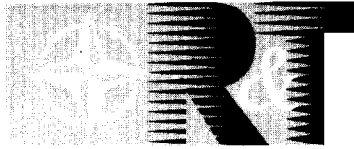


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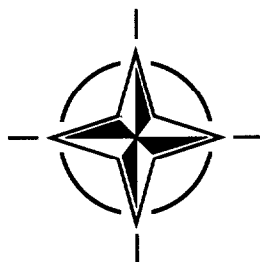
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RTO MEETING PROCEEDINGS 43

6th Saint Petersburg International Conference on Integrated Navigation Systems

(6^{eme} conférence internationale de Saint Petersbourg sur les systèmes
de navigation intégrée)

Papers presented at the 6th Saint Petersburg International Conference organised by the Scientific Council of the Academy of Sciences on the Problems of Motion Control and Navigation, the State Research Center of the Russian Federation — Central Scientific and Research Institute "Elektropribor", and the Systems Concepts and Integration Panel (SCI) of RTO-NATO, held at "Elektropribor", St. Petersburg, Russia on 24-26 May 1999.



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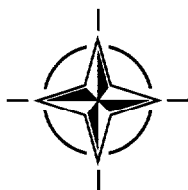
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The Research and Technology Organization (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote cooperative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective coordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also coordinates RTO's cooperation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of initial cooperation.

The total spectrum of R&T activities is covered by 7 Panels, dealing with:

- SAS Studies, Analysis and Simulation
- SCI Systems Concepts and Integration
- SET Sensors and Electronics Technology
- IST Information Systems Technology
- AVT Applied Vehicle Technology
- HFM Human Factors and Medicine
- MSG Modelling and Simulation

These Panels are made up of national representatives as well as generally recognised 'world class' scientists. The Panels also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

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6th Saint Petersburg International Conference on Integrated Navigation Systems

(RTO MP-43)

Executive Summary

This International Conference, which is held annually in Saint Petersburg, brought together this year some 140 engineers and scientists from 17 different countries. It was organised into 4 sessions, covering the main fields involved in integrated navigation systems. The first session, "Inertial Sensors and Systems", emphasised the current importance of laser gyroscopes and the hopes placed in fibre optics gyros. Three interesting papers were presented during the session on the theory and technology of Hemispherical Resonator Gyroscopes (HRG). A triad cluster of accelerometers with common magnet and current source was proposed for inclinometry. The algorithms of dynamics integration in strapdown systems were discussed in two complementary and original presentations. Two generations of redundant strapdown attitude references used in the Alpha International Space Station were described. Theoretical results on fault detection sensitivity in redundant strapdown systems were presented for known and new algorithms.

The second session was entitled "Satellite Navigation". A new technique was described for increasing the accuracy and robustness of GPS receivers by reducing acquisition and tracking thresholds. The comparative performance of a GPS code loop for several suggested new waveforms were analysed but better results were given by the current P(Y) and C/A signals. A presentation was made of the initial results concerning a GPS/GLONASS receiver, tested on SOYUZ in orbital flight, and intended for the station ALPHA. These results show the benefits of using the two constellations for better accuracy and availability as well as the importance of ionospheric errors at negative elevations. An experiment carried out on a GPS receiver in highly elliptical orbital flight demonstrated that it was possible to make measurements at an altitude much greater than that of the GPS constellation. An experimental GPS/GLONASS reference station, used to monitor the integrity of measurements with detection and correction of errors, was described.

The third session, "SatNav/INS Technology", proposed a brief review of existing navigation systems, with emphasis on the exceptional complementarity between inertial and satellite navigations and the benefit of their integration. Some interesting results were presented on the use of an INS for terrestrial geodesy and in-flight gravimetry. A low cost, integrated inertia/DGPS system, in development for flight testing, was described. Simulation results were presented using real flight data. Flight test on an agile aircraft of a GPS receiver in differential mode were commented on. A low cost inertia/GPS/GLONASS preliminary project for civil aircraft was described. A neural technique was proposed for rugged adaptive monitoring of the integrity of an inertia/satellite navigation/barometric altitude system with Kalman filter.

The fourth and final session was given over to "Integrated Navigation" proper. A non-linear Markovian filter was suggested as a solution to the non-linear problem posed by turns in navigation systems with map matching for land vehicles. An experimental integrated inertia/GPS/altitude correlation system, for low altitude flight and CAT2 landing was described and flight test results presented. Integration uses a bank of Kalman filters for fault detection and post-fault reconfiguration. An original presentation was given on federated filters by analogy with electrical networks. This approach casts an interesting light on the loss of optimality of federated filters. Theoretical results concerning stereoscopic image observation equations for navigation and observation were presented. A preliminary study of an integrated system for supervision of the position of an offshore platform was described, with a comparison made between several types of adaptive Kalman filters used to separate low frequency and high frequency movements.

6^{eme} conférence internationale de Saint Petersburg sur les systèmes de navigation intégrée

(RTO MP-43)

Synthèse

Cette conférence internationale, qui se déroule tous les ans à Saint Pétersbourg, a réuni cette année environ 140 ingénieurs et scientifiques venant de 17 pays. Elle était structurée en quatre sessions qui couvraient les principaux domaines concernés par les systèmes de navigation. La première session, "Senseurs et systèmes inertiels", a rappelé l'importance actuelle des gyroscopes Laser et les espoirs mis dans les gyroscopes à fibre optique. Des travaux intéressants ont été présentés sur la théorie et la technologie des gyroscopes vibrants à résonateur hémisphérique (HRG). Un bloc de trois accéléromètres avec aimant et source de courant communs a été proposé pour l'inclinométrie. Les algorithmes d'intégration de la dynamique dans les systèmes à composants liés ont fait l'objet de deux présentations complémentaires originales. Deux générations de références d'attitude à composants liés redondantes utilisées dans la Station Spatiale Internationale Alpha ont été décrites. Des résultats théoriques sur la sensibilité de la détection des pannes dans les systèmes à composants liés redondants ont été présentés pour des algorithmes classiques et d'autres nouveaux.

La deuxième session était intitulée "Navigation par satellites". Une nouvelle technique a été décrite pour l'augmentation de la précision et de la résistance aux interférences des récepteurs GPS par réduction des seuils d'acquisition et de poursuite. Les performances comparées d'une boucle de code GPS pour plusieurs nouvelles modulations de sous porteuses envisagées ont été analysées et montrent de meilleurs résultats pour la modulation actuelle. Les premiers résultats en vol orbital sur Soyuz d'un récepteur GPS/GLONASS destiné à la station Alpha ont été présentés. Ces résultats montrent qu'avec deux constellations on gagne en précision et en disponibilité et que les erreurs ionosphériques sont importantes aux élévations négatives. Une expérimentation de récepteur GPS en vol orbital fortement elliptique a vérifié la possibilité de mesures à une altitude très supérieure à celle de la constellation GPS. Une station de référence expérimentale GPS/GLONASS a été décrite qui permet de surveiller l'intégrité des mesures avec détection et correction des erreurs.

Au cours de la troisième session, "Technologie de navigation inertielle et par satellites", une revue rapide des avantages et inconvénients des systèmes de navigation existants a été présentée. La complémentarité parfaite de l'inertie et de la navigation par satellite a été rappelée. Des résultats intéressants de système inertiel pour la géodésie terrestre et la gravimétrie en vol ont été présentés. Un système intégré inertie/DGPS à bas prix pour essais en vol, en cours de développement, a été décrit et des résultats de simulation de performance ont été présentés. Des résultats d'essais sur avion très manoeuvrant d'un récepteur GPS en mode différentiel ont été commentés. Un projet préliminaire d'intégration inertie/GPS/GLONASS à bas prix, pour aviation civile, a été décrit. Une technique neuronale a été proposée pour la surveillance robuste et adaptative de l'intégrité d'un système inertie/navigation par satellite/altitude barométrique avec filtre de Kalman.

La quatrième et dernière session était consacrée à la "Navigation intégrée" proprement dite. Un filtre Markovian non linéaire a été proposé pour résoudre le problème non linéaire posé par les virages à la navigation intégrée avec corrélation topographique pour véhicules terrestres. Un système intégré expérimental inertie/GPS/corrélation d'altitude, pour vol basse altitude et atterrissage CAT 2, a été décrit et des résultats d'essais en vol ont été présentés. L'intégration utilise une banque de filtres de Kalman pour la détection de panne et la reconfiguration après panne. Une présentation originale de la technique des filtres fédérés a été faite par analogie avec les réseaux électriques. Cette approche apporte un éclairage intéressant sur la perte d'optimalité des filtres fédérés. Des résultats théoriques ont été présentés sur les équations d'observations d'images stéréoscopiques utilisables par des systèmes de navigation intégrée. Une étude préliminaire de système intégré pour la supervision de la position d'une plate-forme de forage a été décrite avec comparaison de plusieurs types de filtres de Kalman adaptatifs utilisés pour séparer les mouvements basse fréquence et haute fréquence.

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Preface

The Saint Petersburg International Conferences on Integrated Navigation Systems, which has been held annually since 1994, has become a very significant international scientific event in the field of navigation, guidance and control. This conference is distinguished among international conferences and symposiums on navigation as it provides the opportunity for scientists and engineers to meet, who for many decades had been separated from each other by the constraints of the Cold War. Because of the economic considerations of Russian participants, it has been found efficient to hold the conference within the territory of Russia. Holding the conference in Russia is also rather convenient for the citizens of other countries within the Commonwealth of Independent States (CIS).

Experience of the last decade indicated St. Petersburg to be the optimal place in Russia for the conference site. Traditions initiated by the emperor Peter the Great, when he founded the city as a “window to Europe”, are still preserved. He also founded, 275 years ago, the Saint Petersburg Academy of Sciences (now the Russian Academy of Sciences). Among the most important problems set before it were research challenges in the field of navigation. Well known to the scientists all over the world were members of the Russian academy; from the great mathematician and mechanician of the XVIII century academician Leonard Euler to the patriarch of modern Russian gyroscopy, academician Alexander Yu. Ishlinsky.

Continuing this tradition, the Scientific Council on the Problems of Motion Control and Navigation of the Russian Academy of Sciences established the conference and assigned responsibility for it to the Saint Petersburg section of the Council. The section works at the institute “Elektropribor”, which considers it an honor to conduct and ensure the conference’s success.

The previous five conferences drew 120-130 participants representing many leading firms and universities from 12 countries. The presented papers were mainly devoted to the following problems:

- gyro sensors;
- inertial navigation systems;
- satellite navigation systems;
- integrated navigation systems GPS/INS.

This same set of topics was considered at the 6th Conference. However, there were some important differences. The Research and Technology Organization of NATO participated in the organization of the 6th Conference. The RTO has some experience in holding scientific events in Russia. Specifically the Lecture Series “System Implications and Innovative Application of Satellite Navigation” was held in St. Petersburg in 1996 with great success. The host organization accepted the RTO conference standards for the format, providing only the plenary sessions.

The extended Program Committee consisted of the scientists from France, Italy, Russia, Turkey, the UK, the USA which examined about 60 paper abstracts. The conference format provided for presentation of no more than 27 papers, so the competition was very serious. The final program includes 25 papers presented by 61 authors working for 28 organizations from 9 countries. The papers were divided into the following subjects:

- gyro sensors - 7 papers;
- gyro systems - 2 papers;
- satellite navigation - 5 papers;
- integrated satellite navigation systems - 6 papers;
- integrated navigation systems - 5 papers.

The papers presented at the conference reflected the principal trends in modern navigation development.

Any scientific conference offers several opportunities for the exchange of technical information. The primary means is via the presentations and content of papers; in this respect the conference had a wealth of valuable technical information. Personal contact with the colleagues from the other organizations and other countries is another very important aspect. Each of the 140 participants representing 70 organizations from 17 countries participated had a excellent opportunity for face to face technical interchange during the plenary sessions and the cultural events.

The number of the conference participants was about evenly divided between Russian and foreign attendees. There was a full representation of the leading scientific organizations and leading scientists of Russia (27 organizations from 6 cities: St. Petersburg, Moscow, Yekaterinburg, Perm, Miass, Orenburg). This was the first conference using simultaneous interpretation in both Russian and English, which gave an opportunity to every specialist from Russia and other CIS countries, as well as those who did not have a command of the Russian language, to participate fully in the conference.

Great contribution was made by the scientists from the USA, France, Germany and Ukraine who participated in our conferences from the very beginning. It should be emphasized that we have never seen at the conferences such a remarkable representation of the leading firms and universities from Germany. In addition to these countries the conference attracted many new participants from Bulgaria, Canada, Holland, Hungary, Iran, Italy, Poland, Romania, South Africa, Spain, Turkey and the United Kingdom.

On the whole, this conference came up the participants’ expectations and its experience will be used when preparing the 7th Conference in 2000. New scientific and technical results contained in the papers presented at the conference, show that the integrated systems development is the most important trend for development of navigation technology both today and for the foreseeable future.

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14. Abstract	The meeting proceedings from this 6th International Conference contains the Technical Evaluation Report and 25 papers presented by 61 authors working for 28 organizations from 9 countries. This Symposium on Integrated Navigation Systems was held in St. Petersburg, Russia on 24 to 26 May 1999. It was jointly organized by the Central Scientific and Research Institute "ELEKTROPRIBOR" and the Systems Concepts and Integration Panel of the Research and Technology Organization of NATO. The papers presented covered the following headings: • Inertial Gyro Sensors and Navigation Systems • Satellite Navigation and Navigation Systems • Integrated Satellite Navigation Systems and Navigation Systems • Satellite Navigation and Inertial Navigation Systems Technology																								



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