LOW-COST LOCATION SYSTEM FOR AIRPORTS

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Abstract- This paper describes a solution to the problem of location in airports, which are places where the use of GPS devices is impossible or not sufficiently precise. The new proposal is based on a combination of methods that allow obtaining useful information about the location in this type of places. In particular, an Android application has been implemented to show the applicability of the proposed solution, which adds a layer of security because it is very important to protect positioning information to avoid the possibility of traceability of system users.

Keywords- Location; Airports; Android; Security.

I. INTRODUCTION

Airports are among the places where the location is more needed because the current systems are not working well today. Outdoors the use of GPS positioning systems usually provides a precise location, but its use indoors is not possible. The traditional way to solve this problem in airports has been to place static signs at many points of the installation, indicating where the different gates and services are. The main disadvantage of this type of signalling is that many times they are not easy to understand or even provide information that is not completely correct for all users, generating stress and wasting users' time.
Smartphones are increasingly essential in our daily lives, since they are no longer used only to make phone calls or send SMS messages, but also to perform many other tasks among which location is remarkable for this work. Due to this, not only outdoors locations systems based on GPS have been developed, but also different indoor location solutions based on smartphones have been proposed in recent years.

A proposal of interest for this work is based on the use of Near Field Communication (NFC) technology [1], which can be used to provideshort-range positioning. Another interesting proposal is based on an Inertial Measurement Unit (IMU) [2], which provides inertial changes to track the user's movement. The combination of both technologies allows providing a real-time position on a smartphone using an interior map of the airport. An important aspect that is not usually studied in this type of systems is its security and, in particular, the impossibility of tracking users. To avoid this, the proposal here presented includes the encryption of all communications between IMU and smartphone.
This work is structured as follows. Section 2 describes some preliminaries. The proposed system is defined in Section 3. Section 4 presents some details of the IMU location seystem. Finally, some conclusions and open questions close this work.

II. PRELIMINARIES

In recent years, different solutions have been proposed based on the use of IMUs to track the movement and/or position of users. A guide to the most common sources of error in the use of IMU for positioning systems and their effects on navigation performance can be found in [3].

Although several types of IMU exist, traditionally, those used to track movements and/or positions have been the 6 DoF (Degrees of Freedom) or 9 DoF IMUs.A 6 DoF IMU generally has a 3 DoF accelerometer and a 3 DoF gyroscope. On the one hand, the accelerometer is used to measure the acceleration in IMU movements in the x,y,z coordinate systems, which can be easily transformed into speed through the first integral of the acceleration, and into position through the second integral of the acceleration. Thus, it can be used to measure changes in speed and position, respectively. A problem that usually arises when obtaining speed and position through the integral appearswhen the intrinsic constant error is not deleted from the original measurement, the acceleration becomes a linear error in the speed and a quadratic error in the position, which would render the system unusable. On the other hand, the gyroscope measures the orientation in the x,y,z coordinate systems. 9 DoF IMUs havea 3 DoF accelerometer and gyroscope and adds a 3 DoF magnetometer, sensor that measures the magnetic field and is generally used to obtain global orientation due to the Earth's magnetic field.

Different proposals for systems to track movements in the space have been presented. A method that is usually based on the aforementioned sensors is called Dead-Reckoning. This method consists of different algorithms based on easy trigonometric equations to obtain the real position of an object or person, by means of operations based on the course and navigation speed. There are multiple algorithms that implement Dead-Reckoning. In thework [4], a comparative study of different pedestrian recognition algorithms is included. A pedestrian recognition algorithm is basically an algorithm that estimates the movement of a person by detecting steps, estimating stride length and directions of movement. The results obtained in that work show how this technique offers promising results with an average rate of the stride length estimation errors of approximately 1% and an estimate below 5% in the total travelled distance. Another method that is generally applied to improve performance and reduce drift error in sensor measurements is the use of static and adaptive filters, and a commonly used filter is the Kalman filter [5].

III. PROPOSAL

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The proposal consists of an Android application that **2.**
shows on a map the current position of the user inside **3.**
an airport. The system combines two technologies to perform this function.

On the one hand, NFC technology is used at the airport entrance to establish the initial position of the user on the airport map. NFC technology was chosen for this purpose because it is a short-range communication technology with no error in the estimation of the initial position. The selection of this technology instead of a cheaper QR code is because NFC technology is easier to protect than QR codes.

On the other hand, IMUs are static reference points such that their use is a more accurate way of collecting data than the smartphone because it produces less noise than the use of smartphone sensors. The IMU is used to collect data from the accelerometer, gyroscope and magnetometer sensors, which are sent to the user's smartphone through the use of Bluetooth Low Energy (BLE) technology [6]. On the user's smartphone, the sensor data is processed by using the Madgwick algorithm, which provides an accurate orientation of the user in the form of quaternion [7]. This system provides an absolute orientation from a relative one. Then, the quaternion is used to orient the position on the inner map.

Finally, an estimate of step length is used to carry out an exhaustive study of different methods. As an initial method, a simple way is used to calculate the step length in centimeters, l, shown in equation $l = hk$, where h represents the height in centimeters of the user and k is a constant that is 0.415 for men and **4.**
0.413 for women [8]. **5.**

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In future versions of the system, more efficient, precise and complex methods of estimating the length of steps will be implemented. In addition, a comparative study of the accuracy of the different methods will be carried out.

The steps that a user of the system must carry out during its use are:

1. The user enters its height the first time it uses the application, to calculate the step length.
2. The user scans the NFC tag located in the entry. This NFC tag contains some identification numbers that represent the building, entrance and floor. This information is important to place the user in the correct place inside the airport.
3. The user can see its initial position on the airport map.
4. The IMU unit starts collecting data and sending it to the user's smartphone. The Madgwick algorithm is used to obtain the real-time orientation. With the quaternary obtained by the algorithm and the step length, the user's position is displayed on the smartphone.

IV. IMU LOCATION SYSTEM

The main part of the indoor location system is the part related to the data collected from IMU and its treatment. In the proposed positioning system, an IMU Metawear CPRO is used that collects measurements of the 3 sensors, accelerometer, gyroscope and magnetometer, obtaining units *g*, *degrees/seconds* and *Tesla*, respectively. The complete specifications of the IMU unit can be found in [9]. This IMU unit transmits the data through BLE. The collected data is transmitted in real time to the smartphone where the different variables are processed, including the conversion of accelerometer units, g, to m/s^2, and the gyroscope units, *degrees/seconds*, to *rad/s*. Then the Madgwick filter is applied to obtain the quaternion that represents the pitch yaw and roll. With these data, step detection and step length, the user's position is displayed on the airport map each time it takes a step.

Different studies have been carried out on the use of filters in IMU units to improve the quality and reduce the noise in the data [10], which shows that the Madgwick filter is the most appropriate in this type of systems. This paper, as a complementary work, included the implementation of tests of three of the most used filters, a Kalman filter, a Mahony filter and the Madgwick filter. During the different tests, the Magdwick filter shows greater precision when comparing the actual position with that obtained in the Android application.

CONCLUSIONS

This work proposes a new indoor location system for airports that offers promising results. The combination of different technologies allows obtaining indoor location with a high level of precision. The use of a low cost IMUs implies that the system could be used by many airport users in the near future. During the simulations, a prototype of the Android application was developed to collect the information from the IMU, proceed with the different calculations, and show the best route on the airport map. Since the security of this type of systems is essential, several security algorithms have been implemented to avoid the possible traceability of the user by a malicious attacker. This is a work in progress, so several lines are still open. The first of them is the study of other sensor fusion algorithms that could be better adapted to the developed system. On the other hand, different security tests and controlled attacks are pending.

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REFERENCES

[1] V. Coskun, K. Ok, and B. Ozdenizci, "Near field communication (NFC): From theory to practice". John Wiley & Sons, 2011.

[2] M. M. Morrison, “Inertial measurement unit”, US Patent 4,711,125. Dec. 8 1987.

[3] W. Flenniken, J. Wall, and D. Bevly, “Characterization of various IMU error sources and the effect on navigation performance”, Ion Gnss, pp. 967–978, 2005.

[4] A. R. Jimenez, F. Seco, C. Prieto, and J. Guevara, “A comparison of pedestrian dead-reckoning algorithms using a low-cost MEMS IMU”,IEEE International Symposium on Intelligent Signal Processing, pp. 37–42, 2009.

[5] R. Van Der Merwe and E. A. Wan, “The square-root unscented Kalman filter for state and parameter-estimation”, IEEE International Conference on Acoustics, Speech, and Signal Processing, vol. 6, pp. 3461–3464, 2001.

[6] C. Gomez, J. Oller, and J. Paradells, “Overview and evaluation of Bluetooth Low Energy: An emerging low-power wireless technology”, Sensors, vol. 12, no. 9, pp. 11734–11753, 2012.

[7] B. K. Horn, “Closed-form solution of absolute orientation using unitquaternions”, JOSA A, vol. 4, no. 4, pp. 629–642, 1987.

[8] I. Bylemans, M. Weyn, and M. Klepal, “Mobile phone-based displacementestimation for opportunistic localisation systems”, IEEE International Conference onMobileUbiquitous Computing, Systems, Services and Technologies. pp. 113–118, 2009.

[9] MambientLab, “Metawear specifications”, https://mbientlab.com/docs/MetaWearCPSv0.5.pdf, accessed: 08/01/2017.

[10] S. O. Madgwick, A. J. Harrison, and R. Vaidyanathan, “Estimation of IMU and marg orientation using a gradient descent algorithm”, IEEE International Conference on Rehabilitation Robotics, pp. 1–7, 2011.

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