COLOUR IMAGE SEGMENTATION USING COMPETITIVE NEURAL NETWORK

Sowmya .B[1] and Sheelarani .B[2]
[1]Research Scholar,Sathyabama University ,Rajiv Gandi Road, Tamilnadu, India.
[2]Department of Electronics and Instr. Engg., Sathyabama University ,Rajiv Gandi Road, Tamilnadu, India.
E-mail : [1]bsowya@yahoo.com, [2]sri_kavi_sheela@yahoo.co.in

Abstract

This paper explains the task of segmenting any given colour image using competitive neural network. Image segmentation refers to the division pixels into homogeneous classes or clusters so that items in the same class are as similar as possible and items in different classes are as dissimilar as possible. . The most basic attribute for segmentation is image luminance amplitude for a monochrome image and color components for a color image. Since there are more than 16 million colours available in any given image and it is difficult to analyse the image on all of its colours, the likely colours are grouped together by image segmentation. For that purpose competitive neural network has been used. Competitive Neural Networks are groups of neurons compete for the right to become active. The activation of the node with the largest net is set equal to 1, and the remaining nodes are set equal to 0. It works on the principle of "Winner Takes All". First, the color image of interest is read as a three dimensional matrix. It is then converted into a two-dimensional matrix. Weight matrix is randomly initialized. Competitive neural network is then created. Then the neural network is trained using the two-dimensional image matrix. This weight matrix is reconstructed to form the segmented image. Quality of the reconstructed image is determined by calculating the Peak Signal to Noise Ratio and found to be reasonable. This work finds vast applications in medical imaging, satellite imaging, military applications and non destructive testing of products in industries.

Key words: Neural Network, Image processing, Image Segmentation.

I. INTRODUCTION

Partitioning of an image into several constituent components is called Image segmentation. Segmentation is an important part of practically any automated image recognition system, because it is at this moment that one extracts the interesting objects, for further processing such as description or recognition. Segmentation of an image is in practice the classification of each image pixel to one of the image parts.

Image segmentation has been the subject of considerable research activity over the last three decades. Many unsupervised algorithms[2] have been developed for segmenting gray scale images. But segmenting the colour images has received much less attention of scientific community. As colours convey more information than the intensities, this paper explains the task of classifying each pixel in an image into one of a discrete level of colour classes using competitive neural network.

Colour image segmentation is done by mapping of a pixel into a point in an *n*-dimensional feature space, defined by the vector of its feature values. The problem is then reduced to partitioning the feature space into separate clusters[1], which is a general pattern recognition problem. This can be done using competitive neural network.

The rest of the paper is organized as follows. Image segmentation is described in section II. In section III Neural Network used in this design is explained. In section IV self estimation algorithm for number of clusters is discussed in detail. In Section V two important quality measurement techniques like PSNR and error image are discussed. Section VI describes the software design. In Section VII concluding remarks are given.

II. IMAGE SEGMENTAION

Extracting information from an image is referred to as Image Analysis. Image segmentation is an essential preliminary step in most automatic pictorial pattern recognition and scene analysis problems.

It is one of the most difficult task in image processing. Image segmentation is the process of partitioning a digital image into multiple regions or clusters. Each region is made up of sets of pixels. Image segmentation simplifies and changes the representation of an image. i.e. the image is transferred into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects of interest and boundaries like lines, curves in an image.

The pixels of a colour image are represented as vectors. Each pixel is represented a triplet containing red, green, blue spectral values at that position. The RGB colour model is shown in fig.1 This is bsed on Cartesian coordinate system A colour expressed by an RGB vector is said to be a colour represented in RGB space.

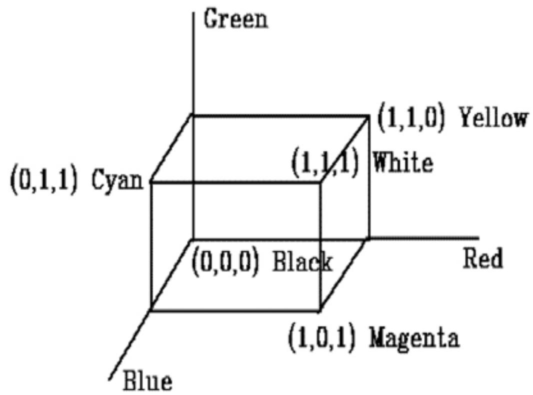

Fig 1. RGB Colour Model

RGB colour representation is one of the numbers of colour models. RGB colour model is chosen for image segmentation due to its simplicity hence the fast processing speed that could be achieved [5]. Image segmentation refers to the process of dividing the image into connected regions where pixels of a region share a common property. For colour images the common property is usually considered is the red:green:blue, colour ratio. This ratio must be reasonably constant over the region.

The colour ratio does not have smoothly varying values when the pixel intensity is low. So colour image segmentation based on colour ratio requires that the intensity of the image must be above a threshold value. So instead of segmentation based on colour ratio other techniques have been evolved. The requirements of good colour image segmentation are as follows. A single region in a segmented image should not contain significantly different colours and a connected region containing same colour should not have more than one label. All significant pixels should belong to the same labeled region. The intensity of a region should be reasonably uniform. Several image segmentation techniques have been suggested for gray scale images. In this paper we suggest the neural network approach for colour images.

III. NEURAL NETWORK

An artificial neural network is nothing but an image processing system[4] neural network can be characterized by the following points.

1. It is composed of simple elements known as neurons. These neurons can operate in parallel.
2. The neural network function is determined by the connections between its elements. The signals are passed between the neurons through these connection links.
3. Each connection link has a weight associated with it. This weight multiplies the signal transmitted.
4. Each neuron has an associated activation function. This activation function determines the output of the neuron.

Fig. 2 Shows the general neuron representation. Neuron has n inputs and 1 bias input. In general the weights of the connecting links are denoted by $\mathbf{w}_{ij}$ where i stands for the input and j is the respective neuron to which the input is connected.

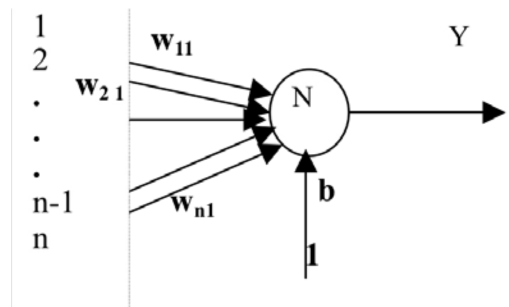

Fig 2. Neuron Representation

The bias input value is always equal to one. Its weight is denoted by b. The neuron output is determined by the activation function associated with it. The activation function is generally denoted by $\mathbf{f(x_i w_{ij} + b)}$ where x_i is the i^{th} input. The activation function can be linear or non linear function depending on the application. In most cases non linear activation functions are used. There are many types of activation functions available like linear function, step function and sigmoid function. Neural networks can be classified as single layer and multi layer networks. The neurons available in the same layer behave in the same fashion. Single layer network has only one layer of neurons or only one layer of connection weights.. The input layer is not considered while counting the no. of layers available in a network because it performs no operation. The activation function used is the same for all neurons in any particular layer of neural network.

The operation of a neural network is separated into two parts. They are,

- Training
- Testing

Training is the process of adjusting the weights of links in such a way that a particular input leads to specific target output. Fig.3 shows the training of a neural network.

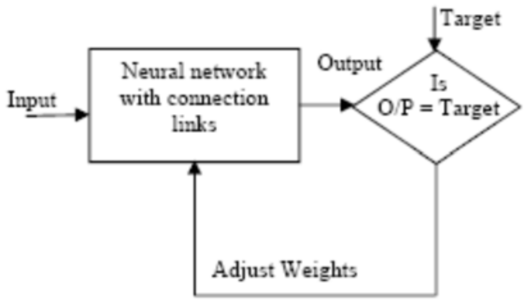

Fig 3. Training of Neural Network

The commonly used iterative learning process is suggested by Widrow and Hoff. It is known as delta rule. The delta rule changes the weights of the neural connections in such a way that the difference between net input (y_{in}) to the output unit (y_j) and the target value (t_j). The activation function of the output unit is assumed to be identity function. The change in weight of connection between i^{th} input unit and j^{th} output unit is given by,

$> w_{IJ}=(t_j-y_j)\, x_i$ where, $y_J= y_{in} = \Sigma x_i w_{ij}$ and i varies from 1 to n

Back propagation training method is derived from the delta rule. This is also known as generalized delta rule.

$> w_{IJ}=(t_J-y_J)\, x_I\, f'(y_{inJ})$ where, $y_J= f(y_{inJ})$, $y_{inJ} = \Sigma x_I w_{iJ}$ and i varies from 1 to n

This formulation reduces error for each pattern and allows for a binary differentiable activation function to be applied to the output neurons. The delta or gradient indicates a change in weight which reduces the mean squared error of the output. So, this method is also known as gradient descent method. The simplest way to update weights and biases in back propagation learning is to update the weights in the negative of the gradient direction. An iteration of back propagation algorithm can be written as

$$W_{k+1}=W_k-\alpha_k > W_k \quad (1)$$

Where W_k is a vector of current weights and biases

$> W_k$ is the current gradient

α_k is the learning rate

There are many neural network architectures available. Perceptron Network, Back propagation networks, self organizing maps are some of the frequently used architectures. In the design proposed competitive neural network has been used for colour image segmentation.

Competitive neural net

A neural network in which a a group of neurons compete for the right to become active is called Competitive neural network [2]. In the most extreme case, i.e. when more than one neuron is about to get fired, the activation of the node with the largest net input is set equal to 1 and the activation of all other nodes are set equal to 0. This condition is known as "*winner takes all*". An example of competitive neural net is MAXNET. The neurons in a competitive layer distribute themselves to recognize frequently presented input vectors

Architecture

The architecture for a competitive neural net is shown in fig. 4. The input vector **p** and the input weight matrix is fed to block D. The output of D block is a vector having S1 elements. The elements are the negative of the distances between the input vector and vectors formed from the rows of the input weight matrix.

The net input of a competitive layer is composed by finding the negative distance between input vector **p** and the weight vectors and adding the biases **b**. When all biases are zero, the maximum net input a neuron can have is 0. This condition occurs when the input vectors **p** equals that neuron's weight vector.

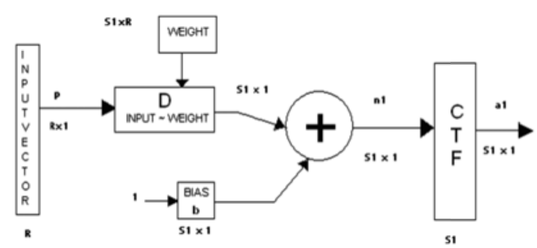

Fig 4. Architecture of Competitive Neural Network

The competitive transfer function block CTF accepts a net input vector for a layer and return neuron outputs of 0 for all neurons except for the *winner.* The winner neuron is the one with the most positive element of net input. The winner's output is 1. If all the biases are zero, then the neuron whose weight vector is closest to the input vector i.e. the neuron with *least* negative net input wins the competition to output a 1.

In general case, the input vector is of size R elements, the weight vector is of size S1 x R elements where S1 is the no. of neurons in the output layer. For colour image segmentation input vector is made up of the primary colours Red, Green and Blue, hence of size 3. The no. of output neuron is equal to the no. of desired clusters.

Algorithm

Step 0 Initialize weights w_{ij}

Set topological neighborhood parameters with its radius as 1

Set learning rate parameters

Slep 1 while stopping condition is false, do steps 2 ∆8

Step 2 for each input vector **x**, do steps 3 ∆5

Step 3 For each *j*, compute:

$$\mathbf{D}(j) = \sum_i (\mathbf{w}_{ij} - \mathbf{x}_i)^2$$

Step 4 Find index *J* such that D(*J*) is a minimum

Step 5 For all units *j* within a specified neighborhood of *J*, and for all *i*:

$$w_{ij}(new) = w_{ij}(old) + \alpha[x_i \Delta w_{ij}(old)]$$

Step 6 update learning rate

Step 7 Test stopping condition

The learning rate α is a gradually decreasing function of training epochs.

The formation of the competitive occurs in two phases. In the first phase the initial formation of the correct order takes place. In the second phase the final convergence. The second phase takes much longer than the first and requires a smaller value for the learning rate.

Random values may be assigned for the initial weights. If some information is available concerning the distribution of clusters that might be appropriate for a particular problem, the initial weights can be taken to reflect that prior knowledge.

IV. SELF ESTIMATION ALGORITHM

If the number of clusters is manually specified, the segmentation may not be effective. Hence there must be a system to calculate the robust number of clusters. A method has been suggested for automatically finding no. of clusters with K means clustering[6]. That algorithm is modified for finding no. of clusters in neural network. The self estimation algorithm used here finds the difference between the weight vectors. If the difference between the weight vectors is greater than the specified value, then the number of cluster centers is increased by one else the clusters are merged.. An alternate method, in which we start with a high number of clusters and merge on the result of the iterations, can also be used. The no. of clusters is equal to the no. of neurons in the output layer.

Algorithm

1. Start with c = 2
2. Find the weight matrix, w
3. Compute difference between the weight vectors, q
4. If min (q) " E, increment c and repeat steps 2, 3

V. QUALITY MEASUREMENTS

Peak Signal to Noise Ratio

Signal-to-noise (SNR) estimates the quality of a reconstructed image compared with the original image. The basic idea is to compute a single number that reflects the quality of the reconstructed image[4]. Reconstructed images with higher metrics are judged better. In fact, traditional SNR measures do not equate with human subjective perception. Several research groups are working on perceptual measures, but for now signal-to-noise measures are used because they are easier to compute. Also to be noted that higher measures do not always mean better quality. The actual metric that is computed in this work is the peak signal-to-reconstructed image measure, which is called PSNR. Assume a source image f(i,j) is given that contains M by N pixels and a reconstructed image F(i,j) where F is reconstructed by decoding the encoded version of f(i,j). Error metrics are computed on the luminance signal only so the pixel values f(i,j) range between black (0) and white (255). First the mean absolute error of the reconstructed image is computed (MAE) as follows

$$MAE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} |F(i,j) - f(i,j)| \tag{2}$$

The summation is over all pixels. PSNR in decibels (dB)[4] is computed by using

$$PSNR = 10 \log_{10} (255^2 / MAE).$$

Typical PSNR values range between 20 and 40. They are usually reported to two decimal points (e.g., 25.47). The actual value is not meaningful, but the comparison between two values for different reconstructed images gives one measure of quality. The MPEG committee used an informal threshold of 0.5 dB PSNR to decide whether to incorporate a coding optimization because they believed that an improvement of that magnitude would be visible.

Some definitions of PSNR use 255/RMAE rather than 255^2/MAE. Either formulation will work because we are interested in the relative comparison, not the absolute values. For our assignments we will use the definition given above.

Error Image

The other important technique for displaying errors is to construct an error image which shows the pixel-by-pixel errors. The simplest computation of this image is to create an image by taking the difference between the reconstructed and original pixels. These images are hard to see because zero difference is black and most errors are small numbers which are shades of black. The typical construction of the error image multiples the difference by a constant to increase the visible difference and translates the entire image to a gray level. The computation is

$$E(i,j)=2[f(i,j)-F(i,j)] \tag{3}$$

The constant (2) or the translation (128) can be adjusted to change the image. Some people use white (255) to signify no error and difference from white as an error which means that darker pixels are bigger errors.

VI. SOFTWARE DESIGN

An image segmentation program using neural network has been developed for portioning the colour satellite images. Fig. 5 shows the original image. The segmented image is shown in fig. 6. Fig. 7 shows the error image. The PSNR value is found to be 34.6169. The Image segmentation and the analysis Algorithm is given below.

1. Load the image file to be segmented
2. Get the mode of operation
3. If the mode is manual get the no. of clusters
4. If the mode is automatic calculate the no. of clusters using self estimation algorithm
5. Use competitive neural network segment the image

Fig 5. Original Image

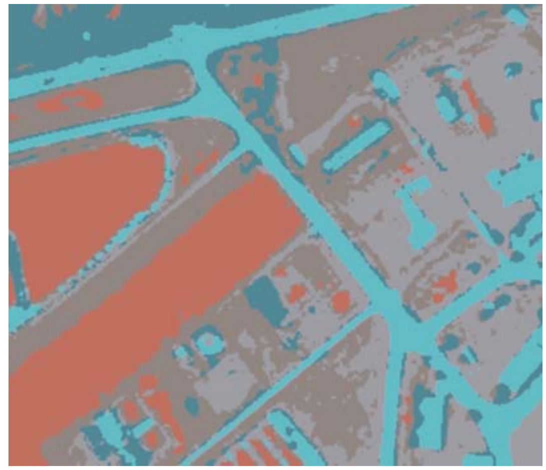

Fig 6. Segmented Image

Fig 7. Error Image

6. Determine PSNR and error image
7. Display the image segmented by competitive neural network
8. Display PSNR values and error images

VII. CONCLUSION

This work has several applications in various scientific fields like Satellite imaging, Map determination, Medical imaging, Optical character recognition (OCR), Non-Destructive testing, etc. The program developed has been tested with various pictures and the results were proven to be fruitful. The program has also been tested for its consistency and its reliability.

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B.Sowmya has born in Chennai on 25.06 1973. She has completed her B.E. degree in electronics and communication from Bharathidasan University, Trichy, Tamilnadu, India in 1994. Completed her M.Tech degree in laser & electro optical Engineering from Anna University, Chennai, Tamilnadu, India in 1999. She is currently pursuing her Ph. D degree in the field of digital image processing. She has 15 years of experience in academic field and published three books for engineering students.

Dr.Sheela Rani has born in Chennai on 21.11.1966. She has completed her A.M.I.E in electronics and communication from Institution of Engineers, Calcutta, India in 1987. Completed her M.S. by Research in digital image processing from Anna University, Chennai, Tamilnadu, India in 2000. Completed Ph. D degree in the field of digital image processing Anna University, Chennai, Tamilnadu, India in 2004. She has 21 years of experience in academic field. She has successfully completed many sponsored R&D projects for ISRO, DRDO, etc