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Current status and future prospects of SLAM technology in the field of blind navigation

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Abstract. This comprehensive review paper explores the progressive integration of Simultaneous Localization and Mapping (SLAM) technology within the realm of blind navigation. The study delves into the current landscape of research and practical implementations where SLAM techniques are harnessed to empower visually impaired individuals in navigating their surroundings. The paper takes a focused approach by elucidating the advancements achieved through RGB-D-based SLAM navigation systems and the intriguing developments within the realm of LSD-SLAM-based navigation. A paramount facet of this exploration involves the design and deployment of interactive devices that bridge the gap between blind individuals and navigation systems. Notably, the paper examines the intricacies of these interaction interfaces, highlighting their pivotal role in enhancing the efficacy and user-friendliness of SLAM-driven navigation. Furthermore, this review critically assesses the existing limitations that persist within the current application of SLAM technology for blind navigation. The discussion encompasses challenges related to environmental diversity, real-time processing constraints, and the need for robustness in complex scenarios. By acknowledging these limitations, the paper paves the way for a comprehensive examination of potential avenues for refinement and enhancement. In conclusion, this paper serves as a comprehensive guide to the progressive incorporation of SLAM technology into blind navigation. It underscores the transformative potential of RGB-D and LSD-SLAM systems, underscores the significance of interaction interfaces, and underscores the evolving trajectory towards a more inclusive and efficient navigation solution for the visually impaired.

Keywords: SLAM, blind navigation, RGB-D, LSD-SLAM, interaction interfaces.

1. Introduction

According to the World Health Organization (WTO), a total of 210 million people worldwide suffer from some degree of vision loss, of which about 3.6% are severely visually impaired or completely blind [1]. It is estimated that visual impairment costs US $411 billion in lost productivity each year [2]. Among people with visual impairments, traditional guidance measures such as guide sticks and guide dogs have their limitations, such as the inability to cover all areas in front of a blind person that may be at risk [3]. At the same time, the existing AIDS for the blind in the market also have low technical content and high

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cost [4]. With the progress of sensor technology since the 21st century, electronic travel AIDS (ETAs) used for blind navigation have shown great potential in solving the problem of injuries caused by blind people not being able to obtain effective navigation [5]. However, today's common ETA devices are often based on simple traditional methods for environment recognition and information acquisition, such as ultrasonic sensors, GPS positioning, inertial odometer and other methods [6]. With the development of computer vision technology, SLAM technology has gradually come into people's field of vision. SLAM is an algorithm used to detect the motion state of a robot, locate it, and plan its path.

The visual-based SLAM algorithm is considered particularly attractive due to its simple sensor configuration, miniaturization and low cost [7]. Therefore, more and more SLAM algorithm based navigation schemes are entering the field of blind navigation, such as monocular camera RGB-D based SLAM algorithm and Large-Scale Direct Monocular SLAM(LSD-SLAM) based navigation system.

This paper will describe the recent development of SLAM technology in the field of navigation for the blind, including the application of RGB-D SLAM and LSD-SLAM in the field of navigation for the blind, and discuss the improvement direction of navigation system for the blind in the future.

2. RGB-D indoor navigation system

When SLAM technology is applied in the field of blind navigation, higher requirements are put forward for SLAM technology. For example, the accuracy, stability and portability of the system in the navigation of the blind and so on. SLAM Blind navigation system based on RGB-D camera is one of the solutions.

2.1. Methods

The basic processing flow of the navigation device based on RGB-D SLAM is roughly (1) to obtain color image and depth information. (2) Processing of image information. (3) camera tracking and obstacle detection (4) information output. In the first step, due to the accuracy limitation of the RGB-D camera itself, the researchers took various measures to increase the accuracy of the RGB-D camera. For example, Ali Fadhil et al. [7] used ultrasonic sensors to increase the perception of transparent objects. In terms of image information processing, due to the complex and unpredictable environment that blind people face when they move, Yoshihiko Nakamura et al. [8] and Gerhard Jaworek et al. [9] proposed new methods for detecting dynamic objects in the scene and making the system work better.

2.2. Interaction

The interaction between the device and the blind also plays a crucial role in the navigation system for the blind. An excellent interactive system can overcome the cognitive barriers between the blind and the device to the greatest extent in a short period of time and reduce the time for the blind to understand the instructions of the device, thus reducing the risk of the blind when moving. SLAM based navigation devices for the blind are generally composed of sensors, data processing devices and interactive devices. The sensor in the RGB-D navigation device is a head-mounted RGB-D camera. In the study of Ali Fadhil et al. [7], the sensor device is shown in the Figure 1.

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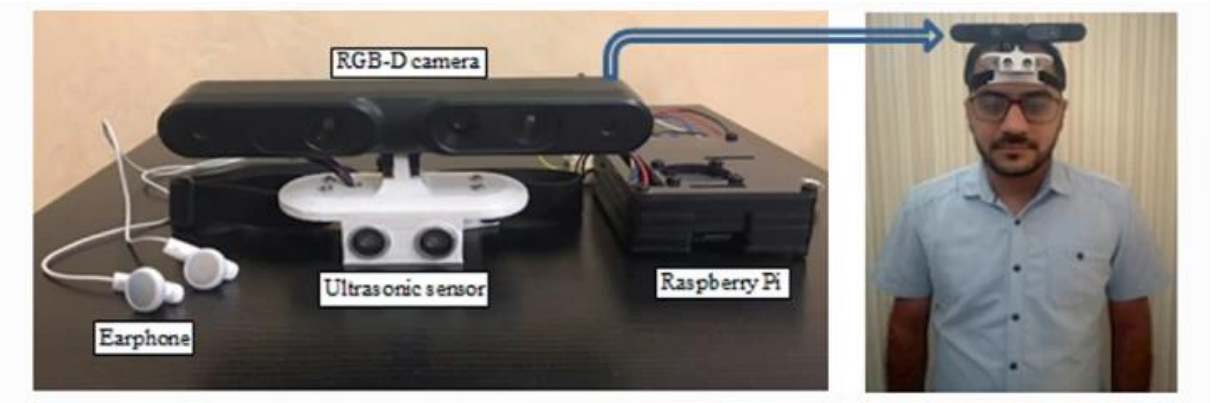


Figure 1. A SLAM-based Navigation System for the Visually impaired using Raspberry PI,RGB-D Camera and Ultrasonic GeneratorA [7].

Using a Raspberry Pi as a data processing device, the headset transmits information. But in this case, just using the headset to relay the information could cause a dangerous delay. In Young Hoon Lee's research [3], they designed more sensible and sensitive devices for transmitting information. The following image shows their methodology in the Figure 2.

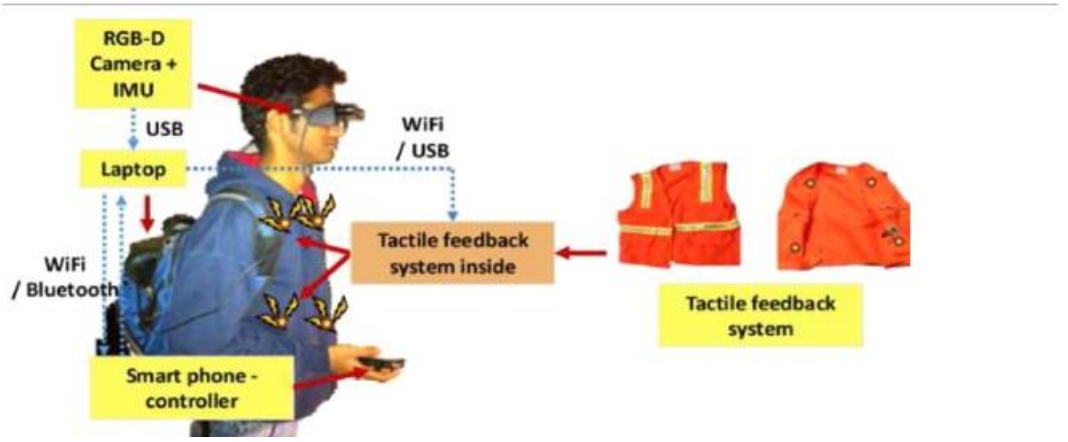


Figure 2. A RGB-D-Based navigation system and interaction device for the visually impaired [3].

A haptic feedback system with a micro-vibrating motor and a smartphone operating system are used to guide the blind to complete the path.

3. The application of LSD-SLAM in navigation for the blind

3.1. Definition of LSD-SLAM

Visual SLAM is a method to solve the problem of SLAM using visual information. LSD-SLAM is one of the visual SLAM technologies, which is used to estimate self-positioning and generate environment map in real time. For outdoor and other large-scale environments, the use of monocular camera has high accuracy.

3.2. The application of LSD-SLAM

3.2.1. Problem proposal. We can obtain three-dimensional point cloud information from LSD-SLAM as environmental information and build a two-dimensional map[10]. Traditional navigation can only design routes according to the map information generated in the past, and there is no way to adapt to the

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changed map, especially some sudden obstacles. Moreover, the route designed by the traditional navigation has a high probability of being close to or even close to the obstacle. However, for the blind navigation, the route close to the obstacle is actually very dangerous, because it means that as long as the blind person slightly deviates from the route, huge losses may be caused. Therefore, we need to avoid the route being close to the obstacle as much as possible.

3.2.2. Route search algorithm. The route from the current position to the destination is composed of the calculated global route and local route.

Obstacle information in the global environment: This is a map of the environment generated by the SLAM algorithm. It is generated by optimizing the map information observed by SLAM in the past. We can roughly input the map information in advance as the initial value

Obstacle information in the local environment: this refers to the use of SLAM algorithm to identify obstacles. In the LSD-SLAM discussed in this paper, LSD-SLAM continuously updates the current key frame point cloud information until a new key frame (new obstacle information) is obtained.

3.3. Application in the actual scenario

a. Our costmap creates the costmap from the plane environment data provided by the point cloud output by LSD-SLAM or stereo camera and the laser rangefinder to find out the target we need to avoid. The following diagram shows the information about obstacles in the path (see Figure 3), the areas to avoid, and the areas that can be passed.

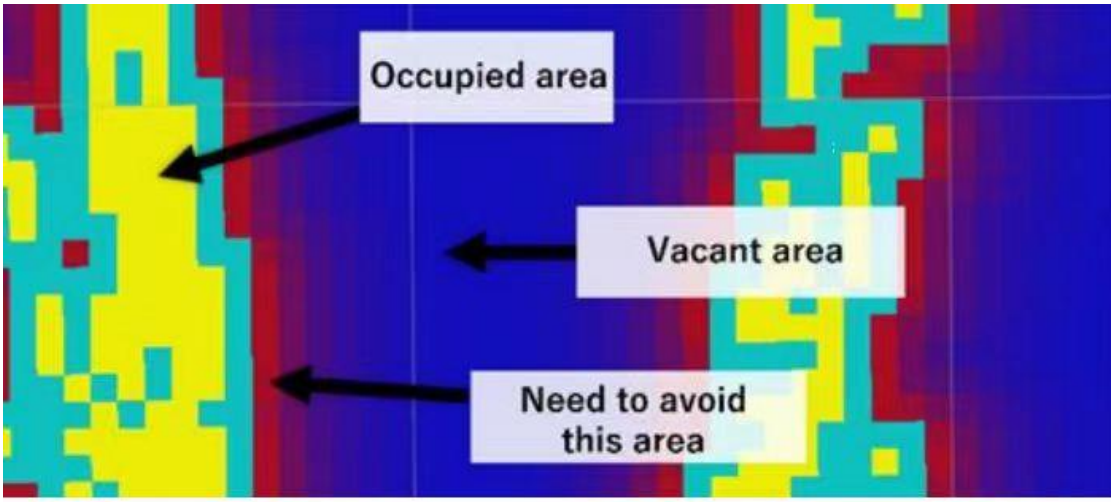


Figure 3. Path information [3].

b. According to the general map constructed by previous observation or input information in advance, determine the initial point and destination, and design a most reasonable route. The following figure shows the route designed based on previous information (see Figure 4).

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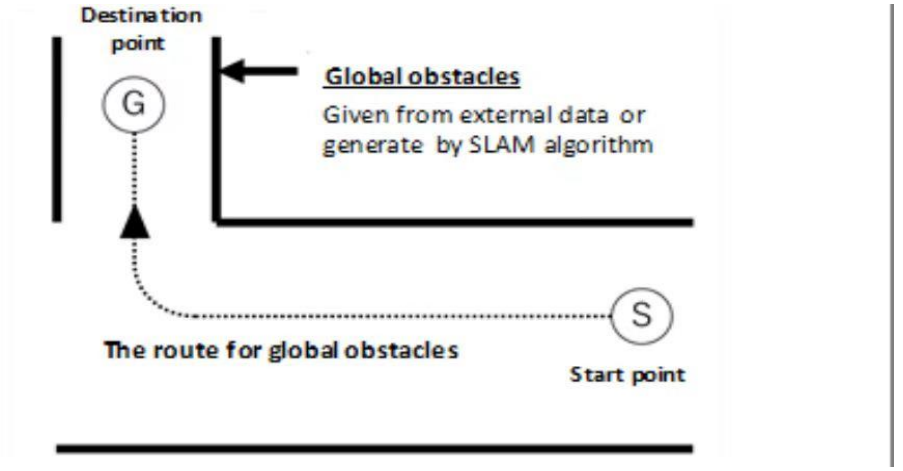


Figure 4. Initial path [3].

c. Figure 5 shows the design of a new route in time when encountering obstacles that are not in the previous input information during navigation.

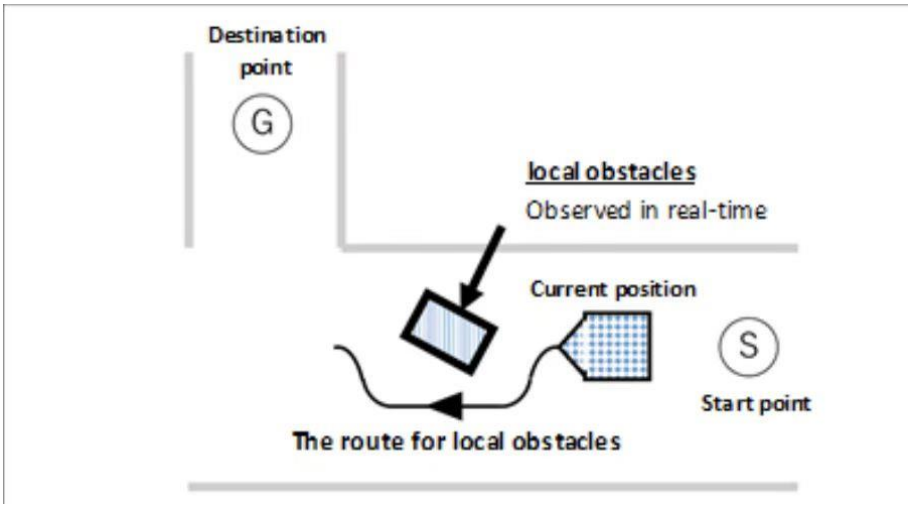


Figure 5. New path [3].

d. LSD-SLAM can identify the newly discovered obstacle information in the local environment, design a new route to avoid it in time. Figure 6 shows that the navigation will automatically return to the original design path after avoiding a new obstacle.

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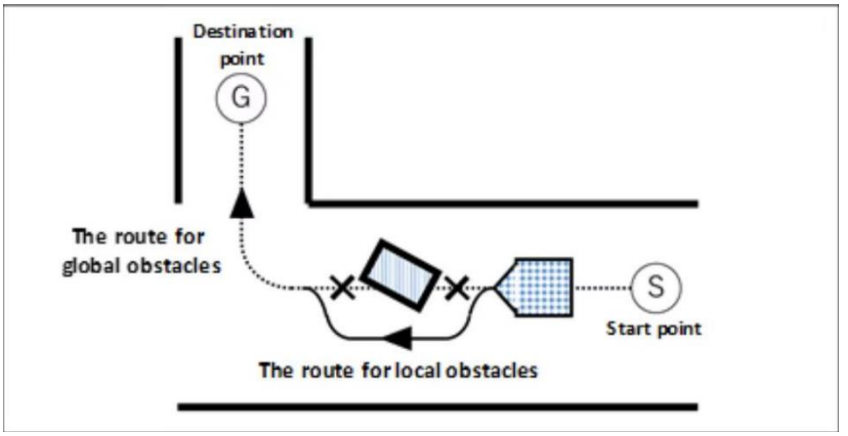


Figure 6. Return to original path [3].

e. Combining the obstacle information in the global environment and the newly discovered obstacle information in the local environment, the two routes are combined to design a route that is most consistent with the reality. Figure 7 shows the final navigation path.

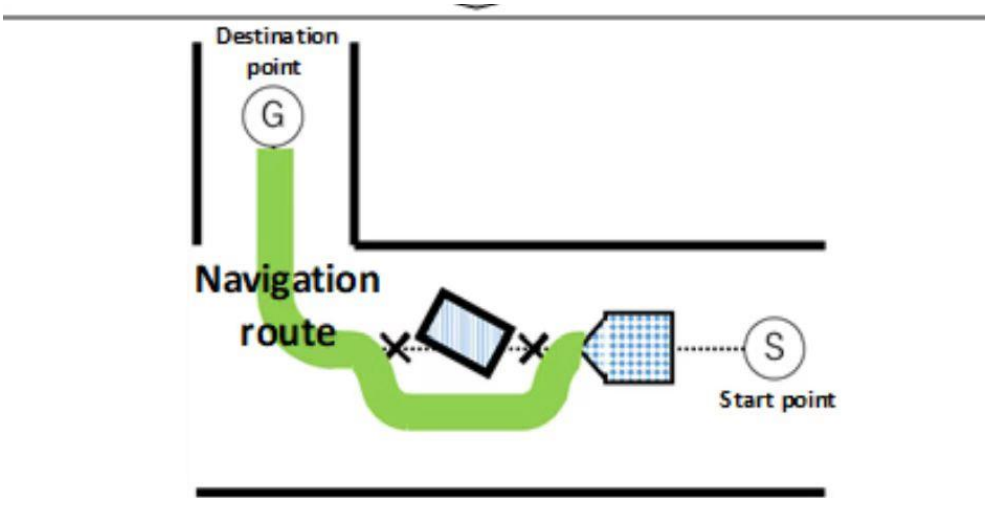


Figure 7. Final path [3].

4. Discussion

4.1. Comparison between RGB-D SLAM and LSD-SLAM

Compared with LSD-SLAM, RGB-D has its advantages and disadvantages: Because of the use of depth camera and binocular camera, RGB-D can restore the scene more accurately, but compared with LSD-SLAM, this means higher cost and structural complexity. In terms of large-scale outdoor scenes, LSD has greater advantages than RGB-D, especially in the environment with poor texture, LSD will be more robust, in terms of reaction speed, higher real-time operations to RGB-D brings faster and more accurate map construction.

4.2. Potential application and future development

With the development of technology and times, more application methods of SLAM technology will emerge. With the development of artificial intelligence and chip technology, the development of deep learning technology will have a very positive impact on SLAM algorithm. By using deep learning to improve data processing and feature extraction of sensors, the performance and robustness of LSD-

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SLAM and RGB-D SLAM can be significantly improved. The SLAM system integrating multiple sensors is expected to become the future development direction, combining the data of cameras, inertial measurement units, lidar and other sensors. It can realize more accurate and robust positioning and mapping.

The use of LSD-SLAM and RGB-D SLAM can achieve real-time tracking of the location of a blind person and provide navigational guidance. By analyzing inputs from cameras or RGB-D sensors, the system can build a map of the environment and provide a blind person with voice or tactile responses to help them navigate and avoid obstacles. In addition, SLAM technology can be combined with voice guidance and location markers to provide guided navigation services for the blind.

All kinds of SLAM based navigation devices for the blind have begun to take shape, but this does not mean that SLAM based navigation devices have reached the ideal state. In the field of blind navigation related to human life, there is still room for improvement in the accuracy of the algorithm's perception and reconstruction of the surrounding environment. For example, in the study of Gerhard Jaworek et al. [3], it is difficult to guarantee the results of panoramic segmentation, and the computational complexity of the system increases with the increase of scene complexity, which slows down the feedback efficiency of the system. Such problems occur in many SLAM navigation systems. On the one hand, there is still room for optimization in the algorithm, on the other hand, the chip's computing power is limited under certain power consumption, and the sensor's accuracy in obtaining scene information is insufficient.

In terms of chips and algorithms, at present, almost all SLAM navigation devices use x86 chips as information processing chips, and ARM chips have more computing power advantages than x86 chips under the same power consumption. The future development of algorithms and workflows based on ARM chips will improve the working efficiency of the system.

On the other hand, more sensors can be introduced to improve the accuracy of the information obtained by the system. For example, the RGB-D sensor itself has its limitations, and the Angle of view of the RGB-D camera to obtain the depth information is still relatively small. LiDAR technology can be introduced into the system to assist the SLAM system to build more accurate maps. So as to improve the efficiency and stability of the system.

5. Conclusion

RGB-D SLAM and LSD-SLAM technology applied to the field of blind navigation, SLAM technology real-time update of obstacle information on the path, will solve the real-time route planning problem in the field of blind navigation, the design of a real-time update of the path for the blind is more worthy of being trusted by the blind. Although there have been many cases and experiments of SLAM technology applied to the field of blind navigation, but the current development of SLAM technology is not mature enough, many technical barriers need to be broken through, many hardware and software facilities are not using the most advanced technology. Traditional SLAM technology is mostly based on visual navigation, but because the blind are blind, so the blind navigation puts forward new requirements for SLAM technology, how to guide the blind to walk according to the predetermined route scientifically has become a key issue for future discussion and development. We always believe that the application of SLAM technology to the field of blind navigation will solve the problem of blind travel well, improve the welfare of the blind all over the world, and create a broad prospect market.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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