

A Comprehensive Study on Vehicle Security by Bio-lock

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Abstract

As vehicle theft and cyber threats continue to rise, the automotive industry is increasingly seeking innovative security solutions to protect vehicles. This research work investigates the implementation of bio-lock systems, which utilize advanced biometric technologies such as fingerprint recognition, facial recognition, and iris scanning to enhance vehicle security. The study traces the evolution of vehicle security measures, highlighting the inadequacies of traditional mechanical and electronic systems in countering sophisticated theft techniques. Through a detailed analysis, the study outlines the technical architecture of bio-lock systems, emphasizing their advantages in terms of security and user convenience, while also addressing challenges related to privacy, data security, and market accessibility. Case studies demonstrate the growing acceptance of bio-locks within the automotive sector, supported by favorable consumer feedback and a comparative analysis with existing security innovations. The research further explores future trends, including the integration of emerging technologies and predictive analytics, as well as the significance of collaborative efforts among industry stakeholders. Additionally, the study examines the regulatory and ethical implications of biometric data usage, offering recommendations for policymakers and industry leaders to ensure the responsible adoption of bio-lock systems in vehicles. Ultimately, this study highlights the transformative potential of bio-lock technology in redefining vehicle security, presenting a compelling alternative to conventional methods and contributing to the creation of safer, more secure automotive environments.

Keywords: Biometric security, vehicle security, bio-lock systems, fingerprint recognition, facial recognition, cyber threats, automotive innovations

INTRODUCTION

Due to developments in technology and increasing complexity of car theft strategies, automotive manufacturing is undergoing an extensive transition.

Traditional security measures, such as mechanical locks and electronic key fobs, have proven inadequate in protecting vehicles from skilled thieves equipped with modern hacking tools [1]. As vehicles become more connected and reliant on complex software systems, the potential for cyber threats has also escalated, necessitating the development of innovative security solutions that can effectively safeguard vehicles from both physical and digital attacks [2].

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Received Date: December 29, 2024

Accepted Date: January 28, 2025

Published Date: February 07, 2025

Citation: Syed Touseef Ali. A Comprehensive Study on Vehicle Security by Bio-lock. Journal of Mechatronics and Automation. 2025; 12(1): 59–70p.

By using distinctive physiological features like fingerprints, face recognition, and iris scans, biometric authentication technologies have become a viable substitute for traditional security measures in making sure that only authorized individuals are able to enter and operate a vehicle [3]. By doing away with the need for physical keys or passwords, the inclusion of biometric technology into vehicle security not only increases protection against

unwanted entry but also promotes user satisfaction [4]. This move to biometric systems is part of a larger trend in auto manufacturing, where producers are embracing cutting-edge technology more often in response to consumer requests for more safety and ease [5].

The installation of biometric alarms in automobiles is not without issues notwithstanding the possible merits. Significant ethical and legal ramifications arise from privacy concerns about collecting and archiving of private biometric data [6].

Additionally, technical limitations, such as sensor accuracy and environmental factors, can impact the reliability of biometric systems in real-world applications [7]. As such, a comprehensive understanding of the advantages and limitations of bio-lock systems is essential for their successful integration into modern vehicles.

This study aims to explore the concept of bio-lock systems for vehicle security, examining their technical architecture, advantages, and challenges. Through a review of existing literature and case studies, the research will highlight the growing adoption of biometric technologies in the automotive industry and their potential to revolutionize vehicle security. By addressing the regulatory and ethical considerations surrounding biometric data usage, this study seeks to provide valuable insights for policymakers and industry stakeholders as they navigate the evolving landscape of vehicle security innovations [8–10]. Ultimately, this research underscores the transformative potential of bio-lock technology in enhancing vehicle security and user experience, paving the way for safer and more secure automotive environments.

LITERATURE REVIEW

The integration of biometric security systems into vehicle security frameworks represents a significant advancement in the automotive industry. This literature review examines the evolution of biometric technologies, their application in vehicle security, and the associated challenges and opportunities.

Evolution of Biometric Technologies

Biometric recognition systems have evolved significantly over the past few decades, transitioning from rudimentary methods to sophisticated technologies capable of accurately identifying individuals based on unique biological traits. Jain *et al.* provide a comprehensive overview of biometric recognition, detailing the various modalities, including fingerprint, facial, and iris recognition [1]. The authors emphasize the importance of accuracy and reliability in biometric systems, which are critical for their adoption in security-sensitive applications such as vehicle access.

The historical development of biometric systems can be traced back to ancient practices, where fingerprints were used as signatures. However, the advent of naturally fingerprint identification technologies (AFIS) in the late 20th century marked the official start of the current era of biometric information technology [2].

This technological leap paved the way for more advanced applications, including facial recognition and iris scanning, which have gained traction in various sectors, including banking, healthcare, and transportation [3].

Application of Biometric Systems in Vehicle Security

The potential of the use of biometric to improve vehicle security is increasingly being recognized in the industry of automobiles.

Bhatia and Gupta discuss the adoption of bio-lock systems, which utilize biometric data to authenticate users and prevent unauthorized access [6]. Compared with conventional key-based procedures, which are open to theft and copying, these systems provide a reliable alternative. The

authors point out that by doing away with any need for physical keys, biometric solutions not only increase security but also improve the experience of users.

Kaur and Kaur further explore the advantages of biometric authentication in vehicles, noting that systems such as fingerprint and facial recognition provide a seamless user experience [9]. These technologies promote overall safety and lessen the threat of unwanted entry by enabling users to enter vehicles using their own physical features.

Additionally, the integration of biometric technologies can facilitate personalized vehicle settings, improving the driving experience for users [6].

Challenges and Limitations

Despite the promising benefits of biometric systems in vehicle security, several challenges must be addressed to ensure their successful implementation. Because the gathering and processing of biometric data presents considerable ethical and legal challenges, concerns about confidentiality are crucial. Khosravi and Khosravi stress on the importance of strict data security protocols to prevent sensitive biometric data from being misused or accessible to unregistered individuals [5].

The authors argue that the potential for data breaches poses a substantial risk, as compromised biometric data cannot be changed like passwords.

The broad use of biometric technology in automobiles is made even harder by technical constraints. Extreme temperatures and light exposure are two examples of environmental elements that may influence biometric sensor performance [8].

Kaur and Singh highlight that fingerprint scanners may struggle in wet or dirty conditions, while facial recognition systems may be hindered by poor lighting [10]. Continuous advancement in research is necessary to address these technological concerns and improve the precision as well as reliability of biometric technologies across a variety of environments.

Future Directions and Innovations

Because of continuous improvements in technology and rising customer demand for improved security features, the future of biometric systems in car security is bright. Alotaibi and Alghamdi talk about advances in biometric authentication, such as the use of artificial intelligence and machine learning to increase both the accuracy and efficacy of biometric systems [7]. By enabling real-time threat detection and response, these technologies can enhance vehicle security even further.

Furthermore, the effective integrating the biometric identification into automobiles depends on partnership between automakers, technology suppliers, and government organizations.

Kaur and Kaur suggest that partnerships can facilitate the development of standardized protocols and guidelines for the implementation of bio-lock systems, ensuring interoperability and security across different vehicle models [9].

OVERVIEW OF BIO-LOCKS

Definition

Bio-locks, or biometric locks, are advanced security systems that utilize unique biological characteristics of individuals to grant or deny access to a physical space or device. These systems use biometric recognition technology in order to examine certain characteristics which include voice recognition, iris patterns, fingerprints, and face features. Since bio-locks do not require standard keys or passwords, its main benefit is their capacity for improving user comfort while maintaining a high degree of security.

Historical Development

The concept of using biological traits for identification dates back centuries, with early examples including the use of fingerprints in ancient Babylon and China. Nonetheless, the latter part of the 20th century saw the start of the current biometric system development. An important turning point had been achieved in the 1980s with the advent of automated fingerprint identification systems (AFIS), which enabled law enforcement companies to swiftly and precisely match fingerprints against enormous databases.

More advanced biometric devices, including as face recognition and iris scanning, were developed in the 1990s as a result of improvements in computing capability and sensor technology. These technologies become popular in a number of fields, including security, healthcare, and finance.

By the early 2000s, biometric locks began to emerge in consumer markets, offering enhanced security for homes, offices, and vehicles. Today, bio-locks are increasingly integrated into smart home systems and connected devices, reflecting the growing demand for secure and convenient access control solutions.

Comparison with Traditional Locks

Bio-locks offer several advantages over traditional mechanical locks and electronic key fobs:

1. *Security*: Traditional locks can be picked, bumped, or duplicated, making them vulnerable to unauthorized access. Bio-locks, on the other hand, are dependent on special genetic features that are very challenging to duplicate or fabricate.
2. *Convenience*: Users do not need to carry physical keys or remember passwords, as access is granted through their biometric traits. This can be particularly valuable when you need rapid access or when your palms are occupied.
3. *Audit trails*: A lot of bio-lock systems embrace the ability to record access events, which shows who left a place and when. This feature enhances security and accountability, especially in commercial settings.
4. *Customization*: Multiple user recognitions may be created into bio-locks, enabling unique access levels and configurations. This is especially helpful in communal settings like homes or schools.

But, in contrast to traditional locks, bio-locks also have shortcomings:

- *Cost*: Because bio-lock systems have sophisticated components and technology, they are typically Costlier than ordinary locks.
- *Technical issues*: Environmental elements like dirt, condensation, or illumination can have an influence on biometric systems, lowering their reliability as well as effectiveness.
- *Privacy concerns*: There are serious concerns regarding security and privacy with the extraction and storing of biometric data. Users can be anxious about the storage and usage of their personally identifiable information.

Types of Bio-Locks

Depending on the kind of biometric characteristic they use, bio-locks may be classified as:

1. *Fingerprint locks*: These locks double-check users using recognition of fingers technology. They are among the most common types of bio-locks and are widely used in residential and commercial applications.
2. *Facial recognition locks*: These systems analyze facial features to grant access. They may be used with surveillance systems for greater security and are commonly employed in high-security locations.
3. *Iris recognition locks*: The distinctive patterns in the colored portion of the eye are scanned using iris recognition technology. These locks are known for their high accuracy and security, making them suitable for sensitive applications.

4. *Voice recognition locks*: These systems use a user's speech habits to authenticate them. Conversational locks are less popular than other kinds, although they may be added to virtual assistants and smart homes.
5. *Vein pattern recognition locks*: This method, which is regarded as extremely secure since vein patterns are hard to replicate, examines the distinct vein patterns in an individual's thumb or finger (Figure 1).

Need for Bio-Locks

The need for bio-locks arises from several factors:

1. *Increasing security threats*: As crime rates rise and security threats evolve, there is a growing demand for more secure access control solutions. Bio-locks lower a chance of unwanted access and offer a trustworthy alternative for conventional locks.
2. *Convenience and user experience*: Convenience is vital in a world that is getting fast by the day. Bio-locks offer a seamless user experience, allowing for quick and easy access without the need for physical keys or passwords.
3. *Technological advancements*: The rapid advancement of biometric technologies has made bio-locks more accessible and affordable for consumers. As technology continues to evolve, bio-locks are becoming more reliable and user-friendly.
4. *Integration with smart systems*: The need for integrated protection measures has increased as a result of the development of technologies for smart houses. Bio-locks offer additional convenience and security and are simpler to integrate into automated home systems.
5. *Regulatory compliance*: Strict procedures for limiting access are required by requirements in several businesses, such as healthcare and financial institutions.

Bio-locks can help organizations meet these compliance standards while enhancing security.

TECHNICAL ARCHITECTURE OF BIO-LOCKS

The technical architecture of bio-locks is a sophisticated integration of hardware and software components designed to provide secure and efficient access control through biometric authentication. This architecture encompasses several key components that work together to capture, process, and verify biometric data. An extensive review of the essential elements and the operation process of bio-lock systems can be obtained below:

Key Components of Bio-Locks

Biometric sensor

- The biometric sensor is the primary component responsible for capturing the biometric trait of the user. Depending on the type of bio-lock, this sensor can be a fingerprint scanner, facial recognition camera, iris scanner, or voice recognition microphone.

Fingerprint Sensors

These usually leverage optical or capacitive gadgets to record the distinct crest and valley patterns found on the fingers.

Facial recognition Cameras

These utilize high-resolution cameras equipped with infrared or 3D imaging technology to capture facial features and contours.

Iris Scanners

These devices use near-infrared light to illuminate the eye and capture the unique patterns in the iris.

Voice Recognition Microphones

These capture the unique vocal characteristics of a user, analyzing pitch, tone, and speech patterns.

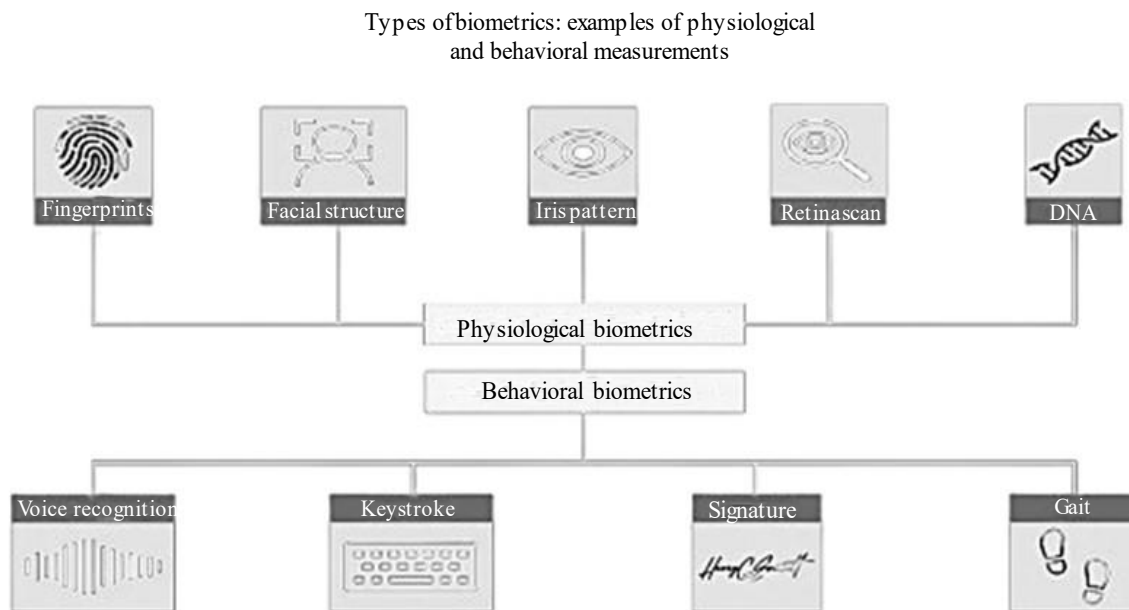


Figure 1. Types of bio-locks.

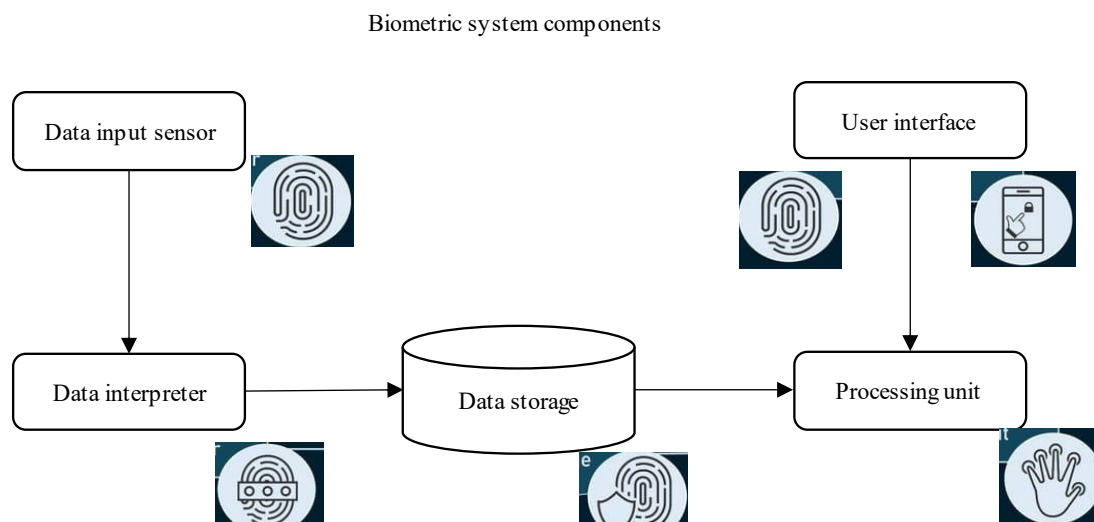


Figure 2. Components of a bio-lock.

Processing Unit

- The processing unit is the brain of the bio-lock system. It is responsible for analyzing the data captured by the biometric sensor and performing the necessary computations for authentication.
- This unit typically includes a microcontroller or microprocessor that executes algorithms for feature extraction, matching, and decision-making.
- The processing unit also manages communication between the biometric sensor, storage, and user interface components.

Storage Module

- The storage module is where biometric templates and user data are securely stored. This can be either local storage (on-device) or remote storage (cloud-based).
- *Biometric templates:* When a user enrolls in the system, their biometric data is processed to create a template, which is a mathematical representation of their unique biometric traits. This template is stored for future comparisons during authentication.

- *User data:* Additional information, such as user profiles, access logs, and settings, may also be stored in this module.

User Interface

- Users can communicate with the bio-lock systems through the user interface. Voice instructions, touchscreens by and actual buttons can all be indications of this.
- The interface provides feedback to users, such as indicating successful or failed authentication attempts, and may also allow users to manage settings or enroll new biometric data.

Power Supply

- Bio-locks require a reliable power source to operate. This can be provided through batteries, direct electrical connections, or solar panels in some cases.
- Power management systems are often integrated to ensure efficient energy use and to provide alerts for low battery conditions.

Communication Module

- Many bio-lock systems are equipped with communication modules that enable connectivity with other devices or networks. This can include Wi-Fi, Bluetooth, or cellular connections.
- This feature allows for remote monitoring, management, and integration with smart home systems or security networks (Figure 2).

HOW BIO-LOCKS WORK

The operation of bio-locks can be broken down into several key steps:

Enrollment

- The first step in using a bio-lock is the enrollment process, where a user's biometric data is captured and converted into a biometric template.
- For example, in a fingerprint lock, the user places their finger on the sensor multiple times to capture various angles and impressions. The system processes this data to create a unique template that represents the user's fingerprint.

Storage

- The generated biometric template is securely stored in the storage module, either locally on the device or in a cloud-based system, along with any associated user information (Figure 3).

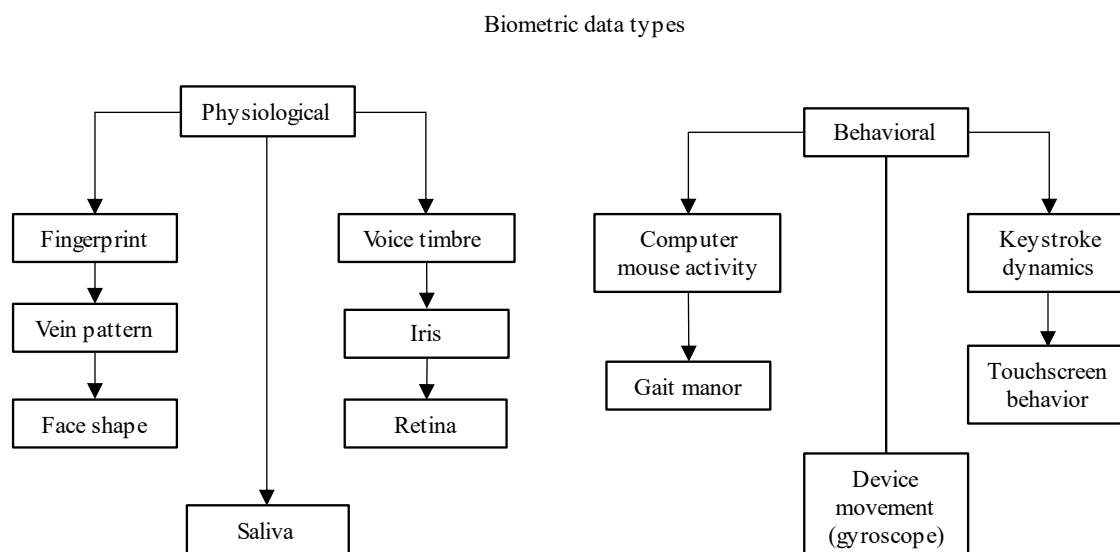


Figure 3. Biometric data types.

Authentication

- When a user attempts to access the secured area or device, they present their biometric trait (e.g., placing their finger on the sensor).
- The processing unit receives the newly recorded biometric data from the biometric sensor and processes it.

Feature Extraction

The processing unit analyzes the captured biometric data to extract relevant features. For example, the system distinguishes minute details like ridge culminates and bifurcations in hands.

Matching

- The extracted features are compared against the stored biometric templates in the storage module. Complicated algorithms can be utilized in this matching procedure to find out how similar the information that was captured and the previously saved templates are.
- The system verifies finding of the user if a match is discovered within a certain range of values.

Access Control

- Upon successful authentication, the bio-lock triggers the access mechanism, which may involve unlocking a door, starting a vehicle, or granting access to a secure area.
- If the authentication fails, the system may provide feedback through the user interface and log the attempt for security monitoring.

Logging and Monitoring

- Many bio-lock systems maintain logs of access attempts, including successful and failed attempts. This data can be used for security audits and monitoring user activity (Figure 4).

ADVANTAGES OF BIO-LOCK SYSTEMS

Enhanced Security

- Bio-lock systems utilize unique biological traits such as fingerprints, facial features, and iris patterns, making them significantly more secure than traditional mechanical locks. Because biometric data is particular, it is very difficult for unidentified individuals to copy or fake access credentials. This lowers the possibility of illegal access and theft of a vehicle.

User Convenience

- One of the most compelling advantages of bio-lock systems is the convenience they offer. Users are no longer required to must learn complicated passwords or carry true keys.

Access is granted through biometric recognition, allowing for quick and seamless entry. This is particularly beneficial in situations where users may have their hands full or need immediate access to their vehicles.

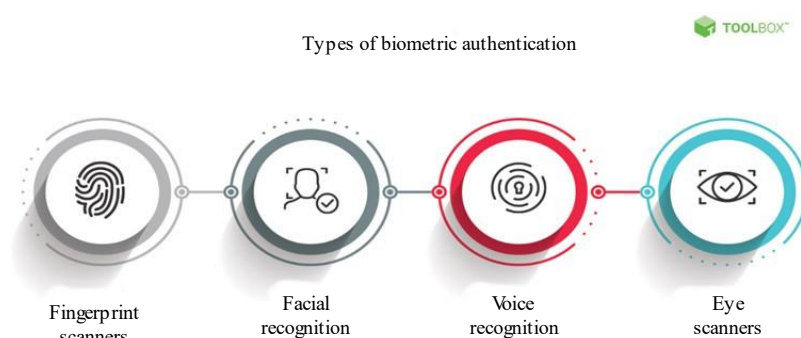


Figure 4. Biometric authentication.

Audit Trails and Accountability

- Many bio-lock systems come equipped with logging capabilities that record access attempts, including successful and failed entries. In addition to improving duties, this feature offers helpful details for security audits.

In commercial settings, such logs can help organizations monitor employee access and identify potential security breaches.

Customization and Personalization

Multiple user identifiers may be encoded into bio-lock systems, giving individual configurations and access thresholds.

- This is particularly useful in shared vehicles or fleet management scenarios, where different users may require different access permissions or vehicle configurations.

Integration with Smart Technologies

Bio-locks can be integrated into broader smart vehicle systems, allowing for enhanced functionalities such as remote access control, vehicle tracking, and personalized settings based on user profiles. This integration fits properly with the expanding trend of smart home and linked car technological advancements.

CHALLENGES OF BIO-LOCK SYSTEMS

Privacy Concerns

There are serious issues with privacy with the gathering and use of biometric data. Concerns over the storage, usage, and confidentiality of their biometric data may arise among users. Sensitive biometric information can get exposed due to data breaches, which might result in misuse.

Technical Limitations

A number of external factors can impact how well biometric systems reside. For instance, fingerprint scanners may struggle in wet or dirty conditions, while facial recognition systems may be hindered by poor lighting. The exactness and dependability of bio-lock systems in everyday uses may be impacted by certain technological limits.

User Acceptance and Trust

Users must have trust for the technology for bio-lock systems to get commonplace.

- Concerns about the accuracy of biometric recognition, potential false rejections, and the fear of being locked out due to sensor malfunctions can hinder user acceptance. Campaigns for education and awareness could be required to increase confidence in these systems.

Regulatory and Ethical Implications

The use of biometric data is subject to various regulatory frameworks that govern data protection and privacy. Implementing bio-lock systems can grow more difficult as a result of legal requirements that organizations must follow to maintain legality. Additionally, ethical considerations regarding consent and data ownership must be addressed.

LIMITATIONS OF BIO-LOCK SYSTEMS

Cost

Bio-lock systems tend to be more expensive than traditional locking mechanisms due to the advanced technology and components involved. For certain consumers and enterprises, the upfront costs connected with installation and upkeep may be prohibitive.

Dependence on Technology

The heavy reliance on science by bio-lock systems can have beneficial as well as adverse consequences. While technological advancements enhance security, they also introduce vulnerabilities.

Cybersecurity threats, such as hacking or spoofing attempts, can compromise the integrity of biometric systems.

Potential for System Failures

Like any technology, bio-lock systems are not immune to failures. Technical malfunctions, software bugs, or hardware issues can lead to system downtime, preventing legitimate users from accessing their vehicles. In an emergency, this could prove quite dangerous.

Limited Acceptance in Certain Markets

While bio-lock systems are gaining traction, their acceptance may vary across different markets and demographics. Some consumers may prefer traditional locking mechanisms due to familiarity or concerns about the reliability of biometric systems.

RESULTS OF IMPLEMENTING BIO-LOCK SYSTEMS

The implementation of bio-lock systems in vehicle security has yielded several positive outcomes, as evidenced by case studies and consumer feedback:

Reduction in Vehicle Theft

Case studies have shown that vehicles equipped with bio-lock systems experience a significant reduction in theft rates compared to those using traditional locking mechanisms. The enhanced security features deter potential thieves, leading to safer automotive environments.

Increased User Satisfaction

Surveys and consumer feedback indicate a high level of satisfaction among users of bio-lock systems. The convenience of keyless access and the personalized experience contribute to a positive user experience, fostering brand loyalty among automotive manufacturers that adopt these technologies.

Market Growth and Adoption

The use of biometric is becoming growing in prominence in automobile manufacturing. As manufacturers recognize the demand for enhanced security features, the market for bio-lock systems is expected to expand, leading to increased competition and innovation in the sector.

Collaborative Efforts Among Stakeholders

The effective deployment of bio-lock systems has led to cooperation between automakers, technology companies, and government agencies. These collaborations are crucial to the creation of universal policies and procedures that guarantee security and usability among various car models.

Future Innovations

It is anticipated that the use of cutting-edge technologies like machine learning and intelligent machines would significantly improve the ability of bio-lock systems.

- These innovations can improve the accuracy of biometric recognition, enable real-time threat detection, and streamline user experiences [11].

CONCLUSION

The evolution of vehicle security has reached a pivotal moment with the advent of bio-lock systems, which leverage advanced biometric technologies to provide enhanced protection against theft and unauthorized access. This research has explored the multifaceted advantages, challenges, limitations, and outcomes associated with the implementation of bio-lock systems in the automotive industry.

As vehicle theft and cyber threats continue to escalate, traditional security measures have proven inadequate in safeguarding vehicles from increasingly sophisticated criminal techniques. A strong substitute is supplied by bio-lock systems, which identify others using distinctive biological

characteristics includes fingerprints, facial recognition, and iris patterns. By doing away with actually keys and passwords, this not only greatly increases security but also boosts user convenience.

The ability to create personalized access levels and maintain audit trails further underscores the potential of bio-locks to transform vehicle security. However, the transition to biometric systems is not without its challenges. Sensitive biometric gathering info and storage raise privacy issues that carry important ethical and legal repercussions.

Additionally, technical limitations, such as sensor performance under varying environmental conditions, can impact the reliability of these systems. Additionally, user approval is key; broad adoption of the technology is dependent on fostering trust in it.

Despite these challenges, the results of implementing bio-lock systems have been promising. Case studies indicate a marked reduction in vehicle theft rates, and consumer feedback reflects high satisfaction levels with the convenience and security offered by these systems. Due to consumer appetite for improved security features and the emergence of smart technology, the car industry is seeing an increasing trend toward the implementation of biometric authentication systems.

Looking ahead, the future of bio-lock systems in vehicle security appears bright. It is anticipated that additional advancements in machine learning and artificial intelligence will improve biometric recognition's clarity and effectiveness even more, allowing for real-time jeopardy detection and responses. Collaborative efforts among automotive manufacturers, technology providers, and regulatory bodies will be crucial in developing standardized protocols that ensure interoperability and security across different vehicle models.

In conclusion, bio-lock technology represents a transformative shift in vehicle security, offering a robust alternative to conventional methods. As the automotive industry continues to evolve, embracing innovative security solutions like bio-locks will be essential in creating safer, more secure automotive environments. Policymakers and industry leaders must work together to address the regulatory and ethical considerations surrounding biometric data usage, ensuring that the adoption of bio-lock systems is responsible and beneficial for all stakeholders involved. In addition to bolstering vehicle security, the integration of these newest innovations opens the door for a future scenario where user comfort and safety are of greatest significance.

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