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Automated Class Attendance Management System using Face Recognition: an Application of Viola-Jones Method

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Abstract

In recent years, facial recognition technology has gained widespread acceptance, finding application in diverse sectors, including education. One notable implementation is in the enhancement of class attendance systems at universities. Departing from traditional manual sign-in processes, the integration of facial recognition has revolutionized attendance tracking, offering an automated and efficient solution. The primary focus of this research is the development of an automatic class attendance management system through facial recognition. This innovative system aims to alleviate the burden on students by eliminating the need for manual attendance sheets, replacing them with a seamless, technology-driven process. Moreover, the recorded attendance data holds significant potential for in-depth analysis, providing valuable insights for both instructors and administrators. The research methodology employed a prototyping software development approach, with the system modeled using UML version 2.0. The Viola-Jones method was chosen as the face detection algorithm, showcasing the commitment to utilizing cutting-edge techniques. Python and PHP were employed as programming languages, demonstrating versatility, while OpenCV served as the computer vision library, ensuring robust functionality. The choice of MySQL as the database management system (DBMS) further underscores the systematic and comprehensive approach to system development. Extensive black box tests were conducted, yielding promising results. The outcome is a fully functional prototype of an automatic class attendance system employing facial recognition. This breakthrough not only simplifies the attendance process but also provides a solid foundation for future advancements in educational technology. As technology continues to evolve, the integration of facial recognition in educational settings is poised to become increasingly prevalent. This research not only contributes to the ongoing dialogue on the intersection of technology and education but also sets the stage for further innovations in automated attendance management systems.

Keywords: Face recognition, class attendance management system, Viola-Jones method, Python, OpenCV

1. Introduction

Attendance is an integral aspect of the educational process, requiring active participation from both students and teachers. The act of being physically present in the classroom is fundamental to the exchange of knowledge, interaction, and effective learning. To ensure the regular attendance of participants, attendance records must be maintained accurately. Unfortunately, the conventional manual attendance method, still widely employed, is susceptible to various shortcomings, including human errors, absenteeism, and operational inefficiencies.

In light of the rapid advancements in technology, particularly in automation and facial recognition technology, we have the means to address and rectify these issues inherent in the manual attendance process. Embracing these technological innovations offers the potential to enhance the accuracy and efficiency of attendance tracking and management. One promising avenue of improvement is the development of an automatic attendance system that incorporates facial recognition technology. This technology can provide a seamless and reliable solution for attendance monitoring, mitigating the challenges of the manual approach.

The manual attendance method's well-documented limitations have spurred a call for innovative solutions, particularly in the form of automated attendance systems. While existing literature explores various aspects of attendance tracking, there exists a notable research gap in comprehensively understanding how automated systems, specifically those incorporating facial recognition technology, can effectively address these issues in educational settings. This research

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aims to bridge this gap by delving into the implementation and evaluation of automated attendance systems, with a particular focus on the Viola-Jones face detection algorithm.

The current landscape of automated attendance systems encompasses diverse technologies, ranging from biometrics and RFID (Radio-Frequency Identification) to mobile applications. Facial recognition technology, propelled by advancements in computer vision and machine learning, has gained prominence across industries, from security to marketing and smartphone authentication. However, its application in educational settings for attendance tracking remains an area requiring further exploration.

Within this context, the Viola-Jones face detection algorithm emerges as a key player, recognized for its efficiency in detecting faces within images. Despite its potential, there is a dearth of empirical research evaluating its effectiveness in improving attendance management, especially in educational environments. Our research seeks to fill this void by building upon the existing state of the art, leveraging developments in both hardware and software components, to create an automatic attendance system that harnesses the power of facial recognition technology based on the Viola-Jones algorithm. In doing so, our aim is to contribute valuable insights to the practical implementation and effectiveness of such systems within the realm of education.

2. Literature Review

In this section, a comprehensive exploration of the literature reviews employed in the current study will be undertaken. The discussions will delve into various facets, beginning with an elucidation of the overarching concept of face recognition. This encompasses a thorough analysis of the theoretical underpinnings and advancements in the field, shedding light on key principles and emerging trends.

Moreover, a critical examination of the Viola-Jones algorithm will be presented, emphasizing its pivotal role as an object detection framework, particularly in the context of identifying human faces. The discourse will unravel the algorithm's intricacies and effectiveness, providing valuable insights into its application within the broader scope of facial recognition technologies.

Furthermore, attention will be directed towards the utilization of Local Binary Pattern (LBP) for the extraction of texture features. A detailed exploration of LBP's contribution to enhancing the accuracy and reliability of facial recognition systems will be elucidated, offering a nuanced understanding of its role in the overall study framework.

The narrative will also touch upon the programming tools harnessed in the course of this research, providing a glimpse into the technological landscape that facilitated the implementation of various algorithms and methodologies. Additionally, an overview of the chosen software development model will be presented, elucidating the systematic approach employed in the design and implementation phases.

In essence, this section aims to furnish readers with a thorough comprehension of the foundational literature that underpins the study, offering a holistic view of the diverse components and methodologies shaping the investigation into face recognition and its associated algorithms.

2.1. Face Recognition

Facial recognition, a cutting-edge technology, enables machines to discern and identify individuals through their facial features captured in images. This transformative technology closely mirrors the human ability to recognize and differentiate faces, utilizing sophisticated algorithms and pattern recognition. Researchers and developers in the field of facial recognition are dedicated to refining and replicating the intricate processes of human facial identification within the realm of computer systems [1]. By delving into the complexities of facial features, expressions, and unique characteristics, they strive to enhance the accuracy and efficiency of facial recognition algorithms. As this field continues to advance, it holds tremendous potential for applications in security, law enforcement, user authentication, and various other domains where precise identification is paramount. The ongoing efforts in facial recognition studies underscore a commitment to bridging the gap between human perception and machine learning, ushering in a new era of technological capabilities with profound implications for society.

2.2. Viola-Jones Framework

The Viola-Jones object detection framework stands as a pioneering milestone in the realm of real-time object detection, marking its inception in 2001 through the collaborative efforts of Paul Viola and Michael Jones [2]. Remarkably, it emerged as the inaugural framework capable of achieving competitive detection rates in real-time scenarios. Originally conceptualized to address the challenges of face detection, Viola-Jones has transcended its initial motivation and evolved into a versatile and dependable tool for detecting various objects. Its enduring significance in the field is underscored by its continued use as a reliable face detection framework, adapted and enhanced over the years to align with the evolving needs of users. The framework's longevity and sustained relevance are testament to its efficacy, making it an integral component in a diverse array of applications that necessitate robust and efficient object detection capabilities. As advancements persist, Viola-Jones remains at the forefront, embodying a testament to the enduring impact of innovative frameworks in computer vision.

2.3. Local Binary Pattern

In this study, Local Binary Pattern (LBP) plays a crucial role in facial recognition. Its application involves the conversion of detected faces into a feature histogram, employing a simple yet highly efficient texture operator. The essence of LBP lies in labeling the pixels of an image by establishing environmental boundaries for each pixel, resulting in a binary number [3]. The outcome of this process is then meticulously recorded into a feature histogram. Subsequently, this method is seamlessly integrated with the Viola-Jones framework, synergistically contributing to the creation of a robust system. The combined approach enhances the system's capability to recognize and identify faces effectively.

The integration of Local Binary Pattern (LBP) in facial recognition involves converting detected faces into a feature histogram. LBP, a straightforward yet powerful texture operator, assigns binary numbers to pixels in an image based on established environmental boundaries for each pixel [3]. The recorded results in the feature histogram serve a crucial purpose in the face identification process within the system. This LBP method is not employed in isolation; instead, it works collaboratively with the Viola-Jones framework. Together, they form a cohesive system that excels in recognizing and identifying faces with precision and efficiency. This dual approach enhances the overall performance and accuracy of the facial recognition system.

2.4. HTML and PHP

Hyper Text Markup Language (HTML) serves as the foundational language for web development, providing the essential tools to structure and present content on the expansive canvas of the World Wide Web. As a declarative language, HTML enables developers to organize textual and multimedia elements within a web page, ranging from simple articles to multimedia-rich presentations. Its versatility and adaptability make HTML the standard programming language for web development, ensuring compatibility across diverse browsers and devices to deliver a consistent user experience [4].

Complementing HTML's structural capabilities is Personal Home Page Tools (PHP), also known as PHP: Hypertext Preprocessor. Unlike HTML, PHP is a server-side scripting language designed for creating dynamic and interactive web pages. It extends beyond the static nature of HTML, empowering developers to incorporate functionalities such as user authentication, database interactions, and real-time content updates [4]. PHP's widespread adoption is evident across the digital landscape, powering websites of various scales, from individual blogs to expansive e-commerce platforms and social media giants. The seamless integration of PHP with HTML allows developers to leverage the strengths of both languages, creating feature-rich and responsive websites that cater to the evolving expectations of online audiences. In essence, the collaborative interplay between HTML and PHP exemplifies the dynamic evolution of web development, ensuring the creation of immersive and interactive online experiences.

2.5. phpMyAdmin and Python

In the realm of database management, phpMyAdmin emerges as a noteworthy tool, given its open-source nature and PHP foundation. Specifically designed to facilitate the administration of MySQL or MariaDB database servers [5], phpMyAdmin plays a pivotal role in this study as the chosen database. Nevertheless, it is crucial to note that alternatives like MySQL and other SQL-based databases could seamlessly replace phpMyAdmin within the context of this research.

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Shifting gears to the programming aspect, Python takes the center stage. Renowned for its interpretative prowess, object-oriented paradigm, and high-level functionality with dynamic semantics [6], Python stands as the language of choice for developing the facial recognition applications in this study. Leveraging the Python version of the facial recognition library, the research delves into the vast possibilities that Python unfolds. Beyond its capabilities in facial recognition, Python's versatility is exemplified through its array of libraries, extending its utility beyond a singular domain. In the scope of this study, Python's prowess extends to establishing connections between Python and the MySQL database, showcasing the language's adaptability and multifaceted application in the technological landscape.

2.6. Prototype Development

Prototype development plays a crucial role in the iterative refinement of systems before their full-scale implementation. This method involves subjecting prototypes, which are scaled-down versions of the intended system, to scrutiny by potential users. Once a prototype is crafted, it is handed over to a group of testers who assume the role of potential users. These testers meticulously interact with the prototype, providing valuable feedback on its functionality, design, and user experience. The iterative nature of prototype development enables continuous enhancements to be made based on the received feedback. Each iteration refines the prototype, addressing identified shortcomings and incorporating suggested improvements. This cyclical process of refinement and feedback persists until the prototype reaches a level of maturity and usability that deems it ready for full-scale implementation within the organization [7]. Through this methodical approach, prototype development ensures that the final system aligns closely with user expectations and organizational requirements.

2.7. Related Previous Works

The existing body of research on automated attendance systems and face recognition has laid a substantial foundation for the development of our proposed system. Among these studies, noteworthy examples include an automated attendance system implemented in a college setting, integrating face recognition and NFC technology [8]. Additionally, a prototype attendance system utilizing face recognition, Arduino technology, and applied at SMKN 5 Tangerang [9], showcases the versatility of such solutions. Another study introduces a cost-effective approach to automobile security, emphasizing the detection and recognition of human faces [10]. Furthermore, a door security system has been designed based on face recognition technology with the integration of Arduino [11]. Notably, a novel solution has been explored by combining RFID tags and facial recognition for monitoring systems [12]. These referenced works serve as vital sources of inspiration and knowledge that have significantly informed the conceptualization and development of our proposed system. Drawing on the insights and methodologies established in these prior studies, our aim is to contribute to the advancement and refinement of automated attendance and face recognition systems, ensuring a robust and innovative solution in our proposed system.

3. Methodology

In Figure 1, we outline the comprehensive research methodology adopted in this study. The study begins with an in-depth literature review to establish the foundation for the design of our facial recognition system, while also identifying the essential supporting studies necessary to inform our research [13] [14]. This literature study serves as the bedrock upon which we build our approach. Following the literature review, a thorough feasibility study is undertaken to assess the viability of our research endeavor. This study not only investigates the potential benefits of the proposed system but also explores the practicality of implementing such a system in real-world educational settings.

The dataset used in this study comprises a multifaceted approach that encompasses various stages of research and system development. The figure presented outlines the comprehensive research methodology employed:

1) Literature Review (References [13] [14]): The study initiates with an extensive literature review aimed at establishing a robust foundation for the design of the facial recognition system. This review not only identifies relevant studies supporting the research but also serves as the bedrock upon which the entire approach is built. The dataset for this phase includes the key findings and insights gleaned from the literature.
2) Feasibility Study: Following the literature review, a thorough feasibility study is conducted to assess the viability of the proposed facial recognition system. This dataset includes an exploration of potential benefits

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and an investigation into the practicality of implementing such a system in real-world educational settings. The findings from this study contribute to understanding the feasibility of the research endeavor.

3) System Prototype Development (References [15] [16]): The next phase involves the development of a system prototype. The dataset for this stage includes the tangible outputs of the prototype, showcasing a facial recognition-based automatic attendance system tailored to the specific needs of classroom attendance management. This dataset comprises the technical specifications, design elements, and any considerations made during the prototype development.
4) Black Box Testing: To ensure the reliability and effectiveness of the developed system, black box testing is employed. This rigorous evaluation method explores the functionalities, interfaces, and user experience of the system. The dataset generated from this testing phase includes information on any identified flaws, shortcomings, or areas requiring refinement. This data is crucial for making necessary adjustments to enhance the overall performance and reliability of the facial recognition-based automatic attendance system.

Subsequently, we proceed with the development of a system prototype, focused on creating a facial recognition-based automatic attendance system tailored to the specific needs of classroom attendance management. This prototype serves as a tangible demonstration of our research concept and a basis for further testing and evaluation [15] [16]. To ensure the reliability and effectiveness of our system, we employ black box testing, a rigorous evaluation method that rigorously examines the system's functionalities, interfaces, and user experience. This testing phase is critical in uncovering any potential flaws or shortcomings and allows for necessary refinements to be made.

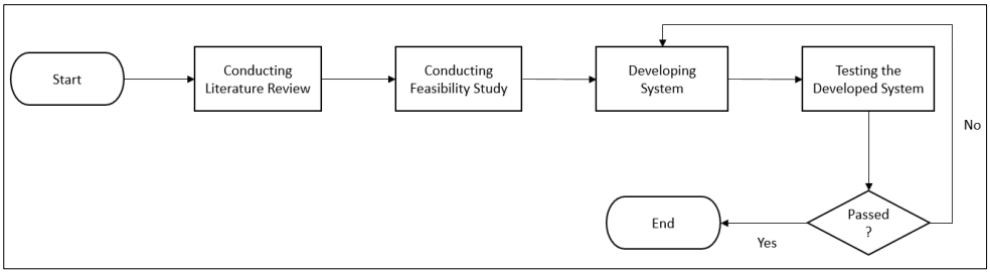

Figure 1. Research flow

In summary, the research methodology depicted in Figure 1 encompasses a holistic and systematic approach to investigating the development and implementation of a facial recognition-based automatic attendance system. This methodological framework ensures that our research is robust, well-informed, and capable of yielding valuable insights and contributions to the field of attendance management in educational contexts [17] [18][19].

4. Result and Discussion

As seen in figure 1, the research method of this study is as follows. First, a literature study will be carried out to determine the facial recognition system design and find supporting studies required to conduct this research. Furthermore, a feasibility study is conducted to determine whether this study will create a viable system or not, which includes the benefits of this system. This system uses the development of a system prototype to make a facial recognition-based automatic attendance system prototype for class attendance. Then, black box testing will be carried out to test the developed system accordingly [20][21][22].

4.1. The System Design

The general mechanism of the automated attendance system for class attendance is shown in Figure 2.

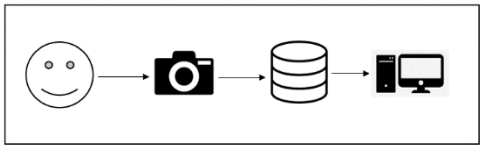

Figure 2. The system mechanism

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As seen in Figure 2 above, the followings are the explanations of how the automated class attendance system was designed:

1) Every registered user comes to the available automatic attendance system.
2) The user shows his/her face directly to the camera until his/her face is detected on the screen.
3) The user confirms his/her registration based on the instructions displayed on the screen.
4) User arrival times are recorded and entered into the database based on their own faces, classes they attended and the date of the sessions they joined.

More detailed system design is reported using data flow diagram (DFD), as illustrated in Figure 3 and 4 respectively.

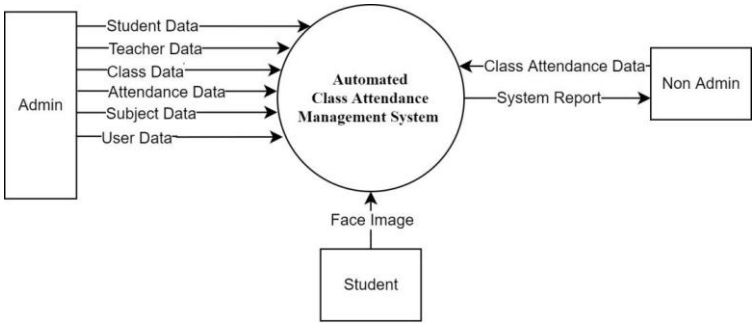

Figure 3. Data flow diagram – context level

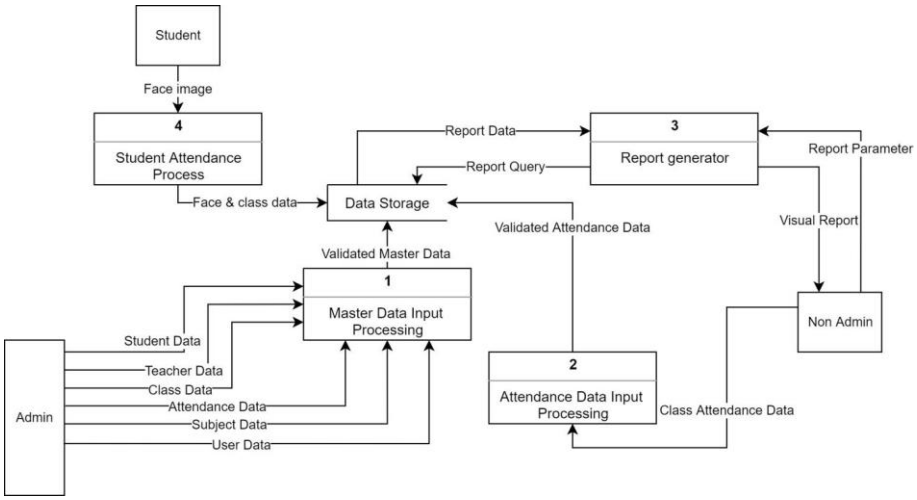

Figure 4. Data flow diagram – level 1

4.2. System Development

The application for the attendance system is divided into two parts, namely the attendance application and the web application (Dashboard). The use case diagram is illustrated in Figure 5 below.

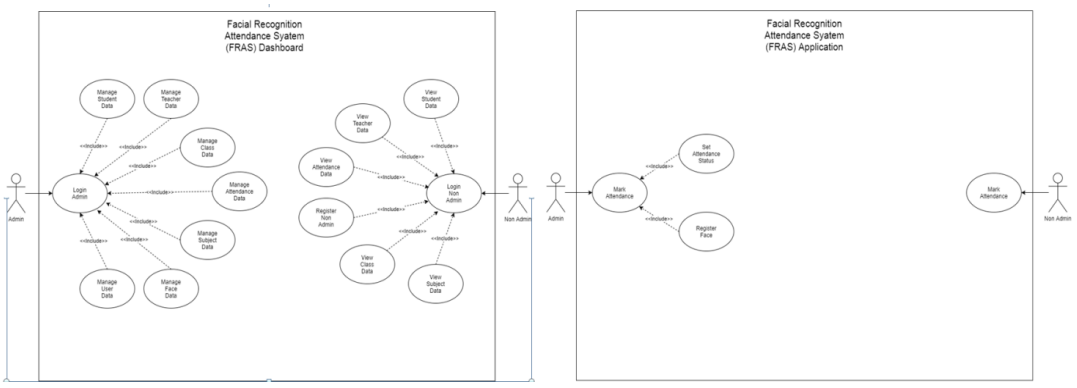

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Figure 5. The user interface for user's attendance application.

The attendance application created using Python programming language, functions to manage and record time of attendance for each instance. On the other hand, the web application which was developed using PHP, functions to view and modify the data in web form. The prototype for the attendance application and the web application are shown in Figure 6 and Figure 7, respectively. While the prototype for the attendance application for administrators is depicted in Figure 8.

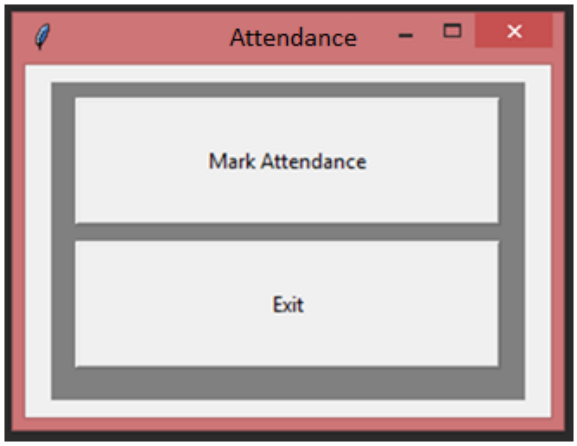

Figure 6. The user interface for user's attendance application.

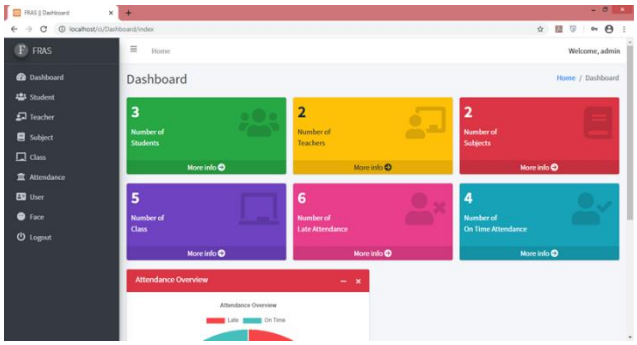

Figure 7. The user interface for web application.

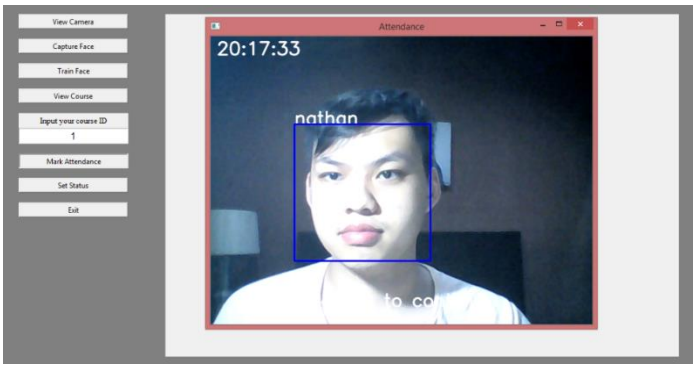

Figure 8. The user interface for administrator attendance application.

The attendance application as shown in Figure 6 is an interface made to mark user attendance. The user only needs to press the button labelled 'Mark attendance' to activate the camera and press the appropriate key as shown on the screen to mark his/her presence on the system. Meanwhile, the web application as seen in Figure 7 is an interface designed to assist administrators in managing existing data related to attendance. Using this web interface most administrative tasks can be completed by the administrator. The attendance application for administrators as illustrated in Figure 8 is an interface created to register data related to attendance processes, such as face registration and updating the status of each attendance in the database. This interface is only available for administrators to enroll new users for attendance processes and change attendance status automatically in the attendance database.

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4.3. Testing Results

In this study, there are three (3) parameters used to record time attendance at correct entries. Those three parameters are user face ID (based on Viola Jones face detection algorithms), user class, and date of attendance. The system will record each user's time of attendance based on the parameters. The test was carried out in twelve (12) attempts to check if the system can detect faces correctly and enter time of attendance accurately into the attendance database. The test result is presented in Table 1.

Table 1. The testing results.

Testing attempt	Face Detection	Update on Database
1	Successfully detected face	Successfully update database
2	Successfully detected face	Successfully update database
3	Successfully detected face	Successfully update database
4	Successfully detected face	Successfully update database
5	Successfully detected face	Successfully update database
6	Successfully detected face	Successfully update database
7	Successfully detected face	Successfully update database
8	Successfully detected face	Successfully update database
9	Successfully detected face	Successfully update database
10	Successfully detected face	Successfully update database
11	Successfully detected face	Successfully update database
12	Successfully detected face	Successfully update database

Of the twelve (12) tests carried out to examine the developed system, it can be seen in Table 1 that the twelve (12) tests have succeeded in entering the correct attendance time in the correct attendance list. This means our developed system has been working properly and thus, to some extent it might be ready to be utilized in the real class settings.

5. Conclusion and Future Research Directions

The findings of this study affirm the positive impact of implementing an automated attendance system utilizing the Viola-Jones algorithm in conjunction with Local Binary Patterns (LBP). The system demonstrates notable benefits for those seeking a more accurate and efficient attendance tracking mechanism. The achieved 100% detection success rate in the conducted tests underscores the system's effectiveness in capturing and recognizing faces for attendance purposes. However, it is crucial to acknowledge the current study's limitations, notably the testing being conducted on limited samples and under specific conditions. The effectiveness of the system in larger or more complex settings remains an area warranting further exploration and analysis. As a result, the study recommends that future research endeavors extend their scope by incorporating a more extensive and diverse set of samples to comprehensively evaluate the efficiency and accuracy of the automated attendance system before considering widespread implementation.

The impact of this research extends beyond the immediate findings. Firstly, it contributes to the advancement of automated attendance systems, providing empirical evidence of the viability and success of the Viola-Jones and LBP-based approach. Secondly, it highlights the importance of continued research and development in this domain to address the scalability and adaptability of such systems in varying educational contexts. In terms of research impact, this study serves as a catalyst for future investigations into refining and optimizing automated attendance systems. The recommendation for testing on a larger scale prompts researchers and practitioners to consider the practical implications and real-world applicability of the proposed system. By emphasizing the need for a more expansive dataset, this research guides subsequent studies towards a more thorough examination of system performance under diverse conditions, thereby enhancing the robustness and generalizability of automated attendance solutions.

In conclusion, the research impact lies not only in affirming the benefits of the Viola-Jones and LBP-based automated attendance system but also in steering the direction of future research toward addressing scalability concerns and expanding the applicability of such systems in broader educational settings.

6. Declarations

6.1. Author Contributions

Conceptualization: A.E.W. and N.J.H.; Methodology: N.J.H.; Software: A.E.W.; Validation: A.E.W. and N.J.H.; Formal Analysis: A.E.W. and N.J.H.; Investigation: H.; Resources: A.R.M.; Data Curation: H.; Writing Original Draft Preparation: H. and A.R.M.; Writing Review and Editing: H. and A.R.M.; Visualization: C.A.H.; All authors, A.E.W., N.J.H., H., A.R.M., and C.A.H., have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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