

## A Wireless Sensor Network based Indoor Localization System for Emergency Application Use

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**Abstract.** Every year, tragedy of indoor emergency accidents lead to immeasurable loss to families, bringing the society great shocks. This is mainly due to the harsh environment of emergency accidents, like firefighting, as the on-fire buildings are usually full of smoke and danger. One of the most directional issues is localization, as it is almost impossible to find the person trapped in the building without knowing the location. Localization is not only critical for evacuees seeking help from outside, but also important for self-evacuation. But unfortunately, a reliable and applicable indoor localization system is not available today, because of accuracy, cost and efficiency. In this paper, we present a novel localization system, which combines pedestrian reckon algorithm with wireless sensor network, hence providing an automatic and reliable solution towards this issue.

### 1. Introduction

As one of the most challenging technologies in localization based services (LBS), indoor localization has gained great concerns over the last decades.[1] Different from outdoor localization with the help of GPS, indoor localization is sensitive to lots of factors, lights, furniture, noise, metal, and etc[2]. So far, many systems have been developed to solve the problem, but almost all of them have certain restrains or flaws. None of them can take the advantage of all the others. According to the hardware deployment requirements, indoor localization systems can be classified into two categories: infrastructure-free and infrastructure-based. Infrastructure-based systems follow the principle of triangulation and direct-sensing, they localized by exchanging information with the installation of beacons at known position, e.g. Wi-Fi[3] and RFID[4]. Infrastructure-free systems are based on inertial sensors, which measure the movement of their own. They need little assistance from the environment, like pedestrian dead reckoning method, which estimate pedestrian location by cumulate movement in each step.

Originally PDR system consists of two parts: step estimation and heading determination [5]. PDR refreshes the position by adding the movement of current step to the previous one, and the process works recursively, without memorizing too much past localization information [6]. Hence it works simply and quickly. But there exists one big problem, that the error is accumulative, which would become intolerable as time goes on. [7] And this becomes the biggest restrain of PDR, to eliminate the error, system have to calls for assistance from the environment. Some systems integrate the PDR with RFID or Wi-Fi; they reset the error by a constant interval time. Some systems do path mapping, they construct the trajectory of the pedestrian and reset the error at the turning points [8]. The first categories have to rely on the installation and the second need to get the floor plan in advance. Both methods have certain restrains.

In this paper, we would present a reliable, accurate and self-adaptive indoor localization system based on wireless sensor network. The system decides the location by PDR algorithm, and interacts with the reference node, hence to eliminate the accumulation error. The collected data is process on the terminal center processor, which is capable to work in varies building and is adaptive to work in complex environment like indoor firefighting and indoor lifesaving.

## 2. System Overview

The system is designed to rely on wireless sensor network, which is mainly composed of reference anchors. The anchor has 2 kinds of devices as coordinator and router. The coordinator is an organizer which startups the network, joins new nodes, and dispels old nodes. It also records communication parameters and present information collected by sensor nodes. Routers are reference nodes for eliminating drift errors, forming an ad-hoc network and collecting sensor information. The wireless sensor network is designed to provide a base station for detecting, preventing and defending danger.

The functionalities are divided into 4 modules, as graph model, user lock-on, indoor navigation and motion engine. Graph model is designed to provide an optimal route for evacuees; motion engine is to detect the movement within each step, as walking forward, backward or turning around; user lock-on module is to estimate heading and initial position for starting the system; and indoor navigation is to provide the localization results as positions and attitudes.

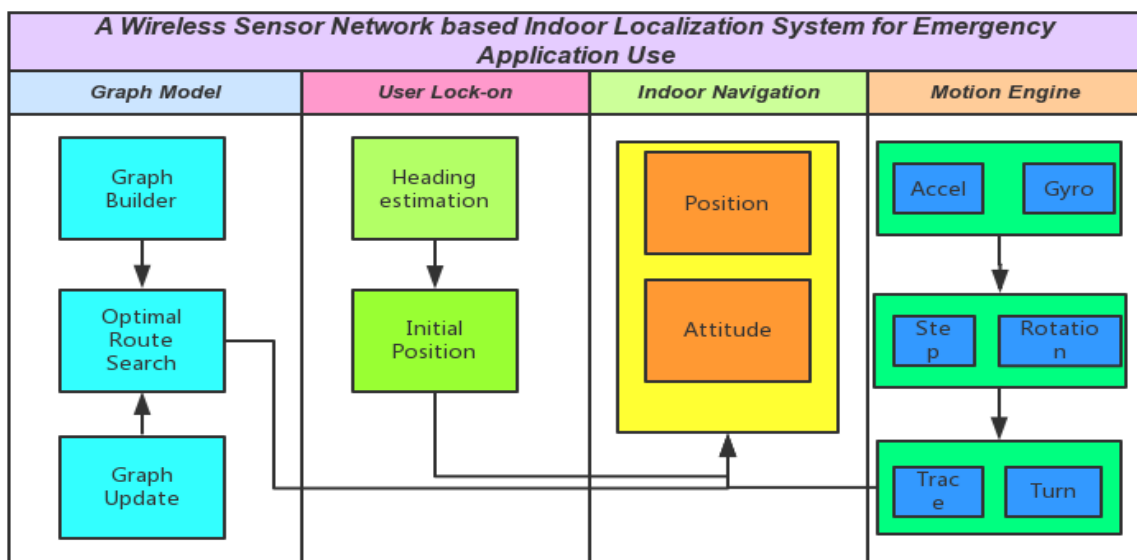


Fig.1. System diagram: First, graph model provides an optimal evacuating route, then user lock-on decides the initial status of the evacuee, next motion engine detect each movement and provides the localization results as positions and attitudes for tracking and life-saving use.

## 3. Pedestrian Dead Reckon

PDR locates the position by adding current step to previous movement, and the process is recursively as Eq. 1, where  $L_t$  is current step movement,  $\theta_t$  is the corresponding heading estimation, and  $X, Y$  are the coordinate, which represents the position.

$$\begin{cases} X_t = X_{t-1} + L_t \cos(\theta_t) \\ Y_t = Y_{t-1} + L_t \sin(\theta_t) \end{cases} \quad (1)$$

The moment the system starts up, user lock-on unit decides the initial position  $(X_o, Y_o)$ , then the motion engine keeps tracking the movement  $(\theta_t, L_t)$  during each step, with the help of trigonometric function, pedestrian dead reckon can hence decides the position for each step.

The algorithm is easy to implement, as it is a recursive process. And PDR can hence be divided into 2 section, step length and step heading. Deciding step length and heading hence become the main task of PDR algorithm.

#### 4. Motion Engine

We employ an inertial micro-process unit to record the movement, the IMU contains 3 modules, as accelerometer, gyroscope and magnetic. The accelerometer is capable to measure the gravity and extra forces results in acceleration, which can hence to determinate the direction and distance. It seems accelerometer is enough for PDR, but unfortunately, accelerometer may be affected by noise of measurement. The gyroscope is able to determinate the direction change, which hence can be utilized for heading estimation. However, gyroscope has a severer problem as drifting error, which means it can't provide a stable result for a long time. As for magnetic, due to the environment change and iron staff within the building, it may easily result in corruption and chaos, making it not applicable to use in an indoor application.

To solve the problem, fusing accelerometer and gyroscope measurement becomes a possible solution. Kalman filter is a typical one, which consists of 2 steps as estimation and measurement [9]. But it has several flaws, especially the computation cost due to high sample rate. So in this paper we utilize an algorithm that has been shown to provide effective performance at a low sample rate [10]. The algorithm employs quaternion for altitude representation. The formula calculation flow is show as Fig.2.

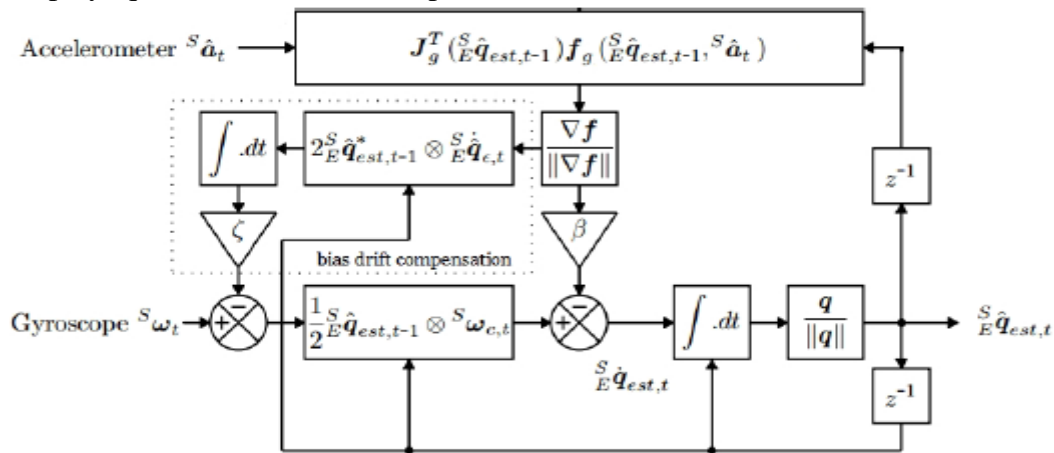


Fig.2. Formula flow: the algorithm utilize accelerometer for gravity direction and gyroscope for angle change rate. By combining the measurement from 2 different sources, it is more robust to reduce noise and drifting error.

#### 5. Accumulated error correction

Though the motion engine has fused accelerometer with gyroscope, the accuracy and reliability are still questionable; as PDR is recursive hence errors within each step are accumulated. This brings PDR method big error, making it not reliable for a long time.

To solve the problem, we employ wireless sensor network to correct the error. Because the reference node is at fixed position, once the evacuee comes by one of them, the absolute position is hence determinate. After the system refresh current position with the absolute position, the accumulated error is eliminated. The experiment result is shown as Fig.3

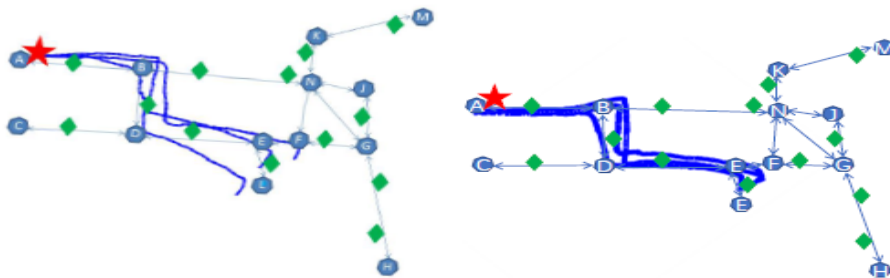


Fig.3 With the help of reference wireless sensor node, the system eliminates accumulated error.

## 6. Conclusion

This paper presents the design, implementation and evaluation of a reliable indoor localization system for emergency application use. It employs a low energy consuming wireless network for accumulation error elimination and the pedestrian dead reckon method for location estimation. The system is adaptive to vary environment change, and it is capable to work stably and efficiently. Compare to state-of-art frame subtraction method, our system can achieve an accurate and real-time result.

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