Self-Driving Car Using Convolutional Neural Network

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Abstract - Self-driving cars have become a popular subject of interest lately because these driverless cars might just bring about the biggest revolution in the society since the industrial revolution. These self-driving cars are proposed as accident-free and time saving urban transportation solution and in military applications. This paper shows implementation of a low-cost prototype of a miniature self-driving car model using simple and easily available technologies. The objective of the paper is to build a self-driving car model that can detect lanes, identify objects in its surroundings and avoid accidents caused due to driver's fault. In this prototype, we are using the Raspberry Pi 4, Pi Camera module and L293D motor driver to build the car model. Deep Learning techniques like Convolutional Neural Network and image processing techniques like Hough Transform Algorithms, Transfer Learning, Canny Edge Detection algorithm are used.

***Key Words*:** Self-driving car, convolutional neural network, image processing, lane detection, traffic sign detection, raspberry pi 4.

1. INTRODUCTION

Everyday around the world, there are millions of people who lose their life due to road accidents and a million others who get injured and disabled for their rest of their life. To decrease this rate, the automotive industry, using the rapid advancements in technology, is proposing new ideas to build self-driving car in order to ensure accident-free transportation. A self –driving car or an autonomous car is a vehicle that is capable of sensing its surroundings and moving around with less or no human input. Self-driving cars can stand to solve problems like traffic delays, traffic collisions, provide greater independence to the visually impaired and senior citizens and make them self-sufficient. Drop in the number of accidents also means less traffic congestion and that leads to drop in harmful emissions. Studies states that harmful emissions will be reduced by 60% after the advent of autonomous vehicles. Autonomous vehicles will appear to take traffic management to a new level. Experiments have been conducted on autonomous driving system since 1920s. The first autonomous car NavLab can be dated back to the 1980s, built in a project funded by the United States Defense Advanced Research Projects Agency. Today companies like Google, Uber and Tesla are leading the global initiative in the design and manufacture of an autonomous car. These self-driving cars use computer vision and deep learning techniques in solving automotive problems, including detecting lane lines, identifying objects and traffic signs, and much more.

2. METHODOLOGY

The main methodology used is Convolutional Neural Network (CNN), The self-driving car should detect and differentiate between objects such as humans, vehicles, traffic lights, roads etc. To accomplish such tasks, CNN is used as a tool for image classification.

2.1 Convolutional Neural Network (CNN)

CNN is a class of deep neural network commonly applied to analyze visual imagery. They are specialized type of neural networks that use convolution in place of general matrix multiplication in at least one of their layers. It uses a system similar to a multilayer perceptron. The CNN consists of an input layer, output layer and a hidden layer which includes multiple convolutional layers, pooling layers, fully connected layers and normalization layers.

2.2 YOLO

YOLO is an abbreviation for You Only Look Once. It is an algorithm that uses CNN, regression for object detection. It scans the entire image at once while processing it and hence the name YOLO.

2.3 Lane Detection

Lane detection is an important substratum in the development of self-driving cars. The road lane detection consists of five major steps:

- Removing noise
- Discard color information
- Detection of edges
- Region of Interest
- Hough Transform

2.4 Traffic Signal and Signboard Detection

An ANN is used for classifying the traffic signals and the sign boards which are trained with real time datasets. Images of road signs are converted to grayscale images and then are filtered using Gabor Wavelets. Region of Interest is extracted using maximally stable external regions algorithm and are classified using support vector machines. Finally, we apply CNN to classify the sign boards and to extract or crop specific signs, A color based segmentation model is employed.

2.5 Object Detection

It is a computer technology related with computer vision and image processing that deals with identifying and locating objects of a certain class in digital images and videos. It is also used to count objects in a scene and also to determine and track their precise location.

3. MODELLING

3.1 System Design:

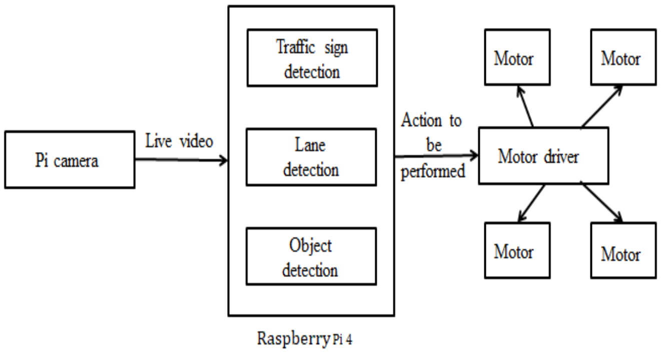

Fig 1: Block diagram

The pi camera sends the live stream of images to the raspberry pi for image processing. The raspberry pi contains the trained model of convolutional neural network. This processes the live stream of images and provides its output. The output is the necessary action(like start, stop, move forward, take a turn etc) required to be performed by the car. This is passed onto the motor driver which provides power to the motors of the car to act accordingly.

3.2 Hardware components:

3.2.1 Raspberry Pi 4:

Raspberry Pi 4 is simply a credit-card sized electronic board and works similar to a PC. It is integrated with a 64 bit quad core cortex- A72 ARM v8, Broadcom BCM2711 and runs at a speed of 1.5GHz . It possesses 8 GB of RAM and has extended 40 pin GP I/O header. It is equipped with a Bluetooth 5.0, BLE, gigabit Ethernet and has 802.11ac wireless at 2.4GHz and 5GHz. It provides a faster data transfer with two USB 3.0 ports, two USB 2.0 ports, micro SD slot for data storage and loading operating systems. The Raspberry Pi 4 has 2 micro HDMI ports, 2 lane MIPI DSI display port, 2 lane MIPI CSI camera port and 4 pole stereo audio and composite video port.

Fig 2: Raspberry Pi 4

3.2.2 Pi camera:

The Raspberry Pi Camera Module can be used to take high-definition video and capture still photographs. It uses a Sony IMX219 8-megapixel sensor. It is attached to the Raspberry-Pi via a 15cm ribbon cable. It supports videos of 1080p30, 720p60 and VGA90 modes. Raspberry Pi controller receives captured images from the pi camera as input. On the received image, Raspberry Pi controller runs real-time object detection algorithm and sends the control signal to motor driver which in turn drives the motor.

Fig 3: Pi Camera

3.2.3 Motor driver:

The L293D is a popular 16 pin motor driver IC. A single L293D IC has the capacity to handle two DC motors at the same time. The IC works on the concept of Half H-Bridge. It is used to bridge the gap between the Raspberry-Pi and the motors of the car. The motor-driver IC receives signals from the Raspberry-Pi and then takes actions on the motors accordingly and facilitates their start-stop motion and movement of the motors in clockwise and anticlockwise direction.

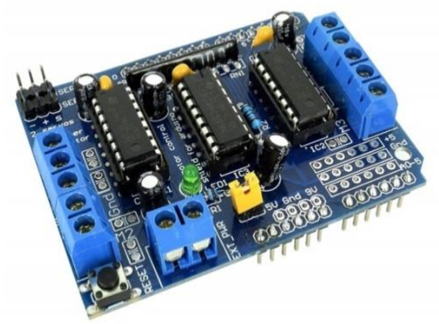

Fig 4: L293D Motor Driver

3.3 Software requirements:

3.3.1 Raspberry Pi Cam Interface:

It is a software where the live images captured by Pi camera can be remotely viewed on a laptop. Live feed captured by Pi camera can be viewed on this interface. Images and videos can be recorded or downloaded in numerous resolutions with the various number of settings.

3.3.2 OpenCV:

OpenCV stands for “Open Source Computer Vision". It is a library for computer vision and machine learning software library. It is a cross-platform library where we can read or write images, videos can be captured or saved, then images are processed i.e different type of image processing filters are applied and images are transformed. It also performs the feature detection on images, it also detects distinct objects in videos or images. OpenCV provides C++, Python, Java and MATLAB interfaces and supports Windows, Linux, Android, and Mac OS. OpenCV has been written natively in C++ and features a templated interface that works seamlessly with STL containers.

3.3.3 TensorFlow:

TensorFlow is an end-to-end open source platform for machine learning. It has an extensive, flexible range of tools, libraries and community resources. It can be used for a variety of tasks but mainly focus on training and inference of deep neural networks. TensorFlow 3D contains state-of-the-art models for 3D deep learning. These models have broad area of applications from 3D object detection (e.g. cars, pedestrians,etc) to point cloud’s registration.

4. RESULTS AND DISCUSSION

4.1 Dataset:

In this paper, public datasets are used to evaluate the effectiveness of the proposed approach. It includes German Traffic Sign Detection GTSDB, the most widely used dataset to evaluate traffic sign detection approaches. GTSDB contains 900 images and is divided into 600 training images and 300 testing images. The resolution of each image in this dataset is 1360 X 800. Each image contains traffic signs which may appear in every perspective and under every lighting condition.

4.2 Video Feed:

The Pi Camera Module takes high-definition live video. The camera starts recording a video with desired resolution, lower resolution results in better frame rate(fps) since fps drop will occur after applying processing techniques to each frame. Live feed captured by Pi camera can be viewed on the Cam interface in the laptop. This feed is used in the raw format for YOLO and Road Lane Detection.

Fig 5: Raw feed from camera

4.3 Road Lane Detection:

4.3.1 HSV color space and detecting edges:

Now after taking video recording as frames from the camera, the next step is to convert each frame into Hue, Saturation, and Value (HSV) color space. The main advantage of doing so is to be able to differentiate between colors by their level of luminance. After converting the image into HSV color space, detect only the color we are interested in (i.e. blue color since it is the color of the lane lines we have used in our project). To extract blue color from a HSV frame, a range of hue, saturation and value should be specified. And to reduce the overall distortion in each frame, edges are detected only using canny edge detector. Selecting region of interest (ROI) is crucial to focus only on 1 region of the frame. Here we want the car to focus on the lane lines and ignore anything else.

4.3.2 Detect Line Segments:

Hough transform is used to detect line segments from an edged frame. Hough transform is a technique to detect any shape in mathematical form. It can detect nearly any object even if it is distorted.

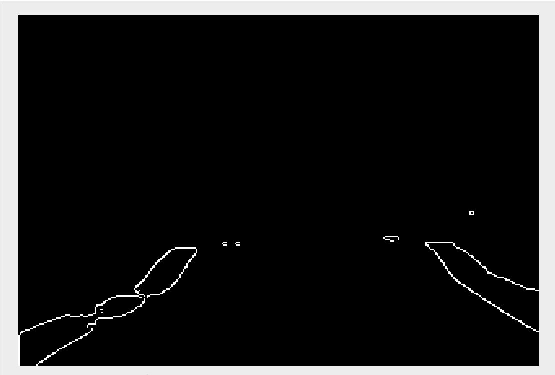

Fig 6: Region of interest

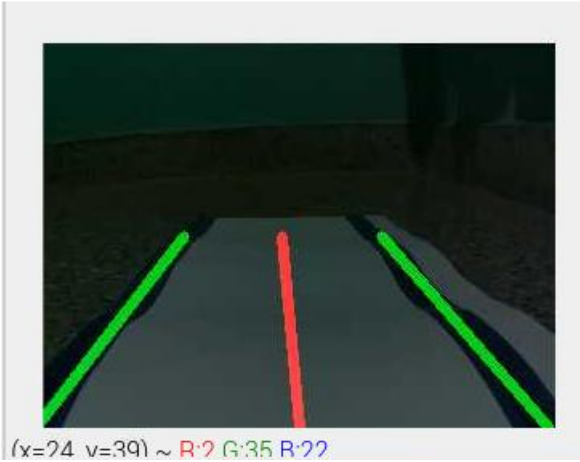

Fig 7: Final lane detected

4.4 Traffic Sign Detection:

There are several different types of traffic signs like speed limits, traffic signals, stop sign etc. Traffic signs classification is the process of identifying which class a traffic sign belongs to. We have built a deep neural network model that can classify traffic signs into different categories. With this model, we are able to read and understand traffic signs which are a very important task for an autonomous vehicle. In this project, a CNN is used for classifying the traffic signal and signs which is trained with real-time datasets. Recognition of traffic signs is carried out in two phases, detection followed by classification. Detection finds or detects the traffic signs in a bounding box of the specific category and classification classifies it by giving a class label specifying which kind of sign is present. The images of the road signs are converted to grayscale. These images are filtered using simplified gabor wavelets. Region of interest is extracted using the minimally stable external regions algorithm and classified using CNN. Finally, convolution neural networks are applied to classify the signs and to extract or crop the specific signs on boards a color-based segmentation model is employed.

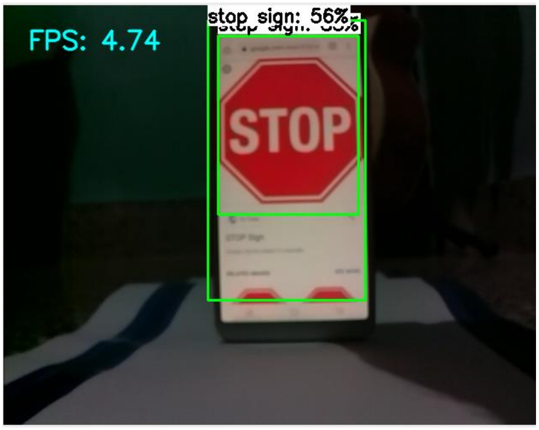

Fig 8: Traffic sign detection

Discussion:

In this paper, a prototype of a self-driving car is conferred. Deep learning algorithms like CNN are employed to make immediate decisions for the self-deriving car. Detection of objects, lane detection, and detection of traffic signs and signals have been studied in this paper. The algorithms like CNN through transfer learning, YOLO, and canny edge detection algorithms have been studied. Our model performed better after 15 epochs and the accuracy was stable. We achieved an accuracy of 91% on the training dataset.

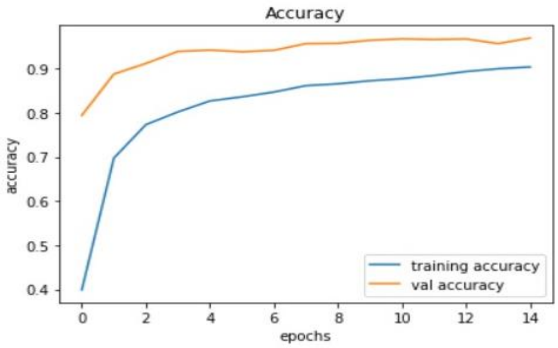

Fig 9: Graph of accuracy v/s number of epochs

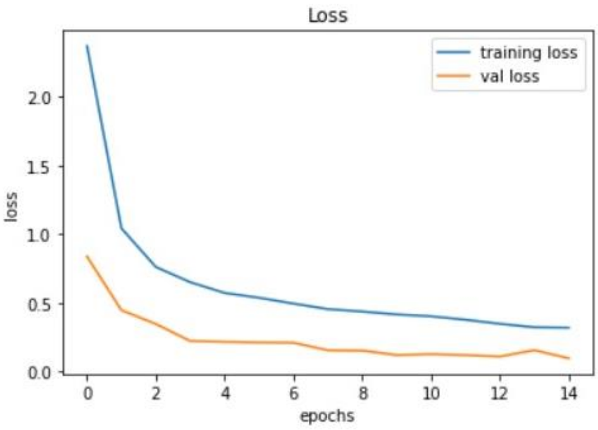

Fig 10: Graph of loss v/s number of epochs

5. Conclusion

In this paper, design and development of a miniature model of self-driving car is demonstrated. The car is able to follow the lane efficiently by making decisions based on the images sent by the Pi Camera and detecting objects on the road. As seen in the results section, the car is able to detect the traffic signs and take correct decisions while driving. The model is 91% accurate in an environment where there are no objects or obstructions, the road is clearly seen and the light not too bright, so the system can detect the color code on the lane line as well as can great track of traffic lane. This model can detect curves and can make turns efficiently. This system has further development areas of research such as including GPS system to track the location of the self-driving system continuously for safety.

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