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Fingerprint and Face Recognition System using A Feed-Forward Artificial Neural Network Paradigm

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Abstract:- This research presents the development of intelligent techniques for fingerprint and faces recognition systems. This was achieved following data collection, data acquisition, data processing, artificial intelligence, training, and result presentation. The intelligent technique was modeled using the structural method to develop the algorithm for face and fingerprint verification systems. The algorithms were implemented with Simulink. The result showed that the average Means Squre Error(MSE) for face is 4.7E-05Mu, that for the fingerprint is 2.05E-05; the regression value for face is 0.973 and 0.995 for the finger. The algorithm was deployed as a face and fingerprint verification system and the result were tested and validated using a tenfold cross-validation approach. An accuracy of 98.6% was achieved for face recognition and 98.87% was achieved for fingerprint verification results. The performance was compared with other algorithms and it was observed that the new algorithm performs better.

Keywords: *Face Recognition, Fingerprint Verification, Training, Artificial Intelligence, Simulink, Artificial Neural Network (ANN).*

I. INTRODUCTION

Over the years, the study of person identification systems has attracted much research interest, especially now when the rate of criminal acts such as impersonation among fraudulent activities has increased drastically. This is because, in most places and cases, people are identified by what they possess such asidentity cards, international passports, registration numbers, voters' cards, key cards,etc other than who they are. This observations has remained a very big loophole to commit all sorts of fraudulent activities [1]. To address this problem, there is a need for a solution that can identify individuals based on who they are. This presented the need for biometric technology in the late 1990s [2].

According to [3, 4, 5], biometric technology achieves person identification using physiological traits classified as either physical or behavioral. The former are traits extracted from human attributes such as the face, voice, eyes, fingerprint, hand geometry, etc. while the latter recognizes a person based on activities such as signature, handwritten, key dynamic, etc. This research focused on the physical traits as they are more reliable than the behavioral traits in-person identification.Among the biometric traits for verification of identity, face and fingerprint have been singled out as the most popular due to the many advantages such as reliability, accuracy, ease to use, and availability of training datasets among others they have over other counterparts. The face traits used the face recognition system to verify a person's identity in [6, 7, 8], etc, while the fingerprint employed fingerprint verification system to verify personalidentity as in [9, 10, 11], etc, and have both achieved great success in human identification when compared to the conventional verification approaches, however despite their success, there is still room for improvement, especially in the area of reliability.

According to [12] reliability is the availability of a system on demand, and in the same vein, it was uncovered that every system has a probability of failure on demand, and hence affects the integrity of the existing facial and fingerprint verification system as reviewed in [13, 14, 15, 16, 17, 18, 19, 20, 26] among others. Fingerprint system for instance despite the techniques employed suffers issues of false alarm due to the problem of mutation, injuries to the finger, etc, and these problems most times are inevitable. For the facial recognition systems, they suffer the problem of age variation, occlusion, etc. All these issues present a gap to be addressed in the conventional system. To solve this problem, this research proposed a multi-model verification system using face and fingerprint technology. The aim is to ensure that when one system fails, the other system can be used to recognize the person. This way the system will be very efficient, smart, and most importantly reliable when deployed for use.

II. METHOD

The method used for the development of the new system involves data collection, data acquisition, data processing, data extraction, training, and results as discussed below;

- **Data collection:** Data samplesof fingerprints and faces were collected for the study. The data collection was done in the Enugu State University of Science and Technology (ESUT), Enugu State Nigeria were 1200 samples of individual faces and fingerprints of staff and students were collected. The location of the data collection center is ESUT asindicated in the mapshown in figure 1;

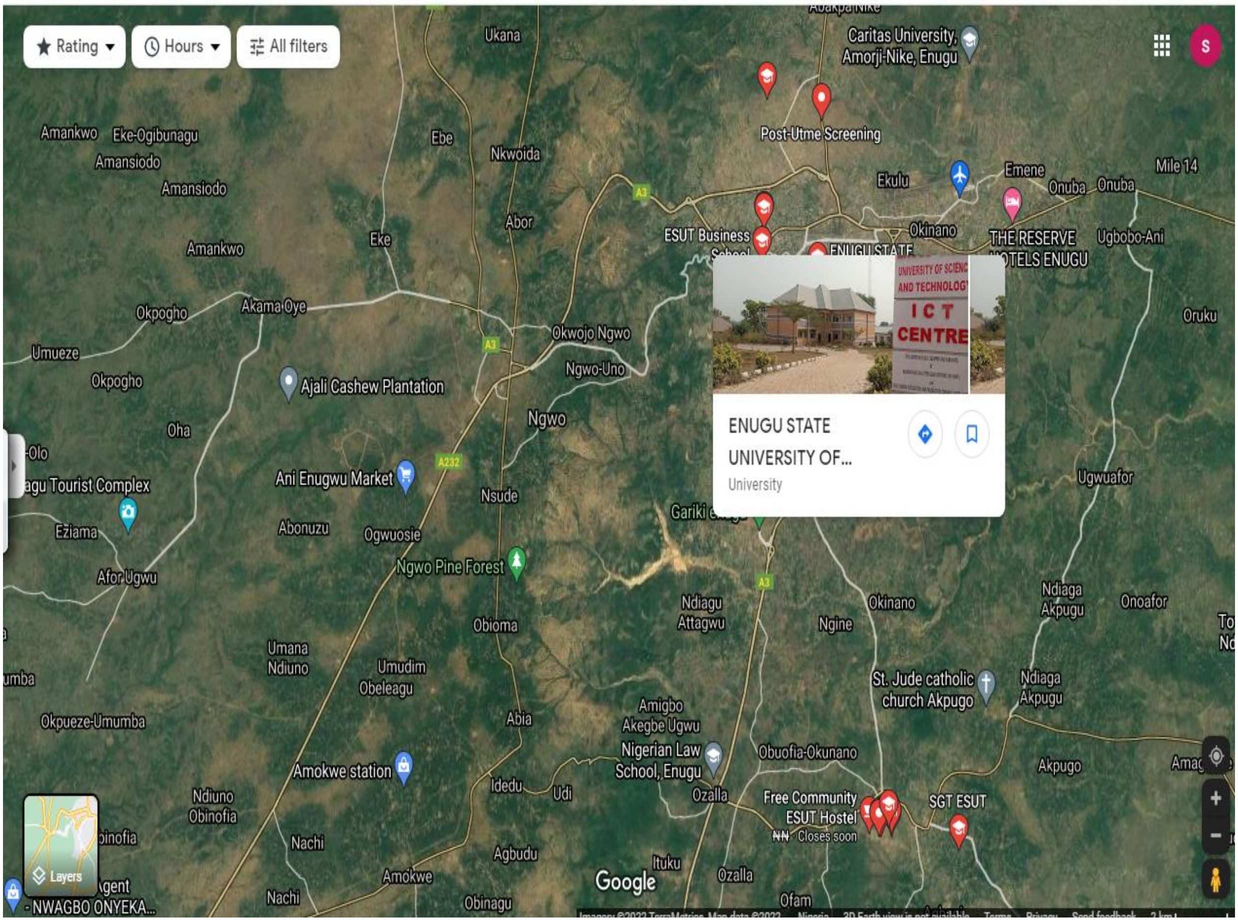

Fig. 1: The location of data collection (ESUT)

These data were collected and used to verify the proposed system. The face data was collected using a High Definition (HD) web camera, while the fingerprint data was collected using an FS80 fingerprint scanner.A few of the collected data samples are presented in figure 2 and figure 3 for the faces and their corresponding fingerprints respectively.


Fig. 2: Data Samples for faces

Fig. 3: Data Samples for fingerprints

- **Data processing:** This process was done to ensure the integrity of both the face and the fingerprint data collected becauseof the presence of noise during the data collectionprocess,and also for data size uniformity before the training process. To achieve this, the Gabor filter model in [1; 6] was adopted and used to process the fingerprint data. This filter was used due to the similar nature of the data and the need for enhancement to reveal interesting features of finger patterns for a better feature extraction process. The face data on the other hand were processed using correlation filters adopted from [21] and were used to process the face data, due to their features such as shit invariance, graceful degradation, and distortion tolerance [22].
- **Data Extraction:** This process involves the statistical manipulation of the data into a compact feature vector for training using the artificial intelligence technique discussed in the next section. The data extraction approach was done using a statistical method that employed histogram-oriented gradient techniques in [1] to extract the facial and fingerprint feature vectors for training of the NN.
- **Training:** This was the system learning operation performedfor the information extracted using an artificial intelligence technique (artificial neural network). The data were divided into training, test, and validation sets in the ratio of 80:10:10;this choice of training model was made based on the ability of the neural network to learn and solve pattern recognition problems and make accurate decisions.

A neural network is a biologically inspired algorithm that has weights, bias, and activation functions, with the ability to learn data patterns and make classifications [27]. The system was trained with the face and fingerprint data collected to generate the verification model used for time series face or fingerprint verification of individuals and then produce the desired results.

III. SYSTEM DEVELOPMENT OF THE BIOMETRIC ALGORITHMS

The development of the systemalgorithm was achieved using a structural method that employed a model diagram supported by object-oriented analysis and design methodology. Figure 4 shows the basic general form of an ANN used to model nonlinear, high dimensional, and predictive problems. ANN models are the simplification of the human neural system which comprises computational units analogous to that of the biological nervous system [28].

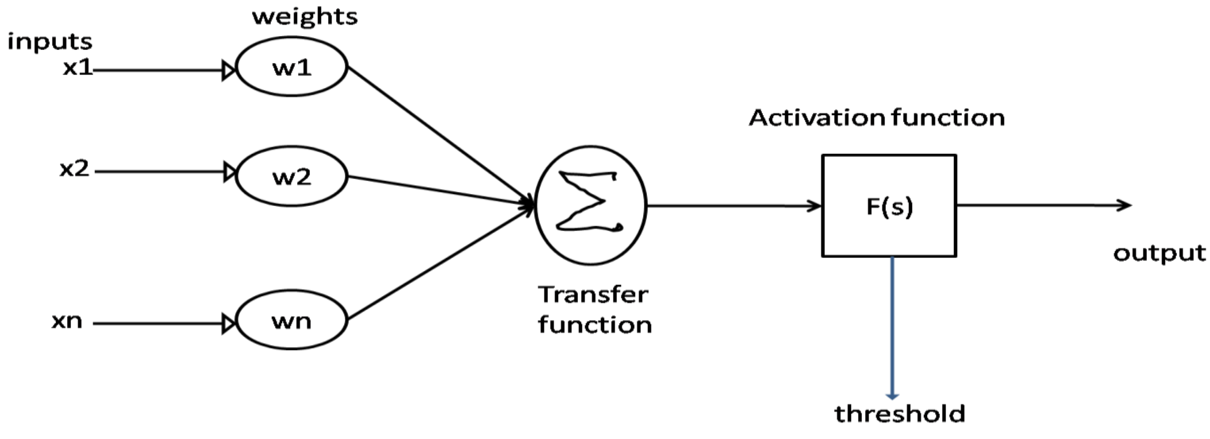

Fig. 4: Generic Model of ANN Architecture

In this work, the neural network was developed considering the number of input layers, hidden layers, activation function, and training algorithm among other parameters presented in Table 1.

Face Training Parameters	**Values**	**Finger Training parameters**	**Values**
Maximum number of epochs to train	72	Maximum number of epochs to train	15
Epoch between display	10	Epoch between display	5
Maximum time to train in sec	Infinity	Maximum time to train in sec	Infinity
Maximum validation failure	5	Maximum validation failure	5
Scale factor for length	60	Scale factor for length	12
Scale factor for weight	40	Scale factor for weight	10
Initial step size	0.01	Initial step size	0.01
Minimum performance gradient	1e-6	Minimum performance gradient	1e-6
Cost horizon	7	Cost horizon	7
Control horizon	2	Control horizon	2
Number of bias function	1	Number of bias function	1
Number of inputs	2	Number of inputs	2
Other training parameters used for both models			
Training algorithm	Back propagation		
Activation function	Tansign function		

Table 1: Training parameters for the ANN

The flow sequence of the actionfor the training of the neural network is presented in figure 5. Figure 5 also shows how the face data was fed to the neural network for the training and generation of a reference face model.

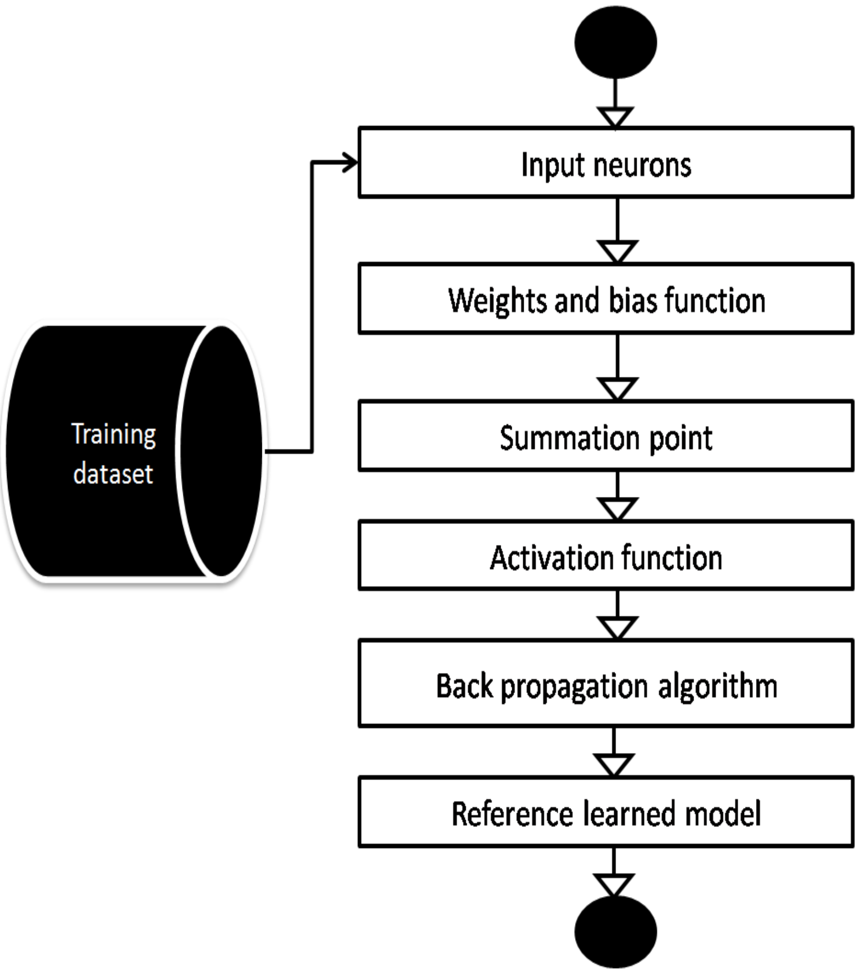

Fig. 5: Training flow Model of the ANN for the face

The neural network architecture was reconfigured as shown in figure 6 to train the fingerprint data using the fingerprint training parameters in table 1 and generate the reference fingerprint model.

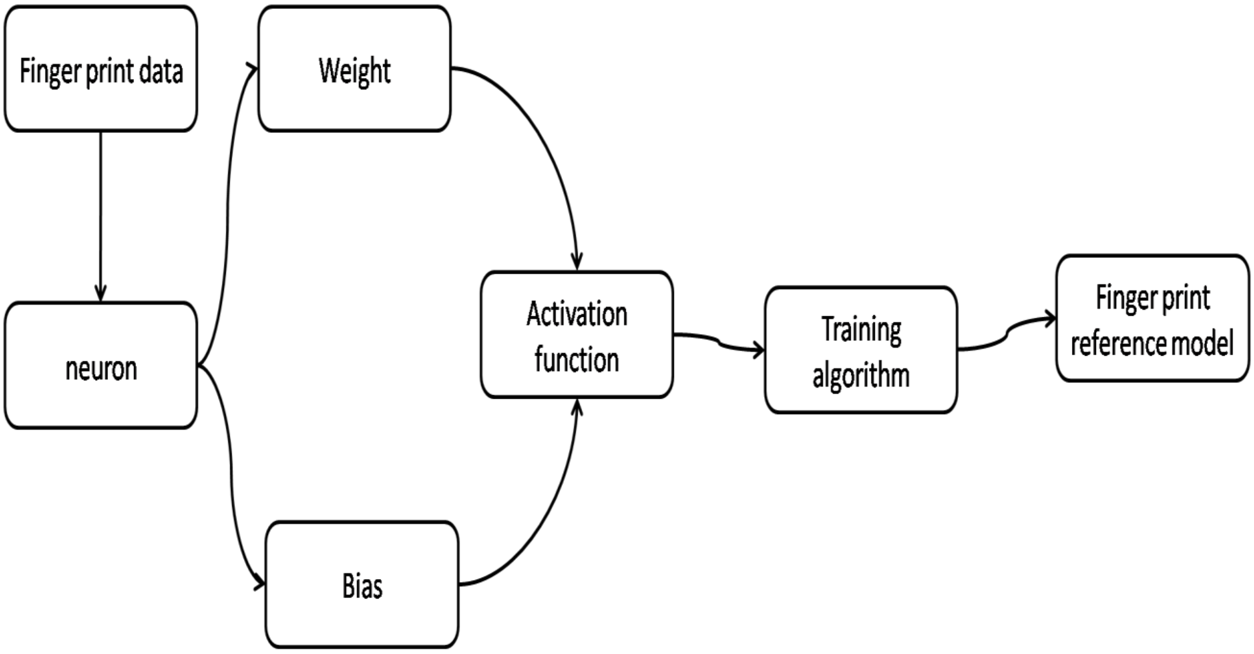

Fig. 6: The ANN model of the trained fingerprint

The face recognition algorithm	The fingerprint recognition algorithm
1. Start 2. Load face data 3. Split data into train, test, and validation set 4. Configure neural network architecture 5. Train data 6. Initialize epoch values 7. Train data 8. Test and validate model 9. If 10. Desired Mean square error and Regression is achieved 11. Stop training 12. Generate face reference model 13. Else 14. Adjust bias and weight function 15. Continues training 16. End if 17. End	1) Start 2) Load fingerprint data 3) Split data into train, test, and validation set 4) Configure neural network architecture 5) Train data 6) Initialize epoch values 7) Train data 8) Test and validate model 9) If 10) Desired Mean square error and Regression is achieved 11) Stop training 12) Generate fingerprint reference model 13) Else 14) Adjust bias and weight function 15) Continues training 16) End if 17) End

Table 2: The System Pseudocode

A. System Flow Diagram

The flow chart model in figure 7 showed how the data from faces and fingerprints were entered into the system. The data entered was processed to remove noise and then extracted into a statistical compact feature vector and then trained with the faces and fingerprint models to make classifications and verification of the identity of individuals.

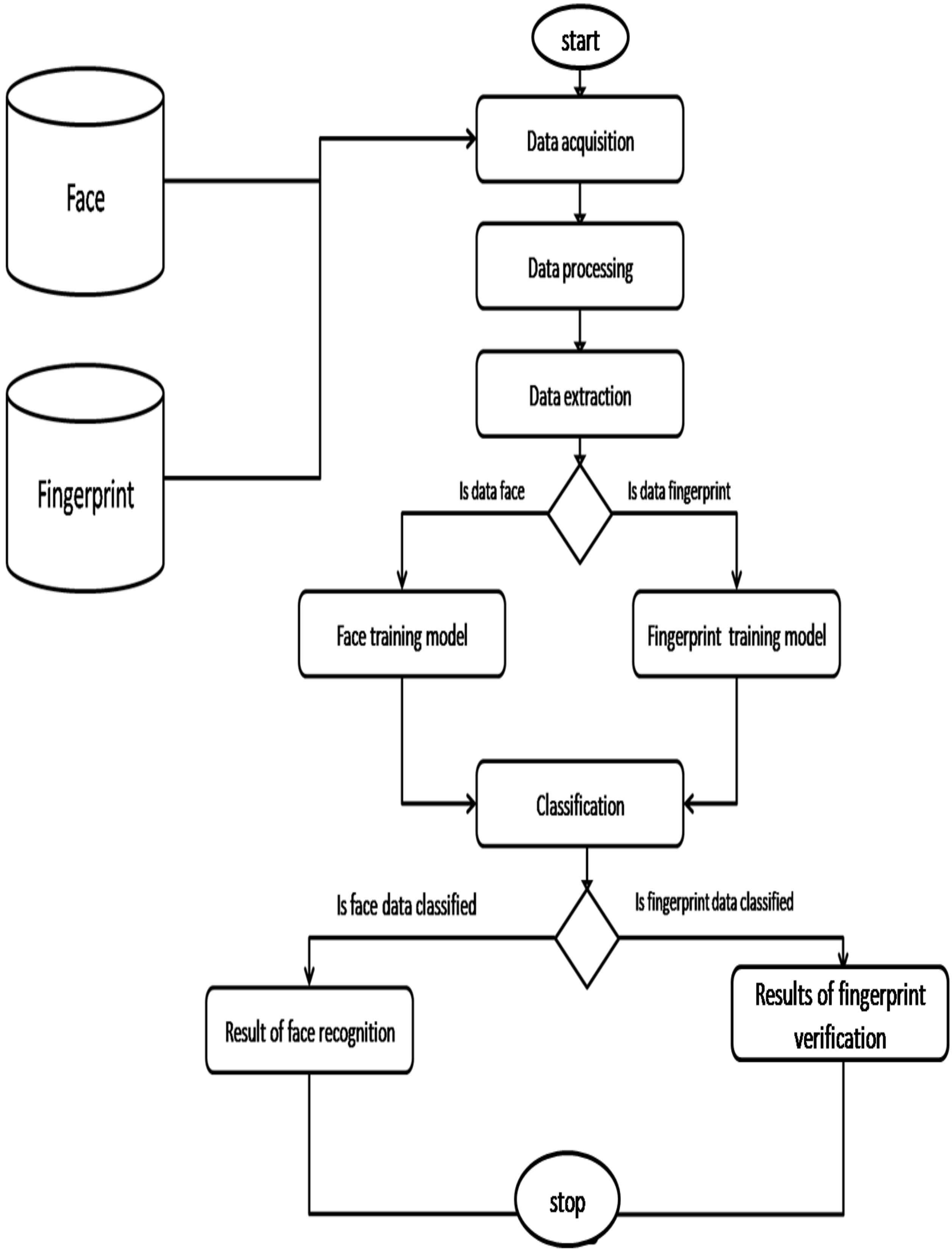

Fig. 7: The Complete system Activity flow chart mode

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IV. IMPLEMENTATION

The proposed system was implemented with a neural network toolbox, signal processing toolbox, statistics, machine learning toolbox, and codes on the MATLAB Simulink application. The signal processing toolbox was used to implement the filters adopted for the data processing, then the statistics and machine learning toolbox were used to apply the feature extraction process adopted, and the neural network toolbox was used to implement the neural network model developed for the training of the face and fingerprint data collected which generated the desired algorithm pattern for implementing the bimodal person identification system. The neural network training tool was presented in figure 8;

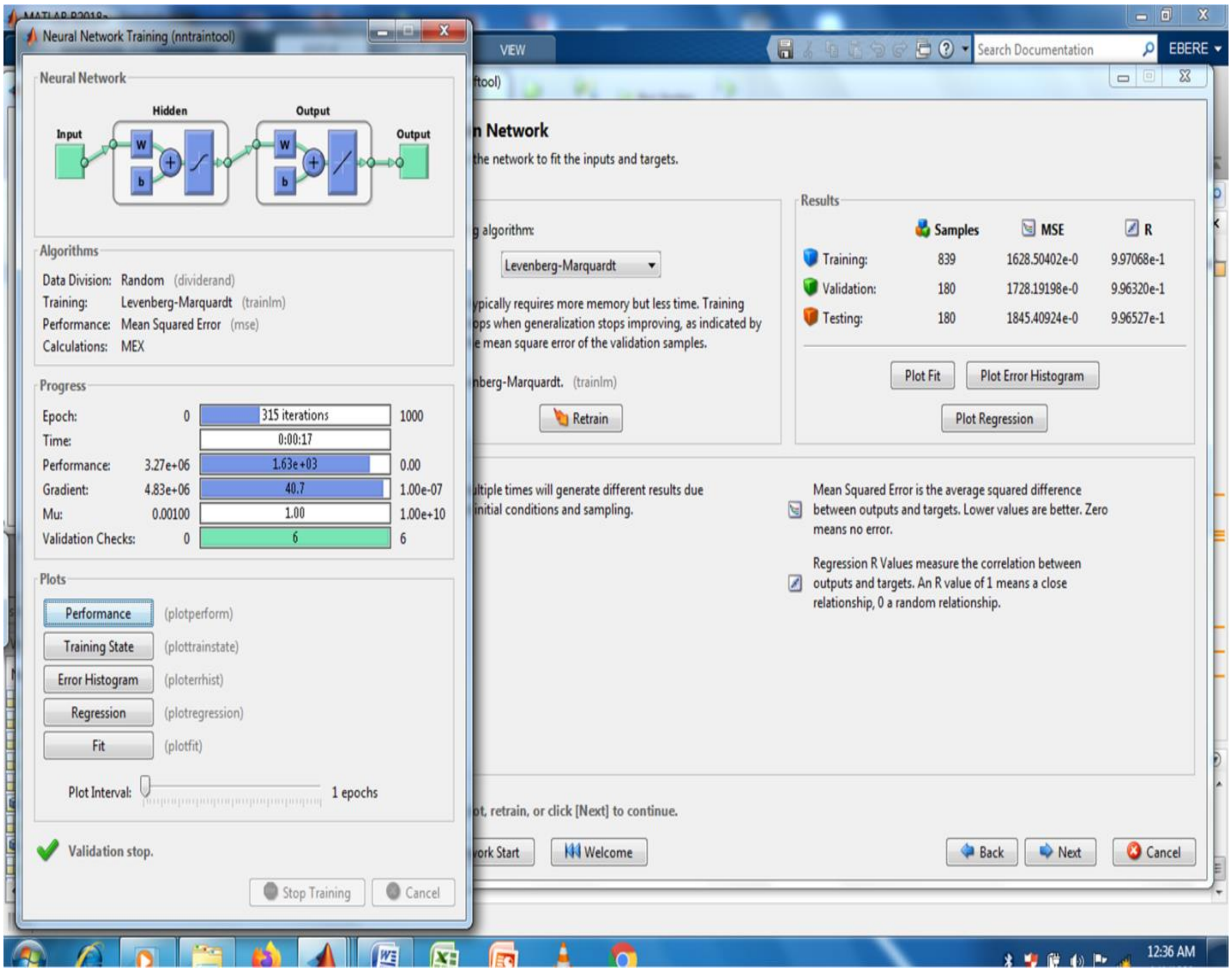

Fig. 8: The neural network training tool in Simulink.

V. RESULTS AND DISCUSSION

This section presented the performance of the neural network training process to evaluate the reliability of the training algorithm for the face and fingerprint verification system. To evaluate the performance of the algorithm the mean square error (MSE) and Regression model below were used.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(A_I - B_i)^2 \quad (1)$$

Where A_i is the predicted values, B_i is the observed values, and n is the number of feature points of the data. The model for regression was also presented as equation 2;

$$R = f(X_i, \beta) + e_i \quad (2)$$

Where R is the dependent variable, f is the function, X_i is the independent variable, β is the unknown parameters and e_i is the error terms. The regression result for the neural network algorithm for face recognition is presented in figure 9;

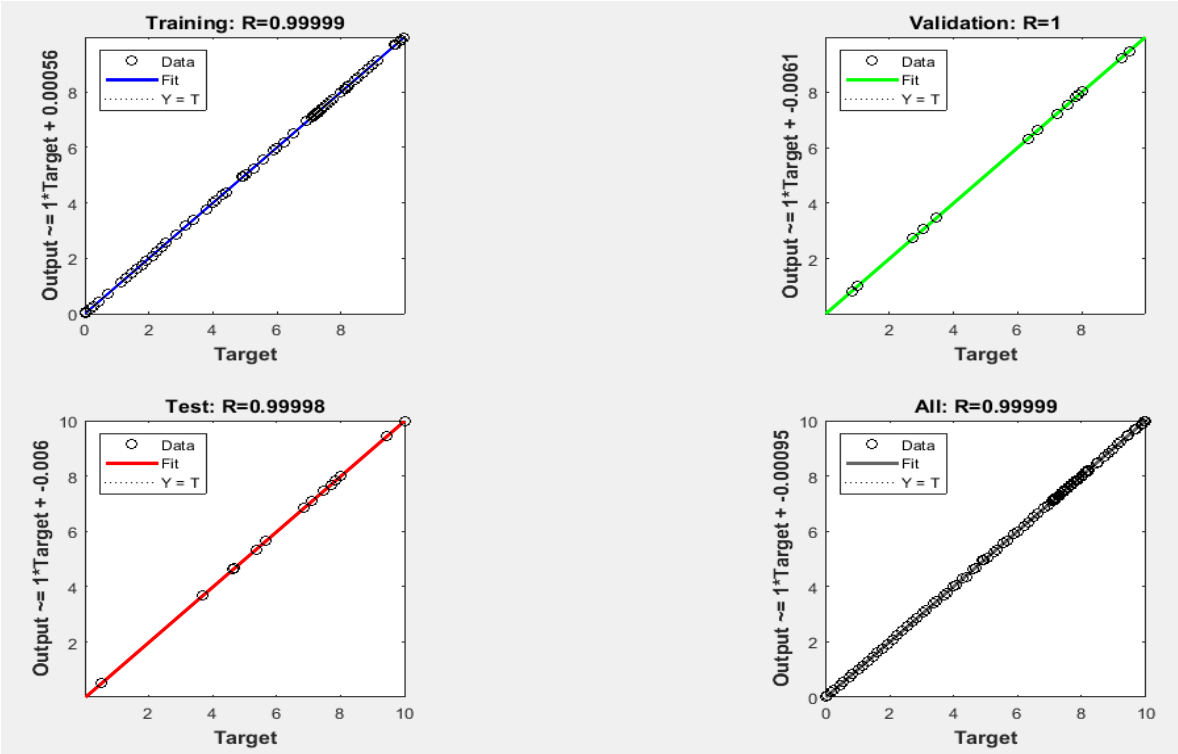

Fig. 9: Regression result for the face recognition algorithm

In the result in figure 9, the performance of the face recognition algorithm was presented using a regression value, measured with the model in equation 2. From the result, it was observed that the overall regression value considering the training, test, and validation sets is 0.99999. the implication of this result showed that the training performance was good as the regression value is approximately equal to the ideal regression value which is 1, indicating success. The result in figure 10 presented the regression values of the fingerprint training algorithm.

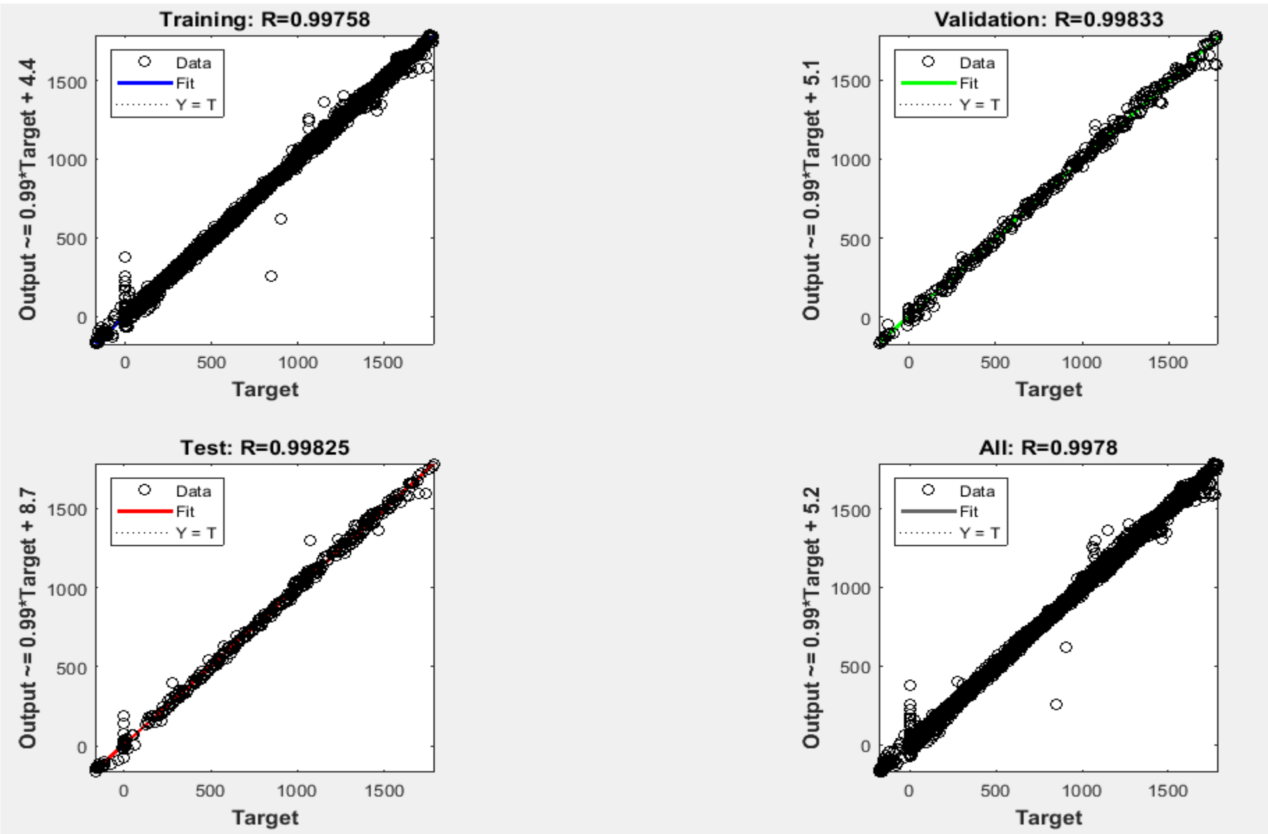

Fig. 10: The fingerprint training regression result

Figure 10 presented the regression performance of the fingerprint training algorithm, using the regression model in equation 2. This was achieved using the average regression of the multisets to achieve the R-value of 0.9978. The MSE was also used to measure the error result during the training process. The result is presented in figure 11;

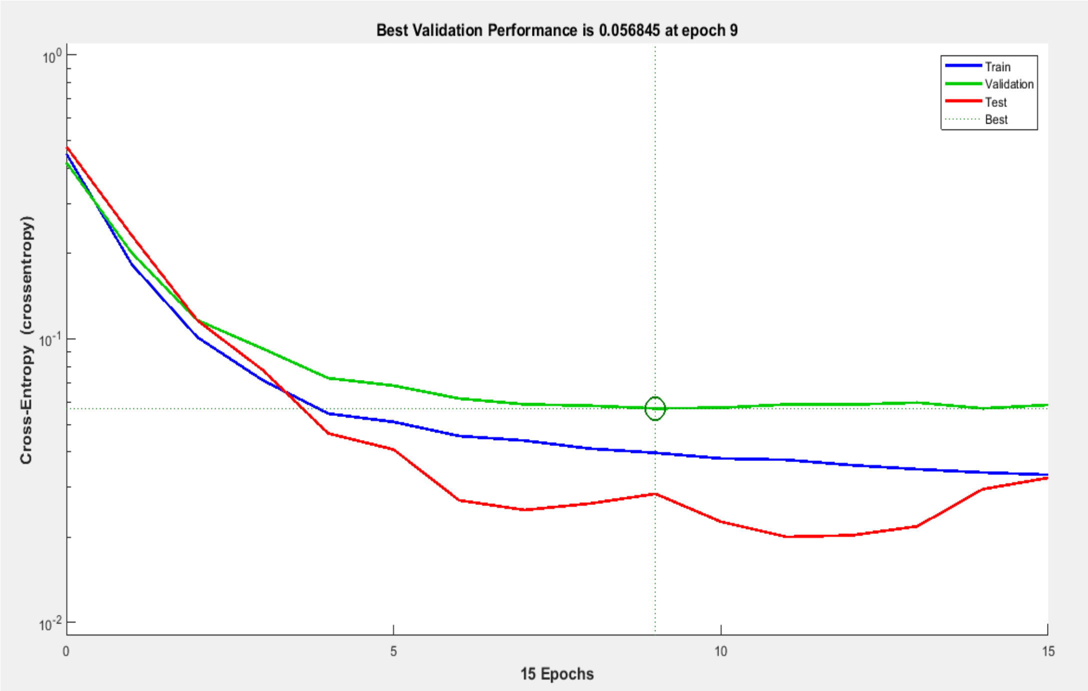

Fig. 11: MSE result for fingerprint algorithm

Figure 11 presented the MSE result for the training algorithm for fingerprints. From the result, it was observed that first the three graphs which presented the training, test, and validation sets correlated in the same direction. The implication showed that the training was good with very negligible overshoot. Secondly, it was observed that the MSE result is 0.056845 which is very good as it is approximately 0. The nest result presented the MSE value for the face recognition training algorithm as presented in figure 12;

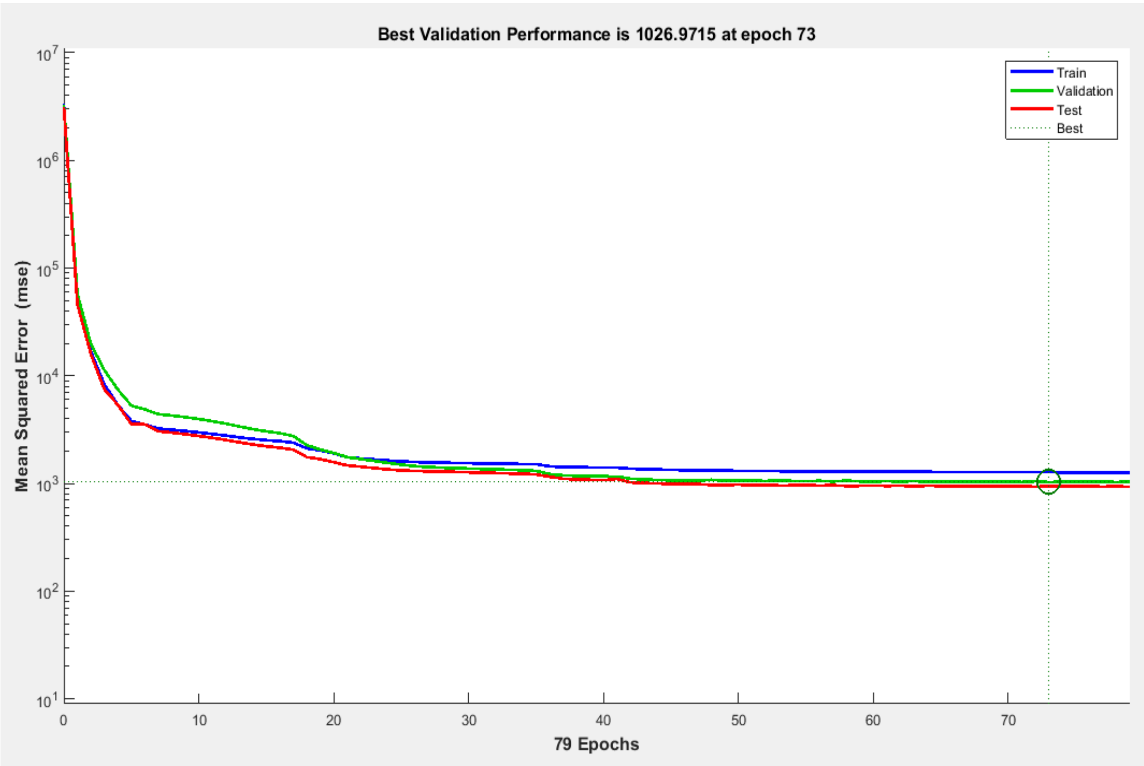

Fig. 12: MSE result of the face recognition algorithm

The result in figure 12 presented the performance of the face recognition training algorithm, showing that the average MSE was achieved at epoch 72 withan MSE value of 1026.9715e Mu which is also very good as it is approximately the ideal MSE value which is 0.

A. System Validation

The results of the face and fingerprint training algorithm were validated using the tenfold cross-validation technique which tests the training algorithms tenfold and then computes the average as the overall results as presented in table 3;

S/N	**MSE (Mu) for face**	**Regression for face**	**MSE (Mu) for fingerprint**	**Regression for finger print**
1	0.0000103	0.99043	0.0000239715	0.99785
2	0.0000100	0.99622	0.0000130254	0.99364
3	0.0001021	0.97712	0.0000119755	0.99268
4	0.0000130	0.99062	0.0000138758	0.99164
5	0.0000141	0.96059	0.0000239333	0.99283
6	0.0000103	0.96042	0.0000238215	0.99864
7	0.0000103	0.95804	0.0000190752	0.99653
8	0.0000930	0.97077	0.0000219753	0.99780
9	0.0001090	0.97016	0.0000239714	0.99704
10	0.0000980	0.95079	0.0000289705	0.99687
Average	4.7E-05	0.972516	2.05E-05	0.995552

Table 3: Validation Results of the Algorithms

Table 3 presented the validation result of the algorithms developed. The result showed that the average MSE for the face is 4.7E-05Mu; that for the fingerprint is 2.05E-05; the regression value for the face is 0.973 and 0.995 for the fingerprint.

B. System Integration

In this section, the performance of the algorithm when deployed as a face and fingerprint verification system were presented in figure 13 and 14 as presented below.

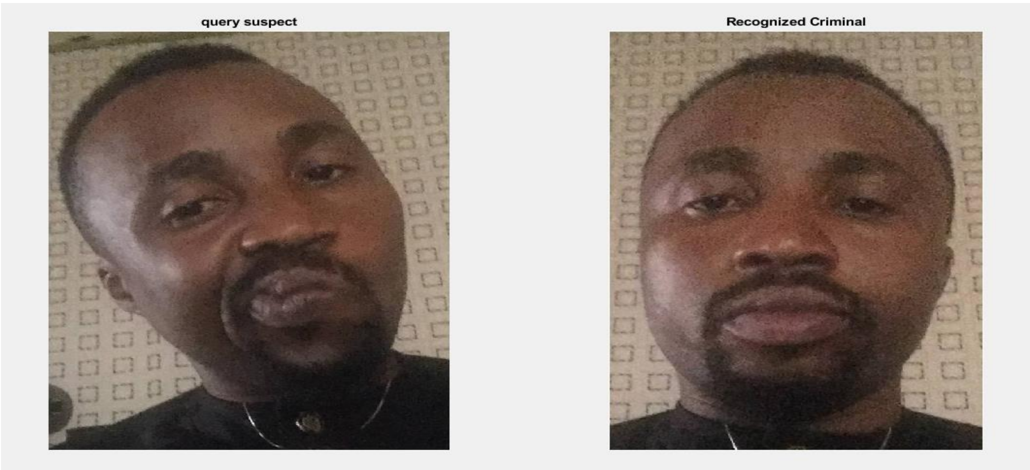

Fig. 13: Result of face recognition.

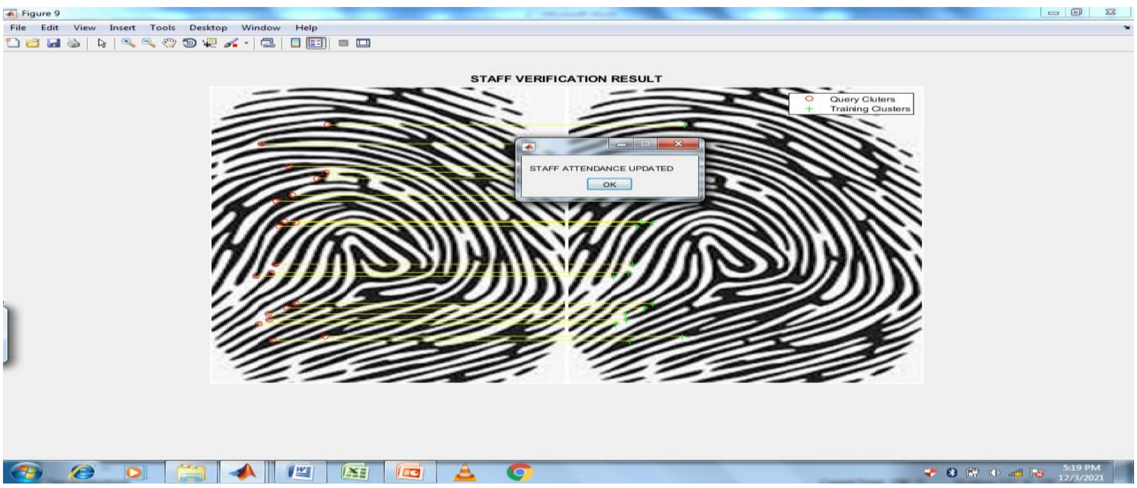

Fig. 14: Results of the fingerprint verification system

Figure 13 presented a face recognition result which shows the query face and the recognized face size by side; while figure 14 also presented the result of a fingerprint verification system that was used to verify the person'sidentity correctly. The results were further validated with a tenfold approach and it was observed that verification accuracy of 98.6% was achieved for face and 98.87% was achieved for fingerprint verification results. The performance was compared with other state-of-the-art algorithms as presented in table 4 and it was observed that the new systems achieved better accuracy.

Face recognition techniques	Accuracy (%)	Fingerprint recognition techniques	Accuracy (%)
Morphological analysis[22]	80.00	HTLM, MYSQL [24]	95.00
Deep Neural Network [23]	95.00	Web-based and MYSQL [25]	98.51
New algorithms with ANN	98.87	New algorithms with ANN	98.6

Table 4: Comparative results

From the result in table 4; it was observed that the neural network performs better than the Deep Neural Network (DNN) algorithm. This was because the accuracy of the DNN is dependent on the amount of data used, and requires very much data size to achieve optimal accuracy, while the simple feed-forward neural network like the new algorithm developed was able to train and learn the data very accurately to provide the best result.

VI. CONCLUSION

This research has successfully developed a bi-modal person identification system using machine learning. The research was embarked on to improve the reliability of the conventional system by creating two means for a person identification system which works as an alternative to support each other in a case when there are technical issues with one since the probability for a system to fail is inevitable. This was achieved by developing a face and fingerprint verification system. The system when tested showed a high-performance rate in terms of regression and MSE, and its effectiveness as a personal identification system.The proposed system ensures efficient, smart, and most importantly reliable human identification when deployed for use.

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