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Design and Implementation of a Frame-work for Integration of Biometric Data

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ABSTRACT

The Nigerian Government has been striving to create a centralized database to be overseen by the National Identity Management Commission, NIMC to store personal information and biometrics data of Nigerian citizens. This research aims to create a model that can be adopted by NIMC to seamlessly integrate biometrics data in order to curb indiscriminate collection of biometrics data which is a major challenge in the country at present. A total of 70 citizens were enrolled in the Database with their fingerprint templates and facial recognition images incorporated. The datasets utilized encompasses soft and hard biometric traits. The soft biometric traits are: Name, Gender, Date of Birth and Height. For the hard biometric traits, the fingerprint templates were captured for both thumbs, as well as the right and left index fingers using the DigitalP ersona U4500 fingerprint scanner which uses minutiae data format and the features are extracted using the Crossing Number, (CN) concept to store fingerprint templates. Frontal facial images are captured using a PC webcam and stored in PNG format. Other datasets included are: Address, Language, Place of Birth, Profession, State of Origin and Local government of origin. A Citizen Bimodal Biometric System was developed with integrated security measures for access control. At the decision level, a logical (OR) technique was used to combine the two biometric datasets. The web application was designed using C#.Net for the Front-end and MySQL for the Back-end. The application includes: Enrollment, Verification, Reports, Advance and Settings Modules respectively. The verification module connects to the central database so that enrollees can be verified using the Fingerprint, Live Facial Image or the National Identification Number, (NIN). The Bimodal Biometric System has a recognition accuracy rate of 83%.

1.0 INTRODUCTION

Biometrics commonly refers to the automated or computerized recognition of individuals through physiological attributes such as fingerprints, facial features, iris and retinal patterns, hand geometry and/or behavioral attributes such as keystrokes, voice patterns, signatures, handwriting,[12]. The term "Biometrics" originates from the Greek words 'bio,' meaning life, and 'metric,'meaningto measure. Due to the inherent inaccuracies of traditional identification methods like PINs or passwords [15], biometric technologies are increasingly favored as superior alternatives for identification across various organizations and government agencies[22].Numerous countries have established national identification systems based on databases that store biometric data of theircitizens, examples include, Unique Identification Authority of India, the United States', Integrated Automatic Fingerprint Identification System ,and the United Kingdom's National Deoxyribonucleic Acid Database. The Nigerian government also recognized the urgent need for a robust identity system to improve access to social services and mitigate crime. Fraudulent activities, such as the proliferation of fictitious bank accounts, embezzlement facilitated by corrupt bank employees, counterfeit passports and driving licenses, e.t.c. prompted the government to introduce biometric technology as a solution. Consequently, the Nigerian government launched the 'National Identity Database,' in 2007; however, its complete implementation is still pending. The objective of the National Identity Database (NID) is to create a unified national repository that consolidates information on Nigerian citizens sourced from various organizational databases to be managed by the NIMC, but despite multiple efforts, the project remains uncompleted. The NIMC is responsible for providing services such as enrollment and issuance of NINs, issuance of national e-ID cards, identity verification, data integration, and authentication [5]. In December 2020, the Federal Government of Nigeria required all citizens to connect their NIN's with their SIM cards, warning of potential disconnection for non-compliance [10].This directive necessitated supplying biometric information, akin to the process for NIN registration to mobile telecommunication companies. Also, in April, 2010, The Nigerian Communications Commission, NCC mandated all telecommunications service providers such as MTN, Airtel, Glo, etc.to register every SIM card, associating each mobile phone number with a biometric profile to facilitate the monitoring of criminal activities [13].Failure to register your mobile telephone number would result in an inability to operate such mobile telephone numbers anywhere in Nigeria. Also, the Central Bank of Nigeria introduced the Bank Verification Number (BVN) in February 2014, which marked one of the earliest biometric measures. It involves recording and storing unique physical traits like fingerprints and facial features to accurately identify customers for transactions [6]. Without a BVN, individuals cannot open or operate personal bank accounts in Nigeria.Consequently, citizens found themselves with multiple biometric profiles across private and government institutions.Moreover, the scattered nature of biometric data across different organizations results in this valuable resource not being fully utilized to address criminal activities effectively, therefore, integrating all these biometrics into a centralized database, while eliminating duplications, could potentially address many of Nigeria's security and criminal issues.The advancement of electronic data processing and the introduction of mainframe computers have empowered governments and large corporations to establish extensive data repositories, thereby improving the gathering, processing, and sharing of personal information. However, this development has come at the expense of individuals' privacy. Privacy is regarded as a fundamental human right, crucial for maintaining autonomy and self-determination in an increasingly digital world [21].Biometric databases are established within the NIMC databases, under the NIMC Act 2007. Section 26(1) of the NIMC Act limits individuals or corporate bodies from accessing data or information within the NIMC database concerning a registered individual without authorization from the Commission. Nonetheless, the Commission is authorized to grant third-party access to individuals' stored information without their consent for national security, crime prevention, or other specified purposes, as determined by the Commission [20].

2.0 REVIEW OF RELATED WORKS

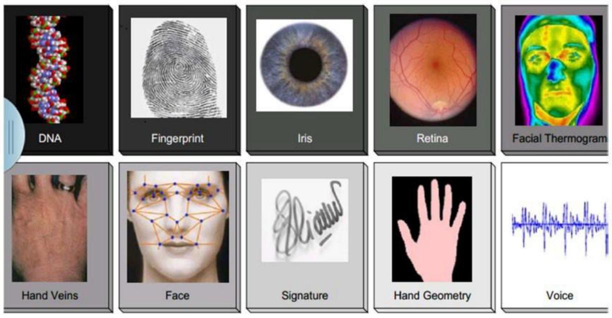


Figure 1: Various Biometric traits
Source : ('Chinedu et al., 2018')

Atuegwu et al., 2018 developed a bimodal biometric student attendance system incorporating both fingerprint and facial traits. Fingerprints capture was facilitated by a DigitalPersonaU4500scanner, with feature extraction performed through a combination of Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA). A thinning algorithm digitized andextracts minutiae points from the scanned fingerprints. The students' facial images were captured via webcam and the facial recognition was conducted using the Support Vector Machine (SVM) Classifier. The MATLAB GUI served as the interface between the database and system users. Student information was stored in a Microsoft Query Language (MySQL) database running on an Apache server. At the decision level, a logical (OR) technique fused the two biometric data sets. While initially enrolling fifty students, the database was scalable to accommodate hundreds of thousands of entries. For each student, ten facial images capturing various postures and expressions ,along with four fingerprint images, were collected for facial and fingerprint matching. The implemented system achieved a minimum recognition accuracy of 87.83%, demonstrating the potential of bimodal biometrics in enhancing automated student systems' recognition accuracy.

Najam et al., 2018 conducted research on a Novel Hybrid Biometric Electronic Voting System, integrating fingerprint and facial recognition methods for voters' identification. The facial recognition component utilizes the Viola-Jones algorithm combined with a rectangular Haar feature selection method for feature detection and extraction using Boosted Local Feature. Facial recognition is achieved through a cascading process of Global Principal Component Analysis (GPCA) and K-Nearest Neighbour (KNN) algorithms. For fingerprint identification, an optical method is employed, and pattern recognition is used to accomplishfingerprint-based identification. The voter registration process begins byassigning a unique voter number to each voter. Instructions are displayed on the screen prompting voters to place their face in front of the camera, capture the image, normalize it, and divide it into24x24sub-windows.This procedure extracts distinct features and creates a vectored biometric layout of the facial image. The resulting biometric template can be used to train the classifier using an Adaboost trainer, forming a codebook for the Eigen vectors. Subsequently, the generated biometric layout is saved in the database against the encrypted ID number, marking the initial step towards facial feature recognition. Next, voters are prompted to place their thumb on the scanner. The thumb sensor scans and creates a biometric layout of the voter's thumb, storing it against the same encrypted voter number in the database. Both facial and thumb print biometric templates are then compared with pre-stored biometric layouts in the database to prevent multiple registrations of the same voter. The distinct features are vectored and compared with the biometric layout in the database. If a match is found, the voter is permitted to cast the vote. However, if no match is found, an error is displayed, and a message is sent to the relevant authority. The system demonstrated an accuracy of 91% for facialrecognition and 98% for fingerprint recognition. Despite its high accuracy, the developed system exhibited slow response times as the number of features extracted and stored in the biometric template increased.

Afolabi et al., 2019 conducted research on enhancing the security of E-Library Systems using a Bimodal Biometric Technique. This system integrates both facial recognition and finger print identification capabilities, requiring both the face and fingerprint provided by the user to match those in the database for access to be granted. Principal Component Analysis (PCA) is employed for face recognition, while a SecuGen thumb print reader is utilized for fingerprint identification. In pre-processing the fingerprint images, coloured images from the database are converted to grayscale images with pixel values ranging from 0 to 255.Fast Fourier Transform (FFT) is applied to enhance the images by dividing them into small processing blocks (32x32 pixels) andperforming Fourier transform. The Euclidean Distance Algorithm (EDA) is used for calculating the distance between each pixel of trained images. If this distance exceeds the threshold, the image will not match. For facial recognition, webcam images were captured within Ladoke Akintola University of Technology, Ogbomosho. These images, stored in JPEG format, include four images per individual, each originally sized at 180x 180pixels.The gray scale images are resized to extract features such as eyes, nose, and mouth regions in reference to the center of each face image in the database, then appropriately represented in matrix format and stored in a vector of size, N .The prototype of the dual biometric security system was tested with approximately 10 individuals. The recognition software accurately identified all the test images and network reported whether a match existed in the database or not. The mean recognition time was recorded as5.6292seconds, and the percentage accuracy of the dual biometrics system was determined to be 90%.

Khan et al., 2019 introduced a facial recognition system employing a Convolutional Neural Network (CNN) known as AlexNet, renowned for its deep learning architecture with numerous layers. They conducted transfer learning on this network, training it on their servers for the purpose of facial recognition. This network requires an extensive database for training, yet it exhibits high precision. The database utilized for training comprised four distinct classes, each containing 1000 images. Training was carried out using epochs equivalent to 20 and a batch size of 10. The precision achieved by training the network with these parameters was 97.95%. MATLAB was employed for implementing the system.

Adewale et al., 2021 conducted research on developing an electronic voting system employing fingerprint and visual semagram techniques. The proposed e-voting model comprises six modules: enrollment, authentication, voting, results, semagramming and desemagramming. These modules were designed to address functional and security requirements: enrollment, authentication, confidentiality, integrity, transparency, and convenience. The E-voting modelwas implemented using Java in Android Studio for the front-end interface, enabling relevant authorities to manage administrative activities like creating election officers, polling booths, wards, local government areas, states, and registering political parties and contestants. The backend utilized Internet Information Server (IIS) to provide services for mobile clients, facilitate fast election configuration, and host the application communicating with the database. Additionally, a desktop version was developed using C-Sharp (C#) programming language for voters' fingerprint biometric enrollment, authentication, voting, transmission and reception of sensitive results. MySQLwas used to create the database for organizing, storing, and retrieving relevant information. The proposed e-voting model underwent testing at FCT College of Education, Zuba, Abuja, during the Deanship election in October 2021. Staff from five faculties participated in the official election to elect respective deans. Each eligible staff member was enrolled and provided with a Voter Identification Number (VIN) card.Voters' data were processed and stored in a database for future reference, involving image pre-processing, minutiae extraction, and matching. Ridge end and bifurcation minutiae were considered, and the crossing number "CN" was utilized for minutiae point identification. After successful authentication, a menu of contestants was displayed for voters to elect their preferred candidate. Sensitive results were encrypted and concealed within an image using the visual semagram technique, producing "Vimago." Steganalysis confirmed that concealed results were undetected. The experiment yielded an Equal Error Rate of 0.0019, a sensitivity of 0.9962, and an accuracy of 99.81%, demonstrating the reliability of the proposed system in addressing identified challenges, restoring confidence, and enhancing citizens' participation in the electoral process.

3.0 Methodology

DataCollection

The dataset utilized for this research encompasses hard biometric traits which are the fingerprint templates and facial recognition images. The soft biometric traits are: Name, Gender, Date of Birth, Height. Other data sets are:

Address, Language, Place of birth, Profession, State of Origin, Local government of Origin

Fingerprint Identification

Each person possesses a distinct fingerprint, with this uniqueness stemming from the local ridge patterns and their relationships, also known as minutiae patterns, as noted by [16].The fingerprint identification system primarily consists of three modules:

i) Preprocessing of fingerprint images, which includes normalization, segmentation, enhancement, and binarization;

ii) Extraction of minutiae, involving thinning and minutiae detection and;

iii) Matching of minutiae [17].

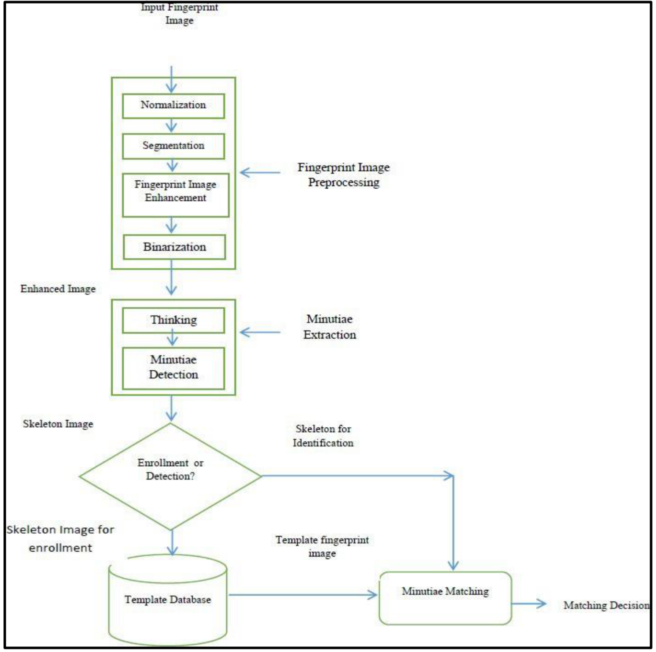


Figure2:Diagram of the Fingerprint Identification System Source:(M.Olagunju *et al.*,2018)

The fingerprint image undergoes processing in the fingerprint image preprocessing stage to generate a skeletonimage, which is then further refined in the minutiae extraction stage to identify minutiae points using the crossing number concept. Following the minutiae extraction stage, if the input fingerprint image is intended for enrolment, the skeleton image is stored as a template fingerprint image in the database; otherwise, the skeleton image isforwarded to the matching stage. In the matching stage, the system compares the skeleton image with templates from the database and determines whether there is a match with the input fingerprint. This research employs minutiae matching and detection, which is a widely used extraction method utilizing the Crossing Number (CN) concept. This approach utilizes the skeleton image where the ridge flow pattern is eight-connected. Minutiae are extracted by scanning the local neighborhood of each ridge pixel in the image using a 3×3window.The CN value is defined as half the sum of the differences between pairs of adjacent pixels in the eight-neighborhood[11]. The CN for a ridge pixel P is given by:-

$$\mathbf{CN} = \frac{1}{2}\sum_{i=1}^{8}\left|\boldsymbol{P\ I} - \boldsymbol{P\ i+1}\ \right|,\ \boldsymbol{P_1 = P_9} \qquad \text{(Eq. 1)}$$

Once the Crossing Number for a ridge pixel has been calculated, the pixel's classification can be determined based on its CN value. The CN value is computed by examining the eight-neighboring pixels of a pixel P in an anticlockwise direction, as illustrated in Table 1 below. Following the computation of the Crossing Number, the pixel is classified into one of three categories (either a ridge ending, bifurcation, or non-minutiae point) based on the properties of its CN value.

Table1:This table displays 3x3 windows for minutiae searching

P_4	P_3	P_2
P_5	P	P_1
P_6	P_7	P_8

Minutiae Matching

Let T and I denote the representations of the template and input fingerprint, respectively. Each minutiae is represented as a triplet m = {x, y, θ}, where x and y represent the coordinates of the minutiae locations, and θ represents the minutiae angle.

T={m1,m2,m3........mm},mi= {x1,y1,q1} (Eq. 2)

i=1,2......m (Eq. 3)

I={m'1,m'2,m'3........m'n},m'j={x'j,y'j,q'j} (Eq. 4)

j=1,2......n (Eq. 5)

Here, m and n represent the counts of minutiae in T and I, respectively. A minutia m'j in I and a minutia mi in Tare deemed "matching" if the spatial distance (sd) between them is less than a specified tolerance r_0, and the directional difference (dd) between the mis smaller than an angular tolerance θ0 [16].

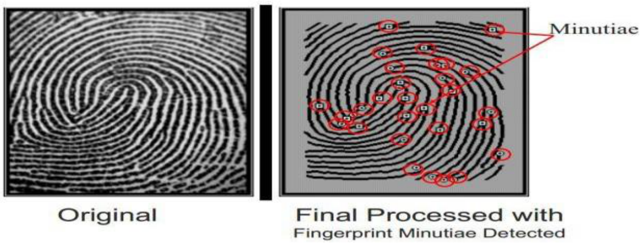


Figure 3: Minutiae points of a processed fingerprint Image Source: (Savvides, 2005)

Distinct locations and types of minutiae features possess the capability to differentiate between various individuals. These characteristics constitute what is stored in the biometric template.

Facial Recognition

Facial recognition technology operates through a specialized neural network known as a convolutional neural network (CNN). CNNs are neural networks designed to handle data through several layers of arrays, making them particularly effective for tasks such as image recognition, including facial recognition software [27].Within CNNs, there are three primary types of layers, which include: Convolution Layer, Pooling layer and Fully-Connected (FC) layer. Within a CNN, multiple layers contain diverse filters, akin to lenses, responsible for identifying distinct characteristics of the target. Early layers prioritize broader features, whereas later ones specialize in precise details. During training, these filter values are fine-tuned using specific datasets. Upon completion, these unique filter values are employed to detect features in new images, aiding in making accurate predictions about their contents [8]. The processes of facial recognition are:-

i) Face Detection and Alignment:- OpenCV (Haar-Cascade) classifier is used to detect faces in the input image.

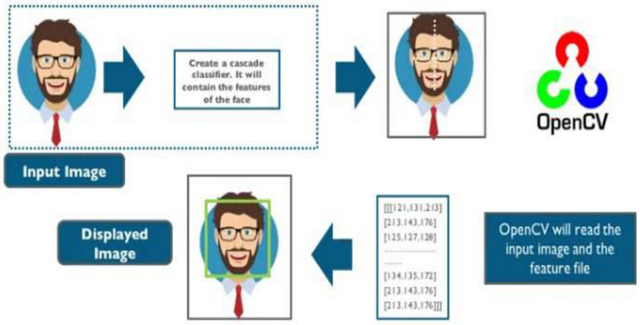

Create a cascade classifier. It will contain the features of the face
OpenCV
Input Image
Displayed Image
[[[121,131,213]
[213.143,176]
[125,127,128]
[134,135,172]
[213.143,176]
[213.143,176]]]
OpenCV will read the input image and the feature file

Figure4: Face Identification using Haar Cascade Classifier
Source: (https://medium.com/geeky-bawa/face-identification-using-haar-cascade-classifier-af3468a44814)

There exists an algorithm known as the Viola-Jones object detection framework, which encompasses all the necessary steps for real-time face detection, outlined as follows:

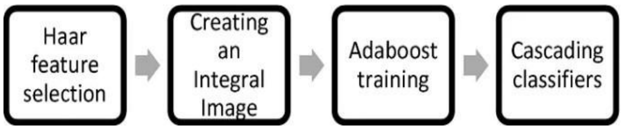


Figure 5: Diagram of the Viola-Jones Object Detection Framework Source: (https://medium.com/geeky-bawa/face-identification-using-haar-cascade-classifier-af3468a44814).

ii) Feature Measurement and Extraction: The Convolutional Neural Network (CNN) is employed to derive features from facial images. Through CNN, high-level features are extracted from an image, subsequently utilized for facial identification within a database. The AlexNet model is employed here because it stands out for face recognition due to its exceptional accuracy in computer vision tasks.

iii) Face Recognition: The final stage involves comparing the extracted features with faces stored in a database. Typically, this comparison utilizes a Euclidean distance metric, which gauges the resemblance between twovectors. The smaller the distance between two vectors, the higher the likelihood of a match between the faces they represent.

$$d=\sqrt{[(x_2-x_1)^2+(y_2-y_1)^2]} \qquad \text{(Eq. 6)}$$

In this formula,"d" represents the Euclidean distance, where(x_1,y_1)denotes the coordinates of the first point and (x_2, y_2) represents the coordinates of the second point. The Eigenface recognizer vector is utilized for face recognition, employing a threshold of ≤2000. If the person being verified is the same as the one registered, the Euclidean distance result will be equal to or less than the threshold, returning 1 to confirm the identity.Conversely, if the Euclidean distance exceeds 2000, indicating a different person from the registered one, it returns 0 to signify a mismatch in identity verification.

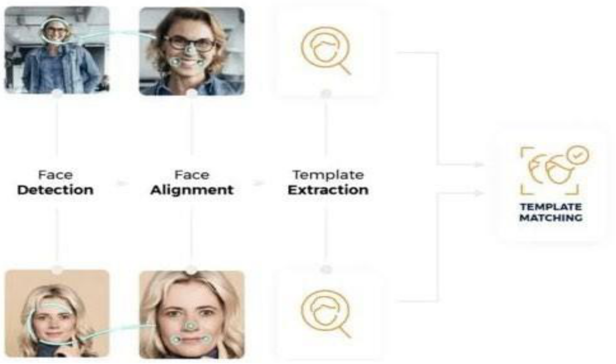


Figure 6: Facial Recognition Process
Source:(https://www.innovatrics.com/facial-recognition-technology/)

Model Description and Architecture

This system aims to prevent the duplication of individuals' biometric records across multiple organizations. The design approach involves the National Identity Management Commission (NIMC) acting as the central repository. Any organization collecting biometrics such as Nigeria Immigration Service, (NIS), Central Bank of Nigeria,(CBN), Nigerian Communications Commission, (NCC), Independent National Electoral Commission, (INEC),etc. must verify with the central database before enrolling an individual. If the individual has been previously enrolled, they will be registered as an Ad-hoc agent under their respective organization without requiring the collection of their biometric data .If the individual has not been enrolled before, they will be registered, and their biometric data will be collected. The system's structure is outlined below: A citizen is registered in the central database by providing their bio-data. Subsequently, the U4500 fingerprint scanner is employed to capture the fingerprint template, utilizing a format that stores fingerprint template using the minutiae data format. These features are then extracted using the CN concept and stored in the central database for identification and verification purposes. Additionally, a frontal facial image is captured using a PC webcam, wherein the facial features are detected, aligned, and then extracted. These facial features are also saved in the database. Finally, the extracted image features are compared with existing ones in the database to facilitate identification and verification

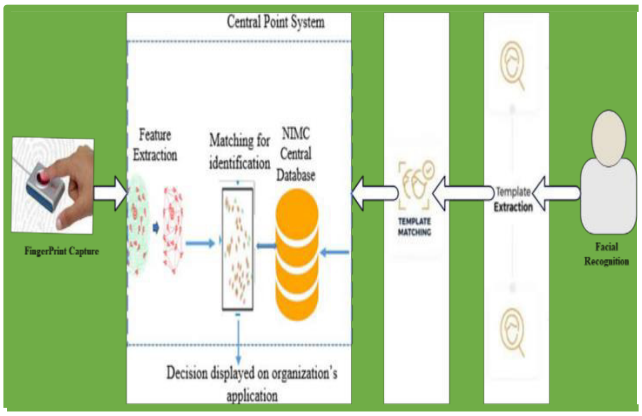


Figure 7: Architecture of the Bimodal Biometric System
Source: (Author, 2023)

4.0 System Implementation

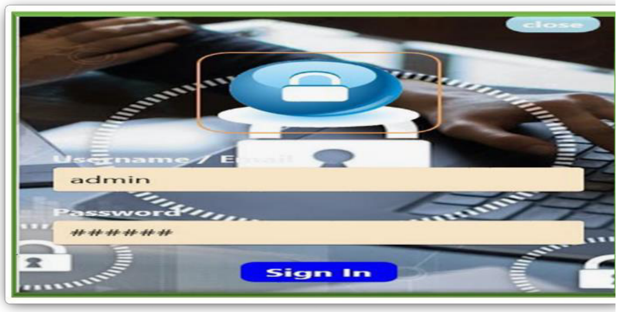
A. Software Requirements: Creation of the database (Back-End Application Design) is accomplished using the MySQL database management system; The web application is crafted with C#. NET within the Visual Studio IDE for Windows Form Development (Front-End Design), functioning as an interface to access the databases; A CloudFlare HTTP web server is employed to link the Front-End and Back-End Applications; Edraw Max is utilized for the design and integration of graphic images and texts.

B. Hardware Requirements: 64 Bit Intel® Core™ Pentium@2Ghz Processor; 8 Gigabytes of RAM/ 320 GB HDD; Minimum of 2GB Hard Diskspace.

The front-end runs on Cloud-Flare web server which makes it a strictly web-based application and therefore highly scalable and very efficient and the back-end runs on MySQL which can accommodate millions of records in the database.

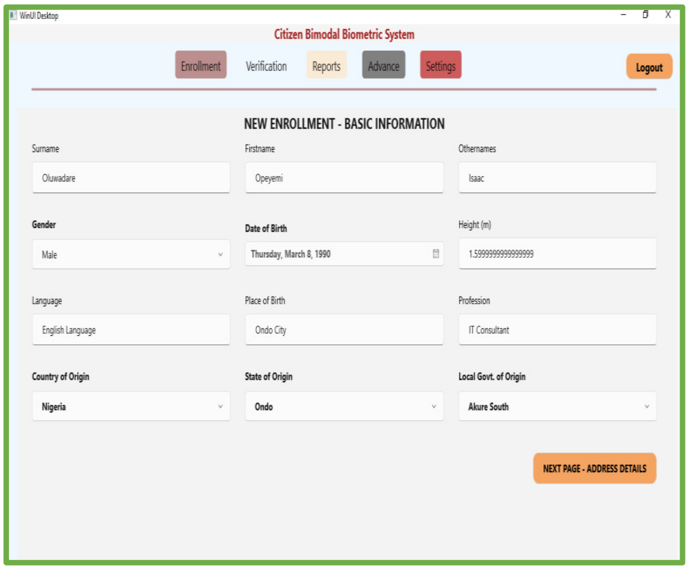
Results

Snapshots of the Citizen Bimodal Biometrics Application



Username / Email
admin
Password
#######

Figure 8: Login Page

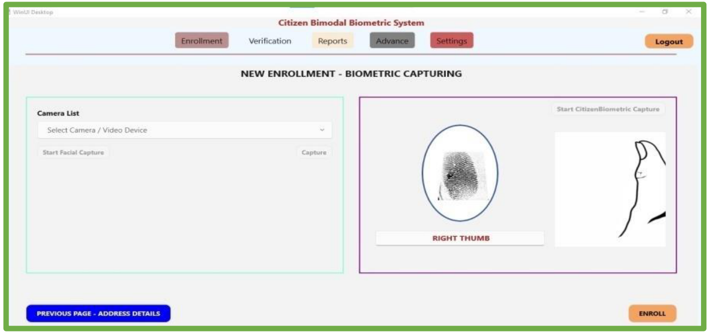


Citizen Bimodal Biometric System

NEW ENROLLMENT - BASIC INFORMATION

Surname: Oluwadare
Firstname: Opeyemi
Othernames: Isaac
Gender: Male
Date of Birth: Thursday, March 8, 1990
Height (m): 1.5999999999999999
Language: English Language
Place of Birth: Ondo City
Profession: IT Consultant
Country of Origin: Nigeria
State of Origin: Ondo
Local Govt. of Origin: Akure South

Figure 9: Enrollment Module (Basic Information Page)

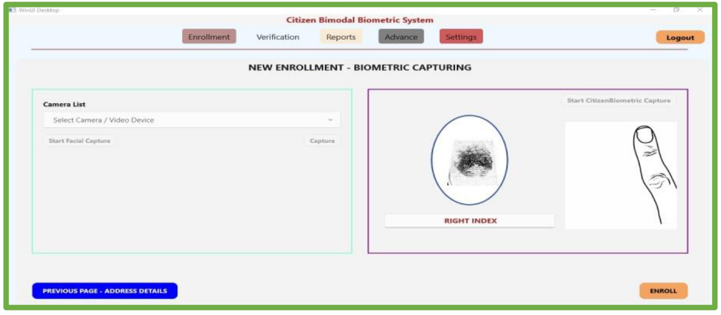


Citizen Bimodal Biometric System

NEW ENROLLMENT - BIOMETRIC CAPTURING

Camera List: Select Camera / Video Device

Figure 10: Enrollment Module: Fingerprint (Right Thumb) Capture

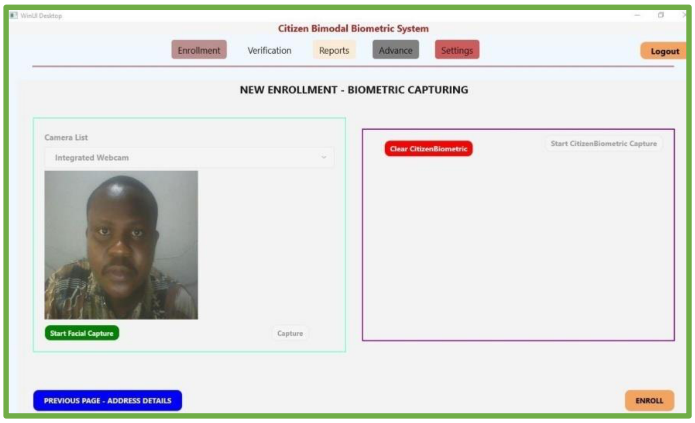


Citizen Bimodal Biometric System

NEW ENROLLMENT - BIOMETRIC CAPTURING

Camera List: Select Camera / Video Device

Figure 11: Enrollment Module: Fingerprint (Right Index) Capture

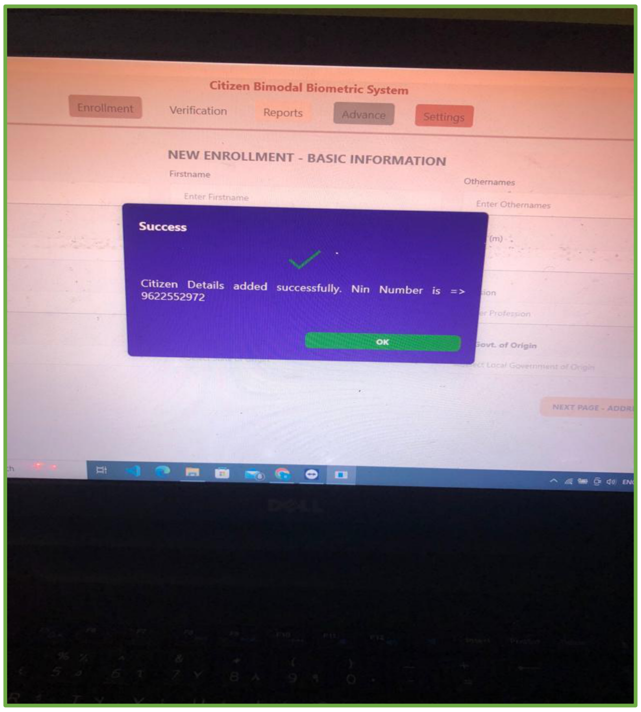


Citizen Bimodal Biometric System

NEW ENROLLMENT - BIOMETRIC CAPTURING

Camera List: Integrated Webcam

Figure 12: Enrollment Module(Biometric-Facial Capture)



NEW ENROLLMENT - BASIC INFORMATION

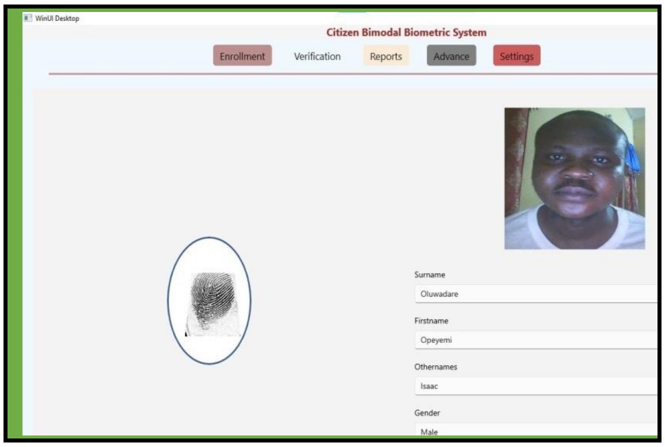
Firstname
Enter Firstname

Othernames
Enter Othernames

Success

Citizen Details added successfully. Nin Number is => 9622552972

Figure 13: Enrollment Module (Citizen enrolled in the Database)



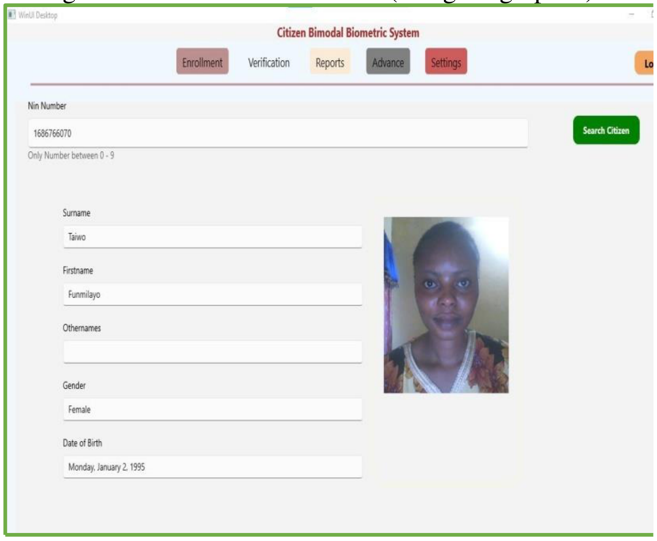
Surname
Oluwadare

Firstname
Opeyemi

Othernames
Isaac

Gender
Male

Figure 14: Verification Module (using Fingerprint)



Nin Number
1686766070
Only Number between 0 - 9

Surname
Taiwo

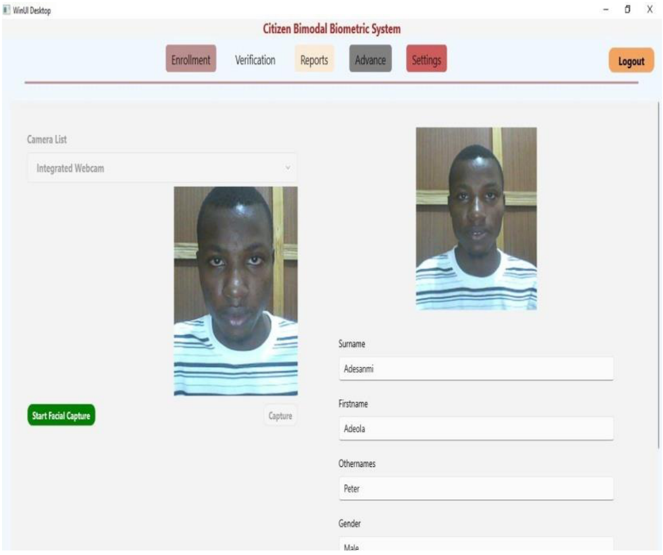
Firstname
Funmilayo

Othernames

Gender
Female

Date of Birth
Monday, January 2, 1995

Figure 15: Verification Module (using NIN (User Validation with Fingerprint))



Camera List
Integrated Webcam

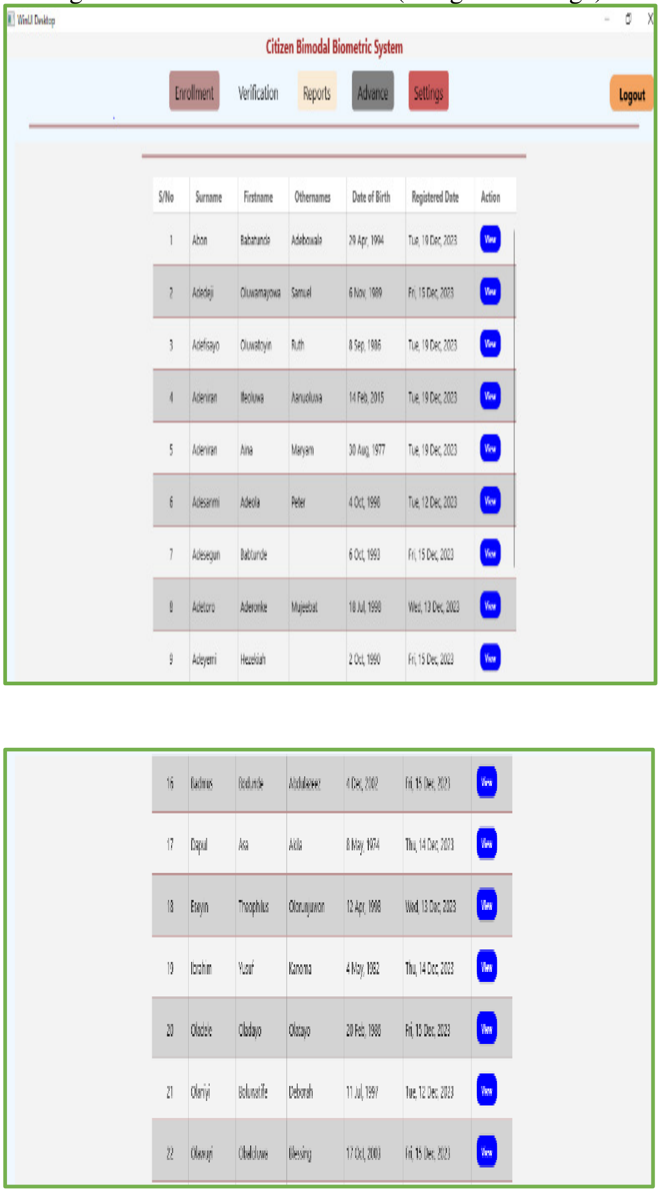
Surname
Adesanmi

Firstname
Adeola

Othernames
Peter

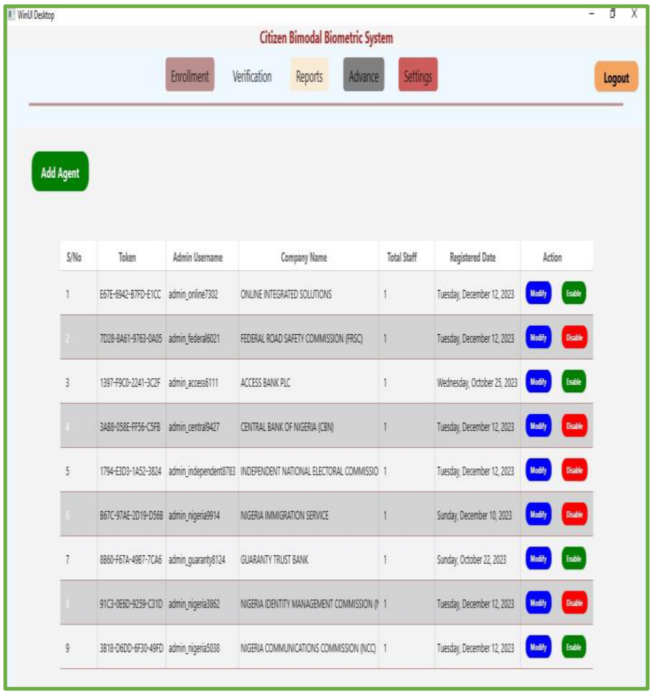
Gender
Male

Figure 16: Verification Module (using Live Image)



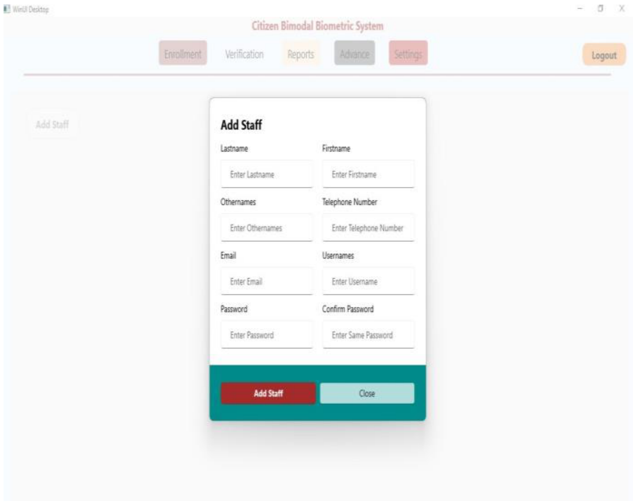
S/No	Surname	Firstname	Othernames	Date of Birth	Registered Date	Action
1	Abon	Babatunde	Adebowale	29 Apr, 1994	Tue, 19 Dec, 2023	View
2	Adedeji	Oluwamayowa	Samuel	6 Nov, 1989	Fri, 15 Dec, 2023	View
3	Adefisayo	Oluwatoyin	Ruth	8 Sep, 1986	Tue, 19 Dec, 2023	View
4	Adeniran	Ifeoluwa	Aanuoluwa	14 Feb, 2015	Tue, 19 Dec, 2023	View
5	Adeniran	Aina	Maryam	30 Aug, 1977	Tue, 19 Dec, 2023	View
6	Adesanmi	Adeola	Peter	4 Oct, 1996	Tue, 12 Dec, 2023	View
7	Adesegun	Babtunde		6 Oct, 1993	Fri, 15 Dec, 2023	View
8	Adetoro	Aderonke	Mujeebat	18 Jul, 1998	Wed, 13 Dec, 2023	View
9	Adeyemi	Hezekiah		2 Oct, 1990	Fri, 15 Dec, 2023	View
16	Badmus	Bodunde	Abdulazeez	4 Dec, 2002	Fri, 15 Dec, 2023	View
17	Dapul	Asa	Akila	8 May, 1974	Thu, 14 Dec, 2023	View
18	Esayin	Theophilus	Olorunjuwon	12 Apr, 1998	Wed, 13 Dec, 2023	View
19	Ibrahim	Yusuf	Kanoma	4 May, 1982	Thu, 14 Dec, 2023	View
20	Oladele	Oladayo	Olatayo	20 Feb, 1988	Fri, 15 Dec, 2023	View
21	Olaniyi	Boluwatife	Deborah	11 Jul, 1997	Tue, 12 Dec, 2023	View
22	Olawuyi	Obaloluwa	Blessing	17 Oct, 2000	Fri, 15 Dec, 2023	View

Figure 17: Reports (Query Citizen)



S/No	Token	Admin Username	Company Name	Total Staff	Registered Date	Action
1	E67E-6942-B7FD-E1CC	admin_online7302	ONLINE INTEGRATED SOLUTIONS	1	Tuesday, December 12, 2023	Modify Enable
2	7D28-8A61-9763-0A05	admin_federal6021	FEDERAL ROAD SAFETY COMMISSION (FRSC)	1	Tuesday, December 12, 2023	Modify Disable
3	1397-F9C0-2241-3C2F	admin_access6111	ACCESS BANK PLC	1	Wednesday, October 25, 2023	Modify Enable
4	3AB8-058E-FF56-C5FB	admin_central9427	CENTRAL BANK OF NIGERIA (CBN)	1	Tuesday, December 12, 2023	Modify Disable
5	1794-E3D3-1A52-3824	admin_independent8783	INDEPENDENT NATIONAL ELECTORAL COMMISSIO	1	Tuesday, December 12, 2023	Modify Disable
6	B67C-97AE-2D19-D56B	admin_nigeria9914	NIGERIA IMMIGRATION SERVICE	1	Sunday, December 10, 2023	Modify Disable
7	8B60-F67A-49B7-7CA6	admin_guaranty8124	GUARANTY TRUST BANK	1	Sunday, October 22, 2023	Modify Enable
8	91C3-0E6D-9259-C31D	admin_nigeria3862	NIGERIA IDENTITY MANAGEMENT COMMISSION (N	1	Tuesday, December 12, 2023	Modify Disable
9	3B18-D6DD-6F30-49FD	admin_nigeria5038	NIGERIA COMMUNICATIONS COMMISSION (NCC)	1	Tuesday, December 12, 2023	Modify Enable

Figure 18: Advance Module (Add Ad-hoc Agent)

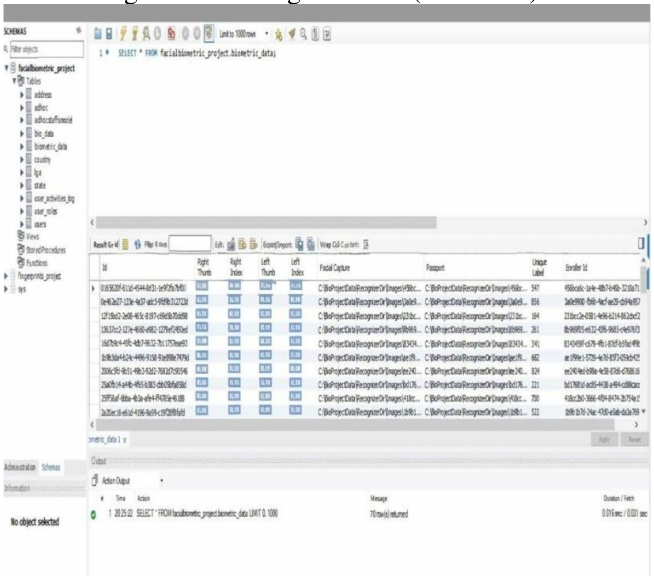


Add Staff

Lastname: Enter Lastname
Firstname: Enter Firstname
Othernames: Enter Othernames
Telephone Number: Enter Telephone Number
Email: Enter Email
Usernames: Enter Username
Password: Enter Password
Confirm Password: Enter Same Password

Add Staff | Close

Figure 19: Settings Module (Add Staff)



```
1 ● SELECT * FROM facialbiometric_project.biometric_data;
```

Id	Right Thumb	Right Index	Left Thumb	Left Index	Facial Capture	Passport	Unique Label	Enroller Id
0165620f-611d-4544-8d31-1e9f2fa7bf00	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\456bc...	C:\BioProjectData\RecognizerDir\Images\456bc...	547	456bca6c-1a4e-48b7-b46b-3210a71
0e462e27-133e-4a37-adc5-9fd9b312723d	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\3a0e9...	C:\BioProjectData\RecognizerDir\Images\3a0e9...	856	3a0e9900-fb6b-4acf-ae29-cb94a957
12f1bd2-2e08-465c-8197-c69d5b70dd98	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\231bc...	C:\BioProjectData\RecognizerDir\Images\231bc...	164	231bcc2e-0581-4e96-b214-862dbcf2
13637cc2-127e-4660-a982-1279ef2450ed	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\8b969...	C:\BioProjectData\RecognizerDir\Images\8b969...	261	8b969f05-e632-43f6-9685-c4e976f3
16d7b9c4-45fc-4db7-9632-7b11757eae93	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\83434...	C:\BioProjectData\RecognizerDir\Images\83434...	341	834349f-c679-4fb1-87df-b5fad4f9
1b9b3da4-b24c-4496-9158-91e898e7479d	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\ae1f9...	C:\BioProjectData\RecognizerDir\Images\ae1f9...	662	ae1f99e1-5729-4e7d-85f3-059cb42
2006c5fd-9b51-49b3-92d2-7682d7c90546	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\ee240...	C:\BioProjectData\RecognizerDir\Images\ee240...	824	ee2404ed-b98a-4e58-87d6-d768616
25a0fb14-a44b-4f65-b383-dbb05bfa858d	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\bd176...	C:\BioProjectData\RecognizerDir\Images\bd176...	221	bd17681d-ad85-4438-a494-cd88cacc
25ff58af-6bba-4b3a-afe4-ff4785e46188	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\418cc...	C:\BioProjectData\RecognizerDir\Images\418cc...	700	418cc2b0-3666-4f04-8474-2b754a1
2a20ec16-e61d-4196-9a99-c19f28f8fafd	BLOB	BLOB	BLOB	BLOB	C:\BioProjectData\RecognizerDir\Images\1b9b1...	C:\BioProjectData\RecognizerDir\Images\1b9b1...	522	1b9b1b7d-24ac-47d0-a5ab-da3a769

#	Time	Action	Message	Duration / Fetch
1	20:25:22	SELECT * FROM facialbiometric_project.biometric_data LIMIT 0, 1000	70 row(s) returned	0.016 sec / 0.031 sec

Figure 20: Database Screenshot

5.0 Discussions

System Evaluation

The effectiveness of the fingerprint verification algorithm is assessed through metrics like False Acceptance Rate (FAR) and False Rejection Rate (FRR),utilizing the default parameters of the DigitalPersona algorithm [9]. False Acceptance Rate (FAR) is quantified as the proportion of anticipated false acceptance errors divided by the total number of verification attempts.

$$\text{FAR} = \frac{\text{FN}}{\text{TP+FN}} \text{X } 100\% \qquad \text{(Eq. 7)}$$

where: FN represents the total number of false negatives, while TP represents the total number of true positives, yielding a result of 0.01%.

False Rejection Rate,(FRR) is characterized as the proportion of anticipated false rejection errors divided by the total number of verification attempts.

$$\text{FRR} = \frac{\text{FP}}{\text{FP+FN}} \text{X } 100\% \qquad \text{(Eq. 8)}$$

where: FP represents the total number of false positives, while FN represents the total number of false negatives, resulting in a value of 1.4%.

The accuracy of the fingerprint verification system is indicated by:-

$$\frac{TP+TN}{Total\ No\ of\ Enrollees} X\ 100\% \qquad \text{(Eq. 9)}$$

$$\text{Therefore, Accuracy} = \frac{70+0}{70} \text{X } 100\% = 100\%$$

The efficacy of the facial recognition algorithm is evaluated through metrics such as False Positivity and False Negativity. False Positive Rate(FPR) is quantified as the count of false positive matches compared to the total face comparisons.

$$\text{FPR} = \frac{FP}{FP+TN} X\ 100\% \qquad \text{(Eq. 10)}$$

$$\text{FPR} = \frac{13}{13+4} X\ 100\% = 76.5\%$$

Where: FP represents the total number of false positives, while TN represents the total number of true negatives, resulting in a valueof 76.5%.

False Negative Rate (FNR) is characterized as the count of false negative matches compared to the total face comparisons

$$\text{FNR} = \frac{FN}{FN+TP} X\ 100\% \qquad \text{(Eq. 11)}$$

$$\text{FNR} = \frac{12}{12+45} X\ 100\% = 21.1\%$$

where: FN represents the total number of false negatives, while TP represents the total number of true positives, yielding a value of 21.1%.

The accuracy of the facial recognition algorithm is indicated by:-

$$\frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} \text{x } 100\% \qquad \text{(Eq. 12)}$$

$$\frac{45+4}{45+4+13+12} \text{x}100\% = 66.2\%$$

The recognition accuracy rate of the Bimodal Biometrics System is therefore computed as:-

$$\frac{100+66.2}{2}\text{x}100\% = 83.1\% \qquad \text{(Eq. 13)}$$

Therefore, the Bimodal Biometric System achieves a recognition accuracy rate of 83%.

6.0 Conclusion

A model has been developed which can be readily embraced by NIMC to fulfill their long-term objective of integrating the biometric data of Nigerian citizens from various sources. This model entails the creation of a Citizen Bimodal Biometric System incorporating both fingerprint and facial recognition technologies, with integrated security measures for access control. The comprehensive system developed enables other organizations collecting biometrics to seamlessly integrate with the central database.

7.0 Recommendations

For future research endeavors, the following suggestions are proposed:

i) Additional biometric traits like iris and hand geometry can be included as alternatives for authentication and verification purposes.

ii) Alternative Software Development Kits (SDKs) can be explored for developing the applications, facilitating deployment on other operating systems such as MacOS.

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