Effect of Delay Time for Chaotic Attractors on Classification Accuracy Using Neural Networks

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1. Introduction

Previous studies of chaotic data classification have known that using attractor images improves classification accuracy[1]. We focused on the delay time that is an important parameter in attractor generation. In this study, reconstruct chaotic data as attractors and classify them by image recognition. In addition, we generated attractors with different delay times and investigated how they affect classification accuracy. As a result, we confirm that classification accuracy changed greatly depending on the delay times.

2. Proposed Methods

The neural network used in this study is shown in Fig. 1. Residual Network 50 (ResNet50) consisting of 50 intermediate layers that incorporates residual learning is used. ResNet50 is used as a method for image classification of chaotic attractors in previous studies. ResNet50 is a Deep Neural Network that overcomes the conventional problems of gradient loss and degradation by incorporating residual learning. In this study, ResNet50 is used to classify attractors.

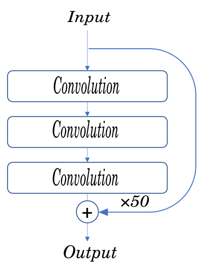

Figure 1: ResNet50.

In this study, image classification was performed on attractors embedded with different delay times. Takens' theorem in Equation (1) was used for embedding. It is known that the reconstruction is valid if the relationship between the dimension m of the attractor to be reconstructed and the original dimension d is $m > 2d + 1$ according to Takens' embedding theorem. In this study, we investigated the effect of delay time τ(>0) on classification accuracy.

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

3. Results

We performed image classification of chaotic data with attractors embedded in Takens' theorem with different delay times. Fig. 2 shows the attractors generated for each of the different delay times. Table 1 shows the classification accuracy with each attractor generated in different delay times.

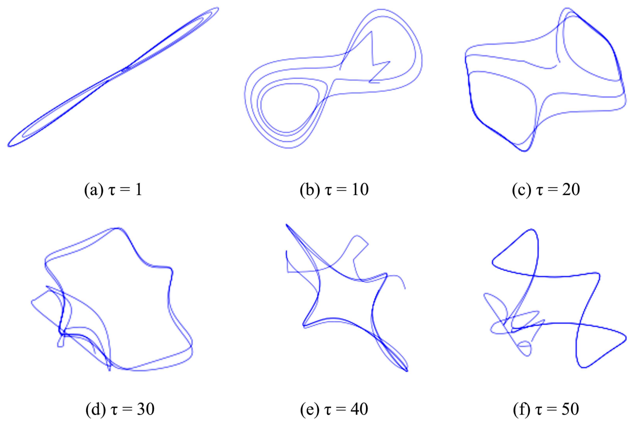

Figure 2: Attractors for each delay times.

Table 1: Test accuracy for each delay times.

	test accuracy(%)
$\tau = 1$	46.4
$\tau = 10$	69.1
$\tau = 20$	83.4
$\tau = 30$	84.7
$\tau = 40$	83.3
$\tau = 50$	82.4

All training settings for each attractor image are same except for delay times. The settings in this study are training data = 1800 images, test data = 1200 images, batch size = 16, epoch = 300. As a result, increasing the delay time improved classification accuracy.

4. Conclusion

In this study, attractors were generated with different delay times by Takens' embedding theorem and investigated the classification accuracy of attractor images.As a result, increasing the delay time greatly improved classification accuracy. We consider that increase in attractor features contributed to the improvement in classification accuracy.

5. Reference

[1]Hiromu Hamanaka, Yoko Uwate, Yoshifumi Nishio, "Chaotic Data Classification Methods for Residual Neural Network" Proceedings of International Symposium on Nonlinear Theory and its Applications (NOLTA'23), Sep. 2023.(accepted)