INTERNATIONAL JOURNAL OF ADVANCED ENGINEERING AND BUSINESS SCIENCES (IJAEBS)

Journal homepage: https://ijaebs.journals.ekb.eg

Self-Driving Car Pilot Based CNN Deep Learning Model

Amin S. Ibrahim[a*], Adel Refky[a], A. M. Abdel Ghany[a,b]

[a] *Electronics and communication department, Thebes Higher Institute for Engineering, Egypt, Cairo*

[b] Faculty of Engineering Helwan University, *Department of Electric Power and Machines, Egypt*, Cairo,

**Corresponding author* Email address: *engamin_s84@yahoo.com*

Received: 02-05-2023 **Accepted:** 01-10-2023 **Published**: 09-10-2023

ABSTRACT

Artificial Intelligent (AI) technology is the simulation of the human on the computer. It is capable of thinking and recognizing environmental things based on the vast amount of historical training data. It can handle a large amount of the complicated processes and computations in an optimal method and minimum processing time. One of the main challenges in our daily life is the spread of traffic accidents that cause deaths as well as lack of commitment of citizens to respect the traffic rules. The paper proposed a self-driving car based on the Convolutional Neural Network (CNN) deep learning model as part of the AI technology to reduce the accidents and deaths on the roads without human errors and develop the smart transportation system. A self-driving car pilot was designed and implemented to prove the concept and validate its experimental model. It is remarked that a porotype is successfully trained and tested by 5000 images data set with very low training and validation losses that are lower than 0.05 and 0.12 respectively.

Keywords-- *Artificial Intelligent, Deep Learning, CNN model, Self-driving Car.*

1 INTRODUCTION

Recently, the traditional cars and vehicles exhibit air pollution and lake of the Oxygen percentage on the roads due to their CO emissions. Electrical cars and vehicles are considered a solution for the air pollution problems, but at the expense of the human being. Both types can suffer from high rates of traffic accidents, which in turn cause deaths and injuries.

AI technology is the study of the nature of intelligent minds to mimic human brains and to think and interact with things at the surrounding environment based on a historical experiment in an intelligent way. This type of technology is concerned with Thinking humanly, acting humanly, thinking rationally, and acting rationally. It can solve a processing issues in the Big data analytics, compared to IoT technology. It can deal with diversified data, handle a hard mathematical computation and process it easily in a very short time. It has an impressive role for diverse applications in an industry 4.0. Such as automated translation services, Robotics, self-driving car, natural language processing, computer vision, speech processing, voice and face recognition…etc [1, 2].

Deep Learning (DL) algorithms is a subset of Machine Learning (ML) as part of AI technology [3]. DL models are neural networks that include neurons, connectors, bias, and weights [4]. A simple DL model consists of one input layer, one hidden layer, and one output layer. DL network could be extended to diverse hidden layer based on the use case. As the number of collected data to be trained increases in the DL model, the hidden layers will increase and the neural network becomes very complicated. DL models aim to minimize the error difference between desired output and the actual output. In DL models, error was minimized by adjusting the weight and bias of the neural network neurons. which is called backpropagation [4, 5].

CNN is one of many Deep learning models that is more suited for image recognition, computer vision, and self-driving car applications. It can handle massive number of images with huge amount of data to extract the major and correlated features and then obtain a suitable output. As seen in Figure 1, CNN model is composed of three main layers: Convolution layer, pooling layer, and Fully Connected Network (FCN). ReLU activation function is added at the end of each mentioned layer. The convolution layer extracts features from images using feature detector (filter). Each input image is convolved with the filter. The result is biased and activated using ReLU activation function to obtain a main feature. The pooling layer reduces the size of an extracted image features (image dimensioning) before flatting onto the fully connected network, called pooling window. The pooling layer includes max. pooling and average pooling. Each pooling window as part of the convolutional window image (main features) is Flattening into one-dimension matrix before training in the FCN model. Finally, the main features were trained and tested for certain number of trails until error was as close to zero as possible. In this moment, a car can drive itself [6, 7].

In this paper, self-driving cars were proposed based CNN deep learning model to reduce the rates of the accidents and deaths by the human error on the roads. In addition, it has a crucial role for developing smart roads and smart transportation systems. A proposed self-driving car basically relies on Artificial Intelligent technology that mimics the driver's behavior such as thinking, decision making to perform smartly the human processes and tasks during the driving process without human interaction. Such as rotation, driving left or right…etc [1].

The proposed self-driving car collects data sets or images (steering angels, center of the road, traffic signs, and obstacles) based on the prototyping model, including controller, sensors, actuators, and camera. The data are simulated using the NVIDIA's model simulator to speed up the training time and handle massive images and data [8]. NVIDIA model creates a realistic environment road to test the behavior of the self-driving car prototype. It simulates the movement of the self-driving car in the physical road to detect accurate road attributes on the realistic road such as the steering angles. The simulated data in the form of images were treated as an input of the CNN deep learning model. The CNN model will train and test simulated images. Once the CNN model completes the training and testing methods, a proposed self-driving car prototype can learn detailed information about the road and can automatically move on the road without human being.

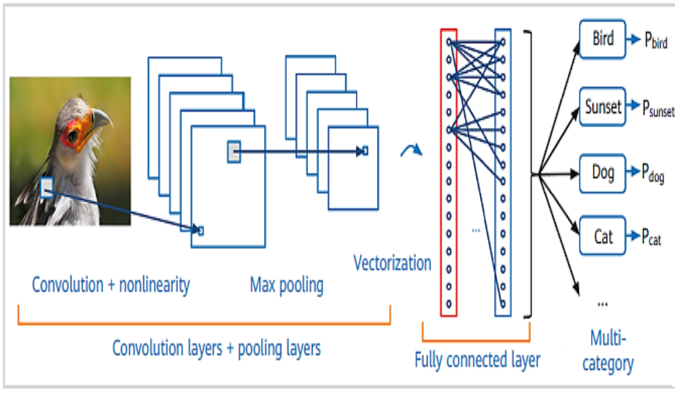


Fig.1 Construction of the CNN deep learning model.

2 LITERATURE REVIEW

Our literature review is passing through three major phases for an evolution of the self-driving car.

In the first phase, the previous works begins to setup the self-driving car prototype without IoT technology.

Dr.T. Manikandan, et.al proposed a smart self-driving car model, composed of the controller, sensors, GPS, actuators, and camera. In this model, the controller (raspberry pi) acquires the surrounding road data through the camera and the sensors (Ultrasonic, LDR, vibration, gyroscope) to drive the actuator (motor) to move along the road. They help the controller to avoid any obstacles and aware of the traffic signs. the designed and implemented controller was applicable for a short scale and didn't handle vast amount of processes at the very short durations [9].

Verma Nilesh Radheshyam, et.al designed a small model, called robotic vehicle. The prototype model consists of the Arduino controller, DC motors, ultrasonic sensor. The Arduino accepts the monitored data from the ultrasonic sensor about the obstacles that faces the prototype during its movement on the road and simply directive the DC motors attached with the right and left wheels to go along the road. This prototype didn't achieve reliability, scalability, interoperability…etc [10].

The second phases, the authors try to impede the IoT technology with the self-driving car in order to enhance the performance of the self-driving car prototypes.

A Manjunathan, et.al designed and implemented Automatic car model using the Raspberry pi controller, ultrasonic sensor, video camera, DC motors, and IoT web. The work talked process steps the existing method-based computer vision algorithms in the automatic car model to get the good decisions for the car automation on the road. The IoT web is important to evaluate the incoming data from the real environment of the road and enhance the controlling of the self-driving car [11].

Furqan Jameel, et.al proposed a novel paradigm that collect between the internet of things and the autonomous vehicle, called Internet of Autonomous Vehicle (IoAV). They discussed the features and enabling technologies of the IoAV for the future of the autonomous vehicle in. The IoAV was architected as physical layer, virtual layer, and management layer. The IoAV was experimentally tested and evaluated to show an impact of both transmission time and the energy versus the Signal –to-Noise ratio SNR [12].

Finally, the authors integrate the IoT technology with the AI technology to optimize the performance of the self-driving car prototype.

GEETIKA MATHUR, et.al studied and discussed the role of both the internet of things and AI technologies to develop the self-driving car concept. They classified the autonomous driving into five main levels. They proposed the self-driving car components required to make a precise and accurate design and implementation for optimizing the self-driving car [13].

Hamid Khayyam, et.al studied the role of the AI technology for solving the big data problems on the cloud of the IoT technology. They proposed an integration of the AI technology with the IoT system on the Edge computing before the cloud computing as a good solution for processing and handling the huge amount of data from massive sensors deployed over the transport roads. The Fog computing can achieve low latency, low processing power and low storage capacity compared to the cloud computing. The authors proposed Fog networks inside the IoT networks for processing the incoming data from the sensory field " Edge computing" instead of the cloud computing in the frontend side [14].

Sangita Lade, et.al proposed the implementation of self-driving cars based on deep learning. The data set were accumulated from the Udacity simulator. These data were imposed into the input of the CNN deep learning model for training the model. They applied the CNN model using two methods called CNN architecture A based Nividia model and the architecture B model. to get high results. The data set are divided onto 1000 images for training and 251 images for testing their models. It was verified that the accuracy of CNN model A is 96.83% compared to the CNN model B of 76.67% [15].

Chirag Sharma, et.al designed autonomous driving cars based on the simulator that reprocess the captured images from the camera mounted on the car to monitor the steering angle of the car. The data reprocessing includes normalization, augmentation, and cropping the images to reject unwanted images. The 80% of the proceed images were trained and 20% of images were validated using CNN model [16].

Mrinal R. Bachute, et.al surveyed the main goals of both Machine Learning and Deep Learning for developing many aspects such as autonomous driving. They described the autonomous driving tasks in details. Authors discussed different types of the perception algorithms and studied their roles for achieving the autonomous driving tasks. The paper summarized different the motion planning algorithms, pedestrian detection, traffic sign detection, road marking detection, self-localization, and automated parking for the autonomous driving system [17].

3 SYSTEM MODEL

Our proposed model follows the third phase in the evolution of the self-driving car that relies on the CNN deep learning model. The self-driving car is passing through five main stages:

- Design and implementation process; is to design and implementation the hardware components of the proposed self-driving car prototype, as seen in Figure 2.
- Collecting process; is a process of accumulating the traffic data by using external sensors and cameras in the designed self-driving car prototype.
- Simulation process; The traffic data are simulated using NVIDIA simulator that simulates a proposed self-driving car prototype on its real road to get the traffic road attributes, which are measured by the hardware components in Figure 2.
- Training process; the images were trained through the CNN deep learning model as one of AI methods.
- Testing process; the self-driving car prototype were tested on the real road as the output of the CNN deep learning method.

4 EXPERIMENTAL SETUP

An experimental setup explores the hardware components used in our proposed system, connectivity among them, and the methodology design to implement it with the help of the software programing, respectively.

4.2 Hardware Components

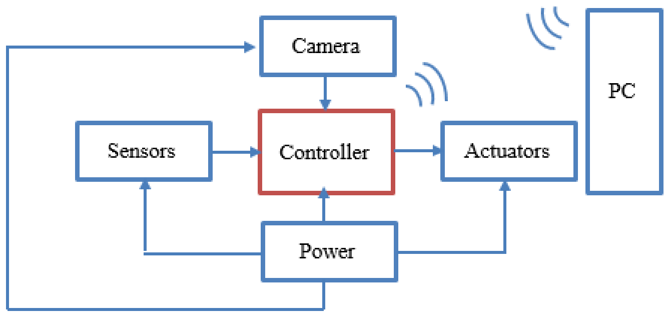


Fig. 2 Generic block diagram of the self-driving car prototype

As shown in Figure 2, a proposed self-driving car porotype consists of six main parts such as sensors, actuators, controller, camera, Personal Computer (PC), and power supply.

The controller is the brain of the proposed self-driving car. It can control and coordinate the driving processes inside the car. It interfaces among camera, sensors, actuators. Sensors detect obstacle's location during the movement of car on the road. Camera captures continuous images about the road borders and traffic signs. Thus, the real data traffic was monitored by sensors and camera. A controller continuously collects data traffic from its associated sensors and camera from one side. It sends main driving commands into the actuators after recognizing, thinking, and performing a suitable task on the other side. At this moment, the actuators begin to move both front and back wheels of the car onto the correct path on the road.

The PC or mobile phone was connected wirelessly with the controller to test the manual driving on the car. Finally, the power system develops all components of the proposed self-driving car by DC battery.

1) *Sensors:* The HC-SR04 Ultrasound Sensor was used to measure the distance between the car and the object (obstacles) by a sonar wave. As listed in Table 1, HC-SR04 Ultrasound Sensor has a range detection of 4-meters, coverage angle of 15 degrees, 5V DC supply voltage, and operating frequency of 40KHz. Ultrasound Sensor consists of a transmitting unit and a receiving unit. A transmitting unit radiates an ultrasonic wave with the sound speed of 340 m/s onto an object. While, a receiving unit receives the reflected wave (echo) from an object. Thus, Ultrasonic sensor can easily measure the round trip time of the sound wave during transmission and reflection. Accordingly, the distance between the car and an obstacle could be evaluated from the following equation as [18, 19]:

$$d = v \times t \qquad (1)$$

TABLE I

HC-SR04 ULTRASOUND SENSOR SPECS

4.1 *Parameters*	**4.2 *Specifications***
4.3 *Operating voltage*	4.4 ***5V DC***
4.5 *Operating frequency*	4.6 ***40KHz***
4.7 *Range*	4.8 ***2 Cm~4m***
4.9 *Coverage angle*	4.10 ***15°***
4.11 *Ranging Accuracy*	4.12 ***3mm***

2) *Actuators:* A self-driving car requires two main types of actuators: 28BYJ48 Stepper motors and the control relay. A steeper motor was installed to precisely move both front and end wheels inside the car. It is more suited for many applications that require precise motion control as car because it can move step by step instead of continuous rotation and works on direct current. The shaft of the steeper motor can rotate every 1.8° with a rate of 200 step per revolution (rev/step). Thus, a steeper motor guarantees a precise and accurate movement for the wheels of the car on the road [20]. Its engine has many coils distributed in groups called "phases". By activating each stage individually, the motor rotates one step at a time (1.8°). The motor was controlled and programmed using the controller for precise positioning and speed control. However, the steeper motor can't directly interface with the controller module. Thus, ULN2003 Driver module enables 28BYJ48 Stepper to connect with the controller module. In addition, it feeds the steeper motor with the required supply voltage (5-12 V) and it regulates the electrical signal onto a series winding coils inside the steeper motor, which in turn moves in a sequence steps until exceeds 200 steps/revolution based on the required movement. On the other hand, the control relay was designed to control the powering in the self-driving car. It turns the electricity ON or OFF based on the status of the car during the driving process on the road. The control relay was operated by programming the controller module.

3) *Controller:* Raspberry pi version 3 module was installed in this paper to control the proposed self-driving car. As depicted in Table 2, it acts as a small computer that includes a processor of 1.2GHz quad-core ARM Cortex-A53 (64-bit), Linux/windows 10 operating system booted by micro SD card, IEEE 802.11 b / g / n Wi-Fi wireless communication, IEEE 802.15 Bluetooth, Micro USB power, Ethernet socket as a gateway for Internet applications, Graphical Processing Unit (GPU) for graphic and video applications, HDMI output, and 1GB memory. In addition, Raspberry pi 3 supports the camera device [21, 22]. Thus, the Raspberry pi 3 was widely used for many use cases such as: Surveillance applications, Robotics, Internet of Things (IoT) applications, Artificial intelligent applications…etc.

TABLE II

RASPBERRY PI 3 MODULE SPECS [23, 24]

Parameters	**Specifications**
Processor	1.2GHz quad-core ARM Cortex-A53 (64-bit)
Operating system	Linux/windows 10
Wi-Fi	IEEE 802.11 b/g/n-maximum range is up to 50 meters
Bluetooth	IEEE 802.15-maximum range is up to 50 meters
memory	Micro SD card
power	+3.3V, 5V- 2.5A
Video output	HDMI (Speed 1.3 and 1.4) Composite RCA (PAL and NTSC)
Ethernet	10/100 Base T Ethernet socket
memory	1GB LPDDR2
GPIO	40-pins
Camera	Available
GPU	Dual Core Video Core IV® Multimedia Co-Processor. Provides Open GL ES 2.0, with hardware acceleration Open the high-level VG 1080p30 H.264 decoder. Capable of 1Gpixel/s or 1.5Gtexel/s or 24GFLOPs with fabric filtering and DMA infrastructure

4) *Camera:* A camera could be easily connected onto the raspberry pi 3 by the act of the camera connector that attributed to15-pin MIPI Camera Serial Interface (CSI-2). Table 3 depicts the specs of the Raspberry pi 3 camera. A camera is a source of video stream and image information that coexists with raspberry pi 3 to perform the required surveillance and image processing applications. GPU built in the raspberry pi 3 is a graphical processor that controls the video and image applications, specifically in the AI technology.

TABLE III

SPECS OF CAMERA V.2 [6]

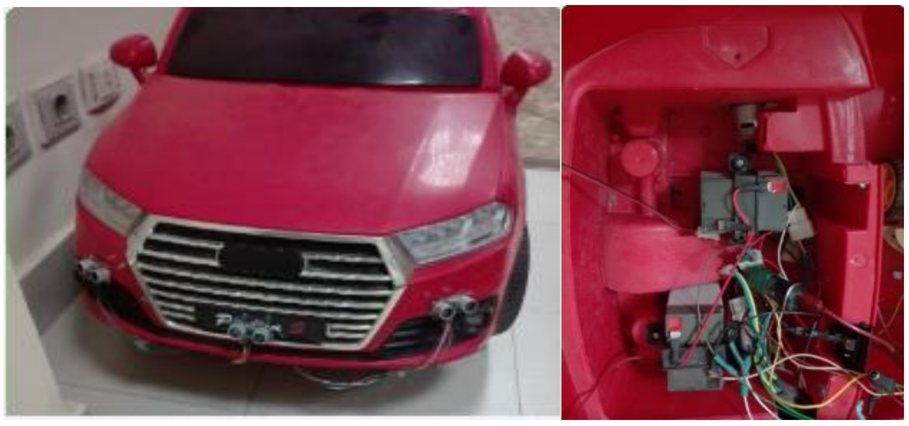
Parameters	Specifications
Resolution	**8 Mega pixels**
Video modes	**1080p30, 720p60, and 640×480p60/90**
Linux integration	**V4L2 driver available**
Sensor	**Sony IMX219**
Sensor resolution	**3280×2464 pixels**
Picture formats	**JPG, JPEG+DNG(raw), BMP, PNG, RGB888, YUV420**

5) *Personal Computer:* PC or the mobile phone has a crucial role in the proposed self-driving car. It connected with Raspberry pi 3 using HDMI cable to setup Linux operating system on Raspberry pi processor chip, typing python codes for programming ultrasonic sensor, steeper motor, configuration of camera on Raspberry pi3. While, it also connected wirelessly to Wi-Fi of the Raspberry pi 3 using its wireless network interface card in order to operate the manual driving python code later in the experimental scenario.

6) *Power Supply:* Our proposed self-driving car has two rechargeable batteries of the type Valve Regulated Sealed Lead-Acid that recharges immediately after discharge process. It is characterized as 6V4AH/20HR to achieve long battery life time with high number of charges. Two batteries energize all hardware components inside the self-driving car based their requirements. Such as Raspberry pi 3 requires 3.3~5 VDC, camera energized from the Raspberry pi 3 itself, Ultrasonic sensor powered by GPIO of the Raspberry pi 3, control relay needs 5V DC supply to operate, steeper motors operate at 5-12VDC.

Finally, a proposed self-driving car consists of 4 Ultrasonic sensors, 3 steeper motors, one Raspberry pi 3 module, 2 control relay, one camera, and two rechargeable batteries. A 4 Ultrasonic sensors are distributed over the car as 3 ultrasonic sensors in the front of the prototype, each with its associated direction (right, left, center), and one ultrasonic sensor located in the end of the prototype. Each one has its associated direction. Three steeper motors are located in the car wheels as two steeper motors for the two back wheels and one steeper motor for the front wheels. The camera is centered at the front of the car. While, Raspberry pi 3 module, batteries, and control relays could be located at any place inside the prototype based on their connections. Figures 3 and 4 show a proposed self-driving car prototype during setup the model and its associated hardware components.

Fig. 3 Proposed self-driving car prototype.



(a) (b)

Fig. 4: Parts of hardware components inside the self-driving car prototype (a) front ultrasonic sensors, (b) Batteries and Raspberry pi 3 module.

4.3 Design Connectivity

The aforementioned prototype elements are connected with the Raspberry pi 3 controller unit via 40-GPIO pins according to the schematic diagram and datasheets for each hardware components except camera that connected by 15-pins video output and the batteries that energize the Raspberry pi 3 module by its power socket. We connect Raspberry pi 3 module with any monitor unit by using HDMI cable to operate it. Figure 5 shows the connection between Raspberry pi 3 with Ultrasonic sensor.

4.4 Design programming

Before the programming process, we begin to power ON the Raspberry pi 3 then setup the Linux (Fedora) operating system on it through the Micro SD memory card. After Linux setup process, we setup Python GPIO library to enable Raspberry pi 3 by typing the command " sudonano file name.py" in Linux to control and manage all prototype elements using python language programming.

In the programming process, a set of procedures were executed based on the experimental scenario of the self-driving car.

4.5 Design Methodology

The realistic experiment was tested and implemented to prove the concept. A self-driving car are placed on the actual road to move as the traditional cars without human interaction. The experiment includes three main scenarios: standby scenario, driving scenario, and termination scenario.

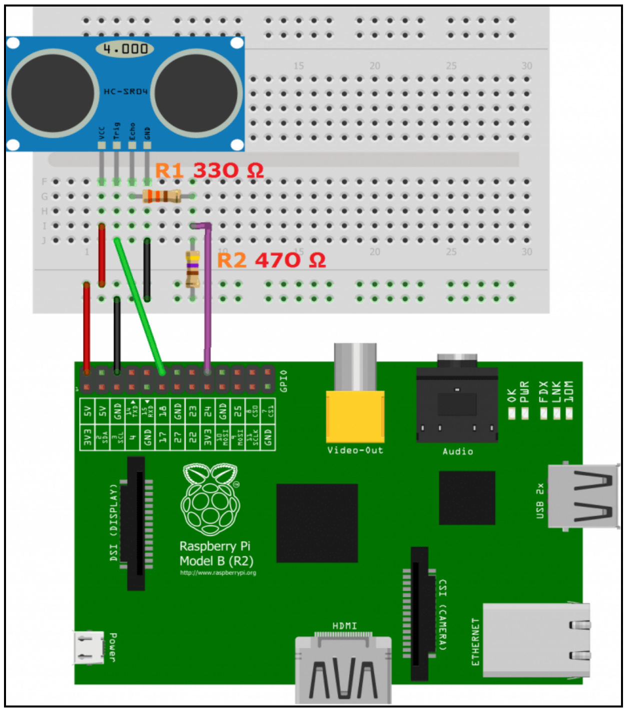


Fig. 5: Schematic diagram of Ultrasonic sensor with Raspberry pi 3.

1) *Standby Scenario: In the standby scenario, the batteries supply the Raspberry pi 3 module by the required voltage (5VDC), which in turn energize control relays, ultrasonic sensors, camera, and steeper motors by the voltage source. In addition, the python codes that are burned on the Raspberry pi processor chip are ready to be operated. In this mode, the control relays will turn ON and allow steeper motors ready to move the wheels of the self-driving car. The speed of steeper motors gradually speeds up until saturated onto the needed speed. Figure 6 shows a part of the python code for the ultrasonic sensor.*

```
    # save time of arrival
    while GPIO.input(GPIO_ECHO) == 1:
StopTime = time.time()
    # time difference between start and arrival
TimeElapsed = StopTime - StartTime
    # multiply with the sonic speed (34300 cm/s)
    # and divide by 2, because there and back
    distance = (TimeElapsed * 34300) / 2
    return distance
```

Fig.6 Part of ultrasonic sensor using python code.

2) *Driving Scenario: In the driving process scenario, a self-driving car was moved along the road. This scenario is divided into two main states: manual driving state and training model state. In the manual driving state, Putty desktop application makes a connection between PC and raspberry pi. It enables a user to send Linux commands to Raspberry pi 3 and runs a manual driving python code. VNC viewer program acts as graphical user interface that views or displays the python codes on Raspberry pi. "MainRaspCode.py" python code were executed on Raspberry pi 3 module to manually drive a car many times on a variety of roads with different traffic signs, borders, geometric shapes, center…etc. In the same time, ultrasonic sensors send sound waves to the road and wait echo (reflected waves) if any object or obstacles are presented. In case of any obstacles were detected, Raspberry pi 3 was programmed to receive reflected wave from the four ultrasonic sensors whether in the front or the back of the car to measure the distance between a car and the object (object location), then it controls the movement of the steeper motors to shift right or left based on the direction of the detected object on the road. For example, if any object is detected in the left of the road by an ultrasonic sensor, Raspberry pi 3 controls steeper motors of the two front wheels to shift right to avoid the collision and vice versa. In the training model state, a car was trained to enable the car to drive itself. Figure 7 shows the block diagram of the sequential processes required to obtain our proposed self-driving car. Table 4 lists the main parameters for creating CNN model.*

TABLE VI

METHODOLOGY DESIGN SIMULATION PARAMETERS

4.13 ***parameters***	4.14 ***values***
4.15 ***Image #***	4.16 ***5649***
4.17 ***Training data***	4.18 ***4332***
4.19 ***Testing data***	4.20 ***1084***
4.21 ***epochs***	4.22 ***30***
4.23 ***# trails***	4.24 ***38***
4.25 ***Epoch***	4.26 ***100 images***
4.27 ***Activation function***	4.28 ***ReLU***
4.29 ***Optimizer***	4.30 ***Adam***

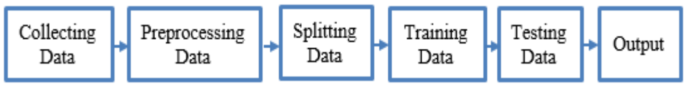


Fig. 7 Methodology design of a proposed self-driving car.

- Before the training process, data were collected by the act of the manual process and simulated by the NVIDIA simulator to minimize the training time per hours compared to the real time in the manual process. In case of the manual driving car, a camera continuously captures massive number of images about the road attributes. Such as center, left, Right, Steering, Throttle. The acquired images from NVIDIA simulator were collected onto Raspberry pi 3 module. In case of the simulation process, a self-driving model simulator were installed from Udamy simulation platform to acquire steering angels and capture diverse images by its camera in order to obtain roads attributes.
- In the preprocessing data, corrupted images acquired by camera will be removed. Images that describe un-useful information about the main features of the road will be discarded. Captured images were visualized versus the steering angels that ranged from -1 to +1 with the center of 0 value. Figure 8 shows the steering angles of thousands of images. It is noted that images that captured steering angels of [-1,+1] range should be discarded and it is not allowed to train these images. During the preprocessing data, about 233 images were removed from 5416 images because these images record steering angels out of range.
- In the splitting process, data images were split into 80% training data and 20 % testing data as shown in Figure 9.
- In the training and testing processes, the CNN model python code was created using Tensor Flow libraries in Figure 10 to extract features from the collected images and convert features onto discrete output (actions). As shown in Figure 11, the acquired images were preprocessed by using convolution layer and pooling layer to obtain the important features from images. The extracted features are sent onto the fully connected neural network. The extracted features the fully connected network were back propagated to adapt or change weights of the neurons until the output data fit the desired output and the error difference is close to zero. Before the training process, the training data consists of multiple epochs to obtain high processing time and minimize the training and testing loss.
- In the output process, a car recognized the center road based on the historical steering angels and automatically drive itself (rotate, shift right, shift left) based on the historical image captured by camera. A car was tested on the real road, carrying the trained CNN model code on its Raspberry pi 3 module. The new captured images on the real road are considered the testing data.

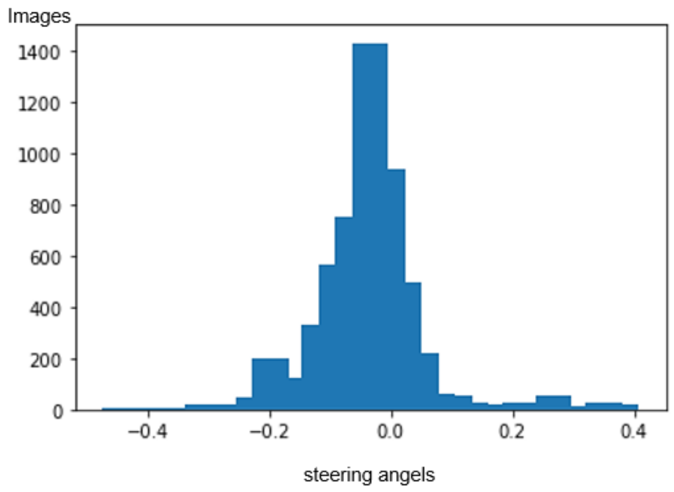
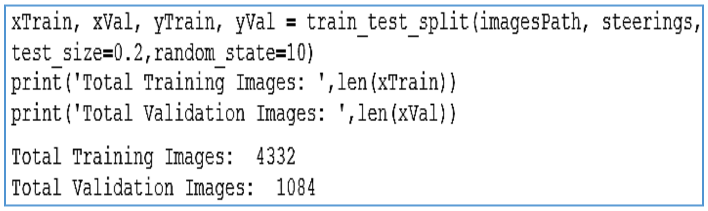


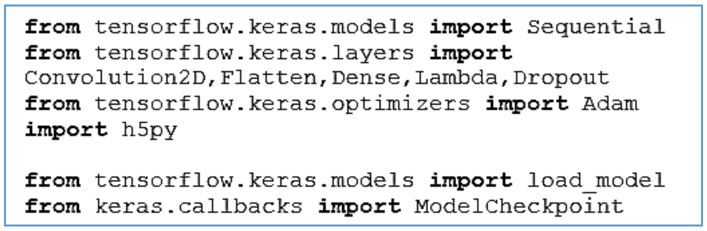
Fig. 8 Visualization of images over various steering angels.



```
xTrain, xVal, yTrain, yVal = train_test_split(imagesPath, steerings,
test_size=0.2,random_state=10)
print('Total Training Images: ',len(xTrain))
print('Total Validation Images: ',len(xVal))

Total Training Images:  4332
Total Validation Images:  1084
```

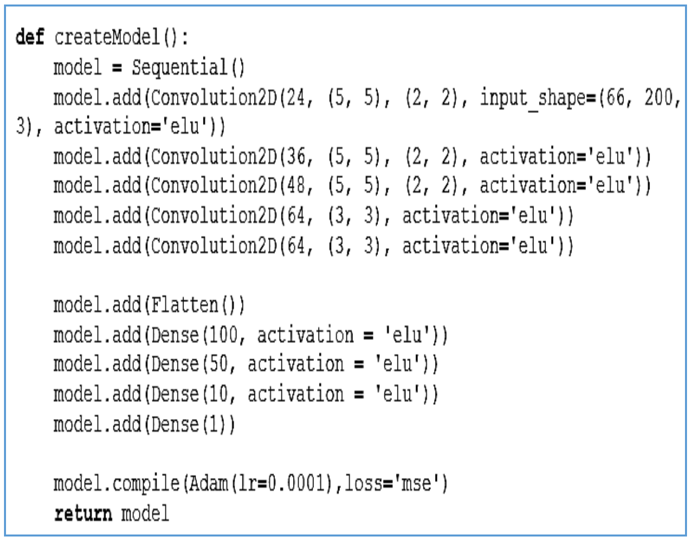
Fig. 9 Splitting input data before training model [23].



```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import
Convolution2D,Flatten,Dense,Lambda,Dropout
from tensorflow.keras.optimizers import Adam
import h5py

from tensorflow.keras.models import load_model
from keras.callbacks import ModelCheckpoint
```

Fig. 10 Tensor Flow libraries for creating CNN model.



```
def createModel():
    model = Sequential()
    model.add(Convolution2D(24, (5, 5), (2, 2), input_shape=(66, 200,
3), activation='elu'))
    model.add(Convolution2D(36, (5, 5), (2, 2), activation='elu'))
    model.add(Convolution2D(48, (5, 5), (2, 2), activation='elu'))
    model.add(Convolution2D(64, (3, 3), activation='elu'))
    model.add(Convolution2D(64, (3, 3), activation='elu'))

    model.add(Flatten())
    model.add(Dense(100, activation = 'elu'))
    model.add(Dense(50, activation = 'elu'))
    model.add(Dense(10, activation = 'elu'))
    model.add(Dense(1))

    model.compile(Adam(lr=0.0001),loss='mse')
    return model
```

Fig. 11 Creating of the CNN model [24, 25].

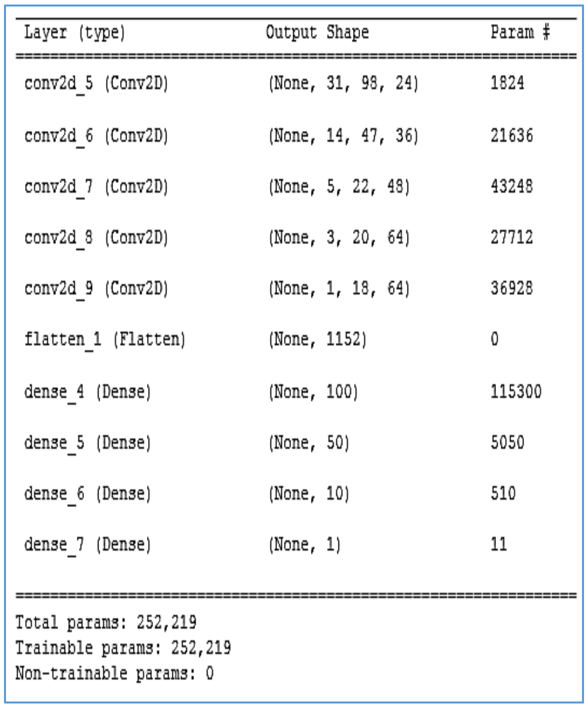
3) *Release Scenario:* the final scenario, the self-driving car stop moving along the road when the Raspberry pi 3 decides to gradually decrease the speed of the wheels by the steeper motors and then stop working by the control relays.

5 EXPERIMENTAL RESULTS

The experimental results shed light on the sequential processes executed in the CNN deep learning model to obtain self-driving car.

Figure 12 shows the results of creating CNN deep learning model, including the structure of CNN neural networks as the number of layers, size of each layer number, and number of trainable parameters for each CNN layer.

After CNN model creation, data were trained through 30 epochs. Each epoch is trained using backpropagation 300 times with total 900,000 operations in the full training process. Figure 13 shows the relationship between the training loss and the validation loss versus the number of epochs. It is noticed that as the number of epochs increases, the training loss and the validation loss will exponentially decrease. As seen in Figure 14, The training loss is decreased from 0.2758 at the first epoch onto 0.0792 at the 15th epoch. The validation loss is reduced from 0.3716 at the first epoch to 0.1537 at the 15th epoch. With low number of epochs, it is remarked that both training and validation loss values appear slightly decrease, as seen in Figure 15.



```
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_5 (Conv2D)            (None, 31, 98, 24)        1824

conv2d_6 (Conv2D)            (None, 14, 47, 36)        21636

conv2d_7 (Conv2D)            (None, 5, 22, 48)         43248

conv2d_8 (Conv2D)            (None, 3, 20, 64)         27712

conv2d_9 (Conv2D)            (None, 1, 18, 64)         36928

flatten_1 (Flatten)          (None, 1152)              0

dense_4 (Dense)              (None, 100)               115300

dense_5 (Dense)              (None, 50)                5050

dense_6 (Dense)              (None, 10)                510

dense_7 (Dense)              (None, 1)                 11

=================================================================
Total params: 252,219
Trainable params: 252,219
Non-trainable params: 0
```

Fig.12 The results of creating a sequential CNN deep learning model

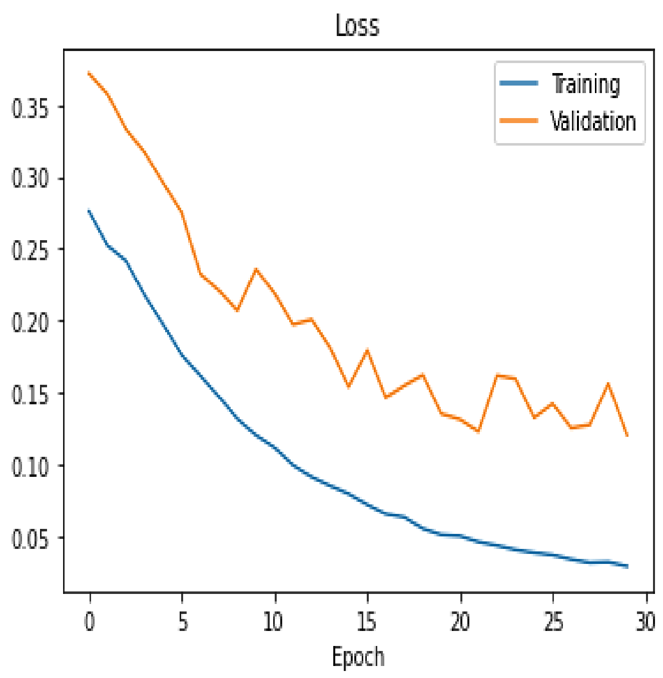
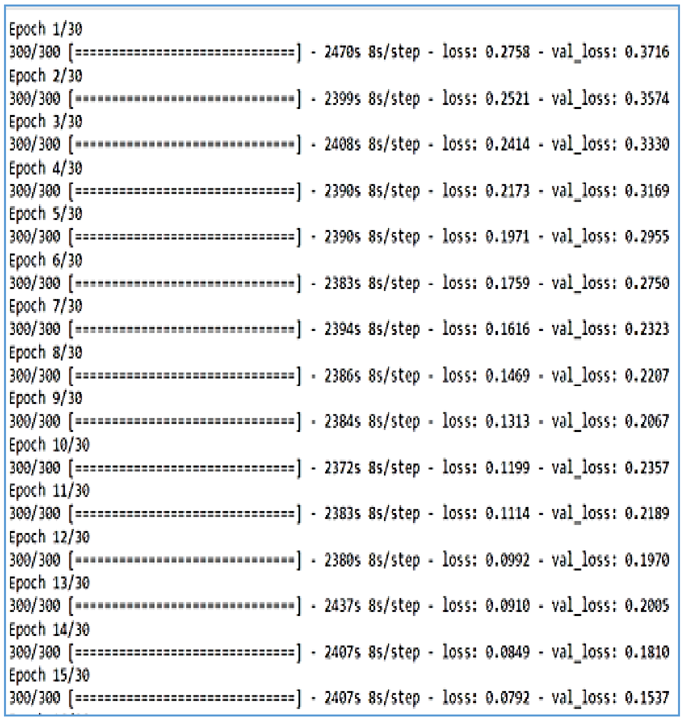


Fig.13 Training and validation loss versus number of epochs



```
Epoch 1/30
300/300 [==============================] - 2470s 8s/step - loss: 0.2758 - val_loss: 0.3716
Epoch 2/30
300/300 [==============================] - 2399s 8s/step - loss: 0.2521 - val_loss: 0.3574
Epoch 3/30
300/300 [==============================] - 2408s 8s/step - loss: 0.2414 - val_loss: 0.3330
Epoch 4/30
300/300 [==============================] - 2390s 8s/step - loss: 0.2173 - val_loss: 0.3169
Epoch 5/30
300/300 [==============================] - 2390s 8s/step - loss: 0.1971 - val_loss: 0.2955
Epoch 6/30
300/300 [==============================] - 2383s 8s/step - loss: 0.1759 - val_loss: 0.2750
Epoch 7/30
300/300 [==============================] - 2394s 8s/step - loss: 0.1616 - val_loss: 0.2323
Epoch 8/30
300/300 [==============================] - 2386s 8s/step - loss: 0.1469 - val_loss: 0.2207
Epoch 9/30
300/300 [==============================] - 2384s 8s/step - loss: 0.1313 - val_loss: 0.2067
Epoch 10/30
300/300 [==============================] - 2372s 8s/step - loss: 0.1199 - val_loss: 0.2357
Epoch 11/30
300/300 [==============================] - 2383s 8s/step - loss: 0.1114 - val_loss: 0.2189
Epoch 12/30
300/300 [==============================] - 2380s 8s/step - loss: 0.0992 - val_loss: 0.1970
Epoch 13/30
300/300 [==============================] - 2437s 8s/step - loss: 0.0910 - val_loss: 0.2005
Epoch 14/30
300/300 [==============================] - 2407s 8s/step - loss: 0.0849 - val_loss: 0.1810
Epoch 15/30
300/300 [==============================] - 2407s 8s/step - loss: 0.0792 - val_loss: 0.1537
```

Fig.14 The results of the data training process

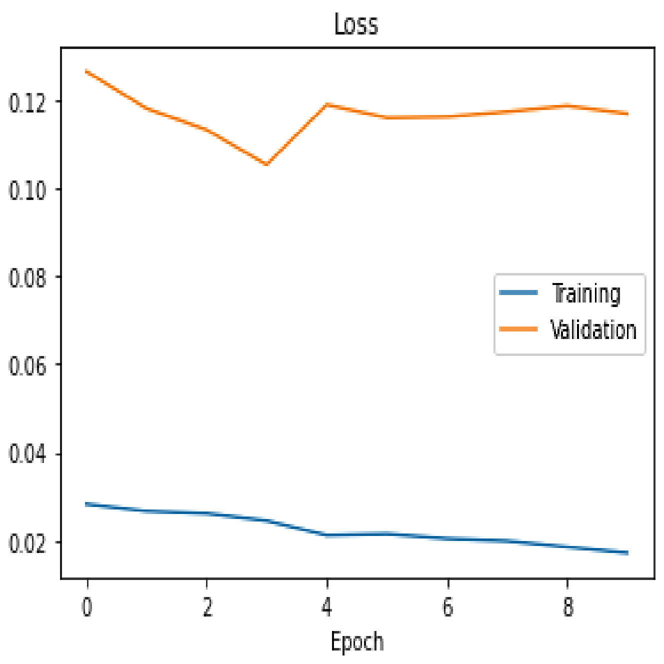


Fig. 15 Training and validation loss for low number of epochs

CONCLUSION

The paper proposed a self-driving car based on the deep learning model as part of AI technology to meet the human driving mistakes, which increase the rates of the deaths. We install a realistic prototype, including hardware components, connectivity among components, programing using python code, and methodology design to implement this work in the real time. Raspberry pi module was considered a good candidate for performing the AI neural network models. Our proposed prototype was trained and tested using CNN model in order to drive itself automatically without t\he human being.

REFERENCES

[1] Roza Dastres, and Mohsen Soori, " Artificial Neural Network Systems", International Journal of Imaging and Robotics, volume 21; Issue No. 2; Year 2021.

[2] Jorge Ribeiro , Rui Lima, Tiago Eckhardt, and Sara Paiva, "Robotic Process Automation and Artificial Intelligence in Industry 4.0 – A Literature review", - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020, Volume 181, PP. 51-58, 2021.

[3] Tanya Tiwari, Tanuj Tiwari, Sanjay Tiwari, "How Artificial Intelligence, Machine Learning and Deep Learning are Radically Different?", International Journals of Advanced Research in Computer Science and Software Engineering, Volume-8, Issue-2, 2018.

[4]Amitha Mathew, P.Amudha, and S.Sivakumari, " Deep Learning Techniques: An Overview",n book: Advanced Machine Learning Technologies and Applications (pp.599-608), 2021.

[5] Amir Mosavi, Sina Ardabili, and Annamaria R. Varkonyi-koczy, " List of Deep Learning Models", Springer Nature Switzerland AG 2020, pp. 202-214,2020.

[6]Anirudha Ghosh, Abu Sufian, Farhana Sultana, Amlan Chakrabarti, Debashis De, "Fundamental Concepts of Convolutional Neural Network", Recent Trends and Advances in Artificial Intelligence and Internet of Things (pp.519-567), 2020.

[7] Sakshi Indoliaa, Anil Kumar Goswamib , S. P. Mishrab , Pooja Asopaa, " Conceptual Understanding of Convolutional Neural Network- A Deep Learning Approach", International Conference on Computational Intelligence and Data Science (ICCIDS 2018).

[8] https://www.nvidia.com/en-us/self-driving-cars/. 2021

[9] Dr.T. Manikandan, J.S. Jayashwanth, S. Harish and K.N. Harshith Sivatej, "Self Driving Car", International Journal of Psychosocial Rehabilitation 24(5), pp.380-388, 2020.

[10] Verma Nilesh Radheshyam, Farooqui Mohammed Tauseef sharif , ManeAshwini Bhimrao, Mohammed Ali, "Self Driving Car", IOSR Journal of Computer Engineering (IOSR-JCE), Volume 22, Issue 1, PP 12-16, 2020.

[11] A Manjunathan, A Suresh Kumar, S Udhayanan , C Thirumarai Selvi, and Albert Alexander Stonier, " Design of Autonomous Vehicle Control using IoT", IOP Conf. Series: Materials Science and Engineering,1055 ,2021.

[12] Furqan Jameel, Zheng Chang, Jun Huang, Tapani Ristaniemi, " Internet of Autonomous Vehicles: Architecture, Features, and Socio-Technological Challenges", IEEE WIRELESS COMMUNICATIONS,

[13] GEETIKA MATHUR, HARSHIT SHARMA, & RISHABH PANDEY, " A STUDY ON SELF-DRIVING CAR AN APPLICATION OF IoT", International Journal of Computer Networking,Wireless and Mobile Communications (IJCNWMC), Vol. 9, Issue 1, , pp.25-34, Jun 2019.

[14] Hamid Khayyam, Bahman Javadi, Mahdi Jalili, and Reza N. Jazar, " Artificial Intelligence and Internet of Things for Autonomous Vehicles
", Nonlinear Approaches in Engineering Applications Book chapter, pp.39-68, 2019.

[15] Sangita Lade, Parth Shrivastav , Saurabh Waghmare, Sudarshan Hon, Sushil Waghmode, and Shubham Teli, "Simulation of Self Driving Car Using Deep Learning", 2021 International Conference on Emerging Smart Computing and Informatics (ESCI), India, 2021.

[16] Chirag Sharma, S. Bharathiraja, and G. Anusooya, "Self Driving Car using Deep Learning Technique", International Journal of Engineering Research & Technology (IJERT), Vol. 9, Issue 06, June-2020.

[17] Mrinal R. Bachute, and Javed M. Subhedar, "Autonomous Driving Architectures: Insights of Machine Learning and Deep Learning Algorithms", Machine Learning with Applications, Volume 6, 15 December 2021.

[18] Fares Ng, "Ultrasonic Sensors", 2020.

[19] https://www.ia.omron.com/data_pdf/guide/50/ultrasonic_tg_e_1_1.pdf

[20] https://lastminuteengineers.com/l298n-dc-stepper-driver-arduino-tutorial/2015

[21] https://static.raspberrypi.org/files/product-briefs/Raspberry-Pi-Model-Bplus-Product-Brief.pdf

[22] https://www.raspberrypi.com/documentation/accessories/camera.html, last accessed 2022

[23] https://docs.microsoft.com/arsa/aspnet/core/signalr/hubs?view=aspnetcore-6.0 2020.

[24]https://www.infoworld.com/article/3278008/what-is-tensorflow-the-machine-learning-library-explained.html 2009.

[25] https://www.nvidia.com/en-us/self-driving-cars/2021.