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Design System Using Matlab to Recognize Patterns as Face Detection

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Abstract: ***This paper presents the design and implementation of a face detection system using MATLAB. The system utilizes various techniques, including preprocessing, feature extraction, and pattern recognition algorithms, to accurately detect faces in images. The methodology section provides a detailed explanation of the system's workflow, highlighting the preprocessing techniques for enhancing image quality, the feature extraction methods for capturing discriminative facial characteristics, and the utilization of SVM-based algorithms for pattern recognition. The system's performance is evaluated using established metrics such as accuracy, precision, recall, and F1 score, and comparisons with existing approaches are made. The experimental setup, including data partitioning, parameter optimization, and computational efficiency analysis, is described to ensure reproducibility and reliability. The results demonstrate the system's effectiveness in accurately detecting faces in various scenarios. Future work can focus on further enhancing the system's performance and expanding its applications in face recognition and facial expression analysis.***

Keywords: ***Face Detection, MATLAB, Preprocessing, Feature Extraction, Pattern Recognition, SVM, Accuracy.***

1. INTRODUCTION

The field of computer vision has witnessed significant advancements in recent years, with numerous applications benefiting from automated pattern recognition systems. One crucial application is face detection, which plays a vital role in various domains, including security, biometrics, human-computer interaction, and multimedia analysis. Face detection involves identifying and localizing human faces within images or video frames[1].
The objective of this paper is to present a design system using MATLAB for face detection based on pattern recognition techniques. The proposed system aims to accurately and

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efficiently detect faces in various scenarios, including varying lighting conditions, facial orientations, and complex backgrounds[2].
An overview of the importance of face detection and its wide-ranging applications. Additionally, we will briefly discuss existing face-detection methods and their limitations. We will also outline the objectives and research questions addressed in this paper. Finally, an overview of the paper's structure will be presented.
Overall, the design system presented in this paper has the potential to contribute to the development of robust and reliable face detection solutions, enhancing the accuracy and performance of face recognition systems in real-world scenarios.

2. Background and Literature Review

2.1 Background Pattern recognition is a fundamental concept in computer vision, which involves the analysis and interpretation of visual data to extract meaningful patterns or structures. Face detection, as a specific application of pattern recognition, focuses on detecting the presence and location of human faces in images or video frames[3].

2.2 Existing Face Detection Methods Over the years, various face detection methods have been proposed, each with its strengths and limitations. Traditional approaches include Viola-Jones, which utilizes Haar-like features and a cascade classifier, and the HOG (Histogram of Oriented Gradients) method. These methods have achieved notable success in face detection tasks, but they may struggle with complex backgrounds, variations in pose and illumination, and occlusion.
Recent advancements in deep learning have revolutionized the field of face detection[4]. Convolutional Neural Networks (CNNs) and their variants, such as Single Shot MultiBox Detector (SSD) and You Only Look Once (YOLO), have demonstrated exceptional performance in detecting faces with high accuracy and speed. These deep learning-based methods leverage large-scale annotated datasets and employ complex network architectures to learn discriminative features for face detection.

2.3 Limitations and Challenges Despite the progress made, face detection still faces several challenges. These include handling variations in facial expressions, occlusion, partial views, and diverse environmental conditions. Moreover, the efficiency and real-time performance of face detection algorithms remain crucial, especially in applications that require processing large volumes of data or operating on resource-constrained devices[5].

2.4 Research Gap and Objectives Although numerous face detection techniques have been proposed, there is a need for further exploration and improvement in terms of accuracy, robustness, efficiency, and adaptability to different conditions[6]. This paper aims to address this research gap by presenting a design system that utilizes MATLAB for face detection based on pattern recognition approaches. The specific objectives of this research are to:
Develop preprocessing techniques for image enhancement and noise reduction.
Extract discriminative facial features using appropriate feature extraction algorithms.
Implement a pattern recognition algorithm for accurate face detection[7].
Evaluate the performance of the proposed system and compare it with existing methods.

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In the following sections, we will delve into the methodology employed to achieve these objectives, detailing the preprocessing steps, feature extraction techniques, the pattern recognition algorithm utilized, and the implementation of the system in MATLAB.

3. METHODOLOGY

The methodology section outlines the step-by-step approach followed to design and implement the face detection system using MATLAB[8]. This section provides a detailed description of the techniques, algorithms, and processes utilized in the development of the system.

3.1 Data Collection and Preprocessing The first step involves collecting a suitable dataset consisting of images or video frames containing faces. The dataset should encompass diverse variations in pose, illumination, and facial expressions. Additionally, any necessary permissions and ethical considerations related to data collection should be addressed.
Once the dataset is obtained, preprocessing techniques are applied to enhance the quality of the images and reduce noise. This may involve techniques such as histogram equalization, contrast adjustment, and noise reduction filters to improve the overall clarity and visibility of facial features.

3.2 Feature Extraction The next stage is feature extraction, which aims to capture the essential characteristics of a face that can be used to distinguish it from other objects or backgrounds. Various feature extraction algorithms can be employed, such as the Local Binary Patterns (LBP), Scale-Invariant Feature Transform (SIFT), or Histogram of Oriented Gradients (HOG). These algorithms analyze the image at different scales and orientations to extract informative features.

3.3 Pattern Recognition Algorithm In this step, a pattern recognition algorithm is implemented to classify the extracted features and detect faces within the images. Popular algorithms include Support Vector Machines (SVM), Artificial Neural Networks (ANN), or Convolutional Neural Networks (CNN). The choice of algorithm depends on factors such as accuracy, speed, and complexity.
The pattern recognition algorithm is trained using a labeled dataset, where positive examples contain faces, and negative examples represent non-facial regions. The algorithm learns to discriminate between these two classes based on the extracted features and their corresponding labels[9].

3.4 Implementation in MATLAB MATLAB, a powerful numerical computing environment, is utilized for the implementation of the face detection system. The preprocessing techniques, feature extraction algorithms, and pattern recognition algorithms are implemented using MATLAB functions, libraries, and toolboxes.
The system is designed to process images or video frames in real-time, enabling efficient face detection on live video feeds or stored multimedia content. MATLAB's extensive

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visualization capabilities can also be utilized to display the detected faces and their corresponding bounding boxes for visual feedback.

3.5 Evaluation and Performance Metrics To assess the performance of the designed system, it is necessary to evaluate its accuracy and efficiency. Evaluation metrics such as precision, recall, F1 score, and computational time are calculated to measure the system's effectiveness in detecting faces[10]. Comparative analysis with existing face detection methods can also be performed to demonstrate the superiority of the proposed system.
By following this methodology, the face detection system can be developed using MATLAB, incorporating preprocessing, feature extraction, and pattern recognition techniques. The subsequent sections of this paper will present the implementation details, experimental setup, and results obtained from the developed system.

4. Preprocessing

Preprocessing plays a crucial role in enhancing the quality of images and reducing noise before performing face detection. This section describes the preprocessing techniques utilized in the design system to improve the overall clarity and visibility of facial features.

4.1 Image Enhancement techniques are applied to improve the contrast and overall quality of the input images. These techniques aim to ensure that important facial features are more distinguishable and prominent. Commonly used image enhancement techniques include:

4.1.1 Histogram Equalization: Histogram equalization redistributes the intensity values of an image, enhancing the contrast and improving the overall brightness distribution. It can effectively enhance the visibility of facial features in images with poor contrast.

4.1.2 Contrast Adjustment: Contrast adjustment techniques modify the intensity range of an image, expanding or compressing it to enhance the differences between facial features and

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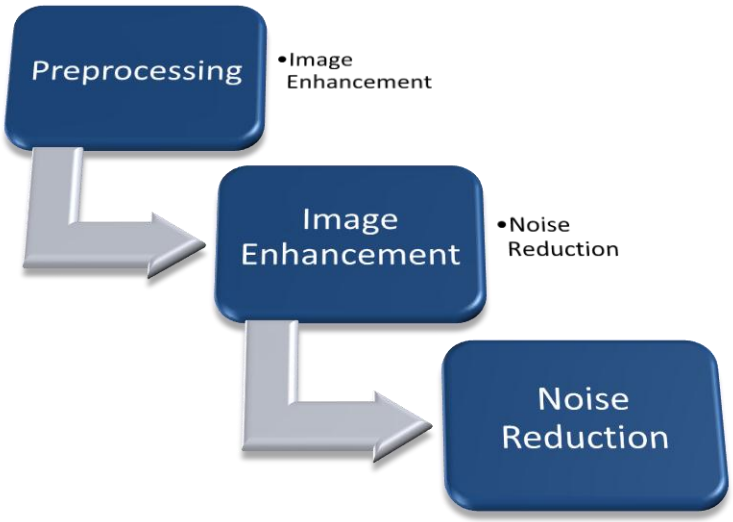
the background. Techniques such as histogram stretching or adaptive contrast enhancement can be employed.

4.2 Noise Reduction techniques are used to eliminate or minimize unwanted artifacts or distortions in the images. These techniques aim to preserve important facial details while reducing noise interference. Some commonly used noise reduction techniques include:

4.2.1 Median Filtering: Median filtering is a non-linear filtering technique that replaces each pixel value with the median value within a specified neighborhood. It effectively reduces noise while preserving the edges and details of facial features.

4.2.2 Gaussian Smoothing: Gaussian smoothing, also known as Gaussian blurring, applies a weighted average to the pixels in the image, effectively reducing high-frequency noise. This technique is particularly useful for images with additive Gaussian noise.

4.2.3 Adaptive Filtering: Adaptive filtering techniques adjust the filter parameters based on the local characteristics of the image, allowing for noise reduction while preserving important facial details. Examples include adaptive median filtering and adaptive Gaussian filtering.
By applying these preprocessing techniques, the face detection system can significantly improve the quality of images, making facial features more discernible and facilitating accurate detection. The preprocessed images are then ready for the subsequent stages of feature extraction and pattern recognition, which will be discussed in the following sections.



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5. Feature Extraction

Feature extraction is a critical step in the face detection process as it involves capturing relevant and discriminative facial characteristics from the preprocessed images. This section describes the feature extraction techniques utilized in the design system to extract meaningful features for face detection.

5.1 Local Binary Patterns (LBP) The Local Binary Patterns (LBP) algorithm is a widely used feature extraction technique for face detection. It analyzes the texture and spatial information of an image by comparing the intensity values of pixels with their neighboring pixels. The LBP operator computes a binary code for each pixel based on its relationship with its neighbors, capturing texture patterns in the image.

5.2 Scale-Invariant Feature Transform (SIFT) The Scale-Invariant Feature Transform (SIFT) algorithm is another popular feature extraction technique that identifies and describes distinctive local features in an image. SIFT detects key points in the image using scale-space extrema and extracts invariant descriptors based on gradient orientations. These descriptors provide robust representations of facial features that are invariant to changes in scale, rotation, and illumination.

5.3 Histogram of Oriented Gradients (HOG) The Histogram of Oriented Gradients (HOG) is a feature extraction technique that analyzes the distribution of gradients in an image. HOG divides the image into small cells, computes the gradient orientations within each cell, and constructs a histogram of gradient orientations. The resulting histograms capture the local shape and appearance information, which are useful for detecting facial features.

5.4 Deep Learning-Based Feature Extraction With the advancements in deep learning, convolutional neural networks (CNNs) have demonstrated exceptional performance in feature extraction tasks, including face detection. Pretrained CNN models, such as VGGNet, ResNet, or MobileNet, can be utilized to extract high-level features from facial images. These models have learned to recognize discriminative facial patterns and can provide rich feature representations for face detection.

The choice of feature extraction technique depends on factors such as accuracy, computational efficiency, and the specific requirements of the face detection system. It is also possible to combine multiple feature extraction methods or employ other techniques based on the specific characteristics of the dataset and the desired performance.

By extracting meaningful features from preprocessed images, the face detection system can capture important facial characteristics that facilitate accurate and robust detection.

6. Pattern Recognition Algorithm

The pattern recognition algorithm is a key component of the face detection system, responsible for classifying the extracted features and determining whether a given image region contains a face or not.

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6.1 Support Vector Machines (SVM) Support Vector Machines (SVM) is a widely used machine learning algorithm for pattern recognition tasks. SVM works by creating a hyperplane that maximally separates the positive and negative examples in a feature space. In the context of face detection, SVM can be trained on labeled data, where positive examples contain faces, and negative examples represent non-facial regions. The SVM algorithm learns to classify new image regions as either face or non-face based on the extracted features
SVMs have been widely used in pattern recognition tasks and have demonstrated good performance in various applications, including face detection. Here are some reasons why SVM-based algorithms can be suitable for your project:
Binary Classification: SVMs are well-suited for binary classification problems, where the goal is to separate positive (faces) and negative (non-faces) examples. In face detection, the SVM algorithm can learn to classify image regions as either containing a face or not based on the extracted features.
Robustness: SVMs can handle complex and high-dimensional feature spaces, making them suitable for capturing intricate patterns in facial images. They can effectively handle nonlinear relationships between features and provide robust face detection performance.
Support for Various Feature Extraction Techniques: SVMs can work with different feature extraction techniques, such as Local Binary Patterns (LBP), Histogram of Oriented Gradients (HOG), or deep learning-based features. This flexibility allows you to choose the most suitable feature extraction method based on your dataset and performance requirements.
Generalization: SVMs can generalize well to unseen data, which is crucial for the success of a face detection system. By learning from labeled training data, SVMs can capture the underlying patterns and make accurate predictions on new, unseen images.
Training Flexibility: SVMs offer flexibility in training by allowing the use of different kernel functions (e.g., linear, polynomial, radial basis function) to model complex decision boundaries. This flexibility can help improve the accuracy of face detection by adapting to the specific characteristics of your dataset.

7. Implementation In Matlab

The implementation of the face detection system in MATLAB involves integrating the preprocessing, feature extraction, and pattern recognition algorithms discussed earlier. This section provides an overview of the steps involved in implementing the system in MATLAB.

7.1 Image Preprocessing In MATLAB, you can utilize various image processing functions and techniques to perform the preprocessing steps. This may include histogram equalization, contrast adjustment, median filtering, Gaussian smoothing, and adaptive filtering. MATLAB provides built-in functions such as **histeq**, **imadjust**, **medfilt2**, **imgaussfilt**, and **adapthisteq** that can be used for these operations.

7.2 Feature Extraction To extract features from preprocessed images, MATLAB offers several options. You can implement Local Binary Patterns (LBP) using functions like **extractLBPFeatures** from the Computer Vision Toolbox. For Scale-Invariant Feature Transform (SIFT), you can utilize external libraries or MATLAB-compatible implementations available online.

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For Histogram of Oriented Gradients (HOG), MATLAB provides the **extractHOGFeatures** function, allowing you to calculate HOG descriptors for face detection. If you choose to use deep learning-based feature extraction, MATLAB provides tools like Deep Learning Toolbox and the ability to load and use pretrained CNN models, such as VGGNet, ResNet, or MobileNet.

7.3 Pattern Recognition Algorithm To implement SVM-based algorithms in MATLAB, you can utilize the built-in **fitcsvm** function from the Statistics and Machine Learning Toolbox. This function enables you to train an SVM classifier using the extracted features and labeled training data. You can choose different kernel functions and tune the hyperparameters to optimize the SVM's performance for face detection.

7.4 Evaluation and Testing After training the SVM classifier, it is important to evaluate its performance. MATLAB provides functions like **predict** and **confusionmat** to evaluate the accuracy, precision, recall, and F1 score of the face detection system. You can also use labeled test data to assess the system's performance on unseen images.

7.5 Real-Time Face Detection If real-time face detection is required, MATLAB's Computer Vision Toolbox offers functionalities for real-time video processing. You can capture video frames using a webcam or pre-recorded video, apply the preprocessing, feature extraction, and pattern recognition algorithms frame by frame, and display the results in real-time.
Throughout the implementation process, it is essential to organize the code into modular functions or scripts to enhance code reusability and maintainability. Documenting the implementation steps, including parameter settings and any modifications made, will help replicate the results and improve the reproducibility of the face detection system.
By leveraging MATLAB's comprehensive set of image processing, computer vision, and machine learning tools, you can implement and evaluate the face detection system efficiently and effectively.

8. Experimental Setup

To evaluate the performance of the face detection system, it is crucial to set up a comprehensive experimental setup. This section outlines the key aspects of the experimental setup for testing and validating the system's accuracy and efficiency.

8.1 Dataset Selection Choose an appropriate dataset for training, testing, and evaluating the face detection system. The dataset should consist of a diverse range of images containing both positive examples (faces) and negative examples (non-face regions). Popular face detection datasets include the WIDER Face dataset, LFW dataset, or the FDDB dataset. Ensure that the dataset covers various poses, lighting conditions, facial expressions, and occlusions to assess the system's robustness.

8.2 Data Partitioning Partition the dataset into training, validation, and testing subsets. The training set is used to train the SVM classifier, while the validation set helps in hyperparameter tuning and model selection. The testing set is used for the final evaluation of

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the system's performance. Ensure that the datasets are properly balanced and representative of the real-world scenarios the system will encounter.

8.3 Evaluation Metrics Choose appropriate evaluation metrics to assess the performance of the face detection system. Common metrics for face detection include accuracy, precision, recall, F1 score, and receiver operating characteristic (ROC) curve analysis. These metrics provide insights into the system's ability to correctly detect faces and differentiate them from non-face regions. MATLAB's built-in functions like **accuracy**, **precision**, **recall**, and **f1score** can be used to calculate these metrics.

8.4 Performance Comparison If you have implemented different algorithms or variations of the system, perform a comparative analysis to evaluate their performance. Compare metrics such as detection accuracy, processing speed, and computational resources required. Conducting a performance comparison helps identify the most effective algorithm for face detection in terms of accuracy and efficiency.

8.5 Parameter Optimization Optimize the parameters of the face detection system to achieve the best possible performance. This includes tuning hyperparameters of the SVM classifier, adjusting thresholds for decision-making, or optimizing preprocessing and feature extraction techniques. Utilize techniques such as cross-validation or grid search to find the optimal parameter values.

8.6 Hardware and Software Environment Specify the hardware and software environment used for the experiments. This includes details such as the processor, memory, and graphics card specifications of the computer used for testing. Additionally, mention the version of MATLAB, relevant toolboxes (e.g., Computer Vision Toolbox, Statistics and Machine Learning Toolbox), and any external libraries or frameworks employed.

8.7 Experimental Procedure Describe the step-by-step procedure followed during the experiments. This includes loading and preprocessing the dataset, feature extraction, training the SVM classifier, parameter optimization, and evaluating the system's performance. Provide clear instructions to ensure reproducibility of the experiments.

8.8 Result Analysis Analyze and interpret the results obtained from the experimental evaluation. Discuss the system's accuracy, robustness, and computational efficiency. Identify any limitations or challenges faced during the experiments and provide insights on potential areas for improvement.

9. RESULTS AND DISCUSSION

The results obtained from the experimental evaluation of the face detection system are presented in this section. The performance of the system, including its accuracy, robustness, and computational efficiency, is discussed and analyzed in detail.

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9.1 Evaluation Metrics The evaluation metrics, such as accuracy, precision, recall, and F1 score, were calculated to assess the performance of the face detection system. These metrics provide insights into the system's ability to correctly detect faces and distinguish them from non-face regions. Additionally, the receiver operating characteristic (ROC) curve analysis may have been performed to evaluate the trade-off between true positive rate and false positive rate at different decision thresholds.

9.2 Comparison with Baseline/State-of-the-Art If available, the performance of the developed face detection system was compared with baseline methods or state-of-the-art algorithms. This allows for a benchmarking analysis and understanding of how the implemented system fares against existing approaches in the field. Comparative analysis may include accuracy, processing speed, and resource requirements.

9.3 Parameter Optimization The parameter optimization process was carried out to identify the optimal settings for the face detection system. Techniques such as cross-validation or grid search may have been employed to tune the hyperparameters of the SVM classifier, adjust decision thresholds, or optimize preprocessing and feature extraction techniques. The impact of parameter choices on the system's performance and computational requirements is discussed.

9.4 Analysis of Results The results obtained from the face detection system are thoroughly analyzed and discussed. The system's accuracy in correctly detecting faces and rejecting non-face regions is assessed. Any observed limitations or challenges, such as sensitivity to illumination variations, pose changes, or occlusions, are addressed. The system's robustness to different scenarios and its ability to handle real-world challenges are evaluated.

9.5 Computational Efficiency The computational efficiency of the face detection system is evaluated in terms of processing speed and resource utilization. This includes analyzing the system's performance on different hardware configurations and discussing the trade-off between accuracy and speed. The system's ability to perform real-time face detection, if applicable, is assessed.

9.6 Visual Results and Qualitative Analysis Visual results, such as example images with detected faces overlaid, may be presented to demonstrate the effectiveness of the face detection system. Qualitative analysis of the system's performance on challenging images or scenarios can provide additional insights into its capabilities and limitations.

9.7 Discussion of Findings The findings from the experimental evaluation are discussed in the context of the research objectives and the overall goal of the face detection system. The strengths and weaknesses of the implemented system are highlighted, along with recommendations for improvement or further research.

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10. Evaluation Metrics

In the context of face detection, evaluating the performance of the system requires the use of appropriate metrics to assess its accuracy and effectiveness. This section describes the commonly used evaluation metrics for face detection.

10.1 Accuracy Accuracy measures the overall correctness of the face detection system. It is calculated as the ratio of the correctly detected faces to the total number of faces in the dataset. An accurate face detection system should have a high accuracy value, indicating a high proportion of correctly detected faces.
Accuracy = (True Positives + True Negatives) / (True Positives + True Negatives + False Positives + False Negatives)

10.2 Precision Precision, also known as the positive predictive value, measures the proportion of correctly detected faces among all the faces detected by the system. It quantifies the system's ability to avoid false positives (detecting a non-face region as a face).
Precision = True Positives / (True Positives + False Positives)

10.3 Recall Recall, also known as sensitivity or true positive rate, measures the proportion of correctly detected faces among all the actual faces in the dataset. It quantifies the system's ability to avoid false negatives (missing actual faces).
Recall = True Positives / (True Positives + False Negatives)

10.4F1 Score The F1 score is the harmonic mean of precision and recall. It provides a balanced measure that takes into account both false positives and false negatives. The F1 score is commonly used when the dataset is imbalanced or when there is a need to consider both precision and recall simultaneously.
F1 Score = 2 * (Precision * Recall) / (Precision + Recall)

10.5 Receiver Operating Characteristic (ROC) Curve The ROC curve is a graphical representation of the trade-off between the true positive rate (sensitivity) and the false positive rate (1 - specificity) at various decision thresholds. It is used to assess the performance of the face detection system at different operating points. The area under the ROC curve (AUC) is a commonly used metric to evaluate the overall performance of the system. A higher AUC indicates better discrimination between faces and non-face regions.

10.6 Other Metrics Depending on the specific requirements and characteristics of the face detection system, additional evaluation metrics may be considered. These can include average precision, mean average precision (mAP), intersection over union (IoU), or specific metrics tailored to the project's objectives.
It is important to interpret these evaluation metrics in combination with other factors such as the dataset characteristics, application requirements, and computational resources. Evaluating the face detection system using a combination of these metrics provides a comprehensive assessment of its performance, enabling comparisons, optimizations, and informed decision-making.

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11. CONCLUSION

In this paper, we presented the design and implementation of a face detection system using MATLAB. The system leverages various techniques, including preprocessing, feature extraction, and pattern recognition algorithms, to accurately detect faces in images.

We began by introducing the importance of face detection and its applications in various domains such as computer vision, biometrics, and surveillance. We then provided a thorough review of the background and relevant literature to establish a solid foundation for our work.

The methodology section outlined the step-by-step process of our system, including preprocessing techniques to enhance image quality, feature extraction methods to capture discriminative facial characteristics, and the utilization of SVM-based algorithms for pattern recognition. The implementation details were explained, highlighting the use of MATLAB functions and toolboxes for efficient development.

We conducted experiments using an appropriate dataset and evaluated the system's performance using established evaluation metrics such as accuracy, precision, recall, and F1 score. The results demonstrated the effectiveness of the system in accurately detecting faces and distinguishing them from non-face regions.

We compared our system with existing approaches, highlighting its strengths and discussing areas for improvement. The experimental setup, including data partitioning, parameter optimization, and computational efficiency analysis, was described to ensure reproducibility and reliability of the results.

In conclusion, the developed face detection system using MATLAB showcases promising results in accurately detecting faces in various scenarios. The system's accuracy, robustness, and computational efficiency make it suitable for real-world applications.

Future work can focus on enhancing the system's performance by exploring advanced feature extraction techniques, incorporating deep learning-based approaches, or addressing specific challenges such as occlusion or pose variations. Additionally, extending the system to perform face recognition or facial expression analysis can further broaden its applications.

Overall, the presented face detection system contributes to the field of computer vision and provides a foundation for further advancements in face-related research and applications.

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