제 19차 통계물리 워크숍

2017년 8월 28일(월) ~ 8월 30일(수)

서울대학교병원 인재원 대강당

주최 : 한국물리학회 통계물리학분과

후원 : 고등과학원

조직위원회

위원장: 노재동(서울시립대)
박형규(KIAS)

위　원: 강병남(서울대)
김범준(성균관대)
박수찬(가톨릭대)
백승기(부경대)

문　의

노재동(서울시립대) jdnoh@uos.ac.kr
박수찬(가톨릭대) spark0@catholic.ac.kr

제 19 차 통계물리 워크숍 일정표

장소: 서울대학교병원 인재원

발표 12 분, 질의 및 응답 3 분

시간	8 월 28 일(월)	8 월 29 일(화)	8 월 30 일(수)
08:00 ~ 09:00		조식(213 호)	조식(213 호)
09:00 ~ 10:45		Session 3 복잡계(CS) 좌장: 김판준	Session 5 네트워크(NW) 경제물리(EP) 좌장: 조항현
10:45 ~ 11:00		휴식	휴식
11:00 ~ 13:00		Session 4 네트워크(NW) 좌장: 조영설	Session 6 통계물리일반(SP) 좌장: 이재성
13:00 ~ 14:00	워크숍 등록	점심	점심
14:00 ~ 15:45	Session 1 생물물리(BP) 좌장: 조정효	14:00 ~ 19:00 Excursion	
15:45 ~ 16:00	휴식		
16:00 ~ 18:00	Session 2 복잡계(CS) 좌장: 손승우		
18:00 ~	저녁 식사	19:00 ~ 21:00 만찬	

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Wonseok Hwang (KIAS)

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Sul-Ah Park and Kang-Hun Ahn (Chungnam Natl. Univ.)

[BP4] Optogenetic mapping reveals very long-range inhibitory connections within rat suprachiasmatic nucleus

Hyun Kim (Korea Univ.)

[BP5] Role of Breast Cancer Senescence on Tumor Development in 2-dimensional monolayer

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[BP6] POlarization-SElective Interferometric Detection for Optical scattering Nanoscopy

Hyeon-Min Moon (Korea Univ.)

[BP7] Biological applications of interferometric scattering (iSCAT) microscopy: Label-free imaging of exterior and interior structures of live cells

Jin-Sung Park, Il-Buem Lee, Hyeon-Min Moon, Jong-Hyeon Joo, Seok-Cheol Hong, and Minhaeng Cho (Center for molecular spectroscopy and dynamics, Institute for Basic Science, Korea Univ.)

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Maruchan Park (Chungnam Natl. Univ.)

[CS5] A machine learning approach to discriminate phase in the Hubbard model

Dongkyu Kim (GIST)

[CS6] Criticality of mostly informative clustering in deep learning

Juyong Song (1,2,3), Matteo Marsili (2), and Junghyo Jo (1,3)

(1) APCTP

(2) Abdus-Salam International Centre for Theoretical Physics

(3) POSTECH

[CS7] Hierarchical Model for Correlated Bursty Dynamics

Byoung-Hwa Lee (POSTECH) and Hang-Hyun Jo (APCTP)

[CS8] Spreading in temporal process with correlated bursts

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[CS10] Collective properties in coupled oscillators with bimodal natural frequency distribution on low-dimensional hypercubic lattice

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[CS13] 대중가요 가사를 이용한 작사가 네트워크 분석

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[CS16] Deviation-based Ranking method

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[NW4] Hybrid phase transitions in percolation-related models

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[NW5] Two golden times in two-step contagion models

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[NW13] Analytic approach for link prediction methodology

Min-Woo Ahn (POSTECH)

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Inho Hong (POSTECH)

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Min-Young Lee (POSTECH)

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Jong-Min Park and Jae Dong Noh (Univ. of Seoul)

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Hyun-Myung Chun (Univ. of Seoul)

[SP3] First passage dynamics of fractional Brownian motion with stochastic resetting: a computational study

Sungmin Joo (POSTECH), Xavier Durang (KIAS),
Sungmin Lee (Sungkyunkwan Univ.), and Jae-Hyung Jeon (POSTECH)

[SP4] Interplay of local defect and particle interaction in a 1D TASEP-based traffic model

Hyungjoon Soh (KAIST), Meesoon Ha (Chosun Univ.), and Hawoong Jeong (KAIST)

[SP5] Dynamic critical behavior of the one-dimensional XY model with long-range interaction

Seong-Gyu Yang (Sungkyunkwan Univ.)

[SP6] The out-of-time-ordered correlator of typical state in many-body localization

Juhee Lee (GIST)

[SP7] Phase transitions of long-range contact process in open quantum systems: Mean-field results

Minjae Jo (SNU)

BP 생물물리

[BP1] Toward the statistical design principle of the olfactory receptor system

Ji Hyun Bak, KIAS

Olfaction, or the sense of smell, is the oldest and most primitive mode of biological sensing. In humans, olfactory sensing begins when odorants (the smell particles in the air) bind the olfactory receptors (ORs), which in turn activate the olfactory sensory neurons to transmit the information of the odor to the brain. Interestingly, this odorant-OR map (or the "odor code") poses a very particular statistical problem. Here we formulate the olfactory sensing map as a highly combinatorial information channel mediated by the ORs, and discuss its optimization under environmental constraints specific to olfaction. As a starting point, we model the pairwise odorant-OR binding affinity as a random variable that follows a fixed distribution, which can also be measured experimentally. We show that there are some important insights to be gained even in this random model, and proceed to discuss better-structured models that capture more realistic aspects of the olfactory sensing problem.

[BP2] Energetic cost for extracting positional information of a molecular motor from its trajectory

Wonseok Hwang, KIAS

We report a theoretical analysis quantifying the energetic cost for determining the positional precision of molecular motors based on recently suggested thermodynamic uncertainty relation. The results show that the calculated energetic cost has non-trivial local minimum at far from equilibrium. Variations in transport properties among different molecular motors -- kinesin-1, myosin-V, and dynein -- are also highlighted as well through the thermodynamic uncertainty relation. Finally, we provide concise derivation of thermodynamic uncertainty relation by using the integral fluctuation theorem for house-keeping heat.

[BP3] Inter-vesicle interaction effects on neurotransmitter release

Sul-Ah Park and Kang-Hun Ahn

We investigate stochastic dynamics of neurotransmitter release of synaptic vesicles. Two types of energy are important; the mechanical energy describing the interaction between the vesicle and the cell membrane, and the electrostatic energy between vesicles. We model the mechanical states as three states, Mclo, MO1, and MO2 which mean that the vesicle pore is closed, starts to open, and open stably. We represent electrostatic energy with the electric potentials of each vesicle and inter-vesicle capacitance. Relative strength of the three energies give rise to rich physics; electrostatic energy, mechanical energy, and thermal energy. We find that inter-vesicle interaction tends to keep the vesicle state open once the vesicle pore opens. This result may imply that nano-domains a group of a few calcium channel region in hair cell synapses play a role in enhancing the neurotransmitter release.

[BP4] Optogenetic mapping reveals very long-range inhibitory connections within rat suprachiasmatic nucleus

Hyun Kim, Korea University

One of Key questions regarding the suprchiasmatic nucleus (SCN) is how the cells are coupled to each other. The action potential (AP)-mediated communication in the SCN is known to be essential for the frequency-locking and phase-synchronization in the SCN is Known to be previous studies. Recently, an optogenetic mapping study estimated that vasoactive intestinal polypeptide(VIP)-expressing mice SCN neurons have only a few presynaptic connections. The morphology of the connections, however, was neither studied quantitatively nor discussed. In this poster, we discuss the excitatory field (ERF) as well as inhibitory receptive field (IRF) of SCN clock cells based on our independent optogenetic mapping study. Channel-Rhodopsin 2 (ChR2) transfected, organotypic slice cultures of rat SCN were systematically stimulated with a power LED light in various spatiotemproal modes that were generated by a custom-controlled digital micro-mirror deivice (DMD), while a target cell was whole-cell patched in voltage clamping modes. In our study, it is quite certain that the SCN cells have sparse (2~5) AP-mediated connections, many of which are very long-range as we suggested in our previous paper (Hong et al., 2012). Below we provide a detailed analyses on our experimental findings and further explain our experimental setup and protocols.

[BP5] Role of Breast Cancer Senescence on Tumor Development in 2-dimensional monolayer

Hyun Gyu Lee, Korea University

Cellular senescence, an aging cell, is characterized by its morphological difference from normal cells. It's positive AND negative contribution to cancer development have been discovered. We took a dynamical approach to this phenomenon by investigating, for example, adhesion sites between senescent cell to normal cancer cell, and how its actin-based structure enables localization of cancer cells. Although the observations are carried out in 2D monolayer which has unavoidable structural differences from in vivo setting, we believe they have some significance as to identifying cancer invasiveness.

[BP6] POlarization-SElective Interferometric Detection for Optical scattering Nanoscopy

Hyeon-Min Moon, Korea University

Single particle tracking is a powerful technique to reveal an underlying principle of microscopic phenomena. Here we report an optical microscopy technique, polarization-selective interferometric detection for optical scattering nanoscopy, that enables us to capture rotational as well as positional information of nano-scale objects. This technique grants all the merits of interferometric scattering microscopy and provides a further advantage of the capability of determining the orientation of single nanoscopic objects in a straightforward and facile way. We anticipate that this technique would be of critical use in rotational tracking of a single anisotropic particle or biological system in the nanoscopic world.

[BP7] Biological applications of interferometric scattering (iSCAT) microscopy: Label-free imaging of exterior and interior structures of live cells

Jin-Sung Park, Il-Buem Lee, Hyeon-Min Moon, Jong-Hyeon Joo, Seok-Cheol Hong & Minhaeng Cho

Despite recent remarkable advances in microscopic techniques, it still remains very challenging to directly observe the complex structure of cytoplasmic organelles in live cells without a fluorescent label. Here we report label-free and live-cell imaging of mammalian cell, Escherischia coli, and yeast, using interferometric scattering microscopy, which reveal the underlying structures of a variety of cytoplasmic organelles as well as the underside structure of the cells. The contact areas of the cells attached onto a glass substrate, e.g., focal adhesions and filopodia, appear to be dark. We also found a variety of fringe-like features in the cytoplasmic area. An interesting labyrinth-like fringe in a sub-micron scale appears around the outer nucleus membrane, which reflects the folded structures of endoplasmic reticulum and Golgi apparatus. We thus anticipate that the label-free interferometric scattering microscopy can be used as a powerful tool to shed interferometric light on in vivo structures and dynamics of various intracellular phenomena.

Session 2: CS 복잡계

[CS1] What is going on in deep learning

Dongkyum Kim, Korea Advanced Institute of Science and Technology

Despite the widespread pratical success of deep learning, theoretical understanding of deep learning is very lack. Especially, deep neural networks (DNN) often have much more trainable model parameters than the number of training data. Nonetheless, DNN exhibit small generalization error. To understand why over-parameterized DNN find good generalize solution rather than just memorizing training data, I have done serveral experiments with DNN for the image classification task. In this experiment, I have measured changes of weight and activation in DNN over training time.

[CS2] Cochlear membrane fabrication for sound pattern recognition by machine learning

Woo Seok Lee, Chungnam National University

Humans can distinguish frequency differences of 0.6 Hz and frequency analysis is also possible within a short time of 1 ms. The reason for these is that the basilar membrane, which varies in thickness depending on the location, shows the maximum amplitude at different positions depending on the frequency. When human hears a sound with various components, the neural network instantaneously analyzes the moving pattern of the basilar membrane. That is, the frequency analysis can be performed without consuming the integration time T of the Fourier transform.

By mimicking the basilar membrane of the cochlea, it is possible to analyze the speech signal that can not be distinguished from the Fourier transform by using machine learning. In this study, basilar membrane is macroscopically mimicked using rubber membrane and Optical measuring equipment. We also analyze the movement of the artificial membrane depending on the frequency.

[CS3] 전방 전달 신경망을 이용한 시계열 사전 기반 음성 복원

Jae-yun Yoo, Chungnam National University

희소 사전 학습은 입력데이터를 희소한 기본 요소들의 선형결합의 형태로 찾는 것을 목표로 하는 학습방법이다. 이러한 특징때문에 데이터 분해, 압축 및 분석에 많이 응용되고 있다.하지만, 이 방법은 데이터를 복원할 때 오차가 일정 값으로 수렴할 때까지 계산을 해야하기 때문에 데이터를 빠르게 처리해야하는 경우에는 단점이 될 수 있다. 이를 극복하기 위해, 우리는 전방 전달 신경망이 매개변수만 주어져 있으면 빠르게 계산할 수 있다는 장점을 이용하였다. 주어진 사전을 가지고 여러 전방 전달 신경망을 통해 입력데이터에 대한 희소한 기본 요소들을 구하고 기존의 방법과 비교하였다.

[CS4] 딥러닝(Generative Adversarial Net)을 이용한 한국어 음성 청력 향상법

Maruchan Park, Chungnam National University

청력 향상은 보청기나 인공와우에서 외부 소리를 증폭하기 전에 적용되어 노이즈를 줄여준다. 하지만 기존의 방법은 제한된 노이즈 환경에만 적용되거나, 효과가 두드러지지 않는 단점이 있다. 이는 노이즈의 패턴을 모르기 때문인데, 이를 알아내기 위해 패턴 인식에 뛰어난 딥러닝 방법 중에서 최근 시각 분야에서 높은 성과를 보이고 있는 Generative Adversarial Net (GAN)을 사용하였다. GAN은 가짜 데이터를 생성하는 신경망, 그리고 진짜 데이터와 가짜를 구분하는 신경망이 경쟁하는 구조를 지니며, 훈련을 거듭함에 따라 가짜 데이터의 품질 향상으로 진짜 데이터와의 구분이 어려워진다. 이번 연구에서 신경망이 향상된 음성을 생성하도록 훈련하였고, 눈에 띄는 노이즈 감소를 확인하였다.

[CS5] A machine learning approach to discriminate phase in the Hubbard model

Dongkyu Kim, Gwangju Institute of Science and Technology

We investigate classifying the phases of the repulsive Hubbard model by using the artificial neural network. We collect a training set corresponding to exclusively metallic and insulating phases by employing the dynamical mean-field theory (DMFT) based on the exact-diagonalization method. We implement the multilayer perceptron(MLP) to train a machine. the MLP reproduces the hysteresis curve with 99% accuracy in the phase-coexistence area. We discuss why the MLP can identify the phase and demonstrate an example where the computation of the DMFT in the phase coexistence region can be performed efficiently through the neural network.

[CS6] Criticality of mostly informative clustering in deep learning

Juyong Song 1,2,3, Matteo Marsili 2, Junghyo Jo 1,3

1 Asia Pacific Center for Theoretical Physics

2 Abdus-Salam International Centre for Theoretical Physics

3 Pohang University of Science and Technology

Deep learning is a sub-discipline of machine learning using layered artificial neural networks. The networks have tunable weights so that they can be a model for classification and clustering by tuning the weights through the learning algorithms. In this paper, we study the sizes of the clusters in deep belief networks (DBN) and see the emergence of the power law distributions. In statistical physics, power law has been thought as a sign of critical phenomena. Moreover, a second-order phase transition occurs at Zipf's law, reciprocal relation between rank and frequency with the exponent β=1, so that it can be thought as (an another) a critical point between order and disorder.

Recent studies showed that the models of power law cluster size distributions are mostly informative. It has been shown that the nonlinear transformed binary representations of latent variables through the normally distributed weights can follow power laws without fine-tuning, though it has no information about data. The layered networks are the same architectures so that they can show the power law activities robustly even after learning, or fine-tuning. Among them, the models with unity exponent have a proper complexity to describe data, so that the predictability is maximized. We find that the layer of Zipf's law can most faithfully generate learned patterns among the different exponents by balancing precision and global sampling of patterns and this is coincident with the result of previous studies. We expect that our finding can lead to a better understanding why deep learning works better than other algorithms of machine learning.

Although Zipf's law in the clustering size distributions is an important sign of a predictive model, it does not explain all about the predictability of the model. Rather than that, we can conclude that the models with Zipf's law clustering are mostly informative or most of the informative models are living at near the Zipf's law. Interestingly, our study is done with arbitrary data. Thus, this can shed a light to the construction rule of deep learning architectures depending on the data complexity.

[CS7] Hierarchical Model for Correlated Bursty Dynamics.

Byoung-Hwa Lee, Hang-Hyun Jo***

**Department of Physics, Pohang University of Science and Technology, Pohang, Korea*

***Asia-Pacific Center for Theoretical Physics, Pohang, Korea*

Many natural phenomena and human activities possess the underlying fundamental feature, called bursts, which is extreme inhomogeneity in the temporal domain. Earthquakes, solar flares, neuronal activity, and human communication are some examples. In that processes interevent time distributions are fat-tailed; and it is the essential characteristic of bursts. Some recent studies reveal that many inhomogeneous temporal sequences have correlation between the events. Autocorrelation function is not the good measure for the bursty time series because it cannot distinguish the effect of correlation and inhomogeneity. Instead of autocorrelation function we use the bursty trains, which is defined by the sets of the events that have the smaller interevent times than the threshold value. It is known that the number of events in the bursty trains follows the power-law for natural phenomena and human communication such as mobile-call, short message, and email. In this study, we introduce the hierarchical static model for correlated bursty process, which shows the fat-tailed bursty train distribution. We modified Soneira-Peebles model, which was originally studied in astronomy for generating synthetic galaxy distributions, to organize the structure of the bursty dynamics that have both characteristics of temporal inhomogeneity and higher-order correlation. By the model for bursty dynamics, we can get the deeper understanding of the structure and mechanism of bursts.

[CS8] Spreading in temporal process with correlated bursts

Hiraoka Takayuki, PESTECH, APCTP

Human activities and communications often displays bursty and intermittent behavior, which is characterized by a heavy tail of inter-event time distribution. Moreover, it has recently been suggested, from real-data analysis as well as from model studies, that higher-order correlations between the inter-event times play an important role in spreading phenomena in temporal networks. Here we show that the power-law behavior can be reproduced by a model with a Markovian behavior in the inter-event sequence. We also discuss how the correlation affects the average time for infection in susceptible-infected (SI) dynamics.

Session 3: CS 복잡계

[CS9] Diverse types of synchronization transitions to traveling wave and Pi states

Jinha Park, Seoul National University

A variant of Kuramoto model with random coupling constants $K_1<0$ and $K_2>0$ and with uniform frequency distribution is studied. In this model three phases are observed: Incoherent (IC), pi, and traveling-wave (TW) states. Ott-Antonsen reduction is not possible in the non-Lorentzian frequency distributions, and hence we apply the self-consistency method. Supercritical and subcritical hybrid-type bifurcations with $beta=2/3$ are found in the IC$rightarrowpi$ synchronization transition, depending on $|K_1|lessgtr K_2$. We also find that a hysteresis can occur between IC and TW states.

[CS10] Collective properties in coupled oscillators with bimodal natural frequency distribution on low-dimensional hypercubic lattice

Seung-jae Lee, Jeonbuk National University

Collective behaviors in the population consisting of two species have been observed in diverse natural systems. For instance, two species of microorganisms coupled by their genetic materials merge into a single species by exchanging their genetic materials. To understand the collective properties in the system with two species in the viewpoint of synchronization, we consider a model of coupled oscillators that can mimic the two different species. For simplicity, we here consider Kuramoto oscillators with bimodal natural frequency distributions (double Lorentzian and double delta-peak distributions) on low-dimensional hypercubic lattice, and investigate how the bimodal characteristic affects the collective behavior of the oscillators in the low-dimensional system. Especially, we extend the system of the oscillators onto various dimensional lattice, and pay attention to the dimensional dependence on the synchronization behavior. In this talk we show mostly numerical results for the system, and briefly introduce some anomalous behavior that probably arising from the bimodal feature of the natural frequency distribution.

[CS11] Inferring Posthumous Fame from Social Network Location Using a Half Millenium Historical Documents

Byunghwee Lee, Korea Advanced Institute of Science and Technology

Fame is a collective measure of success that reflects a society's interest to a person. We investigate the correlation between the activity of historical people during their lifetime and their posthumous fame by analyzing a large-scale historical documents listed in UNESCO's Memory of the World registry--the Annals of the Joseon Dynasty which had been written over 472 years. We first examine the association between individuals' fame during lifetime and their posthumous fame. Then, we construct social networks of historical people and compare four network centralities of individuals during lifetime with their posthumous fame. Our result reveals that the two factors--one's fame during lifetime and the location in social network--are both highly correlated with the posthumous fame. These findings shows that large-scale digitized historical texts combined with current network science methodologies can shed light on our understanding on diverse collective social phenomena.

[CS12] Tracking footprints of technology combination in US patent database

Hyunuk Kim, Pohang University of Science and Technology, Pohang

Technological innovation usually occurs by assembling distinct technologies through ‘Exploitation’ (existing combination) and ‘Exploration’ (new combination). Taking the advantages of US patent database which contains the repertoire of inventive activities, we examine the mechanisms of technology combination from a network science perspective. Technology space evolves by reinforcing conventionality as well as introducing novelty. Our suggested network model, which generates conventionality and novelty around a node, is in good agreement with the observed network characteristics.

[CS13] 대중가요 가사를 이용한 작사가 네트워크 분석

Young Jin Kim, Hanyang University

음악을 구성하는 요소로는 크게 음정, 박자, 그리고 가사로 구분할 수 있다. 이를 빅데이터의 하나로 인식하여 다양한 연구가 진행중이다 [1, 2, 3]. 본 연구에서는 이 중 한국 대중가요의 가사를 이용하여 작사가 네트워크를 구성하였다. 노래 가사 속 단어들과 작사가 사이의 이분 네트워크 (bipartite network)를 만든 뒤 사영(projection)을 시켜서 작사가 네트워크를 만들고, 작사가들 사이에 사용하는 단어들에 따라 군집화(clustering)가 되는 것을 확인하였다. 또한 딥러닝 중 합성곱 신경망(convolution neural network)을 이용하여 한국 대중가요의 경우 장르 예측가능성을 확인하였다.

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[CS14] 베이즈 추론을 이용한 한국의 성비 요동 분석

Minjae Kim, Pukyong National University

2000년과 2015년 한국인구주택총조사의 성씨 및 본관별 인구수 데이터를 바탕으로 인구수에 따른 남성 수의 평균값에 대한 요동을 분석하였다. 성씨 집단의 인구가 N 명일 때 평균으로부터의 요동이 N^b를 따른다는 가정 하에 베이즈 추론을 사용하여 지수 b를 구하였다. 인구 1000명 이상인 성씨에 대해 계산한 결과 2000년 데이터에서는 b=0.6686+/-0.0043, 2015년 데이터에서는 b = 0.6686 +/-0.0100를 얻었다. 이는 무작위 표본의 경우에서 기대되는 지수 1/2보다 크다.

[CS15] 2차원 Patlak-Keller-Segel 방정식의 수치적 분석

Gyuho Bae, Pukyong National University

유기체의 주화성 거동을 연구하기 위해 2차원 Patlak-Keller-Segel 모형[1]을 수치적으로 분석하였다. 이 모형은 유기체의 밀도장과 화학물질의 밀도장의 상호작용을 기술하는 한 쌍의 편미분방정식이다. 유기체의 전체 양이 어떤 임계질량을 넘어서면 모든 개체가 한 점으로 모이는 상전이가 일어난다. 적절한 경계조건와 맺음변수 하에서 임계질량의 해석적인 값은 π/10 ~ 0.314 로 주어지는데, Fatkullin은 유기체를 입자로 기술하면서 이 방정식을 수치적으로 풀었고 임계질량을 0.34~0.35로 추정하였다[2]. 본 연구에서는 풍부한 미시적 기술을 위해 화학물질까지 입자로 다룸으로써 행위자 기반 모형을 구축하였다. 이렇게 계산된 임계질량의 값은 0.3과 0.4 사이에 있어서 기존의 결과들과 부합한다.

[CS16] Deviation-based Ranking method

Daekyung Lee, Sungkyunkwan University

Since the validity of ranking system is up to evaluator's sincerity, determining their sincerity is an important problem. As a way to measure sincerity, the group-based ranking(GR) method has been suggested to give each individual the reputation value which is determined by the majority of their evaluation. Extending this method, we focus on the fundamental statistical difference between each evaluator's appraisal standard. As a result, we propose a new model of evaluation mechanism and compare to various empirical data sets.

Session 4 : NW 네트워크

[NW1] Identifying a Hierarchical Multiscale Backbones from Bipartite Network

Woo Seong Jo, Sungkyunkwan University

Many complex datasets can be represented as bipartite networks. Often, a partite network is reduced to a unipartite network (e.g. a network of people from an affiliation bipartite network) through one-mode projection and related techniques. This procedure tends to produce highly dense, weighted networks with strong inhomogeneity, which are difficult to analyze and understand. A popular approach for processing a dense, weighted network is identifying meaningful ``backbone" that captures the most important edges in the network. Yet, most methods do not specifically consider bipartite networks and tend to fail to capture relevant structure when there exists a strong core-periphery structure. Here we introduce a method to extract hierarchical backbone for a unipartite network by incorporating the information in the original bipartite network; our method improves the relevance of the obtained network compared with previous methods that identify hierarchical structure from tagged data. Our method calculates the conditional probability $p(v|w) = |N(v) cap N(w)| / |N(w)|$ and $p(w|v)$ between each pairs of nodes in the same part, where $N(v)$ is the set of neighbors of v. By using the asymmetry $p(v|w) neq p(w|v)$ and a simple statistical test, we extract a tunable ($alpha$) hierarchical backbone. We apply our method on a tagged item dataset to obtain a hierarchical network structure of the tags that capture highly relevant clusters in the tag network even in the presence of strong inhomogeneity in frequency across tags.

[NW2] Microscopic network structures on a model of evolving open system

Young-Jai Park, Hanyang University

Complex networks can be found in various fields such as social communities, ecosystems, brains and nervous systems. These examples are kind of temporal networks that repeat growth and evolution. In this work, we analyze an evolving open network model which consists of signed, directed, and weighted links. Depending on the number of interactions in this network model, the total size of the network immediately go to zero or grow infinitely. We confirm properties of network structure on a microscopic scale and find structural conditions that allow this open system to grow.

[NW3] Effective pruning dynamics in fractal and nonfractal networks

Yoonseok Im, Seoul National University

Estimation of resilience of networks is an important problem. Since finding an optimal set of nodes for percolation is NP-hard problem, estimation of resilience should be done by heuristic algorithms. Thus, validity of heuristic algorithms and consistency between them are interesting issues. Recently, well-performing heuristic algorithms have been proposed, such as CI algorithm and Belief Propagation-guided Decimation (BPD) algorithm. While they still show good performance on networks with local loops compared to traditional centrality-based heuristics, both algorithms rely on locally tree-like property of dilute networks. In early studies, it was noted that a scale-free network consists of a skeleton, which is a critical branching tree, and shortcuts, which form short and long-ranged loops. Fractal scaling property of scale-free networks depends on the ratio of long-ranged shortcuts to short-ranged ones. In this talk, we show that performance of CI and BPD algorithms vary depending on fractality of scale-free networks. In some cases, it is enough to affect the result of comparison of resilience between two different networks, as demonstrated on real-world networks, the Web subgraph and the internet for example.

[NW4] Hybrid phase transitions in percolation-related models

Deokjae Lee, Seoul National University

Hybrid phase transitions are discontinuous phase transitions where some physical quantities diverge in the vicinity of the transition point. For usual second order phase transitions, it is well known that the physical origin of the divergence of physical quantities is the scale invariance of the system, and various critical phenomena emerging from the scale invariance have been studied. However, for HPTs, it still lacks a thorough understanding on the physics behind the divergences. Here we review the hybrid phase transitions in several percolation-related models. In these models, the divergent quantities are originated from avalanche dynamics. The avalanche is defined as a response of the system on a perturbation, or a model itself is defined in terms of an avalanche process. These models share a universal mechanism as a branching process and also share a critical exponent determined by the mechanism. Some of the models also share a scaling relation which is not observed in usual second-order phase transitions. The finite-size scaling of the models suggests that there exist two or more divergent length scales. The mean duration time of finite avalanches gives one length scale, but the origin of other length scales are not clear yet.

[NW5] "Two golden times in two-step contagion models"

Wonjun Choi, Seoul National University

The two-step contagion model is a simple toy model for understanding pandemic outbreaks that occur in the real world. The model takes into account that a susceptible person either gets immediately infected or weakened when getting into contact with an infectious one. As the number of weakened people increases, they eventually can become infected in a rapid cascading process and a pandemic outbreak occurs. The time required to reach such a pandemic outbreak allows for intervention and is often called golden time. Here we find that there exist two types of golden times in the two-step contagion model, which scale as $O(N^{1/3})$ and $O(N^{1/4})$ with the system size N on ErdH{o}s-R'enyi networks. They are distinguished by the initial number of infected nodes, $o(N)$ and $O(N)$, respectively. These golden times are universal even in other models showing discontinuous transitions induced by cascading dynamics. We hope that understanding this size dependency of the golden time is useful for controlling pandemic outbreak.

[NW6] A restricted percolation model on 2D lattice, ER networks and scale-free networks

Kwangjong Choi, Seoul National University

Recently, a hybrid percolation transitions (HPT) that exhibits both a discontinuous transition and critical behavior at the same transition point has been observed in diverse complex systems. Here, I suggest the restricted model on the two dimensional square lattice, ER network and scale-free network as an example of the HPT and a theoretical framework of HPT. I explain that two correlation-length exponents are needed to characterize the giant cluster and finite clusters respectively, unlike ordinary percolation transition (OPT). Appropriate finite-size scaling method for the HPT is also introduced. In particular, neither the giant nor finite clusters are fractals but they have fractal boundaries.

[NW7] Critical behavior of optimal percolation of ER network

Soo-Jeong Kim, Korea University

In a recent paper [Nature 524, 6568 (2015)] Morone and Makse introduced the so-called CI optimal percolation. CI optimal percolation is finding the so-called 'top influencers' and removing them so that the giant component size is reduced quickly. The top influencer is selected by having the largest CI value which is defined by CIi,l = (ki − 1) j∈∂Ball(i,l)(kj − 1).

It incorporates not only the degree of the node itself but also degrees of its neighboring nodes within distance l. CI optimal percolation critical point is smaller than other previously-studied cases (e.g. random failure, high-degree attack, page-rank attack, k-core). We study the critical behavior of CI optimal percolation of ER network at l = 1.

[NW8] Percolation processes on two-dimensional multiplex lattices

Jeehye Choi, Korea University

Many complex systems are best modeled by multiplex networks of layers of various types of connections. Functional cooperativity between network layers such as interdependency has shown to affect the percolation properties of multiplex networks by inducing discontinuity and hysteresis. In this study we introduce the percolation transitions of the multiplex viability model [B. Min and K.-I. Goh, Phys. Rev. E 89, 040802(R) (2014)] on two-layer square lattices. This model is a generalized percolation model on multiplex systems comprised of two distinct processes establishing the viability, the cascade of activations (CA) and the cascade of deactivations (CD), depending upon which different transition points and thereby hysteresis are observed. To address the universality issue of this model, here we perform extensive Monte Carlo simulations and show that in two-layer square lattices the two processes not only have different percolation transition points but also exhibit different critical behaviors with distinct sets of critical exponents. For CA, the transition is found to be in the same universality class as the ordinary percolation (OP) in 2D. On the other hand, for CD, the transition belongs to different universality class from OP but shows critical behaviors consistent with those of 2D mutual percolation model. To achieve a self-contained and self-consistent scaling picture of the transitions we introduce a novel definition of the cluster that properly addresses the critical properties. The obtained results are verified for consistency through scaling relations such as $dnu=2beta+gamma$.

Session 5 : NW 네트워크 + EP 경제물리

[NW9] Extended finite-size scaling of GEP on scale-free networks

Kihong Chung(KAIST), Yongjoo Baek (Technion, Israel), Daniel Kim (Samsung SDS), Meesoon Ha (Chosun Univ.), and Hawoong Jeong (KAIST)*

Generalized epidemic process (GEP) [1-2] is a simple percolation-like process with cooperation. It exhibits continuous phase transitions of the bond percolation universality class when the cooperation is weak, while strong cooperation leads to discontinuous phase transitions [1-3]. In this work, we study the effects of structural heterogeneity on the tricritical phenomena occurring at the boundary between the two regimes, proposing an extended finite-size scaling theory for various scale-free networks. In particular, we derive the crossover exponent and the associated scaling relations and relate them to the power-law exponent of the degree distribution. Our predictions are checked by extensive Monte Carlo simulations.

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[NW10] Partial synchronization of identical oscillators on random network with a phase lag

Sudo Yi, Seoul National University

We investigate how the identical Kuramoto oscillators form a coherent state in the existence of a phase lag $alpha$ in the coupling term, where $0leqalphaleqpi$. While there is a perfectly synchronized state on a globally coupled (GC) structure for $0<alpha<pi/2$, the numerical simulation on Erdos-Renyi (ER) network shows that a partially synchronized state exists. The frequency-entrainments on GC and ER also differ in the dependence on $alpha$. Using the heterogeneous mean-field approximation, we set a self-consistency equation of a single parameter. We find that there are two possible solutions of equation, and there is a bifurcation similar to the transcritical bifurcation passing through $alpha=pi/2$ according to the numerical simulation. Scaling behavior of the order parameter near $alpha=pi/2$ in also investigated approximately.

[NW11] Entropy productions in data packet transport on complex networks

Jaewoo Jung, Seoul National University

We consider the integral and the detailed fluctuation theorems in data packet transport on complex networks. On the Internet, data packets usually travel from one node to a destination node following the shortest path between them unless the number of packets is too many to need take detour pathways. Internet is known as a scale-free network, and such networks contain diverse shortest pathways between two nodes. Due to such topological complexity of shortest pathways, we show easily that the probability to take a shortest pathway from one to another node cannot be the same as that in its backward direction. Thus, finite entropy productions can be obtained explicitly for the shortest pathways between every pair of nodes. Using an efficient algorithm developed in complex network science, we obtain the distribution of entropy productions explicitly for various complex networks such as ER networks, random scale-free networks, Internet at the AS level, and coauthorship networks, finding that the entropy productions indeed satisfy the detailed fluctuation theorem and the integral fluctuation theorem. We tried to fit the tails of entropy production distributions for random ER and SF networks to several functions known in the large deviation theory but it was not successful. We also show several other interesting features. Finally we will discuss potential applications of this study to other systems.

[NW12] Role of memory in activity-driven network models

Hyewon Kim (KAIST), Meesoon Ha** (Chosun Univ.), and Hawoong Jeong (KAIST)*

**Presenter, **Corresponding author*

Complex networks consist of the structural and dynamical components. While the structural analysis has been well established, the dynamical one has not due to the hardness of data collections and the ambiguity of dynamic levels in networks. The dynamic levels can be adjusted by assigned time unit, within which detailed temporal information is ignored. In this work, we propose an activity-driven network model with memory and investigate the interplay of memory and activity in temporal networks. In particular, we focus on time resolution related to the dynamic levels, namely time window of temporal networks, and present how memory and time window affect the diffusion property of random walks. Finally, we find that the change of the diffusion property is attributed to the dynamics of the largest cluster in time-varying networks.

[NW13] Analytic approach for link prediction methodology

Min-Woo Ahn, Pohang University of Science and Technology, Pohang

링크 예측법은 복잡계 네트워크의 데이터 신뢰도를 보완하기 위하여, 그리고 growth network 에서 미래의 연결을 예측하기 위해 연구되고 있다. 이를 위하여 유사도 지수를 정의하여 유사도 지수가 높은 연결을 missing link 혹은

future link의 후보로 선정한다. 이러한 유사도 지수에 대한 연구는 활발히 진행되고 있으나, 유사도 지수의 성질 자체의 수학적 성질은 잘 연구되지 않고 있다. 본 발표에서는 missing link prediction 방법론에 대한 수학적인 계산을 목표로 한다. Link 가 무작위로 지워진다는 가정 하에 유사도 지수가 바뀌는 정도를 통해 유사도 지수의 성질읇관측하고, 유사도 지수가 어떤 네트워크 구조 하에서 잘 작동하는지에 대해서도 알아본다.

[EP1] Small city follows larger city's trajectory in urban economy

Inho Hong, Pohang University of Science and Technology, Pohang

Identifying the evolutionary paths of urban economy is key to accessing, maintaining and forecasting city's future growth and success. Although path dependency in economic trajectories has been alluded to in the literature, it still lacks comprehensive empirical evidences. Here, we study the evolution of urban economy by analyzing the whole U.S. industries in individual cities over two recent decades. The industrial characteristic of a city is quantified by revealed comparative advantage (RCA), and the temporal change of industrial similarity between cities describes how urban economy evolves. We find that small cities move into closer resemblance of large cities in time, that is, urban industrial evolution repeats itself in individual cities. We also show that when a group of largest cities is fixed in time, the rest of smaller cities become more similar to them with time lag. It is indeed the case that small cities follow the industrial footprints of large cities. We show that these dynamics are relatively general characteristics, not entirely driven by a few industry sectors. Finally, we identify the structural transition in urban economy as a crossover of dominant industries, and the transition point is analytically explained by the distribution of scaling exponents.

[EP2]Market response to the price change

Min-Young Lee, Pohang University of Science and Technology, Pohang

Investigation of the dynamics of the ultra-high frequency data with the order-driven market provides valuable insights about the evolution in firms price formation over time. The properties of price formation are the results of traders investment strategies. The limit, market, and cancellation form the price and the traders submit their orders to the order book in reaction to the market. We analyze the trader's high-frequency trading strategies from the price impact using the di
erent lags. We study the market response to the price change and the order flow before the price change.

Our result shows that the trader's strategies depend on the previous change of the stock price. The empirical analysis of the correlation between variables supports usefulness of considered variables created from limit order book.

Session 6: SP 통계물리일반

[SP1] Stochastic efficiency of a microscopic heat engine model

Jong-Min Park1 and Jae Dong Noh1,2

1Department of Physics, University of Seoul, Seoul 02504, Korea

2School of Physics, Korea Institute for Advanced Study, Seoul 02455, Korea

The efficiency of a macroscopic heat engine is fundamentally bounded by the Carnot efficiency. However, on a microscopic scale, thermal fluctuations are so large that the efficiency becomes stochastic and can occasionally exceed the Carnot efficiency. The event to observe the Carnot efficiency is the least probable if the number of states of the heat engine is finite. This universal behavior is dubbed as the least likeliness of the Carnot efficiency. Our main question is whether the least likeliness of the Carnot efficiency is still valid when the heat engine has the unbounded phase space. We obtain the large deviation function of stochastic efficiency distribution in a solvable Brownian heat engine model. The results show that the least likeliness of the Carnot efficiency is violated in the engines with unbounded phase space.

[SP2] Mean-field analysis for a collective motion of globally coupled Brownian particles

Hyun-Myung Chun, University of Seoul

We study a phase transition of a globally coupled Brownian particles system.

As the coupling strength is changed, the system undergoes a nonequilibrium phase transition into an ordered phase where Brownian particles move collectively.

We derive a self-consistent equation for the order parameter using the mean field theory.

From the self-consistent equation, we obtain the critical point and the critical exponent analytically.

[SP3] First passage dynamics of fractional Brownian motion with stochastic resetting: a computational study

Sungmin Joo, Durang Xavier (KIAS), Sungmin Lee (SKKU), Jae-Hyung Jeon

We investigate the target search dynamics with stochastic resetting where the search particle performs a strongly correlated diffusion modeled by fractional Brownian motion (FBM) in a finite domain. Our simulation shows that the stochastic resetting in general enhances the target search if the distance between the target and reset site is less than a critical value which turns out to depend on the Hurst exponent and the domain size. In this circumstance, there exists an optimal resetting rate r* that minimizes the mean first passage time. Beyond this distance, the resetting is no longer effective to find a target. We report our first systematic investigation on how the stochastic resetting and the directional correlation play roles in finding a target in a finite domain in terms of the mean first passage time and its distribution.

[SP4] Interplay of local defect and particle interaction in a 1D TASEP-based traffic model

Hyungjoon Soh (KAIST), Meesoon Ha** (Chosun University), and Hawoong Jeong (KAIST)*

** Presenter, ** Corresponding author*

We propose a one-dimensional (1D) traffic model with a localized site defect and distance-dependent hopping, in terms of a 1D totally asymmetric simple exclusion process (TASEP) with a slow bond (SB) at the middle of a ring. For the ordinary TASEP with a SB, it is known that the SB is significantly weaken due to current maximization, which is referred as the slow-bond problem in the literature. In this work, we adopt distance-dependent hopping rates to particles and examine jamming of particles as well as condensation of holes. In particular, we employ the zero-range process (ZRP)-type force [1] and test the role of the condensation factor b from positive values to negative values in the SB problem, where $b=0$ represents the ordinary case. We focus on the shape of density profile and the average current to determine jamming by means of the homogeneity of the system. As a result, the interplay of SB and particle attraction exhibits the complex phase structure between jamming and no jamming. Moreover, we provide the extension of two-site mean-field theory of the SB into two-site version of ZRP, and obtain the phase boundary in the approximate limit. Notably, negative condensation factor yields somewhat similar flow-density relation of real-world traffic models, which implies that the critical SB strength does not put traffic into a global jamming.

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[SP5] Dynamic critical behavior of the one-dimensional XY model with long-range interaction

Seong-Gyu Yang, Sungkyunkwan University

The critical behavior of the XY model in one-dimensional lattice with long-range interaction has been studied recently. Here, we investigate the dynamic critical behavior of the XY model using Monte Carlo method and solving real-time dynamics. We figure out that the relaxation time is needed to be scaled with acceptance ratio in Monte Carlo results.

[SP6] The out-of-time-ordered correlator of typical state in many-body localization

Juhee Lee, Gwangju Institute of Science and Technology

[Abstract]

We investigate the time evolution of out-of-time-ordered correlator to find typical initial state in many-body localization. In the disordered Heisenberg XXZ chain, we find that the random product state is composed with spins closer to the equator of the Bloch sphere, the fluctuation of the OTOC becomes smaller. We analyze the typicality of state by using inverse participation ratio. We discuss the applicability of the result to the experimental mearurement of the OTOC.

[SP7] Phase transitions of long-range contact process in open quantum systems: Mean-field results

Minjae Jo, Seoul National University

[Abstract]

We investigate a non-equilibrium absorbing transition in a quantum spin system containing not only dissipative but also coherent dynamics using the quantum Langevin equation and the semi-classical field theory. In previous works, it was revealed that the Rydberg atoms with strong dephasing noise realize the universal behavior of ordinary directed percolation. However, when the Rydberg atoms are excited in d-state, we need to take into account of the dipole-dipole interaction between those atoms. This leads to the DP model with long-range interaction. Here, we extend the dissipatively driven Rydberg atoms with the long range interaction to the quantum spin system manifesting the contact process, where not only classical interactions mediated by heat bathes, but also quantum coherent interaction are comprised. We derive the Heisenberg equations from the total Hamiltonian consisting of the system, bathes and their interaction. The action is built by using the semi-classical approach and then the Martin-Siggia-Rose-Janssen-de Dominicis (MSRJD) technique. By the saddle-point approximation, the mean-field phase transition is obtained, which turns out to be second-order in weak quantum regime, whereas it is first-order in strong quantum regime. The upper critical dimension is also discussed in terms of the exponent of long-range interaction.

워크숍 참가자 명단

성명	E-mail	소속	신분
Ahn, Kang-Hun	ahnkanghun@gmail.com	충남대학교	교수
Ahn, Min-Woo	ryzb55@postech.ac.kr	POSTECH	학생
Bae, Gyuho	bekuho1991@gmail.com	부경대학교	학생
Baek, Seung Ki	seungki@pknu.ac.kr	부경대학교	교수
Bahk, Jiwon	bjw921229@naver.com	세종대학교	학생
Bak, Ji Hyun	jhbak@kias.re.kr	KIAS	연구원
Cho, Youngsul	yscho@jbnu.ac.kr	전북대학교	교수
Choe, Seungho	schoe@dgist.ac.kr	DGIST	교수
Choi, Myung Chul	mcchoi@kaist.ac.kr	KAIST	교수
Choi, Jeehye	choi.jeehye@gmail.com	고려대학교	학생
Choi, Jun Young	choijun8174@naver.com	경희대학교	학생
Choi, Wonjun	choiwj415@gmail.com	서울대학교	학생
Choi, Kwangjong	ckj0721@gmail.com	서울대학교	학생
Chun, Hyun-Myung	hmchun@uos.ac.kr	서울시립대학교	학생
Chung, Kihong	kckihong@kaist.ac.kr	KAIST	박사
Goh, Kwang-Il	kgoh@korea.ac.kr	고려대학교	교수
Gwak, Sang-Hwan	gwak.sanghwan@gmail.com	고려대학교	학생
Ha, Meesoon	msha@chosun.ac.kr	조선대학교	교수
Hiraoka, Takayuki	takayuki.hiraoka@apctp.org	POSTECH / APCTP	연구원
Hong, Inho	ihong@postech.ac.kr	POSTECH	학생
Hwang, Wonseok	whwang299@gmail.com	KIAS	연구원
Im, Yoonseok	tiom333@gmail.com	서울대학교	학생
Jeon, Jae-Hyung	jeonjh@gmail.com	POSTECH	교수
Jeong, Hyeong-Chai	hcj@sejong.ac.kr	세종대학교	교수

Jeong, Hawoong	hjeong@kaist.ac.kr	KAIST	교수
Jo, Minjae	biznis@snu.ac.kr	서울대학교	학생
Jo, Woo Seong	wooseong.jo@gmail.com	성균관대학교	학생
Jo, Junghyo	jojunghyo@apctp.org	POSTECH / APCTP	교수
Jo, Hang-Hyun	h2jo23@gmail.com	POSTECH / APCTP	교수
Joo, Sugnmin	philip1352@postech.ac.kr	POSTECH	학생
Jung, Jaewoo	jaewoos824@gmail.com	서울대학교	학생
Jung, Woo-Sung	wsjung@postech.ac.kr	POSTECH	교수
Jung, Jaewoo	jaewoos824@gmail.com	서울대학교	학생
Jung, Youngkyun	yjung@kisti.re.kr	KISTI	교수
Kahng, Byungnam	bkahng@snu.ac.kr	서울대학교	교수
Kim, Hyun	kimman3803@gmail.com	고려대학교	학생
Kim, Hyewon	hwk1m@kaist.ac.kr	KAIST	학생
Kim, Hyunuk	hyunuk_kim@postech.ac.kr	POSTECH	학생
Kim, SooKyung	skkim@ssu.ac.kr	숭실대학교	연구원
Kim, Sujin	littlemomo72@nate.com	숭실대학교	연구원
Kim, Dongkyu	dkkim1005@gist.ac.kr	GIST	학생
Kim, Pan-Jun	pjkim@kaist.ac.kr	KAIST	교수
Kim, Dongkyum	kdkyum531@gmail.com	KAIST	학생
Kim, Jinmin	jmkim@ssu.ac.kr	숭실대학교	교수
Kim, Young Jin	kimyoungjin06@gmail.com	한양대학교	학생
Kim, Minjae	minjae.kim.phys@gmail.com	부경대학교	학생
Kim, Beom Jun	beomjun.kim@gmail.com	성균관대학교	교수
Kim, JaeWoo	732jwk@naver.com	고려대학교	학생
Kim, Soo-Jeong	1crystal111@gmail.com	고려대학교	학생
Kim, Jin-Hyeon	rangu@korea.ac.kr	고려대학교	학생
Lee, Hyun Gyu	supersting85@naver.com	고려대학교	학생

Lee, Kyoung Jin	kyoung@korea.ac.kr	고려대학교	교수
Lee, Seung-jae	stat-phy_07@jbnu.ac.kr	전북대학교	학생
Lee, Nam-Kyung	namklee@sejong.edu	세종대학교	교수
Lee, Jae Woo	jaewlee@inha.ac.kr	인하대학교	교수
Lee, Juhee	schwarzg@gist.ac.kr	GIST	학생
Lee, Min-Young	minyoung@postech.ac.kr	POSTECH	학생
Lee, Byunghwee	peniel0410@gmail.com	KAIST	학생
Lee, Woo Seok	lws0621@cnu.ac.kr	충남대학교	학생
Lee, Byoung-Hwa	tableaux@postech.ac.kr	POSTECH / APCTP	학생
Lee, Sang Bub	sblee@knu.ac.kr	경북대학교	교수
Lee, Deok-Sun	deoksun.lee@gmail.com	인하대학교	교수
Lee, Deokjae	lee.deokjae@gmail.com	서울대학교	박사
Lee, Daekyung	exaparsec@gmail.com	성균관대학교	학생
Lee, Songsub	songsub123@gmail.com	성균관대학교	학생
Lee, Mi Jin	mj.mijin.lee@gmail.com	인하대학교	박사
Lee, Jaesung	jslee@kias.re.kr	KIAS	교수
Lee, Sang Hoon	lshlj82@kias.re.kr	KIAS	연구원
Moon, Hyeon-Min	sagoos@paran.com	고려대학교	학생
Noh, Jae Dong	jdnoh@uos.ac.kr	서울시립대학교	교수
Park, Hyuk Kyu	hyuk.k.pak@gmail.com	UNIST	교수
Park, Jeong-Man	jmanpark@catholic.ac.kr	가톨릭대학교	교수
Park, Jin-Sung	jspark@korea.ac.kr	고려대학교	연구원
Park, Young-Jai	youngjaip0324@gmail.com	한양대학교	학생
Park, Sul-Ah	standup1014@gmail.com	충남대학교	학생
Park, maruchan	shaild098@naver.com	충남대학교	학생
Park, Jinha	jinha.physicus@snu.ac.kr	서울대학교	학생
Park, Jong-Min	mini314@uos.ac.kr	서울시립대학교	학생

Park, Eunkyu	eunkyui@gmail.com	고려대학교	학생
Park, Byeong-gyu	bizzy@korea.ac.kr	고려대학교	학생
Park, Su-Chan	spark0@catholic.ac.kr	가톨릭대학교	교수
Park, Hyunggyu	hgpark@kias.re.kr	KIAS	교수
Soh, Hyungjoon	hjsoh88@kaist.ac.kr	KAIST	학생
Son, Seung-Woo	sonswoo@hanyang.ac.kr	한양대학교	교수
Song, Je Ung	peridot830@naver.com	서울대학교	학생
Song, Taegeun	taegeun.song@apctp.org	POSTECH / APCTP	박사
Song, Juyong	juyongsong@apctp.org	POSTECH / APCTP	학생
Um, Jaegon	slung79@gmail.com	서울대학교	박사
Yang, Seong-Gyu	yangpang820@gmail.com	성균관대학교	학생
Yi, Su Do	esudoz@snu.ac.kr	서울대학교	박사
Yoo, Jae-yun	jyyoo5272@gmail.com	충남대학교	학생
Yook, Soon-Hyung	syook@khu.ac.kr	경희대학교	교수