INDOOR WIRELESS LOCALISATION NETWORK USING A MOBILE PHONE INTERFACE

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Abstract: In recent years, indoor localisation and movement tracking of people and objects has generated interest for a variety of applications ranging from transport to health care. We present a localisation network designed to track people in an indoor environment. The localisation network consists of static nodes placed at predetermined locations in a building. Users carry a mobile node to track their current position. The mobile node has onboard motion sensors to detect a person's heading direction and motion state. A dynamic tracking mode was used to determine a person's position. The dynamic tracking model was implemented using a Multi-Hypothesis Estimation algorithm. The dynamic tracking model determines the mobile node's position by using the mobile node's proximity to static nodes, mobile node's motion sensor information and the building's floor-plan. We found that by using a multi-hypothesis estimation algorithm, robust localisation accuracy, could be achieved in real-time. The position resolution of the localisation network was found to have a maximum error between 1m and 3.5m. Further work involves extensive testing the localisation network with multiple mobile nodes and over a larger test region. Other areas involve investigating how multiple mobile nodes placed on a user can be used to improve the estimate of the user's position.

1 INTRODUCTION

Tracking the position of people or objects has uses for a wide range of applications in transport management, agriculture and health domains. Our paper presents a wireless localisation network that uses inertial sensors to track a person's position in an indoor environment. The localisation network also used a dynamic tracking model based on a Multi-Hypthosis Estimation algorithm. The dynamic tracking model allowed the localisation network to achieve robust localisation accuracy with low cost inertial sensors and radio transceivers.

The localisation network consists of static nodes placed at predetermined positions throughout a building. The user carries a mobile node which localises their position. The static nodes are used to determine the presence of the user within a particular region of a building. The user's position is determined by the dynamic tracking model. The dynamic tracking model uses the mobile node's movement information (heading), proximity information from the nearest static node and building's floor-plan to track the mobile node. The user can also view their current position using a mobile phone.

Our localisation network architecture is based on the localisation network by Klingbeil et al (Klingbeil and Wark, 2008). One of the disadvantages of that Localisation Network was the use of power consuming sensors in their mobile node, such as a magnetometer to detect a user's heading with respect

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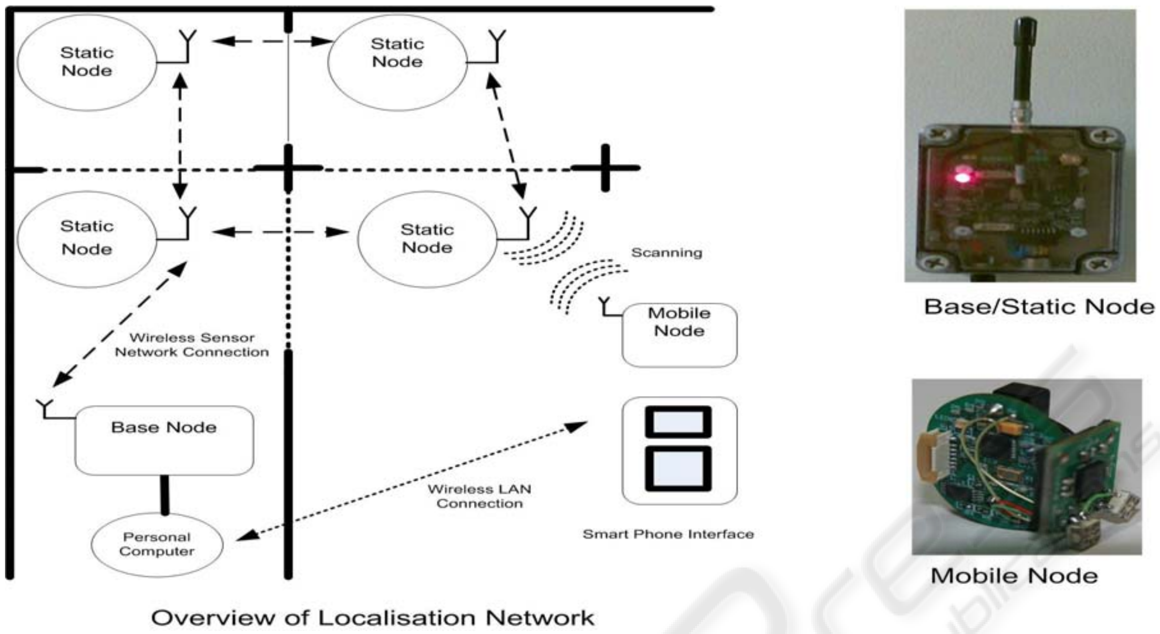

Figure 1: Localisation Network Overview.

to magnetic north. Another disadvantage was the use of a relatively large mobile node, which was found to be too cumbersome to attach to people.

Our localisation network uses the Fleck Nano wireless sensor platform to implement the mobile node and the Fleck^{TM}-3 wireless platform for the static nodes. The Fleck Nano platform was designed to be a small, inexpensive wireless sensor with minimal computation resources that can be used to complement other sensor platforms.

The contributions of this paper can be summarised as:

- Implementation of a localisation network for position tracking.
- Experimental use of small, unobtrusive, wireless sensors for position and motion monitoring.
- Use of a Multi-Hypthesis Estimation based dynamic position tracking model.
- Development of a mobile phone user interface.

This paper is organized into 6 sections. Section 2 presents a review of related work. Section 3 discusses the implementation of the localisation network. Section 4 presents the dynamic position tracking model. Section 5 discusses the testing conducted. Conclusions and futher areas of investigation are discussed in Section 6.

2 RELATED WORK

Different types of wireless technologies, such as GPS have been investigated for outdoor and indoor location systems. Unfortunately, GPS is not suitable for indoor use and this has led to research into the use of other wireless technologies including UWB (Schwarz et al., 2005), ultrasonic and GSM (Otsason et al., 2005) platforms.

Lamarca et al (Hightower et al., 2006, LaMarca et al., 2005) describes the Placelab geophysical location system which localises users in an urban environment. The Placelab system uses the Received Signal Strength Indicators (RSSI) from Wireless LAN hotspots and GSM broadcast towers to determine a user's position. The Placelab software uses a database of known wireless LAN hotspots and GSM broadcast towers. The Placelab software can be used with a PDA or laptop with wireless LAN or GSM connectivity. Localisation accuracy is stated as being less then GPS, with 20-25m using wireless LAN and 100 to 150m for GSM broadcast towers.

A classical case of using wireless beacons for navigation is the Active Badge project, presented in (Want et al., 1992). The Active Badge project achieved a 5-10m accuracy using infrared. The main drawback of this platform is that it required line of sight between beacons.

An extension of the Active Badge project was the ORL location system by (Ward et al., 1997) which developed a prototype network of ultrasonic beacons to perform real-time tracking of tagged mobile devices in an office environment. Other ultrasonic location systems such as the Cricket Mote (Priyantha et al., 2000).

3 LOCALISATION NETWORK

An overview of the localisation network, seen in Figure 1, consisted of static nodes placed at predetermined positions on a building level. The mobile node is carried by a user, which localises their current position. The static nodes are used to determine a mobile node's regional position and general heading. The base node displays the current position of the mobile nodes. This section describes an overview of the network topology and also describes the implementation of the localisation network.

3.1 Base Node

The base node was implemented using the Fleck™-3 wireless sensor platform (Corke et al., 2007). This platform has been used for a variety of wireless sensor applications particularly for environmental monitoring (Corke et al., 2007). The Fleck™-3 uses the Atmega128 micro-controller along with the Nordic NRF905 radio transceiver operating in the ISM band. The Fleck™-3 also incorporates a real-time clock chip to reduce micro-controller overheads for timing operations.

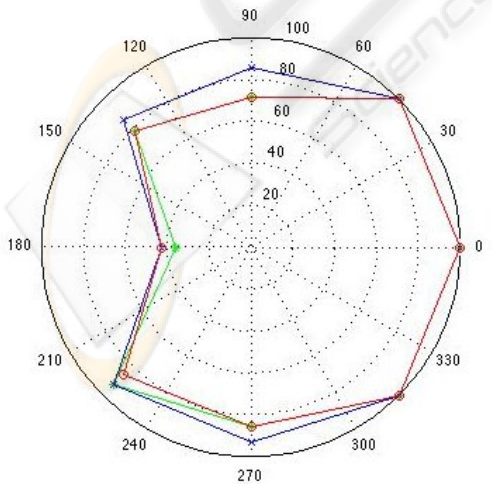

Figure 2: Fleck Nano Packet Delivery Ratio (%) vs Antenna Angular Direction.

An operating system called Fleck Operating System (FOS) was used to provide a priority-based, non-preemptive (cooperative) threading environment. This has the advantage of a simple concurrent programming model. All application software on the static and base nodes ran on top of FOS. The static node can be seen in Figure 1.

The base node is connected via a serial connection to a Personal Computer (PC). The PC implements the dynamic position tracking model used to track the location of the mobile node. The model displays a building floor-plan with the current position of the mobile node.

3.2 Static Node

The Static Node was also implemented using the Fleck™-3 platform. The primary function of the static node is to compute the packet delivery ratio of nearby mobile nodes. The packet deliver ratio is calculated by counting the number of messages received from the mobile node. Once the mobile node's current packet delivery ratio has been calculated, it forwards this and the mobile node's accelerometer data to the base node.

The static nodes are connected to the base node via a wireless multi-hop network. The wireless multi-hop network employs the Link Quality Multi-Hop Network Routing communication protocol (Stephen et al., 2008). The advantage of using a wireless multi-hop network is that static nodes only have to be within range of at least one other static node. This allows static and base nodes to be easily deployed in an indoor environment. Each static node will relay a received message to either the base station or the nearest static node neighbour.

3.3 Mobile Node

The Fleck Nano platform was used to implement the mobile node. It consists of a Nordic 915Mhz RF transceiver, onboard microcontroller, a 3-axis accelerometer and 2-axis gyroscope for motion detection. Figure 1 shows the Fleck Nano as a mobile node. It uses a coin cell battery as a power source. The dimensions are 25mm x 20mm. The Fleck Nano's small physical profile and onboard accelerometer is advantageous for our application because it is unobtrusive. The range of the Fleck Nano's RF transceiver's range was limited to approximately 7m by setting the lowest transmission power level. This allows improves the localisation resolution of the mobile node.

Figure 3: Mobile Phone User Interface Application.

The packet delivery ratio was used to estimate the link quality of the RF Channel because the Fleck Nano's Nordic RF transceiver does not detect the RSSI of intercepted transmissions. Packet delivery ratio is a measure of many packets was received over a wireless link. The directional sensitivity of the Fleck Nano was measured in terms of antenna angular direction and packet delivery ratio. Figure 2 shows the angular direction sensitivity of the Fleck Nano's antenna, which was tested by rotating the Fleck Nano away from a static node. The Fleck Nano has a high packet delivery ratio in its forward direction (0 degrees) but a poor packet delivery ratio in its reverse direction (180 degrees).

The two inertial sensors integrated with the monitoring node were an accelerometer and a gyroscope. Accelerometers measure the acceleration force caused by walking. The accelerometer used on the mobile node was the SCA3100 3-axis accelerometer from VTI Technologies (VTI Technologies). The SCA3100 has a sensitivity of 20mg and a maximum range of ±2g. The dynamic position tracking model used the accelerometer information to determine if the mobile node was moving.

The gyroscope was used to determine the heading of the user by measuring how much the user has turned horizontally. Gyroscopes measure the angular velocity of a moving object. The angular velocity can be used to measure the directional heading the object is moving in. The 2-axis gyroscope module used was the IDG-300 (InvenSense) from Invensense. The IDG-300 has a maximum range of ±500°/s.

Figure 4: Graphical User Display showing the Floor-Plan.

Red Circles represent Static Nodes, Green Dots represent position estimates, Blue Dots high light nearest Static Node and Red line illustrates path of Mobile Node.

3.3.1 Mobile Phone User Interface

A Nokia N96 Mobile Phone can be used to view the user's current position. The Mobile Phone communicates via a Wireless LAN connection to the base node's PC as seen in Figure 1. The mobile phone interface is shown in Figure 3. The mobile phone application dynamically updates the display using the coordinates calculated by the mobile node. The application was implemented using Python scripting.

4 DYNAMIC POSITION TRACKING MODEL

The Dynamic Position Tracking model used a Monte Carlo Multi-hypothesis estimation algorithm or Particle Filtering. The model runs on a PC and positions are updated every time a packet is received from a mobile node. Figure 4 shows the graphical user interface, which displays the current position of a mobile node on the building's floor-plan. The model computes the mobile node's position by combining three key pieces of information:

- Proximity of static nodes determined by the mobile node's packet delivery ratio.
- Motion and heading information derived from the onboard inertial sensors.
- Position of the mobile node on the floor-plan.

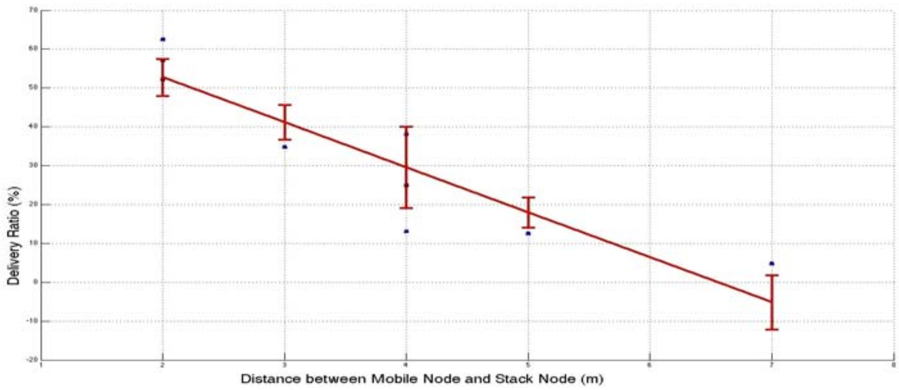

Figure 5: Separation Distance between Mobile and Static Nodes (m) vs Packet Delivery Ratio (%).

As shown in Figure 4, each green dot or particle represents a random estimate of the mobile node's position. The red circles represent the static nodes. The blue dots highlight the static node within range of the mobile node. The mobile node's path is shown by the red line. The dynamic tracking model uses the static-mobile node proximity and the mobile node's motion information (acceleration movement and angular heading) to estimate the next position of each particle (green dot). The position of the mobile node is computed by averaging the coordinates of the particles' positions.

4.1 Proximity Estimation

The proximity of the mobile node to static nodes is determined by the packet delivery ratio. Figure 5 shows the linear relation between the packet delivery ratio and the separation distance between the static node and sequence number. The separation distance between the static and mobile node is used by the dynamic tracking model to estimate a region where the mobile node is likely to be situated.

4.2 Heading Estimation

The packet delivery ratio is also used to estimate the heading of the mobile node. Figure 2 shows the relation between the packet delivery ratio and the mobile node's antenna angular direction. The mobile node's onboard motion accelerometer and gyroscope sensors are also used to determine it's heading. The acceleration sensor is used to determine if the mobile node is moving and the gyroscope is used to estimate the direction the user has turned. The gyroscope can be used to detect sudden changes in heading that cannot be detected using the packet delivery ratio and antenna angular direction relation.

4.3 Floor-Plan Map

The floor-plan map was used by the dynamic tracking model to ensure that the mobile node's estimated position was valid. Validity is determined by checking if the mobile node has to transverse through a wall or barrier, in-order to move to its predicted position. If this is found to be the case, then the dynamic tracking model will then re-estimate the mobile node's position until it determines that the node's position is in a valid location.

5 EVALUATION

Initial testing of the localisation network involved placing static nodes in the level of a building and having a user walk around while carrying a mobile node. Testing was also performed using a robot that moved at a constant velocity. Initial test showed that the static nodes should be placed 5m apart provide the most optimal coverage for the mobile nodes' packet delivery ratio to be reliably estimated and for the mobile node to relay its onboard motion data to the base node via the static nodes. The position resolution of the localisation network was found to have a maximum error between 1m and 3.5m.

6 CONCLUSIONS AND FURTHER WORK

In this paper we presented a localisation network that tracks people in an indoor environment. The localisation network consisted of static nodes placed at known positions in a building. Users carry a mobile node to track their current position. The static nodes communicated with a base node that was connected to a PC. The dynamic tracking model, implemented on the PC, determined a user's position based on a Multi-Hypothesis Estimation algorithm.

The base and static nodes were implemented using the Fleck^{TM}-3 platform. Our localisation network uses the Fleck Nano platform for mobile inertial sensing. The Fleck Nano platform is ideal for our purposes because it has an onboard integrated microcontroller and wireless transceiver, an accelerometer for inertial sensing and also has a small form factor. The user was also able to use a mobile phone to view their current position. The mobile phone was connected via a WLAN link to the base node's PC.

We also developed a dynamic position tracking model for improving the localisation tracking of the mobile node. The model used a Monte Carlo Multi-hypothesis estimation algorithm. The model determines the mobile node's position by combining the mobile node's proximity to static nodes, heading from onboard gyroscope and antenna angular position and the building's floor-plan. We found that by using multi-hypothesis estimation we could achieve robust localisation accuracy, in realtime. The position resolution of the localisation network was found to have a maximum error between 1m and 3.5m.

Further work involves extensive testing the localisation network with multiple mobile nodes and over a larger test region. Other areas of investigation involve looking at how multiple mobile nodes placed on a person, can be used to improve the estimate of the person's position. We will also investigate the use of the motion sensitive mobile phones for estimating a person's position.

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REFERENCES

Corke, P., Valencia, P., Sikka, P., Wark, T. & Overs, L. (2007) Long-duration solar-powered wireless sensor networks. *Proceedings of the 4th workshop on Embedded networked sensors.* Cork, Ireland, ACM.

Hightower, J., LaMarca, A. & Smith, I. E. (2006) Practical Lessons from Place Lab. *Pervasive Computing, IEEE,* 5**,** 32-39.

InvenSense *IDG-300 Integrated Dual-Axis Gyroscope,* 2009, http://www.invensense.com/products/idg_300.html.

Klingbeil, L. & Wark, T. (2008) A Wireless Sensor Network for Real-Time Indoor Localisation and Motion Monitoring. *Proceedings of the 7th international conference on Information processing in sensor networks.* IEEE Computer Society.

LaMarca, A., Chawathe, Y., Consolvo, S., Hightower, J., Smith, I., Scott, J., Sohn, T., Howard, J., Hughes, J., Potter, F., Tabert, J., Powledge, P., Borriello, G. & Schilit, B. (2005) Place Lab: device positioning using radio beacons in the wild. *Pervasive Computing. Third International Conference, PERVASIVE 2005. Proceedings (Lecture Notes in Computer Science Vol. 3468). Springer-Verlag. 2005***,** 116-33.

Otsason, V., Varshavsky, A., LaMarca, A. & de Lara, E. (2005) Accurate GSM indoor localization. *UbiComp 2005: Ubiquitous Computing 7th International Conference, UbiComp 2005. Proceedings (Lecture Notes in Computer Science Vol. 3660) . Springer-Verlag. 2005***,** 141-58.

Priyantha, N. B., Chakraborty, A. & Balakrishnan, H. (2000) The Cricket location-support system. *MobiCom 2000. Proceedings of the Sixth Annual International Conference on Mobile Computing and Networking. ACM. 2000***,** 32-43.

Schwarz, V., Huber, A. & Tuchler, M. (2005) Accuracy of a commercial UWB 3D location/tracking system and its impact on LT application scenarios.

Stephen, R., Wen, H. & Peter, C. (2008) An empirical study of data collection protocols for wireless sensor networks. *Proceedings of the workshop on Real-world wireless sensor networks.* Glasgow, Scotland, ACM.

VTI Technologies *Data Sheet: SCA3100-D04 3-Axis High Performance Accelerometer With Digital SPI Interface,* 2009, http://www.vti.fi/midcom-serveattachmentguid-15dea0383c2711ddbf604fe1cb479fb09fb0/sca3100-d04_accelerometer_datasheet_82_688_00_d.pdf.

Want, R., Hopper, A., Falcao, V. & Gibbons, J. (1992) The active badge location system. *ACM Transactions on Information Systems,* 10**,** 91-102.

Ward, A., Jones, A. & Hopper, A. (1997) A new location technique for the active office. *Personal Communications, IEEE [see also IEEE Wireless Communications],* 4**,** 42-47.