



Intelligent Surveillance and Facial Recognition System for Efficient Border Monitoring and Threats Prediction Using Machine Learning Approach

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Abstract

Border authenticate an integral portion in a country's security, but borders are extremely prone and vulnerable to unauthorized migration, illegal smuggling of goods and drugs, human trafficking and assaults by the extremists as well as intrusion and cohesion between several parties. Border surveillance is the most central task in the area of national security and defense. Basically, borders need to be secured and kept under close monitoring and control for effective surveillance at different border points, which are stretched across hundreds of miles and have extreme terrain as well as climatic conditions. Hence, the need of the moment is to develop an automated border surveillance system which can perform the surveillance task without requiring any human intervention.

The proposed system uses Internet Protocol (IP) camera or thermal imaging (TI) camera for detection of various objects and infiltrators. The Camera is assigned an IP address and connected through local network to the control center. Software code captures video and subsequently the intrusion detection.

Machine Learning (ML) approach with Principal Component Analysis (PCA) and Viola Jones Algorithm was adopted for the intelligence recognition and facial detection of persons from list of images captured based on the surveillance IP camera. Consequently, the data sets were segmented into training set and test set of 300 images and 100 images respectively. Furthermore, we subjected our PCA model to an accuracy test and selected out different individual faces. These faces were all tested with our face recognition system and data was further computed in confusion matrix for performance evaluation and system accuracy. The confusion matrix demonstrated an overall accuracy of 83%, which indicates a good outcome of the Viola Jones Algorithm in

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our intelligent border surveillance system (IBSS).

Keywords Intelligent Border Surveillance System (IBSS), Machine Learning (ML), Thermal Imaging (TI) camera, Principal Component Analysis (PCA), Viola Jones Algorithm

1.0 Introduction

One of the most difficult challenges faced by governments today in the aspect of migration is to find a balance between contending and seemingly conflicting priorities. This is particularly, a matter of facts when mobility and security interests intersect. Border security and immigration control is one of the hottest and most divisive research topics in the world today. Yet technology, not politics, is one of the most important topics for those tasked with securing the borders, countering the influx of illegal drugs, child trafficking and other contraband, and containing a flood of people from all over the world. Border security has become both an indicator for how well states are physically controlling movements of people and goods, as well as a means of communicating the potential impacts of threats such as terrorism (William *et al.*, 2018). The core security problem that any state faces today is protecting its citizens in countering organized crime and terrorism. Border defense and border security are distinct missions requiring different forces with different training and different equipment. Traditionally, border security includes the mission roles of immigration, crime, agriculture, finance, disease control and terrorism. Nigeria as a country has her own share of border security challenges, which are made more complex by poverty, lack of good governance, corruption, chronic armed conflict, armed banditry, porous border security and transnational crime. The activities of smuggling and tax evasion in cross-border movements across Nigeria border provides the transitional features of border economic activities, interaction patterns in the border regions and flouting of international laws and convention on border crossing to the detriment of the national interest and invariably the national security in that era (Collins, 2015).

Nevertheless, border security has evolved into the new frontier of the global war of terrorism against civilization, our way of life, and against the many prospects of stability in our region. The fight against terrorism and the safeguarding of territorial integrity, where a country border is the first line of defense comes to question in view of the nature of border crime related offences today. Hence, effectively securing of border is not just a law enforcement problem, or a wall-building problem rather it's an intelligence problem. Therefore considerations should be made towards prioritizing human smuggling, child trafficking and drug trafficking as a national intelligence priority and also technology should be deployed to monitor people crossing the border illegally and assist border patrol agents in border security. According to Homeland Security, (2018) border security measures are border control policies adopted by a country or group of countries to fight against unauthorized travel or trade across its borders, to limit illegal immigration, combat transnational crime, and prevent wanted criminals from travelling. Adeyinka (2014) bewailed that there is adequate data on irregular migration in and out of Nigeria due to porosity of land borders; making the policy against illegal cross-border movements more complicated. The paper observed that, in rational world, all migration taking place in or out of a state boundary need not constitute a threat to any country should the movements undergo necessary documentations and valid approaches. This is unpleasant incidence, but it is challenging any time migration of humans or items does not undergo the proper regulated statutory approaches thereby elevating questions as to why such movement does not undergo right documentations by government at exiting nation or at recognized destination. As such, countries find it mandatory to apply essential measures put in place in order to protect their borders on both land, air and seaports ways of entry. Nevertheless, border environment is multifaceted and comprises a variety of players with conflicting interests. As O'Dowd states, borders are 'places of economic and political opportunity for nations and states as well as for

a host of other interest groups and agencies, legal and illegal' (O'Dowd, 2002, p. 24).

2.0 Literature Review

A number of studies have analyzed and evaluated strategies for intelligence surveillance at Border point. We summarize a representative sample of the related work below:

Marc *et al.*, (2013) presented a report on Border Security: Understanding Threats at U.S. Borders. In their report, the modern technologies deployed at borders are of significant use for border patrolling and surveillance. Some of these technologies are Fixed, Persistent Surveillance (IFT), Remote Video Surveillance (RVS) System, Mobile capabilities, Air and Marine capabilities etc. Nevertheless, understanding border risks begins with identifying key threats. At their roots, border-related threats are closely linked to the flow of people (travelers) and goods (cargo) from one country to another. Any smuggled item or individual hidden among the legitimate flows potentially constitutes a threat to country security or interests. Therefore, their report pinpoints the risks associated with these diverse types of threats may be modeled under two functions ie. a function of the likelihood that the threat will be realized, and second the potential consequences of a given threat. Hence, their report describes some of these challenges, and suggests questions policymakers may ask to develop their own "maps" of border risks. Several potential border threats are described, and the report summarizes what is known about their likelihood and consequences.

According to Alkhatami *et al.*, (2015), it is important to set up an intelligent integrated border monitoring operation that can conduct surveillance activities without the need of any human intervention. The paper recommended that; the approach could help eradicate the

necessity for deploying individuals at hostile circumstances. Again, Manjarrez, (2015) observed that the overwhelming flow of trade activity, along with legal and illegal movement of individuals across the border, creates high level of chaos and clutter that disrupts the ability of security agencies to identify and focus on more serious threats (drug trafficking organizations and terrorist activity) to border security. Musalli *et al.*, (2015) presented a study on Performance of Border Management Personnel and Its Security Implications in Northern Nigerian Borders: A Pilot Study for Reliability and Validity of Instruments. Their study lays emphasis on the importance of border management in enhancing the socio-economic and political development of West African regions, Nigeria in particular cannot be over emphasised. The objective of their study was to examine the validity and the reliability of measurement instruments of staff development, organization policy and funding of staff welfare that influence the quality performance of border management personnel in Nigeria Immigration Service (NIS). In their study, it was established that instruments for measuring staff welfare on performance of border personnel in Nigeria provides suggested information on how to achieve the objective of border management. Their study employed survey approach in collection of data using 71 questionnaires in Nigeria Immigration Service (NIS). The validation and reliability of all constructs is determined for the acceptability of instruments using SPSS which was reliable in conducting their study.

Umoren and Inyang, (2021) considered a multidimensional fuzzy knowledge-based system for optimizing wireless local area networks performance using a fuzzy knowledge-based (FKB) approach with Triangular Membership Function (TMF) for evaluation of input parameters on selected three (3) mobile network operators in Niger Delta region. This was carried out to justified service quality. Recordings were made for the periods of 21 days to ascertain service capacity. The model for optimizing mobile broadband networks was based on the test data. Results demonstrate that, the selected network operators vary in Quality of Service (QoS). The

deployment of efficient surveillance system is highly dependent on a reliable mobile network.

Lehtonen and Aalto, (2017) carried out research on Smart and secure borders through automated border control systems in the EU, the views of political stakeholders in the Member States. According to their article, border-crossings in and out of the EU are increasing while the border control resources cannot keep pace. These trends drive the technologization and digitalisation of border security. In addition to GPS and satellite-assisted surveillance of “pre-frontier” areas, at the border technologisation includes the use of passport readers, biometrics for identity verification, automated processes and monitoring of flows of people through automated border control (ABC). This shift underpins the ongoing debate on new border control policies, border-crossing practices and more widely the role of the security industry in Europe. Nevertheless, their research address the complex nexus of Automated border Control (ABC) technologies; the privacy, rights and legal issues involved; and further institutional choices as subjectively perceived by Member States’ political stakeholders.

Babatunde *et al.*, (2019) presented article on Border Security Issues and Challenges of the Nigeria Customs Service. However, in their article it was established that the Nigeria Custom Service may not be able to effectively carry out these enormous responsibilities if the inherent challenges besetting their border security operations remained too obscured to be adequately addressed. Therefore, adaptable migration flows containing border disputes remain essential to border security agencies across the world today. The reality, however, is that controlling access to territories and citizens is difficult in the globalised security context, as technology has enabled the increased flow of goods, people and ideas across national boundaries, while global inter-connectedness has increased interactions between people around the world whether for work, sport or entertainment. Thus, in order to counter threats both from within and outside a state border, new patterns of security interaction are required. It is on this basis that thier study

identifies the major challenges militating against border security in the Nigeria Customs Service and also proffer solutions through insightful suggestions and recommendations.

Ayush *et al.*, (2020) presented a paper on Automatic Border Surveillance Using Machine Learning in Remote Video Surveillance Systems. In their research, Machine Learning techniques were employed in Remote Video Surveillance for real-time threat level detection and classification of targets crossing borders. The algorithm used for the machine learning based detection of objects in the videos in their research is the Viola-Jones algorithm. Where this algorithm requires a training set of both positive and negative images, for the purpose of which, a collection of positive and negative images were used for their training of the algorithm for objects such as humans, vehicles, and handguns. A threat level classifier and alert warning system were also added to classify and annotate the videos in real-time for each frame. The threat level classifier performs four-fold categorization of the real-time video into safe, low, medium, and high (danger). The alert warning system specifies the type of warning based on the type of intrusion (human, vehicle, or weapon) detected.

Yukesh (2021) presented an article on Issues in Border Security of Nepal. In their research, analyses on the field issues faced by security personnel at border areas of Nepal was considered. The study uses both primary and secondary data for analysis and interpretation. The findings show geographical problems, socio-economic similarities, operational problems, border laws, values, and ethics. These issues are faced by security forces daily. The study outcome suggests a need for a collaborative approach of stakeholders on strengthening border security.

Matthias *et al.*, (2021) presented a paper on Data Matters: The Politics and Practices of Digital Border and Migration Management. Border control and migration management yields several analytical benefits. In their research, it was shown that digital border arrangements tend to be fragile and prone to failure and breakdown. Secondly, a focus on

the instruments and infrastructures through which data are produced and put to use allows the assessibility on how data do not pre-exist their generation. And thirdly, paying attention to the materiality of the encounters between border crossers and authorities shows that these encounters are not only mediated by various human actors that are not directly involved in the border encounter but also by a range of non-human actors that equally shape decision-making at sites of border control. Hence, paying attention to the matter of data offers multiple points of (analytical) entry and ample opportunities for negotiation and resistance vis-à-vis digital forms of mobility governance that are much less consistent and infallible than their proponents want to make us believe. In Umoren *et al.* (2022), the work considered the direction of Network security optimization. The *End-2-End* behavioural analysis of wormhole attacks on the transmitting networks layer of MANET was realized. To detect the level of wormhole attack in the network several parameters such as *Packet Delivery Ratio*, *Packet Forwarding Probability* and *Packet Dropping Probability* were considered by determining the degree of severity of wormhole attack which may upset the Quality of Service (QOS) delivery. Nevertheless, their research suggested the need to engage with 'Data Matters' in contemporary border control and migration management through three connected registers, which are through the enactment of data as a matter of concern by questioning the constitution and performative effects of data; secondly, through inquiries into the specific ways in which data come to matter in knowledge production and decision-making processes, i.e. to unravel their role in risk assessment, identification, and in regimes of proof; and thirdly through a focus on the matter of data, i.e. the material underpinnings data and its analytics.

3.0 Methodology

3.1 Model Design

Model-Based Design (MBD) is a mathematical and visual method of addressing problems associated with designing complex control, signal processing and communication systems. Model formulation demonstrates the step where the knowledge of a natural system is translated in mathematical form. It involves two steps: the construction of a conceptual model and the formulation of this conceptual model into mathematical equations.

3.2 Architecture of the Proposed Model

Architecture is the essential organization of a system personified in its components, their relationship to each other and the environment, and its principles governing its design and development. Figure 1 illustrates the conceptual architecture of the proposed System Model.

3.2.1 Description of Key Components of the proposed system model

i) Intelligent Monitoring

Intelligent monitoring and control involve observing and guiding the behavior of a physical system toward some objective, with real-time constraints on the utility of particular actions.

ii) Face Detection

Face detection is a computer technology being used in a variety of applications that identifies human faces in digital images. Face detection also refers to the psychological process by which humans locate and attend to faces in a visual scene.

3.2.2 Principal Component Analysis (PCA)

Principal Component Analysis, or PCA, is a dimensionality-reduction method that is often used to reduce the dimensionality of large data sets, by transforming a large set of variables into a smaller one that still contains most of the information in the large set.

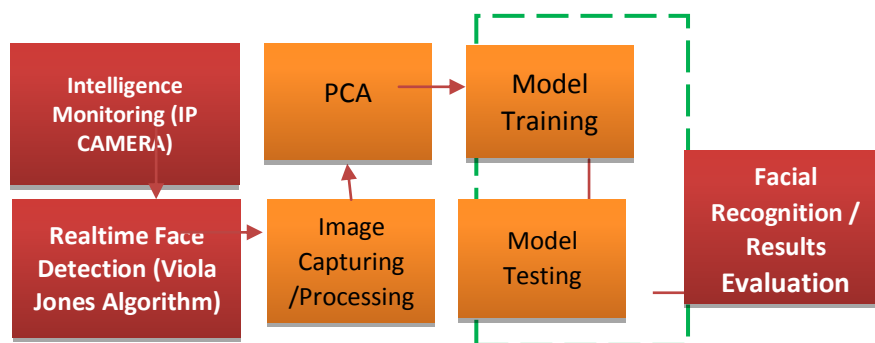


Fig 1: Conceptual Framework of the Proposed Model

3.23 Facial Recognition

Facial recognition is a way of identifying or confirming an individual's identity using his or her face. A facial recognition system is a technology capable of matching a human face from a digital image or a video frame against a database of faces, typically employed to authenticate users through ID verification services, works by pinpointing and measuring facial features from a given image

4.0 Model Training

A machine learning training model is a process in which a machine learning (ML) algorithm is fed with sufficient training data to learn from. Machine Learning (ML) models can be trained to benefit manufacturing processes in several ways. The ability of ML models to process large volumes of data can help manufacturers identify anomalies and test correlations while searching for patterns across the data feed. It can equip manufacturers with predictive maintenance capabilities and minimize planned and unplanned downtime.

4.1 Model Testing

In machine learning, model testing is referred to as the process where the performance of a fully trained model is evaluated on a testing set. The testing set

consisting of a set of testing samples should be separated from both the training and validation sets, but it should follow the same probability distribution as the training set.

4.2 Data Collection

Data collection is the process of gathering quantitative and qualitative information on specific variables with the aim of evaluating outcomes or gleaning actionable perception of the work. Data collection is the systematic process of gathering observations or measurements in research. Most researchers evaluate their hypothesis on the basis of collected data. In most cases, data collection is the primary and most important step for research, irrespective of the field of research. The approach of data collection is different for different fields of study, depending on the required information. The most critical objective of data collection is ensuring that information is rich and reliable and then data is collected for statistical analysis so that data-driven decisions can be made for research. In this research, data was collected using observation method. The observation method entails a method to observe and describe the behavior of a subject. As the name suggests, it is a way of collecting relevant information and data by observing. It is also referred to as a participatory study because the researcher has to establish a link with the respondents and

immerse himself in the same setting as theirs. Only then can he use the observation method to record and take notes. Hence, this research adopted a video-based camera device for remote monitoring and observation of border regions in Akwa Ibom State, Nigeria. Thereby, evaluating complex constructs and interactions in real, complex, and dynamic Border regions plays an important role in improving security system; thus, it is a priority for security parastatals to adopt a video-based observation in different border point across Nigeria and the world in general in order to enhance effective

security at different border points. Hence, figure 2 depicts our Wi-Fi Solar Power Outdoor Waterproof Wireless IP system camera 1080P HD battery PIR motion detection Surveillance Security Camera, that was mounted on a border point in Akwa Ibom State in order to remotely monitor different movement of people across the border region in order to capture different faces of people, which we used in our training data sets, so that we can build our model effectively and efficiently.



Fig. 2: Surveillance Security Camera

4.3 Problem Definition and Model Formulation

Today, every nation and border have its own problems requiring specific solutions. Border security requires thorough monitoring and control in order to detect, track and recognize possible threats and illicit movements on the border. Thus, Border Surveillance Systems (BSS) are a combination of surveillance mechanisms implemented to provide comprehensive situational awareness along the border. Moreover, over the last several years, a growth in the design of surveillance projects and programs mainly focusing on deterring irregular migration has occurred. However, knowledge of those systems is still very limited. Hence, in this research, we have

devised a means to model and develop an intelligence system for border monitoring and control through the adoption of two algorithm which are Viola Jones algorithm and Principal Component Analysis (PCA) for face detection and recognition system from images that are capture from the IP camera, in order for us to recognize each individual that is crossing the border point. Furthermore, in order to perform face recognition, there must be an input to be detected and verified. Hence, an image sensor or typically a camera in our own case was set up for recording or capturing images. The camera is compatible with our software used which is Matlab. The next step is the input image. The input can be images and recorded videos or real-time videos. After the input is

provided, faces in the images or videos are to be detected. When the classifier is trained, it can be utilized to start the recognition work. It can be used in either video or image to recognize one or more persons. Different sets of Matlab scripts are provided to run the detection and face recognition in real time. Nevertheless, we present our PCA model for image recognition by representing a 2-D facial image as 1-D vector by concatenating each row (or column) into a long thin vector. Suppose we have M vectors of size N ($=$ rows of image \times columns of image) representing a set of sampled images, p_j 's represent the pixel values, then:

$$x_t = [p_1 \dots p_N]^T, i = 1, \dots, M \quad (1)$$

The images are mean centered by subtracting the mean image from each image vector. So, we then represent m as the mean image.

$$m = \frac{1}{M} \sum_{i=1}^m x_i \quad (2)$$

Furthermore, we let w_i be defined as mean centered image in equation 3.

$$w_i = x_i - m \quad (3)$$

Therefore, our goal is to find a set of e_i 's which have the largest possible projection onto each of the w_i 's. We wish to find a set of M orthonormal vectors e_i for which the quantity in equation 4.

$$\lambda_i = \frac{1}{m} \sum_{n=1}^m (e_i^T w_n)^2 \quad (4)$$

is maximized with the orthonormality constraint

$$e_i^T e_k = \delta_{ik} \quad (5)$$

It has been shown that the e_i 's and λ_i 's are given by the eigenvectors and eigenvalues of the covariance matrix in equation 6.

$$C = WW^T \quad (6)$$

where W is a matrix composed of the column vectors w_i placed side by side. The size of C is $N \times N$, which could be enormous. For instance, images of size 64×64 create the covariance matrix of size 4096×4096 . It is not practical to solve for the eigenvectors of C directly. A common theorem in linear algebra states that the vectors e_i and scalars λ_i can be obtained by solving for the eigenvectors and eigenvalues of the $M \times M$ matrix $W^T W$. We let d_i and μ_i be the eigenvectors and eigenvalues of $W^T W$, respectively in equation 7.

$$W^T W d_i = \mu_i d_i \quad (7)$$

By multiplying left to both sides by W we have equation 8;

$$WW^T (W d_i) = \mu_i (W d_i) \quad (8)$$

which means that the first $M-1$ eigenvectors e_i and eigenvalues λ_i of WW^T are given by $W d_i$ and μ_i respectively. $W d_i$ needs to be normalized in order to be equal to e_i . Since we only sum up a finite number of image vectors, M , the rank of the covariance matrix cannot exceed $M - 1$ (the -1 comes from the subtraction of the mean vector m). The eigenvectors corresponding to nonzero eigenvalues of the covariance matrix produce an orthonormal basis for the subspace within which most image data can be represented with a small amount of error. The eigenvectors are sorted from high to low according to their corresponding eigenvalues. The eigenvector associated with the largest eigenvalue is one that reflects the greatest variance in the image.

That is, the smallest eigenvalue is associated with the eigenvector that finds the least variance. They decrease in exponential fashion, meaning that the roughly 90% of the total variance is contained in the first 5% to 10% of the dimensions.

However, a facial image can be projected onto M ($\ll M$) dimensions by computing in equation 8.

$$\Omega = (v_1, v_2 \dots v_m)^T \quad (9)$$

where $v_i = e_i^T w_i$. v_i is the i^{th} coordinate of the facial image in the new space, which comes to be the principal component. The vectors e_i are also images, so called, eigen images, or eigenfaces in our case, which was first named by Turk and Pentland, (1991). They can be viewed as images and indeed look like faces. So, Ω describes the contribution of each eigenface in representing the facial image by treating the eigenfaces as a basis set for facial images. The simplest method for determining which face class provides the best description of an input facial image is to find the face class k that minimizes the Euclidean distance depicted in equation 10.

$$\varepsilon_k = ||\Omega - \Omega_k|| \quad (10)$$

where Ω_k is a vector describing the k^{th} face class. If ε_k is less than some predefined threshold θ_ε , a face is classified as belonging to the class k .

4.4 Viola Jones Algorithm

Viola-Jones algorithm is quite powerful, and its application has proven to be exceptionally notable in real-time face detection. This algorithm is painfully slow to train but can detect faces in real-time with impressive speed. Given an image (this algorithm works on grayscale image), the algorithm looks at many smaller sub regions and tries to find a face by looking for specific features in each sub-

region. It needs to check many different positions and scales because an image can contain many faces of various sizes. Viola and Jones used Haar-like features to detect faces in this algorithm.

4.5 Principal Component Analysis Model

In this research work, we have 300 images. Each image is N pixels high by N pixels wide. For each image we create an image vector which is a square, N by N image can be expressed as an N^2 dimensional vector, which is depicted in equation 11.

$$X = (x_1, x_2, x_3, \dots, x_{N^2}) \quad (11)$$

Hence, we then put all the images together in one big image-matrix given by equation 12. This will give us a starting point for our PCA analysis. Once we have performed PCA, we have our original data in terms of the Eigen vectors we found from the covariance matrix. This is very useful especially as it concerns facial recognition, and so our original images were of people's faces that were captured through our IP-camera.

$$\text{image - matrix} = \begin{bmatrix} \text{image vector 1} \\ \text{image vector 2} \\ \text{image vector 3} \\ \vdots \\ \text{image vector 300} \end{bmatrix} \quad (12)$$

Then, the problem is, given a new image, whose face from the original set, is it? (Note that the new image is not one of the 300 we started with). The way this is done in computer vision is to measure the difference between the new image and the original images, but not along the original axes, along the new axes derived from the PCA analysis. It turns out that these axes work much better for recognizing faces, because the PCA analysis has given us

the original images in terms of the differences and similarities between them. The PCA analysis has identified the statistical patterns in the data.

4.6 Dimensionality Reduction

Principal component analysis (PCA) also known as Hotelling Transform (HT) or Karhunen - Loeve Transform (KLT), is used for dimensionality reduction where it is found to be effective in the areas of images and signal

processing. In the area of Image and signal processing, PCA is mainly used for reducing size of feature vectors that is used for object recognition and object classification problems. Hence PCA can be implemented using Eigen Values Decomposition (EVD) or Singular values Decomposition (SVD). In this research we made use of Eigen values decomposition. Hence, figure 3 depicts the dimensionality reduction process.

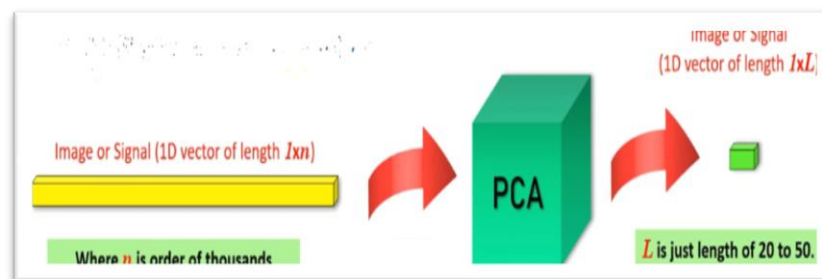


Fig. 3: Dimensionality reduction

In order for us to carry out a dimensionality reduction, we consider a dataset, which is measured in x - y coordinate system as in figure 4 by yellow points.

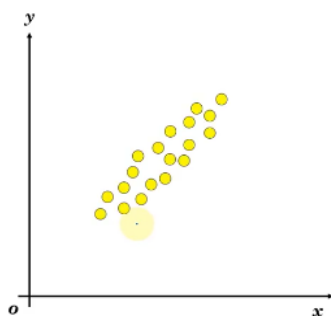


Fig 4: xy coordinates of dataset

In x - y coordinate system, the data representation needs larger values of x and y . Hence, we can observe in figure 5 that data is spread along direction u and hence correlated that the covariance between x and y values is

more. V is another axis that is orthogonal to u , therefore if we choose a new axis system u - v for this data instead of x - y , it gives more compact representation of data with small vibration along v axis. Therefore, the origin point of new axis u - v is placed at mean m of the data. The axis u is known as the Principal Axis 1 and the v is known as the Principal Axis 2.

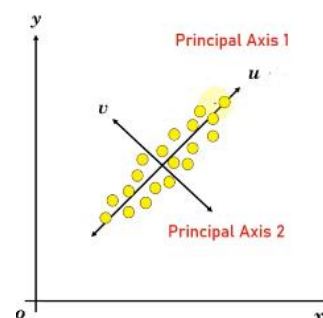


Fig. 5: Principal Axis

Nevertheless, for a given data, Principal Component Analysis finds the axis system defined by the principal directions of variance (i.e., the u-v axis system as shown in figure 5). Hence, if we can reduce the effect of small variations along v axis, then all data points can be assumed on u axis only, therefore, dimensionality is reduced from 2 to 1 in this case.

5.0 Evaluation of Results and Discussion

Result Evaluation is an organized and objective assessment of an on-going or completed project. The purpose is to determine the relevance level of achievement of project objectives, development effectiveness, efficiency, impact and sustainability. This research work adopted a Principal Component Analysis Model and Viola Jones Algorithm for recognition and detection of different faces that were detected and captured from IP camera, which was mounted at a border point in Akwa Ibom state, Nigeria.

5.1 Data Preparation for Training and Testing

The data were collected through our IP camera, where different faces of people were captured at border point.

These images were made up of 30 individuals, where 10 images were captured for each individual giving us a total of 300 images for our training set. Figure 6 depicts the snapshots of the different faces capture from our IP camera.

Additionally, for our training process, a total of 30 persons were selected and 10 images per person were considered. Hence, we took a total of 300 images for our training process. For us to carry out the training, we followed the steps below:

1. We converted all the images of size $M \times N$ 2D and reshaped them to 1D

vector of size $1 \times MN$.

2. Size of images are 227×227 .
3. This size will create a huge 1D vector of size 51529, and will create a memory allocation problem in MATLAB while computing covariance matrix, therefore the size of each image is reduced to 90×100 .
4. Hence, for the testing, the remaining 10 images per person (which are not parts of the training) were considered. For 30 persons, we have a total 300 images for testing.

Finally, our overall training process is depicted in figure 7. From figure 7, we have created a data set matrix in two major domains which are the Spatial Domain and PCA space, where each row is representing one image of size 1×9000 . We took the image 100×90 in size and later get reduced.

Our first image now becomes $x_{11} \ x_{12} \ x_{13} \ \dots \ x_{1mn}$ and so on till we get to our 300 images. Hence the number of rows in our matrix becomes 300 and number of columns becomes 9000.

Additionally, the size of our image data set in spatial domain is 300×9000 , which is very large so we then project it to the PCA space for it to be reduced (i.e., we transformed it to a new matrix which now becomes $[T]_{300 \times 50}$. This matrix becomes our new size matrix.

Again, for the testing procedure, we find the nearest match based on our training image. Figure 8 depicts our testing process. From figure 8, we are to find the nearest match and our input image I_q is our query image, which has the size of 1×9000 which is projected to the PCA, that is then reduced to size 1×50 . Then the new I_q image size is compared to the image (I_{PCA}) from the principal component space to check the similarity between the two images. This similarity check is based on the computation of L1 distance in the equation 13.

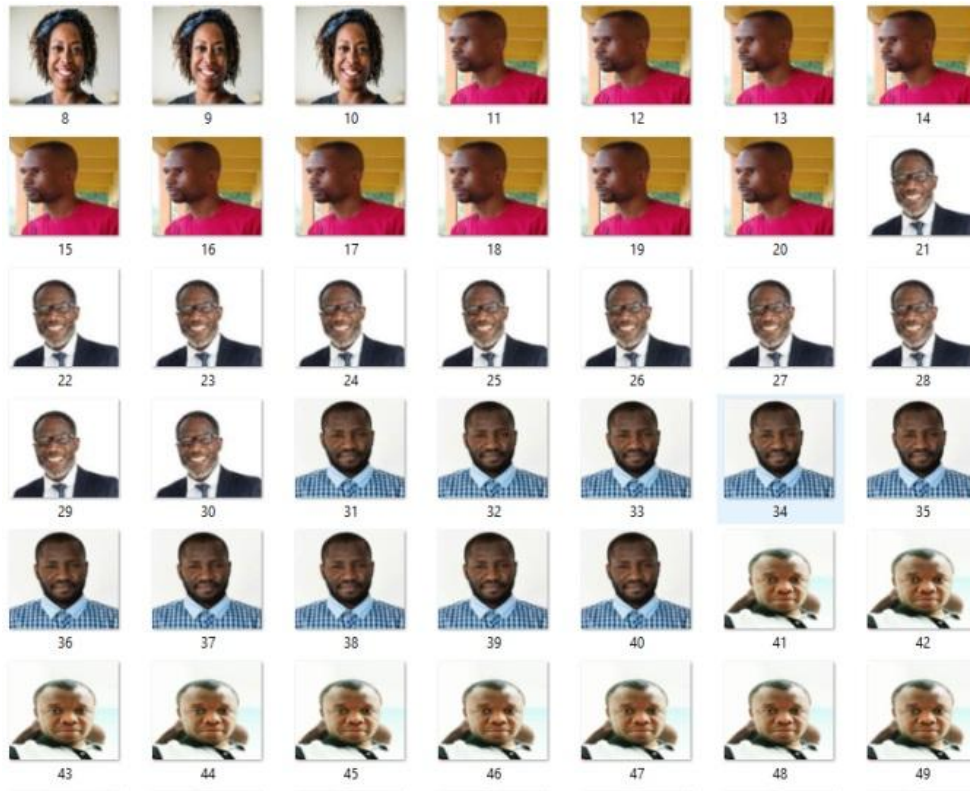


Fig. 6: Face Capture

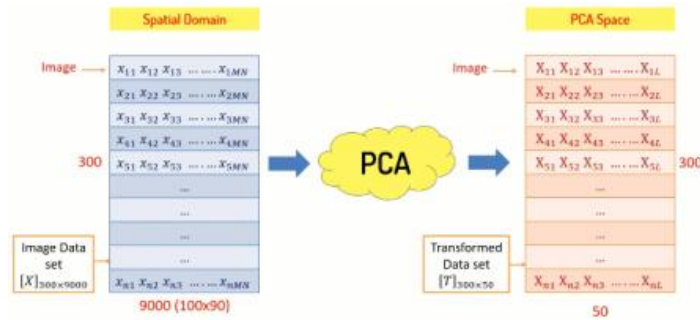


Fig. 7: Overall Training Process

$$(L_1 \text{ distance}) = \sum_{i=1}^L |I_{qi} - I_{pCAi}| \quad (13)$$

So, from the equation 13, we compare image I_q with all the images in PCA space (I_{PCA}) and find the corresponding distance and pick the result with minimum distance (which means

maximum matching). So, when the minimum distance is found, we then take the image index and go the image directory and search for the image with the same name from the location (file). Hence, we get the output image, which we represent as I_o .

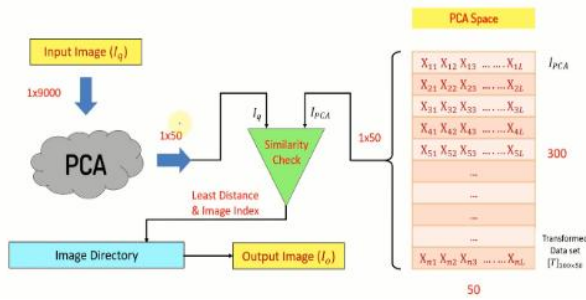


Fig. 8: Overall Testing Process

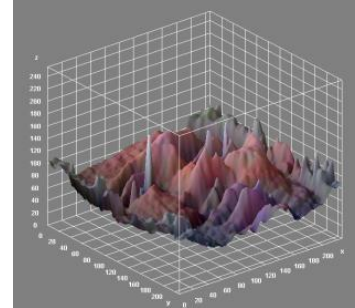


Fig. 10: 3D View of Faces Captured.

5.2 Discussion of Results

The Histogram of faces is as indicated in figure 9. From figure 9, we use image J analysis tool to plot the histogram of all our 300 faces that were collated from our camera. The mean of all our images gives us 66.2, while the mode and standard deviation were 58 and 18.6 respectively.

Additionally, figure 11 shows the 3D surface view of all our faces captured, which were used in our training set where, x, y and z are the different axis rotation coordinate of the faces.

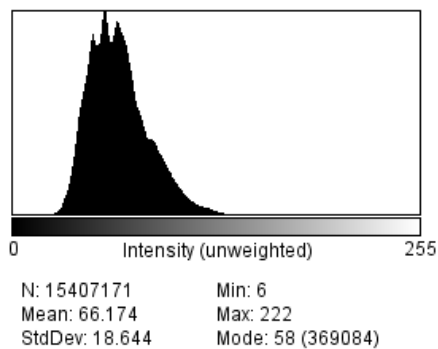


Fig. 9: Histogram of Faces

Again figure 12 shows a mesh plot of our dataset matrix that all our images were converted to 300 x 9000 matrix size.

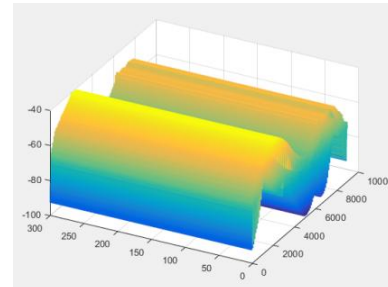


Fig. 11: Mesh Dataset Matrix Plot

Additionally, figure 12 depicts the transformed matrix dataset of our reduced image vector size to 300 X 50, which was transformed into the principal component space.

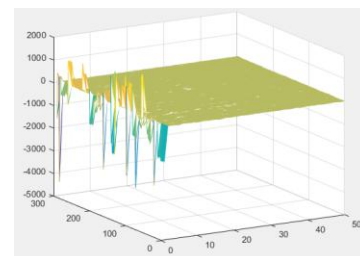


Fig 12: Mesh Transformed Matrix Plot

5.3 Summary of Experimental Results

This work represents some computational results of our program. In Experimental result -1 (Fig. 13), Experimental result-2 (Fig. 14) and Experimental result-3 (Fig. 15), both

search image and recognized image, which are stored in database, have the same pose.

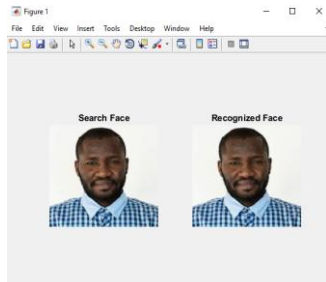


Fig. 13: Experimental result-1(having same pose)

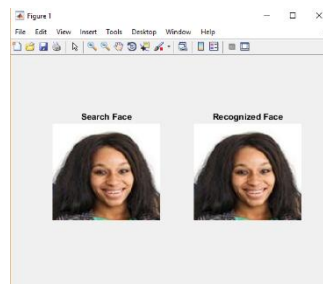


Fig. 14: Experimental result-2 (having same pose)

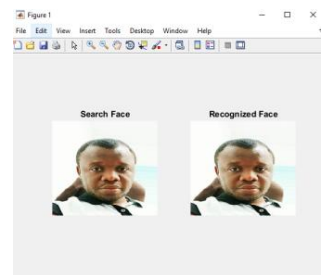


Fig. 15: Experimental result-3 (having same pose)

Additionally, we used photo paint to make a distortion on Search Face for us to determine whether our PCA model will recognized the equivalent face. The experimental results of blurred images being recognized by our model are depicted below in both figures 16 and 17 respectively.

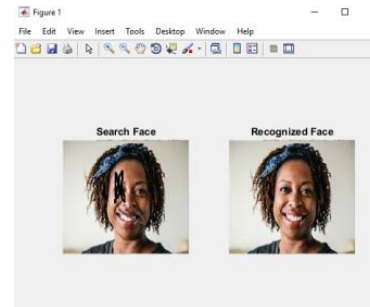


Fig. 16: Experimental result-4 (Blur image recognized)

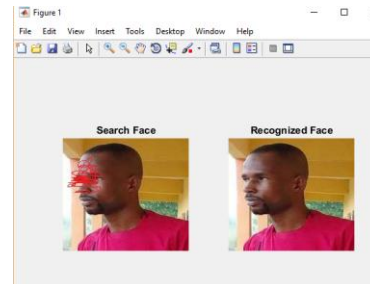


Fig. 17: Experimental result-5 (Blur image recognized).

5.4 Accuracy of Face Recognition based on Captured Image

Several photos that were captured from our IP camera of individuals were loaded into the system to verify the accuracy. A person should have appeared in those photos for 10 times. When the photos were all tested with the search face recognition system, the data was computed in confusion matrix to calculate the accuracy of the system. From Table 1, the true and false recognition done by our recognition system can be observed. For the first person, 8 out of 10 recognitions were true. The true statement means that the identity of person in the photo that is recognized by the system is matched with real identity of the person. For second person, 10 of 10 were recognized correctly recognized. Thus, the accuracy of the system can be calculated as follows;

Table1 Confusion Matrix		
Number of Face Recognized		Results
person 1	person2	
8	2	Person1
0	10	Person 2

Hence our overall accuracy Specificity (true negatives/ all actual negatives) = $TN / (TN + FP) = 10 / (10 + 2) = 10 / 12 = 0.83$ or 83%. Hence, we represent our accuracy in figure 18.

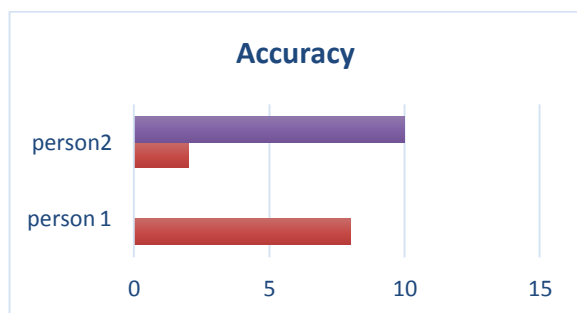


Fig. 18: Accuracy

6.0 Conclusion

Currently, most borders around the world today are being managed in such a way that is prone to easily allow arms/ammunitions and criminals to freely move across. Meanwhile, poor management of these borders has been a major activate of insecurity in the world. Mostly, the porous nature of Nigeria's border with all her neighbouring states has made illegal cross-border activities and undocumented migration possible, thereby contributing immensely to the worsening state of insecurity in the country. Consequently, the demand for effective surveillance at different border point in the world and Nigeria in particular is indispensable requirements in today's world. Though various models have been formulated overtime for border control

and management, gradually, there have been numerous challenges encountered during remote monitoring and control of persons moving across the border. Hence, this research is designed to meet the demand for intelligence surveillance system for border control with a good throughput border security for the security agencies and the country in general. This work focused on adoptions and deployment of an optimal intelligence model to address security challenges based on Machine Learning (ML) approach using Viola Jones Algorithm (VJA) and Principal Component Analysis (PCA). First, we employed intelligence surveillance digital Video camera which was used in capturing of images at border point. The faces of different people crossing the border line were stored in a database system. Practically, the IP surveillance camera was sighted at a distance of 30 meters within the border radius/location, while capturing the images. Nevertheless, there were features in our digital video camera that senses light capturing of image in the dark environment and presents it to be brighter, but such features was not exploited in this work but will be considered in the extended version of this research. The focus on image capturing based on this work is within the day time based on the security concern of the environment at the time of this research. Indeed, all our facial images captured were placed under portrait orientation based on the format of the surveillance camera. Furthermore, we archive face detection by using Viola Jones algorithm for detecting facial look of a person by masking a green box to display the face. However, Viola Jones algorithm in face detection on real-time video for face detection works better in a brighter

environment. The Viola Jones algorithm has different functions that can enhance the detection of different part of human face (such as mouth, nose, eyes etc.). Secondly, we employed a Principal Component Analysis (PCA) model for face recognition, where the different images that were captured were first resized to a vector of [180, 200] for all of our 300 images. Nevertheless, the resized images were converted into gray scale template. The gray scale images required to further be converted to matrix format before sending it to our PCA space. Where each of the 300 faces were transformed to a small vector size of 300 x 90 which is called dimension reduction so that we can match it with the test sets. Basically, we subject our model to performance analysis where we used confusion matrix to measure the accuracy of our model. Hence, the accuracy of our model gave us 83% efficiency. Fundamentally, the optimal model or framework will help solve some of the problems of effective remote monitoring, facial detection and overall quality of service provision in border management activities.

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