THE INFORMATION-ANALYTICAL SYSTEM FOR DIAGNOSTICS OF AIRCRAFT NAVIGATION UNITS

Ilya Prokoshev, Vyacheslav Suminov

Abstract: The operation of technical processes requires increasingly advanced supervision and fault diagnostics to improve reliability and safety. This paper gives an introduction to the field of fault detection and diagnostics and has short methods classification. Growth of complexity and functional importance of inertial navigation systems leads to high losses at the equipment refusals. The paper is devoted to the INS diagnostics system development, allowing identifying the cause of malfunction. The practical realization of this system concerns a software package, performing a set of multidimensional information analysis. The project consists of three parts: subsystem for analyzing, subsystem for data collection and universal interface for open architecture realization. For a diagnostics improving in small analyzing samples new approaches based on pattern recognition algorithms voting and taking into account correlations between target and input parameters will be applied. The system now is at the development stage.

Keywords: technical diagnostics, fault detection, inertial navigation system, navigation, aircraft units, supervision, monitoring, fault diagnostics, diagnostic reasoning

ACM Classification Keywords: B.8.1 Reliability, Testing, and Fault-Tolerance; J.2 Computer Applications: Physical Sciences and Engineering: Aerospace

Introduction

Improvements in the reliability and safety of technical systems require advanced methods of supervision, including fault detection and fault diagnostics. Many modern systems are very complex and it is difficult to manually adjust control functions and settings when departures arise between a system and a system model. It is also difficult to respond manually to the onset of faults before they develop into huge failures. This group seeks to develop and apply effective methods to cope with these problems.

In the recent years, activities in the navigation field have been boosting. There are and will be more and more areas where navigation becomes an important part of a system solution. So far navigation systems have been of major importance for aircraft, missiles, ships, etc. In aircraft systems, the accurate navigation plays an important role. Typical tools today for navigation are inertial navigation systems (INS), which essentially means that acceleration and angular velocity measurements are integrated to a position.

The INS is based on the principle that a Schuler-tuned platform will remain aligned to the local vertical regardless of the movement of the vessel carrying it. Three mutually perpendicular sensitive gyros are gimbaled to create a stable platform on which is mounted a two-axis accelerometer.

Nowadays INS development is aimed to achieving navigation parameters in an unlimited range of mobile object orientation corners with the subsequent information digital output to the consumer.

Growth of complexity and functional importance of INS leads to high losses at refusals of the equipment. Development of INS diagnostic and prediction information systems is necessary for prevention of occurrence of refusals and the malfunctions leading to high breakdown of aircraft units and increase of expenses for its major overhaul.

In the most cases the records analysis and data processing of the flight information is performed by operator. That is a human based approach; it is aimed to compare the received data with the set ranges of control parameters to make a decision about system technical condition. The solution of diagnostic task is made practically in a visual form and not takes into account interrelation between parameters. Thus, in this case it's necessary to use the complex solution that considers the general structure of the output data.

Problem Statement

As one of the main research object, the integrated inertial navigation system INS-2000 developed by Ramensky Instrument Engineering Plant is considered. The development of The INS-2000 system provides definition and delivery of navigating parameters and is intended for new and modern helicopters and planes. The INS-2000 is made as a mono-block consisting of gyrostabilized platform on base of dynamically-tuned gyros, service electronics and computer interface units.

The technical acts analysis research of INS-2000 refusals has shown enough plenty of faults of a product at various production stages (adjustment, trial, refining and so forth).

The experience of inertial navigation systems development shows that the intrinsic error of these units defining their functional reliability is the random parametric drift called by dynamically-tuned gyros, interface electronic cards, control cards and couplers. The given task solution is impossible without more profound analysis of occurrence reasons and influence of design and technological parameters on values and stability of random drift.

According to stated the research of the factors' influential in involuntary drift of system and creation of the effective diagnostic technique permitting to estimate current technical condition of INS-2000 is the actual task.

The main work purpose is development of algorithms for the INS diagnostics, permitting to reveal reasons of refusals and faults on the data on the basis of structural adapting and identification of parameters of navigation model.

The offered technology of solution of the task includes the following stages:

- the structural adapting of the INS equations in view of the detected disorder and model defect in parametric type;
- retrospective estimation of the extended state INS error vector, originating because of defects;
- correlation processing of the received estimations of errors;
- solution of the algebraic equations on parameters, approximating correlation function and included in diagnostic model;
- INS state handle in view of the current state of meters, namely - retargeting of parameters of models of errors and restoring of working capacity of INS.

Given technology will allow solving the following problems:

- optimization malfunctions search strategy;
- separate system units technical condition estimation.

According to the purpose of work, it is possible to solve the following research problems:

- the statistical analysis of INS units parameters accuracy not meeting the quality specifications requirements
- refusals database development of INS interconnected units not past a trial stages;
- open architecture development for processing information from various data sources;
- development realizing automated information capturing for its subsequent processing.

The decision-making task in diagnostic problems starts with observation of behaviour recognized as a deviation from that which is expected or desirable and establishes some hypothesis about the cause of the malfunction. In recent years, two methodologies have been widely applied to approximate the nonlinear assignment rule from the set of observations to the hypothesis: Rule-based systems, characterized by linguistic, logical and cognitively oriented schemes, versus the paradigm of artificial neural networks, characterized by the numeric, associative and adaptive nature.

Fault detection is a key technology in automatic supervision of engineering systems, such as production facilities, machines, airplanes, and appliances. There are a great number of fault detection methods available, ranging from more traditional approaches, such as limit checking, to more advanced model-based methods.

Most model-based methods for fault detection and diagnostics rely on the idea of analytical redundancy that is the comparison of the actual behavior of a system to the behavior predicted on the basis of the mathematical system model. Typical model-based fault detection process consists of two steps: residual generation and residual assessing/classification. Residuals that are the difference between the measurements and the model

predictions are nominally zero, and become non-zero because of faults. Residual assessing is to make a detection decision for the monitored system through evaluating the residuals obtained. The decision making is actually a process of classifying the residuals into one of two classes: normal and fault. Technically, after obtaining residuals, the model-based fault detection becomes a pattern classification problem. Hence, different classification methods can be applied.

It is interesting to observe that almost all of the modern fault detection functions for both unmanned and piloted aircraft are designed by using model-based fault detection methods as described above. This probably contributes to the fact that the model-based fault detection methods have several advantages over the model-free methods, for example, the model-based methods have relatively higher performance and computational straightforwardness, have noise depression capability, and can provide more fault information that can facilitate the subsequent fault isolation and corrections.

Diagnostics Methods

Within the automatic control of technical systems, supervisory functions serve to indicate undesired or unpermitted process states, and to take appropriate actions in order to maintain the operation and to avoid damage or accidents. The following functions can be distinguished:

- (a) *monitoring:* measurable variables are checked with regard to tolerances, and alarms are generated for the operator.
- (b) *automatic protection:* in the case of a dangerous process state, the monitoring function automatically initiates an appropriate counteraction.
- (c) *supervision with fault diagnostics:* based on measured variables, features are calculated, symptoms are generated via change detection, a fault diagnostics is performed and decisions for counteractions are made.

The classical methods (a) and (b) are suitable for the overall supervision of the processes. To set the tolerances, compromises have to be made between the detection size of abnormal deviations and unnecessary alarms because of normal fluctuations of the variables. Most frequently, simple limit value checking is applied, which works especially well if the process operates approximately in a steady state. However, the situation becomes more involved if the process operating point changes rapidly. In the case of closed loops, changes in the process are covered by control actions and cannot be detected from the output signals, as long as the manipulated process inputs remain in the normal range. Therefore, feedback systems hinder the early detection of process faults.

The big advantage of the classical limit-value-based supervision methods is their simplicity and reliability. However, they are only able to react after a relatively large change of a feature, i.e. after either a large sudden fault or a long-lasting gradually increasing fault.

In addition, an in-depth fault diagnostics is usually not possible.

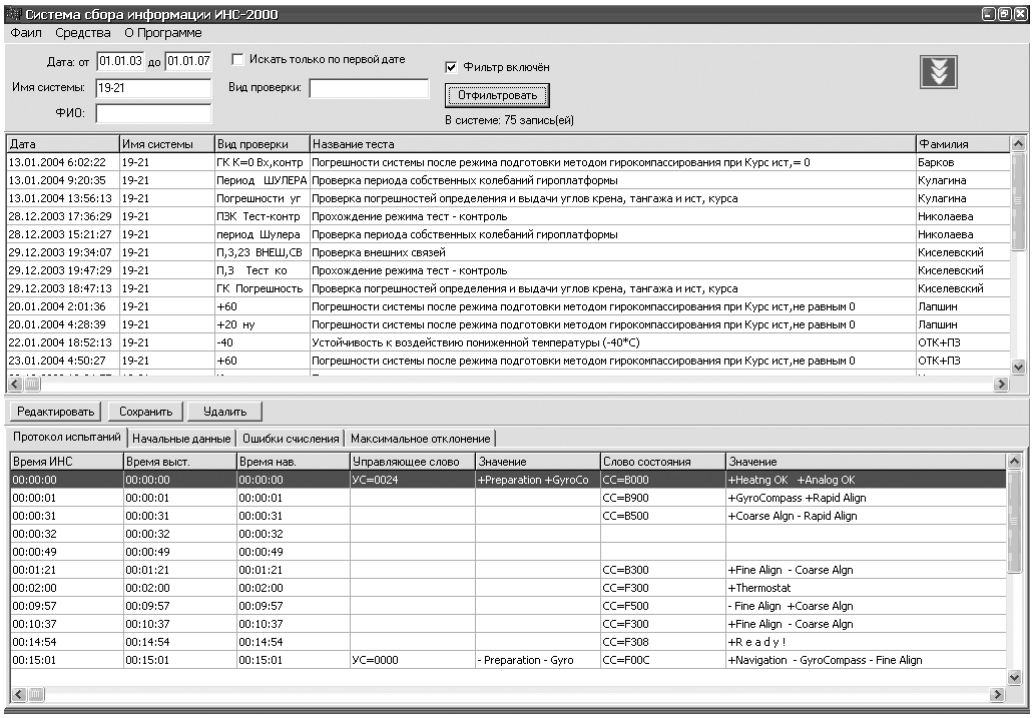
Therefore (c) *advanced methods of supervision and fault diagnostics* are needed, which satisfy the following requirements:

- Early detection of small faults with abrupt or incipient time behaviour,
- Diagnostics of faults in the actuator, process components or sensors.
- Detection of faults in closed loops.
- Supervision of processes in transient states.

The goal for the early detection and diagnostics is to have enough time for counteractions such as other operations, reconfiguration, maintenance or repair. The earlier detection can be achieved by collection more information, especially by using the relationship between the measurable quantities in the form of mathematical models. For fault diagnostics, the knowledge of cause-effect relations has to be used.

INS Monitoring System Developing

The full analysis of various methods has led to expediency of application of complex monitoring systems which use different by the physical nature research methods that, in turn, will allow excluding lacks of one method and use advantages of other methods to realize thus a principle of "redundancy" increasing reliability of INS systems.



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13.01.2004 6:02:22	19-21	ГК К=0 Вх,контр	Погрешности системы после режима подготовки методом гирокомпассирования при Курс ист,= 0	Барков
13.01.2004 9:20:35	19-21	Период ШУЛЕРА	Проверка периода собственных колебаний гироплатформы	Кулагина
13.01.2004 13:56:13	19-21	Погрешности уг	Проверка погрешностей определения и выдачи углов крена, тангажа и ист, курса	Кулагина
28.12.2003 17:36:29	19-21	ПЗК Тест-контр	Прохождение режима тест - контроль	Николаева
28.12.2003 15:21:27	19-21	период Шулера	Проверка периода собственных колебаний гироплатформы	Николаева
29.12.2003 19:34:07	19-21	П,3,23 ВНЕШ,СВ	Проверка внешних связей	Киселевский
29.12.2003 19:47:29	19-21	П,3 Тест ко	Прохождение режима тест - контроль	Киселевский
29.12.2003 18:47:13	19-21	ГК Погрешность	Проверка погрешностей определения и выдачи углов крена, тангажа и ист, курса	Киселевский
20.01.2004 2:01:36	19-21	+60	Погрешности системы после режима подготовки методом гирокомпассирования при Курс ист,не равным 0	Лапшин
20.01.2004 4:28:39	19-21	+20 ну	Погрешности системы после режима подготовки методом гирокомпассирования при Курс ист,не равным 0	Лапшин
22.01.2004 18:52:13	19-21	-40	Устойчивость к воздействию пониженной температуры (-40*С)	ОТК+ПЗ
23.01.2004 4:50:27	19-21	+60	Погрешности системы после режима подготовки методом гирокомпассирования при Курс ист,не равным 0	ОТК+ПЗ

Время ИНС	Время выст.	Время нав.	Управляющее слово	Значение	Слово состояния	Значение
00:00:00	00:00:00	00:00:00	УС=0024	+Preparation +GyroCo	СС=B000	+Heatng OK +Analog OK
00:00:01	00:00:01	00:00:01			СС=B900	+GyroCompass +Rapid Align
00:00:31	00:00:31	00:00:31			СС=B500	+Coarse Align - Rapid Align
00:00:32	00:00:32	00:00:32				
00:00:49	00:00:49	00:00:49				
00:01:21	00:01:21	00:01:21			СС=B300	+Fine Align - Coarse Align
00:02:00	00:02:00	00:02:00			СС=F300	+Thermostat
00:09:57	00:09:57	00:09:57			СС=F500	- Fine Align +Coarse Align
00:10:37	00:10:37	00:10:37			СС=F300	+Fine Align - Coarse Align
00:14:54	00:14:54	00:14:54			СС=F308	+R e a d y !
00:15:01	00:15:01	00:15:01	УС=0000	- Preparation - Gyro	СС=F00C	+Navigation - GyroCompass - Fine Align

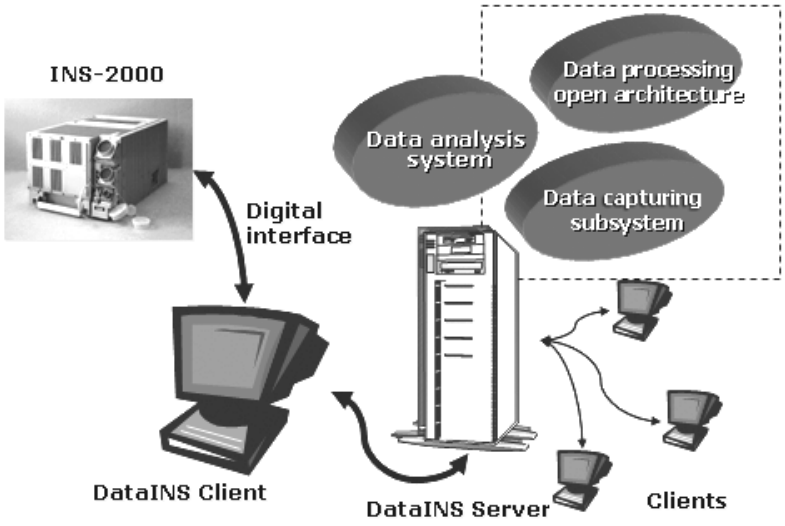
Pic. 1. The screenshot of DataINS system

The improvement of quality of diagnostics and prediction in conditions of small analyzed samples new approaches based on voting of algorithms of recognition and the account of correlations between target and output parameters are developing.

Nowadays, an intellectual system of information capturing and a subsystem of data analysing are developing.

Open architecture of a system allows using different data source based on Microsoft SQL Server, Microsoft Access, Oracle and others. That approach gives a universal model for data analyzing systems.

The general DataINS structure is shown on the following picture.



Pic. 2. DataINS system structure

Conclusion

An overview of the different approaches to fault diagnostics has been given. So far, none of the methods presented solves the remaining task of completeness. Thus, in practical application, principle of "redundancy" increasing reliability of INS systems is able to solve the defined problem. Complex application of quality monitoring and diagnostics methods for fault detection in units and systems is directed to increase the efficiency, validity check, prolongation of system resources working capacity.

For the first part of work the data capturing system is developed. At stage of development, there is an open architecture data processing system, allowing expanding a set of algorithms without system reconstruction.

Sharing a subsystem of capturing information with a subsystem of data analysis will allow eliminating in time the malfunctions both at a level of test of pre-production models, and in operation and perfection of serial samples.

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USING ORG-MASTER FOR KNOWLEDGE BASED ORGANIZATIONAL CHANGE

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Abstract: Enterprises in growing markets with transitional economy nowadays encounter extreme necessity to change their structures and improve business processes. In order to support knowledge processes within organizational change initiative enterprises can use business modeling tools. On one hand software vendors suggest many tools of this kind, but on the other hand growing markets with transitional economy determine quite special requirements for such tools. This article reveals these requirements, assesses existing business modeling tools using these requirements and describes ORG-Master as a tool specially created for support of process improvement initiatives in the growing markets with transitional economy.

Keywords: Business information modeling, business modeling, knowledge process, organizational change, business process improvement, growing markets, transitional economy.

ACM Classification Keywords: I.6.3 Simulation and Modeling: Applications