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Chaotic Data Classification by Using 1D, 3D and 4D Images with Residual Network

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1. Introduction

Chaotic characteristics can be observed in various kinds of time series data such as biological signals and stock price fluctuations. Chaotic theory is also applied for other fields including analysis of pulse wave and communication system. Chaos shift keying is one of the example of application of chaotic theory for communication system. In this method, chaos signals that have different parameters are sent, and receivers need to recognize the differences of chaos parameters in the signals. Therefore, it is important to recognize chaotic features and classify depends on the differences of chaotic statements. As to the analysis of pulse wave, proper recognition of the differences of chaos parameters enable to estimate their bodies and feeling conditions with better accuracies.

In this study, we classify three classes of chaos time series data that have different parameters by using neural networks, and we compare the differences of the input data shape among 1D, 3D and 4D images.

2. Method

By using Takens' embedding theorem, time series data $x(t)$ can be embedded into n-dimensional vector $v(t)$.

$$v(t) = (x(t), x(t+\tau), x(t+2\tau), ..., x(t+(n-1)\tau)) \quad (1)$$

1-dimension (1D) time series data is converted into 3-dimensions (3D) and 4-dimensions (4D) attractors, and it is shown in Fig. 1. In this study, x dimension of Lorenz data is embedded with time lag $\tau = 10$. Image size is 512 × 128 for 1D data, and 256 × 256 for both of 3D and 4D data.

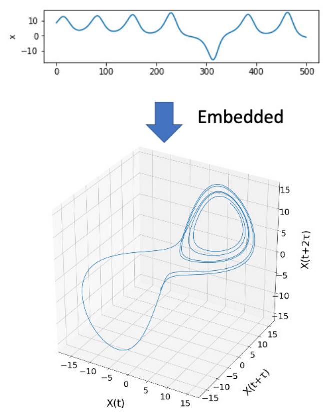

Figure 1: Reconstructed 3D attractor from time series data.

Residual Network (ResNet) is commonly used for the classification of image data. ResNet is the network that enable to have deep layered networks without vanishing gradient problem. Figure 2 shows the structure of ResNet50 that we use, and it is pretrained by ImageNet dataset. To make the figure simple, the repetitions of batch normalization and activation between convolution layers are omitted. Dotted lines indicate the process to increase dimensions with a stride of 2.

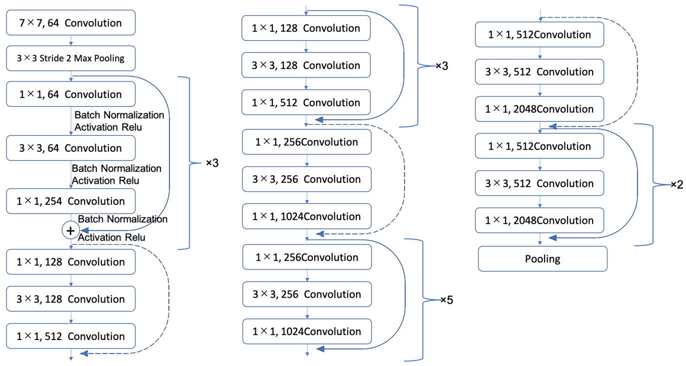

Figure 2: The structure of ResNet50.

Lorenz equations are used as chaotic time series data, and these equations are shown the following Eq. (2).

$$\begin{cases} \frac{dx}{dt} = \sigma(y-x) \\ \frac{dy}{dt} = x(\rho - z) - y \\ \frac{dz}{dt} = xy - \beta z \end{cases} \quad (2)$$

$\sigma = 10$ and $\rho = 28$ are used, and the dataset belongs to three classes β=7/3, 8/3, 15/6. Train data and test data are divided randomly. Train data has 1800 data and test data has 1200 data in total of 3 classes. The data have different initial values. The length of each time series data is 500 time steps.

3. Simulation Results

Table 1 shows the simulation result. Batch size is 16, and the number of epoch is 250.

Table 1: Simulation result

	Train accuracy	Test accuracy
1D	0.8156	0.7000
3D	0.9528	0.9063
4D	0.8539	0.8025

3D data shows the best accuracy result, and 1D data shows the worst accuracy.

4. Conclusion

In this study, we classified 3 classes of Lorenz data by using 1D, 3D and 4D attractors image data from time series data by applying Takens' embedding theorem. For future work, we would like to apply it different kinds of chaos time series data, and also we would like to study for efficient chaos feature extracting.