Hardware Implementation of Obstacle Detection for Assisting Visually Impaired People in an Unfamiliar Environment by Using Raspberry Pi

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Abstract. For assisting blind or visually impaired persons, many computer vision technology has been developed. Some camera based systems were developed to help those people in way finding, navigation and finding daily necessities. The motion of the observer causes all scene object stationary or non-stationary in motion. And hence it is very much important to detect moving object with the moving observer. In this context we have proposed a camera based prototype system for assisting blind person in detection of obstacles by using motion vectors. We have collected dataset of their indoor and outdoor environment and estimated the optical flow to perform object detection. Furthermore we have detected the objects in the region of interest without using costly Depth cameras and sensors. The hardware used in the proposed work is 'Raspberry Pi 2-B' and the algorithms used for object detection is performed using MATLAB (for simulation purpose) and Python language.

Keywords: Optical flow · Computer vision · Blind people · Object detection · Raspberry Pi

1 Introduction

The blind and visually impaired people face many challenges in their everyday life. In known environments the blind person depend on their sense of orientation and memories. But, daily routines like crossing streets, walking, searching, recognizing objects, places and people which becomes difficult or sometimes impossible without vision. Recent statistics from the World Health Organization estimate that in developing countries there are 285 million people worldwide who are visually impaired [10]. Thus there is no other options for the blind and visually impaired people to rely only on their canes [2], guide dogs, or an assistant for navigating in an unfamiliar environment [3, 12].

There are some vision based hardware systems available to assist them. They used stereo cameras [7], depth cameras [1], Microsoft Kinect [3], ARM processors and GPS [4]. But these are very much expensive and bulky. And hence common man cannot afford these costly hardware systems. In this paper we have introduced a new method

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which will help them to identify nearby obstacles without using costly cameras and processors. To address this issue we have used 'Raspberry Pi'. Raspberry Pi is like a mini computer which has its own RAM, expandable memory and many more. It is cheaper, easily available and less bulky as compared to other. In our case the observer i.e. the camera is not stationary. Observer is also moving along with the surrounding environment and hence the stationary objects seems to be moved. So it is very much important to detect moving object with the moving observer. Thus in computer vision and video processing motion detection and tracking is found to be challenging task [9]. And that is the reason why we have selected optical flow technique to detect the obstacles.

2 Literature Survey

Since the technology is new and application development and research era has just begun, the work carried out is limited. So before proceeding, a huge and detailed literature survey is necessary.

As far as hardware implementation is considered, researchers have used stereo cameras [7], depth cameras [1], Microsoft Kinect [3], ARM processors and GPS [4] to build their system. Bhambare, R.R., Koul, A. et al. used ARM 7 LPC2148, which works on traditional power supply of 12 V (made up step down transformer) which makes this system more bulky. GPS technology has been used to locate outdoor objects. For that continuous updating of surrounding environment & satellite communication is required, which makes system more complex in terms of coding as well as system design [2]. Chucai Yi, Roberto W. Flores et al. builds a system which uses number of cameras to locate query object by using SURF (Speeded up Robust Technique) descriptors and SIFT (Scale-Invariant Feature Transform) [3]. For that huge amount of dataset of a single object is required for feature extractions [6, 7]. A small change in environment will not give proper output since the system is trained only for limited area and objects. So we need to adopt a different techniques which will work in an unfamiliar environment and will not affect the change in the size and shape of the objects.

'Raspberry Pi' is tiny low powered computer having more RAM, expandable memory, Ethernet and USB connections and many more. We can say that it is a good substitute for costly processors and micro-controllers. We can adopt either background subtraction algorithm or optic flow technique which are most widely used in surveillance systems. If camera is stationary then background subtraction will be good choice. In our case camera i.e. observer is moving along with the surrounding environment and hence the stationary object seems to be moving. It is very much important to detect moving object with the moving observer. Optic flow technique is used to detect motion area in image sequences. It gives better performance under the moving camera, at the expense of computationally complex algorithms [8]. Optical flow presents an apparent change of a moving object's location or deformation between frames. Thus from this estimation and by using blob analysis we are able to figure out the obstacles in the frames [9].

3 Generation of Database and Some Challenges

Before starting the actual building of the algorithm we have to first generate our own database because readymade database is not available for us. We have visited nearby blind school named 'The Poona School and Home for the Blind Girls', Pune for this purpose. The database is taken by mounting the webcam on girls head and video is captured for a minute. We have taken near about 25 videos of indoor as well as outdoor.

By observing the database we should say that the algorithm should detect and track every single object in the scene. As shown in the figure there are many obstacles present in the scene, so detecting and tracking them was challenging task (Fig. 1(a)).

When we capture the video, it covers almost all the objects which are near as well as far from the observer. In short it covers the entire environment which is in line of sight of the camera. Now those object which are too far from an observer will be identified and informed as the obstacles which is of no use (Please refer Fig. 1(b)). For e.g. suppose you are an observer and wish to go to the second door, for that you need to cross the girls on your right hand side and then the girls present near the door. Further you can proceed further for the next door. Thus we need to frame the region near to blind person. If something comes in this region only then it can be notified as an obstacle (Fig. 1(c)).

(a) (b) (c)

Fig. 1. Illustration of presence of too many objects such as benches, students, table, teacher etc. as shown in (a), and (b) gives illustration of line of sight of a camera & respective ROI

4 Methodology and Software Implementation

Some assumption were made prior to start of the work. We have assumed that the illumination and brightness conditions are constant throughout. The input to the system will be a video of some predefined parameters as discussed below. In every digital video processing, the first step is to convert the given video into frames. And on every single frame we performed the below specified operations step by step. For detection of obstacle we have estimated the motion vectors. After that the segmentation is done in which we have performed tracking part with the help of background subtraction algorithm. Lastly we have detected the obstacles within ROI.

4.1 Optical Flow

Optical flow or optic flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer (an eye or a camera) and the scene. Moving images are often disturbed by noise depending on variety of Conditions. The detected noise can be framed either as additive white Gaussian noise, or due to some weak signals. And hence there is necessity to implement some smoothing operations which can handle different types of noise. So we have used 'Median Filter'. Median filters are widely used since they exhibits excellent performance as compared to that of linear filters.

4.2 Segmentation

The detection of objects can be successfully done by segmenting the image into no of blobs or regions. To accomplish this we may have to take help of some of segmentation techniques such as background subtraction, graph cuts and mean shift clustering. These segmented regions are then re-joined to represent an obstacle. In tracking part the data of each frame is read and the background is determined. The objects which are of no interest are eliminated by background subtraction. The gray to binary conversion can be done by using thresholding. And thus this threshold limit highlights the object of interest.

(1) Morphological Close

In order to extract the significant features from the image frames so as to represent and describe the object we need to use morphological operations. They are most commonly used in the image segmentation and pattern recognition. In our proposed framework we have used both morphological erosion and dilation to remove unwanted portion of floor, road and other unwanted objects. After the closing operation we get the result in which many small holes and separated pixels are combined into one big actual object of interest.

(2) Blob Analysis

To detect 2-dimensional object of any shape 'Blob Analysis' is used. The detection is achieved depending upon some spatial characteristics. Many application where we need to save computational time, blob analysis finds its use. Blob analysis eliminates the blob which are unwanted and preserves only those of necessary. This can be achieved by using spatial characteristics. The blobs which fulfils our System are many moving and stationary object within the region of interest. Other unwanted blobs are eliminated by setting some conditions on the features in the algorithm.

4.3 Region of Interest

Now this is the uniqueness of our proposed framework. One can use depth cameras or the sensors to know the nearby object but it will be costly and bulky system.

The blind person generally walk with their eyesight little bit downward toward floor. And by using this characteristic we have drawn the region of interest at the pixel level only. The following figure will illustrate the operation. We have found out the ROI by extracting the 4 co-ordinates points at pixel level as a rectangular blob.

Then we have used simple 'imcrop' function specifying the pixel value as shown in Fig. 2.

Fig. 2. Illustration of Region of Interest (ROI). They illustrate the value required for writing and simulating the 'imcrop' function.

5 System Design or Hardware Implementation

The system consists of a wearable camera (Logitech C290 having 5 MP resolution and 1920 × 1080 image resolution) which is mounted on the head. The overall processing is done in the Raspberry Pi-2, B model. It has 1 GB RAM, 4 USB ports, 900 MHz quad-core ARM Cortex-A7 CPU, Full HDMI port, Ethernet Port, camera interface, micro SD card slot and many more. We have used MATLAB 2012 for simulation purpose. The Operating System installed on raspberry pi is 'Raspbian' Software used for building algorithm on 'Raspberry Pi' is Open CV2.4.9 which uses Python as one of the programming language.

5.1 Some Hardware Issues

While designing the system, we encountered some hardware issues. We can't install MATLAB directly on Raspberry Pi. We need to install some 'Simulink Support Packages' for Raspberry Pi. We can program Raspberry Pi boards to run our algorithms using Simulink Support Package for Raspberry Pi Hardware. The support package generates code from our Simulink model in a click of a button that then runs on the Raspberry Pi board. These packages are available for MATLAB version which were released after 2015. In MATLAB we have used some computer vision function which supports only '.avi' video file format. If we want to make real time system then it must support every video file format. So we need to build our algorithm in Open CV by using Python language. Python supports every video file format and gives nearly same result as that of MATLAB.

The overall cost of system is near about $200. But it will get increased due to more external memory, RAM and camera resolution.

6 Result

The experimental results were shown in this section. The results were obtained on the standard database which was taken at the blind school. The processing time was taken at initialization and finalization of steps which covers pre-processing, filtering and estimation of motion vectors (Fig. 3). The processing time was near about

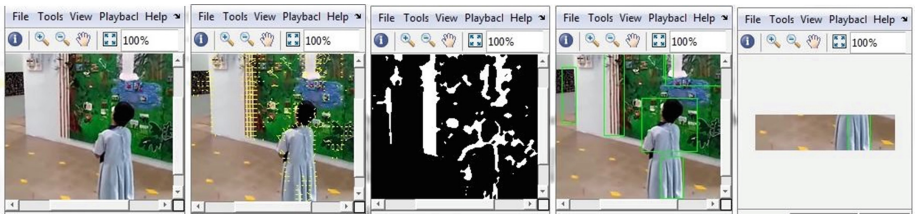

Fig. 3. Illustration of final results. (a) Shows the input video frame. After estimating motion vectors (b) we have done segmentation (c) and then blob analysis (d) to detect nearby obstacles which is shown by green squares. The last frame shows the final detected output (e)

7 Conclusion and Future Work

In this paper we have proposed a simple cost effective system to help visually challenged people. We have given a camera based technique that can detect and track obstacle effectively. In order to evaluate the performance of proposed algorithm we have used database generated at the blind school. Experimental results shows that, the proposed algorithm can effectively detect and track the nearby obstacles. Due to the use of 'Raspberry Pi' the system became more cost effective and less bulky. However this algorithm fails if illumination and brightness conditions are not proper.

In future we will try to classify each objects and obstacles under different categories such as chair, door, table etc., so that blind people will get actual information of the obstacles and they can move freely in any kind of environment.

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