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Lightweight Deep Learning for Object Detection on Mobile Device

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Abstract

Computer vision is a research in the development of technology to obtain information from images and replicate or imitate human visual processes, so that computers can know the objects around them. Deep learning is now the key word as a new era in machine learning that trains computers in finding patterns from large amounts of data. The Convolution Neural Networks (CNN) algorithm has proven impressive in terms of performance for detecting objects, image classification and semantic segmentation. Object detection is a technique used to identify the type of object in an image and also the exact location of the object in the image. Face detection is one of the most challenging problems of pattern recognition. Effective training needs to be done to be able to detect faces effectively. The accuracy in face detection using machine learning does not give good results. This research focuses on the level of accuracy of detecting faces using deep learning methods. This study uses the Convolution Neural Networks (CNN) model in the deep learning method to detect faces in real time on Android. According to the test results, the accuracy obtained in this study reached 97.97% in several normal facial conditions and face masks.

Keywords: CNN; Computer Vision; Deep Learning; Face Detection

1. INTRODUCTION

In today's digital age, computer technology has undergone rapid development and driven profound change in various areas of life[1]. One of the impressive technological advances is computer vision, which allows computers to more accurately analyze and interpret visual data, such as images and videos. It has had a huge impact on various aspects of human life[2]. Computer vision has changed the way we interact with the world around us. It has created new opportunities and delivered innovative solutions in a variety of fields, including industry, robotics, and social media[3]. This technology allows the use of automated systems to detect and predict machine failures, monitor product quality, and optimize production processes[4]. A concrete example is the use of deep learning to identify objects in oil mining facilities, which helps improve efficiency and operational safety[5].

In the field of robotics, computer vision has given a big boost to the development of intelligent robots[6]. Robots can use this technology to understand their surroundings, move autonomously, and provide information and navigation to humans. For example, the use of deep learning in robotics has produced robots capable of providing assistance in a variety of contexts, such as health care, education, and customer service. In social media, computer vision has become an important part of managing and sharing visual content[7]. For example, Facebook has used computer vision technology, machine learning, and photo data to develop highly accurate facial detection systems[8]. This allows these social media platforms to provide recommendations about the parts or faces that need to be researched in photos, improving user experience and privacy[9]. Meanwhile, in wider developments, computer vision technology has accelerated the growth of awareness of the importance of analyzing and interpreting visual data. It opens the door to creative solutions in a variety of sectors, including transportation, security, health care, education, and more[10].

Thus, the rapid development of computer vision technology has brought significant positive changes in various aspects of our lives[10]. The continuous emergence of innovation in this field will continue to reinforce its positive impact in the future and help us understand the world in a better way. Computer vision technology is a real proof of human ability to create tools that can bring positive change to our lives through the use of advanced technology[11].

In industry, computer vision technology has become a leading researcher in the development of object recognition and detection systems thanks to advances in deep learning. in the field of robotics has produced applications that can make significant contributions, such as object recognition and navigation that helps humans[5]. One of the technology companies that utilizes computer vision very effectively is Facebook. They use computer vision technology, machine learning, and photo data in highly accurate facial detection systems. This allows Facebook to give appropriate recommendations regarding the part or face that researchers need to give to the photo. However, computer vision technology is not limited to facial or object recognition. It's part of Machine Learning, which itself is a sub-field of Artificial Intelligence. Machine learning, as defined by Arthur Samuel in 1959, allows computers to learn from data without explicit programming algorithms. This means that machines can make their own decisions based on preferences, classify, predict, and recommend things[12].

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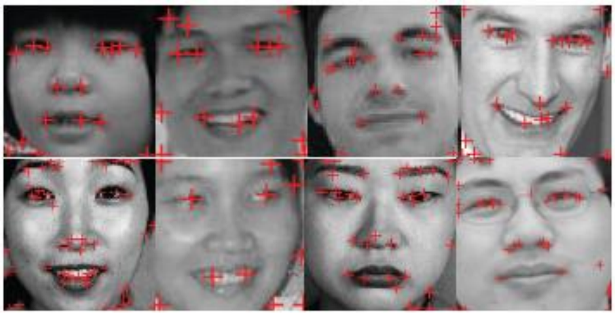

Figure 1. Face Detection Method Based on Corner Verifying[13]

Figure 1 Face Detection Method Based on Corner Verifying by Zhao & Zhang (2011) In the development of facial processing technology, deep learning and CNN have played an important role in improving facial detection accuracy. They are able to identify more complex facial features, even in different situations, such as changing lighting or research angles[4]. This makes deep learning and CNN powerful tools in developing increasingly sophisticated and accurate facial detection applications. Thus, deep learning is one of the key breakthroughs in the development of data processing technology, and especially in the context of face detection and image recognition. Its ability to automatically extract more complex and accurate algorithms has changed many aspects of our lives, from security to the entertainment industry, and continues to be the driving force of innovation in the future[14].

In the context of object processing, there are three main phases: Detection, Alignment, and Recognition, as described[9].Object detection is an initial step that involves finding the position and number of objects in the image, while Alignment aligns objects to have a frontal shape or canonical frontal representation. Finally, Recognition is the classification step of the object detected[15]. Object detection has many relevant applications, ranging from security surveillance to machine inspection, and becoming popular in a variety of industries[16]. With technological advances, object detection is increasingly being applied in many use cases, thus increasing the need for higher levels of accuracy[17]. Object detection in deep learning requires huge resources and large amounts of data to train the system well. However, with the use of lightweight deep learning, the required computing power and resources can be more efficient, so that the system can be implemented more easily, including on mobile devices that are increasingly dominated by society[18].

Several research have used machine learning to develop object or face identification apps that is, In this research, the Convolutional Neural Networks (CNN) method and algorithm produced an accuracy level of up to 99.4%[14], This research discusses a face detection algorithm based on the MobileNet architecture. The algorithm is lightweight and the architecture is designed to work for mobile applications. The architecture is trained and tested using the FDDB dataset[10], In this research about face detection based on angle verification is presented. First detect skin color. Then faces are detected using a combination of the AdaBoost face detection algorithm with skin color detection, but there are some non-faces that can be detected to further reduce the error rate[13] and This research discusses the recognition of emotions through facial images in psychological interactions between humans and machines. This research proposes a different Convolutional Neural Network (CNN) model architecture with batch normalization consisting of three multiple convolution layers with a simpler architectural model for its introduction. Emotional expressions based on human facial images in the FER2013 dataset from Kaggle. The experimental results show that the training accuracy rate reaches 98%[15].

For this study look at the accuracy of facial detection applications created with lightweight deep learning methods and Convolutional Neural Network (CNN) algorithms can vary depending on a number of factors, including the amount of training data, the quality of data sets, network architecture, and how well the model has been trained. To determine the correct level of accuracy, it requires in-depth research, development, and testing. Accuracy results can range from fairly good to very high accuracy levels, depending on how far the model has been optimized. And designed a lightweight-based deep learning face detection app on Android at PT. SAF Eternal Partner. This whole process requires a good collaboration between the software development team and the Eternal Partner of PT SAF. With mature planning and an in-depth understanding of company needs, facial detection applications can help in better decision-making and data reporting to investors.

Research in the development of object or face detection applications has produced a variety of sophisticated solutions, but the level of accuracy remains a challenge to overcome. Especially in the face detection context, some studies have managed to high levels of accuracy using deep learning, but there is still room for improvement. Therefore, the study aims to explore the use of lightweight-based face detection deep learning on the Android platform with a focus on improving facial detection accuracy. The research will be carried out at PT SAF Partner Eternal, a company that focuses on security services and event management. Within this company, facial detection applications will be an important tool in collecting valuable information about the number of visitors and the level of visitor density in an event. This information will serve as an indicator that can help companies in making better decisions, as well as in reporting data to investors.

It is important to note that in this study, we will focus on the use of lightweight deep learning technology. Lightweight deep learning refers to a more resource-efficient approach and allows applications to run on mobile devices,

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such as Android platforms. This is important because mobile devices are one of the most commonly used devices by society, and have great potential in improving face detection efficiency and accessibility. The methods used in this research will include developing and training deep learning-based facial detection models that are more efficient in terms of resource use, so that they can run well on Android devices. In addition, the method will also involve testing models with appropriate and representative datasets, as well as improving models through continuous iteration and adaptation.

The impact of this study is expected to be very positive. An Android-based face detection application with higher accuracy can help PT SAF Eternal Partners optimize event management and provide better security services. In addition, companies will be able to be more efficient in decision-making and reporting data on behalf of investors, which can contribute to their business growth. The whole of this research is expected to make valuable contributions to the development of facial detection technology, especially in the context of use on mobile devices. With the growing need for efficient and accurate facial detection applications, this research has the potential to be an important milestone in addressing these challenges and providing practical solutions in an increasingly growing industry.

2. RESEARCH METHODOLOGY

This research uses a lightweight version of the lightweight deep learning model which is very efficient, small in size, and can be used on devices equipped with limited computing resources such as the mobile in the Figure 2 below:

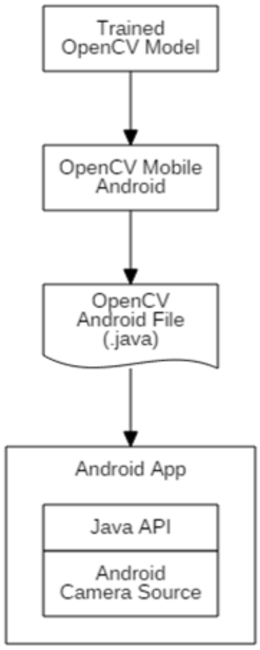

Figure 2. Research Stages

2.1 Data Collection

Gathering representative facial data sets is an important step in developing accurate facial detection models. A good data set should cover a variety of poses, expressions, and lighting conditions so that models can learn well and be able to cope with diverse situations. Here are some guides for collecting representative face datasets:

1. Variasi Pose:
   Collect facial images with a variety of poses, including frontal, tilt, and side poses. Make sure the dataset includes variations of the investigator's angle, such as different head rotations.
2. Lighting Condition Variation:
   Collect images of faces with different lighting conditions, including bright and dark lighting. Consider taking pictures in a variety of lighting environments, such as indoor, outdoor, or under the light of lights.

Gathering representative datasets is one of the key steps in developing high-quality face detection models. A good data set will give researchers a strong san model to understand and recognize various human face situations, which in turn will improve facial detection accuracy in researchers' applications[19].

2.2 Model Training

This research needs to train deep learning models using CNN algorithms. Researchers can use deep learning frameworks like TensorFlow or PyTorch. This model should be optimized for good performance on Android devices[20]. Here are the steps researchers can follow:

1. Selecting a Deep Learning Framework

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Choose a deep learning framework that fits the needs of the researcher. TensorFlow and PyTorch are two very popular options. Researchers can choose based on personal preferences and project needs.

2. Collecting and Pre-Processing Datasets
   Prepare the face datasets that the Researchers have collected, as discussed earlier, and perform data pre-processing, including image normalization and separation of data sets as part of training and testing. Make sure the data is ready to be used for model training.
3. CNN Architecture Selection
   Choose or design a suitable CNN architecture for facial detection tasks. There are proven architectures such as VGG, ResNet, or MobileNet that researchers can consider. Make sure the model has a layer that matches the face detection tasks, such as bounding box detection and face classification.
4. Model Training
   Use training datasets to train CNN models. During the training, models will learn to recognize facial patterns in images, and adjust hyperparameters, such as learning rate, epoch number, and batch size, to optimal results.

2.3 Android App Development

Once the model is trained, researchers need to integrate it into an Android application. Researchers can use programming languages such as Java or Kotlin. Make sure the application can access the camera of the device and have a user-friendly interface. Here are the steps the researchers can follow:

1. Optimization for Android Devices
   Once the CNN model is trained, the next step is to optimize the model for good performance on Android devices, researchers can perform model compression to reduce the size and memory required. Some compression techniques include pruning and quantization and make sure the model can run well in a mobile device environment with limited resources.
2. Model Conversio
   Convert the CNN model to a format that can be run on Android, such as TensorFlow Lite or ONNX and make sure that the converted model stillins good detection accuracy.
3. Integration with the Android App
   Integrate the optimized model into the Android app that the Researchers have designed and make sure the application can take pictures from the camera of the Android device and apply facial detection to the image.

2.4 Testing and Maintenance

Applications need to be thoroughly tested to ensure that facial detection works properly in a variety of situations. In addition, application maintenance needs to be carried out to ensure consistent performance[2].

1. Testing and Evaluation
   Test the application thoroughly to ensure that face detection works well on Android devices and evaluate the performance of the model and make sure the accuracy of facial detection meets the determined researchers.
2. Continued Maintenance and Development
   Advanced Maintenance and Development: After implementation, make sure to perform regular maintenance, including model upgrades if necessary and Researchers can also develop additional features in the application, such as data storage and reporting.

2.5 Implementation in PT. SAF Mitra Abadi

After the application has been successfully developed and tested, the researchers can implement it in Eterna Partners. This application can be used to collect information about the number of visitors and the level of visitor density at an event.

3. RESULTS AND DISCUSSION

3.1 Application Interface Design

The User Interface page of the face detection application created should be designed to be easy to use, informative, and functional. The design of this interface page should create an intuitive and efficient user experience in using the face-detection application. Ensure that the interface design blends good aesthetics with powerful functionality and keeps user data privacy and security as a priority. The description of the face detection application's interface page design is as follows:

3.1.1 Face Detection Page Design

The face detection page contains a section that displays the cameras and labels on the detected faces. The camera and label display on the identified faces are the main elements that enable users to see and understand what is happening in the facial detection process. With this view, users can easily see the detection results and interpret them according to the purpose of the application. The design of the face detection page is shown in Figure 3.

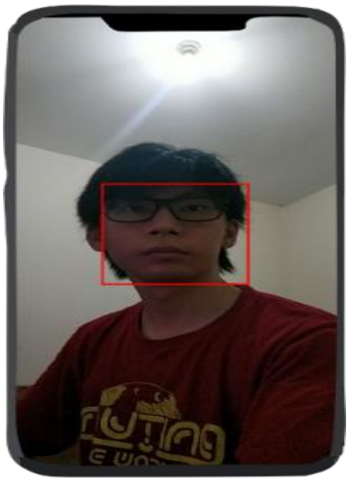

Figure 3. Face Detection Page Design.

3.2 Implementation

In this section, the implementation will be discussed based on the plans that have been made. This includes taking interface design concepts, facial detection models, and application interactions according to the guidelines that have been compiled. Implementation is the stage in which ideas and plans are transferred into real code, so that facial detection applications can operate according to the plan and purpose.

a. Face Detection Application Interface Implementation

This section will describe the implementation of the Android-based face-detection application interface. This implementation is based on a previously created interface design. Here is a description of the interface of the facial detection application created in Figure 4

Figure 4. Face Detection Page Implementation.

b. Testing

1. Face Detection Test
   Face detection test to determine the accuracy of face detection. The conditions used for testing in this study are as follows:
   a. The image used for the test has a minimum of 4 faces and a maximum of 20 faces..
   b. The image used for the test is an image with a straight face and an image in the condition of using between the masks.

   In the table 1 below, researchers will present the results of testing the face detection application that has been carried out. This test aims to evaluate the performance and accuracy of the application in recognizing and detecting faces in various scenarios and conditions. It is hoped that the results of this test will provide valuable insight in understanding the reliability and capabilities of this face detection application in practice.

Table 1. Face Detection Application Test Results.

No	Total Facials	Successfully	Recall	Precision	Accuracy	F *Score*
1.	6	6	100	100	100	100
2.	10	10	100	100	100	100
3.	16	16	100	100	100	100
4.	19	18	94.73	100	94.73	97.29
5.	20	20	100	100	100	100

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No	Total Facials	Successfully	Recall	Precision	Accuracy	F *Score*
6.	5	5	100	100	100	100
7.	6	6	100	100	100	100
8.	8	8	100	100	100	100
9.	12	11	91.66	100	91.66	95.64
10.	15	14	93.33	100	93.33	96.54
Tot	117	114	97.97	100	97.97	98.95

Based on Table 1, there is a total of 3 mistakes. In a straight face condition (1–5 attempts) there is 1 failure and in a straight facial condition using between masks, hats and black glasses (6–10 attempts), there is 2 failures. The accuracy result obtained in the lowest face detection was 95.64%. This suggests that the proposed method can work well on any face image. Out of all 10 digital images, a total of 114 of 117 faces can be detected, so the total average precision rate is 98.95%.

2. Disclosure of sample data
   In this section we will describe the calculation of recall, precision, and accuracy by taking 4 samples from the tests that have been carried out. This discussion will use the Confusion Matrix formula. The conditions used for testing in this study are as follows:
   a. Samples from the Third Test

Figure 5. Samples from the third test

Based on Figure 5 we can see that of the image there are 16 faces and also 16 labels that detect faces correctly and accurately, then the table for the Confusion Matrix is:

Table 2. Confusion Matrix Sample No. 3

	Actual	
Predicted	*TP* (16)	*FP* (0)
	FN (0)	*TN* (0)

From Table 2 it can be concluded that the result of TP (True Positive) is 16 obtained out of 16 box labels that succeeded in detecting faces. FP (False Posive) and FN (False Negative) the result is 0 because there was no false or inaccurate detection in the testing of the sample. Then the formula for recall, precision, and accuracy is:

$$Recall = \frac{\text{TP}}{\text{TP+FN}} = \frac{16}{16+0} = 1{,}0 = 100\%$$
$$\text{Accuracy } = \frac{\text{TP}}{\text{TP+FP}} = \frac{16}{16+0} = 1{,}0 = 100\%$$
$$\text{Accurate} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} = \frac{16+0}{16+0+0+0} = 1{,}0 = 100\%$$
$$\text{F Score} = \frac{2*\text{P}*\text{R}}{\text{P+R}} = \frac{2*1*1}{1+1} = 1{,}0 = 100\%$$

According to the formula and calculations, it can be concluded that the recall calculation result is 100%, since the entire face has been detected successfully, the accuracy of 100% is because all facial detection results are true, then the accurate and F Score of the sample from the third test is 100%.Samples from the Fourth Test.

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b. Samples from the Fourth Test

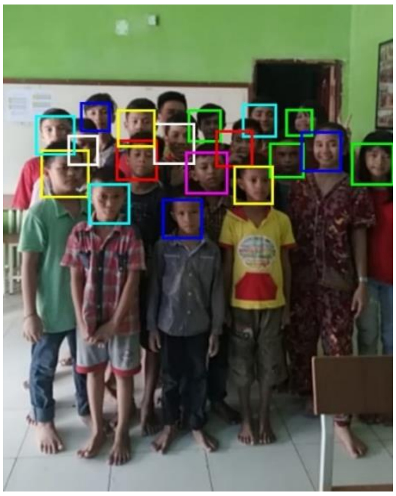

Figure 6. Samples from the Fourth Test

As can be seen from Figure 6, from this image, we can see that 19 faces and 18 facial labels are detected correctly. Here's the Confusion Matrix table of the sample.

Table 3. Confusion Matrix Sample 4

	Actual	
Predicted	*TP* (18)	*FP* (0)
	FN (1)	*TN* (0)

Based on Table 3, it can be concluded that the result of TP (True Positive) is 18 obtained from 18 box labels that succeeded in detecting faces. The result of FP (False Posive) is 0 because there are no incorrect labels in the detection of faces and the result FN (False Negative) is 1 because there is 1 face that failed to be detected by the application. Then the formula for recall, precision, and accuracy is:

$$Recall = \frac{\text{TP}}{\text{TP+FN}} = \frac{18}{18+1} = 0{,}9473 = 94{,}73\%$$
$$\text{Accuracy} = \frac{\text{TP}}{\text{TP+FP}} = \frac{18}{18+0} = 1{,}0 = 100\%$$
$$\text{Accurate} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} = \frac{18+0}{18+0+0+1} = 0{,}9473 = 94{,}73\%$$
$$\text{F Score} = \frac{2*\text{P}*\text{R}}{\text{P+R}} = \frac{2*1*0{,}9473}{1+0{,}9473} = 0{,}9729 = 97{,}29\%$$

Based on the formula and calculations, it can be concluded that the calculation results recall 94.73% because there are faces that can be detected, 100% accuracy because all the face detection results are true, then the precision and F Score of the sample from the fourth test is 94.73% and 97.29%.Sample from the Ninth Test.

c. Sample from the Ninth Test

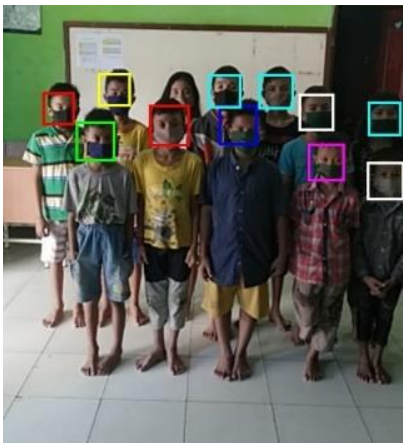

Figure 7. Samples from the Ninth Test

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From Figure 7, we can see that there are 12 faces using masks and also 11 labels that detect faces correctly and accurately, so the table for the Confusion Matrix is Table 4.

Tabel 4. *Confusion Matrix Ninth Sample*

	Actual	
Predicted	*TP* (18) *FN* (1)	*FP* (0) *TN* (0)

From Table 4 it can be concluded that the result of TP (True Positive) is 11 obtained from 11 box labels that succeeded in detecting faces. The result of FP (False Posive) is 0 because there are no incorrect labels in the face detection and the result FN (False Negative) is 1 because there is 1 failed face detected by the application. Then the formula for recall, precision, and accuracy is:

$$Recall = \frac{\text{TP}}{\text{TP+FN}} = \frac{11}{11+1} = 0{,}9166 = 91{,}66\%$$
$$\text{Accuracy} = \frac{\text{TP}}{\text{TP+FP}} = \frac{11}{11+0} = 1{,}0 = 100\%$$
$$\text{Accurate} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} = \frac{11+0}{11+0+0+1} = 0{,}9166 = 91{,}66\%$$
$$\text{F Score} = \frac{2*\text{P}*\text{R}}{\text{P+R}} = \frac{2*1*0{,}9166}{1+0{,}9166} = 0{,}9564 = 95{,}64\%$$

According to the formula and calculations, it can be concluded that the recall result is 91,66%, since there is 1 face failed to be detected, the prescription is 100% because all facial detection results are correct, so the accuration of the Fore and sample scores is 96,66% and 96,64%.

d. Sample from Tenth Test.

Figure 8. Samples from Tenth Test

As can be seen from Figure 8, from this image, we can see that 15 faces using masks and 14 facial labels are properly detected. Here's the Confusion Matrix table of the sample.

Table 5. Confusion Matrix Sample Ten

	Actual	
Predicted	*TP* (18) *FN* (1)	*FP* (0) *TN* (0)

Based on Table 5, it can be concluded that the True Positive result is 14, obtained from 14 label boxes that succeeded in detecting faces. The FP (False Positive) result is 0, because there were no incorrect labels when detection of faces, and the FN (False Negative) result was 1, because the application failed to detect 1 face. Then the formula for recall, precision, and accuracy is:

$$Recall = \frac{\text{TP}}{\text{TP+FN}} = \frac{14}{14+1} = 0{,}9333 = 93,33\%$$
$$\text{Accuracy} = \frac{\text{TP}}{\text{TP+FP}} = \frac{14}{14+0} = 1{,}0 = 100\%$$
$$\text{Accurate} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} = \frac{14+0}{14+0+0+1} = 0{,}9333 = 93,33\%$$

$$\text{F Score} = \frac{2*P*R}{P+R} = \frac{2*1*0{,}9333}{1+0{,}9333} = 0{,}9654 = 96{,}54\%$$

Based on the formula and calculations, it can be concluded that the calculation results recall 93.33% because there are faces that can be detected, 100% accuracy because all facial detection results are true, then the accuration and F Score of the sample from the tenth test is 93,33% and 96,54%.

4. CONCLUSION

In this study, a design of an Android-based face detection application has been carefully designed, and the design has then been implemented into a functional facial detection app. The application uses lightweight deep learning-based face detection methods and Convolutional Neural Network (CNN) algorithms to a high degree of accuracy in facial identification. This implementation allows the application to run well on Android devices, providing reliable and efficient face-detection capabilities, and the results of this study show that the method and algoritms implemented in facial detection applications reach an impressive 97.9% precision level. This indicates that the application can not only operate on the Android platform, but also provide a highly accurate level in facial recognition. This success proves the potential of mobile-based facial detection applications in a variety of use cases, from personal security to data analysis.

REFERENCES

[1] G. Guo and N. Zhang, "A survey on deep learning based face recognition," *Comput. Vis. Image Underst.*, vol. 189, no. November 2018, p. 102805, 2019.
[2] D. Garg, P. Goel, S. Pandya, A. Ganatra, and K. Kotecha, "A Deep Learning Approach for Face Detection using YOLO," *1st Int. Conf. Data Sci. Anal. PuneCon 2018 - Proc.*, pp. 1–4, 2018.
[3] H. Singh, *Practical Machine Learning and Image Processing For Facial Recognition, Object Detection, and Pattern Recognition Using Python-Himanshu Singh*. 2019.
[4] X. Sun, P. Wu, and S. C. H. Hoi, "Face detection using deep learning: An improved faster RCNN approach," *Neurocomputing*, vol. 299, pp. 42–50, 2018.
[5] N. Zhang *et al.*, "Automatic recognition of oil industry facilities based on deep learning," *Int. Geosci. Remote Sens. Symp.*, vol. 2018–July, pp. 2519–2522, 2018.
[6] Y. P. Herdiansyah, "TIN : Terapan Informatika Nusantara Design Prototype Robot Vacuum Cleaner Based on Arduino Microcontroller with Autonomic Mode TIN : Terapan Informatika Nusantara," vol. 4, no. 3, pp. 190–197, 2023.
[7] A. Şengür, Z. Akhtar, Y. Akbulut, S. Ekici, and Ü. Budak, "Deep Feature Extraction for Face Liveness Detection," *2018 Int. Conf. Artif. Intell. Data Process. IDAP 2018*, pp. 5–8, 2019.
[8] F. Nurfadillah, "Sistem Absensi Dengan Face Recognition Menggunakan OpenCV Berbasis Web," 2020.
[9] X. Jiang, A. Hadid, Y. Pang, E. Granger, and X. Feng, *Deep learning in object detection and recognition*. 2019.
[10] A. Almadhor, "Deep Learning Based Face Detection Algorithm for Mobile Applications," *IEEE Reg. 10 Annu. Int. Conf. Proceedings/TENCON*, vol. 2018–Octob, no. October, pp. 1158–1162, 2019.
[11] M. Shen, "Exploration of significant defects based on computer vision," *Proc. - 2017 Int. Conf. Comput. Technol. Electron. Commun. ICCTEC 2017*, pp. 660–663, 2017.
[12] K. Mohd. Ehmer and K. Farmeena, "A Comparative Study of White Box , Black Box and Grey Box Testing Techniques," *Int. J. Adv. Comput. Sci. Appl.*, vol. 3, no. 6, pp. 12–15, 2012.
[13] Q. Zhao and S. Zhang, "A face detection method based on corner verifying," *Int. Conf. Comput. Sci. Serv. Syst.*, pp. 2854–2857.
[14] Y. Pernando, E. L. Febrianti, I. Syafrinal, Y. Roza, and U. F. Afifah, "Deep Learning for Faces on Orphanage Children Face Detection," *JURTEKSI (Jurnal Teknol. dan Sist. Informasi)*, vol. 9, no. 1, pp. 25–32, 2022.
[15] B. K. Triwijoyo, A. Adil, and A. Anggrawan, "Convolutional Neural Network With Batch Normalization for Classification of Emotional Expressions Based on Facial Images," *MATRIK J. Manajemen, Tek. Inform. dan Rekayasa Komput.*, vol. 21, no. 1, pp. 197–204, 2021.
[16] S. E. Li *et al.*, "Kalman filter-based tracking of moving objects using linear ultrasonic sensor array for road vehicles," *Mech. Syst. Signal Process.*, vol. 98, pp. 173–189, 2018.
[17] S. K. Muttoo and S. Badhani, "Android malware detection: state of the art," *Int. J. Inf. Technol.*, vol. 9, no. 1, pp. 111–117, 2017.
[18] Q. Wang and G. Guo, "Benchmarking deep learning techniques for face recognition," *J. Vis. Commun. Image Represent.*, vol. 65, p. 102663, 2019.
[19] W. Li, C. Yen, Y. Lin, S. Tung, and S. Huang, "Proceedings - 2019 IEEE International Conference on Smart Manufacturing, Industrial and Logistics Engineering, SMILE 2019," *Proc. - 2019 IEEE Int. Conf. Smart Manuf. Ind. Logist. Eng. SMILE 2019*, pp. 43–47, 2019.
[20] X. Ye, X. Chen, H. Chen, Y. Gu, and Q. Lv, "Deep learning network for face detection," *Int. Conf. Commun. Technol. Proceedings, ICCT*, vol. 2016–Febru, pp. 504–509, 2016.