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AUTONOMOUS VEHICLE SIMULATION WITH MULTI HUMAN DRIVING BEHAVIOR USING DEEP LEARNING

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ABSTRACT
Advances in Autonomous Vehicle (AV) technology have made this topic popular in recent years, both large and small companies have started to develop this AV technology. Apart from large companies, several researchers are also interested in developing this technology. However, due to cost constraints and security issues, the researchers developed AV using a computer simulation approach. The main objective of this paper is to create a simulation (AV). The simulation was created using Udacity self-driving-car from Unity 3D. The first step we took was to take a dataset in the form of images from a number of participants by manually driving a car in a simulation to get Human-driving-behavior. After the dataset is obtained, the AV model formation process will then be carried out using the deep learning method of the Convolutional Neural Network algorithm. In this research, a good AV simulation has been successfully made, the car can run perfectly following the track without experiencing a collision or going off the track. From the results of the testing carried out, the model that was built got pretty good results where the accuracy was 71% and the loss was 0.0165.

I. INTRODUCTION

Autonomous Vehicle (AV) is an emerging application of automotive technology. They can recognize sights, plan paths, and control their own movements when interacting with drivers [1]. Advances in AV technology have created opportunities for building smart cities. AV has become a popular topic in recent years [2]. Researching various computer vision methods, path planning algorithms and control theory has been a very interesting field for the automotive industry.

The use of AV is expected to reduce transportation costs and the use of human labor. However, to apply it to the environment is actually still a challenge for researchers because it involves issues of cost and safety. An example is an AV developed by Google called Waymo Driver [3], where Waymo uses an original car which of course requires a sizable fee. As an alternative approach in developing AV, the researchers used a simulation approach [4]. This simulation approach offers advantages, for example, it is relatively safer and cost-effective because the simulation is carried out based on computers and software [5]. Therefore the authors create a simulation-based AV system.

In the context of simulation-based autonomous vehicles, there have been many studies that have created simulation-based autonomous vehicles using various types of simulators. In [5] [6] [7] they made a similar simulation using the Udacity self-driving simulator, researchers [5] will drive the car manually and the image data will be captured by 3 cameras installed in the car. The image data will be used to train the model with Convolutional Neural Network (CNN) using Keras and the model output is in the form of steering commands for an Autonomous Vehicle so that the simulated car can walk avoiding obstacles in the form of boxes on the road. In this research, a reliable model has been created so that there are no collisions when the simulation is run autonomously.

CARLA Simulator introduced by [8] is an open-source simulator for autonomous vehicle simulation. CARLA provides several digital assets that can be used free of charge. In their research they succeeded in creating a simulation system to navigate an urban environment that contains various vehicles and pedestrians.

In [9][10], they used The Open Racing Car Simulator (TORCS) to create an autonomous vehicle simulation to avoid physical accidents. In their research, they created an autonomous vehicle simulation system that can mimic the intelligence of human drivers who can adapt self-driving vehicles to real-world road conditions..

Researcher [11] introduced the Simulation for Urban Mobility (SUMO) Simulator. Researcher [12] simulated the flow of road traffic using the Simulation for Urban Mobility (SUMO) Simulator. They stated that with SUMO simulator, a communication network between vehicles on the highway can be created. Researcher [13] created an AV simulation but in the form of a Platooning system using the same simulator. In this study they succeeded in simulating an autonomous vehicle platoon system with the first car being the leader and the car behind it will follow the movement of the car that is the leader of the platoon. Vehicles in this system can communicate with each other and send feedback for actions that will be carried out during the trip.

Researchers [14] also tried to create a self-driving car simulation system using the RoadView simulator. They modeled traffic simulation using image data and Geographic Information System (GIS) on the road. From the results obtained, RoadView can provide a more photorealistic scene.

In the context of deep learning, there have been several studies that apply deep learning methods in their research, including the following:

In [15], researchers created a light enhancement network (LE-net) based on convolutional neural networks for connected autonomous vehicles on dark roads such as in rural areas. They then built a model to compare high-light images in daylight with low-light images. After testing, the LE-net they built had better results than the compared model.

In [16], they discuss advanced deep learning architecture and optimization when used for medical image segmentation and classification. Deep learning can be used to assist in the development of the medical world in detecting various diseases by processing medical imaging data.

From several previous studies, deep learning is widely used in processing image data, therefore, in this study we use deep learning methods in modeling using the CNN algorithm to training our image data. In this study we use previous research [5] as a reference and follow their method.

But, unlike previous research [5], our research does not use objects in the form of boxes on the track, but only uses a simple simulation model in the form of a path for cars to traverse with the same simulator. And also different from previous research [5], in this study we took datasets from several participants so that various kinds of Human-Behavioral-Driving could be obtained to serve as input for the model that was built.

Therefore, this research focuses on creating a deep learning model for AV simulation with udacity self-driving car simulator using the Convolutional Neural Network algorithm to predict steering angle and after that will see the results of the performance of the model built using the Multi Human-Behavioral-Driving dataset.

II. RESEARCH METHODOLOGY

A. Convolutional Neural Network (CNN)

Convolutional Neural Network (CNN) is one of the most well-known algorithms in deep learning. This algorithm is inspired by the natural visual perception mechanism of living things. The architecture of CNN is also fairly similar to the connection patterns in neurons or nerve cells in the human brain. CNN is inspired by the Visual Cortex, which is the part of the brain that is responsible for processing information in visual form. CNN has several basic components, namely convolutional layers, pooling, and fully-connected layers. The convolutional layer aims to learn the feature representation obtained from the input. In this layer there are several convolution kernels that work with the principles of sliding windows and weight sharing (reducing calculation complexity) to get features from the input. The pooling part aims to reduce the number of parameters by using down-sampling or you can say pooling is used to summarize the information generated by a convolution (reducing dimensions). Convolutional layer and pooling are part of feature extraction. After that, the result vector of several convolution and pooling operations in the multilayer perceptron is known as a fully-connected layer which is usually used to perform classification [17].

B. CNN for Autonomous Vehicle Simulator

In this paper, the main task we will do is to create an Autonomous Vehicle simulation by using Udacity self-driving-car and using deep learning method of CNN algorithm. There are several steps that are carried out to create an AV simulation in this research..

Step 1. Generation Dataset

The first step in making this simulation is collecting datasets. The data in question is in the form of Human-Driving-Behavior where several people will be asked to drive the car in the simulation manually, this is done to get diverse Human-Driving-Behavior data. After that, image data will be taken through 3 cameras mounted on the front of the car (left, center, right). The scenario is that the driver must drive the car manually following the available path without crashing or going off the path. Our goal is to mimic the actions performed by the driver in dealing with the given scenario such as avoiding obstacles where the obstacle is a winding road and driving without going off the road (can be seen in Figure 1). So we created a dataset of images by storing the driving experience performed by the driver using this simulator. To save all the images taken by the camera attached to the car can be done by pressing the record button (R on the keyboard) to bring up the file storage directory selection window (can be seen in Figure 2).

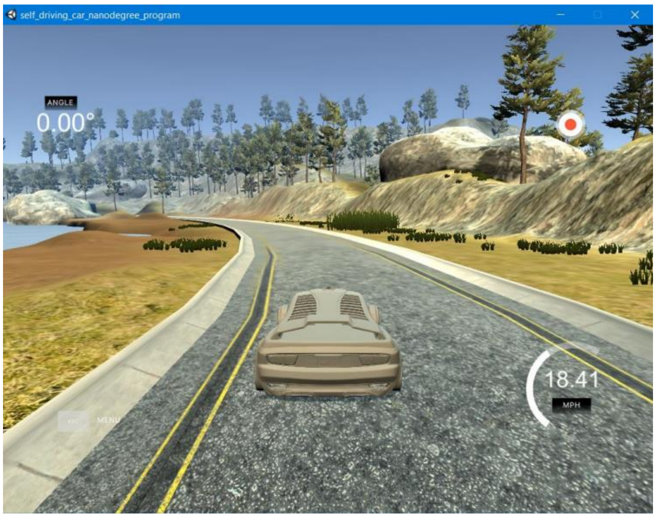

Figure 1 Data generation process

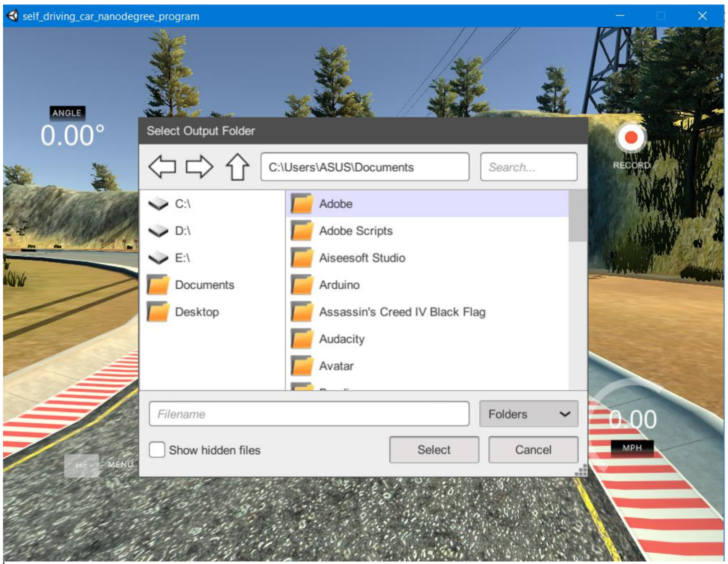

Figure 2 Data recording

After selecting the directory where the file will be saved then after that press the record button once again and drive the car manually like playing a car racing game in general..

After the data is recorded a file will be created containing the driving log that we will use later and there will also be a folder of image files that have been taken through the camera attached to the autonomous vehicle and these two files will become the dataset..

	A	B	C	D	E	F	G
1	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0	0	1.20E-05
2	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0	0	1.77E-05
3	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0	0	1.98E-05
4	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0	0	2.23E-05
5	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0	0	7.99E-06
6	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0	0	1.07E-05
7	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0	0	1.16E-05
8	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0.196305	0	0.14118
9	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0.453278	0	0.425034
10	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0.641321	0	0.77482
11	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	0	0.883507	0	1.601359
12	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	-0.1	1	0	2.554504
13	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger Dataset\IMG\center_	D:\File Gua\Kuliah\Semester 9\Program TA\myData\Bigger	D:\File Gua\Kuliah\Semester 9\Program TA\myDa	-0.25	1	0	3.252074

Figure 3 Dataset

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Step 2. Data Cleaning

At this stage, the process of cutting the file path name will be carried out, in this process we cut the dataset file path name and ignore the right and left camera images because the important parameters for this AV simulation model are images from the center camera along with speed, throttle, steering and break..

Step 3. Image Preprocessing

In Image Preprocessing, two tasks will be carried out, namely first there will be an image sizing process and after that an image augmentation process will be carried out.

In the pre-processing stage there are several stages of image sizing :

- The image will be resized to 66x200 as NVIDIA Model.
- The image will be cropped by cutting out unnecessary environments such as the sky, scenery, etc..
- Converting RGB to YUV
- Blur the end/side of the path to help make the analysis process more efficient.
- Image normalization

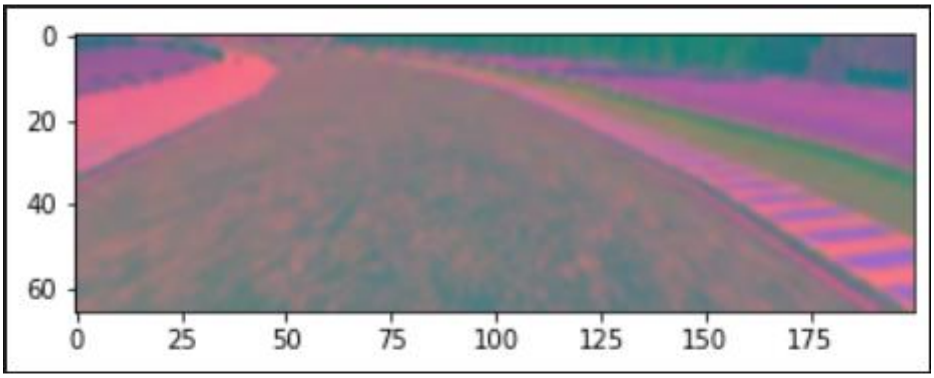


Figure 4 Preprocessing Image

After that, the Image Augmentation process will be carried out where there are several techniques such as :

- PAN, where the image camera will be shifted to simulate the effect of the car being at different positions on the road and adding an offset corresponding to the shift to the steering angle.

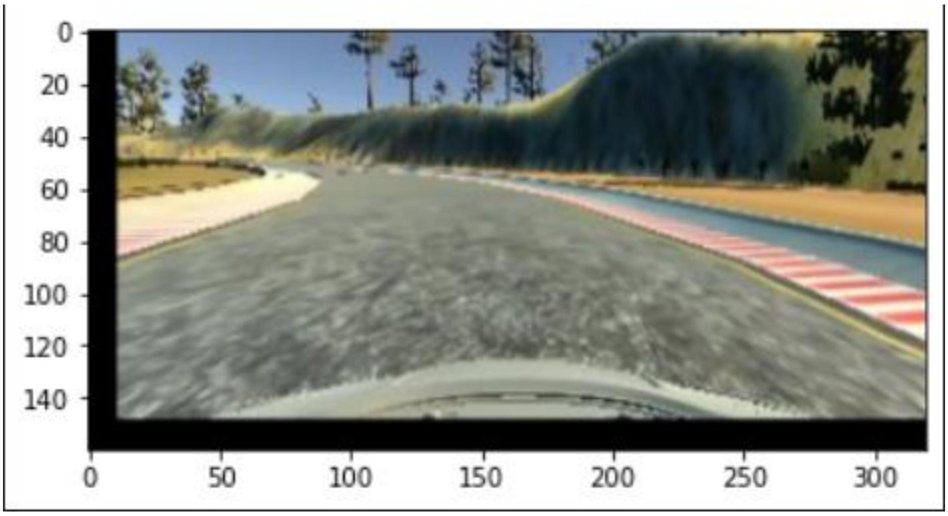


Figure 5 Image Augmentation with PAN

- Zooming is done by zooming in and out

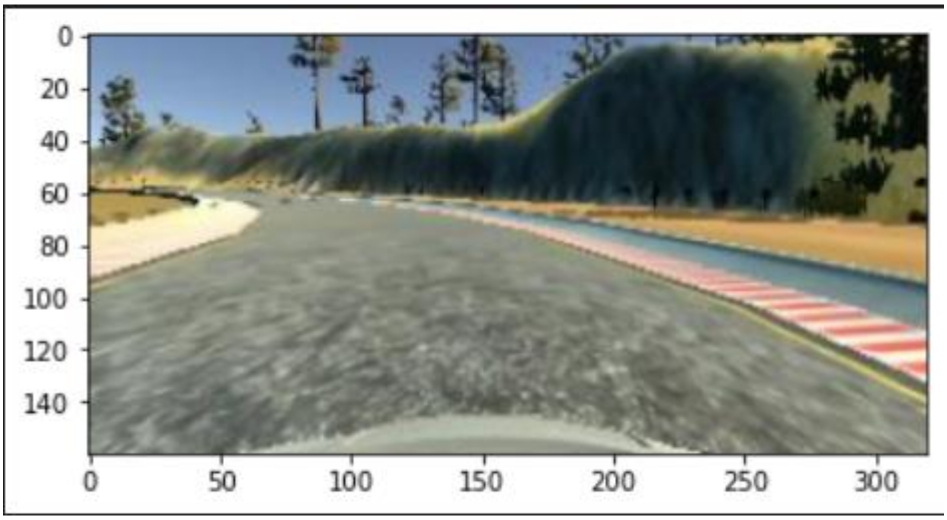


Figure 6 Image Augmentation with Zoom

- Brightness is done to simulate conditions of different brightness levels

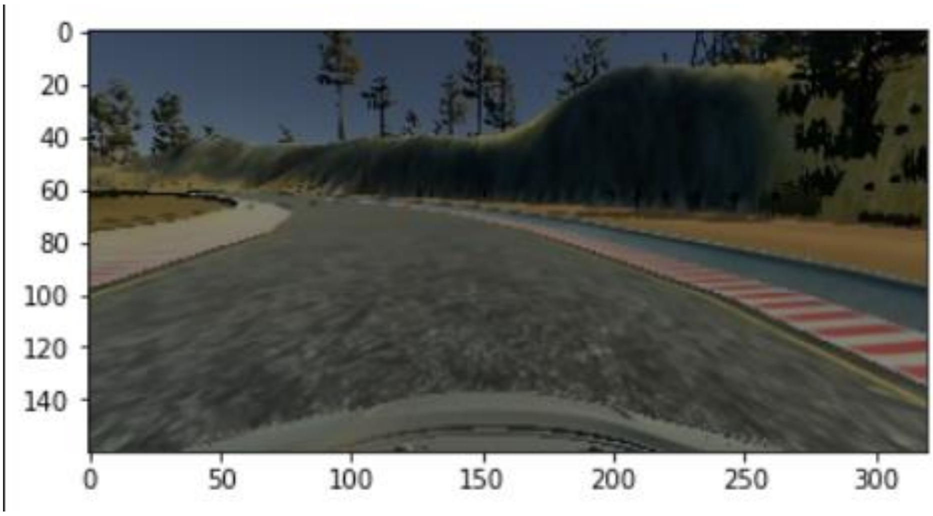


Figure 7 Image Augmentation Brightness

- Flip right/left image

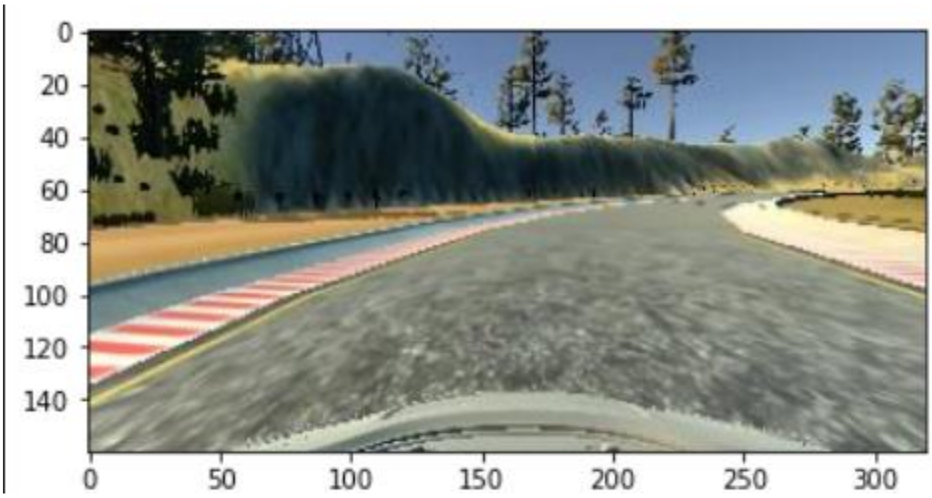
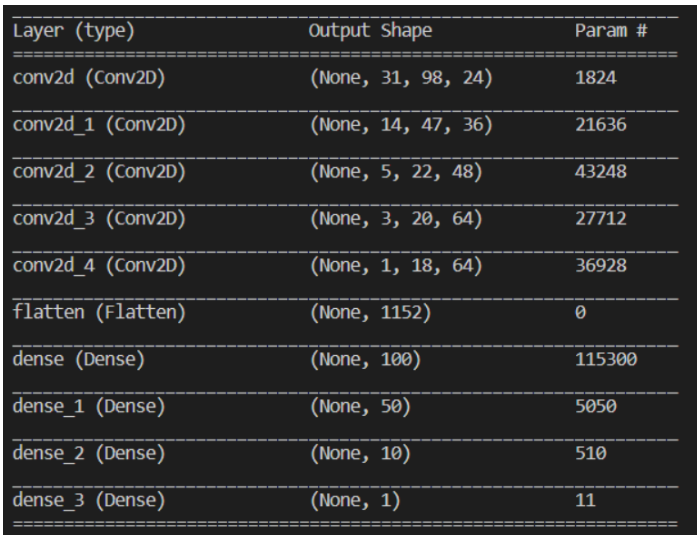


Figure 8 Image Augmentation Flip

Step 4 : Building the Model

In our work, we use the same model as the existing NVIDIA model [18]. This NVIDIA model is a deep convolution network that has been used by NVIDIA for self-driving, where the model structure is as follows :

- Convolution: 5x5, filter 24, strides: 2x2, activation : ELU
- Convolution: 5x5, filter 36, strides: 2x2, activation : ELU
- Convolution: 5x5, filter 48, strides: 2x2, activation : ELU
- Convolution: 3x3, filter 64, activation : ELU
- Convolution: 3x3, filter 64, activation : ELU
- Fully connected: neurons: 100, activation: ELU
- Fully connected: neurons: 50, activation: ELU
- Fully connected: neurons: 10, activation: ELU
- Fully connected: neurons: 1 (output)



Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 31, 98, 24)	1824
conv2d_1 (Conv2D)	(None, 14, 47, 36)	21636
conv2d_2 (Conv2D)	(None, 5, 22, 48)	43248
conv2d_3 (Conv2D)	(None, 3, 20, 64)	27712
conv2d_4 (Conv2D)	(None, 1, 18, 64)	36928
flatten (Flatten)	(None, 1152)	0
dense (Dense)	(None, 100)	115300
dense_1 (Dense)	(None, 50)	5050
dense_2 (Dense)	(None, 10)	510
dense_3 (Dense)	(None, 1)	11

Figure 9 Model Output Structure

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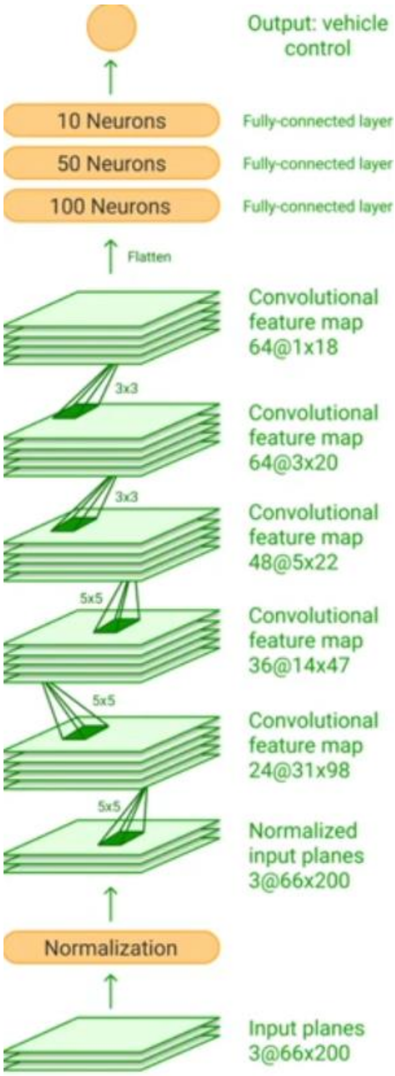

Figure 10 CNN Architecture

After the image has been processed in such a way, the next process is the model training process. Our training process uses Adam Optimizer Keras with learning rate = 1e-4, and to build the CNN training model using TensorFlow Keras. For the deep learning model, we divide it into 20% for validation data and 80% for training data. The number of epochs used is 100 with the number of steps per epoch of 300. The results of the model will be discussed in the results and discussion section.

III. RESULT AND DISCUSSION

A. Metrics of evaluation

The evaluation metrices that will be used in this research are by calculating the accuracy and loss values of the AV model that has been built..

Accuracy: the ratio between the number of correct predictions and the total number of input samples.

$$Accuracy = \frac{number of correct predictions}{total number of input samples} \quad (1)$$

In this study we chose to use the mean-square-loss error (MSE) function. The Mean Squared Error method is usually used to evaluate measurement methods with regression models or prediction models such as Moving

Average, Weighted Moving Average and Trendline Analysis.

$$RMSE = \sqrt{\frac{1}{n}\sum(y1 - \hat{y}1)} \qquad (2)$$

B. Results and Discussion

After the model is successfully built, the next step is to evaluate the performance of the model that has been built. The best results obtained show a loss value of 0.0165 and an accuracy of 71% (can be seen in Table 1). Both metrices are quite good and we managed to make a good model. Output information is stored in a model that can be used for autonomous vehicles. This model is used by the simulator to drive the car autonomously on the path in the simulator.

TABLE I
RESULT

Epoch	Accuracy	Loss
1	68%	0.0222
20	**71%**	**0.0165**
50	70%	0.0167
100	68%	0.0211

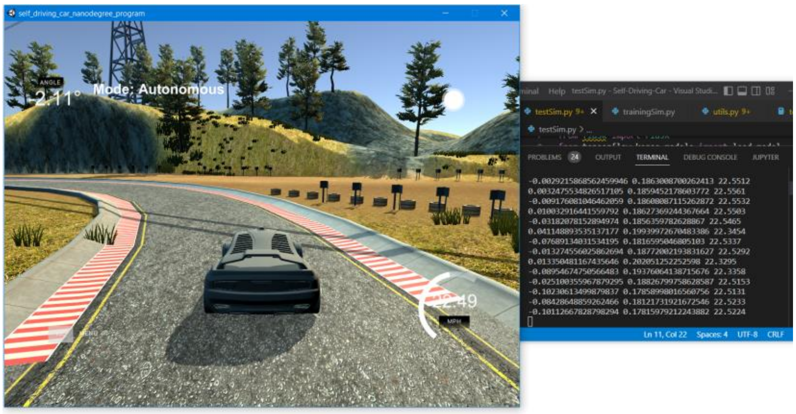

Figure 11 AV Simulation

As can be seen in Figure 11, the AV simulation made can run smoothly without experiencing collisions or going off the road. With an accuracy of 71% and a loss of 0.0165, the model successfully provides steering predictions to the AV simulation car.

This research uses a simpler environment in the simulator used from previous research [5]. Where in this study did not modify the environment of the simulator but the dataset used was different from previous research. The dataset used in our research uses Multi-Human-Driving Behavior, where this data is taken from several participants to take each driving behavior from each person so that diverse data is obtained. From the results shown, the accuracy value of this research is below the results of previous research [5], but the loss value obtained in our research shows a better number than previous research.

The testing results obtained from this research can be influenced by several aspects. For example, the dataset used and the number of epochs used in the data training process. The number of epochs used affects the accuracy and loss obtained, the more the number of epochs, the better the loss value obtained. However, the time required in the training process becomes longer, thus slowing down the experimental process.

IV. CONCLUSION

In this research, an AV simulation using deep learning has been successfully created. The data used is image data so that the model is made using the Convolutional Neural Network (CNN) method. The simulator used is Udacity Self-Driving Car from Unity 3D. The model is built with the aim of imitating human-driving behavior so that the car in the simulation can drive itself. The model is trained using the keras : Python Deep Learning Library. The model created can be used to run the car in the simulator autonomously so that the car can run without going off the track and collision.

This research can be further developed to get more optimal results. For example, using other algorithms, increasing the number of epochs in the training process or combining other deep learning algorithms. In the context of autonomous vehicles, a safety case can also be made to ensure the safety of the AV system built.

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