15th International Conference on Network Analysis NET 2025

Nizhny Novgorod, May 19–20, 2025

Laboratory of Algorithms and Technologies for Network Analysis
National Research University
Higher School of Economics, Nizhny Novgorod

Laboratory of Advanced Combinatorics and Network Applications
National Research University
Moscow Institute of Physics and Technology

Conference onsite location: Nizhny Novgorod, HSE building on Rodionova street 136, room 401 (4-th floor).

Zoom reference to access the conference:
https://us06web.zoom.us/j/81147589981?pwd=skZgaggeb70w1kq2sgbrij4sad82XH.1
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NATIONAL RESEARCH UNIVERSITY

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Panos M. Pardalos, University of Florida, USA and LATNA, NRU HSE

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Conference Organizers

Panos M. Pardalos, University of Florida, USA
Andrey Raigorodskii, MIPT, MSU, Yandex
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Nikita Kuzmin, NRU HSE, Russia
Timur Medvedev, NRU HSE, Russia

Invited speakers

Vasily Gorbounov, HSE University
Andrey Leonidov, Lebedev Physical Institute of RAS, MIPT
Sergey Sidorov, Saratov State University
Panos Pardalos, University of Florida, USA and HSE University, lab LATNA
Mauricio Rezende, University of Washington, UNIFESP-ITA, AND DIMACS
Theodore Trafalis. School of ISE, The University of Oklahoma, USA

Participants with regular talks

Bereberdina Natalia, Moscow Institute of Physics and Technology
Bernhardt Brian Daniel, University of Cassino, Italy
Dunaeva Daria, National Research Tomsk State University
Emelianov Timofei, Saratov State University
Ermolaeva Appolinariia, HSE University, lab for Applied Network Research
Gladyshev Sergei, Moscow Institute of Physics and Technology
Gribanov Dmitry, MIPT and HSE University, Lab LATNA
Grigoriev Alexey, Saratov State University
Guarracino Mario, University of Cassino, Italy and lab LATNA HSE University
Gubanov Dmitry, Institute of Control Sciences of RAS, Moscow
Koldanov Petr, HSE University, Lab LATNA
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Malko Artem, HSE University
Maltseva Daria, HSE University, laboratory for Applied Network Research
Matveeva Natalia, HSE University, laboratory for Applied Network Research
Neshchetkin Gleb, HSE University, Lab LATNA
Pavlova Irina, HSE University, laboratory for Applied Network Research
Petrov Ilya, Institute of Control Sciences of RAS, Moscow
Semenova Anna, HSE University, Center of Decision Choice and Analysis
Tkachev Daniil, HSE University, Centre of Decision Choice and Analysis
Tolmachev Alexander, Moscow Institute of Physics and Technology, Skoltech
Tupikina Liubov, Moscow Institute of Physics and Technology
Tuzhilin Mikhail, Moscow State University

Conference schedule

Monday, May 19. Room 401, Rodionova street 136

	Speaker	Title
Invited talks		
10:00 - 10:45	Panos Pardalos	*Opening talk: Introduction to data analytics for networks – a historical perspective and major advances*
10:45 - 11:30	Vasily Gorbounov	*Invited talk: Algebraic and geometric methods in Black Box network problem*
11:30 - 11:50	**Coffee break**	
Session: 1		
11:50 - 12:10	Artem Malko	*Simplifications of Finite Spaces Equipped with Sheaves*
12:10 - 12:30	Liubov Tupikina, Natalia Bereberdina	*Geometric Machine Learning via Ricci Flow: Unveiling Hidden Structures in Complex Datasets*
12:30 – 12:50	Mikhail Tuzhilin	*Relations between centrality measures and small-world properties*
12:50 - 13:10	Brian Daniel Bernhardt	*Interpretable Aggregation in Graph Neural Networks via Entropy and Dissimilarity*
13:10 - 15:00	**Lunch**	Cafeteria, floor [-1]
Session: 2		
15:00 - 15:20	Daniil Tkachev	*New centrality indices taking into account parameters of vertices, group influence of vertices to a vertex and weights of edges, and their application in social network models*
15:20 - 15:40	Dmitry Gubanov	*Network-Augmented Topical Profiling of Research Publications*
15:40 - 16:00	Darya Maltseva	*Enhancing Bibliometric Network Analysis with AI-Powered Tools*
16:00 – 16:20	Apollinariia Ermolaeva, Irina Pavlova	*Bibliographic Coupling Networks of Russian Sociologists: Identifying Academic Communities and Fragmentation Patterns*
16:20 - 16:40	**Coffee break**	
Session: 3		
16:40 - 17:00	Irina Pavlova	*Application of Multiple Methods to Explore Thematic Evolution of Wellbeing Studies*
17:00 - 17:20	Nataliya Matveeva	*Co-authorship network structures of universities with different ages and statuses*
17:20 - 17:40	Daniil Kovalev, Daria Dunaeva	*Multimodal networks for the analysis of Russian labor market*
Invited talk		
17:40 - 18:25	Theodore Trafalis	*Invited talk: Fairness in Machine Learning: An Application for Prediction for Completion of Drug and Alcohol Rehabilitation*
18:30	**Welcome reception**	Cafeteria, floor [-1]

Conference schedule

Tuesday, May 20. Room 401, Rodionova street 136

	Speaker	Title
Invited talks		
10:00 - 10:45	Andrey Leonidov	*Invited talk: Likelihood equilibria in the Ising game*
10:45 - 11:30	Sergey Sidorov	*Invited talk: Large Power-Law Network Formation via Vertex Merging, Growth and Triadic Closure*
11:30 - 11:50	**Coffee break**	
Session: 4		
11:50 - 12:10	Ilya Petrov	*Links vs. Incentives: A Comparative Study of Interventions in Games on Networks*
12:10 - 12:30	Alexey Grigoriev	*Characterizing Degree Distribution Asymmetry in Complex Networks*
12:30 – 12:50	Timofei Emelianov	*Preferential Merging in Growing and Contracting Networks*
12:50 - 13:10	Anna Semenova	*Robustness of New Centrality Indices in Network Structures*
13:10 - 15:00	**Lunch**	Cafeteria, floor [-1]
Session: 5		
15:00-15:20	Petr Koldanov	*Confidence sets for graphical model and significant inference*
15:20-15:40	Alexander Tolmachev	*On lower bounds of the maximal density of planar periodic sets without unit distances*
15:40-16:00	Gleb Neshchetkin	*Methods of Conflict-Averse Gradient Choosing for Multi-Task Learning*
16:00-16:10	**Coffee break**	
Session: 6		
16:10 - 16:30	Sergei Gladyshev	*Heuristic policy for the specific case of the stochastic single machine scheduling problem with precedence constraints and uncertain job durations*
16:30 – 16:50	Dmitry Gribanov	*Faster Algorithms for ILP Problems of Bounded Codimension via Discrepancy Theory*
Invited talk		
16:50 - 17:35	Mauricio Resende	*Invited talk: Random-key optimizers (RKO): problem independent combinatorial optimization*
17:35	**Closing**	

Invited talks

Vasily Gorbounov

HSE University, Faculty of Mathematics,

Laboratory for Complex Networks, Hypergraphs, and their Applications

Algebraic and geometric methods in Black Box network problem

A network is a graph equipped with positive edge weights denoting conductivities, whose nodes are divided in two non-overlapping sets: a set of inner nodes and a set of boundary nodes. The weights on the edges define a metric on the set of vertices, the usual graph metric or the electrical resistance metric, for example.

Suppose we are given the restriction of such a metric to the set of the boundary vertices, can we recover a graph, minimal in an appropriate sense, and the weights on the edges which produces the given metric on the boundary? This is a form of the Black Box network problem.

In this talk we will present an explicit construction of an embedding of the space of networks to the non-negative part of Grassmannian $Gr(n-1, 2n)$ using the electrical resistance metric. We will sketch a solution to the Black Box network problem derived from the geometric properties of the Grassmannian.

Our result allows to use the methods of reconstruction of the minimal graphs of electrical networks in phylogenetics.

Andrey Leonidov

Lebedev Physical Institute, Moscow Institute of Physics and Technology

Likelihood equilibria in the Ising game

A description of static equilibria in the noisy binary choice (Ising) game on complete and random graphs resulting from maximization of the likelihood function of system configurations is presented. An equivalence of such likelihood equilibria to the competitive Bayes-Nash quantal response equilibria in the special case of self-consistent expectations of agents is established. It is shown that the same expectation equilibria can be obtained using the partition function formalism.

Sergey Sidorov
Saratov State University
Large Power-Law Network Formation via Vertex Merging, Growth and Triadic Closure

The study of network generation principles is a fundamental area in complex network theory, where a key challenge lies in developing algorithms that accurately simulate network evolution to produce synthetic graphs with real-world properties. While extensive research has focused on growth mechanisms via preferential attachment, the dynamics of network contraction -- such as node removal or merging -- remain underexplored. Recent studies have shown that contraction processes significantly influence network structure, often disrupting scale-free properties unless carefully balanced with growth. In this talk we advance existing models by introducing mechanisms that combine network growth, contraction, and triadic closure, enabling the generation of denser networks with small-world and scale-free characteristics. We propose three models: the CG(r) model (contraction and growth), the CGT(r) model (adding triadic closure), and the CGT-P(r) model (probabilistic contraction/growth). Through analytical proofs and simulations, we demonstrate that these models preserve power-law degree distributions while enhancing structural realism.

Panos Pardalos
University of Florida, USA and HSE University, lab LATNA
Introduction to data analytics for networks – a historical perspective and major advances

Data analytics for networks involves the use of advanced techniques and tools to extract insights and knowledge from large and complex datasets generated by network devices, applications, and services. This process involves collecting, storing, processing, and analyzing large amounts of data to identify patterns, trends, and anomalies that can provide valuable information for network operators. By leveraging data analytics, network researchers can make informed decisions about network planning, capacity management, service delivery, and customer experience. Additionally, data analytics can help network operators to detect and respond to security threats and attacks, by analyzing network traffic, identifying abnormal behavior, and detecting potential vulnerabilities. Overall, data analytics is a critical component of massive networks, enabling network researchers to extract valuable insights from massive datasets and improve network performance, efficiency, and security.

BIO Professor Panos Pardalos

University of Florida

Panos Pardalos was born in Drosato (Mezilo) Argitheas GR in 1954 and graduated from Athens University (Department of Mathematics). He received his PhD (Computes and Information Sciences) from the University of Minnesota. He is an Emeritus Distinguished Professor in the Department of Industrial and Systems Engineering at the University of Florida, and an affiliated faculty of Biomedical Engineering and Computer Science & Information & Engineering departments. Since 2011 has been the academic advisor at LATNA, HSE.

Panos Pardalos is a world-renowned leader in Global Optimization, Mathematical Modeling, Energy Systems, Financial applications, and Data Sciences. He is a Fellow of AAAS, AAIA, AIMBE, EUROPT, and INFORMS and was awarded the 2013 Constantin Caratheodory Prize of the International Society of Global Optimization. In addition, Panos Pardalos has been awarded the 2013 EURO Gold Medal prize bestowed by the Association for European Operational Research Societies. This medal is the preeminent European award given to Operations Research (OR) professionals for "scientific contributions that stand the test of time."

Panos Pardalos has been awarded a prestigious Humboldt Research Award (2018-2019). The Humboldt Research Award is granted in recognition of a researcher's entire achievements to date – fundamental discoveries, new theories, insights that have had significant impact on their discipline.

Panos Pardalos is also a Member of several Academies of Sciences, and he holds several honorary PhD degrees and affiliations. He is the Founding Editor of Optimization Letters, Energy Systems, and Co-Founder of the International Journal of Global Optimization, Computational Management Science, and Springer Nature Operations Research Forum. He has published over 600 journal papers, and edited/authored over 200 books. He is one of the most cited authors and has graduated 71 PhD students so far. Details can be found in www.ise.ufl.edu/pardalos

Panos Pardalos has lectured and given invited keynote addresses worldwide in countries including Austria, Australia, Azerbaijan, Belgium, Brazil, Canada, Chile, China, Czech Republic, Cyprus, Denmark, Egypt, England, France, Finland, Germany, Greece, Holland, Hong Kong, Hungary, Iceland, Ireland, Italy, Japan, Lithuania, Mexico, Mongolia, Montenegro, New Zealand, Norway, Peru, Portugal, Russia, South Korea, Singapore, Serbia, South Africa, Spain, Sweden, Switzerland, Taiwan, Turkey, Ukraine, United Arab Emirates, Vietnam, and the USA.

Mauricio Rezende
University of Washington, UNIFESP-ITA, AND DIMACS

Random-key optimizers (RKO): problem independent combinatorial optimization

This talk introduces Random-Key Optimizers (RKO), a problem-independent approach for solving combinatorial optimization problems. Random keys are randomly generated real numbers in the interval (0,1]. A random-key vector is a vector of n random keys and corresponds to a point in n-dimensional unit hypercube. Solutions of combinatorial optimization problems can be encoded as random-key vectors. By using a decoder, a solution can be retrieved from a random-key vector. For example, by sorting a random-key vector, a permutation will result from the indices of the sorted vector. In a TSP these indices correspond to the cities in a tour. In the random-key optimization problem we seek a point in the n-dimensional unit hypercube that optimizes the decoder function. For a TSP, what is the point in the n-dimensional unit hypercube that decoded with the sorting decoder results in the shortest tour on the n cities. We illustrate this concept describing several decoders for different combinational optimization problems, and by presenting several RKOs, including a hybrid system that combines several RKOs into one intelligent system.

Theodore Trafalis and Karen Roberts-Licklider
School of Industrial and Systems Engineering, University of Oklahoma, USA

Fairness in Machine Learning: An Application for Prediction for Completion of Drug and Alcohol Rehabilitation

In this talk we will discuss algorithmic fairness in machine learning exploring the concepts of disparate impact, statistical parity difference, conditional statistical parity ratio, demographic parity, demographic parity ratio, equalized odds, equalized odds ratio, equal opportunity, and equalized opportunity ratio at both the binary and multiclass scenarios. In addition we will apply well established machine learning techniques (considering algorithmic fairness) for prediction of completion of drug and alcohol rehabilitation in the state of Oklahoma.
Specifically, we look at predicting whether a person will complete a drug and alcohol rehabilitation program and the number of times a person attends. The study is based on demographic data obtained from Substance Abuse and Mental Health Services Administration (SAMHSA) from both admissions and discharge data from drug and alcohol rehabilitation centers in Oklahoma. Demographic data is highly categorical which led to binary encoding being used and various fairness measures being utilized to mitigate bias of nine demographic variables. Kernel methods such as linear, polynomial, sigmoid, and radial basis functions were compared using

support vector machines at various parameter ranges to find the optimal values. These were then compared to methods such as decision trees, random forests, and neural networks. Synthetic Minority Oversampling Technique Nominal (SMOTEN) for categorical data was used to balance the data with imputation for missing data. The nine bias variables were then intersectionalized to mitigate bias and the dual and triple interactions were integrated to use the probabilities to look at worst case ratio fairness mitigation. In our findings we highlight the importance of integrating fairness measures into predictive models, demonstrating that decision trees and random forests generally outperformed SVMs and neural networks in accuracy and fairness.

Regular talks. Session 1.

Artem Malko
HSE University, Faculty of Mathematics,
Laboratory for Complex Networks, Hypergraphs, and their Applications
Simplifications of Finite Spaces Equipped with Sheaves

Following the classical results of Stong, we introduce a cohomological analogue of a core of a finite sheaved topological space and propose an algorithm for simplification in this category. In particular we generalize the notion of beat vertices and show that if a vertex of a sheaved space has topologically acyclic downset (with trivial coefficients), then its removal preserves the sheaf cohomology.

Liubov Tupikina,
Moscow Institute of Physics and Technology
Natalia Bereberdina
HSE University
Geometric Machine Learning via Ricci Flow:
Unveiling Hidden Structures in Complex Datasets

Ricci curvature, a fundamental concept from Riemannian geometry, has emerged as a powerful tool for analyzing complex structures in discrete and high-dimensional data spaces. In geometry, curvature describes the local shape of an object, and while there are multiple approaches to discretizing curvature on graphs, the Ricci flow utilizes Ollivier-Ricci curvature [1, 2, 3, 5], defined via optimal transport theory. Ricci curvature then can be discretized for metric measure spaces by using the optimal transport theory. The Ricci flow for a graph is a process that uniformizes the edge Ricci curvature of a graph. By adapting notions of curvature to graphs and hypergraphs, we can use the computational framework that reveals hidden geometric patterns, enabling breakthroughs in clustering, network analysis, and machine learning optimization.

In our work we synthesize advancements in Ricci flow theory and its applications, focusing on its potential to transform data analysis through geometric structures uniformization. The main idea behind the algorithm is that negatively curved edges highlight inter-community connections, while positive curvature indicates dense clusters. Ricci curvature analysis has proven useful across various domains of community detection from social to biological networks. The Ricci framework has been applied to metabolic networks and financial systems to detect fragility and systemic risk, as well as to internet networks to study graph clustering and analysis

of topological structures [1, 4]. In our research context, we were interested to uncover the possibility to develop semi-supervised methods for studying the Ricci flow, as well as to investigate the potential of Ricci flow in data analysis of two datasets, MNIST and textual dataset of scientific articles texts. In general, one potential further application of the Ricci flow framework is application of the procedure of summarization and simplification of data structures to neural network training. Specifically, we are interested in further testing, whether training the algorithm on the data simplified using the Ricci flow could reveal the hidden structural patterns that could simplify and decrease the computational loads of the neural network training.

References:

[1] Chien-Chun Ni, Yu-Yao Lin, Feng Luo, Jie Gao, Community Detection on Networks with Ricci Flow (2019)

[2] Kantorovich, L.V., On the translocation of masses (2006)

[3] Shuliang Bai, Yong Lin, Linyuan Lu, Zhiyu Wang, Shing-Tung Yau, Ollivier Ricci-flow on weighted graphs (2024)

[4] Daniela Leite, Diego Baptista, Abdullahi A. Ibrahim, Enrico Facca, Caterina De Bacco, Community detection in networks by dynamical optimal transport formulation (2022)

[5] Y. Ollivier, Ricci curvature of markov chains on metric spaces (2009)

Tuzhilin Mikhail

Moscow State University

Relations between centrality measures and small-world properties

One of the most important questions in network science is what characteristics distinguish artificial networks from real ones based on real experimental data. Centrality measures, or centrality for short, play a key role in this issue. Two main invariants that distinguish real networks from random ones are well known: the degree of centrality and the local clustering coefficient. For real networks, the degree of centrality obeys a power law, unlike the distribution of random networks (scale-free property). The threshold of the average clustering coefficient distinguishes random networks from real networks (small-world property).

There are many mathematical models that simulate these two properties. For example, the Watts-Strogatz network was the first mathematical network that satisfied the small-world property. However, this network is not scale-free. The Barabasi-Albert network is a scale-free network, but the average clustering coefficient is not large enough. These problems were solved in the network proposed by Boccaletti, Hwang, and Latora, which is scale-free and has a large average

clustering coefficient.
In the first part of our talk, we will present theorems on the relationships between various centralities and other network characteristics. More precisely, we will show the relationships between stress, betweenness, radiality, and other small-world characteristics. We will present simple network properties in terms of local clustering centrality, where the average clustering coefficient is greater than the global clustering coefficient and vice versa. We will also show the case for a geodesic network, where there is a relationship between the average clustering coefficient and the average shortest path.
In the second part of our talk, we will present a new invariant for real networks, called ksi-centrality. We will show that this ksi-centrality not only distinguishes random networks from real ones, but also prove that it is related to the local clustering coefficient, the algebraic connectivity of the network, and the Cheeger constant. Moreover, Watts-Strogatz, Barabasi-Albert and Boccaletti, Hwang and Luthor networks are generally classified as random or artificial networks with respect to this centrality, but there is a narrow set of parameters for which Watts-Strogatz and Barabasi-Albert networks have the same properties as real networks with respect to this centrality. In this case, Watts-Strogatz and Barabasi-Albert networks have a more bow-tie-like structure, like real networks.

Bernhardt Brian Daniel
University of Cassino, Italy
Interpretable Aggregation in Graph Neural Networks via Entropy and Dissimilarity

Graph Neural Networks (GNNs) have become key models for learning from structured data, where neighborhood aggregation plays a central role in updating node representations. In this work, we propose and evaluate a customized aggregation scheme that incorporates two interpretable graph-based factors: neighborhood label entropy and feature dissimilarity. These factors are combined using tunable parameters, α and β, which provide information on the relative importance of structural purity versus feature-based contrast in the learning process. Our approach includes a preliminary analysis of feature separability, which can inform whether the customized model is likely to provide added value over standard GNNs. This framework aims to enhance both performance and explainability, particularly in settings where standard aggregation may overlook meaningful graph properties. Evaluation across multiple datasets is ongoing and will help determine under which conditions the proposed method offers the most benefit.

Regular talks. Session 2.

Daniil Tkachev
HSE University, International Centre of Decision Choice and Analysis

New centrality indices taking into account parameters of vertices, group influence of vertices to a vertex and weights of edges, and their application in social network models

Network analysis methods are used to find solutions to various problems of interaction among vertices in the network. One of the main tasks of network analysis is identifying the most important vertices in the network. A variety of centrality indices defines vertices importance in the network. Classic centrality indices do not take into account parameters of vertices and group influence of vertices to a vertex. During last years new centrality indices taking into account parameters of vertices and group influence of vertices were introduced. However, these centrality indices do not take into account weights of edges—relevant information about vertices connections. In this work we present new centrality indices taking into account parameters of vertices, group influence of vertices to a vertex, and weights of edges. In addition, we present an application of new centrality indices in different social network models.

Dmitry Gubanov
Institute of Control Sciences of Russian Academy of Science

Network-Augmented Topical Profiling of Research Publications

Calculating topical profiles of scientific publications plays a key role in systematizing scientific knowledge and supporting scientific decision-making. We propose a method for constructing publication profiles that combines an expert classifier with relationships between the authors of the publications. This approach increases profile-identification accuracy (precision@3) by 14 percent.

Daria Maltseva
International laboratory for Applied Network Research, HSE University

Enhancing Bibliometric Network Analysis with AI-Powered Tools

Over the last decades, various bibliometric analysis tools have been developed to study scientific disciplines and their evolution. Bibliometric network analysis involves analyzing networks of co-authorship, citation, co-citation, bibliographic coupling, and co-occurrence of bibliometric units. Research typically follows three stages: 1) creating a bibliographic database, 2) preprocessing and constructing bibliographic networks, and 3) analyzing these networks. Tools like VOSviewer,

CitNetExplorer, Bibliometrix, and Biblioshiny offer diverse solutions, catering to different research needs and user expertise levels. In recent years, Artificial Intelligence (AI) technologies have advanced rapidly, transforming research practices by enabling new tools for data analysis, hypothesis generation, process optimization, and result interpretation. However, integrating AI faces technical, organizational, educational, and psychological challenges. The intersection of network analysis and AI offers promising opportunities for mutual enhancement. AI can be applied in bibliometrics for tasks like automated data collection, citation analysis, author disambiguation, co-authorship analysis, research impact assessment, text mining, and recommender systems. Despite its potential, there is a need for a systematic overview of these currently fragmented practices and tools.
Our study explores how AI techniques and tools can enhance bibliometric network research across its three main stages. Using the Open Alex database, we analyze English-language publications (2015-2025) on AI applications in bibliometric analysis. Through a quantitative approach, we identify key areas for AI integration. A qualitative case-study of selected sources highlights practical applications for researchers.

Apollinariia Ermolaeva, Irina Pavlova
HSE University, International Laboratory for Applied Network Research

Bibliographic Coupling Networks of Russian Sociologists: Identifying Academic Communities and Fragmentation Patterns

Russian sociology is often regarded as a fragmented discipline, heavily centralized around institutions in Moscow and St. Petersburg, with limited collaboration between regional and capital-based scholars. This fragmentation is often attributed to geographic, institutional, and ideological divides, where information circulates primarily within localized academic circles. Such structural imbalances can hinder knowledge exchange and methodological innovation across the discipline.
Bibliometric data offers a powerful lens for examining the structure of academic communities. Networks of bibliometric coupling, which measure similarity in citation patterns among authors, serve as indicators of scholarly proximity and potential collaboration, enabling the identification of stable academic clusters and assessment of community integration or fragmentation. This study analyzes a dataset of 7,915 sociology articles published between 1991 and 2022 in the Web of Science, all with at least one Russia-affiliated author. By constructing bibliographic coupling networks—where nodes represent authors and edges reflect similarity in citation behavior—we test whether network fragmentation is based on affiliation and geographic location of an author, as suggested by previous empirical research.

Regular talks. Session 3.

Pavlova Irina
International laboratory for Applied Network Research, HSE University
Application of Multiple Methods to Explore Thematic Evolution of Wellbeing Studies

There has been a consensus among researchers that wellbeing studies are fragmented and are composed of ‘dimensions’. Though the wellbeing research draws its roots from Ancient Greece, there is still not sufficient understanding of how the field is structured and how it has evolved over time. This current study attempts to employ multiple methodologies to disclose evolution patterns and thematic structure of the research domain throughout different historical intervals.
Basing on the publication data from the OpenAlex scientific database (openalex.org) with more that 500,000 publications matching the search query, the study discusses applicability of (1) bibliometric network analysis (keywords co-occurrence networks), (2) semantic network analysis, and (3) topic modeling with Latent Dirichlet Allocation (LDA) to be used as complementary methodologies to disclose thematic and historical development of the scientific field.

Matveeva Natalia
HSE University, International laboratory for Applied Network Research
Co-authorship network structures of universities with different ages and statuses

We study the co-authorship network of universities to estimate whether there are any differences in their collaboration structures. Three university groups are examined: established leading universities, young leading universities, and catching-up universities. We use publications related to the universities’ profiles in the OpenAlex database for the years 2017-2019. Based on this data, two-mode co-authorship networks of 30 universities were constructed. To account for the different impact of authors in the universities' papers, the networks were multiplied and normalized. From the normalized networks, cores with a specified number of authors and links were extracted. Social capital theory was used to operationalize the variables of network characteristics. Linear discriminant analysis and ablation tests were applied to identify the variables that determine the division of university groups. We reveal that universities of different ages and statuses exhibit specific structures of scientific collaboration. To a large extent, the groups differ in the number of nodes and edges, as well as in the presence of "hubs" within the network. Leading universities are characterized by a relatively high proportion of "internal"

authors, a greater number of independent groups, and the presence of hubs connecting these groups. Young leaders typically have a relatively high number of independent groups but exhibit a lower degree of connectivity (compared to the leading universities) and greater isolation among groups. Catching-up universities are characterized by high heterogeneity, a small number of independent groups, few hubs, and a relatively high share of "internal" authors.

Daniil Kovalev,
HSE University, Laboratory for Applied Network Research
Daria Dunaeva
National Research Tomsk State University

Multimodal networks for the analysis of Russian labor market

Multimodal network analysis is an actively developing field in the methodology of social network analysis. Multimodal networks examine relations within and between separated groups of nodes referred to as ‘modes’. The most common use of multimodal data occurs in bipartite networks. A bipartite network consists of two modes or groups of nodes, and each edge in the network has an endpoint in each mode.

Multimodal network analysis can be used to identify trends in the labor market, create educational programmes, and conduct a detailed job search. Accordingly, using the Russian analytical vacancy aggregator "RosNavyk" https://rosnavyk.ru/ as the data source (job descriptions are parsed from four Russian job platforms), we identify the possibilities of multimodal network analysis in constructing bipartite graphs, e.g. networks of employers and skills or job vacancies and skills. Also, one-mode projections are constructed using the generalized Jaccard measure, e.g. a network of employers/job positions based on the hard and soft skills similarity.

Regular talks. Session 4.

Ilya Petrov
Institute of Control Sciences of Russian Academy of Science

Links vs. Incentives:
A Comparative Study of Interventions in Games on Networks

This paper investigates a game-theoretic model of agents interacting on a network to compare the efficiency of direct transfers to participants and changing the interaction network characteristics. We study the effect of various control policies - individual and structural interventions - in network games with linear best-response. It is shown that control of network characteristics can be more effective than homogeneous targeting intervention. The paper investigates methods for influencing outcomes in network games through two types of network interventions [1]: individual (targeted transfers to agents) and structural (modifications to network connections). The analysis focuses on linear best-response game [2,3], a class in which each agent's decision linearly depends on the actions of their neighbors. To simplify the analysis, the model is based on the Erdos-Renyi random graph [4, 5] and is further reduced to a single representative agent framework. The central objective is the maximization of social welfare within given budget constraints. This can be achieved either by altering individual incentives (modifying agents' marginal returns) or by changing the structure of the interaction network (link probability). It is shown that structural interventions can be more effective than uniform incentive targeting, particularly when the network effect—representing the degree of strategic interdependence among agents—is sufficiently strong. Explicit conditions are derived under which one strategy outperforms the other. Specifically, a critical threshold is identified beyond which structural changes yield higher efficiency than incentive-based approaches.

Alexey Grigoriev
Saratov State University

Characterizing Degree Distribution Asymmetry in Complex Networks.

The talk is dedicated to a novel approach to analyzing the friendship paradox in complex networks, based on a rank-based metric friendship rank which eliminates the size dependence inherent in the traditional friendship index. The study examines the limiting distribution of friendship rank in networks generated via the configuration model, where node degrees are produced by independent realizations of a random variable. A convergence theorem for friendship rank is proven for networks with finite moments of degree distribution. Empirical results confirm that,

unlike the friendship index, the friendship rank is a more stable characteristic when comparing networks of different sizes, especially for degree distributions with heavy tails. The proposed method can be useful for comparing networks of varying scales, such as social networks.

Timofei Emelianov
Saratov State University

Preferential Merging in Growing and Contracting Networks

Many real-world systems exhibit both growth and contraction processes, where nodes are added and merged over time. In this study, we introduce a preferential merging mechanism into previously proposed network evolution models based on vertex merging. Unlike earlier versions that selected nodes randomly for merging, the new approach selects nodes with probability proportional to their degrees, capturing the inherent heterogeneity of real networks. This modification significantly impacts the resulting network structure: whereas the original models generated networks with a fixed power-law exponent $\gamma \approx 1.5$, the preferential merging models produce degree distributions with tunable exponents in the range $2 < \gamma < 3$, consistent with empirical observations in many real systems. We provide analytical arguments and extensive simulations to demonstrate the effects of preferential merging on network characteristics such as degree distribution, clustering, and robustness. The proposed framework offers a more realistic and flexible model for understanding the co-evolution of growing and contracting complex networks.

Anna Semenova
HSE University, International Centre of Decision Choice and Analysis

Robustness of New Centrality Indices in Network Structures

The study of the robustness of centrality measures is one of the key directions in network analysis, as an increasing number of methods for ranking nodes in a graph have emerged in recent decades. Assessing how stable these rankings are under small perturbations is especially important for applied tasks, since real-world data often contain mistakes or missing values. The work provides a brief overview of existing approaches to evaluating the robustness of various centrality measures. It presents results on the robustness of both classical and new centrality indices that consider individual node parameters and group influence (Bundle and Pivotal indices) to minimal graph modifications, such as the addition/removal of an edge/node. The results of a series of experiments are provided for five classical network structures.

Regular talks. Session 5.

Petr Koldanov
HSE University, Lab LATNA
Confidence sets for graphical model and significant inference

The problem of constructing a confidence set for a graphical model is considered, along with the related task of identifying statistically significant inferences about the structure of the graphical model. It has been proven that the procedure for constructing a confidence set is equivalent to the procedure for simultaneous testing of hypotheses and alternatives regarding the composition of the graphical model. Some variants of the simultaneous testing procedure for hypotheses and alternatives are discussed. It is shown that under the condition of free combination of hypotheses and alternatives, a simple generalization of the closure method leads to one-step procedures for simultaneous testing of hypotheses and alternatives.
The structure of the confidence set for the graphical model is analyzed, demonstrating how the confidence set leads to a separation of inferences about the graphical model into statistically significant and insignificant categories, or into an area of uncertainty.
General results are detailed for the task of constructing and analyzing confidence sets for undirected Gaussian graphical model selection. Examples are provided that illustrate the separation of inferences about the composition of undirected Gaussian graphical models into signicant results and areas of uncertainty, and a comparison is made with known results obtained using the SINful approach to undirected Gaussian graphical model selection.

Alexander Tolmachev
Moscow Institute of Physics and Technology, Skoltech
On lower bounds of the maximal density of planar periodic sets without unit distances

Determining the maximal density of planar sets without unit distances is a fundamental problem in combinatorial geometry. This paper investigates lower bounds for this quantity. We introduce a novel approach to estimating this value by reformulating the problem as a Maximal Independent Set (MIS) problem on graphs constructed from the flat torus, focusing on periodic sets with respect to two non-collinear vectors. Our experimental results, supported by theoretical justifications of

the proposed method, demonstrate that for a sufficiently wide range of parameters, this approach does not improve the best known lower bound proposed by Croft in 1967. However, the best discrete sets found are approximations of Croft's construction. In addition, several open-source software packages for the MIS problem are compared on this reformulated task. The results presented in this talk are based on my recent paper arXiv:2411.13248.

Gleb Neshchetkin
HSE University, Lab LATNA

Methods of Conflict-Averse Gradient Choosing for Multi-Task Learning

Multi-task learning (MTL) involves training a single model on several tasks simultaneously, allowing the model to learn shared representations that benefit all tasks involved. MTL has shown success in fields such as natural language processing and computer vision. However, training on multiple tasks at once introduces notable difficulties.

One of the main challenges in MTL is that each task may have its own objective, and these objectives can conflict. This means that gradients derived from different tasks may point in opposing directions during backpropagation, which can hinder learning. Effectively managing these conflicting gradients is crucial to ensure that the model learns useful representations without favoring one task over others disproportionately.

This research provides a comparative study of techniques designed to manage gradient conflict in MTL. It explores various approaches that aim to determine a single update direction which accommodates the objectives of all tasks. These methods are experimentally evaluated on computer vision and natural language processing benchmarks.

Regular talks. Session 6.

Sergei Gladyshev
Moscow Institute of Physics and Technology

Heuristic policy for the specific case of the stochastic single machine scheduling problem with precedence constraints and uncertain job duration

We address the single-machine scheduling problem in environments where jobs are subject to precedence constraints, modeled via a disjunctive graph. Each job's processing time is uncertain, taking one of three values pi-1, pi, or pi+1 with known probabilities (and equal likelihood of the shortest and longest durations). We first prove that, in the absence of any precedence relations, sequencing jobs in non-decreasing order of a defined "safety" metric minimizes the total expected start-time deviation under the Right-Shift control policy. We then leverage this optimality insight to design a heuristic for the more general case with precedence constraints: we construct an initial schedule by embedding the safety-ordered sequence within the topology of the disjunctive graph, respecting all precedence arcs. Upon realization of actual durations, any necessary adjustments are handled by Right-Shift while preserving both the precedence-induced order and the relative safety ranking. Computational experiments demonstrate that our heuristic delivers near-optimal performance on benchmark instances of the precedence-constrained problem, offering a practical and robust sequencing rule under tri-modal duration uncertainty.

Dmitry Gribanov
Moscow Institute of Physics and Technology and HSE University, Lab LATNA

Faster algorithms for ILP problems of bounded codimension via discrepancy theory

Consider the following ILP problem in standard form:

$$\begin{aligned} & c^\top x \to \max \\ & \begin{cases} Ax = b \\ x \in \mathbb{Z}^n_{\geq 0}, \end{cases} \end{aligned} \tag{1}$$

where $A \in \mathbb{Z}^{k \times n}$, $\operatorname{rank}(A) = k$, $b \in \mathbb{Z}^k$, and $c \in \mathbb{Z}^n$. It is natural to refer to the parameter k as the *codimension* of the problem, as it corresponds to the codimension of the affine subspace defined by $Ax = b$. In their seminal work [2], K. Jansen and L. Rohwedder develop a novel dynamic programming framework combined with key results from Discrepancy Theory, capable of solving Problem (1) in

$$O\left(\sqrt{k} \cdot \alpha\right)^{2k} / 2^{\Omega\left(\sqrt{\log \alpha}\right)} + T_{\mathrm{LP}}$$

arithmetic operations, where $\alpha = \max_{i,j}|A_{ij}|$ and T_{LP} denotes the computational complexity of solving the linear programming (LP) relaxation. Setting $k = 1$, this yields an $O(n + \alpha^2/2^{\Omega(\sqrt{\log \alpha})})$-time algorithm for the *unbounded knapsack problem*. For the feasibility variant of Problem (1), the work of K. Jansen & L. Rohwedder proposes an algorithm running in

$$O\left(\sqrt{k} \cdot \alpha\right)^k \cdot \log^2(\alpha) + T_{\text{LP}}$$

arithmetic operations. Setting $k = 1$, this results in an $O\left(n + \alpha \cdot \log^2(\alpha)\right)$-time algorithm for the *unbounded subset-sum problem*. In this talk, we provide a concise overview of Jensen and Rohwedder's framework, emphasizing its connection

to Discrepancy Theory. Building on [1], we generalize their approach to weaker parameter regimes. Specifically, we prove that Problem (1) can be solved within

$$O(\log k)^k \cdot \Delta^2/2^{\Omega\left(\sqrt{\log \Delta}\right)} + T_{\text{LP}}$$

arithmetic operations, where Δ denotes the maximum absolute value of $k \times k$ subdeterminants of A. For the feasibility variant of Problem (1), we establish an improved complexity bound of

$$O(\log k)^{k/2} \cdot \Delta \cdot \log^3 \Delta + T_{\text{LP}}$$

arithmetic operations. We observe that applying the Hadamard inequality to the bounds parameterized by Δ yields asymptotically comparable bounds to those parameterized by α. Furthermore, we highlight that the methodology of [1] extends to problems in canonical form with $n + k$ constraints while yielding identical complexity bounds. Formally, these problems are expressed as:

$$c^\top x \to \max$$
$$\begin{cases} Ax \leq b \\ x \in \mathbb{Z}^n, \end{cases}$$

where $A \in \mathbb{Z}^{(n+k)\times n}$, $\operatorname{rank}(A) = n$, $b \in \mathbb{Z}^{n+k}$, and $c \in \mathbb{Z}^n$.

References

[1] D Gribanov, D Malyshev, and Panos M Pardalos. Delta-modular ilp problems of bounded co-dimension, discrepancy, and convolution. *arXiv preprint arXiv:2405.17001*, 2024.

[2] K. Jansen and L. Rohwedder. On integer programming, discrepancy, and convolution. *Mathematics of Operations Research*, 2022.