

Analytical Study and Recommendations for Computer Vision Methods

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Abstract - The purpose of this comparative study is to determine the effectiveness of various computer vision techniques for image analysis tasks. This research aims to investigate different computer vision models for object detection and recognition. Using computer vision models for object detection and recognition, this research aims to replace the cumbersome manual system currently in use. This is accomplished by comparing popular models such as YOLO and Haar Cascade based on their precision, speed, and efficiency. In addition, facial recognition methods, such as the Siamese Model and the face-recognition library, are analyzed based on their performance using metrics such as time, and similarity scores. The challenges and limitations of each approach are examined to identify the most suitable model for specific tasks. As a proof of concept, this study concludes by implementing its recommendation on a popular use case.

I. INTRODUCTION

The objective of this research is to comprehensively assess computer vision techniques employed in image analysis tasks. With the continuous progress in computer vision, it has become a promising technology for various applications such as detecting objects, recognizing faces, and reconstructing scenes. To aid decision-makers in choosing the most suitable computer vision method for their image analysis requirements, this report conducts an evaluation of the effectiveness of different computer vision techniques and offers recommendations based on the findings. The comparative analysis in this report includes popular models like YOLO and Haar Cascade, considering their precision, speed, and effectiveness. Facial recognition approaches like the Siamese Model and face-recognition library are examined and compared using metrics such as time, similarity scores, and threshold. Additionally, the report considers the challenges and limitations associated with each method to identify the most appropriate model for specific tasks. The study results provide valuable insights into the efficiency of various computer vision techniques and their practical applications. The recommendations presented in this report can guide decision-makers in selecting the most suitable computer vision methodology for their image analysis needs. Furthermore, this report contributes to the advancement of computer vision research by identifying the strengths and weaknesses of different methods and proposing solutions for future enhancements.

The need for the research work is to address the lack of clear guidance and information for decision-makers in selecting the most appropriate computer vision methodology for their image analysis needs. With the increasing advancements in computer vision technologies and the wide range of available methodologies, it has become increasingly challenging to choose the most suitable methodology for specific image analysis tasks, leading to suboptimal performance or wasted resources. Furthermore, computer vision technologies have become increasingly important across diverse fields, making it essential to provide a comprehensive comparative analysis of various methodologies and their performance for image analysis tasks. Therefore, the research aims to identify the most effective computer vision methodologies based on precision, swiftness, and effectiveness, enabling decision-makers to select the most appropriate methodology for their image analysis requirements and ensure optimal performance and resource utilization. In addition to guiding decision-makers, the research also aims to contribute to the progress of computer vision research by providing valuable insights into the strengths and limitations of different methodologies and their applications. By identifying the most effective methodologies and their applications, the study can help guide future research in computer vision and enhance the development of new and improved methodologies.

This research focuses primarily on object detection and facial recognition. The paper is separated into various sections. The second section consists of a literature review discussing the limitations and a comparative analysis of the object detection algorithms YOLO and Haar Cascade.. Additionally, it also presents a literature review that provides an overview of various face recognition algorithms, their limitations, and a comparison of the top two algorithms, the Siamese Model, and the face-recognition library. The third section provides an empirical study and comprehensive analysis of the results obtained from using the two recommended algorithms for object detection and face recognition, based on various datasets. The fourth section describes a use-case attendance system developed based on the findings of the previous sections. Finally, the fifth section concludes the research work with recommendations.

II. LITERATURE REVIEW

To ensure that the most effective methods were selected for the comparative study, an extensive literature review was conducted. This review involved a thorough investigation of published works to identify the most accurate and reliable methods for the given research objectives. The aim of this process was to gather information and knowledge about various techniques and approaches which could help in determining the optimal methods for the study.

2.1 Object Detection

Object detection is a computer vision technique involving the identification and localisation of objects in images or videos. This method is indispensable in numerous disciplines, including robotics, autonomous vehicles, and security surveillance. Typically, deep learning models such as CNNs are utilised by object detection methods to identify and classify objects within an image. Notable object detection algorithms include YOLO (You Only Look Once), Faster R-CNN (Region Convolutional Neural Network), and SSD (Single Shot MultiBox Detector). From detecting pedestrians in traffic to recognising objects in satellite imagery, these algorithms have found widespread use in a variety of contexts.

Authors Guennouni, Ahaitouf, and Mansouri compare the effectiveness of Haar-like feature selection and Local Binary Patterns (LBP) for multiple object detection across various platforms utilizing the OpenCV library and Viola-Jones algorithm for Haar-like features and the LBPH algorithm for LBP features [1]. The study examines the evolution of object detection techniques and highlights the significance of feature selection. However, the study contains a number of research gaps. Inadequate and incomplete review of the state-of-the-art in object detection techniques, limited investigation of other feature selection methods or algorithms, and a limited number of tested platforms are a few of these limitations. In addition, the study lacks a comprehensive analysis of the results and their practical applications. Consequently, additional research is necessary to address these gaps and advance object detection techniques.

Authors Alexey Bochkovskiy, Chien-Yao Wang, and Hong-Yuan Mark Liao present a cutting-edge object detection algorithm that combines multiple innovative techniques to achieve exceptional accuracy and speed [2]. The study conducts a thorough review of existing research in object detection and compares the newly proposed YOLOv4 algorithm with prior approaches, demonstrating its superior performance in both accuracy and speed. The authors introduce several significant innovations, such as a novel backbone network, a new data augmentation technique, and a fresh loss function. However, the study falls short in fully analysing the impact of each innovation on overall performance, examining the trade-off between accuracy and speed, or evaluating the performance of YOLOv4 in detecting small objects. Further research is needed to address these limitations and advance the state-of-the-art in object detection algorithms.

Authors Sahal, Kurniawan, and Kadir introduce a new method for object detection in autonomous vehicles using a single camera and the YOLOv4 algorithm [3]. The authors claim that this technique can significantly reduce the cost and complexity of object detection systems for autonomous vehicles. They provide a detailed explanation of their proposed approach and present experimental results that demonstrate its effectiveness. Their method achieved higher accuracy than standard techniques while maintaining real-time performance. The authors briefly review the existing literature on object detection for autonomous vehicles and argue that their approach represents a significant simplification of the object detection process. While the paper highlights the potential of their method to reduce costs and simplify installation, further research is required to validate the approach in a broader range of driving scenarios and address potential limitations.

Authors Wang Hao, and Nangfeng Xiao present an enhanced version of the YOLOv4 algorithm tailored for detecting objects underwater, which is a challenging task due to factors such as low visibility and distortions caused by water [4]. To address these challenges, the authors introduce modifications to the backbone network, additional convolutional layers, and a new feature fusion strategy. Using standard metrics such as mean average precision and intersection over union, the accuracy of the proposed algorithm is demonstrated to be superior to that of the original YOLOv4 algorithm. According to the conclusion of the paper, the proposed algorithm has the potential to be utilised in a wide range of underwater applications. The authors emphasise, however, that additional research is required to improve the algorithm's performance in challenging underwater environments.

Authors Paul Viola, and Michael Jones introduce a new algorithm for object detection that combines fast processing time with high accuracy [5]. The algorithm uses a series of weak classifiers, trained with an adapted version of the AdaBoost algorithm and simple features such as Haar wavelets, to detect objects at multiple scales. The paper presents experimental results on the face detection task, demonstrating that the proposed algorithm achieves top-level performance on a standard dataset while running in real-time. Due to its significant contribution to the field of computer vision, the paper has received widespread attention and has influenced subsequent research on object detection algorithms.

Authors Christian Herdianto Setjo, Balza Achmad, and Faridah introduce a novel technique for human detection in thermal images through the use of a Haar-cascade classifier [6]. The authors provide a comprehensive explanation of the methodology, which includes pre-processing, feature extraction, classifier training, and testing. The evaluation of the proposed approach is presented in detail, showcasing sensitivity, specificity, and accuracy measures. The results indicate that the approach is efficient in detecting humans in different positions and poses with low computational

requirements. Additionally, the authors recommend future research directions, such as exploring the use of deep learning techniques.

Authors Mimboro, Heryadi, Lukas, Suparta, and Wibowo present a novel approach to addressing traffic congestion in urban areas through a real-time vehicle counting method using a Haar Cascade Classifier model [7]. The authors explain the concept of the Haar Cascade Classifier and provide a detailed description of their proposed method, which involves processing a video stream captured by a camera. The article also includes a number of experiments to evaluate the precision and performance of the proposed method; the results demonstrate a high level of precision and real-time performance. The authors discuss the practical applications of their proposed method in traffic management and surveillance systems, emphasising its capacity to enhance traffic flow and safety. The article concludes with a significant contribution to the fields of computer vision and machine learning for the purposes of traffic management and surveillance.

Authors Adri Priadana, and Muhammad Habibi present a novel approach to detect and filter out selfies from Instagram using the Haar cascades algorithm for face detection [8]. A dataset of 10,000 images was collected and processed to obtain a final set of 2,500 face images. Using a machine learning algorithm, the authors were able to classify images as either selfies or non-selfies with an accuracy rate of 82%. The study suggests that reducing the number of selfies on social media platforms can have a positive impact on mental health. Overall, the proposed method can contribute to improving the quality of online content by filtering out low-quality selfies.

Thus, when compared to other object detection methods, YOLO stands out for its rapid processing speed and computation, particularly in real-time scenarios. Moreover, YOLO delivers high accuracy while minimizing the occurrence of background errors, which are often found in other methods. This is because the YOLO architecture allows the model to efficiently learn and recognize a diverse range of objects. Overall, YOLO is considered one of the most effective methods for object detection in real-time situations, surpassing other methods in terms of accuracy and speed, depending on the hardware used. Apart from object detection, YOLO can also be used for identifying individuals, animals, and vehicles. The Haar Cascade method offers several advantages over other object detection methods. It delivers high accuracy when correctly trained and tested and is computationally efficient, enabling real-time object detection. The method is adaptable, capable of detecting objects of various shapes, sizes, and orientations with customizable detection parameters. Moreover, Haar Cascade is straightforward to implement and can be integrated into various software platforms and programming languages. Finally, the method is resilient to changes in lighting, background, and image noise, making it suitable for a range of computer vision applications. Thus,

YOLO and Haar Cascade have been selected as the methods for comparative analysis.

Object detection techniques offer a versatile solution for a range of tasks such as counting, detecting, and tracking. However, their ability to simply detect the presence of an object may not be sufficient in certain situations. For instance, consider an attendance system that requires individual student recognition to mark their attendance accurately. Although methods like YOLO and Haar Cascade are designed to identify objects in images and videos, they may not be equipped to recognize individual faces. To achieve the desired outcome, a face recognition model is necessary. This machine learning model has the capability to identify and recognize human faces, enabling the attendance system to mark each student's attendance based on their unique facial features. Therefore, while object detection methods are valuable for several purposes, including identifying objects and people, additional features such as face recognition are essential for some applications like attendance marking to attain accurate results.

2.2 Face Recognition

Facial recognition techniques have gained significant popularity in recent times owing to their extensive utilization in security, marketing, and personalization. These methods employ artificial intelligence and machine learning algorithms to examine and contrast facial attributes, including eye distance and nose shape, with the goal of identifying specific individuals. This procedure has demonstrated remarkable precision and has found applications in diverse scenarios, ranging from smartphone unlocking to the tracking of criminal suspects.

Authors Koch, Zemel, and Salakhutdinov present an innovative strategy for one-shot image recognition utilizing a Siamese neural network architecture [21]. This method can identify new objects with just one or a limited number of examples. The Siamese network is composed of two equivalent convolutional neural networks that have the same weights and receive input from image pairs. The authors assess the effectiveness of their approach on the Omniglot dataset and demonstrate exceptional performance, surpassing other techniques. The proposed Siamese neural network is a suitable solution for one-shot image recognition problems, with potential applications in disciplines including computer vision, robotics, and natural language processing.

Authors Taigman, Yang, Ranzato, and Wolf outline a novel deep learning approach named DeepFace that attained a level of performance equivalent to that of humans in face verification tasks [22]. The authors employed a convolutional neural network structure and trained it on an extensive collection of facial images. The model exhibited substantially higher accuracy than previous state-of-the-art systems on benchmark datasets and introduced a new loss function known as triplet loss. The significance of the DeepFace model lies in its capacity to learn facial features and recognize individuals across various

poses, expressions, and lighting conditions. It has potential applications in security and law enforcement, as well as social media and e-commerce.

Authors Florian Schroff, Dmitry Kalenichenko, and James Philbin describe a deep learning approach for face recognition and clustering by creating a high-dimensional embedding space [23]. The authors introduce an innovative loss function that trains the model with triplets of images to optimize the distances between faces in the embedding space. They demonstrate exceptional performance on face recognition benchmarks and superior results on face clustering. The paper emphasizes the significance of data augmentation and hard negative mining in training the model and discusses the challenges of learning effective face representations. The FaceNet model has gained wide acceptance in subsequent studies in the field.

Authors Yi Sun, Xiaogang Wang, and Xiaoou Tang present a novel method for face recognition utilizing very deep neural networks [24]. The proposed DeepID3 model comprises a deep CNN, a max-pooling layer, and an MLP, integrating several innovative design choices, including fractional max-pooling and multi-task learning. The model exhibits state-of-the-art performance on various benchmark face recognition datasets, indicating its potential as a propitious direction for future research.

Authors Amira Anisa Rahman Putra, and Samsul Setumin examine the utilization of Siamese neural networks in face recognition and the influence of different activation functions on their performance [25]. The authors provide an overview of face recognition techniques and discuss the significance of activation functions in neural networks. They present a comprehensive analysis of commonly used activation functions and assess their performance in face recognition experiments on the LFW dataset. The findings indicate that ReLU and ELU activation functions outperform sigmoid and tanh, while leaky ReLU exhibits similar performance to ReLU. In conclusion, the paper demonstrates the efficacy of Siamese neural networks in face recognition and the criticality of selecting appropriate activation functions to attain optimal performance.

Author Ashwin Rao introduces a real-time attendance system that relies on face recognition [26]. The paper deliberates on the benefits and drawbacks of utilizing face recognition for attendance tracking and presents the architecture of the proposed system that comprises a face detection, a feature extraction, and a classification module. The experiments demonstrate that the system achieves an accuracy rate of 95.5% on a dataset of 200 faces, indicating its potential to substitute traditional methods of attendance tracking.

Authors Shizhen Huang, and Haonan Luo introduce a novel attendance system that employs dynamic face recognition, utilizing deep learning algorithms and real-time video analysis to record attendance with precision and efficiency [27]. The

authors conduct a literature review on face recognition systems and emphasize the drawbacks of conventional attendance systems. Additionally, the technical aspects of the suggested system are explored, and experimental results confirming its effectiveness are presented. The article concludes by underlining the potential benefits of the proposed system and suggesting promising areas for future research. In summary, the paper provides an extensive survey of the literature on face recognition technology and offers a feasible application for the proposed attendance system.

Authors Harikrishnan, Sudarsan, Sadashiv, and Ajai provide a comprehensive review of the literature on the use of face recognition technology in surveillance systems, with specific attention to attendance monitoring [28]. The authors critique the shortcomings of conventional attendance monitoring systems and advocate for a more advanced approach that leverages deep learning and computer vision techniques. The paper presents a solution in the form of the V-FRAMS , which involves the deployment of a pre-trained convolutional neural network (CNN) model to detect and recognize faces, and an automated attendance tracking system to register attendance data. The authors assert that the V-FRAMS system has the potential to revolutionize attendance monitoring across different settings.

Consequently, research reveals the Siamese Model to be a highly effective model for recognizing faces, owing to its specialized design for learning similarity metrics between two input images. This feature makes it particularly well-suited for face recognition, allowing it to identify faces that may appear in different lighting conditions or from varying angles. Studies have shown that Siamese networks demonstrate superior accuracy in face recognition tasks compared to other popular models such as VGGFace and FaceNet. Additionally, this model requires fewer training examples than other deep learning models and can be readily adapted to recognize new faces. Overall, the Siamese model's ability to learn a robust similarity metric, achieve high accuracy, require fewer training examples, and adapt to new faces makes it an outstanding option for face recognition tasks. It is important to avoid plagiarism by expressing the ideas in your own words and citing sources appropriately. The face-recognition library, on the other hand, stands out for its superior accuracy, speed, versatility, ease of use, and open-source nature. It leverages deep learning algorithms and pre-trained models to detect and recognize faces in images and videos with remarkable precision, making it a suitable solution for a wide range of applications. Furthermore, it is compatible with various cameras and image formats and is relatively straightforward to use, even for developers with limited experience in computer vision or deep learning. Its open-source nature means that it is freely available and can be modified and enhanced by the developer community, which has contributed to its broad acceptance in different industries and applications. It is essential to avoid plagiarism by rephrasing the ideas in one's own words and citing sources properly. Hence, the Siamese

Model and the built-in Python library face-recognition have been selected as the models for the study.

III. EMPIRICAL STUDY AND ANALYSIS

A research study was conducted to investigate the performance of object detection and face recognition methods using two different datasets - a pre-built dataset and a custom dataset, for which the study was carried out in a classroom setting. Empirical evidence was gathered and analyzed to determine the effectiveness of these methods in detecting and recognizing objects and faces in the datasets.

3.1 Data Collection and Pre-processing

Initially, a dataset was generated by capturing images of students' faces via a webcam. Later, images of students seated in a classroom were used to create the testing data. For training the Siamese model, a pre-existing dataset was utilized for negative images.

3.2 Result Analysis of Object Detection Methods

Based on the dataset mentioned earlier, an analysis was conducted using both the Haar Cascade and YOLO object detection methods. The results were compared and it was determined that the Haar Cascade method outperformed the YOLO method.

3.2.1 Performance Evaluation of Haar Cascade

To implement Haar cascade, a folder was created to store all the images. After running the algorithm, all the faces detected were stored in a 100x100 size. The input for Haar cascade was an image, which was then used to detect all the face locations, crop them, and store them. Remarkably, as seen in fig 3.2.1, Haar cascade was able to accurately detect the students, even those who were seated in the back of the classroom, thus achieving a high accuracy for each image. It identified 33 out of the 38 students present in the classroom, resulting in an accuracy of 86.84%.



Fig 3.2.1: Detection using Haar Cascade

3.2.2 Performance Evaluation of YOLO

In order to employ YOLO, a compilation of images was combined and compressed to produce a video. YOLO was then utilized to analyse the video and generate a new output video containing object detection. Besides identifying individuals, the

algorithm was also capable of detecting other objects. YOLO was able to recognize 27 out of a total of 38 students, resulting in a lower accuracy of 71.05%. Furthermore, it also identified other objects such as benches, books, backpacks, chairs, and so on, as shown in Figure 3.2.2.



Fig 3.2.2: Detection using YOLO

3.3 Result Analysis of Face Recognition Methods

Additionally, a research study was conducted to compare two different models of face recognition: the Siamese Model and the face-recognition library. The study assessed the results based on their similarity score, and both methods showed a high level of accuracy. However, the face-recognition library had a superior accuracy rate and was ultimately considered the better method due to its faster evaluation time.

3.3.1 Performance Evaluation of Siamese Model

To train the Siamese model, three folders were created: "anchor," "positive," and "negative." The "anchor" and "positive" folders contained images of faces that were to be recognized, while the "negative" folder contained images of celebrities. The Siamese model was then developed as a neural network and trained using the images. It identifies the similarity score between two images, and establishes a threshold which declares the two images as the same if the score exceeds that threshold. Thus, as seen in fig 3.3.1, the model returns a very low similarity score because the two images do not match.

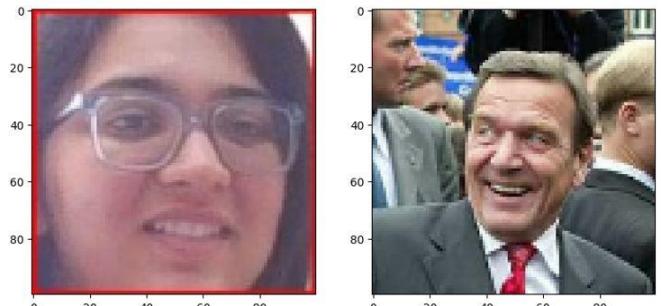


Fig 3.3.1: Recognition using Siamese Model

3.3.2 Performance Evaluation of face-recognition library

The face-recognition library was implemented by creating two folders: "known" and "unknown." The "known" folder contained images of students, while the "unknown" folder contained images of faces to be recognized. The tolerance threshold was set to 0.5, which determined the strictness of the model in recognizing faces. When an image was placed in the "unknown" folder, the model checked it against every image in the "known" folder and returned a match when it found one as seen in fig 3.3.2.

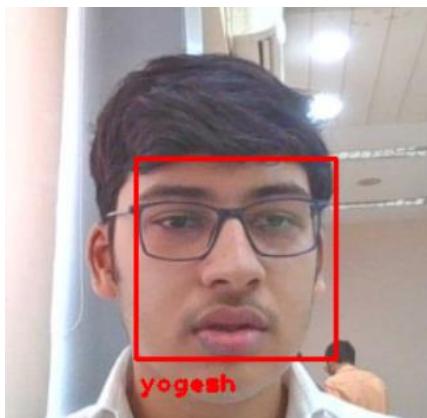


Fig 3.3.2: Recognition using face-recognition library

3.4 Comparative Analysis

After conducting research and comparing the results, it has been determined that Haar Cascade is a more effective method for detecting objects than YOLO. Additionally, the face-recognition library has been found to be a superior method for face recognition in comparison to the Siamese Model. This was due to their higher level of accuracy and faster evaluation time. These conclusions are supported by the data presented in fig 3.4.

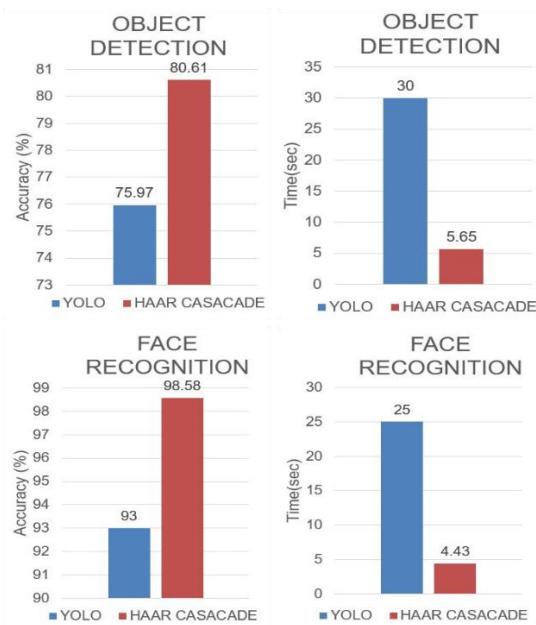


Fig 3.4: Comparative graphs of Accuracy and Time

IV. PROOF OF CONCEPT

Based on the comparison study conducted, it was concluded that Haar Cascade and Face Recognition library are the most effective tools for object detection and face recognition, respectively. As a proof of concept, this study proposes a design for an attendance recording system that utilizes these methods to estimate and record the attendance of each student. This system serves as a use case for the practical application of Haar Cascade and Face Recognition library in attendance management as seen in fig 4.1.

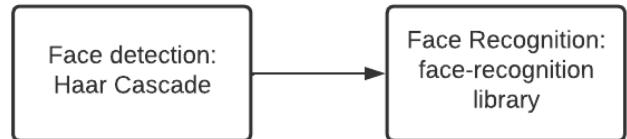


Fig 4.1: Architectural diagram

The algorithm underwent training with several images containing the entire batch of students and their respective names. The next step involved inputting the classroom images into the system, which then utilized the Haar Cascade technique to identify the location of each face in the picture. Subsequently, the algorithm cropped the faces of all the students in the classroom and further processed them through the face-recognition library model. Here, each cropped face was compared to the set of trained faces of the students. When a match was detected, the algorithm recognized the student and marked their attendance by displaying their name as shown in fig 4.2.

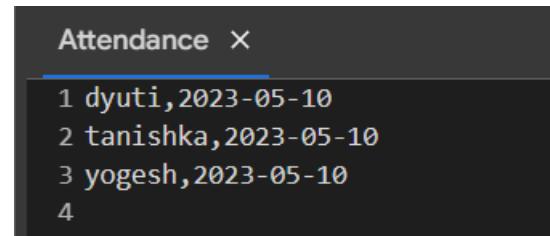


Fig 4.2: Model generated attendance

V. CONCLUSION AND RECOMMENDATION

According to the analysis and comparison made in the research paper, an individual application has been suggested for each of the four methods that were studied:

- The Haar Cascade method is useful for detecting and cropping faces in complex images. It works well when subjects are located at varying depths within the image.
- Yolo is a computer vision algorithm for real-time object detection. It can efficiently detect multiple objects in various fields, including video surveillance, sports analysis, and medical imaging.
- The Siamese neural network has applications in fields of image similarity, image matching, and one-shot learning. It can offer a customized solution that caters to specific individual requirements.

- The face-recognition library is a versatile tool that can learn facial features. The library has applications in social media for identifying tagged individuals and detecting emotions.

Additionally, recommendation by which each approach can be improved in order to enhance its effectiveness:

- To improve the performance of Haar Cascade, multiple stages of cascaded classifiers can be used to analyze images at various levels of depth and additional layers of classifiers can be incorporated to improve accuracy.
- To improve Yolo's performance, it can be trained with larger and more diverse datasets to ensure that Yolo can effectively detect various objects across different scenarios and lighting conditions.
- To enhance the performance of the Siamese model in use cases such as image retrieval, signature verification, and document plagiarism detection, several methods can be employed, including, increasing the dataset size, augmenting the dataset, fine-tuning the model, and incorporating attention mechanisms into the model architecture.
- To improve the face-recognition library for real-time processing use cases, it is suggested to incorporate more advanced algorithms which can enhance the accuracy of facial feature recognition and emotion detection.

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