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Integration of Biometrics into Information Management Systems: Nigerian Correctional Service as a Case Study

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Abstract

The aim of the study was to integrate fingerprint biometrics into Nigerian Correctional Information Management System (NCIMS). The traditional techniques of human identity verification suffer from security vulnerabilities such as identity theft and inconsistency; hence there was need to develop Human Identity Authentication System that verifies the true identity of convicts and ex-convicts. The system was implemented with MS Visual Studio 2013, C# on .Net framework 4.0. The backend database used was Microsoft SQL server. The design method used was Unified Model Language (UML)with tools such as Use case diagram and sequence diagram.For the methods, the existing system was analyzed; centralized database was introduced; authentication module was developed (enrolment). The developed application performance was evaluated with two hundred fingerprints alongside with related individual personal information. The result indicated 97.5% biometric accuracy levels attained with error allowance of 1% False Acceptance Rate (FAR) and 3% False Rejection Rate (FRR). In conclusion, the study showed that the integration of fingerprint biometric system into the Nigerian Correctional Information Management System will reduce identity theft by 98%, detect ex-convicts in case of re-offending and alleviate problem associated with traditional identity verification techniques if properly implemented.

Keywords: *Identity theft, Impersonation, Convicts, Ex-convicts, Fingerprints, Use Case, Sequence diagram, Centralized networked database*

1. INTRODUCTION

The Nigerian Correctional Service, formerly known as Nigerian Prison Service is a government agency of Nigeria which operates prisons. Nigerian Correctional Service manages about 240 prison facilities ranging from maximum security prison, medium term security prison, satellite prison, institutions for the juvenile, open prison camps and female prison[1].

This study has its focus on the “convicts” (a person found guilty of a crime by a court; whose freedom has been deprived either by death penalty, monetary fine or imprisonment). Convicts serving their sentence lose some rights, such as the right to freedom of movement, the right to vote at elections and the right to be elected, the right to exercise one’s ability to work and the right to choose the place of residence [2]. The persons who have served their sentence (also known as “ex-convicts” or “ex-offenders”) often face challenges coping outside the correctional center with their new status as ex-convicts and even their reclaimed freedom sometimes is not enough to deal with the challenge, hence, such persons may decide to deny their true identity.

The Nigerian Correctional Service (NCS) currently faces the following problems: identity theft, lack of automated authentication system, non-comprehensive and localized database, duplication of names and non- accuracy of records and time wastage during record’s search.

This paper is geared towards introducing a Biometric System with a networked database.

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This system as this will enhance the verification of convicts by Nigerian Correctional Service. Nigerian Correctional Service needs a biometric system with networked centralized database for adequate verification of convicts. This should be done as soon as a court of competent jurisdiction declares a person guilty of the crime accused of. This will help the agency to curb some scenarios such as identity swap, jailbreaks, impersonation and intrusion.

The study was implemented using visual studio 2013 on .Net framework 4.0 with C# object-oriented programming language. Microsoft SQL server was used as the backend database; Microsoft SQL Server is a relational database management system developed by Microsoft. As a database server, it is a software product with the primary function of storing and retrieving data as requested by other software application, which may run either on the same computer or on another computer on a network.

2. LITERATURE REVIEW

2.1 Identity Theft

Identity theft is a crime and it has serious implications for all aspects of society, including the economy and national security. Identity theft is a relatively new name for an age-old phenomenon. Early accounts of the crime were a simple form of impersonation. In the legal sense, impersonation is the act of imitating another person with the intent to defraud others for personal gain [3]. An individual who was convicted and had served full term may deny their true identity if caught in another crime scenario as evidenced in James Ibori vs. Great Ogboro, 2003 [4]. Also, the existing database system used in Nigerian Correctional Service is siloed and this enables an ex-convict (or even a jail breaker) from any part of Nigeria to migrate freely to another part of the country with the claim of being a free citizen since ex-convicts are not easily tracked and monitored.

The following fields of information separates an individual from others: a person's name, address, telephone number, birth date, Social Security number (SSN), driver's license number, passport number, health insurance policy number, employee identification number, employment history, student identification number, mother's maiden name, financial account numbers, account passwords, biometric data, e-mail address, and instant messaging screen name. A compromised information can be used in different ways by fraudsters [3]. According to the University of Texas at Austin's Center for Identity, over 99% of identity theft is done in a local geographical region and that Identity theft does not always take place online.

2.2 Biometrics

Biometric technology is the recommended solution to identity theft with the advent of the digital age [5]. Edwards believes that biometrics is the answer to nearly all the challenges facing security-based applications. Biometrics is known as "an automated recognition of individuals based on their biological and behavioral characteristics" [6]. The biometric traits that have been effectively used in practical application include face, fingerprint, palmprint, iris and voice, gaits, voice, typing rhythm [7]. Universality, uniqueness, permanence, measurability, performance, acceptability and circumvention are traits that must be owned by biometrics [8]. Human biometry is, therefore, the holy grail of verification solutions that until now, nobody has made the technology foolproof [5].

In terms of cost, acceptability, mathematical uniqueness and neutrality, fingerprint is believed to be the best biometric option [5]. Fingerprint biometrics can be used for most studies because of its accuracy, uniqueness, and acceptability than any other biometric traits [9]. Fingerprint is the design formed on the epidermis of the fingertip and it is of three (3) kinds: arch, loop and whorl.

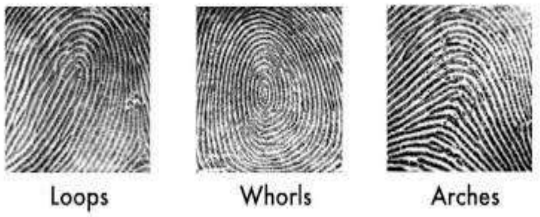


Figure 1.The three major fingerprint pattern types

The most obvious structural characteristic of a fingerprint are the ridges and valleys [10].

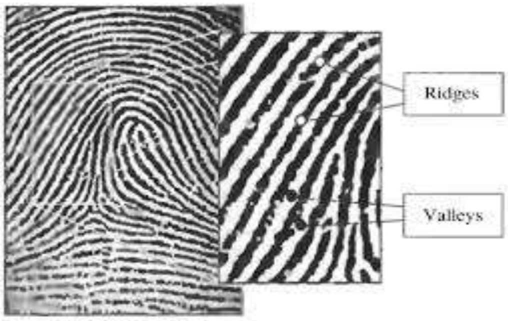


Figure 2. The ridges and Valleys of a fingerprint

The fingerprint of every individual is considered to be unique and that no two persons have the same set of fingerprints [11]. This makes it suitable for identification purpose. The camera and scanning devices are apparatuses used by biometric system to capture images, record, measure the features of an individual and the computer system is used to extract, encrypt, store and relate characteristics.

An important feature to consider in biometrics is “false accept” and “false reject.” The features are the two (2) main possible error occurrences in a biometric technology. They are used to regulate a match or mismatch during the verification process. False accept is when an unlawful person is erroneously accepted and it is denoted by False Acceptance Rate (FAR) while False reject is when a lawful person is wrongly denied access and it is denoted by False Rejection Rate (FRR) -It is the rate of a genuine person getting rejected [12].

Perfect biometrics should have both FAR = FRR = 0, though there is none in real life [13].

2.3 Centralized Database

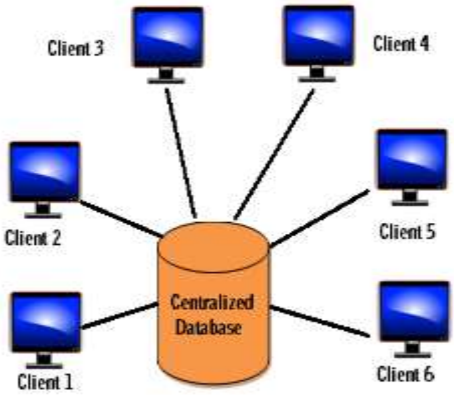


Figure 3: Centralized database

Centralized database stores data or information in a particular location within a network [14]. It allows data from existing database to be collected and stored in a single database for sharing, analysis or updating in an organization. Centralized database when adopted can help government regulator data redundancy and inconsistency for security and maintainable growth.

According to a study by Mohammed and Saleh, it was recommended that the Nigerian government should adopt centralized database that can harmonize records of organizations and agencies which will help in ensuring security and sustainable development in the country [14]. With a centralized database, the Nigerian Correctional Service can access convict’s data or records and use it for decision making whenever the need arise.

3. METHODOLOGY

3.1 Analysis of the Existing System

The manual system of verification based on names, address and signature on paper is still in use in Nigerian Correctional Service without an authentic means of identifying the convicts or ex-convicts. This traditional method is prone to wear and tear within a short period of time. This method can also be subject to constant manipulation and distortion which can affect decision making.

3.2 The Proposed System

The proposed system uses the following processes:

1. The Enrolment /Capturing of fingerprint
2. Storage
3. Authentication of the fingerprint
4. Result

Enrollment: Fingers are placed on the sensor/scanner to capture the fingerprints. The fingerprints are then analyzed with an algorithm that extracts quantifiable features fingerprint minutiae.

Storage: These store biometric traits (fingerprints) alongside other information such as name, address, age and sex in the database.

Authentication of the Fingerprint: there is one to one comparison of a captured biometric with a stored template to verify that the individual is the person who one claims to be. It is done in conjunction with other information stored in the database. The Automated Fingerprint Authentication System compares the inputted fingerprint image and previously registered data to determine the genuineness of the captured fingerprints minutia.

Result: The matching score is compared with the threshold. When the matching score is the same or greater than the threshold, the fingerprints are considered from the same person (matching pairs). When the matching points are below the threshold, they are considered to be from a different person (non-matching pairs).

3.3 System Design and Technique

The Unified Modeling Language (UML) is general-purpose visual modeling language that is used to specify, visualize, construct and document the artifacts of a software system. The UML captures information about the static structure and dynamic behavior of a system.

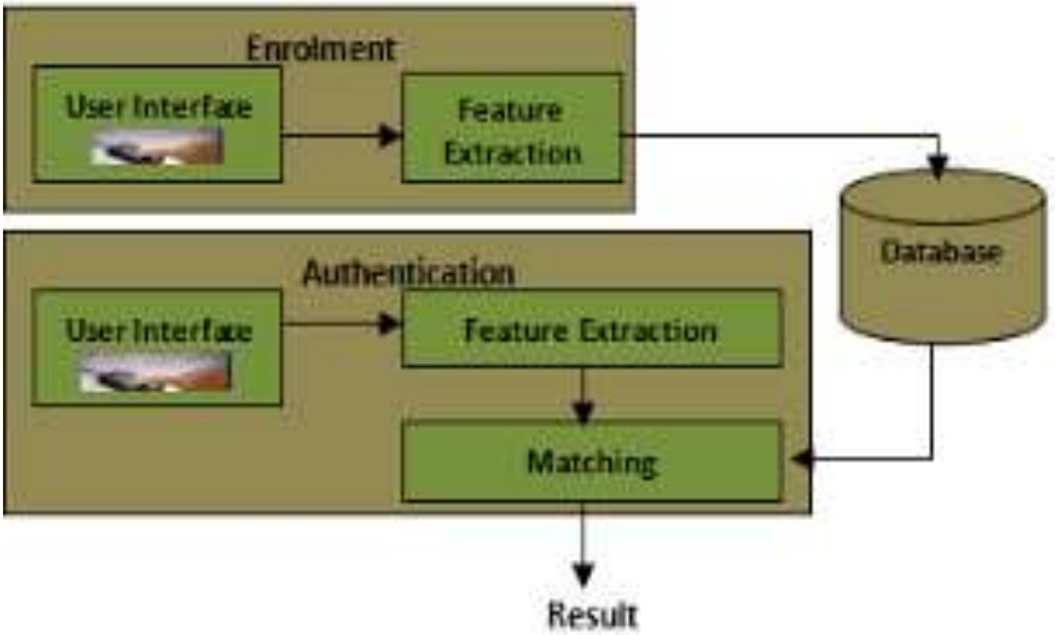


Figure 4: The process of Enrolment, Authentication and Verification of the proposed biometric system

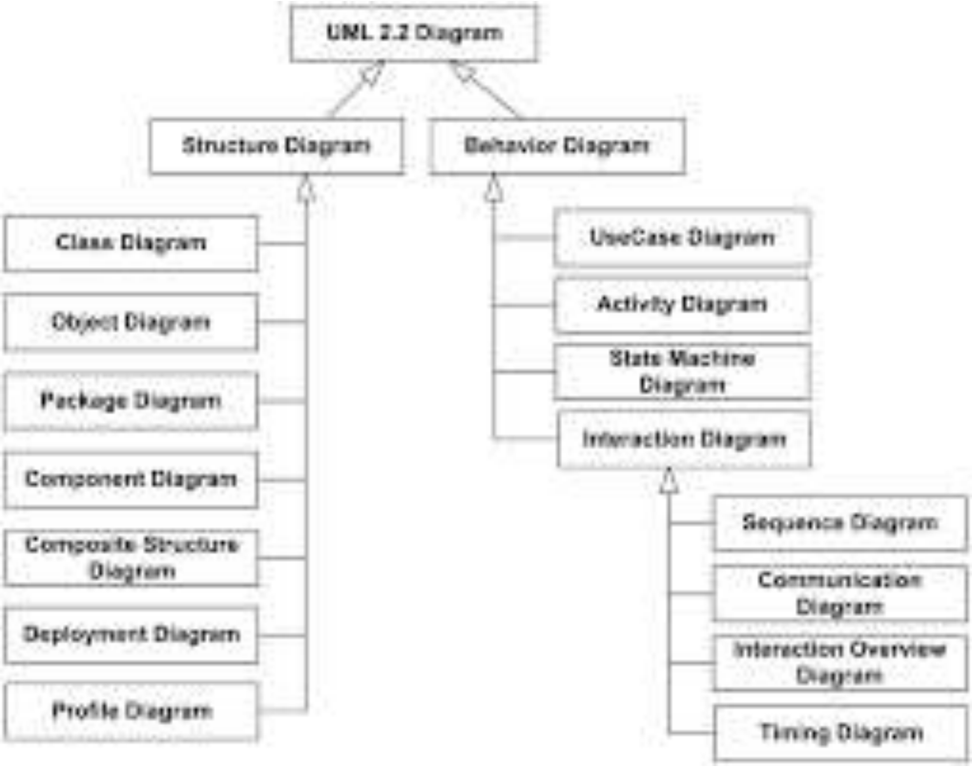


Figure 5. Types of Unified Model Language (UML)

Some behavioral UML diagrams were the tools that were used to design the system and they include: Use-case diagram and Sequence Diagram.

3.3.1 Use Case Diagram

The Use Case diagram is one of the behavioral diagrams of a UML. The diagram is used to visualize the behaviors of the proposed system and is used as the first step in system process modelling which is referred to as data diagramming. Use Cases have attained wide use as a requirement tool for noticeable behavior of systems [15]. Use case description always include expected operators (users) and their system interaction stages that eventually specify system requirements.

3.3.2 Sequence diagram

Sequence diagrams are used to depict graphically how objects interact with each other via messages in the execution of a use case or operation. They illustrate how operations are performed between object and what sequence.

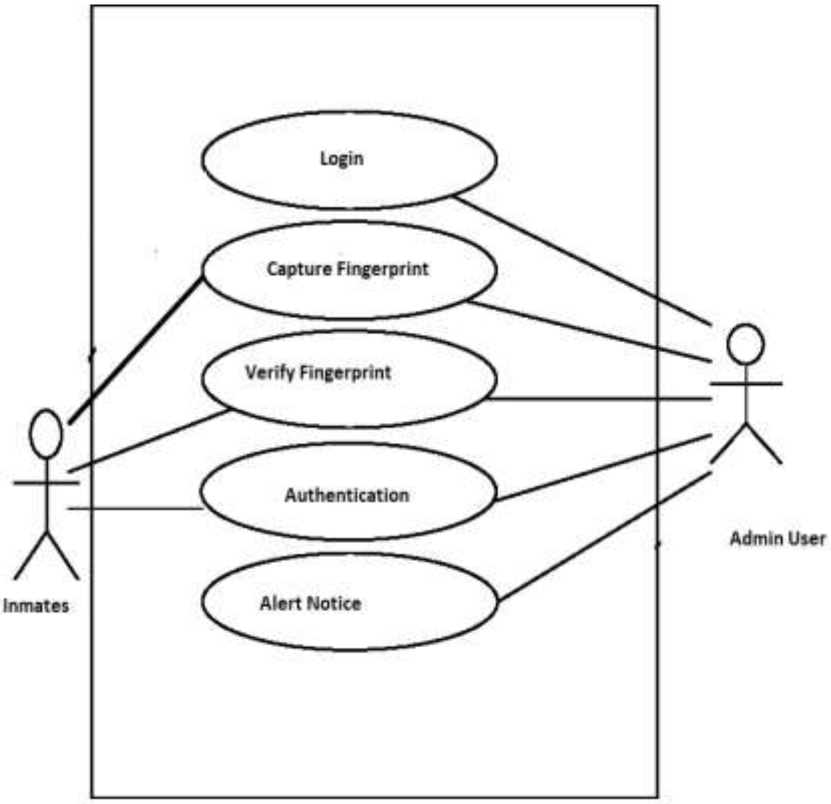


Figure 6. Use Case Diagram of the proposed system (Authors)

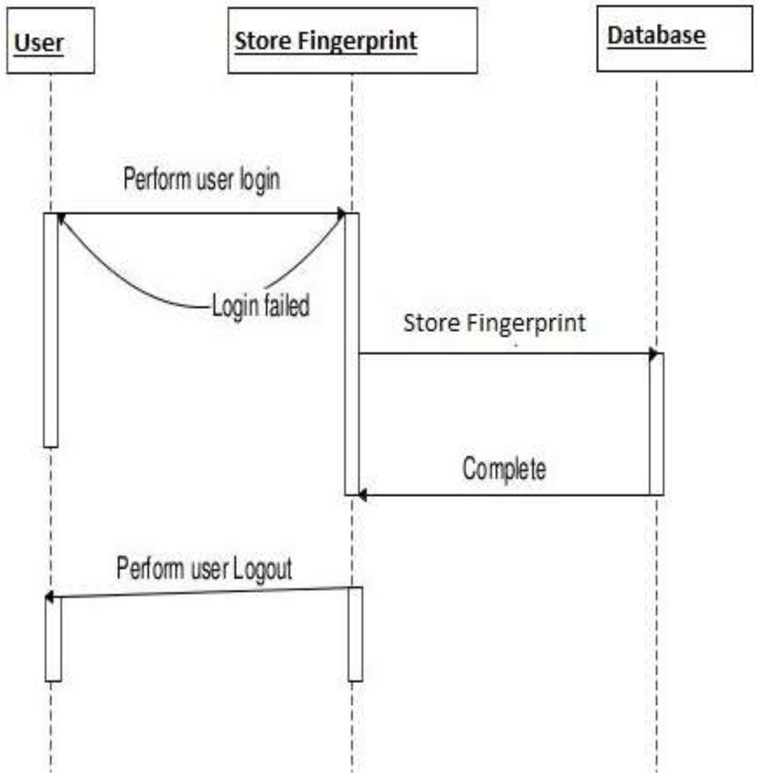


Figure 7. Sequence Diagram to enroll fingerprint (Authors)

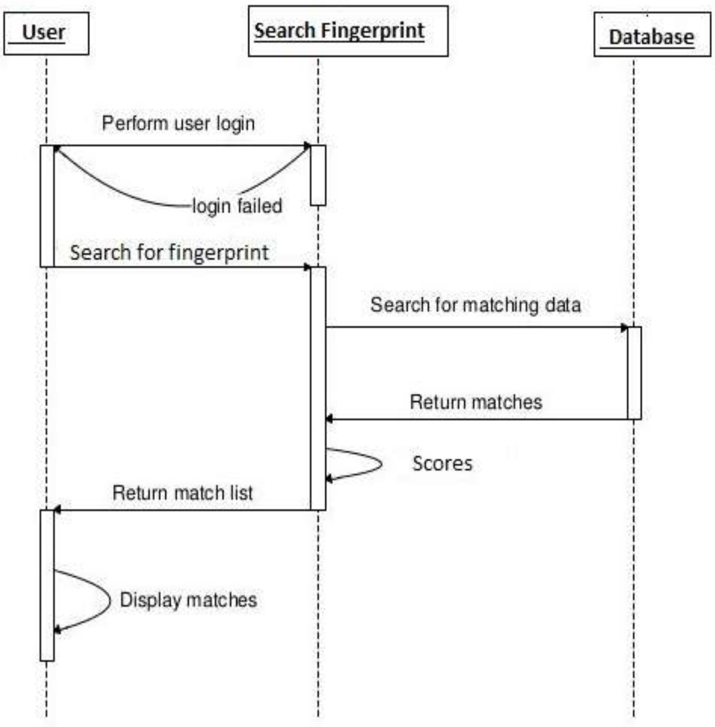


Figure 8. Sequence Diagram to enroll fingerprint (Authors)

3.4 *Performance Evaluation*

The objectives of performance evaluation are to offer some calculable measure on the proficiency of biometrics. The conventional statistical metrics used to calculate the performance of a biometrics include: False Accept Rate (FAR), False Reject Rate (FRR), Equal Error Rate (EER), Receiver (or Relative) Operating Characteristic (ROC), Failure to Enroll Rate (FTE or FER), Failure to Capture Rate (FTC) and Template capacity. However, the False Accept Rate (FAR) and False Reject Rate. (FRR) was used in this study to evaluate the biometric system.

A total of 200 fingerprint images from 50 volunteers with their four fingerprints were used for the study. The images were captured with *Digital Persona* fingerprint scanner. 120 fingerprints were used as templates while 80 fingerprints used for testing. The Table 1 summarizes the number of acceptances and rejections.

Table 1: Number of Acceptances and Rejections

Fingerprints	Accepted	Rejected
Templates (genuine)	117	3
Testing (imposter)	1	79

False Acceptance Rate (FAR)

FAR = NFA / NIVA
Where FAR is the False Acceptance Rate
NFA is the No of False Acceptances
NIVA is the No of Impostor Verification Attempts
FAR = 1/80
=0.013
0.013 X 100 = 1%

False Rejection Rate (FRR)

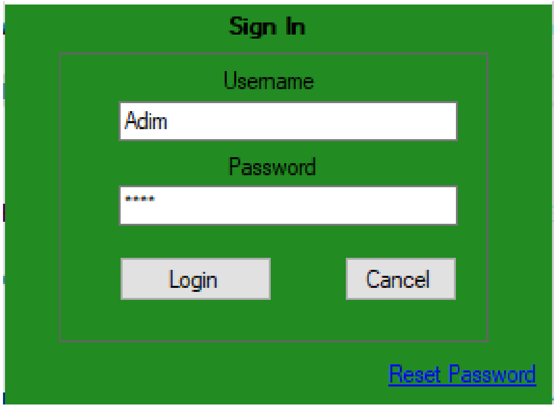
FRR = NFR / NEVA
Where FRR is the False Rejection Rate
NFR is the No of False Rejections
NEVA is the No of EnrolledVerification Attempts
FRR = 3/120
= 0.025
0.025 X 100 = 3%

3.5 Implementation Method

Setup, X-Copy and Publish Web site are different ways to deploy the new system but Setup was used in the implementation of this system.

Log-In Page

To use the proposed biometric system from the PC, launch the developed Authentication system. The first screen that comes up is the Administrator's access page. The aim of this page is to authenticate the administrator via username and password. If the information supplied is correct, the page links to the user interface page.



Username: Adim

Password: ****

Figure 9. Admin login page

On the Admin Login page are the "login" and "cancel" button, also there is a link to reset password in case of forgotten password. When the user clicks the login button, it loads the developed system while the exit button unloads it. The Admin Login Dialog module prevents unauthorized users from using the system. The system administrator has the ability to change and administer access code to users (staff).

Welcome Page: The welcome page consists of three menus; User Manager, Registered User and Settings. The User Manager menu consists of the Add New User and System Users submenus.

Only the administrator has access to these submenus. The Add new user submenu allows him to grant new staff access to the system.

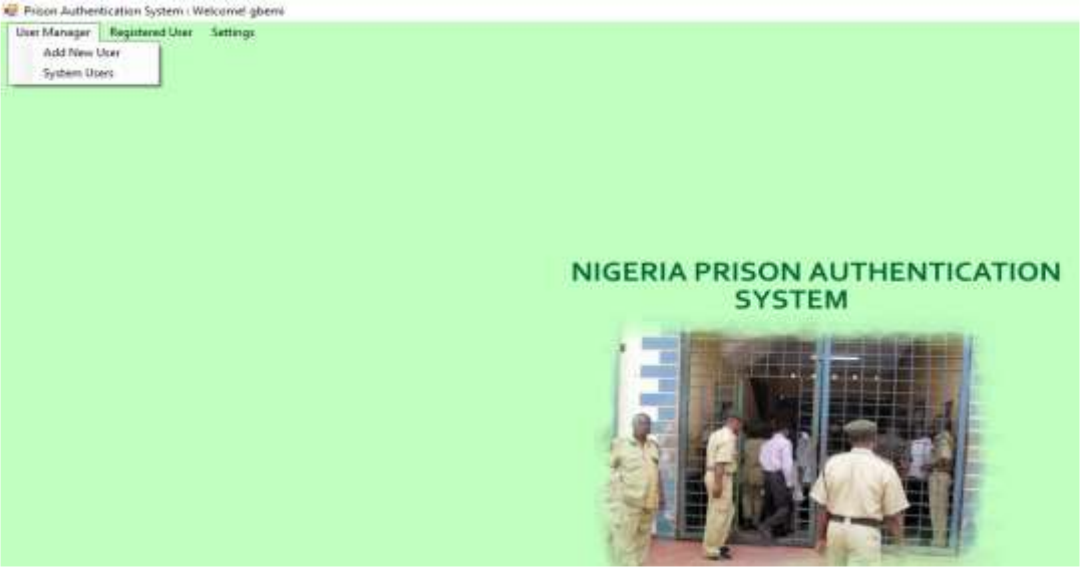
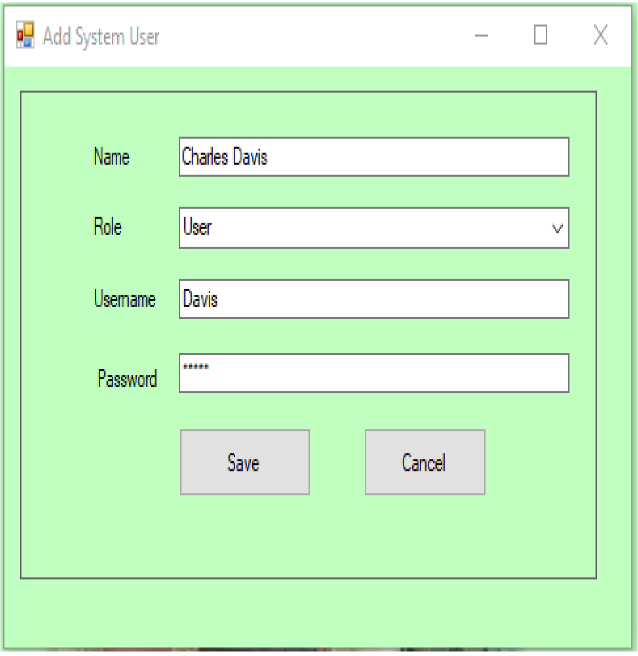

Prison Authentication System : Welcome! gbemi
User Manager
Registered User
Settings
Add New User
System Users
NIGERIA PRISON AUTHENTICATION SYSTEM

Figure 10. User interface page



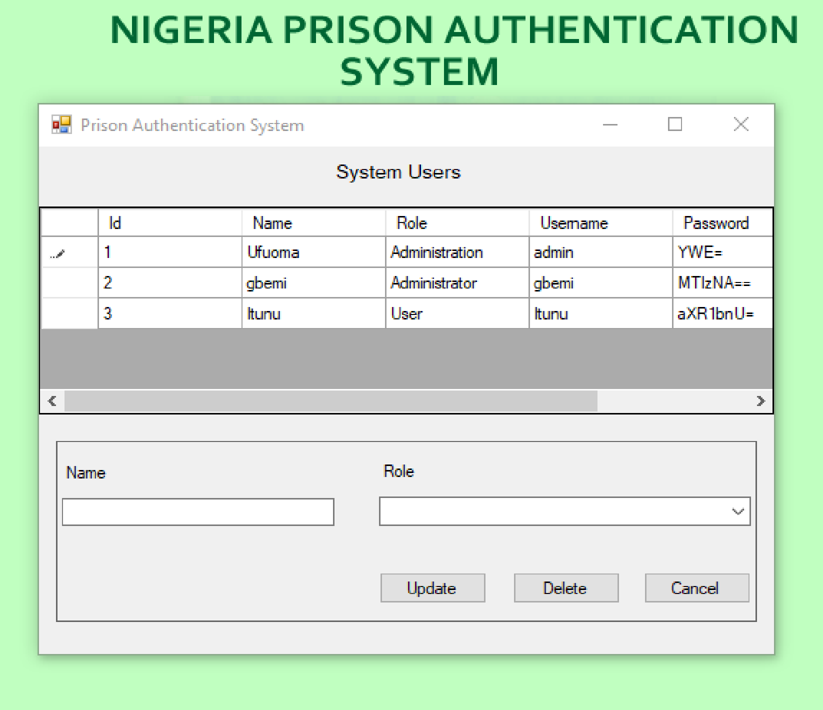
Name: Charles Davis

Role: User

Username: Davis

Password: *****

Figure 11. Add new user page


NIGERIA PRISON AUTHENTICATION SYSTEM
Prison Authentication System
System Users
Name
Role
Update
Delete
Cancel

Id	Name	Role	Username	Password
1	Ufuoma	Administration	admin	YWE=
2	gbemi	Administrator	gbemi	MTIzNA==
3	Itunu	User	Itunu	aXR1bnU=

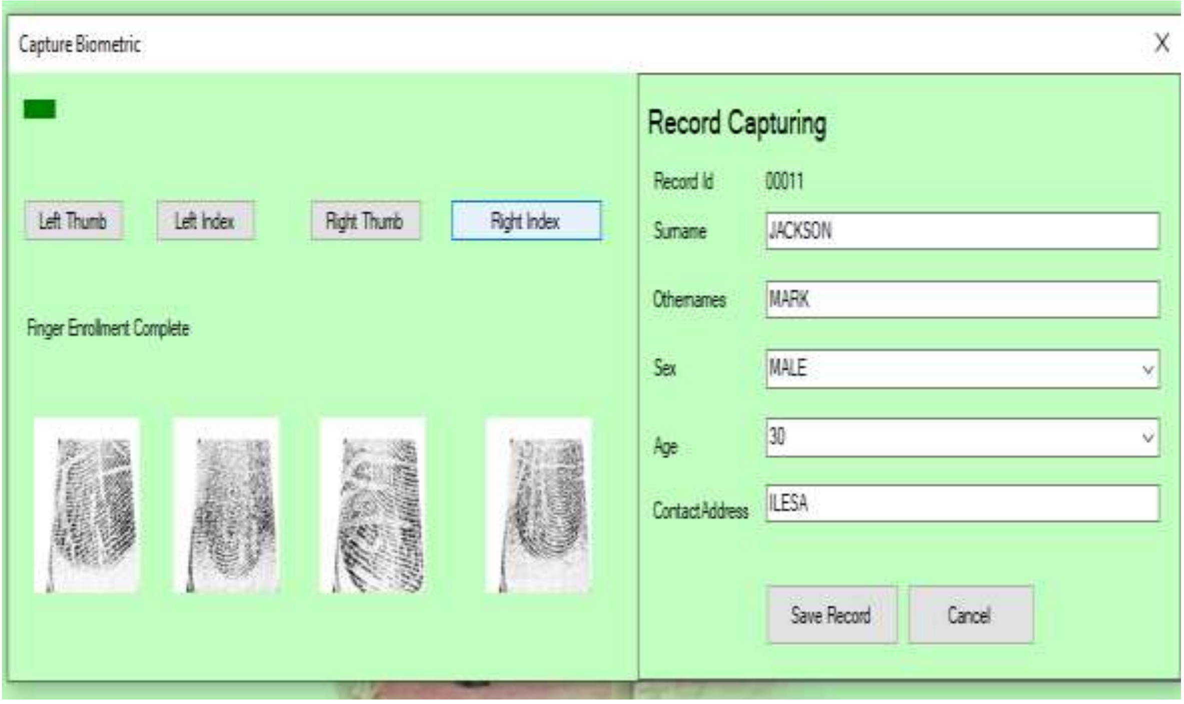
Figure 12. System user page

The system user submenu permits the administrator to view those already granted access. He can also update and delete the record of existing users.

Registered User Menu

The Registered User menu has two submenus namely: Add New Record and Search. The Add new record permits the user (staff) to enroll a new convict into the system by collecting the biometric data via the fingerprint scanner along with other identity details, and encoded for storage, retrieval, and matching. See Figure 13.

The search submenu enables the system user (staff) to authenticate a convict by capturing a live fingerprint and comparing it with the template stored in the database. See Figure 14, the screen shots of the *search page*.

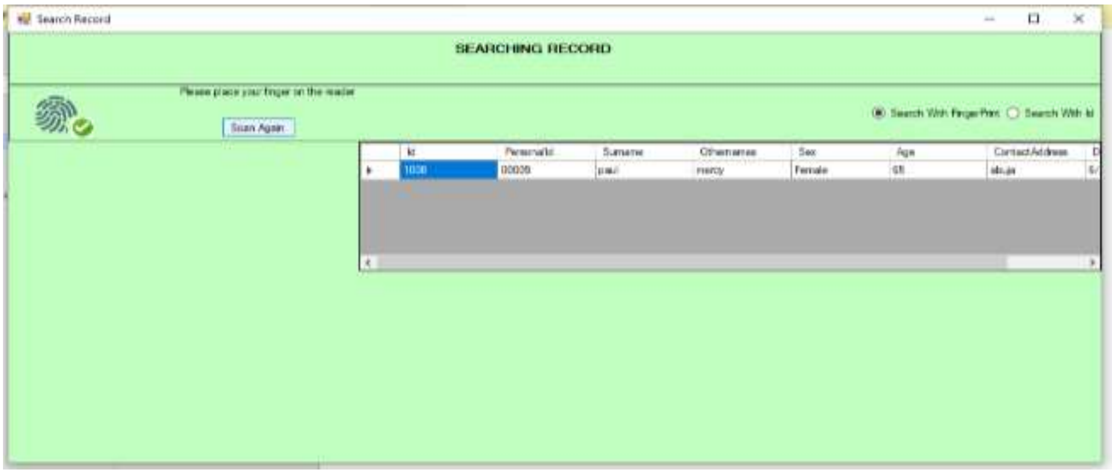


Finger Enrollment Complete

Record Capturing

Record Id	00011
Surname	JACKSON
Othernames	MARK
Sex	MALE
Age	30
ContactAddress	ILESA

Figure 13. Add new record page



SEARCHING RECORD

Please place your finger on the reader

● Search With FingerPrint ○ Search With Id

Id	PersonalId	Surname	Othernames	Sex	Age	ContactAddress	D
1030	00030	paul	mercy	Female	65	abuja	6/

Figure 14. Search page

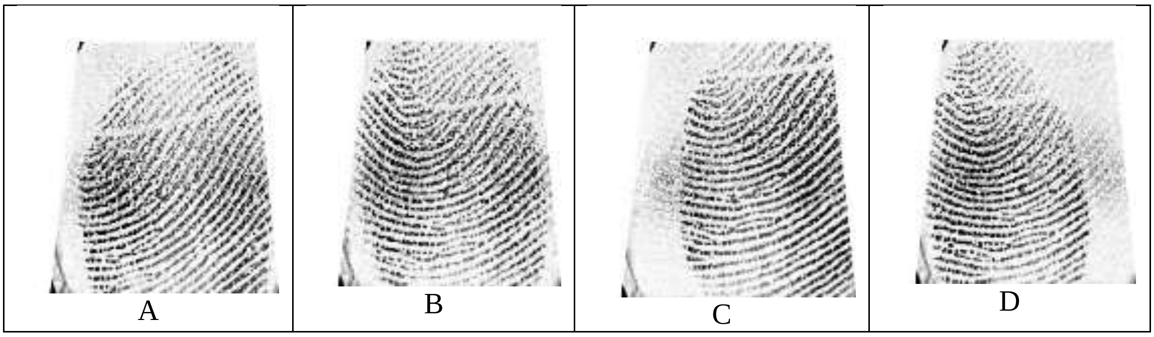
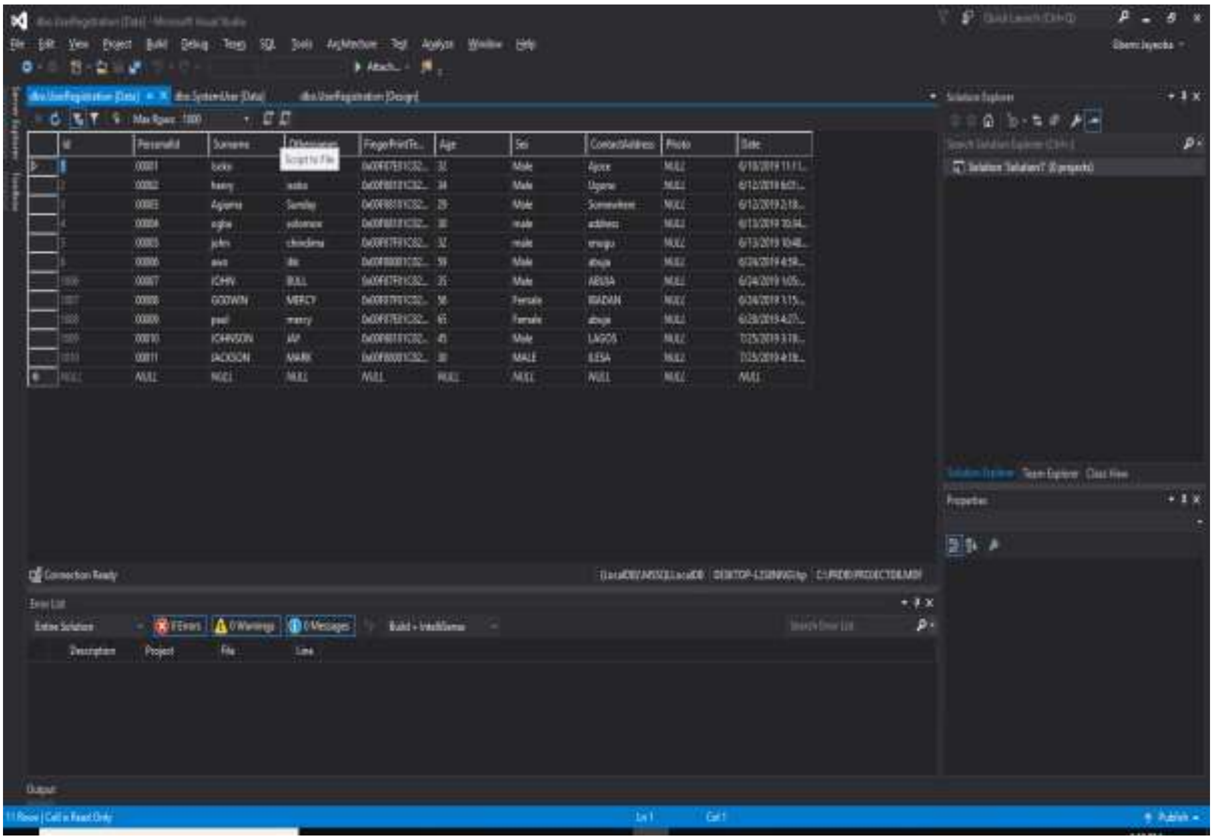


Figure 15. Samples of fingerprints captured: a) left thumb b) index finger c) right thumb d) right index


dbo.UserRegistration [Data] - Microsoft Visual Studio
File Edit View Project Build Debug Team SQL Tools Architecture Test Analyze Window Help
Attach...
dbo.UserRegistration [Data]
dbo.SystemUser [Data]
dbo.UserRegistration [Design]
Max Rows: 1000
Script to File
Solution Explorer
Solution 'Solution1' (0 projects)
Solution Explorer Team Explorer Class View
Properties
Connection Ready
Error List
Entire Solution
0 Errors
0 Warnings
0 Messages
Build + IntelliSense
Search Error List
Output
Ln 1
Col 1
Publish

Id	PersonalId	Surname	Othernames	FingerPrintTe...	Age	Sex	ContactAddress	Photo	Date
8	00001	lucky		0x00F87E81C82...	32	Male	Ajose	NULL	6/10/2019 11:1...
2	00002	harry	isaka	0x00F88181C82...	34	Male	Ugene	NULL	6/12/2019 6:01...
3	00003	Agiama	Sunday	0x00F88181C82...	29	Male	Somewhere	NULL	6/12/2019 2:18...
4	00004	ogbe	solomon	0x00F88181C82...	30	male	address	NULL	6/13/2019 10:04...
5	00005	john	chinedima	0x00F87F81C82...	32	male	enugu	NULL	6/13/2019 10:48...
6	00006	awa	ibe	0x00F88001C82...	59	Male	abuja	NULL	6/26/2019 4:58...
1006	00007	JOHN	BULL	0x00F87F81C82...	35	Male	ABUJA	NULL	6/24/2019 1:05...
1007	00008	GODWIN	MERCY	0x00F87F81C82...	56	Female	IBADAN	NULL	6/26/2019 1:15...
1008	00009	paul	mercy	0x00F87E81C82...	65	Female	abuja	NULL	6/28/2019 4:27...
1009	00010	JOHNSON	JAP	0x00F88181C82...	45	Male	LAGOS	NULL	7/25/2019 3:18...
1010	00011	JACKSON	MARK	0x00F88001C82...	30	MALE	ILESA	NULL	7/25/2019 4:18...
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL

(LocalDB)\MSSQLLocalDB DESKTOP-L33BNNG\hp C:\PROJECT\PROJECTDB.MDF

Description	Project	File	Line

11 Rows | Cell is Read Only

Figure 16: Screenshot of the database (Authors)

4 RESULTS AND DISCUSSIONS

With the adoption and integration of biometric system in Nigerian Correctional Service, there will be 98% reduction of identity theft among ex-convicts in Nigeria and as a result the case of James Ibori vs The State in February, 2003, which portrayed Nigeria in bad light, would not have occurred[4]. However, the Human biometry is the holy grail of authentication solutions and that until now, nobody has made the technology foolproof [5].

A centralized network that will have all the data from different correctional centers stored in a centralized database was also proposed for this study and as a result, there will be sharing and updating of data among the 240 Correctional Centers in Nigeria. The idea will be different from the stand-alone database currently being used in Nigerian Correctional Service which enables a jail breaker from any part of Nigeria to migrate freely to another part of the country with the claim of a free citizen since he cannot be easily tracked and monitored. The proposed integration of a centralized database into Nigerian Correctional Service was in agreement with Mohammed and Saleh's recommendation in their study titled "*Centralized Database: A Prerequisite for Security and Sustainable Development in Nigeria*" that Nigerian government should adopt centralized database that can harmonize records of organizations and agencies which will help in ensuring security and sustainable development in the Country [14]. The centralized database will aid the data sharing and availability of information on convicts by other related agencies and also the data and records can be used for decision making whenever the need arises.

The result indicated 97.5% biometric accuracy levels attained with error allowance of 1% False Acceptance Rate (FAR) and 3% False Rejection Rate (FRR). Which means that the system will make 1 false acceptance for every 100 imposter attempts and reject 3 matches for every 100 authorized attempts. This result is in agreement with [13], which noted that biometric matching cannot be 100 % accurate. Though, in case any of the error occurs while verifying the convicts, other available information can then be used to actually verify the convict.

In normal cases of biometric system, the FAR and FRR are always less than 100%, that is they are never equal to each other – this is because some individual have fingerprints that are hard to capture or verify after capture. The following are the possible reasons why some fingerprints may not be verified after been captured:

- Damaged friction ridges (due to physical labour)
- Dry skin (due to weather)
- Skin ailment
- Uncommon minutiae in the ridge design
- Failure to present proper part of the finger

5. CONCLUSION

The paper Nigerian Correctional Information Management System was about integrating biometrics of Nigerian convicts and updating the existing stand-alone database into a centralized networked database. The implementation will unite all the data on Nigerian convicts into a centralized database and thereby improve accuracy in Nigerian Correctional Service. There will be data sharing and availability of data on Nigerian convicts if the study is adopted.

Not only does use of a centralized database aid in the detection of convicts and ex-convict in case of a jailbreak or re-offending respectively, the data in the centralized database can also be shared among other Nigerian agencies such as National Identity Management Commission (NIMC), Nigerian Police Force (NPF), Independent National Electoral Commission (INEC) and Nigerian Correctional System (NCS) for effective monitoring and tracking of convicts or ex-convicts, though with restriction on access rights.

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