AN OBJECT-ORIENTED MODULAR TECHNOLOGY FOR THE CREATION OF INTEGRATED NAVIGATION SYSTEMS *

A. Chernodarov[1], A. Patrikeev[2]
NaukaSoft Experimental Laboratory, Ltd., 6A, 8 March 4th St., 125167, Moscow, Russia,
Tel/Fax: +7 499 5580049, e-mail: chernod@mail.ru

Yu. Korkishko[3], V. Fedorov[4]
"OPTOLINK" RPC, Ltd., 6A, Bldg 2, Sosnovaya Alleya, 124489, Zelenograd, Moscow, Russia,
Tel: +7 495 6631760, Fax: +7 495 6631761, e-mail: opto@optolink.ru

Abstract

Keywords: integrated navigation systems, modular avionics, object-oriented technology

In this paper, our experience in the employment of an object-oriented modular technology when creating integrated navigation systems is generalized. Typical configuration schemes of hardware and math-based software for strapdown inertial satellite navigation systems having modular architecture are considered. The results of natural condition tests are analyzed.

The evolution of airborne equipment (AE) is characterized by the development and introduction of integrated modular avionics (IMA) [1]. The central IMA idea presupposes AE construction on the basis of unified hardware-and-software modules. The expediency of IMA application is connected with more rigid requirements that are imposed upon the AE reliability and also with the necessity of improving its weight-and-size figures, its operational characteristics, and its repair characteristics. The implementation of such a technology permits one to create navigation systems which can be made to order, in conformity with the requirements of a specific object.

The purpose of this paper is to justify and to implement, in practice, IMA principles in integrated navigation systems (NSs).

Subjects for study have been strapdown inertial satellite navigation systems (SISNSs), which are built around quantum-optic gyros and hemispherical resonator gyros (HRGs). Special features of SISNS construction enable one to effectively map their software/hardware onto the IMA architecture and to increase their information reliability on this basis.

In the designs under consideration, the IMA principles have been implemented on a basis of the object-oriented modular technology intended for construction of hardware and math-based software. The major elements of such a technology are as follows: unification and standardization of processor modules and the modules of math-based software; adaptation of interface modules to an object; buffering of data flows and paralleling of computations; synchronization of data processing procedures in the modules; multilevel RISC organization of the computational process; data exchange among the modules via the system bus; increasing the degree of computational-process homogeneity on a basis of minimizing the number of tests and conditions; making the procedures of primary and second signal processing agree with the computational-core capability; structuring of algorithms with the aim of their mapping onto the unified modules of math-based software; an open architecture which permits 1) computational resources to be extended and 2) integrated NSs to be updated and reconfigured to an object.

The object-oriented modular technology has been approved by the personnel of the "NaukaSoft" Experimental Laboratory in the process of developing and testing a number of SISNSs, among which are the following systems:

- the SINS-500 [2], SINS-501 and SINS-1000 [3] systems (in conjunction with the "OPTOLINK" RPC, Ltd., Zelenograd), which are built around fiber-optic gyros (FOGs);
- the SINS-05-104 system (in conjunction with the "Avionika" Concern, Open JSC, Moscow), which is based on a three-component laser monoblock [4];
- a distributed micronavigation system for a synthetic-aperture radar (in conjunction with the Research Institute for Radioelectronic Complexes, St. Petersburg), which is built around FOGs [5];
- the SINS-HRG system (in conjunction with the "Medicon" RPE, Miass), which is based on HRGs.

---

[1] Dr. Tech. Sc., Ass. Prof., Ch. Res. Wkr.
[2] Cand. Tech. Sc., Head of Department, Deputy Chief Designer.
[3] Dr.Phys & Math. Sc., Professor, General Director.
[4] Dr.Phys & Math. Sc., Professor, Technical Director.

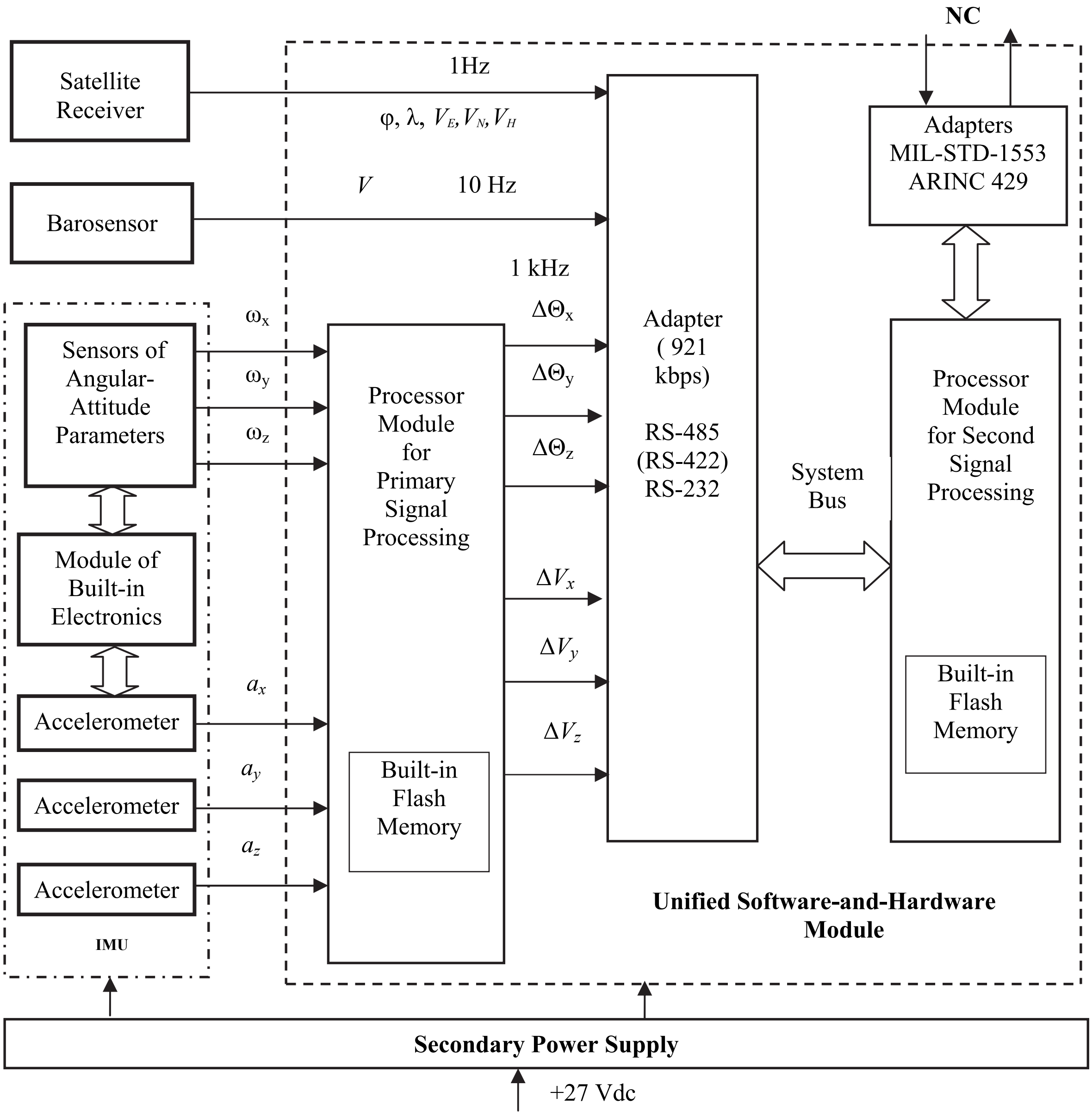

Fig. 1. Typical hardware configuration scheme for SISNSs of modular design

In a generalized form, the hardware of SISNSs of modular design can be represented by a configuration scheme shown in Fig. 1, where φ, λ are the geographical latitude and longitude, respectively, of the position of an aircraft (A/C); V_E, V_N, V_H are components of the vector of A/C path velocity along the axes of the geographical moving frame; IMU is an inertial measurement unite; $\Delta\Theta_x, \Delta\Theta_y, \Delta\Theta_z$ are increments of the rotation angles of an IMU based on ring laser gyros (RLGs) in the inertial space. When the IMU is built around FOGs, components of the vector of A/C absolute angular rotational velocity along the IMU axes are output signals; $\Delta V_x, \Delta V_y, \Delta V_z$ are increments of the components of the vector of apparent velocity along the IMU axes; V is the true airspeed; NC is a navigation complex. When analog accelerometers are employed, components of the vector of apparent acceleration along the IMU axes are IMU output signals. Nonstandard components are marked out by thick lines, and components having standard dimension-types are marked out by thin lines. The IMU is regarded as a fault-tolerant module with the given number of sensors in the structure of a reconfigurable SISNS.

Figure 2 presents a typical configuration scheme of the math-based software (MBS) for SISNSs having modular design, where the following is shown: FNP are flight-and-navigation parameters; SINS is a strapdown inertial NS; SEI are sensors of information that is external with respect to the SINS; ARF is an adaptive robust estimation filter[6]; modules that are marked out by thick lines are developed for specific SINS sensors; unified modules that make up MBS core are marked out by thin lines.

The MBS is supported by the Linux modular real-time operating system and it is adaptable to SINSs built around sensors that vary in the principle of operation. In the above MBS, provision is made for including a digital terrain map. The employment of the object-oriented design technology has permitted us to carry out the walk-through development of SISNS subsystems, namely: from algorithmic support to the math-based software, from mathematical simulation to the natural experiment.

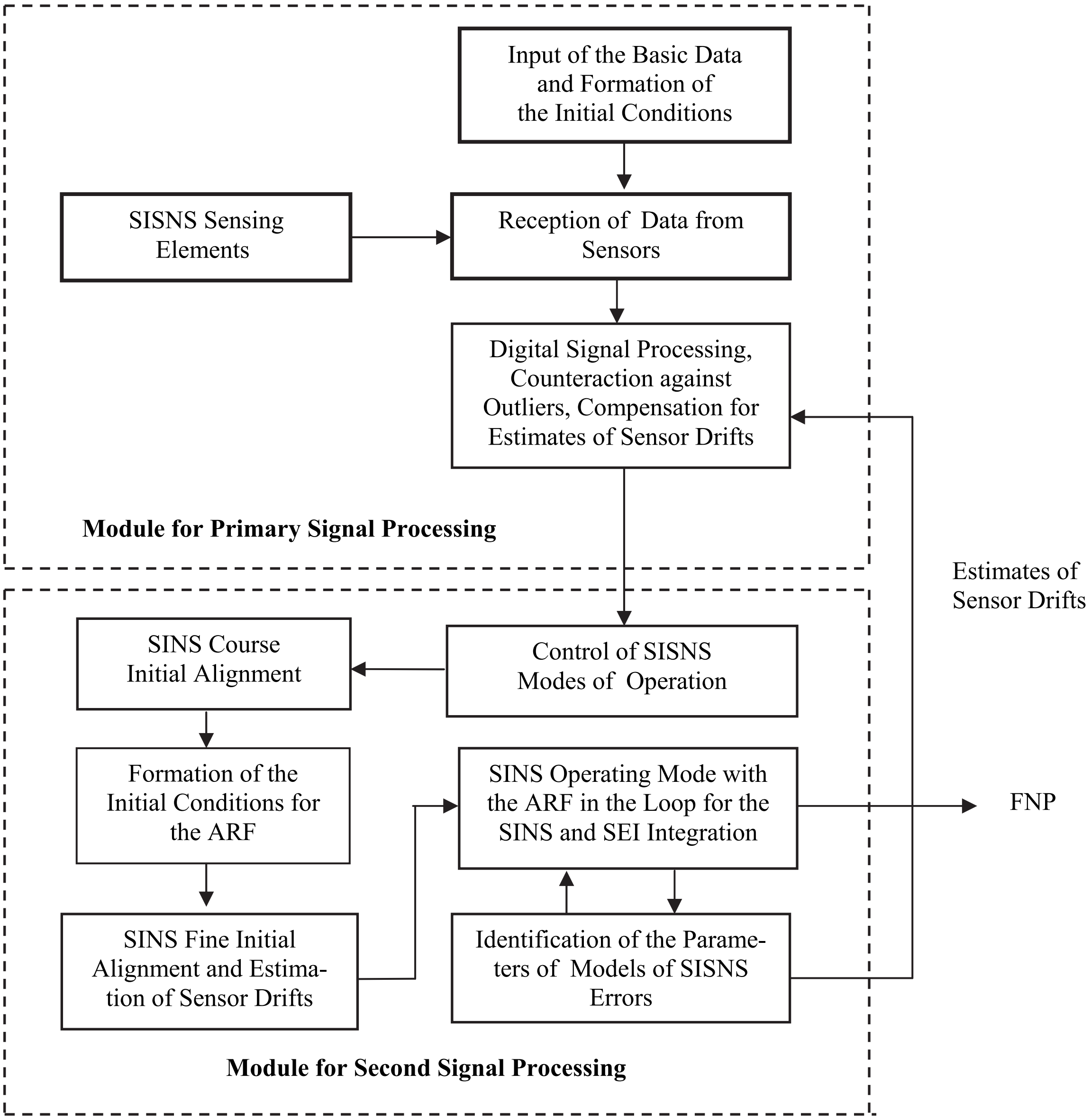

Fig. 2. Typical configuration scheme of the MBS for SISNSs of modular design

Approaches to the unified signal processing, which have been implemented in SISNSs were aimed at solving the following problems: 1) at the stage of primary processing of sensor signals: digital filtering, localization of and counteraction against outliers by the use of the χ^2 / ϑ^2 combined goodness-of-fit test [6]; 2) at the stage of second signal processing: distributed integration of SINS kinematic equations, estimation of and compensation for sensor drifts from observations that are external with respect to the SINS, identification both of the parameters of models of sensor errors and of the parameters of the ARF.

The employment of the object-oriented modular technology has made it possible to do the following: to unify the hardware and math-based software for SISNSs based on sensors that differ in the operating principle; to reduce the time of creation and step-by-step updating of SISNSs; to raise the frequency of updating the primary navigation information from 200 Hz to 1 kHz; to increase the order of the model of SINS errors from 9 to 24 parameters and to reduce, on this basis, the time of SINS initial alignment by half; to raise SINS accuracy characteristics in the autonomous mode no less than by the factor 4. This is corroborated by the results of testing the SINS-1000 system built around FOGs. Figure 3 shows the horizontal path of motion of the testing laboratory when this path has been reckoned from SINS data. When we returned to the position of the initial alignment, having regard to the compensation for estimates of sensor residual drifts, the SINS circular error was no more than 500m (see Fig. 4).

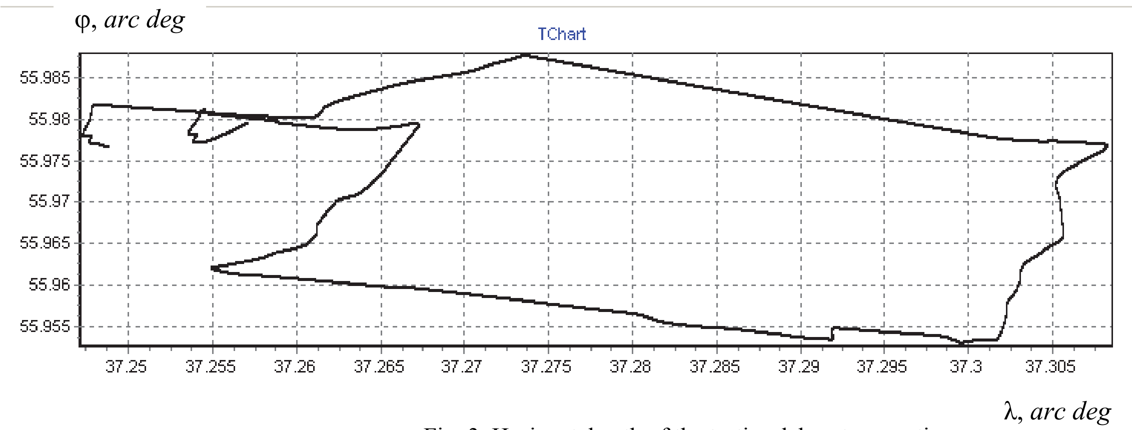

Fig. 3. Horizontal path of the testing-laboratory motion

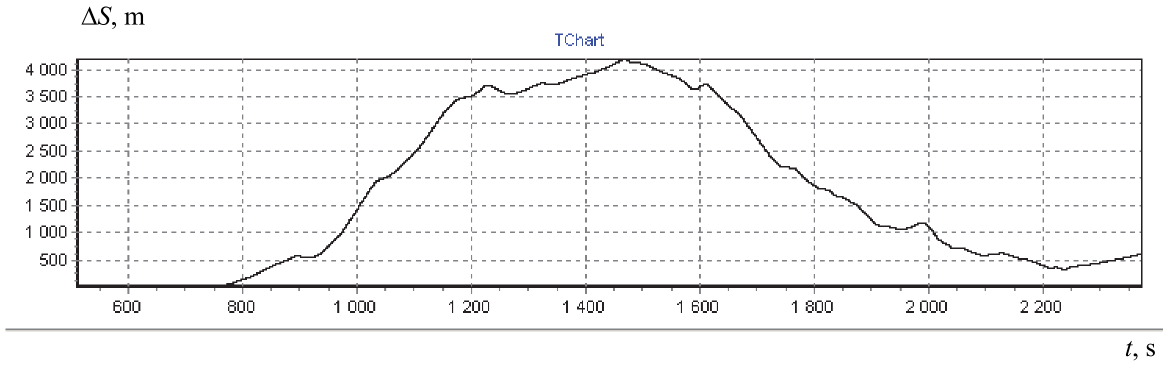

Fig. 4. Circular deviation of the SINS-1000 system from the position of the initial alignment

The research is supported by the grant of the Russian Foundation for Basic Research 14-08-0117a.

References

1. **Fedosov, E.A**., Advanced Complexes of Airborne Equipment of Aircraft on the Basis of Integrated Modular Avionics of the Second Generation, All-Russian Scientific-Technical Conference "Navigation, Guidance, and Aircraft Control", Moscow, Nauchtekhlitizdat, 2012, pp. 14 -17.
2. **Chernodarov, A.V., Patrikeev, A.P., Korkishko, Yu.N., Fedorov, V.A., and Perelyaev, S.E.,** Software Seminatural Development for FOG Inertial Satellite Navigation System SINS-500, Gyroscopy and Navigation, 2010, no 4, pp. 330 - 340.
3. **Korkishko, Yu.N., Fedorov, V.A., Patrikeev, A.P., Chernodarov A.V., and Perelyaev, S.E.,** An Object-Oriented Technology for the Integration of Navigation Sensors and its Implementation in the SINS-1000 Strapdown Inertial System Built Around Fiber-Optic-Gyros, 16th St. Petersburg International Conference on Integrated Navigation Systems, St. Petersburg , CSRI Electropribor, 2009, pp. 18 - 27.
4. **Chernodarov, A.V., Perelyaev, S.E., and Patrikeev, A.P.,** Flight Development of the Math-Based Soft-Ware for an Inertial Satellite Navigation System Built Around a Three-Axis Monolithic Laser Unit, 20th St. Petersburg International Conference on Integrated Navigation Systems, St. Petersburg, CSRI Electropribor, 2013, pp. 216 - 219.
5. **Bilik, V.V., and Kovregin, V.N., Chernodarov, A.V., and Patrikeev, A.P.,** A Spatially Distributed Micronavigation Sysstem for a Synthetic – Aperture Radar, 18th St. Petersburg International Conference on Integrated Navigation Systems, St. Petersburg , CSRI Electropribor, 2009, pp. 207 - 215.
6. **Kolodezny, L.P., Chernodarov, A.V.,** Reliability and Engineering Diagnostics [in Russian], Moscow, Zhukovsky and Gagarin Air Force Academy, 2010.