Development of an Illumination Invariant Face Recognition System

Kennedy Okokpujie1, Samuel John2, Ufuah Donald1, Martins Nwagu1, Etinosa Noma-Osaghae1, Charles Ndujiuba4 and I. P. Okokpujie1

1Department of Electrical and Information Engineering, Covenant University, Ota, Ogun State, Nigeria
kennedy.okokpujie@covenantuniversity.edu.ng
2Department of Electrical and Electronics Engineering, Nigerian Defence Academy, Kaduna State, Nigeria
samuel.john@nda.edu.ng
3Department of Electrical and Electronic Engineering, Air Force Institute of Technology, Kaduna State, Nigeria
charles.ndujiuba@afit.edu.ng
4Department of Mechanical Engineering, Covenant University, Ota, Ogun State, Nigeria
imhade.okokpujie@covenantuniversity.edu.ng

ABSTRACT

The Face recognition systems have gained much attention for applications in surveillance, access control, forensics, border control. Face recognition systems encounter challenges due to variation in illumination, pose, expression, occlusion and most importantly, aging. The effect of the intensity of light on recognition image in contrast with gallery image significantly affect the face recognition system. In this study, an illumination invariant Face Recognition System is developed using a 4-layered Convolutional Neural Network (CNN). The proposed system was able to recognize the different degree of face Illuminated image, thus making the model Illumination Invariant Face Recognition system. The variations caused by illumination was modelled as a form of light varying noise, and it was validated by computing its error statistics and comparing its performance with existing models found in literature. The result of the study showed that an adaptive and robust face recognition system that is illumination invariant could be achieved with CNN. The recognition accuracy achieved by the study was 99.22% with five (5) epochs and iteration of 85.

Key words: Face recognition, Illumination, Convolutional Neural Network and Dataset

1. INTRODUCTION

The main objective of a biometric system is to accurately identify individuals. This implies that biometric systems must have low recognition error rates. Face recognition over the last decade has become an area of interest for many researchers because of its wide range of applications [1]–[4].

Face recognition systems are adversely affected by light variations. The light variation factor could compromises recognition accuracy in face recognition systems. Illumination, as it affects the facial recognition system, has become a hotbed for researchers in the area of image processing and computer vision [5]–[8]. A robust Facial recognition system capable of adapting to variations in the face is necessary to curb the adverse effects of illumination on facial recognition systems. This will reduce the need for re-enrolling individuals and the cost of infrastructure procurement in the long run. In this study, a robust facial recognition system capable of adapting to variations due to trait aging in individuals using Convolutional Neural Networks is considered.

The proposed system was able to recognize/identify face trait of individuals across illumination groups. The variations caused by illumination are modelled as a form of time-varying noise and it was validated by computing its error statistics and comparing its performance with existing models found in literature. The system was able to adapt to changes in facial features as individuals face illuminate. Face detection, pre-processing and feature extraction was done using a 4-layer convolution network of size 3x3, each having 5, 10, and 50 kernels respectively. Dimensionality reduction was done using the pooling layers of the network while face recognition was done using the fully connected layer of the CNN with a Softmax classification function. Training was done using Stochastic Gradient Decent with Momentum (SGDM). The system accepted input images of size 180x200x3 obtained from a moderate trait aging dataset that belonged to the university Essex, United Kingdom. Simulation was done using the MatConvNet toolbox in MATLAB R2017b.

The paper is organized thus, a brief review of existing literature on adaptive illumination invariant face recognition systems is given in the section two (Literature Review). A
thorough expository on the methodology used for the study is
given in section three (Methodology). The results of the study
are elucidated in section four (Results and Discussion). A
conclusion is made and all parties involved in the success of
the study are acknowledged. A list of references is given to
close the study.

2. RELATED WORKS

Use The human face is made up of layers of muscles, skin and
tissue that reside above the bones of the face. The face keeps
changing after birth, and its growth is widely affected by
environmental factors such as body weight, lifestyle, sunrays,
smoke and the type of food being consumed by an individual.
The facial muscles may differ in their control, position, form
and presence. Facial characteristics of individuals changes
with increase in age [9]–[13].

Illumination variation distorts the elasticity of the skin. However, the face is mapped with representations that are
rapid and remain permanent. The illumination features can
be represented using Active Appearance Models (AAMs).
AAMs extract the global features of the face using statistical
and appearance models. They are limited in functionality
because they do not consider the local features of the face
embedded in lighting distortions [14]–[18].

The use of coordinate transformations for modifying the
structure of biological organisms so as to synthesize a
structure of similar but different organisms was proposed by
[7]. As a result of the investigation of the application of
coorindate transformations was employed by some scientist
[7]. This was a trial to imbibe age-associated alterations to the
face. These scientists came up with two of such
transformations which comprise Cardiodal Strain and shear
transformations. The former was effective for changing the
detected face age.

Further work was done shows that by the applied to 3D facial
data. However, the method only created room for the
manipulation of the shape of the face. It was oblivious to how
variations in facial colour could be solved [19]–[21].
Okokpujie et al., also attempted the simulation of age and
illumination effects on the basis of shape and colour detail.
Various face composites obtained from several age groups
and caricature algorithms were utilized to investigate the
aging and illumination processes. The authors concluded that
the subjects’ perceived age (blended images) utilized for
producing respective composites does not change with respect
to the real age employed in producing respective
composites. This means that illumination data for each group is reserved
through the blending process [22]–[29]

3. MATERIALS AND METHODS

The proposed system used Convolutional Neural Network
(CNN) for pre-processing, feature extraction and face
recognition. It used Softmax operator as the classifier. The

- Figure 1: Flow chart of Illumination Face Recognition System

It has an input layer size of 180x200x3, three groups of
convolutional layers, an activation layer (ReLU) and a
pooling layer, followed by a fully connected layer of size 152
and a Softmax classification layer. The Input to the CNN is an image from the dataset. The Convolutional layers are responsible for optimum feature extraction while the pooling layers perform dimensionality reduction. The three Convolutional layers use 5, 10 and 50 filters each of size 3x3 respectively. Each pooling layer uses a filter of size 2x2. The fully connected nodes represent the total image classes in the dataset.

The images in the database used for training and testing were face photographs obtained from undergraduate students of the University of Essex taken in a controlled environment of different illumination, pose, expression and age. Some of the samples are shown in Figure 3.

![Figure 2: CNN Architecture of Illumination Face Recognition System](image)

![Figure 3: Sample Faces from Database](image)

### 4. Results and Discussion

The face recognition system is developed using MATLAB programming language. The output of the training and testing process is shown in the Figure 6 and Algorithm 1. During pre-processing, each subject was scaled to 180x200. The images were partitioned in the ratio, 15:5 for training and testing respectively. When the system executes, the subjects in the training database were trained in mini-batches. Training was done on the mini-batches and stopped when a new accuracy was obtained. Finally, the system selects an image to be tested which displays the user ID identical to the ID tag for each subject. The system was tested with multiple numbers of new subjects. The analysis of the number of epoch and average training time is shown Table 1.

The accuracy report showed that only a few epochs are needed to train the images in the database. Five epochs and 85 iterations were used. The system was able to classify images as either known or unknown with a 0.01 learning rate.

![Figure 4: Testing Process 1](image)

![Figure 5: Testing Process 2](image)
Figure 6: Training Progress of Illumination Invariant Face Recognition System

Table 1: Accuracy Report of the Illumination Invariant Face Recognition System

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Iteration</th>
<th>Time Elapsed (seconds)</th>
<th>Mini-batch Loss</th>
<th>Mini-batch Accuracy</th>
<th>Base Learning Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>18.79</td>
<td>5.0253</td>
<td>0.78%</td>
<td>0.0100</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>742.73</td>
<td>5.0062</td>
<td>1.56%</td>
<td>0.0100</td>
</tr>
<tr>
<td>5</td>
<td>85</td>
<td>1247.57</td>
<td>0.0149</td>
<td>99.22%</td>
<td>0.0100</td>
</tr>
</tbody>
</table>

CNN successfully trained with accuracy = 98.29
CNN successfully testing with accuracy = 99.22
The average training time increased as the network grew, but in this case 20 minutes 50 seconds. This implied that an architecture with more hidden layers would drastically increase the training time. The result showed that the proposed illumination invariant face recognition system had a testing accuracy of 99.22%. Table 2 shows the parameters and results of the experiment.

Table 2: Parameters / Results Table

<table>
<thead>
<tr>
<th>Parameters / Results</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validation accuracy</td>
<td>N/A</td>
</tr>
<tr>
<td>Training finished</td>
<td>Reached final iteration</td>
</tr>
<tr>
<td>Training Time</td>
<td>14-Jun-2020 17:16:02</td>
</tr>
<tr>
<td>Elapsed time</td>
<td>16 min 9 sec</td>
</tr>
<tr>
<td>Epoch</td>
<td>5 of 5</td>
</tr>
<tr>
<td>Iteration</td>
<td>85 of 85</td>
</tr>
<tr>
<td>Iterations per epoch</td>
<td>17</td>
</tr>
<tr>
<td>Maximum iterations</td>
<td>85</td>
</tr>
<tr>
<td>Frequency</td>
<td>N/A</td>
</tr>
<tr>
<td>Patience</td>
<td>N/A</td>
</tr>
</tbody>
</table>

5. CONCLUSION
An illumination invariant face recognition system using convolutional neural networks has been developed. The facial recognition system was invariant to changes in the face because of illumination. The system is built on a four-layered CNN.

Algorithm 1

```matlab
1. datasetPath = fullfile('faces4_all');
2. data = imagedatastore(datasetPath, 'IncludeSubfolders', true, 'LabelSource', 'foldernames');
3. trainingNumFiles = 15; % 15 out of 20 images of each person are used to train, 5 for testing
4. [traindata, testData] = splitEachLabel(data, ...
5.   trainingNumFiles, 'randomize');
6. % Define the convolutional neural network architecture.
7. layers = [...
8.   maxPooling2Layer(4, 'Stride', 10),
9.   reluLayer,
10.  maxPooling2Layer(2, 'Stride', 2),
11.  convolution2DLayer(3, 5),
12.  reluLayer,
13.  maxPooling2Layer(2, 'Stride', 2),
14.  convolution2DLayer(3, 5, 2),
15.  reluLayer,
16.  maxPooling2Layer(2, 'Stride', 2),
17.  fullyConnectedLayer(152), % number of persons/outputs/classes 152
18.  softmaxLayer,
19.  classificationLayer();
20. options = trainingOptions('sgdm', 'MaxEpochs', 5, ...
21.   'InitialLearnRate', 0.01, 'Verbose', 'training-progress');
22. convnet = trainNetwork(trainData, layers, options);
23. yTest = classify(convnet, testData);
24. TTest = testSet.labels;
25. confusion = confusionMat(yTest, yTest);
26. accuracy = sum(Test == TTest)/numel(TTest);
27. fprintf('CNN successfully trained with accuracy = %d \%\n\%', accuracy * 100);
28. disp('Testing the CNN now...');
29. im = imread('test_samples1.png'); % sample image
30. subplot(1, 2, 1);
31. imshow(im); title('Looking for ...', 'FontWeight', 'bold', 'FontSize', 16, 'Color', 'red');
32. disp(classify(convnet, im));
33. im = imread('test_samples2.png'); % sample image
34. subplot(1, 2, 2);
35. imshow(im); title('Looking for ...', 'FontWeight', 'bold', 'FontSize', 16, 'Color', 'red');
36. disp(classify(convnet, im)); end
```

ACKNOWLEDGEMENT

This paper was funded by the Covenant University Center for Research, Innovation, and Discovery (CUCRID), Ota, Ogun State, Nigeria.

REFERENCES


