제 18차 통계물리 워크숍

2015년 8월 20일(목) ~ 8월 22일(토)

전북대학교 자연과학 5관 213호

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워크숍 일정표

발표 12분, 질의 및 응답 3분

시간	8월 20일(목)	8월 21일(금)	8월 22일(토)
8:00 ~ 9:00		조식	조식
9:00 ~ 10:45		Session 3 복잡계(CS) 좌장: 김진민	Session 5 통계물리일반(SP) 좌장: 조항현
10:45 ~ 11:00		휴식	휴식
11:00 ~ 12:45		Session 4 복잡계(CS) 통계물리일반(SP) 좌장: 이상법	Session 6 통계물리일반(SP) 좌장: 김재업
13:00 ~ 14:00	워크숍 등록	점심	점심
14:00 ~ 15:45	Session 1 네트워크(NW) 좌장: 노재동	15:00 ~ 19:00 Excursion	
15:45 ~ 16:00	휴식		
16:00 ~ 17:45	Session 2 경제물리(EP) 생물물리(BP) 좌장: 김상락		
18:00 ~	저녁 식사	19:00 ~ 21:00 만찬	

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Seok-Jong Park, Soon-Hyung Yook and Yup Kim (Kyung Hee Univ.)

[NW3] Criticality in hybrid percolation transitions on interdependent networks
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[NW5] Optimal strategy for spreading dynamics with layer-crossing costs in multiplex networks
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[NW6] Explosive percolation transitions on growth networks
Soomin Oh (SNU), Seung Woo Son (Hanyang Univ.) and Byungnam Kahng (SNU)

[NW7] Complex network analysis for the Korean national R&D activity in terms of research keyword
Min-Woo Ahn and Woo-Sung Jung (POSTECH)

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Kyuseong Lim (KAIST), Soo Yong Kim(KAIST), and Kyungsik Kim (Pukyong Univ.)

[BP1] Structure and Learning of Neural Networks

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[BP2] Small Angle Neutron/X-Ray Scattering Study of Microtubules and Polycations

Juncheol Lee (1), Jimin Lee (1), Chaeyeon Song (2), Herbert P. Miller (2), Kyuhan Kim (2), Leslie Wilson (2), Cyrus R. Safinya (2) and Myung Chul Choi (1), (1. KAIST, 2. UC Santa Barbara)

[BP3] Biconnectivity of the cellular metabolism: A cross-species study and its implication for human diseases

P. Kim, D.-S. Lee, and B. Kahng (Seoul National University)

[BP4] Robustness of the metabolic networks: The impact of enzymatic gene expression

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[BP5] Coevolution of species abundance and topology in mutualistic networks

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[BP6] Fast diffusion along grain boundaries of phospholipid(DPPC)-cholesterol multilayers

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[CS5] Spread of Political Opinions Based On Human Migrations in Presidential Elections

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[CS6] Coupled spatial evolutionary public goods game on interdependent networks

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최원준(Seoul National Univ.), 강병남(Seoul National Univ.)

Session 4: CS 복잡계 + SP 통계물리일반

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[CS9] Understanding Motives of Historical Events through a Half Millennium Chronicle: The Annals of the Joseon Dynasty

Byunghwee Lee (KAIST), Daniel Kim (KAIST), Hang-Hyun Jo (POSTECH), Hawoong Jeong (KAIST)

[CS10] Temporal change of popularity in given names

*Mi Jin Lee (1) , Woo Seong Jo (1) , Il Gu Yi (1) , Seung Ki Baek (2), and Beom Jun Kim (1)

(1): Department of Physics, Sungkyunkwan University

(2): Department of Physics, Pukyong National University

[SP1] Macroscopic Irreversibility of Collective Brownian Particles

*Pyoung-Seop Shim (University of Seoul), Hyun-Myung Chun (University of Seoul) and Jae Dong Noh (University of Seoul)

[SP2] Simulation Study for Magnetic Colloids via Brownian Dynamics and Stochastic Rotational Dynamics

*KIM Hyeok (Konkuk Univ.), KIM Juin (Air Force Academy), GIM Bopil (KAIST), YEO Joonhyun (Konkuk Univ.)

[SP3] Percolation transitions on multiplex lattices under cascade of activations and deactivations

*Jeehye Choi (Korea Univ.), Byoungjoon Min (City College of New York), Kwang-Il Goh (Korea Univ.)

[SP4] Finite-Size Scaling Properties of the One-Dimensional Critical Quantum Ising Model in Matrix Product State Representations

*Sung-Been Park (Hanyang Univ.) and Min-Chul Cha (Hanyang Univ.)

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[SP5] Curzon-Ahlborn Efficiency of a Brownian Heat Engine without Endoreversible Condition

*Hyun-Myung Chun (University of Seoul), Jong-Min Park (University of Seoul) and Jae Dong Noh (University of Seoul)

[SP6] Universality Issues of Generalized Epidemic Process

*Kihong Chung (KAIST), Yongjoo Baek (Technion), Meesoon Ha (Chosun University), and Hawoong Jeong (KAIST)

[SP7] Cyclic information engine with a perpetually moving harmonic potential

*Jong-Min Park (Univ. of Seoul), Jae Sung Lee (KIAS), and Jae Dong Noh (Univ. of Seoul)

[SP8] A Slow Passage Problem

*Jaeyun Yoo and Kang-Hun Ahn (Chungnam National Univ.)

[SP9] Dissipative dynamics of a Brownian particle in Langevin equations

*Woon Hak Baek and Kyungsik Kim (Pukyong National University)

[SP10] Effect of Time Delay in Opinion Dynamics: Mapping Between a Time-delayed Voter Model and a Sleeping Random Walks
Mina Kim and Jae Dong Noh (Univ. of Seoul)

[SP11] Percolation properties in spatial evolutionary prisoner's dilemma game on two-dimensional lattices
Woosik Choi, Soon-Hyung Yook and Yup Kim (Kyung Hee Univ.)

Session 6: SP 통계물리일반

[SP12] Symmetry restoration by pricing in a socio-economic decision making model
Su Do Yi (Pukyong National Univ.), Seung Ki Baek (Pukyong National Univ.), Guillaume Chevereau (ENS Lyon and CNRS), and Eric Bertin (Université Grenoble Alpes)

[SP13] 도서 대출현황의 통계 분석
정남, 맹성은, 이덕선, 이재우(인하대학교)

[SP14] Field Theoretical Approach using Collective Variables to Brownian Particles in Random Media
WonSang Lee and JoonHyeon Yeo (Konkuk Univ.)

[SP15] Korean text analysis using vector representation of words
Seon-Young Jeong, Young-Bin Kim, Young-Jae Park and Seung-Woo Son (Hanyang Univ.)

[SP16] Quantum Phase transitions of a Heisenberg model in one dimension: A modified time-evolving block decimation study using tensor network states
Hwan Bin Choi, Hyowon Lee, Subin Yun,and Ji-Woo Lee (Myongji University)

[SP17] The effect of link density on the surface relaxation in heterogeneous networks
Hyung-Ha Yoo and Deok-Sun Lee (Inha university)

NW 네트워크

[NW1] Multiplex crisis-spreading model on the global economic system

Kyu-Min Lee and Kwang-Il Goh (Korea Univ.)

Modern infrastructures, human society and global economic system consist of various types of relations. These multiplex network system draws much attention in the network science. However, there are few studies of investigating multiplex effect on global economic systems. In this study we introduce the multiplex crisis-spreading model on the world trade network which is based on empirical data. With introducing the measure of individual countries impact as an epicenter and comparing the results of multiplex model with the simplex case, we found that the multiplex network produces more catastrophic avalanche dynamics than the simplex framework. Our simple model would have some implications about real complex systems to investigate the better systemic design for security.

[NW2] Complex networks에서의 meme popularity 분포와 biased random walk

Seok-Jong Park, Soon-Hyung Yook and Yup Kim (Kyung Hee Univ.)

Internet 을 통한 social network service는 인간의 활동과 관련된 system의 가장 대표적인 예이다. social network 에서는, idea나 news와 같은 meme 들이 생성되어, meme들 사이의 경쟁을 통해 생물학에서의 gene처럼 진화해나간다. 또한 social network 그 자체도 성장해나간다. 다양한 관점에서 network의 성장이 미치는 효과는 중요하다고 알려져 있다. 하지만 network의 성장이 meme popularity에 미치는 영향은 여전히 잘 알려져 있지않다. 그러므로, 우리는 간단한 meme 전파모델을 소개하고 network의 성장이 meme popularity 분포에 미치는 영향을 분석하였다. 또한 이러한 모델이 position dependent biased random walk (PDBRW)을 통해 정확히 설명될 수 있음을 보였다.

[NW3] Criticality in hybrid percolation transtions on interdependent networks

이덕재, 최상민, 강병남(서울대학교)

Discontinuous percolation transitions in cascading-failure models in interdependent networks have garnered considerable interests of researchers recent years. It was revealed that the transitions are actually hybrid transitions in which a critical phenomenon appears prior to sudden decrease of the fraction of nodes belonging to a mutually connected component, the order parameter. This critical behavior was shown theoretically using the branching process approach under the assumption that

the mutually connected component is actually in form of tree. However, the assumption has not been checked yet numerically because of the absence of efficient algorithm for such tasks. Moreover, it has not been confirmed either if scaling relations between the critical exponents hold. Here we perform extensive numerical simulations using recently developed efficient algorithm [Hwang et al. PRE 91, 022814 (2015)] for the cascading-failure model in interdependent random networks, and measure various critical exponents. We will show numerically if the scaling relations hold in this talk.

[NW4] Core-Periphery Structures in Networks

**Sang Hoon Lee (KIAS), Mihai Cucuringu (UCLA), Mason A. Porter (University of Oxford), M. Puck Rombach (UCLA)*

Networks often possess mesoscale structures, and studying them can yield insights into both structure and function. It is most common to study community structure, but numerous other types of mesoscale structures also exist. We first examine core-periphery structures based on structural edge density and transportation properties. In such structures, core network components are well-connected both among themselves and to peripheral components, which are not well-connected to anything. We examine core-periphery structures in a wide range of examples of transportation, social, and financial networks. A transport-based notion of node coreness is very useful for characterizing transportation networks. We generalize this notion to examine core versus peripheral edges, and we show that this new diagnostic is also useful for transportation networks. To examine the properties of transportation networks further, we develop a new family of generative models of road-like networks. We also introduce a low-rank approximation of a network's adjacency matrix, which can often be expressed as a tensor-product matrix. Another approach uses the bottom eigenvector of the random-walk Laplacian to infer a coreness score and a classification into core and peripheral nodes. Finally, we suggest a possibly deep connection between such core-periphery structures and "nested" structures of networks, describing the famous notion that generalists and specialists systematically interact in ecological networks.

[1] S. H. Lee, M. Cucuringu, and M. A. Porter, "Density-based and transport-based core-periphery structures in networks", Phys. Rev. E 89, 032810 (2014).
[2] M. Cucuringu, M. P. Rombach, S. H. Lee, and M. A. Porter, "Detection of Core-Periphery Structure in Networks Using Spectral Methods and Geodesic Paths", e-print arXiv:1410.6572.

[NW5] Optimal strategy for spreading dynamics with layer-crossing costs in multiplex networks

Sang-Hwan Gwak (Korea University), Byungjoon Min (City College of New York), K.-I. Goh (Korea University)

In recent years, we live in a world where information or diseases are transmitted from various paths. Thus kind of these systems can be represented as a multiplex with various type of links. Thus, we need to study carefully the multiplex networks in order to figure out numerous phenomena and dynamics. In this study, we study the dynamics of spreading on the multiplex networks based on the SIR(susceptible-infected-recovered) framework for the spreading of information or diseases. We apply two spreading effects on the multiplex networks, the layer-crossing costs and the different link densities, to demonstrate optimal strategy of layer-crossing costs effect on various network densities.

[NW6] Explosive percolation transitions on growth networks

Soomin Oh (SNU), Seung Woo Son (Hanyang Univ.) and Byungnam Kahng (SNU)

We study the percolation transition properties of growing and static networks under an Achlioptas-like process. In our growing networks model, a node is added in the network every time step and randomly m candidate nodes are chosen, which is not connected yet each other. After comparing the sizes of m clusters containing each candidate node, the two smallest clusters are selected. The two candidate nodes which belong to the selected clusters are connected with probability δ. And In our static networks model, the rule is same with growing case except for $\delta = 1$ and nodes are not added. For $m = 3$, we found the rate equation of size distributions. And Using this rate equation and finite-size scaling, we extensively investigate the transition point δ_c and the critical exponent β,γ,τ,σ. We found that the percolation phase transitions are continuous with reference to whether there are growing networks or static networks for $m = 3$. And we expand this model for general m. For various m, we found that the percolation phase transitions are also continuous, but the scaling functions change. Using finite-size scaling and numerical analysis, we extensively investigate the transition point δ_c and the critical exponent β. Interestingly, $1-\delta_c$ and β decay as power of m contrary to the exponential decay of static explosive percolation.

[NW7] Complex network analysis for the Korean national R&D activity in terms of research keyword

Min-Woo Ahn and Woo-Sung Jung(POSTECH)

R&D activity is crucial for the development of science, technology and economy. Therefore, understanding the structure of R&D activity is important problem for managing and developing R&D process. However, the size of R&D activity is too huge to understand macroscopic structure. In this presentation, we investigate the structure of national R&D activity via complex network analysis. We use the NTIS (National Science & Technology Information Service) database which includes various information about research projects (title, classification, investment, keywords, and so on) supported by the Korean government. To observe the relationship between keywords, we construct keyword network. In this network, node is keyword and two nodes are connected when these two nodes are included in the same project. We will discuss about network properties, the time evolution of network and their meanings.

EP 경제물리

[EP1] Analyses of optimal investment conditions for pricing models

Kyuseong Lim (KAIST), Soo Yong Kim (KAIST), and Kyungsik Kim (Pukyong Univ.)

An asset pricing model with each different type of the fundamentalist and the chartist is investigated in the Korean financial markets. Two cases are considered as we investigate the statistical properties of the fundamentalist and the chartist. In the first case, we analyze the overlap values of two prices, as the real closing prices are compared to those simulated from the KOSDAQ and KOSPI. In the second, the three nonlinear equations for the stock's price are compared and analyzed, and the chaotic behaviors of fundamentalist and the chartist are discussed. Since the fractions of these trader types change over time according to evolutionary process, the fundamentalist and the chartist obtain their forecasting rule upon determinations from optimal investment condition of strategies of future prices.

BP 생물물리

[BP1] Structure and Learning of Neural Networks

Juyong Song (POSTECH) and Junghyo Jo (POSTECH, APCTP)

Small-world, scale-free and modular structures have been observed in the brain networks, although their functional roles are not yet clear. Therefore, we broadly examine potential benefits of those structural features on machine learning. In particular, we apply the two well-known algorithms of the Boltzmann machine and the recurrent back-propagation for learning certain tasks with various network structures.

[BP2] Small Angle Neutron/X-Ray Scattering Study of Microtubules and Polycations

Juncheol Lee (1), Jimin Lee (1), Chaeyeon Song (2), Herbert P. Miller (2), Kyuhan Kim (2), Leslie Wilson (2), Cyrus R. Safinya (2) and Myung Chul Choi (1), (1. KAIST, 2. UC Santa Barbara)

Microtubules (MTs) are hollow cylindrical protein nanotubes with 25 nm diameter, composed of α/β-tubulin heterodimers with surface charge density ~ e/nm^2. They are involved in many cellular functions such as cell division, maintaining cell shape, and intracellular trafficking. There have been studies about higher-order assemblies of MTs (e.g. Hexagonal bundle of MTs, inverted tubulin tubes, etc) in the presence of multivalent cations (e.g. Ca^{2+}, spermine, etc). We show our recent findings on the assembly structures of MTs and cationic polymers, which have different structures as the concentration of the polycations changes. Various assemblies are studied both in real and reciprocal spaces using small angle Neutron/X-ray scattering and transmission electron microscopy.

[BP3] Biconnectivity of the cellular metabolism: A cross-species study and its implication for human diseases

P. Kim (SNU), D.-S. Lee (Inha University), and B. Kahng (SNU)

The maintenance of stability during perturbations is essential for living organisms, and cellular networks organize multiple pathways to enable elements to remain

connected and communicate, even when some pathways are broken. Here, we evaluated the biconnectivity of the metabolic networks of 506 species in terms of the clustering coefficients and the largest biconnected components (LBCs), wherein a biconnected component (BC) indicates a set of nodes in which every pair is connected by more than one path. Via comparison with the rewired networks, we illustrated how biconnectivity in cellular metabolism is achieved on small and large scales. Dening the biconnectivity of individual metabolic compounds by counting the number of species in which the compound belonged to the LBC, we demonstrated that biconnectivity is signicantly correlated with the evolutionary age and functional importance of a compound. The prevalence of diseases associated with each metabolic compound quanties the compounds vulnerability, i.e., the likelihood that it will cause a metabolic disorder. Moreover, the vulnerability depends on both the biconnectivity and the lethality of the compound. This fact can be used in drug discovery and medical treatments.

[BP4] Robustness of the metabolic networks: The impact of enzymatic gene expression

**Gyeong-Gyun Ha, and Deok-Sun Lee (Inha University)*

Many of human disorders originate in the outbreak and spread of local abnormality at the cellular level, the likelihood of which depends on the topology and dynamics of the cellular networks. Given that most of the medical and pharmaceutical treatments are made locally to control the concentration and the activity of selected target ingredients, it will be of great importance to evaluate the vulnerability of individual cellular ingredients and identify its determinants from a network viewpoint. Here we quantify the vulnerability of individual metabolic compounds in terms of the prevalence of the associated diseases and show that it is correlated with the network features of the compounds as well as the pattern of the associated enzymatic genes. In particular, we find that the more correlated the enzymatic genes are, the less vulnerable the associated compound is, implying the crucial role of genetic regulation in buffering and preventing the spread of local perturbations in metabolic networks. Classifying the topology of the subgraphs surrounding each metabolic compound, we find that the impact of genetic regulation on the vulnerability of metabolites is differentiated depending on the topological features of each metabolite in the metabolic network.

[BP5] Coevolution of species abundance and topology in mutualistic networks.

Seong Eun Maeng, Jae Woo Lee and Deok-Sun Lee (Inha University)

Mutualistic interactions give rise to highly nested structure in the interaction networks e.g., of plants and pollinators, implying the emergence of hub plant species feeding a large number of animal species. When the structure of a mutualistic network is evolved by link rewiring towards maximizing species abundance, the obtained networks indeed display high nestedness. However, the nature of interspecific interaction in each ecological community is multisided and it can happen that the mutualistic networks are affected by the competitive interactions. Here we present our model for the coevolution of species abundance and topology in mutualistic networks of plants and pollinators. Not only the mutualistic interactions between plants and pollinators but also the competitive interactions between animals pollinating the same plants affect the abundance of each species, which is used for the evolutionary selection of the network topology. We investigate the time course of the topology of the evolving networks and the impact of competitive interactions on the magnitude and scaling of nestedness.

[BP6] Fast diffusion along graion boundaries of phospholipid(DPPC)-cholesterol multilayers

Suho Lee, Kyuhan Kim, Dae-Woong Jeong, Hyunjun Kim, Daegab Kwon, Myung Chul Choi and Siyoung Q.Choi (KAIST)

We report the first experimental results on length scale dependent 2D anomalous diffusion in phospholipid DPPC-cholesterol multilayers. Using fluorescence correlation spectroscopy, we examined the effect of cholesterol on diffusion in the DPPC multilayer. Extremely high diffusion coefficients were found for cholesterol mole fractions f < 0:07 while an order of magnitude slower diffusion was observed for f > 0:07. A mean squared displacement analysis as well as FCS results revealed that such fast diffusion is not simple Brownian but rather anomalous subdiffusion. Moreover, fluorescence recovery after photobleaching (FRAP) experiments showed that fast diffusion occurs only for a small length scale, < 1mm. We demonstrate that the fast diffusion process is strongly correlated with structural change in the DPPC-cholesterol multilayers, including in particular the presence of grain boundaries created by gel phase domains of tilted DPPC molecules. The cholesterol fraction (f = 0:07) in which diffusion coefficients decrease rapidly matches the phase transition point from gel to liquid-ordered where grain boundaries disappear

by chain tilt-untilt transition. The order of magnitude decrease in the diffusion coefficient at the phase transition from gel to liquid-disordered by temperature also supports that the fast diffusion originated from grain boundaries.

CS 복잡계

[CS1] Quantitative analysis of intellectual interchanges in the history of massive online open-editing encyclopedia, Wikipedia

Jinhyuk Yun(KAIST), Sang Hoon Lee(KIAS), and Hawoong Jeong(KAIST)

Wikipedia is a free Internet encyclopedia with enormous amount of contents. This encyclopedia is written by volunteers with various backgrounds in a collective fashion; anyone can access and edit most of the articles. This new paradigm of sharing knowledge is one of the most famous examples of "collective intelligence," yet commonly considered as ambiguous and even inaccurate to utilize in scientific context due to the very nature of open-edit policy. In this work, we suggest an intuitive model of Wikipedia editing process and find its basic properties, based on both the article editing dynamics and interactions among editors including editor-article interactions, the combination of which is considered in modeling studies on Wikipedia dynamics for the first time to our knowledge. We present the condition to observe the phenomenon commonly known as "Wikipedia edit war," which refers to significantly active consecutive editing by multiple users with conflicting opinions.

[CS2] The role of geography and research station in Antarctic science collaboration network

Hyunuk Kim,, Woo-Sung Jung (POSTECH)

National governments have been attracted to Antarctica by its abundant natural resources and interesting ecological features. Due to the large scale of Antarctic science, international scientific cooperation is required for conducting comprehensive research. In this study, we attempt to unravel the role of geography and research station in Antarctic science, especially focus on scientific cooperation on a global level. Collaboration network is constructed based on 42,082 research articles in ISI Web of Science from 1995 to 2014. Through modularity optimization algorithm on collaboration network, we confirmed that regional proximity tends to be important for scientific international cooperation. However, the distance between research stations in Antarctica doesn't have a significant impact on international collaboration. The role of research station will also be discussed by analyzing publication trends and research keywords during the fifteen years.

[CS3] Gravity and Radiation Models for Intra-Urban Mobility by the Korean Urban Bus System

Inho Hong and Woo-Sung Jung (POSTECH)

The radiation model is a recently proposed traffic model for overcoming several drawbacks of the gravity model. Accuracy of both models has been tested for various mobility datasets, and there are still debates on which model is more appropriate for interpreting human mobility patterns. In this study, we applied both models to the Korean urban bus system to understand the underlying mechanism of urban mobility. The traffic matrices extracted from passenger data and bus operation data are modelled with the resident populations at the origin and destination zones. The performances of the gravity and radiation models are compared for both datasets. The differences in the statistical characteristics of two datasets will be discussed in the perspective of bus network planning for public good and economic feasibility.

[CS4] Atypical Technology Combinations and Technological Impact

김영호(KAIST), 정하웅(KAIST), and 윤혜진(University of Oxford)

From a combinatoric point of view, we consider patents as combinations of technology codes used by the United States Patent Office in order to classify technologies. We generalize quantitative arguments used for studying patented invention as a combinatorial process by Youn et al. [J. R. Soc. Interface 12, 20150272]. We find atypical combinations of technology codes by investigating statistical significance of the combinations. We show that a combination of technology codes becomes novel as its first year introduced increases.

[CS5] Spread of Political Opinions Based On Human Migrations in Presidential Elections

Woo Seong Jo (Sungkyunkwan Univ.), and Beom Jun Kim (Sungkyunkwan Univ.)

The voter model has been studied in various systems to understand how opinions spread. Recently, several studies showed that election results can be addressed by applying the voter model with commuter flow. However, political opinions of individuals can be strongly affected by their birthplaces as well as where they are. We apply the voter model to presidential election in South Korea from 1971 to 2012, considering the annual inter-province flow of migration. Keeping information

of birthplace, agents change their political opinions with given probability which is assigned by birthplace. We optimize the probability of changing opinions, comparing the outcome from real elections with simulation results. From several presidential elections, traces of the probability show the evolution of political bias based on a province. In addition, results are robust on fluctuation of population growth. We expect that the long-term evolution of the probability may show the changes in province-wise political opinions.

[CS6] Coupled spatial evolutionary public goods game on interdependent networks

Jinho Kim, Soon-Hyung Yook and Yup Kim (Kyung Hee University)

Interdependent network에서의 spatial evolutionary public goods game(SEPGG)를 연구하였다. 단일 Erdos-Renyi network에서의 SEPGG는 multiplication factor r과 mean degree $\langle k \rangle$에 따라 서로 다른 stationary state를 갖는다. $r < r^*$인 조건에서는 complete graph에서부터 $\langle k \rangle$가 감소시킴에 따라 loner만 존재하는 L-layer, defector만 존재하는 D-layer, cooperator만 존재하는 C-layer가 나타난다. 또한 $r > r^*$인 조건에서는 $\langle k \rangle$가 감소함에 따라 D-layer와 C-layer가 차례로 나타난다. 따라서 우리는 $r < r^*$인 조건에서 서로 다른 stationary state를 갖는 layer를 interlink로 연결한 C-D layer, C-L layer, D-L layer의 interdependent network를 구성하였다. $r > r^*$인 조건에서는 C-D layer로 이루어진 interdependent network를 구성하여 SEPGG에 따른 stationary state를 확인하였다. 첫 번째로 동일한 layer size를 갖고, 모든 agent가 하나의 interlink를 갖는 경우에 biased imitation probability p에 따라 모든 layer에서 cooperator의 수가 최대가 되는 p가 존재함을 확인 하였다. 특히 cooperator가 존재할 수 없는 D-L layer에서도 stationary state에서 cooperator가 존재하는 p를 확인하였다. 두 번째로 동일한 layer size를 갖는 조건에서, interlink의 수를 감소시켜가며 interlink의 수와 p의 감소에 따른 효과를 비교분석 하였다. 마지막으로 서로 다른 layer size를 갖는 interdependent network에 대해 분석하였다. 특히 C-layer의 크기가 다른 layer의 크기보다 작은 경우에 두 layer 모두 cooperation이 일어나는 p의 영역이 존재함을 확인하였다.

[CS7] Hybrid phase transition in spreading of epidemic diseases

최원준(Seoul National Univ.), 강병남(Seoul National Univ.)

Recently, a hybrid phase transition (HPT), including mixed properties of the first-order and the second-order transitions, receives considerable attention. Examples include k-core percolation and cascading-failure model in interdependent networks and so on. For such cases, their HPTs are induced by links deleting processes and the mechanism underneath their HPTs has been uncovered in detail.

On the contrary, research on a HPT induced by links adding processes just begins. In this paper, we investigate a hybrid phase transition for a generalized epidemic model proposed by Janssen et al. This model is a generalization of the so-called SIR (Susceptible, Infected, Recovered) model by introducing an intermediate state, called weakened state, between susceptible and infected states. While this model is known to undergo a discontinuous transition, we find that the model exhibits a hybrid phase transition in links adding processes. The critical behavior emerging above the transition point has been investigated and the critical exponents are determined.

[CS8] How does reputation affect spatial prisoners' dilemma game?

**Young Jin Kim(Hanyang Univ.), Seon-Young Jeong(Hanyang Univ.), Hyunwoo Jeong(Hanyang Univ.), and Seung-Woo Son(Hanyang Univ.)*

In the previous study, we have used replicator dynamics to study an Iterated Prisoners Dilemma Game (IPDG) with single-step memory. We investigated the dynamic motif and fine phase structure of network of strategies with changeable payoffs. In the concept of replicator dynamics, we assumed all the agent interact with all together, i.e., well-mixed case. To study more realistic model, it would be better that one considers agent based model on spatial lattice or social networks. Nowadays, with the well-developed computational environment, experiments have been performed that human plays the IPDG with each other through the computer networks. In the study of Cuesta et al. (2015), they show that reputation is important to drive the cooperative state. In this study, we investigate the spatial prisoners' dilemma game with mobile agents having reputation.

[CS9] Understanding Motives of Historical Events through a Half Millennium Chronicle: The Annals of the Joseon Dynasty

**Byunghwee Lee(KAIST), Daniel Kim(KAIST), Hang-Hyun Jo(Postech), Hawoong Jeong(KAIST)*

There has been a number of studies investigating causes of historical events. However, it is hard to understand motives of the events because of the extremely intricate causalities. Here we quantitatively study long-term causal relationships of consecutive historical events through a half millennium chronicle listed in UNESCOs Memory of the World registry, the Annals of the Joseon Dynasty. We reveal the distinct trends of 40 different types of historical events by analyzing their inter-event time distributions. Constructing a motive network of the

event-categories with their temporal correlations, we show causational chains of historical events. We trace evolving causal relationships of events. This work may overcome the limits of previous studies focusing on specific events within a narrow time period, and provide a new insight into systematic understanding on process of causal interactions in history.

[CS10] Temporal change of popularity in given names

Mi Jin Lee (1) , Woo Seong Jo (1) , Il Gu Yi (1) , Seung Ki Baek (2), and Beom Jun Kim (1) (1: Sungkyunkwan University, 2: Pukyong National University)

In a human society, one can specify an individual's identity by using his or her name. Differently from family names, usually inherited from fathers, a given name for a child is often chosen at the parents' disposal. However, their decision cannot be made in a vacuum but influenced by social conventions and trends. Furthermore, such social pressure changes in time, as new names gain popularity while some ther names are gradually forgotten. We investigate how popularity of given names has evolved over the last century by using datasets collected in Korea, the province of Quebec in Canada, and the United States. In each country, the average opularity of given names exhibits typical patterns of rise and fall with a time scale of about one generation. We also observe that notable changes of diversity in given names indicate major social changes.

SP 통계물리일반

[SP1] Macroscopic Irreversibility of Collective Brownian Particles

Pyoung-Seop Shim (University of Seoul), Hyun-Myung Chun(University of Seoul) and Jae Dong Noh(University of Seoul)

We investigate the collective motion of collective Brownian particles in two dimensions. Each particle is acted on by a nonequilibrium velocity-aligning force and thermal noise. As a nonequilibrium system, the system produces the entropy in the steady state. We find that the system undergoes a nonequilibrium phase transition from a state with subextensive entropy production to a state with extensive entropy production. The macroscopic entropy production is related to the emergence of collective motions. We also derive the scaling relations between the critical exponents describing the entropy production and the collective motions.

[SP2] Simulation Study for Magnetic Colloids via Brownian Dynamics and Stochastic Rotational Dynamics

KIM Hyeok(Konkuk Univ), KIM Juin(Air Force Academy), GIM Bopil(KAIST), YEO Joonhyun(Konkuk Univ).

Magnetic colloids have nano-sized ferromagnet core covered by surfactant molecular layers which help to prevent aggregation each other. One of the most interesting characteristics is that they align to form chain-like structures even if particles still experience thermal effects of solvent. In this talk, we would like to show preliminary simulations for magnetic colloids via Brownian Dynamics and Stochastic Rotational Dynamics which implement fully hydrodynamic interactions in mesoscale. To describe magnetic particles, long-range dipolar interactions which could induce nose-to-tail structure are introduced. For periodic boundary condition of simulation box, Ewald summation is technically used. As a results, we will show static equilibrium properties such as energies, collective diffusion coefficient, magnetization and high-frequency shear viscosity calculated from Green-Kubo formula.

[SP3] Percolation transitions on multiplex lattices under cascade of activations and deactivations

Jeehye Choi (Korea Univ.), Byoungjoon Min (City College of New York), Kwang-Il Goh (Korea Univ.)

Multiplex networks which are constructed by various types of connections have been studied to understand complex systems, i.e. cooperation. We study the percolation transitions of two models, Cascade of Activations (CA) and Cascade of Deactivations (CD) which has multiple resource on boundaries on multiplex lattices. Preliminary results on the transitions and their critical phenomena will be presented.

[SP4] Finite-Size Scaling Properties of the One-Dimensional Critical Quantum Ising Model in Matrix Product State Representations

Sung-Been Park (Hanyang Univ.) and Min-Chul Cha (Hanyang Univ.)

We investigate the finite-size scaling properties of the quantum phase transition in the ground state of the one-dimensional Ising model in a tranverse field with

periodic boundary conditions. By using the matrix product state representations of the ground state, the infinite time-evolving block decimation technique is used to optimize the states. Trace over the product of the matrices as many times as the number of sites yields the finite size effects. For sufficiently large Schmidt ranks, the finite-size scaling behavior determines the critical point and the critical exponents, which are consistent with the analytical results.

[SP5] Curzon-Ahlborn Efficiency of a Brownian Heat Engine without Endoreversible Condition

Hyun-Myung Chun(University of Seoul), Jong-Min Park(University of Seoul) and Jae Dong Noh(University of Seoul)

We consider a coupled two-particle Langevin system in the presence of an external driving force. Each particle is respectively in contact with a heat bath at different temperatures. The system absorbs heat from the hotter heat bath and works against the external force, hence can be regarded as an autonomous heat engine. For the case of the linear force, the exact form of the power and the efficiency in steady state are obtained analytically. Under a suitable condition, the efficiency at maximum power of this model is given by $1-sqrt{T_2/T_1}$, which is called Curzon-Ahlborn efficiency. It has been understood that the Curzon-Ahlborn efficiency requires the property of endoreversibility. Our study shows that the endoreversibility is not necessary for the Curzon-Ahlborn efficiency at maximum power.

[SP6] Universality Issues of Generalized Epidemic Process

Kihong Chung (KAIST), Yongjoo Baek (Technion), Meesoon Ha (Chosun University), and Hawoong Jeong (KAIST)

We study a simple variation of the conventional susceptible-infected-recovered (SIR) model in modular networks, where the infection probability depends on the number of infectious attempts to the target node, commonly called as the generalized epidemic process (GEP) [1]. The similar version in regular lattices has been analytically studied in [1], which discusses both first and second order phase transitions, and the change of the upper critical dimension at the tricritical point as well as logarithmic corrections. The upper critical dimension is directly related to the finite-size scaling (FSS) exponent and the dynamic exponent. Based on analytic

and numerical techniques of finding scaling properties at randomly generated networks [2] and modular networks [3], we discuss how to draw the exact phase diagram of GEP. Finally, we apply the extended FSS theory to various physical properties in the context of the universality class, which is numerically confirmed.

[1] H.-K. Janssen et al., Phys. Rev. E 70, 026114 (2004).
[2] G. Bizhani et al., Phys. Rev. E 86, 011128 (2012).
[3] K. Chung et al., Phys. Rev. E 89, 052811 (2014).

[SP7] Cyclic information engine with a perpetually moving harmonic potential

Jong-Min Park(Univ. of Seoul), Jae Sung Lee(KIAS), and Jae Dong Noh(Univ. of Seoul)

We consider a cyclic information engine with a Brownian particle in contact with a single heat bath and a harmonic potential. Each cycle of period τ consists of three processes: measurement, feedback, and relaxation. During these process, the engine generates a mechanical work and moves to a particular direction. We derive the exact solution for the engine for $\tau = 0$ and ∞ cases and an approximate solution for finite τ. Using the solutions, we obtain the optimal conditions for various physical properties: extracted work, power, efficiency, velocity, and so on.

[SP8] A Slow Passage Problem

Jaeyun Yoo(Chungnam National Univ.) and Kang-Hun Ahn(Chungnam National Univ.)

Nanomechanical devices can have various dynamical states as a characteristic of nonlinear systems. Nanomechanical shuttles can be either static or oscillating depending on their initial conditions of the position and velocity. Usually, it is extremely difficult to control the initial conditions of NEMS and so its dynamics. We provide a reliable method to control the phase-space location of NEMS using slowly varying parameters. NEMS shuttle is described by a nonlinear damped Mathieu equation, which gives the well known phase space of Arnold' tongue. We show that using slowly varying parameters of the system, one can control the dynamical state of NEMS which gives richer dynamics than the original Arnold's tongue.

[SP9] Dissipative dynamics of a Brownian particle in Langevin equations

*Woon Hak Baek and Kyungsik Kim

We study the Langevin equation for the Brownian motion of a free particle. The Fokker-Planck equation with the effective potential in the long time limit contains the Markovian equation with the diffusion energy. We mainly analyze the quantum Brownian motion with the harmonic oscillation in the one-dimensional quantum space. By using the Wigner function technique from the non-Markovian equation, we calculate the velocity distribution function with the diffusion energy and the correlational function. Since such three correlational functions are considered as the exponential, Gaussian, and complementary error functions, the quantum force can be analyzed from the velocity distribution function. Particularly, the quantum force is found with angular frequency proportional to $w^{1/2}$ in the quantum limit, while the classical force is proportional to the temperature $T^{1/2}$ in the classical limit.

[SP10] Effect of Time Delay in Opinion Dynamics: Mapping Between a Time-delayed Voter Model and a Sleeping Random Walks

*Mina Kim(Univ. of Seoul) and Jae Dong Noh(Univ. of Seoul)

To understand the effect of time delay in opinion dynamics, we introduce a time-delayed voter model in a one-dimensional lattice and study its coarsening dynamics. In this model, a voter at each lattice site i has one of two opinions ($s_i = pm$). A voter at site i refers to the opinion of one of its two nearest-neighbors i at a unit rate and updates its opinion with time delay τ ($s_i(t+\tau)$ to $s_j(t)$). Without delay, the voter model is dual to the coagulating random walks. We show that the time-delayed voter model is dual to coagulating sleeping random walks. Using the duality, we find that the density of active bonds $\rho(t) \equiv \left\langle \frac{1-s_i(t)s_{i+1}(t)}{2} \right\rangle$ satisfies the scaling form $\rho(t;\tau) = \rho_0(t/\tau^3)$ for $\tau > 1$, where $\rho_0(x \ll 1) \sim 1$ and $\rho_0(x \gg 1) \sim x^{-1/2}$.

[SP11] Percolation properties in spatial evolutionary prisoner's dilemma game on two-dimensional lattices

*Woosik Choi(Kyung Hee Univ.), Soon-Hyung Yook(Kyung Hee Univ.) and Yup Kim(Kyung Hee Univ.)

We investigate percolation properties of cooperator (C) and defector (D) clusters in spatial evolutionary prisoner's dilemma game (SEPDG) on two-dimensional lattices.

Percolation properties depend on both the lattice structure and the temptation factor b. On the hexagonal lattices, C (D) clusters undergo the percolation transition when $1 < b < 3/2$, whereas a D cluster always percolates regardless of the initial C density p_i^C. On the square lattices, when $1 < b < 4/3$ and $3/2 < b < 2$, percolation transitions occur. When $4/3 < b < 3/2$, a D cluster always percolates. On the triangular lattices, C clusters always percolate regardless of p_i^C when $1 < b < 5/4$. When $5/4 < b < 3/2$, the percolation transitions occur. a D cluster always percolate when $3/2 < b < 2$. By finite size scaling analyses the universality classes of all the percolation transitions belong to that of the random (ordinary) percolation regardless of the lattice structure. We also explain how the specific percolation properties arise from the evolution mechanism of SEPDG on a given lattice.

[SP12] Symmetry restoration by pricing in a socio-economic decision making model

**Su Do Yi(Pukyong National Univ.), Seung Ki Baek(Pukyong National Univ.), Guillaume Chevereau(ENS Lyon and CNRS), and Eric Bertin(Université Grenoble Alpes)*

Competition is a main tenet of economics, and the reason is that a perfectly competitive equilibrium is Pareto-efficient in the absence of externalities and public goods. Whether a product is selected in a market crucially relates to its competitiveness, but the selection in turn affects the landscape of competition. Such a feedback mechanism has been illustrated in a duopoly model by Lambert et al., in which a buyer's satisfaction is updated depending on the freshness of a purchased product. The probability for buyer n to select seller i is assumed to be $p_{n,i} \sim \exp(S_{n,i}/T)$, where $S_{n,i}$ is the buyer's satisfaction and T is an effective temperature to introduce stochasticity. If T decreases below a critical point T_c, the system undergoes a transition from a symmetric phase to an asymmetric one, in which only one of the two sellers is selected. In this work, we extend the model by incorporating a simple price system. By considering a greed factor g to control how the satisfaction depends on the price, we argue the existence of an oscillatory phase in addition to the symmetric and asymmetric ones in the (T,g) plane, and estimate the phase boundaries through mean-field approximations. The analytic results show that the market preserves the inherent symmetry between the sellers for lower T in the presence of the price system, which is confirmed by our numerical simulations.

[SP13] 도서 대출현황의 통계 분석

*정남, 맹성은, 이덕선, 이재우(인하대학교)

인하대학교 도서관의 2004년부터 2015년까지의 10여년간의 대출자료의 도서 및 이용자의 특징과 관계를 분석하였다.
각 도서의 종류에 따른 특징을 확인하기 위해 총 대여횟수와 대여기간의 분포를 구하고 도서별 소장 권수의 분포를 구하였다.
각 도서의 입고 일을 기준으로 한 라이프타임을 기준으로 하여 대출일과 대출횟수를 고려한 두개의 효용도를 정의하여 각 도서가 상대적으로 얼마나 자주 이용되는지를 살펴보았고 효용도와 도서 소장 권수의 관계를 확인하여 도서관이 효용도가 높을수록 해당 도서를 많은 양을 소장하고 있는지 확인하였다.
도서를 종류별로 구분한 경우와 그렇지 않은 경우의 특징을 확인하기 위해 위에서 구한 것과 같은 특징들을 도서를 종류가 아닌 낱개의 책으로 분류하여 그 분포를 구하고, 위에서 구한 도서의 종류에 따른 특징들의 분류와 비교하여 도서를 종류별로 구분한 경우와 그렇지 않은 경우의 그 특징이 어떻게 바뀌는지 알아보았다.

[SP14] Field Theoretical Approach using Collective Variables to Brownian Particles in Random Media

*WonSang Lee(Konkuk Univ.), JoonHyeon Yeo(Konkuk Univ.)

본 연구는 Random media속의, 상호작용하지 않는 브라운 입자들의 운동을 다룬다. 기존의 연구는 개별 입자의 위치를 변수로 사용하였으나 본 연구는 Collective Variable인 밀도를 사용함으로써 입자계의 집합적인 행동을 보는 것을 목표로 한다. 이를 위해 Martin-Siggia-Rose Formalism을 이용하여 장론적인 형식을 구현하고 밀도-밀도 상관함수를 작은 무질서도 극한에서 계산하였다.

[SP15] Korean text analysis using vector representation of words

*Seon-Young Jeong(Hanyang Univ.), Young-Bin Kim(Hanyang Univ.), Young-Jae Park(Hanyang Univ.) and Seung-Woo Son(Hanyang Univ.)

Usually it is very hard to automatically analyze morphemes in Korean texts due to its variety of changes. Utilizing recent natural language process techniques and Korean morphological analysis model-there is no notion of similarity between words. So we studied word2vec. Word2Vec is that Words with the same context, it is assumed that have a close meaning. Word2Vec performs learning through a text document, the other words that appear in the vicinity (around 5-10 about words)

the word as related words to learning of the artificial neural network. Since word of the relevant meaning is likely to appear in the vicinity on the document, in the process of going to repeat the learning, two words are become to have a gradually close vector. Using this algorithm looking for similarities between the words, We investigate the topic modeling that is determined by using the similarity of this word to the topic of the document and word embedding that is to map the vector representations of the words in the n-dimensional space of Korean documents.

[SP16] Quantum Phase transitions of a Heisenberg model in one dimension: : A modified time-evolving block decimation study using tensor network states

Hwan Bin Choi, Hyowon Lee, Subin Yun, Ji-Woo Lee (Myongji University)

We study quantum phase transitions of one-dimensional Heisenberg model for spin $S = \frac{1}{2}, 1, \frac{3}{3} and 2$ by using tensor network states. The ferromagnetic Heisenberg model has two ground states, one of which is XY-type ground state and the other Ising-type ground state. The ground-state energies of the infinite lattice system are obtained by a time-evolving block decimation method. The ground state is represented in tensor network states, which is a core idea in this work. Taking the derivatives of the ground energies with respect to the Ising coupling constant g, we obtained the quantum critical points as a function of g. We also obtained the entanglement entropy which has a peculiar structures in both quantum states.

[SP17] The effect of link density on the surface relaxation in heterogeneous networks

Hyung-Ha Yoo, Deok-Sun Lee (Inha university)

We investigate the effect of link density on the discrete surface growth process with relaxation. To implement a synchronization mechanism in heterogeneous networks, we use the algorithm proposed by F. Family[J. Phys. A 19, L441-L446(1986)] as the random deposition model. It is reported that the above surface growth process and commonly accepted EW (Edwards-Wilkinson) process differ significantly when it comes to the SF network with $2 < \gamma < 3$ although both processes belong to the same universality class for Euclidean lattices. With that in mind, we study the scaling behaviors of the saturated roughness of the three substrates, SF networks with $2 < \gamma < 3$, $3 < \gamma < 4$ and an Erdos-Renyi network vaying the number of links. Also, we investigate the saturated roughness of each case in association with the network's spectral dimension obtainable from performing the random walk on it.

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