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Low Cost Navigation System for the Visually Impaired

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Abstract—*The paper attempts to elaborate the implementation of a cost-effective system that would help the visually impaired to navigate autonomously in a specific indoor/outdoor environment. The system consists of ultrasonic sensors, Raspberry Pi B+ microcontroller, camera and earphones to provide a real-time system for navigation. The system applies picture matching to determine the location of the person with respect to the surroundings and also utilizes object detection technologies to make the system effective.*

Keywords: ultrasonic; Raspberry Pi; picture matching; navigation

1. INTRODUCTION

Autonomous navigation has always been a challenge for the visually impaired. They generally lack information about their surroundings and thus, are unable to effectively navigate autonomously. Conventional navigation systems are quite expensive and somewhat lack efficiency.Nowadays, most of the commercial solutions for visually impaired localization and navigation assistance are based on the Global Positioning System (GPS). However, these solutions are not suitable mainly due to low accuracy, signal loss and unsuitability to work on indoor environments effectively. This research work aims to design a low cost effective navigation system for the visually impaired. This project is a step to alleviate the problems the visually impaired face in navigation and help the user to navigate autonomously mainly in areas like school/college corridors. This work proposes a user study with visually impaired people in order to obtain relevant feedback information about the system. In addition, the proposed obstacle detection system can be easily integrated into more advanced vision based localization systems for the visually impaired.The emphasis has been laid on making the system light-weight and user friendly so that the visually impaired person can easily and effectively use the system in navigation.

2. RELATED WORK:

In past years, many navigation tools such as canes and guided dogs were used by visually impaired people to reduce their mobility constraints. But in the recent years, with the advancement in technology, many electronically controlled gadgets have been designed for assisting visually impaired for navigation [1]. The electronic devices available for the aid of visually impaired person are often complex, needs training sessions and come at much higher cost. This research aims at finding a reliable and easy to implement solution for visually challenged persons at a very small cost.

Most existing systems use technique of GPS to locate the person that require internet network connection, which is not possible all the time [2]. Other systems which exist required computationally intensive software like Matlab and Labview to perform the image processing hence required powerful processor ultimately increasing the cost of the system [3]. This system however circumvents the major problems and is designed to work without an active internet connection. The system utilises an offlinepicture database of the location (where the user needs to navigate) and implements the OpenCVlibraries to implement image processing.

Image comparison methodologies have previously reliedheavilyon human intervention to provide an interpretation of the image content so as to produce tags associated with the images. However, the ever increasing prevalence of large image databases has resulted in the development of algorithms to augment and replace tag based image retrieval with content based image retrieval [4]. These algorithms compare the actual content of the images rather than text which has been annotated previously by a human being. There are a number of features that can be extracted from an image for comparisons based on their content. Colour, texture and shape are the most common characteristics upon which images are compared in content based image retrieval algorithms. They are briefly outlined below.

2.1. Colour Based Retrieval: A number of algorithms have been developed since the late 1980s that use colour information extracted from images for retrievals [5]. Google's image organization and editing software, Picasa 3.0, is an example of a tool that allows users to search for certain colours in images. Even this basic method presents challenges

in implementation due to the difference between a computer and human when it comes to 'seeing' colours. Computers represent all visible colours with a combination of some set of base colour components, generally Red, Green and Blue. Thus, images perceived by a computer to contain a large amount of red may not necessarily appear 'reddish' as perceived by human eye [6]. Image retrieval methodologies rely on specifying more precisely the nature of the colour that is to be retrieved. The basic advantage of this method is that it can be used for an image irrespective of its orientation or size.

2.2. Texture Based Retrieval: Generally, similarity between two images is based on a computation involving RGB separation [7], Euclidean distance or histogram intersection between the respective extracted features of two images. Both RGB separation and Euclidean methods involve an intuitive extension of the mathematical definition of adistance between two objects. This retrieval approach has been used in this work.

2.3.Shape Based Retrieval: Utilizing shape information for automated image comparisons require algorithms that perform some form of edge detection or image segmentation. Segmentation refers to the identification of the major colour regions in an image [8].These regions can then be compared from one image to the next. Edge detection tends to be slightly more complicated as it attempts to identify the major contours and edges in a given image. These edges can then be compared based on their direction, with respect to image edges. The advantages of this method include its applicability to black and white images. However, the performance of the algorithm is not invariant on scale or translation manipulations of images. Information regarding the texture of images can be even harder to extract automatically during retrieval. Generally, algorithms rely on the comparison of adjacent pixels to determine the contrast or similarity between pixels.

2.4. OpenCV(Open Source Computer Vision): OpenCV is an open source computer vision library, with implementations in major programming languages like C and python, optimized for real-time applications. It has many features like image manipulation, basic image processing and image labelling, matrix manipulations and linear algebra tools. Many useful image matching algorithms such as SHIFT, SURF etc. can be implemented using OpenCV libraries.

3. METHODOLOGY

The electronic devices available for the aid of visually impaired people are often complex, need training sessions and come at much higher cost. This research aims at finding a reliable and easy to implement solution for those people at very low cost. In this work, pictures are compared and matched using the modules of OpenCV. The implementation uses technique of calculating histogram information and then comparing those using co-relation between the histogram of the two images.

3.1. Experimental Setup

The main objective of this research was focused on developing a portable and reliable gadget for visually impaired peoplethat can enhance theirmobility intheir surroundings. The approach consists of three basic processes or steps:

- Image comparison and matching
- Obstacle Detection
- Text-to-speech output for guidance

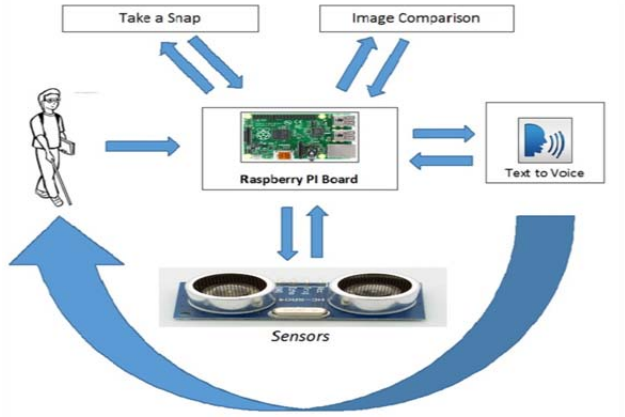

Fig. 1: Methodology

The software and hardware tools required to accomplish the above mentioned approach are as follows:

3.2. Software Tools: A great number of software tools are available today (both paid and free) that assists in the implementation of image comparisons. The tools used by the team to implement the project include:

1. Linux based Raspbian (OS for Raspberry Pi)
2. Python (Coding Platform)
3. Putty (to establish command based network connection with laptop)
4. Tight VNC (to establish GUI based network connection with laptop)
5. Festival (text-to-speech software synthesizer)
6. Leaf-pad (text editor)

3.3. Hardware Tools: The project required compact and portable hardware so as to achieve the best results and yet not compromise on ease of use. The following hardware components were used to implement the project.

1. Raspberry Pi B+ full kit
2. Raspberry Pi Camera Module
3. Ultrasonic Range Sensor Module
4. Headphones/Earphones
5. Power Bank
6. Multi-purpose PCB consisting required sensors

3.4. Algorithms: This system contains three modules – Image Matching, Obstacle Detection and Text-to-Speech conversion.

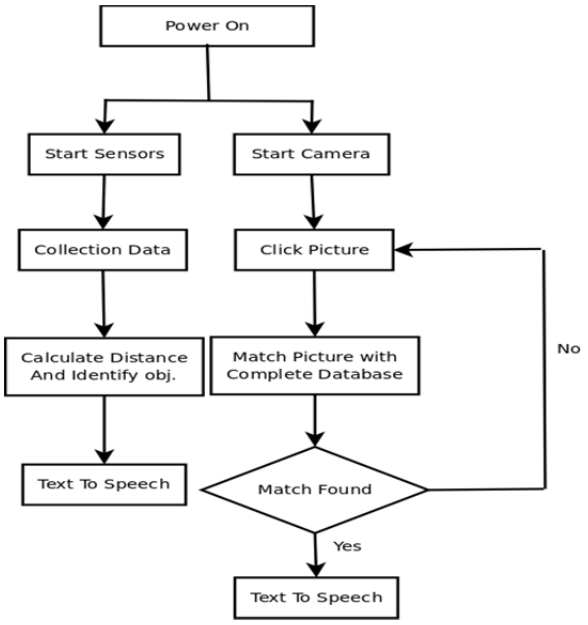

Fig. 2: Working Model Flowchart

The image matching and obstacle detection tasks are performed simultaneously. The results are conveyed to the user via earphones using the text-to-speech conversion. These algorithms are designed to run at startupwithout requiring user input**.**

3.4.1. Image Matching: It is essential to run an image matching algorithm to compare images taken by the visually impaired with the images already stored in database in order to inform the user of his/her location. Two approaches were tried – pixel matching and RGB histogram matching using the open source OpenCV library. However, preference was given to histogram matching algorithm as it was easier to implement andgave promising results in the test environment. The method applied computes similarity between test images andimage stored in the database based on the resemblance of histogram information of the images.

3.4.2. Obstacle Detection: To enable mobility of a visually impaired person, it is important to identify the obstructions and their current location with respect to moving person. With this information conveyed to the impaired person using voice commands, the person can navigate easily in his surroundings. Three ultrasonic sensors are used to detect the long and short range obstacles. One sensor detects for obstacles in front and two sensors detect for obstacles to the left and right. All of the three sensors work simultaneously to provide a complete obstacle detection system.

*Ultrasonic Sensor:*The ultrasonic sensor is based on the SONAR (Sound Navigation and Ranging) principle which evaluates attributes of a target by interpreting the echoes of sound wave received. This converts energy into ultrasonic waves higher than the normal range of human audible frequency. Ultrasonic generated waves and the echo received is evaluated. This provides basis for determining the time duration between transmitted sound and received echo to compute distance of an object [9]. Normally, in ultrasonic sensor, piezoelectric transducers are used to convert electric energy into sound. Piezoelectric crystal vibrates if a voltage is applied across it. Piezoelectric crystals can be used as an ultrasonic detector because it generates voltage when force is applied on it.

The range of target was calculated as:

Range of target = (v x t) / 2

Where, v is the speed of sound and t is the time taken by the wave to reach target and return to the receiver

3.4.3. Text-to-speech conversion using open source software: For effective communication between the gadget and the visually impaired person, the medium of voice is the best option. Text-to-Speech is an efficient way of communication between person and gadget via voice through earphone. For this work, Festival speechsynthesis system is used. The data from the sensors and the results thus obtained are efficientlyconveyed tothe person via voice Text-to-Speech converter [10]. This provides an efficient mechanism by which a person can be made aware of the obstacle in its path and current location.

4. RESULT ANALYSIS AND DISCUSSION

The main objective of the research was to enable a visually impaired person to perform navigation with improved ease using a potentially viable gadget V-eye as shown in the figure 3. For making the proposed gadget, the research work made use of comparison principle for image matching. This image was compared for further processing using OpenCV libraries. Once the match was obtained, the location of the person was determined. Further with the sensor circuit implemented in the device, obstruction and its distance from the user was determined. The results so obtained are the intimidated to the user using text-to-voice converter.

This system has been implemented with different type of images. Matching has been done successfully with static objects and promising results for dynamic objects have been achieved. By using ultrasonic sensors, calculation of short range obstacle distances was done successfully. The correct matching of the object images varied from a minimum difference value 0 (perfect match) to about difference value 0.9. During a test run, 49 images were clicked dynamically and were matched with 40 database images; about 25 pictures were matched successfully. The results were satisfactory with very few false positive results. The average running time of the gadget was around two to four hours.

5. CASE STUDY

A case study was also performed for the device by Mr. Manoj Kumar Garg, Assistant Professor, Department of English. He (being visually impaired himself) was able to identify both the pros and cons of the product and also expressed his expectations on what a product, which aims to provideaid to the visually impaired, should be able to achieve.

On the positive side, the device was compact and portable. However, issues wereexpressed regarding the response time of the product which can be attributed to the hardware capability (hardware limitation) and the delay in converting text to speech by the speech synthesizer. To overcome this, audio output which initially consisted of proper sentences in English followed by obstacle distance information has been changed to a beep followed by obstacle distance information thus improving the response time significantly which is crucial for the successful implementation of the product.

Fig. 3: V-eye

6. CONCLUSION

This project has been mainly focused on three tasks of image matching, obstacle detection and text-to-speech conversion. By analyzing the results, it is to be concluded that image matching has to be precise enough for the device to act as a reliable navigation system for the visually impaired person and for trusted obstacle detection, SONAR based ultrasonic sensors. The concept presented here can serve as a strong base for developing more intelligent systems for autonomous navigation.

7. FUTURE SCOPE

The approach presented in this research work can be further refined to improve upon its accuracy and reliability. Moreover, the approach can be extended to build a more intelligent and robust system. The other scope may include a new concept of optimum and safe path detection based onneural networks for a visually impaired person.

8. ACKNOWLEDGEMENTS

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