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Enhancing Image Processing with Wavelet Technique

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Abstract: *The high levels of noise that are generated by facial images due to environmental factors have hindered the development of facial recognition systems. This issue has also led to the lack of a common system for facial recognition. A review of the previous works has shown that some of the systems that are designed to perform well in identifying and capturing faces do not have high accuracy and are exposed to time delay in recognizing faces. These systems are also prone to failure when it comes to performing pattern recognition. The goal of this research is to develop a robust and efficient pre-processing algorithm for extracting data for a convolutional neural network. Through a wavelet filter, the algorithm will be able to design the input layer of a convolutional neural network before it is fully integrated. This will allow the system to perform various tasks such as image pooling and scanning. It will also provide a reliable and high-quality face recognition algorithm that can handle all types of image data. For the evaluation of the wavelet transformations, the paper chooses the Haar features, orthogonal filter, bi-orhtogonal filters and Adaboast algorithms. The paper found that the wavelet transformations performed by the algorithm are more accurate than the images produced by the conventional methods. This was further tested using query face.*
Keywords: Wavelet, image processing, filters, deep learning, recognition

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I. INTRODUCTION

Image processing is the process of manipulating images using computers and operates on images to extract the data or the information and execute some tasks from the related images. A digital image is an array of the real and complex numbers represented by a finite number of bits. It can also be referred to as a numerical representation of the object to perform a series of operations by using different algorithms to get the desired output. Since the evolution of image processing technology, it is used in various core research and development programs such as in engineering, medical, transportation, forensic examination, photography, weather forecasting and many more areas Horng et al., (2015).

However, noise is a factor which is inevitable when image is concerned as there are many parameters such as poor camera quality, background, face color, face biers, makeup, among others; which induce noise and affect the quality of data collection via face detection. All these parameters induce various types of corruptions in the query image such as impulse noise, background noise and striped noise as discussed in Zeenathunisa et al., (2011) with their various characteristics. The background noise which is a reflection of light from the image background and also from camera lens affects the quality of the image and has to be pre-processed first before the other noise types. This is because the features are of unwanted light reflection dominated other types of noise attributed with the image and has to be managed first to make other noise types visible.

The data pre-processing commonly involves removing low-frequency background noise, normalizing the intensity of the individual particles images, removing or enhancing data images prior to computational processing; and this was done using Histogram Equalization Technique (HET) as specified in Christophe et al., (2007). HET is a contrast adjustment technique developed as a low band pass filter to eliminate unwanted noise attributed with low frequency and was adopted to pre-process the real image.

However, the histogram equalization technique only mitigated the background noise induced in the image due to adverse illumination from the environment and camera used. The impulse noise and stripped noise which cause severe degradation on the image quality according to Mohd et al. (2012), has to be processed to guarantee quality image result. The aim is to ensure that the most interesting features of the face were made available in good quality for optimized training and recognition result. To achieve this, wavelet filtering and normalization techniques were used.

The wavelet transform is a process whereby the features of the image are localized in scales while removing noise. The basic idea behind wavelet filtering is to transform and spatially represent image features in the magnitude of wavelet coefficient. Wavelet coefficients are small value of noise which are transformed without affecting the quality of the main image and then reconstructed. The goal of the wavelet filter is to create an unsupervised neural network's input layer before it is built into a suitable convolutional layer. This method ensures that the data collected by the system is of the best quality.

This process was used to remove the impulse noise in the image captured while the modeling was presented at the system design section.

II. REVIEW OF RELATED WORKS

In Sreesharmila et al., (2015), the use of discrete wavelet transforms in combination with a support vector machine classifier for enhancing the image was performed successfully. The low-frequency component of the transform was then enhanced using the Karhunen-Loeve transform Priyadharsini et al. (2015).

Maragatham and Roomi, (2016) considered a method for enhancing the image's contrast by analyzing the image's contrast factor. This method was then performed by implementing a log-likelilation function to estimate the need for the enhancement. After the need was identified, the application of a particle swarm optimization method was then performed to improve the image's performance.

Chouhan et al., (2012) used a technique in discrete wavelet transform domain known as dynamic stochastic resonance-based technique to enhance the image's contrast. The method was able to achieve a significant improvement in the image's overall performance.

Zhao et al. (2003) proposed a subspace approach to capture local discriminative features in the space-frequency domain for fast face detection. Based on wavelet packet analysis, the discriminant subspace algorithm was developed to search for the minimum cost subspace of the high-dimensional signal space which led to a set of wavelet features with maximum class discrimination and dimensionality reduction. The system decomposes an entire input image into sub-band images which contain the discriminant features. Multiple sliding windows within different sub-bands are aligned to the same spatial location. Features are selected from multiple sub-bands to calculate the likelihood ratios. Face locations are reported where the likelihood ratios exceed a fixed threshold.

Madan et al. (2018) surveyed the various facial recognition techniques. The study revealed that face detection was one of the most challenges pattern recognition problems to solve due to the complexity of the faces attributes. In the study the use of support vector machine (SVM), principal component analysis (PCA), artificial neural network (ANN), independent component analysis (ICA), Gabor wavelet, hidden markov model and graph based approach was considered as some of the most used technique to solve this problem. These techniques were tested on the FERET, LFW, YTF, Yale, AT&T and Yale dataset, respectively. The study concluded that despite the success achieved so far, there was still a lacuna to be filled to enhance reliability and efficiency of digital face recognition system.

Khushbu et al. (2014) presented a research on human face recognition system using image processing. From the study, a home service robot was developed with the capacity to detect a face based on adaptive skin detection algorithm, condensation filter and Haar classifier. The system was implemented using OpenCV software and tested. The detection rate was successful, but can be improved using advanced artificial intelligence technique like deep learning.

Nishtha (2019) studied face recognition using deep convolutional neural network. In the research the architecture was developed and used to train ORL dataset which has 40 classes of different peoples. The result when tested showed that the accuracy is 95%; however, the performance when deployed in real time application may not be accurate as the data used to achieve this 95% accuracy is already processed. Hence there is need to incorporate filter to the system to sustain the same level of accuracy when deployed in real life application.

III. THE PROPOSED APPROACH

In order to perform accurate face recognition, various steps are involved such as data collection, image acquisition, computer vision, face detection, data pre-processing, data processing and training. This research is performed on 1850 different identities as provided by the Nigerian Police Force (NPF). These images form the datasets on which simulations are performed.

To get the most accurate results, the image size should be around 190 x 260 pixels. Preprocessing is then performed to take advantage of the region of interest (ROI). Computer vision is then used to derive appropriate information from the image as discussed below.

3.1 Computer vision

Computer vision as a method involves incorporating intelligence into the camera, which then uses this data to derive useful information from the digital image. Various computer vision algorithms have been developed to achieve this objective. The adoption of a particular algorithm depends on the data it is handling. For instance, if the algorithm is developing a facial recognition system, it should consider the data collected by the human face. A study conducted by Vilmal (2015) focused on the implementation of the Viola Jones algorithm, which allows the camera to not only detect the face but also track it in real time. The main advantage of the algorithm is its invariant detector, which allows it to identify the scales of human features.

The goal of the study was to make the Viola Jones algorithm compatible with the image specifications. In order to ensure that the image captured in time series is of the same size and properties, the data flow model of the algorithm was reconstructed.

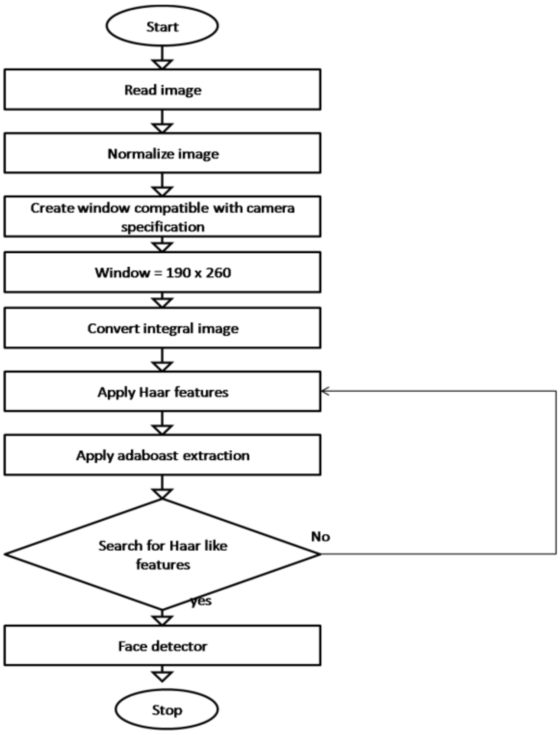

Fig. 1: Re-configured Viola Jones algorithm

The flowchart in fig. 1 shows the steps in developing an algorithm that would align the properties of a camera with those of its recommended model. The algorithm was built using Adaboast and Haar features. When the camera reads image data, it then recognizes facial fudicial points.

3.2 Wavelet Processing Techniques

This is a data processing approach used in many areas to eliminate noise in frequency and time domain without altering the quality of the main signal or data for image set. This approach has been applied to improve pattern recognition problems overtime for purification of unwanted signal. The aim is to ensure filter off unwanted signal from the input data and optimize quality of data output (Vincent et al., 2003).

3.3 Two-Dimensional Filter

This is an image processing tool used to reduce excess frequency or noise from binarize image which is a 2D image type. The four basic ideal filters include low pass filter, high pass filter, band pass filter and band stop filter, even though it is impossible to have a filter that is ideal in practice (Zoran, 2009). The equations below show the four basic filter types and the frequency response of each of the filter (Tan and Lean, 2013).

For the lowpass filter type, the frequency response $h_d(n)$ is as given in equation 1.

$$h_d(n) = \begin{cases} \dfrac{\sin\left(\omega_c(n-M)\right)}{\pi(n-M)} \; ; for \;\; n \neq M \quad (0 \leq n \;\; \leq 2M) \\ \dfrac{\omega_c}{\pi} \; ; \qquad\qquad n = M \end{cases} \qquad \mathbf{(1)}$$

While for equations 2, 3, and 4 represents the frequency responses for highpass, bandpass and bandstop filters respectively.

$$h_d(n) = \begin{cases} -\dfrac{\sin\left(\omega_c(n-M)\right)}{\pi(n-M)} \; ; for \;\; n \neq M \quad (0 \leq n \;\; \leq 2M) \\ 1 - \dfrac{\omega_c}{\pi} \; ; \qquad\qquad\qquad\qquad n = M \end{cases} \quad \textbf{(2)}$$

$$h_d(n) = \begin{cases} \dfrac{\sin\left(\omega_{c_2}(n-M)\right)}{\pi(n-M)} - \dfrac{\sin\left(\omega_{c_1}(n-M)\right)}{\pi(n-M)} ; for \;\; n \neq M \quad (0 \leq n \;\; \leq 2M) \\ \dfrac{\omega_{c_2} - \omega_{c_1}}{\pi} \; ; \qquad\qquad\qquad\qquad n = M \end{cases} \quad \textbf{(3)}$$

$$h_d(n) = \begin{cases} \dfrac{\sin\left(\omega_{c_1}(n-M)\right)}{\pi(n-M)} - \dfrac{\sin\left(\omega_{c_2}(n-M)\right)}{\pi(n-M)} ; \;\; for \;\; n \neq M \quad (0 \leq n \;\; \leq 2M) \\ 1 - \dfrac{\omega_{c_2} - \omega_{c_1}}{\pi} \; ; \qquad\qquad\qquad\qquad n = M \end{cases} \quad \textbf{(4)}$$

Where $M = (N-1)/2$; N is the filter order, n is a variable that ranges from 0 to N, M is a constant which can be expressed as $M = (N-1)/2$, ω_c is the angular cut off frequency $\omega_{c1}$and ω_{c2} is the passband edge frequency and stop band edge frequency (Tan and Lean, 2013).

3.4 Normalization

This was used to vary the changes of pixel intensity values in the image captured. The aim is to convert the image into a range of pixels values which are familiar to ensure that striped noise is removed. The histogram normalization technique was used to achieve this,

IV. SYSTEM DESIGN

The paper focused on the design of a system that includes three main sections: face detection, data processing, and face recognition. The main objective of this paper is to improve the image recognition process by removing noise from the data. The process algortihm as shown in fig. 2 below presents the workflow of the image processing system. It shows how the system acquires datasets to generate a reference model, which then used that model to recognize time series of face images. The image acquisition process was carried out using computer vision technology. The computer vision system used the Adaboast algorithm and Haar features to find and capture face-like images. The data collected during the process is always characterized by noises, such as background noise, impulse noise, and strip noise. To minimize the noise, the system used a combination of wavelet filter and histogram equalization techniques.The output data can then be fed to an appropriate deep learning algorithm.

Fig. 2: Process algorithm

4.1 Data Processing Model

The data processing model was developed using the Discrete Wave Transform (DWT) which uses three filters simultaneously to process image data and remove noise. The filters are the Haar wavelet, orthogonal filter and bi-orthogonal filters based on Wavelet Decomposition Theorem which segments the images into various sub band of Low Low (LL), Low High (LH), High Low (HL) and High High (HH). These regions represent the various part of the image, with the major part within the low low pass bands, while the remaining parts like the edges are shared among the other bands.

The DWT which presents a two-dimensional representation of the face data detected and captured is modeled using equations below.

F(u, v) =

$$\frac{1}{\sqrt{M}}\sum_{s}\sum_{t} W_q(y_o,s,t)q_{yo,s,t}(u,v) + \frac{1}{\sqrt{M}}\sum_{x=H,V,D}\sum_{y=yx}^{\infty}\sum_{s}\sum_{t} W_q^s(y_s,t)\psi^s{}_{y,s.t}(u,v) \quad \textbf{(5)}$$

Where the wavelet coefficients are presented as:

$$W_q(y_o,s,t) = \frac{1}{\sqrt{M}}\sum_{u=0}^{s-r}\sum_{v=o}^{T-1} f(u,v)q_{yx,s,t(u,v)} \quad \textbf{(6)}$$

$$W_q^s(y_o,s,t) = \frac{1}{\sqrt{M}}\sum_{u=0}^{s-r}\sum_{v=o}^{T-1} f(u,v)q^s{}_{y,s.t}(u,v) \quad \textbf{(7)}$$

x = (H, V, D)

Where M is the power of 2, $\frac{1}{\sqrt{M}}$ is the normalization factor, u and v are the dilation and translation parameters in terms of discrete values, $W_q^s(y_o,s,t)$ and $W_Q(y_o,s,t)$ are approximation coefficients, F(u, v) is first scale input, y is scale parameters, s is shift function, T is time reverse scale, t is time domain, f is frequency domain, W or (ψ) *is wavelet function.*

In two dimensional 2D and 3D the scaling function q(u,v) and three 2D wavelets of $\psi^H(u,v), \psi^V(u,v)$ *and* $\psi^D(u,v)$ are used to deduct the wavelet representation of the image as the models below:

q(u,v) **(8)**

$\psi^V(u,v)$ **(9)** $\psi^H(u,v)$ **(10)**

$\psi^D(u,v)$ **(11)**

The models in equation 8 is the scale factor used to decompose the wavelet coefficients of the images into various scales as shown in DWT decomposition modeling diagram in fig. 3.

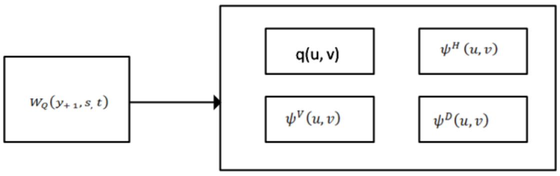

Fig. 3: The Wavelet Decomposition Diagram

The figure shows how the DWT was able to scale the face input whose wavelet coefficients are represented with equation (6) and (7) to form the decompositions block modeled with equation 8 which represents the LL sub section of the band containing the main part of the face data and the other equations 9 to 11 which presented the edges and other features of the image as shown in fig. 4.

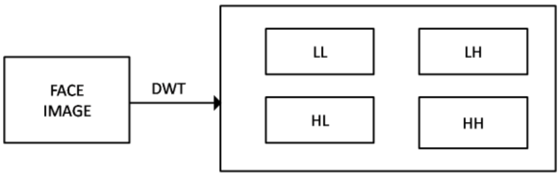

Fig. 4: The Scaling of the Face Image with DWT.

V. RESULT AND DISCUSSIONS

This section presents the performance of the algorithm when implemented as an image processing system. This was tested using the query face in fig. 5.

Fig, 5: Result of Suspected Query Person

The fig. 5 above presented an input query image detected using the face detection model in fig. 2 The model was developed with Viola and Jones algorithm as in fig. 1 to enhance the accuracy of face detection via the tracing of the facial features. From the result, it was observed that the face was accurately detected.

Histogram equalization was further used to transform the lightening intensities from the environment which affects the quality of the image and the result is presented in fig. 6.

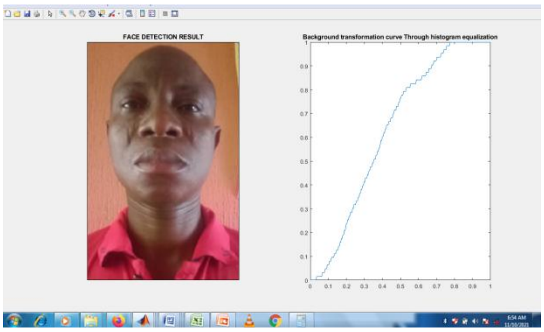

Fig. 6: The Data Pre-processing Result with Histogram Equalization

Now that the pre-processing was completed to reduce background noise, the other forms of noise was processed using discrete wavelet transform, modeled in fig. 3 which shows how the DWT was able to scale the face input whose wavelet coefficients are represented with equation (6) and (7) to form the decompositions block, modeled with equation 8 which represents the LL sub section of the band containing the main part of the face data and the other equation 9 to 11 which presented the edges and other features of the image. These sub frequency bands were collectively used to process the face input and the effect of each of the band is presented in the result as fig. 7

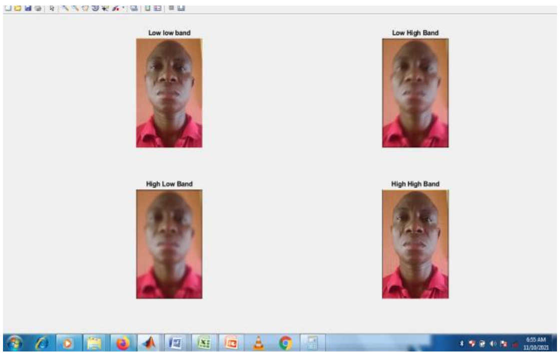

Fig. 7: Wavelet image processing result

The fig. 7 is the equivalent wavelet decomposition model in fig. 3 which showed how each of the sub bands were collectively used to process the image and achieved high quality for training. After this process, the data can be dimensioned by the appropriate convolutional neural network input layer for accurate face recognition.

VI. CONCLUSION

From the beginning of this work, it was established that the major problem of facial recognition is reliability. This is the ability of a system to be available at all times with integrity and no false alarm. We have presented and evaluated the various preprocessing methods that can be used to enhance image quality for the purpose of face recognition. The results of the study revealed that the wavelet transform can be used as the first step in the process before the implementation of the deep learning algorithm. We further evaluated the Haar features, orthogonal filter, bi-orhtogonal filters and Adaboast algorithms. The results of the study revealed that the wavelet transform can be used to enhance image processing for accurate face recognition.

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