# A Meta-heuristic Approach for Image Segmentation using Firefly Algorithm

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***Abstract*** **— Image segmentation is one of the basic and important steps of image processing. Various methods for image segmentation using clustering techniques are available. The paper proposes a new meta-heuristic image segmentation approach which gives better result in comparison of other clustering technique (K-means). The experimental results show the effectiveness of proposed algorithm.**

**Keywords — Image Segmentation; Firefly Algorithm; K-Means Clustering**

## I. INTRODUCTION

Image Segmentation is one of the main steps of image processing, in which any image is being subdivided into multiple segments. Each segment will represent some kind of information to user in the form of color, intensity, or texture. Hence, it is important to isolate the boundaries of any image in the form of its segments [*1*]. Image segmentation is the first step and also one of the most difficult tasks of image analysis, which has objective of extracting information represented in the form of data from image. [*2*] [*3*]. In order to facilitate practical manipulation, recognition, and object-based analysis of multimedia resources, partitioning pixels in an image into groups of coherent properties is indispensable. This process is regarded as image segmentation [*4*]

The k-means algorithm is an iterative technique used to partition an image into k clusters. At first, the pixels are clustered based on their color and spatial features, where the clustering process is accomplished. Then the clustered blocks are merged to a specific number of regions. This approach thus provides a feasible new solution for image segmentation which may be helpful in image retrieval [*5*].

Firefly algorithm is one of swarm based algorithm that use for solving optimization problems and has been found superior over other algorithms in solving optimization problems. This algorithm is based on the flash producing behaviour of fireflies. [*6*]

Firefly algorithm is recently used for data clustering. A hybrid approach for data clustering using firefly algorithm integrated with k-means, called KFA, has been proposed [*7*]

## II. FIREFLY ALGORITHM

Firefly Algorithm (FA) was introduced by X. S. Yang [*8*] in 2008 based on flashing behaviour of fireflies. [*9*] Firefly uses its flash as a communication medium to attract other fireflies [*10*]. Firefly algorithm was developed to solve the continuous optimization problems initially. Firefly algorithm employs three idealized rules [*11*]:

1. All fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex;
2. Attractiveness is proportional to their brightness, thus for any two flashing fireflies, the less brighter one will move towards the brighter one. The attractiveness is proportional to the brightness and they both decrease as their distance increases. If there is no brighter one than a particular firefly, it will move randomly;
3. The brightness of a firefly is affected or determined by the landscape of the objective function.

In the firefly algorithm, there are two important issues: the variation of light intensity and formulation of the attractiveness. For simplicity, we can always assume that the attractiveness of a firefly is determined by its brightness which in turn is associated with the encoded objective function.

The *light intensity I(r)* varies with distance 'r' monotonically and exponentially, is given by:

$$I = I_0 e^{-\gamma r}$$

Where $I_0$the original light intensity and $\gamma$ is is the light absorption coefficient.

The *attractiveness* $\beta$ of a firefly is defined by:

$$\beta = \beta_0 e^{-\gamma r^2}$$

Where 'r' is the distance between each two fireflies and $\beta_0$ is their attractiveness at r = 0

The *distance between any two fireflies* i and j at $x_i$ and $x_j$ can be Cartesian distance given by:

$$r_{ij} = \| x_i - x_j \|_2 = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2}$$

The firefly 'i' *movement* is attracted to another more attractive (brighter) firefly 'j' is determined by:

$$x_i = x_i + \beta_0 e^{-\gamma r^2}(x_j - x_i) + \alpha \varepsilon_i$$

Initialization of the population of fireflies is the basic step in the process of firefly algorithm. The size of the population determines the number of solutions. In the next step, each firefly is evaluated based on their light intensity, called fitness. Distance between any fireflies can be defined as a Cartesian distance. The distance function developed is used to find the distance between two fireflies. Attractiveness function is defined by using light intensity, distance and an absorption coefficient. Movement of firefly is defined by a movement function. It is defined by using current position, attractiveness and a random walk [*12*]

## III. IMAGE SEGEMENTATION USING FIREFLY AND K –MEANS

### A. *Firefly and K-Means*

Data Clustering is a kind of unsupervised learning. K-means algorithm is famous clustering algorithm; it divided data into k clusters. The initial centroids are random selected. Each data point is grouped to the nearest centroid usually calculate the distance by the Euclidean distance. The new centroid is the mean of data in each cluster. The data point is re-grouped to the nearest centroid and the new centroids are calculated again and repeat this until convergence [*13*].

Clustering is a key initial procedure in image processing. A similarity criteria is defined between pixels, and then similar pixels are grouped together to form clusters. K-means is a fast clustering algorithm and can be easily used in image segmentation. [*14*]

In the k-means clustering, k center of cluster initial randomly because of this the algorithm may trapped in local optima. To improve and increase the accuracy of k-means algorithm firefly algorithm can be used to find the centroid of the user specified number of clusters.

To improve and increase the accuracy of k-means algorithm the initial centers are calculated by Firefly algorithm. The formation of centroids, which are computed iteratively from beginning to end, is guided by the searching agents of the firefly algorithm [*15*].

Let S be a solution space that contains a finite number of fireflies, $x_i$ *(i=1…N),* where N is the number of fireflies. K is the number of clusters required to be formed which is usually a user-defined parameter; D is the dimension of the search space, which is the number of attributes a data point has.

Let $cen_{j,v}$ be the centroids at $j_{th}$ cluster and $v_{th}$ attribute. $w_{i,j}$ is weight matrix defined as,

$$w_{i,j} = \begin{cases} 1, & x_i \in cluster_j \\ 0, & x_i \notin cluster_j \end{cases}$$

The centroids can be calcuted by:

$$cen_{j,v} = \frac{\sum_{i=1}^{S} w_{i,j} x_{i,v}}{\sum_{i=1}^{S} w_{i,j}}$$

Where *j*=1. . K, *v*= 1. . K*D

In the proposed method, for D-dimensional data and K clusters there are N fireflies with K*D dimension each. Euclidean distance is the objective function which must be minimum. The K-means clustering refine the centers.

The clustering objective function is defined as:

$$F(cen) = \sum_{j=1}^{K} \sum_{i=1}^{S} w_{i,j} \sum_{v=1}^{K*D} (x_{i,v} - cen_{j,v})^2$$

The clustering is formulated as:

$$clmat_{i,j} = min_{k \in K}\{\| x_i - cen_k \|\}$$

Where *i* =1..*N*, *j*=1..*S*, *k*=1..*K*

When *clmat* is small and is optimized, it means every point is as close as possible to the centroid.

### B. *Image Segmentation using KFA*

Following steps are required for image segmentation using KFA:

1. Let, ***I*** be the input colour image which is to be segmented.
2. The RGB image is then converted to L*a*b colour space.
3. The L*a*b colour space image is then converted into gray scale image.
4. Histogram equalization and frequency calculation is then done.
5. This frequency table is then passed to the K-means Firefly algorithm for clustering.
6. The points with the similar frequencies are grouped together to form clusters.
7. After the clustering is done, the centroid of the clusters is taken and the points corresponding to the cluster are replaced by the centroid in the original image.
8. The new image produces gray scale segmented image.
9. Calculate the peak-signal-to-noise-ratio between gray image and segmented image.

## IV. Experimental Results and Discussions


Figure 4.1.1
(Original Image)


Figure 4.1.2 (Converted Gray Image)


Figure 4.1.3 (Segmented Image using K-Means for 2 Clusters)


Figure 4.1.4 (Segmented Image using Firefly for 2 Clusters)

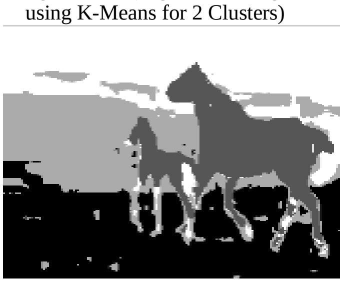
Figure 4.1.5 (Segmented Image using K-means for 4 Clusters)

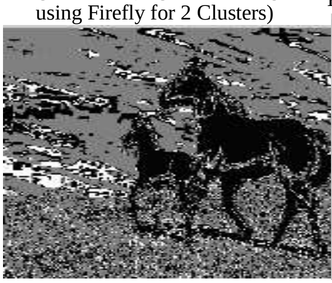
Figure 4.1.6 (Segmented Image using Firefly for 4 Clusters)

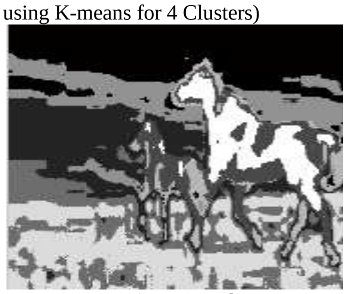
Figure 4.1.7 (Segmented Image using K-means for 8 Clusters)

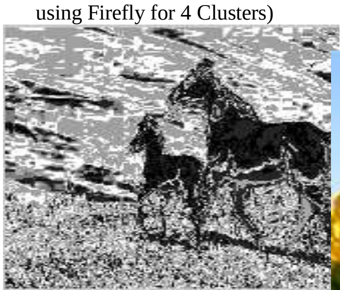
Figure 4.1.8 (Segmented Image using Firefly for 8 Clusters)


Figure 4.2.1 (Original Image)


Figure 4.2.2 (Converted Gray Image)


Figure 4.2.3 (Segmented Image using K-Means for 2 Clusters)


Figure 4.2.4 (Segmented Image Firefly for 2 Clusters)

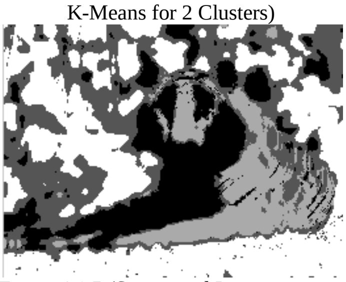
Figure 4.1.5 (Segmented Image using K-means for 4 Clusters)


Figure 4.1.6 (Segmented Image using Firefly for 4 Clusters)

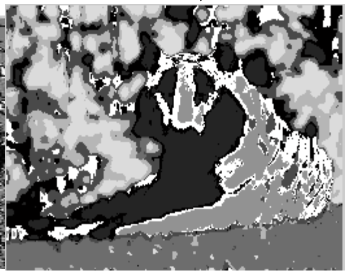
Figure 4.2.7 (Segmented Image using K-means for 8 Clusters)

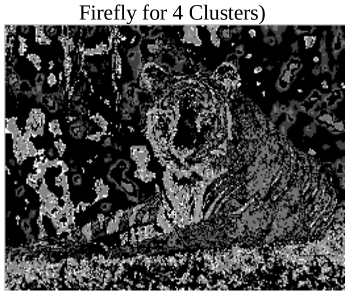
Figure 4.2.8 (Segmented Image using Firefly for 8 Clusters)


Figure 4.3.1 (Original Image)


Figure 4.3.2 (Converted Gray Image)

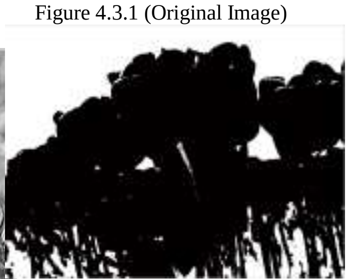
Figure 4.3.3 (Segmented Image using K-Means for 2 Clusters)

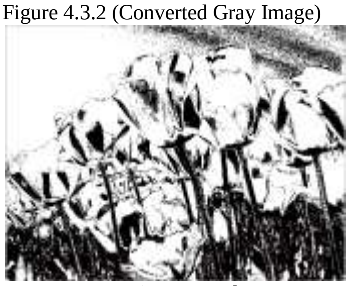
Figure 4.3.4 (Segmented Image using Firefly for 2 Clusters)

Figure 4.3.5 (Segmented Image using K-means for 4 Clusters)

Figure 4.3.6 (Segmented Image using Firefly for 4 Clusters)

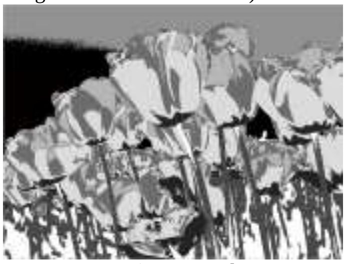

Figure 4.3.7 (Segmented Image using K-means for 8 Clusters)

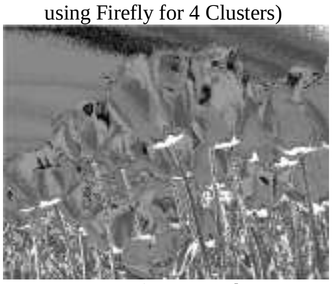

Figure 4.3.8 (Segmented Image using Firefly for 8 Clusters)

Figure 4.4.1 (Original Image)

Figure 4.4.2 (Converted Gray Image)

Figure 4.4.3 (Segmented Image using K-Means for 2 Clusters)

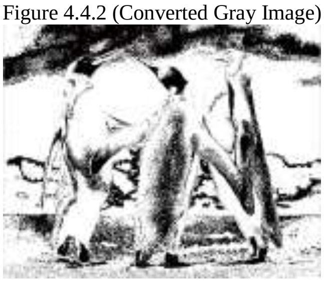

Figure 4.4.4 (Segmented Image using Firefly for 2 Clusters)

Figure 4.4.5 (Segmented Image using K-means for 4 Clusters)

Figure 4.4.6 (Segmented Image using Firefly for 4 Clusters)

Figure 4.4.7 (Segmented Image using K-means for 8 Clusters)

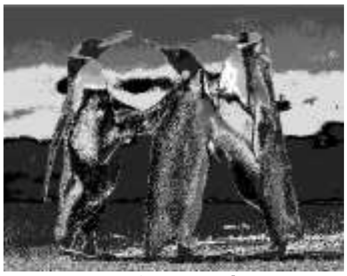

Figure 4.4.8 (Segmented Image using Firefly for 8 Clusters)

TABLE 4.1
TIME REQUIRED FOR EXECUTION OF THE ALGORITHM

| Image | Clusters | Time in seconds | |
|---|---|---|---|
| | | K-means | Firefly |
| Horse.jpg | 2 | 1.447804 | 0.671987 |
| | 4 | 1.599276 | 1.072813 |
| | 8 | 3.558944 | 1.660536 |
| Tiger.jpg | 2 | 1.182539 | 0.723807 |
| | 4 | 1.885442 | 1.680783 |
| | 8 | 5.562079 | 2.673582 |
| Tulips.jpg | 2 | 26.686108 | 8.009679 |
| | 4 | 38.818846 | 17.243903 |
| | 8 | 95.968382 | 17.728666 |
| Penguins.jpg | 2 | 9.820452 | 4.770519 |
| | 4 | 23.8266 | 9.753494 |
| | 8 | 102.249331 | 25.201823 |

TABLE 4.2
(DIFFERENCE OF TIME REQUIRED BETWEEN K-MEANS AND FIREFLY ALGORITHM)

| Image | Time (in seconds) | | Difference (%) |
|---|---|---|---|
| | K-Means | Firefly | |
| Horse.jpg | 1.599276 | 1.072813 | 49.07 |
| Tiger.jpg | 1.885442 | 1.680783 | 12.18 |
| Tulips.jpg | 38.818846 | 17.243903 | 125.12 |
| Penguins.jpg | 23.8266 | 9.753494 | 144.29 |

TABLE 4.3
(DIFFERENCE OF TIME REQUIRED BETWEEN K-MEANS AND FIREFLY ALGORITHM)

| Image | Peak-signal-to-noise-ratio | |
|---|---|---|
| | K-Means | Firefly |
| Horse.jpg | -6.315 | 13.7858 |
| Tiger.jpg | -7.6486 | 9.5653 |
| Tulips.jpg | -7.1146 | 15.2907 |
| Penguins.jpg | -8.4416 | 17.8984 |

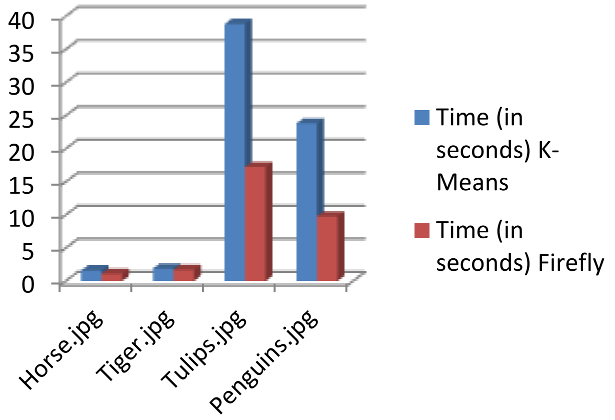


Figure 4.5(Graph for difference of time between K-Means and Firefly Algorithm)

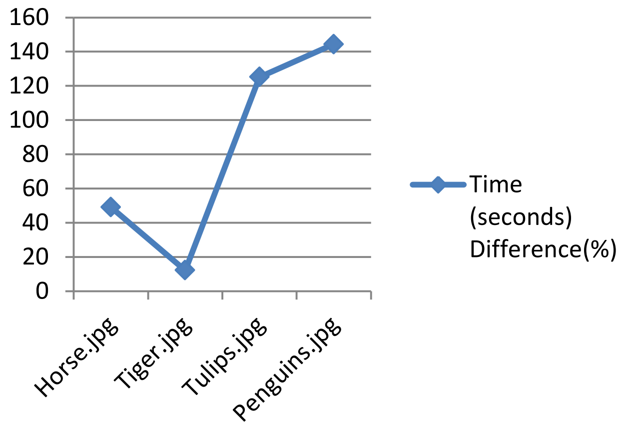


Figure 4.6 (Time gain in percentage)

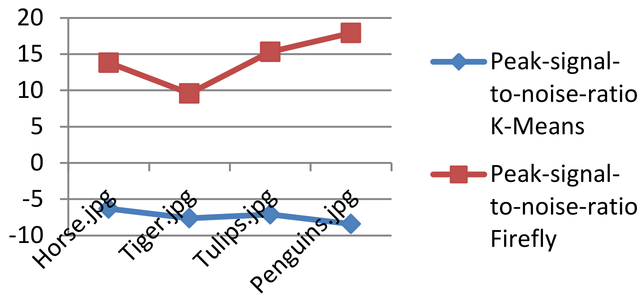


Figure 4.7 (Graph for PSNR)

The proposed algorithm was tested on four images for segmentation namely, Horse, Tiger, Tulips, Penguins. Figure 4.1, 4.2, 4.3 and 4.4 shows the experimental outputs of proposed algorithm and Kmeans Clustering algorithms.Table 4.1 shows the comparison of time required for execution of K-means and proposed algorithm. Table 4.2 depicts the percentage difference of time between K-means and Firefly algorithm. Table 4.3 illustrates the comparison of peak-signal-to-noise-ratio between Kmeans and proposed method. Figure 4.5, 4.6 and 4.7 shows the effectiveness of proposed algorithm over the standard K-means algorithm.

## V. CONLCLUSION AND FUTURE WORK

In this paper we presented a new meta-heuristic approach for image segmentation using Firefly algorithm. The experimental result shows that this approach produce better results compared to the traditional K-means clustering algorithm. Hence, this new approach can be effectively applied for image segmentation. The proposed algorithm can be used for color image segmentation with little or no change.

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