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REAL - TIME FACE DETECTION USING MATLAB HAAR CASCADE ALGORITHM

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Abstract: Face detection remains a challenging task in computer vision due to real-world factors such as uneven lighting, varying viewpoints, distance, and occlusion. This study aims to develop and evaluate a real-time facial feature detection application (detecting face, eyes, nose, and mouth) using MATLAB and a webcam. Detection is performed using the Viola-Jones Cascade Classifier method through the vision.CascadeObjectDetector function. Key parameters that were adjusted include the MergeThreshold (ranging from 4 to 50 depending on the feature) and MinSize (based on estimated feature size within the frame). However, this study does not include tuning of other parameters such as FalseAlarmRate, which constitutes a limitation of the employed method. The adjustment of these parameters proved significant in improving detection accuracy and robustness under varying lighting conditions. Nevertheless, the system still encounters difficulties in detecting facial features in the presence of occlusion. This study also has the potential to serve as a foundation for further developments in face recognition, emotion detection, or biometric authentication.

Keywords: computer vision; haar cascade; MATLAB

Abstrak: Deteksi wajah merupakan tantangan dalam visi komputer karena dipengaruhi oleh kondisi nyata seperti pencahayaan tidak merata, sudut pandang, jarak, dan obstruksi. Penelitian ini bertujuan untuk mengembangkan dan menguji aplikasi deteksi fitur wajah secara real-time (wajah, mata, hidung, dan mulut) menggunakan MATLAB dan kamera webcam. Deteksi dilakukan dengan metode Viola-Jones Cascade Classifier melalui fungsi vision. CascadeObjectDetector. Parameter penting yang disesuaikan adalah MergeThreshold (antara 4 hingga 50 tergantung fitur), MinSize (mengikuti estimasi ukuran fitur dalam frame). Namun, penelitian ini tidak mencakup penyesuaian parameter lain seperti FalseAlarmRate, yang menjadi salah satu keterbatasan metode yang digunakan. Penyesuaian parameter ini terbukti signifikan dalam meningkatkan akurasi deteksi dan ketahanan terhadap variasi kondisi pencahayaan. Namun, sistem masih mengalami kesulitan mendeteksi fitur wajah jika terjadi obstruksi. Penelitian ini juga berpotensi menjadi dasar untuk pengembangan lebih lanjut dalam face recognition, emotion detection, atau biometric authentication.

Kata kunci: visi computer; haar cascade; MATLAB

INTRODUCTION

Face recognition is a process used to determine whether a given region in an image corresponds to a human face and to identify the individual. Prior to face recognition, the initial step is face detection, which involves locating and recognizing facial features within an image. Face detection plays a crucial role in a wide range of applications, such as criminal suspect identification, security systems, and the analysis of visual patterns and imagery in general. Numerous algorithms are available to train computers to recognize objects, one of which is the Haar Cascade Classifier algorithm [1]. With the advancement of technology, various scientific fields have been utilized in image processing to enable computers to recognize images, including human facial images. One such field is digital image processing, which focuses on image matrix computations. This process enables computers to calculate key features such as the position of the nose, eyes, mouth, and the overall face, thereby facilitating the identification and recognition of facial elements within an image [2].

Despite significant advancements in face detection and recognition, the results remain far from perfect, particularly in detecting facial images with varying face orientations. The positional variations referred to in this study include the angle of tilt and the distance of the human face from the camera, which serves as the input device for image acquisition and subsequent processing [3]. The purpose of face detection in video is to utilize a stored database of faces, enabling face recognition to be performed through various methods, one of which is the experimental approach [4]. Given the challenges in detecting human faces, researchers have taken steps to develop an application capable of detecting the presence of a person's face within a given location [5].

This study aims to develop and evaluate a real-time facial feature detection application (detecting face, eyes, nose, and mouth) using MATLAB and a webcam. Detection is performed using the Viola-Jones Cascade Classifier method through the vision.Cascade ObjectDetector function.

To enhance the accuracy of facial feature detection, the approach employs a specialized color space that better distinguishes between face and non-face regions. This color space facilitates the system in recognizing specific facial features, such as the eyes, nose, and mouth, by considering differences in contrast and intensity within the facial area. This method is expected to yield more accurate facial feature detection and can be applied in various applications, including face recognition, security systems, and augmented reality technologies [6].

Detection of facial features such as the eyes and mouth remains a primary challenge in facial image processing, with numerous applications across various research fields. One commonly used method in image processing is the Haar Cascade algorithm, renowned for its ability to detect objects quickly and accurately. Image processing involves the analysis and manipulation of digital images, enabling the automatic identification of facial features. In this context, MATLAB is chosen as the software platform for image processing due to its efficient numerical computation capabilities and advanced mathematics-based programming environment [7].

One of the important processes in this procedure is labeling. Labeling is performed on the segmented faces and then evaluated based on their unique facial characteristics [8]. Face recognition technology has now been widely adopted across various sectors, particularly for authentication and identification purposes. In the context of authentication, this technology functions by analyzing and recognizing the unique

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characteristics of an individual's face, such as the shape of the eyes, nose, mouth, and other facial structures [9].

Several related studies have explored the field of shape extraction, such as the research conducted by Angga Wahyu Wibowo et al. in 2020. Their study, titled "Real-Time Face Detection and Recognition in Photos Using Haar Cascade and Local Binary Pattern Histogram," successfully achieved real-time face detection and recognition at distances ranging from 0 to 40 cm [10].

This study aims to evaluate the performance of a facial feature detection system using the vision.Cascade ObjectDetector function with the Viola-Jones Cascade Classifier method. The key parameters adjusted include MergeThreshold (ranging from 4 to 50 depending on the feature) and MinSize (based on the estimated size of the feature within the frame). However, this study does not cover tuning of other parameters such as FalseAlarmRate, which constitutes one of the limitations of the employed method.

The evaluation was conducted based on the system's capability to detect the face, eyes, nose, and mouth under various conditions, including variations in lighting, face orientation, and camera distance. While previous studies primarily focused on face detection, this study extends detection to include the eyes, nose, and mouth [3].

This research is expected to serve as a foundation for further investigations, such as the development of face recognition, emotion detection, or biometric authentication systems. By testing under real-world conditions (lighting, angle, distance, and occlusion), this study provides practical insights into the strengths and limitations of the detection method.

METHODS

The method used in this study is the Viola-Jones method, which aims to design a comprehensive face identifica tion system using MATLAB application by leveraging digital image processing technology.

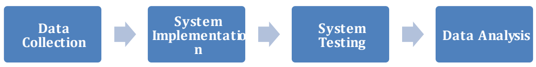

Image 1. Research Stages

Data Collection

Data collection consists of the model and training dataset. The facial feature detection system uses MATLAB'svision.CascadeObjectDetector, which implements the Viola-Jones algorithm with a cascade classifier. This model is pre-trained by MathWorks using standard face datasets, such as the MIT+CMU frontal face dataset, which contains frontal face images with variations in pose and normal lighting conditions. This training dataset enables the detector to recognize main facial features under standard lighting conditions and mostly clear faces. However, this model has not been specifically trained for extreme low-light conditions, highly tilted face poses, or faces significantly covered by accessories.

Testing and dataset: Testing was conducted in real-time using a webcam with volunteer subjects under various lighting conditions (bright and dim), face positions (frontal and tilted up to 45 degrees), camera distances (up to 155 cm), and variations of obstructions such as glasses, masks, and hands partially

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covering the face. This testing aims to evaluate the detector's ability under varied real-world conditions according to the application usage scenarios.

Lighting variations included both bright and dim (low-light) conditions to assess the detector's sensitivity to different levels of light intensity. Face pose variations ranged from subjects directly facing the camera to deviations in pose of up to approximately 20 degrees. Distance variations were tested by positioning subjects at distances of up to 155 cm from the camera. Obstruction variations involved the use of glasses, masks, or hands partially covering the face, with a maximum coverage limit of 50%.

System Implementation

System implementation is the facial feature detection system that was developed using computer vision algorithms, specifically utilizing FrontalFaceCART, EyePairBig, Nose, and Mouth classifiers. The implemen tation process involved several steps, starting with understanding the basic concepts through learning the fundamentals of digital image processing and the Haar Cascade algorithm. Next, system planning was conducted, which included designing the overall facial feature detection system. Subsequently, the vision.CascadeObjectDetector library was used to integrate the Haar Cascade procedure for detecting facial features. Finally, a graphical user interface (GUI) was developed, designed to support real-time detection through a webcam. The main functions of the application include Start Webcam to initiate image capture from the webcam, Face Detection to detect faces directly, Eye, Nose, Mouth Detection to detect eyes, nose, and mouth within the detected face, and Close Webcam to stop the webcam and close the application. Each detection utilizes vision.CascadeObjectDetector, which is an object detection function based on the Viola-Jones Cascade Classifier algori thm.

Haar features detect objects by comparing the differences in pixel intensity between dark and light areas within an image. The classification result determines whether a feature matches a specific Haar pattern (true) or not (false). Important parameters in vision.Cascade ObjectDetector are MergeThreshold and MinSize. For face detection, the MergeThreshold used is 4, which is the default value. For eyes, which are relatively smaller and more detailed, the MergeThreshold value is increased to 8 to ensure more precise and accurate bounding box merging. Similarly, for the nose, due to its smaller size, the MergeThreshold is increased to 16, whereas for the mouth, the MergeThreshold value is set to 50. For MinSize, in face detection, the MinSize is set to [50 50], representing the minimum size in height × width format, considering that the human face is generally larger. For eyes, a smaller size of [30 45] is used; for the nose, [20 20] is applied as the minimum nose size; and for the mouth, MinSize is set to [30 30]. The MinSize parameter is adjusted according to the estimated size of the object within the frame.

System Testing

System Testing is the system was tested under several scenarios: face position and orientation, including facing directly towards the camera and tilted; face-to-camera distance, such as near, medium, and far; as well as obstructions on the face, such as cloth or glasses.

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Data Analysis

Data Analysis is the detection results were evaluated based on detection accuracy, which includes identifying conditions that enabled successful detection despite interference or under normal image acquisition conditions, and obstruction factors, which identify conditions that caused detection failure.

RESULTS AND DISCUSSION

Testing was conducted to evaluate the performance of the real-time facial feature detection system, which includes detection of the face, eyes, nose, and mouth. The testing encompassed various environmental conditions such as variations in lighting, face orientation, distance to the camera, as well as the presence of acceptable and obstructive barriers.

Face Detection

Face detection demonstrated good performance when the face was clearly visible, facing directly towards the camera, and receiving adequate lighting. Detection was successfully carried out under both bright and dim lighting conditions as long as the face remained visible, including environments with uneven lighting. However, detection effectiveness was only applicable when the face was oriented directly towards the camera and in an upright position. When the face was tilted, detection failed. Based on measurements, the face could still be recognized up to a distance of 155 cm from the camera. Obstructions such as cloth, masks, glasses, or hands were still tolerable as long as they did not cover more than 50% of the facial area vertically. The following are images of the face detection results:

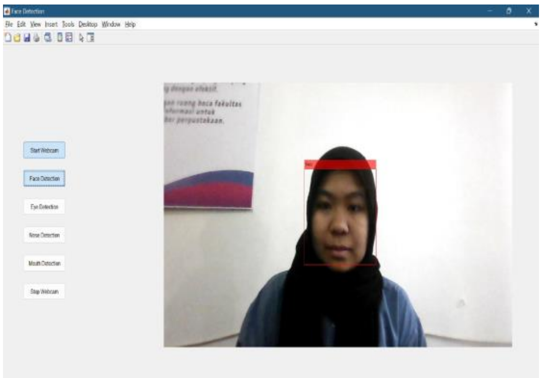

Image 2. Brightly Lit Face Condition

Based on the images above, the face can be reliably detected under conditions of adequate lighting, with the face oriented upright and directly facing the camera, at a close distance, and without any obstructions.

Eye Detection

The EyePairBig algorithm exhibited low detection accuracy. Eyes could only be detected under well-lit conditions and when close to the camera. When the subject wore glasses, the eyes could not be detected. Additionally, eyes were not detected at greater distances or under dim facial lighting, and if the eyes were tilted, detection failed. The following are the eye detection results:

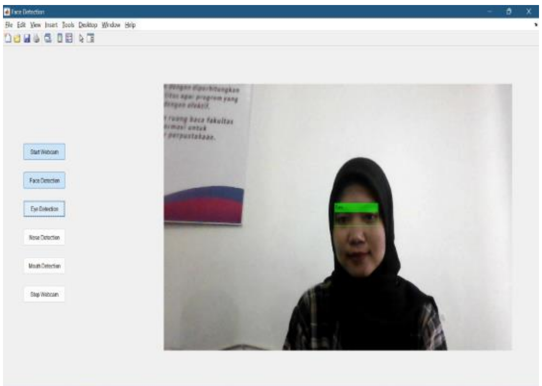

Image 3. Brightly Lit Eye Condition

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Based on the images 3, the eye can be reliably detected under conditions of adequate lighting, with the eye oriented upright and directly facing the camera, at a close distance, and without any obstructions.

Nose Detection

Nose detection showed good results when the face was directly facing the camera; however, nose detection has several limitations, such as being unable to detect at long distances and reduced effectiveness when the user wears glasses or when the lighting in the nose area is dim. Slightly tilted nose positions are still tolerable. The following are the nose detection results:

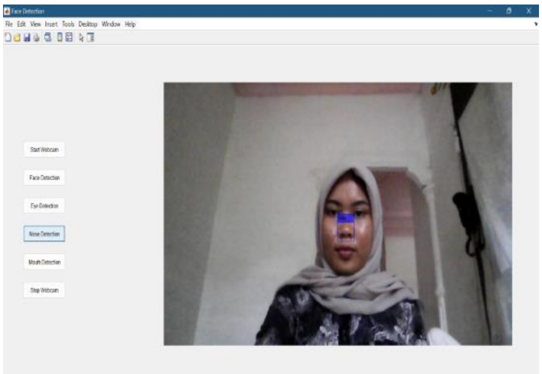

Image 4. Brightly Lit Nose Condition

Based on the images 4, the nose can be reliably detected under conditions of adequate lighting, with the nose oriented upright and directly facing the camera, at a close distance, and without any obstructions.

Mouth Detection

Mouth detection achieves optimal performance when the mouth is clearly visible without obstruction, even under low lighting conditions around the mouth. Detection is successful if the face is facing directly toward the camera and no part of the mouth is covered. However, detection fails at long distances, and even slight coverage of the mouth results in failure to detect. The mouth cannot be detected at all if obstructed by a mask or any other object covering the mouth. The following are the mouth detection results:

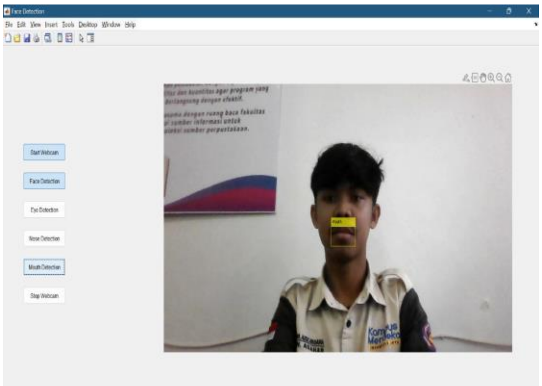

Image 5. Brightly Lit Mouth Condition

Based on the images 5, the mouth can be reliably detected under conditions of adequate lighting, with the mouth oriented upright and directly facing the camera, at a close distance, and without any obstructions.

Discussion

Factors affecting system performance include lighting, where detection performs optimally under sufficient illumination but faces difficulties when facial features are not clearly visible; face position and orientation, with the best results when the face is directly facing the camera; distance from the camera, where proximity improves accuracy while greater distances prevent detection of the eyes, nose, and mouth, allowing only face detection; and physical obstructions, as performance decreases when there are obstructions such as masks or cloth.

CONCLUSION

The developed facial feature detection system demonstrated satisfactory performance under certain conditions, particularly in detecting the face, eyes, nose, and mouth. The algorithm used has the potential to be applied in various fields such as security, healthcare, and human-machine interaction. This study also revealed several limitations, including difficulties in detecting facial features at non-frontal orientations, low lighting conditions, the presence of obstructions, and excessive distance from the camera. To address these issues, it is recommended to integrate deep learning-based algorithms and utilize more diverse training datasets, considering that this research only employed the vision.CascadeObjectDetector function. Future research can explore the development of algorithms capable of detecting facial features from various orientations, optimization for devices with limited resources, and testing in dynamic real-world environments.

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