Visual Analysis of SOM Network in Fault Diagnosis

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Abstract

SOM network (self-organizing feature map neural network) learning with no instructors which has self-adaptive, self-learning features. The advantage is to maintain the topology of original data. It is in extensive application in the field of the data classification, knowledge acquisition, process monitoring fault identification and so on. SOM network is used for rotor fault diagnosis. The U matrix map and D matrix is used as visualization tools to simulate and analyses the classification results, and it is compared with the general SOM network clustering results. The conclusion is that the SOM network visualization method is simple and easy to understand, and has high rate in fault discrimination.

1. Preface

The Kohonen advanced a self-organizing feature map neural network (SOM Network) in 1981 according to the character of brain neural system\textsuperscript{[1]}. SOM Network is learning with no instructor. Compared with the general SOM network clustering results, it can reflect to a curved face or plane and keep the same topology\textsuperscript{\textsuperscript{[2][4]}}. This article introduced its diagnosis applications with motor rotor and focused to simulate and analyze the classification results.

2. SOM Network Topology

There are two layers in SOM Network. Input layer and Output layer. (As shown in figure 1)

![Figure 1. Two-dimensional SOM planar array](image)
Input layer inputs the outside information to each nerve cell of output layer by weight vector. The amount of joint
and sample dimension are same. Output layer also called competitive layer. There are several nerve cells,
one-dimensional linear array, two-dimensional planar array and three-dimensional grid array. The typical structure is
two-dimensional planar array and it is used more because it is similar with brain cortex. Each nerve cell of output layer
is lateral binding with other surrounding cells to arrange the chessboard plane. The output layer is single nerve cell
array.[3]

3. An example of motor rotor failure analysis

The vibrating signal can reflect the failure information of machine by amplitude domain, frequency domain and
time domain timely. The major failure character of motor rotor is that abnormal vibration and noise appeared on the
machine.[1][5] Especially in frequency domain, the characteristic quantity and proportional relation can reflect the
relevant failure type.

3.1 Setup of signal collection system

![Flow Chart of Signal Collection System](image)

3.2 Setup of system parameter

Sampling frequency: f=2 560 Hz; Sampling quantity: 4 (1204 sampling point for 1pc); Motor rated power: P=2.2
kW; Rated speed: n=1 500 r/min; Rated current: I=5 A; Rated voltage: U=380 V

3.3 Setup training sample

Take 6 common failures, including unbalance, non-center, oil whirl, as network output. Take the 8 channels in
vibration signal as characteristic quantity. See Table 1 and Table 2 as below

| Failure Sample | Channel band | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----------------|--------------|---|---|---|---|---|---|---|---|
|                |              | (0.01~0.39)f | (0.4~0.49)f | 0.5f | (0.51~0.99)f | f | 2f | (odd number)f | (even number)f |
| unbalance      | 0.00         | 0.05 | 0.00 | 0.00 | 0.90 | 0.05 | 0.00 | 0.00 |
| non-center     | 0.00         | 0.00 | 0.10 | 0.00 | 0.40 | 0.50 | 0.00 | 0.00 |
| Oil whirl      | 0.10         | 0.80 | 0.00 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 |
| Rotor radial rub | 0.10       | 0.10 | 0.20 | 0.10 | 0.20 | 0.10 | 0.10 | 0.10 |
| Surge          | 0.00         | 0.30 | 0.10 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bearing Block Loose | 0.90       | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 |

Table 2 Test Sample with Noise
4 General SOM network to the results of analysis of failure

The failure sample indicated that the network input layer is 6×8 dimensional matrix. So competitive layer two-dimensional array is 7×9, it can be reach hextop. Distance function using linkdist sequencing and adjusts the phase of the learning rate is set to 0.9, 0.02. The step length in sorting and distance in adjusting stage is 1000,1.

After establish SOM Network and training. The results as shown in table 3.

Table 3 The classification results of digital representation

| Failure Condition | Unbalance | Non-center | Oil whirl | Rotor radial rub | Surge | Bearing block Loose |
|-------------------|-----------|------------|-----------|------------------|-------|--------------------|
| Result            | 57        | 63         | 2         | 39               | 29    | 14                 |

After the SOM network training, the output nerve cell plane is sensitive to each group of input sample. But the numbers showed in Table 3 are indirectly, difficult to understand. If showed by Figure 3, it is easy to see the relationship between input and output. SOM Network can judge and classify failure correctly.

Figure 3 Diagramming of Failure Classification Result
5 Visualization of SOM Network

5.1 U matrix, D matrix and BMU

During the failure mode identify process, the visualization technology is easy to monitor failure type. For SOM Network training result, we usually use U matrix to show training result, that is U matrix map. U matrix is using the grayscale display the distance between imminent nerve cells. The white area stands for center, the dark area stands for long distance between center and other nerve cells. The darker color showed longer distance. U matrix of nodes on the 2d neurons than in the plane of the neurons to many, because a neurons to more than one neurons and around a relationship. Usually \((2nx-1) \times (2ny-1)\), nx \(\times\) ny, a competitive layer of two-dimensional array of neurons settings. D matrix is using three-dimensional to show the distance in imminent nerve cells. The third coordinate showed the distance between nerve cell and imminent nerve cell. BMU (best matching point) is the matrix of input vectors on the response to the biggest point, that cluster center.

5.2 Visualization result

Competitive layer is set up to 7\(\times\)9, the joint of U matrix map is 13\(\times\)17. Visual input to the network fault samples, the results shown in Figure 4, Figure 5

![Figure 4 Classification of 6 Failure Types in U matrix map](image)

![Figure 5 6 kinds of fault classification diagram and the schematic diagram of sensitive neurons](image)
In figure 4 and figure 5 that U matrix made correctly classification and judgment for failure type. Visual effect is obvious.

![BMU Diagram](https://example.com/bmu.png)

**Figure 6 BMU Diagram**

Figure 6 is BMU (best match point, namely clustering center) image said

![2D Neurons Plane and D matrix scheme](https://example.com/2d_neurons.png)

**Figure 7 Output layer 2D neurons Plane and D matrix scheme**

In Figure 7 the left plane diagram of the distribution of neurons, compared with D matrix diagram at right. In the D matrix diagram, the cluster centers and the distance between the other neurons with the same gray-and three-dimensional map that visually. Figure 8 D matrix is another said it with visual neurons size to the distance, the distance of the said was evident from the graph 6 kinds of the classification results of the fault.

![D matrix map](https://example.com/d_matrix.png)

**Figure 8 Another Figure of D matrix map**

After network training, we can discriminate the testing sample. The result showed on Figure 9 and Figure 10.It indicated the following results: A corresponds with b failure; motor rotor is not in center. B corresponds with d failure,
motor rotor rubbing. C corresponds with a failure, motor rotor is unbalance. D corresponds with f failure, bearing block is loose. E corresponds with c failure, the oil whirl happened. F corresponds with e failure, the surge happened. Therefore, Network can classify the failure testing sample correctly.

![U-matrix](image1)

Figure 9 Classification Drawing of Testing Sample

![U-matrix](image2)

Figure 10 Diagram of Classification Drawing of Testing Sample and Corresponding Sensitive Nerve Cells

6 Conclusions

The article focused on the study of SOM Network visualization and introduced the U matrix map, D matrix map and BMU in visualization application. It compared the difference between general SOM network input result and visualization. We can get conclusion that the SOM network visualization method is simple and easy to understand. Since the base is SOM Network, it also showed the SOM Network’s ability to identify and classify the failure. By way of application analysis, the article provided a new method to judge and classify the failure

Reference

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