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A MODEL FOR HANDWRITING DETECTION USING GRAPHOLOGY AND CONVOLUTIONAL NEURAL NETWORK (CNN)

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ABSTRACT:
Detecting crime through handwriting can help reduce crimes involving handwriting, such as forgery, financial misappropriation, exam malpractice (where a paid individual writes an exam for a student), and document fortification. The problem associated with this research focuses on examination malpractice, where it is difficult to detect and identify one's handwriting from another, the aim of this research is to develop an Improved Handwriting Crime Detection Model using Graphology and Convolutional Neural Network (CNN). Python programming language was used to train the images with a Convolutional Neural Network (CNN), a total of 44 images were used in this research for training, 36 images for validation and 15 images were used to test the model. The model achieved an accuracy of 1.000 within a timeframe of 3secs and an overall performance of 98.7%. This model was able to detect and identify the handwriting of an individual from that of another individual.

Keywords: CNN, Crime Detection, Graphology, Handwriting, Model

1. Introduction

The study presented an optimized improved approach to curbing crimes perpetuated with handwriting. Handwriting is a means of communication and recording information in day-to-day life. Handwriting is considered as a principal factor in many criminal offences and has been the subject of expert study.
Handwriting requires the coordination of a complex and fine- tuned mechanism involving multiple muscles (Holmes, 2018).

Handwriting can be defined as writing carried out through the aid of writing tools such as pencil, marker and pen. Furthermore, handwriting can be broken down into penmanship, cursive script and manuscript concepts. A penmanship concept simply illustrates the writing skills art or manner. The cursive script concept illustrates handwriting in which successive letters are joined, while the manuscript concept illustrates handwriting in which the letters are separated (Kocsis, 2016). It is also typically a behavioural exercise that is identifiable because of the presence of characteristic features and qualities within the written matter. For any documentation, the preferred writing surface is a paper and the signature will confirm and complete the process, even after the technology development in documentation. Graphology is a branch of science that looks at a person's handwriting to make predictions about diseases, careers, and other topics. Graphology collaborates with medicine, psychology, sociology, and other observational sciences. In business, graphology is used for employee recruitment, medical diagnosis, forensic identification of criminals, career choice in education, guidance and counselling, and other practices at all social levels. Graphology can be described as the process of scrutinizing patterns and traits of handwriting images in order to trace the writer. Furthermore, it also encompasses investigating the time of the writing. Graphology is still being backed up with non-scientific evidences and is further likened to a pseudoscience. Application area of graphology encompasses crime detection, forensic document examination and image classification processes (Mcnichol, 2010). Convolutional neural networks are a subset of neural networks that use convolution instead of general matrix multiplication in at least one layer, they were inspired by biological processes in that the pattern of connectivity between neurons resembles the organization of the animal visual cortex. Convolutional neural networks are a subset of neural networks that use convolution instead of general matrix multiplication in at least one layer. Image and video recognition, recommender systems, image classification, image segmentation, medical image analysis, natural language processing, brain-computer interfaces, and financial time series are some of the applications. In comparison to other image classification algorithms, they require very little pre-processing (Wikipedia, 2021).

Furthermore, a new model for detecting handwriting crime using graphology and convolutional neural network was developed in the study.

1.2 Statement of the Problem

Handwriting has been used in a variety of crimes. Financial misappropriation, forgery of signatures, and examination malpractice are examples of these offenses (where a paid individual writes an exam for a student). Several models have been developed to combat forgery, but there is still room for improvement because current models are less accurate and time consuming in detecting forged documents. Khan et al. (2019) are among those who have contributed to this work. In order to address a major issue in Nigeria, this research focuses on examination malpractice, where it is difficult to detect and identify one's handwriting from another.

1.2 Aim and Objectives of the Study

The aim of this study is to develop an Improved Handwriting Crime Detection Model using Graphology and Convolutional Neural Network (CNN). The specific objectives of the study include to:

i) Design an image classifier system
ii) Programming languages used is python and the system were trained using Convolutional Neural Network (CNN).
iii) Evaluate performance of the existing and proposed systems

II. Related Literature

This section of the study shed light on some related literatures of different scholars.

2.0 Related Work

Nataraja and Khaja (2019), proposed Handwritings on the wall solved the mystery: A rare crime scene report. The study aimed at shedding light on the importance of image classification of handwriting to robbery investigation. Furthermore, the study proffered useful suggestions on how crime detection can be enhanced via image classification techniques. The authors did a good job using Rapid Application Development Methodology but could not implement the discussed issues with a model and software.

Crineanu (2019), looked at the writing criminal minds criminology and handwriting analysis. The study discussed the concept of Graphology as an experimental science which reveals, by studying the natural graphic movement of the subject, his personality, temper, intellectual behaviour, professional and social capacities and his morbid inner predispositions. The author did a good job. However, further evaluation of the study showed the absence of a tested graphology system.

Ordway (2016), proposed a collection of writing standards in criminal investigation. The author opined that the great majority of non-experts who attempt to make identifications of handwriting base their opinions for the most part upon letter formation, and especially upon those forms which differ most radically from their own writing. The author did a good job but failed to implement the discussed writing standards with a model and software.

Albert (2016), looked at progress proof of handwriting and documents. The author opined that the severe restrictions surrounding handwriting expert testimony in the courts made this testimony weak and unconvincing, and it was so described in the opinions, but the opinions failed to say that the result was due to the restrictions that did not permit scientific and convincing testimony. The author did a good job but was unable to carry out additional survey to quantify the specific effects of language type on usage.

Braga et al. (2018), looked at the effect of hot spots and place-based policing. The study suggested that a series of rigorous evaluations have suggested that police can be effective in addressing crime and disorder when they focus in on small units of geography with high rates of crime. The authors did a good job. However, a major limitation in the study is that the developed model was deficient in benchmarking and cost benefits analysis.

Mark et al. (2010), looked at Handwriting and Hand-printing characteristics. The study described the results from a National Institute of Justice funded statistical research project through the National Center of Forensic Science at the University of Central Florida. In addition, the motivation of the study was to strengthen the statistical basis for handwriting comparisons. The authors did a good job but failed to implement the discussed handwriting and hand-printing features with a model and software.

Sargur (2016), proposed a statistical examination of handwriting characteristics using Automated Tools. The author opined that in the examination of handwritten items, the questioned document (QD) examiner follows a sequence of steps in many of which there is a degree of uncertainty to be resolved by experience and power of recall. The author failed to implement the discussed statistical traits with statistical software.

Ryosuke et al. (2012), developed the Writer Identification for offline Japanese handwritten character using Convolutional Neural Network. The work proposed some features from Convolutional neural network (CNN) for writer identification. They used datasets of Japanese handwritten character, which is made up of 100 kinds of words from each 100 writers. They also evaluated two natures of handwritten words: the potential of writer identification for each word in Japanese and handwritten words contain the writer own unique identities. These natures cause a variation of classification.

Leandro (2010), developed the Patch based Convolutional Neural Network for the writer classification Problem in music score; he suggested that the writer identification problem has been largely studied in the field of image processing. Music score writer identification is a particular problem that requires the identification of a music score writer, which is a complex task for musicologists. In addressing the issue, he developed a deep learning approach based Convolutional Neural Network.

Huang (2018), proposed the theory of object recognition: computations and circuits in the feed forward path of the ventral stream in primate visual cortex. The work discusses the derivation and implementation of Convolutional neural networks followed by a few straightforward extensions. Convolutional neural networks involve many more connections than weights; the architecture itself realizes a form of regularization.

Maggie (2014), published an article on large-scale learning with support vector machines and Convolutional Neural Network for generic object pattern recognition. She analysed Text detection as an important preliminary step before text can be recognized in unconstrained image environments. She also presented an approach based on Convolutional neural networks to detect and localize horizontal text lines from raw colour pixels. The network learns to extract and combine its own set of features through learning instead of using hand-crafted ones. Learning was also used in order to precisely localize the text lines by simply training the network to reject badly-cut text and without any use of tedious knowledge-based post-processing.

Miguel (2009), proposed an interpretation of Convolutional Neural Network for speech Regression from Electrocorticography. In his work, he showed that Convolutional Neural Networks are useful to reconstruct speech from intracranial recordings of brain activity and propose an approach to interpret the trained CNNs. Furthermore, he related the ability of a Convolutional Neural Network to be powered by deep learning technique.

Adetiba (2015), looked at Face detection system for attendance of class students. The study looked at new automated attendance management marking system. Result is Less time consuming than traditional methods. However, the identified system still lacks the ability to identify each student.

Khan et al. (2019) proposed an automatic ink mismatch detection technique that divides the spectral responses of ink pixels in handwritten notes into different clusters that correspond to the document's unique inks using Fuzzy C-Means Clustering. Sauvola's local thresholding technique is used to efficiently segment foreground text from the document image. They achieved 76 percent accuracy, but there was still a mismatch in classification.

3. Methodology

This involves the specification of procedures for collecting and analysing data necessary to define or solve the problem for which the research is embarked upon. Object Oriented Analysis and Design (OOAD) methodology was used during the software development because it has a way of looking at software components and how they interact with one another.

3.1 Analysis of the Existing Model

The existing system is a model developed by Khan et al. (2019). They developed an automatic ink mismatch detection technique that divides the spectral responses of ink pixels in handwritten notes into different clusters that correspond to the document's unique inks using Fuzzy C-Means Clustering. Sauvola's local thresholding technique is used to efficiently segment foreground text from the document image. The proposed technique was evaluated in terms of accuracy, which was defined as the number of correctly labelled pixels of an ink divided by that ink in either predicted or ground truth labelling. The results of experiments with black and blue ink combinations were shown, the high visible band performs the best in terms of discrimination, followed by the mid and low visible bands. Feature selection selects the best subset of features to optimize the best subsets for the best results. The experiments were carried out on a machine powered by an Intel Core i3 @ 2.40GHz processor using MATLAB R2017a. The execution time per hyperspectral document image was 4 seconds. They achieved 76 percent accuracy, but there was still a mismatch in identifying the forged document based on its ink classification.

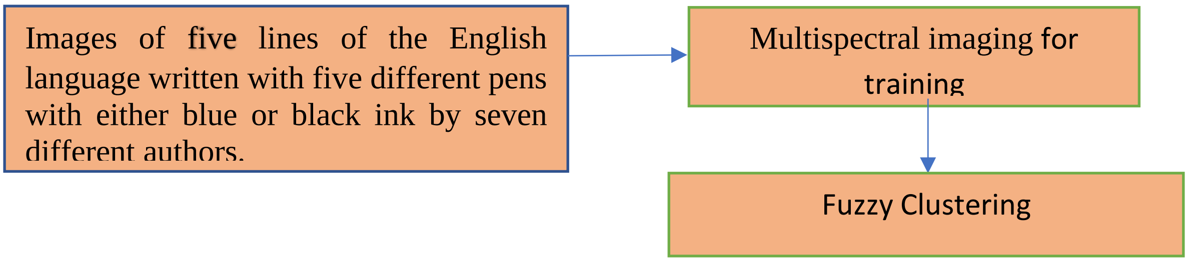

Figure 1a: Existing Model Architecture (Source: Khan et al. (2019).

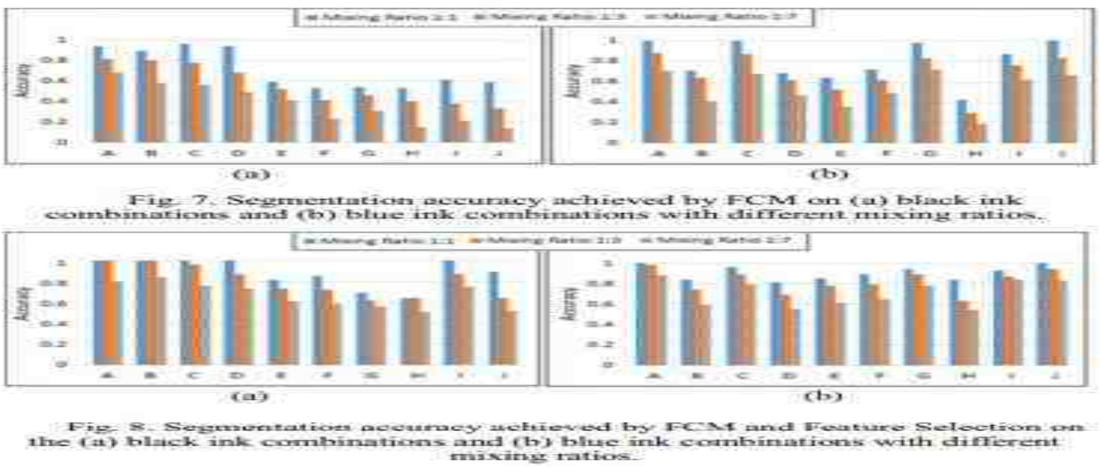

Figure 1b: Result analysis of the existing system. (Source: Khan et al. (2019).

3.2 Disadvantages of the Existing Model

The existing system has the following disadvantages:

v. The existing model noted that blue inks reported better results as compared to black inks because the spectral responses of blue inks are easily separable in the dataset.

vi. The existing model had a slow execution time rate of 4 seconds.

vii. The existing model still had a problem with classification because their system overall accuracy was 76% and 0.8933 accuracy.

3.3 Algorithm of the Existing Model

Step I:

Import the images.

Step II:

Train the images using Multispectral imaging.

Step III:

Predict the forge document using Fuzzy Clustering

3.4 Analysis of the Proposed Model

The proposed model is an enhancement of the existing system by Khan et al. (2019). The main purpose of this research is to ensure the system will be able to detect a person handwriting from that of another person's handwriting. The dataset contains a total of 44 images which is classified into 2 which are Hachi's handwriting and Non Hachi's handwriting. The dataset has 3 groups which are Training which contains 44 images, Validation set which contains 36 images and Test set which contains 15 images. The training dataset was used to train the system on the handwriting that belongs to Hachi and the one that is not Hachi's handwriting, the validation dataset was used to check the accuracy of the trained dataset. The image was called and the arrays of the image pixels where displayed. The images were rescaled 1/255, and the system was able to classify the two classes of image used and the numbers of images trained and produced the class indices. CNN model was used and 3 layers of hidden CNN was implemented in the system and a dense layer was used for activation. An optimizer was used to classify the accuracy of the trained set. The train and validation dataset were trained together in a model with 5 epoch per step and 50 epochs was done. The accuracy of the training set and the validation set is 1.000 at 3 seconds at the end of 50 epoch. At the end of the training the system was able to predict the handwriting that belongs to Hachi and that does not belong to Hachi.

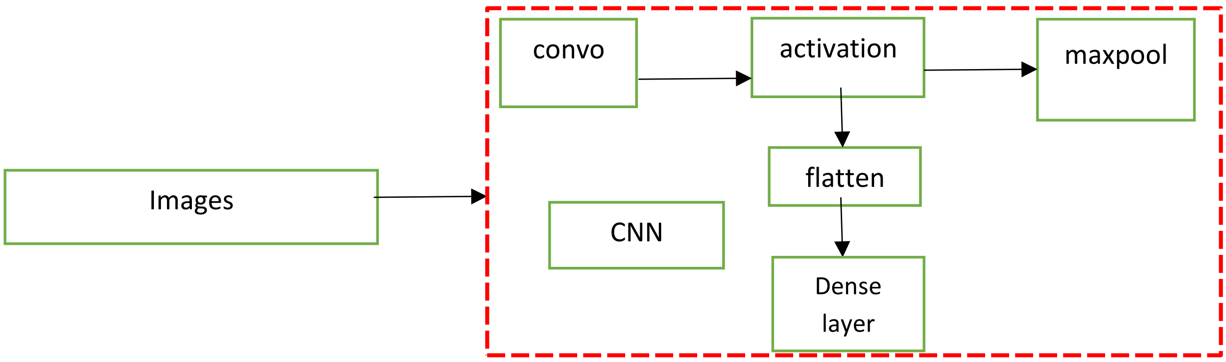

Figure 3a: Architecture of the Proposed Model

3.4.1 Advantages of the Proposed Model

The advantages of the proposed model include the following:

a. The proposed model provides higher performance since it can properly classify images.
b. The proposed model is faster than the existing system.
c. The proposed model uses Convolutional Neural Network which is best for
d. image classification.

3.4.2 Algorithm of the Proposed Model

Step I:

Import images.

Step II

The convolutional neural network train the model to classify the handwriting of the individual, and identifies the handwriting.

4 Implementation

The proposed model was develop using the Python programming language. The dataset used are pictures of two different handwriting with a total of 44 images which comprises of 44 images for Train, 36 images for
Validation and 15 images for Test.

4.1 Discussion of Results

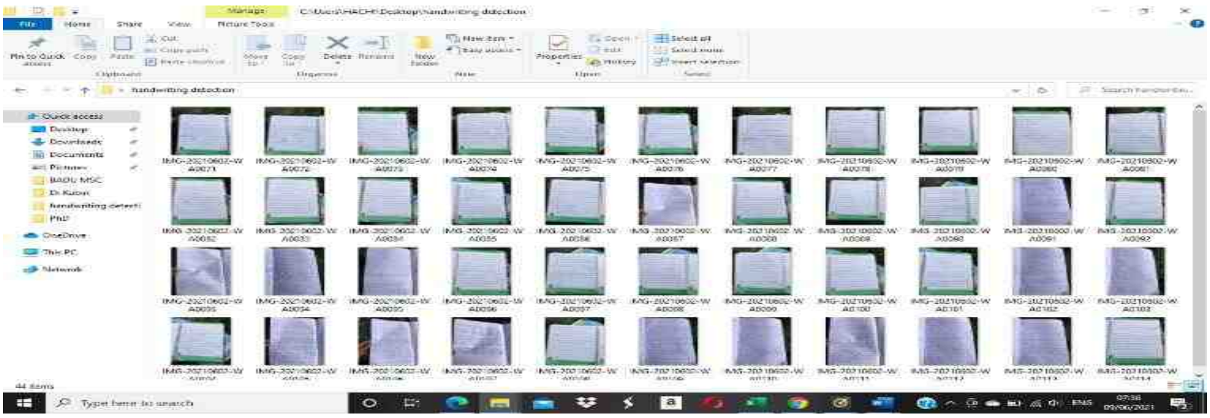

Figure 4 shows Dataset

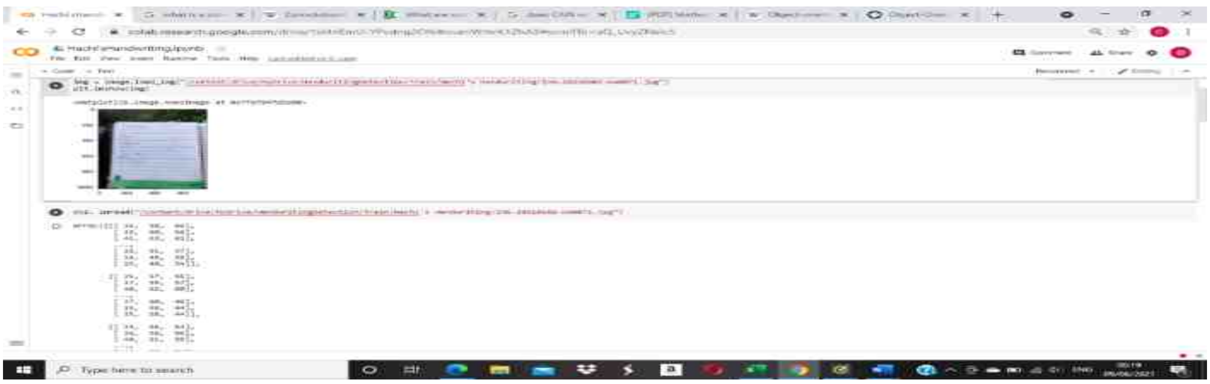

Figure 5: An image with its array size

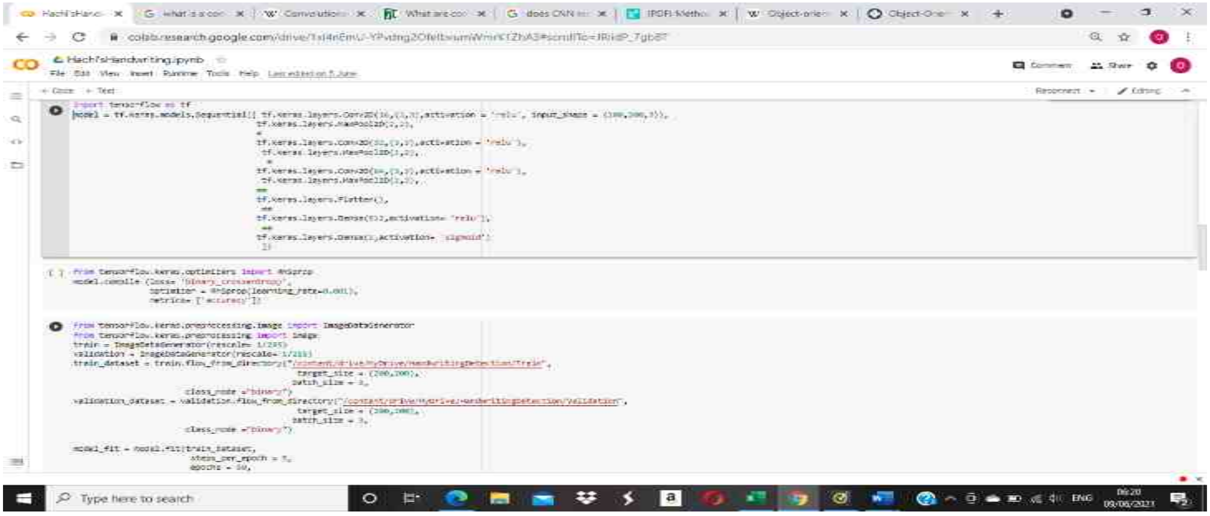

Figure 6: CNN model been used

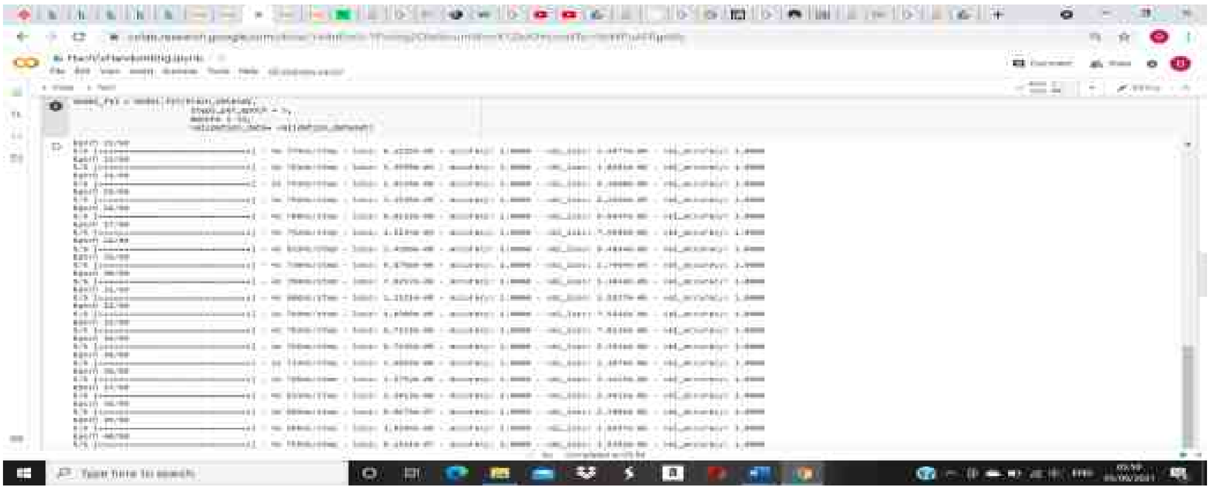

Figure 7: shows the training accuracy, the time it takes to train, the number of times to train and the accuracy result obtained which is 1.000.

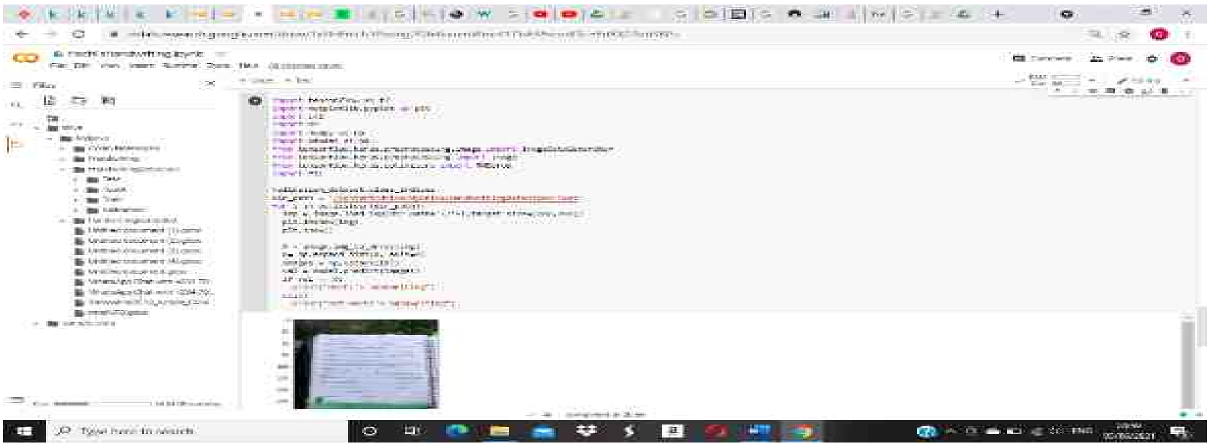

Figure 8a shows the codes used in predicting the results of the training.

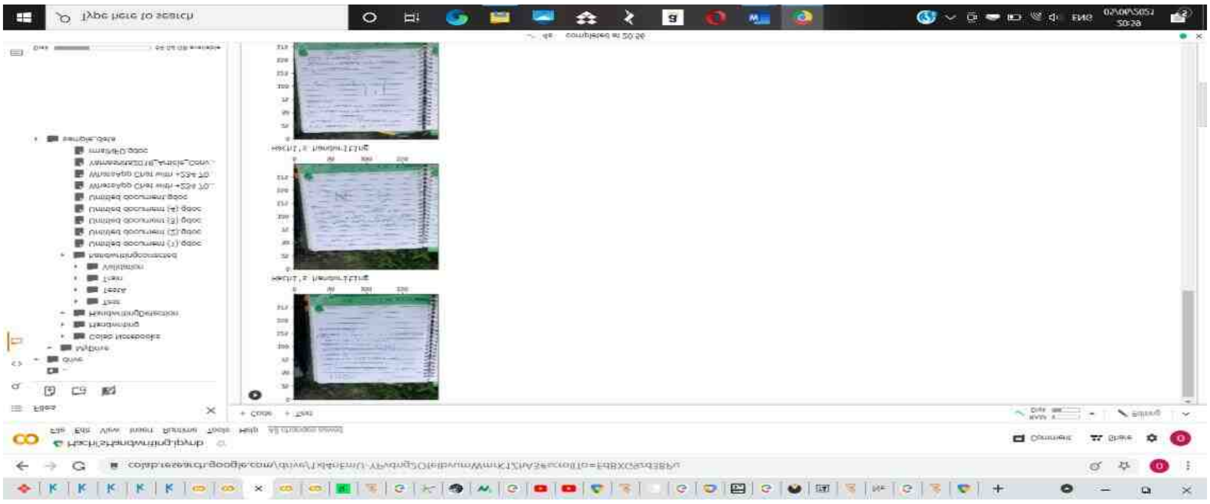

Figure 8b shows the right prediction of Hachi's handwriting.

Figure 8c shows the right prediction of non Hachi's handwriting.

Figure 5-8c shows the coding environment of the Python programming language using Google Colaboratory. The first figure shows the image been called and its array, the training dataset is use in training the model for the model to identify and know the images properly the validation dataset is used to validate the training dataset. The CNN model is use to determine the accuracy of the training dataset against the validation dataset to get the right threshold value, after the threshold value has been determined the model classifies the images by determining which handwriting the image belongs to. This system is fast, its training accuracy value have a threshold value of 1.000 and an accuracy of 98.7%.

Table 1 shows the Accuracy result gotten after training the model.

Epoch	Accuracy
1	0.5333
2	0.5714
3	0.6667
4	0.5333
5	0.7143
6	0.7333
7	0.6667

8	0.7333
9	0.8000 -
10	0.9333
11	0.9286
12	1
13	1
14	1
15	1
16	1
17	1
18	1
19	1
20	1
21	1
22	1
23	1
24	1
25	1
26	1
27	1
28	1
29	1
30	1
31	1
32	1
33	1
34	1
35	1
36	1
37	0.8571
38	1
39	1
40	1
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42	1
43	1
44	1
45	1
46	1
47	1
48	1
49	1
50	1

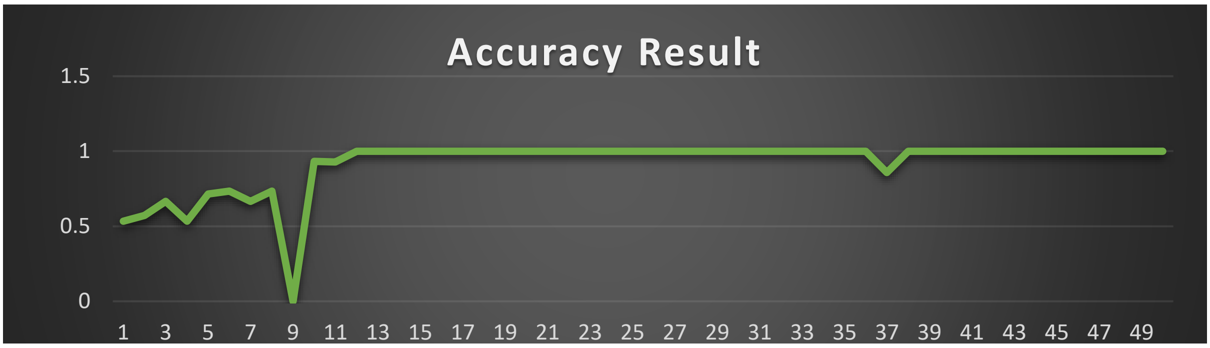

Figure 9 shows the Accuracy result graph.

Table 1 and Figure 9 shows the result of the Accuracy gotten after training the model using CNN.

4.1 Performance Analysis

Table 2 represents the parameters for evaluating the performance of our proposed model against the existing model. Our model achieved a more accuracy result of 1.000, at a less time of 3 secs and an overall performance of 98.7%.

Table 2: Performance Evaluation Table

S/N	Parameter	Existing Model	Proposed Model
1	Accuracy	0.8933	1.000
2	Time	4sec	3sec
3	Overall performance	76%	98.7%

5 Conclusion

Handwriting has been used in perpetuating crimes such as forgery, document fortification, exam malpractice, these crimes has been a major challenge in our society. We have proposed a model that can be used to identify the handwriting of an individual from that of another individual especially in the domain of examination malpractice. Our proposed model out performs the existing model in terms of accuracy of the training dataset, time of execution and overall performance of the model.

6 Contribution to knowledge

This study proposes a model for handwriting detection using graphology and convolutional neural network (CNN). The proposed model outperforms existing Handwriting forgery models.

7 Suggestion for future work

For future work, we suggest that a more areas of crime perpetuation on handwriting should be looked into and more techniques should be developed to solve this problem.

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