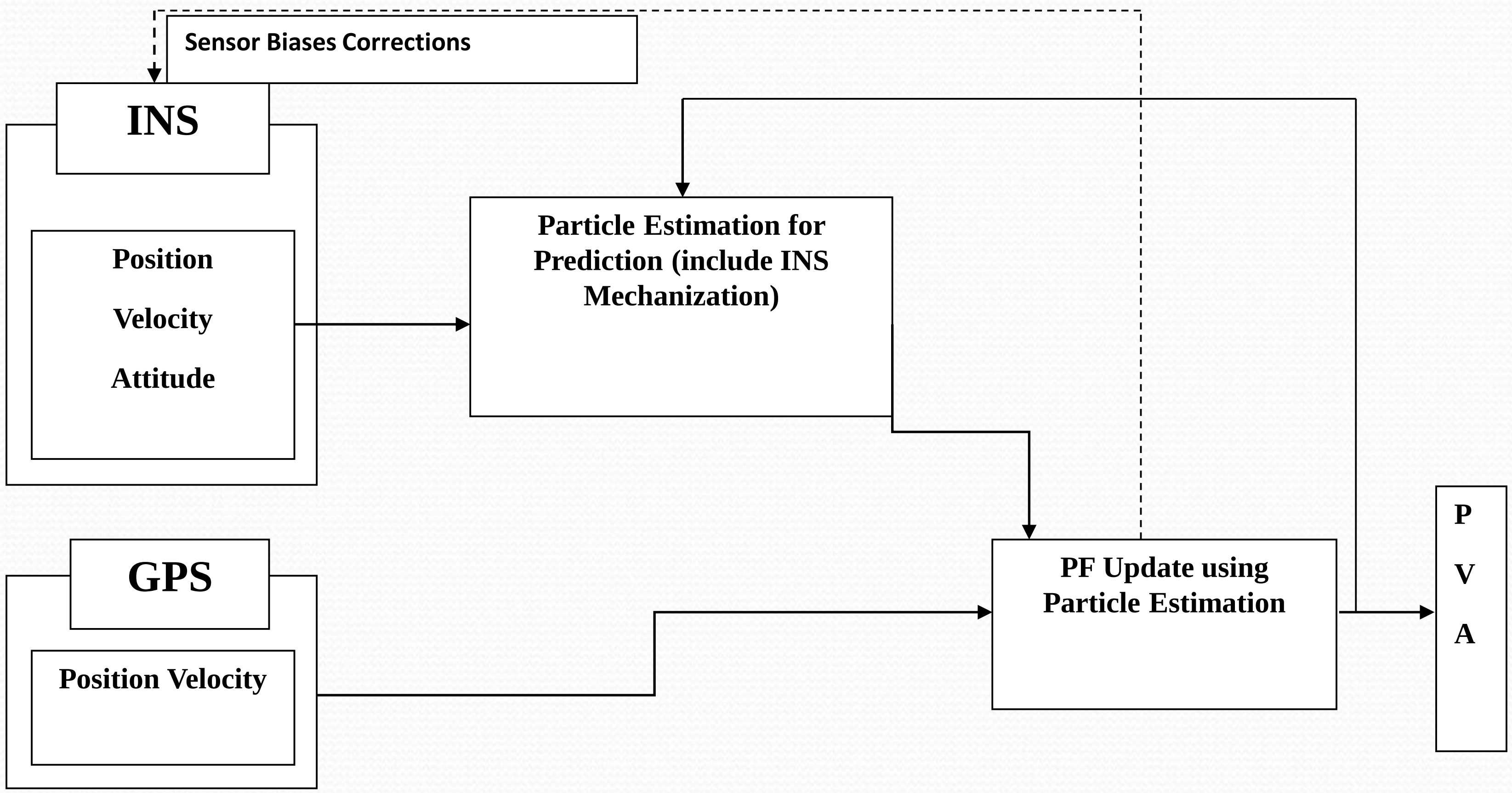
Particle Filter algorithm



‘Select with Replacement’ Resampling algorithm



Block diagram of INS/GPS integration



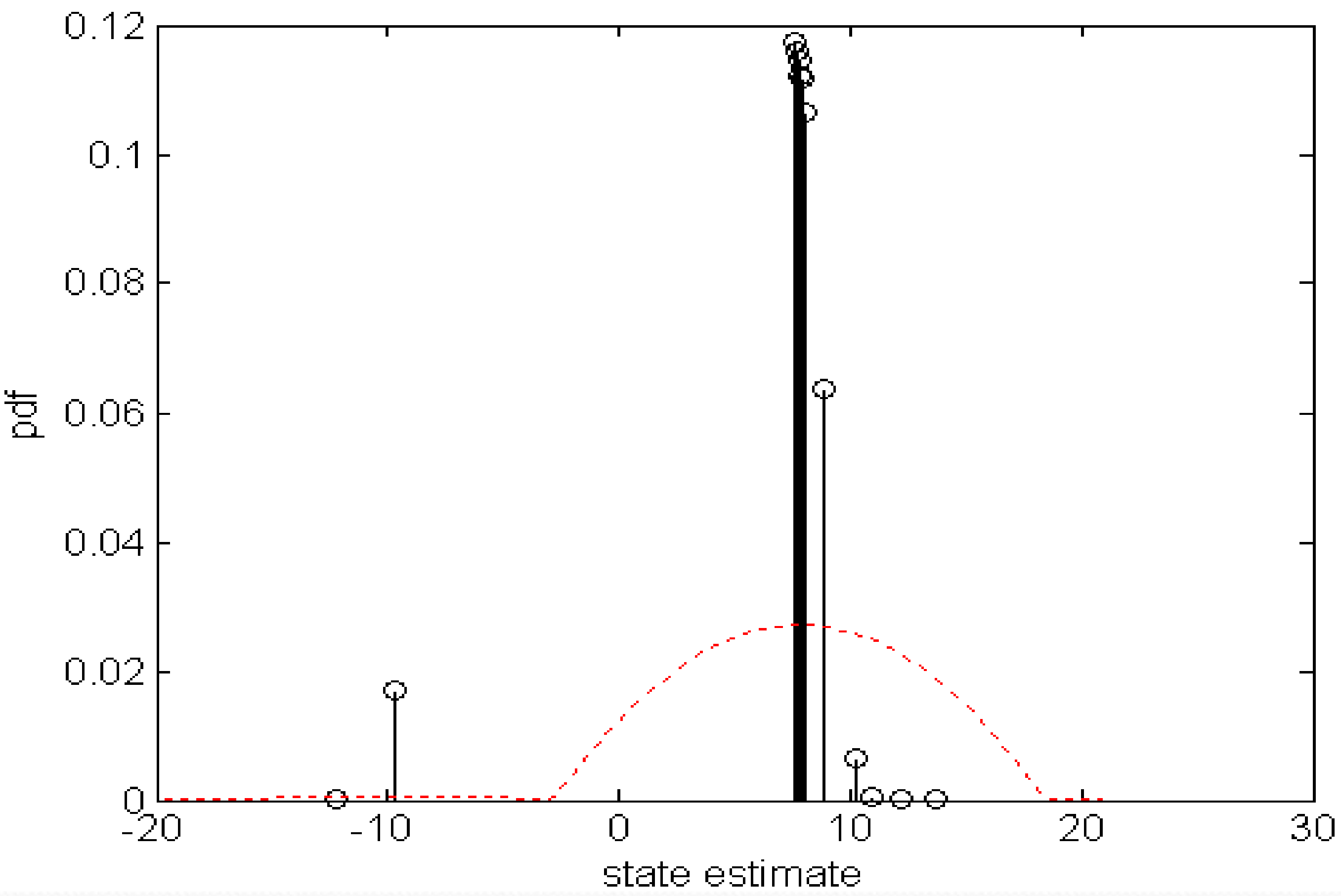
Inputs

In this case technical explanation input of the importance for Particle Filter in the field of moving object tracking and to calculate the RMS Error value, Probability distribute function, Path Prediction are done with help of the below assumption,

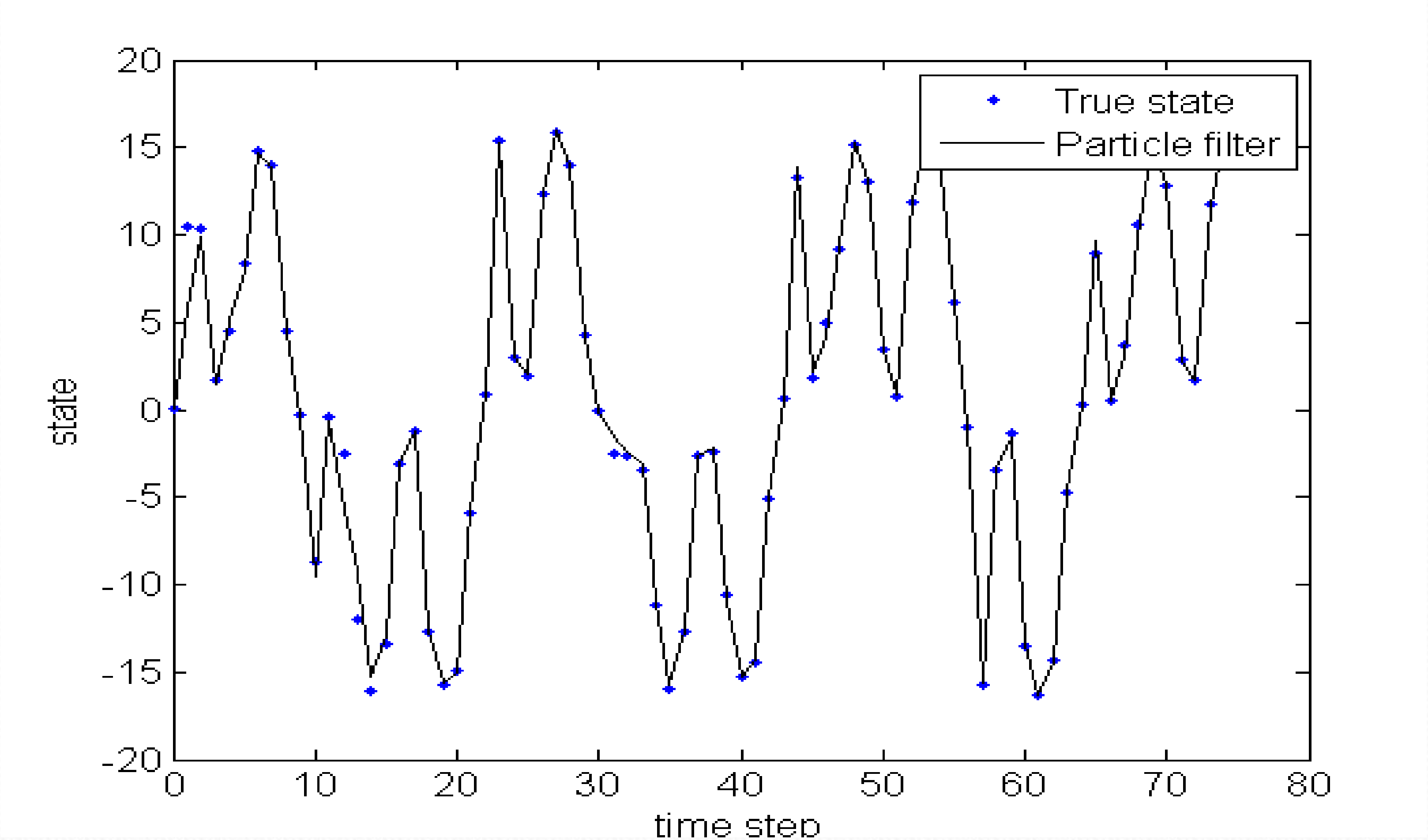
- Initial State [X] = 0.1;
- Velocity [v] = 25 m/s;
- Process Noise Covariance [Q] = 0.001;
- Measurement Noise Covariance [R] = 0.1;
- Simulation Length [t_f] = 75;
- Dimension of the state vector [d] = 0.1;
- Time step value [t] = 75;
- Number of Particles [N] = 100.

Results

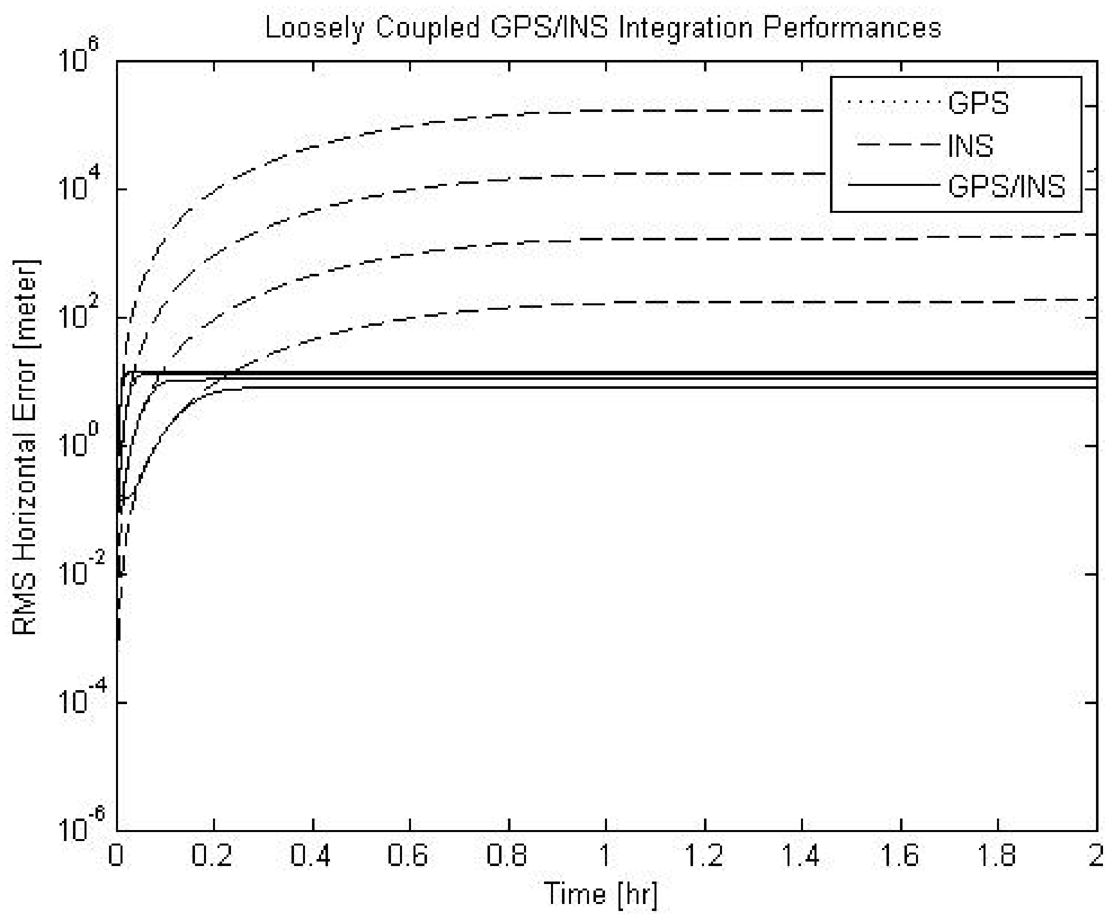
Probability Distribution Function prediction by PF



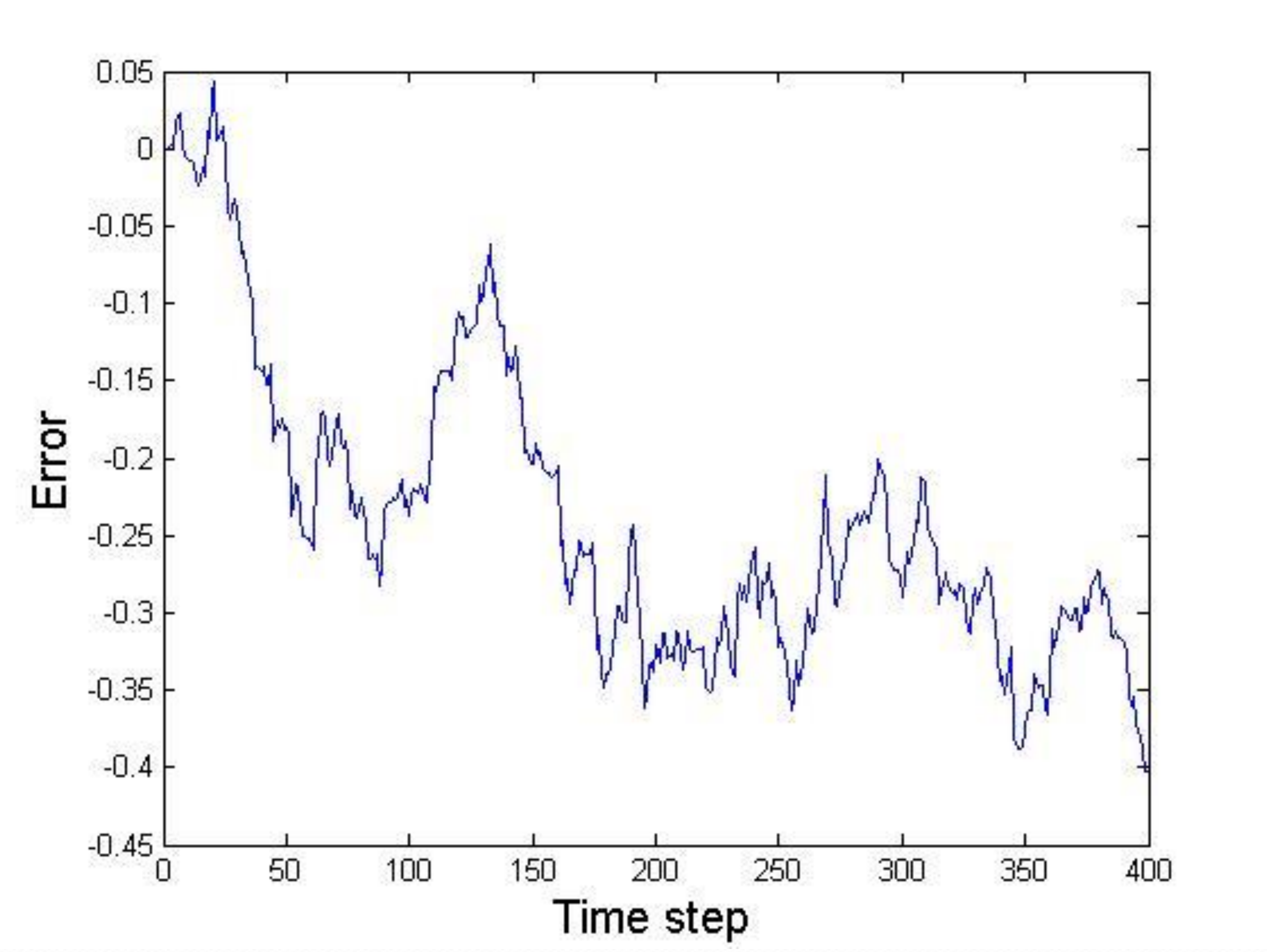
Moving object Position prediction by PF



RMS Horizontal Error Estimation



Error Estimation by Particle Filter



Conclusion

- Providing accurate information for the aircraft is the challenging task. The integration of the aircraft systems is a way to attain more accuracy level of information which is relevant to the aircraft, it is a combination of any two systems, and also it is an efficient way to overcome their individual disadvantages, particle filter is a good approach to integrate any two avionics systems with good solution based on the particle selection method. The basic concept involve in the PF integration approach is to select the particles which is nearby the object, after the first iteration process the less weight particles are eliminated from the prediction technique process. Particle filter approach is independent one, which predicts the exact position of the moving object based probability distribution function of the more weight particles. Low accuracy particles (less weight) are eliminated from the calculation, so the more weight particles give the good solution compare to other integrate approach methods.

REFERENCES

[1] Integration of Inertial Navigation System and Global Positioning System Using Kalman Filtering, Vikas Kumar N, 2009.

[2] Global Positioning System Overview by Peter H. Dana Department of Geography, University of Texas at Austin, 1994.

[3] MEMS INS/GPS Data Fusion using Particle Filter V. Bistrovs, A. Kluga.

[4] A Tutorial on Particle Filtering and Smoothing: Fifteen years later Adam M. Johansen, Arnaud Doucet.

[5] Carpenter, J. Peter Clifford., and Paul Fearnhead, 1999, an improved particle filter for nonlinear problems. IEEE Proceedings Radar, Sonar and Navigation, 146, 2—7.

[6] Arulampalam, Maskell, Gordon, Clapp: A Tutorial on Particle Filters for on-line Non-linear / Non Gaussian Bayesian Tracking, IEEE Transactions on Signal Processing, Vol. 50, 2002

[7] Carmi, A. and Gurfil, P. and Kanevsky, D. 2010,"Methods for sparse signal recovery using Kalman filtering with embedded pseudo-measurement norms and quasi-norms", IEEE Transactions on Signal Processing, 58(4), 2405–2409.

[8] Chui, Charles K.; Chen, Guanrong (2009). Kalman Filtering with Real Time Applications. Springer Series in Information Sciences. 17 (4th Ed.). New York: Springer. pp. 229. ISBN 978-3-540-87848-3.

[9] Dieter Fox, Wolfram Burgard, Frank Dellaert, Sebastian Thrun, “Monte Carlo Localization: Efficient Position Estimation for Mobile Robots”, Proc. 16th National Conference on Artificial Intelligence, AAAI’99, July 1999

[10] C. Johan Masreliez, R D Martin (1977); Robust Bayesian estimation for the linear model and robustifying the Kalman filter (http:/ / ieeexplore. ieee. org/ xpl/ freeabs_all. jsp? arnumber=1101538), IEEE Trans. Automatic Control.

[11] Julier, S.J.; Uhlmann, J.K. (1997). "A new extension of the Kalman filters to nonlinear systems" (http:/ / www. cs. unc. edu/ ~welch/ kalman/ media/ pdf/ Julier1997_SPIE_KF. pdf). Int. Symp. Aerospace/Defense Sensing, Simul. And Controls 3. . Retrieved 2008-05-03.

THANK YOU