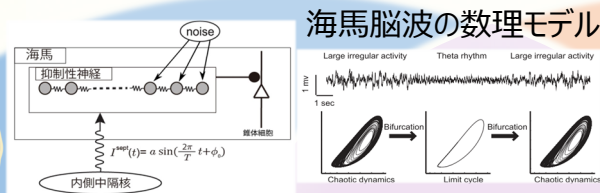
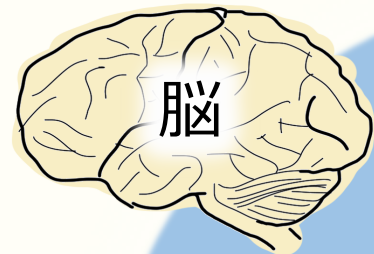




順天堂大学健康データサイエンス学部 脳神経ダイナミクス研究室 Neurodynamics Laboratory

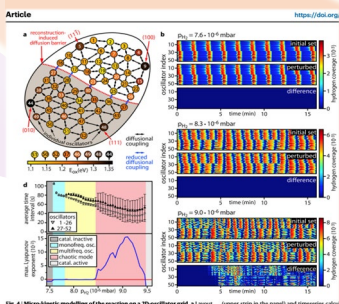
数学で脳をつくる
～数理モデルと脳型人工知能～
数学で天気をあやつる



Tokuda K, Katori Y, Aihara K. Chaotic dynamics as a mechanism of rapid transition of hippocampal local field activity between theta and non-theta states. Chaos. 2019 Nov;29(11)

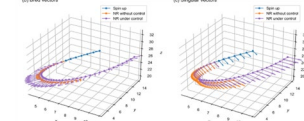
海馬脳波の数理モデル

ナノシステムにおけるカオスの発見

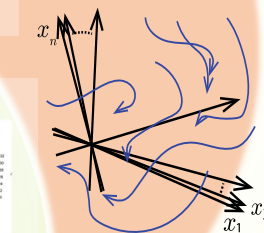
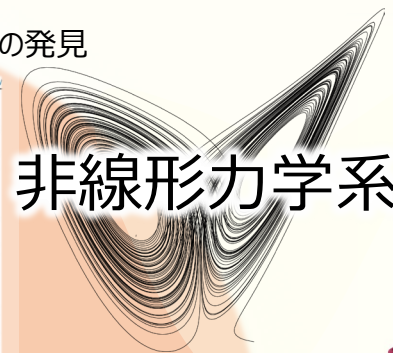


Raab M, Zeininger J, Suchorski Y, Tokuda K, Rupprechter G. Emergence of chaos in a compartmentalized catalytic reaction nanosystem. Nat Commun. 2023 Feb 10;14(1):736.

非線形システムの制御



Ouyang, M., Tokuda, K., and Kotsuki, S.: Reducing manipulations in a control simulation experiment based on instability vectors with the Lorenz-63 model, Nonlin. Processes Geophys., 30, 183–193, 2023.



気象制御



研究テーマ： 中枢神経系の生理および病理を、数理モデリングや、機械学習等データ解析により、解き明かすことを目的としている。主な道具立ては非線形力学系、機械学習、統計など。最近では、物理系の非線形現象の理解のための数理モデリングや制御手法の開発なども行なっている。

キーワード： 非線形ダイナミクス、脳の計算論、脳型人工知能、機械学習、データサイエンス、記憶・学習 AI、レザバー計算、計算論的精神医学、中枢神経系病理

共同研究： ウィーン工科大学、順天堂大学医学部、京都大学、札幌市立大学、千葉大学、中部大学、筑波大学 東京大学、東北大学、はこだて未来大学等多数

研究費： JSPS科研費、JST Moonshot, AMED等

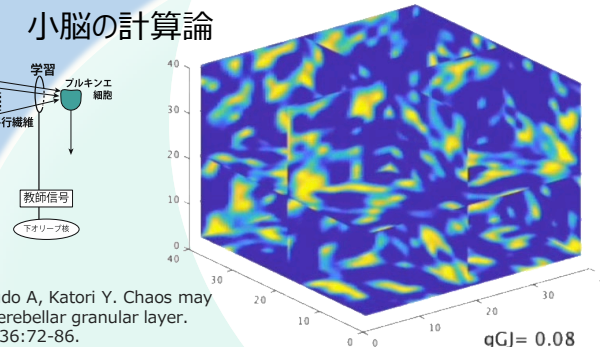
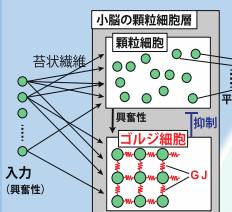


徳田慶太 准教授
Keita Tokuda, Ph.D



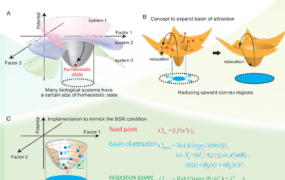
三ツ井孝仁 助教
Takahito Mitsui, Ph.D

小脳の計算論



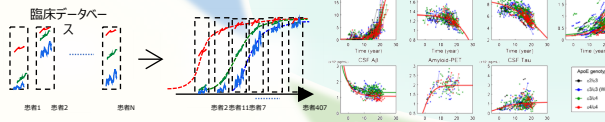
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生体分子システム ダイナミクスの構造解析



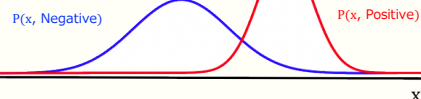
Kariya Y, Honma M, Tokuda K, Konagaya A, Suzuki H (2022) Utility of constraints reflecting system stability on analyses for biological models. PLoS Comput Biol 18(9): e1010441

医療ビッグデータにおける時系列解析手法の開発

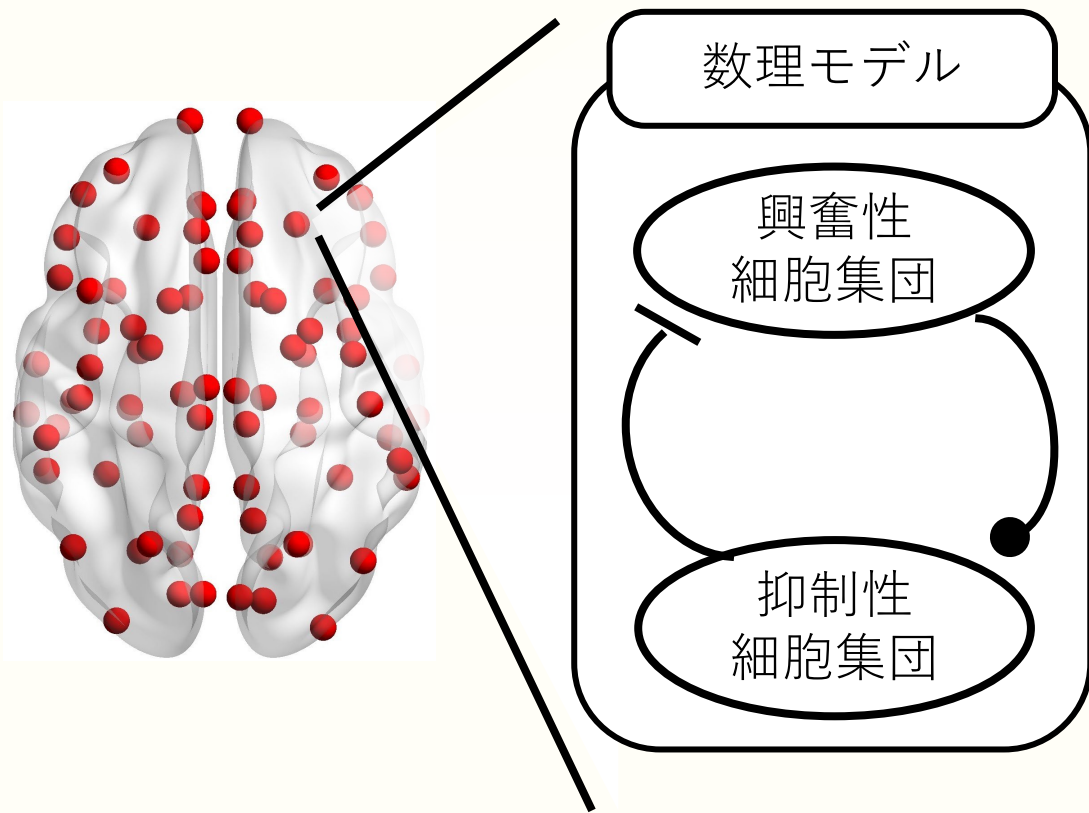


Ishida T, Tokuda K, Hisaka A, Honma M, Kijima S, Takatoku H, Iwatsubo T, Moritoyo T, Suzuki H; Alzheimer's Disease Neuroimaging Initiative. A Novel Method to Estimate Long-Term Chronological Changes From Fragmented Observations in Disease Progression. Clin Pharmacol Ther. 2019 Feb;105(2):436-447.

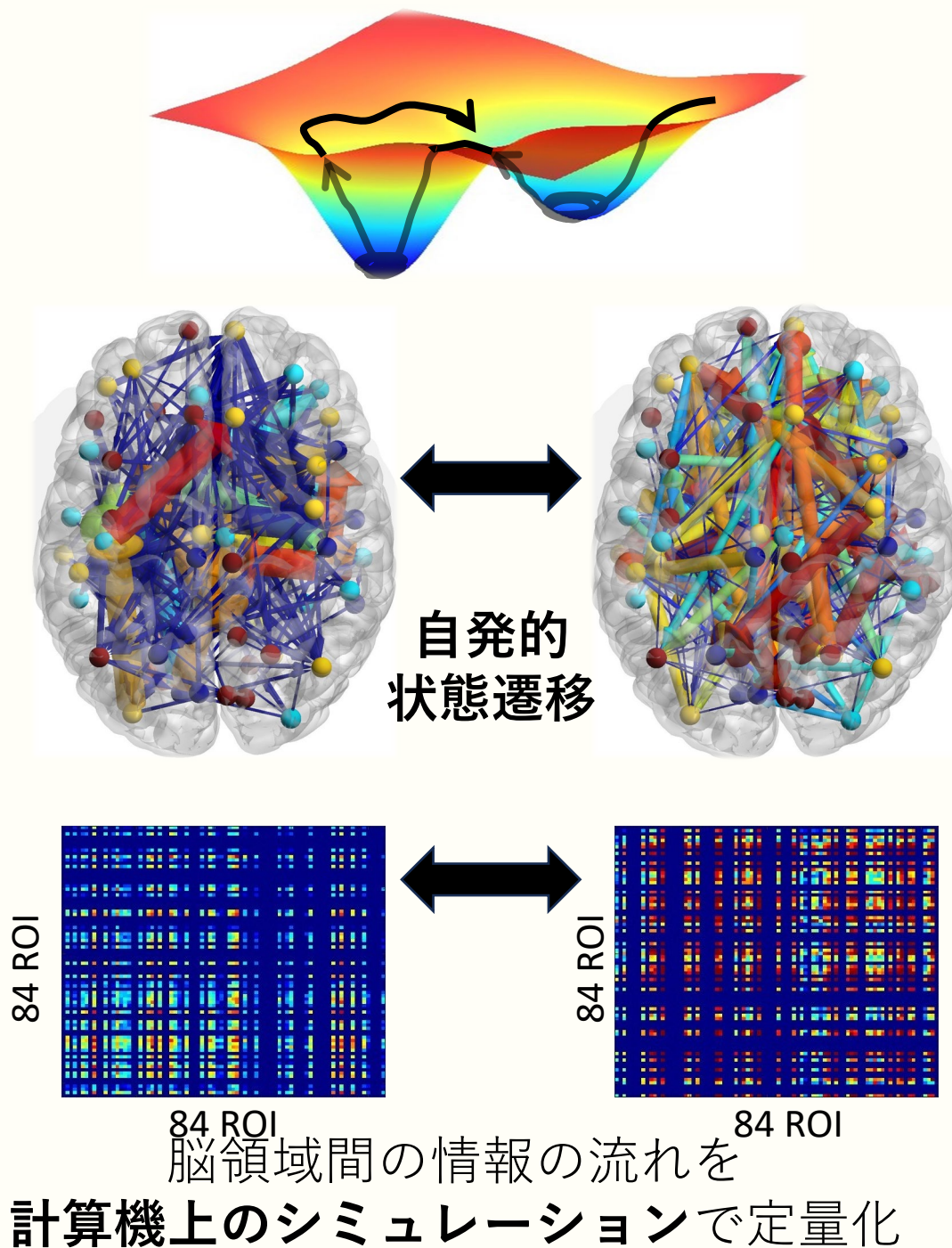
統計・機械学習



脳活動のシミュレーション



コネクトームデータから抽出した隣接行列の上で数理モデルを動かすことで数理解析が可能になる。



脳内の情報伝達過程の不全による解離性障害の計算論的モデルの構築

Computational Model of the Development of Dissociative Disorder

Due to a Failure of Information Flow Process in the Brain

大槻沙津希(順天堂大学)、徳田慶太(順天堂大学)
Satsuki Otsuki (Juntendo Univ.), Keita Tokuda (Juntendo Univ.)

Abstract

Dissociative disorder is characterized by various symptoms, such as the loss of normal integration of memories, consciousness, awareness of identity, somatosensory sensations, and control of body movements, induced by stress. The pathological understanding of dissociative disorders remains unclear, and the detailed neural basis is not yet fully elucidated. In the disruption of consciousness and behavior integration in dissociative disorders, it is believed that there is a failure of information transmission between specific neural circuits in the brain, such as between the amygdala and other brain circuitries [1]. In this study, based on the currently known neural bases associated with dissociative disorders, we aim to develop a dynamical model that describes the computational mechanism of how the failure of information transmission arises as a result of neural interactions.

Dissociative disorder

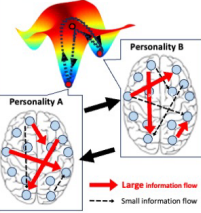
Symptoms

- Dissociative amnesia
- Depersonalization
- Dissociative identity disorder (DID)
- Conversion Disorder

Failure of integration

Dissociative disorder is caused by strong mental stress, and characterized with patient's personalities and consciousness that are not integrated. It is believed that there is a failure of information transmission between specific neural circuits in the brain, such as between the amygdala and other brain circuitries.

Hypothesis



We assume that **failure of information transmission between specific regions in the brain** may cause symptoms such as amnesia and personality change. Furthermore, **spontaneous transition between the information routing patterns** may explain the phenomena such as **transition between multiple personalities** in DID. Therefore, we examine whether **a model of integrated failure due to inhibition of information transmission can be created** using the findings of the following previous studies.

Previous studies found that multiple information sharing and routing patterns of information flow between neurons emerge in collective dynamics [2, 3]. Yamaguchi et al. found that the effective direction of information transmission changes dynamically due to the switching of the phase difference between the two nonlinear oscillators [2].

To examine if their findings can be a good candidate of the model of DD, we increase the system size of the model in Yamaguchi et al and examine the spontaneous transition between multiple patterns of information routing can be observed as well.

Model

System dynamics

System dynamics is given by

$$\dot{X}_j = F(X_j) + K_{jk}(X_k - \bar{X}),$$

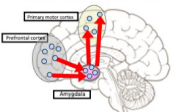
where

$$F(X_j) = \begin{pmatrix} -(y_j + z_j) \\ x_j + ay_j \\ b + z_j(x_j - c) \end{pmatrix}$$

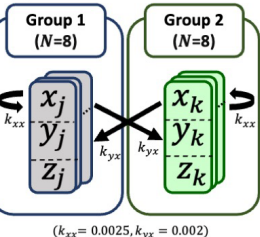
$$\begin{pmatrix} x_j \\ y_j \\ z_j \end{pmatrix}$$

represents the dynamics of an uncoupled brain region modelled with the Rössler system. The matrices K_{jk} is the connection matrix. (Parameter values: $a=0.15$, $b=0.2$, $c=10$.)

Network architecture



Network ($N = 16$) is divided into two groups, 8 nodes each. Variable x of all nodes within a network connect to each other. All x variables connect to y in the other group.



Analysis

Wavelet transform

The phase relation of several oscillatory systems provides useful information about the dynamic relationship between interacting systems. We determine the instantaneous phases $\theta_j(t)$ ($j = 1, 2, \dots, N$) of the chaotic oscillators by means of wavelet transform:

$$W_j(t, f) = \int_{-\infty}^{+\infty} \psi_{t,f}(s) x_j(s) ds,$$

where $\psi_{t,f}(s)$ is a complex conjugate of the Morlet wavelet defined at frequency f and time t by:

$$\psi_{t,f}(s) = \sqrt{\frac{2}{\pi\sigma_\phi^2}} \exp(i2\pi f(s-t)) \exp\left(-\frac{(s-t)^2}{2\sigma_\phi^2}\right)$$

(parameter value: $f=0.16$).

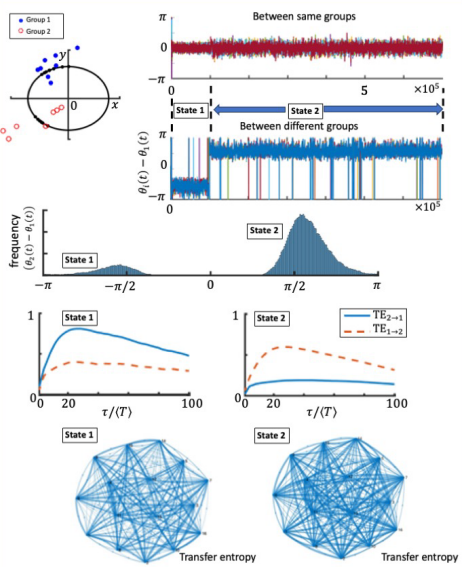
The phase difference between chaotic oscillators is defined as

$$\varphi_{21}(t) \equiv \theta_2(t) - \theta_1(t) \pmod{2\pi}.$$

Transfer entropy (TE)

$$T_{2 \rightarrow 1} \equiv \sum_{i,j,k} p_{i,j,k}(\theta_1(t+\tau), \theta_1^i(t), \theta_2^m(t)) \log \frac{p_{i,j,k}(\theta_1(t+\tau) | \theta_1^i(t), \theta_2^m(t))}{p_{i,j}(\theta_1(t+\tau) | \theta_1^i(t))}$$

Results



Discussion

We confirmed that the spontaneous switching between the routing patterns of information also occurs in interacting multiple nonlinear oscillators reflecting the phase difference between the systems. Dependence of model behavior on parameter values such as the connection strength should be elucidated further. We also plan to incorporate the interaction between the system and the surrounding environment, because the environment is thought to be one of the crucial factor in development of dissociative disorder.

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