

Iris-Based Railway Systems: Advancements in Ticketing and Passenger Verification

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Abstract

As railway transportation continues to expand and modernize, ensuring the safety and security of passengers, staff, and infrastructure has become a major priority. Traditional security methods, including manual identity verification, paper-based ticketing, and conventional access control systems, are often limited in their ability to prevent unauthorized access, identity fraud, and operational delays. To address these challenges, this paper explores the integration of biometric authentication technologies into railway systems as a reliable and advanced security solution. The study focuses primarily on biometric modalities such as facial recognition and iris authentication, which offer accurate, contactless, and efficient methods for passenger identification and access management. It examines how these technologies can streamline ticket verification, minimize impersonation, reduce waiting times, and strengthen security across railway stations and restricted operational areas. In addition, the paper discusses the practical challenges associated with implementing biometric systems, including privacy concerns, data protection requirements, system accuracy under varying environmental conditions, infrastructure costs, and public acceptance. The research also highlights the importance of adopting secure data management practices and regulatory compliance to build user trust. Through a detailed evaluation of current technologies and their potential applications, this study demonstrates that biometric authentication can significantly improve operational efficiency while enhancing overall safety, reliability, and passenger experience within modern railway networks. The findings provide valuable insights for policymakers, railway authorities, and technology developers seeking to implement intelligent, secure, and future-ready railway transportation systems.

Keywords: Passenger identification, Biometric authentication, unauthorized access prevention, safety enhancement

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INTRODUCTION

The current train ticket checking system comprises many challenges, such as the tickets must be checked manually by the conductor of the train, and the passenger must carry physical identification proof, without which they cannot travel. The conductor of the train takes care of the entire process of checking tickets and managing any vacancies of a seat that may occur during the course of the journey. In the case of any contingencies during travel, there is no alert system that can notify the respective passenger. If any confirmed passenger does not board the train for the journey, their seat must be manually reallocated to any passenger who may request the seat, without either party getting any notification of the same.

Iris recognition, a cutting-edge biometric technology, is poised to revolutionize the efficiency of the railway sector. By implementing iris recognition systems, railways can significantly enhance the speed and accuracy of identity verification processes, thereby mitigating the challenges associated with traditional ticket checking methods. This innovative technology allows for swift and non-intrusive passenger authentication, eliminating the need for manual ticket inspections and physical identification proofs. The utilization of iris recognition in railway operations not only streamlines the ticket verification process but also enhances security measures. The unique and virtually immutable nature of iris patterns ensures a high level of accuracy in identifying passengers and reduces the likelihood of unauthorized travel.

Moreover, the integration of iris recognition technology facilitates real-time monitoring of passenger movements, enabling railway authorities to promptly address any anomalies or contingencies that may arise during the journey.

LITERATURE REVIEW

A foundational aspect of related work encompasses the broader domain of biometrics in transportation security. Scholars have extensively studied the use of biometric modalities, including fingerprint and facial recognition, to enhance security measures across various transportation sectors [1]. The insights derived from these studies provide a valuable backdrop for understanding the potential impact of biometrics on railway security. Examining specific case studies in which biometric authentication systems have been successfully implemented in transportation settings provides crucial insights into real-world applications [2]. An in-depth analysis of a biometric-based access control system in a major international airport sheds light on its positive implications for security and efficiency. These case studies offer tangible examples that can be extrapolated to the unique challenges faced by railway operations [3].

Researchers have explored the efficiency gains associated with biometric integration in public transportation systems [4, 5]. This broader perspective allows for a comprehensive understanding of how biometrics can streamline processes, reduce operational bottlenecks, and enhance the overall passenger experience—insights that can be directly applied to the railway industry [6].

They delved into the ethical implications and privacy concerns associated with the widespread adoption of biometrics in various sectors, including transportation. Addressing these considerations is critical, particularly in railway operations, where a balance must be struck between enhanced security and the protection of individual rights [7]. Understanding the ethical landscape is imperative for the responsible deployment of biometric technologies.

They provide an overview of recent technological advancements in biometric systems, exploring emerging trends and innovations [8]. Understanding cutting-edge developments in biometrics ensures that any proposed solutions for railway operations remain at the forefront of technological progress, enhancing their efficacy and adaptability [9].

PROJECT DESCRIPTION

Biometrics consists of methods for uniquely recognizing humans based on one or more intrinsic physical or behavioral traits [1]. In computer science, biometrics are used as a form of identity access management and access control. It is also used to identify individuals in groups that are under surveillance. Biometric information possesses merits, including being unique, hard to lose, and stable over a certain period of time, which has enormous market prospects.[7] The iris of the eye has been described as the ideal part of the human body for biometric identification for several reasons [3]. The eye is an internal organ that is well protected against damage and covered by a highly transparent and sensitive membrane. An iris scan is similar to taking a photograph and can be performed from approximately 10 cm to a few meters away [4]. While some medical and surgical procedures can

affect the color and overall shape of the iris, the fine texture remains remarkably stable. A biometric system can operate in the following two modes:

1. *Verification*: A one-to-one comparison of a captured biometric with a stored template to verify that the individual is who they claim to be. Can be done in conjunction with a smart card, Can be done in conjunction with a smart card username, or an ID number [2].
2. *Identification*: A one-to-many comparison of the captured biometric data against a biometric database to identify an unknown individual. The identification only succeeds in identifying the individual if the comparison of the biometric sample to a template in the database falls within a previously set threshold [3].

Iris recognition has been studied and developed for many decades. It is rarely impeded by glasses or contact lenses [4]. The iris is the colored ring around the pupil of every human being and, like a snowflake, no two are alike. Each is unique, exhibiting a distinctive pattern that forms randomly in the uterus in a process called chaotic morphogenesis. The iris is a muscle that regulates the size of the pupil and controls the amount of light that enters the eye [10].

AUTHENTICATION PROCESS

The implementation of biometric authentication in railway systems involves a two-phase process: enrollment and verification. During enrollment, individuals voluntarily submit their biometric data, such as iris scans or facial features, which are securely stored in a database. When seeking access to secure areas, individuals present their biometric identifiers, and the system compares them with the stored template during the verification phase. If there's a match within an acceptable threshold, access is granted. Biometric authentication is applied in various railway scenarios, including passenger boarding, employee access control, and security checkpoints. Key considerations include user-friendly interfaces, high accuracy, and robust security measures to protect the stored biometric information [9]. The integration of biometric procedures contributes to streamlined operations and heightened security in the evolving landscape of railway transportation.

Enrollment

The enrollment process for iris recognition involves capturing and digitizing unique patterns within an individual's iris. During enrollment, a person's eye is scanned, and the distinctive features of the iris are extracted to create a digital template for the eye. This template, which represents an individual's unique iris characteristics, is securely stored in a database [10]. The enrollment process is typically a one-time procedure that creates a biometric reference that serves as a key for subsequent identification and authentication. This ensures that each individual's identity can be accurately and securely verified using their iris patterns in various applications, including access control in railway systems.

Verification

The verification procedure for iris recognition involves capturing a high-resolution image of an individual's iris using a specialized camera. The captured iris image is then processed to extract unique features and create a digital template, as shown in Figure 1. During subsequent verification attempts, the individual presents their iris, and the system compares the captured image with the stored template image. Advanced algorithms analyze the iris patterns, and if a match is found within an acceptable threshold, the verification is successful, granting access or authentication to the user. This streamlined process ensures efficient and secure identification based on the distinct and stable iris.

PROPOSED SOLUTION

Ticket Booking

The iris recognition procedure within the railway system follows a systematic flowchart for efficient implementation. Initially, as passengers approach the ticketing area, they voluntarily participate in the iris scanning process, wherein the unique patterns of their irises are captured using specialized iris recognition cameras. Subsequently, the captured iris data undergo preprocessing steps, including noise reduction and image enhancement, to ensure optimal quality for subsequent analysis.

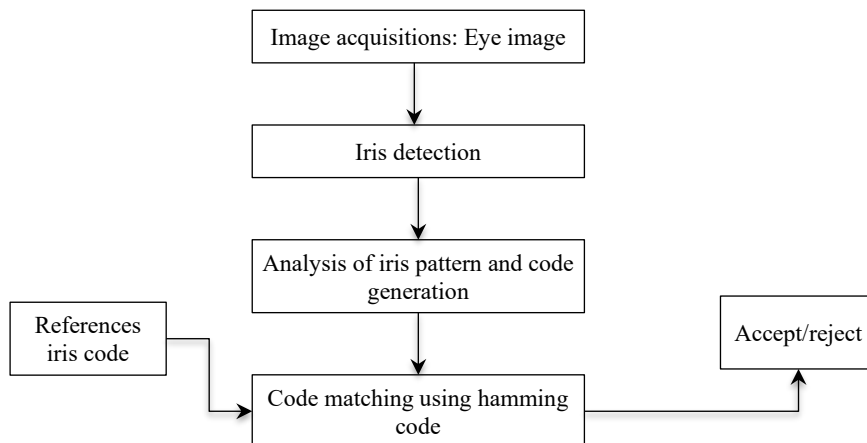


Figure 1. Enrollment of iris [5].

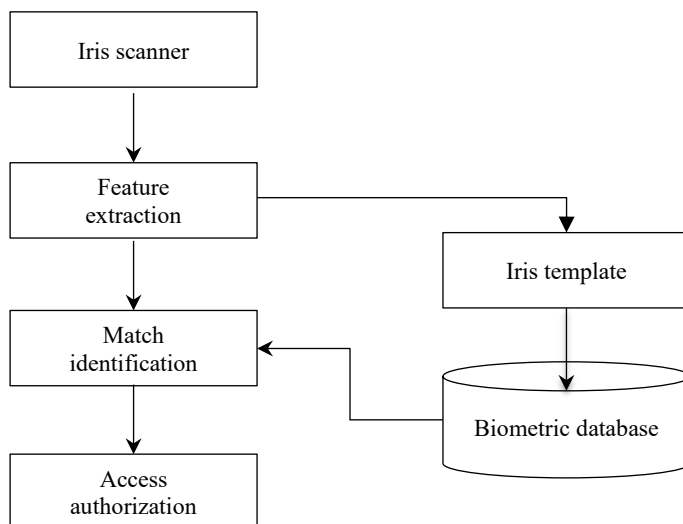


Figure 2. General block diagram of iris recognition [7].

Following preprocessing, the system employs a Haar cascade classifier based on the Haar wavelet technique to analyze and categorize iris patterns. The Haar cascade classifier utilizes integral image concepts to compute the detected features and employs the AdaBoost learning algorithm to select a subset of crucial features from an extensive set. This step enhances the efficiency of the classification process.

Cascading techniques are then applied to detect and verify the iris patterns against the stored database of registered passengers. If a match is found, the system proceeds to authenticate the passenger's identity and link it to their digital ticket information. In the case of a mismatch or absence of a registered iris pattern, the system may prompt alternative verification methods or flag the situation for manual intervention by railway personnel. Once authentication is successful, the smart ticketing system seamlessly updates the passenger's travel status, eliminating the need for physical tickets. The system then generates a digital record of the passenger's journey, contributing to efficient and paperless ticket management. Additionally, real-time monitoring features allow railway authorities to track passenger movements and address any anomalies promptly, as shown in Figure 2.

Iris-Based Railway Boarding

The iris verification procedure implemented during train boarding is a sophisticated and secure biometric process. As passengers approach the boarding gate, a designated iris recognition system captures high-resolution images of their irises. The image is then processed using advanced image

recognition algorithms that focus on the unique patterns in the iris. The system employs the Haar cascade classifier and AdaBoost learning algorithm to efficiently identify key features in the iris patterns, ensuring accurate and reliable verification.

Once the iris patterns are analyzed, the system compares them with pre-registered data in the database to confirm the identity of the passengers. This swift and non-intrusive process eliminates the need for traditional ticket checks and physical identification, thereby streamlining the boarding experience. The implementation of iris verification not only enhances security by minimizing the risk of unauthorized travel but also contributes to the operational efficiency of the airport.

The system is designed to provide real-time verification results to ensure a seamless boarding process. To further improve accuracy, the model was continuously trained using iris images specific to the train station location. This adaptive approach ensures that the system remains robust and reliable, offering a technologically advanced solution for enhancing security and efficiency during train boarding.

For Individuals with Visual Impairments

To address the accessibility challenges faced by visually impaired individuals within the railway system, the implementation of an alternative to iris recognition is imperative. Considering inclusiveness, a viable option involves the integration of advanced voice recognition technologies. This alternative authentication method allows visually impaired passengers to interact with the railway system using voice commands, ensuring a seamless and independent experience. Passengers can verbally authenticate their identity, engage in ticketing processes, receive real-time information, and navigate through the station. By prioritizing inclusivity through innovative technologies, the railway system can ensure that all passengers, including those with visual impairments, have equal access to the services provided, contributing to a more accessible and user-friendly transportation environment for all.

CONCLUSION

The integration of biometric authentication systems represents a pivotal step towards advancing efficiency and fortifying security in railway operations. Through streamlined access control, enhanced passenger identification, and the prevention of unauthorized access, biometric technologies offer tailored solutions to the unique challenges of the railway industry. As this technology evolves, its seamless integration with existing railway infrastructure promises a future marked by secure, efficient, and technologically advanced transportation systems. The multifaceted benefits of biometric authentication underscore its transformative potential, positioning it as a cornerstone for modernizing railway efficiency and security.

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