MULTIMODAL BIOMETRIC AUTHENTICATION FOR A COMPUTER-BASED TEST (CBT) APPLICATION

Desmond Bala Bisandu  
Department of Computational Engineering Sciences, Cranfield University, UK  
desmond.bisandu@cranfield.ac.uk; bisandud@unijos.edu.ng

Akos Shalom  
Department of Computer Science, University of Jos, Nigeria  
akosshalom@gmail.com

Farouk LawanGambo  
Department of Computer Science, Federal University Dutse, Nigeria  
farouk gambo@fud.edu.ng

Abstract: This paper proposed a computer-based test (CBT) mobile application with a multimodal biometric authentication. Authentication is a vital process in verifying the identity of a person based on certain input requirements. The need for such a system has become necessary due to the increasing number of examination malpractice cases during the conduct of examinations in Nigerian tertiary institutions. One of the major forms of examination malpractices identified is impersonation. The study was carried out on the state of computer-based tests in the University of Jos, Nigeria, it was implemented and used to get observations, findings, and relevant information on how the proposed system can address impersonation. In the case study, discomfort, faulty computers, network failure were part of the issues faced during the conduct of computer-based tests. The implementation of the mobile application was done with Flutter (a framework of dart programming language). Python (python facial recognition package server) was used to handle face recognition. The backend uses a No SQL database known as Firebase (Firebase collections/real-time database) which was used to store all data and carry out other related user validation functions. The work presented has rebounded to solving the problem of examination malpractice and impersonation in computer-based tests in the University of Jos as observed during validation with up to 97% level of reliability at different levels of authentication which make the solution a highly recommended system with state-of-the-art results.

Keywords: Biometrics, examination malpractice, authentication, facial recognition, fingerprint

I. INTRODUCTION

Malpractices in examinations have become a serious issue in Nigerian institutions today. This problem has led to increasing number of graduates who are not knowledgeable and are incompetent in their various fields of studies. It also makes students to lose confidence in them and depend on other students in examinations for solutions. One of such examination malpractices is impersonation, where a student claims to be another student, gets access to exam hall and writes the examinations for another student.
In the University of Jos for example, impersonation during examinations has been one of the difficult forms of malpractice to handle. Other problems in line with this issue are:

i. Increase in rate of imposters in examination hall.
ii. Increase in dependence of students in other students.
iii. Leak of examination questions and solutions.

Another set of issues observed is that, in the current state of CBT examinations in the University of Jos for example, several complain have been made with regards to how examinations are conducted:

i. Students complain about congestion during entrance to the examination hall due to large number of students taking the examinations.
ii. Students complain about network failure during the examination sessions.
iii. Students complain about power failure.
iv. Faulty computers. Students complain about their computers going off during the examination which usually destabilizes them.

In order to examine the problem of the study, the paper focuses on the development of a multimodal biometric recognition system for computer-based tests. This proposed a three-level authentication which could help improve the monitoring of the examinations.

1.1. Concept of biometrics

The term biometrics refers to a method of identification and verification of a person based on his or her physical or behavioral traits. This method is gradually being generally accepted as a means of identification of an individual. Traditionally, individuals are verified using passwords or identification cards (ID), which can easily be bypassed. Hence, both methods are unreliable [1],[2]. In a biometric system, recognition, identification, and verification of an individual work by obtaining information from an individual through feature extraction and compares it with the model stored in a database.

1.1.1. Biometric authentication

This is a computer-based method which is used to verify and grant access to an individual seeking for access into a system. Improvements were made on conventional techniques of authentication due to their poor reliability, through the development of biometric authentication which is a more reliable method for identifying persons in systems. It is considered as ‘biometrics’ most of the time. Reference [3] defines biometric authentication as the means of utilizing biological traits or behavioral characteristics for the purpose of authenticating a user. Similarly, [1], highlighted various factors of authentication, some of which are: fingerprint, face, iris, retina, gait and palm.

1.1.2. A brief history of biometric authentication systems

The use of biometrics can be dated as far back as three decades ago. It was used for the purpose of capturing, analyzing and storing records of criminals. Ever since, it has evolved to become a very important aspect of authentication in diverse sectors. For instance, the attorney in advanced countries uses biometrics to take records and data of law defaulters. Similarly, The Federal Bureau of Investigation (FBI) of the United States Department of Justice makes use of a fingerprint matching system (automated) known as the IAFIS to capture rolled prints [4],[5]. The development of this technology began in 1999. It holds over fifty-five million records, which makes it the largest biometric database in the world. Most Immigration systems in foreign and advanced nations also make use of this technology. The ‘US-VISIT’ biometric authentication system is another similar project by the United States Department of Homeland Security (DHS) which is used for collecting, maintaining, and sharing information, that includes biometric identifiers on selected foreign citizens who are applying for visas or entry into the country [6]. Due to lack of technological advancement in Africa caused by issues related to poverty, education, manpower, and general underdevelopment, traditional authentication methods such as user passwords and identification cards to gain access to resources in various systems are still in use. However, in more developed countries, biometric authentication systems are widely used in banking and finance sectors. Over time, there has been a little improvement lately in one of the most widely used banks in Nigeria: Diamond-Access bank. Their mobile banking application contains a fingerprint authentication method for protection of data.

The use of fingerprint authentication to authenticate users in mobile applications was pioneered by the Royal Bank of Scotland (RBS) and NatWest [7]. In 2015, the Gartner Financial Services Cool Business awarded Citibank twice, for the implementation of voice recognition for identification. As a result of the increased level of security they provide, multimodal biometric authentication systems have recently got major attention. Reference [8], proposed the use of face and iris to protect medical documents. Similarly, a multimodal system which uses online digital signature and voice recognition to secure medical records was proposed by Krawczyk, [9]. Furthermore, a multimodal biometrics system which was used to secure internet banking applications was introduced by Catalin [10],[11].

There are various modes of biometric authentication systems in existence.
1.1.3. Modes of biometric authentication

Inasmuch as there are a variety of biometric authentication mechanisms or approaches, all of them fall under one of these categories or modes:

1.1.3.1. Unimodal: There is many biometrics in use today. Most are still in the developmental stage, while others are widely used. Unimodal as the name suggests is a mode of biometrics in which its modes of operation are carried out in “one form”. We will discuss some of the biometrics that is part of this mode of operation.

1. Fingerprint: This is a biological pattern of valleys and ridges located on the tip of the finger which is used for verifying people's identity. Its permanence, universality, accuracy, uniqueness, and low cost currently make it the leading biometric technology [1]. This technology has existed from about 7000 to 6000 BC [12]. In 1880, Henry Fauld established a scientific foundation on modern fingerprint recognition by introducing the minutiae feature for fingerprint matching [12]. Currently, the classification of fingerprint recognition technique is the minutiae-based, the ridge feature-based, correlation-based [13], and the Gradient based [14]. Most automated fingerprint identification systems make use of techniques which are based on minutiae points [13]. However, during acquisition of fingerprints, the noise and distortion of every finger leads to errors in minutiae extraction and hence results in missing features [15]. The ridge feature-based method is therefore used to overcome the weakness of the minutia-based method. It makes use of features of ridges such as the frequency and orientation, shape and texture information for matching fingerprint. The ridge feature-based method also has its disadvantage. It suffers from low discrimination capability [12]. The correlation-based techniques superimpose two fingerprint images and correlate them (at the intensity level). These techniques are very sensitive to condition of the skin, non-linear distortion, different finger alignment and pressure [16].

2. Face: this mode of recognition is difficult to bypass and very easy to use. There are a proposed number of algorithms for this method. They are divided into two: geometric feature-based and appearance-based. The geometric feature performs recognition by analyzation of specific local features alongside their geometric relationships. They are robust against determinants in illumination and viewpoints but are also very sensitive to the process of feature extraction. Because of lighting, changes in expression and poses in the image’s recognition of faces from still 2-Dimensional images is difficult. Hence, the 3dimensional face recognition has been proposed to counter these problems stated above. The disadvantages of the 3dimensional face recognition are its lack of sufficiently powerful algorithms, low accuracy for other acquisition types, decreased ease-of-use for laser sensors and high cost.

3. Voice recognition: this method uses factors related to physiology and behavior to produce patterns of that can be captured by a speech processor. Different properties are used for speech authentication. They include basic frequency, cadence, nasal tone, inflection etc. A voice recognition system is generally classified into two: the text-dependent and text-independent modes. A dependent system usually performs better than a text-independent system due to the foreknowledge of what is said can be exploited to align speech signals into more discriminate classes. The text-dependent systems on the other hand need a user to pronounce specific words, which usually contains the same text as the data used for training. Voice recognition is broadly used today in diverse areas of life such as human verification systems in banks, mobile applications and lots of other verification systems.

4. Iris: It is a thin circular diaphragm which is located between the lens of the human eye and cornea. In 1987, Flom and Ara established the first concept of automated iris recognition whose implementation was further carried out [19]. Though his system is the most very popular and successful, several other systems have been developed. Reference [20], deployed an automatic algorithm for segmentation which was based on the circular Hough transform. Similarly, reference [21] extracted iris features by making use of a 1dimenional wavelet transform. There are other several which have also been developed for the iris recognition. Reference [22], proposed the use of Daugman’s 2-Dimensional Gabor filter which contains quality measure enhancements. Furthermore, reference [23], also proposed making use of 1-Dimensional local texture patterns and [24] established making use of the moment-based iris blob for matching.

5. Palm-print: this region lies between the wrist and fingers. Its features such as ridges, minutia points, principal lines, singular points, texture and wrinkles can as well be used for verification [25]. Palm-print verification systems are of two types: the high-resolution and low-resolution palm-prints. The high-resolution systems use high resolution images, while the low-resolution systems make use of low-resolution images. The Figure 1 shows the diagram that explains the process of enrollment (registration), verification, and identification in a unimodal biometric system is done. Enrollment is the first process of registering a user’s characteristics information into the database.
Required factors are scanned, which produces a signal or an image. In order to enhance the efficiency of this procedure and minimize the noise in a data, images that are scanned directly are being pre-processed. The registered template includes vector data which is used for the matching stage. Identification and verification are used interchangeably in literature sometimes, but both are distinct in nature. Identification means carrying out a one-to-many relationship (matching), where a scanned input is run through the templates of the database to get a match. Verification on the other hand simply means mapping an initially scanned input with an input that was scanned previously, thus, containing a one-to-one relationship system.

1.1.3.2. Multimodal
This type of biometric system combines multiple sources of information to establish human identification. This method is highly effective and can significantly enhance accuracy. Most biometric systems used in practical applications today make use of single pieces of information for recognition which can be referred to as unimodal biometrics. Unimodal biometric systems however have several problems related to universality, prone to spoofing, noise in sensitive data, variations in intraclasses, similarities in inter-class. Some of these issues can be eliminated by making use of the multimodal systems. The multimodal systems comprise of two or more behaviors or traits to result in a more reliable system in terms of security and robustness. In this section, insight related to the architecture and implementation of biometric systems will be provided. A unimodal biometrics system generally works in three phases’ enrolment, verification and identification. Like the unimodal systems, these three processes also take place in the multimodal systems. In multimodal biometrics, fusion of information can be achieved at various levels: at the sensor level, at feature extraction level, at the matching score level and at the decision level. The sensor level fusion is barely used because it requires the obtained data from different biometric sensors to be compatible. Similarly, at the feature extraction level, fusion is not always achieved because feature sets that are used by several biometric modes might be incompatible or inaccessible. There is usually a limited amount of data available in the decision level due to its rigidity. Furthermore, as a result of the availability of enough information and ease of access and match scores combination, the matching score level is preferred [26].

1.2. Computer based tests
Computer-based test as the name implies, is the use of computers to carry out a test or assessments for students. Other terminologies that could be used interchangeably to describe Computer-Based Tests (C.B.T) include Computer Assisted Test (C.A.T), Computer Based Assessment (C.B.A), Online Assessment, Web-Based Assessment, Technology Enhanced Assessment, Automation Assessment, and E-Assessments or Examinations or Tests [27]. In Nigeria, the evaluation and assessment of students’ performance is traditionally carried out through paper and pen, and Computer-based tests (CBT). The paper-based test is the most common and widely used mode of assessment in Nigeria. This system is vulnerable to different forms of examination malpractices like illegal materials, writings on currency notes, spying other candidates, and altering of examination scores or grades. Other predominant modes are impersonation, leakage of exam questions to students before examinations, supervisors and school authorities conniving to cheat and writing on the body [28],[29]. Due to the highly effective tools they provide, computers and other related systems help to tackle the challenges related to the design and implementation of assessments methods that transcend the usual practices and enhance acquisition of cognitive skills and knowledge.

1.2.1. Concept and procedure of computer-based tests concept

Computer-Based-Tests (CBT) is of two categories- the linear/fixed and the adaptive. The linear CBT method is a full-length assessment. Here, the system selects different questions for a person without putting into consideration his level of performance [30]. This method is almost like the paper-based test. Reference [31], described computer-based testing as a method of administering tests in which the responses are electronically recorded, assessed, or both. Reference [32], furthermore, in a computer-based adaptive test, the difficulty level of each question given to the user is according to their ability. When each question is attempted, the computer makes use of the option to determine the next question to be presented. Compared to the traditional paper-based-examinations (PBE), computer-based-examinations (CBE) have a number of advantages which include lower cost of printing, easy administration, increased security level, rapid feedback in terms of multiple-option examinations, and a number of standard support tools [33]. In computer-based assessments, test timing can easily be managed, which ensures that every student is offered equal amount of time during each test. Unlike the paper-based tests, CBT’s which come in the format of an electronic file, makes things easy and reduces the necessity to print, keep track of, and mail tests. Then can be scored instantly, hence providing useful feedback to teachers and students. They also allow for students to access some support tools like dictionaries, text-to-speech, calculators, and permit using these tools when appropriate and necessary [34]. Furthermore, CBE’s promote authentic and innovative assessments because of more enhanced technological performance. Some examples include using video clips and slide shows to evaluate the performance of medical students in surgeries or using computer-based simulations to evaluate social skills. However, there exist several disadvantages when carrying out CBE’s. These include the need for adequate facilities, back-up measures in the case of a technical fault, test-security, power failure and time for the staff and students to become acquainted with the new technologies.

1.2.2. Procedure

During Computer-Based Tests, each student (after taking attendance or passing through verification on entrance to the examination hall) is assigned to a computer where he sits in front of, and attempts the questions presented on the computer monitor. After answering all questions, submission of answers is made using a mouse or keyboard [31]. In some CBT systems, results are displayed immediately after the student submits. For some, the results are computed afterwards, and students will see on their various notice boards.

1.3. Biometrics of computer-based examinations

Over the years, the increase in the use of Computer Based Tests is very evident. However, the unethical conduct of students during e-learning has now become a major concern [35]. There is an argument that this unethical conduct has increased greatly due to the use of technology [36]. Most teachers’ focus is on one form of unethical behavior, which is known as [37],[38]. Reference [39], pointed out some mechanisms such as Turnitin.com which are used to detect and curb plagiarized works. Although, there are numerous materials on how to detect plagiarism, references [40]-[44], little effort and attention is given for preferring solutions to other unethical acts like cheating in CBTs.

Yu and Tsao (2003) addressed the security issues of e-learning environments. However, their proposition focused on the aspect of shielding the infrastructures against unauthorized access. The current security procedures in e-learning systems rely greatly on the use of password authorization factors. Reference [45], addressed several security related technologies which were not integrated to e-learning. One of the solutions is biometric technologies which might potentially result in an integral aspect of e-learning systems. Similarly, [46] noted that biometric technology has been commonly used to replace traditional password systems. Furthermore, Coventry, [47] noted and argued that with the needs for an increase in security, remembering passwords is becoming more difficult, whereas the fingerprints are a unique feature to a person. Yang and Verbauwhede identified a fingerprint biometric system where the fingerprint template is stored on a server when initiation takes place.
While scanning the finger is carried out, an input device runs a biometric signal and sends it to the server, where it is later processed for matching. In the event to guard the system against security breach, Yang and Verbauwhede suggested that the fingerprint template be encrypted upon storage on the server. Fingerprints templates can be decoded whenever a matching takes place [42], [43] hereby recommended a secured procedure for fingerprints matching in a biometric system. They also argued that biometric systems provide more security than existing password systems. Biometric systems are more reliable, accurate and as well simpler to use compared to conventional password systems. Employing any biometric feature increases security to a system, especially for authentication sake. The subsequent parts of this paper are structured as such: Section 2 describing related concepts; Section 3 describing materials and methods, Section 4 describing design interface, experimental results, and discussions, and Section 5 which concludes with the future work.

II. RELATED CONCEPTS

The growth of the body of research which is focused on adopting better methods of managing e-examinations systems and e-learning system is rapidly increasing. Several research works have been carried out to see that there's high efficiency in the use of computers for the sake of learning and assessments. Some of these projects are as follows:

A web-based examination platform was developed and tested in Covenant University, Nigeria [5]. In this system, all registered applicants are subjected to participate in online entrance examination, to curb unethical conducts. This procedure was proposed by the examination body responsible for organizing entrance exams into Nigerian universities which is known as the Joint Admissions Matriculation Board (JAMB).

Similarly, another web-based examination application is developed to curb the issues related to unethical conduct in examination. The system has a multiple-choice set of questions and on submission of answers, a student is scored and at once [5]. The application depends was designed using Microsoft technologies such as Microsoft.net, ASP.NET, C# and Microsoft SQL. It solely depends on these technologies for its operation to be achieved.

A theoretical concept and approach were employed; which incorporates any available fingerprints authentication technology in collaboration with online learning environments to help in curbing any unethical conduct during the e-learning examinations [27]. This approach recommends practical solutions which could incorporate any random fingerprint authentication during e-examinations.

Reference [30], described a web-based e-learning system which allowed for giving out and grading arithmetic questions, alongside the capability to accept input, return output, plot graphs dynamically and generate random mathematical expressions and digits. Reference [8], proposed an e-examination software that contained multiple options of questions, especially for the hearing impaired. This generic software is organized such that the examination materials are translated into finger spelling and sign language. The software also presents an empty template, making it possible for a teacher to employ the required exam for a topic (Mathematics, English, etc.) and any desired type of exams (Subjective or Objective etc.).

Reference [20], examined how paper-based, web-based and mobile-based assessments influence the performance of students. To study the impact, 38 students were used for the assessment experiment. This procedure was carried out for 3 weeks. In the first week, there was no significant different in the grades obtained by the students. However, there were observable differences that emerged in the second week. Hence, this paper brings to light that the students had a positive attitude towards using web and mobile based assessments due to their ease and simplicity of use, and feedback gotten instantly.

This Section explored how computer-based tests have been carried out over time, their advantages over the traditional paper-based tests, their similarities with related literature and their drawbacks. The focus was centered on identifying certain features and functionalities that these systems possess, maximizing and integrating the key functionalities of the related work into a multimodal biometric mobile application for user authentication during computer-based tests. As observed from the literatures discussed above, all the systems mentioned are web-based applications. Therefore, this research will be focused on the mobile platform. This proposed solution is focused on enhancing the current process of authentication, by fusing fingerprint and facial recognition biometrics together to further help in curtailng examination impersonation in Nigeria.

III. MATERIALS AND METHODS

The method of software development which was employed for this project is the Object-Oriented Analysis and Design approach. This approach visualizes individual components of the system as objects, interacting together to produce the desired display system. In the System Development Life Cycle there is no overlapping in the phases consisting of the Analysis, Design, Implementation and Testing. Hence, this section addresses the methods and approach used to design the proposed system.
3.1. Proposed methodology
The summary of the proposed system is explained in the subsections that follow. Figure 3 shows the framework and workflow of the developed application. The application is structured into three components.

A. The Computer Based Test Application: This is the medium through which the student takes assessments and examinations and receives his scores for the written examinations and assessments and addresses any issue he is facing to the school.

B. Image Recognition Server: This section of the application takes student details, alongside his image and fingerprint and stores in the database. The data is then retrieved during operation of the app. Image and fingerprint recognition is then carried out during the process of logging in.

C. Backend Server and Database: This is where the data retrieved from the mobile application is stored. It contains various collections (databases) which contain all information about the users, the examinations, records, assessments etc. This section is handled by Firebase (a google backend service). It also contains an admin dashboard where the admin uses to see information on the application and carries out desired or required operations.

The application makes use of the multimodal approach for biometric operations, for enrollment, verification and identification. The image recognition server and the fingerprint recognition component work together during the authentication process (Fusion), to give access to the application as shown in Figure 4.

3.1.1. Framework and method of operations
For the purpose of implementation, Flutter (a framework of dart programming language), which supports object-oriented programming, was used to design the user interface and logic processes as shown if Figure 5.
It is designed in a way that it contains two stages of authentication the username and password, the image recognition and fingerprint. On registration in the application, alongside the username and password, the user is prompted and expected to register his photo. When the user comes to sign in, the first stage of the authentication is the username and password. If correctly entered, he’s navigated to the fingerprint recognition module. The fingerprint component on the mobile device carries out the recognition. If it matches the details, it navigates to the facial recognition module. The python server for recognition collects a captured image and matches it with the other image stored in the database during registration. If properly matched, fusion between the image recognition feature and the fingerprint takes place, and lead to a successful signing into the application. The case study will be carried out in the University of Jos, Plateau State Nigeria and it is explained in this section.

3.2.1. University of Jos current state of computer-based-tests

Computer-based tests in the University of Jos is a commonly used in writing general subjects such as GST’s, computer science courses, and a good number of other courses. The university consists of about 12 faculties. Every session, students in their first and second years of studies are expected to sit for these examinations. These examinations are usually conducted in the multipurpose auditorium of the university. Before writing the examinations, the students are usually given a brief orientation on how the examination will hold, alongside other useful information regarding the examinations. Then they proceed to write the examinations.

3.2.2. Problems associated with the current method

Over the years, a lot of issues have been repeatedly observed by exam officers and students with regards to the state of computer-based examinations in the school. Some of the issues are that:

1. Computers usually go off during examinations.
2. Network failure affects some of the students during the examinations, which causes their sessions to be lost while taking the exam.
3. Exhaustion in both staff and students due to the number of students that must take the examinations.
4. Impersonation is on the increase. Imposters come into the examination halls and write examinations for other students.

3.2.3. Advantages of proposed system

Following the review on previously existing and current systems, it is obvious that most of them are web-based systems. The proposed system on the other hand is taking another approach, which is the mobile application system. In the current case study, the mode of taking examinations is that the students, taking the CBT’s from all faculties in the university, assemble at the multipurpose auditoriums and are being verified at the entrance before they go in to take the examinations. This process is usually tiring, time consuming and discomforting due to the number of students taking the tests. The proposed system seeks to ensure that each student is expected to have the application installed on their smart phones (with the requirements of the application). Instead of all the students to assemble at the multipurpose auditorium, the students will use their lecture halls for the examinations. In faculties or departments where the students are numerous, the lecturers will share the students in groups depending on their desired arrangements. The students will go into the halls depending on the number it can contain. At the desired time, the students will be asked to proceed the examinations or tests. This will greatly reduce stress and discomfort as mentioned above. The thought of using a mobile application to take tests and examinations seems to be a factor that would likely encourage malpractice. The user might want to minimize the application and communicate using other applications on the phone or browse answers. However, the application is designed in a way that if the user tries to leave the app once an examination or test session is going on, the application will automatically exit. This feature has countered that possibility. Also, the application will contain similar features with previously existing system such as user authentication, taking of test and examinations etc. together with more additional functionalities:

It will give the user ability to see his results after writing a test or an examination, instead of trying to check it manually through boards. Since the CBT will be in form of an application, there will be a great reduction in congestion due to large number of students from different faculties coming to write the exam. Hence, the examinations will be taken in their various lecture halls or around the premises remotely. Unlike the other systems that contain one mode of biometric authentication, the proposed system consists of a more secured authentication procedure which consists of the fingerprint and facial recognition functionalities. This feature makes it almost impossible for another person to impersonate another student. In order to counter the possibility of trying to minimize the application and probably try to cheat by browsing or going through any materials on the phone, the app is designed in such a way that it exits an exam session immediately the student minimizes the application.

3.2.4. Architecture of the proposed multimodal biometric mobile application

Architectural design is concerned with understanding how the system should be organized and design of the overall structure of the proposed system. It is the first stage in system development/design process. On initialization of the mobile application, the user is required to register or login if he/she already is registered. During the login process, a user is required to update a snapshot of an image, for the purpose of recognition.
Once the process runs successfully, the user is navigated to the homepage. The system is made up of the following components: login component (which is done by the email, password and image recognition), signup components, profile, courses, examinations, tests, contact school, notification and logout. Figure 6 below shows the architecture of the mobile application.

3.2.4.1. System algorithm (Pseudocode)

Pseudocode is an informal high-level description of the operating principle of a computer program or other algorithm. The pseudocode for the proposed multimodal biometric authentication mobile application from the administrators and students view is as shown in Figure 6a and Figure 6b.

![Figure 6: Architecture of the Proposed CBT application](image)

![Figure 6a: Snippet of pseudo-code for mobile application (students view)](image)

![Figure 6b: Snippet of pseudo-code for mobile application (Administrators view)](image)
3.2.4.2. Entity relationship diagram (ERD)

ERD is composed of entity types and the various relationships that exist between them. Figure 7 shows the entities in the system and how they relate with each other.

![Entity Relationship diagram of application](image)

Figure 7: Entity Relationship diagram of application

3.2.4.2. Activity diagram (AD)

An activity diagram represents the sequence of activities available in an application in order to achieve a task. Figure 8a and Figure 8b shows the activity diagram of the proposed mobile application for students and administrators respectively.

![Activity Diagram of mobile application (Student view)](image)

Figure 8a: Activity Diagram of mobile application (Student view)
3.2.4.2. Sequence diagram (SD)
Sequence diagram shows the interaction between the user and the system in the order they occur. Figure 9 shows the sequence of interactions between users and the system.

Figure 8b: Activity Diagram of mobile application (Administrators view)

Figure 9: Sequence diagram of the system
3.2.5. System Modeling
This process involves developing models (abstract) of the system. Each of these models developed present different perspectives or views of the system. It also involves the representation of the system using graphical notations which are usually based on Unified Modeling Language (UML). System models are developed as part of the requirements of engineering and design processes. The models used for developing the system is describe as follows:

3.2.5.1. Use case diagram
This is an analysis concept which describes the actions of the systems from the user’s point of view. It visually represents relationships between users (actors) and the use cases, alongside documenting the intended behavior of the system which is usually focused on satisfying the goal of a user. Actors refer to entity or component that interacts with the system (i.e. a user or another system etc.). Lines and arrows are usually drawn between use cases and actors to indicate the relationships between them. A use case captures every possible way the system and user can interact towards achieving a goal as shown in Figure 10.

Figure 10: CBT system case showing interaction between administrators and users use

3.2.5.2. Flow chart
This is a diagram that represents an algorithm, workflow or sum of processes that describe the operation of the application as shown in Figure 11.

Figure 11: Flowchart process of the CBT application
IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The discussion and results related to experiment are explained in this section. Where the various processes to check and reliability of the system and validity in real life situation was carried out and findings were recorded accordingly.

4.1. Choice of integrated development environment (IDE) and technologies
An IDE (integrated development environment) is software that provides a computer programmer with tools for software development. The choice of IDE influences the speed of application development. For the sake of this research, a Microsoft technology which contains a variety of tools, integrations and programming languages known as Visual Studio Code is used.

4.2. Prototype operations
The following sub sections illustrate the operation of the multimodal biometric authentication mobile application. The system consists of a 2-way mode of operation; students use the app on their phones, while the lecturer (administrator) makes use of the Firebase console dashboard to control the backend. The admin section is the medium through which questions can be pushed, notifications sent, students’ result being assessed etc. The application on the other hand, is used by the students to carry out their tests and examinations, submit, make reports to the administrator, and register for new courses and so on.

4.2.1. Registration screen
The registration field contains fields which are required to be filled by the student in order to be registered in the database. Figure 12 shows the registration screen for a student and the respective input fields.

![Figure 12: Registration page](image12.png)

4.2.2. Login page
The login page is the first page to be displayed after the app has been launched. It contained 3 fields: the password field, the email field, and then the picture taken from the camera to be used for authenticating the user. This is shown in Figure 13.

![Figure 13: Login page with multimodal authentication](image13.png)
4.2.3. Home page and navigation menu
After authentication is carried out successfully, the user is navigated to the homepage. By the left side is also the navigation menu which contains various pages of the app. Figure 14 shows the navigation menu which provides access to other application features and functionality.

![Figure 14: Side-navigation of application](image)

4.2.4. Course page
This page contains an available list of courses selected by a student during the period of registration as shown in Figure 15.

![Figure 15: Course page](image)

4.2.5. Examinations page
The examinations page is one of the core activities of the mobile application. It contains various courses registered by the student for the purpose of taking an examination. Figure 16 explains the examinations page.

![Figure 16: Examination page of the CBT application](image)
4.2.6. Profile page
The profile page contains all the information about the student as shown in Figure 17.

Figure 17: Profile page

4.3. System testing and evaluation
This section is concerned with testing the prototypes to ensure it satisfies all necessary requirement specification. Evaluation and testing are an unavoidable part of any software and information technology project.

a) System reliability: This shows the capability of the software system in maintaining a desired rate of performance at a given duration in terms of recoverability, fault tolerance and maturity. System functionality

b) This checks how efficient the system software is in meeting client’s needs, usually in terms of how suitable, accurate, interoperable, and secure it is. Ease of use

c) This criterion evaluates the effective usability of the software system; the amount of effort needed by users to properly make use of the software.

4.4. Testing
The aim of this process is to identify any defect in a program. Even when the testing phase is completed, it is difficult to guarantee a hundred percent freedom from errors. The terms error, fault, bug, and defect are synonyms in the area of program testing.

The goals of testing process are:

a. Validation testing: this process is done to ensure that the developed software meets its intended requirements.

b. Defect testing: the aim of this process is to discover and eliminate any faults, defects or errors that may be present in the software, and any behavior or component which is not in line with the intended specification.

4.5.1. System testing
This process involves testing the whole system. The software system is tested through the following test stages for error detections and corrections.

4.5.2. Unit/Component testing
This the lowest phase of the testing process. It involves testing individual units of the software. In this stage, the units (modules) of the software were tested to verify that each met its intended specification.

4.5.3. Integration testing
This is the testing phase in which all the units are combined and are tested as functional groups. All the modules were integrated and further tested as a full system in order to make sure the specifications are met.

4.5.4. Installation testing
The purpose of this process is to ensure that installation of the software is successful on various devices (android), which run on varieties of android versions and android operating systems. Table 1 shows the results of testing and issues identified on various android operating systems. Table 1 on the other hand shows the installation test plan result.

| S.No | Android OS System Version            | Result          |
|------|--------------------------------------|-----------------|
| 1    | Android X (version 10)               | Installation was ok |
| 2    | Android 9.0                          | Installation was ok |
| 3    | Android 8.0                          | Installation was ok |
| 4    | Android 7.0                          | Installation was ok |
| 5    | Android 6.0                          | Installation failed |
As seen in the table above, the application was tested on different operating systems. The results of the test were collected is shown. Due to compatibility, the prototype was not able to run on all operating systems.

4.5.5. Usability testing
Usability testing is done to see the ease with which software can be operated, by making use of ‘real users’ for the testing process. To determine the user experience of the software, users were given tasks to complete under supervision in case they encountered problems and experienced confusion. Traditionally testing might be done by the developer, designer or project manager. However, usability testing eliminates any possible bias by collecting feedback directly from the end user. The goal of conducting this test is to observe if users were able to complete task adequately while documenting errors they encountered. The experiment recorded the problems encountered that can be employed to ensure a more positive user experience. Thus, overcome the usability issues encountered. During the testing of the mobile application, 5 users were given the mobile application prototype to use. Table 2 and Table 3 show the expected tasks to be accomplished by each user, sum of participants for each task and the number of users that successfully completed each task respectively.

| S.No | Tasks               | No. of Participants | No. of Users to successfully Complete Task |
|------|---------------------|---------------------|------------------------------------------|
| 1    | Register new user   | 5                   | 4                                        |
| 2    | Take an exam        | 4                   | 4                                        |
| 3    | Submit problems     | 4                   | 4                                        |

During the testing of the mobile application, 5 users were given the mobile application prototype to use. The users’ task description table shows the expected tasks to be accomplished by each user, the sum participants for each task and the number of users that successfully completed each task respectively.

| User ID  | User Complains                                      | Observations                                  |
|----------|------------------------------------------------------|-----------------------------------------------|
| Tester 1 | Some parts of the user interface design were dull.   | The user had no problem with registration and taken examinations and tests. |
| Tester 2 | User should be able to update profile.               | User completed tasks successfully.            |
| Tester 3 | Having difficulty trying to sign in after creating an account. | Registration was successful but user was unable to login with the fingerprint feature due to version compatibility. |
| Tester 4 | Poor color combination.                              | The user completed tasks successfully.        |
| Tester 5 | User interface not proportional to phone screen.     | Some user interface components were not proportional due to the small size of the phone. Other tasks were successfully carried out. |

The table above shows a summary of information (feedback) obtained from the users of the prototype. As shown, the table describes the various complains, observations by users and suggestions towards making improvements on the system.

4.6. Summary of tests
The testing of the prototype was done through the installation and usability tests. Installation testing and functionality testing were done by the researcher/developer to verify that the mobile application was installed successfully on android. The testing mainly involved black box testing and it is not concerned with the source code of the prototype. By providing appropriate and expected input, verifying the output and comparing the actual results with the expected results, every functionality of the software was successfully tested. The goal of the usability testing process was to identify any issues related to usability, and this was performed by the users. The complaints from the users of the mobile application were noted. Findings from the usability testing showed that some users were able to use the application with ease. Other complaints and observations were implemented, and changes were made.

V. CONCLUSION AND FUTURE WORK

This paper has identified the critical aspects needed to develop a multimodal biometric mobile application for computer-based tests. The features of the proposed system were obtained hence leading to the development of the final prototype that serves as a proof of concept. Furthermore, the research can be said to have achieved it targeted objectives. It is hoped that the use of this prototype addresses the problem of examination impersonation beyond University of Jos, Nigeria.
5.1. Future work
To ensure that the system improves in performance and usability in the nearest future, the following will be considered in the future work:

1. The fingerprint authentication module will be improved and redesigned in a way that the finger ID of every user is stored on the cloud storage. (This is because the prototype makes use of local authentication to give the user access to the application).
2. Due to observations and suggestions from external sources, the user interface will be improved in order to give the user of the application a more enjoyable user experience.
3. The application was built with flutter framework which is used to build hybrid mobile applications for both iOS and android but due some limitations, restrictions, and compatibility issues with iOS devices; it was only tested on android devices. Therefore, and iOS version will be sort out in the future.

REFERENCES
1. Aggarwal G., Ratha N. K., Tsai-Yang J., & Bolle R. M. (2008). Gradient based textural characterization of fingerprints. In proceedings of IEEE International conference on Biometrics: Theory, Applications and Systems.
2. Akinsanmi O.A, Olatunji, T.R., & Soroyewun, M.B. (2010). Development of an E-Assessment Platform for Nigerian Universities, Research Journal Applied Sciences, Engineering and Technology; 2(2): 170-175.
3. Alabi, A. T., Isaa, A. O., & Oyekunle R. A., (2012). The Use of Computer Based Testing Method for the Conduct of Examinations at the University of Ilorin. International Journal of Learning & Development, 2(3). 51-90.
4. Al-Bayati, M.A., & Hussein, K.Q. (2008). “Generic Software of e-Exam Package for Hearing Impaired Students (Mathematics as Case Study)”, 2nd Conference on Planning & Development of Education and Scientific Research in the Arab States, 955-962.Al-Hijaili, S. (2011). Multimodal biometrics fusion techniques.
5. Aronowitz, H., Hoory, R., Pelecanos, J.W., and Nahamoo, D. New Developments in Voice Biometrics for User Authentication” Book New Developments in Voice Biometrics for User Authentication“ (2011),17-20.
6. Ayo C. K. (2007). The Prospects of e-Examination Implementation in Nigeria. Turkish Online Journal of Distance Education-TOJDE2007; 8(1), 58-66.
7. Batiz-Lazo, B., and Reese, C. “Is the future of the ATM past?”. Financial Markets and Organizational Technologies“ (Springer, 2010),137-165.
8. Bisandu, D. B., Prasad, R., & Liman, M. M. (2018). Clustering news articles using efficient similarity measure and N-grams. International Journal of Knowledge Engineering and Data Mining, 5(4), 333-348.
9. Bisandu, D. B., Gurumdimma, N. Y., Alams, M. T., & Datiri, D. D. (2018). An enhanced text mining approach using dynamic programming.
10. Bisandu, D. B., Prasad, R., & Liman, M. M. (2019). Data clustering using efficient similarity measures. Journal of Statistics and Management Systems, 22(5), 901-922.
11. Bisandu, D. B., Datiri, D. D., Onokpasa, E., Thomas, G., Haruna, M. M., Aliyu, A., & Yakubu, J. Z. (2019). Diabetes Prediction Using Data Mining Techniques. International Journal of Research and Innovation in Applied Science (IJRIAS), 4(6), 103-111.
12. Bisandu, D. B. (2018). Clustering news articles using K-means and N-grams (Doctoral dissertation, American University of Nigeria, School of Information, Technology and Computing).
13. Boles W.W., & Boashash B. (1998). A Human Identification Technique using images of the iris and wavelet transform. IEEE Trans.Signal Process, 46(1), pp. 1185–1188.
14. Chellappa R., Wilson C. L., & Sirohey C. (1995). Human and machine recognition of faces: A survey. Proc. IEEE, 83(5), 705-740.
15. Daugman J. G. (2003). The Importance of being random: statistical principles of iris recognition. Pattern Recognition 36, pp. 279–291.
16. Decoo, W. (2002). Crisis on campus: confronting academic misconduct. Cambridge, MA: MIT Press.
17. Du Y., Ives R. W., Etter D. M., And Welch T. B. (2006). Use of one-dimensional iris signatures to rank iris pattern similarities. OptEng, Vol. 45, 037110–201.
18. Epstein, C. (2007). Guilty bodies, productive bodies, destructive bodies: Crossing the biometric borders”, International Political Sociology, 2007, 1 (2), pp. 149-164.
19. Fang B., Leung C., Tang Y.Y., Kwok P., Tse K.W., And Wong I.K., (2002). Off-line Signature Verification with Generated Training Samples. IEEE Proc. Vision Image Signal Process, 149 (2), pp. 85–90.
20. Flom L. And Aran S., (1987). Iris Recognition System, U.S. Patent 4,641,349.
21. Jain A. K., Ross A., And Pankanti S. (2006). Biometrics: A Tool for Information Security. IEEE Transactions on Information Forensics and Security,1(2), 125 - 143.
22. Jain, A., Flynn, P., and Ross, A. A. (2007). Handbook of biometrics“ (Springer Science & Business Media).
23. Karadeniz, S. (2009). The Impacts of Paper, Web and Mobile Based Assessment on Students’ Achievement and Perceptions. Scientific Research and Essay, 4(10), 984 – 991.
24. Kennedy, K., Nowak, S., Raghuraman, R., Thomas, J., & Dacis, S. (2000). Academic dishonesty and distance learning: student and faculty views. College Student Journal, 34(2), 309-315.
25. Krawczyk, S., and Jain, A. K. (2005). Securing electronic medical records using biometric authentication, In Editor (Ed.). Book Securing electronic medical records using biometric authentication (Springer edn.), 1110-1119.
26. Levy, Y., and Ramim, M. M. (2007). “A Theoretical Approach for Biometrics Authentication of E-Examinations”, USA: Nova Southeastern University.
27. Liu L. And Zhang D. (2005). A novel palm-line detector. In Proceedings of the 5th AVBPA, pp. 563–571.
28. Lim S., Lee K., Byeon O., And Kim T (2001) Efficient iris recognition through improvement of feature vector and classifier. ETRI Journal, 23(2), 61–70.
29. Lupu, C., Găitan, V.-G., and Lupu, V.: „Security enhancement of internet banking applications by using multimodal biometrics”, in Editor (Ed.)(Eds.): Book Security enhancement of internet banking applications by using multimodal biometrics” (IEEE, 2015, edn.), 47-52.
30. Maltoni D., Maio D., Jain A. K., and Prabhaker S., (2003). Handbook of Fingerprint Recognition. Springer. 978-0-387-21587-7.
31. McGinity, M. (2005). Staying connected: Let your fingers do the talking. Communications of the ACM, 48(1), 21-23.
32. McLaugherty, C. L., & Foust, K. M. (2004). Electronic plagiarism as a college instructor’s nightmare prevention and detection: Cyber dimensions. Journal of Education for Business, 79(3), 186-190.
33. Naouma, E., & Hörne, T. (2006). Cheating or collaborative work: Does it pay? Issues in Informing Science and Information Technology, 3(2), 459-466.
34. Oboma, G., Junaidu, I., & Ajagun, G. (2013). The Automation of Educational Assessment in Nigeria: Challenges and Implications for Pre-service Teacher Education. A paper presented at the 39th Annual Conference of the International Association for Educational Assessment (IAEA), Tel-Aviv, Israel, October 20 – 25.
35. Ogunlade, O. O., and Olafare, F. O. (n.d). Lecturers’ Perceptions of Computer-Based Test in Nigerian Universities.
36. Pankanti, S., Bolle, R.M., and Jain, A (2000). Biometrics: The future of identification [Guest Editors’ Introduction] “Computer, 33, (2), pp. 46-49.
37. Pillsbury, C. (2004). Reflections on academic misconduct: An investigating officer’s experiences and ethics supplements. Journal of American Academy of Business, 5(1/2), 446-454.
38. Ross A., (2007). An Introduction to Multi-biometrics. In Proceedings of the 15th European Signal Processing conference (EUSIPCO), Poznan, Poland.
39. Schramm,T. (2008), “E-Assessments and E-Examinations for Geomatics Studies”, Department of Geomatics Hafen City University.
40. Hamburg Hebebrandstrasse 1,22297 Hamburg, Germany.
41. Shu W. And Zhang D., (1998). Automated Personal identification by Palmprint. Optical Engineering, Vol. 37(8),2359-2362.
42. Siskin, A. (2012). Visa waiver program. Current Politics and Economics of the United States, Canada and Mexico, 14, (23), pp. 255.
43. Sun Z., Wang Y., Tan T., and Cui J. (2005). Improving iris recognition accuracy via cascaded classifiers. IEEE Trans. Syst. Man. Cybern.—Part C: Appl Rev, 35.
44. Wildes R. P., 1997. Iris Recognition: An Emerging Biometric technology. Proc. IEEE, Vol. 85,1348–1363.
45. Yousiff A. A. A., Chowdhury M. U., Ray S., And Nafaa H. Y., (2007). Fingerprint Recognition System using Hybrid Matching.
46. Techniques. 6th IEEE/ACIS International Conference on Computer and Information Science, 234-240.
47. Yu, C., & Tsao, C. C. (2003). Web teaching: Design, security, and legal issues. Delta Pi Epsilon Journal, 45(3), 191-203.