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Time Series Analysis Using Attractors Made from Multidimensional Space with Convolutional Neural Network

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1. Introduction

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 increase, the amount of information of data increase.

2. Proposed Method

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 τ, this system is represented by Eq. (1).

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

In this study, we propose to make images from multidimensions (Fig. 1). The amount of information in the multidimensional space is extracted as the feature of the image. Figure 2 shows the flowchart of this study.

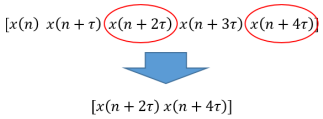


Figure 1: Method to make an image.

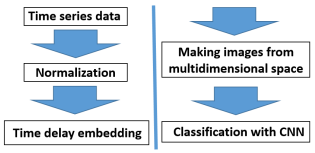


Figure 2: Flowchart.

3. Simulation Result

In this study, the data are time series data obtained by sensor with surface shapes of fabric A and B. Table 1 shows the number of data of each fabric which is used in this study. CNN is used for analyzing images of attractors. 1D-CNN and RNN are used for analyzing time series data.

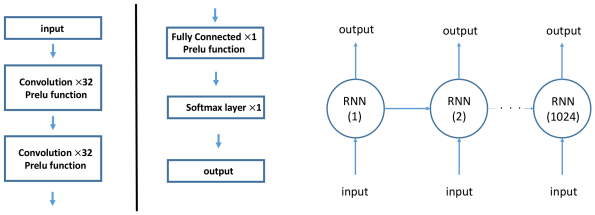
Table 1: The number of the time series data

data	time series data	images of attractors
train data	100	100
test data	20	20

Figure 3 shows the images of attractors made by using time delay embedding. These images of (342×288) pixels are resized into those of (32×32) pixels. Figure 4 shows the structures of CNN and RNN which are used in this study.

(a) fabric A. (b) fabric B.

Figure 3: Attractor of each fabric.



(a) CNN. (b) RNN.

Figure 4: Structures of CNN and RNN.

We investigate the averages of ten times of train and test accuracies. Table 2 shows the accuracies when the number of dimensions is determined to 5 dimensions. For example, attractor2-5 is the plane made by $x(n+2\tau)$ and $x(n+5\tau)$.

The test accuracy when using attractor1-5 is the best. However, the test accuracies when using other attractors are less than the test accuracy when using RNN. It turns out that a specific attractor is effective as a feature of CNN.

Table 2: Train and test accuracies

	train accuracy(%)	test accuracy(%)
1D-CNN	100	67.5
RNN	100	72.0
attractor1-5	100	75.2
attractor2-5	100	69.0
attractor3-5	100	55.5
attractor4-5	100	62.8

4. Conclusion

In this study, binary classification is carried out by using proposed method. Some of test accuracy when using proposed method are better than those when using conventional methods.

In the future, we will clarify how to extract multidimensional features to obtain sufficient accuracy of classification.