Fixed Obstacle Detection for Autonomous Vehicle

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Abstract—Obstacle detection in autonomous vehicles is mandatory for maintaining the safety of the driver and the vehicle during the trip to the required destination. Currently, vehicles are integrated with alert system to help the driver to drive the vehicle safely through the path. However, autonomous vehicles must detect the obstacles by itself and start navigating through the surrounding objects safely. Various systems were introduced for obstacles detection using different sensor types such as lidar, camera and radar. Raspberry pi camera is used to detect the obstacles ahead of the vehicle during the trip. The obstacles which the vehicle should deal with is divided into two types: fixed obstacles (e.g. Stop signs and traffic lights) and sudden obstacles. The work presented is focusing on fixed obstacles detection using a monocular camera and Raspberry Pi. Python and OpenCv's machine learning libraries are used for image processing using Haar feature-based cascade classifiers method, which detects the objects with high accuracy and low computational time. Moreover, a software made using deep learning technique to identify the obstacle. The output of the two obstacle detection techniques is compared in terms of speed and accuracy. Finally, an I2C (Inter-integrated Circuit protocol) is used for communication between the Raspberry Pi and the main controller of the targeted vehicle, to take the required decision based on the detection result.

***Index Terms*-- Computer vision, Obstacle detection, Autonomous vehicle , Raspberry Pi, Python , OpenCv**

I. INTRODUCTION

TODAY'S relation between mankind and machines is highly developed. The relation is based on how to utilize the machines to help us in our daily life tasks to make it easier, safer ,effort and time saving. Research and development is the main key for utilizing the machines to serve the mankind with new prospects. Autonomous vehicles is a great example for the machines developed by researchers to help the human being [1]. The word autonomous means "independent and having the power to make your own decisions" [2]. That is exactly the purpose of the autonomous vehicles , it is a driverless vehicle capable of making decisions without any human interference, based on information provided from various sensors [3].

Nowadays, automotive companies spends billions on the research and development of self-driving vehicles to stay competitive and innovative, as it is the future of transportation [4]. Google's driverless car gave the autonomous vehicle a push in terms of publicity. It was tested for 1.5 million kilometers and it suffered only from 14 accidents during that distance. However, it wasn't Google's car fault that caused the accidents, actually the fault lead to the accidents came from the other driver [5].

Nevertheless, Google's car first fault that lead to an accident was in Feb 2016, as the car crashed into the side of a bus [6], yet still safe to ride Google's self-driving car. That leads us to one of the advantages of autonomous vehicles. Humans are blamed for their mistakes that leads to accidents. Therefore, autonomous vehicles should be able to avoid the mistakes made by humans reducing the amount of accidents and save lives. That could be done using different types of sensors and monitoring technologies to avoid fixed obstacles and sudden obstacles in the route of the vehicle. Fixed obstacles are the objects that the vehicle regularly meet during any trip like traffic lights and stop signs. Sudden obstacles are the objects that the vehicle may meet during the trip or not, it depends on the situation. Various types of sensors and monitoring technologies is used by the researchers for obstacle detection in the autonomous vehicles.

Radar (radio detection and ranging) it transmits and receives radio waves to detect the distance from the objects in the surrounding environment. The main drawback for the radar in autonomous vehicle, that it can detect only the objects made from metal like other vehicles in the road, which means that it can't detect the people crossing the street for example. Although, radar can predict the relative speed of the detected object, which will be very helpful for the autonomous vehicle's system in decision making [7]. Also, it detects the objects in long ranges and reliable in case of bad weather situation [8].

Lidar (Light detection and ranging) is a remote sensing device for measuring distances similar to the radar, it is based on transmitting and receiving process [9]. In comparison, lidar sends laser beams for measurement the distance of the objects. These laser beams are analyzed to get an accurate and precise information for the shape of the objects to be visualized [10]. A map of the surrounding objects could be generated using this information, which is used to avoid the obstacles [11]. A

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downward 2-D Lidar sensor was used for road boundaries and obstacles recognition. The presented method was implemented on driverless car A1, which won in Hyundai's A.V. competition in Korea [12].

Ultrasonic Sensor, ability is to send acoustic wave at high frequency that human ear can't listen too, like bats to recognize the surroundings in darkness or dolphins underwater [13]. Ultrasonic detection similar to lidar and radar, it is based on transmitting and receiving the high frequency acoustic waves, which provides accurate short range data. Therefore, ultrasonic can be used for parking assistance systems or as secondary sensor for warning systems in autonomous vehicles [14].

Camera based systems is relatively cheap compared to other devices, it see and cover a wide range of the environment around the vehicle. The Images taken through the camera needs to go through a stage called image processing stage [15]. After the processing stage the processed information is used for example to detect traffic lights, street signs, street lanes and any obstacles in the sight of the camera. However, its limitation is the need of calibration to deal with harsh weather conditions. Also, the image processing algorithm is very complicated and challenging to detect and recognize the surrounding objects [16].

This work introduce a camera based system using raspberry pi camera with python and OpenCv libraries to detect traffic lights and stop signs. There is a hardware implementation on a raspberry pi controller to control an electrical vehicle to response with the traffic lights and stop signs. The paper is organized as follows. Section II discusses different work done related to this paper's work. Section III describes the methodology used throughout this paper. Section IV shows the hardware implementation for the introduced methodology. Section V shows and discusses the results obtained from the work done. Section VI presents the paper's conclusion.

II. Related Work

Obstacles detection for autonomous vehicles is a basic problem, which is extensively researched recently. Different methods of obstacles detection is proposed based on the type of sensor used. Other methods use a sensor fusion between some sensor types to get an optimum result.

Vision system is the most used system for obstacles detection [17]. Extensive research is done to process the image to classify the objects. A lot of machine learning techniques applied, such as extreme learning machines [18] and neural network [19].In [20], they used MR code (Mobile Robot) due to its ability to detect different locations and identify various objects, under different lighting schemes with different viewing angles. Also, Kinect camera is used to detect the objects within its field of view and the distance is measured from Kinect's depth sensor to the detected object [21]. Another vision based detection approach for lane detection using ridge detector and sequential RANSAC (Random Sample Consensus), this method showed an accurate estimation to the vehicle's position with respect to the road [22]. While other topology relied on Raspberry Pi camera with ultrasonic sensor to measure the distance and detect the obstacles accurately by fusing both of the two sensors [23]. Other approach used OpenCv libraries for processing the images detected from Pi camera to keep the vehicle on the lane [24]. Another technique for image processing converted the RGB color space recorded from the camera into HSV, it identifies the traffic light intensity on the converted HSV color space [25]. In [26], they suggested a new idea for detecting traffic lights based on analyzing the nearby vehicles movement. It was shown a promising results, however if there is a lack of vehicles around the targeted vehicle that will lead to a fault traffic light prediction. In contrast, a real-time traffic lights detection methodology based on convolution neural network, showed a great accurate results concerning different weather conditions [27].

III. System Overview

In this work, a monocular vision approach is made to detect stop signs and traffic lights in front of the autonomous vehicle, to give the required action to the main controller of the vehicle. In fig.1. shown an overview chart for the proposed work.

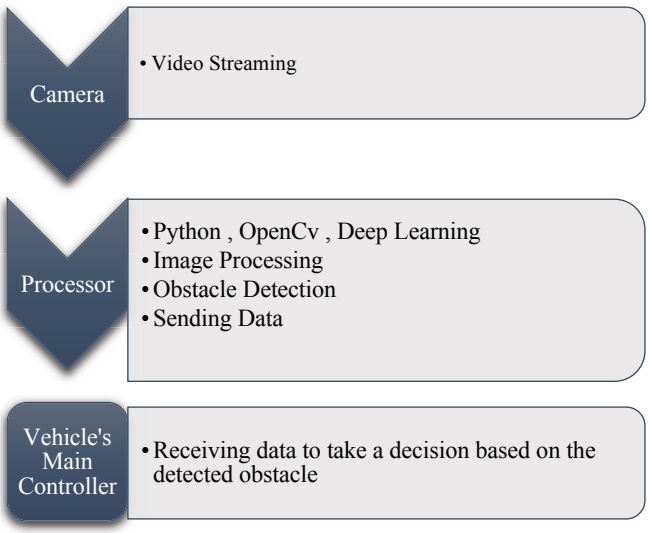

Fig. 1. System Overview Chart

Raspberry Pi camera is used to detect the objects. Raspberry Pi 3 Model B is programmed by Python and OpenCv libraries for image processing. The processing for object detection is done by using Haar feature-based cascade classifiers method. It was first introduced by P. Viola and M. Jones to detect the objects with minimum processing time and high accuracy [28]. Haar feature-based cascade classifiers is a machine learning technique , which takes true and false images for training. Then it is used to detect the objects in images different from those it was trained on. OpenCv is used for both training and predicting the objects. Finally, a communication protocol is needed to communicate between the raspberry pi and the main controller of the vehicle. In this work, I2C (Inter-integrated Circuit protocol) is used for its ability for allowing many of slaves integrated to communicate with one or more master. Another advantage that it requires only 2 pins to connect any number of slaves.

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In fig.2. a chart is presented for the stages of image processing to detect stop sign. At the beginning, a Haar cascade detection is used for eliminating the false results from the image, using a series of classifiers on each part of the image. If all of the image parts passed through all the classifiers then the detection of the stop sign occurs, which it called the region of interest (ROI). On the other hand, if the a part does not pass through the classifiers then the image is rejected . The main advantage of Haar cascade detection is providing an accurate results with a short time of processing.

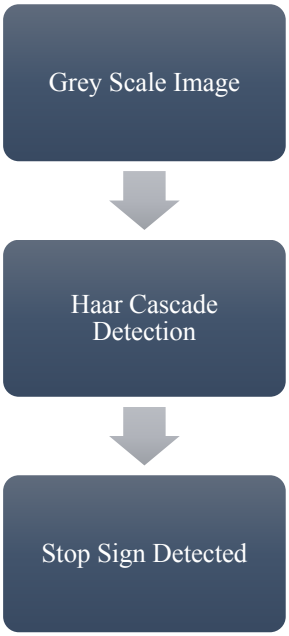

Fig. 2. Stop Sign Detection Using Machine Learning

Moreover, deep learning or convolution neural network was used to detect the stop sign as well. Deep learning is a type of machine learning in which a model learns to perform classification tasks directly from images, text, or sound. Deep learning is usually implemented using a neural network architecture. The term “deep” refers to the number of layers in the network—the more layers, the deeper the network. Traditional neural networks contain only 2 or 3 layers, while deep networks can have hundreds. A set of images with different categories of object where labeled and given to the network for training. Using this training data, the network can then start to understand the object’s specific features and associate them with the corresponding category.

Each layer in the network takes in data from the previous layer, transforms it, and passes it on. The network increases the complexity and detail of what it is learning from layer to layer. There is a three groups of layers the input layer, middle layer and output layer. The input layer is for image entry only. The middle group layer is responsible for feature detection which contains the convolution layer that puts the images through a set of convolution filters, pooling layer to simplify the output by reducing the number of parameters needed by the network to learn and the last layer is the rectified linear unit which gives a faster and effective training by excluding the negative values and maintaining the positive values. The previously mentioned layers is repeated three time in the middle group layer.

IV. Hardware Implementation

A. Components

1) Raspberry Pi 3 Model B :

Raspberry Pi features a mini portable Computer which contains an ARM CPU with 1.2 GHz speed, graphics processing unit and 1-GB RAM. Its operating system is stored on a SSD card. Raspberry Pi output can be provided through general purpose I/O pins, which also supports I2C communication protocol.

2) Raspberry Pi Camera Module V2 :

The camera module supports 1080p30 and 720p60, using its five megapixel focus camera. It is used to take normal images or taking a high definition videos. Raspberry Pi’s CSI port is connected with it through a 15cm ribbon cable. There are many libraries built for the Pi camera, such as Python library.

3) Adafruit T-Cobbler Plus for Raspberry Pi :

It is a simple way to wire up any components with the Raspberry Pi, because of its compact shape. The Cobbler breakout is connected with the Pi 3 through a ribbon cable. The Cobbler can be attached to any breadboard, allowing easy connection between raspberry pi and any other components.

4) Arduino Uno :

It is a microcontroller board, with 14 digital I/O, 6 analog inputs, a 16 MHz quartz crystal, a USB connection and a reset button. It is mainly used for validating the I2C communication protocol between it and the raspberry pi.

B. Schematic Diagram

Shown in fig.3. a schematic diagram for the I2C connection between Raspberry Pi and Arduino.

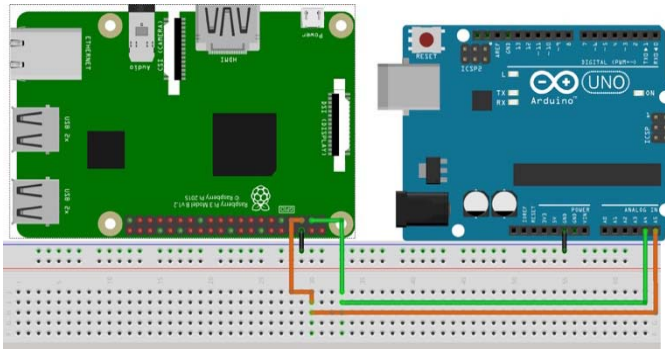

Fig. 3. I2C Connection Schematic

C. Software

1) Python :

Python is a high level programming language. It enable the programmers to write there codes in less lines compared with any other programming language. That’s why it used in many general purposes and specifically in the academic researches.

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As result, Harvard university started a course under the title " Using Python for Research" two years ago.

2) OpenCv :

It is mainly a real time vision libraries of programming functions. Which can be used for image processing and object identification. OpenCv libraries allows these functions to be easily installed on a computer to provide computer vision. It is based on C++ but it can be compiled to Python.

V. Results

A. Haar cascade classifiers

The trained classifiers were tested on multiple images of stop signs with different conditions. It showed a great results in terms of speed. However, sometimes it can't identify the stop sign in case of images with poor quality. Also, if the stop sign is tilted or not is its right position that increases the possibilities of identification failure.

Fig.4 Haar stop sign identification

B. Deep Learning Technique

The convolution neural network trained on many images of stop signs The constructed network in that work achieved 74% accuracy which is enough for using this network to detect the stop sign. The data used for testing were classified to 10 objects the network had some issues with the identification of cats and dogs most of the time the network thought that the dogs is cats or vice versa. Despite of this issue, this network is not really made to detect the objects it was trained on, the training objective was to make the network learn how to extract features from the input images using the weighted filters and able to classify them.

The developed network as explained previously of an object identifier using a 15-layer convolutional neural network, is used to train another neural network with 50 images only for stop signs. Also, the software is developed to detect the stop sign live from a streaming video. The network trained on multiple of stop sign images in different positions. The trained network showed a great accuracy in term of its ability to identify the stop signs and its position in the images. As shown in fig.5 the network shows the area inside the box which is the detected stop sign and the probability of that detected object is a stop sign. A multiple tests done with many images to the network and a live video streaming also used to test the network, it was able to detect the stop sign accurately in many cases, such as if it is tilted, upside down or even if there is many of them in the same image. Also, it has been tested under low light conditions at it managed to detect the stop sign accurately.

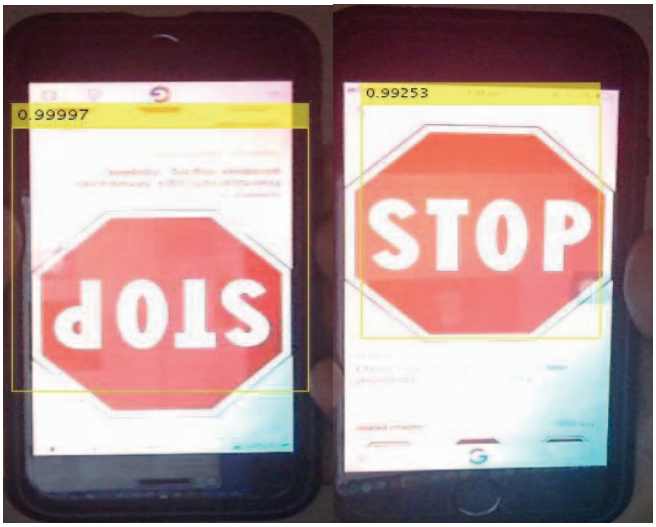

Fig.5 Deep Learning stop Sign Identification

The connection between the Raspberry Pi and Arduino Uno is implemented on a breadboard using the Adafruit cobbler as shown in fig.6. The I2C communication protocol is validated and tested, through sending data using a python test program from the Pi to the Arduino.

Fig. 6. Implemented Circuit for I2C Communication

VI. Conclusion

Monocular vision based system is inexpensive and can achieve the required accuracy for obstacle detection in autonomous vehicle. This work introduced an approach based on the camera and raspberry pi for image processing using python and OpenCv. Moreover, a software made using deep learning technique to identify the obstacle. The output of the two obstacle detection techniques is compared in terms of speed and accuracy. The comparison showed that in terms of low

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computational time the Haar cascade is better and cheaper for hardware implementation . In Contrast, the deep learning technique requires a higher specs hardware to apply beside it needs more time for training, but it provide higher accuracy in different situations. The results of the processing stage used for alarming the autonomous system in the vehicle to take the required action based on the obstacle's type, done by I2C communication protocol is validated and tested, through sending data using a python test program from the Pi to the Arduino.

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