

11th International Conference on Network Analysis NET 2021

Nizhny Novgorod, October 18-20, 2021

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

Location: Zoom

The Conference is dedicated to the 10-th anniversary of the lab LATNA.
It is connected with International Conference
[‘Cultural transfer: formation of creative human capital’](#)
dedicated to 25-th anniversary of HSE NN.



NATIONAL RESEARCH
UNIVERSITY

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Nikolay Zolotykh, Lobachevsky State University, Nizhny Novgorod

Andrey Savchenko, NRU HSE

Conference Organizers

Panos M. Pardalos, University of Florida, USA

Andrey Raigorodski, MIPT – Yandex, Russia

Valery Kalyagin, National Research University Higher School of Economics, Russia

Plenary speakers

Fuad Aleskerov (HSE Moscow)

Polarization of the society and patterns of electoral behavior

(The lecture is given October 19 at 10:30 in the framework of International Conference '[Cultural transfer: formation of creative human capital](#)' dedicated to 25-th anniversary of HSE NN)*

Sumi Helal (University of Florida, USA)

Internet-of-Things: From Networking to Meaningful Interactions

Eric Maskin (Harvard University, USA)

Arrow's Theorem, May's Axioms, and Borda's Rule

(The lecture is given October 19 at 20:00 in the framework of International Conference '[Cultural transfer: formation of creative human capital](#)' dedicated to 25-th anniversary of HSE NN)*

Cristina Masoller (Universitat Politecnica de Catalunya, Spain)

Application of network techniques to ophthalmic image analysis and outlier detection

Giovanni Stracquadanio (University of Edinburgh, UK)

Discovering cancer driver genes and pathways using stochastic block model graph neural networks

* Zoom connection to the International Conference 'Cultural transfer: formation of creative human capital' dedicated to 25-th anniversary of HSE NN

<https://zoom.us/j/98947260691?pwd=cVVCcko1VkdyQWJNcFFtOXdzNk9Jdz09>

Conference ID: 989 4726 0691

Password: 233510

Monday, October 18

Zoom

<https://zoom.us/j/94594689639?pwd=eFZmMDJJZU1UMnVrVmdJZGlicXRHUT09>

Meeting ID: 945 9468 9639

Password: 589027

15:00 – 15:40 Cristina Masoller (Universitat Politecnica de Catalunya, Spain)

Plenary lecture: Application of network techniques to ophthalmic image analysis and outlier detection

15:40 – 16:05 Leonidas Pitsoulis (University of Thessaloniki, Greece)

Graphs and Data Science in Industry

16:05 – 16:30 Alex Dainiak (Moscow Institute of Physics and Technology)

Visualizing hypergraphs: a survey

16:30 – 16:55 Mario Guarracino (University of Cassino and ICAR-CNR, Italy)

On resiliency and robustness of whole graph embedding

16:55 – 17:10 Coffee break

17:10 – 17:50 Ilya Chernykh (Sobolev Institute of Mathematics, Novosibirsk)

Instance reduction and problem transformation as a way of research simplification in scheduling

17:50 – 18:15 Theodore Trafalis (University of Oklahoma, USA)

Affinely adjustable robust optimization under dynamic uncertainty set for a novel robust closed-loop supply chain

18:15 – 18:40 Mauricio Rezende (Amazon, and University of Washington)

Multi-parent biased random-key genetic algorithm with implicit path-relinking and some real-world applications

18:40 – 19:00 Egor Churaev (HSE NN)

User-dependent Adaptation of Neural Network Model in Video-based Facial Emotion Recognition

Tuesday, October 19

Zoom

<https://zoom.us/j/94594689639?pwd=eFZmMDJJZU1UMnVrVmdJZGlrRXRHUT09>

Meeting ID: 945 9468 9639

Password: 589027

15:00 – 15:40 Giovanni Stracquadanio (University of Edinburgh, UK)

Plenary lecture: Discovering cancer driver genes and pathways using stochastic block model graph neural networks

15:40 – 16:10 Vladimir Batagelj (University of Ljubljana, Slovenia and HSE)

Network multiplication and derived networks

16:10 – 16:35 Daniil Musatov (Moscow Institute of Physics and Technology)

Fair division on graphs and hypergraphs

16:35 – 16:50 Coffee break

16:50 – 17:20 Anuška Ferligoj (University of Ljubljana, Slovenia and HSE)

Connecting cluster analysis and network analysis

17:20 – 17:45 Roman Belavkin (Middlesex University, UK)

Entropy, Free Energy and Phase Transitions in Power-Law Graphs

17:45 – 18:10 Dmitry Ignatov (HSE, Moscow)

On the optimal Boolean Matrix Factorization algorithm for contranominal scales and its outcomes for recommender systems

18:10 – 18:35 Vladimir Boginski (University of Central Florida, USA)

Graph-based Exploration and Clustering Analysis of Semantic Spaces

18:35 – 19:00 Ilias Kotsireas (Wilfrid Laurier University, Waterloo, Canada)

20 years of Legendre Pairs

Wednesday, October 20

Zoom

<https://zoom.us/j/94594689639?pwd=eFZmMDJjZU1UMnVrVmdJZGlrRHRHUT09>

Meeting ID: 945 9468 9639

Password: 589027

15:00 – 15:25 Mikhail Khachai (Ural Federal University, Ekaterinburg, RF)

Problem-specific Branch-and-Bound algorithms for the Precedence Constrained Generalized Traveling Salesman Problem

15:25 – 15:50 Ivan Shumilov (Lobachevskii State University, Nizhny Novgorod)

Simple bound on integer vertices of general Δ -modular polyhedral

15:50 – 16:15 Viktor Zamaraev (University of Liverpool, UK)

Sharp Thresholds in Random Simple Temporal Graphs

16:15 - 16:40 Oleg Prokopyev (University of Pittsburg, USA)

On Exact Solution Approaches for a Class of Bilevel Fractional Programs

16:40 – 16:50 Coffee break

16:50 – 17:10 Polina Demochkina (HSE NN)

Neural network model for fast video-based emotion recognition

17:10 – 17:30 Andrey Shilov (LATNA, HSE NN)

Optimization of computational graphs for deep learning models

17:30 – 17:50 Evgenii Burashnikov (LATNA lab, HSE NN)

A recent approach to optimization of computational graphs for deep learning models

17:50 – 18:30 Sumi Helal (University of Florida, USA)

Plenary lecture: Internet-of-Things: From Networking to Meaningful Interactions

Plenary lectures

Fuad Aleskerov

HSE Moscow

Polarization of the society and patterns of electoral behavior

I consider several different views in the groups of society and evaluate the polarization of this society. Based on these evaluations and Maslow's model of basic needs I try to forecast the patterns of electoral behavior in the first half of XXI century.

The lecture is given October 19 at 10:30 in the framework of International Conference '[Cultural transfer: formation of creative human capital](#)' dedicated to 25-th anniversary of HSE NN

Zoom connection to this lecture

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Sumi Helal

University of Florida, USA

Internet-of-Things: From Networking to Meaningful Interactions

Understanding how to expressly program the Internet-of-Things (IoT) as we have programmed previous generations and forms of the Computer is an essential requirement to any meaningful proliferation and adoption of this emerging technology. With the exception of a few ideas and tools that exist today, the programmability view of IoT lacks clarity and, in fact, there are no clear boundaries that separate IoT as a highly distributed Computer from IoT as applications that can be programmed and deployed over such new form of Computers. In this talk, I will present an IoT programming framework in which the logic of applications is built around the notion of “meaningful interactions” in which internetworking of the IoT things is not about transporting bits and data but rather aims at understanding the mutual opportunities for application forming. The framework is simultaneously service-and relation-oriented and calls for a new roles-model that redefines and redistributes several standard responsibilities. I will present the programming framework and its implementation within the Atlas Thing Architecture. I will then present RIDE—a run-time IDE for the lay-user to develop IoT applications on the user’s smartphone. Finally, I will conclude with a discussion of remaining challenges that need to be addressed by the relevant research communities.

BIOSKETCH

Prof Helal is a Computer and Information Science and Engineering Professor at the University of Florida, USA, and Director of its Mobile and Pervasive Computing Laboratory. He co-founded and directs the Gator Tech Smart House, a real-world deployment project that aims at identifying key barriers and opportunities to make the Smart Home concept a common place (creating the “Smart Home in a Box” concept). His active areas of research focus on architectural and programmability aspects of smart spaces and the Internet of Things, and on pervasive/ubiquitous systems and their human-centric applications with special focus on proactive health/wellness, patient empowerment and e-coaching, and assistive technology in support of personal health, aging, disabilities, and independence. Professor

From 2017 to 2020, and while on leave from Florida, he was professor and Chair in Digital Health at Lancaster University, UK, where he led interdisciplinary research initiatives in digital health in both the School of Computing and Communications (Faculty of Science and Technology) and the Division of Health Research (Faculty of Health and Medicine). As Director of Lancaster University’s Center on Digital Health and Quality of Life Technologies, he led several projects on Connected Health Cities, Healthy New Towns design and implementation, suicide prevention using cybernetics and analytics, Airport Accessibility for the hearing impaired, and intelligent primary care GP-Patient interactions.

Prof Helal served as the Editor-in-Chief of IEEE Computer (2015-2018), the Computer Society’s flagship and premier publication. He also served as member of the Board of Governors of the IEEE Computer Society, and Chair of its Magazine Operational Committee. He is a Fellow of the IEEE, Fellow of the IET, Fellow of the AAAS, and since July 2020, a member of Academia Europaea.

Eric Maskin

Harvard University, USA

Arrow's Theorem, May's Axioms, and Borda's Rule

We argue that Arrow's (1951) independence of irrelevant alternatives condition (IIA) is unjustifiably stringent. Although, in elections, it has the desirable effect of ruling out spoilers (Candidate A spoils the election for B if B beats C when all voters rank A low, but C beats B when some voters rank A high - A splits off support from B), it is stronger than necessary for this purpose. Worse, it makes a voting rule insensitive to voters' preference intensities. Accordingly, we propose a modified version of IIA to address these problems. Rather than obtaining an impossibility result, we show that a voting rule satisfies modified IIA, Arrow's other conditions, and May's (1952) axioms for majority rule if and only if it is the Borda count (Borda 1781), i.e., rank-order voting.

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Cristina Masoller

Universitat Politecnica de Catalunya, Spain

Application of network techniques to ophthalmic image analysis and outlier detection

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Recent advances in computer science and machine learning (ML) have generated highly efficient and unsupervised algorithms for the analysis of biomedical images, enabling cost-effective remote early detection of diseases. In this talk I will present various methods for ophthalmic image analysis, which use ML and network analysis. First, I will present a ML algorithm for the analysis of optical coherence tomography (OCT) images, which extracts features that discriminate between healthy and unhealthy subjects [1]. Then, I will show that network analysis applied to the tree-like structure of the network of vessels in the retina returns features that discriminate between healthy subjects and those with glaucoma or diabetic retinopathy [2]. Finally, I will discuss how the network percolation transition can be used for mining outliers in wide range of high-dimensional data sets, including ophthalmic images [3].

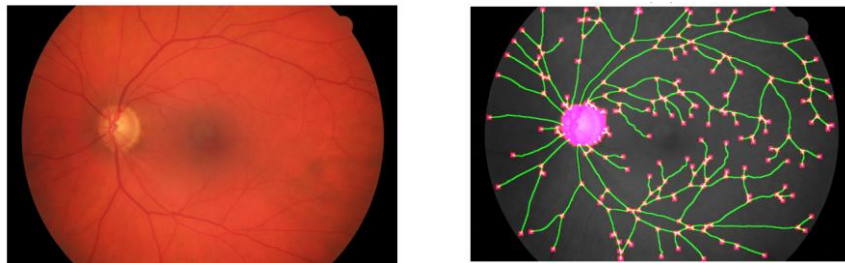


Figure 1: Example of a retinal fundus image and the extracted network.

References

- [1] P. Amil, L. Gonzalez, E. Arrondo, C. Salinas, J. L. Guell, C. Masoller, and U. Parlitz, Unsupervised feature extraction of anterior chamber OCT images for ordering and classification, *Sci. Rep.* 9, 1157 (2019).
- [2] P. Amil, F. Reyes-Manzano, L. Guzmán-Vargas, I. Sendiña-Nadal and C. Masoller, Novel network-based methods for retinal fundus image analysis and classification, *PLoS ONE* 14, e0220132 (2019).
- [3] P. Amil, N. Almeida and C. Masoller, Outlier mining methods based on network structure analysis, *Front. Phys.* 7, 194 (2019).

Giovanni Stracquadanio

University of Edinburgh, UK

Discovering cancer driver genes and pathways using stochastic block model graph neural networks

Abstract: The identification of genes and pathways responsible for the transformation of normal cells into malignant ones represents a pivotal step to understand the aetiology of cancer, to characterise progression and relapse, and to ultimately design targeted therapies. The advent of high-throughput omic technologies has enabled the discovery of a significant number of cancer driver genes, but recent genomic studies have shown these to be only necessary but not sufficient to trigger tumorigenesis. Since most biological processes are the results of the interaction of multiple genes, it is then conceivable that tumorigenesis is likely the result of the action of networks of cancer driver and non-driver genes.

Here we take advantage of recent advances in graph neural networks, combined with well established statistical models of network structure, to build a new model, called Stochastic Block Model Graph Neural Network (SBM-GNN), which predicts cancer driver genes and cancer mediating pathways directly from high-throughput omic experiments. Experimental analysis of synthetic datasets showed that our model can correctly predict genes associated with cancer and recover relevant pathways, while outperforming other state-of-the-art methods.

Invited talks

Network multiplication and derived networks

Vladimir Batagelj^{1,2,3}

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Let UV (on sets U and V) and VZ (on sets V and Z) be matrices of the corresponding two-mode networks $\mathcal{N}_{UV} = ((U, V), L_{UV}, w_{UV})$ and $\mathcal{N}_{VZ} = ((V, Z), L_{VZ}, w_{VZ})$; L – set of links, w – weight on links. Their product $UZ = UV \cdot VZ$

$$UZ[u, z] = \sum_{v \in V} UV[u, v] \cdot VZ[v, z]$$

determines the corresponding network $\mathcal{N}_{UZ} = ((U, Z), L_{UZ}, w_{UZ})$. The definition can be extended to semirings (Cerišek and Batagelj, 2017). What is the complexity of computing the product of large sparse networks (Batagelj and Cerišek, 2013; Batagelj et al., 2014) ?

The product provides a new network linking set U to set Z . In special cases (projections), $UU = UV \cdot UV^T$ and $VV = UV^T \cdot UV$, it transforms a two-mode network to an ordinary (one-mode) network. This turns out to be very useful in the analysis of collections of networks.

If both networks are binary ($w_{UV} = 1$ and $w_{VZ} = 1$) then $UZ[u, z] = |N_{UV}(u) \cap N_{VZ}(z)|$ (N – set of neighbors) – it counts the number of ways we can move from the node $u \in U$ to the node $z \in Z$ through some node $v \in V$ first using the link $(u, v) \in L_{UV}$ and afterward using the link $(v, z) \in L_{VZ}$.

To get the right answers to some questions we have often to normalize networks used in products (Batagelj, 2020). A "standard" normalization is $n(UV)$

$$n(UV)[u, v] = \frac{UV[u, v]}{\sum_{s \in V} UV[u, s]}$$

Networks obtained from basic networks from a collection using multiplications or normalizations are called **derived networks**.

In our presentation, we provide some details and applications of these constructions.

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- Batagelj, V., Doreian P., V., Ferligoj, A., Kežar N. (2014). *Understanding Large Temporal Networks and Spatial Networks: Exploration, Pattern Searching, Visualization and Network Evolution*. Wiley.
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- Batagelj, V. (2021). Analysis of the Southern women network using fractional approach. *Social Networks* 68, 229–236.
- Cerinšek, M., Batagelj, V. (2017). Semirings and Matrix Analysis of Networks. in *Encyclopedia of Social Network Analysis and Mining*. Reda Alhajj, Jon Rokne (Eds.), Springer.

Roman Belavkin

Middlesex University, UK

Panos Pardalos

LATNA lab HSE and University of Florida

Entropy, Free Energy and Phase Transitions in Power-Law Graphs.

Large networks tend to follow a common pattern, when the number of nodes with degree k is described by the power-law $N(k) \propto k^{-\beta}$. This degree sequence can be obtained as solution to a maximum entropy problem with a constraint on the expected value of the logarithm of the degree. This formalism will allow us to analyse thermodynamic and information-theoretic potentials, such as entropy and free energy, in the power-law graphs. I will show that the famous disconnectedness result due to Aiello, Chung, and Lu (2000) for the power-law graphs correspond to a phase transition of the first kind.

Vladimir Boginski

University of Central Florida, USA

Graph-based Exploration and Clustering Analysis of Semantic Spaces

The goal of this study is to demonstrate how network science and graph theory tools and concepts can be effectively used for exploring and comparing semantic spaces of word embeddings and lexical databases. Specifically, we construct semantic networks based on word2vec representation of words, which is "learnt" from large text corpora (Google news, Amazon reviews), and "human built" word networks derived from the well-known lexical databases: WordNet and Moby Thesaurus. We compare "global" (e.g., degrees, distances, clustering coefficients) and "local" (e.g., most central nodes and community-type dense clusters) characteristics of considered networks. Our observations suggest that human built networks possess more intuitive global connectivity patterns, whereas local characteristics (in particular, dense clusters) of the machine built networks provide much richer information on the contextual usage and perceived meanings of words, which reveals interesting structural differences between human built and machine built semantic networks. To our knowledge, this is the first study that uses graph theory and network science in the considered context; therefore, we also provide interesting examples and discuss potential research directions that may motivate further research on the synthesis of lexicographic and machine learning based tools and lead to new insights in this area.

Evgenii Burashnikov

LATNA lab, HSE NN

A recent approach to optimization of computational graphs for deep learning models

One of the major optimizations employed in deep learning frameworks is graph rewriting. The key idea here is finding the same equivalent computational graph which can be computed faster than the original graph. Because of the exponential number of variants of the new subgraph only small substitutions can be found. For tensor graph superoptimization frameworks apply substitutions in a sequential manner and often only explore a small fragment of the exponential space of equivalent graphs. Here we will talk about the new approach TENSAT (A tensor graph superoptimization framework that employs equality saturation) where all possible substitutions at once are considered.

Ilya Chernykh

Sobolev Institute of Mathematics, Novosibirsk

Instance reduction and problem transformation as a way of research simplification in scheduling

Instance reduction is a well-known technique, which is used for different purposes, including designing efficient approximation or even exact algorithms and approximation schemes. However, sometimes a simplification of an instance leads to a generalization – and therefore complication - of the problem settings. The goal of my talk is to discuss two such cases and connected results for two variants of a routing open shop problem, which combines the classical TSP with so-called open shop scheduling problem.

Egor Churaev, Andrey V. Savchenko

HSE University, Nizhny Novgorod

User-dependent Adaptation of Neural Network Model in Video-based Facial
Emotion Recognition

Nowadays, video-based facial emotion recognition is one of the most acute and challenging problems in computer vision. The state-of-the-art algorithms are characterized by 50-80% accuracy for various datasets. In this talk, we consider an opportunity of increasing model accuracy by adapting it to facial expressions of a target user. At first, train a user-independent emotion classifier of the facial features extracted by deep convolutional neural network is trained. Next, it is proposed to adapt this classifier by using the small video dataset of a concrete person. As a result, every user is associated with his or her own emotion recognition model. The concrete fine-tuned classifier may be chosen using a face recognition algorithm or even fixed if the identity of a user is known. The experimental results on the RAVDESS dataset demonstrates that the proposed approach makes it possible to significantly improve the quality of conventional user-independent emotion classifier.

Alex Dainiak

Moscow Institute of Physics and Technology

Visualizing hypergraphs: a survey

We present a survey of hypergraph and set systems visualization techniques, highlighting some discrete optimization and mixed integer optimization challenges in this area. Parts of this talk are based on joint work with Mohsen Nafar.

Polina Demochkina, Andrey V. Savchenko

HSE University, Nizhny Novgorod

Neural network model for fast video-based emotion recognition

Recently, the task of facial expression recognition has been gaining more popularity due to a wide range of applications in the field of human-computer interaction. With the extensive use of smartphones in the modern world, it is important to develop solutions that can be implemented on mobile devices in real-time systems. Our solution to the problem is a two-stage procedure, in which, firstly, deep features are extracted from each video frame using an EfficientNet-based model. This model has been pre-trained to identify the age, gender, and identity of a person, and further fine-tuned on the AffectNet dataset to classify emotions in static images. Secondly, the frame-level features are aggregated using multiple statistical functions into a single video descriptor that is classified by a SVM. This approach leads to state-of-the-art results on the AFEW 8.0 dataset (59.79%), beating the baseline by 20.8%.

Anuška Ferligoj

University of Ljubljana, Slovenia and HSE Moscow

Connecting cluster analysis and network analysis

A large class of clustering problems can be formulated as an optimizational problem in which the best clustering is searched for among all feasible clustering according to a selected criterion function. This clustering approach can be applied to a variety of very interesting clustering problems, as it is possible to adapt it to a concrete clustering problem by an appropriate specification of the criterion function and/or by the definition of the set of feasible clusterings. Both, the blockmodeling problem (clustering of the network data) and the clustering with relational constraint problem (clustering of the attribute and network data) can be very successfully treated by this approach. It also opens many new developments in these areas.

Mario Guarracino

University of Cassino and ICAR-CNR, Italy

On resiliency and robustness of whole graph embedding

Graph embedding techniques are becoming increasingly common in many fields ranging from scientific computing to biomedical applications and finance. These techniques aim to automatically learn vector representations for a variety of network analysis tasks. Several methods show very promising results in terms of their usability and potential. Despite their recent spreading diffusion, little is known about their resilience and robustness, particularly when applied to the real world of data, where adversaries or malfunctioning/noising data sources may supply deceptive data.

We will analyze vulnerabilities emerging when inserting limited perturbations on the input data, to understand when these can lead to a dramatic deterioration in performance. To this end, an analysis of different adversarial attacks in the context of whole-graph embedding is proposed. The attack strategies involve a limited number of nodes based on the role they play in the graph. The study aims to measure the resiliency and robustness of different whole-graph embedding approaches to those types of attacks, when the network analysis task consists in the supervised classification of whole-graphs. Extensive experiments carried out on synthetic and real data provide empirical insights on the vulnerability of whole-graph embedding models to node-level attacks in supervised classification tasks.

*Joint work with Maurizio Giordano, Lucia Maddalena, and Mario Manzo

Dmitry Ignatov

HSE, Moscow

On the optimal Boolean Matrix Factorization algorithm for contranominal scales
and its outcomes for recommender systems

In this talk, we examine certain properties of the GreConD algorithm for Boolean matrix factorisation, a popular technique in Data Mining with binary relational data. This greedy algorithm was inspired by the fact that the optimal number of factors for the Boolean Matrix Factorisation (BMF) can be chosen among the formal concepts of the corresponding formal context. In particular, we consider one of the hardest cases (in terms of the number of possible factors), the so-called contranominal scales, and show that the output of GreConD is not optimal in this case. Moreover, we formally analyse its output by means of recurrences and generating functions and obtain the closed form for the returned number of factors. An algorithm generating the optimal number of factors and the corresponding product matrices P and Q is also provided by us for the case of contranominal scales. In addition to algorithmic studies, we provide the listeners with a short summary of our previous results on BMF applications for Collaborative Filtering (in collaboration with E. Nenova, M. Ahmaturov et al.) along with some recent results for Boolean tensors as well.

This is a joint work with A. Yakovleva

Mikhail Khachai

Ural Federal University, Ekaterinburg, RF

Problem-specific Branch-and-Bound algorithms for the Precedence

Constrained Generalized Traveling Salesman Problem

The Generalized Traveling Salesman Problem (GTSP) is a well-known combinatorial optimization problem having numerous valuable practical applications in operations research. In the Precedence Constrained GTSP (PCGTSP), any feasible tour is restricted to visit all the clusters according to some given partial order. Unlike the common setting of the GTSP, the PCGTSP appears still weakly studied in terms of algorithmic design and implementation.

To the best of our knowledge, all the known algorithmic results for this problem can be exhausted by Salmans's general branching framework, a few MILP models, and the PCGLNS meta-heuristic proposed by the authors recently. In this paper, we present the first problem-specific branch-and-bound algorithm designed with an extension of Salman's approach and exploiting PCGLNS as a powerful primal heuristic. Using the public PCGTSPLIB testbench, we evaluate the performance of the proposed algorithm against the classic Held-Karp dynamic programming scheme with branch-and-bound node fathoming strategy and Gurobi state-of-the-art solver armed by our recently proposed MILP model and PCGLNS-based warm start.

Ilias S. Kotsireas

CARGO Lab, Canada & Athena RC, Greece

ikotsire@gmail.com

20 years of Legendre Pairs

Legendre pairs were introduced in 2001 by Seberry and her students, as a means to construct Hadamard matrices via a two-circulant core construction. A Legendre pair consists of two sequences of odd length ℓ , with elements from $\{-1, +1\}$, such that their respective autocorrelation coefficients sum to -2 , or (equivalently) their respective power spectral density coefficients sum to $2\ell + 2$. Legendre pairs of every odd prime length ℓ exist, via a simple construction using the Legendre symbol. We will review known constructions for Legendre pairs. We will discuss various results on Legendre pairs during the past 20 years, including the concept of compression, introduced in a joint paper with Djokovic, as well as the computational state-of-the-art of the search for Legendre pairs. In particular, we recently contributed the only known Legendre pair of length $\ell = 77$ in a joint paper with Turner/Bulutoglu/Geyer. In addition, we recently contributed in a joint paper with Koutschan, several Legendre pairs of new lengths $\ell \equiv 0 \pmod{3}$ as well as two algorithms that allows one to determine the full spectrum of values for the $(\ell/3)$ -rd power spectral density value. We also elaborated the issue of integer power spectral density coefficients and showed that they appear due to a very

specific autocorrelation constancy property. The importance of Legendre pairs lies in the fact that they constitute a promising avenue to the Hadamard conjecture.

Daniil Musatov

Moscow Institute of Physics and Technology

Fair division on graphs and hypergraphs

Cake-cutting is a classical framework for fair division. A group of agents want to share a heterogeneous private good in a fair way. There are two main notions of fairness: proportionality and envy-freeness. Under the former condition each of the N agents values his share as at least $1/N$ of the whole cake. Under the latter one each agent values her share at least as much as any other agent's share. We consider a similar framework where agents form a social network and compare their share with shares of their neighbors. We consider two types of network: a usual network with bilateral connections and a hypergraph consisting of clubs. We analyze three types of fairness: global, local and club, and establish connections between them.

Leonidas Pitsulis

University of Thessaloniki, Greece

Graphs and Data Science in Industry

Although it is well known that graph theoretical and machine learning methods enjoy a plethora of applications in the industry, in most academic papers the focus is on the methods while the implementation typically involves artificial data. In this talk we will present an end-to-end artificial intelligence system which employs methods from these domains, to deliver services to customers which are members of an organisation or team, for enhanced collaboration and communication. Emphasis will be given to the way that concepts from data representation, natural language understanding, complex networks and graph algorithms blend together in a scalable data infrastructure to deliver the final services to the user.

Oleg Prokopyev
University of Pittsburg, USA

On Exact Solution Approaches for a Class of Bilevel Fractional Programs

We consider a class of bilevel programming problems (BPPs), where the leader's decision variables are all binary, the follower's decision variables are all continuous, and a fractional objective function appears in the follower's problem. This class of problems generalizes standard bilevel linear mixed-integer programs with a linear program (LP) in the lower level. One motivating application example for this generalization arises in a network interdiction context, where the follower (i.e., the evader) instead of minimizing his/her shortest path, optimizes some fractional objective function, e.g., a cost-to-time ratio. By applying Charnes-Cooper transformation, we first reformulate the original BPP as an equivalent BPP with a fractional objective in the upper level, but an LP in the lower level. Using a combination of the LP strong-duality property and linearization techniques, we show how to address the resulting reformulation via a parametric approach that solves a sequence of linear mixed-integer programs. The latter can be handled by off-the-shelf solvers, which implies that our overall solution scheme is easy to implement. Finally, we perform a brief computational study to illustrate the performance of the proposed approaches

Mauricio Rezende

Amazon, and University of Washington, USA

Multi-parent biased random-key genetic algorithm with implicit path-relinking and
some real-world applications

We present the Multi-Parent Biased Random-Key Genetic Algorithm with Implicit Path-ReLinking (BRKGA-MP-IPR), a variant of the Biased Random-Key Genetic Algorithm that employs multiple (biased) parents to generate offspring instead of the usual two, and is hybridized with a novel, implicit path-relinking local search procedure. By operating over the standard unit hypercube, such path-relinking mechanism leverages the population representation of the BRKGA and thus

provides complete independence between the local search procedure and the problem definition and implementation. This approach contrasts with traditional path-relinking procedures that are tied to the problem structure. Having both BRKGA and IPR operate over the same solution space not only makes the intensification/diversification paradigm more natural but also greatly simplifies the development effort from the perspective of the practitioner, as one only needs to develop a decoder to map unit random-key vectors to the solution space of the problem on hand. Apart from such key benefits, extensive computational experiments solving real-world problems, such as over-the-air software upgrade scheduling, network design problems, and combinatorial auctions, show that the BRKGA-MP-IPR offers performance benefits over the standard BRKGA as well as the BRKGA with multiple parents.

This is joint work with CARLOS E. ANDRADE (AT&T Labs Research, Bedminster), RODRIGO F. TOSO (Microsoft, Bellevue), and JOSÉ F. GONÇALVES (Amazon, Bellevue).

Andrey Shilov

LATNA lab, HSE

Optimization of computational graphs for deep learning models.

Performance optimization is an important challenge during production deployment of deep learning models as their computational time may be rather high. To address this problem, several approaches have been developed in recent years. Based on combinatorial optimization methods, they optimize the computational graph of a neural network by recombining its operators and choosing better data layouts. Some of these approaches, e.g. TASO (Tensor Algebra Super Optimizer), are reviewed in this talk.

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Simple bound on integer vertices of general Δ -modular polyhedra

Let P be an n -dimensional polyhedron defined by a system $Ax \leq b$, where A is an integer matrix of the rank n and b is an integer vector. Let P_I be the polyhedron induced by a convex hull of the set $P \cap \mathbb{Z}^n$. We show that the number of vertices in P_I is bounded by $2 \cdot m/n \cdot \Delta^{n-1}$, where Δ is the maximum of absolute values of all $n \times n$ sub-determinants of A . For $\Delta = O(n^2)$ our bound is stronger, than the state of the art bound $m^n \cdot O(n)^{n+3} \cdot \log^{n-1}(n \Delta)$ due to A. Yu. Chirkov and S. I. Veselov. acuation time (AET).

Theodore Trafalis and Ismail Ibrahim Abbas Al-Maraj

University of Oklahoma, USA

Affinely adjustable robust optimization under dynamic uncertainty set for a novel robust closed-loop supply chain

In this paper, we propose a novel closed-loop supply chain design with multiple periods, echelons, and uncertainties. The model assumes that the quality of the produced lot size is imperfect. Thus, the amount of quality loss as conforming products deviate from the specification (target) value is measured. In addition, we assume that the screening is not always perfect, and inspection errors are more likely to take place in practice. The affinely adjustable robust formulation based on “wait and see” decisions is presented. That is, the decisions are made over two sequential stages where multiple uncertainties are included. Moreover, we propose a budget dynamic uncertainty set to mimic the dynamic behavior of the market demand over time. The introduced dynamic uncertainty set is formulated according to Vector Autoregressive (VAR) models where the temporal and spatial correlations of customer demand zones are captured. Also, we utilize different a priori probability bounds to approximate probabilistic constraints and provide a safe solution. The objective is to minimize the total cost of the supply chain network. Finally, numerical examples are provided to illustrate the proposed models. The proposed approach can significantly improve market demand

forecasting and produce less conservative robust solutions. Also, our findings provide to the decision-maker an overview of a conservatism comparison between the introduced uncertainty set under different probability bounds.

Viktor Zamaraev

University of Liverpool, UK

Sharp Thresholds in Random Simple Temporal Graphs

A graph whose edges only appear at certain points in time is called a temporal graph (among other names). Such a graph is temporally connected if each ordered pair of vertices is connected by a path which traverses edges in chronological order (i.e., a temporal path). In this work, we consider a simple model of random temporal graph, obtained from an Erdős-Rényi random graph $G_{\{n,p\}}$ by considering a random permutation π of the edges and interpreting the ranks in π as presence times. Temporal reachability in this model exhibits a surprisingly regular sequence of thresholds. In particular, we show that at $p=\log n/n$ any fixed pair of vertices can a.a.s. reach each other; at $2\log n/n$ at least one vertex (and in fact, any fixed vertex) can a.a.s. reach all others; and at $3\log n/n$ all the vertices can a.a.s. reach each other, i.e., the graph is temporally connected. Furthermore, the graph admits a temporal spanner of size $2n+o(n)$ as soon as it becomes temporally connected, which is nearly optimal as $2n-4$ is a lower bound. This result is significant because temporal graphs do not admit spanners of size $O(n)$ in general (Kempe et al, STOC 2000). In fact, they do not even admit spanners of size $o(n^2)$ (Axiotis et al, ICALP 2016). Thus, our result implies that the obstructions found in these works, and more generally, all non-negligible obstructions, must be statistically insignificant: nearly optimal spanners always exist in random temporal graphs.

All the above thresholds are sharp. Carrying the study of temporal spanners further, we show that pivotal spanners -- i.e., spanners of size $2n-2$ made of two spanning trees glued at a single vertex (one descending in time, the other ascending subsequently) -- exist a.a.s. at $4\log n/n$, this threshold being also sharp. Finally, we show that optimal spanners (of size $2n-4$) also exist a.a.s. at $p=4\log n/n$.

This is a joint work with Arnaud Casteigts (University of Bordeaux), Michael Raskin (Technical University of Munich), Malte Renken (Technical University of Berlin)

Arxiv: <https://arxiv.org/abs/2011.03738v3>

**NET 2021
Schedule
October 18**

	Speaker	Title
15:00-15:40	Plenary lecture: Cristina Masoller	Application of network techniques to ophthalmic image analysis and outlier detection
15:40-16:05	Leonidas Pitsoulis	Graphs and Data Science in Industry
16:05-16:30	Alex Dainiak	Visualizing hypergraphs: a survey
16:30-16:55	Mario Guarracino	On resiliency and robustness of whole graph embedding
16:55-17:10	Coffee break	
17:10-17:50	Ilya Chernykh	Instance reduction and problem transformation as a way of research simplification in scheduling
17:50-18:15	Theodore Trafalis	Affinely adjustable robust optimization under dynamic uncertainty set for a novel robust closed-loop supply chain
18:15-18:40	Mauricio Rezende	Multi-parent biased random-key genetic algorithm with implicit path-relinking and some real-world applications
18:40-19:00	Egor Churaev	User-dependent Adaptation of Neural Network Model in Video-based Facial Emotion Recognition

NET 2021
Schedule
October 19

	Speaker	Title
15:00-15:40	Plenary lecture: Giovanni Stracquadanio	Discovering cancer driver genes and pathways using stochastic block model graph neural networks
15:40-16:10	Vladimir Batagelj	Network multiplication and derived networks
16:10-16:35	Daniil Musatov	Fair division on graphs and hypergraphs
16:35-16:50	Coffee break	
16:50-17:20	Anuška Ferligoj	Connecting cluster analysis and network analysis
17:20-17:45	Roman Belavkin	Entropy, Free Energy and Phase Transitions in Power-Law Graphs
17:45-18:10	Dmitry Ignatov	On the optimal Boolean Matrix Factorization algorithm for contranominal scales and its outcomes for recommender systems
18:10-18:35	Vladimir Boginski	Graph-based Exploration and Clustering Analysis of Semantic Spaces
18:35-19:00	Ilias Kotsireas	20 years of Legendre Pairs

NET 2021
Schedule
October 20

	Speaker	Title
15:00-15:25	Mikhail Khachai	Problem-specific Branch-and-Bound algorithms for the Precedence Constrained Generalized Traveling Salesman Problem
15:25-15:50	Ivan Shumilov	Simple bound on integer vertices of general Δ -modular polyhedra
15:50-16:15	Viktor Zamaraev	Sharp Thresholds in Random Simple Temporal Graphs
16:15-16:40	Oleg Prokopyev	On Exact Solution Approaches for a Class of Bilevel Fractional Programs
16:40-16:50	Coffee break	
16:50-17:10	Polina Demochkina	Neural network model for fast video-based emotion recognition
17:10-17:30	Andrey Shilov	Optimization of computational graphs for deep learning models
17:30-17:50	Evgenii Burashnikov	A recent approach to optimization of computational graphs for deep learning models
17:50-18:30	Plenary lecture: Sumi Helal	Internet-of-Things: From Networking to Meaningful Interactions