Using PIR Sensor Node and Distributed Wireless To Implement Human Localization

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ABSTRACT

There are many techniques exists, by which we can position humans using wireless devices such as smart phones in an outdoor environment using GPS, global positioning system. It is unfortunate that, this technology does not work in indoor environments.

In hospitals when tracking hospital beds and patients, in prisons in ord[1]er to track prisoners, in malls when a customer is searching for a store and in smart home to control electronic appliances motion detection and localization is necessary. Indoor positioning could also be used to analyze human behaviour. There are many several methods and techniques existing today that could benefit to an indoor positioning solution, all of them provide different results.

We can localize the human target by using distributed wireless **pyroelectric infrared (PIR) sensor**. The localization algorithm is used to get the data stream generated from different PIR sensor nodes within the wireless network. The Kalman Filter and Kalman Smoother are utilized to refine the estimation of the human position. We conduct simulations in a Matlab environment using Fuzzy Inference System Modeling tool and the average root-mean-square error (RMSE) of one or more human target tracking at different speed. The promising result confirmed the efficiency of our system.

Key words: Wireless Sensor Node, PIR, Motion Detection, RMSE, FKF.

1. INTRODUCTION:

In recent years, indoor positioning systems (IPSs) have become a growing field of research involving theoretical and applicative challenges. Object detection and tracking are the basis of many applications, such as surveillance and activity recognition. Numerous methodes have been proposed. Active badges are the first indoor location sensing system developed by AT&T Cambridge, which belongs to the Infrared technology. To provide better and more accurate indoor positioning, they developed an ultrasonic tracking technology, name bats. Distributed Object Locating System for Physical space Inter networking (DOLPHIN). To provide high temporal resolution and accurate Time of Arrival (TOA) measurements in multi-path environment, Ultra Wide band (UWB) impulse radio signals are employed for indoor location and tracking . Based on the Received Signal Strength Information (RSSI) attenuation, Radio Frequency Identification (RFID) was employed to estimate the distances between transmitters and receivers, and the position can be achieved with high accuracy. These systems have been successfully used in many applications such as asset tracking and inventory management. To implement human indoor positioning, device-free techniques are more suitable, because that means the human target does not have to wear any device. Recent advances in CCD technologies, processing speed and image understanding have been driving the development of the camera-based positioning systems. However, some disadvantages of continuous surveillance by video cameras are difficult to overcome. It is susceptible to light illumination, and its computational load for continuous surveillance is high. Most importantly, it is inevitable to violate the privacy, which will make the human target feel uncomfortable. Recently, more and more researchers employ the Pyroelectric Infrared Radial (PIR) sensors to achieve indoor positioning. In this paper we proposed the distributed wireless PIR sensor nodes, which give the tracking information. The simulation is done in Matlab to track and locate the path of human motion.

System Overview:

In this section, we proposed a human indoor localization system based on ceiling mounted PIR sensor nodes which are simulated in MATLAB.
Our tool works by performing following major task in series:

Device-Free Localization

Device-free techniques utilize the installed distributed wireless PIR sensor networks to detect changes in the environment and track the location of entities without attaching any special devices to the entities. It is useful in many applications such as intrusion detection and tracking for homes and offices, and security systems such as motion detection and video surveillance. Computer vision based approaches are considered as device-free; however, these techniques depend on ambient light and can only track objects that are within the line of sight of the camera. Radio tomography based techniques can track moving objects; however, these approaches are not scalable because of their high cost.

Localization using PIR Sensors

In our system, five sensor nodes are utilized to form distributed wireless sensor networks (WSNs). In each sensor node, reference structure is used to modulate the FOV of each PIR sensor. So the spatial information is embedded in the PIR signal triggered by the human movement. Spatial information will be decoded based on the coding scheme. There may chances of false triggering of sensor, in that case we will not receive accurate data. To calculate exact position Kalman filter, the Kalman smoother and the Fuzzy Kalman filter are applied.

Kalman Filter, Kalman Smoother and Fuzzy Kalman filter

Kalman filter is an algorithm that is generally used to reduce noisy data and provide estimate of parameters of interest. Kalman filter is used in many applications, including Global Positioning System receivers, tracking objects, phase-locked loops in radio equipment. They are also used in many computer vision applications. In our thesis work, we used Kalman filter to track the human subject and remove the noise in the system. We used the Kalman filter as suggested by Ramsey Faragher and Dave. the Kalman Smoother will be used to refine the location estimation of the human target. In our experiments we are tracking a human subject who could travel in two dimensions in real world. The human subject can travel in both X and Y directions. Fuzzy Kalman filter is used to provide accurate reading with less error. We conduct experiments in MATLAB environment, and the results confirm the efficiency of our system.

2. LITERATURE REVIEW:

This paper provides an overview of the existing wireless indoor positioning solutions and attempts to classify different techniques and systems. Three typical location estimation schemes of triangulation, scene analysis, and proximity are analyzed. We also discuss location fingerprinting in detail since it is used in most current system or solutions. [1]

This paper proposes a compact received signal strength (RSS) based real-time indoor positioning and tracking systems using CS theory that can be implemented on personal digital assistants (PDAs) and smartphones, which are both limited in processing power and memory compared to laptops.[2]

This paper aims to study the capability of Ultra Wide Band (UWB) communication technology to be used for indoor real-time positioning. The integration of an inertial measurement unit (IMU) to increase positioning accuracy was also evaluated. We designed and implemented a novel evaluation method for positioning systems that compares each of the position estimates with the ground truth position at the same moment.[3]

This paper presents a human indoor localization system using ceiling mounted pyroelectric infrared (PIR) sensors. The field of views (FOVs) of the PIR sensors is modulated by two degrees of freedom (DOF) of spatial segmentation. The localization algorithm is proposed to fuse the data stream generated from different sensor nodes within the wireless network. The Kalman Filter and Kalman Smoother are utilized to refine the estimation of the human position. [4]

This paper presents an algorithm of fuzzy based Kalman filter for trajectory estimation of dynamical objects. The Fuzzy subsystem is designed to tune dynamically the process noise covariance matrix of the discrete time Kalman Filter. The main adaptation strategy is based on the heuristic knowledge/practical expertise of the human observer/control engineer. [5]

3. PROBLEM STATEMENT:

In designing wireless PIR nodes using Kalman Filter and smoother various parameters are to be calculated such as motion path and RMSE are analyzed.

A human indoor localization system is used pyroelectric infrared (PIR) sensors wireless sensor node which is mounted on ceiling. The field of views (FOVs) of the PIR sensors is modulated by two degrees of freedom (DOF) of spatial segmentation. TO fuse the data from different sensor nodes within the wireless sensor network the localization algorithm is proposed. The Kalman Filter, Kalman Smoother and Fuzzy Kalman filter are utilized to get the estimation of the human position. We conduct simulation in a MATLAB environment, and the average root-mean-square error (RMSE) of single human target tracking at different speed is about 0.6 meter. The promising results confirm the efficacy of our system.

4. IMPLEMENTED WORK:

The MATLAB using FIS tools (Fuzzy inference System) software is used for the project. In this section , we present result of experiments carried out on MATLAB and evaluate the performance of the system.

Object Detection, Tracking And Smoothing:

In our system, there are eight sensor nodes s1 to s8 , forming a wireless sensor network (WSN). The objection space of each sensor node is overlapped to enhance the Localization precision by data fusion. Define $\mathbf{z}k$ as the target's estimated position (xk, yk) at measurement time tk. The choice of localization algorithm is based on the number of sampling cells being triggered simultaneously

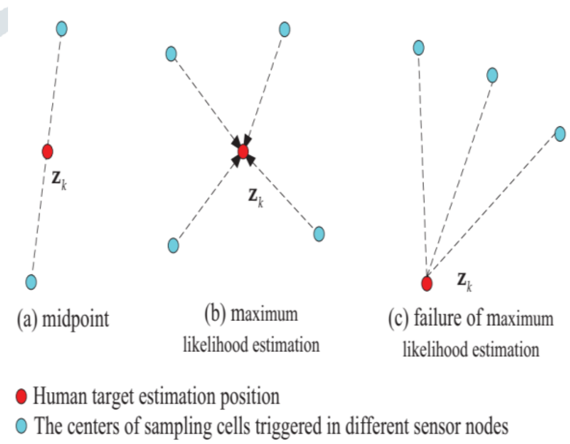

Figure 1 Localization Algorithms

Two sampling cells: the midpoint of these centers is regarded as $\mathbf{z}k$, as shown in Fig. 7 (a);
• More than two cells: Maximum Likelihood Estimation algorithm is used to figure out $\mathbf{z}k$, as shown in Fig. 7 (b).

However, sometimes this method will fail, as shown in Fig. 7 (c). The distance between the human target estimation position and three triggered sampling cells is the same, but obviously it is not correct. At such situation, we have to judge the relationship between the estimation position and sampling cells: if the estimation point **z***k* is outside the convex region formed by the cell centers, the geometric center of these cell centers will be the **z***k* estimation. The localization result **z***k* will be used as the measurement of the target's position in the tracking algorithm. The localization algorithm gives the measurement of the target's position denoted as **z***k*, so the measurement model is given by

$$\mathbf{z}_k = \mathbf{H}\mathbf{x}_k + \mathbf{n}_k \ldots\ldots\ldots\ldots (1)$$

where

$$\boldsymbol{H} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \ldots\ldots\ldots\ldots (2)$$

and $\mathbf{n}_k$ represents the measurement noise, with covariance $\mathbf{R}_k$.

Trilateration Method is used to estimate the location of target.

Kalman Filter and Kalman Smoother:

The Kalman filter is an efficient recursive filter that could estimate the state of a dynamic system from a series of incomplete and noisy measurements.

The discrete-time Kalman smoother, also known as the Rauch-Tung-Striebel-smoother (RTS) can be used for computing the smoothing solution for observation model.

The Fuzzy-Kalman Filter:

The output of Kalman Filter and smoother is applied to Fuzzy Kalman filter, it will remove the output of PIR sensor which is having more error. The error is identified from the measured distance, if the distance of target is more the chances of error will be more. FKF will remove those outputs and give more accurate result.

5. SIMULATION PARAMETERS:

Table 1: Simulation parameters

No. of nodes	8
Number of Target	1
Number of movement	10
Target motion speed	Slow, medium and fast
Filter	Kalman filter & smoother
Performance metrics	RMSE

Comparison:

Table 2: Comparison of parameter for different routing speed

Movements	Speed	RMSE Kalman	RMSE Kalman + Fuzzy
5	Slow	0.1280	0.0580
5	Medium	0.2570	0.0790
5	Fast	0.3350	0.0910
10	Slow	0.1480	0.0780
10	Medium	0.2770	0.0990
10	Fast	0.3550	0.1110
15	Slow	0.1630	0.0930
15	Medium	0.2920	0.1140
15	Fast	0.3700	0.1260
25	Slow	0.1797	0.1097
25	Medium	0.3087	0.1307
25	Fast	0.3867	0.1427
50	Slow	0.1997	0.1297
50	Medium	0.3287	0.1507
50	Fast	0.4067	0.1627

Comparison of parameter for different routing speed

CONCLUSION:

In this thesis we have implemented human indoor localization and activity recognition using distributed PIR motion sensors. We have implemented software Simulation setup to achieve this goal. In the hardware setup we assume Passive Infrared sensor node output, which provide human presence or absence and variation in signals based on activity of human target. Matlab was used to simulate to read sensor data received from the sink node. Post processing of data for localization and activity recognition was also implemented using Matlab platform. We have successfully implemented indoor human localization. Kalman filter and Smoother are used to find exact position and activity of target.

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