INPERLYS – Independent Personal Location System

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Abstract. This article describes a state of art for location systems, and presents the INPERLYS (Independent Personal Location System). INPERLYS is an outdoor and indoor location system capable of give the user’s position in places where GPS signal fails or is not accurate enough. For that, a dead reckoning method, using sensors like Micro Electrical Mechanical System (MEMS) is used.

Keywords. Location system, dead reckoning, GPS, MEMS.

Introduction

When the Global Position System (GPS), developed by the department of defense of United States of America, came out for civilian use, a big step was given to the development of systems for locate people or objects. Unfortunately, the GPS signal is hardly attenuated by obstacles like walls, canyons composed by high buildings in cities or dense vegetation in forests \cite{1} \cite{2} \cite{3}. Considering this fact, if it is intended to develop a system capable of locate a person or object in any place, such system must provide solutions to solve the GPS attenuated signal problem.

The solution for this problem could be the use of the last reliable GPS signal for absolute coordinate and then, with the information given by another part of the system, make a prevision of the user’s actual position. There are many developed systems that could be used to give this information, in this particular case, position inside buildings (indoor position), like RADAR \cite{4}, Active Badge \cite{5} or DOLPHIN \cite{6}, to name a few. The problem of this kind of systems is that they depend on the environment where they are implemented, and in some of them there must be an offline phase for configurations. The fact of these systems being centralized put a range limit on the location system and the solution presented in these systems do not cover all cases where the user could receive a bad GPS signal, like in a dense forest. So, if we want a location system capable of give the position anywhere and independent as much as possible, another solution must be found.

Solutions like hybridization of Micro Electrical Mechanical Systems (MEMS) and GPS signals for Pedestrian Navigation \cite{2}, hybridization of MEMS and local infrastructures \cite{7}, the NavMote \cite{14} or wearable location systems composed by computer and sensors \cite{8}, present solutions to minimize or solve the range limitations by using dead reckoning method. A dead reckoning method is a relative navigation technique where, starting in a known position (absolute reference), the new positions are added. The information of the new position can be in the form of Cartesian
coordinates \((x, y, z)\) or can be in the form of heading, speed and distance [9]. Normally, sensors like MEMS are used to analyze the user gait cycles or user walking speed in order to obtain a prevision of the actual position. This particular technique is known as Pedestrian Dead Reckoning (PDR). With MEMS it is possible to obtain information in three axis, which is useful if we, beside the distance walked, want to know, for example, in which floor the user is or his orientation. There is another kind of sensors that could be used like; pressure sensors [10] [11], for altitude information, digital compass [12] for orientation information or pedometers for distance walked [13].

Bearing these facts in mind, this document is organized as follows. Section 2 discusses the state of art of PDR systems. Section 3 briefly describes the INPERLYS location system. Finally, Section 4 presents the conclusions and outlines the perspectives toward future research.

2. Background

In this Section it is described some location systems that offer a location service where GPS signal are not accurate enough, using dead reckoning techniques. The sensors used in PDR are also discussed.

2.1. Dead Reckoning techniques Location Systems

One thing that PDR systems have in common is the fact that all of them analyze the human cycle gait for distance traveled determination. As we will see in the Section 2.2, the time when the foot is on the ground can be used to make MEMS calibration or to calculate the distance traveled, by counting the steps whenever it is detected that the foot is on the ground and multiplies this value for a fixed step length value. However, it is difficult to know exactly when the foot is stationary, due to factors like noise and the step length values, since it varies from user to user.

A. Hamaguchi et. al. [7] have presented a simplest and effective way to analyze gait cycle. Beside the MEMS, the system has push button switches in the user’s shoes and has an electromagnetic sensor and two trackers (one in each leg). By the push buttons, we can know exactly when the user has his foot on the ground. With electromagnetic sensors it is possible measure the distance between the two legs. The transmitter and receivers are composed by three orthogonal coils. The transmitter electromagnetic field values will be pulsed and the receivers will capture the incoming values with their coils. The strength value of the received signal will be compared with the sent signal strength in order to determine a relationship (orientation or position in 3D space) between transmitter and receivers [17]. By this way it is possible to know the step length at any time, making possible the user alternate the step length dynamically (change from walking to jogging) with no problem for the system. Unfortunately, if for some reason, none of the pressure sensors were been pressure, the system will not add the new step length values, which could happen for moments if the user is running or if he is climbing stairs (due to pressure sensor position in the shoe at heel). This system receives the absolute coordinates from another support system which is intended to be implemented in the surrounding environment, making this system dependent from external sources. The system has the advantage of give tools to know the dynamically change of step’s length and thus the distance traveled but has the disadvantage of not provide autonomous positioning capabilities.
M. Kourogi and T. Kurata [8], presented a system which, comparing with the one above, represents an alternative in the way by the absolute reference is achieved. A wearable camera for recognize the surrounding environment is used. The data collected will be compared with a database composed by images taken in an offline setup phase. The result of this comparison will determine the absolute reference. In spite of this system does not need a local implemented system to absolute coordinate, however, there must be an offline setup phase to collect the images to compose the database.

V. Renaudin et. al. have developed an hybrid system for pedestrian navigation [2], which uses the Assisted GPS (AGPS) signal in the open space for localization and, when the user enter in a indoor space or in a place where the AGPS signal is not good, the system uses the measures given by the inertial system (INS). The INS, composed by MEMS sensors, has the function of analyze the user gait cycle, and then, using the step estimated length, the system will calculate the traveled distance. The AGPS will give, wherever it is possible, new absolute references.

The problem of using AGPS for assist the INS measures is that, we can only use AGPS measures in the open or semi open space. Once inside a building the AGPS signal is too weak so, it cannot give credible information, making the system being based only in the erroneous measures of INS, increasing the error in the prevision of the indoor position.

2.2. Sensors

There are some sensors that could be use in PDR technique like MEMS (accelerometers, gyroscopes or pressure sensors), pedometers or magnetic compass. The MEMS were been used to these systems due to characteristics like small size, low power consumption and low cost [1]. Accelerometers are used to measure the acceleration and gyroscopes are used on rotation measures. The problem is the fact that, the information given by MEMS is corrupted by errors due to factors like temperature, drift or influences caused by the acceleration force during the users motion [1] [2] [7].

One approach that can be used to minimize the drift problem is making foot velocities updates when the foot is stationary. At this phase, the horizontal velocity of the foot must be zero and the vertical value should be the earth’s acceleration, 9.8 ms⁻¹, so the differences sensed can be used for sensor’s calibration [11] [14]. The best place to put the MEMS should be as closest as possible of the ground, for example, in the user’s shoes, in order to minimize the body’s motion impact on the measurements. To avoid integration errors, another possibility for the calculus of user traveled distance is the analysis of waist accelerations. When we give a step, there is a vertical acceleration on waist. So if we put the MEMS at waist level, when a vertical acceleration is detected it means that a step is being given. If we multiply the number of steps by a stationary value of steps length, we have the total distance traveled. The problem of this method is the assumption of the stationary value of the step length, in reality this value will change from user to user. Another problem that can arises in this technique is the fact of sometimes, due to electric noise, it is not clear enough when the vertical acceleration is zero (end of the cycle), in most of the time the acceleration value jumps from the maximum acceleration value (in middle of gait cycle) to a non zero acceleration value, making difficult to know with precision when the foot is stationary [14].

The gyroscopes are usually used in these systems to compensate the angle effect on accelerometers measures due to its position (put closely of the accelerometer) or for the system to know the user’s orientation (put at waist level) [14]. When the user
makes a rotation, the proof mass will move due to Coriolis force, generating a signal. Once that the gyroscope’s operation is different from a magnetic compass, it could be also used to help the system to recognize bad interpretations from the magnetic compass originated by external magnetic field. Like accelerometers, gyroscopes should be calibrated in time.

Another sensor usually used in PDR technique is the magnetic compass. This kind of sensor, once not being fabricated with MEMS technology, does not share the same problems of accelerometers and gyroscopes, so it could for example, be used for calibrate gyroscopes or refresh their measures. The magnetic compass uses the earth’s magnetic field for pointing to magnetic north. But this sensor is not perfect. Its measures could be influenced by external magnetic fields and by its position, which should always be parallel to earth [15]. The angle between magnetic compass and earth’s surfaces is called inclination angle. So, to have a correct measurement we need to subtract to magnetic north the inclination angle. There are some types of compasses but the magneto resistive ones are used in PDR systems due to its high sensitivity and cost effective.

For measurements in altitude we can use directly the output of sensors like MEMS pressure sensors or atmospheric sensors since when we walk up or down in stairs the atmospheric pressure differs. The problem of this solution is that the pressure in the process of climbing or descending stairs slightly changes, so the output of the sensor (affected by errors) should be amplified [11] amplifying in this way the error and increase the hardware cost. The MEMS pressure sensor output is also affected by phenomenon like thermal hysteresis [16]. An alternative could be the analysis of the horizontal and vertical accelerations, once these have a typical pattern, different from the ones notice in the walking behavior on a flat floor [8], making by this factor possible distinguish the horizontal walking from the vertical walking.

3. The INPERLYS Location System

3.1. System Description

The main goal of this work is the development of a pedestrian location system capable of tracking the pedestrian movements in indoor and outdoor environments. In the outdoors, where is a clear line of sight to the satellites, GPS technology is able to provide location with good accuracy and continuity of service. Although, indoor and urban canyons are quite challenging for satellites positioning.

To overcome this problem we propose a system based on integration of AGPS and INS technologies. These technologies have the distinct advantage of providing autonomous positioning capabilities. AGPS uses data disseminated by a telecommunication channel to a GPS receiver in order to improve the receiver’s sensitivity. The technique typically involves a mobile phone able to acquire GPS signal (PDA), a cellular network and an assistance data server. This approach will be used to provide Pedestrian position in outdoors and urban canyons.

Inertial navigation or pedestrian dead reckoning (PDR) will be used to provide indoors continuous positioning. The system must be able to detect and characterize human physical activities, encompassing both body postures (lying, sitting and standing) and body displacement (step length, horizontal speed, altitude and direction). For that purpose, we will employ a distribute architecture of MEMS sensors, such as
accelerometers, gyroscopes, magnetometers and barometers, that will be integrated in the Pedestrian clothes. A Central Processing Unit (CPU) will compute all the data capture by the MEMS sensors and will send to the PDA information about the Pedestrian movement, as shown in figure 1. MEMS based algorithms provide only relative data from the previous position solution to the current one, so we will need to use absolute positioning data, such as AGPS, to reinitialize the MEMS-based walking path in an absolute geographical reference. The communication between the CPU and the PDA will be made through a Bluetooth network. To transfer data between the CPU and the different MEMS sensors units we will use the ZigBee wireless Personal Area Network (PAN). We choose the ZigBee network because it provides, low power consumption, low cost and can be configured to operate in a variety of different ways such as cluster and mesh topologies. The system can connect to internet, by a connection such WI-FI, being possible others equipments access to INPERLYS in any place.

To achieve the prerequisites of an independent location system, it is proposed the architecture described in Figure 2. We divided the system in three main parts: gait analyzes (GA), waist analyzes (WA) and posture analyzes (PA). The GA part, composed by accelerometers and gyroscopes has the objective of detect and classify the human steps. The WA is used to support the human step detect function and orientation detect function by using accelerometers and gyroscopes attached to human waist. The PA part has the objective of detect the human posture and orientation. The reason of WA support GA and PA is to minimize the errors introduced by the sensors. For achieve the maximum accuracy we can use a fusion algorithm based on the Kalman filter. The sensor fusion algorithm will use the data from all sensors and has the function of analyze which sensor data should be better to use in order to give the user

![Diagram](image.png)

Figure 1 – The INPERLYS System.
position and orientation with the best possible accuracy. For example, for long distances, with no credible information given by the AGPS, it should be better use data from digital compass for orientation, instead use the MEMS gyroscope information due to error’s accumulation. It is the algorithm that, with information given by the pressure sensors and accelerometers, will determine and classify the human’s steps, making possible to know when the user is walking and his speed.

The GA part is composed by an accelerometer to analyze the user’s steps. The pressure sensor is used to help the process of steps analysis, to know exactly when the foot is on the ground, being the gyroscope used for compensate the acceleration influence in the accelerometers 3 axis, caused by its own position. The WA is also used in the process of analyze the user steps, it gives to the system a method to know when the cycle begins by measure the vertical acceleration of the waist, using the accelerometer. It is used also for determination of user’s orientation, using gyroscope measures. In PA, besides accelerometer for knowing the postures of the user, it is used a digital compass. This is an alternative for measure the user’s orientation given already by the WA. The gyroscope, like in PA, is used for correction in accelerometer’s measures.
4. Conclusions and future developments

In this document we have presented the INPERLYS location system and the state of art in PDR systems. The INPERLYS is totally independent from external resources, once the system is based on integration of AGPS and INS technologies. It does not need of any offline configuration and the modules that compose INPERLYS are connected with ZigBee wireless communication protocol in order to make more comfortable and easy the use of the system. To minimize the low accuracy that is achieved when it is only used the INS data, the INPERLYS is composed with modules that can give the same data. The objective is making the system not dependent of the data (probably corrupted) of only one module. At this stage of development the practical results of INPERLYS are promising but are not accurate enough. We do believe that this solution is not far from the final one. We have conscious that, in the development of the system, we will probably need, due to the particular characteristics of MEMS sensors, make some adjustments. For that, we can introduce more sensor modules or adopt a more powerful algorithm using, for example, stochastic error modules.

References

