JITE, 7 (1) July 2023 ISSN 2549-6247 (Print) ISSN 2549-6255 (Online)

JITE (Journal of Informatics and Telecommunication Engineering)

Available online http://ojs.uma.ac.id/index.php/jite **DOI : 10.31289/jite.v7i1.9851**

Received: 19 June 2023	Accepted: 20 July 2023	Published: 28 July 2023

The Effectiveness Of OpenCV Based Face Detection In Low-Light Environments

Julham1), Sandy S T Hutagalung1)*, Kevin Christian Simalango1) & Samuel Lumbantobing1)
1) Prodi Teknologi Rekayasa Perangkat Lunak, Jurusan Teknik Komputer dan Informatika, Politeknik Negeri Medan, Indonesia

*Corresponding Email: sandysamueltheophanihutagalung@students.polmed.ac.id

Abstrak

Sebuah penelitian pendeteksian wajah berdasarkan pada OpenCV adalah teknologi yang digunakan untuk mengidentifikasi dan menemukan wajah manusia dalam citra digital atau video. Teknologi ini menggunakan algoritma dan teknik pemrosesan gambar untuk menganalisis piksel dalam gambar atau video frame dan menentukan apakah mereka mengandung wajah manusia. Tujuan penelitian ini adalah untuk menentukan efektivitas pendeteksian wajah berbasis OpenCV menggunakan algoritma Viola-Jones dengan kondisi lingkungan intensitas kecerahan rendah. Penelitian ini dilakukan dengan tingkat intensitas cahaya 10 Lux, 30 Lux, dan 50 Lux dan dilakukan menggunakan kamera pada laptop ASUS TUF DASH 15 FX517ZC. Data dalam evaluasi menggunakan metrik evaluasi yang berisi rumus recall, precision, F-Score, dan accuracy. Hasil penelitian menunjukkan bahwa eksperimen dengan intensitas cahaya yang lebih tinggi pada 50 Lux menunjukkan tingkat efisiensi terbaik sesuai dengan nilai accuracy (99,2%), f-score (0,996) dan recall (0,993), sehingga sistem terbaik dilakukan dengan kecerahan 50 Lux. Pendeteksian wajah dipengaruhi oleh kamera yang digunakan, selain itu, rotasi wajah penting terhadap sistem untuk mendeteksi wajah, terlepas dari rekaman video di lingkungan intensitas cahaya tinggi.
Kata Kunci: Pendeteksian Wajah, OpenCV, Intensitas Kecerahan

Abstract

A face detection experiment based on OpenCV is a technology used to identify and find human faces in digital images or videos. This technology uses algorithms and image processing techniques to analyze the pixels in an image or video frame and determine if they contain a human face. The aim of this research is to determine the effectiveness of OpenCV-based face detection using the Viola-Jones algorithm with low-intensity brightness environmental conditions. The research was conducted with light intensity levels of 10 Lux, 30 Lux, and 50 Lux and was carried out using the camera on the ASUS TUF DASH 15 FX517ZC laptop. Data in evaluation using evaluation metrics containing the formula recall, precision, F-Score, and accuracy. The results of the study showed that experiments with higher light intensities up to 50 Lux showed the best level of efficiency according to the accuracy values (99.2%), f-score(0.996), and recall (0.993), so the system is best done with a brightness of 50 Lux. Face detection is affected by the camera that used, in addition, rotation of face is important for the system to detect faces, despite video recording in high light intensity environments
Keywords: Face detection, OpenCV, Light Intensity.

How to Cite: Julham, J., Hutagalung, S. S., Simalango, K. C., & Lumbantobing, S. (2023). The Effectiveness Of OpenCV Based Face Detection In Low-Light Environments. JITE *(Journal of Informatics and Telecommunication Engineering*), 7(1), 209-220.

I. INTRODUCTION

Face detection is a technology used to identify and locate faces in digital images or videos. This technology uses algorithms and techniques for processing images to analyze pixels in an image or video frame and specify if there is a human face in it (Sinurat, 2022;Tasfia & Reno, 2022) . This analysis includes checking color, texture, and shape pixels to recognize patterns typical of humans' faces (Forsyth & Ponce, 2011)(Setia, 2021)(Mohibullah et al., 2022). *Face detection* has applications in various fields like system security and surveillance, devices for soft editing photos and videos, and social media platforms.

The face detection process usually involves a number of stages, such as preprocessing, extraction of features, and classification. At this stage of *preprocessing*, images or video frames are cleaned and prepared for analysis. At the stage of feature extraction, algorithms analyze pictures or video frames to identify feature keys associated with human faces, like location of eyes, nose, and mouth. In stage classification, algorithms use these features to define There is a face present in images or video frames (Hirzi et al., 2021;Suprianto et al., 2013;Naveenkumar & Vadivel, 2018).

OpenCV is an *open-source library* for extensive *computer vision* and *machine* learning used in various industries, like robotics, automotive, and medical. This *library* has rich functions and algorithms that can be used to process and analyze pictures and videos. One main feature of openCV is *face detection* (Khan et al., 2019;Kasanah et al., 2019;Suresh & Niranjanamurthy, 2021). This library provides various algorithms, including the Viola-Jones algorithm and the Local Binary Patterns (LBP) algorithm, that make use of *machine learning* techniques to identify distinctive features of the human face, like the position of the eyes, nose, and mouth (Susim & Darujati, 2021;Nagpal et al., 2018;Đorić et al., 2018).

OpenCV has its own *pre-trained model* for the system's *face detection*, which has been trained on various datasets of picture faces. This model can be loaded and used directly in applications that are OpenCV-based. *Face detection* models in openCV are based on the Viola-Jones algorithm and use Haar features to detect faces in digital images.

Light intensity is the amount of light energy that is transmitted through a given area per unit time. It is often measured in units of watts per square meter (W/m2) or lux (lx), which is a unit of illuminance that takes into account the sensitivity of the human eye to different wavelengths of light (Sukma et al., 2021;Tähkämö et al., 2019).

Previous research has shown that the system can detect faces but has never been done at low light intensity so research is needed to know the effectiveness of OpenCV in performing face detection in low light environments.

II. RESEARCH METHOD

Study will done use the camera on the ASUS TUF DASH 15 FX517ZC Laptop. Camera the will record video online realtime with the process of taking frames per second on the video . Study was carried out by taking videos for 120 seconds each , 30 times with 3 s meaning that each trial takes 10 videos as sample experiment . The experiment was used with lighting 50 Lux (experiment I), 30 Lux lighting (experiment II), and lighting 10 Lux (experiment III). Video capture on each Light treatment took as many as 10 videos with a different number of people and two different positions. Each light treatment is taken from as many as 10 videos with the following criteria among others: 1) Video 1: 1 person; 2) Video2 : 2 person; 3) Video 3: 1 person face turn his head; 4) Video 4: 3 person,5) Video 5: 1 person peek_position 1, 6) Video 6: person position 2, 7) Video 7: 2 person position 2, 8) Video 8 :1 person face Turn his head, position 2, 9) Video 9:3 person position 2; 10) Video 10: person peak-position 2. After that the frame will changed become processed grayscale image use the Viola-Jones algorithm .

Viola-Jones algorithm is The algorithm used to detect various type object , but the most frequent used is for detection face . The Viola-Jones algorithm makes use of technique *Haar -like feature*, *integral image* and *Adaboost* to speed up the detection process (Chhoriya, 2019).

A. Haar-Like Feature

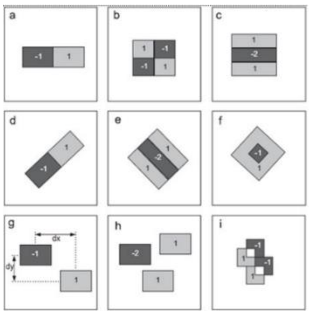

Figure 1. Box Variation of Black-White Haar Feature in Face Detection (Pavani et al., 2010).

Information picture :
a,b : Haar Features by Papageorgiou (Papageorgiou & Poggio., 2000)
c,i : Haar Feature by Viola & Jones (Viola & Jones, 2001)
d,e,f : Variation feature Haar by Lienhart (Lienhart & Maydt, 2002)

Figure 1 shows box variations in the *Haar-like feature. Haar-like feature extraction* is a feature extraction method that is often used in object recognition or face detection in the fields of image processing and computer vision. This method is based on measuring the difference in intensity between pixels in an image by extracting features using a black and white box, as shown in Figure 1. The black and white box will extract features from the face by taking the differences in pixels from the face part. (Bibave & Patil, 2022)

B. Integral Image

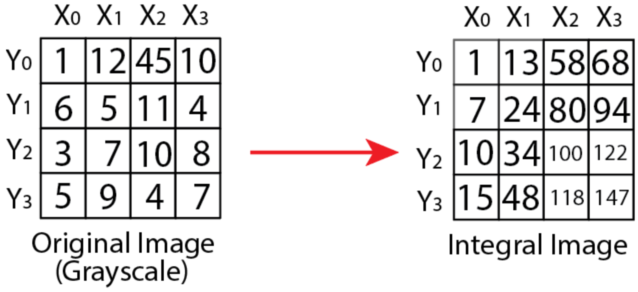

Figure 2 Changes from Original Image Pixels to Integral Image.

Figure 2 shows how to change the original image pixels to the integral image. An integral image is a technique in computer vision that involves summarizing pixels in a picture along the rows and columns to create a new picture. This new image can be used to quickly calculate the amount of mark pixels in each shape region, rectangle in the original picture. Integral image is in general used in algorithmic *face detection*, where this technique allows calculation of features similar to Haar and is quickly used to classify image regions as containing faces or not. The use of integral images accelerates the calculation of these features, making face *detection* more efficient. The integral image is obtained by adding up pixels on the part left and up pixels that are in the original image (Ismael & Irina, 2020;Dhabre & Pol, 2020).

$$ii(x,y) = \sum_{x' \leq x, y' \leq y} i(x', y')$$

(Suprianto et al., 2013)

C. AdaBoost

AdaBoost (Adaptive Boosting) is a machine learning algorithm used to build powerful predictive models of some simpler or weaker models. AdaBoost works using a weak learner or learning model that has a relatively poor performance*. The weak* learner will then add a greater weight to each repetition when the data has errors in classification and decrease the weight if the data is classified correctly to become a *strong learner* with better performance*.*

After the Viola-Jones algorithm's Integral Image creation procedure is finished, Adaboost begins to function. Following the creation of an Integral Image, the most informative Haar-like feature subset for face detection is chosen using Adaboost.

D. Cascade Classifier

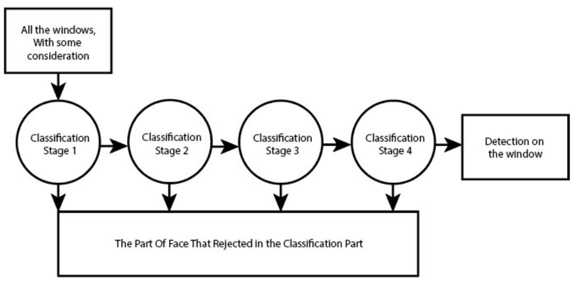

Figure 3 Cascade Classifier System

Figure 3 shows how the cascade classifier works. Cascade Classifier is a speeding algorithm classifier method that is real-time. The first thing to do is to extract the features in such a way that the original image becomes an integral image on the part window. After that, extract it using *Haar-like features.* Then, on stage, classification is carried out using *adaptive boost.* By doing classification can be concluded identified as part face or not, in order carry out the classification process more efficient so done system *cascade* (Mridha & Yousef, 2021;Yamini et al., 2019;Sinha & Barde, 2023).

E. Face Detection

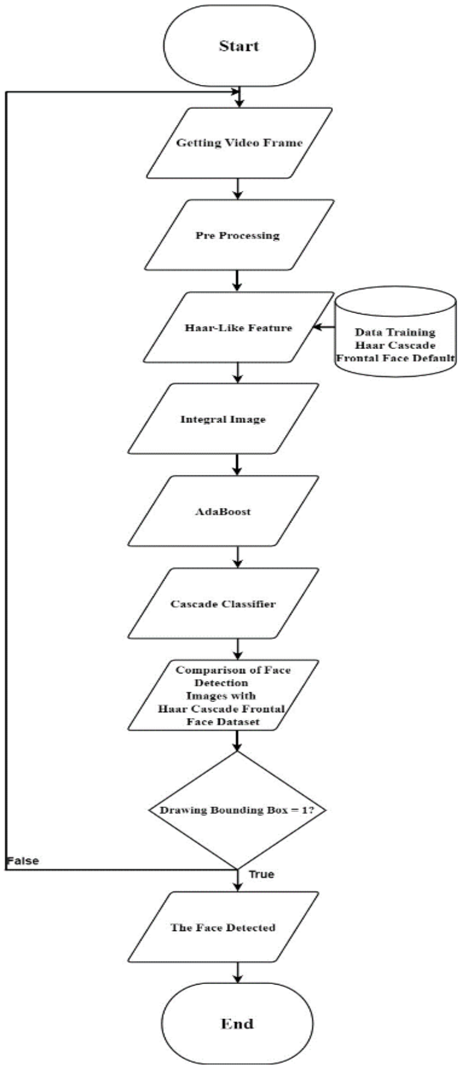

Figure 4 How it Works Face Detection.

In Figure 4,the frame from the video that is taken is the testing data. Video is running then make it to the frame, then do Pre-processing activities. In Pre-processing activities the Activity that will be do is the frame will be converted into Grayscale, Histogram Equalization, Scale reduction and noise removal.After that, it will do the Viola-Jones algorithms. On each image, the Haar-like feature is extracted. Haar-like features include variations of intensity patterns such as edges, horizontal, vertical lines, and boxes. To speed up the calculation, an Integral Image is used. At the Integral Image stage, each image in grayscale format is converted to an integral image. Integral Image is used to speed up the calculation of Haar-like features. Integral Image calculates the number of pixels in a square area from the left top point of the image. Once the integral image is generated, the next step is to use Adaboost to select the most informative Haar-like feature subset for face detection. Further in the Cascade classifier phase, the Cascade classifier allows to quickly reject sub-windows that are most likely not the object sought, thus accelerating the process of identifying objects, such as faces. Then the system will compare the frame(testing data) with the *Haar Cascade Frontal Face Default* dataset(training data) that have prepared with openCV. The training data have the file extension (.xml). After that if the face is found then it is finished, or otherwise it will return to the starting stage (Setia, 2021).

F. Confusion Matrix

The *confusion matrix* is A table used to evaluate performance from a prediction or classification model The confusion matrix consists of four values, namely true positive (TP), false positive (FP), true negative (TN), and false negative (FN). TP value shows amount prediction true that an object or incoming data in certain category . FP value shows the amount of wrong prediction that an object or incoming data in category certain is in fact no. TN values indicate amount prediction true that an object or data is not including in category certain. The FN value shows an amount of wrong prediction that an object or data is not included in a certain category but should be included.

Based on the confusion matrix, it can be determined the value of accuracy, precision, recall, and F-Score (Anand et al., 2022;Rahmadi et al., 2020).

G. Face Detection System

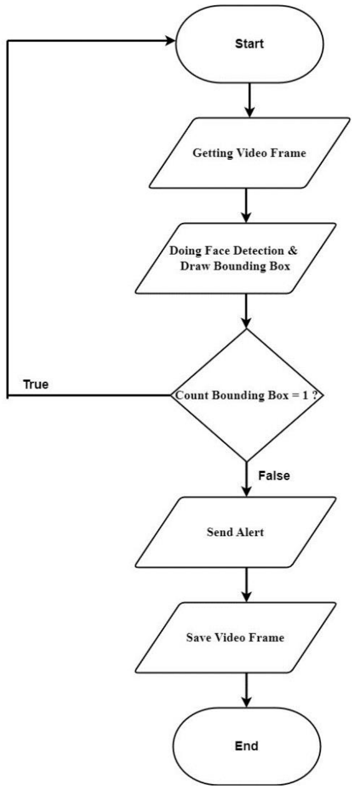

Figure 5 System Flow in *Face Detection.*

In Figure 5, the activities carried out first by the system are taking video frames from the camera, then doing face detection *and drawing* a bounding box on the detected face. If there is a bounding box totaling 1, then the system will proceed to take the video frame back. Then, if there is a smaller bounding box of 1 or more from 1, the system will continue delivery alerts and save video frames that have more people of 1 or less from 1 (Suprianto et al., 2013).

Table 1. Design Test

	Intensity Light (Lux)	Length (s)
Experiment - 1	50	120
Experiment - 2	30	120
Experiment - 3	20	120

After system has built , then will done Experiment with Intensity Different lights with nominal lux of 50 lux, 30 lux, and 20 lux are used with each video duration of 120 seconds. Then, results from experiments that have been tested will be analyzed using the method of evaluation.

H. Evaluation Method

After test has done, then furthermore is do evaluation from a number of aspects of the design this system . Evaluation uses results from the confusion matrix that has been tested to determine *recall, precision, F-Score,* and *accuracy*.

Recall is the ratio between the amount of correct prediction to the class positive (true positive) and the whole amount of data in the class positive (including true positive and false negative).

$$\text{Recall} = \frac{TP}{TP+FN}$$

Precision is the ratio between the amount of correct prediction to class positive (true positive) and the amount of whole prediction positive (true positive and false positive).

$$\text{Precision} = \frac{TP}{TP+FP}$$

The *F-score* is A, and the metric that combines precision and recall becomes the One score. The F-score yields a harmonic average score between precision and recall.

$$\text{F-Score} = \frac{2.(Precision.Recall)}{Precision+Recall}$$

Accuracy is the ratio between the correct predictions (true positive and true negative) and the overall amount of data.

$$\text{Accuracy} = \frac{TP}{TP+FN+FP} \times 100\%$$

(Kalmegh & Padar, 2023; Arias-Duart et al., 2023)

I. Display Design

Following is design view to be built

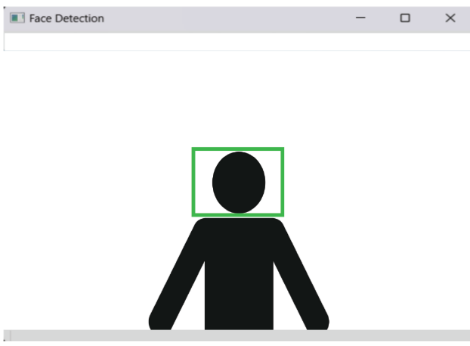

Figure 6 Design normal view.

In Figure 6, the face detected by the system is 1. Then system not doing any activity because there are only 1 person detected.

Figure 7 Design of the display if more than one face is identified.

In Figure 7, the faces detected by the system are 2. The system then takes a picture when two faces are detected, and displays an alert on the screen.

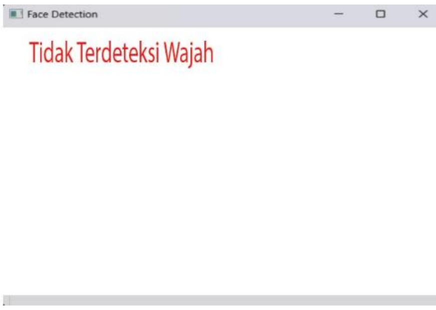

Figure 8 Design appearance if the face identified is not enough from 1.

In Figure 8, there is no face detected by the system. So the system takes pictures when two faces are detected, as well as display alerts on the screen.

J. System Implementation

Trial system carried out on the ASUS TUF DASH 15 FX517ZC laptop. With specifications:

- *Processor* : 12th Gen Intel(R) Core(TM) i5-12450H, 2000 Mhz, 8 Core(s), 12 Logical Processor(s)
- *Operation System* : Microsoft Windows 11 Home Single Language
- RAM type and nominal : 8GB DDR SO-DIMM

With specifications, the camera used in the test is 40 MP .

III. RESULT AND DISCUSSION

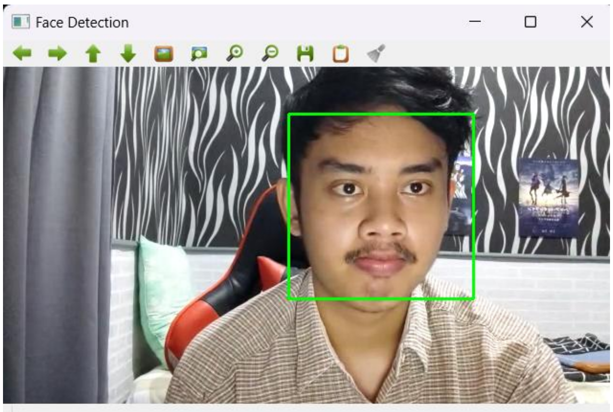

Figure 9. Example Appearance Normal conditions with an intensity of 50 lux

After my system does *face detection,* it can conclude that part of the filling pixels criteria is human. To test *face detection* on the system (Figure 9), the intensity of light used in data collection is 50 Lux.

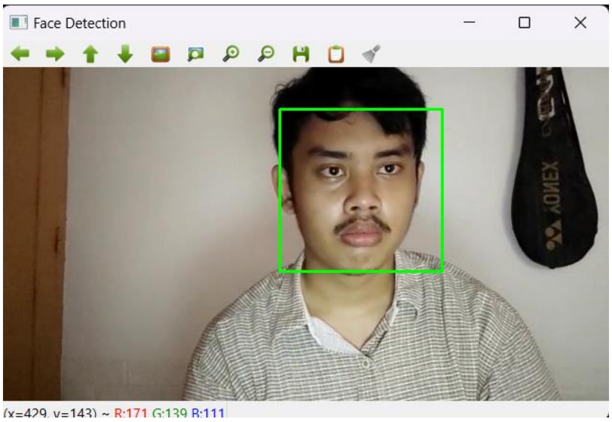

Figure 10 Example Appearance Normal conditions with an intensity of 30 lux.

In this test (Figure 10), the intensity of light used in data collection is 30 lux.

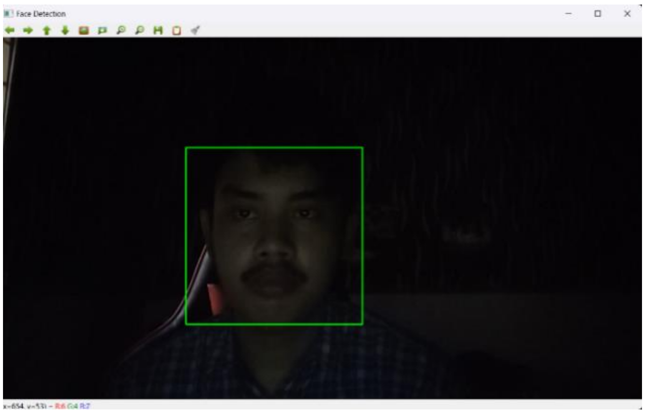

Figure 11 Example Appearance Normal conditions with intensity 10 Lux.

In this test (Figure 11), the intensity of light used in data collection is 10 lux.

Figure 12 Example Appearance If Face is detected more than 1

In Figure 12, video data retrieval is carried out at a level of brightness of 50 Lux, then the system concludes that 2 faces were identified as human, then the system will display the alert "Wajah Terdeteksi Lebih dari 1" and save the frame at the moment there are 3 *bounding boxes* (3 faces).

Figure 13 Example Appearance if Face Less than 1 is detected

In Figure 13, video data capture was performed at a brightness level of 50 Lux, then the system did not identify any of the faces. The system will then display the "Tidak Terdeteksi Wajah" alert and will save the frame when there is no Bounding Box.

With the camera, it has taken 30 sample videos at different brightness levels; each of these videos has an average duration of 120 seconds. Take the video aim to find out if the system is effective to level different brightness. Data obtained from video capture as in Table 2.

Table 2. Observation results of each variable TP,FP,FN,TN on each video with light intensity treatment 50 Lux ,30 Lux and 10 Lux.

	count	TP	FP	FN	TN	Saved Frame	Unsaved Frame	TP ‘
Lux 50								
Video 1	3.900	0	1	0	0	1	3.899	3.900
Video 2	2.814	198	0	0	0	198	2.616	2.814
Video 3	3.860	8	8	16	281	308	3.552	3.560
Video 4	3.800	2.076	4	40	0	572	3.228	5.304
Video 5	3.763	196	0	0	0	98	3.665	3.861
Video 6	3.900	0	0	0	0	0	3.900	3.900
Video 7	3.694	0	0	0	0	256	3.438	3.438
Video 8	3.686	0	0	177	293	308	3.378	3.378
Video 9	3.718	800	0	42	0	572	3.146	3.946
Video 10	3.763	85	1	0	0	43	3.720	3.805
Total	36.898	3.364	14	275	574			37.906
Lux 30								
Video 1	3.750	0	0	0	0	0	3.750	3.750
Video 2	3.795	284	0	0	0	142	3.653	3.937
Video 3	3.796	0	0	30	285	315	3.481	3.481
Video 4	3.720	131	3	0	0	68	3.652	3.783
Video 5	3.798	325	2	146	25	201	3.591	3.916
Video 6	3.731	0	0	0	0	0	3.731	3.731
Video 7	3.795	426	0	0	0	213	3.582	4.008
Video 8	3.704	5	5	31	286	142	3.562	3.567
Video 9	3.673	172	0	0	0	86	3.587	3.759
Video 10	3.709	492	0	246	0	86	3.623	4.115
Total	37.471	1.835	10	453	596			38.047
Lux 10								
Video 1	3.812	0	0	139	14	152	3.660	3.660
Video 2	3.663	122	9	153	0	305	3.358	3.480
Video 3	3.661	52	0	16	0	42	3.619	3.671

	count	TP	FP	FN	TN	Saved Frame	Unsaved Frame	TP ‘
Video 4	3.699	0	0	1.250	256	1.506	2.193	2.193
Video 5	3.710	0	0	88	305	430	3.280	3.280
Video 6	3.759	0	0	58	0	58	3.701	3.701
Video 7	3.706	0	0	18	0	18	3.688	3.688
Video 8	3..697	86	2	26	0	70	3.627	3.713
Video 9	3.705	0	0	57	244	301	3.404	3.404
Video 10	3.695	0	0	2175	259	2.434	1.261	1.261
Total	37.107	260	11	3980	1078			32.051

Based on Table 2, the data is the test data taken from the recorded video. The variable count on the table refers to the number of frames generated when a video is played to detect faces. TP is obtained if the face detected corresponds to the face that is in the frame. Saved Frame is obtained through a frame that is saved if more than one face has been detected or no face is detected. Saved frame will be saved into .jpg file. Then on Unsaved Frame, the Variable is obtained through Variable count which is reduced by the variable Save Frame.The unsaved frame is a TP variable because the frame is not saved because the number of faces detected is only 1 face. Then on the variable TP' is obtained through, Variable TP added with Unsaved Frame. The TP is the true TP. Table 3 represents the Total of TP,FP,FN, and TN of each Treatment with different light intensities.

Table 3. Calculation of True Positive (TP), False Positive (FP), False Negative (FN), True Negative (TN) at the different brightness

	TP	FP	FN	TN
Trial-1 (50 Lux)	37.906	14	275	574
Trial-2 (30 Lux)	38.500	10	453	596
Trial-3 (10 Lux)	32.051	11	3980	1.078

Note: TP=True Positive; FP= False Positive; FN=False Negative: TN= True negative

Based on Table 3, it shows that the true positive value at 30 Lux brightness gives the highest mark, followed by brightness 50 Lux and experiment 10 Lux, which are 37,906, 38,500, and 32,051. False positive, false negative, and true negative values indicate a 50-lux brightness gives the highest yield, followed by a brightness of 30 lux and a brightness of 10 lux (Table 1). The more tall brightness light the more effective camera takes video exactly. Even at True Positive, the brightness is 50 lux lower compared to 30 lux. This is a possibility caused by lighting on the object image face under normal conditions of recognition. face from position Rotation matters a lot to accuracy in introduction. For example, in rotation position, face turned to the left or right, shaken your head to the left or right, and looked up to the sky or down to the ground. Ideally, a face that can be identified properly is facing the camera sensor in an upright, straight manner. Tolerable slope around 10 degrees from the normal position. However, normally (no disabled physical), most faces are in an upright, straight position with the camera sensor, so that application still detects faces well. Introduction Facial expressions are also affected by facial expressions. The expression that was tried was smile (corner lips kind of up to the top), laugh (looks). In addition to attribute faces, including headscarves, sideburns, and hair and beard styles, object image faces are still well recognized. As for additions, glasses and mustaches can go a long way to degrade quality. teeth), and sad (frown and angular lips flat or down to the bottom). From the mimic test, it turns out that there is enough significant influence application to recognize faces (Suprianto et al., 2013).

Table 3. Calculations Recall,Precision ,F-Score,Accuracy on level different brightness

	Recall	Precision	F-Scores	Accuracy
Trial-1 (50 Lux)	0,993	0,9996	0,996	99,2%
Trial-2 (30 Lux)	0,988	0,9997	0,994	98,8%
Trial-3 (10 Lux)	0,889	0,9997	0,993	88,9%

From the results of data analysis, it shows that: on the rate of brightness 50 Lux, the level shows the highest accuracy of 99.2%, followed by the level of brightness 30 Lux, which is 98.8%, and the lowest is 88.9% with the level of brightness 10 Lux because face difficulty is recognized by being lit little. Likewise, based on the F-Score data, the level of brightness 50 Lux shows the highest value of 0.996, followed by the level of brightness 30 Lux of 0.994, and the lowest level of brightness 10 Lux of 0.993. Likewise, more high-level brightness indicates that the recall rate is also increasing. The recall rate at 50 lux brightness was 0.993, followed by 30 lux brightness at 0.988, and the lowest at 10 lux brightness was 0.889. It shows the more tall level brightness so ability system or model to correctly detect and identify all relevant or positive data instances the more effective . For precision on all three levels of brightness tests, show the same number. (Table 2)

From all over experiments carried out if *Face detection* based on OpenCV implemented to run in a manner effective so should done under conditions brightness 50 Lux.

A previous *face detection* study by [7] found that when intensities fluctuated between 0 and 1700 lux, face images were not recognized at all, or faces were misrecognized due to lack of light. However, in this study, *face detection* can still be done with a light intensity of 10-50 lux. This is because another factor is the camera used to record videos. Cameras with high resolution, a wide dynamic range, good light sensitivity, and good noise processing capabilities tend to produce clearer and better quality images. This can help OpenCV more accurately recognize faces regardless of the intensity of light.

IV. CONCLUSION

A system that has been developed can do face detection. However , there is difference results evaluation from third level different brightness . After that the Experiments with higher brightness up to 50Lux showed the best level of effectiveness corresponding to the highest level of accuracy, precision, and recall. Face detection is affected by the camera that used, in addition, rotation of face is important for the system to detect faces, despite video recording in high light intensity environments.

DAFTAR PUSTAKA

Anand, M., Velu, A., & Whig, P. (2022). Prediction of Loan Behaviour with Machine Learning Models for Secure Banking. *Journal of Computer Science an Engineering (JCSE)*, *3*(1), 1-13.

Arias-Duart, A., Mariotti, E., Garcia-Gasulla, D., & Alonso-Moral, J. M. (2023). A Confusion Matrix for Evaluating Feature Attribution Methods. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops* (pp. 3708-3713).

Bibave, A. S., & Patil, R. (2022). Smart Attendance using Face Recognition. *Compliance Engineering Journal*, 336-344.

Chhoriya, P. (2019). Automated Criminal Identification System using Face Detection and Recognition. *International Research Journal of Engineering and Technology (IRJET)*, *6*(10), 910-914.

Dhabre, S., & Pol, R. (2020). Automated Face Recognition Based Attendance System Using LBP Face Recognizer. *International Journal Of Advance Scientific Research And Engineering Trends*, *5*(4), 35-40.

Đorić, D., Crnobrnja, S., & Punt, M. (2018). Implementation of an Application for Real-Time Video Face Tracking. *Paper presented at the 2018 26th Telecommunications Forum (TELFOR)*, Belgrade, Serbia (pp. 1-4).

Forsyth, D. A., & Ponce, J. (2011*). Computer Vision: A Modern Approach (2nd ed.)*. Pearson.

Hirzi, M. F., Efendi, S., & Sembiring, R. W. (2021). Literature Study of Face Recognition using The Viola-Jones Algorithm. *Paper presented at the 2021 International Conference on Artificial Intelligence and Mechatronics Systems (AIMS)*, Bandung, Indonesia (pp 1-6).

Ismael, K. D., & Irina, S. (2020). Face recognition using Viola-Jones depending on Python. *Indonesian Journal of Electrical Engineering and Computer Science*, *20*(3), 1513–1521.

Kalmegh, S. R., & Padar, B. R. (2023). Empirical Study on Evaluation Metrics for Classification Algorithms. *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)*, 3(2), 656-660.

Kasanah, A. N., Muladi, & Pujianto, U. (2019). Penerapan Teknik SMOTE untuk Mengatasi Imbalance Class dalam Klasifikasi Objektivitas Berita Online Menggunakan Algoritma KNN. *JURNAL RESTI (Rekayasa Sistem dan Teknologi Informasi)*, *3(2)*, 196-201.

Khan, M., Chakraborty, S., Astya, R., & Khepra, S. (2019). Face Detection and Recognition Using OpenCV. *Paper presented at the 2019 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS)*, Greater Noida, India (pp. 116-119).

Lienhart, R., & Maydt, J. (2002). *An extended set of Haar-like features for rapid object detection. Paper presented at the Proceedings. International Conference on Image Processing, Rochester*, NY, USA (pp. I-I).

Mohibullah, M., Ahammad, M. K., Muzammel, C. S., Hosen, M. S., & Islam, M. R. (2022). Face Detection and Recognition from Real Time Video or Recoded Video using Haar Features with Viola Jones Algorithm and Eigenface Approach with PCA. *International Journal of Research Publications*, 93(*1*), 122-133.

Mridha, K., & Yousef, N. T. (2021). Study and Analysis of Implementing a Smart Attendance Management System Based on Face Recognition Technique using OpenCV and Machine Learning. *2021 10th IEEE International Conference on Communication Systems and Network Technologies (CSNT)* (pp. 654-659).

Nagpal, G. S., Singh, G., Singh, J., & Yadav, N. (2018). Facial Detection and Recognition using OpenCV on Raspberry Pi Zero. *Paper presented at the 2018 International Conference on Advances in Computing, Communication Control and Networking (ICACCCN)*, Greater Noida, India, (pp. 945-950).

Naveenkumar, M., & Vadivel, A. (2018). OpenCV for Computer Vision Applications. *Proceedings of National Conference on Big Data and Cloud Computing (NCBDC'15)*, Trichy,India, (pp. 52-56).

Papageorgiou, C., & Poggio, T. (2000). A Trainable System for Object Detection. *International Journal of Computer Vision*, 38(1), 160-172.

Pavani, S. K., Delgadoa, D., & Frangi, A. F. (2010). Haar-like features with optimally weighted rectangles for rapid object detection. *The Journal of the Pattern Recognition Society*, *43*(1), 160-172.

Rahmadi, L. B., Laksmana, K. M., & Rhomanzah, D. (2020). LBP Advantages over CNN Face Detection Method on Facial Recognition System in NOVA Robot. *Indonesia Journal of Computing*, 5(2), 1-13.

Setia B. I. K. (2021). Penerapan Pengenalan Wajah Untuk Aplikasi Absensi dengan Metode Viola Jones dan Algoritma LBPH. *Jurnal Media Informatika Budidarma*, *5(3)*, 1008-1017.

Sinurat, J. H. (2022). Application Of The Viola Jones Algorithm On Face Detection. *International Journal Of Health, Engineering And Technology (IJHET)*, *1(2)*, 166-179.

Sinha, A., & Barde, S. (2023). Multi Invariant Face Detection Via Viola Jones Algorithm. *European Chemical Bulletin*, 12(1), 24-32.

Sukma, I. B., Azis, A., & Pebrianti, I. K. (2021). Perencanaan Lampu Penerangan Jalan Umum Menggunakan Tenaga Surya (Solar Cell) Untuk Alternatif Penerangan Jalan Talang Pete Plaju Darat. *TEKNIKA: Jurnal Teknik*, 8(2), 140-146.

Suprianto, D., Hasanah, R. N., & Santoso, P. B. (2014). Sistem Pengenalan Wajah Secara Real-Time dengan Adaboost, Eigenface PCA & MySQL. *Jurnal EECCIS (Electrics, Electronics, Communications, Controls, Informatics, Systems)*, *7*(2), 179–184.

Suresh, H. S., & Niranjanamurthy, M. (2021). Image Processing Using OpenCV Technique for Real World Data. In M. N. Favorskaya, S. L. Peng, M. Simic, B. Alhadidi, & S. Pal (Eds.), *Intelligent Computing Paradigm and Cutting-edge Technologies. ICICCT 2020. Learning and Analytics in Intelligent Systems*, Volume 21 (pp. 285-296).

Susim, T., & Darujati, C. (2021). Pengolahan Citra Untuk Pengenalan Wajah (Face Recognition) Menggunakan OpenCV. *Jurnal Syntax Admiration*, *2(3)*, 534-545.

Tähkämö, L., Partonen, T., & Pesonen, A. K. (2019). Systematic review of light exposure impact on human circadian rhythm. *The Journal of Biological and Medical Rhythm Research*, 36(2), 151-170.

Tasfia, S., & Reno, S. (2022). Face Mask Detection Using Viola-Jones and Cascade Classifier. *Proceedings of the 2022 International Conference on Augmented Intelligence and Sustainable Systems (ICAISS*), Trichy, India (pp. 563-569).

Viola, P., & Jones, M. (2001). Rapid object detection using a boosted cascade of simple features. *Paper presented at the Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*. CVPR 2001, Kauai, HI, USA (pp. I-I).

Yamini, K., Kumar, S. M., Sonia, S., Yugandhar, P. V., & Kumar, T. B. (2019). Class Attendance Using Face Detection and Recognition with OPENCV. *International Research Journal of Engineering and Technology (IRJET)*, *6*(4), 3822-3826.