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2023 International workshop for Future Values of

Mathematics and Its Applictions

supported by BK21 FOUR Project, Leading Mathematical Scientists Fostering Program For Creating Future Values

Dates 7 – 9 August 2023

Venue Online Zoom

Organizing Committees

- Hahng-Yun Chu *(Chungnam National University)*
- Myeongmin Kang *(Chungnam National University)*
- Hyenho Lho *(Chungnam National University)*
- Jinhae Park *(Chungnam National University, Chair)*
- Seong-Mi Seo *(Chungnam National University)*
- Dongsoo Shin *(Chungnam National University)*

Invited Speakers

- Sung-Soo Byun *(Seoul National University)*
- Jaehoon Cha *(Science and Technology Facilities Council, UK)*
- Jaewoong Choi *(Korea Institutes for Advanced Study)*
- Jaeyoo Choy *(Korea Institute for Advanced Study)*
- Honglu Fan *(University of Geneva, Switchland)*
- Michel van Garrel *(University of Birmingham, UK)*
- Beom-Seok Han *(Korea Advanced Institute of Science and Technology)*
- Jiyoung Han *(Korea Institute for Advanced Study)*
- Hansol Hong *(Yonsei university)*
- Geonho Hwang *(Korea Institutes for Advanced Study)*
- Jaekwan Jeon *(Chungnam National University)*
- Hong Chang Ji *(Institute of Science and Technology Austria, Austria)*
- He Jin *(Chungnam National University)*
- Jaewoo Jung *(Institute for Basic Science)*
- Seongjai Kim *(Mississippi State University, USA)*
- Kyeongsoo Kim *(Xi'an Jiaotong-Liverpool University, China)*
- Se-Hyun Ku *(Chungnam National University)*
- Sanghoon Kwon *(Catholic Kwandong University)*
- Byungjoon Lee *(The Catholic University of Korea)*
- Jinyeop Lee *(Ludwig Maximilian University of Munich, Germany)*
- Sanghyuk Lee *(New Uzbekistan University, Uzbekistan)*
- Yeachan Park *(Korea Institutes for Advanced Study)*
- Jinhae Park *(Chungnam National University)*
- Youngho Yoon *(Chungbuk National University)*

충남대학교 CHUNGNAM NATIONAL UNIVERSITY

충남대학교 수리과학연구소

2023 International Workshop for Future Value of Mathematics and Its Applications

Time Table

Numerical analysis and deep learning

Zoom ID : 897 8621 3202			
Monday, August 7th, 2023			
Time	Chair	Title	Speaker
9:30 – 10:10	Myeongmin Kang (Chungnam National Univeristy)	mCLESS: The Multi-Class Least-Error Square Sum for Interpretable Classification	Seongjai Kim (Mississippi State University, USA)
10:10 – 10:50		Super-convergence property on Poisson solvers with adaptive grids	Byungjoon Lee (The Catholic University of Korea)
11:00 – 11:40		Generative Modeling through the Semi-dual Formulation of Unbalanced Optimal Transport	Jaewoong Choi (Korea Institutes for Advanced Study)
11:40 – 12:20		Integrability of the training dynamics of gradient flows and differential Galois theory	Yeachan Park (Korea Institutes for Advanced Study)
12:20 – 13:00		Minimal Width for Universal Property of Deep RNN	Geonho Hwang (Korea Institutes for Advanced Study)

Algebraic Goemetry I

Zoom ID : 838 5424 5730			
Monday, August 7th, 2023			
Time	Chair	Title	Speaker
9:50 – 10:30	Hyenho Lho (Chungnam National Univeristy)	Local-local for irreducible nodal divisor	Michel van Garrel (University of Birmingham, UK)
10:30 – 11:10		Machine learning models learned on mathematical tasks	Hansol Hong (Yonsei University)
11:10 – 11:50		Floer aspects of Aganagic-Vafa branes	Honglu Fan (University of Geneva, Switzerland)

Probability and Mathematical Physics

Zoom ID : 897 8621 3202			
Monday, August 7th, 2023			
Time	Chair	Title	Speaker
15:00 – 15:40	Seong-Mi Seo (Chungnam National University)	Large deviations and fluctuations of real eigenvalues of elliptic random matrices	Sung-Soo Byun (Seoul National University)
15:50 – 16:30		Deriving Vlasov equation from a many-body quantum system	Jinyeop Lee (Ludwig Maximilian University of Munich, Germany)
16:40 – 17:20		The uniqueness, existence, and regularity of solutions to stochastic Burgers' equations with time fractional derivatives and multiplicative space-time white noise	Beom-Seok Han (Korea Advanced Institute of Science and Technology)
17:30 – 18:10		Density of Brown measure of free circular Brownian motion	Hong Chang Ji (Institute of Science and Technology Austria, Austria)

Algebraic Geometry II

Zoom ID : 313 252 8553			
Tuesday, August 8th, 2023			
Time	Chair	Title	Speaker
10:00 – 10:40	Dongsoo Shin (Chungnam National University)	Hankel Index and Almost Real Rank	Jaewoo Jeong (Institute for Basic Science)
10:50 – 11:30		Deformations of Singularities and Kollár Conjecture	Jaekwan Jeon (Chungnam National University)
11:40 – 12:20		Ideals and Spectrum	Youngho Yoon (Chungbuk National University)

Dynamical Systems I

Zoom ID : 897 8621 3202			
Tuesday, August 8th, 2023			
Time	Chair	Title	Speaker
10:00 – 10:40	Hahng-Yun Chu (Chungnam National Univeristy)	Automorphic spectrum of the standard non-uniform weighted triangle comple	Sanghoon Kwon (Catholic Kwandong University)
10:50 – 11:30		Moment Formulas for The Siegel Transform and Quantitative Khintchine-Groshev Theorem	Jiyoung Han (Korea Institute for Advanced Study)
11:40 – 12:20		Partial hyperbolicity on Hilbert schemes of points	Jaeyoo Choy*[1], Hahng-Yun Chu[2] ([1]Korea Institute for Advanced Study, [2]Chungnam National University)

Dynamical Systems II

Zoom ID : 897 8621 3202			
Tuesday, August 8th, 2023			
Time	Chair	Title	Speaker
14:00 – 14:40	Se-Hyun Ku (Chungnam National Univeristy)	Topological properties on functional dynamics	Hahng-Yun Chu, Se-Hyun Ku*, Van Sang Hong Nguyen (Chungnam National Univeristy)
14:50 – 15:30		Recommendation System Design based on Preference and Lexicographic Ordering for the Multi-Criteria Systems	Sanghyuk Lee (New Uzbekistan University, Uzbekistan)
15:40 – 16:20		Exploiting Unlabeled RSSI Fingerprints in Multi-Building and Multi-Floor Indoor Localization through Deep Semi-Supervised Learning Based on Mean Teacher	Kyeongsoo Kim (Xi’ an Jiaotong-Liverpool University, China)

Applied Analysis and Neural Networks

Zoom ID : 897 8621 3202			
Wednesday, August 9th, 2023			
Time	Chair	Title	Speaker
10:00 – 10:40	Jinhae Park (Chungnam National Univeristy)	The heat kernel on hyperbolic space and its application	Jinhae Park (Chungnam National Univeristy)
10:50 – 11:30		Orthogonality-Enforced Latent Space in Autoencoders: An Approach to Learning Disentangled Representations	Jaehoon Cha (Science and Technology Facilities Council, UK)
13:00 – 13:40		Study of Defects arising in the Landau-de Gennes energy by way of Fourier spectral method	He Jin*, Jinhae Park (Chungnam National University)

Special Session: Interdisciplinary Mathematics

Room 1204			
Wednesday, August 9th, 2023			
Time	Chair	Title	Speaker
14:00 – 14:40	SeungBum Cho (Chungnam National Univeristy)	Neural ODE and stability of an algorithm	Juyeb Yeo (Chungnam National Univeristy)
14:40 – 15:20		Understanding Normalization in Contrastive Representation Learning and Out-of-Distribution Detection	Ge Tai Le (Chungnam National Univeristy)
15:20 – 16:00		Ginzburg-Landau theory in Liquid Crystals	Khai An Tran*, Jinhae Park (Chungnam National Univeristy)
16:00 – 16:40		Image Restoration Using Fixed-point-like and split Bregman Methods for A TVL2D2 Regularization Model	Yujin Won (Chungnam National Univeristy)
16:40 – 17:20		Introduction to Generative AI models based on Variational Inference	Sangmin Ji (Chungnam National Univeristy)
17:20 – 18:00		Topological dynamics in orbital inverse limit systems	Hahng-Yun Chu, Nakyoung Lee* (Chungnam National Univeristy)

Abstract

Numerical analysis and deep learning

Chair : Myeongmin Kang (Chungnam National Univeristy)

1-1 Seongjai Kim (Mississippi State University, USA) : mCLESS: The Multi-Class Least-Error Square Sum for Interpretable Classification

Some machine learning algorithms are considered as black boxes, because the models are sufficiently complex and they are not straightforwardly interpretable to humans. Lack of interpretability in predictive models can undermine trust in those models in many application areas. The article introduces a new interpretable machine learning algorithm, called the Multi-Class Least-Error Square Sum (mCLESS). It is linear, simple to implement, and interpretable. Its nonlinear expansion is discussed. This simple algorithm turns out to be superior to many popular machine learning algorithms. Various experimental results involving synthetic datasets and UCI datasets are given to verify the claim.

1-2 Byungjoon Lee (The Catholic University of Korea) : Super-convergence property on Poisson solvers with adaptive grids

The Hodge decomposition, that is an important feature of incompressible fluid flows, is orthogonal and the projection taking its incompressible component is therefore stable. The decomposition is implemented by solving the Poisson equation. In order to simulate incompressible fluid flows in a stable manner, it is desired to utilize a Poisson solver that attains the orthogonality of the Hodge decomposition in a discrete level.

When a Poisson solver induces the orthogonality, its associated linear system is necessarily symmetric. With this regard, the symmetric Poisson solvers by Losasso et al. [1, 2] are more advantageous not only to efficiently solving the linear system but also to stably simulating fluid flows than nonsymmetric ones. Their numerical solutions were empirically observed to be first and second order accurate, respectively. One may expect that each of their numerical gradients has convergence order that is one less than that of its numerical solution.

However, we in this work show that super-convergence holds true with both Poisson solvers. Rigorous analysis is presented to prove that the difference is one half, not one between the convergence orders of numerical solution and gradient in both solvers. The analysis is then validated with numerical results. We furthermore show that both Poisson solvers, being symmetric, indeed satisfy the orthogonal property in the discrete level and yield stable implementations of the Hodge decomposition in octree grids.

References

[1] F.Losasso, F.Gibou, and R.Fedkiw, *Simulating water and smoke with an octree data structure*, ACM SIGGRAPH, 2004.
[2] F.Losasso, R.Fedkiw, and S.Osher, *Spatially adaptive techniques for level set methods and incompressible flow*, Computer and fluid, 2006.

1-3 Jaewoong Choi (Korea Institutes for Advanced Study) : Generative Modeling through the Semi-dual Formulation of Unbalanced Optimal Transport

Optimal Transport (OT) problem investigates a transport map that bridges two distributions while minimizing a given cost function. In this regard, OT between tractable prior distribution and data has been utilized for generative modeling tasks. However, OT-based methods are susceptible to outliers and face optimization challenges during training. In this talk, we introduce a generative model based on the semi-dual formulation of Unbalanced Optimal Transport (UOT). Unlike OT, UOT relaxes the hard constraint on distribution matching. This approach provides better robustness against outliers, stability during training, and faster convergence. We validate these properties empirically through experiments. Moreover, we study the theoretical upper-bound of divergence between distributions in UOT. Our model outperforms existing OT-based generative models, achieving FID scores of 2.97 on CIFAR-10 and 5.80 on CelebA-HQ-256. This talk is based on the joint work with Jaemoo Choi and Myungjoo Kang.

1-4 Yeachan Park (Korea Institutes for Advanced Study) : Integrability of the training dynamics of gradient flows and differential Galois theory

It is well recognized that understanding the training dynamics of neural networks is difficult to analyze. If the dynamical system is integrable, we can analytically understand the system, and it is governed by analytic first integrals. The differential Galois theory is the study of the solvability of linear differential equations, and it also has a connection with the integrability of the dynamical system by investigating the Galois group of the variational equations of the system. We discuss the integrability of the training dynamics of gradient flows of the neural network by means of the differential Galois theory. The results are expected to help understand the complex and chaotic behavior of neural networks.

1-5 Geonho Hwang (Korea Institutes for Advanced Study) : Minimal Width for Universal Property of Deep RNN

A recurrent neural network (RNN) is a widely used deep-learning network for dealing with sequential data. Imitating a dynamical system, an infinite-width RNN can approximate any open dynamical system in a compact domain. In general, deep narrow networks with bounded width and arbitrary depth are more effective than wide shallow networks with arbitrary width and bounded depth in practice; however, the universal approximation theorem for deep narrow structures has yet to be extensively studied.In this study, we prove the universality of deep narrow RNNs and show that the upper bound of the minimum width for universality can be independent of the length of the data. Specifically, we show a deep RNN with ReLU activation can approximate any continuous function or L^p function with the widths $d_x + d_y + 3$ and $\max\{d_x + 1, d_y\}$, respectively, where the target function maps a finite sequence of vectors in $\mathbb{R}^{d_x}$ to a finite sequence of vectors in $\mathbb{R}^{d_y}$. We also compute the additional width required if the activation function is sigmoid or more. In addition, we prove the universality of other recurrent networks, such as bidirectional RNNs. Bridging a multi-layer perceptron and an RNN, our theory and technique can shed light on further research on deep RNNs.

Algebraic Goemetry I

Chair : Hyenho Lho (Chungnam National Univeristy)

2-1 Michel van Garrel (University of Birmingham, UK) : Local-local for irreducible nodal divisor

The log-local correspondence relates logarithmic and local Gromov-Witten invariants. I will describe joint work with Navid Nabijou and Yannik Schüler, where we prove an all genus version of the correspondence for surfaces with irreducible nodal anticanonical divisor. This is a version of the analogous result for smooth anticanonical divisor proven by Bousseau-Fan-Guo-Wu.

2-2 Hansol Hong (Yonsei University) : Machine learning models learned on mathematical tasks

Aganagic-Vafa branes are distinguished special Lagrangian submanifolds of toric Calabi-Yau. There has been extensive studies on their associated open Gromov-Witten invariants by Fang-Liu, etc. This talk aims at an informal discussion on these enumerative invariants in view of Lagrangian Floer theory and mirror symmetry.

2-3 Honglu Fan (University of Geneva, Switzerland) : Floer aspects of Aganagic-Vafa branes

Starting with a joint work with Gergely Berczi and Mingcong Zeng (https://arxiv.org/abs/2307.00252), I will present the general methodology in a rising trend from the machine learning community that trains and interprets models on mathematical tasks.

Probability and Mathematical Physics

Chair : Seong-Mi Seo (Chungnam National University)

3-1 Sung-Soo Byun (Seoul National University) : Large deviations and fluctuations of real eigenvalues of elliptic random matrices

In this talk, I will discuss the real eigenvalues of elliptic random matrices, exploring both the strong and weak non-Hermiticity regimes. Specifically, I will present the central limit theorem governing the number of real eigenvalues, as well as the large deviation probabilities associated with the absence of real eigenvalues.

3-2 Jinyeop Lee (Ludwig Maximilian University of Munich, Germany) : Deriving Vlasov equation from a many-body quantum system

In this presentation, we will derive the effective dynamics governed by a partial differential equation (PDE), namely the Vlasov equation, from the N-body Schrödinger equation with interactions in the large N limit. To achieve this, we will begin by exploring quantum mechanics and its key concepts. Then, leveraging the insights gained from the discussion of many-body quantum mechanics in this talk, and considering the appropriate conditions for each scenario, we will derive the Vlasov equation, which accurately describes the effective motion of the system.

3-3 Beom-Seok Han (Korea Advanced Institute of Science and Technology) : The uniqueness, existence, and regularity of solutions to stochastic Burgers' equations with time fractional derivatives and multiplicative space-time white noise

Time fractional Burgers' equation has been used to describe various physical phenomena, such as electrochemical processes, dielectric polarization, and viscoelastic materials. In this talk, we suggest the existence, uniqueness, and regularity of solutions to stochastic time fractional Burgers' equations driven by multiplicative space-time white noise:

$$\partial_t^\alpha u = a^{ij}u_{x^ix^j} + b^i u_{x^i} + cu + \bar{b}^i u u_{x^i} + \partial_t^\beta \int_0^t \sigma(u)dW_t, \quad t > 0; \quad u(0,\cdot) = u_0$$

where $\alpha \in (0,1)$, $\beta < 3\alpha/4 + 1/2$, and $d < 4 - 2(2\beta-1)_+/\alpha$. The operators ∂_t^α and ∂_t^β are the Caputo fractional derivatives of order α and β, respectively.

Additionally, we also suggest the Hölder regularity of the solution. For instance, for any constant $T < \infty$, small $\varepsilon > 0$, and almost sure $\omega \in \Omega$, we have

$$\sup_{x\in\mathbb{R}^d} |u(\omega,\cdot,x)|_{C^{\left[\frac{\alpha}{2}((2-(2\beta-1)_+/\alpha-d/2)\wedge 1)+\frac{(2\beta-1)_-}{2}\right]\wedge 1-\varepsilon}([0,T])} < \infty$$

and

$$\sup_{t\le T} |u(\omega,t,\cdot)|_{C^{(2-(2\beta-1)_+/\alpha-d/2)\wedge 1-\varepsilon}(\mathbb{R}^d)} < \infty.$$

3-4 Hong Chang Ji (Institute of Science and Technology Austria, Austria) : Density of Brown measure of free circular Brownian motion

We consider the Brown measure of the sum $\boldsymbol{a} + \sqrt{t}\boldsymbol{x}$, where a general operator $\boldsymbol{a}$ and a circular element $\boldsymbol{x}$ are $*$-free in a tracial von Neumann algebra and $t > 0$. In this talk we show that, under a mild assumption on $\boldsymbol{a}$, the density of the Brown measure of $\boldsymbol{a}+\sqrt{t}\boldsymbol{x}$ can only have two types of asymptotic behavior at each point on the boundary; (i) its density has a sharp (jump) discontinuity along the boundary of its support, resembling that of $\boldsymbol{x}$; or (ii) its density decays quadratically around certain critical points on the boundary. We also present several examples, one of which showing the necessity of our assumption on $\boldsymbol{a}$. This talk is based on a joint work with László Erdős.

Algebraic Geometry II

Chair : Dongsoo Shin (Chungnam National University)

4-1 Jaewoo Jeong (Institute for Basic Science) : Hankel Index and Almost Real Rank

Determining the non-negativity of even-degree polynomials becomes computationally challenging as the number of variables and degree increase. However, when a polynomial can be expressed as a sum of squares, verification of its non-negativity becomes immediate. This condition is equivalent to ensuring that the eigenvalues of the corresponding matrix of quadratic forms are nonnegative, simplifying the problem significantly. In this talk, we delve into cases where the collections of sums of squares polynomials and non-negative polynomials are identical and investigate scenarios where constraints may alter this equivalence. Our exploration involves modern real algebraic geometry theory to interpret the problem geometrically and provide answers. Additionally, we will highlight open problems and potential projects. This is joint work with Greg Blekherman and Justin Chen.

4-2 Jaekwan Jeon (Chungnam National University) : Deformations of Singularities and Kollár Conjecture

Because the deformation space of a singularity has many irreducible components whose even their dimensions are different,

a major problem is to find descriptions of the components of a deformation space.

On this problem, J. Kollár gives a conjecture that some partial resolutions describe all components of deformation spaces of rational surface singularities.

I will review the basic notions and the result(by J. Kollár and N.I.Shepherd-Barron) that the conjecture holds for (cyclic) quotient surface singularities and other related descriptions too.

Then I will present the recent result on sandwiched singularities and weighted homogeneous surface singularities with some conditions. This is a joint work with D. Shin.

4-3 Youngho Yoon (Chungbuk National University) : Ideals and Spectrum

Algebro geometor uses rings to understand geometry. Since singularity is local, we study ideals of local rings to understand the geometry of singularies. Spectrum encodes geometric information of hypersurface singularities. We observe how to recover the information from (higher) multiplier ideals and Hodge ideals.

Dynamical Systems I

Chair : Hahng-Yun Chu (Chungnam National Univeristy)

5-1 Sanghoon Kwon (Catholic Kwandong University) : Automorphic spectrum of the standard non-uniform weighted triangle comple

Expander graphs, which are highly connected finite sparse graphs, play a fundamental role in computer science and combinatorics. Among these graphs, Ramanujan graphs stand out as optimal expanders from a spectral perspective. Certain advanced mathematical concepts in group theory and number theory (e.g. Kazhdan's property (T) and Ramanujan conjecture) have been used to construct expanders and Ramanujan graphs. The fruitfulness of this theory calls for a generalization to high-dimensional theory.

We will review basic notions such as buildings and Hecke operators, and demonstrate the connection between representation theory and combinatorics. Additionally, we explore the automorphic spectra of the natural weighted adjacency operator on the infinite complex arising as a $PGL(3, F_q[t])$ quotient of the affine building of $\widetilde{A_2}$-type. As a byproduct, we re-establish a proof that the standard arithmetic triangle complex is weakly Ramanujan but not a Ramanujan complex, from a combinatorial aspect. This talk is based on joint work with Soonki Hong.

5-2 Jiyoung Han (Korea Institute for Advanced Study) : Moment Formulas for The Siegel Transform and Quantitative Khintchine-Groshev Theorem

It is known by Dirichlet that any irrational number can be approximated by the rational p/q within the error $1/q^2$. Replacing $1/q^2$ by an arbitrary non-increasing function $\psi(q)$ of the denominator, where $\psi : \mathbb{N} \to \mathbb{R}_{\geq 0}$, one can find the condition of ψ that for almost all (and almost no, respectively) $x \in \mathbb{R}$, there are infinitely many rational solutions p/q satisfying the inequality $|x - p/q| < \psi(q)$. More generally, one can replace x by a vector in $\mathbb{R}^d$ and p by a vector in $\mathbb{Z}^d$ (Khintchine-Groshev theorem). If there are infinitely many solutions for almost all $x \in \mathbb{R}$, one can consider the function counting rationals with $q < T$ and seek the asymptotic formula for T as T goes to infinity.

In this talk, I would like to introduce the way to reach the quantitative Khintchine-Groshev theorem using the first and second moment formulas for the Siegel transform. We will start with reviewing the Dani correspondence, which is one of the important concepts applying homogeneous dynamics to problems related to Diophantine approximation in number theory.

5-3 Jaeyoo Choy* (Korea Institute for Advanced Study), Hahnh-Yun Chu (Chungnam National University) : Partial hyperbolicity on Hilbert schemes of points

The Hilbert schemes of points on a manifold X are spaces modeling multiple particles in theoretic physics. In talk, I brief some geometric (and representation-theoretic) viewpoints to understand these spaces. Related to dynamical systems as a joint project with Prof. H.-Y. Chu, given a discrete or continuous dynamics on X with a partial hyperbolicity, we extend the hyperbolicity over Hilbert schemes of points of X.

Dynamical Systems II

Chair : Se-Hyun Ku (Chungnam National Univeristy)

6-1 Hahng-Yun Chu, Se-Hyun Ku*, Van Sang Hong Nguyen (Chungnam National Univeristy) : Topological properties on functional dynamics

Let $S(X)$ be the space of all continuous maps from compact metric space X to itself equipped with the uniform metric. The *functional envelope* of a dynamical system (X, f) is the dynamical system $(S(X), F_f)$ defined by

$$\begin{aligned} F_f : S(X) &\to S(X) \\ \phi &\mapsto F_f(\phi) := f \circ \phi. \end{aligned}$$

In this talk, we deal with expansivity and shadowing property on functional dynamics. And we discuss the topological stability of the functional envelopes.

6-2 Sanghyuk Lee (New Uzbekistan University, Uzbekistan) : Recommendation System Design based on Preference and Lexicographic Ordering for the Multi-Criteria Systems

Recommendation system design has been considered based on preference and similarity design to evaluate attributes to the criterion. For multi-criteria decision preference, subjective judgement is defined in advance. Next, similarity also considered to evaluate the closedness to each criterion. Considering the criterion and each attribute information, data are regarded as the fuzzy data which are including like, dislike and hesitation. For the general information on data intuitionistic fuzzy sets (IFSs) are used for the criterion and attribute. With help of existing similarity measure knowledge, similarity measure on IFSs is proposed and verified. With the obtained results, lexicographic ordering on the attributes are carried out. The lexicographic order is illustrated by the numerical example, the objective derivation on the attribute order help to use in the recommendation system. To concrete the proposed result, data lattice structure is proposed.

6-3 Kyeongsoo Kim (Xi'an Jiaotong-Liverpool University, China) : Exploiting Unlabeled RSSI Fingerprints in Multi-Building and Multi-Floor Indoor Localization through Deep Semi-Supervised Learning Based on Mean Teacher

The conventional indoor localization techniques based on Wi-Fi fingerprinting under a supervised learning framework cannot exploit unlabeled received signal strength indicators (RSSIs) measured at unknown locations: Unlabeled RSSIs, in addition to labeled ones, could be (1) part of an initial, static fingerprint database, which are submitted by volunteers during the offline phase when the database is constructed, or (2) newly measured ones submitted by the users of an indoor localization system already deployed in the field during the online phase. In this talk, a new indoor localization framework is proposed exploiting those unlabeled RSSI fingerprints in multi-building and multi-floor indoor localization through deep semi-supervised learning based on the *Mean Teacher* method. The proposed framework consists of three neural network models trained in two phases: An initial model in pre-training, and student and teacher models in semi-supervised training. The pre-training phase aims to train the initial model with labeled data for a limited number of epochs to mitigate the cold start problem and expedite the subsequent semi-supervised training. During the semi-supervised training, the student and the teacher models, which are cloned from the pre-trained initial model, are trained with unlabeled as well as labeled data for fine tuning of their parameters. To evaluate the performance of the proposed framework, experiments are conducted with the scalable indoor localization model based on a deep neural network and the UJIIndoorLoc database, both of which are well-accepted benchmarks in multi-building and multi-floor indoor localization. Different real-world scenarios are simulated with both labeled and unlabeled data by randomly splitting the data in the UJIIndoorLoc database into labeled and unlabeled data.

Applied Analysis and Neural Networks

Chair : Jinhae Park (Chungnam National Univeristy)

7-1 Jinhae Park (Chungnam National Univeristy) : The heat kernel on hyperbolic space and its application

Heat kernel is very important in the areas in PDEs on Euclidean space and generally on manifolds. In this talk, we briefly introduce the heat kernel in the Euclidean spaces and its important properties together with some basics on hyperbolic spaces. We then discuss some important estimates including Harnack's inequalities and their applications.

7-2 Jaehoon Cha (Science and Technology Facilities Council, UK) : Orthogonality-Enforced Latent Space in Autoencoders: An Approach to Learning Disentangled Representations

The talk will cover a novel, non-probabilistic disentangling framework for autoencoders, based on the principles of symmetry transformations that are independent of one another. This is the first deterministic model that is aiming to achieve disentanglement based on autoencoders using only a reconstruction loss without pairs of images or labels, by explicitly introducing inductive biases into a model architecture through Euler encoding. The proposed model can offer better disentanglement compared with other state-of-the-art models, relevant to disentanglement, especially when variances of the features are different. This model opens several opportunities for linear disentangled representation learning based on deterministic autoencoders.

7-3 He Jin*, Jinhae Park (Chungnam National University) : Study of Defects arising in the Landau-de Gennes energy by way of Fourier spectral method

In this talk, we study structure of defects for equilibrium states of the Landau-de Gennes energy in liquid crystals occupying a thin domain between concentric cylinders. We investigate directions of molecules using the second order tensor Q which describes liquid crystals. In particular, we focus on locations of defects and their symmetry issues. We apply Fourier spectral methods to the Euler-Lagrange equations corresponding to the Landau-de Gnnes energy. We discuss Fourier spectral methods applied to the problem and some results.

Special Session: Interdisciplinary Mathematics

Chair : SeungBeom Cho (Chungnam National Univeristy)

8-1 Juyeb Yeo (Chungnam National Univeristy) : Neural ODE and stability of an algorithm

In this talk we introduce Neural ODE, the model applying the solving method of ordinary differential equation(ODE). Neural ODE has a similar structure to ResNet, but it uses ODE solver instead of backpropagation which drastically reduces the number of memory required. We introduce the pros of this model and talk about the structure and operation of neural ODE . We also talk about the stability of machine learning models. Machine learning is suitable for learning with a given data, but the results may vary if data for training is slighlt perturbed. In the case of stable learning algorithm, consistent results are derived regardless of perturbation. In this talk, we will introduce several stabiliry theories and whether stability is satisfied with some well-known machine learning models.

8-2 Ge Tai Le (Chungnam National Univeristy) : Understanding Normalization in Contrastive Representation Learning and Out-of-Distribution Detection

Contrastive representation learning has emerged as an outstanding approach for anomaly detection. In this work, we investigate the ℓ_2-norm of features on contrastive layer space and explore its applications in detecting anomalies. We propose a simple method based on contrastive learning, which incorporates out-of-distribution data by discriminating against normal samples in the contrastive layer space. Our method can be flexibly used as a fully self-supervised learning, where the out-of-distribution data is self-generated by applying distribution-shifting transformations, or used as an outlier exposure (OE) approach, where the out-of-distribution data is a huge collective of random images. The flexibility to incorporate additional out-of-distribution samples enable a feasible solution for datasets where AD methods based on contrastive learning generally underperforms, such as aerial images or microscopy images. Furthermore, the high-quality features learned through contrastive representation learning consistently enhance the performance in OE scenario even when the available out-of-distribution dataset is not diverse enough. Our extensive experiments demonstrate the superiority of our proposed method under various scenarios, including one-label and multi-label settings, with various image datasets.

8-3 Khai An Tran*, Jinhae Park (Chungnam National Univeristy) : Ginzburg-Landau theory in Liquid Crystals

Ginzburg-Landau theory has been developed in order to study properties materials in superconductor states and theory have played an important role in studying singularities of nonlinear partial differential equations. In this talk, we discuss some important properties of Ginzburg-Landau equations developed by Brezis-Bethuel-Helen and some applications. We also talk about some problems applying Ginzburg-Landau theory to liquid crystals.

8-4 Yujin Won (Chungnam National Univeristy) : Image Restoration Using Fixed-point-like and split Bregman Methods for A TVL2D2 Regularization Model

In this paper, we first propose a new total variation TVL2D2 regularization model for image restoration. We next propose two iterative methods which are fixed-point-like method and split Bregman method, using CGLS (Conjugate gradient least squares method), for solving the new TVL2D2 model, and then we provide convergence analysis for the two iterative methods. In order to evaluate the effectiveness of two iterative methods for the TVL2D2 model, we provide numerical experiments for several test problems. This can be done by comparing their performances for TVL2D2 model with those of the fixed-point and split Bregman methods for the existing TVL2I2 model.

8-5 Sangmin Ji (Chungnam National Univeristy) : Introduction to Generative AI models based on Variational Inference

In Deep learning, Generative models are showing many achievements in various fields such as anomaly detection and image generation. In this talk, introduce the famous generative models, Variational Autoencoder(VAE), Generative Adversarial Network(GAN) and diffusion model.

8-6 Hahng-Yun Chu, Nakyoung Lee* (Chungnam National Univeristy) : Topological dynamics in orbital inverse limit systems

In this talk, we deal with the topological properties for shift maps on orbital inverse limit systems. The orbital inverse limit system is induced from the two cross bonding maps f and g on a compact metric space X. In the orbital inverse limit systems, the horizontal directions express inverse limit systems for f on X and the vertical directions mean g-orbits based on horizontal axes. We mainly investigate the dynamical properties especially the notions of shadowing properties, recurrence and chain recurrence for the shift maps on the systems.

9:30 - 10:10 Monday, August 7th, 2023 Numerical analysis and deep learning

mCLESS: The Multi-Class Least-Error Square Sum for Interpretable Classification

Seongjai Kim
Mississippi State University, USA

Abstract

Some machine learning algorithms are considered as black boxes, because the models are sufficiently complex and they are not straightforwardly interpretable to humans. Lack of interpretability in predictive models can undermine trust in those models in many application areas. The article introduces a new interpretable machine learning algorithm, called the Multi-Class Least-Error Square Sum (mCLESS). It is linear, simple to implement, and interpretable. Its nonlinear expansion is discussed. This simple algorithm turns out to be superior to many popular machine learning algorithms. Various experimental results involving synthetic datasets and UCI datasets are given to verify the claim.

10:10 - 10:50 Monday, August 7th, 2023 Numerical analysis and deep learning

Super-convergence property on Poisson solvers with adaptive grids

Byungjoon Lee
The Catholic University of Korea

Abstract

The Hodge decomposition, that is an important feature of incompressible fluid flows, is orthogonal and the projection taking its incompressible component is therefore stable. The decomposition is implemented by solving the Poisson equation. In order to simulate incompressible fluid flows in a stable manner, it is desired to utilize a Poisson solver that attains the orthogonality of the Hodge decomposition in a discrete level.

When a Poisson solver induces the orthogonality, its associated linear system is necessarily symmetric. With this regard, the symmetric Poisson solvers by Losasso et al. [1, 2] are more advantageous not only to efficiently solving the linear system but also to stably simulating fluid flows than nonsymmetric ones. Their numerical solutions were empirically observed to be first and second order accurate, respectively. One may expect that each of their numerical gradients has convergence order that is one less than that of its numerical solution.

However, we in this work show that super-convergence holds true with both Poisson solvers. Rigorous analysis is presented to prove that the difference is one half, not one between the convergence orders of numerical solution and gradient in both solvers. The analysis is then validated with numerical results. We furthermore show that both Poisson solvers, being symmetric, indeed satisfy the orthogonal property in the discrete level and yield stable implementations of the Hodge decomposition in octree grids.

References

[1] F.Losasso, F.Gibou, and R.Fedkiw, *Simulating water and smoke with an octree data structure*, ACM SIGGRAPH, 2004.
[2] F.Losasso, R.Fedkiw, and S.Osher, *Spatially adaptive techniques for level set methods and incompressible flow*, Computer and fluid, 2006.

11:00 - 11:40 Monday, August 7th, 2023 Numerical analysis and deep learning

Generative Modeling through the Semi-dual Formulation of Unbalanced Optimal Transport

Jaewoong Choi
Korea Institutes for Advanced Study

Abstract

Optimal Transport (OT) problem investigates a transport map that bridges two distributions while minimizing a given cost function. In this regard, OT between tractable prior distribution and data has been utilized for generative modeling tasks. However, OT-based methods are susceptible to outliers and face optimization challenges during training. In this talk, we introduce a generative model based on the semi-dual formulation of Unbalanced Optimal Transport (UOT). Unlike OT, UOT relaxes the hard constraint on distribution matching. This approach provides better robustness against outliers, stability during training, and faster convergence. We validate these properties empirically through experiments. Moreover, we study the theoretical upper-bound of divergence between distributions in UOT. Our model outperforms existing OT-based generative models, achieving FID scores of 2.97 on CIFAR-10 and 5.80 on CelebA-HQ-256. This talk is based on the joint work with Jaemoo Choi and Myungjoo Kang.

11:40 - 12:20 Monday, August 7th, 2023 Numerical analysis and deep learning

Integrability of the training dynamics of gradient flows and differential Galois theory

Yeachan Park
Korea Institutes for Advanced Study

Abstract

It is well recognized that understanding the training dynamics of neural networks is difficult to analyze. If the dynamical system is integrable, we can analytically understand the system, and it is governed by analytic first integrals. The differential Galois theory is the study of the solvability of linear differential equations, and it also has a connection with the integrability of the dynamical system by investigating the Galois group of the variational equations of the system. We discuss the integrability of the training dynamics of gradient flows of the neural network by means of the differential Galois theory. The results are expected to help understand the complex and chaotic behavior of neural networks.

12:20 - 13:00 Monday, August 7th, 2023 Numerical analysis and deep learning

Minimal Width for Universal Property of Deep RNN

Geonho Hwang
Korea Institutes for Advanced Study

Abstract

A recurrent neural network (RNN) is a widely used deep-learning network for dealing with sequential data. Imitating a dynamical system, an infinite-width RNN can approximate any open dynamical system in a compact domain. In general, deep narrow networks with bounded width and arbitrary depth are more effective than wide shallow networks with arbitrary width and bounded depth in practice; however, the universal approximation theorem for deep narrow structures has yet to be extensively studied.In this study, we prove the universality of deep narrow RNNs and show that the upper bound of the minimum width for universality can be independent of the length of the data. Specifically, we show a deep RNN with ReLU activation can approximate any continuous function or L^p function with the widths $d_x + d_y + 3$ and $\max\{d_x + 1, d_y\}$, respectively, where the target function maps a finite sequence of vectors in $\mathbb{R}^{d_x}$ to a finite sequence of vectors in $\mathbb{R}^{d_y}$. We also compute the additional width required if the activation function is sigmoid or more. In addition, we prove the universality of other recurrent networks, such as bidirectional RNNs. Bridging a multi-layer perceptron and an RNN, our theory and technique can shed light on further research on deep RNNs.

9:50 - 10:30 Monday, August 7th, 2023 Algebraic Goemetry I

Local-local for irreducible nodal divisor

Michel van Garrel
University of Birmingham, UK

Abstract

The log-local correspondence relates logarithmic and local Gromov-Witten invariants. I will describe joint work with Navid Nabijou and Yannik Schüler, where we prove an all genus version of the correspondence for surfaces with irreducible nodal anticanonical divisor. This is a version of the analogous result for smooth anticanonical divisor proven by Bousseau-Fan-Guo-Wu.

10:30 - 11:10 Monday, August 7th, 2023 Algebraic Goemetry I

Floer aspects of Aganagic-Vafa branes

Hansol Hong
Yonsei University

Abstract

Aganagic-Vafa branes are distinguished special Lagrangian submanifolds of toric Calabi-Yau. There has been extensive studies on their associated open Gromov-Witten invariants by Fang-Liu, etc. This talk aims at an informal discussion on these enumerative invariants in view of Lagrangian Floer theory and mirror symmetry.

11:10 - 11:50 Monday, August 7th, 2023 Algebraic Goemetry I

Machine learning models learned on mathematical tasks

Honglu Fan
University of Geneva, Switzerland

Abstract

Starting with a joint work with Gergely Berczi and Mingcong Zeng (https://arxiv.o-rg/abs/2307.00252), I will present the general methodology in a rising trend from the machine learning community that trains and interprets models on mathematical tasks.

15:00 - 15:40 Monday, August 7th, 2023 Probability and Mathematical Physics

Large deviations and fluctuations of real eigenvalues of elliptic random matrices

Sung-Soo Byun
Seoul National University

Abstract

In this talk, I will discuss the real eigenvalues of elliptic random matrices, exploring both the strong and weak non-Hermiticity regimes. Specifically, I will present the central limit theorem governing the number of real eigenvalues, as well as the large deviation probabilities associated with the absence of real eigenvalues.

15:50 - 16:30 Monday, August 7th, 2023 Probability and Mathematical Physics

Deriving Vlasov equation from a many-body quantum system

Jinyeop Lee
Ludwig Maximilian University of Munich, Germany

Abstract

In this presentation, we will derive the effective dynamics governed by a partial differential equation (PDE), namely the Vlasov equation, from the N-body Schrödinger equation with interactions in the large N limit. To achieve this, we will begin by exploring quantum mechanics and its key concepts. Then, leveraging the insights gained from the discussion of many-body quantum mechanics in this talk, and considering the appropriate conditions for each scenario, we will derive the Vlasov equation, which accurately describes the effective motion of the system.

16:40 - 17:20 Monday, August 7th, 2023 Probability and Mathematical Physics

The uniqueness, existence, and regularity of solutions to stochastic Burgers' equations with time fractional derivatives and multiplicative space-time white noise

Beom-Seok Han
Korea Advanced Institute of Science and Technology

Abstract

Time fractional Burgers' equation has been used to describe various physical phenomena, such as electrochemical processes, dielectric polarization, and viscoelastic materials. In this talk, we suggest the existence, uniqueness, and regularity of solutions to stochastic time fractional Burgers' equations driven by multiplicative space-time white noise:

$$\partial_t^\alpha u = a^{ij}u_{x^ix^j} + b^i u_{x^i} + cu + \bar{b}^i u u_{x^i} + \partial_t^\beta \int_0^t \sigma(u)dW_t, \quad t > 0; \quad u(0,\cdot) = u_0$$

where $\alpha \in (0,1)$, $\beta < 3\alpha/4 + 1/2$, and $d < 4 - 2(2\beta-1)_+/\alpha$. The operators ∂_t^α and ∂_t^β are the Caputo fractional derivatives of order α and β, respectively.
Additionally, we also suggest the Hölder regularity of the solution. For instance, for any constant $T < \infty$, small $\varepsilon > 0$, and almost sure $\omega \in \Omega$, we have

$$\sup_{x\in\mathbb{R}^d} |u(\omega,\cdot,x)|_{C^{\left[\frac{\alpha}{2}((2-(2\beta-1)_+/\alpha-d/2)\wedge 1)+\frac{(2\beta-1)_-}{2}\right]\wedge 1-\varepsilon}([0,T])} < \infty$$

and

$$\sup_{t\le T} |u(\omega,t,\cdot)|_{C^{(2-(2\beta-1)_+/\alpha-d/2)\wedge 1-\varepsilon}(\mathbb{R}^d)} < \infty.$$

17:30 - 18:10 Monday, August 7th, 2023 Probability and Mathematical Physics

Density of Brown measure of free circular Brownian motion

Hong Chang Ji
Institute of Science and Technology Austria, Austria

Abstract

We consider the Brown measure of the sum $\boldsymbol{a}+\sqrt{t}\boldsymbol{x}$, where a general operator $\boldsymbol{a}$ and a circular element $\boldsymbol{x}$ are $*$-free in a tracial von Neumann algebra and $t>0$. In this talk we show that, under a mild assumption on $\boldsymbol{a}$, the density of the Brown measure of $\boldsymbol{a}+\sqrt{t}\boldsymbol{x}$ can only have two types of asymptotic behavior at each point on the boundary; (i) its density has a sharp (jump) discontinuity along the boundary of its support, resembling that of $\boldsymbol{x}$; or (ii) its density decays quadratically around certain critical points on the boundary. We also present several examples, one of which showing the necessity of our assumption on $\boldsymbol{a}$. This talk is based on a joint work with László Erdős.

10:00 - 10:40 Tuesday, August 8th, 2023 Algebraic Geometry II

Hankel Index and Almost Real Rank

Jaewoo Jung
Institute for Basic Science

Abstract

Determining the non-negativity of even-degree polynomials becomes computationally challenging as the number of variables and degree increase. However, when a polynomial can be expressed as a sum of squares, verification of its non-negativity becomes immediate. This condition is equivalent to ensuring that the eigenvalues of the corresponding matrix of quadratic forms are nonnegative, simplifying the problem significantly. In this talk, we delve into cases where the collections of sums of squares polynomials and non-negative polynomials are identical and investigate scenarios where constraints may alter this equivalence. Our exploration involves modern real algebraic geometry theory to interpret the problem geometrically and provide answers. Additionally, we will highlight open problems and potential projects. This is joint work with Greg Blekherman and Justin Chen.

10:50 - 11:30 Tuesday, August 8th, 2023 Algebraic Geometry II

Deformations of singularities and Kollár conjecture.

Jaekwan Jeon
Chungnam National University

Abstract

Because the deformation space of a singularity has many irreducible components whose even their dimensions are different,
a major problem is to find descriptions of the components of a deformation space.
On this problem, J. Kollár gives a conjecture that some partial resolutions describe all components of deformation spaces of rational surface singularities.
I will review the basic notions and the result(by J. Kollár and N.I.Shepherd-Barron) that the conjecture holds for (cyclic) quotient surface singularities and other related descriptions too.
Then I will present the recent result on sandwiched singularities and weighted homogeneous surface singularities with some conditions. This is a joint work with D. Shin.

11:40 - 12:20 Tuesday, August 8th, 2023 Algebraic Geometry II

Ideals and Spectrum

Youngho Yoon
Chungbuk National University

Abstract

Algebro geometor uses rings to understand geometry. Since singularity is local, we study ideals of local rings to understand the geometry of singularies. Spectrum encodes geometric information of hypersurface singularities. We observe how to recover the information from (higher) multiplier ideals and Hodge ideals.

10:00 - 10:40 Tuesday, August 8th, 2023 Dynamical Systems I

Automorphic spectrum of the standard non-uniform weighted triangle comple

Sanghoon Kwon
Catholic Kwandong University

Abstract

Expander graphs, which are highly connected finite sparse graphs, play a fundamental role in computer science and combinatorics. Among these graphs, Ramanujan graphs stand out as optimal expanders from a spectral perspective. Certain advanced mathematical concepts in group theory and number theory (e.g. Kazhdan's property (T) and Ramanujan conjecture) have been used to construct expanders and Ramanujan graphs. The fruitfulness of this theory calls for a generalization to high-dimensional theory. We will review basic notions such as buildings and Hecke operators, and demonstrate the connection between representation theory and combinatorics. Additionally, we explore the automorphic spectra of the natural weighted adjacency operator on the infinite complex arising as a $PGL(3, F_q[t])$ quotient of the affine building of $\widetilde{A_2}$-type. As a byproduct, we re-establish a proof that the standard arithmetic triangle complex is weakly Ramanujan but not a Ramanujan complex, from a combinatorial aspect. This talk is based on joint work with Soonki Hong.

10:50 - 11:30 Tuesday, August 8th, 2023 Dynamical Systems I

Moment Formulas For The Siegel Transform And Quantitative Khintchine-Groshev Theorem

Jiyoung Han
Korea Institute for Advanced Study

Abstract

It is known by Dirichlet that any irrational number can be approximated by the rational p/q within the error $1/q^2$. Replacing $1/q^2$ by an arbitrary non-increasing function $\psi(q)$ of the denominator, where $\psi : \mathbb{N} \to \mathbb{R}_{\geq 0}$, one can find the condition of ψ that for almost all (and almost no, respectively) $x \in \mathbb{R}$, there are infinitely many rational solutions p/q satisfying the inequality $|x - p/q| < \psi(q)$. More generally, one can replace x by a vector in $\mathbb{R}^d$ and p by a vector in $\mathbb{Z}^d$ (Khintchine-Groshev theorem). If there are infinitely many solutions for almost all $x \in \mathbb{R}$, one can consider the function counting rationals with $q < T$ and seek the asymptotic formula for T as T goes to infinity.
In this talk, I would like to introduce the way to reach the quantitative Khintchine-Groshev theorem using the first and second moment formulas for the Siegel transform. We will start with reviewing the Dani correspondence, which is one of the important concepts applying homogeneous dynamics to problems related to Diophantine approximation in number theory.

11:40 - 12:20 Tuesday, August 8th, 2023 Dynamical Systems I

Partial hyperbolicity on Hilbert schemes of points

Jaeyoo Choy[*1)], Hahng-Yun Chu[2)]
[1)]Korea Institute for Advanced Study
[2)]Chungnam National University

Abstract

The Hilbert schemes of points on a manifold X are spaces modeling multiple particles in theoretic physics. In talk, I brief some geometric (and representation-theoretic) viewpoints to understand these spaces. Related to dynamical systems as a joint project with Prof. H.-Y. Chu, given a discrete or continuous dynamics on X with a partial hyperbolicity, we extend the hyperbolicity over Hilbert schemes of points of X.

14:00 - 14:40 Tuesday, August 8th, 2023 Dynamical Systems II

Topological properties on functional dynamics

Hahng-Yun Chu, Van Sang Hong Nguyen, Se-Hyun Ku*
Chungnam National University

Abstract

Let $S(X)$ be the space of all continuous maps from compact metric space X to itself equipped with the uniform metric. The *functional envelope* of a dynamical system (X, f) is the dynamical system $(S(X), F_f)$ defined by

$$\begin{aligned} F_f : S(X) &\to S(X) \\ \phi &\mapsto F_f(\phi) := f \circ \phi. \end{aligned}$$

In this talk, we deal with expansivity and shadowing property on functional dynamics. And we discuss the topological stability of the functional envelopes.

14:50 - 15:30 Tuesday, August 8th, 2023 Dynamical Systems II

Recommendation System Design based on Preference and Lexicographic Ordering for the Multi-Criteria Systems

Sanghyuk Lee
New Uzbekistan University, Uzbekistan

Abstract

Recommendation system design has been considered based on preference and similarity design to evaluate attributes to the criterion. For multi-criteria decision preference, subjective judgement is defined in advance. Next, similarity also considered to evaluate the closedness to each criterion. Considering the criterion and each attribute information, data are regarded as the fuzzy data which are including like, dislike and hesitation. For the general information on data intuitionistic fuzzy sets (IFSs) are used for the criterion and attribute. With help of existing similarity measure knowledge, similarity measure on IFSs is proposed and verified. With the obtained results, lexicographic ordering on the attributes are carried out. The lexicographic order is illustrated by the numerical example, the objective derivation on the attribute order help to use in the recommendation system. To concrete the proposed result, data lattice structure is proposed.

15:40 - 16:20 Tuesday, August 8th, 2023 Dynamical Systems II

Exploiting Unlabeled RSSI Fingerprints in Multi-Building and Multi-Floor Indoor Localization through Deep Semi-Supervised Learning Based on Mean Teacher

Kyeongsoo Kim
Xi'an Jiaotong-Liverpool University, China

Abstract

The conventional indoor localization techniques based on Wi-Fi fingerprinting under a supervised learning framework cannot exploit unlabeled received signal strength indicators (RSSIs) measured at unknown locations: Unlabeled RSSIs, in addition to labeled ones, could be (1) part of an initial, static fingerprint database, which are submitted by volunteers during the offline phase when the database is constructed, or (2) newly measured ones submitted by the users of an indoor localization system already deployed in the field during the online phase. In this talk, a new indoor localization framework is proposed exploiting those unlabeled RSSI fingerprints in multi-building and multi-floor indoor localization through deep semi-supervised learning based on the *Mean Teacher* method. The proposed framework consists of three neural network models trained in two phases: An initial model in pre-training, and student and teacher models in semi-supervised training. The pre-training phase aims to train the initial model with labeled data for a limited number of epochs to mitigate the cold start problem and expedite the subsequent semi-supervised training. During the semi-supervised training, the student and the teacher models, which are cloned from the pre-trained initial model, are trained with unlabeled as well as labeled data for fine tuning of their parameters. To evaluate the performance of the proposed framework, experiments are conducted with the scalable indoor localization model based on a deep neural network and the UJIIndoorLoc database, both of which are well-accepted benchmarks in multi-building and multi-floor indoor localization. Different real-world scenarios are simulated with both labeled and unlabeled data by randomly splitting the data in the UJIIndoorLoc database into labeled and unlabeled data.

10:00 - 10:40 Wednesday, August 9th, 2023 Applied Analysis and Neural Networks

The heat kernel on hyperbolic space and its application

Jinhae Park
Chungnam National University

Abstract

Heat kernel is very important in the areas in PDEs on Euclidean space and generally on manifolds. In this talk, we briefly introduce the heat kernel in the Euclidean spaces and its important properties together with some basics on hyperbolic spaces. We then discuss some important estimates including Harnack's inequalities and their applications.

10:50 - 11:30 Wednesday, August 9th, 2023 Applied Analysis and Neural Networks

Orthogonality-Enforced Latent Space in Autoencoders: An Approach to Learning Disentangled Representations

Jaehoon Cha
Science and Technology Facilities Council, UK

Abstract

The talk will cover a novel, non-probabilistic disentangling framework for autoencoders, based on the principles of symmetry transformations that are independent of one another. This is the first deterministic model that is aiming to achieve disentanglement based on autoencoders using only a reconstruction loss without pairs of images or labels, by explicitly introducing inductive biases into a model architecture through Euler encoding. The proposed model can offer better disentanglement compared with other state-of-the-art models, relevant to disentanglement, especially when variances of the features are different. This model opens several opportunities for linear disentangled representation learning based on deterministic autoencoders.

13:00 - 13:40 Wednesday, August 9th, 2023 Applied Analysis and Neural Networks

Study of Defects arising in the Landau-de Gennes energy by way of Fourier spectral method

He Jin*, Jinhae Park
Chungnam National University

Abstract

In this talk, we study structure of defects for equilibrium states of the Landau-de Gennes energy in liquid crystals occupying a thin domain between concentric cylinders. We investigate directions of molecules using the second order tensor Q which describes liquid crystals. In particular, we focus on locations of defects and their symmetry issues. We apply Fourier spectral methods to the Euler-Lagrange equations corresponding to the Landau-de Gnnes energy. We discuss Fourier spectral methods applied to the problem and some results.

14:00 - 14:40 Wednesday, August 9th, 2023 Special Session: Interdisciplinary Mathematics

Neural ODE and stability of an algorithm

Juyeb Yeo
Chungnam National University

Abstract

In this talk we introduce Neural ODE, the model applying the solving method of ordinary differential equation(ODE). Neural ODE has a similar structure to ResNet, but it uses ODE solver instead of back-propagation which drastically reduces the number of memory required. We introduce the pros of this model and talk about the structure and operation of neural ODE . We also talk about the stability of machine learning models. Machine learning is suitable for learning with a given data, but the results may vary if data for training is slighlt perturbed. In the case of stable learning algorithm, consistent results are derived regardless of perturbation. In this talk, we will introduce several stabiliry theories and whether stability is satisfied with some well-known machine learning models.

14:40 - 15:20 Wednesday, August 9th, 2023 Special Session: Interdisciplinary Mathematics

Understanding Normalization in Contrastive Representation Learning and Out-of-Distribution Detection

Ge Tai Le
Chungnam National University

Abstract

Contrastive representation learning has emerged as an outstanding approach for anomaly detection. In this work, we investigate the ℓ_2-norm of features on contrastive layer space and explore its applications in detecting anomalies. We propose a simple method based on contrastive learning, which incorporates out-of-distribution data by discriminating against normal samples in the contrastive layer space. Our method can be flexibly used as a fully self-supervised learning, where the out-of-distribution data is self-generated by applying distribution-shifting transformations, or used as an outlier exposure (OE) approach, where the out-of-distribution data is a huge collective of random images. The flexibility to incorporate additional out-of-distribution samples enable a feasible solution for datasets where AD methods based on contrastive learning generally underperforms, such as aerial images or microscopy images. Furthermore, the high-quality features learned through contrastive representation learning consistently enhance the performance in OE scenario even when the available out-of-distribution dataset is not diverse enough. Our extensive experiments demonstrate the superiority of our proposed method under various scenarios, including one-label and multi-label settings, with various image datasets.

15:20 - 16:00 Wednesday, August 9th, 2023 Special Session: Interdisciplinary Mathematics

Ginzburg-Landau theory in Liquid Crystals

Khai An Tran
Chungnam National University

Abstract

Ginzburg-Landau theory has been developed in order to study properties materials in superconductor states and theory have played an important role in studying singularities of nonlinear partial differential equations. In this talk, we discuss some important properties of Ginzburg-Landau equations developed by Brezis-Bethuel-Helen and some applications. We also talk about some problems applying Ginzburg-Landau theory to liquid crystals.

16:00 - 16:40 Wednesday, August 9th, 2023 Special Session: Interdisciplinary Mathematics

Image Restoration Using Fixed-point-like and split Bregman Methods for A TVL2D2 Regularization Model

Yujin Won
Chungnam National University

Abstract

In this paper, we first propose a new total variation TVL2D2 regularization model for image restoration. We next propose two iterative methods which are fixed-point-like method and split Bregman method, using CGLS (Conjugate gradient least squares method), for solving the new TVL2D2 model, and then we provide convergence analysis for the two iterative methods. In order to evaluate the effectiveness of two iterative methods for the TVL2D2 model, we provide numerical experiments for several test problems. This can be done by comparing their performances for TVL2D2 model with those of the fixed-point and split Bregman methods for the existing TVL2I2 model.

16:40 - 17:20 Wednesday, August 9th, 2023 Special Session: Interdisciplinary Mathematics

Introduction to Generative AI models based on Variational Inference

Sangmin Ji
Chungnam National University

Abstract

In Deep learning, Generative models are showing many achievements in various fields such as anomaly detection and image generation. In this talk, introduce the famous generative models, Variational Autoencoder(VAE), Generative Adversarial Network(GAN) and diffusion model.

17:20 - 18:00 Wednesday, August 9th, 2023 Special Session: Interdisciplinary Mathematics

Topological dynamics in orbital inverse limit systems

Hahng-Yun Chu, Nakyoung Lee*
Chungnam National University

Abstract

In this talk, we deal with the topological properties for shift maps on orbital inverse limit systems. The orbital inverse limit system is induced from the two cross bonding maps f and g on a compact metric space X. In the orbital inverse limit systems, the horizontal directions express inverse limit systems for f on X and the vertical directions mean g-orbits based on horizontal axes. We mainly investigate the dynamical properties especially the notions of shadowing properties, recurrence and chain recurrence for the shift maps on the systems.