Review statement of the official opponent on:
Modern Approaches in Nonlinear Filtering Theory Applied to Original Problems of Aerospace Integrated Navigation Systems with non-Gaussian noises
by Hamza Benzerrouk for a degree of doctor of philosophy in Mathematics
at Saint Petersburg State University

Increasingly, for many application areas, it is becoming important to include elements of nonlinearity and non-Gaussianity in order to model accurately the underlying dynamics of a physical system. Moreover, it is typically crucial to process data on-line as it arrives, both from the point of view of storage costs as well as for rapid adaptation to changing signal characteristics. The results of the candidate Mr.Hamza Benzerrouk are related to nonlinear estimation in Gaussian mixture noise and applied to different original problems of integrated navigation. To start, the candidate has analyzed and compared al previous well known techniques presented as the state of the art in nonlinear estimation community. Extended Kalman filter and its information version are carrying out the preliminary need to use more advanced filtering algorithms due to linearization drawbacks.

The candidate has the moved to more advanced techniques very correlated with statistical linearization and without Jacobian/Hessian computation beginning by the divided difference Kalman Filter DDF at the first order, then at the second order are compared and computed for multiple integrated navigation initialization values. These filters use Stirling polynomial at the first order, then at the second order in order to approximate the nonlinear functions of the system and the observer. Nevertheless, due to some numerical instability, the candidate investigated more advanced and recent algorithms also very closed to DDF idea, they are called SPKF (Sigma Point Kalman Filter including Unscented Transformation based Kalman filter (UKF) and Central Difference Kalman Filter (CDKF). Finally as primary analysis, the Candidate investigated the last developed methods called Cubature Kalman Filter (CKF) based on Cubature rule and Gauss Hermite Kalman Filter (GHKF) based on Gauss Hermite Polynomial coefficients.

The second part of the thesis is devoted to adaptive fading based EKF, SPKF and CFK after a selection of these four categories from the first part. Different adaptation based on adaptive fading factors computation and based also on the innovation matrix has been carried out. Adaptive algorithms AEKF, ASKPF and ACKF have been compared with an interesting impact in the convergence speed of each algorithm and also on the instability of these modern approaches during bad initialization process. So, all filters, EKF and modern approaches are instable due to specific high error in initialization. The candidate solves this problem with the proposal of the novel adaptive forms. In parallel to all benchmarking computation, the candidate offer an approximation of the CRLB based on Extended Kalman Filter equations and specific initialization.

Then, the problem is transformed into non Gaussian estimation problem with nonlinear state space modem for multiple navigation problems. The model of impulsive noise which affects measurements based on Alpha Stable pdf is shown as the best non Gaussian noise and the most realistic present in many

telecommunication problems. The candidate has extended the previous methods and the modern transformed approaches to solve this new problem for integrated navigation based on GNSS corrupted measures and affected by impulsive noises. Multiple simulations have been computed and also experimental work based on original telecommunication and positioning information processing source has been proposed to solve the problem of GNSS jamming and/or spoofing conditions using the model of Gaussian mixture “alpha-stable noise”. The best nonlinear non Gaussian estimator for Gaussian mixture density of “impulsive GNSS noise” has been selected as the Gaussian Mixture adaptive Cubature Kalman Filter GMACKF.

Finally, it has to be mentioned that the Candidate Hamza Benzerrouk has published more than 30 publications with distinguished abstracted papers and also indexed in world wide database, among them: two, indexed in Thomson Reuters Web of Science; five, indexed in Scopus; four, indexed in IEEE Xplore; seven, indexed in Russian ISC (www.elibrary.ru), and eight publications in the sources, indicated in the VAK list of demands (http://vak.ed.gov.ru/87). This demonstrates the importance and the significance of his results and completely satisfies the existing requirements to the thesis of a doctor of philosophy degree.

My evaluation is that the author of the thesis deserves the defense of a degree of doctor of philosophy in Mathematics.

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