Wireless Indoor Positioning System with Inertial Sensors and Infrared Beacons

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***Abstract*— The paper presents a wireless electronic system for indoor positioning of people. It uses inertial sensors to track the movement of a person inside buildins. To improve the accuracy of the system infrared beacons were successfully applied. The results of the experiment made with the prototype system have shown that usage of infrared beacons could limit error accumulation in a positioning system based on inertial sensors.**

***Index Terms*—indoor positioning, inertial sensors, infrared transmitters.**

I. INTRODUCTION

Localization of people indoor has significant importance to many systems that are being designed to improve people's security and comfort. A growing number of publications concerning this subject proves that this task is challenging and leads to various solutions depending on the application scenario [1]. Among many technologies that are being applied for this purpose one of the most widely used radio beacons[2-3]. It is based on the analysis of the parameters of radio link that allows to find the distance between the user terminal and the transmitters of known positions. Another popular technology employs inertial sensors (accelerometers and gyroscopes) to track the motion of the subject. The movements can be then converted to the position [4-5]. A very important limitation of the inertial systems is the accumulation of measurement error that results with decreasing the localization precision in time.

In this paper a novel method of improving the accuracy of inertial positioning system is presented. The positioning system was designed to track the location of a person who is walking inside the building. The aim of the system was to locate a watchman who is supervising a large object and may be subject to a life- threatening situation, such as a heart attack or an accident. Having the information about localization of the watchman inside the building, the emergency unit can find the person faster, increasing the chance of bringing successful help.

For the purpose of this research a very simple localization system that was using inertial system was used to show the possibility of improving this with infrared beacons. The original system used a simple motion tracking algorithm that was based on detection of steps and rotation of the body. In the paper it is shown that the accuracy of this system was significantly improved by the application of infrared beacons using IrDA technology that enables the detection of actual position of subject with reference to radio base stations (radio beacons).

II. SYSTEM STRUCTURE

The structure of the positioning system is presented in Figure 1. It consists of a mobile unit that is attached to the arm of the moving person and a set of base units that are located inside the building. The mobile unit that is presented in Figure 2 uses accelerometers and gyroscopes to measure the linear and axial acceleration of the person and sends the data over radio to the base units and then to the monitoring computer. For transmission of data 2.4 GHz ISM band was used because of its availability and a wide variety of transceivers that are available for this band (in this project ADF 7242 circuit was used). In the preliminary phase of the project standard dipole antennas that were design to operate in the ISM band were used in the base stations and the mobile unit. However, the design of the mobile unit allows to use also wearable textile antenna designed by the author [6-7].

The data gathered by the sensors are processed by the personal computer where the localization algorithm is implemented. Base units are equipped with short range IrDA transmitters that emit infrared signal containing the base unit identifier. The mobile unit is capable of receiving the infrared signal if only the person is passing by the base unit, what is possible only in a small and controlled region in its vicinity.

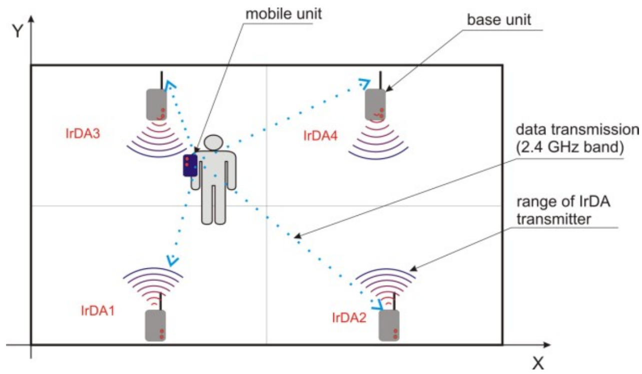

Fig. 1. Structure of positioning system

Thw inertial navigation system uses angular and linear acceleration sensor MPU6050 which is connected to an ARM microcontroller LPC1768, responsible for the acquisition of data from sensors, its processing and radio transmission to the personal computer. The MPU6050 is a motion processing technology. It combines a 3-axis MEMS gyroscope and a 3-axis accelerometer integrated on the same small silicon package together with DMP (Digital Motion Processor), which is capable of processing complex 9-axis motions algorithms. It has also dedicated I2C sensor bus, so it directly takes inputs from an external 3-axis compass to provide a complete 9-axis MotionFusion (firmware algorithms) output. DMP processor fuses the accelerometer and gyroscope data together to minimize errors form each sensor. The DMP computes the results in terms of quaternions which describe rotations in three dimensions using scalar values. Three of these scalars define an axis and the fourth rotation around axis.

Fig. 2. Mobile unit and IrDA sensor

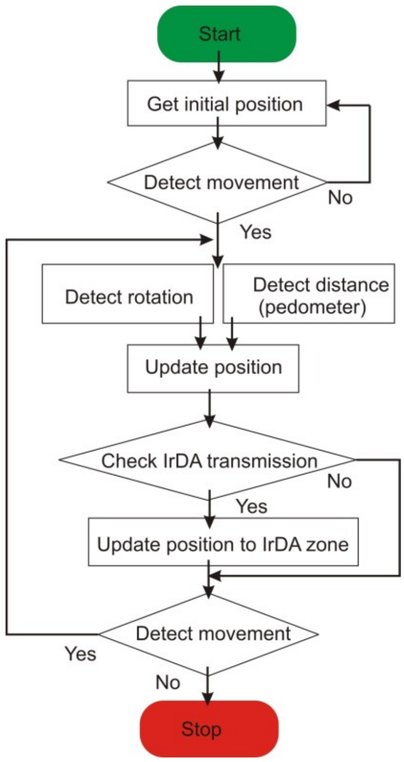

Fig. 3. Positioning algorythm

III. Positioning Algorithm

The basic algorithm of positioning uses data from DMP to track motion of the monitored person. It is assumed that the dimensions of the localization area are given as well as the initial position of the observed person. This assumption was made because in the considered application scenario there are only one entrance doors to the building. Another assumption concerned the location of the mobile unit towards the body of the watchman. It was designed to be placed in the pocket on the arm because other pockets may contain objects that will disturb the radio transmission (portable radio, torch etc.).

The DMP applied in mobile unit computes quaternions that are converted to the rotation angle around three axis Cartesian coordinate system: yaw-around z axis (vertical), pitch – around y axis, and roll around x axis. For the purpose of the navigation in building only yaw angle (rotation around z axis) is needed to know the direction of movement. Distance walked by the monitored person is computed on the basis of a pedometer. The linear acceleration data that are filtered in DMP to remove gravity force form measurement, are taken to calculate the resultant vector. Empirically defined threshold value of acceleration is used for the step detection. Yaw angle and steps counter are placed in data frame and send via radio to the personal computer for further processing.

The original algorithm did not give satisfactory accuracy. The assumption that forced the placement of the mobile unit on the arm of the person made the algorithm to be very sensitive to the arm movements of the walking person. Also, a low data rate that resulted from a power source limitations had a negative impact on the step detection reliability and the overall performance of the tracking algorithm. It motivates further improvements of the system.

The basic algorithm that originally tracked walk direction and distance was extended with procedures that correct the position of person with the data available from the IrDA sensor that can receive the base unit identifier. The building in which the watchman is walking was already equipped with the set of alarm sensors placed in different rooms. It was assumed that it will be possible to use the supply network of alarm system to power IrDA sensors that ware used for localization system. The IrDA transmitters were located in the 4 rooms of the one floor of the considered building, so the localization of the watchman in a particular room would be possible.

The range in which the infrared signal from base unit can be received by the mobile unit was fixed experimentally. It was limited to 1.5 m and the sector width is approximately 60° in the horizontal plane. This was achieved by placing base unit above the level of mobile units and tilting down the infrared transmitting diodes. The range of IrDA transmitter defines the zone associated with one of forth base units what was presented in Figure 1. The detection of signal by mobile unit updates the position of user to the centre of the zone associated with given base unit. The final positioning algorithm applied in the system is presented in Figure 3.

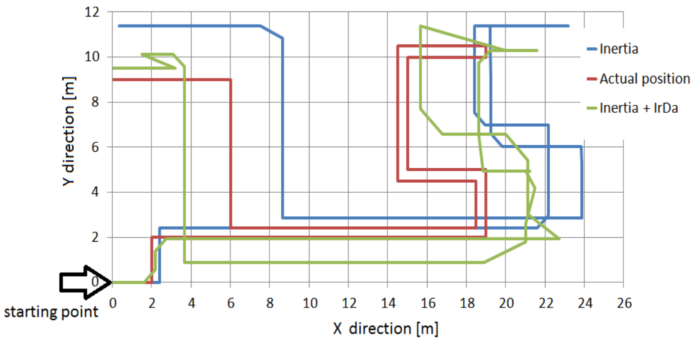

Fig. 4. Result of experiment: position of person estimated with inertial algorythm and inertial algorythm supported with IrDA technology

IV. Results of Experimental Verification

The positioning algorithm was verified experimentally in the building of the inner dimensions equal to 26 m along x axis and 12 m along y axis. The person walked around the predefined route that is presented with red line in the Figure 4.

In the first stage of experiment the position was estimated with the algorithm that utilized only the data from inertial sensors (blue line in Figure 4). The estimated position compared to the real location of the person (red line) differed in worst case even up to 5 m. The error accumulates and the final position was far from the real one.

The second experiment was carried out with the new algorithm that used bothe the inertial sensors and the infrared transmitters. The result of positioning obtained with this algorithm is presented in Figure 4 with green line. Four base units with IrDA transmitters (infrared beacons) were placed along the border of the localization area, facing with IrDA transmitters the center of the localization zones. The maximal error of positioning obtained with this algorithm did not exceed 2 m. In this case error accumulation was significantly reduced and the final position was estimated with mach better accuracy than in the case of first experiment.

V. Conclusions

In the paper the positioning system that utilizes inertial sensors and infrared beacons was presented. The original system that uses only the data from accelerometers and gyroscopes suffered from accumulation of estimation error. It was shown that infrared beacons can be successfully used to improve the accuracy of positioning system. The proposed system uses inexpensive IrDA transmitters and a receiver to detect the proximity of the user to the base unit what refers to the given location of the user.

The analysis of the experimental results obtained with the described system shows that the application of infrared beacons can improve the accuracy of inertial system. The maximal positioning error was decreased from 5 m to 2 m.

Another application of infrared beacons to the positioning system could be the detection of initial position of the user. In the current version of the system the initial position is assumed a priori but it is possible to place additional base units in every door leading into the building and it can be automatically detected by the system when the watchman passes them .

This system, like other indoor positioning systems, was designed to meet the requirements of a particular application scenario. Thus it can be used only if the infrared detector can be located on the person in such a way that it cannot be covered by the garment or other equipment worn by people. It is also sensitive to the appropriate placement of base units that defines the range of infrared transmitters.

Acknowledgment

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