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Wearable Navigation System for the Visually Impaired and Blind People

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***Abstract*- A wearable navigation system for visually impaired and blind people in unknown indoor and outdoor environments is presented. This system will map and track the position of the pedestrian during the exploration of the unknown environment. In order to build this system the well known Simultaneous Localization and Mapping (SLAM) from mobile robotics will be implemented. Once a map is created the user can be guided efficiently by a route selecting method. The user will be equipped with a short range laser, an inertial measurement unit (IMU), a wearable computer for data processing and an audio bone headphones. This system does not intent to replace the use of the white cane. However, the purpose is to gather contextual information to aid the user in navigating with the white cane.**

***Keywords*—Wearable computing; Pedestrian Navigation; Visually Impaired and Blind People**

I. INTRODUCTION STATE OF THE ART

Computer science researches in recent years have been focusing their work in the area of healthcare. The goal is to assist and aid people with technology in their daily life. The visually impaired and blind people have the need of support for interacting with the world in the same way a seeing person would do. Available solutions helping visually impaired and blind people to read, write and navigate have still the need of improvement.

Navigation in unknown outdoor and indoor environments for visually impaired and blind people is a major problem to be solved. Navigation systems are available; however they are not capable of providing the precision that the visually impaired and blind people require. The lack of precision is due to the localization method used and the guiding through selected routes. These methods have to be categorized into two groups, outdoor and indoor navigation support.

For outdoor localization for example GNSS, field strength measurements (WLAN, GSM, Bluetooth), PDR, etc. [2] are possible solutions. Preferred methods for indoor localization are the use of pre-installed indoor communication infrastructures, laser, radar, sonar, camera, motion sensors, etc. Assuming that not all buildings have a pre-installed communication infrastructure, the field strength measurements methods cannot be used if one requires an infrastructureless support. For a precise indoor independent localization, it is crucial to perform sensor fusion [2].

A precise navigation system intended for visually impaired and blind people in indoor and outdoor environments necessarily needs to integrate the different available localization methods.

To cover all scenarios for outdoor localization a GPS based method in combination with PDR can be used. In an indoor environment the well known approach for mobile robots simultaneous localization and mapping (SLAM) is a possible solution. The required sensor data for SLAM can be provided in this case by a body worn inertial measurement unit (IMU) and a laser scanner.

Blind pedestrians will explore the unknown environment while the system builds a map and simultaneously tracks the position of the person.

The main goal of the system is, once a map is constructed of the unknown environment, to be able to take decisions on choosing safe and effective routes to guide the blind person from a starting point to destinations previously explored. The best way to provide orientation commands to the blind person is via audio. Since blind people rely on external audio information, the use of conventional head phones is not an appropriate solution because these cover the ears of the person. The solution for this purpose is the use of bone phones transmitting audio information at the back of the ear via the bone [6].

II. STATE OF THE ART AND NAVIGATION OF UNKNOWN ENVIRONMENTS

For the millions of people around the world who have a visual impairment, technological and non-technological innovations have contributed fundamentally to their quality of life. Thanks to modern technology it is possible to browse the web, send and receive e-mails almost as easily as a sighted person does. This is enabled by two factors: computer hardware and software interfaces that try to present information through speech or using Braille, and the fact that many web pages and applications are designed due to accessibility requirements.

When it comes to navigating in the physical world the scenario is more complex; in fact navigating independently in unfamiliar environments is nearly

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impossible for someone who does not pick up much of the contextual mostly visual information provided by the environment. For instance, if a person found him/herself in a random building, a quick glance around the current location tells a lot already about the building. Things such as signs, furniture, corridors and staircases, and the view from windows can tell about the purpose of the building, and a location can be approximated from the outside view. Most of this information will be completely missed by someone who cannot pick it up with the eyes, and so a major challenge is to design a system that can transmit this information, or provide the knowledge in another way.

A blind person navigates in a highly structured manner using both physical and artificial landmarks. Examples of the former include walls, pavement edges, material changes and auditory information such as the beeps of a traffic light or how the sound reverberates in the location. Artificial landmarks are, for example, "third door on the left" when walking in a corridor. Since route familiarity is important, it is desirable to reuse as much of a route as possible, because straying from the path might means probably a complete loss of the route. If this should happen, it is important being able to retrace back to a known landmark in order to regain the sense of location and orientation. Routes that stay fairly static might often be preferred because of the lower risk of encountering a large obstacle forcing a different route.

Unless the visually impaired person walks with someone else, there are two widely employed solutions to make navigating easier: the white cane and the guide dog. They both provide basic assistance in avoiding obstacles and detecting stairs. Though the guide dog can learn routes and help much more than the cane when something has changed along the route. The cane on the other hand is very simple and is intuitively to use because it behaves like an extended arm. Because of this, it is easy to trust completely in the information the white cane provides.

Aside from the white cane or the guide dog, some navigation systems (known as electronic travel aids, ETA's) specifically designed for the visually impaired are available [5]. These range from simple sound-emitting beacons that can be positioned in strategic places of the environment, to Smartphone's with GPS. This can be useful at a high level but it has some major disadvantages. Firstly it is based on static maps and therefore cannot provide dynamic information on-the-fly, and secondly it does not work indoors. The GPS devices that are tailored for the visually impaired, like they usually have some extra features like easy tagging of locations, route logging and retracing functionality, and a "where am I?" feature which tries to describe the current location in terms of tagged locations around it [4].

III. SIMULTANEOUS LOCALIZATION AND MAPPING

Simultaneous Localization and Mapping (SLAM) is a well-known approach in mobile robotics. This is the process in which a mobile robot can build a map of the environment and at the same time computes its location [8].

The essential SLAM problem can be explained with the following diagram of Fig. 1.

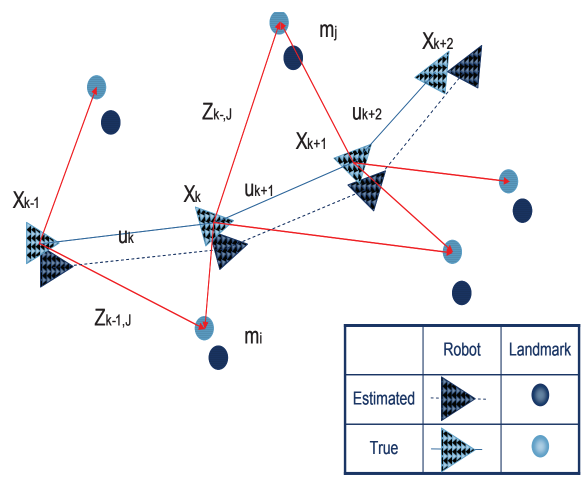

Figure 1: SLAM diagram

At the instant of time k the following quantities are defined:

x_k: The state vector describing the location and orientation of the mobile robot.

u_k: The control vector, applied at the instant of time k-1 to drive the mobile robot to a state x_k at time *k*.

m_k: A vector describing the location of the i^{th} landmark whose true location is assumed time invariant.

z_{ik}: An observation taken from the mobile robot of the location of the i^{th} landmark at time k.

The diagram in Fig.1 shows a mobile robot that moves in an unknown environment. This robot is equipped with sensors that provide observations of different landmarks and its odometry. The observation of landmarks can be obtained with a laser scanner [11] that provides distance and angle obtained from different positions. Landmarks are features in an environment that can be used as reference and for the registration of multiple scans when combining different measurements from various positions. Landmarks are chosen by their uniqueness of features, this property makes it easy to find them again in the environment. For example, in an indoor environment, landmarks could be walls, corners, edges or more specific obstacles [8]. So basically the SLAM approach is to obtain an estimation of the position based on different types of observations. An extended explanation of the SLAM problem can be read at H. Durrant-Whyte et al[8].

Mapping can be accomplished by using a grid mapping method. It basically works by dividing the environment into small grids and deciding whether a grid is occupied or not by scanning the environment. If a grid is occupied, the system assumes a solid object there, marked on the emerging map.

IV. Pedestrian Dead Reckoning (PDR)

PDR is a form of positioning based on a known starting point. Based on the initial location the pedestrian is tracked with every move made. Thus it is possible to estimate new positions any time. One form of tracking the movement of a pedestrian is by using an inertial measurement unit (IMU), which usually contains accelerometers, gyroscopes and magnetometers. This can be placed on different parts of the pedestrians' body to detect movements. The most precise way to obtain step length and direction from the pedestrian is done by a foot mounted IMU. Step length can be calculated by using the acceleration vectors obtained by the IMU [2]. Direction or orientation on the other hand can be obtained by fusing gyroscope and magnetometer data. However, the magnetometer data is not always consistent with the true orientation [3].

V. Wearable Navigation System

A. Indoor Navigation

The SLAM approach of mobile robots can be used for pedestrians (visually impaired and blind) adapted to specific movement conditions. Pedestrians have a much more complex odometry than mobile robots. They differ with respect to the type of movements and the involved degrees of freedom. The laser scanner position with mobile robots is fixed relative to the surface [11]. This cannot be guaranteed for pedestrians. Furthermore, the measures of the human body are individual for each person, as is motion. Thus, the challenge is to extract the odometry for each pedestrian and to obtain stabilized laser scanner data.

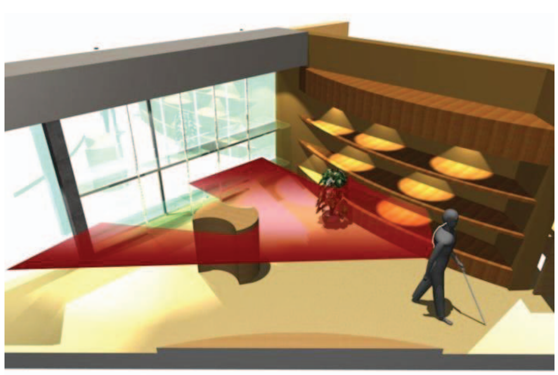

Figure 2: Blind pedestrian wearing the SLAM system

To extract precise pedestrian odometry, step length and orientation a foot mounted IMU will be used. The pedestrian is exploring an unknown environment, so there won't be a fixed known starting point (See Fig. 2).

For landmarks observations the pedestrian will be equipped with a short range laser scanner in the low back area. The decision to place it there is due to its stability avoiding interference from the hand by using the white cane. To obtain horizontal laser scans, the raw data will be projected onto the horizontal plane with an IMU that is placed underneath the laser scanner.

With the data from the sensors (IMUs and laser scanner) it is possible by using the Extended Kalman Filter to achieve a precise localization. Simultaneously with the scanner reading a map of the environment will be constructed by using the above mentioned grid mapping.

The pedestrian can interact with the system, by adding important landmarks or preferred locations in the environment, while exploring.

Once the user has a map the position can be tracked in the previously unknown but once personally explored environment. The navigation is supported by audio commands of the system.

The data processing will be accomplished by the wearable computing devices. The system will be totally independent of any network or networked computer.

B. Indoor Open Space Navigation

In indoor open spaces the mapping problem has to be addressed in a different manner due to the short range of the laser scanner. Here the system will place anchors with specific coordinates and create a map based on them. The global map will be formed out of micro maps, like shown in Fig. 3. Each of these anchors has a specific position and the anchors are connected with each other.

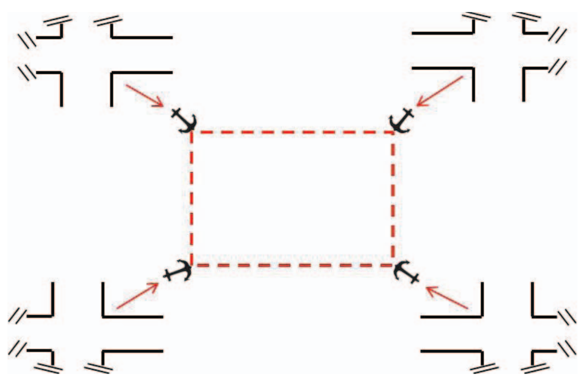

Figure 3: Anchor mapping

Pedestrian navigation in the micro maps will be achieved by SLAM-PDR and between anchors just by PDR.

C. Outdoor Navigation

GPS based navigation cannot be used in a straight forward manner, due to measurements errors and the lack of outdoor maps suited for pedestrians. PDR will therefore be incorporated. The system will guide the pedestrian starting from GPS fixed points by PDR enabling a precise navigation. PDR navigation has an accumulative error [2]. However this will be set to zero each time the pedestrian reaches a GPS fixed point.

D. Route Planning

In case a map was constructed of an environment the main goal of this system is to implement an algorithm capable of finding the most appropriate route guiding blind or visually impaired pedestrians from a starting point to a desired destination on the available map.

Seeing persons explore an unknown environment most of the time searching for visual landmarks helping them in navigation and avoiding to get lost. Once they feel familiar with an environment, seeing pedestrians will usually select the most efficient (shortest) route to arrive at a desired destination. This is not appropriate for blind and visually impaired people.

Blind pedestrians are not able to recollect visual information of the environment. The system will be in charge of doing so. Once the blind person has explored the unknown environment the available for future navigation has to provide this information in an convenient way.

Blind persons returning into a once by them explored environment will provide the guidance within the map. For an effective route selection the system will consider convenient features of the path and avoid unnecessary challenges. Blind people prefer to walk in straight lines and aside walls. Big open spaces, stair cases, and cross roads they like to avoid.

The route planning will be active; , it will recalculate the route as the blind person is . Thus occurred changes like mobile land marks will be taken into account providing alternative paths if available.

User interaction is crucial for adding contextual information and deciding if the selected route was according to the preferences of the user. This is enabled by a personalized route selection. Once the system has found a route satisfying the user needs, it will guide with updated contextual information.

Conclusions and Future Work

This paper presents an integrated framework of a precise navigation system for visually impaired and blind people. It uses pedestrian tracking methods, SLAM as known from mobile robots, and GPS. The importance of a for the blind and visually impaired adapted route planning is shown. The system could be for those people a great improvement allowing the navigation and exploration of unknown environments.

Tests with visually impaired people will be performed. General preferences for indoor at outdoor navigation will be studied. Based on these results the system will be implemented for route planning of visually impaired and blind people.

The system has currently been tested with recollected data, and field tests with visually impaired and blind people are planned.

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