# Analyses on Nonlinear Dynamics with Multiple Time-Scales in the Brain

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| その他のタイトル | 脳における多重時間スケールを有する非線形ダイナミクスの解析 |
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# 論 文 の 内 容 の 要 旨

論文題目　Analyses on Nonlinear Dynamics with Multiple Time-Scales in the Brain
（脳における多重時間スケールを有する非線形ダイナミクスの解析）

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We analyzed nonlinear dynamics with the multiple time-scales structure emergent from the brain, and mainly focused on the three distinctive time-scales: deterministic slow, deterministic fast, and stochastic fast oscillations, with the aim at understanding the dynamics generating macroscopic oscillatory phenomena, often observed as electroencephalographic (EEG) signals —which reflect huge information of cell assemblies in the brain and accordingly would involve higher brain functions such as consciousness.

First, we developed a novel nonlinear time series analysis method called time series dimension (TSD), which was derived from the conventional fractal dimension through a key approximation. Owing to this approximation, the TSD was a function of the level of dynamical noise behind time series, where the dynamical noise was defined in the sense of the Gaussian white noise so that this noise was the origin of the stochastic fast oscillations. Based on such a functional TSD, we succeeded in detecting the level of dynamical noise included in unknown dynamics behind time series, so as to analyze any signal composed of both the deterministic oscillations and the stochastic fast oscillations. Via applying the TSD to EEG signals, we revealed that the visual inputs can control the level of dynamical noise in the frontal lobe; this result suggests that temporal changes of the extracted dynamical noise level contribute to characterizing nonlinear oscillatory phenomena.

Second, we developed an extended discrete-time neural network model, comprising excitatory and inhibitory stochastic neurons with dynamic synapses, so as to analyze signals composed of the deterministic slow oscillations and the deterministic fast oscillations. Owing to the mean field approximation, a set of variables representing neurons was converted to a macroscopic variable resembling an EEG signal, and furthermore the stochastic model was transformed into a discrete-time dynamical system. Via the bifurcation analysis, we revealed that the interactions between the above two different networks can generate the two subtypes of phase-amplitude cross-frequency coupling phenomena, which were separated by the cyclic saddle-node bifurcation of a one-dimensional torus in a map, named MT1SNC bifurcation; this result suggests that the underlying dynamics of cross-frequency coupling phenomena effectively switches between the two submodes, depending on external environmental changes.

We believe that the aforementioned two mathematical analyses, namely nonlinear time series analysis and bifurcation analysis will help us approach the comprehensive elucidation of complex dynamics in the brain.