Smart Automated Border Control System for Pakistan Airports Using ML-based Biometric Measures

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Abstract

With the global population on the rise, the substantial increase in cross-border travel poses heightened security risks, the potential for the spread of pandemics such as COVID-19, congestion, delays in the check-in and checkout process, and various other challenges. This paper introduces a novel smart Automated Border Control system referred to as ABC system tailored for Pakistan. Employing advanced biometric technologies, including contactless facial and palm recognition systems, the proposed system aims to mitigate the spread of the COVID-19 pandemic at border crossings. A travel document reader system, leveraging Optical Character Recognition (OCR) technology, retrieves passport-based information from the database. State-of-the-art machine learning-based facial recognition algorithms and recent contactless palm recognition methodologies authenticate and validate passengers entering Pakistan. Furthermore, the proposed system is designed for seamless integration with existing services such as the Integrated Border Management System (IBMS) for immigration, Exit Control List (ECL), NADRA (National Database and Registration Authority) database, online Visa database, Passport database, and Advance Passenger Information (API) or Passenger Name Record (PNR) systems. By expediting the authentication process, the system significantly reduces delays in immigration procedures.

Keywords—Smart authentication, Machine learning, Facial recognition, COVID-19, OCR systems, Border control system, Biometric authentication, Contactless immigration

1 Introduction

As the world's population continues to grow, the significant surge in cross-border travel presents a range of challenges, including elevated security risks, the potential for the transmission of pandemics like COVID-19, increased congestion, delays in the check-in and checkout process, and various other associated difficulties. Contactless immigration features in the modern age leverage advanced technologies to enhance efficiency, security, and public health. These features aim to streamline the immigration process while minimizing physical contact. To be effective, Pakistan must look towards the integration of different technologies, target specific border environments and issues, and automate information processing wherever possible to simplify the task of processing so many people. The reliable identification of travelers leads to the safety and security of the state and its people and brings clear social and economic advantages to support tourism and business and to facilitate cross-border workers. In the contemporary era, contactless immigration features leverage advanced technologies to optimize efficiency, bolster security, and safeguard public health. These functionalities are designed to streamline immigration procedures while minimizing physical contact. Prominent examples encompass biometric authentication methods such as facial or iris recognition. Facial recognition technology enables contactless identity verification by analyzing distinctive facial features, while iris recognition systems capture unique iris patterns for identity verification without physical contact. Electronic Passports (e-Passports)

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equipped with embedded microchips storing biometric data and digital signatures facilitate automated identity verification at immigration checkpoints without necessitating physical contact. Travelers have the convenience of using mobile apps to electronically submit passport information and customs declarations, thereby diminishing reliance on physical documents and reducing interactions with officers. Self-service kiosks, equipped with biometric technology like facial or fingerprint recognition, empower travelers to independently complete immigration procedures, eliminating the need for physical contact. Electronic visa (e-Visa) systems allow travelers to apply for visas online, streamlining processes, reducing paperwork, and expediting processing upon arrival. Advance Passenger Information (API) and Passenger Name Record (PNR) systems expedite the immigration process by collecting and analyzing traveler data before arrival. Thermal imaging cameras or infrared thermometers swiftly measure body temperature for potential health screening, while digital platforms enable travelers to submit health declarations electronically, providing information on potential health risks. Blockchain technology enhances the security and integrity of immigration records, ensuring data is tamper-resistant and easily verifiable. Automated Fingerprint Identification Systems (AFIS) technology facilitates contactless capture and comparison of fingerprints for robust identity verification. Radio-frequency identification (RFID) tags on travel documents enable quick and contactless scanning at immigration checkpoints. The implementation of these contactless immigration features not only elevates security measures but also contributes to a more seamless and efficient travel experience for individuals. This becomes particularly crucial in addressing public health concerns, especially in the context of global pandemics. In order to reach these goals, ABC is a global border control software that includes two main components:

(a) A risk assessment solution based on the collection and analysis of data coming from API and PNR [1]. This will perform a set of verifications in advance before the traveler reaches Pakistan airport. In this way, travelers identified as high-risk profiles will be quickly oriented towards in-depth border checks at their arrival, whereas low-risk profiles will be able to experience smoother and quicker border control.
(b) A redesigned border control process at the airport including a high level of automation in order to reduce waiting time without compromising security. The introduction of process automation through border control gates coupled with multimodal biometric enrollment and verification will optimize the flow of passengers through faster verification for low-risk travelers. The process automation shall also be complemented with self-boarding gates allowing domestic passengers fast and secure boarding with the use of their biometrics.

1.1 Research Purpose

The aim of this document is for a new Border Control Solution at a typical Pakistan Airport. This document defines the high-level requirements and technical specifications required for the development of the ABC System.

(a) Customer satisfaction: where the traveler shall have a fast, secure, and easy process. Border crossing shall be as intuitive as possible to minimize the need for assistance and increase the efficiency of airport operations. The operational procedure of the ABC system involves passengers arriving at the airport and using a device with a screen that guides them through the process of laying down their travel documents on a Document Reader. This is facilitated by visual instructions (GIFs) displayed on the screen. In case of any error, the system provides guidance on correcting the document placement or facial recognition process. This user-friendly interface ensures a fast, secure, and easy border-crossing process, enhancing customer satisfaction.
(b) Traveler's minimal contact: where the traveler shall be identified, authenticated, and securely processed with minimal interaction with officers. The ABC system includes major components such as a facial recognition system, travel document reader system (OCR), and contactless palm recognition system. These components are designed to minimize physical interaction with officers, ensuring minimal contact experience.
(c) Better anticipation: where the collection and analysis of airline's data enable the officers to identify risky travelers and manage alerts prior to the arrival/departure of the flights in/from Pakistan. The system is developed on a comprehensive turnkey platform configured to collect, process, and analyze Advance Passenger Information (API) and Passenger Name Record (PNR) data. This data allows for systematic screening and profiling of passengers, enabling officers to better anticipate and identify high-risk travelers.
(d) Intelligent operations: as officers are supposed to focus on high-risk travelers, the proposed system

shall allow officers to monitor a number of eGates at the same time, providing intelligent indicators and highlighting the travelers that need attention. The use of multiple machine learning-based facial detection algorithms in the ABC system allows for accurate identification of individuals, even under varying conditions like pose, expression, makeup, and lighting. This intelligent system ensures that only authenticated passengers are allowed to proceed, enabling officers to focus on high-risk travelers.

(e) Enhance security: by adopting biometrics into the process, the system shall detect and eradicate fraudulent attempts to cross the border. The biometric system in the ABC System operates in two phases: enrollment and authentication. During the enrollment phase, biometric components of the user such as palm detection are collected and stored. In the verification stage, these biometric patterns are used to authenticate the identity of the user, enhancing the security of the border control process.

(f) Expandable: the solution shall be easily expandable to integrate additional Immigration eGates, counters, and boarding eGates to cover additional throughputs and airport expansions. The ABC system's platform is designed for extensive airline connectivity and integration with various databases like the existing immigration system, Exit Control List (ECL), NADRA database, online Visa database, Passport database, and API/PNR systems. This design facilitates the easy expansion of the system to integrate additional Immigration eGates and counters, covering additional throughputs and airport expansions.

1.2 Scope of research product

A global approach for border security is to deliver the ability to identify travelers [2]. The ultimate aim is to deter or stop an unwanted person from entering the country or conversely, to stop a wanted person from leaving the country as well as monitor domestic travelers within the Country. The following describes the scope of ABC System under this SRS in detail:

(a) Deliver fully integrated solutions, including professional services for passengers and crews in Pakistani airports, and propose advanced technologies for frictionless biometric controls on travelers.

(b) Implement comprehensive solutions for border control, including Entry/Exit processes with API-PNR functions, self-service biometric boarding eGates at domestic terminals, and ensure high availability services to prevent service failures at the border.

(c) Develop the solution based on a comprehensive turnkey platform, which is configured to provide an integrated application package to collect, process, and analyze API and PNR passenger data. This global solution offers a comprehensive plan for an advanced aviation security and data management system. Key features include the collection of passenger booking (PNR) and check-in (API) information for systematic screening, extensive airline connectivity using standard protocols, the development of a central workflow management engine integrating various systems, and the storage of results in a secure database. The system also emphasizes reliable traveler data screening, a smart targeting tool for risk analysis, innovative profiling functions, data control, and consolidation, full compliance with international privacy and security regulations, extreme flexibility for diverse user organizations, an end-to-end solution with the latest technology, and native external interfaces for direct interaction with governmental and international information systems.

2 Related Work

In the realm of security, face detection and recognition have garnered significant attention in recent years. P. Singhal et al. [3] delved into the intricacies of face identification, highlighting challenges such as fluctuating face postures, diverse lighting conditions, fuzzy faces, post-surgery facial changes, variations in illumination, occlusion, facial expressions, and low-resolution issues. Their research proposed various machine learning algorithms to effectively tackle these challenges. In another research at [4] , scientists emphasized the inefficiency of conventional supervision signals, which neglect class distribution and suffer from excessive localization. For the purpose of training deep Equi distributed representations in face recognition, the author introduces a novel supervision objective known as uniform loss. Unlike current approaches that primarily focus on acquiring discriminative facial features by promoting significant inter-class distances and minimizing intra-class variances, the proposed method aims to achieve a more balanced distribution in the learned representations. The authors at their research [5], have outlined numerous challenges associated with recognizing a face in a crowd, giving rise to significant apprehensions regarding individual freedoms and ethical considerations. Furthermore, the author has underscored drawbacks in 2D face recognition methods, including challenges related to illumination, viewing angle, and the distance between the camera and the subject. The effectiveness of these methods is substantially compromised when environmental conditions, such as lighting, or facial characteristics, such as position or expression, undergo changes. Therefore 3D models have been introduced to overcome these issues and provide greater reliability with higher immunity to different variations in the face [6]. The authors' emphasis in [7] about security concerns that needs to be improved in order to overcome security risk. Hence proposed a security measure using artificial intelligence (AI). For this purpose, the author proposed a combination of Open CV and Python for targeting specific persons in public as well as their identity. In [8], the author proposed a border security mechanism in Indonesia, representing an integrated BCM (border control management). Another solution for Border Control Management was proposed by the authors in [9] i.e. biometric technologies for identification of persons based on the behavioral characteristics and biological features. Researchers at [10] elaborate the concept of smart airport which contains all the information of the passengers and services. According to the authors identification and verification of the passengers prior to boarding is an important issue and biometric technologies can easily monitor and identify the passengers with the help of smart CCTVs cameras and it can also be used to check the accuracy of the travel document. Authors proposed in [11] a secure mechanism for ABC (Automated Border Control) which provide more security against morphing which is one of the threatening attack. In morphing attack a fake face is generated by combining two faces (genuine and fake) which can cause a risky situation at border crossing. Hence the authors proposed a demorphing architecture using Convolve Neural Network CNN. Table 1 represents the Comparative representation of important researches with limitations and contributions to support this research.

This paper introduces an intelligent automated border control system (ABC) designed specifically for Pakistan. The system employs advanced biometric technologies, including contactless facial and palm recognition systems, to minimize the potential spread of the COVID-19 pandemic at the border. Additionally, a travel document reader system, utilizing OCR technology, is implemented to retrieve passport-related information from the database. Our approach incorporates state-of-the-art machine learning-based facial recognition algorithms and contactless palm recognition methods, ensuring the authentication and validation of passengers arriving in Pakistan.

3 Research Methodology

3.1 Research Perspective

Pakistan is a third world country and have many challenges around its vicinity [12]. Hundreds of people across the world are interested to visit Pakistan daily for its tourism beauty and business transactions [13]. To ensure safe and secure arrival of passengers, proper authentication of each passenger is required. It is also very important that the check-in and check-out process at Pakistani Airports should be contactless to avoid the spreading of COVID-19 variants. Various variants of COVID-19 are currently in existence and spreading globally. There is a potential for travel restrictions to be implemented at any moment, so it is advisable to have contingency plans in place to address potential challenges [14]. In the current situation, smart border gateway solutions are not yet implemented to cater immigration process of passengers. We analyze several smart border gateway solutions recently implemented at the airports in advanced countries. The main perspective of this research is to facilitate Pakistan Airports a systematic smart border gateway solution which should be cost-effective, reliable and utilizes the recent technology to integrate with other relevant services like Smart National Identity Cards and e-passports. Several contactless biometric measures are also taken into consideration for fast and smart authentication of passengers. Figure 1 illustrates our scheme's comprehension. The process begins with passengers presenting their travel documents, which are scanned using OCR technology. Then, the system guides them to capture their facial image for recognition using an array of machine learning algorithms. If the algorithms detect the face successfully, the system authenticates the passenger. Concurrently, contactless palm recognition technology verifies the individual by matching the palm pattern using algorithms like SIFT. The successful verification by both facial and palm recognition systems, along with document authentication, allows the passenger through. All this information is managed and processed using Python, with Tkinter used for the GUI. The system is connected with database systems from Exit Control List, NADRA, API/PNR systems and more, for verification of passenger data and authentication. The aim is to provide a fast, secure, and minimal contact experience for passengers, with a focus on enhancing security and handling high passenger volumes efficiently.

3.2 Key features of proposed system

To understand the operational procedure of proposed ABC system, it is essential to understand the overall

TABLE 1: Comparative representation of important researches with limitations and contributions to support this research

Ref.	Limitation of Research	Contribution
[3]	Highlights the face identification challenges	Underscores the role of machine learning algorithms in achieving precise object matching for face detection.
[4]	Emphasized the inefficiency of conventional supervision signals, which neglect class distribution and suffer from excessive localization.	To train deep equidistributed representations for face recognition, a novel supervision objective called uniform loss is proposed.
[5]	Identifying a face in a crowd, which raises severe concerns regarding individual liberties and ethical concerns. Highlight the issues in 2D methods of face recognition such as illumination, angle of view, and camera-subject distance.	Detailed review of face recognition technique and comparison of 2D and 3D techniques with their advantages and limitations. Emphasis on the role of machine learning and deep learning in the domain
[6]	Highlighting the issues in 2D methods of face recognition such as illumination, angle of view, and camera-subject distance.	Use an iterative closest point approach to correct the head rotation in 3D. Extraction of several features such as multi-scale local binary patterns (MSLBP), innovative statistical local features (SLF), Gabor wavelets, and scale-invariant feature transform (SIFT).
[7]	Inefficiencies in face recognition systems in 2D systems include blurred images, inefficient detection, makeup, etc.	Face detection combined with speech and biometric technologies to improve security measures
[8]	identified several issues and challenges at the airport regarding security.	Proposed a border security mechanism to deal with illegal activities in Indonesia, representing an integrated BCM (border control management).
[9]	Highlighted major challenges related to air security including passenger check-in process, passenger identification process and pre-flight inspection process.	Usage of biometric technology in airport passenger processing. Several factors can be eliminated by implementing biometric technologies at specific stages of the passenger processing
[10]	Presented some of the failures in biometric technologies systems related to translating genders and uncertain errors in biometric recognition	Identification and verification of the passengers prior to boarding with the help of smart CCTV cameras and checking the accuracy of the travel document.
[11]	Few attacks in automated border control systems including presentation Attack, which is relatively easy to perform, morphing is the most common attack on security on automated border control systems and due to this, authentication systems are unable to detect them correctly.	A de-morphing architecture based on a convolutional neural network (CNN) architecture is presented. This method makes use of two images: the potentially altered image contained in the passport and the snapshot of the individual stored in the ABC system.
[17]	Highlighted several issues in the detection and identification of face recognition techniques.	A comparison of the advantages and disadvantages of different techniques has been offered for identification and detection of face recognition.
[20]	The author elaborates the challenges in detecting facial expressions with machines and problems associated with images that are captured in controlled environment.	Introduced a unique data-centric strategy for dealing with misclassification, a typical issue in face picture collections. The method is to gradually refine the dataset by consecutive training of a fixed CNN model.

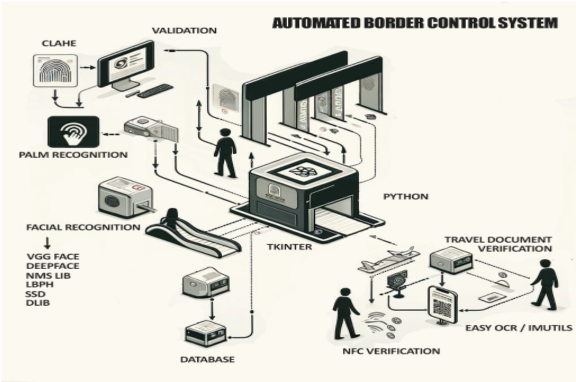

Fig. 1: An illustration of our scheme's comprehension

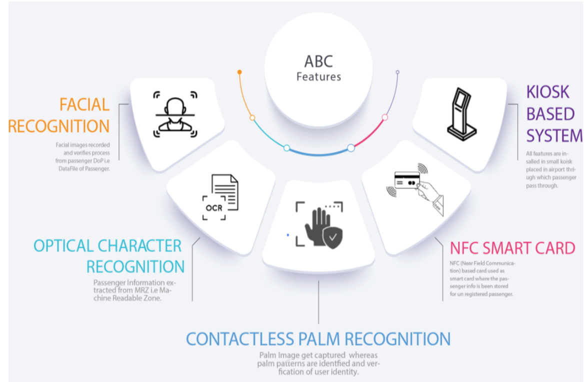

Fig. 2: Key features of proposed Automated Border Control (ABC) System

workflow. Passengers arrive at the Airport. The screen on the device indicates the passengers to lay down their Travel Document on the Document Reader in front of them. This is done through a GIF that describes the exact procedure of the process, to the passenger. If in case the document isn't placed correctly, the system will indicate this message on the screen and will guide the passengers on how to properly record the document on the reader. After the travel document is scanned, the passenger is instructed to look at the camera positioned directly in front of his/her face. Wherein a GIF on the display screen will guide them on how they are instructed to record their face for the Facial Recognition System. In case of any error during the image capture, the screen will ask the passenger to repeat the process. After both the above processes are completed, the user will have to wait for a few moments until the system verifies the passenger. Upon confirmation the screen will display a green light, indicating successful user verification. But in case the user data doesn't match the data stored in the database, the screen will display a red light, indicating unsuccessful user verification (and an airport official will guide them on the later procedures that will happen). Figure 1 shows the key features of the proposed ABC system.

Our proposed smart automated border control system comprises the following major components (a) a Facial recognition system (b) a Travel documents readers system (OCR System) (c) a Contactless palm recognition system, (d) a device to display visual instructions, which guide the passenger through the border control and (e) NFC smart card. A document reader and numerous biometric capture devices are used to read the traveler's document and record the facial image. Incorporated into the user interface are monitors, LEDs, signals, and audio devices.

3.3 Operational Requirements

Operational technologies for this research product include Windows 10 as an operating system; Python as a programming language because of its diverse compatibility and support of multiple programming paradigms like structured, object-oriented and functional while Tkinter is used for the python interface. MySQL is applied for implementing the database system for storing records of each individual.

4 Travel documents Reader System (OCR System)

The decision to employ Optical Character Recognition (OCR) technology in the Smart Automated Border Control System (ABC System) is supported by several key factors aimed at improving functionality, cost-efficiency, and user experience. Unlike dedicated passport readers, OCR offers flexibility by processing various document types, enhancing system effectiveness across a wide range of travel documents. Cost-effectiveness is achieved through the integration of OCR with existing hardware, reducing the need for specialized and expensive equipment. The scalability and future proofing of OCR, facilitated by software updates, make the ABC System adaptable to evolving technological standards. Integration with facial recognition and biometric systems enhances security, creating a comprehensive identity verification framework. OCR's reduced dependency on specialized hardware contributes to improved reliability and durability, as OCR solutions are more resilient to hardware failures. OCR's data processing capabilities extend beyond basic reading, allowing integration with advanced tools like pattern recognition and artificial intelligence, adding significant value to the ABC System. Compliance with global standards is ensured through easy updates, aligning the system with international travel document standards. The user experience is positively impacted by OCR's efficient information processing, resulting in faster processing times and a smoother experience for travelers. In summary, the strategic use of OCR in the ABC System balances flexibility, cost-effectiveness, technological integration, and future-readiness, ensuring the system's effectiveness, efficiency, and adaptability in the dynamic global travel environment. One of the key components of the border crossing procedure is travel documents [15]. They are required by travelers for identification and verification at the ABC e-gates. There isn't, however, a single, standardized travel document that can be used at all international borders. The system's fundamental duties include verifying the validity of the travel document, confirming that the traveler is the legitimate owner of the document, checking border control records, and then automatically checking the entrance requirements. Figure 3 demonstrates the use case scenario of a proposed Travel document Reader System.

There are two types of MRZ region passports and travel cards: Type 1 and Type 3 [16]. Three lines, each comprising 30 characters, make up a Type 1 MRZ. There are only two lines in the Type 3 MRZ, however each line has 44 characters. In either scenario, the MRZ encrypts data that can be used to identify a particular citizen, such as passport ID, type of passport, country name, nationality, Date of expiry, etc. We will accomplish MRZ identification utilizing simply fundamental image processing methods including thresholding, morphological operations, and contour characteristics rather than Histogram of Oriented Gradients and Object Detection. This is due to the fact that we are not required to look for MRZ in a picture. The position of MRZ will always be assured if the requirements of our image extraction are met. Imutils will be used to make basic OpenCV image processing tasks simpler and faster. Figure 4 represents the passport information having MRZ embossed at the bottom of the passport.

To start, we initialize two kernels that will be used later on while performing morphological operations, specifically the closing operation. The first kernel has a rectangular shape with a width that is roughly three times greater than its height. Another kernel is square-shaped. We can close spaces between MRZ characters and MRZ lines using these kernels. Our original image is loaded, then it is resized to a maximum height of 600 pixels.

In order to minimize high frequency noise, gaussian blurring is used. We next do a blackhat morphological operation on the grayscale image that is blurred. To make light backgrounds and dark areas (like the MRZ writing) visible, a blackhat operator is utilized (i.e., the background of the passport itself). A blackhat procedure is appropriate because the passport text is always black on a light background (at least in terms of this dataset). Then, using the Scharr operator, we construct the gradient magnitude representation of the blackhat image. The blackhat image uses the Scharr gradient along the x-axis to highlight areas that are not just dark against a light background but also have vertical gradient variations, such as the MRZ text region. Then, using min/max scaling, we scale this gradient image back into the range [0, 255]. Basically, the goal of this is to lower false-positive MRZ detections.

Using the rectangle kernel we put up earlier, we now apply the closure operation. To fill up spaces between MRZ characters, use the closure procedure. After that, we automatically threshold the image using Otsu's technique. With the aid of our square kernel, we fill in spaces between the several MRZ lines to produce a single, sizable region that is representative of the MRZ. To separate related components that might have been coupled during the closing procedure, a series of erosions are subsequently carried out. Small blobs that are not significant to the MRZ can be eliminated with the aid of these erosions. For some passport scans, the MRZ zone may have grown attached to the border of the passport during the closing process. We fixed this by setting 5% of the left and right image borders to zero (i.e., black). In order to identify the MRZ, we must lastly locate the contours in our thresholded image. Then, we take these contours and arrange them in descending order of size, starting with the largest contours. We start a loop across the contours in our sorted list. We will calculate the bounding box for each of these contours and use it to calculate the aspect ratio and coverage ratio. For calculating the aspect ratio simply the width of the bounding box is divided by the given height and the width of the bounding box divided by the width of the actual image size is known as the coverage ratio. Figure 5 shows the flow control of the Travel Document Reader System.

We can determine if we are looking at the MRZ zone by using these two qualities. The MRZ is a rectangle whose width is significantly greater than its height. Additionally, the MRZ must cover at least 75% of the input image. If these two scenarios are valid, we draw the bounding box on our input image using the (x, y)-coordinates of the bounding box to extract the MRZ.

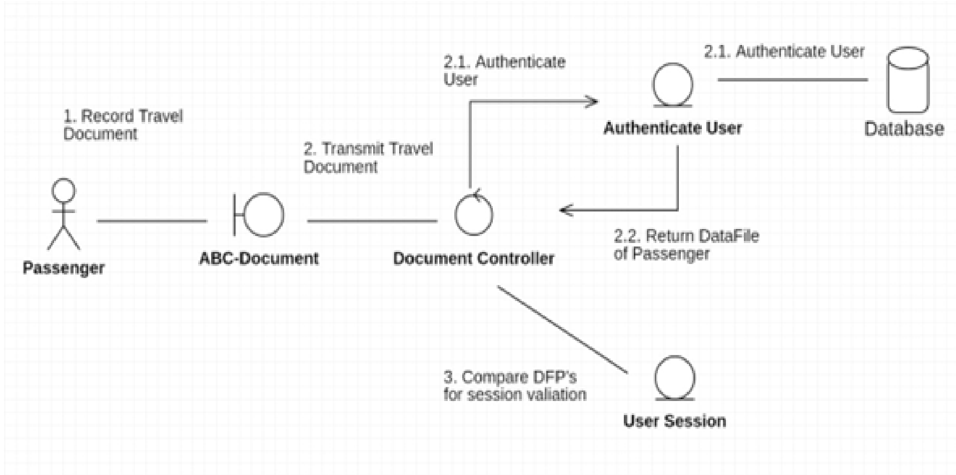

Fig. 3: Use case scenario of Travel document Reader System

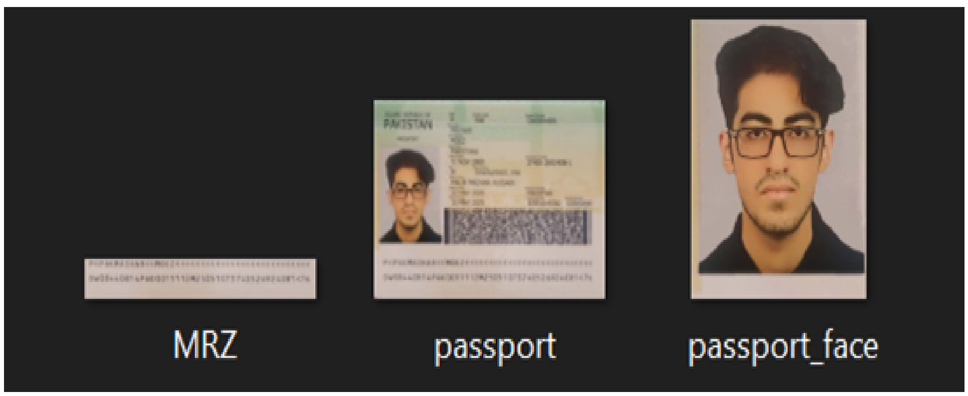

Fig. 4: The passport having Picture and MRZ at bottom

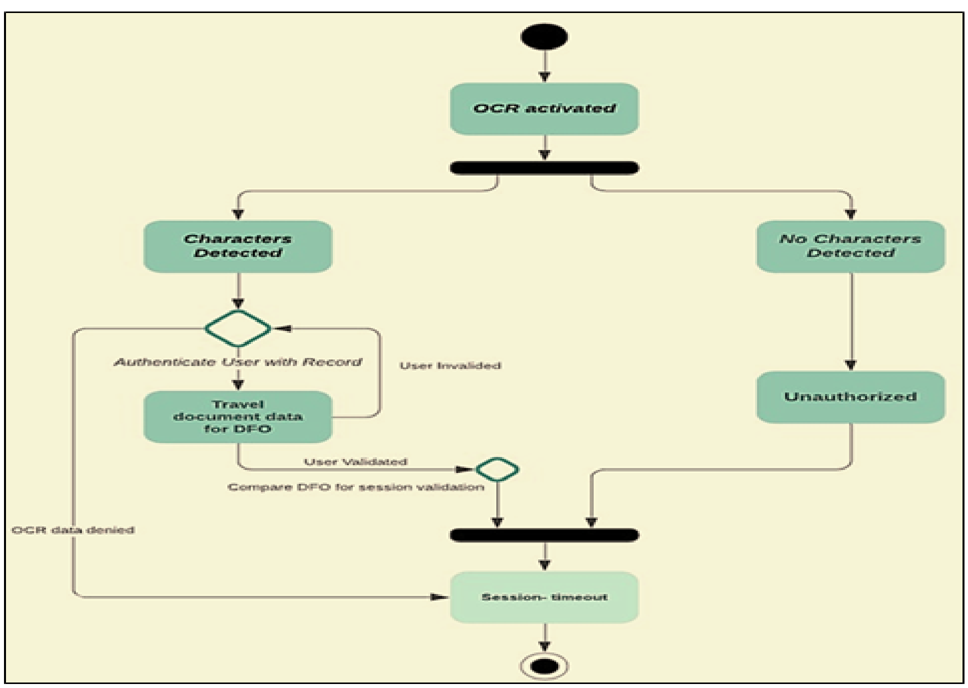

Fig. 5: Flow control of Travel document Reader System

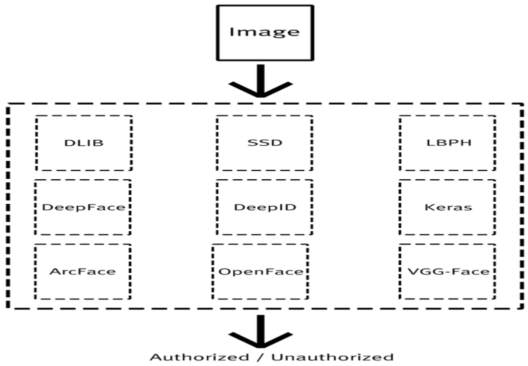

Fig. 6: ML-based Face detection algorithm used in proposed ABC system

5 Face Recognition System

Contactless biometric measures for authentication are the need of time to deter the COVID-19 pandemic. Biometric face detection is also one of the important factors of such measures [17][18]. For the detection of Face in the ABC gateway, different ML-based algorithms can be utilized in the proposed system. Most ML-based algorithms require high-resolution images for the proper detection of faces inside a picture [19]. It is also very important to note that the accurate detection of the face for the recognition of a person is a highly challenging task since the face structure changes according to the pose, expression, lighting impact, and occlusions [20]. This is the reason that we adopt multiple ML-based face detection algorithms in our proposed system. In the available ML base algorithms bucket of the ABC system which contains nine ML-based facial detection algorithms, if three algorithms detect the face successfully, the ABC system verifies that person as authenticated and allows the passenger to proceed. Figure 6 shows the ML-based algorithms for face detection used in the proposed ABC system for authorization of a person.

Similar to OpenCV, Dlib is a potent library that is widely used in the image-processing field [21]. Its face alignment and detection module is mostly used by researchers which is why we select it for face recognition. The four general phases of a contemporary face recognition pipeline are detected, lined up, depicted, and confirmed. Tactfully, dlib's implementation covers each of those phases. Single shot detector (SSD) is one of the important face detection models [22]. The SSD model requires inputs of the size (300, 300, 3). Figure 7 demonstrates the Ensemble method using machine learning algorithms for facial detection.

SSD may be fully trained for greater precision. Position, size, and dimensions are better covered by SSD, which also produces more estimates. With the advancements, SSD may reduce the input image resolution to 300 x 300, or a passport image, while still performing with a comparable degree of precision which is desired in our proposed ABC system. Figure 8 depicts the use case scenario of the face detection process in the proposed ABC system.

Local binary pattern histograms (LBPH) are one of the easiest face recognition algorithms [23]. Local aspects in the photographs can be represented by it. It can withstand monotonic grey-scale conversions. Compared to Facebook's Deep Face, VGG-Face is more deeper. It has 22 layers and 37 deep units. Figure 9 depicts the 22 layers of the VGG-Face model.

We have vectorized the supplied pictures. Finding the separation between two vectors may be done in two methods i.e. cosine distance and Euclidean distance. Whichever metric we choose to use, they are all useful for identifying vector commonalities.. We have converted photos into vectors and calculated the resemblance indices between two vectors. If both photographs are of the same guy, the measurement should be tiny; alternatively, if the two pictures are of different people, the measurement should be huge. Feeding discovered faces significantly improves model accuracy. In addition, according to research from Google FaceNet, merely alignment enhances model accuracy by 1%; fortunately, the Deepface package can handle both the identification and alignment processes with a single line of code. [24]. Face pairings belonging to the same person should be close together, whilst face pairs belonging to different people should be far apart. Here, we need to establish a limit. Our research indicates that the cosine distance should be 0.25 and the Euclidean distance 0.60 as thresholds. Deepface provides you to run a face recognition pipeline with a few lines of code in order to learn how to choose the appropriate threshold value. It incorporates cutting-edge facial recognition technologies including DeepID, Facebook DeepFace, Google FaceNet, OpenFace, and VGG-Face. In DeepID models, there are 4 convolutional layers and 1 fully connected layer. To begin with, the model was trained to categorize n IDs using a standard classification task. Once training is complete, the final classification softmax layer is removed, and the inputs are represented as 160 dimensional vectors by an early fully connected layer. The model is able to depict unfamiliar faces in this manner. In Keras, we may construct a DeepID model. The DeepID model is in charge of converting facial pictures into vectors. FaceNet, a deep learning-based facial recognition algorithm, was introduced by Google. On the pre-qualification process, it was constructed. Es-

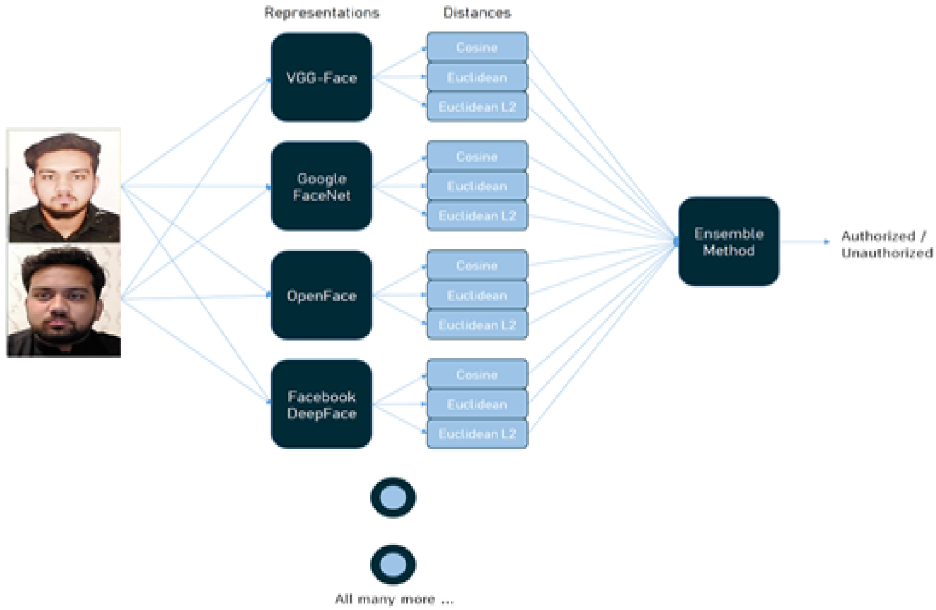

Fig. 7: Ensemble Method using machine learning algorithms for facial detection

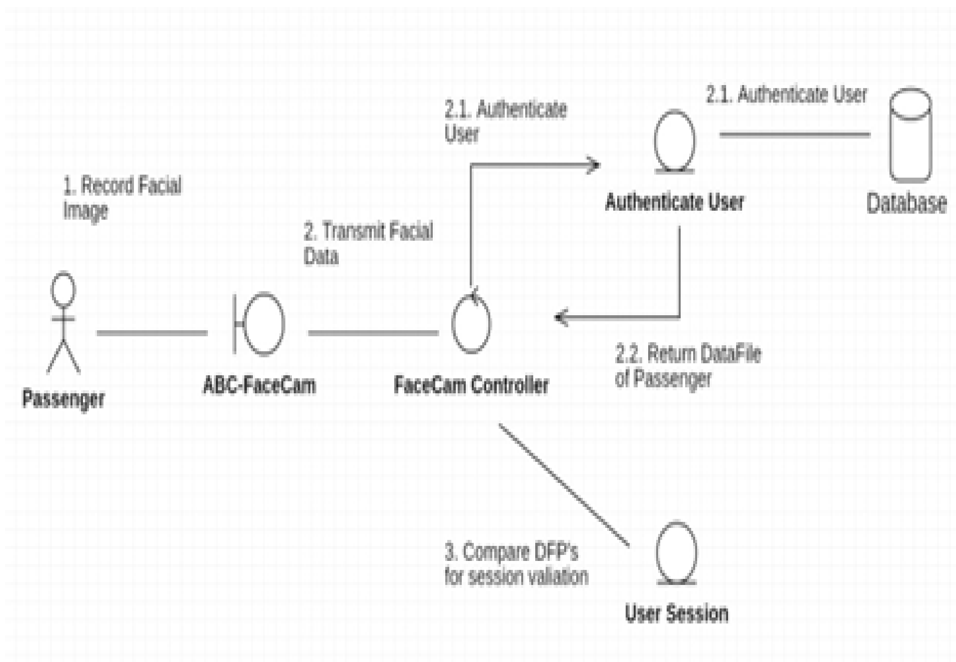

Fig. 8: Use case scenario of face detection process in the proposed ABC system

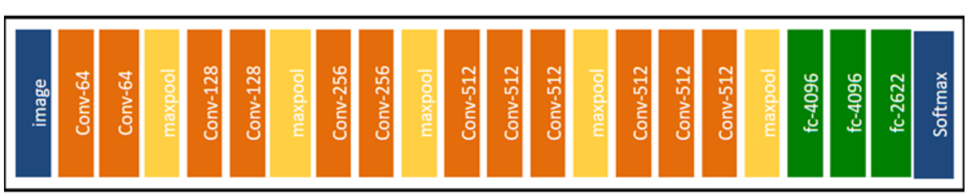

Fig. 9: VGG-Face model exploits in its 22 layers

sentially, the notion behind encoding two pictures as lower dimension vectors and deciding identification based on similarity, much as in Oxford's VGG-Face, is what allows humans to recognize faces. FaceNet model generates 128-dimensional representations but anticipates 160x160 RGB pictures. The input for the OpenFace model is (96x96) RGB pictures. Its output is 128 dimensional. Although the model appears sophisticated, it has far less parameters than VGG-Face. While various faces should have a large distance, multiple images of the same individual should have a low distance. The metric in this case might be cosine or euclidean distance. NMSLIB, often known as the Non-Metris Space Library, is a powerful similarity search tool. A CNN model receives a face picture and outputs an interpretation. The verification stage measures the separation between two depictions of the same face and, if it is less than a threshold, verifies that they indicate the same face. First, we will identify and align the target image's faces. Second, use the Dlib ResNet model to describe the face picture as a 128-dimensional vector; then as expected by NMSLIB, make it a 2D matrix. The vector representations of the faces are then added to the index.

5.1 Limitations of Facial Recognition Systems

Facial recognition systems, while technologically advanced, have several limitations that affect their widespread adoption and effectiveness in various scenarios, such as border control systems. Changes in a person's physical appearance, like aging, hairstyles, facial hair, or cosmetic use, can affect the accuracy of facial recognition systems. These systems may struggle to identify individuals accurately if their current appearance differs significantly from the images in the database. The performance of facial recognition systems can be impacted by environmental factors such as lighting, camera quality, and angles. Poor lighting conditions or low-quality camera images can lead to incorrect or unreliable recognition. Some facial recognition algorithms may have inherent biases or limitations, leading to higher error rates for certain demographic groups. This can result in unequal performance across different genders, ages, or ethnicities. The use of facial recognition raises significant privacy concerns. The collection, storage, and use of biometric data can be intrusive, and there are risks associated with data breaches or misuse of information. Different countries and regions have varying regulations regarding the use of biometric data, including facial recognition. Navigating these legal frameworks and ensuring compliance can be challenging for organizations. The effectiveness of facial recognition is largely dependent on the quality and size of the existing image databases. Inaccurate, outdated, or limited databases can severely hamper the system's effectiveness. There are ways to deceive facial recognition systems, such as using photographs, masks, or other techniques to spoof the system. This poses a security risk, especially in sensitive areas like border control. Due to these limitations, while facial recognition technology offers promising capabilities, its practical application, especially in sensitive areas like border control, is approached with caution and is often supplemented with other security measures.

6 Fingerprint System (Contactless Palm Recognition System)

The integration of palm-based biometric data collection into Pakistan's e-passport application process is a practical and efficient strategy. Aligning this new collection method with the existing nationwide e-passport system streamlines implementation. The established framework of the e-passport system ensures systematic and uniform palm data collection, facilitating smooth integration into the national database.

Palm prints offer greater uniqueness compared to fingerprints, with a larger surface area containing more ridges and points. This uniqueness enhances reliability and security, reducing the likelihood of false matches, which is especially advantageous in a large-scale national database. The complexity and infrequency of palm prints on surfaces make them harder to forge, adding an extra layer of security.

Palm prints remain consistent across age groups, making them more reliable than fingerprints, which may lose distinctiveness with age-related skin changes. The durability of palm prints, less susceptible to wear and tear, ensures reliable biometric data over an extended period.

Palm scanners, designed for contactless scanning, provide a hygienic and user-friendly method, aligning with post-COVID'19 health and hygiene awareness. Incorporating palm biometrics enhances the security, reliability, and efficiency of the e-passport system. Furthermore, it establishes a foundation for broader use of palm biometrics in other applications, potentially strengthening national security and identity verification processes.

A biometric system has been proposed to meet airports' future border control demands as a result of the worldwide increase in passenger volume. The smart ABC systems function in two phases: enrollment and authentication, and they employ immoral biometric systems for access control. The user's biometric components are collected during the enrollment phase using a biometric scanner and saved as a marked pattern in a database. The biometric patterns are recorded during the verification stage in order to identify and confirm the digital credentials.

A useful scale-invariant feature transform (SIFT) for palm pattern detection is the Handprint System. a fingerprint recognition system that works well for fingerprint pattern-based personal identification. Because it might be readily taken from people, this strategy encourages fraud. The aforementioned issue is solved by the SIFT approach, which combines a rapid crucial point detector and a visual descriptor. Contactless palm pattern pictures may be captured, matched, recognized, and verified using the SIFT method, and OpenCV can be used to mimic the matching performance of these images. The experimental findings demonstrate that the SIFT approach performs substantially faster and better than the traditional methods, such as orientated FAST and rotating BRIEF (ORB). The hands were extracted from the image as foreground pixels segmented from the background based on skin detection algorithms. The image was subject to rotation to 90 degrees to test the accuracy of feature descriptor algorithms. A comparison study was carried out where SIFT, SURF, and ORB detectors were tested against the number of correct matches produced for image rotation.

A feature is an attribute or a characteristic property of an object, which is tracked. Local image features can be defined as a specific pattern, which is unique from its neighbor pixels; it can be an edge, corner, or a region. An edge refers to the pixel pattern where an intensity changes abruptly. A corner is the intersection of two or more edges in a local neighborhood. A region is a closed set of connected points with a similar intensity. These local features are converted into numerical descriptors; and provide a powerful tool in computer vision and robotic applications such as image retrieval, object tracking, video mining, etc.

6.1 Palm Pattern Recognition

The contactless palm print and palm vein recognition system makes use of a hand sensor that can take a low-resolution picture of the palm print and palm vein [25]. While removing luminous error, the local ridge enhancement (LRE) approach maintains a valuable connection between the print template and the backdrop image [26]. Systems for biometric identification offer further benefits and strong anti-spoofing features. The system evaluates the attributes contemporary in palm print and palm vein images using the contourlet transform [27]. By evaluating the picture knowledge and creating a local determination at each image location, feature detection is used to determine whether an image feature of the specific subset is represented there. This method encourages fraud because it can be obtained simply from people. We suggest an innovative feature-based palm pattern identification system to prevent such fraud. Shape As according to earlier related research, segregating colored visuals has detrimental impacts. Prior to segmentation, our suggested method transforms BGR images into grayscale images. Hand form segmentation is possible to derive from the ROI of the palm pattern. Additionally, poor photos could be a result of the illumination. The hand shape is segmented using the SIFT method to prevent such a noisy region.

6.1.1 Rationale for using Palm Pattern Recognition

It is important to clarify that the palm recognition system, much like facial recognition, operates on a contactless principle. The primary difference lies in the biometric attribute being captured – palms instead of faces. The palm recognition system in the Automated Border Control (ABC) System captures an image of the hand from a close range without physical contact. This maintains the essential feature of being contactless, akin to facial recognition systems. The rationale for using palm recognition alongside facial recognition is multifaceted:

(a) Enhanced Security: Palm recognition provides an additional layer of security. Each individual's palm print is unique, and when used in conjunction with facial recognition, it increases the system's ability to accurately verify identities.

(b) Reduced Error Rates: The combination of facial and palm recognition can potentially reduce false positives and false negatives, leading to a more reliable system.

(c) Flexibility in Various Conditions: Palm recognition can be particularly useful in situations where facial recognition might face challenges, such as poor lighting conditions, or when the subject's face is partially covered or not in an optimal position for recognition.

(d) Public Health Considerations: In the context of health concerns like COVID-19, a contactless system is crucial. The palm recognition system ensures no physical contact is required, thus maintaining hygiene and reducing the risk of disease transmission.

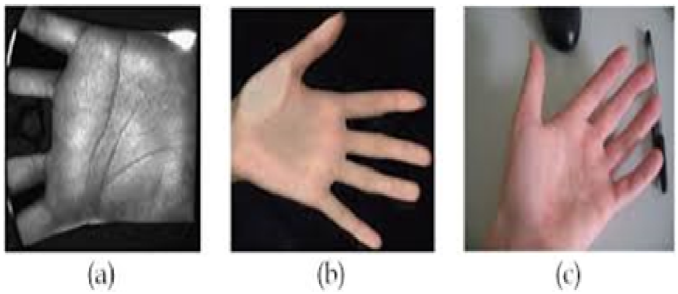

Fig. 10: Illustration of the identification of crucial hand shape compositions

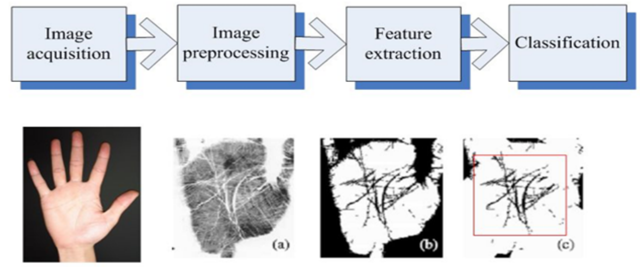

Fig. 11: Palm image processing for feature extraction and classification

The implementation of a contactless palm recognition system complements facial recognition in providing a secure, efficient, and hygienic method of authentication. It addresses various operational challenges while maintaining the integrity of the system as a contactless solution. This dual-modality approach not only enhances security but also adapts to various environmental and situational challenges, thereby improving the overall efficacy of the Automated Border Control System.

6.2 Extraction and normalization of ROI

To extract a ROI from a picture of a palm pattern, the palm pattern's midpoint is used as a reference. A bilinear grey value differential method can be used to normalize palm sample scaling and rotation rectification. The palm pattern ROI is defined by the square of the normalization.
Core ideas of interest are spatial or point locations that are utilized to produce modifications in images like rotation, stringing, or distortion. Key point detection depends heavily on scale and orientation. After key point extraction, it is possible to receive information about the image's position and coverage area. The primary features that are recognized on the given palm pattern image and matched based on the target's orbit measurement. For our convenience, the number of important parameters can be changed based on the image. For instance, Figure 10 illustrates the identification of crucial hand-shape compositions.

Pixel-based arrays of rows and columns build up images. Shared rows and columns are used to identify key points. Key point measurements may be used to identify the target palm pattern image, and structural similarity might be used to compare it to the suggested palm pattern image (SSIM). Then, by creating the structure of lines among the sampled points on the detected image and the reference, matched key points are found. The amount of matching key point lines can be used to calculate the matching percentage accuracy.

Figure 11 illustrates the critical point matching based on distance measurement, for instance. Key point measurements are used to compare the texture of the target palm pattern image and the suggested palm pattern image.

6.3 SIFT Algorithm

The SIFT algorithm is unaffected by changes in brightness, scale, or rotation. Massive feature data can be computed using the SIFT feature, and it can be used with other kinds of feature matching including blood that is existing in the body makes up the patterns on the palms [28]. Infrared rays can be used to obtain it, and it offers defense in case of exterior damage, impersonation, and spoofing. Some benefits of contactless palm patterns include cleanliness and non-contact acquisition. In our suggested method, scale-invariant feature transform 49 is used to segment palm patterns using SIFT Palm pattern recognition. The SIFT algorithm, which is invariant to rotations, scaling, and translations of the sample, is used for image matching and recognition. Using the difference of Gaussian (DOG), SIFT is utilized to calculate the scale space extrema before being used to locate the sampled point localization for removing the low disparity points [29]. Eventually, a key point orientation assignment based on the local picture gradient was completed. Using picture gradient magnitude and orientation, we then determine the image descriptor for each key point. Obtaining the target sample and computing the image's scale space extrema using the DOG function are the first two steps of the SIFT algorithm. (3) Localization of the key point; (4) Image descriptor computation.

6.4 Verification of Key points

The first step is to convert our image into greyscale, after which we apply Gaussian blur, to cover up image noise caused by higher ISO light sensitivities. Figure 12 shows the conversion of the original palm image to a grayscale.

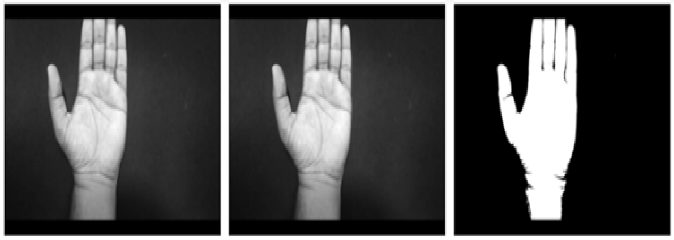

Fig. 12: Ensemble Method using machine learning algorithms for facial detection

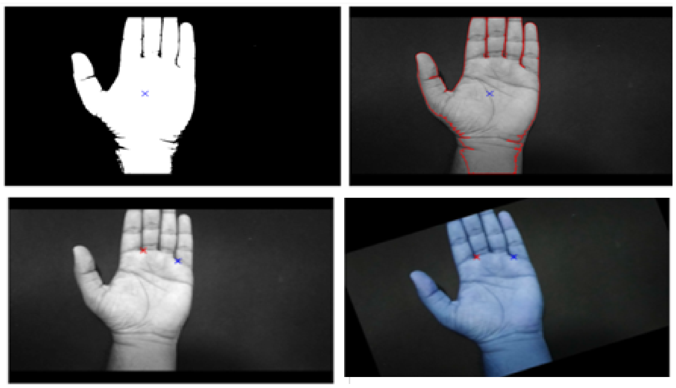

Fig. 13: Illustration of valley points in the palm

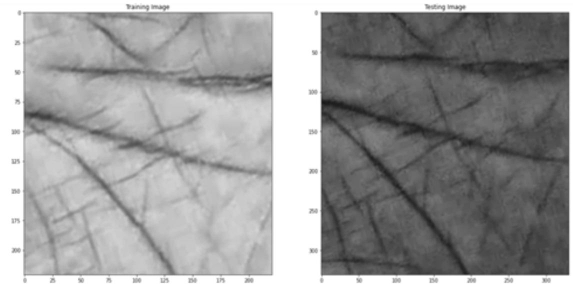

Fig. 14: Training image and Testing image

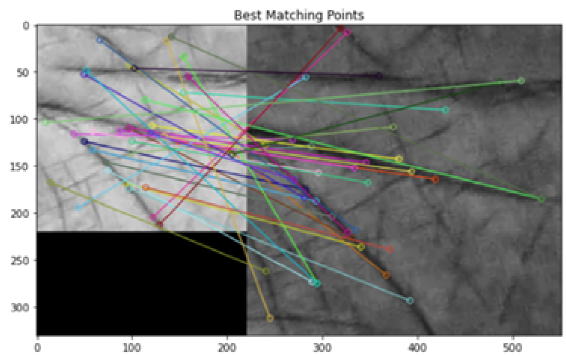

Fig. 15: Brute force matching illustration of matching points

The next step would be to extract the hand from this blurred image and we do this using a greyscale threshold (otsu threshold)[30]. Upon extracting the hand from the background, we need to find out the center of the hand and in order to do this we use OpenCV moments. In OpenCV, moments are the average of the intensities of an image's pixels. We further iterate our image through a kernel matrix, because when a computation is done over a pixel neighborhood, it is common to represent this with a kernel matrix. Then we find the contours in our image and then fetch the largest contour value. Then we can easily find the distance between the counters and the center. In order to get the x and y axis of this ROI, we need to find the valley points i.e. between the nearest fingers (middle, index) and farthest fingers(ring, pinky). These valley points allow us to create a new image that covers the region of interest i.e. the palm of our hand. Figure 13 illustrates the valley points of a palm. After having created a ROI of our initial image we then create a CLAHE object. Contrast Limited AHE (CLAHE) adaptable histogram equalization form has a restricted amount of contrast amplification reducing noise amplification. The slope of the transformation function determines the contrast amplification in CLAHE near a particular pixel value[31] .

Further removing the noise from our image and applying the Gaussian filter and Otsu's Thresholding we find a normalized histogram and its cumulative distribution function. Then we can load this image as our training image and compare it with a test image that has already gone through this process as shown in Figure 14.

Both the images have to go through SIFT descriptors.detectAndCompute, allowing us to find the key points with and without size. Upon completion of this task, we allow a Brute Force matcher object to perform the matching between the SIFT descriptors of the training image and the test image. The matches with shorter distances are the ones we want. The brute force matching illustration can be shown in Figure 15. Upon countless tests based on our test environment, we came to the conclusion that a threshold of 85% is accurate to provide verification of our image comparison.

7 The Role of Machine Learning in ABC system

The application of machine learning (ML) in creating a smart Automated Border Control (ABC) system for Pakistan's airports. ML techniques are chiefly used in two components: The system employs state-of-the-art ML algorithms for facial recognition, tailored to accurately identify individuals even under varied conditions such as different poses, expressions, makeup, and lighting levels. These algorithms are a crucial part of the biometric authentication process, ensuring that only verified passengers can proceed.

Alongside facial recognition, the system utilizes advanced ML-based methodologies for contactless palm recognition. This component enhances the system's ability to authenticate individuals without physical contact, contributing to the system's goal of minimizing the spread of infections like COVID-19. The integration of ML in these areas significantly improves security measures, passenger processing speed, and health safety at border checkpoints. By using advanced ML algorithms, the system can process a high volume of passengers efficiently, reducing wait times and improving the overall airport experience.

Leveraging deep learning models for facial and palm recognition to ensure a high level of accuracy in identifying individuals. These models are trained on diverse datasets to handle variations in appearance, ensuring robust performance across different passenger profiles. Utilizing ML algorithms to identify and flag any discrepancies or unusual patterns in passenger data, which might indicate potential security threats. This proactive approach helps in maintaining airport security. The application of ML in analyzing and predicting passenger flow patterns enables the system to dynamically allocate resources and manage queues efficiently, thereby reducing wait times and enhancing the passenger experience.

8 Ethical considerations and security concerns of the proposed system

This section thoroughly addresses the crucial topics of required permissions, data security, and ethical considerations, aiming to guarantee the sustainability and ethical implementation of the proposed Automated border control (ABC) system. The system offers efficiency and convenience, but raises critical ethical and security concerns. Here are some key points to consider:

8.1 Ethical Considerations

Privacy: The extensive data collecting on travelers (biometrics, trip history, etc.) poses privacy issues. Ensure transparent data management methods, data anonymization whenever feasible, and unambiguous opt-out mechanisms.

8.1.1 Nondiscrimination

ABC systems' algorithms must be extensively verified for bias against certain groups based on race, ethnicity, religion, or other characteristics. Regular audits and independent monitoring are critical.

8.1.2 Transparency and Explainability

The decision-making process of ABC systems should be discernible and intelligible, allowing travelers to contest judgments as needed.

8.2 Security concerns

Implement strong cybersecurity measures to safeguard sensitive passenger information against breaches, leaks, and unwanted access.

(a) System Integrity: Ensure that the ABC system is not vulnerable to manipulation, hacking, or other cyberattacks. Regular penetration testing and vulnerability assessments are required
(b) Physical Security: Protect the physical infrastructure of the ABC system and prevent unwanted access to hardware components.
(c) Backup and Redundancy: Have reliable backup and redundancy solutions in place to ensure continuous operation even in the event of a loss.

9 Approval Authorities Responsible in Pakistan

The implementation of an ABC system in Pakistan would require approvals from various authorities, including:

(a) National Database and Registration Authority (NADRA): NADRA, as an administrator of citizen data, is vital for combining biometric verification and data exchange.
(b) Ministry of Interior: The Ministry of Interior would be in charge of comprehensive border security and immigration policy, developing guidelines and overseeing execution.
(c) Federal Investigation Agency (FIA): The FIA oversees national security and border crime investigations, including security evaluations and surveillance for suspected criminal activities.
(d) Civil Aviation Authority (CAA): If deployed at airports, the CAA must work to integrate with current security infrastructure and passenger processing procedures.
(e) Data Protection Authority (DPA): Once constituted, the DPA would be in charge of ensuring compliance with data privacy legislation governing ABC systems.

9.1 Additional Considerations

(a) Public engagement and awareness are crucial to addressing concerns and building trust in the ABC system.
(b) Regular independent audits and assessments of the system's ethical and security implications are essential.
(c) Continuously evaluate the effectiveness and appropriateness of the ABC system in light of evolving technologies and threats.

Fig. 16: Epson WorkForce ES-60W portable wireless scanner

10 Experimental Setups and analysis of Results on Processing Time

We employ the Epson WorkForce ES-60W as shown in Figure 16, a compact and wireless portable document scanner, to handle the scanning of passenger documents. Featuring swift scanning speeds, battery-operated functionality, and Wi-Fi connectivity, this scanner is an excellent fit for professionals with demanding schedules. It efficiently scans documents of various sizes at high resolutions, streamlining digital document management processes. In terms of contactless passenger authentication, we leverage Near Field Communication (NFC) RFID cards as shown in Figure 17. These NFC Cards (NTAG215, 13.56MHz) are versatile and programmable, seamlessly compatible with any NFC-enabled device. They are well-suited for contactless transactions, access control, and personalized NFC applications, boasting 504 bytes of usable memory and robust security features. Furthermore, the mobile phones utilized in our experiment come equipped with built-in NFC card readers. For example, the Samsung Galaxy S10 incorporates this feature as shown in Figure 18, facilitating effortless contactless payments and data transfer. This technology supports various functions such as mobile payments, device synchronization, and NFC tag/card detection, enhancing both connectivity and user convenience. For facial recognition, we utilize the Hikvision vision, an 8MP 4K HD PoE IP Dome Security Camera as shown in Figure 19. This camera offers EXIR night vision capabilities up to 98ft, Smart H.265+ technology for optimized storage, Wide Dynamic Range (WDR), an SD card slot, and an IP67 weatherproof rating, ensuring reliable surveillance in diverse environments. Alternatively, a high-quality mobile phone camera can suffice when connected with a low-latency connection, provided that it is positioned at the appropriate height (utilizing a tripod or similar support) and under suitable lighting conditions.

Fig. 17: NFC RFID cards for contactless authentication

Figure 20 illustrates a comparative analysis of the processing time between the conventional and the proposed Automatic Border Control (ABC) system. We examined the processing time at five immigration checkpoints, including document check, face recognition, background checking process, authorization, and final check. The results of the comparative analysis demonstrate that our proposed scheme excels in processing time across all five checkpoints. The statistical data in the graph reveals that manual immigration would consume nearly four times more processing

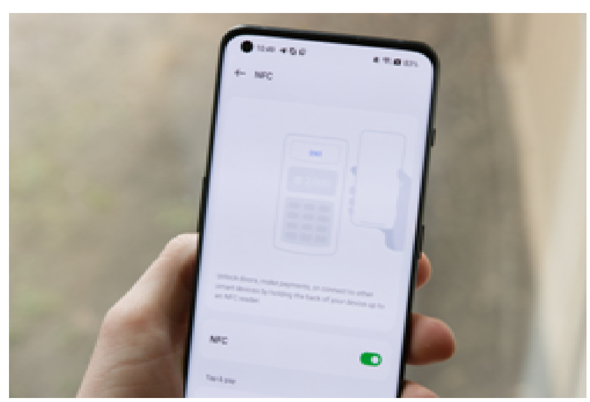

Fig. 18: Epson . Samsung Galaxy S10 with built-in NFC card reader functionlality

Fig. 19: Epson Hikvision vision Security Camera for facial detection

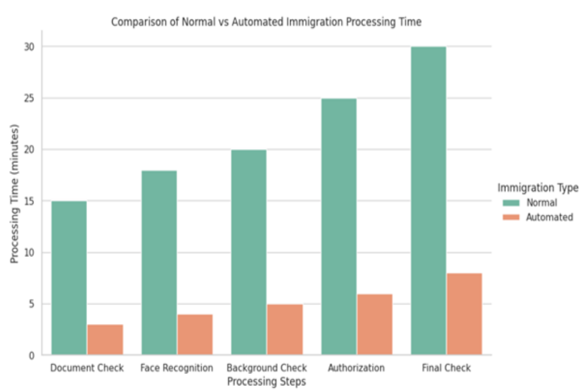

Fig. 20: Analysis of Results on Processing Time

time for a single passenger compared to our proposed ABC system. Therefore, our proposed system not only ensures security but also proves to be time-efficient for passengers.

11 Conclusion

In this paper, we proposed a smart automated border control system (ABC), especially for Pakistan. The proposed system uses the latest biometric contactless facial and palm recognition systems to ensure the minimal spread of the COVID-19 pandemic across the border. A travel document reader system is applied based on OCR technology for the retrieval of passport-based information from the database. We have used recent machine learning-based facial recognition algorithms and contactless palm recognition methodology based on recent algorithms to authenticate and validate the passengers coming to Pakistan. The proposed system can be integrated into other services like the existing immigration system (IBMS), Exit Control List (ECL), NADRA database, online Visa database, Passport database, and API/PNR systems. The proposed system fastens the authentication process and minimizes the delay in the immigration process.

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