Transactions of the VŠB – Technical University of Ostrava, Mechanical Series
No. 1, 2011, vol. LVII
article No 1833

Pavol BOŽEK*, Jozef ŠURIANSKY**

CONTROLLING ROBOT ON THE INERTIAL BASIS

RIADENIE ROBOTA NA BÁZE INERCIÁLNEHO SYSTÉMU

Abstrakt

The structure of manufactured robots is not unified. There are a lot of conceptual and constructional solutions of robots resulting from the expected utilization. A robotic system can be divided into a mechanical and control subsystem irrespective of their solution. The motion of working organs of a robot is provided by mechanical parts. The activity of all the parts of the robot and programing of its expected activity are enabled by the control subsystem.

Abstrakt

Štruktúra vyrábaných robotov nie je unifikovaná. Existuje množstvo koncepčných a konštrukčných riešení robotov vyplývajúcich z predpokladaného použitia. Bez ohľadu na ich riešenie sa dá robotický systém rozdeliť na mechanický a riadiaci podsystém. Analýza vlastností inercialneho navigačného systému na báze elektronických gyroskopov naznačuje možnosti ich využitia v robotickom systéme.

1 INTRODUCTION

The robot or its part (gripper, arm) has to meet the requirement of three degrees of freedom of motion in the X-axis, Y-axis, and Z-axis at a minimum to achieve a random point in space. The next three degrees of freedom are needed for the random orientation in a given point towards a manipulated object. It means that a universal robot must have six and/or more degrees of freedom. A mechanical conception of the robot is determined by a number of degrees of freedom.

2 THE ANALYSIS OF DYNAMIC QUALITIES OF AN ELECTRONIC GYROSCOPE

The possibility of the utilization of electronic gyroscopes in robotic systems issues from their metrological parameters in determining the data as well as from dynamic characterizations. The analysis of the mentioned parameters was determined by measuring on a laboratory model, which is created by a test electronic gyroscope, a discrete linear drive and a control microcomputer. The linear discrete drive is realized by the four-phase KM, which by means of the SD20M MICROCON control system is operated by the MCBSTM32C (ARM) development board. A gear of control impulses to linear periodic motion, which is scanned by an inertial sensor of acceleration, was achieved by controlling and mechanical arrangement. A flow chart of an electric drive model is illustrated in (Fig.1).

* doc. Ing. Pavol BOŽEK, CSc., STU Bratislava, Faculty of Material Science and Technology, Department of Informatics and Automation, Hajdóczyho , 917 24 Trnava, Slovakia, e-mail: pavol.bozek@stuba.sk

** prof. Ing. Jozef ŠURIANSKY, CSc., Technical University in Zvolen,Fakulty of Environmental and Manufacturing Technology, Department of Informatics and Automation Technology T.G. Masaryka 24, 960 53 Zvolen, Slovenská republika, email: surian@vsld.tuzvo.sk

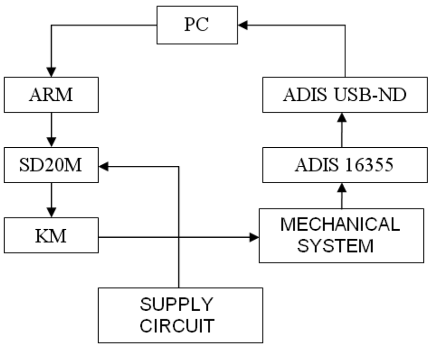
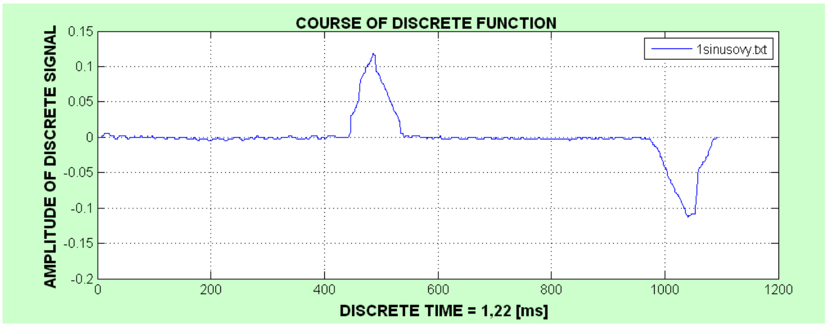
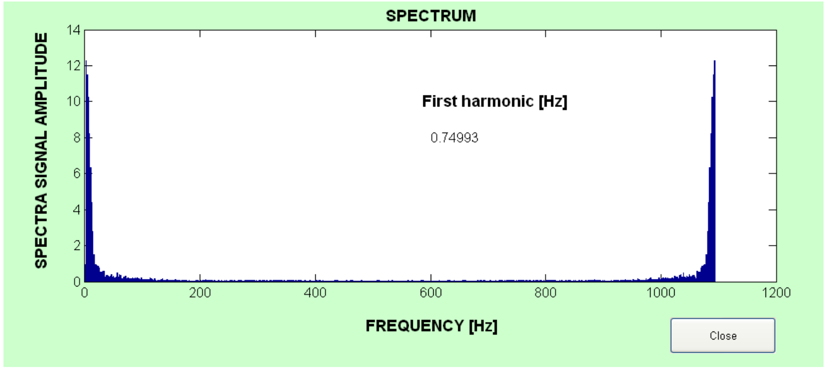


Fig.1 A flow chart of an electric drive model.

The principle of monitoring is based on the scanning of acceleration of linear periodic motion by the MEMS sensor. Next, the analysis of the influence of acceleration dynamic changes by different modes of driving a stepper motor follows. Prior to scanning the acceleration of the linear periodic motion a sequencer was set for basic microstepping so that the influence of a shape of the KM actuating current was the most striking on the scanned acceleration of a rotor. Signals were scanned to a PC by a constant period T=1.22 ms by means of the Analog Device – AdiS 163xx Evaluation Software – Rev 14.



a.



b.

Fig. 2 A graphic environment in Maltaba for the analysis of measured signals. A course in a time area together with the DFT in a sinus actuating shape of the KM is illustrated in the figure.

A graphic environment in Maltaba with the utilization of functions for the discrete Fourier transform – DFT and filtration (Fig.2) was created for the analysis of the measured signals. A band pass filter is needed to identify an item distinctive for the analysis of dynamic parameters of the electronic gyroscope. The Maltaba fir1 function was used to propose the filter. The fir1 function uses a classical window method of a proposal of the digital FIR filter with a final impulse response. A vector of b-coefficients is returned by the function. Using the FIR band pass filter in the interval from 11 Hz to 33 Hz the courses in the time area for a used actuating signal are obtained. In (Fig.3) there is a time function with a medium value of the acceleration amplitude 7.1x10-3 ms^{-2}, which responds to the sinus actuating signal and in (Fig.4) there is a time function with a medium value of the acceleration amplitude 10.2x10-3 ms^{-2}, which responds to the special actuating signal.

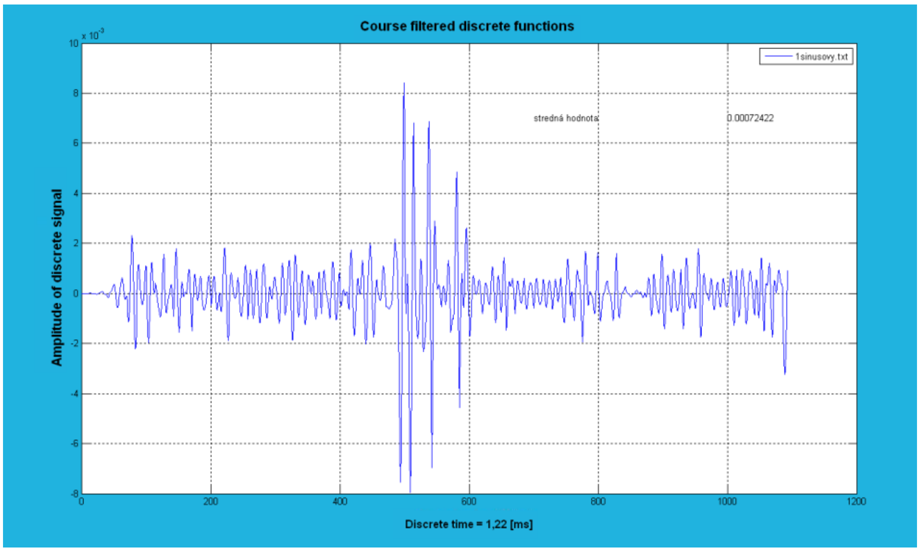


Fig. 3 The FIR signal filtered off by a band-pass filter – the sinus actuating shape.

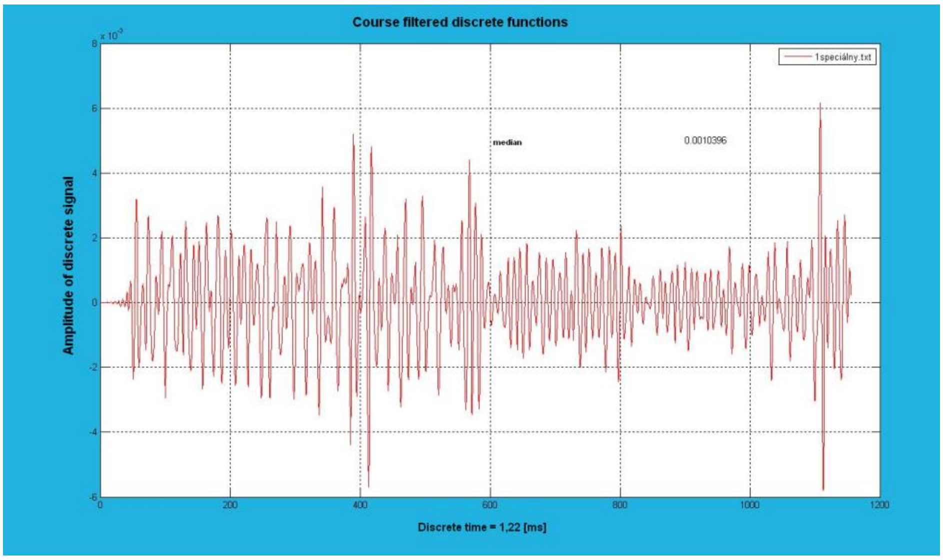


Fig.4 The FIR signal filtered off by a band-pass filter – the special shape of actuating.

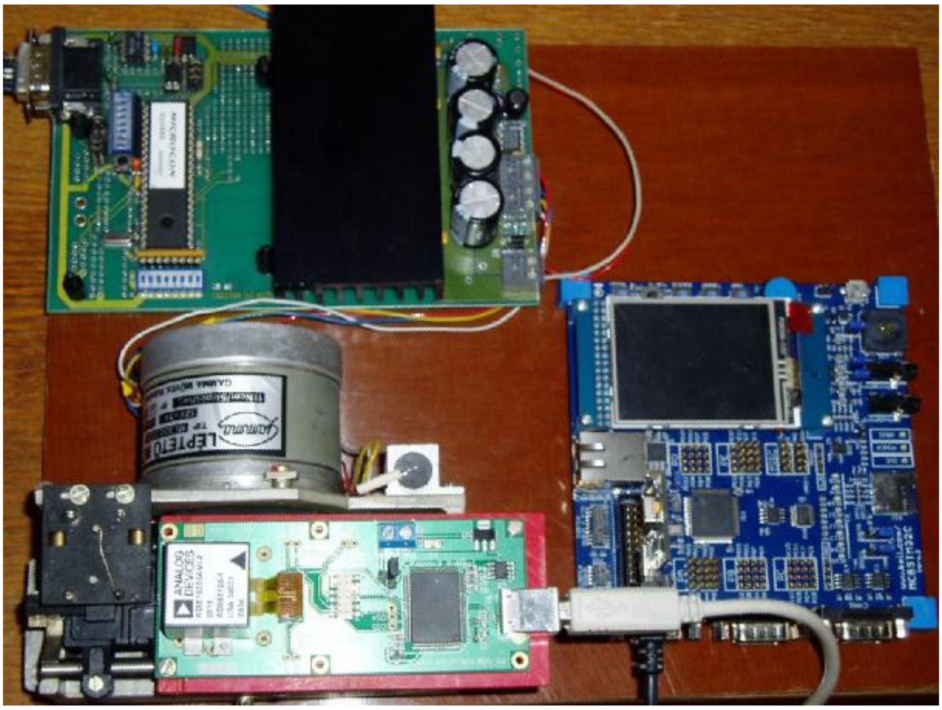


Fig.5 A laboratory model for measuring the dynamic parameters of electronic gyroscopes.

3 THE APPLICATION OF AN INERTIAL SYSTEM

In implementing the inertial system to the controlling of an industrial robot with five degrees of freedom the connecting to a control process computer is also needed. To connect the robot to the control computer is the most frequent and the simplest way of controlling in practice.

The immediate position of single mechanisms of the robot is identified by a common control system via integrated position sensors.

By implementing the inertial system on a robot arm the position sensors are not needed, the arm position is evaluated by an autonomous inertial system. The robot arm position is evaluated by the mentioned system on the basis of knowledge in the initial (reference) position and subsequent scanning of the arm motion by the inertial sensor.

4 THE ADIS 16355 INERTIAL SENSOR

The ADIS 16350 Sensor seems to be a suitable inertial sensor. The ADIS 16350 Sensor is the inertial sensor for measuring angular velocity and acceleration in three axes. The sensor consists of the MEMS components and circuits of signal processing with the aim of a highly integrated solution. Calibrated digital measurements of position and acceleration are thus enabled. The sensor output data are accommodated to the communication by the SPI bus standard. The SPI bus guarantees structurally a simple input-output interface and the comfort of programing. The characterizations of a described sensor with a rising working temperature are markedly deteriorated. The ADIS 16350 electronic gyroscope achieves higher temperature resistance. The temperature characterizations of the mentioned sensors are compared and illustrated in (Fig.6).

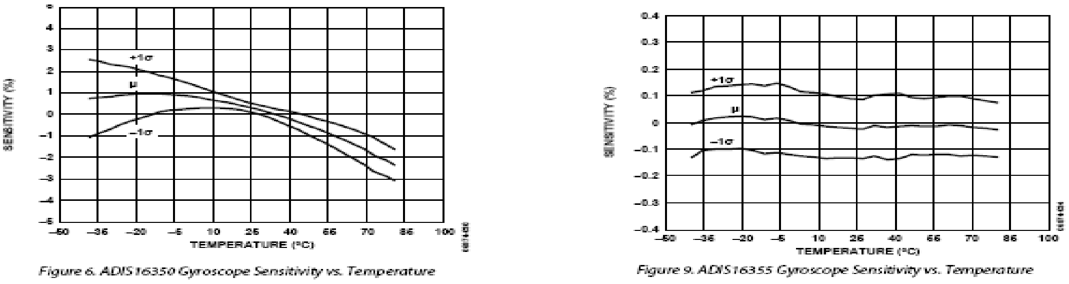


Fig.6 The comparison of characterizations of the **ADIS 16350** and **16355** sensors.

From the basic technical parameters of the ADIS 16355 sensor follows that it is needed to provide its operation in thermally stabilised space. As the sensor shows deviations in measuring depending on time, as long as this data increases exponentially, carrying out of the sensor calibrating in short time intervals is needed. The calibration lies in a transfer of the robot arm to a reference point (i.e. a point with known coordinates from zero points of a machine and work piece, e.g. X, Y, Z, OX, OY = 0, 0, 0, 0, 0). After this work it is controlled whether a monitored measuring system shows zero coordinates. If different data is shown, an instruction for correcting the measuring system comes and by means of it the system is set up to the reference coordinates / the reference point.

Fig.7 Constructing the ADIS 16355 sensor.

5 A FLOW CHART OF THE INERTIAL SYSTEM APPLIED IN THE CONTROLLING OF THE ROBOT

The control computer, as it is illustrated in (Fig.8), is a basic part of the system. Signals from sensors are processed and evaluated by the control computer and on their basis it carries out an action hit by which the robot arm motion is provided, (e.g. a process of welding after a required trajectory). The robot can work in an automatic mode but also in a manual mode when the control computer processes and carries out instructions from a service of the robot. The control computer communicates via the A/Č converter with a block controlling the process of welding and thereby it also controls the process of welding. On the basis of the signals from the sensors and instructions from the service or program servomotors carrying out the motion of a robot welding arm are controlled.

Servomotors have circuits (interpolator, bidirectional counter, incremental scanner of position) which are able to regulate the velocity of motion. This is used mainly in the manual mode when the velocity of motors is lowered due to the protection and safety of the service. An incremental scanner of position generates an impulse by the change of position of a servomotor shaft about a unit of position. The impulses from the interpolator and incremental scanner of position are added up in the bidirectional counter in such a way that in a required positive motion the impulses from the interpolator are added up and they are subtracted from the incremental scanner. An error voltage arises in the output. In a polarity of this voltage a sense of the error is expressed. An amplifier is connected either to the bidirectional counter or to the scanner of absolute position, its shaft is joined tightly with the servomotor shaft by means of the gear. Switching is controlled by the control computer, by which the velocity information is given to the interpolator and a value of new position is given to the register of position.

A camera is connected to the control computer via the A/Č converter. Signals from the camera are analysed and utilized for the control of welding accuracy. A touch sensor is represented by an infrared detector which serves for detecting obstacles in a near environment of the robot, the tens of centimetres. This sensor provides a binary signal – it detects a reflected IR signal/ it doesn´t detect a reflected IR signal or it detects an obstacle / it doesn´t detect an obstacle. These sensors are utilized in setting up the zero and reference points, they are also utilized in guiding the arm to these points in order to avoid a collision between the arm and work piece in the raid to the reference position.

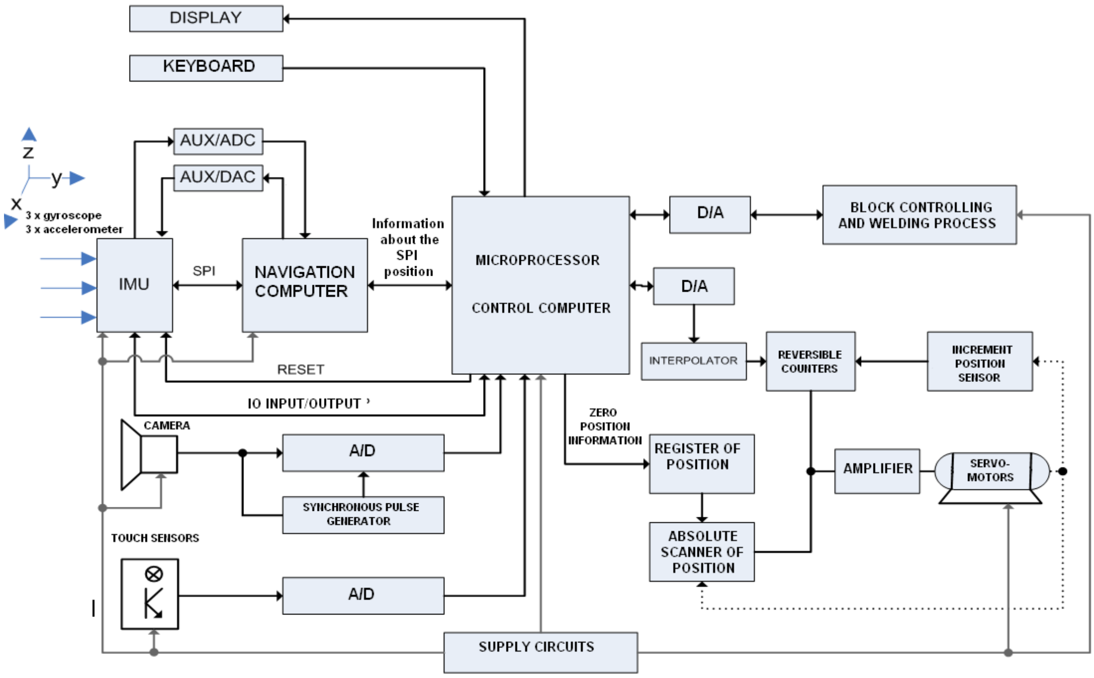


Fig.8 A flow chart of the robot with the applied inertial system.

An inertial measuring unit (IMU) block consists of gyroscopes, accelerometers, temperature sensors (Fig.9). The robot arm motion is recorded by them and the information about direction and velocity of motion is given to the navigation computer, by which the information is given to the control computer. The information is depicted on a display by the navigation computer, then it is compared with the coordinates required by the program or service, and consequently the motion of the robot is controlled in order to achieve the required coordinates. Connecting between the INS (IMU + navigation computer) and the control computer is realised via the SPI duplex bus. Next, the mentioned bus is used for resetting the inertial system or triggering diagnostics and system tests.

6 AN APPLICATION FOR THE CONTROLLING OF THE ROBOT BY THE INERTIAL SYSTEM

An application robot has five degrees of freedom. It means it works in the 3D coordinate system X, Y, Z. The next two degrees of freedom are in the rotary movements of the robot arm (Fig.10).

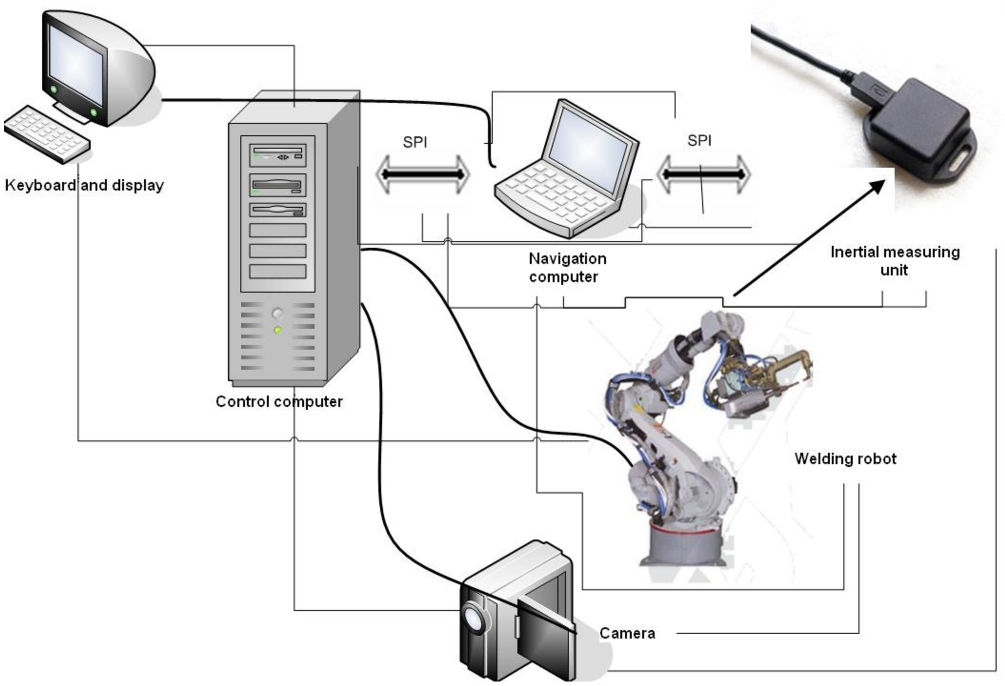


Fig.9 A scheme of the robot with the applied inertial system.

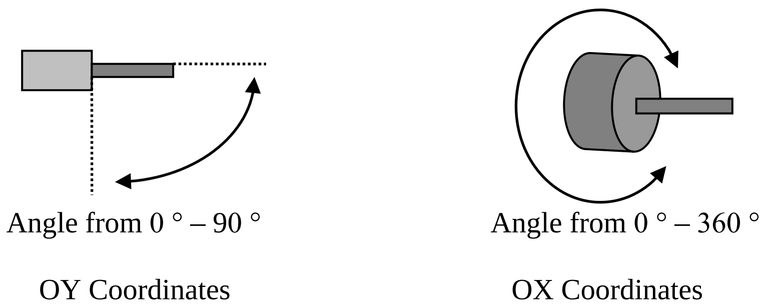


Fig.10 Rotary movements of the robot arm.

After switching off the control system looses the information about position. Therefore there is a reference point on the robot. The system recognizes the distance of the reference point from zero points of the machine and work piece. Therefore after switching on the robot arm must be given to the initial point by the system so that the initial (reference) coordinates were set up. The coordinates of the reference point are determined by the position of the sensor and they can be changed according to the need in the pod MENU – CALIBRATION AND TESTS OF SENSORS (Fig.11). After switching on the system the TEST INS function is activated as the first.

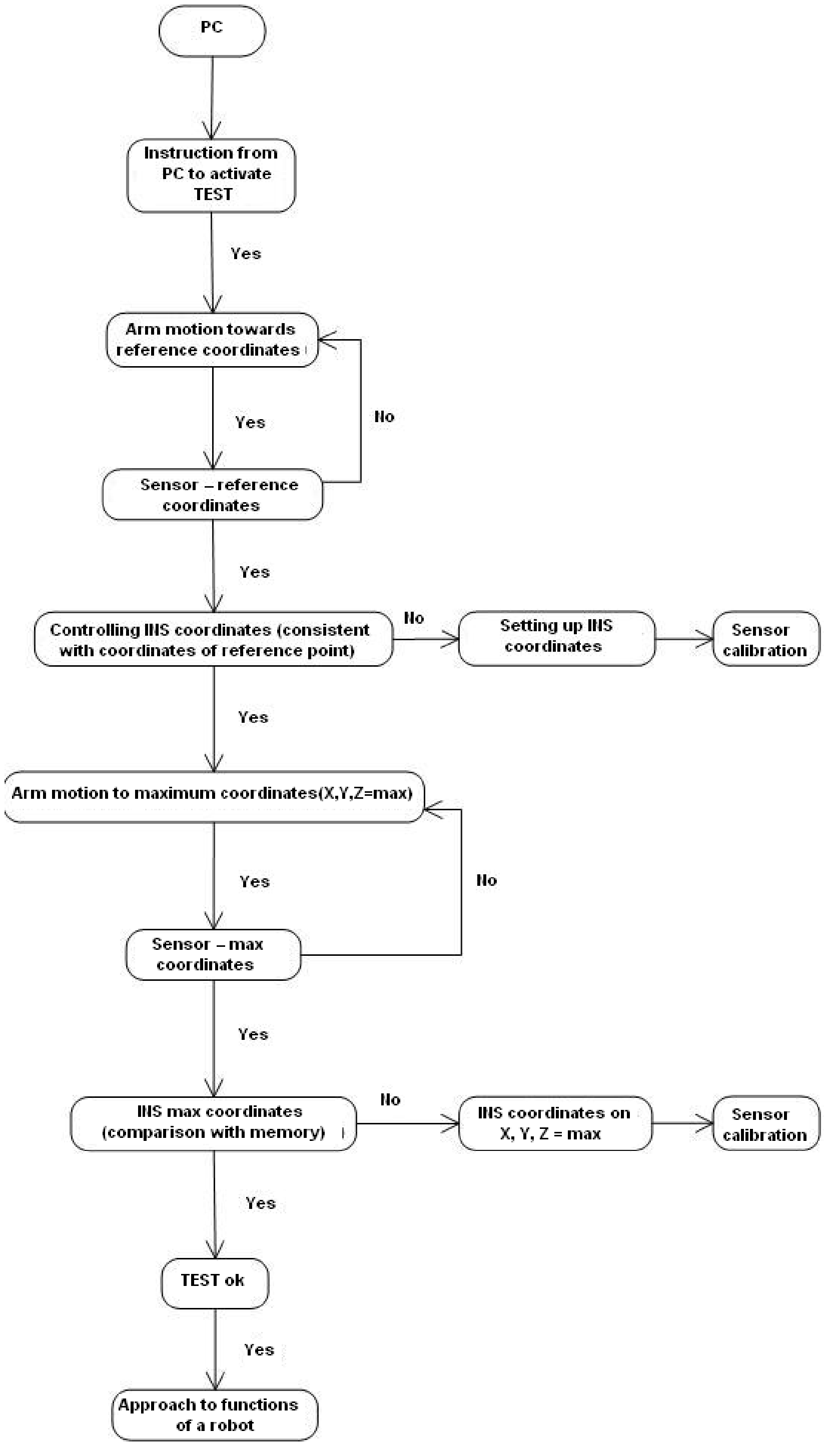


Fig.11 An algorithm of the TEST function.

The course of the TEST function is following: the robot arm is set up to the position of the reference point, it is controlled whether the coordinates consistent with the coordinates of the reference point are returned by the inertial system. If not, the inertial system for the defined coordinates is calibrated. Then the arm transfer to the maximum coordinates follows. It is then controlled whether the coordinates consistent with the coordinates of the maximum point are returned by the inertial system. If not, the correct coordinates are set up in the inertial system. After these steps the inertial system is calibrated and the functions of the robot can be opened up.

7 CONCLUSION

The TEST function, which is carried out after activating the robot, is necessary for the correct function of the inertial system applied in the controlling of the robot. Consequently, the motion to the reference position of the robot arm after each manufactured product is performed. This mode is also utilized in classical gauging systems, which are equipped with relative sensors of the IRC position (e.g. CNC machines). The calibration of the system is realized by guiding the movable part to the reference position after each machined piece work.

ACKNOWLEDGEMENTS

The contribution was elaborated within the research **project KEGA project No. 3-7285-09** *Contents Integration and Design of University Textbook "Specialised Robotic Systems" in Print and Interactive Modules for University of Technology in Zvolen, Trenčín University and Slovak University of Technology in Bratislava.*

LITERATURE

[1] KING, A.D.: Inertial Navigation – Forty Years of Evolution,

[2] TÚMA, J.: Automatizace a kybernetika , 1965

[3] LUKÁČ, P.: Dizertačná práca: *Inerciálne navigačné systémy,* Košice 2007

[4] SOTÁK, M. a kol.: Integrácia navigačných systémov. 1. vyd. Košice 2006

[5] HLAVATÝ, I., SCHMIDOVÁ, E., HAJDÍK J.: Parametry jakosti svarových spojů hodnocené metodami obrazové analýzy (Quality characteristics of weld joints valued by method of image analysis). In *Sborník přednášek sekce č. 6 (Mechanická technologie) Mezinárodní vědecké konference při příležitosti 55 let založení Fakulty strojní*: 7. – 9. 9. 2005, Ostrava. Ostrava: VŠB-Technická univerzita Ostrava, 2005, s. 25. ISBN 80-248-0907-9.

[6] HLAVATÝ, I., PASYNKOV, S.N., KORSHUNOV, A.I. An Automated System for the Evaluation of the Complexity and the Prediction of Labour Input of Fitting and Assembly Operations (Automatizovaný systém pro hodnocení složitosti a predikce práce ve výrobě na vstupu, montáži a při montážních operacích). *University Review.* 2010. Alexander Dubček University of Trenčín, Trenčín, SK, 2010, Volume 4, No 2/2010, p. 44 - 48. ISSN 1337-6047.