Optimal Output Layer Configuration of Artificial Neural Networks for Multi-class Classification

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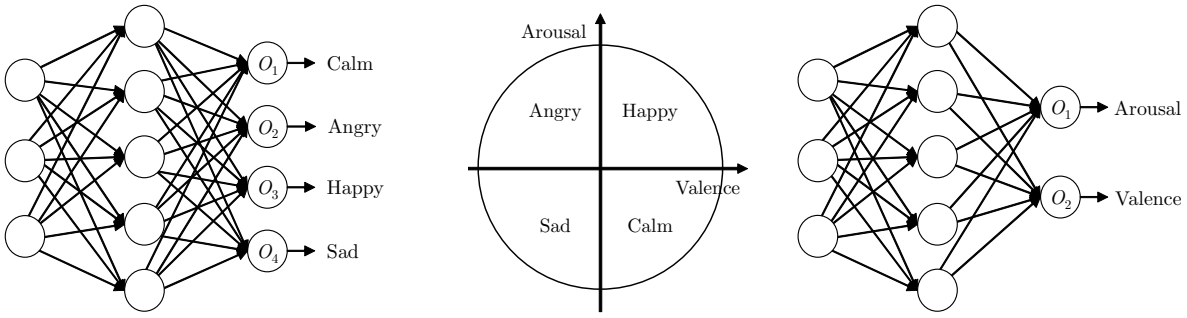
Typical artificial neural networks (ANN) for multi-class classification problem have the number of output neurons equal to the number of classes as shown in Figure (a). They use the traditional one-hot encoding method to configure the output layer neurons. This paper suggests that the simpler ANN model with the fewer number of output neurons than the number of classes may perform better or compatible results. For example, ANN with 2 output neurons can solve 4 class emotion classification problem by the Russell's circumplex model as shown in Figure (b) and (c).



(a) ANN with 4 output neurons

(b) Russell's circumplex model

(c) ANN with 2 output neurons

Figure 1: Output neuron configuration for ($m = 4$) class classification

Experiments were conducted using the standard MNIST digit image data set [1] to test whether fewer number of output neurons is better or compatible and to find an optimal output layer configuration. First, Convolutional Neural Networks (CNN) with the traditional 10 one-hot encoding method resulted in the accuracy of 98.9%. Two methods of reducing k, the number of output neurons were examined. The first obvious method is the minimal method which uses the ($k = \lceil \log m \rceil$) number of output neurons. 4 output neurons are minimal to represent 10 classes. However, it did not produce better results. The next proposed method uses the following minimization technique.

$$\text{minimize } k \text{ such that } \binom{k}{\lfloor \frac{k}{2} \rfloor} \geq m$$

It encodes each class to binary number with $\binom{k}{\lfloor \frac{k}{2} \rfloor}$ number of 1's where the encoded binary number has roughly half 1's and 0's. For example of digit dataset, 5 output neurons are needed and it resulted in 99.2% accuracy rate. The experimental results suggest that simpler ANN is better and the number of output neurons can be fewer than the number of classes.

References

[1] Y. LeCun, C. Cortes, and C. J.C. Burges, *The MNIST Dataset Of Handwritten Digits*, https://yann.lecun.com/exdb/mnist/