A novel artificial fish swarm algorithm for
pattern recognition with convex optimization

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Abstract—Image pattern recognition is an important area in
digital image processing. An efficient pattern recognition
algorithm should be able to provide correct recognition at a
reduced computational time. Off late amongst the machine
learning pattern recognition algorithms, Artificial fish
swarm algorithms one of the swarm intelligence
optimization algorithms that works based on population and
stochastic search. In order to achieve acceptable result, there
are many parameters needs to be adjusted in AFSA. Among
these parameters, visual and step are very significant in view
of the fact that artificial fish basically move based on these
parameters. In standard AFSA, these two parameters remain
constant until the algorithm termination. Large values of
these parameters increase the capability of algorithm in
global search, while small values improve the local search
ability of the algorithm. In this paper, we empirically study
the performance of the AFSA and different approaches to
balance between local and global exploration have been
tested based on the adaptive modification of visual and step
during algorithm execution. The proposed approaches have
been evaluated based on the four well-known benchmark
functions. Experimental results show considerable positive
impact on the performance of AFSA. A Convex optimization
has been integrated into the proposed work to have an ideal
segmentation of the input image which is a MR brain image.

Keywords—Image segmentation, fish school algorithms,
convex optimization, recognition rates

I. INTRODUCTION

Pattern recognition is a widely researched area ever
since the advent of intelligent machine learning algorithms.
Contribution in pattern recognition algorithms have been
more focussed towards increasing the classification
accuracy with minimum computation time over the past
decade. It finds a wide area of applications including
bioinformatics, document classification, image analysis,
data mining, industrial automation, biometric recognition,
remote sensing, handwritten text analysis, medical
diagnosis, speech recognition, GIS and many more.
Similarity between all these applications is that for a
solution-finding approach features have to be extracted and
then analyzed for recognition and classification purpose.
Three processes take place in pattern recognition task. First
step is data acquisition[7] [8]. Data acquisition is the
process of converting data from one form (speech, character, pictures etc.) into another form which should be
acceptable to the computing device for further processing.
Data acquisition is generally performed by sensors,
digitizing machine and scanners. Second step is data
analysis. After data acquisition the task of analysis begins.
During data analysis step the learning about the data takes
place and information is collected about the different
events and pattern classes available in the data. This
information or knowledge about the data is used for further
processing. Third step used for pattern recognition is
classification. Its purpose is to decide the category of new data on the basis of knowledge received from data analysis process. Data set presented to a Pattern Recognition system is divided into two sets: training set and testing set. System learns from training set and efficiency of system is checked by presenting testing set to it [3]. The performance of the pattern recognition techniques is influenced by mainly three elements (i) amount of data (ii) technology used(method) (iii) designer and the user. The challenging job in pattern recognition is to develop systems with capability of handling massive amounts of data. The various models opted for pattern recognition are: Statistical Techniques, Structural Techniques, Template Matching, Neural Network based techniques, Fuzzy models and Hybrid Models [2] [10]. They include a wide area like information about ocean depths, the arctic and Antarctic glacial drift and breakdowns, weather currents, gulf streams etc., SAR images have the edge over their optical counterparts in the fact that they have good penetration abilities and can be used as an all-weather and terrain data acquisition method.

![Pattern Recognition Scheme](image.png)

**Figure 1. General pattern recognition scheme**

In Statistical method of Pattern Recognition each pattern is described in terms of features. Features are chosen in such a way that different patterns occupy non-overlapping feature space. It recognizes the probabilistic nature both of the information we seek to process, and of the form in which we should express it [7]. It works well when the selected features lead to feature spaces which cluster in a recognizable manner, i.e. there is proper interclass distance. After analyzing the probability distribution of a pattern belonging to a class, decision boundary is determined [9], [3]. Here patterns are projected to pre-processing operations to make them suitable for training purposes. Features are selected upon analyzing training patterns. When conditional probability density distribution is known, parametric classification schemes are used otherwise non parametric classification scheme need to be used. Various decision rules are there to determine decision boundary like, Bayes Decision Rule, Optimal Bayes Decision Rule, The Maximum Likelihood Rule, Neyman-Pearson rule and MAP rule. As feature spaces are partitioned, system becomes noise insensitive, therefore in case of noisy patterns. The choice of statistical model is a good solution.

Depending upon whether the method opted is supervised or unsupervised statistical technique can be categorized as: Discriminant Analysis and Principal Component Analysis, where the former is a supervised technique in which we approach for dimensionality reduction [13]. Here linear combination of features is utilized to perform the classification operation. For each pattern class, a discriminant function is defined which performs the classification function. There is not a well-defined rule regarding the form of discriminant function like minimum distance classifier uses one reference point for each class, and discriminant function computes minimum distance from unknown vectors to these points, on the other hand nearest neighbor classifier uses set of points for each class.

Template matching is simplest and most primitive among all pattern recognition models. It is used to determine the similarity between two samples, pixels or curves. The pattern to be recognized is matched with the stored templates while assuming that template can be gone through rotational or scalar changes. The efficiency of this model depends upon the stored templates. Correlation function is taken as recognition function and is optimized depending on the available training set. The shortcoming of this approach is that, it does not work efficiently in the presence of distorted patterns. Neural networks are the massively parallel structures composed of “neuron” like subunits [9]. Neural networks provide efficient result in the field of classification. Its property of changing its weight iteratively and learning [14], give it an edge over other techniques for recognition process. Perceptron is a primitive neuron model. It is a two layer structure. If output function of perception is step, then it performs classification problems, if it is linear than it perform regression problems. The most commonly used family of neural networks for pattern classification is the feed forward networks like MLP and RBF networks [11]. Different types of neural networks are used depending upon the requirement of the application.

Feed Forward Back-propagation Neural Network (FFBP- NN) is used to implement non-linear differentiable functions. Increase in the learning rate in back-propagation neural network leads to decrease in convergence time [12]. General Regression neural network (GRNN)
is a highly parallel structure in which learning is from input side to output side [16]. General Regression Neural Network (GRNN) performs efficiently on noisy data than Back-propagation. FFBP Neural Network does not work accurately if available data is large enough. On the other hand in GRNN, as the size of data increases, the error approaches towards zero [33]. Kohonen-Networks are mainly used for data clustering and feature mapping [5]. Kandel et al has defined various techniques of fuzzy pattern recognition. Syntactic techniques are utilized when the pattern sought is related to the formal structure of language. Semantic techniques are used when fuzzy partitions of data sets are to be produced. Then a similarity measure based on weighted distance is used to obtained similarity degree between the fuzzy description of unknown shape and reference shape. Primitive approaches to design a Pattern Recognition system which aims at utilizing a best individual classifier have some drawbacks [10]. It is very difficult to identify a best classifier unless deep prior knowledge is available at hand. Statistical and Structural models can be combined together to solve hybrid problems. In such cases statistical approach is utilized to recognize pattern primitives and syntactic approach is then utilized for the recognition of sub-patterns and pattern itself. The works described in [8] gave the concept of attributed grammars which unifies statistical and structural pattern recognition approach. To enhance system performance one can use a set of individual classifiers and combiner to make the final decision. Tumer and Ghosh experimentally proved that using a linear combiner or order statistics combiner minimize the variance of actual decision boundaries around the optimal boundary. Multiple classifiers can be used in several ways to enhance the system performance. Each classifier can be trained in a different region of feature space or in other way, each classifier can provide probability estimate and decision can be made upon analyzing individual results. To achieve optimum results, a large set of combination functions of increasing complexity, ranging from simple voting rules through trainable combination functions is available to designer.

This paper is organized as follows. Section II describes the proposed methodology. Section III illustrates the experimentation results and analysis followed by conclusion in section IV.

II. PROPOSED WORK

A. Artificial Fish swarm algorithm

The artificial swarm or school algorithm is adapted from the social behavior exhibited from swarm of fish underwater. In underwater world, fish can find areas with more food based on their individual or swarm search. The proposed algorithm searches the problem space by those behaviors. The environment the artificial fish lives becomes the problem space. Objective function is to find maximum food density. Current position of AF is shown by vector \( X=(X_1, X_2, \ldots, X_n) \). The visual is equal to visibility domain of AF and \( X_0 \) is an intended position in visual where the AF selects to move towards. If \( X_n \) has better food density than current position, AF moves one step towards \( X_{n+1} \), which results in displacement of AF from \( X \) to \( X_{n+1} \). Otherwise, if the current position of AF is better than \( X_n \), it selects another position in its visual. Food density in position \( X \) is the fitness value of the position and is shown with \( f(X) \). The step is equal to maximum length of the movement. The distance between two AFs which are placed in \( X_i \) and \( X_j \) is shown by (Euclidean distance) \( \text{Dis}(ij)= || X_i - X_j || \). AF model consists of variables and functions. Variables are \( X \) (current AF position), step (maximum length step), visual (visibility domain), try-number (maximum attempts for finding better positions in visual), and crowd factor. It is an intelligent optimization algorithm which is designed by imitating the behaviors of fish swarm. The algorithm is an autonomous model based on four major behaviors, preying behavior, swarming behavior, following behavior, and random behavior, which fully perform the local search so that the population diversity is ensured maximally and local optimal solution avoids premature convergence.

B. Convex Optimization

Image segmentation is one of the most important problems in image processing and computer vision. The task is to group the image pixels into several regions or objects based on their intensity values. Energy minimization has become an established paradigm to formulate such problem mathematically, where both data/scene consistency and the regularity of the segmentation regions are encoded in an energy potential. A major challenge is to solve the resulting NP-hard optimization problems numerically. This work presents a jointly convex optimization framework for minimizing energy potentials of the form (4) over the regions and the parameters
associated with each region.

Figure 2. Flow process of optimization process

III. RESULTS AND DISCUSSION

The experimentation has been done on an Intel I3 3.5GHz processor with input test images taken from medical image database containing MR brain images for identifying the tumour patterns. The tumor image is pre processes and segmented by using convex optimization technique and features extracted followed by searching of optimal features by Fish swarm algorithm. Here it is clearly seen that the object is segmented from the background. The tumor part of the brain is seen separately from the other part of the brain. In this the recall rate and the execution time is calculated and compared with the different conventional methods with the support of number of input dataset.

Figure 3. Segmented MR image by a. FCM and Proposed method

The recall would indicate the proportion of correctly clustered states to the total number of actual positive states. Thus, a high precision and high recall are desirable for browsing behaviour detecting system. Figure 4 represents the recall rate comparison among the two different algorithms. This graph shows the recall rate of two different conventional methods based on two parameters of recall and number of Input images. From the graph we can see that, when the number of training size is improved the recall rate also improved in proposed system which is represented as blue line but when the number of number of Input images is improved the recall rate is reduced in existing system than the proposed which are represented. From this graph we can say that the recall rate of the proposed technique is increased which will be the best for the image segmentation.

Figure 4. Recall comparison of two different algorithms

The extracted features include mean, variance, standard deviation, area of segmented region, min and maximum pixel values. The recorded values are tabulated in table 1.

Table 1. Comparative analysis of feature extraction

| Images | Extracted Features |
|--------|-------------------|
|        | Mean   | Std_Dev | Min    | Max    |
| Proposed | 0.1314 | 2.0145  | 1.941  | 3.52   |
| Neural  | 4.110e-29 | 1.24e-32 | 0.14e-22 | 0.995e-12 |
| SVM     | 6.254e-30 | 1.98e-27 | 0.025e-2 | 0.418e-18 |

It could be seen that the proposed work provides a drastic reduction in the computation time. The accuracy results of the proposed work are also shown in table 2. The computation time is depicted in table 2.
Table 2. Computation time comparison

| S.No. | Algorithm   | Computation time (s) |
|-------|-------------|----------------------|
| 1.    | Proposed work | 09.14                |
| 2.    | Fuzzy       | 12.58                |
| 3.    | PCA         | 14.66                |

IV. CONCLUSION

For complex patterns and applications utilizing large number of pattern classes, it is beneficial to describe each pattern in terms of its components. A wise decision regarding the selection of Pattern grammar influences computations efficiency of recognition system. Pattern primitives and pattern grammar to be utilized depends upon the application requirements. Low dependence of neural networks on prior knowledge and availability of efficient learning algorithms have made the neural networks famous in the field of Pattern Recognition. Although neural networks and statistical pattern recognition models have different principles most of the neural networks are similar to statistical pattern recognition models. To recognize unknown shapes fuzzy methods are good options. As each model has its own pros and cons, therefore to enhance system performance for complex applications it is beneficial to append two or more recognition models at various stages of recognition process.

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