# Time Series Analysis with Noise-Mixing Effects Using Neural Networks

Takuya Nakamura, Ryosuke Shimizu, Yoko Uwate and Yoshufumi Nishio
Dept. of Electrical and Electric Engineering, Tokushima University
2-1 Minami-Josanjima, Tokushima, 770-5806, Japan
e-mail:{takuya, shimizu, uwate, nishio}@ee.tokushima-u.ac.jp

*Abstract*— **One-dimensional convolutional neural networks (1D-CNNs) are used for time series analysis. However, noise mixed in the data can interfere with time series analysis. We propose a method of injecting noise into the original data and the autocorrelation function data for feature extraction of training data. The test accuracy of neural network is compared with the original data and the autocorrelation function data.**

**Keywords; neural networks; time series analysis;**

## I. Introduction

There are many phenomena in the world that have time-series characteristics, such as temperature and seismic waves. Many studies have been conducted to analyze the characteristics of those time series. As a method to observe those characteristics, many time series have been converted into data and time series analysis using neural networks (NN) such as recurrent neural networks (RNN) and one-dimensional convolutional neural networks (1D-CNN) have been studied in recent years. However, the data often contain information that is not needed for analysis, called noise. If the amount of noise mixed in the data is too large, time series analysis becomes complicated and very troublesome. In this study, the classification accuracy of the neural network is investigated when noise is injected into the training data.

## II. One-Dimensional Convolutional Neural Networks

Convolutional neural network (CNN) is a structure that adds a process called convolution and pooling to conventional NN. CNN is mainly used for image recognition, natural language processing, and time series analysis. However, since images are two-dimensional data in image recognition, the number of input data increases and the computational cost increases. Therefore, the use of a one-dimensional convolutional neural network (1D-CNN), which allows the number of data to be input as it is, makes it possible to reduce the computational cost. In addition, a 1d-residual network (1d-ResNet) is used to prevent gradient loss problems.

## III. Proposed Methods

In this study, the following approach is taken to check classification accuracy in the presence of mixed noise.

**Step 1.** White noise is added to the original data and the autocorrelation function.

**Step 2.** The data to be trained is replaced with autocorrelation functions from the original data.

**Step 3.** The autocorrelation function is trained on the 1d-ResNet.

### *A. Autocorrelation Function*

The autocorrelation function (ACF) is defined as the product of time $t$ and the data shifted by $k$ from $t$ in time series data. The correlation between the current data and the data of the past time shifted by $k$ is examined.

The autocorrelation function is expressed by the following Eq. (1).

$$r_k = \frac{\sum_{i=k+1}^{n}(x_t - \bar{x})(x_{t-k} - \bar{x})}{\sum_{i=1}^{n}(x_t - \bar{x})^2} \tag{1}$$

$n$ is the sampling number and $k$ is the time lag.

Figure 1 shows the example of the original data. Figure 2 shows autocorrelation of the original data.

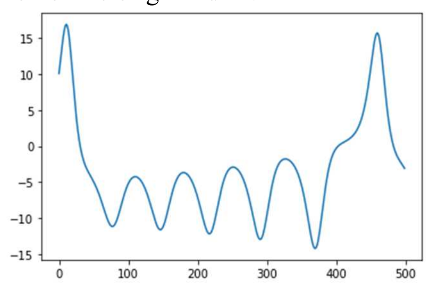


Figure 1. Original data.

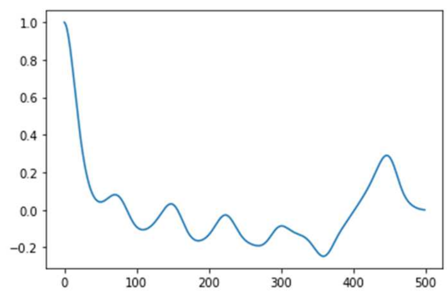


Figure 2. Autocorrelation function (ACF).

### *B. White Noise*

White noise is used in this case. One of the characteristics of white noise is that the energy is uniformlypresent in all frequency bands. White noise is often mixed in with data such as audio. We investigate the learning of 1d-ResNet when white noise is added to the training data.

## IV. VERIFICATION SIMULATION MODEL

In this study, two types of classification accuracy are tested using original data for training data and using an autocorrelation function, and original data is used for test data. A dropout layer is also used to prevent over-training.

The 1d-ResNet is used as the classification model 1d-resnet is used to solve the gradient loss problem, which is a problem of multilayer networks, by learning residuals. Figure 3 shows the structure of residual learning. Convolution(1 × 1, 128) means convolution layer with 1 × 1 filter and 128 channel.

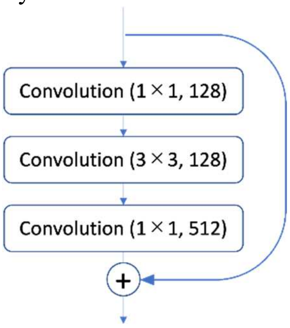


Figure 3. Structure of residual learning.

## V. DATASET

As a chaotic data, Lorenz data, which is famous chaotic equation is used. These equations are shown the following Eq. (2).

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

In this study, as the parameters, $\sigma = 10$ and $\beta = 8/3$ are used, and the dataset has threee classes that have the different $\rho$, and recognize the parameters differences by using 1d-resnet.Table I shows the number of the train data and test data.

TABLE I. THE NUMBER OF THE TRAIN DATA AND TEST DATA

| ***Data*** | ***ACF*** | ***Original*** |
|---|---|---|
| Train data | 1800 | 1800 |
| Test data | 1200 | 1200 |

## VI. SIMULATION RESULTS

Table II shows the autocorrelation function and the classification accuracy of the original data, verified with noise rates from 0.0 to 1.0 in increments of 0.1. From Table II, it can be seen that as the noise rate increases, the classification accuracy decreases from approximately 64[%] to 62[%] in both cases. Although there are some areas where the original data has higher classification accuracy, overall, the classification accuracy is higher using the autocorrelation function.

TABLE II. ACCURACY OF PROPOSED METHOD AND AUTOCORRELATION FUNCTION

| ***Rate of noise*** | ***Classification accuracy (ACF)[%]*** | ***Classification accuracy (Original)[%]*** |
|---|---|---|
| 0.0 | 64.81 | 64.52 |
| 0.1 | 64.31 | 64.30 |
| 0.2 | 64.37 | 63.00 |
| 0.3 | 64.73 | 64.98 |
| 0.4 | 64.30 | 64.45 |
| 0.5 | 63.83 | 62.88 |
| 0.6 | 64.65 | 61.27 |
| 0.7 | 63.13 | 62.56 |
| 0.8 | 63.66 | 61.63 |
| 0.9 | 62.09 | 62.71 |
| 1.0 | 62.65 | 62.11 |

## VII. CONCLUSION

In this study, 1d-ResNet is trained on training data containing white noise using an autocorrelation function. The results showed that the classification accuracy is higher when the autocorrelation function is used. As a future work, we would like to conduct similar validation with algorithms other than 1d-ResNet.

## REFERENCES


[1] T. Furugaki, Y. Uwate and Y. Nishio, “Time Sries Classification Using Autocorrelation Function as Training Data in 1D-CNN”, 2020.

[2] K. He, X. Zhang, S. Ren, J. Sun, “Deep resiual learning for image recognition”, In Proceeedings of the IEEE. Conference on computer vision and pattern recognition, pp.770-778, 2016.

[3] T. Furugaki, “Influence of Surrogate Data and Autocorrelation Function on Classification Accuracy of Neural Networks”, 2021.

[4] M. Matsugu, K. Mori, Y. Mitari and Y. Kaneda, “Subject independent facial expression recognition with robust face detection usnig a convolutional neural network”, Neural networks 16, vol.5, pp.555-559, 2003.