A Novel Approach to Image Segmentation using Artificial Neural Networks and K-Means Clustering

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ABSTRACT

This paper depicts the image processing algorithms that treat the problem of image segmentation. Both K-means cluster and neural network based on pixel RGB space colour are described like segmentation algorithms. A popular K-means clustering algorithm is used to obtain the homogenous regions of an image by grouping pixels in an image based on color and texture. A Biological Neural Network or simply BNN is an artificial abstract model of different parts of the brain or nervous system, featuring essential properties of these systems using biologically realistic models Artificial Neural Networks (ANNs) have been developed for a wide range of applications such as image enhancement, segmentation, feature extraction, and object recognition. Among these, image segmentation is more important as it is a critical step for high-level processing such as object recognition. With the K-means algorithm, one may get some faulty segmented pixels while the use of neural network techniques may increase the performance but some errors might remain. Artificial neural networks usually results in improved quality of segmentation reflecting the mean square error to be minimum. In this paper, we focus on the combination of all these methods and found that a much better performance can be achieved.

Keywords - **Backpropagation, Feature extraction, K-means, Segmentation, Wavelets**

1. INTRODUCTION

Images are considered as one of the most important medium of conveying information. Understanding images and extracting the information from them such that the information can be used for other tasks is an important aspect of Machine learning. K-Means algorithm is an unsupervised clustering algorithm that classifies the input data points into multiple classes based on their inherent distance from each other. In this paper, we focus at K Means clustering and neural networks and compare them for image segmentation. The comparison is based on various error metrics and time complexity of the algorithms. Nowadays, artificial neural networks (ANN) are applicable in many scientific fields such as medicine, computer science, neuroscience and engineering. They can be also applied in information processing system to solve pattern analysis problems or feature vectors classification [1] for example. The feed forward neural network is the most used neural network for medical image segmentation.

It has been observed that the feed forward neural networks based segmented images appear less noisy. However, most feed forward neural network based methods have a very slow convergence rate and require a priori learning parameters In our work, K-means clustering and artificial neural networks (ANN) are studied with the purpose of obtaining a set of algorithms that can be combined in order to achieve a better performance in image segmentation and a comparative study has been carried out to find out which algorithms perform best.

2. IMAGE SEGMENTATION

The main idea of the image segmentation is to group pixels in homogeneous regions and the usual approach to do this is by 'common feature'. Features can be represented by the space of colour, texture and gray levels, each exploring similarities between pixels of a region. The segmentation is treated as an image division of regions which are not coincident [2]. Image segmentation is the first step and also one of the most critical tasks of image analysis. There are different techniques that would help solve the image segmentation problem. Byoung [3] in his review of the previous related studies, categorized these techniques into the following: thresholding approaches, contour based approaches, region based approaches, clustering based approaches and other optimization based approaches using a Bayesian framework, neural networks [3].The clustering approaches can be categorized into two general groups: partitional and hierarchical clustering algorithms. Partitional clustering algorithms such as K-means are widely used in many applications such as data mining [4], compression, image segmentation [5], [6] and machine learning. Therefore, the advantage of clustering algorithms is that the classification is simple and easy to implement. Similarly, the drawbacks are of how to determine the number of clusters and decrease the numbers of iteration [7]. The feed forward neural network is the most used neural network for image segmentation .It has been observed that the feed forward neural networks based segmented images appear less noisy. Based on dynamic event-driven processing, spiking neuron networks open up new horizons for developing models with an exponential capacity of memorizing and a strong ability to fast adaptation [8]. The use of spiking neurons promises high relevance for biological systems and, furthermore, might be more flexible for computer vision applications [9]. Many of the existing segmentation techniques, such as supervised clustering use alot of parameters which are difficult to tune to obtain segmentation where the image has been partitioned into homogeneously colored regions.

3. ARTIFICIAL NEURAL NETWORKS

Artificial neural networks are computational paradigms based on mathematical models that unlike traditional computing have a structure and operation that resembles that of the mammal brain. Artificial neural networks or neural networks for short, are also called connectionist systems, parallel distributed systems or adaptive systems, because they are composed by a series of interconnected processing elements that operate in parallel Artificial neural networks (ANNs) [10] are networks of simple processing elements operating on their local data and communicating with other elements. One of the original aims of artificial neural networks (ANN) was to understand and shape the functional characteristics and computational properties of the brain when it performs cognitive processes such as sensorial perception, concept categorization, concept association and learning. One of the significant advantages to use ANN is the fact that it can take decisions based on complex and noisy data. Moreover, the ANN can generalize patterns which were not manipulated in its learning stage [2]. Hence, the new patterns can be correctly classified.

3.1 BACKPROPAGATION ALGORITHM

The algorithm we'll use to train the network is the Backpropagation Algorithm. The general idea with the backpropagation algorithm is to use gradient descent to update the weights so as to minimize the squared error between the network output values and the target output values. The update rules are derived by taking the partial derivative of the error function with respect to the weights to determine each weight's contribution to the error. Then, each weight is adjusted, using gradient descent, according to its contribution to the error. The back-propagation algorithm has emerged as the workhorse for the design of a special class of layered feed forward networks known as multilayer perceptrons (MLP). As a training algorithm, the purpose of back-propagation is to adjust the network weights so the network produces the desired output in response to every input pattern in a predetermined set of training patterns. The error function measures the cost of differences between the network outputs and the desired values. The sum-of-square error (SSE) defined in equation (1) is a common choice.

$$E_{SSE} = \sum \sum (t_{pi} - y_{pi})^2 \qquad (1)$$

In equation (1), p indexes the patterns in the training set, i indexes the output nodes, and tpi and ypi are, respectively, the target and actual network output for the ith output node on the pth pattern. The mean-squared-error (MSE) normalizes E_{SSE} for the number

$$E_{MSE} = (1/PN)\, E_{SSE} \qquad (2)$$

of training patterns P and network outputs N as indicated in equation (2). Advantages of the SSE and MSE functions include easy differentiability and the fact that the cost depends only on the magnitude of the error.

3.2 SEGMENTATION WITH ANN

The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image.. In the proposed work, we have implemented image segmentation using artificial neural networks (ANN). Initially, the feed forward neural networks are initialized and trained with faster back-propagation algorithm. After training, these networks are simulated. The various features extracted from the image are assigned as the input patterns to the ANNs. As the network is two layered, we take into account two activation functions. For training the network, we have defined parameters such as sum squared error performance function which is used to calculate the performance of the network during training whenever train is called. To create a network that can handle noisy input vectors, it is best to train the network on both ideal and noisy vectors. Network is first trained on ideal vectors until it has low sum squared error. All training is done using back-propagation with both adaptive learning rate and momentum with the function trainbpx. An optional parameter is defined to set the number of epochs between feedback during training. Finally a trained network is created. This trained network is further simulated. Wavelets are used for feature extraction .We have also computed difference (errors) between the ANN output and targets. We found that when there exists no error then the difference between the ANN outputs and the targets are zero. The classification stage is composed of a 3-layered NN, which is based on the multilayered perceptron (MLP) The segmentation system classifies each region automatically.

4. VARIOUS CLUSTERING TECHNIQUES

Clustering refers to the process of grouping samples so that the samples are similar within each group. The groups are called clusters. Clustering is a data mining technique used in statistical data analysis, data mining, pattern recognition, image analysis etc. Different clustering methods include hierarchical clustering which builds a hierarchy of clusters from individual elements. Because of its simplicity and efficiency, clustering approaches were one of the first techniques used for the segmentation of (textured) natural images [11].In partitional clustering; the goal is to create one set of clusters that partitions the data in to similar groups. Other methods of clustering are distance based according to which if two or more objects belonging to the same cluster are close according to a given distance, then it is distance based clustering. In probabilistic clustering, data is picked from mixture of probability distribution and we use the mean, variance of each distribution as parameters for cluster. In this paper, we have focused on K-means clustering approach for performing image segmentation using Matlab software. K-Means clustering generates a specific number of disjoint, flat (non-hierarchical) clusters.. Hierarchical clustering is also widely employed for image segmentation [12][13]. The most popular method for image segmentation is k-means clustering [14][15].

4.1 K-MEANS CLUSTERING

Clustering refers to the process of grouping samples so that the samples are similar within each group.The groups are called clusters. The K-Means is a nonhierarchical clustering technique that follows a simple procedure to classify a given data set through a certain number of K clusters that are known a priori. The K-Means algorithm updates the space partition of the input data iteratively, where the elements of the data are exchanged between clusters based on a predefined metric (typically the Euclidian distance between the cluster centers and the vector under analysis) in order to satisfy the criteria of minimizing the variation within each cluster and maximizing the variation between the resulting K clusters [16]-[17].. In addition, it is sensitive to the initialization process that selects the initial cluster centers. If the initial cluster centers are initialized on outliers, the algorithm will converge to local minima and this is one of the major drawbacks of this space partitioning technique.
Since the pixel assignment is performed only by evaluating the color information in a certain color space, the connection between the data point under evaluation and its neighbors is not taken into account, a fact that will lead to a partition of the input data into regions that are not related to the scene objects [18]-[19]. Although this clustering is convergent and its aim is to optimize the partitioning decisions based on a user-defined initial set of clustering that is updated after each iteration, K-Means algorithm produces accurate segmentation results only when applied to images defined by homogenous regions with respect to texture and color since no local constraints are applied to impose spatial continuity.

5. SIMULATION RESULTS

5.1 SEGMENTATION RESULTS OF K-MEANS

a) deer.jpg

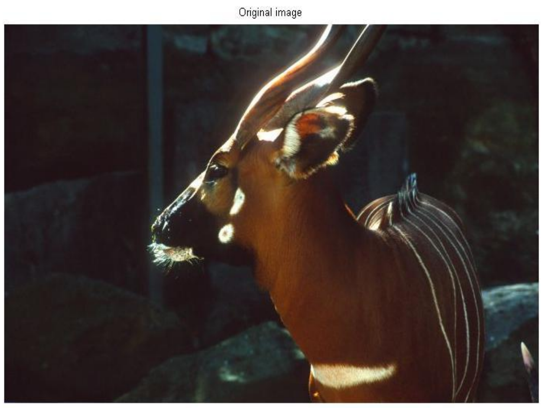

Figure1: Original Image of deer.jpg

Figure2: Segmented Image of deer.jpg

b) flower_foveon.jpg

Figure3: Original Image of flower_foveon.jpg

Figure4. Segmented Image of flower_foveon.jpg

Figure 1 and Figure 3 represents the original image to be segmented. Using the results of k-means clustering, every pixel of the image is labelled. Once all the pixels are labelled, we can separated them based on colour resulting in different segmented images. Figure 2 and Figure 4 shows the segmented image of deer.jpg and flower_foveon_glass.jpg respectively.

5.1.1 SEGMENTATION RESULTS WITH K-MEANS

Parameters	Image 1 deer.jpg	Image 2 flower_foveon.jpg
PSNR	17.6332	15.6654
MSE	11150.1	11333.7
MAE	73.0987	80.0612
NCD	1.63193	1.24175

. 5.2 SEGMENTATION RESULTS WITH ANN

Parameters	Image 1 deer.jpg	Image 2 flower_foveon.jpg
Algorithm applied	Back Propagation Algorithm	Back Propagation Algorithm
R	2	2
S1	400	400
S2	1	1
Q	1024	1024
Momentum Constant	0.1	0.1
Gradient	1.7251	1.0167

The above table shows the segmentation results of ANN where [R,Q] denotes the size of the input patterns to the ANN and [S2,Q] denotes the size of targets.

5.2.1 RESLTS OF ANN DURING TRAINING

In the proposed work, the feed forward neural networks are initialized and trained with faster back-propagation algorithm.. The general idea with the backpropagation algorithm is to use gradient descent to update the weights so as to minimize the squared error between the network output values and the target output values. The update rules are derived by taking the partial derivative of the error function with respect to the weights to determine each weight's contribution to the error. Then, each weight is adjusted, using gradient descent, according to its contribution to the error. . The various features extracted from the image are assigned as the input patterns to the ANNs. For training the network, we have defined parameters such as sum squared error performance function which is used to calculate the performance of the network during training whenever train is called. To create a network that can handle noisy input vectors, it is best to train the network on both ideal and noisy vectors. Network is first trained on ideal vectors until it has low sum squared error. All training is done using back-propagation with both adaptive learning rate and momentum with the function trainbpx. An optional parameter is defined to set the number of epochs between feedbacks during training. Finally a trained network is created. This trained network is further simulated.

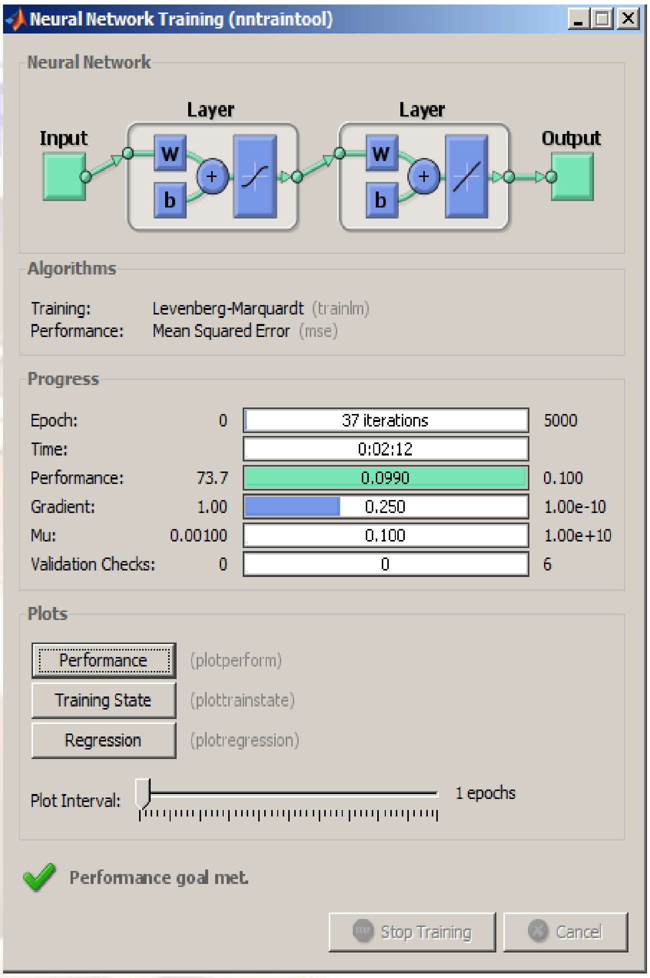

Figure5: Training Neural Network with Levenberg-Marquardt Algorithm for image flower_foveon.jpg.

In the proposed work, we adapted 5000 epochs for training the network and the progress display is shown after every 20 epochs. Finally the trained network is tested for errors. The neural network took 37 iterations to meet the performance goal. Network goal is kept minimum for good accuracy.

5.2.2 GRAPHICAL ANALYSIS

The performance plot shows a graph plotted between mean square error and number of epochs. It is seen that the best training performance was meet at epoch 2 and the mean square error gradually decreases with the gradual increase in number of epochs.

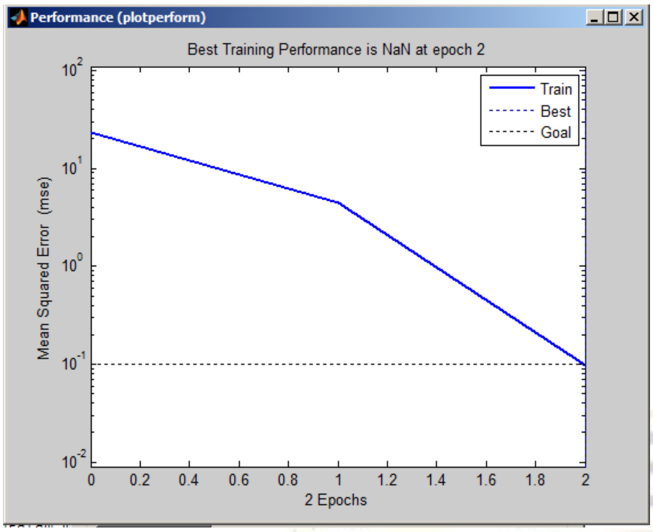

Figure6: Plot of MSE versus number of epochs for the image deer.jpg

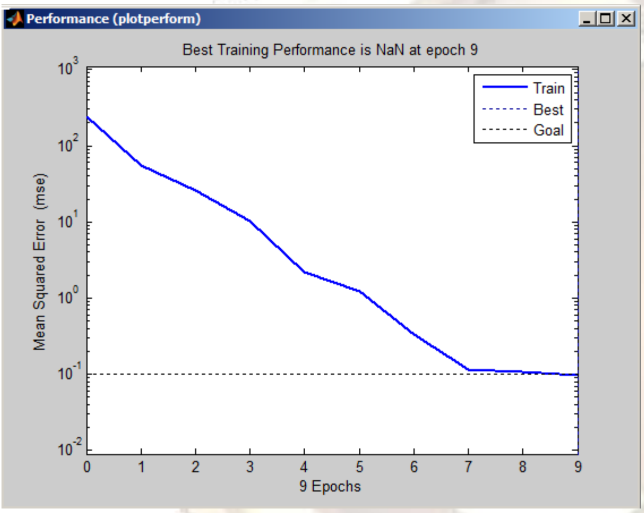

Figure7: Plot of MNSE versus number of epochs for the image flower_foveon.jpg

CONCLUSION

In the current work, we have reviewed some existing methods of segmentation based on clustering and neural networks. K-Means works well when clusters are not well separated from each other. It minimizes intra-cluster variance, but does not ensure that the result has a global minimum of variance. MLF neural networks are very robust,i.e. their performance degrades gracefully in the presence of increasing amounts of noise .The big problem is the fact that ANNs cannot explain their prediction, the processes taking place during the training of the network are not well interpretable and this area is still under development [20,21].The number of weights in an ANN is usually quite large and time for training the ANN is too high... To see if segmentation is close to the original image, an error metric is needed. For this evaluation we had used the Peak Signal Noise Ratio (PSNR), the Mean Square Error (MSE), the Mean Absolute Error (MAE) and Normalized Color Difference (NCD) are therefore considered to evaluate the segmentation. It is clear that with the K-means algorithm, one may get some faulty segmented pixels while the use of neural network techniques may increase the performance but some errors might remain We found that amongst the two segmentation methods used, an improved quality of segmentation is obtained with the second generation artificial neural networks reflecting the mean square error to be minimum.

REFERENCES

[1] R.Nayak, L.C.Jain and B.K.H. Ting. Artificial Neural Networks in Biomedical Engineering:A Review. *In Proceedings Asia-Pacific Conference on Advance Computation.2001.*

[2] Roberto Figueiredo, Leizer Schnitman, José A.M. Felippe de Souza" Using Neural Networks and K-Means Cluster for Image Segmentation in outdoor scenes" *Revista Ciencias Exatas – UNIVERSIDADE DE TAUBATÉ (UNITAU) – BRASIL – VOL. 2, N. 1, 2008*

[3] B. Jeon, Y. Yung and K. Hong "Image segmentation by unsupervised sparse clustering," *pattern recognition letters 27science direct,(2006)1650-1664*

[4] Zhang, Y. J. (2002a). "Image engineering and related publications" *International Journal of Image and Graphics,(2002a) 2(3), 441-452.*

[5] G. B. Coleman, H. C. Andrews (1979) "Image segmentation byclustering", *Proc IEEE 67:773–785.*

[6] A. K. Jain, M. N. Murty, P. J. Flynn, 1999. "Data clustering: A review",*ACM Comput. Surveys 31 (3), 264–323.*

[7] Y. J. Zhang, (2006). "A study of image engineering", In M.Khosrow-Pour (Ed.), *Encyclopedia of information science and technology (2nd ed.)*

[8] H.Paugam-Moisy, "Spiking neuron networks a survey", *IDIAP-RR, 06-11, 2006.*

[9] S. J. Thorpe and A. Delorme and R.VanRullen, "Spike-based strategies for rapid processing", *Neural Networks, 14(6-7), 715-726,2001.*

[10] W.S. McCulloch, W. Pitts, A logical calculus of ideas immanent in nervous activity, *Bull. Math. Biophys. 5 (1943)115-133.*

[11] S. P. Lloyd, —"Least squares quantization in PCM," *IEEE Trans. Inf.Theory, vol. IT-28, no. 2, pp. 129–136, Mar.1982.*

[12] A.M Uso,F.Pla,P.G Sevila," Unsupervised Image Segmentation using a Heirarchical Clustering Selection Process".*Structural Syntactic and Statistical Pattern Recognition Vol 4109,pp.799-807,2006*

[13] A.Z Arifin,A.Asano,"Image Segmentation by histogram thresholding using hierarchical cluster analysis"*Pattern Recognition Letters,Vol.27,no.13,pp. 1515-1521,2006*

[14] J.L Marroquin,F. Girosi,,"Some Extentions of the K-Means Algorithm For Image Segmentation and Pattern Classification", *Technical Report,MIT Artificial Intelligence Laborartory,1993.*

[15] M.Luo,Y.F.Ma H.J. Zhang,"ASpecial Constrained K-Means approach to Image Segmentation",*proc. The 2003*

Joint Conference of Fourth International Conference on Informations Communications and Signal Processing and the Fourth Pacific Rim Conference on Multimedia,Vol.2,pp.738-742,2003.

[16] Wei Sun and Yaonan Wang, *"Segmentation Method of MRI Using Fuzzy Gaussian Basis Neural Network Neural Information Processing", Letters and Reviews, Vol.8, No.2, August 2005, pp.19-24*

[17] Ibrahiem M. M. El Emary, "On the Application of Artificial Neural Networks in Analyzing and Classifying the Human Chromosomes", *Journal of Computer Science, vol.2(1), 2006, pp.72-75.*

[18] Bouchet A, Pastore J and Ballarin V, "Segmentation of Medical Images using Fuzzy Mathematical Morphology", *JCS and T, Vol.7, No.3, October 2007, pp.256-262.*

[19] Wilson, E., D.W. Sutter, and R.W. MahThe Application of Watershed in Segmentation of Overlapping Cells.. 2004. *Honolulu, HI, United States: Acta Press, Anaheim, CA, United States.*

[20] R. Andrews, J. Diedrich, A.B. Tickle, A survey and critiques for extracting rules from trained artificial neural networks, *Internal printing of the Neurocomputing Research centre, Queensland University of Technology, Brisbane,199*

[21] J.W. Shavlik, A Framework for Combining Symbolic and Neural Learning, *CS-TR-92-1123, November 1992, The University of W Wiscons*