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Application of OCR Technology for License Plate Detection and Yolo V8 for Car Counting

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ABSTRACT

The development of urban mobility and the growth of the number of motor vehicles has created significant security challenges in security management in residential environments, parking areas, and office areas. In this context, the use of Automatic License Plate Recognition (ALPR) technology and object detection emerged as potential solutions. Through the implementation of a smart camera system equipped with license plate detection and object detection, this research aims to reduce the risk of human error in maintaining safety and preventing the loss of users' vehicles. In answering this problem, this research offers a solution in the form of the development of a smart camera system that can detect the presence of vehicles and recognize license plates with a high level of accuracy. Through the integration of ALPR and object detection, this system is expected to overcome obstacles that arise in residential, office, and parking lot environments, improve efficiency, and effectively prevent vehicles from changing hands. The implementation of automatic bars, access cards, and integrated CCTV surveillance will further strengthen security. With the results of the research, the proposed smart camera system has succeeded in achieving a vehicle and license plate detection accuracy level of above 90%. The quantitative and qualitative data collected supports the effectiveness of this solution in improving the safety and comfort of the area. In conclusion, this research makes a positive contribution to facing security challenges in cities through the use of advanced technology, opening up the potential for widespread application in the context of urban mobility that continues to grow.

Keywords: object detection; optical character recognition; facial recognition; automatic license plate recognition; smart camera.

Introduction

Motor vehicles are one of the important elements in the increasing urban mobility rapid urbanization and population growth. (Aulia et al., 2019). The rapid growth of urban mobility and the number of motor vehicles pose security challenges in residential areas, offices, and parking lots. License plates are a form of identity for every vehicle, both motorcycles and cars. Vehicle license plates consist of a combination of letters and numbers, where each letter and number contains information about the provincial code and the area code where the vehicle is registered.

Advances in AI have allowed us to develop systems that can mimic humans' ability to recognize objects. One example is object detection, where computers can be trained to find and identify specific objects in images, such as vehicle license plates. This training process involves providing a large amount of data to the computer to learn to recognize the distinctive features of the object it wants to detect (Samek, 2017). Object detection determines the existence of an object, its scope, and its location on the image. Detection objects identify the class of objects present in the database that have been trained. Object detection begins with the recognition of an object. It can be treated as second-class object recognition, where one class represents an object class and another class represents a non-object class. Object detection is divided into two, namely soft detection and hard detection. Soft detection can only detect the presence of an object whereas hard detection detects the presence of an object and the location of the object on the image. Object detection is usually done by searching each part of the image to localize the part, which is photometric or whose geometry matches the target object in the database training. This can be achieved by scanning the object template across the image in different locations, scales, and rotations, and detection is declared if the similarity between the template and the image is high enough. The similarity between the template and the image region can be measured by their correlation. Recent years have proven that image-based detection objects are sensitive to training data. (Jalled & Voronkov, 2016).

Object detection is a technique in artificial intelligence that allows computers to identify specific objects in images or videos. This process involves training a computer model using a large amount of data. One of the important applications of object detection is Optical Character Recognition (OCR) which aims to convert text in images into a computer-readable format. (Zhao et al., 2019).

This vehicle license plate detection is known as Automatic License Plate Recognition (ALPR) technology, ALPR is a technology used to detect and recognize the character of vehicle license plates, and this technology has been implemented in daily life (Galahartlambang et al., 2023) The method used to take license plate objects in a vehicle image is the Deep Learning method. Deep Learning has become a hot topic in recent years, some of fx which are used to create object detection and face detection (Winarno et al., 2020). YOLO (You Only Look Once) (Andwiyan et al., 2021), as one of the leading object detection algorithms, has proven to be effective in a wide range of applications, including vehicle detection (Garg & Phadke, 2023) YOLO is capable of producing fast and accurate results, which is crucial in real-time applications (Zou et al., 2023) (Wang et al., 2023).

In this study, a method is used in terms of detection in real time. The method used is YOLO (You Only Look Once). The YOLO method is one of the state-of-the-art methods for the detection of objects in real-time conditions. YOLO is a detector with a unified model that predicts bounding boxes and class probabilities directly on a full image in one evaluation. The YOLO base model can process images at 45 FPS (frames per second) in real-time conditions. However, the YOLO method is still far from perfect to be applied to autonomous driving, because errors that can occur in the size of the bounding box lead to limited determination of the distance of the detected object [22]. There are several studies as considerations in this study, the following previous research related to this study that has been conducted previously explains the implementation of the YOLO method to detect people. The basis of the YOLO method used is YOLO with 7 convolutional layers, they built a human action recognition system using the YOLO method. The dataset used is the Lyris Human Activities dataset, which is a video-shaped dataset. The model used takes the input frame after a certain period and assigns a label based on a single frame, describing the application of Fast YOLO to the detection of objects embedded in videos in real-time using the Pascal VOC 2007 dataset. Although YOLOv2 can achieve real-time performance on powerful GPUs, it is still a challenge to utilize it on devices with limited computing power and memory. Fast YOLO is proposed by accelerating YOLOv2, to reduce power consumption on the device.

For this study, car calculation and car detection will use the YOLO method because this method has good speed and accuracy in detecting objects. To carry out the process of retrieving license plate data from the image will be carried out using Optical Character Recognition (OCR) which generates text from the captured image. At this time, the implementation of OCR has been simplified with the help of the Tesseract OCR library and the accuracy level is also relatively high. This process is carried out to retrieve the license plate serial code which will later be stored in the database. Face Detection will use the Haar Cascades method as it offers a compact and efficient method for detecting faces. (Shinde et al., 2018).

The purpose of this research is to develop and implement a smart camera system that can detect vehicles, license plates, and face detectors and calculate the number of vehicle arrivals and departures in parking areas, and residential and office areas. In addition, this research aims to improve the level of security in residential areas, offices, and parking areas by providing additional protection through vehicle and license plate detection. This is expected to prevent illegal parking practices and related criminal acts. In addition, the objectives of this project also include modernization of the security system area, optimization of identification accuracy, and provision of accurate information. By presenting real-time data on the number of vehicles entering and exiting, the project is expected to improve efficiency and enable real-time monitoring for quick response to emergencies. Another goal is to provide a higher level of security. Furthermore, this project aims to optimize the use of parking facilities by monitoring capacity and managing parking spaces efficiently. Through the achievement of these goals, it is hoped that this research can make a positive contribution to efficient parking management and improve safety in parking areas, housing, and offices.

Research Methods

Research Stages

This stage is carried out for the creation of system designs and program creation flows that will be used as guidelines or guides in conducting research. The design can be in the form of program flows, steps, or flowcharts. (Alhaq et al., 2021). The following Figure 1 shows a more detailed overview of the stages of the research methodology.

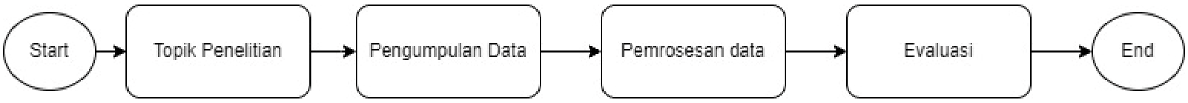

Figure 1. Research Stages

Data Collection

This data collection was carried out directly at the Buah Batu Housing Gate and Cherry Field Complex. There are 2 stages of data collection, namely by video recording and in real-time. When the data has been stored, the data processing stage will be carried out.

Data Processing

Object Detection

The following are the stages of data processing of the Object Detection subsystem:

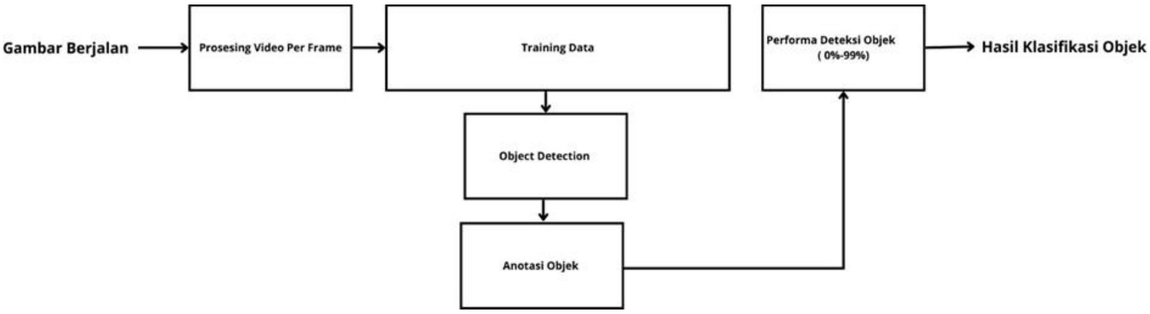

Figure 2. Object Detection Block Diagram

The image that has been obtained from the camera sensor is further processed by the system using machine learning to carry out the detection process by pre-processing the video per frame, then with data training to match the frames to be detected, then if the object is detected, object annotation will be carried out to determine the detection performance with a scope of 0%-99%, after which the detection results will be entered into the next process, namely the classification process.

The measurement method is carried out by determining the CNN accuracy model, determining the threshold intersection over union (IoU) to obtain detection accuracy, evaluating performance per frame to achieve detection stability per FPS, and validating to calculate the accuracy and recall of the vehicle's object detection capability.

1. Use the training dataset to train the vehicle detection model.

2. Calculate the IoU between the detection result and the ground truth to determine the appropriate IoU threshold to obtain accurate results.
3. Measure FPS during testing to determine the limits of hardware performance and ensure detection speed meets real-time requirements.
4. Using validation data to calculate precision and recall and perform sensitivity analysis to model parameter variations.

Pre-Trained Data In the pre-processing stage of the data, the important step to take is to make all the datasets into a size of 640 x 640 pixels, the size of 640 x 640 pixels is chosen as a compromise between good image quality and computational efficiency during training and conclusion. Furthermore, the dataset that has been manually annotated is divided into two parts, namely training data and test data. As many as 80% of the total dataset is used as training data, while the remaining 20% is used as test data. This division is important to objectively evaluate the model's performance on data that has not been seen before during training. (Garg & Phadke, 2023).

Vehicle License Plate Detection

The vehicle license plate detection process begins with the input of an image containing the vehicle and license plate. This input is then processed video per frame. Each frame is processed separately to detect license plates. Furthermore, character segmentation is carried out to identify and separate the characters on the license plate from the background. After that, the identified characters are extracted character traits, which involves capturing important information such as pixel shape, size, intensity, training layers, or machine learning models using the results of the feature extraction. This training process aims to build a model that can recognize license plate characters accurately. After the model is trained, it will be used to detect license plates on each frame. The model is used to recognize the characters on the license plate, and the detection results from each frame are collected. The final output is object classification information, which is text that represents the vehicle's license plate number.

The Optical Character Recognition (OCR) process is simple: Imagine we have a photo that contains text. OCR will work like a detective trying to make sense of the writing. The process can be divided into several stages:

1. Choosing a Photo: First, we select the photo we want to read the text on. These photos are usually in .bmp or .jpg format.
2. Cleaning Photos: Just like cleaning the house before guests arrive, photos also need to be cleaned. This stage aims to remove unimportant parts, such as smudges or doodles, to make the writing clearer.
3. Separating the Writing: Once the photo is clean, we will separate each letter or number into different parts. It's like separating the fruits from the basket.
4. Equalize Size: Each letter or number that has been separated will be equalized in size and thickness. This is so that the computer can more easily compare it with existing data.

5. Finding Distinctiveness: Each letter or number has its distinctive characteristic. This stage aims to find the distinctive features of each letter or number that has been separated.
6. Recognizing Letters: The features that have been found will be compared to the data already on the computer. That way, the computer can guess what letters or numbers are in the photo.

Pre-processing methods

1. Unsharp Mask

The unsharp mask technique works by increasing the contrast between the edges of the object and the surrounding area, making the image look sharper and more detailed. This method is very useful for reducing the effect of blur on images, especially on photos taken in low light conditions or camera movement. (Dar & Mittal, 2020).

2. Grayscale

Converting an image to grayscale can reduce the complexity of image processing, as each pixel has only one intensity value, which is grayscale. This is very beneficial for reducing the computing load.

3. Histogram Equalization

Histogram equalization is a technique to sharpen the contrast of an image. By sharpening the contrast in the image to be used, it will be easier to capture the information in the image and the result will be better when compared to the image before processing (Mau, 2016). This is because when an image is applied to histogram equalization, the intensity of a pixel in the image will be evenly distributed which will make the image quality better. (Azam, 2016).

4. Median Filtering

Median filtering is an effective method of removing noise in an image without removing important details. This method works by replacing the pixel value with the median value of its neighbor so that random noise can be reduced.

5. Gaussian Blur

Gaussian blur is a technique used to smooth an image by averaging the value of the surrounding pixels. This method is often used to reduce noise and unwanted details before the segmentation or binarization process.

6. Otsu Binarization

Otsu binaryization is an automated method of converting grayscale images into binary (black and white) images. This method optimally determines the threshold value based on the distribution of pixel intensity in the image, resulting in good segmentation between the object and the background.

7. Dilation

Dilation is a morphological operation used to zoom in on objects in an image. This operation is useful for filling small holes in objects and connecting disconnected parts of objects.

Results and Discussion

Data Collection

Data was obtained from cars entering and exiting the gate of the Buah Batu Housing and Cherry Field Complex.

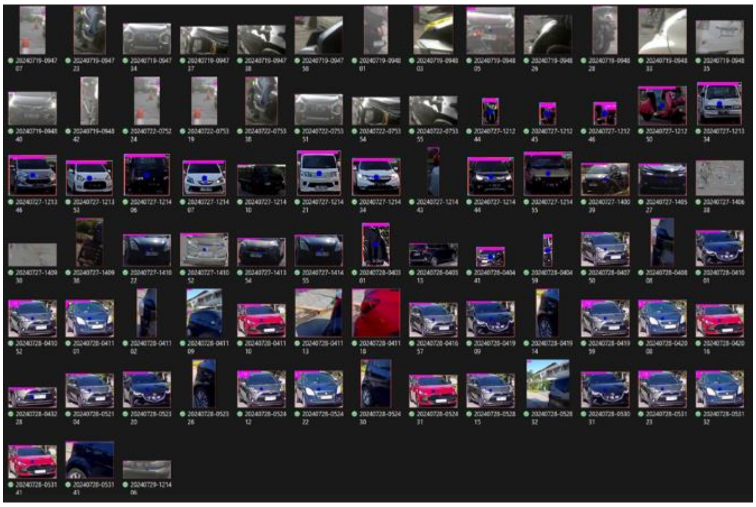

Figure 4. Object Detection Data Collection

Figure 5. License Plate Detection Data Collection

Data Processing

1. Object Detection

This vehicle detection and counting system uses cameras to capture traffic video and process frames in real time to detect and count the number of vehicles crossing a certain line. The system utilizes the YOLO V8 model for object detection and tracking algorithms to track detected vehicles from frame to frame. The code also includes a feature to store images of detected vehicles and calculate vehicle detection times.

YOLO v8 was used in this study because it offers improved performance and better accuracy compared to previous versions. The model is designed to be faster and more efficient, enabling real-time object detection with low latency, which is essential for vehicle detection and counting applications. With more advanced neural network architecture and better data augmentation techniques, YOLO v8 can identify objects more precisely and accurately. In addition, better generalization capabilities and compatibility with the latest technologies make YOLO v8 more flexible and easy to use, making it an ideal choice for this research.

Table 1
Training Results

EP and	Box_ loss	Obj_l us	Cls_ Loss	Precision	Recall	Map _0.5	mAP_0. 5:0.95

1	0.8745	0.336177	0.301361	0.529893	0.612314	0.586869	0.446080
2	1.446348	0.669926	0.366049	0.486774	0.407225v	0.572984	0.476401
3	1.224577	0.674360	0.304363	0.524420	0.406874	0.409915	0.353631
4	1.088737	0.739463	0.250935	0.621485	0.491841	0.524161	0.335731
5	0.648120	0.798532	0.269102	0.583086	0.538615	0.538666	0.353082
…	…	…	…	…	…	…	…
300	0.054854	0.060002	0.028556	0.811487	0.826173	0.746705	0.531407

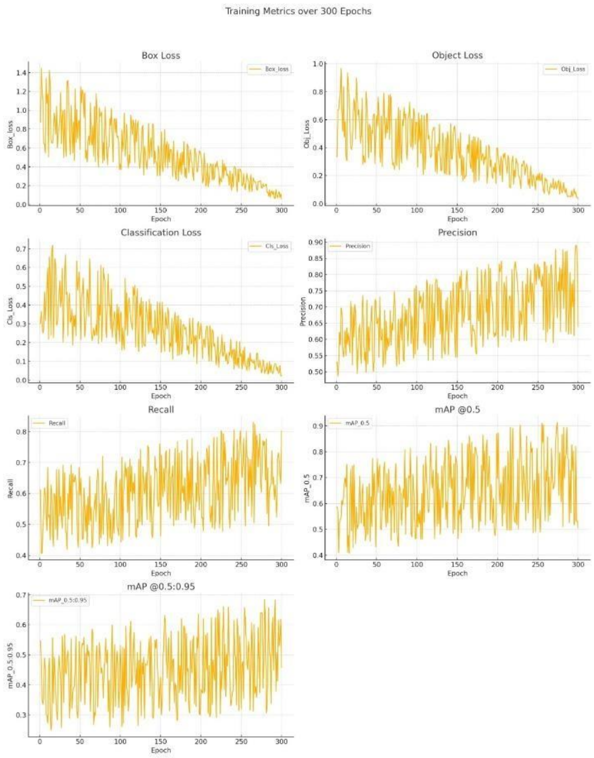

Figure 6 Training Results Graph

The table above shows the results of training the YOLOv8 model for 300 epochs, In the initial epoch the values of Box loss, Obj_loss, and Cls_loss were 0.874540, 0.336177, 0.301361 respectively and in the last epoch, the values of the training results showed a consistent decrease Where in the 300th epoch the values were 0.054854, 0.060002, 0.028556. Meanwhile, Precision, Recall, mAP_0.5, and mAP_0.5:0.95 showed a consistent increase from 0.529893, 0.612314, 0.586869, 0.446080 to 0.811487, 0.826173, 0.746705, 0.531407. This shows that the model has achieved quite good and stable performance in detecting objects with a high level of accuracy.

Vehicle License Plate Detection

a. OCR-Based Vehicle License Plate Detection System

The system is designed to automatically recognize and read vehicle license plates using Optical Character Recognition (OCR) technology. OCR allows the system to convert the text contained in an image or video into digital data that can be processed by a computer

b. System Working Principle

This system works in the following ways:

1. Image Acquisition: The camera captures images of the vehicle's license plates from a distance of at least 1 meter. The camera position is arranged in such a way that the entire entrance area can be captured clearly.
2. Pre-processing: The captured image will be processed to improve the quality of the image and make the character recognition process easier.
3. License Plate Detection: The system will detect the presence of license plates on the image using an object detection algorithm.
4. Character Recognition: Once the license plate is detected, OCR will be used to recognize the characters on the license plate.
5. Output: The character recognition results will be displayed or stored in the database.

Reasons to Use OCR

OCR was chosen because of its excellent ability to recognize text from images. This technology has developed rapidly and is widely used in a wide range of applications. Some of the advantages of OCR include:

a. High Accuracy: Modern OCR can recognize text with very high accuracy, even in less-than-ideal image conditions.
b. Speed: The character recognition process can be done in real-time.
c. Flexibility: OCR can be used to recognize different types of fonts and languages.

Using Roboflow for Data Labeling

To train an object detection model, pre-labeled training data is required. In this study, the Roboflow platform is used to carry out the data labeling process. Roboflow provides a user-friendly interface and features that make the labeling process easy, such as:

a. Labeling: Users can easily label objects in images, such as marking areas of license plates.
b. Bounding Box: Roboflow automatically generates a bounding box to delimit the area of an object that has been labeled.
c. Dataset Management: Roboflow allows users to easily manage datasets, including organizing, filtering, and exporting data.

Figure 7. Labeling on license plates

OCR and Object Detection Integration

By combining OCR technology and object detection, the system can perform a more complex task, which is not only detecting the presence of a vehicle but also accurately recognizing the vehicle's license plate.

Testing

1. Object Detection

Testing was carried out at the CherryField Complex security post when vehicles entered and exited the housing.

Test Results

The following are the test results of the object detection subsystem with moderate light conditions in the afternoon using YOLO V8.

Figure 8. Real-time test results

Figure 9. CCTV Recording Video Testing Results

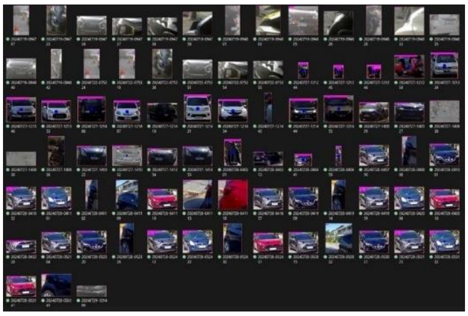

Figure 10. Vehicle Detection Results

Figure 9 shows the results of the model prediction in the experimental video. Which contains a vehicle that passes through the security gate. Boxes mark detected objects with labels that provide information about the object's category and object prediction confidence. This visualization allows a qualitative evaluation of the model's performance in detecting and classifying objects in real-time conditions.

Table 2
Description of the detection results

Vehicle	Information	Counter Results
1	Detected	1
2	Detected	2
3	Detected	3
4	Detected	4
5	Detected	5
6	Detected	6
7	Detected	7
8	Detected	8
9	Detected	9
10	Detected 2 times due to noise	10, 11
11	Detected 2 times due to noise	12, 13
12	Detected	14
13	Detected	15
14	Detected	16
15	Detected	17
16	Detected	18
17	Detected	19

In the table, it was found that the number of vehicles that passed through the entrance was 17 vehicles at the time of data collection.

Vehicle License Plate Detection

Application of the method on the image

1. Unsharp Mask

In this study, images taken through PiCamera will be applied with an unsharp mask to sharpen the image quality so that it can be processed better in the future by the program.

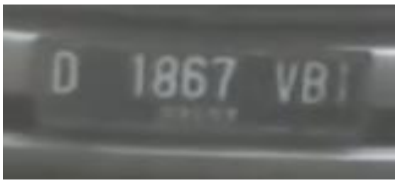

Figure 11. Examples of images taken by CCTV cameras

Figure 12. Example of an image after the application of Unsharp Mask

2. Grayscale

After the program has obtained the license plate image in the initial image, grayscale will be applied to ease the computational process that must be carried out by CCTV at the next stage.

Figure 13. Image to grayscale conversion

3. Histogram Equalization

Once the license plate image is converted to grayscale, the program will apply an equalization histogram to increase the contrast in the image.

Figure 14. Results of the application of histogram equalization

4. Gaussian Blur + Otsu Binarization

Next, the image will be converted into binary so that it can be read by Tesseract OCR. However, before converting the image to binary, Gaussian Blur will be done on the image first to reduce the noise in the image before converting it to binary.

Fig15. Image to binary conversion results

Figure 16. Test Results

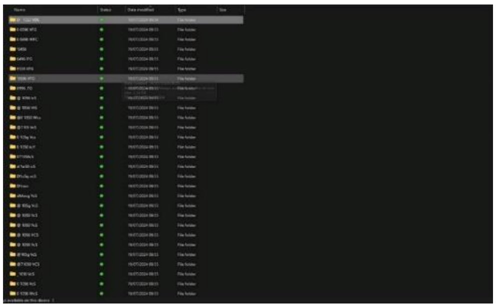

Figure 17. Test Results

Table 3
Test Results

Actual License Plate	License Plate Detected	Detection Accuracy	Detection Results

D 1867 VBI	D 1867 Vei	88%	
D 1322 VDE	D 1322 VDE	100%	
D 1898 VZB	D 1898 VZB	100%	
D 1474 IWA	D 1474 IWA	100%	
D 1650 YCS	D 1650 YCS	100%	
B 2980 KGW	B 2980 KGW	100%	

Analysis of the Test Results of the Object Detection Sub-System

The tests carried out on the Object Detection Sub System showed quite satisfactory results, where the system successfully detected the vehicle as expected. However, there are several obstacles related to noise or interference in data that cause double detection in vehicles. This is mainly due to the high speed of the vehicle. When the vehicle is traveling at high speed, the frames per second of the camera are not able to capture the image enough, resulting in a shadow or blur effect. As a result, the object detection system interprets the shadow as a separate object, thus counting the vehicle twice or more.

Factors Affecting System Performance

Some of the factors that affect the performance of this object detection system include:

1. Vehicle Speed: Vehicles traveling at high speeds tend to produce blurry images, making it difficult to distinguish between one vehicle and another.
2. Camera Quality: Camera resolution and low frame rate rates can affect the quality of the images produced.
3. Lighting: Poor lighting conditions, such as dim or too bright light, can interfere with the detection process.
4. Detection Algorithm: The performance of the object detection algorithm, in this case YOLOv8, also has a significant impact on the detection accuracy.

YOLOv8 Model Training Results

The YOLOv8 model was trained using 300 epochs. The training results showed a significant increase in the mAP (mean Average Precision) value, which indicates an improvement in the model's ability to detect objects. However, there is still room for improvement, especially in reducing the number of false positives. The discussion of the analysis results shows that the YOLOv8 model training was carried out for 300 epochs with initial results Box_loss 0.874540, Obj_Loss 0.336177, Cls_Loss 0.301361, Precision 0.529893, Recall 0.612314, mAP_0.5 0.586869, mAP_0.5:0.95 0.446080, up to mAP_0.50.746705 and mAP_0.5:0.95 0.531407.

Vehicle Detection Test Results

From the test results, 17 detections with 100% accuracy and 19 vehicle counting results with 89% accuracy were obtained. This shows that the system can detect most vehicles accurately. However, the existence of double detection causes the accuracy of vehicle counting to be slightly reduced.

Test Results of Vehicle License Plate Detection Sub-System

Tests conducted on the Vehicle License Plate Detection Sub System show that the performance of the system is greatly influenced by several main factors, namely the position of the camera, lighting, and the preprocessing method used.

Comparison of Preprocessing Method Results

1. Combinations of pre-processing methods Grayscale
   For the first test, the image will be converted to grayscale then the image will be converted to binary for Tesseract to read. For the reading of license plate characters with the grayscale-only pre-processing method, the average accuracy obtained reached **71.46%.**
2. Grayscale + Histogram Equalization
   For the second experiment, the pre-processing method applied to the image was grayscale, which was followed by Histogram Equalization, which was then converted into binary. The accuracy of reading license plates obtained by applying this pre-process method reached **64.97%**
3. Without Using Dilation
   In the last experiment, a grayscale pre-processing method will be performed, but when it is read by the program, the image will only be converted to binary, without applying dilation first. The accuracy of the license plate reading obtained reached a value **of 67.08%.**

Influence of Camera Position and Lighting

For the system to accurately detect vehicle license plates, it is necessary to strategically place cameras so that the entire entrance area can be captured. In addition, adequate lighting is also very important to ensure that the license plate can be read properly by the camera. Lack of lighting or uneven lighting conditions can cause difficulties in the process of character detection and recognition.

The Influence of Preprocessing Methods

In this study, several experiments have been carried out using various preprocessing methods to improve the quality of the image before character recognition. The methods used include:

1. Grayscale: Convert images to grayscale to simplify the processing process.
2. Binarization: Converts images into binary images (black and white) to make character segmentation easier.
3. Histogram Equalization: Distributes the image intensity histogram more evenly to improve contrast.
4. Dilation: Perform morphological operations to zoom in on objects (characters) in the image.

Test and Analysis Results

From the results of the tests carried out, it can be concluded that:

1. Effect of Lighting: Sufficient and even lighting is essential to improve detection accuracy. Photos taken during the day with good lighting produce the highest accuracy compared to photos taken at night, even using flash.
2. Effect of Preprocessing Method: The combination of grayscale and binarization methods gives quite good results. The addition of histogram equalization can improve the contrast of the image, but it does not always provide a significant increase in accuracy. The use of dilation operations can help connect the disconnected parts of the character, but it is important to be careful not to cause the characters to merge.
3. Detection Accuracy: The accuracy of license plate detection is affected by several factors, including image quality, preprocessing methods, and the character recognition algorithm used. In this test, the highest accuracy was obtained under good lighting conditions and by using a combination of grayscale and binarization methods.

Conclusion

Testing on each specification of the smart camera to detect license plates and count cars in the parking area, to ensure the functionality of the three specifications with test results that meet the target, which has been determined previously. The results of the test include:

1. Sub Sistem Object Detection

In object detection, the accuracy level has reached above 89%, but there is some noise found when collecting data in the field, namely if the vehicle passes through the gate at the same time, one of the vehicles is not detected by the camera, and if the vehicle passes through the gate at high speed, the camera detects 2 passing vehicles.

Implementation and testing of the model in dark and bright light conditions can certainly result in different detection conditions. The conclusion confirms that the trained YOLOv8 model has achieved high detection performance and the real-time implementation using CCTV cameras is going well.

2. Vehicle License Plate Detection Sub System

Based on the test results, the OCR-based vehicle license plate character detection and reading system that has been developed can be said to be successful. The system can achieve 100% accuracy in recognizing license plates at a distance of 50 cm and 88% at a distance of 80 cm. This shows the great potential of this system to be applied in various systems that require automatic vehicle identification. Vehicle License Plate Detection has reached an accuracy level of above 88% with several shortcomings where the camera must be placed in the appropriate position so that the camera can detect the vehicle and has a bright light to detect the vehicle license plate.

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