유비쿼터스 헬스케어를 위한 저비용, 수동형 실내 위치추적 시스템

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Passive and Cost Effective People Indoor Location Tracking System for Ubiquitous Healthcare

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요 약

유비쿼터스 헬스케어용 초음파와 RF 기술을 이용한 무선센서네트워크 기반의 실내 위치추적 시스템을 구현하고 테스트하였다. 개발된 실내 위치인식 시스템은 헬스케어를 위한 홈네트워크 장치의 하나로서 노인이나 만성질환자의 이동성과 활동성을 측정하는데 주안점을 두어 개발되었다. 천장에 설치된 비컨들은 RF 신호를 사용하여 위치정보를 listener에게 전송하게 되며, listener는 삼각측량법을 사용하여 3개의 비컨들로부터 얻어진 좌표 값을 계산하여 실내에서의 사람이나 물체의 위치 측정 뿐만아니라 환자의 활동성측정이 가능하도록 개발되었다. 본 연구에서는 위치에 대한 보안이 가능하도록 수동형식의 위치인식 시스템을 구현하고 비용절감을 위해 센서노드 사이의 연결이 무선으로 되도록 ad-hoc 알고리즘을 개발하였다.

ABSTRACT

Wireless sensor network plays a prominent role in tracking the location of the target outdoor and indoor. This paper describes the implementation of the passive indoor location tracking system using ultrasonic and RF technologies that provides accurate location in the form of user space and position in three dimensions. Our system used a combination of RF and ultrasonic technologies to provide a location-support service to users and applicants. Ceiling-mounted beacons were spread through the building, publishing location information on an RF signal. The person carried a listener and the listener determined the location by calculating the distance from three beacons using triangulation algorithm.

Keywords

Wireless Sensor Network, Ultrasonic, Listener, Beacons, Indoor Location, Space

Ⅰ. Introduction

Advances in the fabrication and integration of sensing and communication technologies have facilitated the deployment of large scale sensor networks. Typical indoor applications require different types of location information such as physical space, position and orientation. Tracking and analysis of human motion is a technology that has numerous commercial applications. One of the most important areas where the advantages of sensor networks can be exploited is for tracking mobile targets. Scenarios where such network may be deployed can be hospital (tracking the patient), home care (tracking the elderly person), tracking the activities of the suspicious person etc. The importance and promise of location-aware applications have led to the design and implementation of systems for providing location information, particularly in indoor and urban environments where the GPS does not work well [1]. There are many indoor locations tracking system available like RADAR [2], Active Bat [3], Active Badge [4] etc. User privacy, accuracy, architecture and cost etc. determine the usefulness of the tracking system. Our goal is to develop an architecture that is different from existing active indoor location systems like the Active Badge or Active Bat, which use passive ceiling mounted beacons. The active bat give the information to the beacons and the beacons calculate the position of the bat in active bat project. It has the disadvantage that we have to connect each beacons in ceiling. In our study, the passive location system was designed. Active ceiling mounted beacons give RF and ultrasonic signals to the active listener which combined with PDA terminal and carried by user. In this system the beacons were working as an active transmitters and the listener as a passive listener. It used a combination of RF and ultrasonic hardware to enable a listener to determine the distance to beacons, from which the closest beacon can be easily determined. This system used the decentralized mechanism i.e. all beacons were independent to each other and there was no need to connect each other.

Ⅱ. System Design

This indoor tracking system uses the commercialized motes with an ultrasonic sensor and a receiver, MCS410CA(Crossbow Technology Inc. USA)[5]. This sensor node is designed for low-power operation and can be used as a location-aware sensor computing node (running TinyOS[6]), to which a variety of sensors can be attached. Our system consists of location beacons that were attached to the ceiling of a building, and receivers, called listeners, attached to the target and the base station connected with a base node using RS-232 serial interface. The person to be tracked carries a listener. A beacon is a small device attached to some location within the geographic space it advertises. A listener is a small device that listens to message from beacons, and uses these messages to infer the space it is currently in. The listener, beacons, base node had same structure but we distinguish each other in their program. Beacons periodically transmit an RF message containing beacon specific information such as a unique space ID, the beacon's coordinates, the physical space associated with the beacon, etc. With an RF message it also sends an ultrasonic signal. As the speed of the RF signal is much higher (>=106 times) than the ultrasonic signal, the listener determines the time difference of arrival (TDOA) between these two signals. If the speed of the ultrasonic signal is known than by multiplying this speed with TDOA, determines the distance from the beacons. The listener listens from each beacon and calculates its distance from each beacon. At the same time the listener also transmits the distance message to the base station mote which is connected with a server PC. At the base station all the calculation is done and the space and the coordinate of the listener are determined. Our tracking system works on the triangulation algorithm[7]. For implementing this algorithm the listener at least receive three beacons message. The beacons are localized manually i.e. they are assigned the space ID and the three dimension coordinates by using a reference coordinate system. Space id is user- or application-specified names associated with spaces such as rooms or parts of rooms. The range of the beacons message also plays a prominent role as at least a listener should hear three beacon messages for determine its location. It should be insured that the beacons should not form a circle or square when deployed. The position of the target is calculated using triangulation algorithm at the base station. The GUI of the program running on the base station is developed in JAVA. The location of the listener is displayed on GUI and continuously updated as the user moves in the environment. Figure 1 shows the schematic of the proposed tracking system. The location information at the base station can be transferred further to the doctor's computer and the caregiver of that patient. We can make this system more effective by providing the information to the concerned person handheld devices.

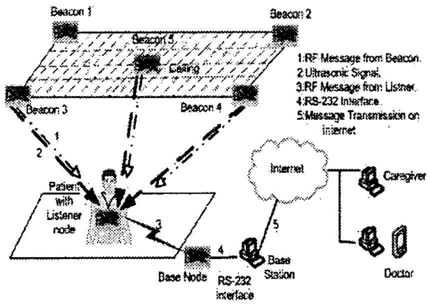

Fig. 1. Schematic of the proposed Location Tracking System.

III. EXPERIMENTAL TEST BED

Initially performance is evaluated using four beacons that were placed in the ceilings of a room and the target to be tracked carried the PDA attached with the listener . In the figure 2, the placement of the beacons in the ceilings is shown. For getting space information, beacons were named as DSU0, DSU2, DSU3, and DSU4 as per our convention. The target to be tracked was carried by the handheld device like laptop or PDA with a listener. The beacons send the messages one by one to the listener. The beacons message contains its location information in three dimensions with space information.

Fig. 2. Deployment of the Beacons in the Ceilings for Test.

In figure 2 the beacons'messages scheduling on the PDA was shown. The listener receives the messages and transfers the distance messages to the base station. At the base station the distance information is displayed on the GUI (graphical user interface) and further can be transferred to concerned authority. In figure 3, each beacons message arrival and the sequence as each beacon reaches at the listener is shown. In figure 4, the location of the target in 3D is shown and the location is continuously updated as the user moves in the environment.

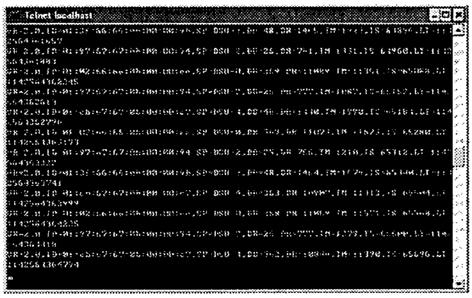

Fig. 3. Beacons Message arrival on the Listener.

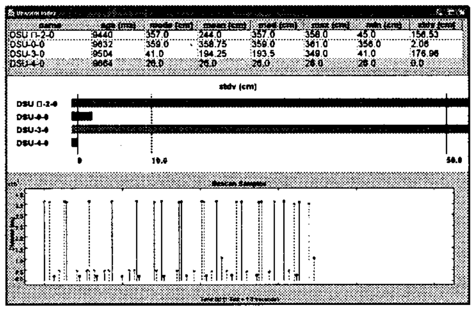

Fig. 4. Distance and Beacons Message Scheduling on the Base station.

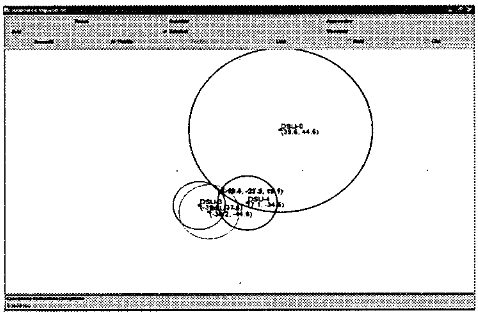

Fig. 5. Location information in three dimensions at Base Station.

IV. PERFORMANCE

The location of the target was tested by putting four beacons in the ceilings and the coordinate and space information was measured at the base station. The testing was done by putting the beacons 250 cm apart and 500cm apart As the user moves in this testing environment, his 3D coordinate and space information is determined at the base station and displayed on GUI as shown in the figure 5. The coordinate and space information provided by this tracking system sufficiently accurate as the comparison is done between this information and the information calculated by scale manually. The accuracy of the coordinate was 5~10 cm. As the distance between the two beacons increased beyond 500 cm the space information is correct but the accuracy of the 3D coordinates deteriorate. This accuracy problem can be recovered by putting the beacons closer to 500 cm. The location information provided by our system is sufficiently accurate and fine-grained for location awareness in context-aware applications. These result are determined by the performing experimental test under two various beacons position. Table 1 shows the performance comparison of existing systems in terms of parameters like cost, privacy, accuracy, scaling etc. Our proposed system has the advantages in terms of accuracy and cost among all existing indoor tracking methods.

V. FUTURE WORK

In the future effort will be made to evaluate the system performance under various environment. We are actively pursuing efforts in deploying experimental infrastructure and applications in our existing work environment. Finally a large-scale wireless sensor nodes deployment have to be done in wide floor of our new building, which we will occupy soon. Further work must now be done to design the map of the area where these beacons are deployed such that the healthcare processionals can find the persons location by seeing the map of the area.

VI. CONCLUSIONS

A location tracking system was designed for context aware application in ubiquitous healthcare which can track the elderly persons or patients location efficiently at home. Its innovative aspects include the use of beacons with combined RF and ultrasound signals in a decentralized, uncoordinated architecture. It uses independent, randomized transmission schedules for its beacons and a receiver decoding algorithm that uses the minimum of modes from different beacons to compute a maximum likelihood estimate of location. Using this kind of architecture and technique our system approach using wireless sensor network can play a vital role in human tracking and other context aware applications.

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Table 1. Performance comparisons of our system with existing systems

Network Type	System Name (Technology)	User Privacy	Cost	Accuracy	Device carried by Target	Scale	Research Center	Ref.
Satellite Network	GPS (RF)	Yes	High	1~5 meters	GPS Receiver	24 Satellites	Aerospace Corporation	1
Wired Network	Active Bat (RF+Ultrasonic)	No	High	9 cm.,	Active Bat	1 base per 10 square meter	Cambridge University	3
	Active Badge (Infrared)	No	High	Room Size	Active Badge	1 base per room	Olivetti Research Ltd.	4
WLAN	RADAR (RF)	Yes	Less	300 cm.	Mobile Device.	3 bases per floor	Microsoft	2
Active Tag	RFID (RF)	no	-	-	RFID Tag	-	HP	-
Wireless Sensor Network	Cricket (RF+ Ultrasonic)	Yes	Medium	3~10 cm.	Cricket mote with PDA	1 beacon per 16 square ft.	MIT	8
	Our System (RF+Ultrasonic)	Yes	Low	4~12 cm	mote	1 beacon per 16 square ft.	**Dongseo University**	-