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Research Article

AI based ETA for Visually Impaired in Indoor Environment

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Abstract

According to WHO-world health report on vision (2019), more than 1 billion people have vision impairment globally. The main challenge of the People with visual disability is to navigate within the crowded working place and they need to depend on others for their mobility. A novel AI (Artificial Intelligence) based Electronic Travel aid (ETA) is proposed which performs object detection and obstacle avoidance to overcome these barriers and guide the visually challenged people by giving voice commands which allows them to navigate without the requirement of any assistance.

AI-ETA consists of a Raspberry Pi-3 processor Loaded with a pre trained Convolutional Neural Network (CNN) model. The camera which is connected in the USB port of the processor captures an image in real time which is processed by the processor. CNN model identifies the obstacles with boxes and category index. The ultrasonic sensor finds the distance at which the obstacle is present. The obstacles identified and the corresponding distances are stored in the text file which is converted to voice using the Google Text To Speech module. The proposed system uses obstacle avoidance algorithm to guide visually impaired by giving proper voice commands. The system starts monitoring the heart rate of the user using heart beat sensor. If the heart rate is out of the threshold value which is set then the guardian will receive an alert message consist of heart rate detail along with their location (using GPS) information. The proposed system is tested on visually impaired people in indoor environment at different locations to prove the system effectiveness.

Keywords: *AI, ETA, CNN, heart beat sensor, object detection and obstacle avoidance, vision impairment, GPS*

Introduction

According to 2019 global health report, more than 1 billion people are suffering with visual impairment. This embraces people with modest or austere vision impairment to find distance, blindness due to refractive error, color blindness, cataract, glaucoma, diabetic retinopathy, and near vision deficiency etc. The world celebrates International day as people with disabilities on December 3rd and the aim of Global Action Plan(GAP) 2014– 2019 states at

the World Health Assembly is to ensure free access to visually challenged people and to reduce visual loss.

Visually challenged people have major difficulty in recognizing and intermingling with the surroundings. As the technology progresses rapidly, there is a drastic improvement in the industry of small-scale sensors for various applications in the field of robotics and vehicle automation. These sensors are upgrading the functionality of the smart devices like mobile phones, tabs and wearable electronic gadgets. This improvement makes our lives more vibrant and pleasing. But we must remember the fact that there are large numbers of people who straightway need these sensors even to fulfill their basic needs of daily life. This sensor technology can be extended to human beings. The ETAs "translate" the sensor's signals into other customs of hints, such as acoustic signals, tactile cues and stereophonic images decipherable by visually impaired people. Fortunately, with the advancement of technology many Electronic Travel Aids are presented for visually challenged people.

Associated Works

This work concentrates on the object detection, Navigation using sensors and obstacle avoidance to guide visually impaired, Literature survey has been done mainly on these areas.

Traditionally, White cans were used by most of the visually impaired people for their mobility. They regularly swaying it in the front for detecting the obstacles. But the essential information like distance & volume of the object cannot be detected by white cane. Comparably, ETA with integrated multiple sensors [4] could provide ample information about the ambiances and guide visually impaired people in a better way.

J. Bai et al [10] developed system in the shape of eye glasses to guide the visually challenged. This smart guiding device recommends a novel obstacle avoiding algorithm. The transparent objects like French doors are detected using depth sensor and for weak sighted persons, AR (Augment Reality) technique is used to direct them.

A wearable glove [7] is developed which can be worn by the visually challenged people which in turn guide them by providing haptic and voice feedback. But there was the problem of precision the object was not accurately detected by the used sensors. However this work provided the emergency alert system using GPS and GSM modules.

Inside the Japan Railway station the system with BLE technology [8] has been tested successfully with the help of in-built compass in the Smart phones for providing voice direction. But this work also relies on Fast Internet Connectivity.

Ultra-wide band locating technique [9] is used to guide visually impaired in known indoor areas. This work digitizes the floor plan of the building and database is developed with the information of obstacles in the building. But this work can be used only for the particular building and the database must be updated whenever there is a change in the floor settings.

Visually restricted people are more liable to hearing. Using this concept a system which provides alert by vibrations and vocal sound [11] is proposed. Based on the varying distance between hindrance and handler, different strength rates were prearranged to the sensor which vibrates to guide them.

RGB-Depth sensor with a range-expanding capability is used in a system [12] to monitor and guide visually restricted people in this system the sensor enables the target recognition and provides audio instructions by using segmentation and mapping techniques.

Iıı Artıfıcıal Intellıgence And Cnn

Artificial intelligence (AI) technology empowers a machine to learn automatically from the past data without programming explicitly. Deep Learning technology is a subclass of Machine Learning which forms networks capable of learning without supervision from unlabeled and unstructured data. It enables a machine to simulate human conduct.

A convolutional neural network (CNN) is a neural network which is a subclass of deep learning technology. It is universally pragmatic for exploring pictorial imagery. Convolution is the process of multiplying pixel values of the image by a constructed coefficients and adding them. Henceforth this process got the name convolutional neural network-CNN. Convolution is the mathematical operation which convolves the image matrix with kernel as shown in figure 1.

Figure 1: 5X5 image matrix and 3X3 kernel

A 5X5 image matrix is multiplied with 3X3 kernel produces the output which is called “Feature Map” is shown in Figure 2 with a stride of 1. Stride denotes the number of pixel shifts over the input matrix.

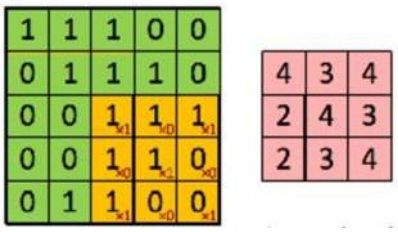

Figure 2: Image matrix and Convolved Feature Map

A CNN is typically poised of numerous layers of convolution. When an image is given to CNN, several activation maps are generated by every layer. The first layer of CNN perceives the elementary features such as vertical, horizontal and transverse edges. More multifaceted features such as corners and combination of edges are extracted by the subsequent layers for which the previous layer’s output is given as input.

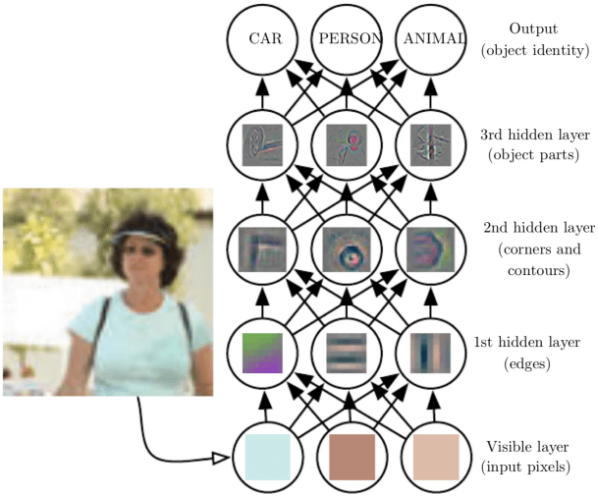

Figure 3: Layers of CNN

When it is moved deeper, the layers flinch detecting advanced level features such as faces, persons and indoor objects. The classification layer gives a set of confidence score (between 0 and 1) as output created on the galvanization map of the final convolution layer and specifies how probably the image belongs to a "class." The different layers and its detection of CNN are shown in figure 3.

The next layer after convolution is pooling layer. Spatial size can be reduced by the method called Pooling. Max pooling is applied in this case. Filter of size k*k is taken and maximum operation is applied over the k*k portion of the image. If the width is w, height is h and depth is d then after pooling the image having w*h*d will be changed as:

W = (w-k)/S+1 H = (h-k)/S+1

D = d Where k*k is the filter size and S is the stride.

In the beginning, random weights are used in CNN. The developer should provide a large dataset of images annotated with their corresponding classes (car, dog, person etc.,). CNN processes each image with random value and then compares the output with its corresponding classes. If the output does not match then small adjustment is done in the weights. This process continues until get the correct answer. In the proposed work COCO data set is used to train CNN.

Proposed System

Serious treads made in AI and Machine Learning technologies is to help the visually impaired. Text-to-speech translations shall describe the objects identified by the system that pave a path for vision-free communications. The goal is to develop an intelligent machine which will guide visually challenged people.

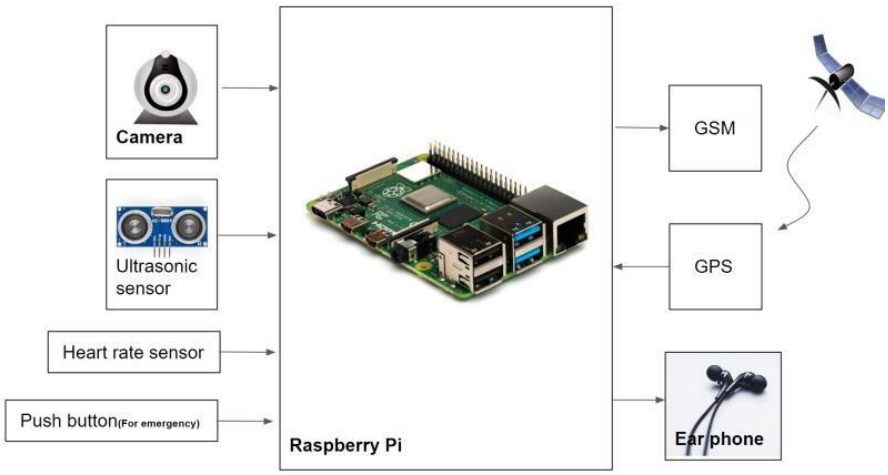

Figure 4: Block diagram of the proposed AI-ETA

The proposed system AI-ETA consists of raspberry pi board, Camera, ultrasonic sensor, heart rate sensor, pushbutton, and GPS & GSM modules as shown in figure 4. The camera connected with the raspberry pi board captures the images of the surroundings around the user. CNN model identifies the obstacles with boxes and category index. The ultrasonic sensor finds the distance at which the obstacle is present. The obstacles identified and the corresponding distances are stored in the text file which is then converted to voice using the Google Text-To-Speech module. The proposed system uses obstacle avoidance algorithm to guide visually impaired by giving proper voice commands. The heart rate of visually

challenged people is measured using heart beat sensor. The user can set the high as well as low level of heart beat limit. The system starts monitoring the heart rate of the user. If the heart rate is out of threshold value, then the alert message will be send to the guardians along with their location using GPS. The push button is used by the visually impaired, to send the message to their guardian when they are facing the health issues suddenly, and simultaneously the location of visually impaired is send to the guardian by using GPS module.

Hardware And Software Usage

The hardware and software used in the Proposed Travel aid is described below. The Hardware usage is explained followed by the software packages.

A .Raspberry pi 3 model

In the proposed AI-ETA, the raspberry pi 3 is the heart of the system which gets information from sensors and guides the visually impaired accordingly. In Emergency, the raspberry pi triggers the GPS and GSM modules to send the message which includes the heart rate and Current location information to the guardian of visually impaired. In this project, raspberry pi 3 is used with Quad-core Processor of 64-bit ARM Cortex A53 and is clocked at 1.2 GHz having Video Core IV multimedia GPU of 400MHz and SDRAM of 1GB LPDDR2-900.

B. Ultrasonic Sensor

The ultrasonic sensor (HC SR04) is used to find distance of the obstacles detected. The sensor module includes trigger pin which is used to transmit ultrasonic waves and echo pin is used to receive the reflected waves by the obstacles. These two pins are connected with the Raspberry pi 3 which will calculate the range of obstacle and store it in text format which will be converted into voice instruction to the user.

C. Heart Rate sensor

AI-ETA uses MAX30100 which is an integrated pulse oximetry and heart rate monitoring module. MAX30100 conglomerates two LEDs: one red LED & one IR-LED, one photo detector, augmented optics, and a low-noise analog signal processing unit to sense the signals of pulse oximetry and heart-rate. When there will be increase in volume of blood flow with each heartbeat and will result in more light getting absorbed by the finger so that less light reaches the photo-detector. One can see the troughs/peaks in reflected light occur at each heartbeat. The duration between two spikes can be used to measure the persons Heart Rate.

D. GSM and GPS module

GPS (Global positioning system) provides the geo-location and time information to a GPS receiver anywhere on or near to the Earth. The GR87 GPS receiver module is utilized in the proposed system used to track up to 12 satellites at a time while providing fast time-to-first fix and one-second navigation updates. It provides three dimensional position values (latitude, longitude and altitude) of the visually impaired people to the guardian in an emergency with the usage of GSM module SIM 900A.

E. Pushbutton

In AI-ETA, the push button is used by the visually impaired people, to send the message to their guardian when they are facing the health issues at any instants. Whenever visually

impaired press the push button, it sends the pulse signal to the raspberry pi board which in turn triggers the GSM module to send the message.

F. TensorFlow API (for object recognition)

Google Brain team developed the TensorFlow using Python. TensorFlow is an open source library created for Machine learning. Different algorithms are combined with different models in this API to enable the user to perform image identification easily. This can be done by implementing deep neural network. It compiles many different algorithms and models together, enabling the user to implement deep neural networks for use in tasks like image recognition/classification. In this work TensorFlow object recognition API is utilized to identify the obstacles. After detecting the obstacle, navigation guidance is provided to the user. The TensorFlow framework has many pre trained datasets such as ImageNet, CIFAR (Canadian Institute For Advanced Research), Common Objects in Context (COCO) dataset, MNIST (Modified National Institute of Standards and Technology), KITTI dataset and the Open Images Dataset etc.

AI-ETA uses the COCO dataset to train the system. This dataset can perform large-scale object detection, image segmentation, and image captioning. It can distinguish more than 300 objects. For training purpose MobileNet V2 architecture is used. In real time the image captured by USB camera is compared with pre trained COCO model, and provided name of object identified as voice output. When AI-ETA is investigated in our college premises, it is observed that it can be able to identify people and objects accurately in Indoor Environment. Further it can be upgraded and tested for outdoor environment also.

G. OpenCV-Python

OpenCV is a computer vision library written in python which contains all kind of image processing techniques. OpenCV has some features to apply the Machine Learning Classification and regression algorithms to the data. There are three functions that enable three different algorithms to get applied. They are K-Nearest neighbors, Support Vector Machines and K-mean clustering. Support vector machines find a hyper plane that best divides a dataset into two classes using simple command.

Cascading method is used to find the facial feature which has been extracted from the classifier. It takes each 24X24 window and applies 6000 features to it then check if it is face or not. Face detection using Haar-cascade object classifier is shown in figure 5.

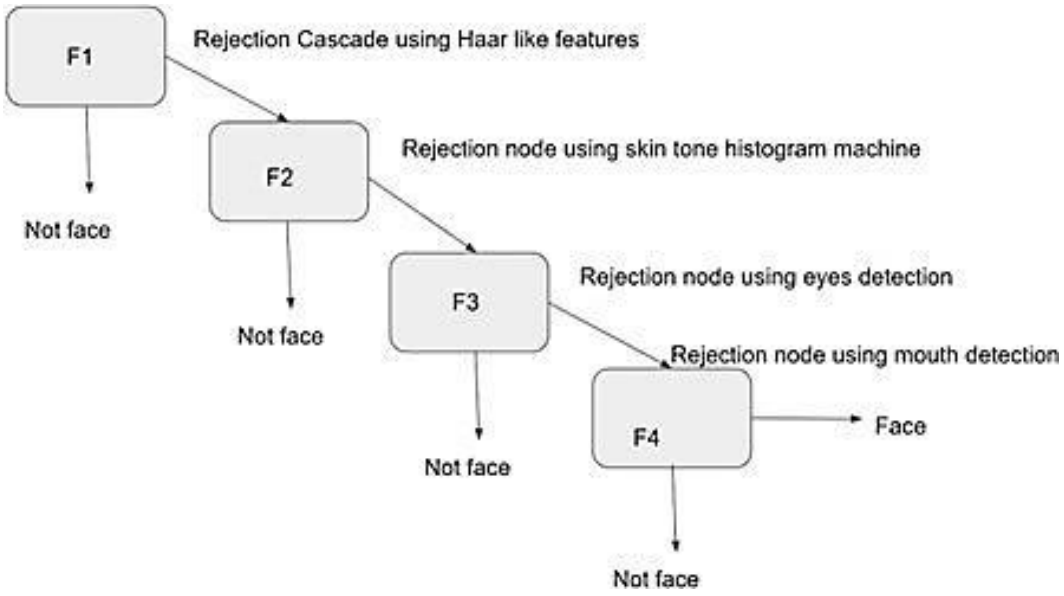

Figure 5: Cascade classifier

Histogram of Oriented Gradients (HOG) is a descriptor which describes all features. This is widely used on several dominions to describe objects through their shapes.
By the distribution of edge direction or local intensity gradients, local object appearance and shape can often be described. Human can be detected using the following command.
hog.detectMultiScale(image,winStride,padding,scale)

H. Text to Voice Converter

AI-ETA uses eSpeak which is an open source speech synthesizer. Speech Synthesis Markup Language is used to format speech synthesis method. Objects detected by the system will be stored in data base in text format which will be converted into voice.

Work Flow Dıagram

Workflow diagram visualizes the flow of tasks between resources, whether they are people or machines. It describes the conditions which permit the sequence to move ahead. The work flow diagram shown in figure 6 depicts the overview of the series of actions in the usage of AI-ETA.

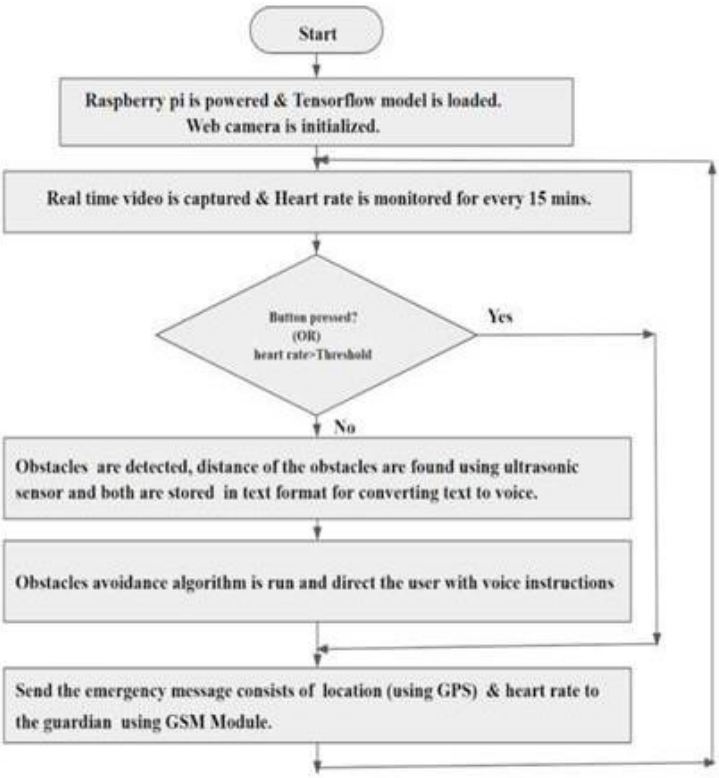

Figure 6: Workflow diagram of AI-ETA

Exprımental Setup

The hardware setup of AI-ETA which includes Raspberry pi, USB Camera, Ultrasonic sensor, Heart beat sensor and microphone is shown in the Figure 7.

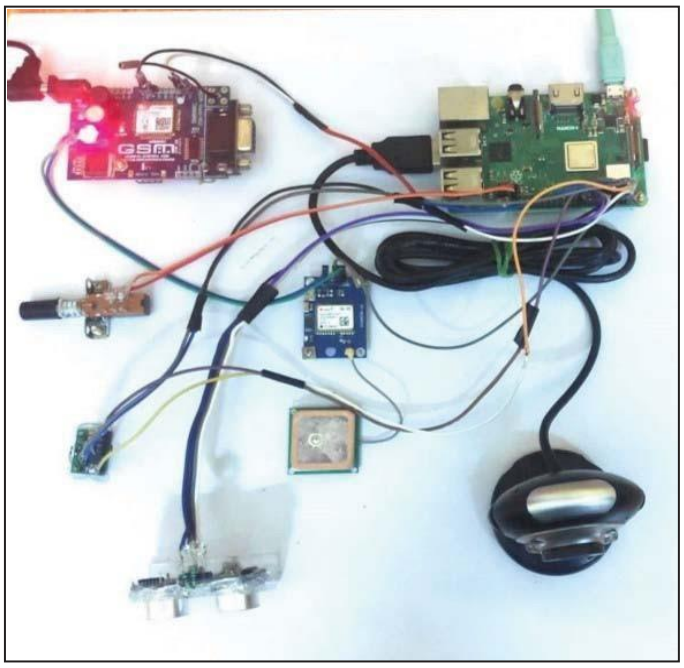

Figure 7: Hardware setup of AI-ETA

Four GPIO pins (GPIO 5V [Pin no. 2] for power supply) , GPIO GND [Pin No. 6] for Ground, GPIO 23 [Pin No. 20] for Trigger to ultrasonic sensor (Output from Rpi) and GPIO

24 [Pin No. 21] for ECHO from ultrasonic sensor (Input to Rpi) are used for connecting ultrasonic sensor. In Data sheet the output of the heart beat sensor HC-SR04 is specified as 5V. But the rating of the input pin GPIO is 3.3V only. A small voltage divider circuit is used to protect Raspberry pi's GPIO pin. MAX30100 (digital heart rate sensor) is connected Pi using UART. Camera is connected using USB port and microphone is connected to 3.5mm audio jack of pi board to provide voice guidance for users.

MAX30100 is a GPS module which has 4 connection pins. They are namely: TX, RX, VCC and GND. Tenth GPIO pin (RX) of Raspberry Pi processor is connected to the GPS module's TX pin. GPS module's GND pin is connected to the GND pin of the RPi board (6^{th} pin). SIM 900 is connected to USB Port or raspberry pi. Latitude, Longitude and time information is extracted from NMEA GPGGA string received from GPS module using Python code and on request or in emergency it will be sent to the guardian as a message using GSM module. By using these latitude and longitude, Guardian can locate the current position on Google Map.

Conclusıons

The proposed system AI-ETA is experimented on visually challenged people in real time at different locations in indoor environment to demonstrate the utility of the system. It worked satisfactorily. AI-ETA is not only offers vocal guidance, but also provides safety by monitoring the health of the user and give emergency alert to the guardian of the user. . In emergency the guardian can easily track visually impaired with the GPS coordinates sent by the system using Google map. So the proposed system ensures quality life to visually challenged people.

In future augmented reality can be used to make a smart glass with the proposed camera affixed at the center of the glass and 2 glasses can be used as screen to display augmented reality. For weak sighted people who have some degree of visual perception, vision could offer more information than other senses like audio, vibration etc. The popular AR (Augmented Reality) technique can be used for exhibiting the surroundings and the directional guidance on the eyeglasses to help partially blind people and voice guidance can be given for fully blind people. In future low cost depth camera can be used to detect transparent objects like French doors. In near future, the face recognition can also be incorporated with identifying the person's name by storing the faces of blind people's relatives and friends in data base and strangers can be identified easily by the visually challenged.

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