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Research paper

An Automated Script Classification System Using Structure Optimization with Firefly Algorithm

T. S. Suganya,[1]*, Dr. S. Murugavalli[2],

[1] *Research Scholar, Sathyabama University Chennai, India*
[2] *Professor and Head, CSE Department, Panimalar Engineering College, Chennai, India*
**Corresponding Author Email: tssuganya@yahoo.com*

Abstract

The Tamil language is very ancient one with a very rich literature. Several writers used many different materials such as copper plates, mural paintings, conch shells, cloth, palm leaves, wood, and pottery, metal and stone for encrypting their writing. Any information that was gathered from such inscriptions has given us plenty of knowledge on education, administration, economic tax, religion, culture, history, and astronomy. All these epigraphical inscriptions have played a critical role in revealing the knowledge on past civilization and the character classification that belongs to the different time periods. This way, the system has been proposed for reading all ancient Tamil characters which belong to different periods by means of testing a very small amount of these characters in the Tamil language. All the characters that are examined have been obtained from the script and have been coordinated with all characters that belonged to the different periods by using machine intelligence. Thus, this system proposed contained several modules like the like segmentation, extraction of features, pre-processing, binarization, and acquisition of image, prediction, and classification of the script by employing the Artificial Neural Network (ANN). For this work, the metaheuristic algorithm inspired by nature called the Firefly Algorithm (FA) is introduced to train the ANN and to solve the problem of optimization. This FA has been based on the movements of the fireflies and their behaviour towards the light. For this, the behaviour of convergence and the performance of this proposed ANN training by using the FA has been analysed with the Back Propagation (BP) algorithm. The results of the simulation have proved the efficiency of computation in the process of training by making use of the technique of FA optimization.

Keywords: *Tamil Script Language; Handwritten Character Recognition; Neural Network (NN); Back Propagation (BP); Structure Optimization and Firefly Algorithm (FA);*

1. Introduction

Document image analysis is a very active area of research in the last few decades and this facilitates the establishment of paperless offices all the world over. The process of conversion of various textual symbols present in the printed and the handwritten paper for a format which is understandable by machines is called an Optical Character Recognition (OCR). This is found to be the very core of a document image analysis. An OCR technology for the Indian documents is now in an emerging stage and in most of the Indian systems of the OCR the documents are written using a single script. According to the Indian Constitution's [1] trilingual formula, every state Government will have to produce a document in the national language (which is Hindi) and an official knowledge (which is English) and the language spoken in the state (or the regional language).

India is a country which is both multi-lingual and multi-script having about 13 official scripts with another 23 official languages. A script is one set of notations representing one single language or a class of languages. If a certain script has been used for one single language, the identification of its script and the identification of its language are of the same meaning. Some examples of these scripts are Oriya and Dogri. At the same time, there have been several languages available with a common script for all. An example is the Devnagari script used by many languages like Hindi, Sindhi, Sanskrit, Nepali, Maithili, Marathi, Konkani and Bodo. The Roman script is used in English and the Santali languages in India. Thus, in the cases wherein there was a compulsory priori script identification, the system of Script Identification will vary based on the manner an input data is acquired (the text image), and the mode of the text that is acquired (either printed or handwritten). Since it has been mentioned already, the systems of script identification have been divided in accordance with raw data (the image) acquisition which is into two systems which are the Off-line and the On-line script systems of identification. It can be further divided into the Printed and the handwritten category depending on the acquired text [2].

The Script identification is the main step involved in the analysis of document image mainly when the environment is both multi-lingual and multi-script. An automatic scheme of the identification of the script is made useful to (i) sort all the document images, (ii) choose some suitable script-specific OCRs and (iii) the archives of an online search of document images that contain a certain script. The currently existing approaches to the script classification have been classified into two categories which are the local and the global approaches. By means of a local approach the analysis of a document image will be based on the level of a list of the components connected (such as the Line, the Word and the Character (LWC)) where components need image segmentation as a step in pre-processing. The global approach will employ an analysis of

the regions that comprise of a minimum of two lines and not need a fine segmentation like the LWC [3].

The character recognition in the Tamil language has been a very active research topic for the computer scientists throughout the world owing to their useful and real-life applications such as automatic data entry, form processing, and mail processing. The character recognition is an extremely classic problem in image processing and in Neural Networks (NN). A script that is used by the inscriptions is called the Tamil script and this differs in several ways from that of the given standard Asokan Brahmi [4].

The handwritten character recognition has been a very challenging task in the system of pattern recognition. There are several difficult things that are needed in several techniques of image processing. There are many difficulties for separating the cursive characters and the manner in which the unlimited styles of writing and character fonts can be recognised with the shape and different meanings like the character "o" and the number "0". There are also many different researchers that try applying the techniques to break through the complex problems in the character recognition. There are also several other applications taking advantage of handwritten character recognition such as the automatic mailing along with its classification, the non-keyboard system, and the automatic reading system. The Tamil alphabet contains 12 vowels and 18 consonants, and a combination of both vowels and consonants of about 216, along with a single Ayutha letter. The actual structure of the words in Tamil is written in a style of a four-line level.

Traditionally, the techniques in pattern recognition have been duly classified as the template based approach and the approach that is generally feature-based. In that of the former approach, there exists an unknown pattern which is superposed on the pattern of the template and their degree of correlation between two different decisions and classifications. There were some early OCR systems that had employed only the approach that had been based on the template but modern systems combine them with the approaches that are feature-based. The approaches that are feature-based will derive their properties (the features) from all their test patterns and employs them in a model which is very sophisticated classification. These feature-based approaches are of two different types which are the spatial domain and the transform domain. The former has derived its features directly from the representation of this pattern. In the technique of transform domain, a pattern image has been transformed into yet another space by means of using the Fourier, the Cosine, the Slant or the Wavelet transform with all their useful features derived from the transformed images. The syntactic or formal grammars, the moment-based, and the graph-theoretic based approaches have been tested for problems found in the OCR [5].

A group of modern techniques which have evolved and have not explicitly derived a feature from these patterns has been found. In the case of the training phase, either the raw or the normalized patterns will be fed to the system and this system will by its own adjust itself to bring down the error of such misclassification of patterns. The Artificial Neural Network (ANN) is the example of this system and it adjusts the link weight from the training patterns. The weights also work implicitly for the classification [6]. There is very little work that is done on the script recognition of the Indian languages. Most of these currently existing work are connected to the Bangla and the Devnagari script. There are, however, certain studies made on the recognition of other Indian languages such as Punjabi, Tamil, Telugu and, Gujarati. The NN classifier, their structural and their topological features had been based on a tree classifier have been used mostly for the recognition of Indian script. The technique of optimization was used for a better classification and also for ensuring an improvement in its accuracy.

For this work, an optimized structure of the NN that makes use of the FA for an automated script and its classification system is used. The rest of the work has been structured as below: All related work in the literature have been discussed in Section 2. The techniques employed in the work have been discussed in Section 3. Empirical outcomes are discussed in Section 4 and the work is concluded in Section 5.

2. Related Works

Obaidullah et al., [7] had proposed one more new word-level document image dataset containing 13 Indic languages that were from a total of 11 official scripts. This was composed of about 39K words equally distributed into 3K words in each language. For the various baseline results, there were five classifiers: The Multi-Layer Perceptron (MLP), the Fuzzy Unordered Rule Induction Algorithm (FURIA), the Simple Logistic (SL), the Bayesian Network (BayesNet) and the finally Library for linear classifier (LibLINEAR) using three different features which were state-of-the-art had been employed. They were the Spatial Energy (SE), the Wavelet Energy (WE) and finally the Radom Transform (RT), was used for extraction of the features with various combinations. The authors further observed that an MLP was able to aptly provide some better results when the features were used and this achieved a new accuracy which was bi-script of about 99.24% (considering the Roman common), about 98.38% (considering the Devanagari common) and the tri-script accuracy of about 98.19% (considering both the Devanagari and the Roman common).

Chaudhari and Gulati [8] had further presented a script identification of both Gujarati and English at the word level. For the case of a feature extraction, there was a directional energy distribution for the word by employing the Gabor filters has been used with some suitable orientations, as well as frequencies. This system proposed makes use of the Support Vector Machine (SVM) which was feature based classifier for classifying the features extracted found in the script. All results obtained were extremely encouraging.

Chaudhari and Gulati [9] had presented a new script identification of the Gujarati and the English language at the word level. In the case of a feature extraction, there are two different approaches that were used. In the very first approach the statistical features and in the next approach, Gabor features of the word that used the Gabor filters having suitable frequencies along with orientations that were extracted. The system that was proposed made use of two different classifiers, the K-Nearest Neighbour (KNN) and the SVM with many different kernel functions that had been used for the classification of the features extracted in a script. From this experiment, it was perceived that the SVM had outperformed the KNN.

Chacko et al., [10] had presented recognition of the handwritten Malayalam language by employing the Wavelet Energy Feature (WEF) and the Extreme Learning Machine (ELM). Wavelet energy (WE) is the new and robust parameter derived by using the wavelet transform. This further brings down the influence of various types of noise at all levels. The WEF also reflects the characters along with their WE distribution in different directions in various scales. All types of traditional learning algorithms for classifiers are slower than necessary and this makes it necessary to make use of that of a fast learning algorithm known as the ELM for the Single Hidden Layer Feed Forward Networks (SLFN), that will randomly identify all input weights and this will determine analytically all the output weights of an SLFN. Prasetio et al., [11] had constructed another new feature representation which was semi-automated which can further improve a model of machine learning application for feature recognition. This Deep Belief Network (DBN) had a new accuracy found in data classification which was dependant on a DBN structure. This work further makes use of a structure optimization of the DBN based on the evolutionary computation along with its combined technique. The experimental results of structural optimization of the DBN and

this indicates a new structure along with an improvement of about 100% of a simple and traditional dataset.

3. Methodology

There have been several other tasks that need completion even before the performance of character recognition. There is a handwritten image that has to be scanned and then converted into a format that is suitable for the purpose of processing. The pre-processing contains certain types of sub-processes for deciphering images and make them appropriate to continue the process of recognition in an accurate manner. These sub-processes that are involved in pre-processing are noise removal and binarization [12]. A Binarization converts the grey scale image (from 0 to 255 of the pixel values) into a binary image (from 0 to 1 of pixel values) by means of choosing a global threshold that separates the foreground from a background. In the case of noise removal, an input image of the historical inscriptions of Tamil have been degraded owing to the broken, the erased and the touching characters, the distortion owing to fossils that are settled along with the irrelevant symbols that are engraved. Non-uniform spacing existing between lines and characters in the epi-graphical images along with the skew may complicate the deciphering of a script. Thus, a technique known as the median filter was adopted for the removal of noise from all scripted images. As soon as a pre-processing is complete, there is an image that is free from noise which is passed to a segmentation phase in which the images are decomposed within some of the individual characters.

The feature extraction is the method with an automatic pattern recognition that is by making some measurements on patterns that need recognition and deriving the features from the measurements [13]. The strategy has been used for the recognition which is classified broadly into the structural, the statistical and the hybrid. The object and its shape will refer to the physical structure and the shape is represented by the moment, the region or the boundary. Such representations may also be used for the matching of shapes, making the measurement of the shapes and the recognising of objects. Hough transform is the technique that is used for detecting objects, curves and lines and also for extracting the linear features from datasets that are geo-scientific. The methods of conventional fusion of features will concatenate or also integrate different types of features.

3.1. Artificial Neural Networks with Back Propagation (ANN-BP)

The ANN is used as a tool for a resolution of various problems in decision modelling. The ANN being non-parametric does not make any guesses connected to the data sharing and permits the data to explain itself. This has made it a perfect option for the modelling of the medical issues which has huge datasets with clinical information. There are also three input layers found in the ANN that are the input, the intermediate (called hidden layer) and the output layers. There are several hidden layers present between two different layers [14].

- **Input –** the input units' behavior indicates the raw data given to networks.
- **Hidden –** the behavior of the hidden units gets decided by input unit activity and the weights on the links between input and hidden units.
- **Output –** the actual behavior of these output units will be dependent on the hidden units and also the output units.

The hidden layers will accept all data from input layers and the input values will be modified through the weight values and also a novel value sent to output layers. The output layer will process this information which is obtained from hidden layers and will generate output. The outputs will be processed using activation functions and the ANNs will be flexible with adaptive learning and also adjusting with both external and internal stimuli. The ANNs are used in a sequence along with the systems of pattern recognition, modelling and data processing. The structure of the ANN is depicted in Figure 1.

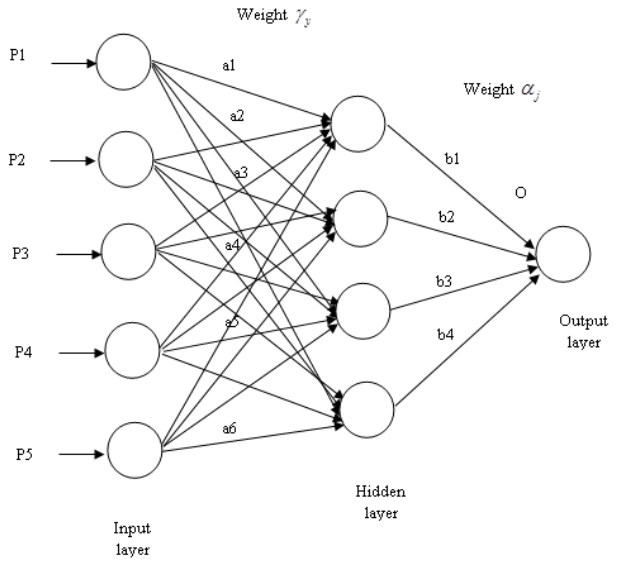

Fig 1: ANN structure

Generally, the ANN contains three different layers that are the input, hidden and the output. All these layers contain a set of neurons. For this, every neuron in the input will be linked with some hidden layer neurons and they are linked with that of the output layer having an arbitrary weight. There are some random weights that are assigned to every such interconnected layer.

Back Propagation (BP) [15 and 16] is an extremely popular technique that trains the ANNs and is employed with the optimization methods like the gradient descent. The method further calculates all the functions of the gradient of loss in relation to the weights that are found within the network. With the quantity of nodes which are found in the input, the hidden and the output layers n, k, and m. The overall quantity of all these instances in the input is the x_{pi} which implies that the P instance's ith input value, v_{ki} denotes the ith node for the input to a hidden layer of a kth node weight. The ω_{jk} implies a new node weight from the hidden layer of the k to that of its output layer of j. For making it convenient, the threshold is in the connection weights and the output of a hidden layer node which is k as per (1):

$$z_{pk} = f(net_{pk}) = f\left(\sum_{i=0}^{n} v_{ki} x_{pi}\right) \tag{1}$$

The output layer nodes for the node j will be as in (2):

$$y_{pj} = f(net_{pj}) = f\left(\sum_{i=0}^{n} w_{jk} z_{pk}\right) \tag{2}$$

Wherein, there is a standard sigmoid function that is selected to be the incentive function in (3):

$$f(x) = \frac{1}{1+e^{-x}} \tag{3}$$

A global error function will be as given in equation (4):

$$E = \sum_{p=1}^{P} E_P = \frac{1}{2} \sum_{p=1}^{p} \sum_{j=1}^{m} (t_{pj} - y_{pj})^2 \quad (4)$$

Wherein the E_P denotes the error of sample p, t_{pj} denotes its ideal result. The formulae for the adjustment of weights has been shown as:

A weight adjustment equation for neurons in the output layer are shown as in (5):

$$\Delta\omega_{jk} = \eta \sum_{p=1}^{p} \left(\sum_{j=1}^{m} \delta_{pi} \omega_{jk} \right) z_{pk} (1 - z_{pk}) x_{pi} \quad (5)$$

Wherein, the η duly represents the rate of learning and the general range falls between 0.1 - 0.3.

The equation for the adjustment of weights of the hidden layer neurons will be as in (6):

$$\Delta v_{ki} = \eta \sum_{p=1}^{p} \left(\sum_{j=1}^{m} \delta_{pi} \omega_{jk} \right) z_{pk} (1 - z_{pk}) x_{pi} \quad (6)$$

The actual notion of a BP will be is process of learning which has been further split into two different phases which are: the process of forward propagation with the input data which has been given through the processing that is made layer by layer for every hidden layer and also the actual output value that is for the unit of y_{pj} which has been computed. A 2nd phase will be its reverse procedure wherein if there is a failure of the output layer, it may get an anticipated value of output with the difference of an error that is the expected output. The technique that is called the Gradient descent will then alter the weights of the $\Delta v_{ki}, \Delta\omega_{jk}$, thus ensuring an overall error function to be at its minimal level.

The ANN architecture has been determined by the topological structure and its evolution enables them to adapt topologies to the various tasks without any human intervention. The learning rules have also be evolved and further regarded to be the process known as the "learning to learn" wherein the ANN adapts to these learning rules. It is considered to be the adaptive process of its automatic discovery of the learning rules [17]. The design of the optimal architecture found in the ANN is formulated to be a search problem in the space of the architecture for the wherein every point represents the architecture.

3.2. Structure Optimized Neural Network using Firefly Algorithm (FA)

The metaheuristic is also duly established to be a practical approach to the optimization of simulation. One such technique is the popular FA. The fireflies and their flashing light is a beautiful sight in the summer sky in the temperate and tropical regions. The flashing pattern is normally different from one species to the other. This is created by a process of bioluminescence and all functions of signalling systems are found to be quite confusing. But there are two main functions for drawing their mating partners. The intensity of the light in a certain distance that is r from a source of light that decreases with an inversely proportional distance. There is one more such restriction where air can absorb light getting weaker and further weak with travel. The fireflies are attracted towards more such brightness. The light, as well as its intensity, have been formulated in a way in which it is associated directly with the objective function which is to be optimized and create certain new algorithms known as the FA [18].

For the purpose of simplicity of the FA [19], there are three idealized rules which are considered: 1) all the fireflies are unisex and one gets attracted to the other irrespective of its sex; 2) the attractiveness is proportional to its brightness and the one that is less bright moves towards the one that is bright. The attractiveness will decrease with the distance and thus the intensity also decreases. In case there is no brighter firefly available, it will start moving randomly; 3) the firefly's brightness gets determined by that of the objective function's landscape. For the problem of an optimization for increasing a function, the brightness will be proportional to the objective function's value.

A procedure will begin with its initial population of their individuals that are generated randomly and the actual quality of these individuals are calculated through (7) thus choosing the best solution.

In the FA, the final form of attractiveness function for any firefly has been depicted by (7):

$$\beta(\gamma) = \beta_0 \exp(-\gamma r^2) \quad (7)$$

In which the r = denotes the distance which is found between two fireflies β_0 = denotes the initial attractiveness at the r = 0 and has been set to 1 as in this study γ = the absorption coefficient which controls the decrease of light intensity and has been to 1 in the work.

The actual distance between two fireflies i and j, at the positions x_i and x_j, are defined to be the Cartesian or the Euclidean distance as in (8):

$$r_{ij} = \| x_i - x_j \| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \quad (8)$$

Where the d denotes a dimensionality of a certain problem.

The actual movement of a firefly i towards its more attractive firefly j has been determined as in (9 and 10):

$$x_i = x_i + \beta_0 e^{-\gamma r_{i,j}^2} (x_i - x_j) + \alpha (rand - \frac{1}{2}) \quad (9)$$

$$x_i = x_i + \alpha * \left(rand - \frac{1}{2} \right) \quad (10)$$

As per equation (9), the term current position of a firefly and the second one has been used to consider the firefly's attractiveness towards its light intensity by its neighbouring fireflies and its third term denotes the random movement for a firefly which is the random part when it does not have the ones that are brighter. Coefficient α is the parameter of randomization which is determined by its problem of interest and the rand is the random number generator which is generated consistently within this space (0, 1). As per equation (10), the movement of its best candidate that is done randomly.

These solutions are encoded using the binary representation. The matrix representing an ANN architecture with the nodes that indicate either its presence or its absence of any connection from one node to another node. '1' will indicate a connection and '0' will indicate the connection.

The FA further generates the initial population for their candidate solutions in the ANN architecture weights. Once this is done, a light intensity will be calculated for the fireflies and the attractive one (the best candidate) gets identified from within the population. After this, the attractiveness along with the distance is calculated for the fireflies and finally, the attractive one will move within the search space in a random fashion. The process gets repeated until such time a termination criterion is duly met which means the maximum number of its generations have been reached

4. Results and Discussion

In this section, the shape features, Hough features and concatenation of features are used. Structure optimized NN using firefly and neural network with BP methods are also used. The classification accuracy, precision, recall and f measure as shown in tables 1 to 4 and figures 2 to 5.

Table 1 Classification Accuracy for Structure Optimized NN using Firefly

	Structure Optimized NN using Firefly	Neural Network with BP
Shape features	93.02	90.48
Hough features	93.97	91.75
Concatenation of features	94.92	93.02

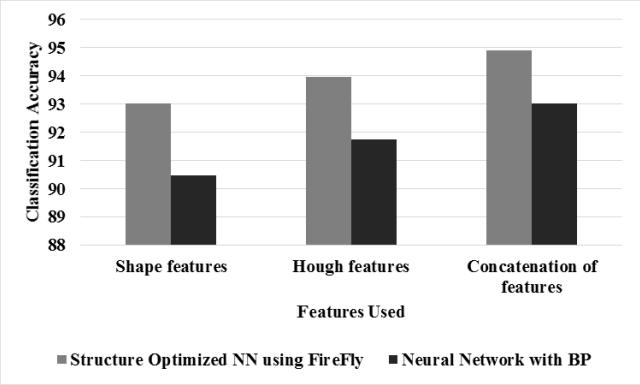

Fig. 2: Classification Accuracy for Structure Optimized NN using Firefly

From the figure 1, it can be observed that the structure optimized NN using firefly has higher classification accuracy by 2.76% for shape features, by 2.39% for Hough features and by 2.02% for concatenation of features when compared with neural network with BP.

Table 2 Precision for Structure Optimized NN using Firefly.

	Structure Optimized NN using Firefly	Neural Network with BP
Shape features	0.930177778	0.904766667
Hough features	0.939688889	0.917477778
Concatenation of features	0.949211111	0.930188889

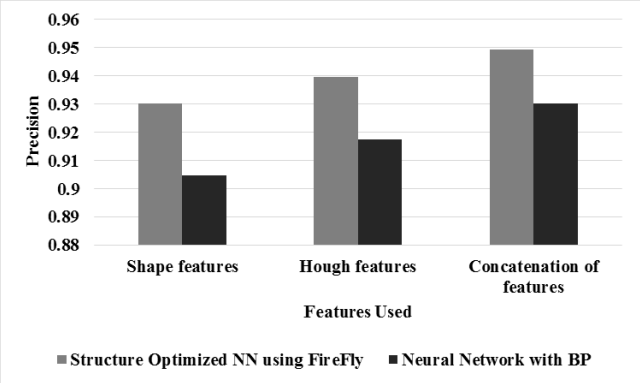

Fig 3: Precision for Structure Optimized NN using Firefly

From the figure 2, it can be observed that the structure optimized NN using firefly has higher precision by 2.76% for shape features, by 2.39% for Hough features and by 2.02% for concatenation of features when compared with neural network with BP.

Table 3 Recall for Structure Optimized NN using Firefly.

	Structure Optimized NN using Firefly	Neural Network with BP
Shape features	0.932777778	0.906033333
Hough features	0.941855556	0.918088889
Concatenation of features	0.950677778	0.930933333

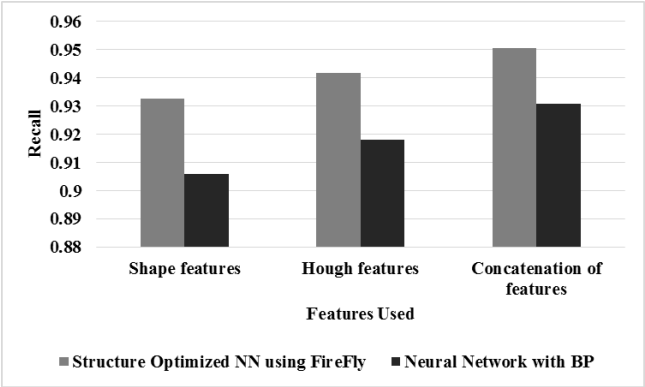

Fig 4: Recall for Structure Optimized NN using Firefly

From the figure 3, it can be observed that the structure optimized NN using firefly has higher recall by 2.9% for shape features, by 2.55% for Hough features and by 2.09% for concatenation of features when compared with neural network with BP.

Table 1: F Measure for Structure Optimized NN using Firefly

	Structure Optimized NN using Firefly	Neural Network with BP
Shape features	0.930644444	0.905
Hough features	0.939933333	0.917488889
Concatenation of features	0.949344444	0.9303

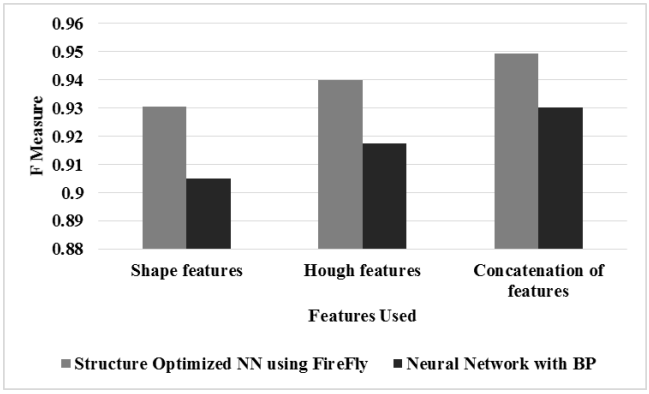

Fig 2 F Measure for Structure Optimized NN using Firefly

From the figure 4, it can be observed that the structure optimized NN using firefly has higher f measure by 2.79% for shape features, by 2.41% for Hough features and by 2.02% for concatenation of features when compared with neural network with BP.

5. Conclusion

The work further describes the system that recognizes the offline Tamil characters that make use of the ANN. The NNs are also used for solving problems in the classification of the human body and in calculating weights connecting various nodes. For this work, the hidden layer structure will not be modified since the interest is based on the weights and their calculation. For obtaining a feasible result, the NN and its weights will be calculated and further optimized by bringing down the function error or its cost. The FA is a simple and efficient metaheuristic technique of optimization that is inspired by the fireflies and their natural motion towards the light and is used for the purpose of training the NNs. The results have shown that this optimized structure with the NN that makes use of the firefly has a classification that is higher by about 2.76% for the shape features, by about 2.39% for the Hough

features and by about 2.02% for the concatenation of all the features on being compared to the actual neural network with the BP.

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