CNN-Based Traffic Light Classifier

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***Abstract*— Traffic lights are an essential part of our road infrastructure; they are in charge of keeping traffic moving and making sure everyone on the road is safe. Evidence suggests that smart cars will become more common in the coming years, and traffic light classification is an important component of the advanced driver assist technology.**

The classification of traffic lights will aid vehicle drivers in avoiding accidents caused by human error. In this paper, we propose the use of our CNN-Based Traffic Light Classifier to identify the state of the traffic light through deep learning, which may work in conjunction with automatic driving support systems.

Keywords— ***traffic light classification; image processing; deep learning; classification; traffic light; CNN.***

I. INTRODUCTION

The increasing prevalence of "smart" cars has resulted in the development of a number of technologies whose combined effects improve the driving experience. Smart cars are "vehicles equipped with system-driven forms of artificial intelligence." [1] The widespread adoption of intelligent vehicles is a key component of the expansion of the automotive industry that would significantly improve the safety of our roads. The advanced driver support system provided by smart cars prioritizes road safety, and other features such as collision detection and emergency alerts contribute to creating a stress-free and convenient driving environment. One of those innovations is a feature that adjusts a car's speed and notify the driver by detecting the traffic light state.

According to a research article [2] by Masaki et al. (2021) Traffic light recognition is an important task for automatic driving support systems. Model-based approaches to traffic light recognition are particularly vulnerable to external factors like sunlight. Because of their inability to effectively represent features, machine learning-based methods have trouble detecting far-off and obscured traffic lights. To recognize distant traffic lights, they proposed a method that employs semantic segmentation to isolate the lights themselves from images and a convolutional neural network (CNN) to label their status. Experimental results showed that their semantic segmentation-based detection is capable of identifying distant traffic lights greater than that of any other detection techniques with great accuracy.

Niu and Li (2022), in their study [3] highlight the significance of traffic light detection and recognition to the larger field of intelligent transportation. Using machine vision to detect and identify traffic light states is a vital step in the evolution of both assisted driving and autonomous vehicle technologies. With their built-in cameras, autonomous vehicles can monitor traffic signals and react accordingly. It is possible to reduce traffic accidents by reminding drivers of important traffic light status via voice if they have acquired this information.

The dramatic increase in road traffic over the past few decades has necessitated the installation of traffic lights in nearly every major city around the world. However, many metropolitan areas are rethinking their reliance on traffic lights because of concerns that they encourage risky behavior and encourage cities to instead favor alternative strategies for slowing down motorists. [4] Similarly, they aim to improve conditions for public transportation and modes of transportation that don't rely on motorized vehicles. The Metro Manila Accident Recording and Analysis System (MMARAS) reports an average of 299 road crash incidents every day in Metro Manila. [5] According to the reports that were collected by MMARAS between the years of 2010 and 2016, human error was the primary factor in most of the traffic collisions that occurred in Metro Manila. The MMARAS defines human error as any of several factors, including but not limited to, a driver's own carelessness or external factors like weather or traffic, that contribute to a crash.

The increasing prevalence of traffic congestion in urban areas has spurred the need for efficient and accurate traffic management systems. One key component of these systems is the ability to automatically detect and classify traffic lights in real-time [6]. In recent years, convolutional neural networks (CNNs) have emerged as a powerful tool for image classification tasks.

A traffic light classifier is one of the features that works with the other smart technologies to help drivers make fewer mistakes and avoid accidents. Deep learning, in the form of a convolutional neural network, is utilized in order for a traffic light classifier to accomplish its task of determining the color of a traffic light. This is the primary objective of the traffic light classifier.

In this paper, we propose a CNN-based approach for traffic light image classification. We present the design and implementation of our model and evaluate its performance on a dataset of traffic light images. Our results demonstrate the effectiveness of our approach and its potential for use in real-world traffic management systems.

II. METHODOLOGY

The methods of data collection and processing used in the subsequent study are described, and data preparation techniques for the traffic lights classification are discussed. Following that is an explanation of the procedure for visually representing the traffic lights classification model.

A. Raw data collection

The images constituting the traffic light dataset we used are from GitHub [7]. The dataset contains three classes representing each traffic light state (red, yellow, green). The raw images are composed of a total of 1,500 images, 500 images of each traffic light state.

B. System's ideal functionality

This model's ideal functionality is that modern vehicles can use this model to classify traffic lights, which has the potential to radically alter public transportation in cities by making it more accessible, reliable, and less congested.

The researchers have determined that smart cars are the future of vehicles on the road. And so, the researchers aims for their CNN-based traffic light classifier to work in conjunction with the other features of a smart vehicle such as object detection to provide a safe and improved driving experience and hope that the model will be of help in keeping people safe and prevent accidents.

C. Data understanding

The researchers started with familiarizing themselves with the domain of traffic and gained insights on traffic lights before the raw data collection from GitHub. Afterwards, proceeded with activities that enable the developers to become familiar with the data, identify data quality problems, watching guidelines regarding the topic that was selected and how data will help them to manage the problems.

D. Data preparation

Since the images the researchers gathered are of different dimensions, the images were promptly transformed into 50x50 pixels and converted to greyscale. Afterwards, the images were assigned their corresponding labels. The researchers promptly applied one-hot encoding to the images to prepare it for the model creation. Labels were attached to the data matrix The reshaped images were then split for training and testing sets. The generated sets were then converted to categorical form

III. RESULTS AND DISCUSSION

The researchers utilized the usage of convolutional neural network to maximize accuracy. The resulting model was effective at accurately identifying and classifying the traffic lights in an image. This is because convolutional neural networks are specifically designed to work with grid-structured data, such as images, and can automatically learn spatial hierarchies of features, which is useful for tasks such as object recognition.

The researchers conducted several experiments, adjusting the hyperparameters to optimize the CNN prediction model. Table 1 refers to the result of applying convolutional neural networks on traffic light classification is the ability to accurately identify traffic light states. Model 6 achieved an accuracy of 91%. This means that the neural network has an acceptable accuracy rate of traffic light classification.

TABLE I. EXPERIMENTS CONDUCTED

Models	**Hyperparameter Experiments**				
	Epoch	***Dropout***	***Optimizer***	***Learning rate***	***Accuracy***
Model 1	30	0.3	Adam	0.0001	83%
Model 2	10	0.3	Adam	0.001	85%
Model 3	30	0.3	Adam	0.03	88%
Model 4	10	0.5	Adadelta	0.0001	66%
Model 5	30	0.10	Adam	0.001	90%
Model 6	20	0.3	Adam	0.001	**91%**

The precision, recall, F1 score, and support refer to different metrics that are commonly used to evaluate the performance of a machine learning model. Precision is a measure of the model's ability to correctly classify positive examples. Recall, on the other hand, is a measure of the model's ability to correctly classify all the positive examples in the dataset. The F1 score is a metric that combines precision and recall into a single score. It is calculated as the harmonic mean of precision and recall and is often used as a single metric to evaluate the overall performance of a model.

Finally, the support is the number of examples in the dataset that belong to each class. In summary, our model has achieved 91% accuracy which means it made correct predictions for 91% of the examples in the dataset. This is generally considered to be a good performance. As can be seen in table 2.

TABLE II. Performance Report

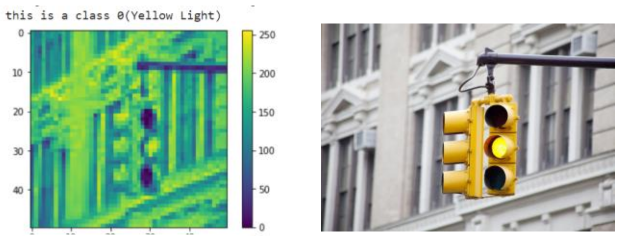
	Precision	Recall	F1 Score	Support
class 0 (Yellow Light)	0.88	0.95	0.91	112
class 1 (Green Light)	0.93	1.00	0.96	93
class 2 (Red Light)	0.94	0.78	0.85	95
accuracy			**91%**	300

The confusion matrix of the model as shown in table 3, is analyzed and interpreted. The main diagonal (104, 93, 74) gives the correct predictions. Also defined as where the actual values and the model predictions are the same. The first row are the actual values of the yellow light class. The model predicted 104 of these correctly and incorrectly predicted 1 yellow light to be red light and 5 to be green light. Similar interpretations apply to the other classes.

TABLE III. Confusion Matrix

	Yellow	Red	Green
Yellow	104	1	5
Red	0	93	0
Green	15	6	74

The model has displayed desirable outputs being demonstrated in predicting an image, since the model achieved a 91% accuracy. Figure 1 displays the model prediction vs the actual image.



(a) predicted image (b) actual image

Figure 1. Model prediction of an image (a) vs the actual image (b)

IV. CONCLUSION

In this paper, we have created a CNN-based traffic light classifier in hopes for the model to be of use in driver-assist technologies in a smart vehicle and concluded that a convolutional neural network is well-suited for this task as shown that the model achieved a 91% accuracy. This is because a convolutional neural network is specifically designed to work with grid-structured data, such as images, and can automatically learn spatial hierarchies of features, it is effective at accurately identifying and classifying the traffic lights in an image.

Additionally, because convolutional neural networks use a technique called convolution to extract relevant features from the input data, they can be trained to recognize a wide range of different traffic light patterns and colors, making them highly versatile for use in traffic light classification.

The result of applying convolutional neural networks on traffic light classification is the ability to accurately identify traffic light states. The model achieved an accuracy score of 91% this means that the CNN-based traffic light classifier can accurately identify whether a traffic light is red, yellow, or green. This can be used to improve traffic flow and safety by providing real-time information to drivers and traffic control systems.

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MEMBER CONTRIBUTIONS - PAPER

Member	Contribution
Rodney Tayuni - Leader	Methodology, Research Problem, Paper formatting
Yancie Troy H. Saludo	Abstract, Introduction, Dataset
Louise Clark Fernandez	Results and Discussion, Tables, Conclusion