Hybrid Firefly Algorithm with Artificial Neural Network (FA-ANN) Classification Model for Handwritten Character Recognition

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Abstract. This paper acknowledged the issues regarding HCR performances particularly in the classification stage. It is generally agreed that one of the main factors influencing performance in HCR is the development of classification model. As for the classification stage, the problems identified are related to classification model particularly in Artificial Neural Network (ANN) learning problem that results in low accuracy of handwritten character recognition. Thus, the aim of this study is to develop and enhance the ANN classification model in order to identify the handwritten character better. This paper proposed the hybrid Firefly Algorithm with Artificial Neural Network (FA-ANN) classification model for handwritten character. Firefly algorithm acts as optimisation approach in enhancing ANN particularly by optimize network training process of ANN. National Institute of Standards and Technology (NIST) handwritten character database was applied in the experiment.

1. Introduction

To date, Handwritten Character Recognition (HCR) still a challenge task among researchers although almost four decades the researchers working on it. Despite the fact that the research in HCR has been studied extensively for more than five decades, but yet still an active and challenging area since many researchers have been engaged in this topic in present [1,2, and 3]. In this paper, a recognition of handwritten character is proposed. HCR system usually has preprocessing, feature extraction and classification stages. However, this paper only concentrated on the final stage of HCR, the development of classification model for handwritten character. The process to implementing this stage begin with metaheuristic feature extraction algorithms that have been proposed from previous study [4 and 5] which were employed as chain code extractor in order to obtain the chain code features to represent the handwritten character image for recognition purpose as input for the classification model. As a classification model, hybrid firefly algorithm with artificial neural network (FA-ANN) classification model of handwritten character is proposed.

2. Proposed FA-ANN

This section describes the development of the proposed hybrid FA-ANN classification model for handwritten character. The FA that has been hybridized into the ANN classification model in the network training process. The FA is inserted into the ANN classification model at the same process the training of network started. An algorithm is created to be implemented in Microsoft Visual Studio programming. Figure 1 shows the algorithm of FA-ANN.
Step 1: Handwritten character dataset declaration  
Step 2: ANN parameter declaration  
Step 3: FA parameter declaration  
Step 4: FA Optimisation in Network Training  
  Step 5: Generate initial population of fireflies  
  Step 6: Train the Network  
  Step 7: Calculate the fitness function. MSE is utilised as fitness function.  
  Step 8: Choose the most attractive firefly based on lower MSE value.  
  Step 9: Improvisation of the population using (Equation 2.21)  
  Step 10: Calculate the fitness function for the new population.  
  Step 11: Update the position of fireflies with lower MSE value in the new population. Otherwise, keep the fireflies in their positions.  
  Step 12: Check the termination criterion. The algorithm stops if the termination criterion is satisfied. Otherwise, return to step 8.  
Step 13: Network Testing  

Figure 1. The FA-ANN Classification Algorithm

The FA-ANN is performed by used the data of handwritten character dataset of the source from the NIST database. Experiment on the proposed FA-ANN classification model is conducted using a list of feature vectors as an input and the output is character classes label. Whilst for the ANN parameter declaration, we set the layer for input, hidden and output. The number of nodes in hidden layer is based on Kolmogorov Theorem with $2n+1$ where $n$ is number of input layer. Later, FA parameter declaration as Step 3 of the proposed algorithm. There are four parameters declared a number of firefly, attractiveness ($\beta$), absorption coefficient ($\alpha$), and randomized parameter ($\gamma$). To clarify the terminologies and basic processes of the FA, Table 1 shows the equivalents terminologies of FA based on this study. The declaration of FA parameter values is based on previous work. The values suggested by previous work is in a range that gives advantage to reduce time as it gives a smaller range of trial and error in producing parameter values.

Table 1. FA Main Terminology of FA based on this study

| Terminology of FA          | Equivalent Terminology                                      |
|----------------------------|-------------------------------------------------------------|
| Firefly                    | Weight and biases of ANN as solution vector                 |
| Population of Firefly      | Population of solution                                      |
| Fitness Function           | Means Square Error (MSE) as error of ANN Network            |
| Attractiveness             | Best Solution according to Fitness Function                |
| Termination Criterion      | Minimum value of MSE and Maximum number of iterations       |
| Number of iterations       | Number of Epoch in ANN                                      |

Next is FA optimisation in network training process as Step 4 of the proposed algorithm. Supervised training is utilised as network training approach and FA as optimisation approach. Roughly, the input signal is propagated by each layer which is from input layer, hidden layer and the output layer. Each node in one layer connects with a certain weight to every node in the following layer. The input is processed by the network and the output results and desired outputs are compared. Errors are then propagated through the system and adjust the weights which control the network. The outputs from the training are the resulting map that contains the winning neurons and its associated weight vectors. Afterwards, these weight vectors are optimised by FA optimisation approach. This process is repeated over and over again until reaches the minimum error. The stopping conditions for the training are either Means Square Error (MSE) that has reached less than minimum error (0.05) or reach a maximum number of iteration (10000). The best error convergence rate of all the iteration until it achieves optimal solution is recorded and evaluated to investigate the behaviour of the network. Figure 2 shows the illustration process of FA towards optimising the ANN network. The illustration shows the process optimising the network of network training as covering the Step 5 until Step 12 of the FA-ANN algorithm. In order to design FA to train the network, there are some terms need to be highlighted:
i. The weights and biases of the network are presented as firefly in population of FA.
ii. The fitness function is defined as the light intensity in FA.
iii. The minimum error of MSE of the network is utilised as fitness function.

Figure 2. Illustration of Firefly Algorithm Optimisation in Network Training

3 Results Analysis and Evaluation

This section describes the analysis result of the proposed FA-ANN classification model for handwritten character. The result of proposed FA-ANN models is analysed based on the performance of the model in classifying the handwritten character. In order to have a clear understanding of the finding in each character class, an analysis using a confusion matrix is conducted for testing dataset. A 62x62 of confusion matrix is constructed. Based on the confusion matrix, there are four possible outcome which are True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN).

Then, the evaluation of the proposed FA-ANN classification model for handwritten character with the previous work is conducted. The proposed FA-ANN is compared to single ANN classification model [6] based on performances measurement in term of performance measurement. The performance measurement in term of precision, sensitivity, specificity, are utilised to evaluate the classification models for handwritten character.

Precision is a positive predictive value defined as the proportion of the TP against all the positive results (both TP and FP). Then, specificity measures the proportion of the negatives which are correctly identified (TN). As a result, in term of precision, sensitivity and specificity if the proportion is closer to 1 means the margin error is smaller, so indicates the better performances of classification model. Consecutively, the results of evaluation of performances of the proposed FA-ANN and ANN models in term of precision, sensitivity and specificity for each character are illustrated in Figure 3. The illustration clearly show that the FA-ANN model is better than ANN model in classifying the handwritten character recognition by obtained small margin error as the result of precision and sensitivity are closer to 1 for all character compared to ANN model. Subsequently in term of specificity, the illustration shows there is no different of distribution result obtained by both classification model. This mean both models are successfully performed in recognising the negative or the non-character correctly.
Lastly, to summarize the overall performances of the proposed classification model, a common performance measurement in terms of accuracy of the model and error rate are presented. Additional performance measurement F-score is also presented to obtain harmonic mean between the precision and sensitivity as the weight average is calculated between this two performances measurement. The result is shown in Figure 4.

4 Conclusions

This paper described the enhancement of the ANN by metaheuristic approach firefly algorithm as development of the proposed hybrid FA-ANN classification model for handwritten character recognition. The development of the hybrid FA-ANN consisted of three major processes and an algorithm of thirteen step is created based on the three major processes. Lastly, the evaluation of proposed hybrid FA-ANN with single ANN was presented in terms of precision, sensitivity, specificity, F-score, and accuracy. As a result, the proposed hybrid FA-ANN classification model obtained 1.59 percent incremental in terms of accuracy model. As a contribution, this paper presented the enhancement of ANN classification model by optimised
network the learning process of ANN with Firefly Algorithm (FA). FA acted as optimisation approach by modified the weights of the interconnections in satisfying the objective to minimise the error of the network. Summarily labelled as hybrid FA-ANN classification model to be executed in classifying the handwritten character.

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