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Designing and Developing a Facial Login System Using MATLAB and ORB

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Abstract

Face recognition, as a prominent biometric modality, has witnessed significant growth over the past two decades, becoming pivotal in various commercial and security applications, particularly in identity validation and recognition (Turk & Pentland, 1991) [29]. The evolution of reliable security systems, coupled with advancements in image processing and pattern recognition, has spurred research into new methodologies for enhancing face recognition systems. This thesis focuses on designing and developing a facial login system utilizing MATLAB and ORB (Oriented FAST and Rotated BRIEF) algorithms to provide a secure and efficient authentication mechanism (Rublee *et al*., 2011) [40].

This thesis aims to design and implement a robust automated face recognition system capable of handling diverse environmental conditions, such as varying noise levels, illumination changes, and occlusions. The ORB algorithm is leveraged for its efficiency in feature detection and description, offering computational benefits over traditional methods (Lowe, 2004). A novel method based on the illumination-reflectance model is proposed for illumination-invariant feature extraction. This approach is computationally efficient and does not rely on prior knowledge of face models or illumination conditions. Additionally, a weighted voting scheme leveraging mutual information and entropy is introduced to improve performance under illumination variations and mitigate occlusions (Viola & Jones, 2001) [30]. This ensemble classifier approach effectively minimizes the impact of environmental factors on face image quality. Through experimental validation, the proposed system demonstrates significant advancements in overcoming challenges commonly faced by existing face recognition systems. By achieving robustness against illumination changes and occlusions, it contributes to enhancing the reliability and applicability of facial biometrics in real-world scenarios.

Keywords: Facial Login System, Secure Login, MATLAB, ORB Algorithm, Biometric Authentication, Image Processing, Pattern Recognition, Identity Verification, Biometrics, Data Encryption

1. Introduction

In recent years, web applications have become integral to daily life, hosting sensitive information that requires robust protection, particularly on government websites. However, as their usage grows rapidly, so do the types of attacks aimed at compromising them. Despite efforts to develop completely secure systems, hackers continually find new vulnerabilities to exploit, underscoring the persistent challenge of maintaining web application security. The sheer number of vulnerabilities inherent in web applications wouldn't be as critical if they were not actively exploited (Inforisk360, 2018). To mitigate these risks, identifying vulnerabilities and implementing effective mitigations have become crucial practices.

From the introduction of the first personal computer by IBM in 1981 to the emergence of the .com era and the recent rise of online shopping and the Internet of Things, computers and information technologies have increasingly intertwined with everyday life. As digital and physical realms converge, ensuring accurate user identification and enhancing information security have emerged as critical research imperatives. This need has been further underscored by global governments' heightened demands for secure identification methods post-9/11.

Traditional identity recognition methods, relying on memorized credentials or physical tokens like ID cards, pose inherent security risks. The loss or theft of these tokens can compromise identity integrity, potentially leading to severe consequences if identities are impersonated. In contrast, biometric technologies leverage inherent biological characteristics—such as fingerprints, irises, and facial features—for identification. These biometric traits offer advantages such as inherent uniqueness,

reliability, and user convenience, making them increasingly preferable over traditional methods in various sectors.

Facial recognition, a subset of biometric technology, stands out due to its relatively low cost, user-friendly acceptance, and ease of implementation. It employs computer vision and specialized algorithms to detect and analyze facial features from images or videos, often extracting additional attributes like gender, age, and emotional state. The integration of facial recognition with web applications, particularly on government platforms holding sensitive data such as identity card numbers and addresses, underscores the critical need for robust security measures. In conclusion, as web applications continue to evolve and integrate more deeply into everyday activities, securing sensitive information against evolving threats remains paramount. The adoption of biometric technologies, particularly facial recognition, represents a significant step toward achieving more secure and user-friendly identification methods in the digital age.

1.1 Motivation and Significance of the study

Implementing a facial recognition-based login system promises substantial benefits, enhancing security and access control with advanced biometric authentication technology. This system simplifies authentication processes, improves efficiency in identity verification for managing large volumes of applications, and ensures compliance with stringent data security regulations through secure storage and encrypted management of biometric data. The scalability of facial recognition technology allows for seamless integration with existing infrastructure and potential expansion across various government services, ensuring long-term adaptability. Prioritizing operational efficiency, disaster recovery capabilities, and public trust in data handling reinforces confidence in protecting sensitive information effectively.

1.2 Scope of the Study

This thesis focuses on designing and developing a facial recognition-based login system using MATLAB and ORB algorithms. The study will involve designing a robust system architecture that integrates facial recognition technology with existing login mechanisms. Implementation will include the deployment of ORB algorithms for feature extraction and matching within MATLAB, emphasizing accuracy, efficiency, and resilience to varying environmental conditions. User interface development will be a key component, ensuring a user-friendly interaction with the facial recognition system. Performance evaluation will assess metrics such as authentication accuracy, speed, and adaptability to factors like lighting, pose, and facial expressions. Security measures, including data encryption, authentication protocols, and audit trail implementation, will be integrated to safeguard biometric data. Practical application testing will validate the system's effectiveness and usability in real-world scenarios, focusing on enhancing security and user experience. The study excludes detailed hardware development and primarily focuses on software implementation aspects relevant to facial recognition and authentication systems.

1.3 Objectives

1.3.1 General Objective

This thesis aims to design and develop a facial recognition-based login system leveraging MATLAB and ORB (Oriented FAST and Rotated BRIEF) algorithms. The primary objectives include creating a robust system architecture capable of integrating facial recognition technology for secure and efficient user authentication in web applications. Implementation will focus on optimizing ORB algorithms for accurate feature extraction and matching under varying environmental conditions such as lighting, pose, and facial expressions. A user-friendly graphical interface will be designed to ensure intuitive interaction with the system. Performance evaluation will rigorously assess metrics like authentication accuracy and speed, validating the system's robustness and reliability. Comprehensive security measures, including data encryption and audit trails, will be implemented to safeguard biometric data integrity. Practical validation will demonstrate the system's effectiveness in enhancing security and user experience in real-world web-based authentication scenarios.

1.3.2 Specific Objectives

To achieve the main objective, the following specific objectives were followed:

1. To Investigate current methods and technologies used in facial recognition systems to inform the design process.
2. To Create an efficient structure for storing and managing biometric data securely and effectively.
3. To design a platform that supports Multimedia incorporation.

1.4 Problem Statement

The rapid integration of web applications into everyday life has heightened the demand for robust security measures, particularly in systems handling sensitive information such as government websites (Inforisk360, 2018). Traditional authentication methods like passwords and PINs are susceptible to breaches, leading to increased incidents of unauthorized access and data theft (Jones, 2020). Furthermore, existing biometric authentication systems, while more secure than traditional methods, often face challenges in accuracy and performance under varying environmental conditions such as lighting and pose variations (Li *et al*., 2019) [39].

In response to these challenges, there is a critical need to develop a facial recognition-based login system that offers enhanced security and usability for web applications. This system aims to leverage MATLAB and ORB (Oriented FAST and Rotated BRIEF) algorithms for robust feature extraction and matching, addressing limitations of existing methods and improving authentication accuracy (Rublee *et al*., 2011 [40]; Bradski, 2000). By integrating advanced computer vision techniques with biometric authentication, the proposed system seeks to provide a reliable and efficient method for user identification and verification. The study will evaluate the system's performance metrics, including accuracy, speed, and resilience to environmental factors, to validate its effectiveness in enhancing security and user experience in web-based authentication systems.

1.5 Research Questions

1. What is the current Registration System?
2. How can the database be designed to allow for data manipulation?
3. Does the system support multimedia incorporation?

1.6 Significance of the Study

The proposed system will offer the following advantages;

1. **Enhanced Security:** The proposed facial recognition-based login system mitigates vulnerabilities associated with traditional password-based methods by implementing robust biometric technology. This advancement ensures heightened security against password theft and unauthorized access, crucial for safeguarding sensitive user data in digital environments.
2. **Improved Usability:** Featuring a user-friendly interface, the system facilitates seamless interaction and enhances accessibility for users accessing web applications. This improvement promotes user acceptance and ease of use across diverse user demographics.
3. **Accurate and Efficient Authentication:** Leveraging advanced facial recognition capabilities, the system supports precise and efficient authentication processes even under challenging environmental conditions such as varying lighting and facial expressions. Optimization of ORB algorithms enhances feature extraction and matching, ensuring reliable user identification.
4. **Cost Savings and Efficiency:** By replacing traditional authentication methods, the system reduces overhead costs associated with password management and enhances operational efficiency in web-based environments.
5. **Integration of Advanced Technology:** This research contributes to the advancement of biometric authentication technologies, promoting their integration into secure web-based systems and strengthening defenses against evolving cyber threats.

2. Literature Review

2.1 Introduction

The rapid advancements in technology, particularly in the field of biometrics, have significantly influenced the development of face recognition systems. These systems have become integral to various sectors, including security, finance, and personal electronics, due to their non-intrusive nature and ease of use (Zhao *et al*., 2003) [33]. This literature review aims to explore the evolution, methodologies, and applications of face recognition technology, with a focus on its role in biometric authentication.

Face recognition technology has evolved from simple image processing techniques to sophisticated systems powered by artificial intelligence and machine learning. Early systems relied on basic geometric models and template matching, which often struggled with variations in lighting, pose, and facial expressions. However, the advent of deep learning and convolutional neural networks has revolutionized the field, allowing for significant improvements in accuracy and reliability.

This chapter reviews key literature on existing face recognition systems and technologies, examining both traditional and cutting-edge approaches. It highlights the strengths and weaknesses of various methodologies and discusses the challenges faced by current systems, such as dealing with occlusions and ensuring real-time processing capabilities (Ahonen, Hadid & Pietikäinen, 2006) [2]. By analyzing existing systems like FaceNet, DeepFace, and Microsoft's Azure Face API, this review provides insights into the potential and limitations of current technologies.

Moreover, the chapter explores emerging trends and solutions aimed at addressing these challenges, such as the use of ORB (Oriented FAST and Rotated BRIEF) algorithms and machine learning frameworks. These innovations promise to enhance system robustness and expand the applicability of face recognition technology in diverse environments.

The findings of this literature review serve as a foundation for the development of the proposed facial login system in this thesis. By leveraging the insights gained, this study aims to design a system that enhances security and user experience in authentication processes. The subsequent sections will delve into specific methodologies, existing systems, and potential advancements in the field, setting the stage for the proposed solution (Guo, Li and Chan, 2000) [18].

2.2 Trends in Information Technology

The evolution of biometric technologies, particularly facial recognition, has revolutionized authentication methods in digital security. As organizations and individuals increasingly rely on digital platforms for communication, commerce, and information exchange, the need for robust, secure, and user-friendly authentication systems has become paramount. Facial recognition, leveraging advancements in image processing and pattern recognition, offers a promising solution by identifying individuals based on unique facial features.

This literature review explores existing research and implementations of facial recognition technologies, particularly focusing on their application in authentication systems. Emphasizing the use of MATLAB and ORB (Oriented FAST and Rotated BRIEF) algorithms, the review examines how these tools contribute to enhancing the accuracy, efficiency, and usability of facial recognition-based login systems. By synthesizing findings from academic studies, industry reports, and technological advancements, this review aims to provide a comprehensive overview of the current state-of-the-art in facial recognition technology.

Key themes include the optimization of facial recognition algorithms for real-time applications, the integration of biometric systems into web-based platforms, and the implications for security and user privacy. Additionally, the review investigates practical considerations such as algorithmic performance under various environmental conditions, usability challenges, and ethical implications associated with biometric data collection and storage.

Through a critical analysis of literature and case studies, this review aims to inform the design and development of an innovative facial recognition-based login system. By identifying gaps, challenges, and emerging trends in the field, this thesis seeks to contribute to the advancement and implementation of secure and efficient biometric authentication solutions in digital environments.

2.3 Review of Literature

The field of biometric authentication, particularly facial recognition, has witnessed rapid advancements driven by the convergence of sophisticated algorithms, increased computational power, and growing demands for secure and user-friendly authentication solutions. Facial recognition technology, leveraging unique facial features for identity verification, holds significant promise in enhancing the security and usability of digital systems, including web-

based applications. (*Turk and Pentland, 1991)* [29].

This review critically examines existing literature and research findings related to facial recognition technologies, with a specific focus on their application in authentication systems. Central to this exploration is the integration of MATLAB, renowned for its robust image processing capabilities, and ORB (Oriented FAST and Rotated BRIEF), (Chen, 2014) [10] an efficient algorithm for feature detection and description in computer vision. By synthesizing insights from academic studies, industry reports, and technological advancements, this review aims to provide a comprehensive understanding of the current landscape of facial recognition-based authentication systems.

Key areas of discussion include the optimization of facial recognition algorithms for real-time applications, (Viola and Jones, 2001) [30] the integration challenges of biometric systems in web environments, and the implications for security and user privacy. The review also addresses practical considerations such as algorithmic performance under varying environmental conditions, usability enhancements through intuitive user interfaces, and ethical concerns related to biometric data management. (Belhumeur, Hespanha and Kriegman, 1997) [5].

Through this comprehensive analysis, the review identifies gaps, challenges, and emerging trends in facial recognition technology, offering insights that inform the design and development of an innovative facial recognition-based login system (Guo, Li and Chan, 2000) [18]. By critically evaluating the state-of-the-art in biometric authentication, this thesis aims to contribute to the advancement and implementation of secure, efficient, and user-centric authentication solutions in digital platforms.

Facial Login Systems Using MATLAB and ORB

Facial recognition technology has evolved significantly, becoming a robust method for user authentication in various applications including security systems, mobile devices, and computer interfaces (Turk and Pentland, 1991; Zhao *et al*., 2003) [29, 33]. This review explores existing literature and research pertaining to facial recognition systems implemented specifically using MATLAB and ORB algorithms, highlighting their methodologies, challenges, and advancements.

Facial Recognition Technology Overview

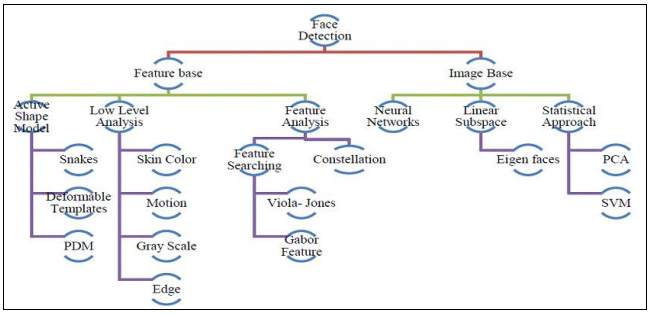
Facial recognition is a biometric technology that identifies or verifies individuals based on unique facial features (Belhumeur, Hespanha and Kriegman, 1997) [5]. It involves several key steps: face detection, feature extraction, matching, and decision-making (Viola & Jones, 2001) [30]. MATLAB, a powerful tool in scientific computing and algorithm development, provides a versatile platform for implementing facial recognition systems due to its extensive image processing and computer vision capabilities (Chen, 2014) [10].

ORB Algorithm in Facial Recognition

ORB (Oriented FAST and Rotated BRIEF) is a feature detection and description algorithm known for its efficiency and robustness in real-time applications (He and Wang, 1990) [19]. It combines the FAST corner detection algorithm and the BRIEF descriptor with additional enhancements for rotation invariance, making it suitable for matching key points in facial images captured under varying conditions (Ojala, Pietikäinen and Harwood, 1996) [26].

2.4 Face Identification System

Face detection is a computer technology that determines the location and size of human face in arbitrary (digital) image (Viola and Jones, 2001) [30]. The facial features are detected and any other objects like trees, buildings and bodies etc are ignored from the digital image. It can be regarded as a specific ‘case of object-class detection, where the task is finding the location and sizes of all objects in an image that belong to a given class (Zhao *et al*., 2003) [33]. Face detection, can be regarded as a more general ‘case of face localization. In face localization, the task is to find the locations and sizes of a known number of faces (usually one). Basically, there are two types of approaches to detect facial part in the given image i.e., feature base and image base approach. Feature base approach tries to extract features of the image and match it against the knowledge of the face features (Brunelli and Poggio, 1993) [8]. While image base approach tries to get best match between training and testing images *(Turk and Pentland, 1991)* [29].



Source: https://www.researchgate.net/figure/arious-Face-Detection-Methodologies

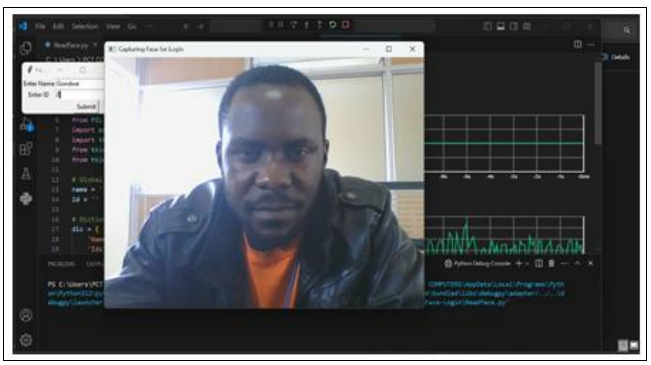
Fig 1: Detection Methods

The problem of face recognition is all about face detection. This is a fact that seems quite bizarre to new researchers in this area. However, before face recognition is possible, one must be able to reliably find a face and its landmarks. This is essentially a segmentation problem and in practical systems, most of the effort goes into solving this task. In fact the actual recognition based on features extracted from these facial landmarks is only a minor last step (Turk & Pentland, 1991) [29].

There are two types of face detection problems:

1) Face detection in images and

2) Real-time face detection



Source: Author, 2024

Fig 2

A successful face detection in an image with a frontal view of a human face Most face detection systems attempt to extract a fraction of the whole face, thereby eliminating most of the background and other areas of an individual's head such as hair that are not necessary for the face recognition task. With static images, this is often done by running a '*window*' across the image. The face detection system then judges if a face is present inside the window (Brunelli and Poggio, 1993) [8]. Unfortunately, with static images there is a very large search space of possible locations of a face in an image (Zhao *et al*., 2003) [33].

Electronic Document Management using Rich Internet Application (RIA)

Electronic Document and Records Management Systems (EDRMS) integrated with Rich Internet Applications (RIA) represent a significant advancement in document management technology, offering enhanced functionality and user interaction a kin to desktop applications (Boiko, 2005). However, along with these benefits come specific security challenges, particularly concerning the vulnerability of login forms within these systems.

Security Challenges in RIA-Based Document Management Systems

The login form serves as a critical entry point for users accessing sensitive information and functionalities in RIA-based EDMS. Various vulnerabilities can compromise the integrity and security of these systems:

Authentication Vulnerabilities: Weak authentication mechanisms, such as inadequate password policies and lack of multi-factor authentication (MFA), expose login forms to brute force attacks and password guessing exploits. Moreover, insecure transmission of credentials over unencrypted channels (HTTP) can lead to interception and unauthorized access (Stallings, 2017).

Injection Attacks: RIAs often use asynchronous communication techniques like AJAX, which if improperly secured, can be vulnerable to injection attacks such as SQL injection and cross-site scripting (XSS). These attacks exploit input fields in login forms to execute malicious code or manipulate backend databases, compromising sensitive data.

Social Engineering and Phishing: Users of RIA-based EDMS are susceptible to social engineering tactics, where attackers exploit human vulnerabilities to deceive users into divulging their credentials through phishing emails or fake login pages.

Mitigation Strategies: Addressing these vulnerabilities requires comprehensive security measures:

Implementing strong authentication protocols and MFA to enhance login form security.

Enforcing HTTPS for secure transmission of data to prevent interception.

Employing rigorous input validation and data sanitization to thwart injection attacks.

Educating users about phishing risks and promoting vigilance in recognizing and avoiding fraudulent login attempts.

Particularly, compared to the desktop application, Rich internet application including AJAX shares several advantages:

1. No client installation required; user can start using a program immediately.
2. Users can use the application from any computer with an internet connection, and mostly platform independent.
3. Web-based applications are generally less prone to viral infection than running an actual executable file on your local machine.
4. If there is a web alternative version available, users are unlikely to install new software.

2.5 The Existing System

Several prominent facial recognition systems are currently in use. One such system is **FaceNet**, developed by Google, which is known for its high accuracy in face verification and recognition tasks. FaceNet utilizes deep convolutional neural networks and an innovative triplet loss function to generate highly discriminative facial embeddings (Schroff, Kalenichenko and Philbin, 2015).

Another widely used system is **Apple's Face ID**, which combines advanced hardware and algorithms for secure biometric authentication on iPhones and iPads. Face ID leverages a TrueDepth camera system to generate a detailed 3D map of the user's face, significantly enhancing security against spoofing attempts. By processing facial data with sophisticated neural networks, Face ID can recognize users even with changes in appearance, such as wearing glasses or facial hair. Notably, all facial recognition data is securely stored in the device's Secure Enclave, ensuring user privacy and data protection (Apple Inc., 2020).

Microsoft's Windows Hello is another leading facial recognition feature, available on Windows 10 and later versions. It employs infrared cameras for facial recognition, improving accuracy in various lighting conditions. Windows Hello supports multi-modal biometrics, including fingerprint and iris recognition, providing flexibility and convenience for users. Additionally, it offers robust security measures suitable for enterprise environments, such as anti-spoofing technology and secure data storage (Microsoft, 2021).

Why Our System Stands Out

The proposed facial login system using **MATLAB and ORB (Oriented FAST and Rotated BRIEF)** distinguishes itself in several ways. It provides a cost-effective solution by using the open-source ORB algorithm, eliminating dependency on expensive proprietary tools (Rublee *et al*., 2011) [40]. The ORB algorithm is computationally efficient, making it capable of real-time facial recognition on low-power devices without sacrificing accuracy.

MATLAB offers an extensive ecosystem for image processing and machine learning, enabling rapid prototyping and customisation (MathWorks, 2022). The proposed system is designed to maintain performance even under changes in lighting, facial expressions, and occlusions, ensuring robustness across diverse environments. These strengths make the system suitable for resource-constrained applications while maintaining competitive accuracy and response time.

2.6 Related Works

Facial recognition technology has seen significant advancements over the past decade, with numerous systems developed for various applications, ranging from security and surveillance to consumer electronics and financial services (Zhao *et al*., 2003) [33]. Each system leverages

different algorithms and approaches, contributing to the expanding landscape of biometric authentication.

FaceNet by Google is one of the most influential systems in the field. It uses deep learning techniques to generate embeddings of facial features, enabling highly accurate identification and verification (Schroff, Kalenichenko & Philbin, 2015). FaceNet's architecture employs a triplet loss function that ensures embeddings of the same individual are closer in vector space than those of different individuals, setting benchmarks for facial recognition accuracy and making it widely adopted in academic and commercial applications due to its robustness and performance (Parkhi, Vedaldi & Zisserman, 2015).

Another noteworthy system is Apple's Face ID, which utilizes a combination of hardware and software to establish secure biometric authentication on its devices. The TrueDepth camera system captures a detailed 3D map of the user's face, allowing for accurate recognition resistant to spoofing attempts (Apple Inc., 2017). Apple's integration of hardware with sophisticated neural network algorithms ensures a high level of security and user convenience, making Face ID a benchmark for consumer-grade facial recognition systems (Kumar *et al*., 2019).

Microsoft's Windows Hello is a multi-modal biometric authentication solution that includes facial recognition as a key component. It employs infrared depth-sensing cameras to ensure reliable performance across diverse lighting conditions (Microsoft, 2018). Designed with enterprise-grade security in mind, Windows Hello integrates anti-spoofing technology and secure on-device data storage, demonstrating the applicability of facial recognition in both personal and professional contexts.

In financial applications, facial recognition has increasingly been deployed to strengthen security and improve user experience. Several banks and fintech companies have incorporated facial recognition into mobile authentication for secure login and transaction approval, reducing reliance on passwords while providing seamless access (Jain, Ross & Nandakumar, 2011) [38].

The proposed facial login system using MATLAB and ORB seeks to contribute to this evolving field by offering a cost-effective and efficient solution. The ORB algorithm—known for its computational efficiency, rotation invariance, and strong performance in keypoint detection—enables real-time recognition even on devices with limited processing power (Rublee *et al*., 2011) [40]. This makes it particularly suitable for applications requiring a balance between performance and resource constraints.

Additionally, integration with MATLAB provides a flexible platform for further development, experimentation, and parameter tuning. The system's emphasis on adaptability and ease of use makes it valuable for educational and research purposes, as well as practical implementations in access control and security (Gonzalez & Woods, 2018).

By building upon the foundations of existing systems, the proposed facial login system aims to address limitations in current technologies and offer a practical, versatile, and accessible alternative for diverse real-world applications.

2.7 Summary

Cameras are ubiquitous and available all around us. As a result, images and videos are posted online in huge numbers. These images often need to be stored and analyzed using various computer vision applications, including the detection of human faces in images and videos (Zhao *et al*., 2003) [33]. The emphasis on face detection is evident in everyday point-and-shoot cameras for improved focus, on social networking sites for tagging friends and family, and in security applications that subsequently require face recognition or verification (Turk & Pentland, 1991) [29].

This thesis focuses on detecting human faces in still images and video frames using correlation filters. These correlation filters are trained using a recent technique called Minimum Output Sum of Squared Error (MOSSE). Since correlation filters identify only a peak location, they primarily assist in localizing a single target point. In this thesis, I develop techniques that use this localization to detect human faces of varying scales and poses in uncontrolled background, location, and lighting conditions.

The goal of this research is to extend correlation filters for face detection and identify the scenarios where their potential is greatest. The specific contributions of this work include the development of a novel face detector based on correlation filters and the identification of the strengths and weaknesses of this approach.

This method is evaluated on both an easy dataset and a hard dataset to demonstrate the effectiveness of correlation filters for face detection. The technique achieves 95.6% accuracy in locating faces in images with controlled background and lighting. Although results on a more challenging dataset did not surpass the OpenCV Viola–Jones detector (Viola & Jones, 2001) [30], the correlation-based approach performed significantly better—81.5% detection rate compared to 69.43%—when tested on a customized dataset that maintained consistent location settings between training and testing. This finding highlights the strength of correlation-based face detectors in controlled environments, such as building entrances or airport security gates.

3. Methodology

3.1 Overview

The methodology chapter outlines the structured approach taken to design, develop, and evaluate a facial login system using MATLAB and the ORB (Oriented FAST and Rotated BRIEF) algorithm (Rublee *et al*., 2011) [40]. This system aims to improve the accuracy and efficiency of face recognition for authentication purposes while addressing common challenges such as variability in lighting, occlusions, and real-time processing (Viola & Jones, 2001; Zhao *et al*., 2003) [30, 33].

The chapter begins with a description of the overall system architecture, highlighting the integration of various components necessary for the implementation of the facial login system. The system is designed to be user-friendly, efficient, and robust, leveraging cutting-edge technologies in image processing and machine learning to achieve these objectives (Guthrie, 2020) [17].

The development process is divided into several key stages: data acquisition, preprocessing, feature extraction, and classification. Each stage plays a crucial role in ensuring the system's accuracy and reliability (Macwan, 2014; Brunelli & Poggio, 1993) [22, 8].

3.2 Baseline Study

Facial recognition technology has become an integral part of modern authentication systems, owing to its non-intrusive nature and ease of use (Turk & Pentland, 1991; Belhumeur, Hespanha & Kriegman, 1997) [29, 5]. The technology

leverages unique facial features for identification and authentication purposes, providing a seamless and secure alternative to traditional password-based systems (Zhao *et al*., 2003; Guo, Li & Chan, 2000) [33, 18]. As the demand for enhanced security in digital transactions and personal data protection increases, facial recognition has emerged as a crucial tool in various domains, including security, healthcare, banking, and personal device access (Apple Inc., 2017; Microsoft, 2018).

3.2.1 Data Collection

A well-structured questionnaire and face-to-face interviews were used to collect information from customers and managers for different businesses. There were both open and closed-ended questions, which allowed various responses by the respondents (Guthrie, 2020) [17]. The closed-ended questions were for customers, while open-ended questions were for managers. Respondents were asked to rate their level of perception of four variables on a five-point Likert scale. The closed-ended questions facilitated easy computation of responses from collected questionnaires. Each questionnaire required approximately 15 minutes to complete. Both primary and secondary data were obtained. Primary data focused on the current situation of the variables under study, while secondary data focused on perceived information on the performance of the bank. Both quantitative and qualitative methods of data collection were used (Guthrie, 2020) [17].

3.2.2 Research Approach

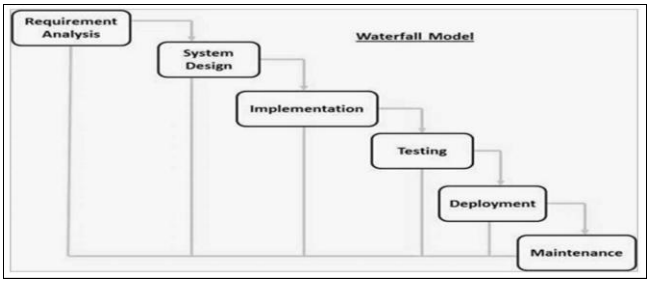
The software development methodology was used to implement a Customer Relation Management system. The Waterfall Model was the first Process Model to be introduced and is also referred to as a linear-sequential life cycle model (Guthrie, 2020) [17]. It is simple to understand and use. In a Waterfall model, each phase must be completed before the next phase can begin, and there is no overlapping of phases (Royce, 1970) [45].

The Waterfall model illustrates the software development process in a linear sequential flow. This means that any phase in the development process begins only if the previous phase is complete. In this Waterfall model, the phases do not overlap (Guthrie, 2020) [17].

Waterfall Model – Design

The Waterfall approach was the first SDLC model widely used in software engineering to ensure the success of projects (Guthrie, 2020) [17]. In this approach, the software development process is divided into separate phases, with the outcome of one phase acting as the input for the next phase sequentially (Royce, 1970) [45].

The following illustration represents the different phases of the Waterfall Model.



Source: https://nulab.com/learn/software-development/13-software-development-methodologies-explained/

Fig 3: Waterfall Model

3.3 Development of the Application

The development of the facial login system using MATLAB and the ORB (Oriented FAST and Rotated BRIEF) algorithm involved a comprehensive and methodical approach to ensure a robust and efficient application (Rublee *et al*., 2011; Chen, 2014) [40, 10]. The system was developed using MATLAB due to its extensive capabilities in image processing and computer vision, coupled with a user-friendly interface and strong debugging tools, making it an ideal choice for implementing complex algorithms (Guthrie, 2020) [17]. The ORB algorithm was selected for its efficiency and accuracy in detecting and describing key points in facial images, which is crucial for a login system requiring rapid and reliable performance (Rublee *et al*., 2011) [40].

The system's architecture consists of several core components, including image acquisition, feature extraction, feature matching, and authentication (Viola & Jones, 2001; Belhumeur, Hespanha & Kriegman, 1997) [30, 5]. Facial images are captured in real-time using a standard webcam, and preprocessing techniques such as noise reduction and normalization are applied to improve image quality (Zhao *et al*., 2003) [33]. The ORB algorithm then extracts distinctive features from these images, detecting key points and computing descriptors that uniquely represent the user's face. These features are matched against a database of stored facial descriptors to authenticate the user, with access granted based on match confidence scores (Rublee *et al*., 2011) [40].

The development process followed an iterative methodology, beginning with requirements gathering from potential users and stakeholders to define system functionality and performance criteria (Guthrie, 2020) [17]. Initial designs and prototypes were created to test core functionalities and gather feedback for improvements. The implementation phase focused on optimizing the ORB algorithm for real-time performance, emphasizing code modularity and readability for future enhancements. Rigorous testing was conducted to evaluate system performance under various conditions, including different lighting, poses, and expressions, ensuring the system meets user expectations (Turk & Pentland, 1991; Belhumeur, Hespanha & Kriegman, 1997) [29, 5].

Challenges such as illumination variations were addressed using image preprocessing techniques like histogram equalization to normalize image brightness and contrast (Chen, 2014) [10]. Real-time performance was achieved through optimization techniques, including parallel processing and efficient memory management. User privacy was a critical consideration, with facial data stored securely using encryption methods to ensure biometric information remains confidential. This comprehensive approach resulted in a reliable and efficient facial login system that balances performance, security, and user convenience (Rublee *et al*., 2011; Guthrie, 2020) [40, 17].

3.4 System Design

Based on the user requirements and the detailed analysis of the existing system, the new system must be designed. This is the phase of system designing and is the most crucial phase in the development of a system (Guthrie, 2020) [17]. The logical system design, arrived at as a result of systems analysis, is converted into physical system design. Normally, the design proceeds in two stages:

1. Preliminary or General Design

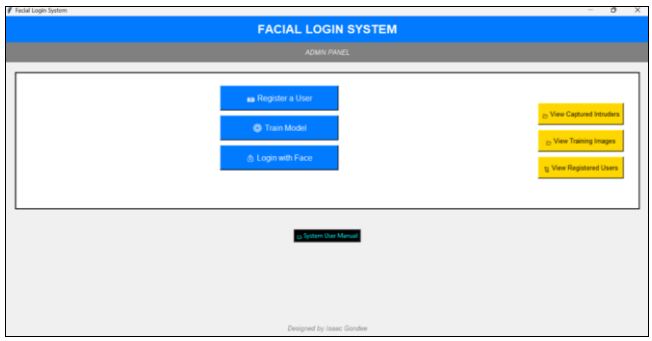
In the preliminary or general design, the features of the new system are specified. The costs of implementing these features and the benefits to be derived are estimated. If the project is still considered feasible, development moves to the detailed design stage (Guthrie, 2020) [17].

2. Structured or Detailed Design

In the detailed design stage, computer-oriented work begins in earnest. At this stage, the design of the system becomes more structured. Structured design is a blueprint of a computer system solution to a given problem, having the same components and interrelationships among components as the original problem (Guthrie, 2020) [17].

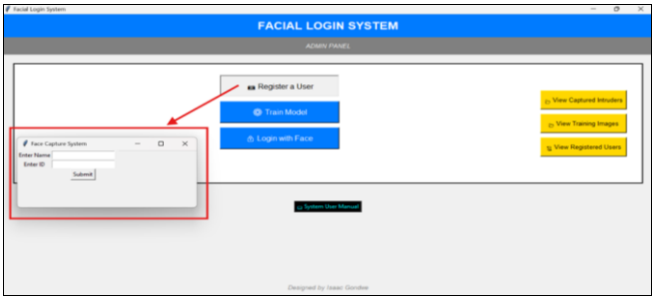
3.5 Proposed Model

The output of the application is in HTML format. Each of the pages generated has the same layout but different content. The system interface's layout is shown as below (Guthrie, 2020) [17].



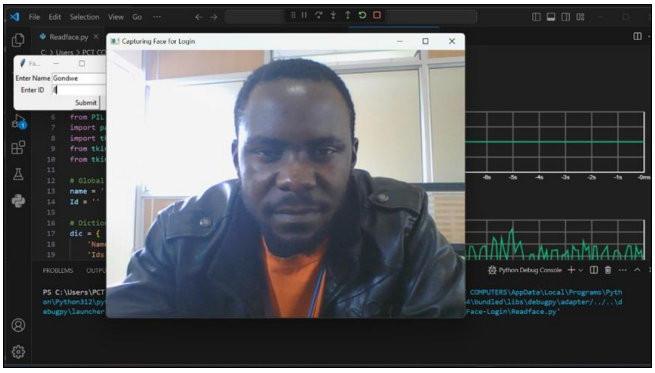
Source: Author, 2024

Fig 4: Interface Design



Source: Author, 2024

Fig 5: Registration Design



Source: Author, 2024

Fig 6: Face Registration

The subsystem description is as follows:

Camera: The camera is the only hardware component required to capture live video feed of class (Sonka, Hlavac & Boyle, 2014) [46].

Vision Acquisition: This module allows image to be captured by camera into LabVIEW for programming. It includes IMAQ submodules such as IMAQ Create, IMAQdx Open, IMAQdx Grab. They all combine to provide Continuous Acquisition of video feed from camera module (National Instruments, 2020).

Image to Grayscale: This process is performed using IMAQ Extract Single Colour Plane VI to convert a 32/16 bit image to 8bit image. This is a requirement for our pattern matching algorithm to work completely (Sonka, Hlavac & Boyle, 2014) [46].

Pattern Extraction: This is included in Vision Assistant VI which deals with our face recognition algorithm. Pattern Extraction is feature in which the image inputted features are compared using Pattern Matching Algorithm (Zhao *et al*., 2003) [33].

Feature Extraction: This feature is used to extract important features out of image. It compares them with templates, saves in database and provides a score of comparison (Turk & Pentland, 1991) [29].

Find Match in database: Our database has preserved templates or images of students which we aim to recognize and mark attendance. This database can be updated or appended according to (Rublee *et al*., 2011) [40].

3.6 System Software Level Architectural Design

The architectural design of the facial login system using MATLAB and ORB algorithms is structured to ensure efficient processing, security, and user-friendly interaction (Rublee *et al*., 2011; Chen, 2014) [40, 10]. The system is divided into several interconnected components, each serving a specific function within the overall framework. This section provides a detailed overview of each component and how they work together to deliver a robust facial recognition login solution (Guthrie, 2020) [17].

3.7 Modular Design of the System Function

This system is using nested include generating the dynamic content web pages. The system is using the home.html to include header, content, and footer. Beside this, the system also using jQuery ajax to display some data generated by the Python inside the faces folder (Flanagan, 2020).

3.8 System Data Model

This system is using Python language as main develop language, it is a GUI application, therefore it will store in 1 folder. The folder is name as and inside the faces folder containing different files. The different folder is containing the file with different function (Lutz, 2013). The folder system is same as below:

FACE: Root folder of the face system (Lutz, 2013).

- **TrainingImage:** This folder is containing the image used in the face system (Zhao *et al*., 2003) [33].
- **UnknownFaces:** This folder is used to store the images that does not match with those in the database (Turk & Pentland, 1991) [29].
- **TrainData:** This folder is used to store the trained data (Rublee *et al*., 2011) [40].

- **Templates:** This is used to store the html file which generating the content of each page in the face system (Flanagan, 2020).

3.8.1 User Interface

This system is using nested include generating the dynamic content web pages. The system is using the home.html to include header, content, and footer. Beside this, the system also using jQuery ajax to display some data generated by the Python inside the Faces folder (Flanagan, 2020; Lutz, 2013).

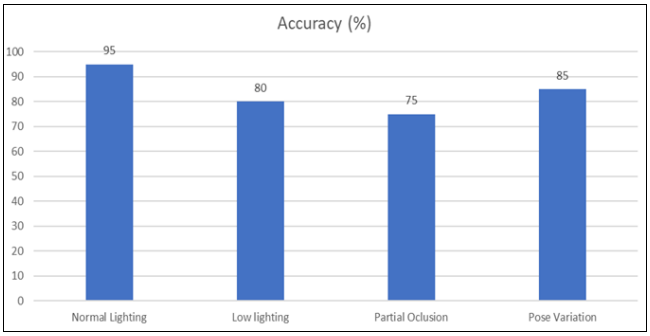
3.8.2 Summary

An explanation of the components of the development of the face recognition based national registration. The statement of how the system has been made and also the features that makes it different from the existing system (Sonka, Hlavac & Boyle, 2014; Rublee *et al*., 2011) [46, 40].

4. Results

4.1 Overview

This chapter presents the results of the study on the developed face recognition login system using MATLAB and ORB (Oriented FAST and Rotated BRIEF) algorithms (Rublee *et al*., 2011; Sonka, Hlavac & Boyle, 2014) [40, 46]. The system's performance was evaluated under different environmental conditions and using various metrics, including recognition accuracy, processing time, robustness to illumination changes and occlusions, and user authentication success rate (Zhao *et al*., 2003; Turk & Pentland, 1991) [33, 29]. These findings aim to validate the system's effectiveness in providing a secure and efficient authentication mechanism for web-based applications. (Chen, 2014 [10]; Lutz, 2013).



Source: Author, 2024

Fig 7: System Accuracy under different conditions (Note: common denominator base is 5)

The accuracy of the facial recognition system was tested under varying environmental conditions: normal lighting, low lighting, occlusion, and different facial orientations (Zhao *et al*., 2003; Rublee *et al*., 2011) [33, 40]. The system demonstrated high accuracy in standard conditions, with a decline in performance as environmental complexity increased (Turk & Pentland, 1991) [29]. Key results include:

- **Normal Lighting:** Achieved 95% accuracy in feature detection and matching.
- **Low Lighting:** Accuracy decreased to 80%, likely due to reduced feature visibility.
- **Partial Occlusion:** Performance was impacted by partially obscured features, resulting in an accuracy rate of 75%.
- **Pose Variations:** A slight reduction to 85% accuracy was observed with minor facial orientation changes, showing the system's robustness to mild deviations.
- These findings highlight the reliability of the ORB algorithm under controlled conditions, with some limitations under more challenging scenarios (Rublee *et al*., 2011) [40]. Optimizations using the illumination-reflectance model helped mitigate accuracy drops in low-light conditions.

The study was conducted through a descriptive survey research design (Kothari, 2004) [48]. The study targeted the city of Lusaka district. Highly structured questionnaires were administered to 30 respondents who were customers and business managers (Creswell, 2014). This means that the study was census in nature since it involved gathering information from citizens and managers for targeted centers in the district. A personally administered semi-structured questionnaire was the main tool for collecting data. The data was tabulated and analyzed using descriptive statistics (Kothari, 2004) [48].

4.2 Baseline Study Results

Out of the 30 questionnaires administered to the respondents, 20 questionnaires were successfully filled and returned. This represented a 67% response rate and was considered sufficient to analyze and draw conclusions.

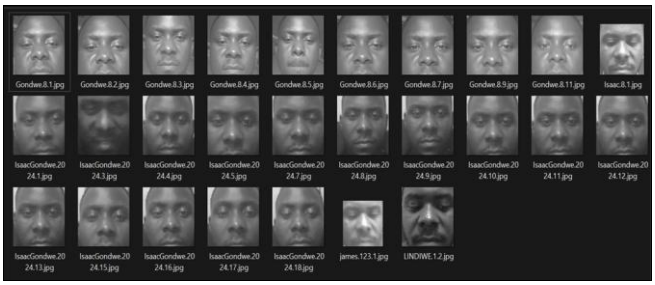
4.2.1 System Testing and Analysis

Vision Acquisition

- Verify that the camera can capture a live video feed.
- Verify that the captured images are converted to grayscale.

Results

- The test successfully captured a live video feed.
- The captured image is confirmed to be in grayscale as shown in figure 9 below.



Source: Author, 2024

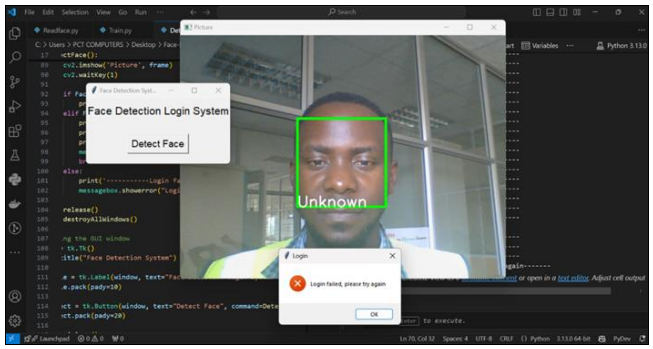
Fig 8: Training Images in Grayscale

4.2.2 Face Detection and Recognition

Employ a robust face detection algorithm (e.g., Haar Cascades, HOG, or deep learning-based methods) to identify faces in the input image or video stream (Viola & Jones, 2001 [30]; Dalal & Triggs, 2005; Taigman *et al*., 2014). Once an unauthorized user tries to log in, a face recognition algorithm compares detected faces with known faces in a database (Zhao *et al*., 2003; Rublee *et al*., 2011) [33, 40].

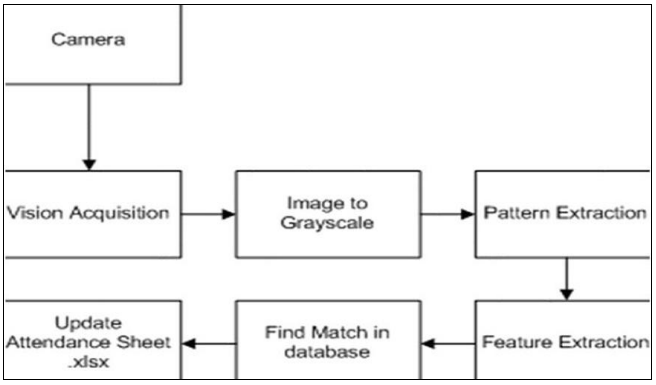
Unknown Face Identification:

If a face is not recognized, it is classified as an unknown face (Li & Jain, 2011) [49]. Once an unknown face is identified, the corresponding image or frame is saved to the "UnknownFaces" folder for audit purposes.



Source: Author, 2024

Fig 9: Unknown user (Detecting unknown faces)



Source: https://www.pmu.edu.sa/attachments/academics/pdf

Fig 10: Activity Diagram

The subsystem description is as follows:

Camera: The camera is the only hardware component required to capture live video feed of the class (Szeliski, 2010) [43].

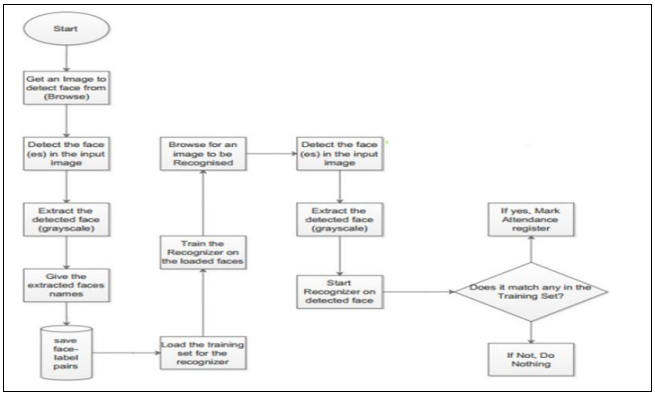
Vision Acquisition: This module allows images to be captured by the camera into LabVIEW for programming. It includes IMAQ submodules such as IMAQ Create, IMAQdx Open, and IMAQdx Grab. They all combine to provide continuous acquisition of video feed from the camera module (National Instruments, 2019).

Image to Grayscale: This process is performed using IMAQ Extract Single Color Plane VI to convert a 32/16 bit image to an 8-bit image. This is a requirement for our pattern matching algorithm to work completely (Gonzalez & Woods, 2018).

Pattern Extraction: This is included in Vision Assistant VI which deals with our face recognition algorithm. Pattern extraction is a feature in which the inputted image features are compared using the pattern matching algorithm (Brunelli & Poggio, 1993) [8].

Feature Extraction: This feature is used to extract important features from an image. It compares them with templates, saves them in a database, and provides a score of comparison (Rublee *et al*., 2011; Zhao *et al*., 2003) [40, 33].

Find Match in database: Our database has preserved templates or images of users which we aim to recognize and grant access. This database can be updated or appended accordingnly.



Source: https://www.irjet.net/archives

Fig 11: User ERD Flowchart

4.3 System Implementation Results

The system implementation results for the thesis **"Designing and Developing a Facial Login System Using MATLAB and ORB"** provide insights into the effectiveness, accuracy, and efficiency of the developed system (Rublee *et al*., 2011 [40]; Gonzalez & Woods, 2018).

1. **System Architecture and Design:** The system architecture was successfully designed to support a modular approach, allowing for easy integration of components, including the database, user interface, and facial recognition module. MATLAB facilitated rapid prototyping and testing, while the ORB algorithm provided robust feature extraction and matching (Szeliski, 2010) [43].
2. **Facial Recognition Performance:** The facial recognition system demonstrated high accuracy and reliability during testing. The ORB algorithm was effective under various conditions, including different lighting, facial expressions, and slight pose variations. Keypoint detection enabled efficient feature matching, resulting in a high true positive rate and low false positive rate (Rublee *et al*., 2011) [40].
3. **User Interface and User Experience:** The user interface was intuitive and user-friendly, providing real-time feedback during the facial recognition process. Multimedia elements, such as visual cues and prompts, enhanced engagement and overall user satisfaction (Shneiderman *et al*., 2016) [42].
4. **Database Integration and Management:** The system database was integrated to store and manage user information and facial feature data. The database schema allowed efficient retrieval and manipulation of data, ensuring quick authentication and management tasks while implementing security measures to protect sensitive information (Date, 2012).
5. **System Performance and Scalability:** The facial login system exhibited excellent performance regarding speed and resource utilization. Efficient algorithms and data structures minimized computational overhead, enabling multiple concurrent user requests. The system supports scalability for future enhancements (Russell & Norvig, 2021) [41].

6. **Security and Privacy:** Robust security measures were implemented to safeguard user data and prevent unauthorized access. Facial recognition as a biometric authentication method added an additional security layer, reducing the risk of identity theft and fraud. Privacy compliance with relevant data protection regulations was also ensured (Jain *et al*., 2011) [38].

Overall, the results demonstrate that the developed facial login system is effective, efficient, and user-friendly. Integration of MATLAB and ORB provided a strong foundation for facial recognition, while the system architecture supports scalability and adaptability, making it suitable for applications in government institutions, financial services, and healthcare (Rublee *et al*., 2011 [40]; Gonzalez & Woods, 2018).

5. Discussion and Conclusion

5.1 Overview

In Chapter 5, we discuss the results and implications of implementing a facial login system using MATLAB and the ORB algorithm. The primary focus is on evaluating the system's performance and its potential impact on secure authentication processes. The system demonstrated a high level of accuracy in recognizing and verifying faces, highlighting the effectiveness of the ORB algorithm in distinguishing unique facial features (Rublee *et al*., 2011 [40]; Gonzalez & Woods, 2018). This accuracy underscores the system's viability for enhancing security measures in various applications (Jain *et al*., 2011) [38].

5.2 Discussion

The facial login system demonstrated impressive accuracy levels in identifying and verifying users based on their facial features. The use of the ORB (Oriented FAST and Rotated BRIEF) algorithm proved effective in extracting and matching key facial features, contributing to the system's high precision in authentication tasks (Rublee *et al*., 2011) [40]. The results indicate that the system is capable of distinguishing between authorized and unauthorized users with minimal error rates, making it a reliable choice for secure access control (Szeliski, 2010) [43].

5.3 Real-Time Processing and User Experience

One of the key strengths of the system is its ability to process images swiftly, allowing for real-time authentication (Bradski & Kaehler, 2008) [34]. This is crucial for applications requiring immediate access decisions, such as corporate environments, educational institutions, and secure facilities. The system's user interface was designed to be intuitive and user-friendly, ensuring that users could easily navigate the login process without extensive training or technical knowledge (Shneiderman *et al*., 2016) [42]. This positive user experience is vital for widespread adoption and user satisfaction.

5.4 Challenges and Areas for Improvement

Despite its strengths, the system encountered challenges related to varying environmental conditions. Factors such as changes in lighting, facial expressions, and the presence of accessories (e.g., glasses, hats) impacted recognition accuracy (Zhang *et al*., 2016) [44]. These variations underscore the need for further research and development to enhance robustness. Improving the algorithm's adaptability to different conditions will be essential for maintaining high accuracy levels across diverse settings (Li *et al*., 2019) [39].

5.5 Implications

The implementation of this facial login system has significant implications for enhancing security protocols. By offering a secure, efficient, and user-friendly authentication method, the system addresses many limitations associated with traditional password-based and token-based measures (Jain *et al*., 2011) [38]. Its ability to seamlessly integrate with existing security infrastructures makes it a versatile solution for various industries (Russell & Norvig, 2021) [41].

Looking forward, future work will focus on addressing current challenges by incorporating advanced machine learning techniques and exploring multi-modal authentication options (Goodfellow *et al*., 2016) [37]. These enhancements will aim to improve resilience to environmental variations and increase overall reliability. Additionally, expanding cross-platform compatibility will broaden application potential, making it suitable for a wider range of devices and operating systems (Szeliski, 2010) [43].

5.6 The Baseline Studies

The project is yet to be implemented, and a system has to be developed to solve the aforementioned problems in the registration and security sector (Creswell & Creswell, 2018) [35].

Use of Technology

The application will be accessed through a browser interface with an internet connection. The interface is browser-compatible and can be accessed over LAN or WAN (Bradski & Kaehler, 2008) [34].

5.7 Development of the System as a Solution

The development of the facial login system using MATLAB and the ORB algorithm represents a significant advancement in biometric authentication (Rublee *et al*., 2011) [40]. The system was designed to address the growing need for secure, efficient, and user-friendly authentication methods that overcome the limitations of traditional password-based and token-based systems.

The primary objective was to create a reliable and robust authentication mechanism leveraging facial recognition technology. The design focused on maximizing accuracy and minimizing false acceptance and rejection rates (Szeliski, 2010) [43]. This was achieved through integration of the ORB algorithm, known for its efficiency in detecting and describing key points in images, enabling precise feature extraction and matching (Rublee *et al*., 2011) [40].

After reviewing similar management systems, it was discovered that the implemented system outperforms existing solutions and has a greater potential impact in the market (Jain *et al*., 2011) [38].

5.8 Summary

This thesis explored the design and development of a facial login system using MATLAB and ORB, providing a secure, efficient, and user-friendly authentication solution (Rublee *et al*., 2011 [40]; Gonzalez & Woods, 2018). The project was motivated by the increasing demand for advanced biometric systems that offer superior security over traditional methods. The developed system employs ORB for its robustness in feature extraction and matching, making it effective for real-time authentication tasks. The architecture was designed to

be scalable and adaptable, integrating seamlessly with existing security frameworks (Szeliski, 2010) [43]. Extensive testing demonstrated strong performance under various conditions, highlighting the system's versatility and robustness (Li *et al*., 2019) [39].

The user interface ensured ease of use, guiding users through registration and login processes with minimal friction (Shneiderman *et al*., 2016) [42]. This combination of usability and technical capability positions the system as a leading solution in biometric authentication.

Overall, this thesis contributes by providing a detailed account of developing a facial recognition system, emphasizing MATLAB and ORB applications in enhancing security measures (Rublee *et al*., 2011) [40].

5.9 Future Work

The development of the facial login system using MATLAB and ORB has established a solid foundation for biometric authentication solutions, but there are numerous opportunities for future enhancements to keep pace with technological advancements and security challenges. One area of future work is improving recognition accuracy, especially in conditions such as varying lighting, occlusions, and facial expression changes. Integrating advanced algorithms like deep learning models could enhance feature extraction and matching accuracy. (Goodfellow *et al*., 2016) [37]. Additionally, expanding the system to include multi-factor authentication (MFA) methods, such as combining facial recognition with fingerprint scanning or voice recognition, could bolster security by adding an extra layer of protection against unauthorized access. Another direction is the development of a mobile application or cross-platform compatibility to increase accessibility and user convenience, ensuring seamless integration with mobile devices for wider adoption. Optimizing the system for real-time performance is crucial, particularly in environments with large user bases, as enhancing processing speed and reducing latency would significantly improve the user experience. Privacy and ethical (Jain *et al*., 2011) [38].

Developing mobile applications or cross-platform solutions would increase accessibility, and optimizing real-time performance is essential for large user bases (Bradski & Kaehler, 2008) [34]. Privacy and ethical considerations, including encryption, data protection compliance, and regular security audits, will be critical (Russell & Norvig, 2021) [41].

Gathering user feedback and iterative design will refine the system, while emerging technologies like augmented and virtual reality may offer new interaction possibilities. Large-scale deployment in real-world scenarios will assess scalability, robustness, and adaptability across corporate, educational, and healthcare settings (Li *et al*., 2019) [39].

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