Indoor Navigation Using Smartphones

Nagesh Potdar, Dipak Pawar, Sachin Jain, Bhumil Haria, Seema Shrawne

Abstract— This project is for implementation and analysis of the usage of smart phone sensors for indoor navigation, without the use of Global Positioning Systems. This is to extend advantages of outdoor navigation for indoor navigation, by making use of existing technologies and devices to facilitate navigation for achieving this, without the use of extra/expensive hardware.

Keywords— Navigation, local positioning system, motion tracking, smart-phone, GPS alternative

I. INTRODUCTION

This paper details the development of an indoor navigation system on a smart-phone running Android operating system. Research of previous work in the field preceded the development of a new approach that uses data from the device's accelerometer, and compass to determine user's position, direction of motion. A routing algorithm calculates the optimal path from user position to destination. This technique shows promise for future handheld indoor navigation systems that can be used in malls, museums, hospitals, and college campuses. The problem with indoor navigation using outdoor locating systems is that the signals used by outdoor locating technologies are often inadequate in this setting. Systems that rely on the use of cellular communication signals or identification of nearby Wi-Fi access points do not provide sufficient accuracy to discriminate between the individual rooms of a building. GPS based systems can achieve sufficient accuracy –and even this is not always true- but are unreliable indoors due to signal interference caused by walls, floors, furniture, and other objects. Due to these limitations, navigation inside unfamiliar buildings is still accomplished by studying large maps posted in building lobbies and common areas. If created, a system capable of locating a person and directing them to their destination would be more convenient and would provide functionality that a static wall map cannot.

II. POTENTIAL TECHNOLOGIES

The proliferation of mobile devices and the growing demand for location aware systems that filter information based on current device location have led to an increase in research and product development in this field.

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***** Correspondence Author (s)
Nagesh Potdar, Computer Technology Department,Veermata Jijabai Technological Institute, Mumbai, Maharashtra, India
Dipak Pawar, Computer Technology Department,Veermata Jijabai Technological Institute, Mumbai, Maharashtra, India
Sachin Jain, Computer Technology Department,Veermata Jijabai Technological Institute, Mumbai, Maharashtra, India
Bhumil Haria, Computer Technology Department,Veermata Jijabai Technological Institute, Mumbai, Maharashtra, India
Seema Shrawne, Computer Technology Department,Veermata Jijabai Technological Institute, Mumbai, Maharashtra, India

However, most efforts have focused on the usability aspect of the problem and have failed to develop innovative techniques that address the essential challenge of this problem: the positioning technique itself. These are some of the current technologies that may be used for positioning.

- Satellites
- Cellular communication network
- Wi-Fi
- Bluetooth
- Infrared

However, due to their scale, they are not sufficiently accurate. Therefore, we introduce the idea of inertial navigation systems for positioning, that is, using sensor data from accelerometers and gyroscopes for accurate detection of movement.

III. INERTIAL NAVIGATION SYSTEM

An Inertial Navigation System (INS) is a navigation system that estimates the devices current position relative to the initial position by incorporating the acceleration, velocity, direction and initial position. An INS system typically needs an accelerometer to measure motion, a gyroscope or similar sensing devices to measure direction, and a computer to perform calculations. The position relative to initial position can be calculated from the accelerometer measurements, which provides movement information relative to a previous location. With the accelerometer alone, the system could detect relative motion. The use of additional hardware such as a compass is necessary to tell the direction of movement. The output of the accelerometer is a measure of the acceleration in three dimensions; the velocity in an inertial reference frame can be calculated by integrating the inertial acceleration over time. Then the position can be deduced by integrating the velocity. The INS is usually subjected to "integration drift," which is the error in measurement of acceleration and angular velocity. Since these errors are integrated each iteration, they will be compounded into greater inaccuracy over time. Therefore, it is necessary to employ error correction mechanisms to restrict error propagation in INS.

A. *Dead Reckoning*

Dead Reckoning (DR) is the process used to estimate the position of an object relative to an initial position, by calculating the current position from the estimated velocity, travel time and direction course. Modern inertial navigation systems depend on DR in many applications, especially automated vehicle applications. A disadvantage of dead reckoning is that the errors could be potentially large due to its cumulative nature.

The reason is that the new position is estimated only from the knowledge of a correct previous position; therefore any probability of error will grow exponentially over time. Another challenge of this approach is implementation on personal device is difficult due to the low quality sensors available. The sensor noise will blur the signal and increase the potential error. A method developed by the Geodetic Engineering Laboratory of EPFL utilizes a low cost inertial system that detects human steps and identifies the step length based on biomechanical characteristic of the step. The type of step can depend on different factors such as gender, age, height and weight of the person. Their model is constructed and tested with blind people whose steps vary greatly depending on familiarity with the area.

B. *Map Matching*

Map matching is a method for merging data from signal positioning and the digital map network to estimate the location of the mobile object that best matches the digital map. The reason that such techniques are necessary is that the location acquired from positioning techniques is subject to errors. Map matching is often helpful when the position is expected to be on a certain path, such as in the problem of tracking a moving vehicle on the route of GPS device.

Figure 1 provides a general system block diagram of a map matching process. The inputs of the process are a digital map and positioning data. The digital map data is not a graphical picture representation of an area but often in the form of a list of polylines in a graph. The positioning estimates are often not on the polyline provided, but scattered due to errors in the positioning system. The map matching process will produce outputs that lay on the polyline. An example output is a GPS device in a driving vehicle that matches the position of the car to the nearest road.

Figure 1: Using Map matching to estimate the position of device

IV. MAPPING TECHNIQUES

Mapping a building involves gathering information that describes the building's layout and converting this information into a form that is usable by other processes. Types of data typically extracted include:

- The location and size of walls, hallways, doors, floors, staircases, elevators, windows, etc.
- Position of the map relative to other locations (latitude and longitude, elevation, floor number, orientation)

The navigation process finds the shortest path from the current location determined by positioning techniques to a desired destination within an unfamiliar area.

A. *Mapping Information Formats*

There are currently two common formats for building mapping information:

- Two-dimensional map images are often posted to provide aid in navigation or to show fire escape routes. The appearance of these maps varies depending on the software used to create them or applicable building standards. The information that can be gathered from a map image is primarily the floor plan of a building. The scale and coordination are generally not present, but can be found in more technical maps such as printed blueprints.
- Three-dimensional building models are available for structures constructed recently that were designed with 3-D modeling utilities. This form of building mapping stores much more information than the two dimensional images. Scale, Height, and connections to other floors are all available. These models do not provide information regarding the location and orientation of the building. The primary limitation of this file format as a resource is that it is available for few buildings.

B. *Map Creation Techniques*

To make map images or models useful in software applications they are often converted into a new data structure, which provides the necessary information in an accessible format. There are four aspects of spatial relationship that a map data structure often needs to represent: connectivity, proximity, intersection and membership. Different map data structures may focus on some aspects more than others. In one example a map creation process was used to convert to a data structure composed of points, arcs and polylines that represent different objects like rooms, doors, corridors, and stairs. If the raw data is a CAD file, the process is simpler because the structure has already been decomposed into simple elements. Less complex processing techniques are necessary. If the map layout is in an image format such as .jpg, .png, or .pdf the process of converting from raw data to a primitive data structure requires the use of image processing techniques including object recognition and data filtering. If a lower quality format is obtained (i.e. a photograph) further steps to correct skewed perspectives or discoloring could be necessary.

C. *Graphing Representation*

In order to perform graphing algorithms to determine the shortest path between two locations, it is necessary to convert the representation of a map data structure from layout with walls, halls, and doors structure into nodes and links. In graphing representation, rooms, intersections, staircases, elevators and other building units will be represented by nodes while the hallway will be represented by links that connect between nodes. A node will also carry information related to the location including coordination, and a link to a software database so that a user can get more information about the person which the room belongs to. A link between two nodes represents an existing path in the building where a person can walk between two locations directly. The assignment of the nodes is constructed so that every link must be a straight line and represents the actual direct line of sight path.

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Curves and turns will be represented by more than one link. The reason for this design is for the algorithm to perform effectively.

D. *Routing Algorithm*

Routing techniques use algorithms that find the shortest path between two locations. Typically a link relationship between nodes in a graph will be represented by a two dimensional matrix. The relationship between nodes is the weight or the cost of traveling from one to the other such as distance, time, or degree of convenience. The relationship can also be represented by a list of edges. The choice of data structure will affect the size of the database as well as the performance of the algorithm. Some common algorithms are Dijkstra, Ford-Bellman, and A*. We have used Dijkstra's algorithm, explained below.

Dijkstra's Algorithm

Dijkstra's algorithm is one of the most used routing algorithms. The Dutch scientist Edsger Dijkstra invented the algorithm in 1959. This algorithm is suitable for problems dealing with a single source node and one or more destination nodes. The algorithm works by advancing a single node at a time, starting from the source node. At each step during the loop, the algorithm chooses a node that has the minimum cost from the source node. This node has been visited from the source and has not yet been optimized. This node is then marked as optimized and the cost to all the adjacent nodes will be evaluated. The Dijkstra algorithm is mathematically proven to find the shortest path. The optimized cost to the destination is found once the algorithm reaches the destination nodes. The path can be deduced inversely by creating a tracking array.

V. Positioning

The capability to determine a user's position within a building is a necessary part of a navigation system. The system described in this project uses measurements from compass, magnetic, and acceleration sensors to estimate the user's position. The inertial navigation system is presented consisting of the acceleration and magnetic sensors.

Inertial Navigation System

The inertial navigation system computes a new position relative to an initial reference position. It uses data from the motion sensors to detect movement. An inertial navigation system design involves four different phases: calibration, alignment, state initialization, and current state evaluation.

Figure 1: An inertial navigation system design

1. **Calibration:** This stage provides coefficients for use in the interpretation of the raw motion sensor output.
2. **Alignment:** This stage provides the axis and orientation to interpret the calibrated data in relation to the Earths coordination.
3. **State Initialization:** This stage provides the initial position and velocity, which it gets from another reference positioning method.
4. **Current State Evaluation:** This stage computes the position relative to the reference position.

VI. Conclusions

Three objectives were identified that embody the functionalities necessary in an indoor positioning system. First, the device must be capable of determining its location in the building. Second, it must be capable of determining the optimal route to a destination. Third, an intuitive user interface must provide the user with access to these features.

Contributions made through the completion of this project include the use of an integrated propagation model to simulate wireless propagation and hence negate the need for data collection in a Wi-Fi- fingerprinting like system. The development of these techniques make possible an innovative approach to the challenge of indoor positioning and navigation that is less difficult to implement and is compatible with existing handheld devices.

The application can be implemented in large places such as malls, college campuses, museums or hospitals. The idea of the indoor navigation system is to allow people to navigate themselves around unfamiliar places. This application could be integrated into a large mapping system for an entire city that integrates outdoor GPS based systems with multiple indoor navigation systems. Combining this application with RFID technology, it could be used in supermarkets for quick navigation and access.

References

I. Silke Feldmann, Kyandoghere Kyamakya, Ana Zapater, and Lue Zighuo, "An indoor Blutooth-based positioning system: concept, Implementation and experimental evaluation," Institute of Communications Engineering, Hanover,.

II. Changdon Kee et al., "Centimeter-Accuracy Indoor Navigation," GPS World, November 2001.

III. Kamol Kaemarungsi and Prashant Krishnamurthy, "Modeling of Indoor Positioning Systems Based on Location Fingerprinting," 2004.

IV. Vasileios Zeimpekis, George M. Giaglis, and George Lek, "A taxonomy of indoor and outdoor positioning techniques for mobile location services," sigecom Exchange, 2003.

V. E. W. Dijkstra, "A Note on Two Problems in Connexion with Graphs," Numerische Mathematlk 1, pp. 269-271, 1959.

Nagesh Potdar is a Sun Certified Java Programmer and is currently pursuing his B. Tech Computer Engineering in VJTI, Mumbai.

Born on 23rd October,1990, he started programming since he was in Grade 9. He bears keen interest in Unsupervised Machine Learning Models & developing technology aimed at aiding the poor & underprivileged.

Dipak Pawar Computer Science undergraduate student from VJTI,Mumbai. He had worked as intern at Cisco Systems during summer of 2011 on android project. He is currently working as intern at Mirraw and will be joining Microsoft as SDE from October 2012.

Sachin Jain He is a final year undergraduate from VJTI with computer as a major. He is a coder who intends to do research in algorithms, and looks at hislef dealing with finance and analysis in related fields. A person who wants technology and management to go hand in hand.

Bhumil Haria is currently pursuing his B. Tech Computer Engineering in VJTI, Mumbai. He has keen interest in technology in general, and in software design and scalability, automation and robotics in particular.

Mrs. Seema Shrawne graduated with a Bachelor's Degree in Engineering in computer science from Government College of Engineering, Amravati, in 1992. She has been a Senior lecturer in the computer technology department at Veermata Jijabai Technological Institute, Mumbai (India) for the last 11 years. Her areas of interest are Databases, Computer Networks and Information Retrieval, System Security.

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