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PROPOSAL OF EFFECTIVE DIMENSIONS MEASUREMENT ON THE INERTIAL BASIS

NÁVRH EFEKTÍVNEHO SPÔSOBU MERANIA ROZMEROV NA PRINCÍPE INERCIÁLNEHO MERACIEHO SYSTÉMU

Abstrakt

Práca približuje problematiku automatizovaných metód merania rozmerov, pričom rozširuje doteraz známy obzor používaných prístupov K meraniam O návrh novej, doteraz nepoužívanej, metódy. V práci popisovaný spôsob merania rozmerov vychádza Z princípu vlastnej lokalizácie inerciálnych senzorov, schopných popisovať aktuálne hodnoty uhlových rýchlostí a zrýchlení V smere jednotlivých súradnicových osí priestoru. Nutným predpokladom presnosti týchto meraní je jasná definícia nulovej polohy systému V priestore a zohľadnenie širšieho spektra vplyvov okolia. Metóda by mohla umožniť meranie rozmerov tvarovo zložitých objektov S vysokou presnosťou, a to dokonca aj na miestach, kde by to pri použití konvenčných metód meraní nemuselo byť vždy možné. Príspevok taktiež informačne popisuje princípy funkcie inerciálnych navigačných systémov a technológie MEMS, ktorá značne znižuje náklady na použitie týchto pokrokových technológií.

Abstract

The work presents automated methods of dimensions measurement, extending the known horizont of used approach to measuring by the draft of a new unused method. a method described in the paper is based on the principle of self-localization of inertial sensors that are able to describe the actual value of angular velocity and acceleration in the direction of each coordinate axis. Prerequisite accuracy of these measurements is a clear definition of zero position in space and taking into account a wide range of ambient effects. The method should allows to measure dimensions of objects of complex shape with high accuracy even in places where usage of conventional methods is not always possible. The contribution also describes principles of inertial navigation systems and MEMS technology, which significantly reduces the cost of mentioned advanced technologies.

1 INTRODUCTION

A continual development of science and technology has been a limiting factor of implementation of most kinds of approaches and methods in the long run that everyone takes for granted in the current time. It is in the area of dimensions and lengths measurement as well. The recognized methods of distance measuring derived from units of the human body (slap, thumb,

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fathom, elbow) in long time ago, through the principles using of surveying ropes or plates, humanity gradually have reached to manual measurement methods based on general application of length standards, that we know in the present. Hatiar (2006) [3].

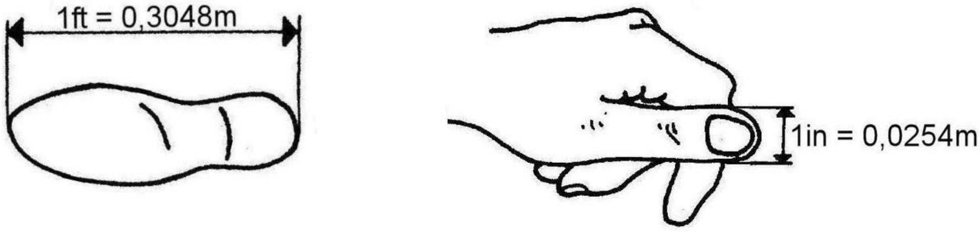

Fig. 1 The examples of old length measures.

The observation mainly focus on the ways and methods of automation process length measurements in this time. These approaches are usually very closely focused and do not sufficiently define many types of dimensions. The proposal of automated method for measuring moves this barrier to completely different dimensions, but its accuracy and cost depends on quality and availability of inertial navigation sensors, which are constantly liable to considerable development.

2 INERTIAL MEASUREMENT SYSTEMS

By simultaneous evaluation of acceleration and rotation of navigated solid is possible to achieve autonomy of its location in space. The principle of positioning is based on continuous measurement of object movement. Thus performed systems are known as inertial measurement systems and their structure consist of a base on which are mounted three mutually perpendicular accelerometers and gyroscopes.

The division of inertial measurement systems (INS):

- Cardan system INS (Inertial navigation system gimballed)
- Non-Cardan INS (Inertial navigation system strap-down)

The Cardan INS is based on location of accelerometer´s sensors on so-called stabilized platform. This platform is stabilized in a horizontal position of considered coordinate system according to data obtained from the gyroscopes. Usually, they are systems containing a lot of mechanical parts, causing a higher failure rate.

The second group is non-cardan systems. These systems do not contain a stabilized platform, but the platform is firmly associated with pursued object and thus accelerometers are not maintained in a stabilized position on the base. Therefore it is necessary to transform the measured accelerations to the direction of each coordinate axis.

3 MEASUREMENT OF ACCELERATION

For a clear definition of the pushes in space, there are used sensors known as accelerometers or otherwise called as acceleration sensors in practice.

From the view point of the activity principle of these sensors, we know accelerometers that are working on the following principles:

- Inductive - measuring deflection of the physical body using transformer

• Capacitive - measuring deflection of the physical body by changing the capacity of the condenser

• Tensometric - measuring deflection of the physical body by means of shoulder strain, to which the body is fixed

• Piezoelectric (electric-charge) - measuring the size of the generated charge by piezoelectric crystal as a result of mechanical stress caused by external force

• Piezoresistive - measuring changes in resistance of silicon-mechanical structure, depending on the mechanical stress caused by external force

• Oscillatory - change in frequency of the sensor's output signal, based on the pressure of the physical body on vibrating plate

• Thermic - principle is based on the heat transfer in gas, it is scanning of heat distribution around the heating element in the gas, depending on action of the acceleration

• MEMS accelerometers - using mainly capacitive or piezoresistive principle

4 MEASUREMENT OF ROTATION

Deflections of the object from the equilibrium position due to rotations in the space, around each coordinate axis, can be note by sensors for rotation measurements, so called gyroscopes. For measurement of small rotations, gyroscopes can be replaced by less sensitive sensors of angular acceleration or force. In general, we know the gyroscopes with three, two, or one degree of freedom. For the inertial measurement systems are typically used either gyroscopes with one degree of freedom in direction of each coordinate axis or gyroscopes with two degrees of freedom mounted in direction of two axes of the coordinate system.

In terms of activity principle of the gyroscopes, they can be classified as follows:

• Mechanical gyroscopes - change of location is indicated by rotating flywheel, rotate around one axis, locate to two gimballed hinges

• Laser gyroscopes - measuring of time delay of rays, reflected from the mirror system after impact on detector

• Fiber gyroscopes - measuring of phase shift of two rays sent from one source

• MEMS gyroscopes - operate on principle of Coriolis force changes

In the inertial measurement systems there are used mainly gyroscopes with one degree of freedom, where one gyroscope in the direction of each of the coordinate axis is used, or gyroscope with two degrees of freedom, which are usually placed in the direction of axis x and y. Kopáčik (2003) [1].

5 MEMS TECHNOLOGY

MEMS technology (it means Micro Electro-Mechanical Systems) is a technology for making miniaturized systems with size of several millimeters integrating sensors, mechanical parts, integrated circuits, control and evaluation systems into one compact unit. It is a technology combining knowledge of technical disciplines such as micro-mechanics and micro-electronics. Micro-miniaturized 3D mechanical elements are mostly produced by selective corroding or implementing of new layers and for production of electrical components are used in conventional technology, types of CMOS, Bipolar, or BiCMOS. The main advantages of this technology are reducing size, lower consumption of equipment, mechanical strength and lower price in larger series.

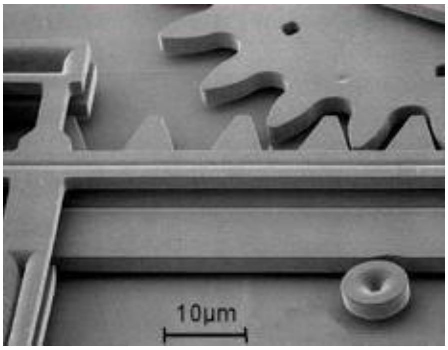

Fig. 2 MEMS Technology.

6 PROPOSAL OF A MEASUREMENT PRINCIPLE

A current trends in the field of length measurements lead to automation of this process, either through electromagnetic or sound waves. Thus targeted automation of length measurement process face several problems in practice and therefore its applicability is very limited [4]. The main limiting factor is the necessity of wave reflection from the barriers or obstacles and oscillation return to the sensor. Such approaches therefore disallow to measure distance of points located behind the barrier, or behind the shape-indented surface, because characteristics of these measurement methods result from the determination of size dependent on the circumstances of measurement area between border points of measured dimension (Fig.3). This problem is solvable by the manual length measuring instruments in certain circumstances, usually operating on the principle of pushing or rotating mechanical parts, which are significantly limited in measured length and therefore are not generally applicable. This solution is further in deep contrast to the efforts to automate these measurements. Another possible solution would be to use the method of photometry. Photometry is the measurement method based on reading of length size from photograph or other image of the measured object in pursuance of knowledge about relative size of the actual length to the length of the same size displayed on the slide. This method is almost globally applicable, but not sufficiently precise for each application.

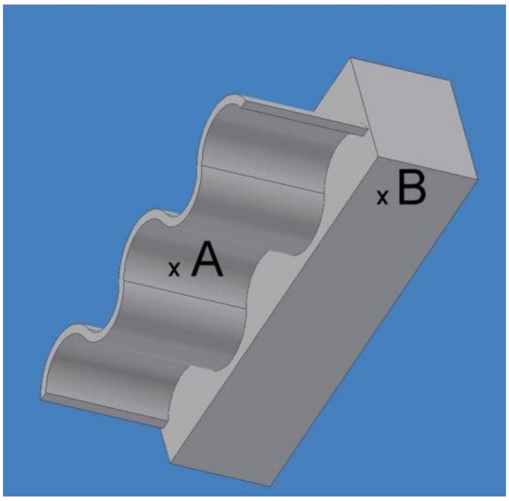

Fig. 3 Complex body shape, with an indication of the border points for conventionally difficult dimensions measurement.

Therefore we try to look at the problem of automation a little differently. We think of the measuring that deny the existing approaches to length measurement and understand the border points of dimensions just as definitions of their location in the reserved space. If we have two such clearly defined points in space in the same coordinate system, their identification and subsequent calculation of the distance is only an elementary matter, based on the principles of Euclidean geometry theorems, namely Pythagorean theorem. But we face the question, how to clearly define the location of points in the space?

Due to the efforts to preserve the general applicability of the proposed principle of length measurement, we don't reflect the position of measured points of real solid, but the position of the end point (point of mobile meter located in the border points of the measured dimension).

Every object in space has 6 degrees of freedom, 3 linear degrees in direction of each coordinate axis and 3 rotation degrees around each axis. For unambiguous determining of solid location in space, in our case the end point of the gauge, would be therefore necessary to know information about all displacements and rotations, according to the zero starting position.

Thus, if we place the gauge together with the measured object, into space, which is assigned for our measurement, and the gauge is able to locate itself and unequivocal determination of their own location, using such a measuring device we prove to determine the location of any point on the measured object.

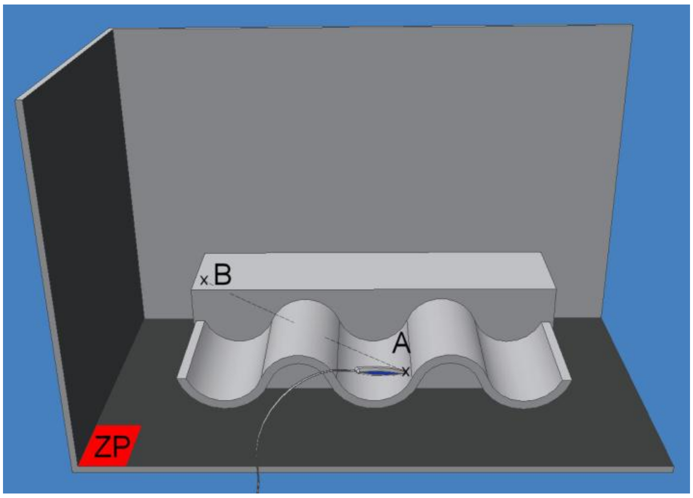

Fig. 4 Housing in the measuring area.

For coordinates determining of end points of the gauge, the method deals with using of accelerometric and gyroscopic sensors, nowadays successfully implemented to systems that achieve a sufficient accuracy for such purpose. We speak about so-called inertial navigation systems. The development of these facilities began shortly after the Second World War, when in 1949, Charles Stark Draper built and successfully tested the first operational inertial navigation system. Originally, these systems were primarily designed for military marine, aviation and cosmic technology sphere. The purpose of their use corresponded to their availability. The inertial navigation systems, such as we know them in the present, are the result of long-term development, whose limiting factor at any time was the current technology progression in the manufacture of inertial sensors. By the time this progression allows a significant reduction of cost and increase of accuracy of these systems, what facilitate their wider use in practice.

Accelerometers included in inertial systems determine the acceleration of each observed object in the direction of coordinate axis and gyroscopes define rotation around these systems axis.

Thus, if we implement a set of such sensors to the mobile length measuring device, we can mark up coordinates of the border points of the measured dimension, based on the initial identification of the zero position (Fig.4). The zero position of the measuring system can be either the starting point of each measured dimensions, or the starting point of reserved measuring area, depending on the type of the current measurement. All measured data are processed and then filed down by the software contained in a portable computer unit, which also evaluates the size of the measured distance and displays the measurement result. The disadvantage of inertial navigation systems is the high precision of navigation information, only for a short period of time, because there are integration errors of the system sensors. This time-depending increase of integration errors is advantageous to use the principle of defining the starting position before each length measurement.

The issue of design and construction of such a system is closely related to the problem of eliminating errors caused by the environment impact on the measurement system, such as the Coriolis force and gravity. The solution to this issue also relates with designing of appropriate data filtering, such as calibration of the system.

The inertial measurement systems manufactured by MEMS technology get to the forefront nowadays. It is a technology, which miniaturize inertial systems into a single compact unit and in larger series of production allows a substantial price reduction of the final product, it facilitate the extension use of these systems in the commercial sphere.

7 CONCLUSION

Proposed principle of dimensions measurement, based on inertial navigation systems very likely allows us to automate dimensions measurement with high precision of obtaining data in the near future. a big advantage of these facilities will be their high mobility, the possibility of automation of the measurement, regardless of the area skills between border points of determining dimension and general applicability in practice. The question is just the pace of technological development of production of accelerometers and gyroscopes, as components of inertial navigation systems, and their price accessibility.

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