Effect of Mutual Information on Chaotic Attractor Classification Accuracy Using Neural Network

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Abstract— **Chaotic attractors can be classified by neural networks. However, its accuracy is incomplete. Because it varies greatly depending on the shape of the attractor. Also, the shape varies depending on mutual information. We investigated how the amount of mutual information in embedding affects the accuracy of attractor classification by neural networks.**

Keywords; Chaotic Attractor, Neural Networks, Mutual Information

I. Introduction

Previous studies of chaotic data classification have known that using attractor images improves classification accuracy [1]. Chaotic phenomena can be confirmed by physical data like brain waves. And it can be reconstructed as 3 dimensions (3D) chaotic attractors from 1D chaotic data by embedding. We focused on the delay time and mutual information 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 mutual information and investigated how they affect classification accuracy. As a result, we confirm that classification accuracy changed greatly depending on the mutual information.

II. Methods

A. Chaotic Attractor

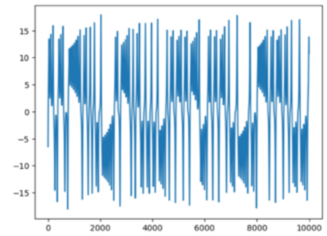
In this study, we use Lorentz equation (1). It is one of the typical chaos models. However, we use 1D data of brain waves. Therefore, 1D data needs to be extended to 3D data.

Then, we use Takens' embedding theorem (2). It is known that the reconstruction is valid if the relationship between the dimension n of the attractor to be reconstructed and the original dimension d is $n > 2d + 1$ according to Takens' embedding theorem.

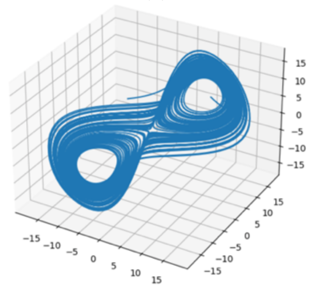
$$\begin{cases} \frac{\partial x}{\partial t} = \sigma(y - x) \\ \frac{\partial y}{\partial t} = x(\rho - z) - y \\ \frac{\partial z}{\partial t} = xy - \beta z \end{cases} \quad (1)$$

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

Fig. 1 shows extension from 1D data to 3D attractor using Takens' embedding theorem.



(a)



(b)

Fig. 1: (a) 1D data of Lorenz equation, (b) 3D attractor embedded using Takens' theorem.

B. Neural Networks

The neural network used in this study is shown in Fig. 2. Residual Network 50 (ResNet50) consisting of 50 intermediate layers that incorporates residual learning is used [2]. ResNet50 is used as a method for image classification of chaotic attractors in previous studies [3]. 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.

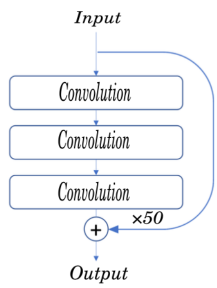


Fig. 2: ResNet50.

C. Mutual Information

Information of 1D data needs to be transferred when extending to 3D. Fig. 3 shows relationship between mutual information and delay times. It is known that mutual information can be used as an indicator of the transfer. Mutual information varies depending on the delay time in embedding.

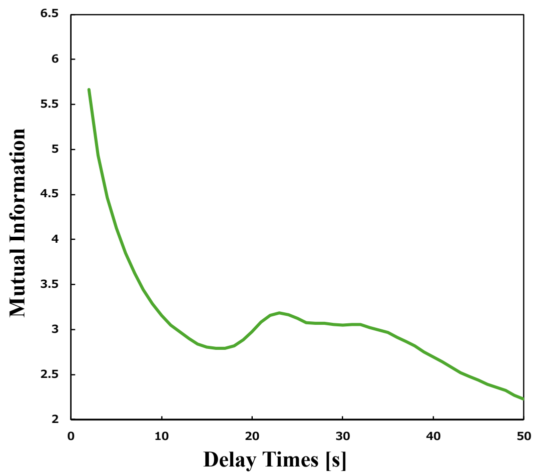


Fig. 3: Mutual Information.

III. Results

We performed image classification of chaotic data with attractors embedded in Takens' theorem with different delay times. The delay time is related to the mutual information.

A. Generated chaotic attractors

Fig. 4 shows the attractors generated for each of the different delay times. It can be seen that shapes of chaotic attractors varies depending on delay times. In this study, we classify each of those attractors with different parameters of the Lorenz equations(1).

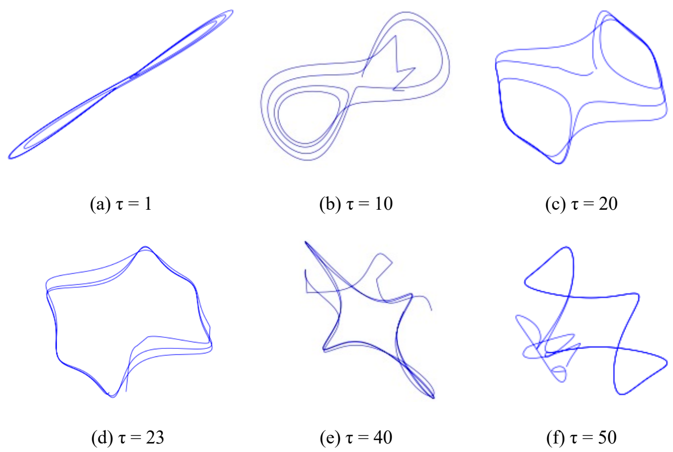


Fig. 4: Chaotic attractors for different delay times.

B. Classification accuracy

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.

Fig. 5 shows the classification accuracy and mutual information with each chaotic attractor that generated in different delay times.

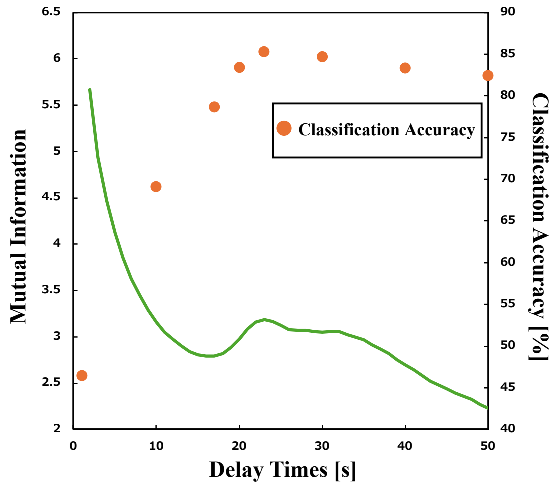


Fig. 5: Mutual Information vs Classification Accuracy

IV. Discussion

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 and we found maximum value of classification accuracy. We consider that increase in attractor features contributed to the improvement in classification accuracy.

References

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