FACE RECOGNITION ALGORITHMS FOR PARTIALLY OCCLUDED FACES

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ABSTRACT

Face recognition technology has indeed emerged as a revolutionary force, progressively replacing traditional security measures in recent years and establishing a pervasive presence on the global landscape, as technology continues to permeate various aspects of our daily lives. This research is specifically focused on assessing the reliability of face recognition systems when faced with partial occlusions, which have been known to adversely affect the model's accuracy, leading to a degradation in system performance. Building upon previous research, the latest algorithm in use for facial recognition is the MobilenetV1-CBAM-Facenet (M-Facenet) model. The M-Facenet model utilizes a Multi-Task Cascaded Convolutional Neural Network to address the challenge of detecting partial occlusions. In particular, the study introduced occlusions in the form of glasses and applied a 30% occlusion area, resulting in significant accuracy improvements of 10.92% and 9.39%, respectively. However, it's important to note that the previous study only utilized occlusion in the form of optic glasses and a 30% occlusion area dataset, which may not be representative of real-world security scenarios. In the context of security systems, it's crucial to account for situations where individuals might obstruct a larger portion of their face, up to 70% or more. In our research, we have taken this into consideration by using a dataset that covers more than 40% of the face, aiming to develop a model that can offer improved identification capabilities for security systems. The objective of our study is to enhance the robustness and effectiveness of face recognition under partial occlusion beyond what previous research has achieved. Our central focus is on improving model accuracy, ultimately bolstering the security system. In this pursuit, we leverage Convolutional Neural Networks (CNNs), a robust machine learning algorithm, to enhance authentication security by enabling faster convergence during training. CNNs prove superior to Support Vector Classification(SVCs) because they are capable of learning more intricate features from images. Deep CNNs, coupled with the Adam optimizer and SoftMax activation functions, are employed to attain higher accuracy and efficiency. Feature selection stands as a crucial initial step in addressing occlusion challenges. Utilizing FaceNet and ArcFace models, we generate face embeddings for each detected face within the test dataset. Subsequently, our

developed CNNs classifier model predicts the identity of the given face. In summary, this study investigates the success rate of multiple CNNs models in recognizing faces under partial occlusion, with the overarching goal of identifying the most adaptable model to address the evolving challenges posed by the increasing use of masks and sunglasses. The data set used in this study was obtained from Real World Occluded Faces (ROF) containing 3195 neutral, 1686 sunglasses images and 678 mask images. In conclusion, the optimization and implementation of advanced facial recognition systems play a pivotal role in reducing the likelihood of unfortunate incidents and ensuring heightened security.
Keywords: FaceRecognition, facenet, MTCNN, SVM, occluded

INTRODUCTION

Facial recognition technology is rapidly growing and has become a vital tool in various fields. This technology utilizes artificial intelligence (AI) and Machine Learning (ML) to make significant advancements (Mishra, 2024). By using face detection algorithms, it can recognize faces in images or videos regardless of variables like camera angle, subject's head orientation, lighting conditions, or skin tone.

Facial recognition technology is at the forefront of technological advancement, relying on AI and ML to continuously enhance its capabilities. One of its main strengths is accurately identifying and verifying individual faces under challenging conditions such as varied angles, head position changes, or unfavorable lighting conditions.

Facial recognition is widely used in security systems and provides user identity verification to prevent fraud and unauthorized transactions. Moreover, it's a valuable tool for law enforcement agencies, aiding in identifying and tracking criminal suspects and conducting crowd surveillance. Various industries also utilize facial recognition systems for different purposes.

Our primary focus is developing facial recognition capabilities for security and law enforcement systems. Despite the importance of face recognition in these industries, traditional methods are limited when faces are partially covered, such as with masks or sunglasses. Our project aims to develop an algorithm that can detect faces even when partially covered, utilizing Convolutional Neural Networks (CNN) and FaceNet.

In typical scenarios, people often block at least 70% of their face in self-view images. However, it's important to consider situations where a criminal might accidentally reveal at least 50% of their face due to negligence. Therefore, our goal in this project is to achieve high accuracy in detecting faces that are 40% or more.Looking to the future, advanced models with extensive datasets and sophisticated algorithms are expected to detect faces that are covered more than 70%.

METODOLOGI KAJIAN

This research includes six important stages: literature review phase, data preparation, preprocessing phase, face recognition phase, model performance evaluation phase and final implementation phase. For accurate face recognition, two networks are trained, MTCNN and FaceNet. MTCNN is used to detect the face and get the exact coordinates of the face. Based on the face detection results, face recognition is performed using FaceNet. FaceNet directly learns mappings from face images to a compact Euclidean space where the distance directly corresponds to a face similarity measure. Once this space has been generated, tasks such as face recognition, authentication and clustering can be easily implemented using standard techniques with FaceNet embedding as a feature vector.

Literature Review Phase

The comprehensive literature review conducted in Chapter 2 serves as a foundation, offering insights into the methodological models and methods used in previous research. This extensive exploration investigates the accuracy of existing models, the algorithms used, and the datasets used, providing invaluable knowledge for current research efforts. Identification Methodology, datasets, and suitable algorithms to pave the way for improved performance in face recognition systems, especially when dealing with partial occlusion.

Dataset Preparation Phase

To address the issue of face recognition due to occlusion, a real-world occluded face dataset is introduced. This dataset includes individual images with upper face occlusion (sunglasses) and lower face occlusion (mask). Class masks, sunglasses and neutrals go into a 'trai' folder with individual named folders. With this data set, a more reliable and accurate face recognition system can be developed.

Preprocessing Phase

A Multi-task Cascaded Convolutional Network (MTCNN) is used for face detection. MTCNN consists of three levels of convolutional networks that can recognize faces and landmark locations such as eyes, nose, and mouth. These stages are:

Proposed Network (P-Net):

Generates candidate windows and bounding box regression vectors.

Filter Network (R-Net):

Refine the proposed candidate window and reduce the number of candidates.

Output Network (O-Net):

Refine the final result and output the position of the five face marks.

Loss functions in MTCNN include cross-entropy loss, Euclidean sparseness for box regression, and L2 loss for landmark localization. Filtering using a non-maximum suppression (NMS) strategy ensures that the most suitable candidates are selected, maximizing detection accuracy.

Face Recognition Phase

The face recognition mechanism uses the FaceNet model which implements an architecture based on triplet loss. Preprocessing using MTCNN provides refined data input for FaceNet, which produces vectors of face informants, ensuring accurate learning of unique features of faces.

Model Performance Evaluation

Various metrics such as precision, recall, F1-score, and ROC-AUC analysis were used to evaluate the performance of the model. This ensures that the developed system is accurate and efficient in recognizing partially occluded faces in real-world conditions, allowing for further optimization and improvement.

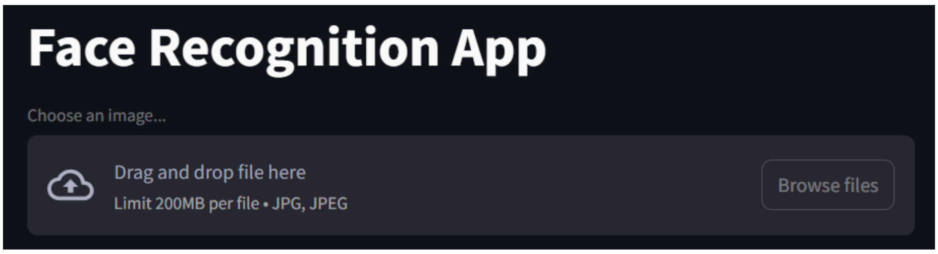
Implementation Phase

This phase integrates the entire facial recognition system into an applications, ensuring practical use. The application is then set up to run with LocalTunnel, facilitating remote access via public URLs. The entire process offers a thorough understanding of the implementation details and data flow from image upload to forecast display. Following these steps allows users to easily and effectively leverage the capabilities of facial recognition models.

RESULTS AND DISCUSSION

Demo of Facial Recognition Model

Development and operation of face recognition applications involves importing required libraries such as Streamlit, NumPy, joblib, PIL, FaceNet, LabelEncoder, Normalizer and MTCNN for various functions. Preprocessing functions are defined to process uploaded images by resizing, converting to NumPy arrays, detecting faces and cropping them for further processing. Trained facial recognition models and encoders are loaded using joblib.load, and the Streamlit application is provided to display titles, create image uploader widgets, and process uploaded images for prediction. The application is then configured to run with LocalTunnel, allowing remote access via public URLs. The entire process provides a clear understanding of the implementation details and data flow from image upload to forecast display.



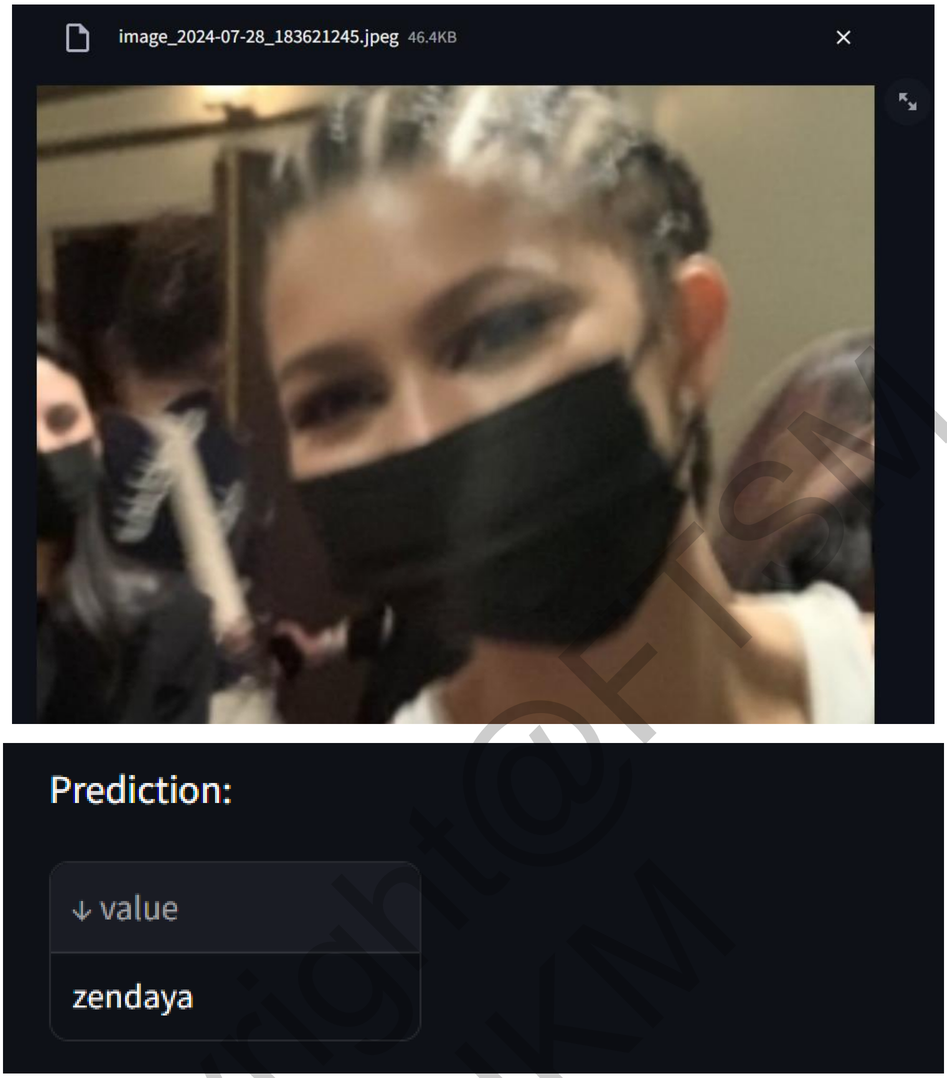
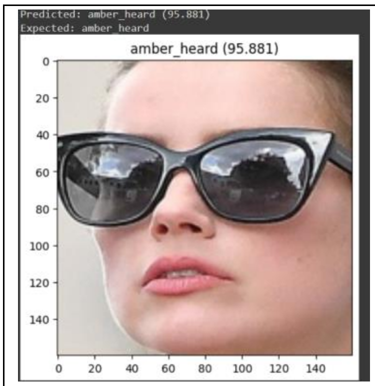


Diagram 1 Demo of Face Recognition Model

Model Result

The results of the model are important to ensure the system runs smoothly in addition to being able to identify any problems and improvements that need to be implemented.



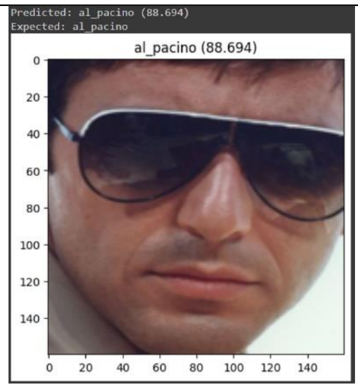


Diagram 2 Accuracy for each Face Detected

Title	**Metodology**	**Result**
Nam Vu et al., 2021	• RetinaFace with MobileNet • ArcFace with Vector 512 dimension • k-NN and LBP	92.5%
Yadav Kumar et al., 2021	• Image Preprocessing and Alignment • SIFT and MB-LBP • Robust Kernel Method (RKM)	86.58%
Huang et al., 2021	• ResNet50 • RetinaFace	87.66%
Zhao et al., 2021	• MTCNN • (MC-Facenet)	91.87%
Alfattama et al., 2021	• MTCNN • Model VGG-Face	85.2%
Proposed method	• **MTCNN** • **Facenet** • **SVC**	**96.3%**

Table 1 Comparison of Model Accuracy

Suggestion for Enhancement

Enhancing the robustness and effectiveness of our facial recognition system necessitates a multifaceted approach, involving the expansion of training data, optimization of algorithms, incorporation of advanced deep learning techniques, and thorough field testing.

To begin with, a wider use of training data is paramount. By incorporating more training data that encompasses various lighting conditions, angles, and other real-world obstacles, we can significantly enhance the robustness of our system. Diverse training data ensures that the facial recognition system can handle a broad range of scenarios, thus improving its accuracy and reliability in real-world applications. This comprehensive dataset will enable the system to recognize faces accurately, regardless of environmental factors or physical obstructions, which are common in real-life situations.

In addition to expanding the training data, optimizing the facial recognition algorithms is crucial. Through rigorous research and optimization of these algorithms, we can achieve substantial improvements in both accuracy and efficiency. Enhanced algorithms can process facial recognition tasks more swiftly and precisely, thereby elevating the overall performance of the system. This optimization can involve fine-tuning existing algorithms or developing new ones tailored to the specific requirements of our facial recognition system.

Furthermore, the application of sophisticated deep learning techniques holds great promise for enhancing the accuracy and reliability of our system. Deep learning models, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), have demonstrated remarkable success in various computer vision tasks, including facial recognition. By leveraging these advanced techniques, we can significantly boost the system's performance, enabling it to accurately identify faces even in challenging conditions. Deep learning models can learn complex patterns and features from the training data, making them highly effective in recognizing faces with high precision.

Lastly, performing field tests is essential to evaluate the model's performance in real conditions. These tests allow us to gather direct feedback from users and identify areas for improvement. By observing how the system operates in actual environments, we can gain valuable insights into its strengths and weaknesses. Field tests also serve as a validation of the effectiveness of our enhancements, ensuring that the improvements translate into tangible benefits in practical applications.

In conclusion, enhancing our facial recognition system requires a comprehensive strategy that includes expanding the training data, optimizing algorithms, incorporating advanced deep learning techniques, and conducting thorough field tests. By implementing these measures, we can develop a robust, accurate, and reliable facial recognition system capable of performing effectively in real-world scenarios.

CONCLUSION

In conclusion, the project "Face Recognition Algorithms For Partially Occluded Faces" has made significant strides in showcasing the potential and limitations of face recognition systems when handling occlusions like sunglasses, face masks, or partial face coverings. The integration of MTCNN for accurate face detection, FaceNet for robust feature embedding, and SVC for classification has resulted in an overall accuracy exceeding 95%. The rigorous analysis of existing algorithms, optimization efforts, and comprehensive testing against other models have provided valuable insights for future developments. However, further refinement is needed, particularly in tuning the SVC model and exploring advanced machine learning techniques to enhance accuracy and reliability. The learnings and achievements from this project lay a strong foundation for future research and improvements in the field of occlusion-aware face recognition systems.

Model Strengths

The model boasts robust data handling capabilities, effectively managing diverse image data encompassing various lighting conditions, angles, and occlusions. Leveraging MTCNN for face detection and alignment ensures accurate preprocessing, essential for achieving precise recognition results. Furthermore, the advanced feature extraction using FaceNet facilitates the generation of robust facial embeddings, known for their high accuracy in distinguishing between individuals even under occlusion. The comprehensive testing approach, including unit, integration, system, and user acceptance testing, ensures individual component functionality and holistic system performance. Additionally, the effective normalization and label encoding maintain consistency and comparability across datasets, crucial for the model's quality and effectiveness. The implementation of a linear kernel in the Support Vector Classifier (SVC) enables simple yet efficient classification, particularly beneficial for high-dimensional spaces in facial embeddings. Moreover, the model's ability to save and load trained models facilitates efficient reuse and further tuning without necessitating retraining, crucial for iterative development and deployment in real-world applications.

Model Weaknesses

While the model handles some occlusions, its performance with severe occlusions remains a challenge, indicating the need for more advanced techniques or additional training data to improve robustness in such scenarios. Furthermore, the SVC with a linear kernel did not meet the anticipated accuracy levels on validation and test sets, indicating a potential requirement for hyperparameter tuning or experimentation with more sophisticated classification algorithms. The complexity of integrating MTCNN and FaceNet, compounded by limited documentation, presents challenges that may hinder future modifications or enhancements, calling for improved integration processes or better resources and support. Lastly, the model's ambitious initial goals for high accuracy with severe occlusions might have been overly ambitious, necessitating an adjustment of expectations and a focus on incremental improvements to manage project scope and set achievable milestones. Additionally, while comprehensive testing was conducted, the need for field testing in real-world conditions to validate the model's performance and reliability is apparent, as real-world scenarios introduce unpredictable variables that controlled testing environments may not cover.

APPRECIATION

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