ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 3, Issue 7 , July 2016

Recognition of Handwritten Digits using Histogram of Oriented Gradients

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ABSTRACT: Off-line recognition of text plays a significant role in several applications, such as cheque verification and mail sorting. However, the selection of the technique for feature extraction remains a big challenging step for achieving high recognition accuracy. This paper presents an efficient handwritten digit recognition system based on HOG to capture the discriminative features of digit image. HOG features are extracted from all locations of a grid on the normalised digit image. These features are fed to the ANN for the purpose of classification. This work is tested with the ADBase database containing 70,000 digit images and a comparison is made against some of the existing techniques and promising results are obtained.

KEYWORDS: Handwritten digit, HOG, ANN.

I. INTRODUCTION

Today, off-line handwritten digit recognition in different languages of the world plays a significant role in several applications, such as automated processing of bank checks and automatic sorting of postal mail. Recognition of handwritten digits and assigning them to one of the 10 sets in Arabic (Indian) numerals is a difficult task due to the wide variety of styles, sizes and orientations of digit samples between different writers. There are several challenges in handwritten digit recognition which arise due to the nature of the handwriting style. Arabic (Indian) numerals are composed of 10 digits (0–9). Fig. 1 shows some sample images of handwritten Arabic (Indian) digits.

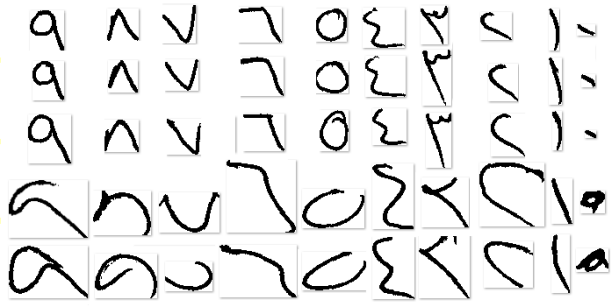

Fig. 1 Different Sample Images of Handwritten Digits

However, little research has been carried out in the field of Arabic (Indian) handwritten digit recognition compared to research in its Latin numbers [1 – 4] counterpart. Sabri [5] presented a system based on Gabor filters and Support Vector Machines (SVMs) for the recognition of Arabic (Indian) handwritten digits. Rashnodi et al. [6] proposed a technique using SVMs for recognition of handwritten Persian digits where Discrete Fourier Transform (DFT) is used for extracting features of the digit. EL Qacimy et al. [7] introduced an approach based on Discrete Cosine Transform (DCT) to extract features of handwritten digits. Al-Omari et al. [8] presented a system using an Artificial Neural Network (ANN) for recognition of handwritten digits. Babu et al. [9] proposed a system for handwritten digit recognition based on structural and statistical features and K-nearest Neighbour (KNN) classifier. Ebrahimzadeh and Jampour [10] presented an approach using Histogram of Oriented Gradients (HOG) and linear SVM for handwritten digit recognition. Lawgali [11] presented a technique based on Discrete Wavelet Transform (DWT) and DCT to capture the discriminative features of handwritten digits. A comparison between DCT and DWT to capture features of Arabic handwritten characters was introduced by Lawgali et al. [19]. However, the selection of the method for feature extraction remains a big challenging step for achieving high recognition accuracy. Therefore, in this paper, HOG is

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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used to capture discriminative features of Arabic (Indian) handwritten digits. These features are fed into the ANN for the purpose of classification.
The paper is organised as follows: Section 2 describes data acquisition and pre-processing; Section 3 discusses the technique used for feature extraction; Section 4 describes the classification stage; Section 5 discusses the results and their analyses; Section 6 concludes the paper.

II. DATA ACQUISITION AND PRE-PROCESSING

Arabic digits are read from the ADBase database [12], which is composed of 70,000 digits images and written by 700 different writers. The database is divided into two sets (60,000 digits for training and 10,000 digits for testing). The pre-processing task is used to remove the details that have no discriminative power in the process of recognition. Noise removal and binarisation are carried out in the development of the database [12]. Before extracting the features of the digits, the original digits are normalised by normalising the thickness and size. This is achieved by extracting the skeletons of the digits, which are then increased at a steady rate for all digits to achieve normalisation. The images of digits are resized to 45x45 for the purpose of normalisation [11].

III. FEATURE EXTRACTION

Selection of the method for feature extraction remains the most important step for achieving high recognition accuracy. Feature extraction techniques differ from one application to another. Techniques that may succeed in one application, may not be successful in the case of others [20]. These features should possess the essential characteristics of the digit which make it different from another. Therefore, in this paper, HOG is adopted to extract the features of the digits.

A. HISTOGRAM OF ORIENTED GRADIENT

Histogram of Oriented Gradient (HOG) was proposed by Dalal and Triggs [13] for the purpose of human body detection. Today, it is one of the most successful and popularly used descriptors in computer vision and image processing for the purpose of object detection [10]. HOG counts occurrences of gradient orientation in localised portions of an image. The essential thought behind the HOG descriptors is that local object appearance and shape within an image can be described by the distribution of intensity gradients or edge directions. This technique divides the image into small square cells and then computes the histogram of gradient directions or edge directions based on the central differences. HOG features are calculated by taking orientation histograms of edge intensity in a local region [14]. In this paper, HOG features are extracted from all locations of a grid on the digit image as candidates of the feature vectors.

IV. CLASSIFICATION

A classifier is used to identify the shape of digits by using the features obtained by applying HOG. These features are compared and saved as models for the trained classes. Features of an unknown a digit are extracted and compared with the features of the training models to identify the unknown digit shape. The common method used in the classification stage is the use of an ANN. ANN is widely used in the field of pattern recognition [15]. Therefore, it is used to identify the unknown shape of handwritten Arabic (Indian) digits via the features captured by HOG.

A. ARTIFICIAL NEURAL NETWORK

An Artificial Neural Network (ANN) is used to deal with the features that have been extracted from the digit. An ANN consists of processing elements with weights which are learned from the training data. Three layers are used in this paper for the architecture of the network: the input layer, the hidden layer and the output layer. Fig. 2 depicts an example of the architecture of the three-layered ANN. The input layer is fed by the features of the digit. The number of nodes in this layer depends on the number of features extracted by HOG for each digit. The last layer is called the output layer and the number of its nodes is based on the desired outputs. The hidden layer lies between the input and output layers. Feed-forward network Multi-Layer Perception (MLP) Back Propagation (BP) with supervised training

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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algorithm is used in this work. It is the best known paradigm of training that the ANN uses to classify patterns [16, 21]. A classifier is used to identify the digits by using their features obtained by applying HOG. 576 features are fed to the network as input signals. The number of nodes in the output layer depends on the number of digits (10 classes). The number of nodes in the hidden layer is chosen experimentally to be 160 nodes to achieve the best performance.

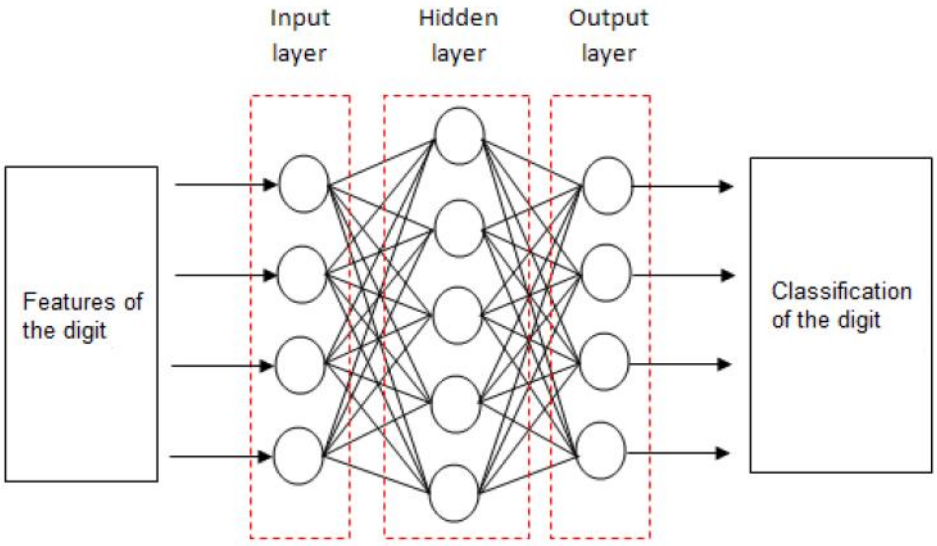

Fig. 2 The Architecture of the ANN Used

V. EXPERIMENTAL RESULTS

Experiments are carried out using an ADBase database containing 70,000 digits images written by 700 different writers, which are divided into two sets (60,000 digits for training and 10,000 digits for testing). HOG features are extracted from all locations of a grid on the normalised digit image. 576 features are used to recognise the digit. These features are fed to the ANN in the classification stage. The size of the images was set to 45x45 for experiments. The result achieved in the experiments is 98.26% recognition rate. Table 1 shows the performance of the system to recognise each class.

Class	Accuracy
0	97.50%
1	98.80%
2	97.70%
3	98.60%
4	97.80%
5	97.40%
6	99.20%
7	98.60%
8	98.70%
9	98.30%

Table 1. Recognition Rate for Each Class in the Proposed System

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 3, Issue 7 , July 2016

This current work has been compared with the previous approaches used. These approaches were assessed on the same dataset and the results of the comparison are shown in Table 2.

Approaches	Recognition rate
Approach 1 [17]	97.18 %
Approach 2 [18]	85.26 %
Approach 3 [11]	97.25 %
Our approach	**98.26 %**

Table 2. Comparison of our Results with Previous Works

Approach 1 [17] used polygonal approximations and fuzzy directional edges for recognition of handwritten digits while the DCT and Dynamic Bayesian Network (DBN) classifier is used in approach 2 [18]. Approach 3 [11] used DCT and ANN for recognition of handwritten digits. Fig. 3 shows the comparison of the performance of the effectiveness of HOG and DCT in capturing discriminative features of each class of Arabic handwritten digit with ANN in the classification stage. The results show that the feature extraction by HOG yields a higher recognition rate.

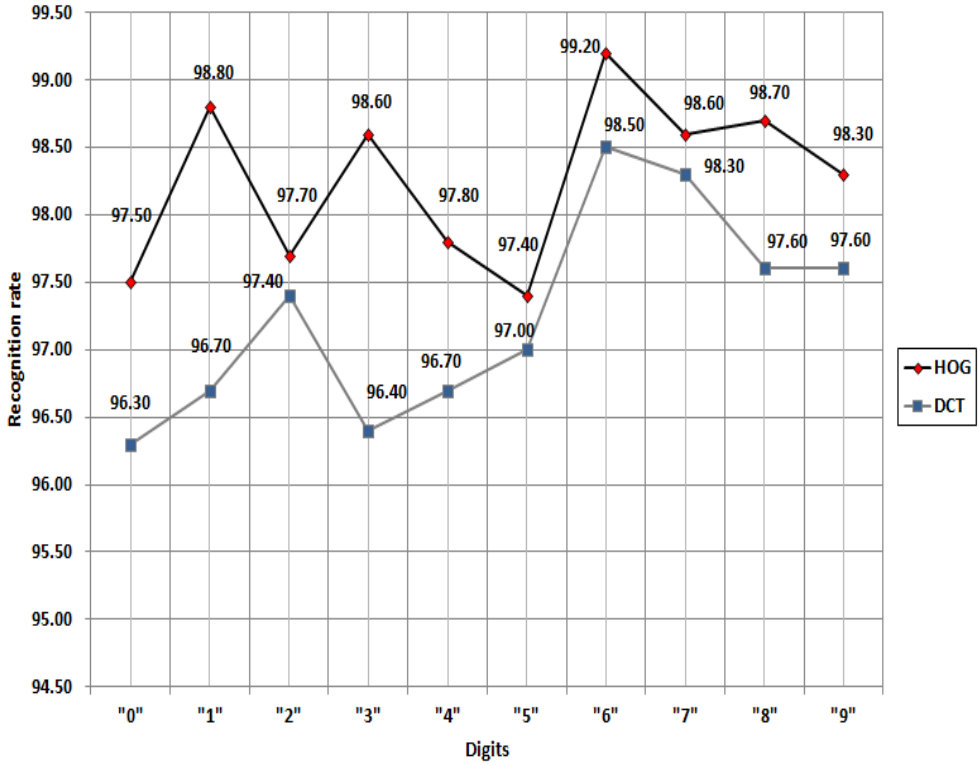

Fig. 3 A Comparison of two Methods to Recognise Each Class

VI. CONCLUSION

This paper presents a technique based on HOG to capture the discriminative features of handwritten digits. The experiments were applied on the ADBase database containing 70,000 digits images to classify them into 10 classes.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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Dr. Ahmed Lawgali obtained his bachelor's degree in Computer Science from the Faculty of Science, University of Garyounis, Benghazi, Libya in 1993. He obtained his master's degree in Computer Science from the Academy of Post Graduates Studies, Benghazi, Libya in 2006. His MSc thesis was the Traceability of Unified Modelling Language Diagrams from Use Case Maps. In 2013, Lawgali obtained his PhD in Computer Science from Northumbria University, Newcastle Upon Tyne, UK. His PhD thesis was the Investigation of Arabic Handwriting Recognition Based on Segmentation. He joined the College of Arts and Sciences (Al Abyar) – Benghazi University in 2007 as an assistant lecturer. In 2013, he was promoted to a lecturer and head of the Computer Science department. In 2016, Lawgali joined the Faculty of Information Technology – Benghazi University as a lecturer. Lawgali has published several scholarly articles in the area of handwriting analysis and recognition. His research interests lie in area pattern recognition, handwriting analysis and recognition, document recognition and biometrics.