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ScienceDirect

Procedia Engineering 149 (2016) 352 – 358

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Manufacturing Engineering and Materials, ICMEM 2016, 6-10 June 2016, Nový Smokovec, Slovakia

Trends in Control of NC Machines

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Abstract

The paper comments on the new possibilities of utilizing the inertial navigation system in robototechnics. It deals with the application of a new inertial measurement system for a robotic workplace calibration. The calibration is necessary so that the simulation model of the production device can adjust to the real geometric conditions. The aim is to investigate and develop a new combined inertial navigation system based on electronic gyroscopes, magnetic and barometric sensors. The crucial activity is focused on three basic fields: 1. the first goal is to analyze accelerometer and gyroscopic sensors and their possibilities of utilization for inertial navigation. The simulation of the effect of sensors with different metrological parameters and their effect on the properties of the proposed combined navigation system, 2. the second goal is to optimize a specialized processor system for processing the data from the defined sensors in connection with controlling items of an industrial robot. The proposal of an algorithm of combined navigation with respect to the used processor system and 3. the third goal is to verify experimentally the proposed inertial navigation system in real conditions of the industrial robot operation.

Peer-review under responsibility of the organizing committee of ICMEM 2016

Keywords: inertial navigation system; sensors; control system; robot; processor system; machines operations.

1. Introduction

Current needs of production technology place requirements on the application of mechanization, automation and robotization of the production process. It is not so long ago when the industrial robots were implemented into less demanding working environments determined for manipulation operations while taking over the command and synchronizing the activities of individual production devices and technology. At present, the requirements for the product quality and quantity, for new complex technological procedures as well as for constructing the complex technological mechanisms are very demanding and still increasing. To meet these requirements the elaboration of new technological procedures is not sufficient. The design, development and construction of new automated and robotic devices and their modernization are needed.

One of the important robot properties implemented in the production technology is represented by their accuracy and reliability related to their capability execute a precisely defined procedure, motion in/on the programmed trajectory or other spatial operations. Current spatial demands as well as the efficient utilization of the space make the robot often operate in constricted conditions. The motion of the tool or manipulation with components requires maximum accuracy. The industrial robots they are position sensors that are used to determine the current position of robot´s parts (gripper, arm) and for the measurement of the position without calibration preparations the following is used:

- photogrammetric methods – allowing the measurements of dynamic objects,
- geodetic methods – allowing the measurements of static objects.

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Peer-review under responsibility of the organizing committee of ICMEM 2016
doi:10.1016/j.proeng.2016.06.678

Obviously, this leads to really high requirements for appropriate calibration of the robotic device as the robots´ collisions, their mechanical damage frequently occur and the production line has to be stopped and the production losses grow [1,2,3].

Continuous assessment of the controlled and navigated robot using the sensors for motion detection, i.e. gyroscopes and accelerometers can be ensured by inertial navigation. Via the navigation computer and data obtained from the motion detectors the position, orientation as well as the direction can be constantly determined without using external information sources. The current position of the object is assessed on the basis of knowing the initial position and subsequent continual measurement of acceleration and direction of the motion in the reference system. The inertial navigation principle is based on Newton´s laws expressing the motion change at using the external forces as well as the acceleration which is proportional to the orientation and size of the external force.

2. Inertial navigation system

Currently, for the 3D inertial navigation execution the inertial navigation system (INS) is used and you can encounter it on the board of army or civil aeroplanes where it is the primary source of navigation information. INS includes one navigation computer at minimum and a platform or module comprising accelerometers and gyroscopes. The reason to use INS for navigation is its autonomy and impossibility of purposeful interrupting its operation from the outside. The sensors of acceleration (accelerometers) as well as the sensors of angular velocity (gyroscopes) are firmly attached to the platform connected the navigated means [4,5].

The basic element INS is represented by IMU, Inertial Measurement Unit. Sensors whose outcome is influenced only by object motion on which the IMU is located are considered as primary sensors of IMU. These primary sensors in the inertial navigation are used for n are represented by angular velocity/speed sensors whose output signals after integration are used for the determination of orientation in space and the accelerometers whose output signals after precise compensating the gravitation acceleration and Coriolis force can be integrated into the velocity and position. Platform-free systems have the sensors located into the 3D coordinate system so that each axis of the navigated object corresponds to the accelerometer´s sensitivity axis as well as to the angular velocity sensor. Such an inertial measurement unit has six degrees of freedom, i.e. it allows the measurement of transaction and rotation movements in three-orthogonal axes. The inertial sensors accuracy is of key significance in the autonomous navigation.

For less demanding applications we can utilize cheaper IMU whose lower accuracy is compensated by the implementation into integrated navigation systems in which the required velocity is acquired by the integration of navigation information from several navigation systems. The navigation computer is the core of the inertial navigation system. The navigation computer processes measured data from the inertial measurement unit and prepares information on the angular position, velocity and the navigated object position on the bases of known initial conditions. The measured data from gyroscopes represent the navigated object vector against the inertial coordinate system indicated by index „i" and measured in the individual axes of Cartesian coordinate system of the navigated object indicated by „b".

$$\omega_{ib}^{b} = \left[\omega_{ib}^{bx}, \omega_{ib}^{by}, \omega_{ib}^{bz}\right]^{T} \tag{1}$$

Via mathematical adjustments and integration of angular velocity/speed we obtain the information on the angular position of the navigated object against the reference system (incline) (náklon). The data measured by three-component accelerometer represent the vector of acceleration measured in the navigated object axes.

$$a^{b} = \left[a^{bx}, a^{by}, a^{bz}\right]^{T} \tag{2}$$

After the primary processing these data are transformed into the reference system, compensation by gravity and Coriolis acceleration are executed and subsequently, double integration is carried out. By the first integration the information on the navigated object velocity/speed is obtained and by the other one the information on the object position.

Eq. 3 represents the mathematical model of INS operating in the navigation coordinate system, i.e. the selected reference system is navigation one with the orientation of axes to North-East-Down [6].

$$\begin{bmatrix} \dot{r}^{n} \\ \dot{v}_{E}^{n} \\ \dot{C}_{b}^{n} \end{bmatrix} = \begin{bmatrix} v_{E}^{n} \\ C_{b}^{n} \cdot a^{b} - \left(2 \cdot \Omega_{ie}^{n} + \Omega_{en}^{n}\right) \cdot v_{E}^{n} + g^{n} - \Omega_{ie}^{n} \cdot \Omega_{ie}^{n} \cdot r^{n} \\ C_{b}^{n} \cdot \left[\left(\omega_{ib}^{b} - C_{n}^{b} \cdot \left(\omega_{en}^{n} + C_{e}^{n} \cdot \omega_{ie}^{e}\right)\right) \times\right] \end{bmatrix} \tag{3}$$

where

$r^{n} = \left[x^{n}, y^{n}, z^{n}\right]^{T}$ - position vector in navigation coordinate system,