XVI Summer School on Operational Research, Data and Decision Making

May, 23-24, 2024

National Research University Higher School of Economics,

Nizhny Novgorod

Faculty of Informatics, Mathematics and Computer Science

Laboratory of Algorithms and technologies for network analysis

НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ

НИЖНИЙ НОВГОРОД

LATNA

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School Lecturers

Roman Belavkin, Middlesex University, London, UK

Lecture 1: Data, Information and its Value: Applications of the Value of Information to Model Selection and Parameter Control.

Lecture 2: New Developments of the Value of Information Theory: Optimal Transport and Dynamic Value of Information

Mario Guarracino, University of Cassino, Italy and lab LATNA HSE University

Lecture 1: A Short Journey through Whole Graph Embedding Techniques (Part I)

Lecture 2: A Short Journey through Whole Graph Embedding Techniques (Part II)

Panos Pardalos, University of Florida, USA and lab LATNA HSE NN.

Lecture: Exploring Twin Support Vector Machines: Advances and Applications

Sergey Slashchinin, lab LATNA HSE NN.

Lecture: Introduction to Graph Neural Networks with Applications to Combinatorial Optimization

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

Zoom reference to access the summer school:
https://us06web.zoom.us/j/81147589981?pwd=skZgaggeb70w1kq2sgbrij4sad82XH.1
Conference ID: 811 4758 9981, Password (if any): 412208

Day 1, Thursday, May 23.

	Panos Pardalos, University of Florida, USA and lab LATNA HSE NN
15:00 – 15:50	**Lecture:** Exploring Twin Support Vector Machines: Advances and Applications.
	Mario Guarracino, University of Cassino, Italy and lab LATNA HSE University
16:00 – 16:50	**Lecture 1.** A Short Journey through Whole Graph Embedding Techniques (Part I)
17:00 – 17:50	**Lecture 2**. A Short Journey through Whole Graph Embedding Techniques (Part II)

Day 2, Friday, May 24.

	Sergey Slashchinin, lab LATNA HSE NN.
10:00 – 10:50	**Lecture:** Introduction to Graph Neural Networks with Applications to Combinatorial Optimization
	Roman Belavkin, Middlesex University, London, UK
11:00 – 11:50	**Lecture 1:** Data, Information and its Value: Applications of the Value of Information to Model Selection and Parameter Control.
12:00 – 12:50	**Lecture 2:** New Developments of the Value of Information Theory: Optimal Transport and Dynamic Value of Information

Roman Belavkin
Middlesex University, London, UK

Lecture 1: Data, Information and its Value: Applications of the Value of Information to Model Selection and Parameter Control

Information is often understood as processed or analysed data, which are records of past observations of some random variables or processes. The amount of information is often understood, according to Shannon's information theory, as a difference between the amounts of uncertainty before and after the observation, and it is measured in bits (binary information units) that have no monetary value. The value of information (VoI) theory, pioneered and developed by Ruslan Stratonovich, considers the maximum possible gain of expected utility that one bit of information can achieve. This allows us not only to price information, but also to estimate tight bounds on performance of various systems. In the context of data-driven models, the amount of information can be estimated from the training data, and the value of this information as a difference in performance of a perfect (optimal) model after and before training. Although an optimal model is usually unavailable (or unknown), it turns out that its optimal performance can often be estimated using the value of Shannon's information. I will consider three main examples:

1) Binary classification models and performance measured by accuracy from a confusion matrix;

2) Regression models and performance measured by root mean-square error;

3) Evolutionary algorithms and performance measured by the mean Hamming distance of strings (e.g. DNA strings) from an optimum.

The first two examples will demonstrate how VoI can help in model selection and parameter tuning. The last example will also demonstrate how the VoI theory can bring new insights about evolutionary systems, and in particular about self-adaptation and control of mutation.

Roman Belavkin
Middlesex University, London, UK

Lecture 2: New Developments of the Value of Information Theory: Optimal Transport and Dynamic Value of Information

In this second lecture I will discuss several recent developments of the Value of Information (VoI) theory. First, I will demonstrate the relation between VoI and the optimal transport problem (OTP) in the Kantorovich formulation. The latter is used to define the Kantorovich-Wasserstein (KW) metric. I will show that OTP is equivalent to the VoI with one additional constraint fixing the output probability measure. This means that VoI gives a lower bound on the KW-metric. Then we shall consider an extension of the VoI theory to multistep optimization problems, such as the optimal control problems in the Bellman's dynamic programming formulation. I will formulate the corresponding variational problems with multistep information constraints that lead to a generalization of the Bellman's equation that can be used to estimate optimal bounds and parameters of certain optimal control systems.

Mario Guarracino,
University of Cassino, Italy and lab LATNA HSE University

Lectures 1-2: A Short Journey through Whole Graph Embedding Techniques (Part I and II)

Networks provide suitable models in many applications, ranging from social to life sciences. Such representations are able to capture interactions and dependencies among variables or observations, and can be extended to consider ensembles of networks, thus providing simple and powerful modeling of phenomena. Whole graph embedding involves the projection of ensembles of graphs into a vector space, while retaining their structural properties. In recent years, several embedding techniques using graph kernels, matrix factorization, and deep learning architectures have been developed to learn low dimensional graph representations.
These embeddings can then be used for feature extraction, graph clustering or for building classification models. In these lectures, we survey embedding techniques which jointly embed whole graphs for classification tasks. We compare them and evaluate their performance on undirected synthetic and real world network datasets on different learning tasks.

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

Lecture: Exploring Twin Support Vector Machines: Advances and Applications

The Twin Support Vector Machine (TSVM) is a powerful extension of the conventional Support Vector Machine (SVM) algorithm, designed to address classification tasks in real world data sets. Developed as an enhancement to traditional SVMs, TWSVM offers improved robustness and efficiency, making it a compelling choice for various machine learning applications.

In this lecture, we delve into the theoretical foundations and practical implications of the Twin Support Vector Machine. We begin by elucidating the fundamental concepts behind SVMs and the motivation for the development of TWSVM. We explore the key principles underpinning TWSVM, including the formulation of the twin optimization problem and the incorporation of twin constraints for enhanced classification performance.

Furthermore, we delve into the algorithmic intricacies of TWSVM, elucidating its training procedure, kernelization techniques, and model evaluation methods. We highlight how TWSVM effectively addresses the challenges posed by high-dimensional datasets, thereby enhancing its applicability across diverse real-world scenarios. Moreover, we investigate recent advancements and extensions of TWSVM, particularly focusing on optimization techniques that have been developed to further improve its performance and scalability.

Through this lecture, participants will gain a comprehensive understanding of the Twin Support Vector Machine and its significance in modern machine learning research and applications. We aim to equip attendees with the knowledge and insights necessary to leverage TWSVM effectively in their data analysis endeavors, fostering innovation and advancement in the field of computational intelligence.

References:

Moosaei, Hossein, Fatemeh Bazikar, Milan Hladík, and Panos M. Pardalos. "Sparse least-squares Universum twin bounded support vector machine with adaptive Lp-norms and feature selection." Expert Systems with Applications (2024): 123378. https://doi.org/10.1016/j.eswa.2024.123378

Moosaei, Hossein, Fatemeh Bazikar, and Panos M. Pardalos. "An improved multi-task least squares twin support vector machine." Annals of Mathematics and Artificial Intelligence (2023): 1-21. https://link.springer.com/article/10.1007/s10472-023-09877-8

Sergey Slashchinin
Lab LATNA HSE University

Lecture: Introduction to Graph Neural Networks with Applications to Combinatorial Optimization

The first part of the lecture introduces the fundamentals of Graph Neural Networks (GNN), a rapidly evolving machine learning architecture that exploits the natural graph structure in data. We will cover the basic principles of GNNs, including their architecture, how they process information, and the types of problems they are suited to address.

The second part of the lecture focuses on the application of Graph Neural Networks (GNN) for solving combinatorial optimization problems. We will explore modern approaches on how GNNs can be applied to a variety of operations research issues, including minimum vertex cover, maximum independent set, etc.