Research Article

Adaptive Algorithm to Improve the Image Quality of Vehicle License Plates based on Lighting Parameters

1st Suhartono, 2nd Iwan Suhardi, 3rd,* Indah Angraini

1,2 Department of Computer Engineering, Universitas Negeri Makassar, Makassar 90222, South of Sulawesi, Indonesia

*Corresponding Author: indahnara0712@gmail.com

Citation: Suhartono, I.Suhardi, I.Angraini"Adaptive Algorithm to Improve the Image Quality of Vehicle License Plates based on Lighting Parameters". *Iota*, **2023**, ISSN 2774-4353, Vol.03, 04. https://doi.org/10.31763/iota.v3i4.646

Academic Editor : Adi, P.D.P

Received : August, 05 2023

Accepted : September, 13 2023

Published : November, 06 2023

Publisher's Note: ASCEE stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract:
This study aims to develop an Adaptive Algorithm to Improve the Image Quality of Vehicle Number Plates Based on Lighting Parameters. The type of research used by the Author is Research and Development. This research was conducted at the Computer Engineering Laboratory for six months. This research consists of several stages, from the potential and problem stages, needs analysis, literacy studies, building prototypes, system design, and system testing. The collected datasets were taken using smartphone cameras and webcams, with 207 image datasets divided into two categories: training data and validation. The training dataset of 207 objects was 100% successful. System testing was carried out in two conditions, namely during the day and at night, for each two-wheeled and four-wheeled vehicle object. The results of adaptive algorithm testing to improve the quality of vehicle license plate images based on the light parameter experienced a change in the average MSE and PSNR values between the original image and the quality-improved image, although not too much of a difference. Based on this, it can be interpreted that the adaptive algorithm can produce better photos than before.

Keywords: Vehicle License Plates, Adaptive Algorithm, Lighting, Improved image quality, Validation

1. INTRODUCTION

Thanks to modern technological advances, computer systems now have large computational capacities to enhance data processing into information. Because a computer system processes data, one type of data can be in the form of photos or digital images that can be processed to produce better and more practical information. Information in an image often does not match the information we are looking for because it is too bright, too dark, or contains much more information than our eyes can see. One of the first steps in image preprocessing is image enhancement. The need for quality improvement is because the images [2] that are often used as research objects are of poor quality, such as noise when channeling through transmission lines, excessive brightness or darkness, lack of sharpness or blurring, and other problems. The amount of information conveyed by the image may be reduced due to the limited ability of the camera to capture objects in detail. Therefore, the information under the picture makes it difficult to interpret. Image processing is done to overcome this problem. Image processing attempts to change the original image into a better-quality photo. The first step in image processing that will be used for image analysis purposes is image improvement. Various techniques or algorithms for enhancing images have been used in applications, such as object recognition in images [1,9,17].

Many traffic applications, such as Plate Recognition (LPR), including parking lots [3], traffic monitoring, and road safety control, have used plate recognition[2]. Systems for reading license plates are used in the real world at all hours of the day and night. There are different brightness levels in each of these states. Recognizing vehicle license plates is easy when using imagery with sufficient brightness. The results of detecting vehicle license plates are not ideal due to poor image quality, such as dark, unclear, or blurry images, making it difficult to segment characters [10,11,12].

Development of smart parking using vehicle [4,5,6] license plate recognition based on light intensity using the Kohonen neural network to recognize vehicle license plates, which will later be used by light sensors that will send light intensity values to Arduino, are just a few examples from previous research. A total of 15 vehicle license plates were used for testing the Kohonen network. The Kohonen network can fully recognize the vehicle license plate characters used for the network training process with 1000 epochs and a learning rate of 0.9, and 71% of the vehicle license plate characters can be recognized accurately. [3]

Previous research on dark images includes Image Enhancement on CCTV Screen Capture Using the Histogram Equalization Method[4]. However, the Equalization Histogram method is an algorithm to improve image quality based on intensity and does not make improvements to image gradients. Because gradients are more visible to the human visual system (HVS) [5], other studies have focused on improving the quality of grayscale images using the Fuzzy Possibility Distribution Method. However, this technique can only improve the quality of grayscale images and only reduces the gray level of pixels [6]. Comparison between two or more devices or algorithms is necessary to get specific and more comprehensive analysis [13,14,16].

However, the system is dependent on the quality of the input image. In particular, the system performs well with high-quality input data but poorly with low-quality input data. Various studies have been carried out in enhancing low light images, such as restoring brightness (Image Brightness) and contrast (Contrast) and suppressing visual effects such as color distortion (Color Distortion). The existing methods are divided into two: the Histogram Equalization method, which is optimized by optimizing pixel brightness based on histogram equalization. In contrast, the Retinex Theory-based method restores the scenic illumination map and enhances different image areas. While tremendous progress has been made, much remains to be done. For example, existing approaches tend to rely on certain assumptions about pixel statistics or visual mechanisms, which may not apply under certain conditions.

In this study, researchers propose a new lowlight image enhancement method [15]. The heart of this method is the proposed convolutional neural network, namely an adaptive lowlight enhancement algorithm. In this way, the adaptive lowlight image enhancement Algortima can improve image quality from various aspects and improve low light quality to the fullest. So this research was made, Adaptive Algorithm to Improve the Image Quality of Vehicle License Plates Based on Lighting Parameters [18,19,20].

2. METHOD

The development process in this study consists of 6 stages: literature study, preparation of tools and materials, development process, validation, testing, and Revision. If the revision process runs smoothly without any problems, then the process has been completed. The development procedure can be described as follows. The development procedure can be seen in Figure 1.

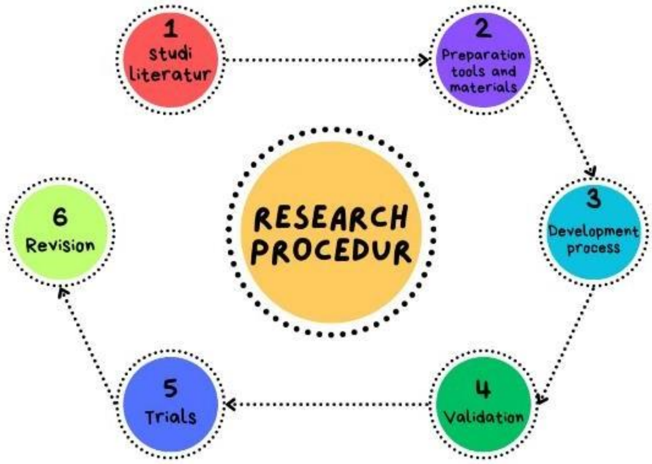


Fig.1 Research Stages Workflow

[1] Study of literature: For research, it is necessary to conduct a study study to obtain more information about the research to be carried out. In this case, the development of adaptive algorithms to improve the image quality of vehicle license plates based on lighting parameters. [2] Preparation of Tools and Materials Then, determine what tools and materials are needed in this study to develop adaptive algorithms to improve the quality of vehicle license plate images based on lighting parameters. [3] System Design and Design: In the next stage, the researcher designed a prototype with a temporary design focused on serving parking service providers [7,8]. The next step is validation [4], Trials [5], and Revision [6]. When planning and carrying out tests to develop adaptive algorithms to improve the quality of license plate images based on lighting parameters [21,22,23,24,25], this is done in stages to produce output according to plan and supporting theory. There are two phases in design and engineering, i.e., hardware and software design.

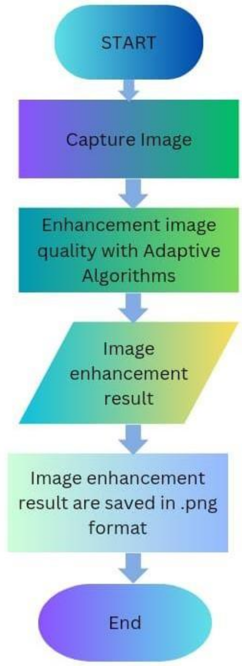


Fig.2 Flowchart System

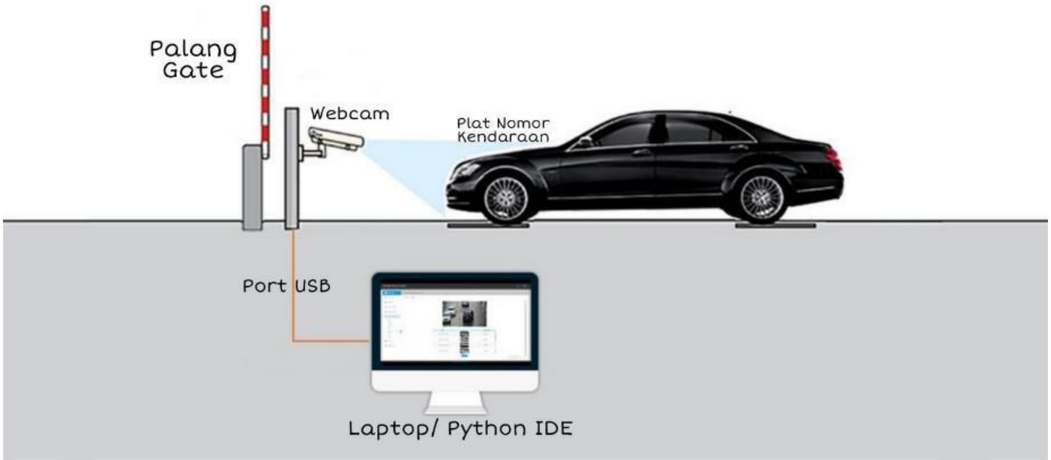


Fig.3 System Architecture

Researchers designed a prototype with a temporary design focused on serving parking service providers to develop and conduct tests on adaptive algorithms to improve the quality of vehicle license plate images based on lighting parameters; this is carried out in stages to produce outputs following the theoretical plans that support them. The process of designing an adaptive algorithm to improve the image quality of vehicle license plates based on lighting parameters is made in the flowchart in Figure 2. In Figure 2, we can see the overall system algorithm. The first process, namely the Webcam, will capture objects in real-time (directly). Therefore, the adaptive algorithm will work to improve image quality. The results of the image quality improvement are then stored in PNG format.

In Figure 3, the hardware design design has a laptop as a monitor and a portal. In this hardware design, the Webcam is positioned in front of the portal at a distance of approximately 1 meter. The vehicle license plate image will be captured via Webcam and processed in Visual Code using the Python language, namely the OpenCV library, and the CNN algorithm, e.g., lowlight image enhancement. Furthermore, the output of the output image processing results will be displayed on the laptop monitor screen. Testing: Furthermore, after the MIRNet model has been obtained, it will be tested on 30% of test data. The MIRNet that has been received is then tested for performance to improve the image quality of vehicle license plates when it is bright (during the day) and dark (at night).

Image Improvement Results: At this stage, there are results of image quality improvement. The repair results are the output of the data used as input. This research's case study is whether a vehicle license plate image increases image quality in light or dark conditions. Trials: In the trial phase, the system testing process is carried out in the form of functionality. This is done to ensure that all components used work properly. Validation: At this stage, tool validation is carried out to find out whether all the tool components can work properly. In this case, whether the Webcam can take the image properly. Revision: Based on the conclusions of the validation and the tool as a whole, this stage includes adjustments and repairs if a device doesn't function as described previously.

3. RESULT AND DISCUSSION

3.1 Datasets Collection

Data from dark images was collected from August to November, as many as 486 images, consisting of 2 folders: 70% training data and 30% testing. The higher the brightness levels of the image collected, the more accurate the data obtained during system testing. In Figure 3, a collected image dataset will be used in the training process. The dataset that has been collected is 486 dark images. Furthermore, the image quality improvement will be carried out to obtain good quality.

Fig.4 Dark image dataset

Fig.5 Dark Image Quality Improvement Results

A process is defined at this stage to perform dark image enhancement using a pre-trained MIRNet model. This process involves converting the input image to a tensor, adding padding to the tensor if needed, and passing the tensor through the model to get the enhancement results. Figure 5 shows the output results; the image quality has increased from darker to brighter. The results of improving image quality are then carried out in the training phase.

3.2 Training Datasets

The training dataset is the next step after getting the output by improving the quality of the previous image. The purpose of the training dataset is to obtain a model of an object that has been enhanced in the image quality of the dataset so that running the image quality improvement program can be appropriate. Objects that experience an increase in image quality in this training are dark images. Furthermore, the dataset training process is carried out using a Jupyter Notebook divided into 2 dataset folders: 70% train and 30% value. The dataset that has been divided is then ordered to carry out the training process so that it can obtain the model. The results of the training dataset of 207 objects were 100% successful.

3.3. Parking Lot Coordination Mapping

The code is generated to create a Graphical User Interface (GUI) using the Tkinter module. Then, a frame is created and placed in the main window. Widget frames are containers that can be used to group other widgets together. Frames can also be used to create visual separations between different parts of the GUI. In this case, two frames are made with the same size, color, and background and are placed parallel, namely, the top to capture the input image, and the bottom window is placed to output the image improvement results based on light intensity.

Fig. 6 Display Output Graphical User Interface (GUI)

3.4 Image Quality Improvement Process Coding

At this stage, a process is defined to improve image quality using a model that has been previously trained. This process involves converting the input image to a tensor, adding padding to the tensor if needed, and passing the tensor through the model to get the enhancement results. The result is then delimited between 0 and 1 and converted back to its original size before being converted back into a numpy array and stored as an 8-bit integer array.

```
import lib low light import torch
import torch.nn.functional as F import os
from runpy import run_path
from skimage import img_as_ubyte import cv2
import time
# star setup low light
task = "lowlight_enhancement" parameters = {
'inp_channels': 3,
'out_channels': 3,
'n_feat': 80,
'chan_factor': 1.5,
'n_RRG': 4,
'n_MRB': 2,
'height': 3,
```

```
'width': 2,
'bias': False,
'scale': 1,
'task': task
}
weights = os.path.join('Enhancement', 'pretrained_models',
'enhancement_lol.pth')
load_arch = run_path(os.path.join('basicsr', 'models', 'archs',
'mirnet_v2_arch.py'))
mod el = load_arch['MIRNet_v2'](**parameters)
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
model.to(device)
checkpoint = torch.load(weights) model.load_state_dict(checkpoint['params'])
model.eval()
img_multiple_of = 4
# end star setup low light
```

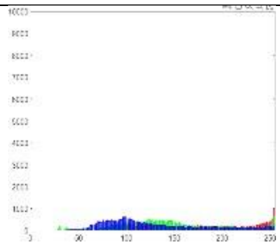
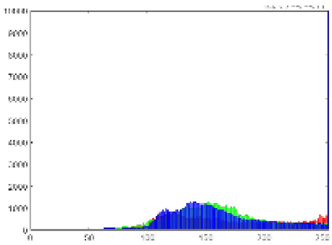
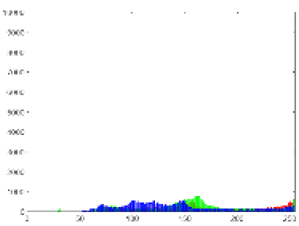
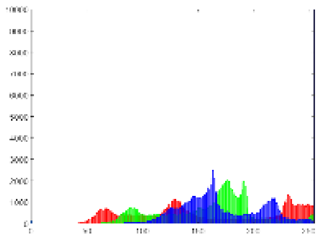
-------------------------------- **Program 1** --------------------------------

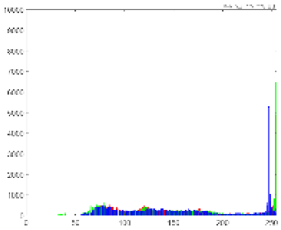
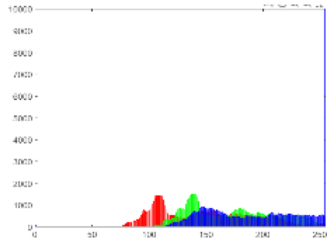
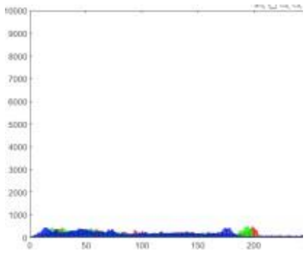
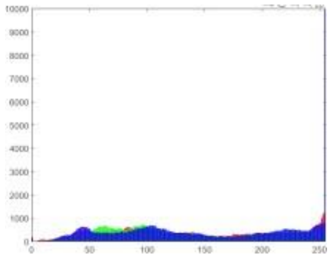
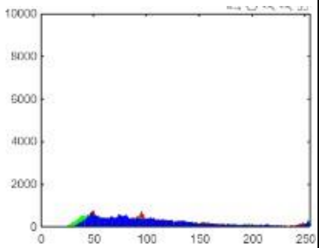
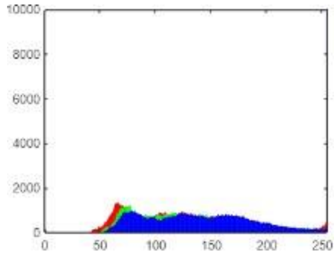
3.5 Testing for Improving the Quality of Vehicle License Plate Image Quality

At this stage, the images to be used in the test are RGB images with sample data of 20 daytime car images, 20 night car images, 20 daytime motorcycle images, and 20 night motorcycle images. Furthermore, the 20 image data will be divided into two tables: the table containing the original image and the image table resulting from the repair. This image quality test is intended to compare the intensity quality of the original image before and after processing and whether there is a change in contrast in the image. The test scenarios in this study are:

3.5.1 Testing Based on Scenario One

Table 1. Test Results for Vehicle Number Plate Images During the Day

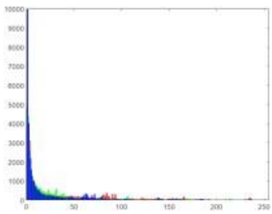
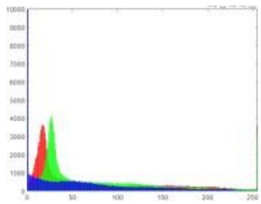
Original Citra	Histogram Original Citra	Repair image results	Histogram Repair image results
 Car 1			
 Car 2			

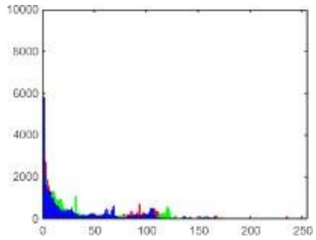
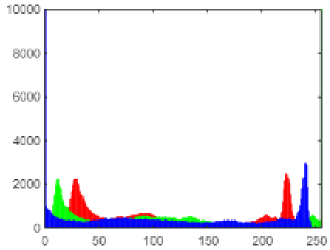
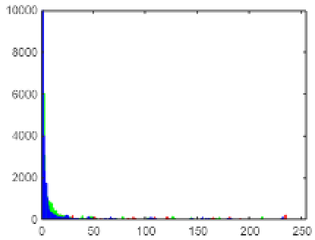
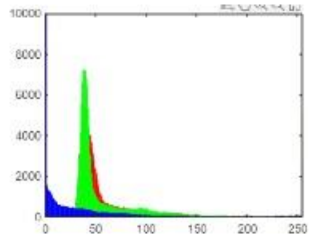
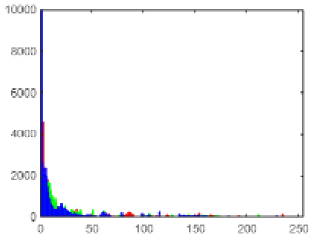
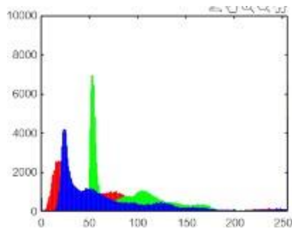
Original Citra	Histogram Original Citra	Repair image results	Histogram Repair image results
 Car 3			
 Car 4			
 Car 5			

The data in Table 1 shows that visually, the original image of the vehicle license plate obtained looks bright and clear. Then, after processing, it becomes brighter and clearer. The purpose of a clearer image is that the vehicle number plate is clearer than the unprocessed image. Meanwhile, other objects around the vehicle license plate become brighter after processing.

3.5.2 Testing Based on Scenario Two

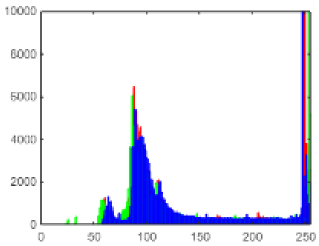
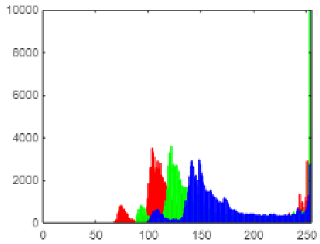
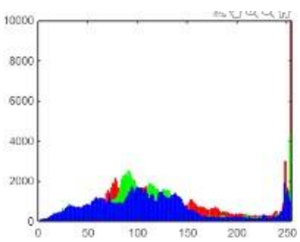
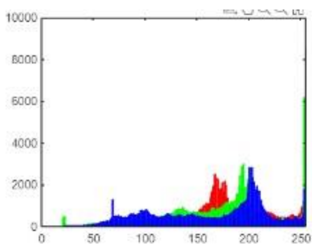
Table 2. Test Results for Vehicle Number Plate Images at Night

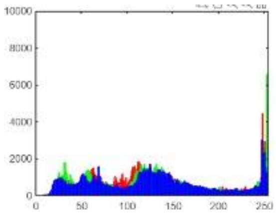
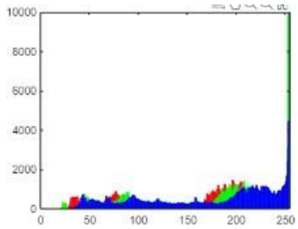
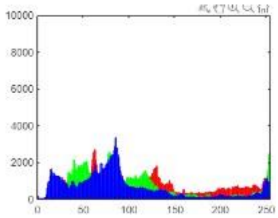
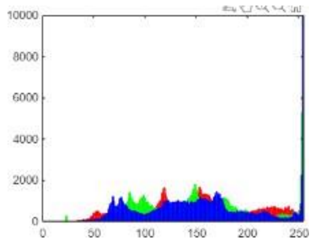
Original Citra	Histogram Original Citra	Repair image results	Histogram Repair image results
 Car 1			

Original Citra	Histogram Original Citra	Repair image results	Histogram Repair image results
 Car 2			
 Car 3			
 Car 4			

3.5.3 Testing Based on Scenario Three

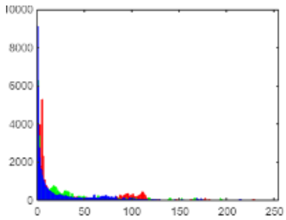
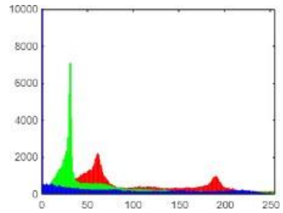
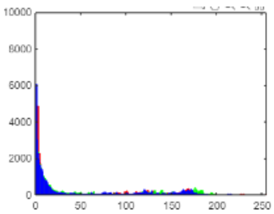
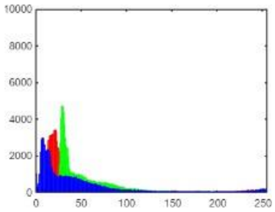
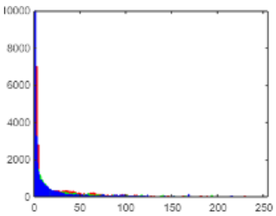
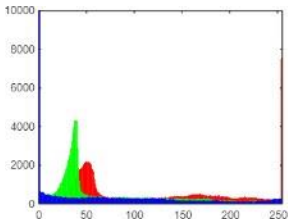
Table 3. Test Results for Vehicle Number Plate Images During the Day

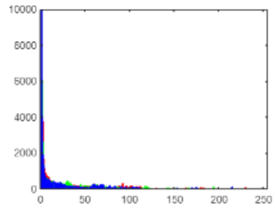
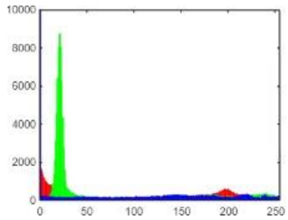
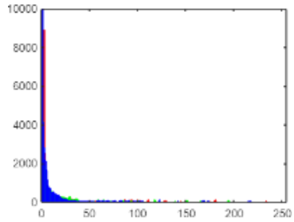
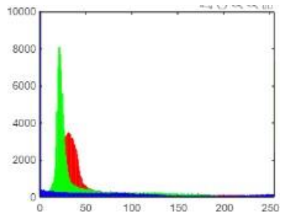
Original Citra	Histogram Original Citra	Repair image results	Histogram Repair image results
 Motorcycle 2			
 Motorcycle 3			

Original Citra	Histogram Original Citra	Repair image results	Histogram Repair image results
 Motorcycle 4			
 Motorcycle 5			

3.5.4 Testing Based on Scenario Four

Table 4. Test Results for Vehicle Number Plate Images at Night

Original Citra	Histogram Original Citra	Repair image results	Histogram Repair image results
 Motorcycle 1			
 Motorcycle 2			
 Motorcycle 3			

Original Citra	Histogram Original Citra	Repair image results	Histogram Repair image results
 Motorcycle 4			
 Motorcycle 5			

The data in Table 4 shows that visually, the results of the vehicle license plate image obtained appear dark and unclear. Then, after processing, it becomes brighter and clearer. The purpose of a clearer image is that the vehicle number plate is clearer than the unprocessed image. Meanwhile, other objects around the vehicle license plate become brighter after processing.

3.5.5 Measurement of Vehicle Number Plate Image Quality

the adaptive low light image enhancement algorithm used to find out the differences in the quality of vehicle license plate images can be based on the difference in pixel error values from the original image and the quality-enhanced image using MSE (Mean Square Error) and PSNR (Peak Signal to Noise Ratio) calculations. The MSE and PSNR values are measured based on the mean square error values obtained by comparing the difference in pixels of the original image with the quality improvement image at the exact pixel location. This is a parameter to compare the methods used. This will be the parameter for the comparison of the method used.

Table 5. MSE and PSNR Mean Values of Car License Plate Images in Bright Conditions (Day)

Citra	**The average value of the original image**		**Average repair image value**	
	MSE	**PSNR**	**MSE**	**PSNR**
Car 1	5,93	22,2	4,42	26,1
Car 2	3,65	24,3	3,45	25,5
Car 3	3,38	24,7	1,71	26,1
Car 4	5,71	22,4	4,73	26,1
Car 5	5,23	22,8	3,02	25,4

Table 6. MSE and PSNR Average Values of Car Number Plate Images in Dark Conditions (Night)

	MSE	PSNR	MSE	PSNR
Car 1	6,23	22,1	3,33	25,6
Car 2	5,81	22,3	1,89	28,8
Car 3	5,53	22,6	4,64	25,4
Car 4	7,21	21,4	3,57	25,7
Car 5	6,71	21,7	4,16	26,1

Table 7. MSE and PSNR Average Values of Motorcyclecycle Number Plate Images in Bright Conditions (Day)

Citra	The average value of the original image		Average repair image value	
	MSE	PSNR	MSE	PSNR
Motorcycle 1	2,45	26,1	1,16	29,4
Motorcycle 2	2,54	26,1	1,12	29,6
Motorcycle 3	4,34	23,7	1,51	28,2
Motorcycle 4	4,22	23,8	2,17	26,8
Motorcycle 5	3,41	24,6	1,74	27,6

Table 8. MSE and PSNR Average Values of Motorcyclecycle Number Plate Images in Dark Conditions (Night)

Citra	The average value of the original image		Average repair image value	
	MSE	PSNR	MSE	PSNR
Motorcycle 1	5,44	22,6	4,12	25,5
Motorcycle 2	5,17	22,9	4,89	26,1
Motorcycle 3	4,45	23,5	3,33	25,5
Motorcycle 4	3,91	24,1	3,11	26,1
Motorcycle 5	3,82	24,1	3,91	25,7

From Table 5, Table 6, Table 7, and Table 8, it can be seen that the average value of MSE and PSNR changes in the average value between the original image and the image resulting from the quality improvement, although not too much in value. The higher the

MSE value, the worse the display on the image will be; conversely, the smaller the MSE value, the better the display on the image will be. This is in contrast to the PSNR value; the greater the PSNR value, the better the image quality, but the higher the PSNR value, the worse the image quality.

3.6 Discussion

This research produces an output as an adaptive algorithm to improve the image quality of vehicle license plates based on the lighting parameters used to improve the quality of bright and dark images to improve the quality of light in this study; a method was used in the form of an adaptive lowlight image to increase from a low light image to a higher light image. With this adaptive lowlight algorithm, you can improve the light intensity that was previously low or dark so it can be seen more clearly. This study retrieved datasets using a webcam, and 200 datasets were collected. The tool was tested using black-box testing techniques or directly by researchers testing adaptive algorithms to improve the image quality of vehicle license plates. The dataset training process uses Jupyter Notebook software. The duration of the training process depends on the size of the data set or dataset that has been prepared. The more images prepared, the longer the training process will take, but the more accurate the results will be. The image quality improvement program is designed to test the accuracy of improving the image quality of vehicle license plates in real-time. The data will be processed using an adaptive lowlight image enhancement algorithm with the MIRNet model with lighting parameters. The output of this program is the result of improving the image quality of vehicle license plates.

As for the results of improving the image quality of car vehicle license plates obtained during the day, it can be visually analyzed that the resulting image becomes brighter and clearer after processing. In the image histogram table, the information content used to measure image quality calculation compares the pixel error values from the image enhancement results with the original image. The next step is to measure the quality of the image quality improvement results using MSE and PSNR with an average value of a low MSE and a higher PSNR value; that is, in daytime conditions, car vehicle plates have an average MSE value of 3.60 and a PSNR of 26.2 (image repair results) compared to MSE values of 4.97 and 22.8 (original image) for Table 5, in night conditions the average MSE value is 3.06 and PSNR 26.2 (improved image) compared to MSE value of 5.23 and PSNR value of 22 .4 (original image) for Table 6. In daytime conditions, the license plate of a motorcycle vehicle has an average MSE value of 1.83 and a PSNR value of 27.2 (improved image) compared to an MSE value of 3.51 and a PSNR value of 24.7 (original image) for Table 7, at night the average MSE value of 3.61 and PSNR value of 25.6 (improved image) compared to MSE value of 4.51 and PSNR value of 23.5 (original image) for Table 8. The higher the MSE value, the worse the image will appear; conversely, the lower the MSE value, the better the image display. This is the opposite of the PSNR value because the higher the PSNR value, the better the image quality, but the lower the PSNR value, the worse the image quality.

4. CONCLUSION

The conclusion that can be obtained from making adaptive algorithms to improve the quality of vehicle license plate images based on lighting parameters is that the visual results of enhancing the quality of vehicle license plate images show that the image results that previously appeared dark and less clear after processing become brighter and clearer. Likewise, ideas with sufficient lighting become brighter than images not processed before. The higher the MSE value, the worse the image will appear; conversely, the lower the MSE value, the better the image display. This is the opposite of the PSNR value because the higher the PSNR value, the better the image quality, but the lower the PSNR value, the worse the image quality. From this study, it can be concluded that using adaptive algorithms to improve the quality of vehicle license plate images based on lighting parameters displays better results than the original image. This shows that this method can improve the image quality of vehicle license plates.

5. ACKNOWLEDGMENTS

This research and publication would not have been possible without funding support from guidance from lecturers and Universitas Negeri Makassar. Special to the Department of Computer Engineering, Universitas Negeri Makassar, for the guidance of the lecturers and the cooperation of fellow students, who have supported this research so that it can be completed well. Hopefully, this paper can be developed in more detail.

AUTHOR CONTRIBUTIONS

All Author is responsible for building Conceptualization, Methodology, analysis, investigation, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision of project administration, funding acquisition, and have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Suhartono, S., Zain, S. G., & Sugiawan, S, 2022. “Sistem Object Recognition Plat Nomor Kendaraan Untuk Sistem Parkir Bandara,” Journal of embedded system security and intelligent system. DOI: 10.26858/jessi.v3i2.38458
2. Y. Wu, J. Zheng, W. Song, and F. Liu, 2019, “Low light image enhancement based on non- uniform illumination prior model,” J. Inst. Eng. Technol., vol. 13, no. `3, pp. 2448–2456. DOI: 10.1049/iet-ipr.2018.6208 , Print ISSN 1751-9659, Online ISSN 1751-9667
3. J. Šilar, J. Růžička, Z. Bělinovà, M. Langr and K. Hlubučková, "Smart parking in the smart city application," 2018 Smart City Symposium Prague (SCSP), Czech Republic, 2018, pp. 1-5, doi: 10.1109/SCSP.2018.8402667.
4. I. Aydin, M. Karakose and E. Karakose, "A navigation and reservation based smart parking platform using genetic optimization for smart cities," 2017 5th International Istanbul Smart Grid and Cities Congress and Fair (ICSG), Istanbul, Turkey, 2017, pp. 120-124, doi: 10.1109/SGCF.2017.7947615.
5. P. Melnyk, S. Djahel and F. Nait-Abdesselam, "Towards a Smart Parking Management System for Smart Cities," 2019 IEEE International Smart Cities Conference (ISC2), Casablanca, Morocco, 2019, pp. 542-546, doi: 10.1109/ISC246665.2019.9071740.
6. C. Ajchariyavanich et al., "Park King: An IoT-based Smart Parking System," 2019 IEEE International Smart Cities Conference (ISC2), Casablanca, Morocco, 2019, pp. 729-734, doi: 10.1109/ISC246665.2019.9071721.

7. A. Somani, S. Periwal, K. Patel and P. Gaikwad, "Cross Platform Smart Reservation Based Parking System," 2018 International Conference on Smart City and Emerging Technology (ICSCET), Mumbai, India, 2018, pp. 1-5, doi: 10.1109/ICSCET.2018.8537282.
8. M. Assim and A. Al-Omary, "A survey of IoT-based smart parking systems in smart cities," 3rd Smart Cities Symposium (SCS 2020), Online Conference, 2020, pp. 35-38, doi: 10.1049/icp.2021.0911.
9. Z. Zhang, W. Sun, X. Min, T. Wang, W. Lu and G. Zhai, "A Full-Reference Quality Assessment Metric for Fine-Grained Compressed Images," 2021 International Conference on Visual Communications and Image Processing (VCIP), Munich, Germany, 2021, pp. 1-4, doi: 10.1109/VCIP53242.2021.9675389.
10. G. A. G. M. Hendriks et al., "Comprehensive Comparison of Image Quality Aspects Between Conventional and Plane-Wave Imaging Methods on a Commercial Scanner," in IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 69, no. 6, pp. 2039-2049, June 2022, doi: 10.1109/TUFFC.2022.3165632.
11. Z. Zhou, Y. Wang, Y. Guo, Y. Qi and J. Yu, "Image Quality Improvement of Hand-Held Ultrasound Devices With a Two-Stage Generative Adversarial Network," in IEEE Transactions on Biomedical Engineering, vol. 67, no. 1, pp. 298-311, Jan. 2020, doi: 10.1109/TBME.2019.2912986.
12. N. Kawabata and T. Nakaguchi, "Optimal Design of Color Laparoscopic Super-Resolution Image Quality Based on Generative Adversarial Networks," 2023 International Conference on Computer Graphics and Image Processing (CGIP), Tokyo, Japan, 2023, pp. 1-7, doi: 10.1109/CGIP58526.2023.00009.
13. P. D. P. Adi et al., "ZigBee and LoRa performances on RF Propagation on the Snow Hills area," 2021 International Conference on Converging Technology in Electrical and Information Engineering (ICCTEIE), Bandar Lampung, Indonesia, 2021, pp. 36-41, doi: 10.1109/ICCTEIE54047.2021.9650623.
14. PDP.Adi et al. 2021, "Application of IoT-LoRa Technology and Design in Irrigation Canals to Improve the Quality of Agricultural Products in Batu Indonesia", 2ndInternational Conference On Smart Cities, Automation & Intelligent Computing Systems (ICON-SONICS), doi: 10.1109/ICON-SONICS53103.2021.9617175
15. Rachmat, R., & Suhartono, S., 2020. "Comparative Analysis of Single Exponential Smoothing and Holt's Method for Quality of Hospital Services Forecasting in General Hospital", Bulletin of Computer Science and Electrical Engineering, 1(2), 80-86. DOI: 10.25008/bcsee.v1i2.8
16. P.D.P.Adi, V.M. M.Siregar, 2021, "A Soil Moisture Sensor Based on Internet of Things LoRa", Internet of Things and Artificial Intelligence Journal, DOI: 10.31763/iota.v1i2.495
17. P.D.P.Adi, Y.Wahyu, "A Performance evaluation of ESP32 Camera Face Recognition for various projects", Internet of Things and Artificial Intelligence Journal (IOTA), ISSN 2774-4353, Vol.2.No.1, 2022, DOI: 10.31763/iota.v2i1.512
18. Rachmat, R., & Suhartono, S. 2020. "Comparative Analysis of Single Exponential Smoothing and Holt's Method for Quality of Hospital Services Forecasting in General Hospital", Bulletin of Computer Science and Electrical Engineering, 1(2), 80–86. DOI: 10.25008/bcsee.v1i2.8
19. K. Huang et al., "A No-Reference Image Quality Measurement Approach for Mobile Video Calling Applications in Low Light Environment," 2020 IEEE 5th International Conference on Signal and Image Processing (ICSIP), Nanjing, China, 2020, pp. 180-184, doi: 10.1109/ICSIP49896.2020.9339348.
20. Y. Zhu, C. H. Yeung and E. Y. Lam, "Digital holography with polarization multiplexing for underwater imaging and descattering," 2021 International Workshop on Metrology for the Sea; Learning to Measure Sea Health Parameters (MetroSea), Reggio Calabria, Italy, 2021, pp. 219-223, doi: 10.1109/MetroSea52177.2021.9611560.
21. J. Xiang, G. Jiang, M. Yu, Z. Jiang and Y. -S. Ho, "No-Reference Light Field Image Quality Assessment Using Four-Dimensional Sparse Transform," in IEEE Transactions on Multimedia, vol. 25, pp. 457-472, 2023, doi: 10.1109/TMM.2021.3127398.
22. L. He, Y. Yan and C. Cai, "Underwater Image Enhancement Based on Light Attenuation Prior and Dual-Image Multi-Scale Fusion," 2022 Global Conference on Robotics, Artificial Intelligence and Information Technology (GCRAIT), Chicago, IL, USA, 2022, pp. 478-482, doi: 10.1109/GCRAIT55928.2022.00105.
23. S. Jiao, M. Sun, Y. Gao, T. Lei, Z. Xie and X. Yuan, "Blur Removal and Quality Enhancement for Reconstructed Images in Dynamic Single-pixel Imaging," 2020 Conference on Lasers and Electro-Optics Pacific Rim (CLEO-PR), Sydney, NSW, Australia, 2020, pp. 1-2, doi: 10.1364/CLEOPR.2020.C1G_2.
24. S. -L. Lee and S. -H. Yang, "Efficient Low Light Video Enhancement Based on Improved Retinex Algorithms," 2023 IEEE International Conference on Multimedia and Expo Workshops (ICMEW), Brisbane, Australia, 2023, pp. 494-497, doi: 10.1109/ICMEW59549.2023.00094.
25. Z. Han, L. Li, W. Jin, X. Wang, G. Jiao and H. Wang, "Convolutional Neural Network Training for RGBN Camera Color Restoration Using Generated Image Pairs," in IEEE Photonics Journal, vol. 12, no. 5, pp. 1-15, Oct. 2020, Art no. 6802815, doi: 10.1109/JPHOT.2020.3025088.