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The Framework of Vehicle Detection and Counting System for Handling of Toll Road Congestion using YOLOv8

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Abstract—The Global COVID-19 pandemic and the increasing number of vehicles have exacerbated traffic congestion, particularly in developing countries. In Jakarta, Indonesia, congestion on toll roads is a significant issue that needs to be addressed through an Intelligent Transportation System (ITS). One of the key solutions proposed is vehicle detection and traffic prediction on toll roads. This study introduces a computer vision-based approach utilizing YOLOv8 to detect, track, and count vehicles to predict traffic congestion. The system operates by identifying vehicles (cars and trucks), preprocessing the data, and calculating the total number of vehicles within the camera's range. If the vehicle count surpasses the threshold set by the toll road provider, the system updates the traffic status (normal or congested) and triggers a warning. The vehicle detection system can identify cars and trucks within a range of up to 150 meters. Experimental results using test videos demonstrate that the YOLOv8-based system achieves an accuracy of 98% with an average detection speed of 83.6 milliseconds, ensuring highly efficient performance. With its high accuracy and speed, this system can be effectively integrated into traffic management solutions to alleviate congestion and enhance transportation efficiency in Jakarta.

Keywords—Intelligent Transportation Systems; vehicle detection; Computer Vision; Yolov8

I. INTRODUCTION

The evolution of the modern transportation system and the development of the sophisticated Intelligent Transportation System (ITS) is a direct result of technical advancements that have enhanced the effectiveness and performance of transportation systems [1]. ITS applies advanced technolo-gies of communications, computers, embedded system, IoT and sensing and utilizing real-time data for detection in various transportation systems to enhance efficiency, safety, and traffic conditions. In a nation like Indonesia, where there were over 4 million automobiles and trucks in total in 2018, an integrated vehicle recognition and counting system for toll roads is crucial to an intelligent transportation system, particularly for traffic management.

In many ITS applications, it is crucial to estimate traffic data accurately, including speed, journey duration, and congestion level. In order to increase safety and efficiency and solve a variety of issues, such as traffic monitoring and control and road condition monitoring, transportation infrastructure and service providers are increasingly depending on computer vision. Among the techniques for addressing toll road congestion are traffic flow analysis and vehicle categorization [2].

Around the world, controlling the growing volume of traffic on toll roads is a difficult and significant issue. Many researchers try to solve traffic volume prediction based on computer vision. To extract these road conditions from the image, Shao Peng-Lu et al. suggested an image processing system that consists of a distance conversion (DC) method and a curve detection algorithm (CDA). Road conditions, such as the geometry of the road and the separation between

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the lead and host vehicles, are crucial for increasing the precision of trajectory prediction in the future. The camera mounted on the car can provide information about the road conditions [3]. Although geostatistical techniques were put forth for traffic problem assessment and geographical prediction, they can produce predictions that are not correct. Suggested segment-based regression kriging (SRK) for predicting traffic volume while distinguishing between heavy and light vehicles [4]. Even though their volume only makes up 21% of traffic, the overall effects of heavy vehicles account for more than 82% of the road maintenance burden, according to implementation results of SRK-based predictions. The impact of heavy vehicles on road maintenance is significantly greater than that of light vehicles and varies across space.

We must make specific framework in Jakarta-Indonesia, because the system is to-tally different compared with other countries, such as for daily activities based on odd/even plate number relating with the date. By getting big data of traffic in toll road, a provider like Jasa Marga (Provider of toll road in Indonesia) can make a fast and effective decision for making a traffic engineering. For example, usually workers from Bekasi city need 2 hours to get to his/her office at Jakarta using toll road. Pres-ident Republic of Indonesia, according to Jokowi, the National Development Planning Agency's investigation shows that traffic congestion in Jakarta, Bogor Tangerang, and Bekasi City costs Indonesia USD 4.6 billion annually. If the provider detects the toll road congestion in the morning, then the action should be released such as using contra flow at toll road. This paper try to make an initial research for vehicle detection and counting system for handling toll road density in Indonesia. This paper proposes a framework and method for handing toll road congestion with a case study at Jakarta-Indonesia. Using general image, the proposed framework with object detection based on deep learning will detect and count the vehicles at highway road.

Figure 1. Workers at Jakarta use private car rather than public transportation caused by Covid-19 pandemic with more than 205,000 confirmed cases in Indonesia until 15 September 2020 [5].

II. Literature Review

A. Intelligent Transportation Systems

The term ITS was coined in 1994, broadly refers to a mobility system that has become more sophisticated via the use of Big Data Analytics and Information Technology (IT). By carefully utilizing information technology, ITS aims to improve traffic and transportation safety, efficiency, environmental concerns, and convenience. ITS is an integrated system that uses a variety of electronics, communication, control, and vehicle sensing technologies to manage and resolve traffic issues. While ITS has been in use over the past 20 years in industrialized nations, it is still a novel idea in developing nations like South Africa, Indonesia, India, and others.

In order to monitor and manage traffic flow, reduce congestion, give travelers the best routes, increase system productivity, and save lives, time, and money, Intelligent Transportation Systems (ITS) integrate a variety of communication, control, vehicle sensing, and electronics technologies. Following the occurrence of non-recurring congestion, Logi and Ritchie presented the Real-time Knowledge Based System (KBS) to assist in decision-making when choosing integrated traffic control plans. The findings of the validation demonstrated that the use of Traffic Congestion Management (TCM) decreased average stop speed by 14.8% to 55.9% and travel time by 1.9% to 29.0% [6]. P. Singh and U. P. Bijnor proposed an intelligent road traffic congestion control system with image mosaicking technique [7].

Current studies on the application of GPS in traffic management systems for ITS. GPS was used in their study to gather traffic data on 64 main highways, including trip duration, speed, and delay. No discernible difference was found when the mean and variance of the outcomes produced by the two approaches were compared. It was discovered that GPS data was 50% more manpower efficient [8]. He and Zhang [9] presented a multi-agent based public transportation dispatch and decision support system. Personal computers serve as the user interface for the suggested system, which answers user questions. Big data on traffic may help in measuring congestion, predicting crashes in real time, and preventing rear-end collisions. The emergence of big data presents both opportunities and obstacles for theoretical research and real-world implementation in the creation of intelligent transportation systems [10].

B. *Object Detection and Tracking with Computer Vision*

Object detection is a task that includes both classifying each object in a picture and locating one or more objects inside it. It is a difficult computer vision task that calls for tracking and object classification to determine the correct class of localized objects, as well as successful object localization to identify each object in an image and draw a bounding box around it [11]. Cvlib is a straightforward, high-level, user-friendly, open-source Python computer vision library. Calling the detect_common_objects() function will identify objects in a picture and return the bounding box coordinates, labels, and confidence scores for those objects. You Only Look Once, or YOLO, is a technique for object detection. It is the method by which the code will identify things in the picture [12]. The most recent iteration of Ultralytics' YOLO (You Only Look Once) object recognition and picture segmentation model is called YOLOv8. The YOLOv8 model is a great option for a variety of object recognition and image segmentation applications because of its quick, accurate, and user-friendly architecture. It can operate on a range of hardware platforms, including CPUs and GPUs, and can be trained on big datasets. The NVIDIA® T4 GPU, which can speed up a variety of cloud workloads, such as high-performance computing, machine learning, data analytics, deep learning training and inference, and graphics, is used in this study. We should install ByteTrack, Tracking utils, and Roboflow Supervision for the YOLOv8 experiment. The accuracy rate of YOLOv8 is high as determined by Roboflow 100 and COCO [16][17]. Architecture of Yolov8 shown in figure 2:

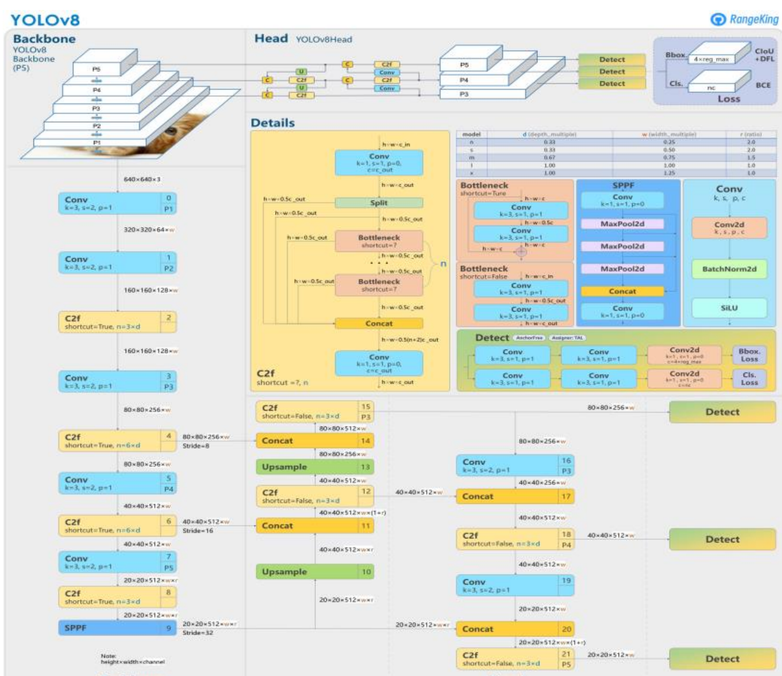


Figure 2. An anchor-free model is the YOLOv8 architecture. This implies that rather than predicting the offset from a known anchor box, it predicts the center of an item directly.

III. Proposed Method

A. Proposed Method

Intelligent traffic management and highway control greatly depend on vehicle detection and statistics in highway monitoring video sequences. A huge collection of traffic video footage has been gathered for examination as a result of the widespread installation of traffic surveillance camerasFor instance, a new high-definition highway vehicle dataset comprising 11,129 photos and 57,290 annotated occurrences was proposed by the researcher and published [14]. Accurate classification data are also fundamental to traffic operation and transportation planning. In this research we proposed Framework for Vehicle Detection and Prediction System as shown in figure 2 below, where we need an integrated database such as big data of ITS in Indonesia as shown in Figure 3:

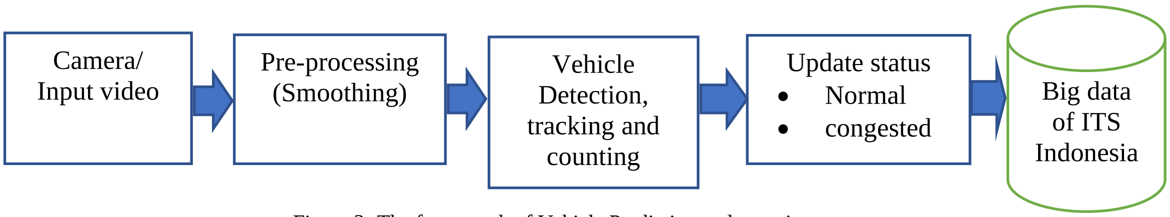


Figure 3. The framework of Vehicle Prediction and counting system.

The program for vehicle detection and counting developed using Python and deep learning implementation of YOLOv8. We limit the normal traffic is < 40 and congested if ≥ 40 based on the observation from the camera [15]. So, we defined the status of traffic:

$$\text{Status} = \begin{cases} normal, if\ total < 40 \\ congested, if\ total \geq 40 \end{cases} \quad (1)$$

The proposed algorithm for our system is shown in algorithm 1:

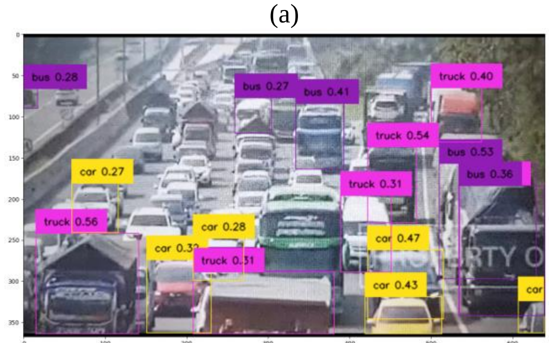
Algorithm 1: Vehicle prediction and counting system for ITS

```
Import libraries
Begin
    Configuring GPU.
    Download video.
      Read input video.
      Filtering a video.
      Load pre-trained YOLOv8
      Detect and tracking vehicle.
      Predict and annotate single frame.
      Predict and annotate the whole video.
      Print total of vehicle
      Update total car and truck
      If total <40 then
        Update status: normal
      Else
        Update status: congested
Endif
End
```

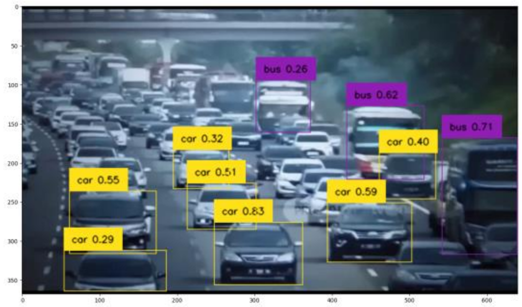
IV. Experimental Result

For the experiment, we use google Collaboratory with NVIDIA Tesla 4 GPU and 12GB RAM as the environment. The result of vehicle detection and counting shown in figure 4, and when the total vehicle reaching the threshold of congestion, then it will update the status of the traffic to the database.

(a)



(b)



(c)

Figure 4. The input image (a) and result of vehicle detection and counting (384x640 6 cars, 6 buss, 6 trucks, 48.0ms Speed: 1.4ms preprocess, 48.0ms inference, 1.9ms postprocess per image) (b) and (384x640 7 cars, 3 buss, 118.5ms, Speed: 6.7ms preprocess, 118.5ms inference, 18.8ms postpro-cess per image) (c).

The main driving force behind YOLOv8 research was empirical assessment using the COCO benchmark. Table 1 displays the accuracy and speed results of our system. We are happy with YOLOv8 because of its extremely quick speed (about 83.6 ms).

Table 1. Result of accuracy and speed of detection of our system

Input	Accuracy	Speed
video 1	100%	48.0ms
video 2	100%	118.5ms
video 3	100%	70.0ms
video 4	100%	70.0ms
video 5	90%	112.0ms
Average:	**98%**	**83.6ms**

V. Conclusion

This research develops a traffic jam detection and prediction system on Jakarta-Indonesia toll roads using YOLOv8-based computer vision technology. The system is able to detect, track and count the number of vehicles within the camera range of up to 150 metres. If the number of vehicles exceeds the limit set by the toll road provider, the system will update the traffic status (normal or congested) and provide a warning. The test results show that the system has a detection accuracy of 98% with an average speed of 83.6 ms, so it can be effectively used in intelligent traffic management. For future work, we will propose and implement this framework to the provider at Jakarta.

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