A Cloud and Vision-based Navigation System Used for Blind People

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ABSTRACT
Safe navigation and detailed perception in unfamiliar environments are a challenging activity for the blind people. This paper proposes a cloud and vision-based navigation system for the blind. The goal of the system is not only to provide navigation, but also to make the blind people perceive the world in as much detail as possible and live like a normal person. The proposed system includes a helmet molded with stereo cameras in the front, android-based smartphone, web application and cloud computing platform. The cloud computing platform is the core of the system, integrates object detection and recognition, OCR (Optical Character Recognition), speech processing, vision-based SLAM (Simultaneous Localization and Mapping) and path planning, which are all based on deep learning algorithm. The blind people interact with the system in voice. The cloud platform communicates with the smartphone through Wi-Fi or 4G mobile communication technology. For testing the system performance, two groups of tests have been conducted. One is perception and the other is navigation. Test results show that the proposed system can provide more abundant surrounding information and more accurate navigation, and verify the practicability of the newly proposed system.

CCS Concepts
• Networks ➝ Network services ➝ Cloud computing • Computing methodologies ➝ Artificial intelligence ➝ Computer vision ➝ Computer vision tasks ➝ Vision for robotics.

Keywords
Navigation; cloud; deep learning; object detection and recognition; speech processing.

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1. INTRODUCTION
According to World Health Organization (WHO) official statistics, there are 285 million visually impaired persons in the world in which 13.68% of them are blind and 90% of them are from developing countries [1]. China currently has about ten million visual impaired people, and the number increases 450 thousand every year, rising to 18% of the global total [2]. It has become an important topic nowadays to help the blind be able to live like a normal person.

In this paper a new navigation system is designed not only to provide guidance for the blind, but also to let the blind perceive the real world, such as where he is, what the object (e.g. car, traffic light, money and chair) is or who he is in front of him, etc. This system contains four modules: helmet mounted with stereo cameras, smartphone, cloud computing platform, web application. The stereo cameras capture the video sequence of surrounding environment. The smartphone interacts with the blind through voices and transmits the video sequence captured by stereo cameras and audio signals to the cloud computing platform through Wi-Fi or 4G mobile communication. The cloud computing platform can locate the position of blind, detect and avoid obstacles, guide the blind and recognize the object by the video of surrounding. The web application exhibits the surroundings, but above all, others can effectively help the blind in emergency through this web application.

This system provides a common navigation platform for both outdoor and indoor environments. This system is more safe, practical and information fruitful than the present novel navigation system.

2. RELATED WORK
Many navigation systems have been proposed, which are based on different approaches and combine different technologies. Traditionally, the blind use white canes or guide dogs to help them move around. But they are limited to move only around familiar places [3] and can perceive little information.

Ultrasonic-based navigation systems [2] use ultrasonic to measure the distance to the obstacles and indicate the information to the blind through voice or vibration. However, these systems cannot detect the exact location of obstacles due to the wide beam angle of ultrasonic. Besides, these systems cannot recognize the type of the obstacles (e.g. a car or a bicycle).

Some researchers develop navigation system using RFID [4, 5]. These systems use RFID tags to label the places and RFID readers to recognize the places. But RFID tags cannot be installed at every location. Furthermore, RFID systems are generally expensive and attempting to read several tags at a time may result in signal collision and ultimately to data loss [6, 7].

Most of the commercial products for providing mobility assistance are based on GPS [8]. However, the accuracy of GPS is not reliable when operating indoors or in cities with tall buildings due to limited satellite reception [6]. Moreover, these products also cannot determine the obstacle in the near surrounding of the blind [9].

Some limitations can be overcome using systems based on computer vision. For example, [10] implements ego motion tracking indoors by utilizing visual-inertial sensors. [11, 12] can detect the obstacles more accurately by the Kinect which contains the IR depth sensor. In [13] a stereo vision system is introduced that estimates a 3D map which is used to detect obstacles during navigation. These systems can provide more accurate location of the blind and the obstacles. However, they are not smart enough to tell the blind what the object is or who the man is.

[14] uses external GPS receiver to improve the locating accuracy, combines an existing Intelligent Transportation System to help the blind in crossing road and uses Text-to-Speech engine installed on a smartphone to interact with the blind. But this system can only be applied outdoors. Multi-sensor fusion-based navigation system is presented in [15]. It uses GPS and vision to implement outdoor navigation, use Wi-Fi and vision to implement indoor navigation and use RFID to detect the landmarks placed in the ground and thus recognize the place. Although this system can provide information about surrounding points-of-interest (POI), this system still have limitations due to the utilizing of GPS and RFID as above-mentioned.

This paper proposed a cloud and vision-based navigation system. The proposed system utilizes smartphone to interact with the blind through voice, to transmit the voice and the video captured by the stereo cameras to the cloud computing platform through Wi-Fi or 4G mobile communication. The cloud computing platform integrates the speech recognition and synthesis, visual SLAM, global path planning, navigation, object detection and recognition. It can be divided into two main functions: navigation and perception.

Navigation: firstly, the blind tells the smartphone where he want to go and the smartphone send this voice information to the cloud platform. Next, the platform calls the speech recognition module to convert the voice to text, the global path planning module to generate a global path, which can be seen through web application. Then the visual SLAM module, navigation module and object detection module run synchronously and yield indication command. The indication command can be convert to voice through speech synthesis module, and the voice can be transmitted to the smartphone to tell the blind where he should go.

Perception: the blind just tells the smartphone what he want to know, such as what it is, how much it is, who he is. The smartphone then captures the image in front of the blind, and also transmits it to the cloud platform. The platform then uses object recognition to identify the type of the object and also convert the result to voice to tell the blind. This system can help the blind to perceive the world like a normal person.

The main contribution of this paper is solving the navigation issues only through vision processing approaches, integrating many vision-based processing module to provide fruitful information for the blind and introducing human assistance to ensure safety of the blind in emergency. The proposed system can make the blind travel safely by themselves and live like a normal person.

3. PROPOSED FRAMEWORK

The proposed system (as shown in Figure 1) is based on wearable sensors, i.e. a helmet mounted with stereo cameras, smartphone integrated with a software platform, and the cloud computing platform. It takes advantage of the powerful parallel computing ability and adequate storage capacity of the cloud platform. All vision and speech processing algorithms are run on the cloud platform. The cloud platform acts like a brain, indicating the blind where they can go or letting the blind know what the object is. Above all, to ensure the safety of the blind, the proposed system introduces human assistance to cope with the emergency situation or complex situation where the navigation or perception cannot work well. The web application, which provides the surrounding information, is designed for the support staff to assist the blind. The proposed system is detailed in the following paragraphs.

Figure 1. Cloud and vision-based navigation system

3.1 Wearable Sensors

The sensors mainly include stereo cameras, microphone and speaker. All the sensors are mounted on a helmet. These sensors communicate with the smartphone through Bluetooth.

The stereo cameras are used to acquire surrounding information. The information retrieved from the camera is the requisite of the whole system. Because without it, the position of the blind cannot be located, the obstacles cannot be detected and the guidance cannot be provided.

The microphone is used to let the blind easily interact with the smartphone. When the blind want to start the navigation function, he just say “start navigation”, then the application integrated in the smartphone and the navigation module integrated in the cloud will run. When the blind want to know something, he can launch the object detection and recognition function just by means of saying “what is it?” or “who is he or she?”.

All the information produced by the system (e.g. guiding instruction, object type) is transmitted into voice and informs the blind through the speaker. Note that, because too frequent sounding can disturb the blind to listen other helpful information, when guiding the blind, the speaker just reminds the blind at key position or emergency situation. Besides, infrequent sounding can save power.

3.2 Smartphone

The smartphone integrates a software platform (called Smart-Assistance) (as shown in Figure 2) which acts as a bridge between the blind or the wearable sensors and the cloud platform. The smartphone transmits the information achieved by the wearable sensors to the cloud platform and receives the return information from the cloud platform through Wi-Fi or 4G mobile communication.

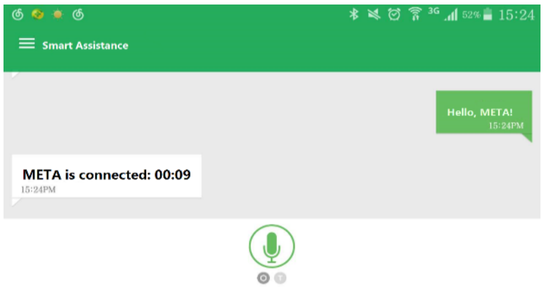

Figure 2. Smart-Assistance software interface

3.3 Cloud Computing Platform

The cloud computing platform, put simply, is the algorithms implementing platform, mainly includes three modules (as shown in Figure 3): perception, navigation and speech processing. The speech processing module is the communicating interface between the smartphone and the other two modules. The speech processing and the perception module depend on the deep learning algorithm. The navigation module is based on the stereo vision algorithm.

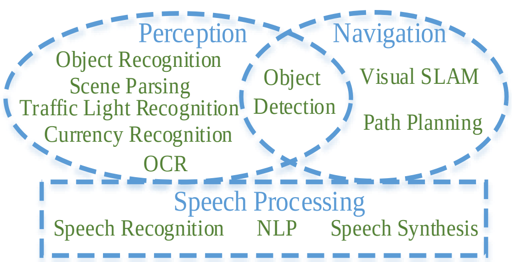

Figure 3. Cloud computing platform framework

3.3.1 Speech Processing Module

The speech processing module is dedicated to analyze voice commands. This module transfers the blind's voice commands into formal language that computer can understand. These commands, such as reach someplace, recognize the blind's friend or an object in front of him and query his position, can be translate into some key information that the perception and the navigation module can accept. Similarly, the return results of the perception and the navigation module need to be converted into voice through this speech processing module in order to make the blind understand these results. This module is resorted to the state-of-the-art NLP (Natural Language Processing) algorithm which is based on RNN (Recurrent Neural Network) [16, 17].

3.3.2 Perception Module

The perception module integrates object detection and recognition [18, 19], scene parsing [20, 21], OCR (Optical Character Recognition) [22, 23], currency recognition [24] and traffic light recognition [25] function. Furthermore, it has good scalability with other deep learning-based algorithms. The datasets that is used for object recognition can be download from http://image-net.org/download-images. The Optical Character Recognition datasets can be obtained from http://tc11.cvc.uab.es/datasets/type. The traffic light recognition datasets are available on http://www.lara.prd.fr/benchmarks/trafficlightsrecognition. Since the currency recognition datasets (i.e. RMB datasets) cannot be found on the websites, many currency images are manually captured at different backgrounds and different perspectives. The RMB datasets that is established by ourselves include 90, 000 images and are divided into 9 classes according to the denominations of the RMB (i.e., ￥0.1, ￥0.2, ￥0.5, ￥1, ￥5, ￥10, ￥20, ￥50, ￥100).

3.3.3 Navigation Module

The navigation module (understanding where the blind is and how to reach the target while contemporaneously avoiding obstacles) resorts to the Simultaneous Localization and Mapping (SLAM) algorithm [26, 27]. However, the SLAM algorithm in the proposed system is different from [26, 27]. It is based on vision-SLAM and not relied on ROS (Robot Operating System). The vision-based SLAM algorithm extracts the image features and reconstruct the camera's motion trajectory. Thus, it can be used to build map. Besides, it can be used to tracking the position and orientation of the blind (in practice, the stereo cameras). It has higher precision, reliability. Even without GPU acceleration, the operation speed is quick enough to compute in real time. Although the map is insufficient due to the limited time and manpower, we believe that with the increasing of the users, the map can be more and more abundant since the users will build map when they go to unfamiliar places. The map will be stored on the cloud computing platform and can be shared with other blinds.

In terms of avoiding obstacles, the object detection is firstly utilized to detect the obstacles. Then the distance of the obstacles can be calculated according to the stereo parallax, the focal length and the baseline of the stereo cameras. Next, based on the above obstacles information, the local path planning will make a decision (e.g. turn right or turn left).

3.3.4 Web Application

To ensure adequate safety of the blind's traveling, the web application is introduced for the customer service staff to help the blind cope with some complex situations where the automatic navigation module cannot work well. As shown in Figure 4, the web application can provide real time surrounding information through the video, the location of the blind and the obstacles in front of the blind. The staff can guide the blind safely when the blind met with some complex or emergency situations according to the above information.

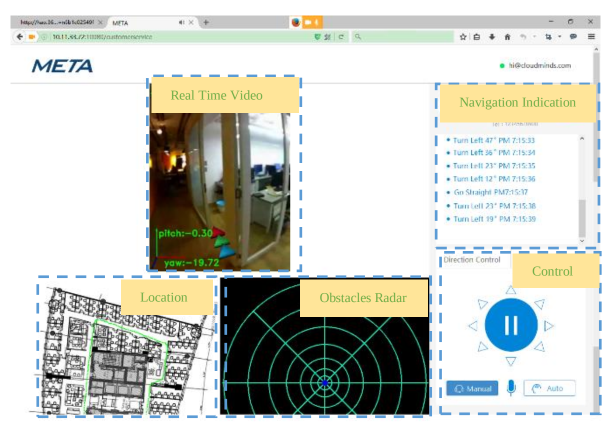

Figure 4. Web application interface

4. SYSTEM PERFORMANCE

In order to evaluate overall system performance, two groups of experiments have been conducted. One is perception test, including object detection and recognition, currency recognition, OCR and scene parsing. The other one is navigation test, including indoor and outdoor navigation.

4.1 Perception Test

4.1.1 Object detection and recognition

The object detection and recognition module can identify 1000 kinds of common objects, the results are shown in Figure 5 (a). The proposed module introduces goods recognition (as shown in Figure 5 (b)), which can tell the blind what the good exactly is. Due to limited pages, we just show some most common objects detection and recognition results.

(a) Object detection **(b) Goods Recognition**

Figure 5. Object detection and recognition

4.1.2 OCR

The OCR module can recognize alphabetic, digital and Chinese character. As is shown in Figure 6, even if the image is blurred, the recognition results are still very accurate.

Figure 6. Optical Character Recognition

4.1.3 Obstacles detection

The obstacles detection module can determine the feasible region that is significant to guide the blind safely. As is shown in Figure 7, the green boundary is the passable area. Whenever in outdoor or indoor situation, this module can accurately detect the path which the blind can travel through.

Figure 7. Obstacles detection

4.1.4 Scene parsing

The scene parsing module can describe the scenario in the image (as shown in Figure 8). In spite of its simplicity, the description can explain the main implicit idea in the image. This will be improved in the future studies so as to depict more complicated scenario and depict more definitely.

Figure 8. Scene parsing

4.1.5 Currency recognition

The currency recognition module is mainly designed for RMB recognition. The detailed recognition results are shown in Figure 9. The recognition accuracy is up to 99.9%. However, this module cannot identify whether the currency is fake or not. We will combine other technology (e.g. ultraviolet ray) to discriminate the authenticity of currency.

Figure 9. Currency recognition

4.2 Navigation Test

The navigation module mainly operates vision-based SLAM, path planning and obstacles avoiding. To explicitly and expediently test the navigation module, we take advantage of the web application to intuitionally observe the navigation results. As is shown in Figure 4, the 3D arrow in the real time video can indicate the direction which the blind should follow; the location display area can mark the real time location of the blind; the obstacles radar display area can show the obstacles in front of the blind; the navigation indication display area records the historical data of navigation command; the control area is used for customer service staff to guide the blind manually.

4.2.1 Indoor navigation

The indoor navigation is tested in a region of office. The distance between the initial position (the door of our office) and the destination (the reception of our company) is about 90 m. As is shown in Figure 10, the blind can go through the narrow corridor safely. When the blind deviated the normal path (as shown in Figure 10, the second image of the first row), the navigation module can remind the blind in time (as shown in Figure 10, the second image of the first row, the 3D arrow show that the blind should turn right). The proposed navigation module can guide the blind reaching the destination safely.

Figure 10. Indoor navigation test sequences

4.2.2 Outdoor navigation

The outdoor navigation is tested in a pedestrian street. The distance between the initial position (the entrance of the street) and the destination (a restaurant) is about 1.2 km. As is shown in Figure 11, the proposed navigation module can guide the blind avoiding pedestrian, walking through the street and arriving to the destination without collision.

Figure 11. Outdoor navigation test sequences

Both indoor and outdoor navigation test show that the proposed navigation module has great value of practical application.

5. CONCLUSION

In this paper, a cloud and vision based navigation system for the blind people has been proposed. The system utilizes stereo cameras, android-based smartphone, web application and a cloud server which operates all the algorithm.

The proposed system provides object detection and recognition, scene parsing, currency recognition, OCR and so on. Thus, the blind can perceive the world in detail. Moreover, the system provides navigation in both indoor and outdoor situations. It is worth mentioning that we introduce real-person navigation to ensure the safety of the blind in some complex or emergency situations.

Two groups of tests has been conducted. One is perception test and the other is navigation test. The results show that the proposed system can provide 1000 kinds of common objects detection and recognition. Particularly, we established the RMB recognition dataset. The RMB recognition accuracy can be up to 99.9%. Besides, the vision-based navigation module works better, especially in poor signal or indoor situations, than GPS-based navigation. Although vision-based navigation exhibits many benefits in comparison with GPS-based navigation, it still has some drawbacks, such as the requirement of building vision-based map of the whole world, which is a daunting work and the similarity of the scenario, which results in wrong locating. Furthermore, the perception module also can be improved, such as scene parsing which is too simple, currency recognition which cannot determine whether the currency is fake or not and the object recognition which can be improved to recognize more than 1000 kinds of objects.

The future work will pay attention to the multi-sensor fusion-based navigation in order to improve the locating accuracy and the guiding efficiency. Besides, the object detection and recognition accuracy can be improved through tuning the deep learning network model. Another aspect which can be improved is the number of recognizable objects that can be realized by enlarging the dataset.

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