Initial Pattern Library Algorithm Based on Mean/Variance Classification for 3D SOM

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Abstract - *Initial pattern library algorithm is an important part of three-dimensional self-organizing feature maps (3D SOM) algorithm. To overcome disadvantages of existing initial pattern library algorithm such as random algorithm and splitting algorithm, a new initial pattern library algorithm based on mean/variance classification for 3D SOM was proposed and applied to the image pattern recognition. Experimental results for image coding show that initial pattern library algorithm based on mean/variance classification has advantages of less invalid pattern vectors and high performance of pattern library. It is an effective way to improve the performance of 3D SOM.*

Keywords: image pattern recognition; image coding; three-dimensional self-organizing maps

1 Introduction

Kohonen's self-organizing maps (SOM) [1] is a very effective clustering method, and has been widely used in data mining and pattern recognition [4]-[8]. SOM algorithm is used to design an optimal pattern library by training a lot of samples.

Image coding based on pattern recognition is a new image coding method; the pattern library design is the key to it. Li et al. [9] propose an image coding scheme based on pattern recognition, the scheme use SOM algorithm to train pattern library, the initial pattern library generates by random algorithm, and experiment results show that the proposed coding scheme is better than JPEG2000.

In pattern library design, the initial pattern library plays an important part. Random algorithm and splitting algorithm are two common methods. Random algorithm is simpler, but has some disadvantages such as slower convergence speed, many invalid pattern vectors, etc. Splitting algorithm is more complex and needs a great deal of calculation. Li et al. [10] propose a sorting algorithm based on minimum distance between pattern libraries. In this paper, initial pattern library algorithm based on mean/variance classification for 3D SOM is proposed. The basic idea is that the similar pattern vectors in the initial pattern library are put together. Experimental results show that the proposed algorithm has advantages of less invalid pattern vectors and high matching degree with source.

This paper was supported by The Natural Science Foundation of China (No.61261035) and Innovation Project of GUET Graduate Education (No.GDYCSZ201451).

2 3D SOM algorithm

2.1 The principle of 3D SOM

SOM network consists of double-layer network structure, including the input layer and the mapping layer. The input layer receives input patterns, the mapping layer exports result, each input neuron connects with every mapping layer neurons through the connection weights, and mapping layer neurons connect to each other. Traditional SOM network generally adopts one-dimensional input layer and two-dimensional mapping layer; it can effectively deal with one-dimensional and two-dimensional signal. In recent years, the three-dimensional signal processing such as three-dimensional image and video increasingly attract attention, however, the traditional SOM algorithm can’t be used in it directly. Three-dimensional self-organizing feature maps (3D SOM) algorithm solves this problem, it can map two-dimensional input to three-dimensional output, achieve the three dimensional signal nonlinear mapping. The network structure of 3D SOM algorithm is shown in Fig.1. The mapping layer neurons are arranged in a three-dimensional structure, the number of rows, columns and layers can take different values. Obviously, different three-dimensional network structure usually result in different performance. The shape of three-dimensional neighborhood can have different choice, we usually choose spherical neighborhood, square neighborhood or orthogonal cross neighborhood, algorithm performance varies when selecting different three-dimensional shape of neighborhood. 3D SOM network is the same as ordinary competition network, for each input pattern, there is corresponding winning node in mapping layer, winning nodes represent the most similar pattern, the winning nodes and all nodes in its three-dimensional neighborhood adjust their own weight according to certain rules. When the input pattern changes, there will be a different pattern win through competition. In this way, the network adjusts the network weights through a large number of training samples by means of the self-organizing way. Finally the weight vector space is in accordance with the probability distribution of input patterns, namely the weight vector space can reflect the statistical characteristics of input pattern [5].

The neighborhood of 3D SOM algorithm is a three-dimensional structure; the number of nodes within the same neighborhood radius is more than two-dimensional plane structure, so the probability of nodes to be adjusted is increasing. Therefore, 3D SOM algorithm is used to design the pattern library of image pattern recognition can reduce the proportion of invalid mode vector, so as to improve the performance of the pattern library. SOM algorithm derived from the concept of biological neural networks, and the topology of biological neural network is a more complex three-dimensional structure, so use SOM neural network based on three-dimensional neighborhood to simulate the three-dimensional structure and function of biological neural network is more reasonable, and has achieved good effect in practical application.

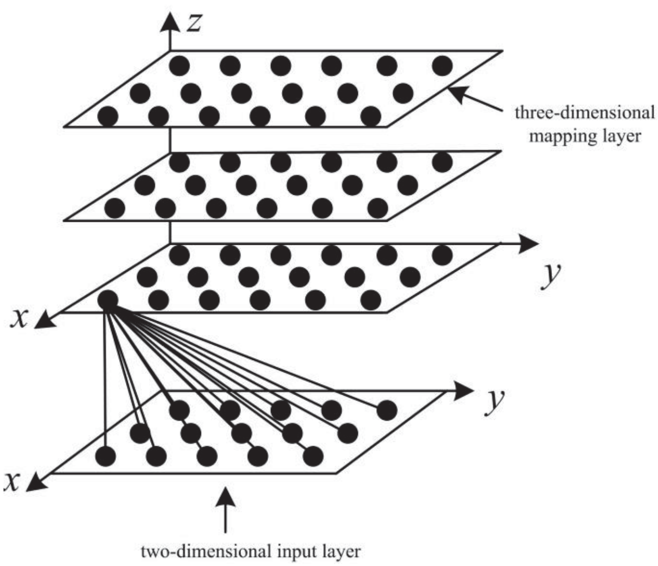

Fig.1 The network structure of 3D SOM algorithms

2.2 Steps of 3D SOM algorithm

Step-1: Given a neural size of network (N, M), and a training vector set $\{\mathbf{X}(t), t = 0,1,\cdots, L-1\}$, while N is the size of pattern library, M is the size of each pattern vector, and L is the number of training vectors. Initialize the pattern library $\{\mathbf{W}_j(0), j = 0,1,\cdots, N-1\}$ by initial pattern library algorithm based on mean/variance classification. Then the pattern vector are arranged in a three-dimensional structure $a \times b \times c$, where a, b and c represent the number of rows, columns and layers.

Step-2: Initialize the neighborhood $NE_j(0), j = 0,1,\cdots, N-1$.

Step-3: Input a new training vector $\mathbf{X} = (x_1, x_2, \cdots, x_M)^{\mathrm{T}}$.

Step-4: Compute the distortion d_j between the input vector and each pattern vector in the pattern library with some distortion measure, and select j^* as the winning pattern vector.

Step-5: Modify the winning pattern vector j^* and its neighboring pattern vectors by

$$\mathbf{W}_j(t+1) = \begin{cases} \mathbf{W}_j(t) + \alpha(t)[\mathbf{X}(t) - \mathbf{W}_j(t)] & j \in j*, NE_{j^*}(t) \\ \mathbf{W}_j(t) & else \end{cases}$$

Where, $NE_{j^*}(t)$ is Euclidean distance neighborhood around the winning pattern vector which is decreased with t, $NE_{j^*}(t) = A_0 + A_1 \mathrm{e}^{-t/T_1}$, A_0 and A_1 are constants determining the range of the neighborhood, and T_1 is a constant determining the decreasing rate.

The learning rate $\alpha(t)$ determines the modification amount of pattern vectors. Theoretically, if $\alpha(t)$ is small enough, the average error function of the system will reach the minimum after a long time training. In practice, learning rate is usually determined by $\alpha(t) = A_2 \mathrm{e}^{-t/T_2}$. Where, A_2 is a constant determining the maximum of learning rate, and T_2 is a constant determining the decreasing rate.

Step-6: Go to Step-3.

3 The original initial pattern library algorithm

3.1 Random Algorithm

Random algorithm can be classified to random data setting and random sampling. In random data setting algorithm, the initial pattern vectors are set to random data. Because the initial pattern library is independent with the training set, and some invalid pattern vector often exist in the pattern library after training, thus random data setting algorithm is not usually used.

In random sampling algorithm, the initial pattern vectors are elected randomly from the training set. For example, if the training set is denoted by $\{\mathbf{X}(t), t = 0,1,\cdots, L-1\}$, the initial pattern library can be obtained by selecting vectors $\mathbf{X}(0), \mathbf{X}(p), \mathbf{X}(2p), \cdots \mathbf{X}((N-1)p)), \quad p = L/N$. This algorithm has two advantages: it doesn't need any calculation; there will be few invalid pattern vectors in the pattern library. However, sometimes many similar vectors are selected, and the pattern library performance will degrade.

3.2 Splitting Algorithm

The splitting algorithm proposed by Linde, Buzo and Gray can be implemented as follows:

Step-1: Compute the centroid (represented by $\mathbf{W}(0)$) of all training vectors, split $\mathbf{W}(0)$ to two close vector $\mathbf{W}_1(0) = \mathbf{W}(0) + \mathrm{e}$ and $\mathbf{W}_2(0) = \mathbf{W}(0) + \mathrm{e}$, where e is a fix perturbation vector.

Step-2: Use $\{\mathbf{W}_1(0), \ \mathbf{W}_2(0)\}$ as the initial pattern library, design the pattern library with two pattern vectors by

LBG algorithm. The resulting pattern library is represented by $\{\mathbf{W}_1(1),\ \mathbf{W}_2(1)\}$.

Step-3: Split $\{\mathbf{W}_1(1),\ \mathbf{W}_2(1)\}$ to four pattern vectors as Step-1.

Step-4: Design the pattern library with four pattern vectors as step- 2, and the resulting pattern vectors are split to eight pattern vectors. Repeat this procedure until N initial pattern vectors are created.

The defect of splitting algorithm is too complex, and it can not adapt statistic characteristic of information sources.

3.3 The Average Separation Algorithm

In average separation algorithm, the training vector set is divided into segments, each segment length is $p=(L/N)$ where L is training vector number and N is the pattern library size. Take average in each section will get pattern vector. The initial pattern library can be obtained by

$$\mathbf{W}_j(0)=\frac{\mathbf{X}(jp+1)+\mathbf{X}(jp+2)+\cdots+\mathbf{X}(jp+p)}{p} \qquad j=0,1,\cdots,N-1\cdot$$

In practice, the average separation algorithm is an improved method of random algorithm, the performance has improved, but its enhancement is definite.

4 Mean/variance classification algorithm

In 3D SOM algorithm, neighborhood pattern vectors will influence each other. The basic idea of mean/variance classification algorithm is to put the similar pattern vectors together in the initial pattern library which can reduce the bad influence between neighborhood pattern vectors. Training vector of similar average is likely to constitute a similar pattern. When the average is similar, training vector of similar variance is more likely to constitute a similar pattern. So, we can obtained pattern library based on mean/variance classification algorithm. Specific steps are as follows:

Step-1: Compute the mean value of each vector in the training set $\{\mathbf{X}(t), t=0,1,\cdots,L-1\}$.

Step-2: Sort the training vectors by mean value from small to large order, and divide the adjusted training vectors into four parts: $\{\mathbf{X}_1(t)\}$、$\{\mathbf{X}_2(t)\}$、$\{\mathbf{X}_3(t)\}$、$\{\mathbf{X}_4(t)\}$.

Step-3: Sort the training vectors in each part by variance.

Step-4: Choose $N/4$ training vectors in each part at the same intervals, put them together to form initial pattern library which contain N pattern vectors.

5 Experimental results

We use standard testing grayscale images ('Lena') to test mean/variance classification algorithm. In our experiments, distortion measure is calculated by square error criterion $d_j(t)=\|\mathbf{X}(t)-\mathbf{W}_j(t)\|^2$, and the size of image block is $M=8\times 8$. The reconstructed image quality is measured by PSNR, where $R_{\mathrm{PSNR}}=10\lg\frac{255^2}{E_{\mathrm{MSE}}}\mathrm{dB}$, and MSE is the mean square error between the original image and the reconstructed image. Ratio of image compression is calculated by $C_{\mathrm{R}}=\frac{M\times B_{\mathrm{O}}}{B_{\mathrm{C}}}$, while M is the dimension of the pattern vector, B_{O} is bits of the original image pixels, B_{C} is the bit of pattern vector class indexes. All experimental data is obtained after a large number of experiments and constantly adjusting the experimental parameters.

In the experiment, we use random sampling algorithm, average separation algorithm and mean/variance classification algorithm to design initial pattern library of 3D SOM algorithm, then compare their performance by the reconstructed image quality. The pattern library size is $N=40960$. When the pattern library size varies, the PSNR of the reconstructed image of the three kinds of initial pattern library algorithm is shown in Table I. It is clear that when the pattern library size is small, the PSNR of the reconstructed images is similar, but when the pattern library size is big, the PSNR of the reconstructed image based on mean/variance classification algorithm is obviously higher. When the pattern library size is 1024 (compression ratio $C_{\mathrm{R}}=\frac{64\times 8}{10}=51.2$), compare with random sampling algorithm and average separation algorithm, the PSNR of the reconstructed image based on mean/variance classification algorithm increase 0.26dB and 0.21dB. When the pattern library size is 2048 (compression ratio $C_{\mathrm{R}}=\frac{64\times 8}{11}=46.5$), the PSNR of the reconstructed image increases 0.51dB and 0.55dB.

Table 1
The PSNR of the reconstructed image

pattern library size	random sampling algorithm (dB)	average separation algorithm (dB)	mean/variance classification algorithm (dB)
2048	36.068 5	36.034 8	36.583 7
1024	33.152 6	33.195 8	33.411 9
512	30.859 9	30.925 9	31.008 7
256	28.965 8	28.876 3	29.071 2
128	27.506 3	27.440 5	27.576 7

Fig.2 illustrates the comparisons of the reconstructed image between initial pattern library based on random sampling algorithm, average separation algorithm and mean/variance classification algorithm. Fig.2 (a) show the original image, Fig.2 (b) show the reconstructed image when initial pattern library algorithm is random sampling algorithm, Fig.2 (c) show the reconstructed image when initial pattern library algorithm is average separation algorithm, Fig.2 (d) show the reconstructed image when initial pattern library algorithm is mean/variance classification algorithm. Obviously, the reconstructed images using mean/variance classification algorithm have better subjective equality.

Fig.2 Original image and reconstructed images; (a) Original image ('Lena'); (b) reconstructed image by random sampling algorithm; (c) reconstructed image by average separation algorithm; (d) reconstructed image by mean/variance classification algorithm.

6 Conclusion

In this paper, a new initial pattern library algorithm based on mean/variance classification for 3D SOM algorithm is proposed. Experimental results show that initial pattern library algorithm based on mean/variance classification has advantages of less invalid pattern vectors and high matching degree with source. The next work is applying 3D SOM based on the proposed initial pattern library algorithm to three-dimensional video coding and doing further improvement to get better performance.

7 References

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