The Netherlands Press
Journal of Airline Operations and Aviation Management

Article

A Surveillance-and-Blockchain-based Tracking System for Mitigation of Baggage Mishandling at Smart Airports

Yirui Jiang[1], Trung Hieu Tran[2*], Leon Williams[3]

[1]Centre for Design Engineering, School of Water, Energy and Environment, Cranfield University, Bedfordshire, UK

E-mail: yirui.jiang@cranfield.ac.uk, Orcid id: https://orcid.org/0009-0006-0601-0535

[2]Centre for Design Engineering, School of Water, Energy and Environment, Cranfield University, Bedfordshire, UK

E-mail: t.h.tran@cranfield.ac.uk, Orcid id: https://orcid.org/0000-0002-3989-4502

[3]Centre for Design Engineering, School of Water, Energy and Environment, Cranfield University, Bedfordshire, UK

E-mail: l.williams@cranfield.ac.uk, Orcid id: https://orcid.org/0000-0003-2860-1150

DOI: https://doi.org/10.56801/jaoam.v2i2.4

Abstract.

Baggage mishandling has received much attention by airport operators. Traditional baggage tracking methods (e.g., manual, barcode, and radio-frequency identification) have not been able to deal with the challenge of baggage mishandling due to their unreliable and inefficient performance. Baggage data comprises sensitive personal information, linking individuals to their personal details and travel history, with the potential to expose security vulnerabilities. This paper proposes a smart baggage tracking system based on surveillance and blockchain technology for mitigation of baggage mishandling at airports. Surveillance including a network of airport cameras is used to recognize and monitor locations of baggage and passengers. Blockchain technology is utilized to manage and process baggage and passenger databases, guaranteeing the security, privacy, and transparency of baggage information. Surveillance-captured images of baggage and passengers undergo processing through computer vision algorithms to determine the current whereabouts of baggage, subsequently synchronized and updated within the blockchain storage. Additionally, a user interface is developed to present real-time baggage tracking information. Preliminary experiments have demonstrated the applicability of the smart baggage tracking system for airports.

Keywords: Baggage Mishandling; Blockchain; Internet of Things; Smart Airport; Smart Aviation; Surveillance; Tracking System.

Journal of Airline Operations and Aviation Management Volume 2 Issue 2

Received Date 27 September 2023
Accepted Date 26 October 2023
Published Date 26 October 2023

1. Introduction

The International Air Transport Association (IATA) anticipates that the number of air passengers will surpass 10 billion by 2050, creating significant challenges in managing baggage flow within airport terminals [1]. Baggage handling is a complex process susceptible to various disruptions, including extreme weather and human error, as evidenced by the mishandling of 6.3 million baggage in 2020, incurring a cost of US$600 million for the airline industry [2, 3]. In anticipation of the forthcoming challenges in 2050, the majority of airlines and airports are actively exploring new solutions to enhance the safety and efficiency of baggage handling processes. Baggage tracking serves as an essential solution for the industry, aiming to reduce costs and enhance services [4]. Optical scanning, the most common tracking method, records real-time data by scanning barcodes on tags, it has limitations [5]. Its reading rate during baggage transfers is relatively low, at approximately 60 - 70%, resulting in the risk of misrecording [6]. Radio frequency identification (RFID) is a simple and high-precision method of automatically acquiring tracking records that uses a small chip in the tag for baggage identification. However, the RFID-based method comes with a relatively high cost.

The trend of digitization, coupled with the impact of the pandemic, has spurred airlines and airports to persistently pursue environmentally friendly, sustainable, and contactless baggage tracking approaches [7]. The aviation industry is being compelled by automation and intelligent technology to reconsider its approaches to baggage handling [8, 9]. Many airports and airlines now offer touchless self-bag drop, mobile check-in, and self-boarding options, significantly enhancing passenger satisfaction [9, 10]. Nevertheless, the adoption of self-service and mobile technology in the realm of baggage tracking remains relatively limited [11]. Retrofitting airports with the necessary technology and infrastructure to support widespread mobile baggage tracking can be a costly and complex endeavor. Some airlines and airports may still rely on legacy systems that are not easily compatible with modern self-service and mobile technologies. Replacing or upgrading these systems can be a significant undertaking. The implementation of baggage tracking systems necessitates coordination among various stakeholders, encompassing airlines, airports, and technology providers. This collaborative effort can introduce coordination complexities and potential delays in the deployment process. Leveraging existing airport facilities to implement innovative baggage tracking systems is the most advantageous approach.

Baggage tracking involves sensitive passenger data, and ensuring the security of this data in self-service and mobile systems is a significant concern. Airlines and airports must implement robust security measures to protect passenger information. Throughout the baggage tracking process, the Internet of Things (IoT), RFID technology, mobile devices, autonomous systems, and cloud computing generate, gather, and manage extensive volumes of sensitive passenger data [12]. This digital data is collected and transmitted across multiple stakeholders and international borders without adequate oversight, resulting in an opaque, asynchronous, and susceptible baggage tracking process, vulnerable to cyberattacks [13]. Privacy concerns primarily from accidental or intentional errors, such as manipulating stored data in cloud servers, unauthorized alterations to information, altering stored data without permission, and leaking data to third parties in edge computing [14]. Therefore, many airports opt to utilize their distinct operational data within a secure and isolated intranet environment rather than relying on third-party services. Furthermore, these baggage data are confined to specific locations and can only be accessed externally through authorized systems, minimizing the risk of security breaches. Developing a universal Software-as-a-Service (SaaS) system for baggage tracking across all airlines is a complex endeavor, and it poses difficulties in establishing trust, privacy, and transparency [15]. Numerous data protection solutions, including multi-dimensional encryption algorithms, security-as-a-service frameworks, and government-signed agreements, have been suggested to guarantee the confidentiality, integrity, availability, and non-repudiation of shared information [16]. Nonetheless, obstacles persist in achieving transparent, secure, and efficient data sharing within baggage services.

The protection of passenger personal data, baggage tag details, baggage content descriptions, baggage tracking data, and other sensitive information is essential to uphold passenger privacy. Baggage lost or stolen at airports can pose a risk of personal information exposure. To enhance the security of baggage information, airlines and airports should consider investments in data security technologies [17-19]. Blockchain has proven its capability to securely store data in public domains and establish trust among unfamiliar stakeholders, all while preserving an adequate level of privacy and transparency [20]. As baggage travels from its point of departure to its final destination, it typically encounters multiple checkpoints across airports and undergoes transportation by numerous logistics providers. Blockchain can be configured to track key points in baggage journeys, often involves various independent parties. A tamper-proof blockchain structure records location, timestamps, and responsible parties for each specific piece of baggage, with all stakeholders can retrieve and share this information. To employ blockchain for baggage tracking, the initial step involves the collection of pertinent data at critical junctures during the baggage journey. Subsequently, the establishment of a secure, tamper-resistant blockchain network is crucial, coupled with data encryption and the deployment of smart contracts to automate processes. Authorized stakeholders can add data to the blockchain as baggage progresses, while a consensus mechanism ensures data integrity. The blockchain-based baggage tracking system should encompass decentralized storage, privacy safeguards, user interfaces, and monitoring systems to facilitate an efficient and secure tracking process.

This paper introduces a surveillance-and-blockchain-based tracking system to reduce the risk of baggage mishandling at airports. Computer vision and artificial intelligence (AI) are employed to match baggage images taken during check-in, sorting, and throughout the journey, potentially eliminating the requirement for traditional baggage tags and transitioning towards a contactless tracking solution. Blockchain technology is utilized to establish a decentralized, trustworthy, and transparent baggage tracking system that fosters collaboration between airports and airlines, ultimately reducing the lost or mishandled baggage. An overview of the generalized architecture is shown in Figure 1 (grey boxs are employed technologies; white boxs are the technologies that will be explored). The proposed system delves into seven layers, encompassing APP services (User Layer), access control and standard API (API Layer), writing and searching engine (Engine Layer), third-party distributed storage and blockchain (Storage and Blockchain Layer), 3G/4G/5G networks and TCP/IP (Network Layer), cameras (Perception Layer), and baggage, passengers, airports, airlines, and ground staff (Physical Layer). This paper outlines a conceptual framework and carries out preliminary experiments, but the system has not yet deployed in practical airports. This paper makes the following contributions:

i. Introduction of the automated image-based baggage tracking system, incorporating surveillance devices at key airport tracking points.

ii. Investigation into the feasibility of applying blockchain technology in baggage tracking within the aviation industry, accompanied by a comprehensive evaluation of representative test cases.

iii. Development of blockchain-based system to enable transparent, secure, and accessible sharing of baggage information among trusted parties.

iv. Creation of a user-friendly mobile application designed for airport operators and passengers, facilitating continuous access to real-time updates on baggage status.

The remainder of the paper is structured as follows: Section 2 presents a comprehensive literature review, encompassing traditional baggage tracking methods, person Re-Identification (Re-ID) algorithms, and the integration of blockchain technology in aviation data security. Section 3 provides an in-depth description of the methodology, design, architecture, and functionality of the proposed baggage tracking system. Section 4 presents the passenger detection and recognition algorithm, while Section 5 introduces the baggage detection and search algorithm. Section 6 discusses the application of blockchain in managing baggage and passenger information. Section 7 conducts preliminary experiments on various scenarios. Finally, Section 8 presents the conclusion and outlines potential future research.

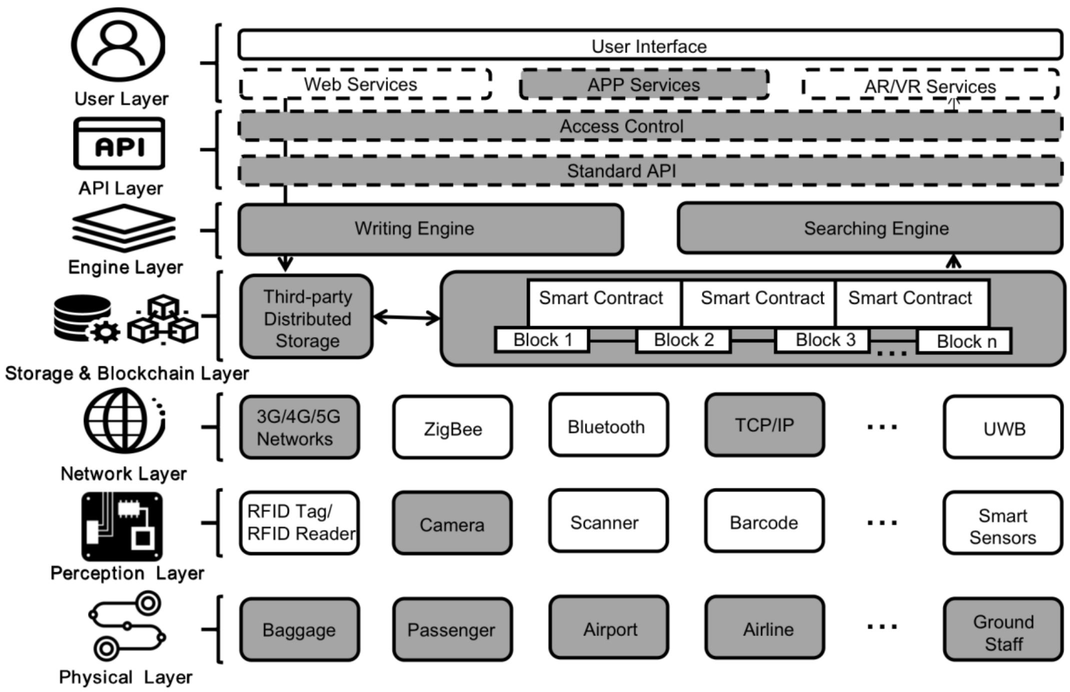

Figure 1. An overview of the generalized architecture for the smart baggage tracking system.

2. Literature Review

This algorithms and a wide variety of existing traditional baggage tracking methods, presents state-of-the-art person Re-ID algorithms, and investigates innovative blockchain solutions to facilitate data sharing among airlines while preserving privacy and security.

2.1. Traditional Baggage Tracking Methods

In baggage management, the most common traditional tracking method is optical scanning, wherein the barcode on the baggage tag is scanned for real-time data recording. However, the successful rate of this method is typically around 60% to 70% [5]. In cases of optical scanning failures, manual recording becomes necessary. While manual recording does not demand additional equipment, it is not only time-intensive but also carries a higher risk of errors [21]. RFID technology exhibits a superior ability to read baggage tags with greater accuracy and efficiency compared to barcodes. Recently, several airports and airlines have adopted hybrid solutions that incorporate both barcodes and RFID tags to enhance the reliability and cost-effectiveness of their baggage handling processes. Despite the information-rich nature of barcode and RFID-based methods, they still suffer from time and cost inefficiencies.

Wireless technologies, such as GPS, Bluetooth, and Wi-Fi, offer viable options for baggage tracking. GPS is known for its high-precision positioning capabilities, but it faces limitations in the indoor airport environment due to restricted retransmission of GPS signals [22]. Bluetooth scanners are strategically placed within airports to continuously scan wireless Bluetooth signals emitted by embedded baggage chips, registering each detection to facilitate non-participatory monitoring of airport spatiotemporal activity [23]. Wi-Fi tracking employs a unique MAC address for baggage identification, although it is generally less accurate than Bluetooth and is primarily suited for indoor use, making it less suitable for outdoor applications [24].

Airports are enthusiastic about collaborating with diverse disciplines to experiment with innovative baggage tracking solutions, capitalizing on the development of advanced image processing algorithms. Baggage tracking, emerging as a branch of automatic video surveillance systems, holds significant potential in various security applications, such as identifying baggage in restricted areas and detecting unclaimed baggage in public spaces [25]. Enabling the seamless transmission of standardized baggage tracking data empowers passengers to monitor their baggage in real-time, thereby reducing mishandled baggage incidents and nurturing passenger loyalty. The computer vision-based approach diminishes the reliance on manual processing, liberating staff for value-added tasks. The surveillance-based baggage tracking system can enhance airport capacity without extensive infrastructure investments and offer valuable insights into data-driven baggage operations.

2.2. Person Re-Identification Approaches

Person Re-Identification (Re-ID), a multi-camera tracking problem, retrieves person-of-interest across multiple non-overlapping cameras to determine distinct times and locations of person appearance [26, 27]. Originally designed to recognize re-entering individuals, early Re-ID research predominantly relied on image-based methods employing diverse matching functions [28, 29]. The image-based multi-shot person Re-ID approaches assessed the similarity between sets of frames and trained discriminative boosting models using covariance features. A spatial-temporal graph is generated to identify stable spatial-temporal regions for foreground segmentation, followed by clustering techniques to compute local descriptors over time, thereby enhancing matching performance [30]. Time cues, spatiotemporal descriptors, pose estimation, walking cycle detection, and motion features are carefully selected and matched through differentiated video ranking models to improve accuracy [31]. However, the effectiveness of Re-ID has been challenged by factors such as varying viewpoints, low image resolution, dynamic lighting conditions, diverse poses, occlusions, heterogeneous modalities, and complex camera environments.

With the advancements in deep learning, person Re-ID methods have demonstrated remarkable performance on widely recognized benchmarks [32]. Extracting person images from raw surveillance video data across diverse environments involves employing person detection or tracking algorithms, often within complex and noisy background settings [33, 34]. The integration of feature learning, person detection, and tracking into an end-to-end Re-ID system sets the stage for future applications. Airports and airlines are increasingly investing in surveillance processes to enhance the safety and efficiency of passenger journeys. In the early stages of airport surveillance, the focus was on the broad movements of individuals, without distinguishing one passenger from another, and primarily concerned with overall passenger patterns. However, as technology progresses, surveillance has shifted its attention to individuals, serving as a stable form of identity verification. To establish authentication, this system record passenger information, securely stored in a database. Implementing Re-ID in airports can enhance customer satisfaction while reducing maintenance costs and manual labor requirements.

2.3 Blockchain for Data Security in Aviation

Passenger and baggage data creates substantial value for airlines, airports, service providers, as well as aviation companies [35]. In traditional aviation information systems, extensive data related to passengers and baggage is collected through IoT devices, but the storage and management of all this data are centralized, leading to security vulnerabilities and concerns related to confidentiality, privacy, and integrity [36-38]. Blockchain technology has the potential to eliminate the necessity for a centralized authority and promote the active involvement of various stakeholders in establishing a resilient data security architecture [39-41]. Blockchain facilitates instantaneous data sharing among air traffic control, airlines, and airports, leading to enhanced flight route optimization, reduced congestion, and increased safety. Blockchain enhances data sharing among airport systems and stakeholders. It ensures that data remains secure, unaltered, and accessible, leading to better decision-making and smoother operations [42-45].

The primary reason for baggage mishandling in traditional logistics systems is the absence of visibility, traceability, and transparency in the baggage chain. As intelligent technologies continue to advance, there is an increasing feasibility for high-quality baggage services. The integration of various IoT devices into the digital chain generates actionable data [46, 47]. Blockchain can enable the aviation industry to securely and transparently update records on the ledger whenever these assets change ownership or custody within organizations. Blockchain records every piece of baggage, tracking sensors, carriers, and shippers within the platform. These sensors gather data, including baggage location, and transmit it to the server for storage on the ledger, ensuring enhanced visibility. Decentralized ledger provides a unified and trustworthy source for baggage data, significantly lowering the chances of mishandling or loss. The tracking and traceability functionalities can assist in identifying missing baggage by examining transaction logs, which enable ground handler to pinpoint the last known person or location responsible for handling the baggage. Passengers can conveniently track the live status of their baggage using a mobile application, thereby enhancing their trust in the airline services [48]. Smart contracts can be implemented to enhance the reliability, speed, and trustworthiness of compensating passengers by insurance companies for lost or damaged baggage. Utilizing blockchain technology, diverse stakeholders engage in a credit evaluation system, exchanging data while preserving their anonymity. These system enhance the transparency and accountability of baggage chain management, mitigate risks in commercial transactions, and strengthen the credibility, authenticity, resilience, and traceability of privacy data.

3. A Surveillance-and-Blockchain-based Tracking System

This paper introduces a surveillance-and-blockchain-based tracking system designed to address the limitations of conventional baggage tracking methods and minimize baggage mishandling. The process of the proposed system is shown in Figure 2. This innovative system is designed to provide real-time updates on the location and status of their baggage throughout its journey, from check-in to final destination. Passengers can conveniently access this information on their smartphones or other mobile devices, ensuring peace of mind and reducing the stress associated with traveling. Prior to arrival at the airport, passengers can conveniently upload photos of their baggage to the blockchain database (Figure 2: steps 1 - 3). Upon reaching the airport, surveillance cameras at each tracking point automatically capture baggage and passenger movements, subsequently synchronizing this data with the blockchain database (Figure 2: steps 4 and 5). The proposed system leverages cutting-edge image processing algorithms to enhance passenger and baggage management (Figure 2: steps 6 and 7):

- Passenger detection and recognition: The system identifies and recognizes passengers, ensuring seamless tracking throughout their airport journey.
- Baggage detection and search: The system efficiently detects baggage items, enabling monitoring and management of passenger belongings.
- Passenger-and-baggage matching: The system establishes a reliable link between passengers and their baggage, ensuring they are correctly paired.

As passengers monitor their baggage, their queries trigger a series of operations within the data storage system (Figure 2: steps 8 - 11). These include retrieving the necessary information and subsequently relaying it to passengers through an interactive user interface. The mobile application allows passengers to conveniently access real-time updates regarding the status and location of their baggage.

This paper identifys and analyzes the key baggage tracking points within the airport environment (see Figure 3). These tracking points are pivotal in ensuring the efficient and secure handling of baggage throughout their journey. The majority of baggage mishandling incidents tend to happen during specific stages of the baggage handling process, primarily at acceptance, loading, transfer, and arrival points. The identified tracking points typically include transfer point, aircraft unload point, bag custody change point, check-in counter point, bag drop point, security screening point, gate point, and transfer points for connecting flights. Each of these stages presents a unique set of challenges and opportunities for implementing advanced tracking technologies, such as surveillance cameras, RFID sensors, and blockchain integration. Understanding the significance of these tracking points allows airports and airlines to strategically deploy resources and technologies to minimize mishandling, loss, or theft of baggage.

This paper utilizes open-source and commercially available algorithms to offer the aviation industry a highly commercially viable solution by integrating computer vision and blockchain for baggage tracking, thereby avoiding the need to create entirely new solutions from scratch. The proposed baggage tracking system can facilitate the sharing of passenger-baggage data across the aviation industry, reducing operational information exchange costs, and alleviating passenger apprehensions regarding baggage mishandling. The proposed system can foster a culture of collaboration by securely sharing passenger and baggage data with all stakeholders.

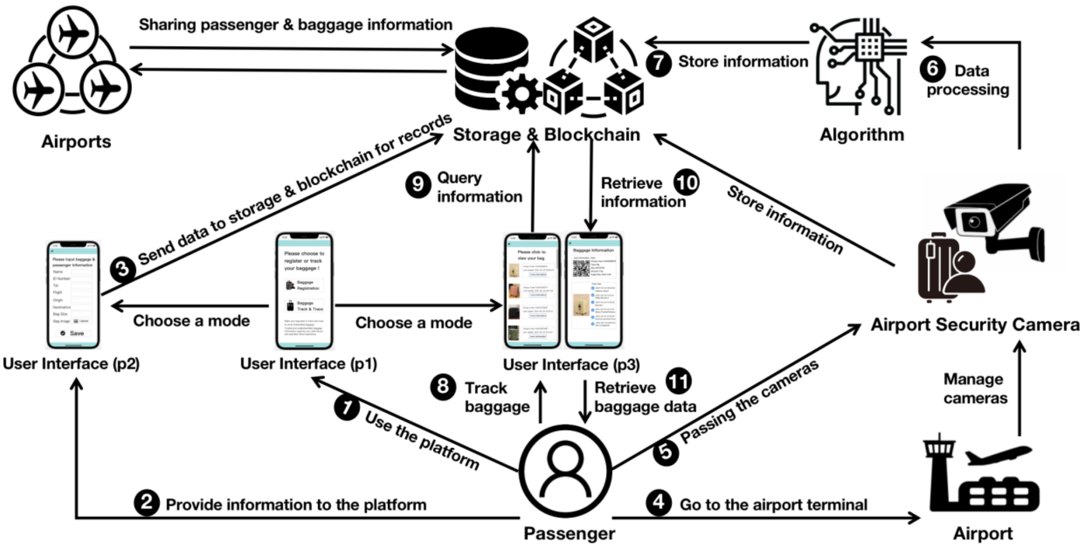

Figure 2. The process of a surveillance-and-blockchain-based baggage tracking system.

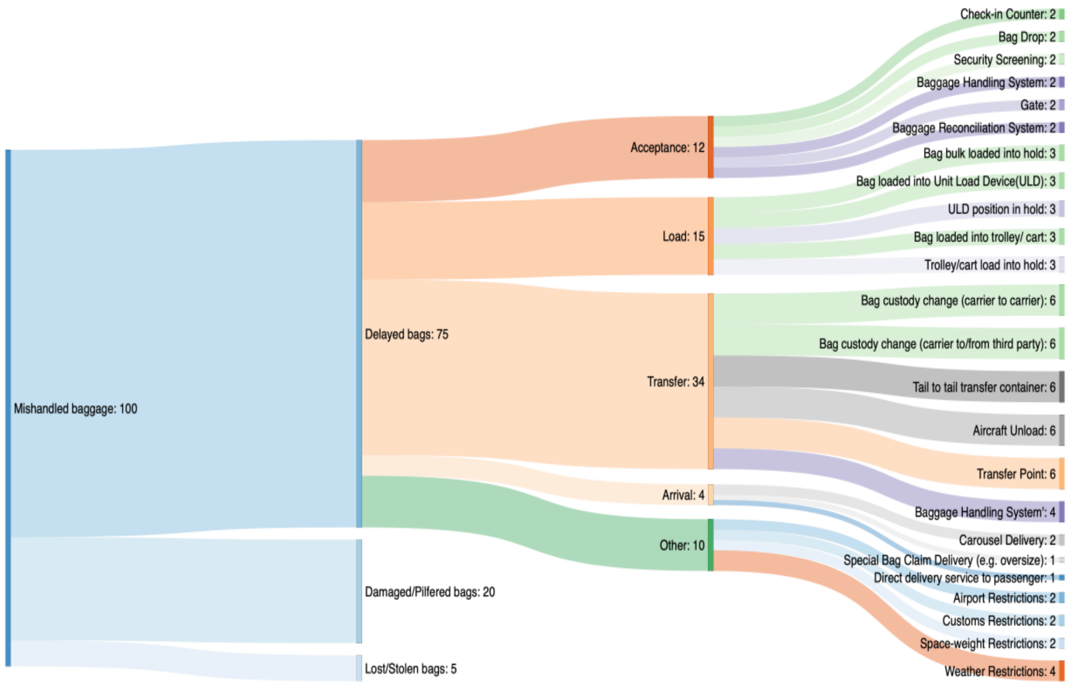

Figure 3. The key tracking points for baggage mishandling by percentage.

4. Passenger Detection and Recognition

4.1 Passenger Detection

Airport surveillance systems are often deployed in intricate environments with challenging lighting conditions, leading to the capture of blurry photos of passenger and baggage. Sophisticated face detection algorithms have the capability to identify small, blurred, and partially obscured human faces across diverse environmental conditions. The proposed baggage tracking system incorporates the open-source PyramidBox algorithm, for its effective performance in face detection benchmarks [49]. PyramidBox leverages both head and body contextual information, seamlessly combining high and low-level contextual features through feature pyramid networks. The results illustrate that PyramidBox can detect passenger faces and extract their facial features, there is room for improvement in accuracy, particularly in cases where passenger images are blurry or obscured (see Figure 4).

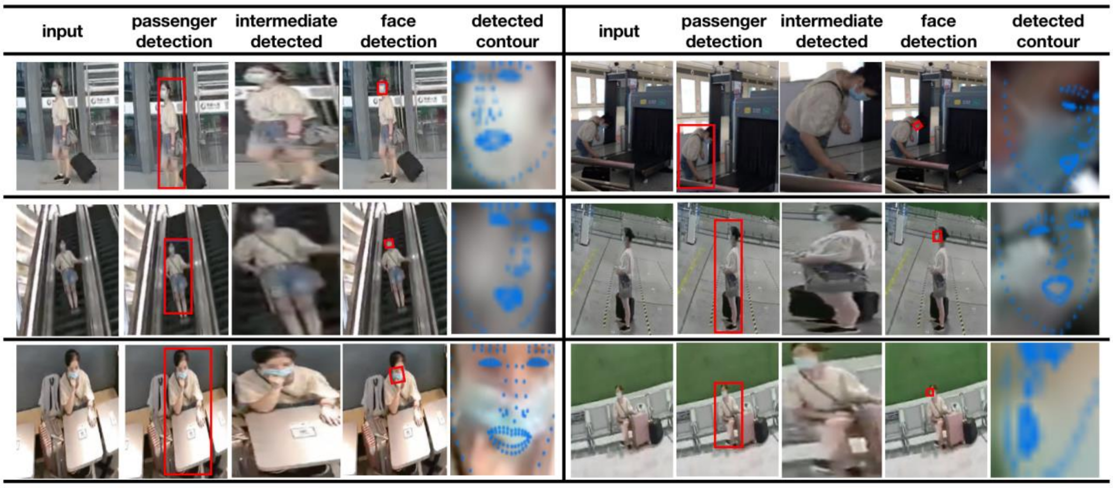

Figure 4. PyramidBox for passenger face detection through airport surveillance.

4.2. Passenger Recognition

The proposed system utilizes face recognition algorithms to locate large-scale unconstrained face photos within noisy airport scenes. The face search algorithm introduced by Wang et al. [50] is employed, which combines a rapid search process with a commercially available off-the-shelf COTS matcher as developed by Liu et al. [51]. A face gallery is generated by selecting and filtering face photos from the databases of Cao et al. [52], Yang et al. [53], and Fburaschi et al. [54]. In the baggage tracking system, passenger photos captured by airport surveillance are processed by the passenger detector. The face search system subsequently utilizes the results of passenger detection as input, employing an efficient COTS matcher to rapidly identify the most similar passenger faces within the face gallery. The recognized passenger's information is stored both in the blockchain storage and a third-party database for future matching with baggage information. Figure 5 illustrates the face search process within the face gallery.

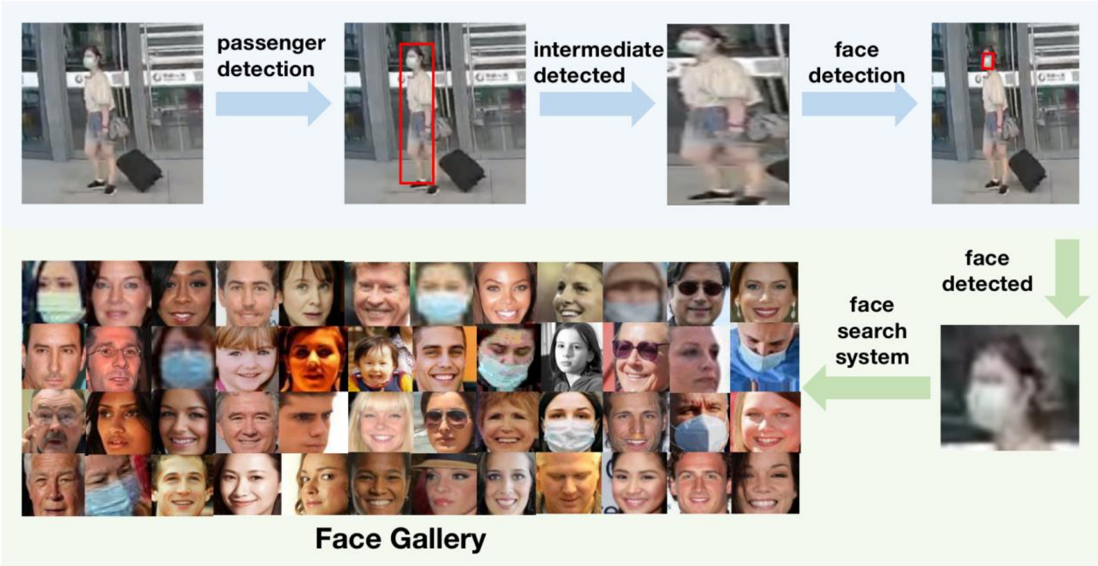

Figure 5. A face search process within the face gallery.

5. Baggage Detection and Search

5.1. Baggage Detection

The baggage tracking system must be capable of detecting millions of baggage from surveillance images, encompassing diverse and highly intricate airport environments. Object detection is a key task in the field of computer vision, and there are various models and algorithms available, such as Faster R-CNN [55], YOLO [56], RetinaNet [57], Mask R-CNN [58]. In the baggage tracking system, choosing YOLO over other models is balancing and considering factors such as performance, real-time capability, resource requirements, and deployment complexity. YOLO stands out for its ability to rapidly and precisely detect multiple objects, a critical feature in airport settings demanding swift responses. Moreover, YOLO boasts relatively lower computational demands, rendering it suitable for resource-limited embedded devices. Additionally, YOLO streamlines the process with end-to-end object detection, reducing system complexity and error risks. YOLO also offers numerous variants that can be chosen based on specific tasks and resource requirements [59]. This paper presents the development of a baggage detection system for complex airport surveillance images, utilizing a combination of ImageAI and YOLOv3 [60, 61]. The baggage detection model is trained using the COCO dataset and then tested on the compiled airport surveillance dataset. During testing, it identifies the location of detected baggage items and provides a likelihood score (see Figure 6). Subsequently, each detected item is extracted and stored individually for potential future baggage search.

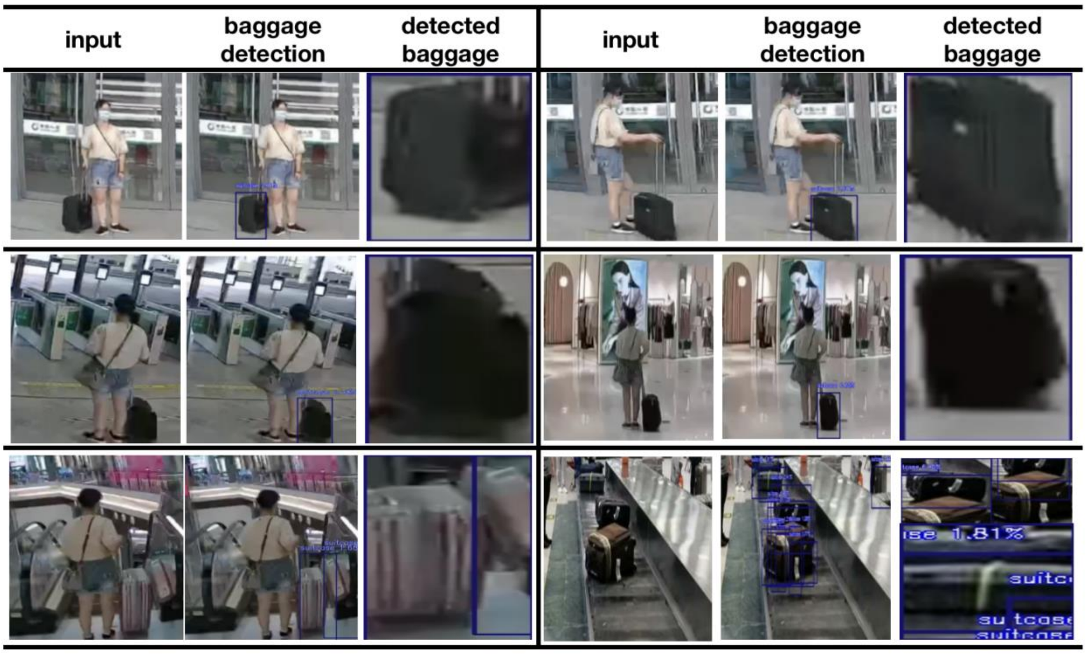

Figure 6. Performance evaluation of baggage detection algorithm on the airport surveillance dataset.

5.2. Baggage Search

Baggage search involves identifying comparable images within the baggage database. Due to the noisy of airport surveillance images, performing efficient similarity retrieval tasks within extensive baggage databases is a formidable challenge. In baggage tracking system, deep neural networks and hashing techniques are employed to transform the raw pixel data from detected baggage images into sophisticated image representations. Convolutional deep neural networks have demonstrated remarkable achievements in tasks involving millions of images, such as the ImageNet retrieval task [62]. Hashing methods are among the most widely used techniques for image search, offering benefits such as low storage requirements, rapid retrieval speeds, and applicability in video retrieval [63].

This paper establishes a baggage gallery to build an informative and efficient baggage search function. The gallery comprises baggage images sourced from the web and those captured at airports, resulting in a diverse baggage dataset. The images within the baggage gallery exhibit variations in scale, angle, lighting, and noise levels. Despite efforts to clean and optimize the baggage dataset images for improved model training, there is still inherent noise. The detected baggage are input into the baggage search system, which has been trained on the baggage gallery (see Figure 7). Using a similarity-based approach, the system arranges the baggage images in the database in order of relevance. The baggage image with the highest similarity is selected, and its details are logged and stored both in the blockchain and a third-party database, facilitating the subsequent passenger-baggage information matching process.

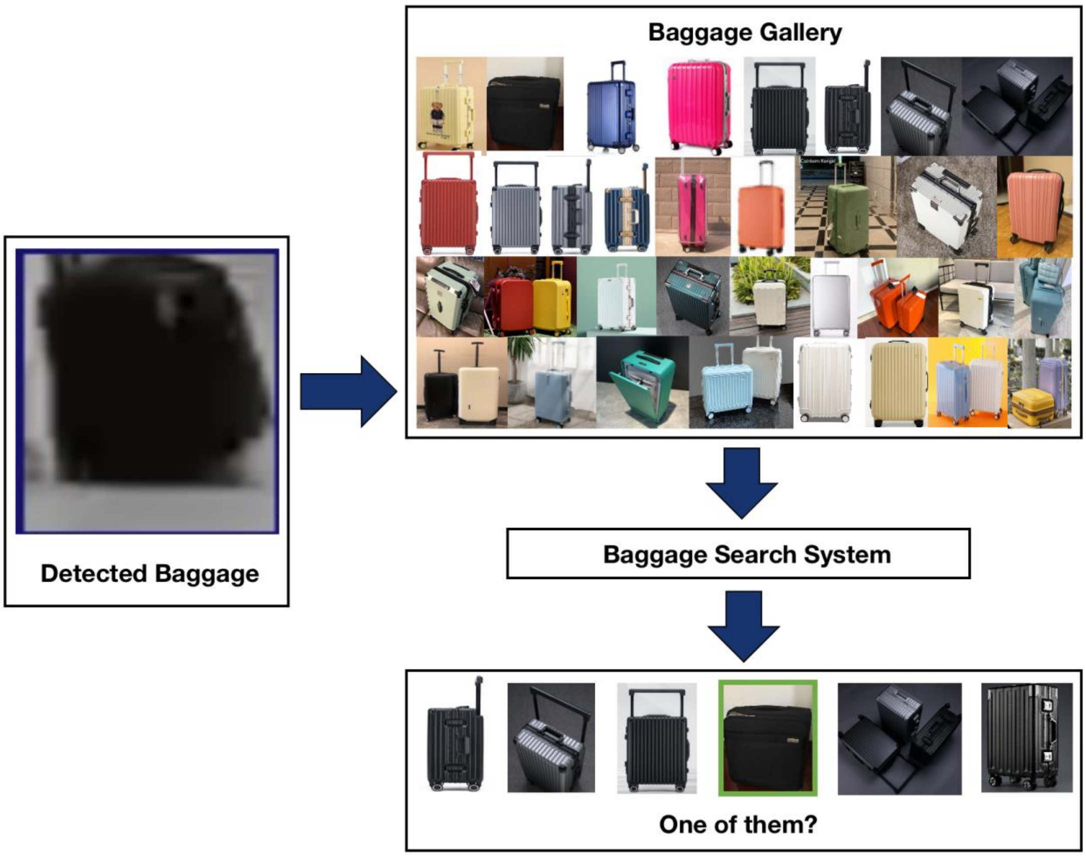

Figure 7. A large-scale baggage search process in the baggage gallery.

6. Blockchain for Passenger-Baggage Information Management

The aviation industry is harnessing emerging digital technologies to enhance collaboration among airport facilities, data, and applications. Nevertheless, the extensive volume of sensitive information presents significant challenges concerning private data collection, storage, and utilization. Blockchain offers transparency, security, and privacy to tracking systems through consensus-driven decentralized data management on a peer-to-peer distributed computing system. The tamper-proof blockchain technology prevents unauthorized alterations, while the consensus algorithm limits the propagation of false or fraudulent data. Information is stored immutably across the network using smart contracts. Timestamps, public audits, and consensus mechanisms govern the addition of new data. These protective measures mitigate the risks associated with single points of failure and network attacks. Blockchain enables each stakeholder to become a part of a unified interconnected network, eliminating the need for manual processes and reducing costs. This paper investigates the applicability of blockchain in baggage tracking systems, examines various aviation use cases, and develops a framework for managing passenger-baggage information.

The proposed baggage tracking system utilizes smart contracts and leverages blockchain technology to establish a mechanism for updating passenger-baggage information (see Figure 8). Passengers and their corresponding baggage are assigned unique identifiers, creating an interconnected link between them. This system tracks the movement of passengers and their baggage at every stage of the airport journey, recording the data in a sequence of data blocks [20]. Each data block is interconnected with others through pointers, safeguarding the integrity of passenger-baggage information. Transactions among aviation stakeholders can be tracked and made irreversible without relying on a third party. In case of a baggage mishandling incident during the journey, the shared ledger records can be promptly accessed to ascertain responsibility, streamlining the process of recovering lost baggage. The blockchain-based tracking system is comprised a web platform layer, a cloud middleware layer, and a blockchain network layer. The web platform and cloud middleware layers oversee the management of various types of metadata, while the blockchain network layer offers secure and scalable data storage. The back end of the information system is composed of certification bodies, node clusters, and load balancers [64]. The IBM Blockchain Platform is used to establish trust between passengers and airlines by using cryptographic hashing to create blocks and ledgers via the Hyperledger Fabric [65]. This system promotes data sharing, reduces system costs, and guarantees data availability, privacy, and integrity.

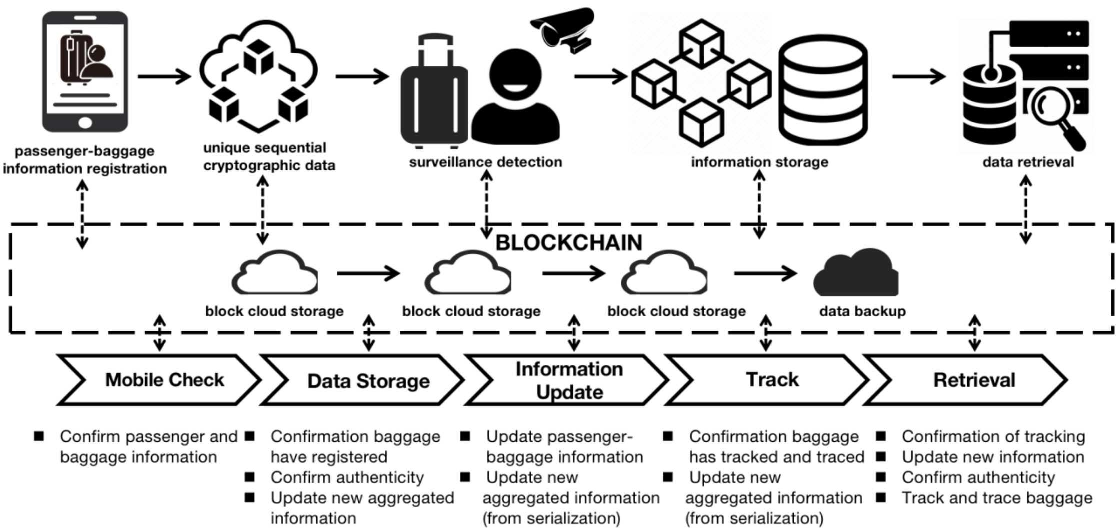

Figure 8. Blockchain-based process for passenger-baggage information management.

7. System Evaluation and Implementation

7.1. Dataset

The current baggage datasets predominantly focus on identifying items within baggage, such as hazardous materials, liquids, or other prohibited items. These datasets hold great value in applications related to security checks, border control, and airport safety [66]. Nonetheless, identifying two similar pieces of baggage presents a more intricate challenge, necessitating a dataset that encompasses a variety of baggage types along with their respective information. Such datasets are currently not widely available. A dedicated benchmark dataset is created to assess the performance of the baggage tracking system (see Figure 10). The dataset is constructed using surveillance images from an International Airport, encompassing dense crowds and intricate passenger and baggage scenarios. The dataset comprises external attributes, shapes, and color information of diverse types, shapes, and dimensions of baggage. The dataset follows a passenger's complete airport experience, from their entrance through security, shopping, ticketing, and boarding. It encompasses numerous airport situations and key baggage tracking points. Variations in airport lighting, weather conditions, and time are taken into account to create a diverse set of scenarios. Additionally, the dataset includes scenarios with different passenger behaviors, such as queuing, interacting with airport staff, shopping, and moving between terminals. This diversity of scenarios and passenger activities contributes to a more realistic and challenging dataset for testing the baggage tracking system.

Figure 10. A dataset of airport surveillance.

7.2. Strategic Surveillance Camera Placement

Surveillance cameras play a pivotal role in data analysis and decision-making processes. Precise camera positioning is imperative for an efficient baggage tracking system. Strategic camera placement guarantees comprehensive coverage while mitigating potential blind spots. This placement is instrumental in securing clear, unobstructed images, a critical factor in computer vision applications like passenger and baggage detection, where image quality significantly influences algorithm accuracy. Moreover, optimal camera placement minimizes the requirement for extra cameras, resulting in cost savings and the efficient utilization of existing resources.

Airports deploy hundreds of surveillance cameras to continuously monitor and record all activities. The vast network of surveillance cameras covers key areas such as terminals, security checkpoints, baggage claim, and boarding gates. These cameras capture passengers and their baggage at various stages of their journey, providing a comprehensive dataset for analysis. However, the placement of these cameras introduces variability in image quality, which can be influenced by factors such as lighting conditions, camera locations, camera heights, and camera angles. In order to help airports identify optimal surveillance camera placements for computer vision-based baggage tracking, initial experiments are conducted to evaluate passenger and baggage detection rates at various surveillance camera locations. In the experiments, a consistent camera configuration is maintained while instructing the same passenger to carry identical baggage at varying distances from the surveillance camera. The horizontal and vertical distances of the passenger from the surveillance camera are tested within a range of 1 to 5 meters. The resulting videos from the experiments are recorded and edited to eliminate redundancies and extraneous parts, to ensure video clarity and usability during distance testing.

After processing, the experimental images are input into the passenger and baggage detection algorithm, and the results are depicted in Figure 11. The algorithm's performance exhibits significant variation based on both horizontal and vertical distances. The passenger recognition rate ranges from 40% to 80%, while the baggage recognition rate ranges from 0% to 50%. When the passenger is closer to the surveillance camera, with horizontal and vertical distances of 1 meter, passenger images are clearer, resulting in a higher recognition rate. However, extremely close horizontal distances make it challenging to capture baggage images, leading to an exceptionally low baggage detection rate. The best results are achieved when the horizontal distance between the surveillance and the passenger ranges from 2 meters to 3 meters. Good performance is also observed at vertical distances between 3 meters and 4 meters. Beyond these distances, unclear images and poor detection rates are encountered. The experimental results indicate that for optimal performance of the passenger and baggage detection algorithm, airport surveillance cameras should be installed at a vertical distance of 3 meters to 4 meters, and passenger images should be captured at a horizontal distance of 2 meters to 3 meters (by adjusting the surveillance angle).

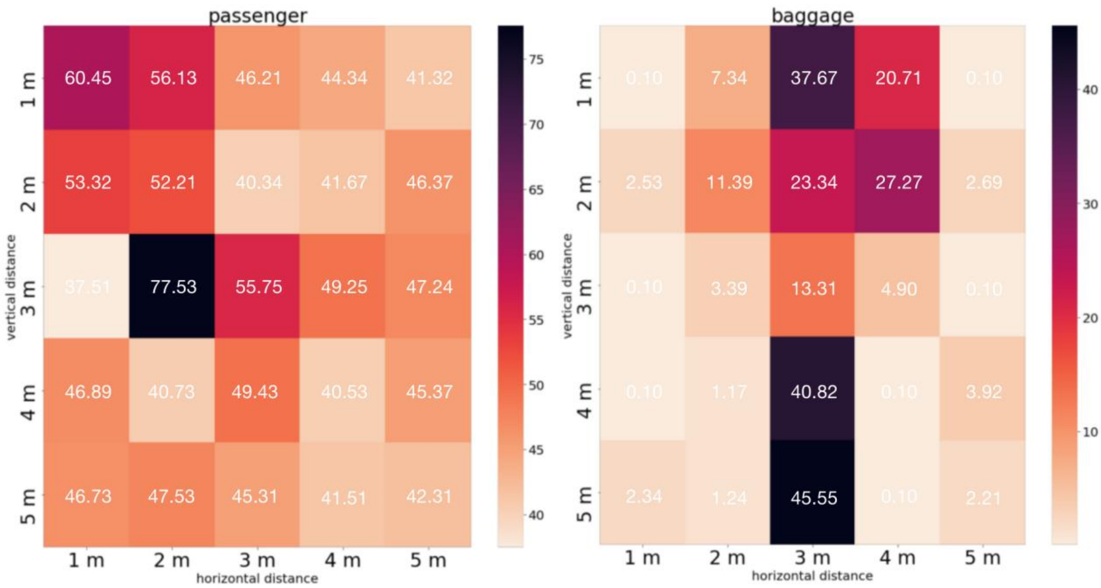

Figure 11. Evaluation of passenger and baggage detection across surveillance camera positions.

7.3. User Interface Design

A user interface (mobile APP) is created for the baggage tracking system (see Figure 9). The APP offers several features, such as baggage registration, baggage tracking, notifications, and lost baggage assistance. A user-friendly visual interface provides a clear and intuitive representation of the baggage journey [67-69]. Passengers can view detailed maps, timelines, and status updates. Passengers can register and track their baggage journey remotly using a mobile APP. Within the APP, passengers input their user and flight information, and upload photos of their baggage, which are then stored in the baggage database. Each user has the capability to register details for multiple pieces of baggage simultaneously, with each piece of baggage assigned a unique code and QR code for identification purposes. Baggage data can be accessed from both the blockchain and cloud database. Passengers can easily track the exact location of their baggage at any given moment. This includes updates on whether it's been loaded onto the aircraft, is in transit, or has arrived at the destination airport. When the smart system detects a discrepancy between the passenger and their baggage, it promptly sends an alert to the passenger, prompting them to verify the situation. This early detection of mishandled baggage accelerates the baggage retrieval process, reducing the time required to locate the baggage. By utilizing this APP, passengers can enjoy a smoother, more transparent travel experience while maintaining full control over their baggage. It not only enhances passenger satisfaction but also contributes to the overall efficiency and reliability of baggage handling at airports.

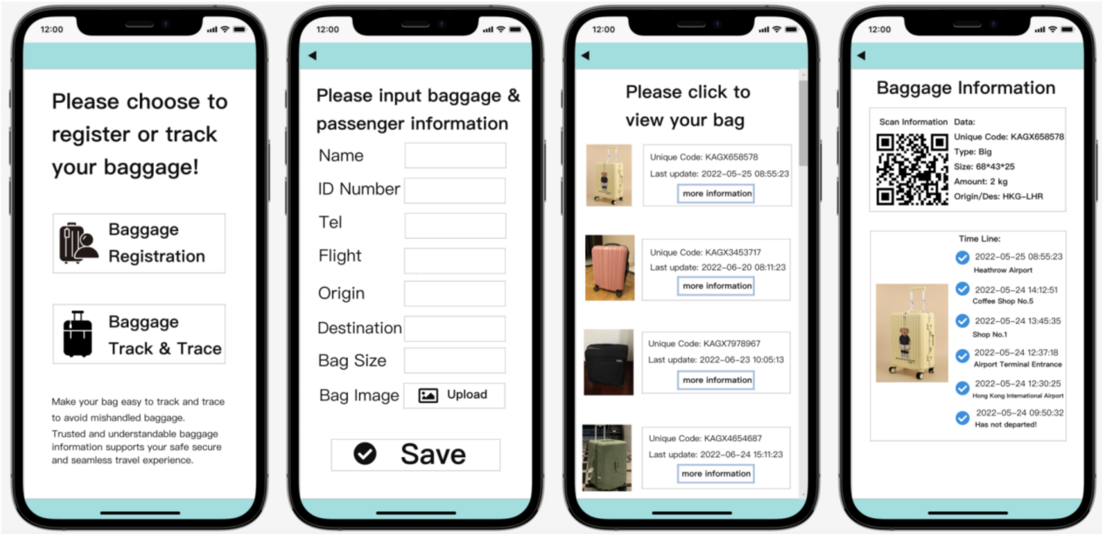

Figure 9. A user interface (mobile APP) for the baggage tracking system.

8. Conclusion and Future Works

In conclusion, this paper presented a surveillance and blockchain based baggage tracking system to mitigate the baggage mishandling at airports. By combining advanced surveillance capabilities with the security and transparency of blockchain, this system has potential to offer a solution for enhancing the baggage handling process and ensuring a seamless travel experience for passengers. This paper utilized computer vision algorithms for passenger and baggage detection, recognition, and search based on the images obtained from airport surveillance. Algorithms offers real-time monitoring and tracking of both passengers and their baggage throughout the entire airport journey, thereby reducing the probability of baggage mishandling incidents. Blockchain technology was utilized to securely and transparently manage passenger and baggage information. Its integration adds an extra layer of security and trust to the system, ensuring passengers of the integrity of their confidential baggage data. Additionally, the mobile APP empowers passengers to actively participate in monitoring their baggage, offering them peace of mind and control over their travel belongings. The proposed smart baggage tracking system marks a substantial advancement in airport logistics and passenger services.

To further enhance the effectiveness of the smart baggage tracking system, it is essential to conduct comprehensive and large-scale studies. Preliminary results have certainly highlighted the system potential in reducing baggage mishandling at airports. However, these initial findings need to be validated and refined through extensive real-world testing and deployment. One promising avenue for improvement lies in the integration of advanced neural network-based algorithms. Neural networks have demonstrated remarkable capabilities in various computer vision tasks such as recognition and detection. The integration of advanced neural networks has the potential to distinguish between different baggage types, shapes, and sizes with remarkable precision. Neural networks can be trained to handle such as varying lighting, occlusions, and cluttered environments, making the system more adaptable and resilient to real-world scenarios. Large-scale real-world testing is crucial to validate the performance enhancements achieved through advanced neural networks. This involves deploying the system in diverse airport environments, capturing a wide range of baggage scenarios, and continuously fine-tuning the algorithms based on real data feedback.

The aviation industry is subject to strict regulations and standards, including those related to baggage and passenger data. Data privacy and security are paramount concerns. As the aviation industry relies increasingly on data-sharing mechanisms such as blockchain, safeguarding passenger data remains a top priority. Future work should center on continuous enhancements in data privacy and security measures to align with evolving best practices and regulatory requirements. Future work will aslo center on the continued advancement of blockchain technology within the baggage tracking system, from security, compliance, compatibility, flexibility, and scalability. The development will involve bolstering the security of the blockchain network through the implementation of enhanced authentication methods and strengthened data encryption and privacy safeguards. These measures will ensure that only authorized individuals can access and modify critical data. Collaborative efforts with regulatory bodies will be essential to align blockchain applications with data privacy, security, and regulatory compliance requirements. Moreover, future enhancements will prioritize broader compatibility, enabling seamless interoperability with various existing systems and standards. As the aviation industry continues to expand, the baggage tracking system must demonstrate a high degree of scalability to effectively manage large volumes of data and transactions. Consequently, future work will revolve around optimizing the blockchain system's performance to accommodate increasing workloads while simultaneously reducing costs and energy consumption.

Future work in the baggage tracking system must encompass a multifaceted approach. This approach should address regulatory compliance, technological innovation, data security, scalability, user experience, sustainability, and international cooperation. By tackling these areas collectively, the aviation sector can look forward to safer, more efficient, and passenger-centric air travel experiences.

Acknowledgment

The authors would like to thank the Editor and the anonymous reviewers for their valuable comments.

References

1. *IATA, Airline Industry Financial Forecast, Outlook for the global airline industry. Accessed: September. 7, 2023. [Online]. Available: https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance---april- 2021---report/*
2. Kazda, A. and R.E. Caves, *Airport design and operation*. 2010: Emerald Group Publishing Limited.
3. *SITA, 2021 BAGGAGE IT INSIGHTS. Accessed: September. 7, 2023. [Online]. Available: https://comms.sita.aero/rs/089-ZSE-857/images/baggage-it-insights-2021.pdf.*
4. Kalakou, S., V. Psaraki-Kalouptsidi, and F. Moura, *Future airport terminals: New technologies promise capacity gains.* Journal of Air Transport Management, 2015. **42**: p. 203-212.
5. Butler, V. and R.W. Poole, *Rethinking checked-baggage screening*. 2002, Reason Public Policy Institute Los Angeles, CA.
6. Koldkjær, K.P., *RFID for Baggage Handling and Tracking.* Whitepaper, Lyngsoe Systems, 2017.
7. Albers, S. and V. Rundshagen, *European airlines' strategic responses to the COVID-19 pandemic (January-May, 2020).* Journal of air transport management, 2020. **87**: p. 101863.
8. Martin-Domingo, L. and J.C. Martín, *Airport mobile internet an innovation.* Journal of Air Transport Management, 2016. **55**: p. 102-112.

9. Halpern, N., et al., *Segmentation of passenger preferences for using digital technologies at airports in Norway.* Journal of Air Transport Management, 2021. **91**: p. 102005.
10. Gures, N., H. Inan, and S. Arslan, *Assessing the self-service technology usage of Y-Generation in airline services.* Journal of Air Transport Management, 2018. **71**: p. 215-219.
11. Velayudhan, D., et al., *Recent advances in baggage threat detection: A comprehensive and systematic survey.* ACM Computing Surveys, 2022. **55**(8): p. 1-38.
12. Alabsi, M.I. and A.Q. Gill, *A review of passenger digital information privacy concerns in smart airports.* IEEE Access, 2021. **9**: p. 33769-33781.
13. Zhang, R., et al., *Analysis of message attacks in aviation data-link communication.* IEEE Access, 2017. **6**: p. 455-463.
14. Cui, L., et al., *Security and privacy in smart cities: Challenges and opportunities.* IEEE access, 2018. **6**: p. 46134-46145.
15. Mohammed, C.M. and S.R. Zeebaree, *Sufficient comparison among cloud computing services: IaaS, PaaS, and SaaS: A review.* International Journal of Science and Business, 2021. **5**(2): p. 17-30.
16. Rajapaksha, A. and N. Jayasuriya, *Smart airport: A review on future of the airport operation.* Global Journal of Management and Business Research, 2020. **20**(3): p. 25-34.
17. Viorescu, R., *2018 reform of eu data protection rules.* European Journal of Law and Public Administration, 2017. **4**(2): p. 27-39.
18. Dove, E.S., *The EU general data protection regulation: implications for international scientific research in the digital era.* Journal of Law, Medicine & Ethics, 2018. **46**(4): p. 1013-1030.
19. Tikkinen-Piri, C., A. Rohunen, and J. Markkula, *EU General Data Protection Regulation: Changes and implications for personal data collecting companies.* Computer Law & Security Review, 2018. **34**(1): p. 134-153.
20. Bodkhe, U., et al., *Blockchain for industry 4.0: A comprehensive review.* IEEE Access, 2020. **8**: p. 79764-79800.
21. Koenig, F., P.A. Found, and M. Kumar, *Innovative airport 4.0 condition-based maintenance system for baggage handling DCV systems.* International Journal of Productivity and Performance Management, 2019. **68**(3): p. 561-577.
22. Rizos, C., et al. *Experimental results of Locata: A high accuracy indoor positioning system*. in *2010 International Conference on Indoor Positioning and Indoor Navigation*. 2010. IEEE.
23. Versichele, M., *Sensing and making sense of crowd dynamics using bluetooth tracking: an application-oriented approach*. 2014, Ghent University.
24. Abedi, N., A. Bhaskar, and E. Chung, *Tracking spatio-temporal movement of human in terms of space utilization using Media-Access-Control address data.* Applied Geography, 2014. **51**: p. 72-81.
25. Shahbano, M. Abdullah, and K. Inayat, *Robust baggage detection and classification based on local tri-directional pattern.* International Journal of Internet Technology and Secured Transactions, 2022. **12**(2): p. 91-102.
26. Zheng, L., Y. Yang, and A.G. Hauptmann, *Person re-identification: Past, present and future.* arXiv preprint arXiv:1610.02984, 2016.
27. Chen, Y.-C., et al., *Person re-identification by camera correlation aware feature augmentation.* IEEE transactions on pattern analysis and machine intelligence, 2017. **40**(2): p. 392-408.
28. Gheissari, N., T.B. Sebastian, and R. Hartley. *Person reidentification using spatiotemporal appearance*. in *2006 IEEE computer society conference on computer vision and pattern recognition (CVPR'06)*. 2006. IEEE.
29. Ma, B., Y. Su, and F. Jurie. *Bicov: a novel image representation for person re-identification and face verification*. in *British Machive Vision Conference*. 2012.
30. Karanam, S., Y. Li, and R.J. Radke. *Sparse re-id: Block sparsity for person re-identification*. in *Proceedings of the IEEE conference on computer vision and pattern recognition workshops*. 2015.
31. Cho, Y.-J. and K.-J. Yoon. *Improving person re-identification via pose-aware multi-shot matching*. in *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2016.
32. Wei, L., et al. *Person transfer gan to bridge domain gap for person re-identification*. in *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2018.
33. Wang, X., *Intelligent multi-camera video surveillance: A review.* Pattern recognition letters, 2013. **34**(1): p. 3-19.
34. Ye, M., et al., *Person reidentification via ranking aggregation of similarity pulling and dissimilarity pushing.* IEEE Transactions on Multimedia, 2016. **18**(12): p. 2553-2566.
35. To, K., *Reimagining the future of aviation with blockchain.* Stern School of Business New York, 2020.
36. Comitz, P. and A. Kersch. *Aviation analytics and the Internet of Things*. in *2016 Integrated Communications Navigation and Surveillance (ICNS)*. 2016. IEEE.
37. Makhdoom, I., et al., *Blockchain's adoption in IoT: The challenges, and a way forward.* Journal of Network and Computer Applications, 2019. **125**: p. 251-279.
38. Wang, X., et al., *Survey on blockchain for Internet of Things.* Computer Communications, 2019. **136**: p. 10-29.
39. Lu, Y., *The blockchain: State-of-the-art and research challenges.* Journal of Industrial Information Integration, 2019. **15**: p. 80-90.
40. Monrat, A.A., O. Schelén, and K. Andersson, *A survey of blockchain from the perspectives of applications, challenges, and opportunities.* IEEE Access, 2019. **7**: p. 117134-117151.

41. Nguyen, D.C., et al., *Integration of blockchain and cloud of things: Architecture, applications and challenges.* IEEE Communications surveys & tutorials, 2020. **22**(4): p. 2521-2549.
42. Novo, O., *Blockchain meets IoT: An architecture for scalable access management in IoT.* IEEE internet of things journal, 2018. **5**(2): p. 1184-1195.
43. Javaid, M., et al., *Blockchain technology applications for Industry 4.0: A literature-based review.* Blockchain: Research and Applications, 2021. **2**(4): p. 100027.
44. Marchesi, L., et al., *A blockchain architecture for industrial applications.* Blockchain: Research and Applications, 2022. **3**(4): p. 100088.
45. Pal, S., A. Dorri, and R. Jurdak, *Blockchain for IoT access control: Recent trends and future research directions.* Journal of Network and Computer Applications, 2022. **203**: p. 103371.
46. Manavalan, E. and K. Jayakrishna, *A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements.* Computers & industrial engineering, 2019. **127**: p. 925-953.
47. Kumar, M., et al., *Enablers to achieve zero hunger through IoT and blockchain technology and transform the green food supply chain systems.* Journal of Cleaner Production, 2023. **405**: p. 136894.
48. Ahmad, R.W., et al., *The role of blockchain technology in aviation industry.* IEEE Aerospace and Electronic Systems Magazine, 2021. **36**(3): p. 4-15.
49. Tang, X., et al. *Pyramidbox: A context-assisted single shot face detector*. in *Proceedings of the European conference on computer vision (ECCV)*. 2018.
50. Wang, D., C. Otto, and A.K. Jain, *Face search at scale.* IEEE transactions on pattern analysis and machine intelligence, 2016. **39**(6): p. 1122-1136.
51. Liu, J., et al., *Targeting ultimate accuracy: Face recognition via deep embedding.* arXiv preprint arXiv:1506.07310, 2015.
52. Cao, Q., et al. *Vggface2: A dataset for recognising faces across pose and age*. in *2018 13th IEEE international conference on automatic face & gesture recognition (FG 2018)*. 2018. IEEE.
53. Yang, S., et al. *Wider face: A face detection benchmark*. in *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2016.
54. *Face Mask Dataset. Fburaschi, Abdelrahman Soliman, and Mahendra Singh Rajpoot. Accessed: September. 7, 2023. [Online]. Available: https://www.kaggle.com/datasets/shiekhburhan/face-mask-dataset.*
55. Ren, S., et al., *Faster r-cnn: Towards real-time object detection with region proposal networks.* Advances in neural information processing systems, 2015. **28**.
56. Redmon, J., et al. *You only look once: Unified, real-time object detection*. in *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2016.
57. Lin, T.-Y., et al. *Focal loss for dense object detection*. in *Proceedings of the IEEE international conference on computer vision*. 2017.
58. He, K., et al. *Mask r-cnn*. in *Proceedings of the IEEE international conference on computer vision*. 2017.
59. Jiang, P., et al., *A Review of Yolo algorithm developments.* Procedia Computer Science, 2022. **199**: p. 1066-1073.
60. Redmon, J. and A. Farhadi, *Yolov3: An incremental improvement.* arXiv preprint arXiv:1804.02767, 2018.
61. *ImageAI. Accessed: September. 7, 2023. [Online]. Available: http://www.imageai.org/.*
62. Bai, Y., et al., *Learning high-level image representation for image retrieval via multi-task dnn using clickthrough data.* arXiv preprint arXiv:1312.4740, 2013.
63. Zhang, J. and Y. Peng, *SSDH: Semi-supervised deep hashing for large scale image retrieval.* IEEE Transactions on Circuits and Systems for Video Technology, 2017. **29**(1): p. 212-225.
64. Abeyratne, R. and R. Abeyratne, *Blockchain and aviation.* Aviation in the Digital Age: Legal and Regulatory Aspects, 2020: p. 109-120.
65. *IBM, IBM Blockchain Platform. Accessed: September. 7, 2023. [Online]. Available: https://www.ibm.com/blockchain/platform.*
66. Hassan, T., et al., *Tensor pooling-driven instance segmentation framework for baggage threat recognition.* Neural Computing and Applications, 2022: p. 1-12.
67. Marchesi, L., M. Marchesi, and R. Tonelli, *Abcde–agile block chain dapp engineering. Blockchain: Research and Applications 1 (1), 100002(2020)*. 2020.
68. Fahmideh, M., et al., *Engineering Blockchain-based Software Systems: Foundations, Survey, and Future Directions.* ACM Computing Surveys, 2022. **55**(6): p. 1-44.
69. Six, N., N. Herbaut, and C. Salinesi, *Blockchain software patterns for the design of decentralized applications: A systematic literature review.* Blockchain: Research and Applications, 2022. **3**(2): p. 100061.