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HUMAN NOSE RECOGNITION SYSTEM BASED ON CURVATURE-BASED LANDMARK DETECTION AND NOSE RIDGE PROFILE TECHNIQUES

F.O. Aranuwa[1], J. A. Odimayomi[2], O.S. Abolarin[3]

[1,2,3] *Department of Computer Science, Adekunle Ajasin University, Akungba – Akoko, Ondo State, Nigeria,*
Email: felix.aranuwa@aaua.edu.ng

KeyWords
Human nose, curvature-based, ridge profile, nasal morphology, nasal index, recognition system, biometric identifiers

ABSTRACT

The human nose is a prominent facial feature with good potentials for human recognition. Its morphology is particularly very vital to forensic analyses, gender differences, personality identification, facial reconstructions and biological variability amongst ethnic groups. Studies have revealed that noses unlike other facial features, such as eyes or ears are difficult to conceal and cannot be disguised without looking suspicious. Additionally, human nose recognition processing methods are relatively simple, reliable and showed good potentials for use as a biometric trait with better recognition rate than the whole face recognition, however it has not been well considered in the domain. Therefore, this work explored the general morphology of human nose, present nose recognition methodologies and further developed a nose biometric recognition system using the two robust recognition approaches considered the nest in this work (the curvature-based landmark detection technique and nose ridge profile approach) as a result of their computational efficiency and intrinsic simplicity. The approach involves measuring the width and length of the nose, calculation of nasal index and nose resemblance degree respectively. Data used for the study were randomly collected from 105 adult subjects comprises of 50 females and 55 males from different tribes in Nigeria. Experimental results showed that the two approaches showed a good performance of 98 % and 96% in terms of average recognition rate (ARR) with average time taken of 17 seconds and 1 seconds respectively. The results obtained were considered better, when compared to state-of-the-art works published in the domain.

Introduction

Biometric identifiers are distinctive and measurable features used to label and describe individual. Many of these identifiers in many identification and verification applications has the potential to work extremely well. However, they require a lot of computing time and power. In addition, they require an individual to step close and stand still for scanning during enrolment and recognition processes unlike the human nose, which possessed features that can be captured and recognized without the cooperation of the subjects (Adrian et al., 2009).

By classification, the human nose belongs to the physiological elements of biometric technology, and has been discovered to be a viable biometric trait for human recognition. Its nasal morphology is particularly very vital to forensic analyses, facial reconstructions, gender differences examinations and biological variability amongst ethnic groups (Adams, 2019). Noses unlike other facial features such as eyes or ears are difficult to conceal and do not changed much by facial expression. By description, the human nose is the most protruding part of the face, it bears the nostrils and it is the first organ of the respiratory system. According to Michael, (2015),

the nose is not only a respiratory sense organ, but also can be used to recognize and determine the personality of an individual.

Literature Review

Human Nose Anatomy

Geometrically, the human nose is situated between the eye and the mouth of an individual as depicted in Figure 1. It is both unique and easily sighted, making it a good biometric identification marker (More et al., 2010; More et al., 2018).

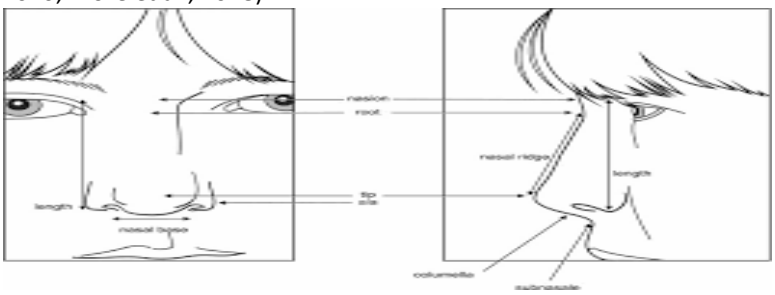


Figure 1: Face Geometry

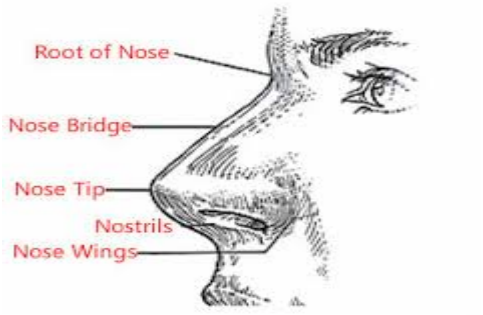
The structure of human nose come in different shapes and sizes, from narrow, straight and long to wide, flat, curved and other characteristics (Holton et al., 2016). The shape of a nose is usually determined by the nasal bones and cartilages, including the nasal septum which separates the nostrils and divides the nasal cavity into two. Variation in the shape of human nose are widely due to genetics and injury.

According to Holton et al (2016), the average male nose is 10% larger than that of female. The study found that the reason for the larger nose size in men is because men are equipped with more lean muscle mass, and require more oxygen to account for the creation of extra tissue and muscle maintenance. The average length of an adult male's nose is 5.8 cm (about 2.2 inches long) and stick out of 2.6cm, while that of a female is 5.1cm (about 2 inches long). Ideally, the nose is balanced with the rest of a person's facial features, fitting inside of its appropriate section when the face is divided into imaginary horizontal thirds or vertical fifths. If a nose exceeds these boundaries, it is usually considered an oversized or large for a person's face (Williams, 2015).

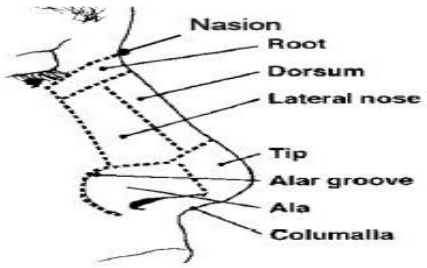
An online average nose length calculator to measure the nose length and nose stick out from the face is presented in Figure 2. The distance between the eyes is usually measured as nose length which is known as the paranasion. For both male and female, the nose size stand at similar rate until the age of 11 and it gradually increases once they attains the puberty stage. The size of nose is directly based on lean body mass.

Figure 2: Online average nose length calculator
Source: easycalculation.com

Figure 3(a) and 3(b) respectively show a typical anatomy of the human nose.



3(a)

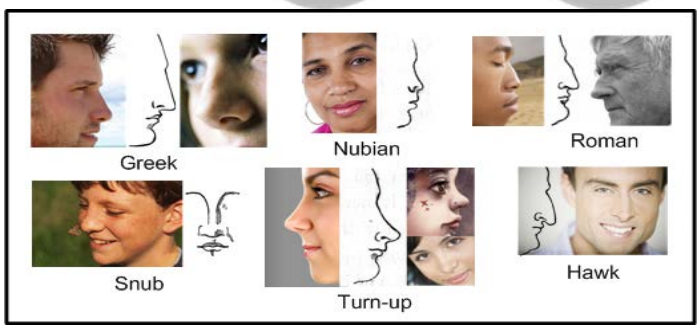


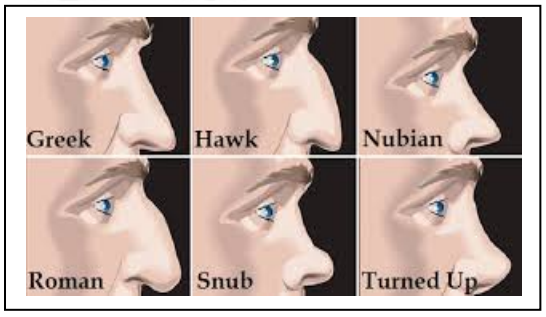
3(b)

Figure 3(a) and 3(b): Typical Anatomy of Human Nose

(i). The Nasal root/Nasion (root of nose): is the most depressed and superior part of the nose along the nasal ridge. It is positioned between the nasal ridge and the forehead.
(ii). The Nose bridge: is the upper, bony part of the human nose, which overlies the nasal bones (Moore et al., 2018). It is midline points just superior to the nasal root overlying the naso-frontal suture.
(iii). The Nose tip: is the junction of the inferior margin of the nasal ridge and the columella. Commonly, it is the part of the nose furthest from the plane of the face.
(iv). The Nostrils: is the two openings in the nose. They lead to two nasal cavities that are separated by the septum (a wall of cartilage).
(v). The Nose wings (Ala): is the lower lateral surface of the external nose, shaped by the alar cartilage and covered in dense connective tissue.

Common Types Human Nose
There are six common types of human nose as shown in Figure 4(a) and 4(b) respectively. They are, the Greek, Nubian, Roman, Snub, Turn-up and the Hawk. The shape of human nose usually falls into one of these types, and has a lot to reveal about individual personality (Adrian et al, 2009). According to Ahmet and Fikri (2014), the size, angle, shape and type of nose are a signature indicating race, age and sex.





4(a) 4(b)

Figure 4(a) and 4(b) Common types of Human Nose
Source: Adrian et al., (2009)

The Greek Nose: is the most distinctive characteristics of Greeks. It is seamlessly straight and has pretty narrow nostrils. People born with this type of nose are highly skilled, and driven by logic. They are naturally intelligent, disciplined and dependable (Akshita, 2017). But notably they very headstrong, and ambitious in nature.

The Nubian/African Nose: Nubian nose has a wider base with more prominent nostrils with a smoother and longer bridge. According to Fedok and Sedgh (2012), this type of nose is common in the African descent, and those who possessed this type of nose are naturally creative in their approach to a subject. They are usually characterised by curiosity and open mind to things.

The Roman Nose: This type of nose features a sloping curve that prominently protrudes from the face. The nose resembles the noses on the faces of many ancient Roman sculptures, hence its name. It is also referred to as the Aquiline nose, a name taken from the Latin word for "eagle-like", an allusion to the curved beak of an eagle. It is found in many geographically diverse populations, but more frequent in certain ethnic groups originating from Southern Europe, the Balkans, the Caucasus, South Asia, the Middle East, North Africa, Central Asia, and the Horn of Africa. (Heidari, 2009; Adams, 2009). People with this type of nose are good organizers and usually perform their activities with proper planning.

The Snub Nose: Snub noses appear distinctly thin and pointy alongside a smaller, slightly curved silhouette. They also feature a subtle angle that goes upward at the tip. This structure is similar to that of a turned-up nose, but softer and rounder. The nostrils can be seen from the front of the nose. It is commonly found among England citizens. People with this type of nose are usually optimistic. They love experimenting and risk things to make a new change. They are full of enthusiasm and can be very faithful (Rgyan, 2017).

The Turned-up Nose: The turned-up nose is also referred to as the 'Celestial' nose. This nose has a tip that is angled upward. The angle can vary from slightly upturned to an exaggerated angle that makes the nose appear short and the nostrils prominent. It is commonly found in the Northern Europe**,** mostly Russian from Gris. People with this type of nose are optimistic and kind. They think differently and have great humanity skills. They are loving, supportive and their personality makes them fiercely loyal friends.

The Hawk Nose: Those with hawk noses have features that are very crisp, sharp, and defined structurally. Hawk noses are characterized by a small bent in the middle of the nose with sharp edges. It is similar in shape to the beak of a hawk. Hawk nose doesn't look fancy but gives strong impression. In medical terminology, it is called a polybeak. It is generally more frequent in certain ethnic groups from Afghanistan, Dardistan, Pakistan and Kashmir, as well as a prominent feature in the Greco-Buddhist statuary of Gandhara. People who have the Hawk Nose are confident, different and stand out from crowd (Buzzhawker, 2018).

Human Nose Recognition Techniques

Notable nose recognition approach includes: Nose ridge profile, Geometric ratio proportion, Curvature-based landmark extraction and Nose region segmentation, (Adrian et al., 2009).

The Nose Ridge Profile (NRP)

The Nose ridge profile is the most common nose recognition approach in literature. The approach involves the capturing of the following feature points: the nasion (*point n*), the nose tip (*point sn*) and the width of the nose wings (*point (al-al)*) as depicted in Figure 5. The nasion is the most anterior point of the frontonasal suture that joins the nasal part of the frontal bone and the nasal bones. It marks the midpoint at the intersection of the frontonasal suture with the internasal suture joining the nasal bones.

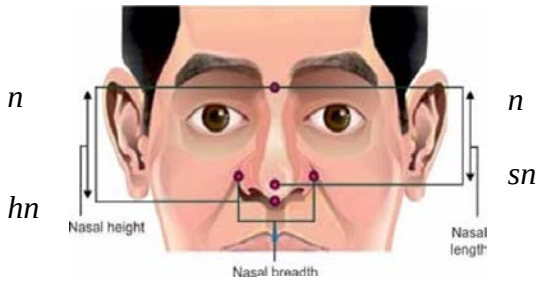


Fig. 5: Nose Feature Points Measurements: (nasal length (*n-sn*), nasal height (*n-hn*), and nasal breadth (*al-al*))
Source: (Sahni, 2014)

This approach is intrinsically simple with computational efficiency. It involves the measuring of nose breadth (width) (*al-al*) and total length of the nose (n-sn) as labelled in figure 5. The nose ridge profile are calculated by

the ratio of nasal width to the nasal length of the nasal multiplied by 100, called the nasal index. The Nasal index is mathematically expressed as stated in equation 1 (Hall et al., 2007; Sahni, 2014).

$$\text{Nasal Index} = \frac{\text{width of the nose(al-al)} \times 100}{\text{total nose length(n-sn)}} \qquad \text{..... Equation 1}$$

The Geometric Nasal Proportions (GNP)

The GNP technique involve the process of capturing the geometric vector of the nose. It is calculated considering the saddle ratio and nose tip ratio. The saddle ratio and the nose tip ratio are combined in a two-element feature vector. These are mathematically represented in equation 2. Figure 6 shows the geometric nasal proportions.

$$\text{Saddle ratio} = \frac{\text{Saddle width}}{\text{Ridge length}}$$

$$\text{Nose tip ratio} = \frac{\text{Nose tip width}}{\text{Ridge length}}$$

..... *Equation 2*

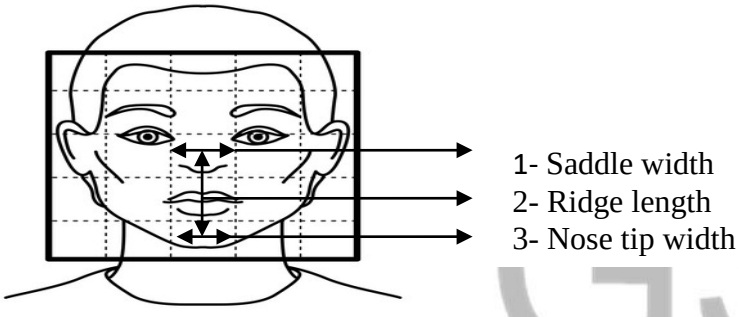


Figure 6: Geometric Nasal Proportions

The Curvature-Based Landmark Detection approach (CBLD)

This approach is a robust technique for identifying nasal landmarks (Mynard et al., 2007). It is normally applied to the surface of normal image. The feature region of the human nose as represented by a strip of points are shown in Figure 7.

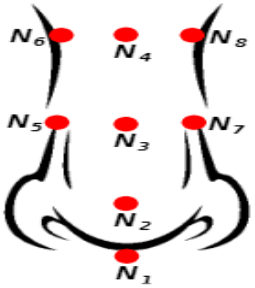


Figure 7: Feature points of the Nose
Source: Prantl et al., (2017)

According to Prantl et al., (2017), the feature points N_1 to N_8 can be extracted photometrically or manually. The point N_2 is the nose tip (P_{nose}), the position of N_4 is the root nose or the (nasion) and, can be predicted as a center point (P_{pred}) between the two inner eye corners. N_3 is the point with the minimal distance from the average of N_2 and N_4. N_1 (collumala) is located under N_2. To find the correct position of the point N_1, the

measure of resemblance to M_{NBi} is calculated for each vertex V_i from the predefined strip of points: N_1 is usually the point with the maximal value of M_{NBi}.

$$M_{NB_i} = \frac{K_{H_i}}{d_i}, \quad \text{.....Equation 3}$$

Where K_{Hi} is mean curvature at the vertex V_i, d_i is the distance between the vertex V_i and P_{nose} which is the nose tip in the z-coordinate.

In the geometry of planar curves, a vertex is a point of where the first derivative of curvature is zero. (Agoston. 2005; Gibson, 2001).

N_5 to N_8 in Figure 7 are localized with K_H and the distance from N_3 or N_4. The measure of resemblance to the side point is calculated for each vertex *Vi* with equation 3. In this case, d_i is the distance between the vertex V_i and the corresponding feature point (N_3 for the detection of N_5 and N_7; and N_4 for N_6 and N_8). N_3 and N_4 are two points with the maximal value calculated from *Equation 3*. By this, the technique is mathematically calculated as stated in equation 4.

$$CBLD = S_iC_i \quad \text{.....Equation 4}$$

Where S_i stands for the shape index and C_i is the curvedness at the vertex $V_{i,}$. This can as well be represented as:

$$CBLD = Shape\ index\ x\ (N4 - N1) - (N4 - N2) \quad \text{.....Equation 5}$$

The Nose Region Segmentation (NRS)

The nose region segmentation is a multistage classifier for face recognition. The method considered the distance between the forehead and mouth top lip with the nose tip which is the closest object to the camera.

Materials and Method

Architectural System Model

The architectural system model for the proposed nose recognition system designed for the work is structured in Figure 8.

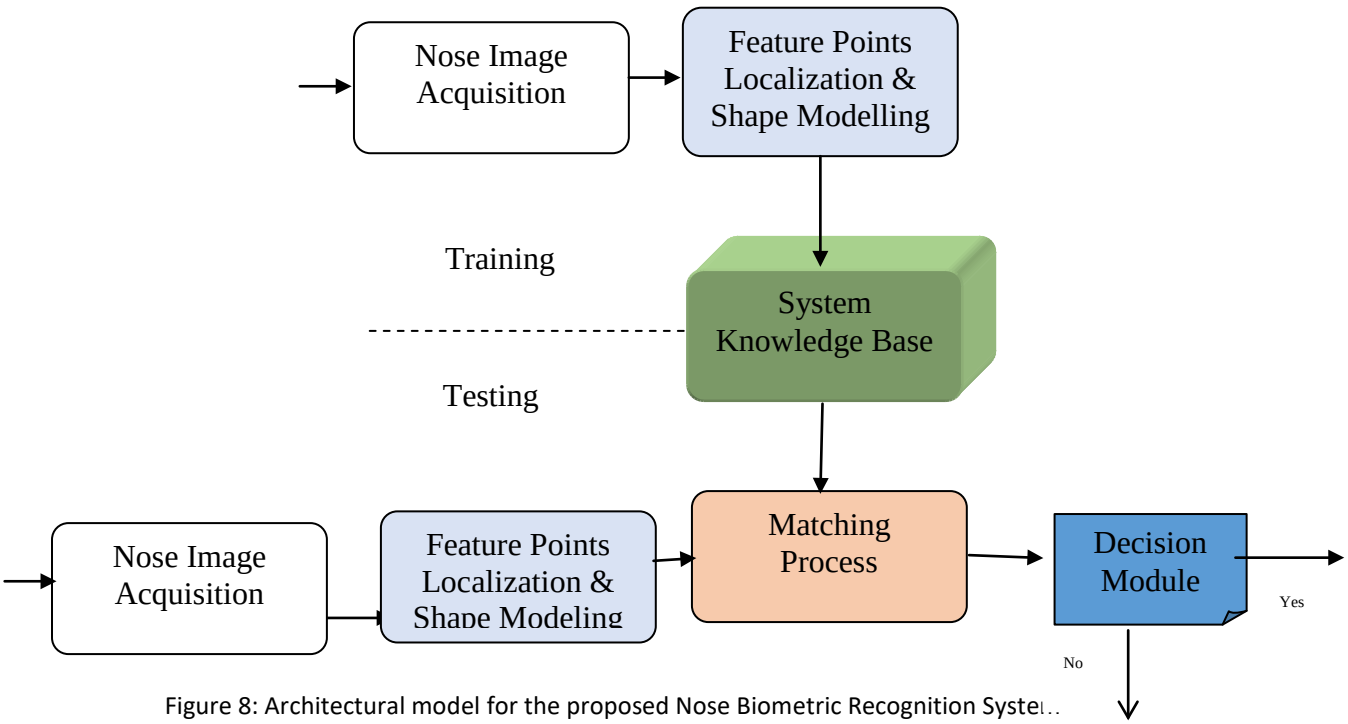


Figure 8: Architectural model for the proposed Nose Biometric Recognition Syste...

The model considered five (5) major modules for its processes. The first module handles the nose image acquisition considering the feature points *which can be* extracted either photometrically or manually. The second module models the shape of the nose using the two robust techniques considered in this work. The feature point localization procedure is based on the position of the nose tip with other feature points. The third module is the system knowledge base which house the model template where references are drawn during matching process. The data acquired are trained and tested to arrive at the final templates stored in the knowledge base. The fourth module is the matching module which compares the template stored in the database during enrolment with that of the pattern obtained for verification. The fifth module authenticates claims from individual enrolled in the system and decides identification or rejection using the automatic detection algorithm presented in Figure 9.

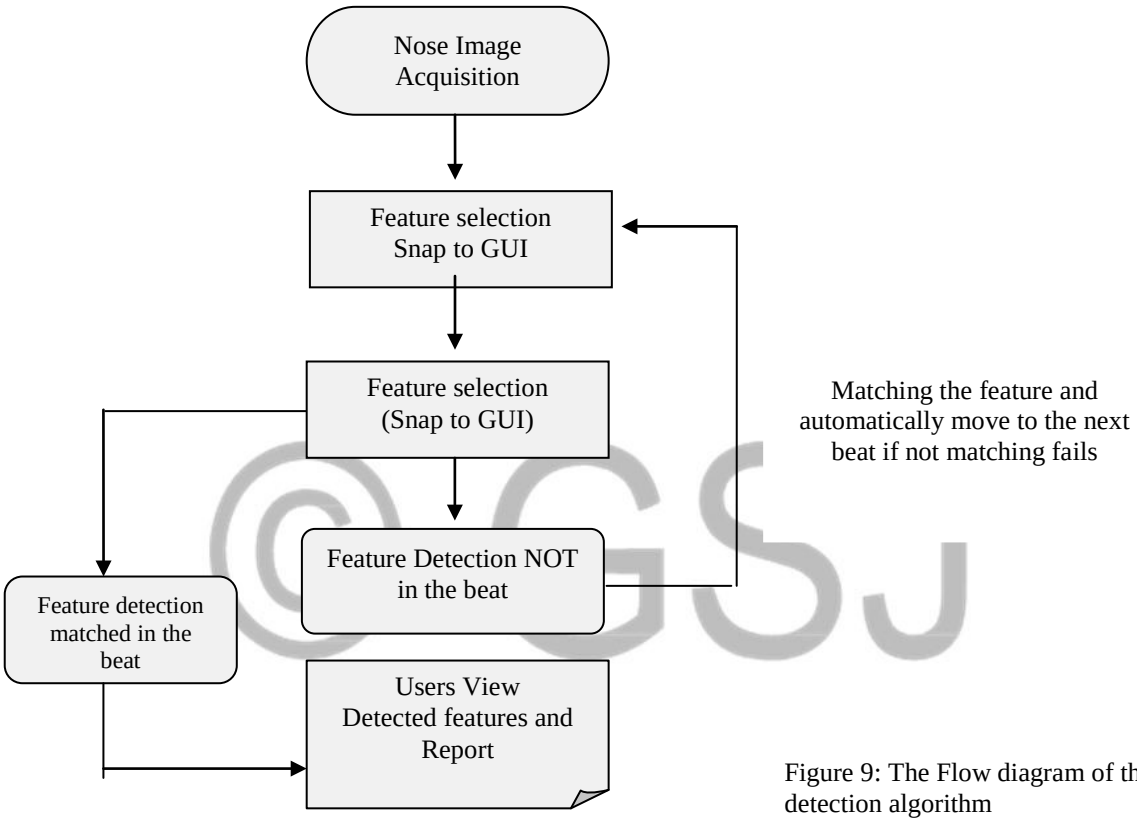


Figure 9: The Flow diagram of the automatic detection algorithm

Data Collection

Nose images used for the study were randomly acquired from 105 adult subjects comprises of (55 males and 50 females) across different tribes in Nigeria. The length, the width of the nose of each subject and other subject's details were considered during enrolment. The data obtained was statistically analyzed, the nasal index and curvature-based landmark detection techniques were computed for each nose captured as shown in Table 1.

Table 1: Sample Data

S/N	Personality	Length *(n-sn) (cm)*	Width *(al-al) (cm)*	Nasal Index Si = *(width*100)/length)*	(Height – length) Ci =(N_4-N_1)- N_4-N_2)	$M_{Ni} = S_iC_i$
1	P1	4.5	4.0	88.8	1.2	106.5
2	P2	5.0	5.0	100.0	1.3	130
3	P3	3.8	3.5	92.1	1.1	101.3
4	P4	3.8	4.4	115.7	1.2	138.8
5	P5	3.5	4.0	114.2	1.3	138.4
6	P6	3.5	3.8	108.5	1.0	109.3

7	P7	4.0	3.8	95	1.15	109.2
8	P8	3.5	3.6	102.8	1.16	116.2
9	P9	5.2	4.1	78.8	1.25	98.5
10	P10	5.4	4.0	74.0	1.21	89.5
"	"	"	"	"	"	"
105	P105	3.2	3.0	93.7	1.0	93.7
	Mean			*96.69091*	*1.08*	*102.3*
	Standard Deviation			*0.960909*	*0.35*	*16.6*

System Design and Implementation

The proposed system designed was implemented using Java Programming Language. Various pre-programmed libraries were referenced and used. Nose recognition libraries such as OpenCv library and nose classifier techniques considered the best were used in the implementation. Figure 10 through Figure 14 showed the snap shots of the system output.

3.3.1 Login Screen: The login screen is mainly to register and authenticate users in order to gain access to the system.

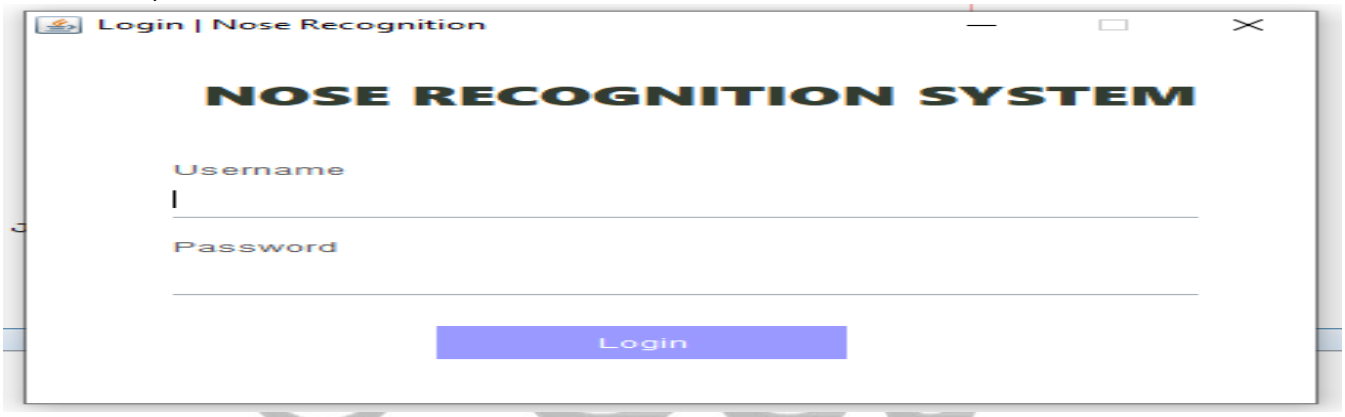


Figure 10: Login Screen

3.3.2 Main Menu:

The main menu provides users with the enrolment and verification process options as shown in Figure 11. User can as well view previously saved information using the view saved data button.

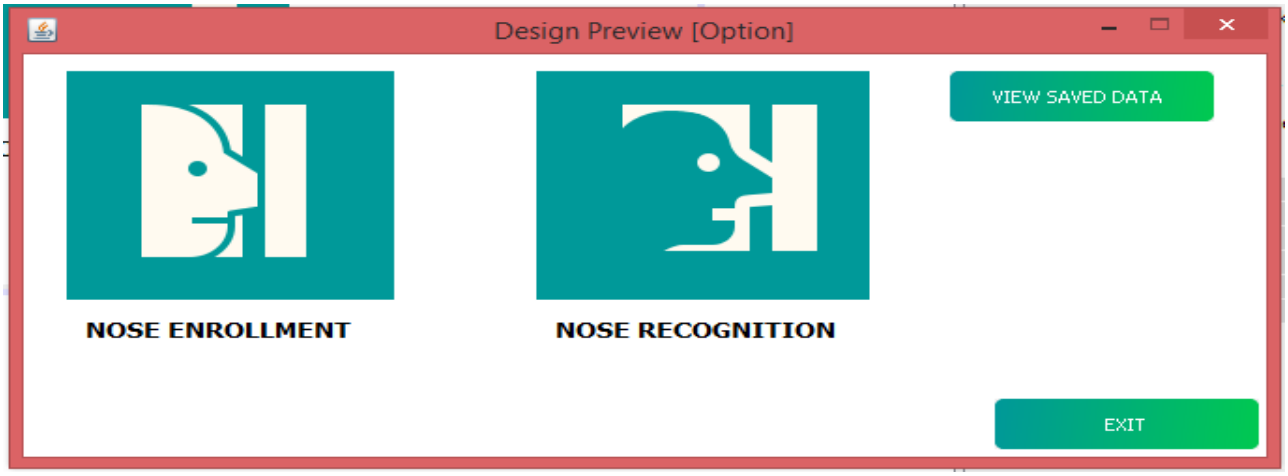


Figure 11: Design View of the Main Menu

Figure 12 and Figure 13 showed the enrollment/capturing and verification pages respectively. In the enrolment section, the noses of a users are captured as well as the details associated with the user, while in the verification stage, a user's claim is verified in the system database. Once a match is gotten. The user's details and matching rate are displayed appropriately.

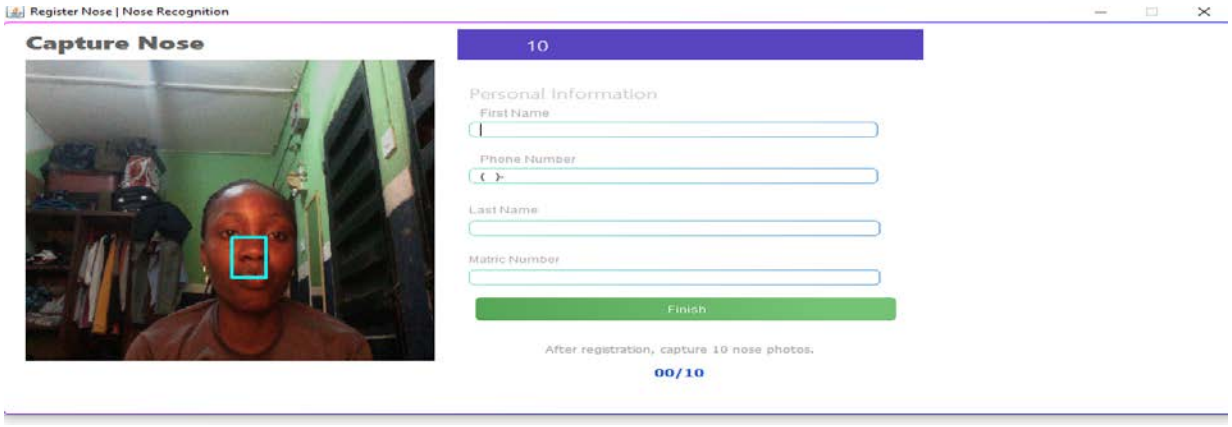


Figure 12: Enrolment/Capturing Page

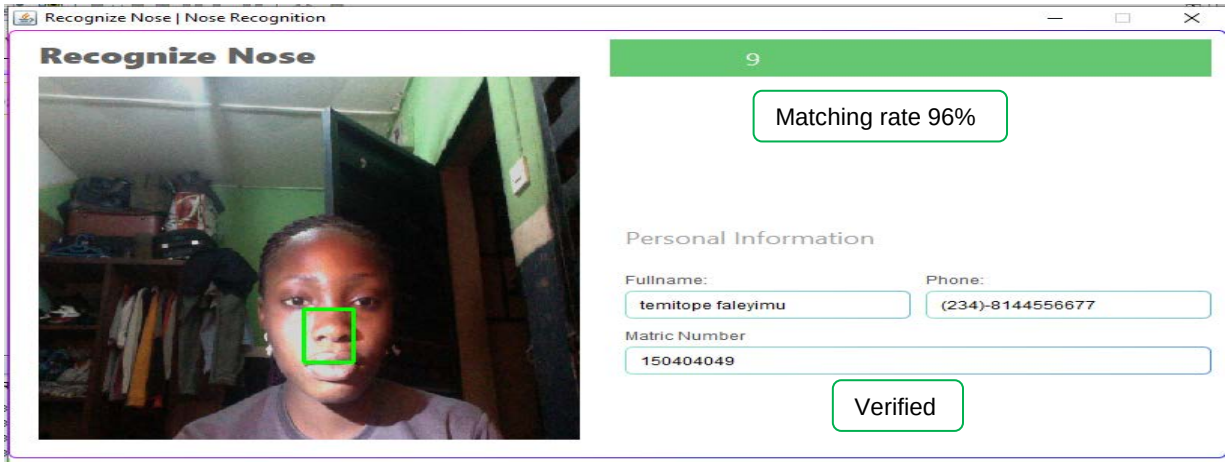


Figure 13: Verification/Recognition Page

Figure 14 shows the sampled information previously saved in the system database.

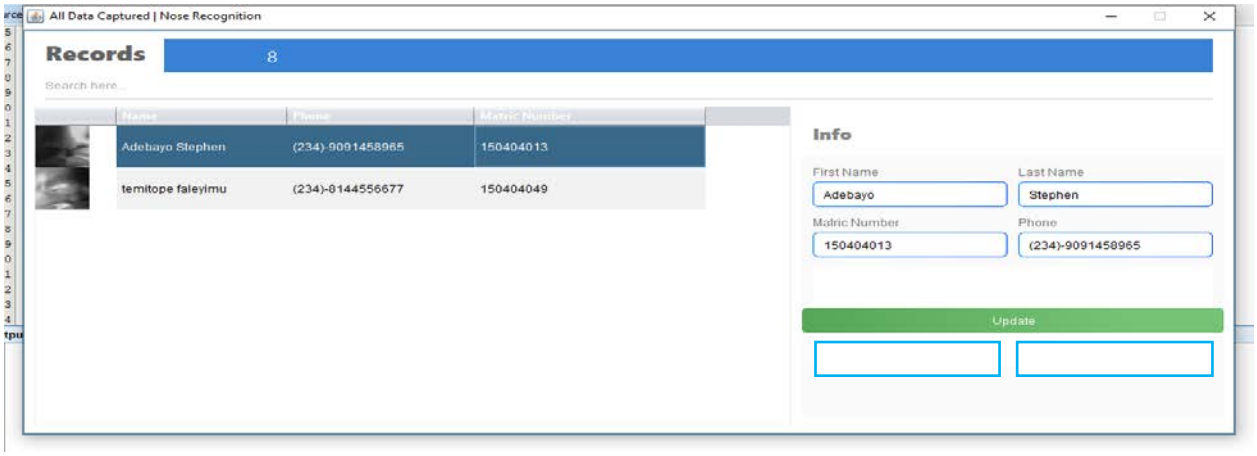


Figure 14: Sampled information previously saved in the system database.

Experimental Results

Table 1 shows the results of the system performance with respect to the two recognition techniques considered in this work (Nose Ridges Profile (NRP) and Curvature based landmark detection (CBLD)) techniques. The approaches showed a good performance of 98 % and 96% in terms of average recognition rate with average recognition time taken of 17 seconds and 1 seconds respectively. The performance metric also considers the FAR and FRR with an average of 1 % each with respect to both the NRP and CBLD respectively.

S/N	Personality	Nose Ridges Profile		Curvature-based landmark detection	
		Average Recognition Rate %	Time Taken (seconds)	Average Recognition Rate %	Time Taken (seconds)
1	P1	97	1	97	16
2	P2	96	2	98	17
3	P3	95	1	97.5	17
4	P4	97	1	98	16
5	P5	96	2	97	17

Conclusion

The importance of biometric in identification and authentication systems cannot be undervalued. Many of the biometric identifiers has been tested and found to possess the potential to work extremely well in many applications with good upshot. However, they require a lot of computing time and power. Additionally, they require an individual to step close and remain still for scanning during enrolment and recognition processes unlike the human nose, which possessed features that can be captured and recognized without the cooperation of the subjects (Adrian et al., 2009). Hence, this work considered the human nose, one of the prominent facial feature with good potentials for human recognition. Its morphology is particularly very vital to forensic analyses, gender differences, personality identification, facial reconstructions and biological variability amongst ethnic groups. More importantly, its processing methods are relatively simple, reliable and showed good potentials for use as a biometric with good recognition rate more than the whole face recognition system. Explicitly, the work explored the general morphology of human nose, present nose recognition methodologies and subsequently developed a nose recognition system using the two robust recognition approaches considered the best in this work (the curvature-based landmark detection technique and nose ridge profile approach) as a result of their computational efficiency and intrinsic simplicity. Data acquired for the work was tested on the system framework designed and the performance results showed that the approaches performed well in terms of recognition rate and time taken during the enrolment and verification processes. The researcher proposed in the future works to consider a larger database covering more ethnic groups and more robust techniques for *gender differences and personality identification* using the trait.

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