# Time Series Classification Using Information of Multiple Dimensions

**T. Takata** [1], Y. Uwate [1,3], H. Takao [2,3], Y. Nishio [1]

[1] *Tokushima University*
{*tomoya, uwate, nishio*}*@ee.tokushima-u.ac.jp*
[2] *Kagawa University*
*Takao@eng.kagawa-u.ac.jp*
[3] *JST-CREST*
*crest@jst.go.jp*

It is difficult to analyze unpredictable time series data using 1-Dimensional Convolutional Neural Network (1D-CNN) and Recurrent Neural Network (RNN). In this study, 2-Dimensional Convolutional Neural Network (CNN) is used for time series data to solve this problem. By using time delay embedding, 1-Dimensional data (1D-data) is converted into multidimensional data. As much as the value of the dimensions increases, the amount of information of data increases [1].

CNN is widely used for image and video recognition. It is generally composed of convolutional layers, pooling layers and fully connected layers (Fig. 1). The convolution is the feature extraction part that read images and create feature maps (Fig. 2). For each learning image, multiple filters of the convolution layer with different resolutions are applied. Filters begin with the detection of very simple features such as brightness and edges. Furthermore, filters increase the level of complexity of features that uniquely define objects [2].

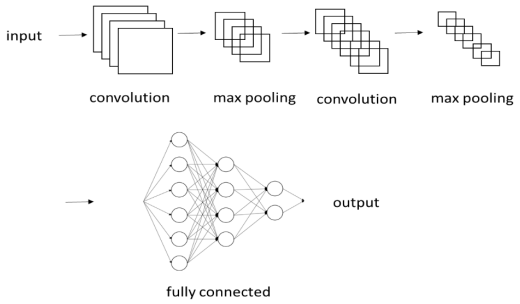


Figure 1: *An example of CNN structure.*

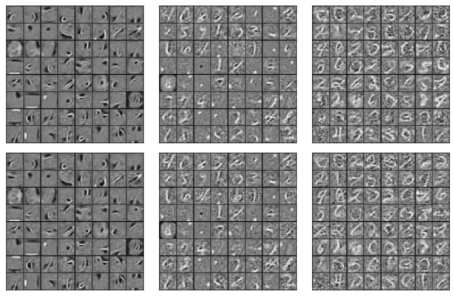

Figure 2: *An example of the feature maps.*

In this study, 1D-data are converted into multidimensional data by using time delay embedding. Let the value of data at a certain time be $x(n)$. Furthermore, if the time delay value is $\tau$, this system is represented by Eq. (1).

$$f(x) = [x(n)\ x(n+\tau)\ x(n+2\tau)\ ...] \tag{1}$$

Thereupon, we propose to make images from multiple dimensions (Fig. 3). The amount of information in the multidimensional space is extracted as the feature of the image. Figure 4 shows one of the images of attractors made by using time delay embedding.

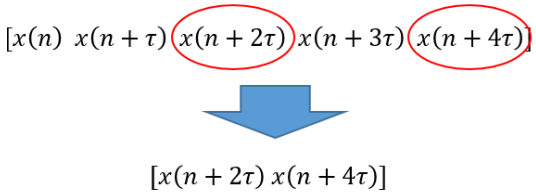


Figure 3: *Method to make an image.*

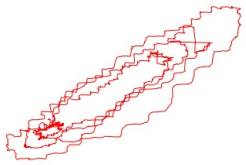

Figure 4: *An example of the attractor.*

Firure 5 shows the flowchart of this study. First, the time series data is normalized by using mean and variance values. Second, the data is converted into the images by the proposed method. Finally, the images are analyzed by using CNN.

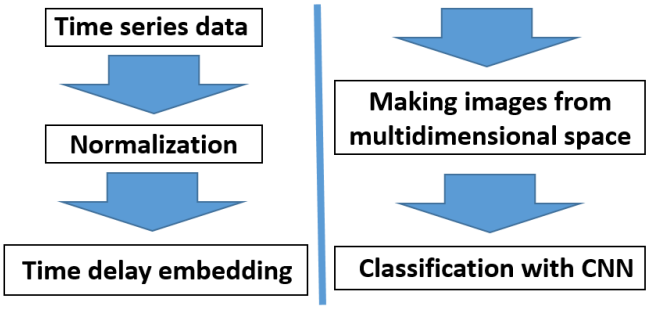


Figure 5: *Flowchart of this study.*

# References

[1] K. Aihara, T. Ikeguchi, Y. Yamada and M. Komuro, "Fundamentals and applications of chaotic time series analysis", Industrial book, p.23, 2000.

[2] M. Masakazu, K. Mori, Y Mitari and Y. Kaneda, "Subject independent facial expression recognition with robust face detection using a convolutional neural network", Neural Networks 16., vol.5, pp.555559, 2003.