

Smart Indoor and Outdoor Guiding System for Blind

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ABSTRACT: This paper presents a smart system for visually impaired, that makes use of ultrasonic sensor and camera. The main aim of this work is to design a voice based alerting system for the blind people. Visually impaired individuals find navigation difficult as they struggle everyday in performing actions for bypassing obstacles and hurdles in their path. In order to help blind people navigate safely and quickly this system is proposed. Ultrasonic sensor is placed on the spectacle which is used for obstacle detection with distance indication. The camera is used to detect the object in front of the blind people and alert them using APR voice module. This system prevents the blind people accidents and identifies the object in front of them.

I. INTRODUCTION

The visually impaired people usually have difficulties in walking in an unfamiliar and complex place independently. To provide them an automatic navigation device with effective guidance on their move, three problems should be considered:

1. Where is the person? The device has to know where the person is located in order to make a correct decision for guiding the person. This refers to be the localization problem.
2. Where does the person want to go? In order to help the visually impaired person reach his destination, the device has to identify the destination. This is known as goal recognition.
3. How does the person get there? This includes way-finding, route following and obstacle detecting. Way finding is to plan a shortest path from the starting position to the destination, route following is to make sure the blind person follow the planned path and obstacle detecting is to help him avoid obstacles.

So far, there are many navigation systems trying to solve the above problems, such as the low-cost white cane, guide dog and ETAs (Electronic Travel Aids). However, white cane is unable to find a globally shortest path and provide the location information. Guide dog is incapable of detecting overhanging object, and needs costly training, which may be unaffordable to the visually impaired individuals. Most existing ETAs are only intended for obstacle detecting or/and feedback, and cannot provide way-finding and route following functions. Although some ETAs were designed with way-finding and route following functions, such as the cactus tree based algorithm, obstacle (especially the dynamic

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 8, Special Issue 2, March 2019

obstacles) detecting and avoiding are ignored. A wearable indoor navigation system based on visual marker recognition and ultrasonic obstacle perception, but the localization precision is not high enough for guiding the blind due to the error increase of the inertial measurement sensor, and the goal recognition scheme is less efficient on planning a global path. A successful navigation system for the blind is the visual SLAM (Simultaneous Localization and Mapping) and Po I (Point of Interest)-graph based indoor navigation system. However, the obstacle detection heavily relies on the white cane swaying, which is not efficient and portable.

This paper aims to develop an effective wearable navigation system which can locate the user, follow the virtual-blind-road and avoid obstacles at the same time, in order to provide automatic navigation for the visually impaired people. The main contribution of this paper is the proposal of a novel dynamic sub-goal selecting based virtual-blind-road following scheme which combines the obstacle avoiding algorithm for guiding the blind people to follow the globally shortest virtual-blind-road without collision. This scheme can help the visually impaired people to avoid obstacles while following a path precisely to the destination, which realizes the automatic navigation for them. As the GPS-based blind navigation technology cannot be used due to the severely degradation of GPS signal in indoor environment, the visual SLAM (e.g. ORB-SLAM (Oriented Brief-SLAM) was adopted in this paper for the building of the virtual-blind-road and the localization. The Section II reviews the related works on the navigation for the visually impaired in indoor environment. The hardware configuration of the proposed navigation device is presented in Section III. Section IV describes the navigation scheme in detail. .

II. RELATED WORK

Navigation for the blind in indoor environment should consider the problems of localization, way-finding, route following and obstacle detecting. Many ETAs were reviewed in details, which utilize ultrasonic, laser scan, camera or multi-sensor fusion technology for obstacle detecting and/or avoiding. These ETAs can help the visually impaired avoid the obstacles, but they are unable to provide the location information, and do not have way -finding and route following functions. Thus, the related works on localization, way-finding and route following for blind navigation in indoor environment are reviewed in this section.

A. Indoor localization

Indoor localization can be broadly classified into two categories: wireless localization and vision-based localization. There are many wireless localization systems that utilize UWB (Ultra Wide Band) radar, RFID (Radio Frequency Identification), ZigBee, Bluetooth and Wi-Fi. UWB radar has been a particularly attractive technology for indoor localization because it is not susceptible to interference from other signals (due to its drastically different signal type and radio spectrum), and the UWB signal (especially the low frequencies included in the broad range of the UWB spectrum) can penetrate a variety of materials, including walls. UWB radar achieves very high localization accuracy, which can be up to 10cm. However, the slow progress in the UWB standard development has limited the use of UWB in consumer products and portable user devices. RFID based systems can be used for localization and object tracking as they have a reasonable range, low cost and can be easily embedded in the tracking objects. However, the limited range makes them unsuitable for high precision indoor localization. ZigBee is concerned with the physical and MAC (Media Access Control) layers for low cost, low data rate and energy efficient personal area networks. It is favourable for localization of sensors in WSN (Wireless Sensor Network), but it is not suitable for indoor localization as it cannot provide the distance between the user and the labelled sensor. Most of the existing Bluetooth based localization systems rely on RSSI (Received Signal Strength Indicator), however, they are prone to multipath fading and environmental noise, lower localization accuracy due to its signal band (2.4 G) which is the same with other signals. Thus, only Bluetooth based localization system has very large uncertainty in localization Most of portable consumer devices (e.g. smart phones, laptops) are Wi-Fi enabled, which makes Wi-Fi an ideal candidate for indoor localization. However, existing Wi-Fi networks are normally deployed for communication (i.e., to maximize data throughput and network

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 8, Special Issue 2, March 2019

coverage) rather than localization purposes. Therefore their localization accuracy still needs improvement. Moreover, all these systems require special hardware.

The vision-based localization takes advantage of image processing and objects recognition. An effective way for indoor navigation using IMU (Inertial Measurement Unit) in conjunction with QR (Quick Response) code was proposed in QR code based system requires proximity recognition; nevertheless, the blind people have difficulty in approaching the QR code. Therefore, it is inappropriate to blind localization. Recently visual SLAM technology including state filter based SLAM and pose-graph SLAM become more and more popular in indoor navigation as its localization error can be effectively reduced at a loop-closing point and the positioning accuracy can be up to the centimetre scale. Besides, the visual SLAM based localization systems require no other special hardware except for a camera, stereo camera or RGB-D camera. Therefore, the visual SLAM was utilized to locate the visually impaired individuals accurately in this paper.

B. Way-Finding and Route Following

The sparse map built by visual SLAM module becomes a kind of PoI-graph after some PoI were tagged on it. This PoI-graph was utilized in this paper as the global map. There are many PoI-graph based way-finding algorithms, such as Dijkstra, etc. However, this is not the focus of this paper. It is just for providing the global path (i.e. the path to be followed). Hence, any of these algorithms can be used for planning the globally shortest path. In this paper, algorithm was adopted as the way-finding algorithm.

After the globally shortest path from the starting position to the destination was found, the route following algorithm will provide accurate guidance information to ensure that the user can follow the globally shortest path and avoid obstacles. The route following algorithm in takes the globally shortest path and a priori knowledge of indoor environment as inputs, and outputs a control strategy that makes the user's trajectory remain close to the globally shortest path. It selects some special nodes (e.g. entrance node, room node and intersection node, etc.) as sub-goals to guide the user. The method proposed a path deviation detecting method which is based on measuring the similarity between the current frame and the training frame of the pre-defined path. However, the dynamic obstacles and changes of the environment were not considered. Hence, it is not able to help the blind avoid dynamic obstacles. To overcoming the above problems, a dynamic sub-goal based route following algorithm was proposed in this paper. The sub-goal is selected dynamically, which includes but is not limited to the special node as mentioned in. The above route following algorithm combining the obstacle detecting method which takes the dynamic obstacles and changes of environment into account, and the globally shortest path, output the optimal walk able direction to ensure the user follow the globally shortest path closely, meanwhile, avoid obstacles.

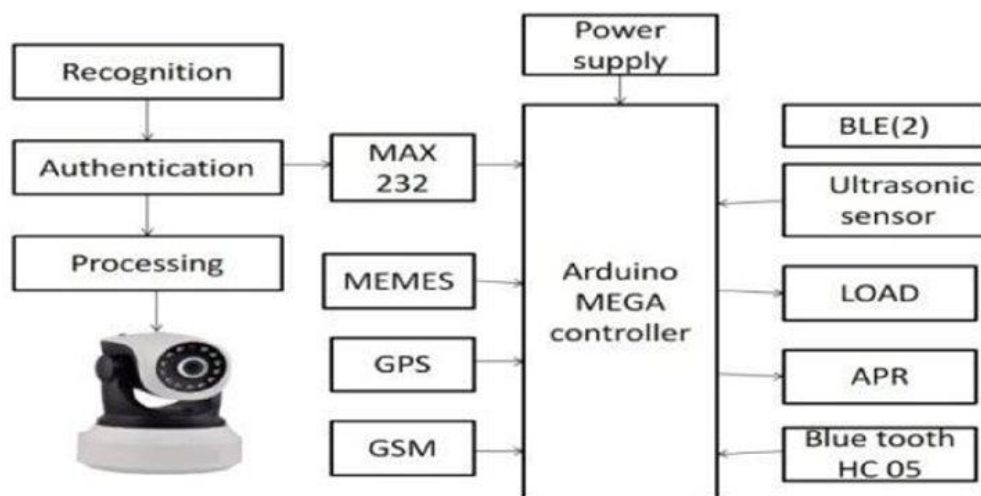
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Vol. 8, Special Issue 2, March 2019

III. HARDWARE CONFIGURATION



BLOCK DIAGRAM OF PROPOSED SYSTEM

The proposed navigation device consists of a fisheye and a depth camera, an ultrasonic rangefinder, embedded CPU board, a pair of OST (Optical See-Through) glasses, and an earphone. These sensors are low cost, small volume, and easy integration, and thus can be widely used in consumer market. The depth camera and the fisheye camera are used for building the virtual-blind-road and locating the user precisely with visual SLAM algorithm. Besides, the depth camera is also used for obstacle detection. To compensate for the limitations of the depth camera, such as passing through the transparent objects, being absorbed by some special materials, etc., the ultrasonic rangefinder is utilized. It consists of an ultrasonic sensor and a MCU (Micro programmed Control Unit) to measure the distance of an obstacle in front of the user. Fusing the depth camera and the ultrasonic rangefinder for obstacle detection can ensure adequate safety of the visually impaired individual. The CPU operates at 1.44GHz with a 2 GB RAM. All the algorithms such as visual SLAM, obstacle detecting, way-finding, route following, speech synthesis, etc. are performed on the CPU. The OST-glasses have two display screens for displaying the guiding information and surrounding information to the partially sighted individual. In addition, the glasses have two loudspeakers for playing the guiding sound. The earphone is used for playing the guiding sound to the totally blind individuals when they are in a noisy indoor environment (e.g. supermarket).

IV. THE NAVIGATION SCHEME

The architecture of the proposed navigation system which includes visual SLAM, Po I-graph, way finding, obstacle detection and route following module. The rendering module converts the guiding information produced by the navigation system into audio or/and visual cues. The obstacle detection and rendering modules have been presented in our previous work, and thus will not be repeated here. The visual SLAM module utilizes the RGB image and depth image to build the virtual-blind-road (offline) and locate the user (online). After the virtual-blind-road is tagged with some key positions (offline), it becomes a sparse map (i.e. Po I-graph). The way finding module plans a globally shortest path from the starting position to the destination according to the Po I-graph. The obstacle detection module provides many candidates walk able directions according to the current depth image. The route following module takes the current pose of the blind user, the globally shortest path, the candidate walk able directions, and the obstacle

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Vol. 8, Special Issue 2, March 2019

distance measured by the ultrasonic rangefinder as inputs, and uses a dynamic sub-goal selecting method to produce the guiding information. This allows the user to follow the globally shortest path as closely as possible and avoid obstacles at the same time.

The ORB-SLAM2 was utilized in this paper. It has three main parallel threads: Tracking, Local Mapping and Loop Closing. The tracking thread can locate the camera through feature matching with the local map. The local mapping thread can insert new point into the local map and optimize the local map by performing local BA (Bundle Adjustment). The loop closing thread can detect large loops, and optimize the pose graph. Besides, the loop closing thread will launch a fourth thread to perform full BA after the pose graph optimization, to compute the optimal global structure and motion solution.

In this paper, the ORB-SLAM2 was used to solve two main problems:

1.) Building the virtual-blind-road. Before providing navigation information for the visually impaired, it is necessary to build the virtual-blind-road. The virtual-blind-road is built by a sighted person wearing the proposed navigation device and performing all threads of the ORB-SLAM2. The virtual-blind-road is actually the motion trajectory of the sighted person. The process of building the virtual-blind-road is completed offline.

2.) Locating the user. When navigating the visually impaired to walk from the starting position to the destination, only the tracking thread of the ORB-SLAM2 is operated for localization.

V. CONCLUSION

Our project presents a smart system for visually impaired, that makes use of ultrasonic sensor and camera. The main aim of this work is to design a voice based alerting system for the blind people. Visually impaired individuals find navigation difficult as they struggle everyday in performing actions for bypassing obstacles and hurdles in their path. In order to help blind people navigate safely and quickly this system is proposed. Ultrasonic sensor is placed on the spectacle which is used for obstacle detection with distance indication. The camera is used to detect the object in front of the blind people and alert them using APR voice module. This system prevents the blind people accidents and identifies the object in front of them.

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