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Vision based Assistive Cane for Visually Impaired

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Abstract

Computer vision is a man-made tool that improvises and enables the traditional application processes to transform into an automated process in industrial use cases. This is generalised for several applications that require unguided workflow in our day-to-day life. Our work mainly focuses on reducing the cost factor of an existing vision-based smart assistive cane. Our cane is integrated with a vision system that is capable of notifying the user in case of any obstacle with audio feedback. The main ideology behind this work is to provide a cost efficient assistive cane for the nominally earning visually impaired. The cane is integrated with raspberry pi that handles the object detection and the voice feedback process. A camera is interfaced with the raspberry pi, where the live video feed of the surroundings is obtained and then transferred to the raspberry pi for navigation. Appropriate sounds are given to the user, depending on the surrounding situation and how the user must act about it.

***Keywords**—Raspberry pi, YOLOV4, Computer Vision, assistive cane, tf lite.*

I. Introduction

India being the second most populous country in the world, constitutes up to 20 percent of its population to the visually impaired. Assisting the visually impaired with the help of recent technological advancements is comparatively simpler and efficient than finding a permanent solution for retrieving their vision in the short run. A survey by WHO (World Health Organization) states that around 2.2 billion people all around the world suffer from visual impairment. Out of those, at least a billion such cases could have been prevented according to [6]. Technology has reached heights of advancements that could be of great use for the visually impaired. There are assistive features in smartphones where the blind could use them with the help of a voice assist that announces the notifications received. Although there is an improvement in their lifestyle, their locomotion from one place to another has remained consistent.

There are a few assistive products that have entered the market like the Microsoft Soundscape app [7], which notifies the user through an audio system with a mixture of sounds referring to a straight path or to stop walking. The app notifies the user of the current place and the upcoming places on that route. A destination can be set for planning a route to a particular place. Cost of the existing solutions of assistive devices play an important role in their lives. The lifestyle of the visually impaired is not as lavish as that of those with clear vision. Their everyday expenditure would be close enough to their income, thus making it a harder process for them to maintain their savings. Our work mainly focuses on reducing the cost factor of a smart assistive cane. The cane is integrated with a vision system, which is capable of notifying the user in case of any obstacle with an audio feedback.

Low cost assistive canes are usually integrated with ultrasonic sensors that are able to detect the obstacles within a distance of around four meters. They are most likely to be interfaced with arduino and a motor that notifies the user with a vibration in case of any obstacle. Some are integrated with water sensors, which can be used to detect water content on roads that may cover potholes and be of great danger to the users. In, Dada Emmanuel Gbenga et al. [2] had designed a smart walking cane that could aid the visually impaired people. The stick consists of an ultrasonic sensor for obstacle detection and a water sensor for detection of water on the ground.

If an obstacle is detected by the ultrasonic sensor, then the buzzer is activated once. If water is detected, then the buzzer is activated twice the time and if any signal is detected, then the buzzer is activated thrice. With the number of times the buzzer is activated, the user could become aware of the type of obstacle in front of them.

The white canes used by the visually impaired are specially designed to be weightless and compact. The weight factor can be reduced by using lighter materials like PVC that are hollow inside and are integrated with components in the out. Although it is heavier than the conventional canes, the weight factor is compensated with the hollow structures. Sularso Budilaksono et al. [3], had made a prototype design of a walking stick which can assist the visually impaired people for their movement. The prototype works based on sensor technology that alerts the user based on the environment. The stick uses an ultrasonic sensor for distance calculation and Arduino Uno as the main controller. There are three ultrasonic sensors, one facing left side, one facing right side and another facing straight. The design detects objects at a minimum distance of 7 centimeters and output will be provided in the form of vibrations and sounds to the user. The stick is made of PVC material which could be lighter to carry.

In some assistive canes, the navigation feature has been integrated that enables the user to travel from one place to another with ease. This feature is improvised with a front end application, where the user can enter the destination in a smartphone and the navigation process takes place through voice feedback. Pooja Mind et al. [4], proposed a smart stick for the visually impaired. The stick consists of a raspberry pi with wifi module through which the android application can be connected. When the user gives the destination via voice command to the app, the navigation instructions are provided along with the information of obstacles on the way of the user. Three ultrasonic sensors are fixed to the stick and the commands are given using TTS (Text To Speech) IC. There is also an emergency button that sends an alert message to the guardians of the user when pressed. A total of three emergency mobile numbers can be added for receiving the alert messages.

Alexey Bochkovskiy et al. [5], designed yolov4 which is an improvised version of yolov3. It is an object detector algorithm. Prior to yolov4 all the object detector algorithms had to run with the help of many GPUs in small batch sizes. But yolov4 improvised the object detection method to train in a single GPU thus increasing the operating speed and to perform better parallel processing.

II. DESIGN AND DEVELOPMENT

A. Proposed System

The proposed system consists of a simple USB cam, a Raspberry pi module and a bluetooth speaker. The system alerts the user if there are objects within a short distance from the user using a buzz. The distance between the camera and the objects are measured using the relative sizes of the objects in the image. This proposed system can remove the requirement of a high power ultrasonic sensor that is currently being used in most of the products available in the market. Figure 1 depicts the 3d model that had been designed for the proposed system.

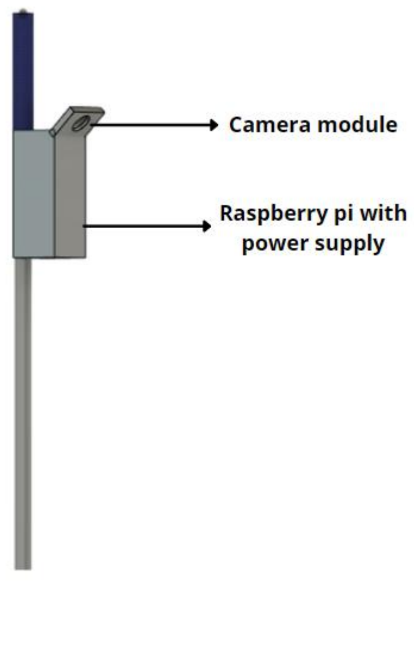

Fig. 1 3D model of assistive cane

B. Hardware

A cane of around 55 inches on average was designed to be integrated with a compact rectangular box that comprises the raspberry pi, Bluetooth speaker and the power bank. The raspberry pi used here is of model 4 with 4 GB RAM. The USB camera is selected and interfaced on the upper side of the box and is tilted slightly towards the ground to ensure the correct viewing angle of the surroundings. A power bank is added to be the source for the raspberry pi, throughout the navigation process. A bluetooth speaker module is interfaced to alert the user in case of any obstacles on the path. Figure 2 depicts the sequence of the hardware components interfaced together. The input is provided to the raspberry pi and then the output after processing the data is provided to the speaker module for notifying the user.

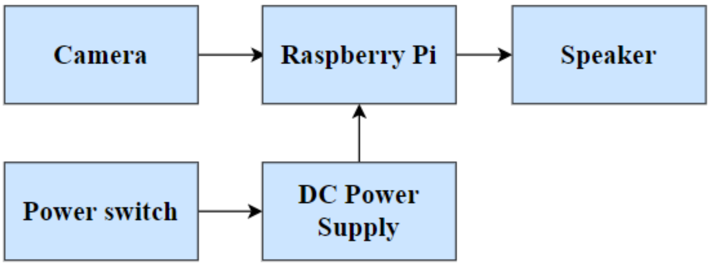

Fig. 2 Block diagram of the hardware connection

C. Software

The Algorithm is prominently based on the idea of recognizing and localising the objects images in edge devices efficiently in real time. This was made possible due to the work presented in Zicong Jiang et al. [1]. This paper proposes a novel method to reduce the time consumed on object detection and localisation.

The camera feed is passed to a yolov4 tiny deep learning model optimised for edge devices using tensorflow lite, pre-trained on the coco dataset. This model was chosen because the MS COCO dataset on which the model has been trained includes most objects in the road and has state of the art architecture.

The model gives out the probabilities, probable classes and the bounding boxes for each object that has been detected. These values have been used to create a rule based system based on which the user will be alerted. The figure 3 illustrates the sequence flow happening in the software part. Initially, the video feed is obtained from the camera and the data is transferred to the close object detector. The close object detector detects the obstacles on the input feed and sends instructions to the user through the bluetooth speaker.

D. Close object detector

The close object detector is a rule based system in which the rules are designed based on the principle that the objects near the camera are larger in the image than those in farther. The detected objects' size and the approximate angle where the object is located are calculated and this information can then be used to alert the user if there are any obstacles in the user's path. Initially the system is designed to detect humans and has been implemented. The proposed rule based detector's flowchart is shown in figure 4.

Initially the object area is calculated from the bounding box values taken from the yolov4 tiny. If the area of the object is greater than 50 percent of the total image the object is close to the user and the user is warned. The relative center crop of the image is 30 to 70 percent of the complete camera view. If the object is within this area the object is considered to be in the path of the user and the user is given a buzz.

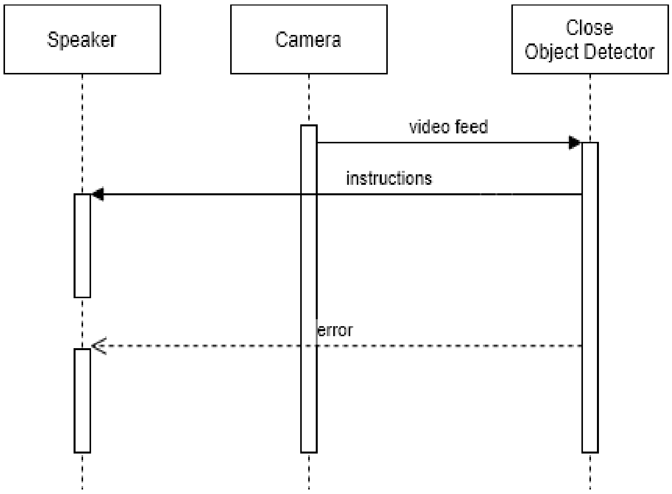

Fig. 3 Sequence Flow Diagram

III. IMPLEMENTATION

The proposed algorithm was implemented on a raspberry pi 4 4 GB module with a Raspbian OS. The Raspberry Pi 4GB model has Quad core 64-bit ARM-Cortex A72 processor running at 1.5GHz. Since it is being intended to be used for a processor demanding application a heat sink and a cooling fan has been used. The algorithm was implemented in python 3. The Yolov4 tiny model was imported in tensorflow and had been converted into a tensorflow lite model on a personal computer. This is in turn used for detections on the raspberry pi. The yolo v4 tiny is one of the State-of-the-art models available for Object Detection in edge. This model was chosen among the other available models like SSD, Faster RCNN and other models primarily because of its speed and accuracy. Initially, models yolo v3 tiny, yolo v4 and yolo v4 tiny were taken into consideration. The frames per second (fps) varied in larger amounts when implemented in raspberry pi than on a laptop integrated with the Nvidia Geforce GTX 1050-Ti graphic processing unit. As for yolo v3 tiny, it came up to around 70 fps in the laptop and around 4 fps when implemented in the raspberry pi. This model seemed to be the fastest when compared among the other models. The only drawback of this model was that the localisation of the detected object was poor. As for the yolo v4 model, it reached up to 10 fps while testing in the laptop, whereas

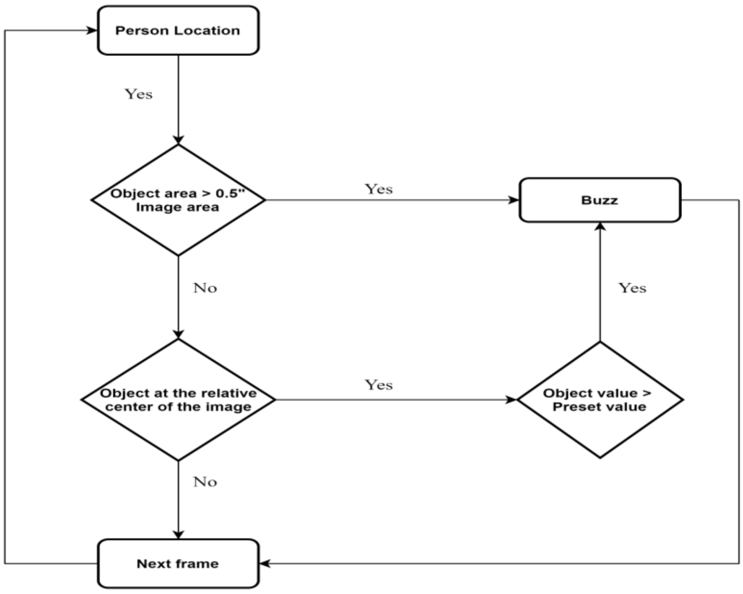

Fig. 4 Flow chart of the Close Object Detector

when implemented in raspberry pi, it reached a fps of 0.1 which is considered to be poor in performance. The yolo v4 tiny on the other hand reached up to 50fps on the laptop and up to 3.5 fps when implemented on raspberry pi. The Text to speech module is also used to provide info on the object in front of the user.It is being done using the pyttsx3 module which runs offline.

IV. Results and Analysis

The proposed algorithm was successfully implemented and the results have been validated. The setup can run smoothly with a fan to cool the raspberry pi from its heat dissipation. A 10000 mAh battery is used as the power supply and so the setup can run for more than 3 hours continuously and provide appropriate results.

The system works well on well lighted environments and can be reliably used during daytime. Further the system can perform well if a TPU or Jetson Nano module is used instead of a raspberry pi since it can do object detection faster than the Raspberry Pi 4 Gb module. Figure 5 depicts the object detection taking place in the sample video that was input to the raspberry pi. As per the flowchart that has been depicted in figure 4, the model does not alert the user since the object value does not exceed the preset value. Whereas in figure 6, an alert message can be seen in the terminal window, enclosed within a red box. The lady in figure 6 seems to be at the relative center of the frame and the pixel values covered by her are greater than the preset value, which leads to the alert message being printed in the terminal.

A. *Advantages*

One of the main advantages of our work is the cost factor. There are several vision based solutions available that are higher in cost. Comparatively, our work provides a lower cost solution. Conventionally used ultrasonic sensor based solutions are inefficient in providing the details of the obstacles that are farther away. Since our work is a vision based solution, the details of the objects are easily obtained and the user is notified respectively.

B. Disadvantages

The use of the USB camera restricts the use of data obtained during night or in dim light. Compromising clarity of the video feed may introduce technical processing complications. Another notable point is that the objects that move very fast may fail to be detected. Some objects like a fast moving car cannot be captured clearly by the camera. At present, the model is incapable of detecting static objects that are difficult to differentiate such as poles, walls and buildings.

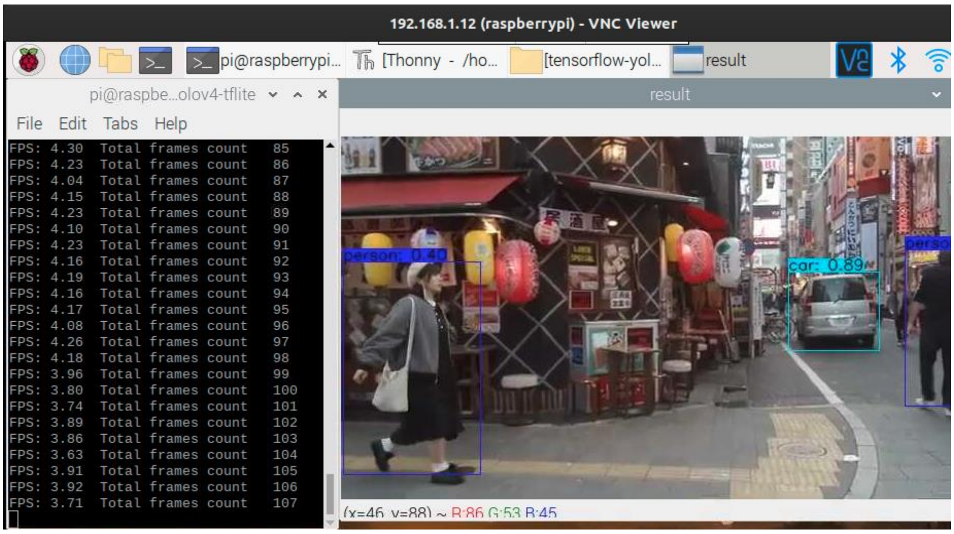

Fig. 5 Does not alert the user

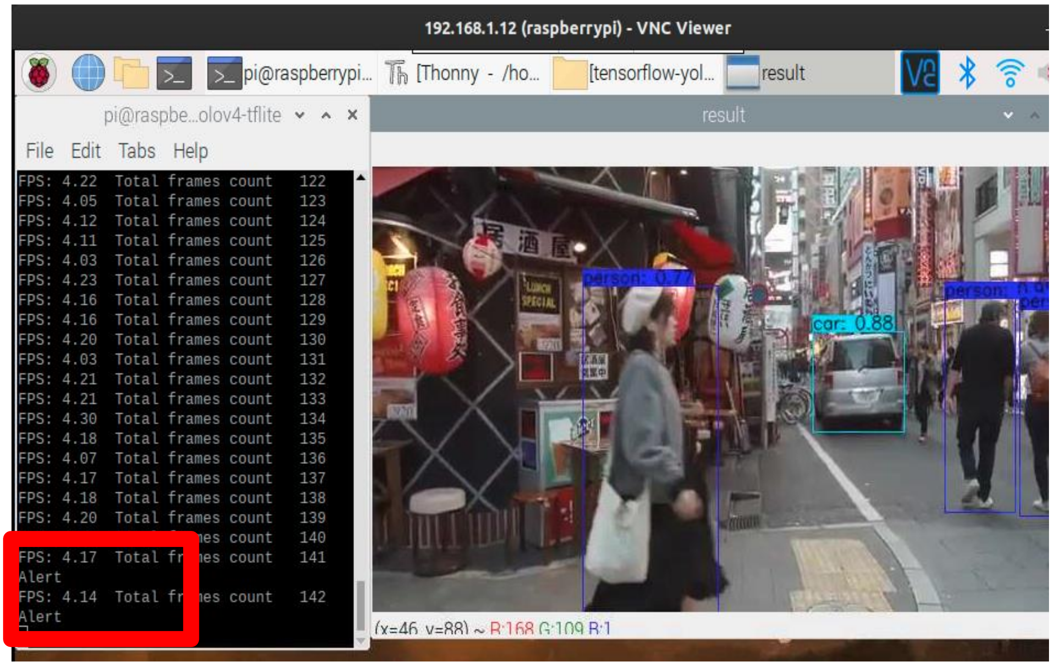

Fig. 6 Alerts the user when a person is in area of interest

V. CONCLUSION

The selection of the deep learning model yolo v4 tiny has been done after a comparison of various other models. The video input obtained by the camera module is transferred to the yolov4 tiny model where object detection takes place. The yolo v4 tiny having a value of 3.5 fps when implemented on raspberry pi, seems appropriate to process the input video feed and perform the object detection process.

The obstacles are successfully detected and then the user is notified accordingly. The choice of microprocessor had to be raspberry pi since this was a basic model and to test the process with ease. This model could further be improvised to the use of Raspberry Pi pico that raspberry pi 4. It is comparatively way smaller than raspberry pi, drastically cheaper and less power consuming. The battery life of raspberry pi comes up to around 45 minutes of continuous usage, whereas for the pico model, the battery capacity could be reduced, sustaining the usage time. The reduction in the battery capacity could reduce the weight of the model, making it light enough. This shift in microprocessor would demand a change in the camera module used as the pico version does not come with the usb ports. Several camera modules that could be interfaced with pico are readily available in the market that go up to a 5 megapixels.

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