The Global COE Program

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Bilateral International Exchange Program (BIEP, invite) report

Send report to: Your responsible Professor in Kyoto University

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(Year/Month/Day) 2012/12/29

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Research Project

Title	Application of copula Gaussian graphical models
Duration	2012/09/16 – 2012/12/14

Please summarize your activities and results during your stay in Kyoto University.

Also please describe how your stay has been beneficial to the graduate students in the institute. You can add a sheet, if you need more space.

You can also write any comments and requests to the GCOE program.

Here I summarize my activities in brief during the 90-day stay in in Nonlinear Dynamics Group, Physics Department, Kyoto University. The report is organized as follows: the research activities, the main purpose of this visit, are presented in the first section. Next, academic activities are reported. The last section is concerned with other activities.

1. Research Activities

1.1 Talks about my previous research

To collaborate efficiently, I first gave 6 detailed talks about my research in Nanyang Technological University to let Prof. Shinomoto's group have a global view of my models. The main content can be summarized in two parts

1.1.1 Copula Gaussian Graphical Models

The copula Gaussian graphical model is a general notion in which we employ to Gaussian copula to model the interdependencies between marginals with different distributions, either continuous or discrete.

In this presentation, we introduce the definition of copula and different types of copula in at the beginning. After that, we focus on copula Gaussian graphical models for continuous case. Specifically, we first present the standard copula Gaussian graphical model. In this model, non-Gaussian observed variables are transformed to Gaussian via Gaussian copula and next a sparse graphical model is learned from the Gaussian data by maximizing the log-likelihood with an ℓ_1 penalty on the inverse covariance.

Second, the case of hidden variables (no sample of these variables can be observed) is considered and copula Gaussian hidden variable graphical models are proposed to solve this problem. This model separates the influence of the hidden variables from the observed variables and only models the direct interactions between observed variables. Application of this model on time-series is also described in the following.

Third, since standard copula Gaussian graphical model is devoid of the capability of modeling long-range dependence between far-apart variables, copula Gaussian multiscale graphical models are explained. This model exploits the latent quad-tree structure to capture the long-range dependence and further capture the short-range dependence by introducing in-scale structure, resulting in a sparse representation of the complex dependencies. This model is very useful to analyze the spatial dependence in a large spatial domain, such the sea temperature of Pacific ocean and Asian precipitation.

Forth, we further extend our copula Gaussian graphical models to discrete data using the framework of expectation-maximization. We aim to find the dependence structure in the Gaussian latent layer that best describe the discrete data we observe. In the E-step, an efficient Gibbs sampler is applied, and in the M-step, the sparse graphical model is inferred from the Gaussian data.

1.1.2 Statistical Modeling of Extreme Events

Modeling of extreme events is of significant importance nowadays, since extreme events always have damaging effects, causing loss of property and life, as well as indirect effects, such as increased costs for strengthening infrastructure and higher insurance premiums.

In this presentation, we first introduce the fundamental theorems about the asymptotic distributions of extreme value: Generalized Pareto (GP) distribution and Generalized Extreme Value (GEV) distribution. The former is used to model peaks over a certain high enough threshold and the latter to model block maxima (such as monthly maxima or annual maxima).

Based on the fundamental theorems, we illustrate the model for marginal analysis, whose objective is to accurately model marginal distribution at each place and further select the optimal locations or set design criteria based on the accurate model. It has been shown that considering the spatial dependence between the parameters of GP distribution for different measuring sites can improve the accuracy of estimation. Here, we use a Gauss-Markov random field prior to model GP parameters by setting its structure to be a thin-membrane model.

Next, we present the model for joint analysis, whose aim is to model both the parameter dependence and extreme value dependence. A Gaussian copula graphical model with predefined thin-membrane model structure is used in this case to “glue” all the GEV distributed marginals together, after modeling the parameter dependence between GEV distributions for different measuring sites. Efficient interpolation method is then introduced to predict the extreme values at unmonitored sites.

1.2 Data Analysis

After discussing with Prof. Shinomoto, we tried to apply those models introduced above to several data sets, including earthquake, social communication, and spike.

1.2.1 Earthquake Data

We use GEV distribution to model the weekly maximum magnitude of earthquakes occurring in predefined small regions, and further infer the spatial dependence by using copula Gaussian graphical models, including the standard one and the one with hidden variables. Specifically, we analyze the earthquake data in Japan, New Zealand and around the world. For worldwide data, we adopt the standard Flinn-Engdahl partition to divide the world into 50 seismic zones as shown in Fig. 1.

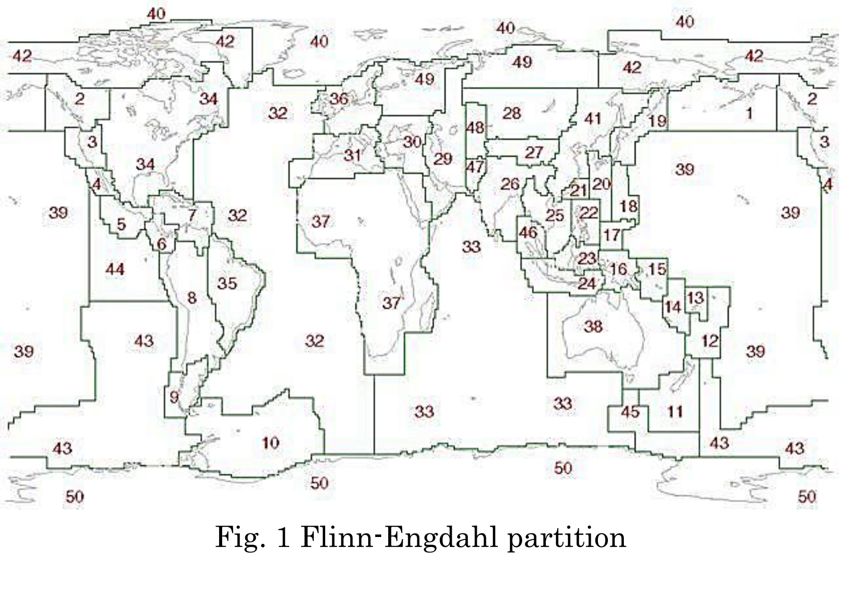

Fig. 1 Flinn-Engdahl partition

1.2.2 Functional Multineuron Calcium Image

We use the 1100s spike recordings of 62 neurons in the region named hippocampal CA3. After removing those neurons with less than 100 spikes, only 23 neurons remain. Our objective is to detect the stable connections between neurons and try to check whether nearby neurons tend to have more connections than distant neurons. Moreover, we are also interested in the excitatory and inhibitory connections and try to use them to identify excited and inhibited neurons. The model we used here is the discrete copula Gaussian graphical models since spike counts are discrete.

1.2.3 Spike Data of Rats

The dataset we analyze contains more than 12000s recordings. 4 tetrodes were used in this experiment and the spike data of 49 neurons were recorded. We are concentrated on analysis of two types of dependence stability: short-term stability and long-term stability. For short-term analysis, we choose 3 time intervals; each of them contains 2000s recordings. We retain all the neurons available (having spikes) in each interval and we check the stability of the connections by further dividing the interval into 20 windows and infer a graphical model for each window. The result of the first time interval is shown in Fig. 2.

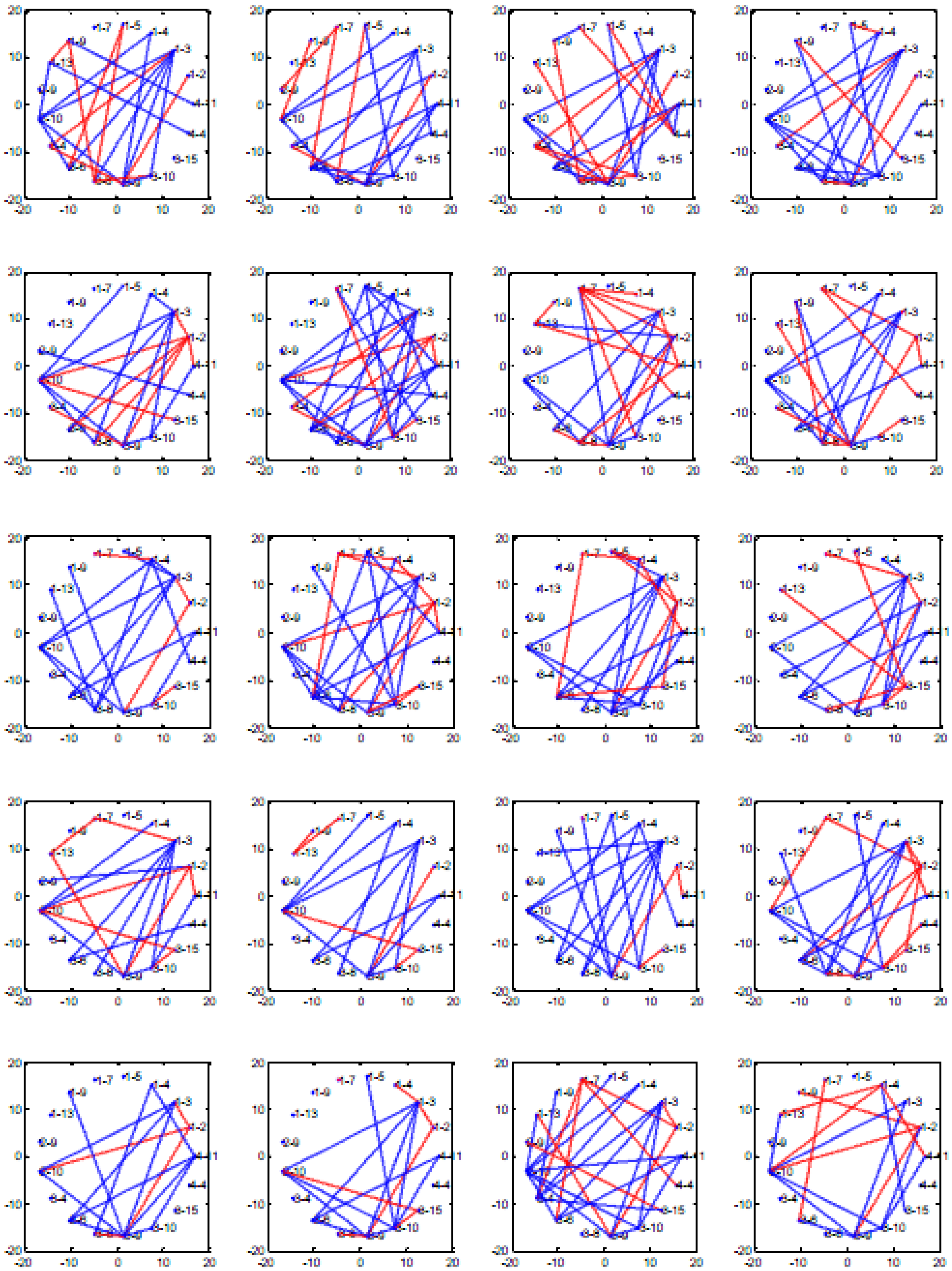

Fig. 2. Results of the first time interval: red (blue) edges denote positive (negative) connections

We can find that the graphical model structure changes gradually. However, there are some edges stable all the time.

For long-term analysis, we retain 8 neurons with firing rate greater than 1Hz in all the three intervals.

2. Academic Activities

Prof. Shinomoto held a workshop on statistical aspects of neural coding on Nov. 1st and 2nd (http://www.ton.scphys.kyoto-u.ac.jp/~shino/nousemi/workshop121101.htm) and we presented the work about extreme events modeling. Furthermore, there was a wide variety of interesting talks in the workshop, ranging from theory to applications. Thus, I learnt a lot by listening to the talks and communicating with those brilliant professors and researchers.

3. Other Activities

During the stay, I got familiar with students in Nonlinear Dynamics Group and we had a lot of discussions, both inside and outside of the office, on research, life, culture and almost everything I could think of. Discussing research can give us more inspirations since everyone thinks in a different way. Talking about life and culture in different countries and places can broaden our horizon and enrich our spiritual life. Communication is like the most amazing talent of human-beings and I really enjoyed and learned a lot from each other via communication.

Other unforgettable activities, such as the welcome and farewell party, the excursion to Nara, are also very unique experiences. The following is a photo taken when we traveled in Nara.

Acknowledgement

I am incredibly grateful to Prof. Shinomoto for inviting me to his amazing group and for his unrelenting guidance, support and care during these three months. Special thanks also go to the graduate students Kim-san, Mochizuki-san and Shintani-san for their kind assistance and concern. One of my best experiences in Year 2012 is to do research in this inspiring and harmonious group. Also, I would especially like to thank Nishikawa-san for helping me apply the visa and rent the apartment. Finally, many thanks to GCOE community for offering me such a good opportunity.