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Inertial navigation microsystems for indoor person navigation

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Anotace:
Tento článek se zaměřuje na porovnání a testování dvou různých systémů pro inerciální navigaci určené zejména do míst bez signálu GPS. Tyto inerciální navigační systémy byly porovnávány s GPS systémem. Dále byl zjišťován rozptyl získaných dat od více stejných systémů inerciální navigace. Rovněž byl zjišťován vliv umístění inerciálního systému na přesnost.

Abstract
This article is focused on comparison and testing of two different microsystems for an inertial navigation intended especially for places without GPS signal. These inertial navigation systems were compared with GPS system. The next research work was focused on dispersion detection from the more same systems of inertial navigation. Also it was detected influence of location of inertial system on human body for accuracy increasing.

INTRODUCTION

Navigation systems have become a common part of many people's lives. They are mainly used in transport. The most used systems for navigation are GPS, GLONASS and GALILEO [1]. These systems allow determine position in the whole world with help of satellites. Disadvantage of these systems is limitation for their function only outdoors. Therefore, there is needed other solutions for indoors and generally places where is not available signal of global satellite position systems. One of the possible solution of this problem is an inertial navigation system. Accuracy of these systems depends on a number of parameters, therefore motivation of this work was comparison of different inertial navigation systems, finding of their accuracy and repeatability. Those parameters also will use for next research in integrating such a system in smart textiles.

PRINCIPLE OF SYSTEM FOR INERTIAL NAVIGATION

In order to determine the position using an inertial system, an accelerometer, a gyroscope and a magnetometer are used. Accelerometer is acceleration measuring device. Gyroscope is angular velocity measuring device. Magnetometer is magnetic field measuring device. The data from these sensors is processed in a relative position measurement (so-called dead reckoning). This is the process where the current location is determined based on the specified location. Therefore, it is necessary to know the initial position in order to determine
the relative position from the initial position. This method of determine position is also used in tested systems. [1, 2]

The basic calculation principle for positioning is given in Equations 1 - 4 [1]. In equation 2 is computed rotation and in equation 3 is computed new position which is computed from acceleration.

The data at the beginning (position, speed, rotation)

$$x(t_0), v(t_0), \varphi(t_0) \tag{1}$$

Rotation

$$\varphi(t) = \int_{t_0}^{t} \dot{\varphi}(\tau) d\tau + \varphi(t_0) \tag{2}$$

Position

$$\begin{aligned} \boldsymbol{x}(t) &= \int_{t_0}^{t} \boldsymbol{v}(\tau) d\tau + \boldsymbol{x}(t_0) \\ &= \iint_{t_0}^{t} \boldsymbol{a}(\tau) d\tau + \boldsymbol{v}(t_0) t + \boldsymbol{x}(t_0) \end{aligned} \tag{3}$$

Final data

$$x(t), \varphi(t) \tag{4}$$

For calculation is used method which is called zero velocity update. That means calculation is done when the sensor is not moving. It is a moment when the speed of the sensor is zero. This state is reached by the right position of the sensor on human body. Usually is the sensor placed on the foot. Figure 1 shows the moment when is speed of moving zero. Location of the sensor on human body was also tested with results in the next part of this paper.

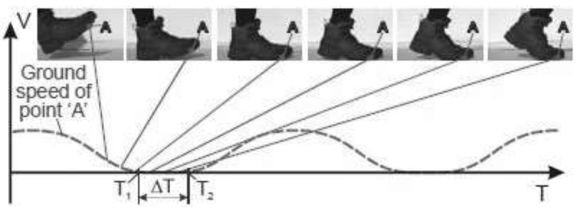

Fig. 1: Speed of the foot during the walk [3]

SYSTEMS TESTING

Comparison of the inertial systems with GPS

For testing were chosen following systems from Dune and InvenSense companies. These systems are based on getting data from gyroscope, accelerometer and magnetometer [2]. With help of these systems is possible to get location of person in x,y,z coordinates. Testing of chosen systems was firstly done outdoors because of data comparison from inertial systems with data obtained by GPS. Example of obtained data from two sensors of inertial systems are in Figure 2. Data obtained by GPS are presented in Figure 3 for comparison.

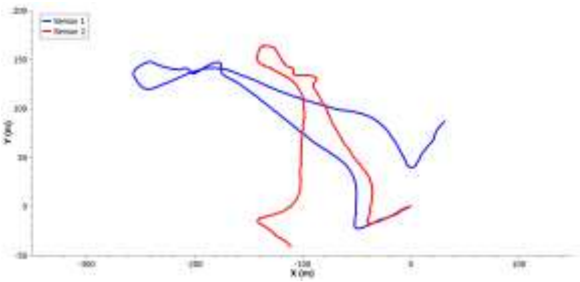

Fig. 2: The recorded routes from both inertial navigation sensors

From the results, it is clear that the trajectory pattern recorded by inertial navigation systems roughly corresponds to the trajectory pattern recorded by GPS. In both systems, the route differs after turning and following the route back to the starting point of the measurement. Nevertheless, one of the systems showed more accurate results, especially in the measured maximum distance.

Fig. 3: The recorded route by GPS

The table 1 shows measured distances in straight way from start point to the most distant point. Reference value is distance obtained from data of GPS system and measured on maps.google.com. Values of distances from inertial navigation sensors were calculated from coordinates of start point and the most distant point.

Tab. 1: Comparison of measured distances

	Maps google	*Dune*	*InvenSense*
DIST [m]	293	290	213
DIST [%]	100	99	72,7

In addition to the example below, additional measurements were performed to verify reliability and accuracy. The results of these measurements are in table 2. During measuring distance 1, it was not possible to measure the maximum distance for the module from InvenSense because the recorded route absolutely did not match the actual route. Further, during measuring distance 2, a significant error was recorded. It was caused by that all steps were not detected during the walk. In the other cases were results with the smaller errors but still larger than the system Dune.

Tab. 2: Comparison of measured distances

	Maps google	*Dune*	*InvenSense*
DIST 1 [m]	1138	1152	-
DIST 1 [%]	100	101,2	-
DIST 2 [m]	469	476	105
DIST 2 [%]	100	101,5	22,4
DIST 3 [m]	296	298	278
DIST 3 [%]	100	100,7	93,9
DIST 4 [m]	621	634	581
DIST 4 [%]	100	102,1	93,6

Multiple modules comparison

Another point of testing was to verify the accuracy of multiple modules in one system. Based on the previous comparison, a Dune Module was selected for this test.

Figure 4 shows a record of ten measurements from different Dune modules. It can be seen in the picture that some of the displayed routes differ significantly from others, especially

records 2, 3 and 7. For these measurements, the initial direction has been incorrectly identified at the beginning. This error has continued to increase, and especially at measurement 3, it has made the route record absolutely unrealistic. For these modules, the error was probably caused by a magnetometer error.

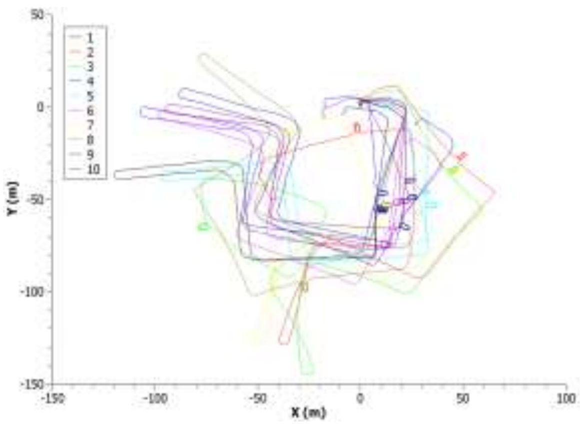

Fig. 4: The same trajectory from ten modules

Influence of location of inertial system on human body

In this part was tested influence of location of the sensor on human body. By the theory is the best place for sensor on the foot. Especially near the fingers, it can be under them, that means in the sole of the shoe or above them, that means on the shoe. According to this assumption was done first test with the sensor on the shoe. After that were done other tests with the sensor placed above the knee and on the belt. Each of these tests were done twice.

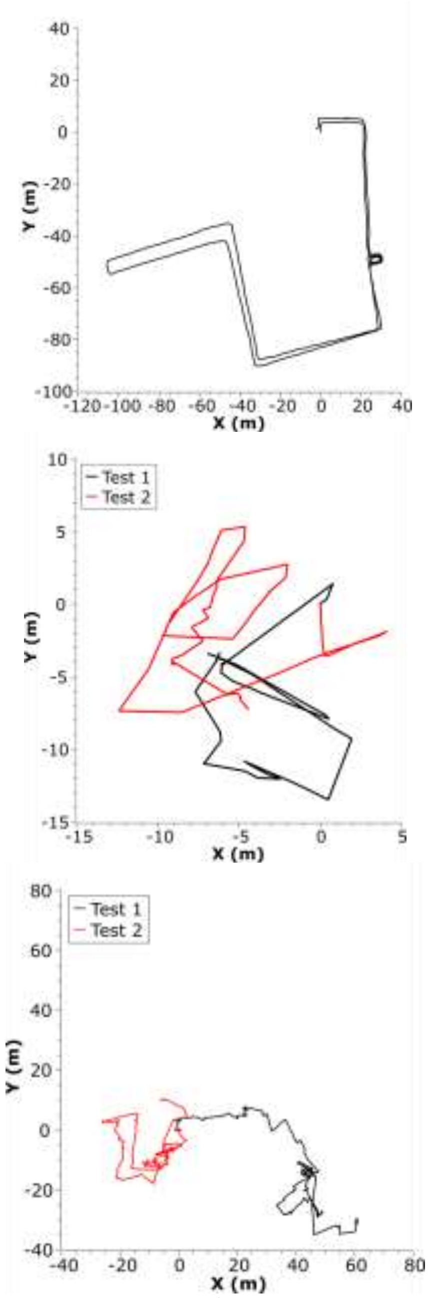

Fig. 5: a) Sensor placed on the foot; b) Sensor placed above the knee; c) Sensor placed on the belt

Figure 5 shows results of the testing with sensor on the other part of the body than is foot. From the figure 5 b) and c) is clear that results of these measurements are very inaccurate. These measurements were done repeatly and the results were different but still very inaccurate. Instead of that measuremets with sensor on the shoe had very good result.

CONCLUSIONS

The aim of the research work was to compare and evaluate the possibilities of two inertial navigation systems. The results show that both systems are characterized by inaccuracies, especially when changing the direction of movement. The angle of rotation is detected incorrectly, resulting in an error that is reflected in the next recording. Despite this error, one of the systems provides much more credible data on the recorded route. With this system was made another testing. It was tested repeatability with ten modules and influence of location of sensor on human body. Repeatability shows that some of the sensors had bad results probably because of error of magnetometer. Testing of placing of sensor confirmed that the best place for sensor is on the foot. On the base of this research work it will continue research in integrating the system into smart textiles. That means in this case integrating of the inertial navigation into the shoes.

REFERENCES

[1] Terrestrial Navigation: Basic principles of terrestrial navigation. *Institute for Communications and Navigation* [online]. 2012 [cit. 2017-09-20]. Dostupné z: http://www.nav.ei.tum.de/fileadmin/w00bkq/www/Terrestrial_Navigation_Chp_3.pdf

[2] NOVÁK, Jakub. Snímání a zpracování údajů lokalizace dopravního prostředku. Brno, 2005.

[3] OJEDA, Lauro a Johann BORENSTEIN. Personal Dead-reckoning System for GPS-denied Environments. In: *2007 IEEE International Workshop on Safety, Security and Rescue Robotics* [online]. IEEE, 2007, s. 1-6 [cit. 2017-10-12]. DOI: 10.1109/SSRR.2007.4381271. ISBN 978-1-4244-1568-7. Dostupné z: http://ieeexplore.ieee.org/document/4381271/