PREDICTION OF VEHICLE'S MOVEMENT USING CONVOLUTIONAL NEURAL NETWORK (CNN)

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ABSTRACT
This paper is concerned with the development of a self-driving vehicle model that can navigate its way around the virtual simulator from source to destination by detecting lanes, objects and making predictions for vehicle movement. The source and destination for the vehicle is provided as input at first and a shortest route is calculated using A* search algorithm. Then, the images captured from the live stream of the simulator and other vehicle measurements are passed into the pipeline which is responsible for detecting road lanes, objects in the image and finally making accurate predictions for driving the vehicle. Road lanes are detected using Canny Edge Detection and Hough Transform. Faster R-CNN algorithm is used for object detection. Convolutional Neural Network (CNN) is trained and used to predict the movement of the vehicle. The project is shown in Carla simulator.

Keywords: A* search, Canny Edge, Hough Transform, Faster R-CNN, Convolutional Neural Network

INTRODUCTION
Self-driving car, also known as a robot car, autonomous car or driverless car, is a vehicle that is capable of sensing its environment and moving with little or no human input. Driverless cars are ubiquitous in imagined future scenarios. Autonomous vehicle technology is still at its infancy but currently various prototypes are being tested and demonstrated. The main drivers for achieving autonomous driving is the reduction of traffic accidents by eliminating human error, increasing road capacity and traffic flow. A driverless car requires the combination of several techniques among which are artificial intelligence, navigation system and information retrieval through sensors. These techniques will enable to guide autonomously a land vehicle from one point to another using public roads. Governments of countries in Europe and of the USA are creating regulations for self-driving cars, as a result of the latest advances of the industry. [1]
The benefits of fully autonomous vehicles can go way beyond removing the need of a human driver. Transportation services will start using self-driving cars instead of human drivers, and might become a cheaper and better alternative for end consumers than owning a car. This will represent a shift on the way cities are planned, as fewer parking places will be needed, and most importantly, in a smart city with most of its vehicles

being connected and autonomous, traffic optimization will be able to be heavily applied by coordinating movement. This will result in a major decrease in travel time, and it will also save lives as emergency services will be able to reach their destinations faster. Autonomous vehicles can be used for performing routine monotonous works such as garbage collection, delivery services, etc. [2]

Literature Survey

A. Uber's Self Driving Car

On September 14, 2016, Uber launched its first self- driving car services to select customers in Pittsburgh, including Pittsburgh Mayor Bill Peduto, using a fleet of Ford Fusion cars each equipped with 20 cameras, seven lasers, Global Positioning System, lidar and radar equipment that enabled the car to create a three-dimensional map utilizing landmarks and other contextual information to keep track of its position. In November 2017, Uber announced a non-binding plan to buy up to 24,000 Volvo XC90 SUV vehicles designed to accept autonomous technology (including different types of steering and braking mechanism and sensors) between 2019 and 2021. [5] In March 2018, the death of Elaine Herzberg by an Uber self-driving vehicle in Tempe, Arizona resulted in temporary pause to Uber's self-driving vehicle testing. The company changed its approach to self-driving vehicles after Herzberg's death, inviting both Waymo and General Motors' Cruise self- driving vehicle unit to operate vehicles on Uber's ride- hailing network. [6]

B. Tesla's Self Driving Car

Tesla autopilot is an advanced driver-assistance system feature offered by Tesla that has lane centering, adaptive cruise control, self-parking, the ability to automatically change lanes, navigate autonomously on limited access freeways, and the ability to summon the car to and from a garage or parking spot. As an upgrade to the base Autopilot's capabilities, the company's stated intent is to offer full self-driving (FSD) at a future time, acknowledging that legal, regulatory, and technical hurdles must be overcome to achieve this goal. All these cameras and sensors combine to form a fusion of sensors and eyes of the vehicle making Tesla cars almost military-grade, unmanned navigation systems. According to Tesla, starting 19 October 2016, all Tesla cars are built with hardware to allow full self- driving capability at the highest safety level (SAE Level 5).
[7] But as advanced as this technology may seem, Musk said that it isn't at full self-driving capability yet. In January of 2019 Musk tweeted that Tesla motors would slowly depart from the autopilot feature and introduce its first-ever self- driving technology. As early as the year's end, Tesla car owners would be able to safely drive from Los Angeles to New York City without ever touching the vehicle's steering wheel. That's almost 3,000 miles. [8]

Features

1. The vehicle moves from source to defined destination using the shortest path.
2. The vehicle detects objects like other vehicles, pedestrians, etc and avoid collision.
3. The vehicle detects traffic lights, road signs and lanes and follow correct traffic instructions.

IMPLEMENTATION

These are some of the process implemented in our project:

A. Data Collection

About 32 hours of driving data were collected from the CARLA simulator on a wide variety of roads. The dataset D = {(i, m, o)} consists of tuples, each of which contains an image i, measurements m and outputs o. The image is obtained from the forward facing camera of the vehicle. Measurements include current speed, acceleration, brake, steering angle, direction command for next intersection and traffic light state. The direction command is one of 'Straight', 'Left' or 'Right'. The outputs are predicted acceleration, steering angle and brake.

The sample data is shown below:

```
array ([list([array([[135, 135, 136, ..., 148, 148, 148],
[135, 135, 136, ..., 148, 148, 148],
...,
[114, 117, 118, ..., 101, 92, 97]], dtype=uint8),
[8.080735958253673e-07, 0.0, -0.0036648220848292112,1.0, 'Green', False, 'straight']]),
list([0.0, -0.0036648220848292112, 1.0])], dtype=object)
```

B. Data Preprocessing

Before feeding the collected data for training the neural network, data preprocessing is vital for obtaining better results. The preprocessing steps applied are as follows:

1. The collected dataset was heavily imbalanced at first as it contained a lot of data of vehicle moving forward and little data of vehicle moving left or right. So the first step was to balance the dataset.
2. The images were an array of pixels whose values were in the range (0,255). First, the images were converted to grayscale and the values were normalized by dividing by 255 and thus converted to the range (0,1).

[normalized image] = 1/255 * [input image]

3. Steering angle was also normalized from (-1,1) to (0,1) using a min-max scaler.

normalized steering angle = (steering angle + 1) / 2

4. The categorical values such as traffic light (GREEN, RED) and direction command (STRAIGHT, LEFT, RIGHT) were converted from string to numerical representation.

STRAIGHT = [0,1,0]
LEFT = [1,0,0]
RIGHT = [0,0,1]

Before processing the data:

```
[list([array([[141, 135, 135, ..., 146, 146, 145],
[141, 136, 136, ..., 147, 146, 146],
...,
[122, 116, 118, ..., 124, 59, 52]], dtype=uint8),
[33.03531246186619, 0.5, 0.0013826158829033375, 0.0,
'Green', False, 'straight']]
```

After processing the data:

```
[array ([[[0.55294118], [0.52941176], [0.52941176],
...,
[0.6], [0.59607843], [0.59607843]],
[0.49019608], [0.48627451], [0.33333333]]]),
array ([5.10102315e-06, 0.00000000e+00, 4.97699229e-01, 1.00000000e+00, 0.00000000e+00, 1.00000000e+00, 1.00000000e+00, 0.00000000e+00, 0.00000000e+00, 1.00000000e+00, 0.00000000e+00])
array ([[0, 0.49769923, 1]
```

C. Training the data

We train the weights of our network to minimize the mean absolute error between the outputs predicted by the network and the observed ground truth. Our network architecture is shown in the figure below. The network consists of 2 input layers, 8 convolutional layers, 4 pooling layers, 6 fully connected layers 6 dropouts and 1 batch normalization layer. The convolutional kernel size is 5 in the first layer and 3 in the following layers. The number of channels increases from 32 in the first convolutional layer to 256 in the last. We used ReLu activation function after each layer, performed batch normalization after convolutional layers, and applied 20% dropouts in convolutional layers and 50% dropouts in the fully connected layers.

The improvement in mean absolute error values over time while training the CNN are shown in the graphs below:

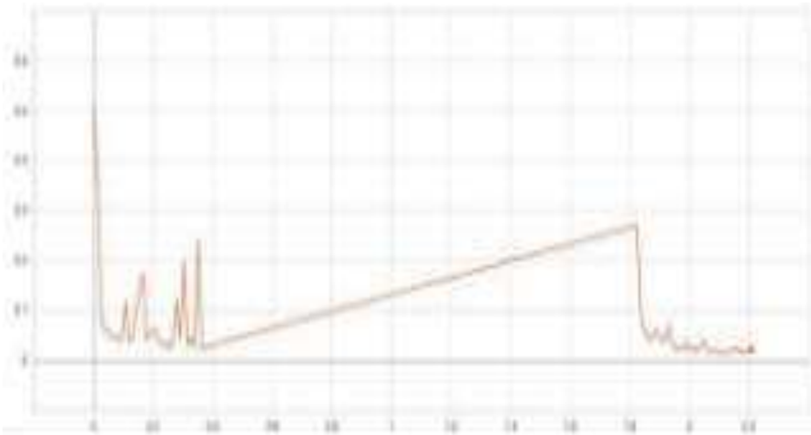

Figure 1. Validation mean absolute error

RESULTS

A. Lane Detection

The input image is converted into a grayscale image from color (RGB or BGR) image. Canny edge detection is applied to the gray image and the output is masked such that pixels within the region of interest are only seen. Then, a Hough transformation method is applied to find the lines in the masked image. The lines are filtered out by their slope and the remaining lines make up the required road lanes.

Figure 2. Original Image

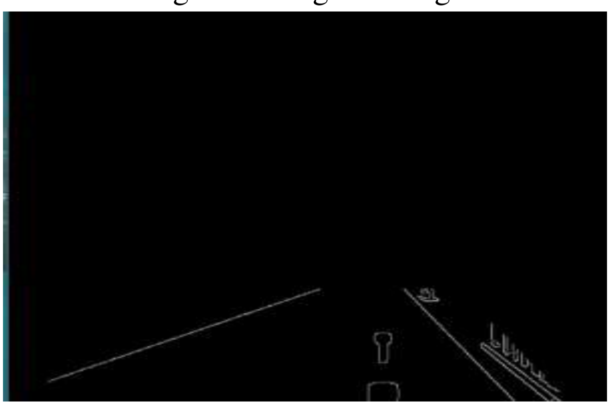

Figure 3. Lane Detection

B. Object Detection

We have performed object detection using the Faster R- CNN algorithm. The frames captured from the simulator are provided as input to the algorithm continuously and the algorithm outputs the position of objects in the image with their predicted class and prediction accuracy.

Figure 4. Object Detection

C. Trace Route

The shortest route to vehicle destination from vehicle's starting position is determined using A* algorithm. The topology of the map is taken from the simulator and mapped to a graph. The coordinates obtained from the simulator are mapped to graph nodes and the distance calculated between the coordinates using Euclidean distance are mapped to graph edges. After the graph of the map is obtained, A* algorithm is applied to find the least cost path from the source to destination. Source and destination coordinates are provided from the command line as arguments.

Figure 5. Shortest Route Tracing

D. Vehicle Movement Control

Convolutional neural networks have been trained for controlling vehicle movement. About 32 hours of driving data were collected from the simulator. Each data contained two inputs (image, vehicle measurements) and three outputs (throttle, steer and brake). Data preprocessing steps such as balancing the dataset and normalizing the values were performed. Then, the training data were fed into the neural network for training. Finally, the trained neural network is used to control the vehicle movement given the input images and input measurements.

Figure 6. Vehicle turning right at intersection

CONCLUSION

A virtual model of self-driving car was developed that can navigate its way around the Carla simulator without violating traffic rules and regulations. First, the model finds the shortest route from the source to the destination. While driving, it detects the road lanes and stays on the correct lane, recognizes traffic lights and performs corresponding action, identifies the objects in front of the car and avoids collision.

FUTURE ENHANCEMENTS

The possible enhancements that could improve our self-driving car model are as follows:

- Adding multiple stops between source and destination, and showing navigation route
- Identifying hand gestures of pedestrians
- Be able to drive safely in different weather conditions (rainy, snowy) and road conditions (no proper lane markings, no traffic lights, off-road)

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