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RESEARCH AND DEVELOPMENT OF A NEW SYSTEM OF THE AUTONOMOUS CONTROL OF ROBOT TRAJECTORY

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Abstract: The article deals with one of the options respectively control of the trajectory of movement of a laboratory robot with three degrees of freedom in a predefined area. To do this we used data obtained from inertial sensors, a gyroscope and accelerometer. The inertial navigation is self-supporting navigation technique utilizing for measuring accelerometers and gyroscopes. By them it is possible to watch a position and orientation of an object relative to a known starting point. A basic element of each inertial navigate system (INS) is inertial measure unit, that consists usually of three gyroscopes for angle speed measurement and three accelerometers for linear speeding-up measurement.

1 Introduction

The inertial navigation is self-supporting navigation technique utilizing for measuring accelerometers and gyroscopes. By them it is possible to watch a position and orientation of an object relative to a known starting point. A basic element of each inertial navigate system (INS) is inertial measure unit, that consists usually of three gyroscopes for angle speed measurement and three accelerometers for linear speeding-up measurement. By processing of the signals from this equipment it is possible to watch the position and orientation.

A continual economic force of cost minimization and technological processes streamlining require innovations and improving. The new methods require detailed analysis of the issue and searching for new solutions. Among effects that require practical attention there belong also manufacturing technique inertial navigation systems applications, which can be applied for machines stability control, vibration progress observation in mechanical technologies, robots and robotized production systems operative.

Inertial navigation is known by its application especially in aircraft industry, tactical and strategic missiles, space ships, submarines and ships navigation. The small, light and price accessible navigation systems with a chance to be applied also in other areas are produced on the present thanks to the MEMS (Micro-Electro-Mechanical Systems) technologies expansion.

Nowadays, we have experienced the expansion of industrial automated robotic workstations used in particular for mounting purposes in manufacturing enterprises. Hence is the need for management of industrial robot in a defined area. In the case of industrial robot the system has 3 or more degrees of freedom, which depends on the particular robot. In this article, we will consider the processor, which has three degrees of freedom (Figure 1), three movable arms with translation movement around the area defined by the rotation of the floor and around the normal area.

The requirement for systems that are able to continuously monitor the orientation and position of the object led to the expansion of the investigation and of the autonomous control of inertial navigation. These systems mainly contain a number of sophisticated sensors to gather data on the position of the object in all six axes of Cartesian coordinate system. From the data collected from these sensors and by using the right arithmetic operation we are able to determine the position of the object in the inertial area [8].

In the inertial sensors so far presented a diverse range of sensors, there is still a place for improvement in particular as regards the accuracy. For example, the gyros are commonly used to measure angular tilt and angular velocity. The requirements for the accuracy of the gyros are constantly increasing their price, while becoming fragile and complicated. However, there are sectors in which they are the only sensible and reliable choice of gyros. This article describes the use of inertial measurement units, mainly in the field of management of the robot by the gyro [1], [2].

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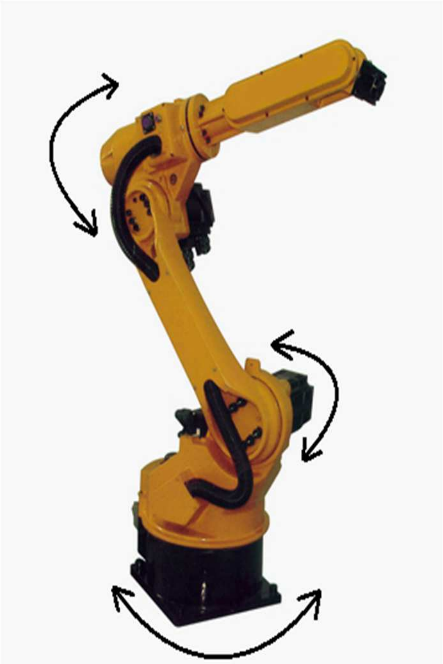
Figure 1 - Robot with three degrees of freedom

2 Analysis of Inertial Navigation System

Inertial navigation system consists of a measurement unit comprising gyroscopes rotating around three axes X, Y, Z, then three accelerometers operating in these axes X, Y, Z (Figure 2) and a navigation computer assessing data obtained from measurement devices/instruments.

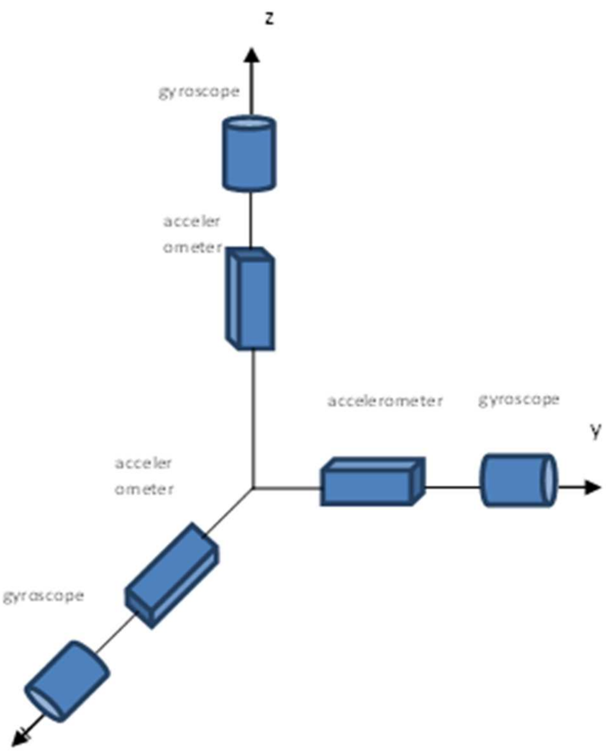

Figure 2 - Principle if inertial navigation system

The basis is represented by the system of autonomous robot´s trajectory control aimed at the prevention of collisions. In the new concept, the control of the current position is dealt with by the autonomous system of accelerometers and gyroscopes in three axes. Another progressive method, not frequently used so far, is the utilization of INS in the system of robot´s trajectory control. If the robot´s position is not calibrated on a regular basis, the deviation will continuously increase and big differences between the real robot´s position and programmed position can grow which is unacceptable for practice.

The navigation autonomy, i.e. independence on external sources of navigation information was the main reason for INS implementation. In contrast to all other navigation systems the inertial navigation is completely self-sufficient and independent on external environment, i.e. the system can resist external influences such as magnetic faults, electronic disturbances and signal deformation.

If we implement INS as an independent control into the robot´s control system, the programmed position will be constantly compared to its real position in the working environment. Thus, the robot´s position will be continuously checked and calibrated via the navigation computer. The deviation does not grow and there are no differences between the real and programmed positions of the robot [3], [4].

3 Determine the Position of the Robot

In determining the position of a robot as well as its management is the ability to use the device, which works in the inertial coordinate system and can determine the position of the arm of the robot in its workspace. In this case, the robot arm is equipped with a detection device (an inertial navigation system), which detects the speed, acceleration and rotation of the arm of the robot in the coordinate system. Using this system, it is possible to determine the position of a robot in space very well where the other methods for the detection of the position cannot be used. The position can be obtained subsequently adjusted according to the requirements and the robot arm is then able to watch any route to reach the desired position.

Location data obtained from the inertial measuring device are sent to the management computer, which compares it with the required values and those are subsequently adjusted, so the required position can be reached by the robot arm. The data from the management computer are sent to the robot using a robot control system. The process of sending and checking data is called reverse validation (Figure 3) [5].

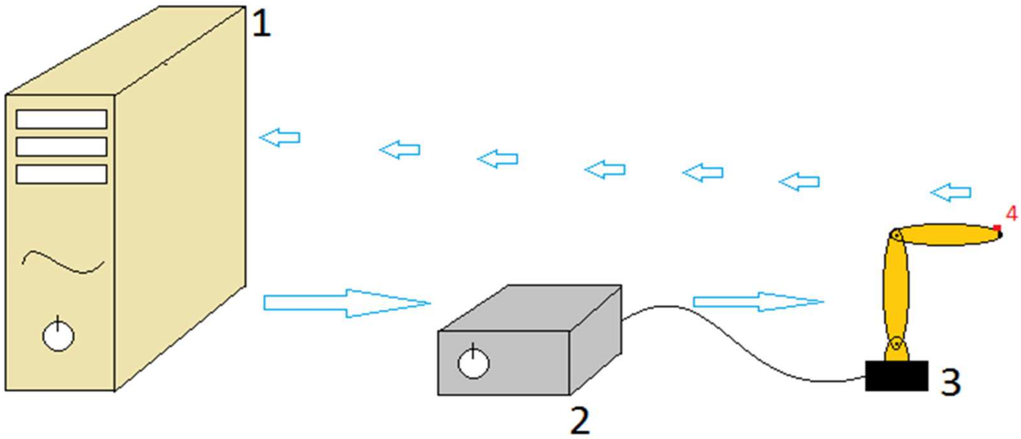

Figure 3 - Robot trajectory control, 1. -Control computer, 2. -The control system of the robot, 3. -Robot, 4. -Inertial navigation system

3.1 Determine the Position of the Robot Using the Accelerometer

Inertial measurement unit measures the kinematic values - angular velocity and linear acceleration. The earth can be considered an inertial system if we neglect spin, then taking into account a kinematic theory is true: if we know the initial position of the object as well as its initial speed at the object at the time while we measure R, together with the acceleration using accelerometer placed on the shoulder of the robot, so we can determine the speed of the object at the time as:

$$\mathbf{v}(t) = \mathbf{v}_0 + \int_0^t \left(\mathbf{R}(t)^{-1} \cdot \mathbf{a}_{\text{local}}(t) - \mathbf{g}\right) dt \qquad (1)$$

Where g is represent the vector of gravity acceleration. It is possible to determine the location of the object:

$$\mathbf{d}(t) = \mathbf{d}_0 + \int_0^t \mathbf{v}(t)\,dt = \mathbf{d}_0 + \mathbf{v}_0 t + \int_0^t \int_0^t \left(\mathbf{R}(t)^{-1} \cdot \mathbf{a}_{\text{local}}(t) - \mathbf{g}\right) dt^2 \qquad (2)$$

Due to the use of mathematical operations integration occurs over time position error. The size of this error depends on the type of inertial measuring system or on the quality of the accelerometer in the system. One of the options to remove the positioning error is resetting the zero point of inertial measurement system at regular intervals [6].

3.2 Determine the Position of the Robot Using the Gyroscope

In determining the position of a robot using a gyroscope, inertial measurement unit using the angular velocity ω measured around the axes *x, y, z* in Cartesian coordinate system. From the measured angular velocity using mathematical adjustments we calculate the angular rotation φ. This represents a motor rotation respectively rotation of each arm of the robot. So thanks to the output data of the gyro we can determine the position of the robot arm in space. The output of the gyro can be analogue or digital. Processing outputs is using the management computer to calculate the necessary change in order to move the robot arm to desired position in space. This type of controlling position is called a reverse validation.

When measuring the rotation of gyroscope an error occurred when integrated, which increases over time. This is also possible as in accelerometer removed by resetting the zero inertial measurement system. A fundamental difference between the accelerometer and gyroscope is that error of integration in accelerometer is greater than in gyroscope due to a double integration [6], [7].

4 The Management of the Experimental Platform of Robot

Our experimental platform (Figure 3) is designed with the ease of possible forms management model laboratory robot using inertial control system. Model of the laboratory robot consists of three dc motors. This means that the robot has three degrees of freedom; each motor is one degree of freedom. For controlling the robot is used inertial navigation system named x-IMU. Using three gyroscopes contained in an inertial navigation system we measure the rotation in three axes. These gyroscopes represent the rotation in axes x, y and z, which are arranged as in Cartesian coordinate system. By the application created in the programming language C # running on the management computer, the collected data are transferred to the degrees of rotation, and then they are sent to the control interface, which manages the individual robot motors [9].

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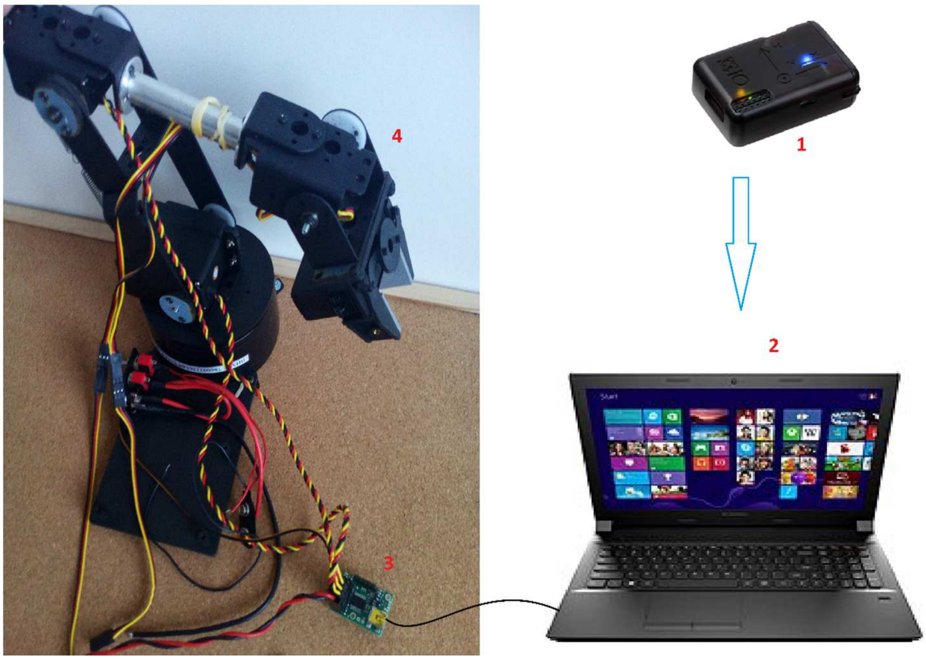

Figure 4 - The involvement of an experimental platform. 1- x-IMU, 2. -control computer, 3. - control interface, 4. - model of the robot

Conclusions

Inertial navigation placed on the robot arm allows to precise determination of its position in space. This information can be used in managing as well as the correction of the movements of the robot. The advantage of such a solution is independence from the other devices in the vicinity of the robot as well as the low intensity of the installation. The options of control the robot by using data obtained from the gyro, we have demonstrated on an experimental platform.

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Review process

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