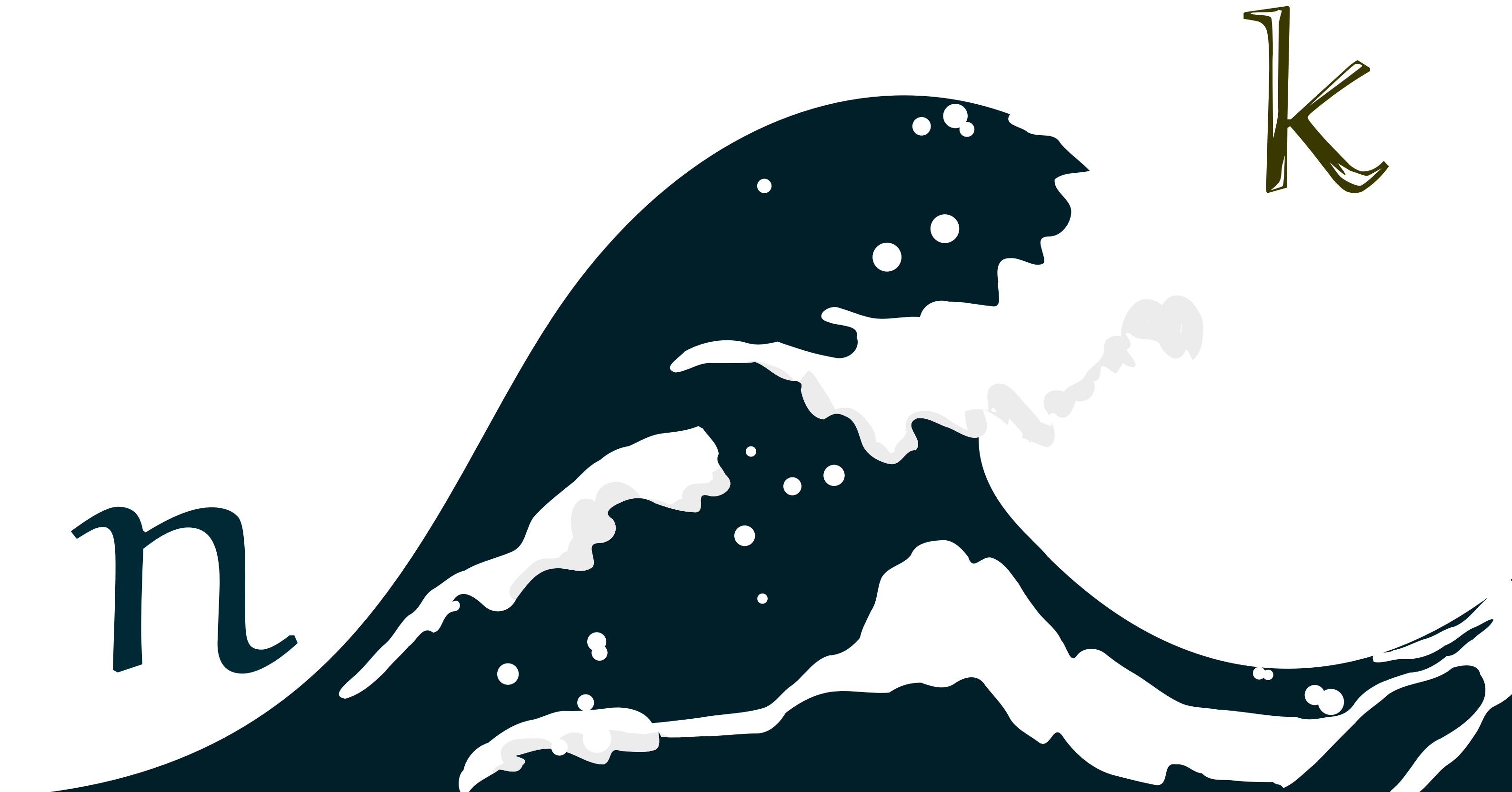
FPT Fest 2023

in the honour of Mike Fellows

June 12 — June 16
2023



Contents

Slots 1

Invited talks

Flow-augmentation

Marcin Pilipczuk

Day: Monday

Time: 09:00—10:00

Abstract. The recently introduced technique of *flow-augmentation* turned out to be not only an important missing ingredient in determining parameterized complexity of some graph separation problems, but also plays a crucial role in exploring tractability of the MinCSP problem in various settings. The MinCSP problem asks to find an assignment to a given constraints satisfaction problem instance that violates at most k constraints, where k is the parameter.

In the talk I will explain the technique, show basic usage on some examples, survey the recent developments, and outline future directions.

Parameterized Algorithms and Computational Experiments

André Nichterlein

Day: Monday

Time: 16:30—17:30

Abstract. The Parameterized Algorithms and Computational Experiments Challenge (PACE) was conceived in Fall 2015 to deepen the relationship between parameterized algorithms and practice. Topics from multivariate algorithms, exact algorithms, fine-grained complexity, and related fields are in scope.

PACE aims to:

- Bridge the divide between the theory of algorithm design and analysis, and the practice of algorithm engineering
- Inspire new theoretical developments
- Investigate in how far theoretical algorithms from parameterized complexity and related fields are competitive in practice
- Produce universally accessible libraries of implementations and repositories of benchmark instances
- Encourage the dissemination of these findings in scientific papers

I will start the talk with a brief overview of PACE. The main part is on discussing opportunities and research challenges PACE presents to the parameterized algorithms community.

Visibility Problems, Geometric Intersection Graphs, and Graph Drawing

Meirav Zehavi

Day: Tuesday

Time: 09:00—10:00

Abstract. We will discuss three topics in *Computational Geometry* that have received significant attention from the perspective of Parameterized Complexity in the past few years. First, we will consider visibility problems, focusing on Art Gallery and Terrain Guarding. Second, we will consider the design of subexponential parameterized algorithms for problems on *geometric intersection graphs*, particularly (unit) disk graphs. Lastly, we will discuss parameterized graph drawing problems, with emphasis on crossing minimization.

For each topic, we will briefly discuss some basics and related works, as well as some technical details of a result in that area.

History of Parameterized Algorithms and Complexity

Dániel Marx

Day: Wednesday

Time: 09:00—10:00

Abstract. Since its inception in the 80s, the field of parameterized algorithms and complexity has undergone enormous developments. A wide range of algorithmic problems have been studied, a rich toolbox of techniques has been created, and novel questions have been posed and solved. The talk will provide a historical overview of these developments.

Parameterized complexity and the model-checking problem

Szymon Toruńczyk

Day: Thursday

Time: 09:00—10:00

Abstract. I will discuss old and new developments in the areas of algorithmic meta-theorems and model-checking of first-order formulas on graphs. For instance, it is known that model-checking of monadic second-order formulas is FPT on classes of bounded clique-width, and that model-checking of first-order formulas is FPT on nowhere dense classes.

More recent results concern classes of bounded twin-width and interpretations of nowhere dense classes.

Computing treewidth

Tuukka Korhonen

Day: Thursday

Time: 16:30—17:30

Abstract. The graph parameter treewidth is fundamental in the field of parameterized algorithms, both as a widely studied structural parameter in itself and as a building block of other algorithms. As algorithms using treewidth require a tree decomposition of small width as an input, the problem of finding such a tree decomposition is important.

In this talk I will first give an overview about the classical algorithms on computing treewidth, and then talk about recent new methods and results in treewidth computation.

Counting complexity

Marc Roth

Day: Friday

Time: 09:00—10:00

Abstract. Classically, computational problems ask to find solutions, optimise solutions or to decide whether a solution exists. As the name suggests, problems considered in counting complexity theory require to compute the number of solutions. Some of the earliest results stem from applications in statistical physics. Arguably the most famous example is the computation of the partition function of the dimer model; in the language of graph theory, this problem is equivalent to counting perfect matchings in planar graphs. Independently, in the late 60s, Fisher, Kasteleyn, and Temperley proved that this problem can be solved in polynomial time by what we call today the *FKT algorithm*.

It took almost another 20 years until the (structural) foundations of computational counting have been laid out by Valiant, and it has since turned out that counting appears to be inherently more difficult than decision. For example, works of Valiant and Toda show that counting perfect matchings (in not necessarily planar graphs) is harder than any problem in the polynomial-time hierarchy — in sharp contrast, the decision problem of finding a perfect matching is solvable in polynomial time.

With few exceptions, such as the FKT algorithm and Kirchhoff's Theorem for counting spanning trees, similar hardness results have been established for most interesting counting problems. For this reason the community started to tackle those problems from different angles of relaxations. One natural example is the field of approximate counting, where the goal is to approximately compute the number of solutions with a reasonably high probability; one of the most famous results in this context is the celebrated Markov–Chain Monte–Carlo algorithm for approximating the number of perfect matchings in bipartite graphs due to Jerrum, Sinclair, and Vigoda, which sparked a renaissance in the study of Markov–Chains from the perspective of complexity theory.

Another relaxation, the one we focus on in this talk, is to consider the parameterised complexity of counting problems. After parameterised counting was independently introduced by Flum and Grohe, and by McCartin in 2002, the field stayed relatively calm for about a decade until it suddenly flourished into a well-established subfield of parameterised complexity theory with a burst of exciting new results and techniques that find applications beyond just the world of FPT such as fine-grained complexity theory, database theory, network science, and bioinformatics.

In this talk, I will provide an introduction to parameterised counting and present a selection of the most influential results and techniques that have been introduced in the last decade. Moreover, I will discuss a couple of open problems that are either fundamental for our structural understanding of parameterised counting or that have prominently been studied in recent years but evaded a resolution so far. The talk does not assume any background in counting complexity theory.

Slots 2

Mini–symposia

MINI–SYMPOSIUM

Mathematical programming

Martin Koutecký

Day: Monday

Time: 10:30—12:30

Track: A

10:30 — 11:00
Hans Raj Tiwary: Extended Formulation through the FPT lens

11:00 — 11:10
Tiny break

11:10 — 11:40
Alexandra Lassota: Block Integer Programs, Graver Elements, and How to Use Them

11:40 — 11:50
Equally tiny break

11:50 — 12:30
Open Problems Session (bring your favorite problem explainable in < 7min)

Extended Formulations through the FPT lens
Hans Raj Tiwary (Charles University)

Extended formulations provide a powerful framework to reducing the size of an LP (sometimes) dramatically. More recently they have also been used to prove unconditional lower bounds showing limitations of LP-based approaches. In this talk I will provide a brief introduction to this notion and cover some known results related to some problems that are popular in the FPT community.

Block Integer Programs, Graver Elements, and How to Use Them
Alexandra Lassota (EPFL)

This talk is about a fixed-parameter tractable case of integer programs, namely block-structured IPs. The aim is to give a lightweight overview on known results, (algorithmic) techniques, and applications of these IPs for problems from combinatorial optimization.

Open Problem Session
Chair: Martin Koutecký

Bring your favorite problem explainable in ≤ 7 min

MINI–SYMPOSIUM

Flow augmentation and cut problems

Magnus Wahlström

Day: Monday

Time: 10:30—12:30

Track: B

Flow Augmentation is a natural, simple-to-state result with significant consequences in parameterized complexity, including breakthrough FPT algorithms for a range of cut problems and supporting MinCSP complexity characterization results (some of which is surveyed in other sessions this week).

In this mini-symposium, following on Marcin's talk on the topic, we will dig deeper into flow augmentation to give an idea of how the flow augmentation procedure works, and give a selection of more advanced applications.

> **The flow augmentation procedure**
> Magnus Wahlström
>
> In this session, we look at the flow augmentation procedure itself, to give an idea of its workings and the principles of its correctness proof. We may (to the extent of time) also discuss possible extensions.

> **Parameterized complexity landscape of weighted cut problems: thanks to flow augmentation**
> Roohani Sharma
>
> In this talk, we provide more applications of flow augmentation, and the MinSAT fixed-parameter tractability islands that it yields. In particular, using, as a black-box, the results that Marcin presents in his *Flow Augmentation* talk, we will focus on designing FPT algorithms for Weighted Subset Directed Feedback Arc Set and Weighted Multicut. We then highlight some simple reductions via which these FPT results can be extended to other problems. We conclude by painting a fairly complete picture of the parameterized complexity landscape of some classical *weighted* cut problems.

Weighted Almost 2-SAT with flow-augmentation

Eunjung Kim

In the problem Almost 2-SAT, we are given as input a 2-CNF formula and a non-negative integer k, and asked to find a truth assignment that violates at most k clauses. An FPT-algorithm was presented by Razgon and O'Sullivan in 2008, and whether the weighted version of Almost 2-Sat can be solved in FPT-time remained open along with other graph separation problems. In this talk, we shall see how the weighted Almost 2-Sat can be cast as an (s, t)-cut problem and how the flow-augmentation technique is deployed based on the structure of the instance.

This talk is based on a joint work with Stefan Kratsch, Marcin Pilipczuk and Magnus Wahlström.

MINI–SYMPOSIUM

Twinwidth

EUNJUNG KIM

Day: Monday

Time: 14:00—16:00

Track: A

Twin-width is a graph parameter introduced in 2020 by Bonnet, Kim, Thomassé, Watrigant, which quickly gained much traction since then.

Brief overview on twin-width
EUNJUNG KIM

Many well-studied graph classes like bounded tree-width and rank-width graphs, unit interval graphs, strict hereditary classes of permutations, minor-closed graph classes are known to have bounded twin-width, thus the list of bounded twin-width classes include both spare and dense graph classes. In this talk, we give an overview of twin-width.

Algorithms on graphs of bounded twin-width
RÉMI WATRIGANT

In this talk we will present the main algorithmic techniques in order to solve problems on graphs of bounded twin-width. In particular we will focus on efficient parameterized algorithms, existence of polynomial kernels, and approximation algorithms for fundamental problems such as MAXIMUM INDEPENDENT SET and MINIMUM DOMINATING SET. We will also present some open problems in this line of research.

Compact representation for matrices of bounded twin-width
MAREK SOKOŁOWSKI

We will sketch how to design, for every fixed $d \in N$, a data structure that represents a binary $n \times n$ matrix that is d-twin-ordered (an example of such a matrix is, for instance, an adjacency matrix of a graph of small twin-width). The data structure occupies $O_d(n)$ bits, which is the least one could hope for, and can be queried for entries of the matrix in time $O_d(\log \log n)$ per query.

Bounded twin-width graphs are polynomially chi-bounded

Romain Bourneuf

In 2020, Bonamy and Pilipczuk proved that graphs of bounded rank-width are polynomially chi-bounded. We extend this result to graphs of bounded twin-width.

In the talk, I will present some tools we introduced to prove this result, and mention some applications of these tools in the field of twin-width.

This is joint work with Stéphan Thomassé

Fixed-parameter tractability of Directed Multicut with tree terminal pairs parameterized by the size of the cutset: twin-width meets flow-augmentation

Marcin Pilipczuk

We show fixed-parameter tractability of the Directed Multicut problem with three terminal pairs (with a randomized algorithm). This problem, given a directed graph G, pairs of vertices (called *terminals*) (s_1, t_1), (s_2, t_2), and (s_3, t_3), and an integer k, asks to find a set of at most k non-terminal vertices in G that intersect all $s_1 t_1$-paths, all $s_2 t_2$-paths, and all $s_3 t_3$-paths. The parameterized complexity of this case has been open since Chitnis, Cygan, Hajiaghayi, and Marx proved fixed-parameter tractability of the 2-terminal-pairs case at SODA 2012, and Pilipczuk and Wahlström proved the W[1]-hardness of the 4-terminal-pairs case at SODA 2016.

On the technical side, we use two recent developments in parameterized algorithms. Using the technique of *directed flow-augmentation* [Kim, Kratsch, Pilipczuk, Wahlström, STOC 2022] we cast the problem as a CSP problem with few variables and constraints over a large ordered domain. We observe that this problem can be in turn encoded as an FO model-checking task over a structure consisting of a few 0-1 matrices. We look at this problem through the lenses of twin-width, a recently introduced structural parameter [Bonnet, Kim, Thomassé, Watrigant, FOCS 2020]: By a recent characterization [Bonnet, Giocanti, Ossona de Mendes, Simon, Thomassé, Toruńczyk, STOC 2022] the said FO model-checking task can be done in FPT time if the said matrices have bounded grid rank. To complete the proof, we show an irrelevant vertex rule: If any of the matrices in the said encoding has a large grid minor, a vertex corresponding to the "middle" box in the grid minor can be proclaimed irrelevant — not contained in the sought solution — and thus reduced.

MINI–SYMPOSIUM

Graph Isomorphism

Daniel Neuen

Day: Monday

Time: 14:00—16:00

Track: B

The mini-symposium discusses the parameterized complexity of the graph isomorphism problem. For this problem, our focus lies on structural parameterizations (e.g., maximum degree, tree-width, genus, size of a forbidden minor, rank-width, etc). While XP algorithms for many parameters have been known for several decades, FPT algorithms have either only been obtained recently (e.g., tree-width, genus, size of a forbidden minor) or remain elusive (e.g., maximum degree, rank-width). Also, following Babai's quasipolynomial isomorphism test, a series of parameterized algorithms with a running time of the form $n^{\mathrm{polylog}(k)}$ have been obtained.

The symposium features four talks on recent developments on the parameterized complexity of isomorphism testing. The results rely on a variety of different techniques including combinatorial and group-theoretic approaches, graph-theoretic methods and logical tools.

> **Parameterized Algorithms for Graph Isomorphism - Decompositions via Regularity**
> Daniel Neuen
>
> We discuss a decomposition-based approach to the graph isomorphism problem where we aim to decompose an input graph in an isomorphism-invariant manner into irregular pieces (for some suitable notion of irregularity). In combination with combinatorial and group-theoretic approaches to graph isomorphism, this allows us to design new parameterized algorithms for isomorphism testing.
>
> In part based on joint works with Martin Grohe, Pascal Schweitzer, and Daniel Wiebking.

Fixed-parameter tractability of Graph Isomorphism in graphs with an excluded minor

Marcin Pilipczuk

We prove that Graph Isomorphism and Canonization in graphs excluding a fixed graph H as a minor can be solved by an algorithm working in time $f(H) \cdot n^{\mathcal{O}(1)}$, where f is some function. In other words, we show that these problems are fixed-parameter tractable when parameterized by the size of the excluded minor, with the caveat that the bound on the running time is not necessarily computable. The underlying approach is based on decomposing the graph in a canonical way into unbreakable (intuitively, well-connected) parts, which essentially provides a reduction to the case where the given H-minor-free graph is unbreakable itself. This is complemented by an analysis of unbreakable H-minor-free graphs, which reveals that every such graph can be canonically decomposed into a part that admits few automorphisms and a part that has bounded treewidth.

This is joint work with Daniel Lokshtanov, Michał Pilipczuk, and Saket Saurabh.

Testing isomorphism of chordal graphs of bounded leafage is fixed-parameter tractable

Peter Zeman

The computational complexity of the graph isomorphism problem is considered to be a major open problem in theoretical computer science. It is known that testing isomorphism of chordal graphs is polynomial-time equivalent to the general graph isomorphism problem. Every chordal graph can be represented as the intersection graph of some subtrees of a representing tree, and the leafage of a chordal graph is defined to be the minimum number of leaves in a representing tree for it. We prove that chordal graph isomorphism is fixed parameter tractable with leafage as parameter. In the process we introduce the problem of isomorphism testing for higher-order hypergraphs and show that finding the automorphism group of order-k hypergraphs with vertex color classes of size b is fixed parameter tractable for any constant k and b as fixed parameter.

This is joint work with Vikraman Arvind, Roman Nedela, and Ilia Ponomarenko.

Canonical decompositions of graphs of bounded shrubdepth

Szymon Toruńczyk

We use a fundamental tool from model theory, called forking, to obtain decomposition results for some graph classes. As an application, we show that for any fixed graph class $\mathcal{C}$ of bounded shrubdepth, there is an $O(n^2)$-time algorithm that given an n-vertex graph $G \in \mathcal{C}$, computes in an isomorphism-invariant way a structure H of bounded treedepth in which G can be interpreted. A corollary of this result is an $O(n^2)$-time isomorphism test and canonization algorithm for any fixed class of bounded shrubdepth.

This is joint work with Pierre Ohlmann, Michał Pilipczuk, and Wojciech Przybyszewski.

MINI–SYMPOSIUM

Structural parameterizations

Ignasi Sau

Day: Tuesday

Time: 10:30—12:30

Track: A

This mini-symposium will focus on *structural parameterizations*, a topic which has been steadily receiving attention within the parameterized complexity community in the last years. In a nutshell, the motivation is to parameterize a problem by a parameter that quantifies some relevant aspect of the structure of the input of the problem (typically, a graph). In particular, this paradigm has given rise to the definition of several parameters that have triggered new insights to tackle a number of problems, and the four talks of this mini-symposium will provide an overview of some of the recent results on this area. Each talk will last 30 minutes, including questions.

Efficient algorithms with $\mathcal{H}$-treewidth

Michał Włodarczyk (Ben Gurion University of the Negev, Israel)

$\mathcal{H}$-treewidth generalizes treewidth by treating subgraphs from the graph class $\mathcal{H}$ as 'simple' and allowing the bags in a decomposition to have unbounded size as long as they induce subgraphs from $\mathcal{H}$. While $\mathcal{H}$-treewidth can extend the horizon of tractability for various problems, there are two algorithmic challenges on the way of getting 'reasonable' running times. The first one is how to compute a decomposition of a graph promised to have low $\mathcal{H}$-treewidth and the second is how to exploit the decomposition for solving problems like $\mathcal{H}$-Vertex-Deletion. I will begin with a survey on what happened in this area in the last years, explaining two different approaches to these challenges. Then I will move on to our recent result about computing an almost optimal-width decomposition efficiently.

Joint work with Bart M. P. Jansen and Jari J. H. de Kroon.

Universal obstructions of graph parameters

Dimitrios M. Thilikos (LIRMM, Université de Montpellier, CNRS, France)

We propose a graph-parametric framework for obtaining obstruction characterizations of graph parameters with respect to partial ordering relations. For this, we define the notions of class obstruction, parametric obstruction, and universal obstruction as combinatorial objects that determine the asymptotic behavior of graph parameters. Our framework permits a unified framework for classifying graph parameters. Under this framework, we present several universal obstructions of known and of new graph parameters.

Joint work with Laure Morelle, Christophe Paul, Evangelos Protopapas, and Sebastian Wiederrecht.

Kernelization of hitting problems under structural parameterizations

Marin Bougeret (LIRMM, Université de Montpellier, France)

We consider the kernelization of classical hitting problems on graphs, such as Vertex Cover or Triangle Hitting, under structural parameters, rather than classical parameterization by solution size. In this talk we will

- explain why the so-called "distance-to-triviality" parameters are good candidates for kernelization,
- give some insights on kernelization techniques with these parameterizations (role of minimal blocking sets, importance to have a measure quantifying the triviality, etc.), and
- if time permits, give a word on hardness results and the complexity dichotomies we are currently aiming for.

Based on joint work with Bart M. P. Jansen and Ignasi Sau.

Structural graph parameters based on edge cuts

Robert Ganian (Institute of Logic and Computation, Technische Universität Wien, Austria)

While treewidth is a decompositional graph parameter which guarantees the existence of a graph decomposition along small vertex separators, in some settings it is necessary to decompose the graph along small edge cuts instead. The targeted study of decompositional parameters which allow us to decompose graphs along small edge cuts has only begun in the last decade, and this talk provides a brief survey of the area with a focus on recent breakthroughs and algorithmic applications.

MINI–SYMPOSIUM

Exact algorithms

Jesper Nederlof

Day: Tuesday

Time: 10:30—12:30

Track: B

During this workshop, Jesper Nederlof will first give a general presentation about the field of exact algorithms, starting with an overview and ending with some recent results. Afterwards, Daniel Lokshtanov will speak about an algorithm for the min k-cut problem and subsequently Alexandra Lassota will speak about the vector bin packing problem.

Exact algorithms
Jesper Nederlof

We give a general presentation about the field of exact algorithms, starting with an overview and ending with some recent results.

The min k-cut problem
Daniel Lokshtanov

We present an exact algorithm for the min k-cut problem.

Vector Bin Packing with Few Small Items
Alexandra Lassota

(Vector) Bin Packing, in general NP-hard, can be solved in polynomial time for instances with just large items via Matchings. Measuring the distance to trivially solvable instances in the parameter, (Vector) Bin Packing can be solved in time FPT parameterized by the number of small items.
This talk presents such an algorithm that uses Fast Exact Matchings and a lower bound proving its optimality.

MINI–SYMPOSIUM

Computational Social Choice

Jiehua Chen (TU Wien, Vienna)

Day: Tuesday

Time: 14:00—16:00

Track: A

Computational Social Choice (COMSOC) is concerned with the computational and algorithmic aspects of problems arising from social choice and decision making such as how to aggregate individual preferences or judgments to reach a consensus, how to shortlist candidates or select representatives, how to match schools or colleges to students based on their preferences, how to divide players into groups based on their utilities, or how to fairly allocate a set of resources to some agents.

Many COMSOC problems are known to be computationally difficult. Despite this difficulty, exact solutions are crucial in various domains, making it important to explore these problems through the lens of parameterized complexity. In this minisymposium, we will examine four highly relevant COMSOC topics presented by experts in their respective fields.

Each presentation will provide an overview of the current research in the field, shedding light on the need for parameterized algorithmic investigation and unveiling potential research directions for future exploration.

> **The Complexity of Detecting Ties in Multi-winner Elections (And Related Problems)**
>
> Piotr Faliszewski (AGH University of Science and Technology)
>
> Over the recent years, study of multi-winner voting has made great progress. We currently know quite a number of rules that find committees that achieve individual excellence, diversity, or proportionality. Some of these rules are intractable, but there are many ways of circumventing this problem (e.g., by using FPT algorithms), and some rules are computable in polynomial time. However, finding some winning committee may not be enough in practice. Indeed, surprisingly often small and medium-sized elections lead to ties and it is important to both detect the ties and have a good way of dealing with them. In this talk I will present recent progress on this issue, together with some challenges for parameterized algorithms.

Recent Advances in Parameterized Matching Markets

Ildikó Schlotter (Budapest University of Technology and Economics)

We survey the role of parameterized complexity in recent research about matching markets. We first look at classic problems in the area such as the Stable Matching, the Stable Roommates, and the Hospitals / Residents problems and their computationally hard variants. We exhibit how the parameterized complexity framework has influenced the study of these problems. We also consider problems that capture aspects or scenarios that are not reflected in the classic models: prominent examples include the investigations of dynamic settings, questions about manipulation by external agents, or generalizations to hypergraphs in various forms. These areas have been the subject of intense research in the last few years, and parameterized complexity has greatly contributed to the understanding of their computational complexity.

We finish with highlighting possible directions for future research.

Coalition Formation Games

Jörg Rothe (Heinrich–Heine–Universität Düsseldorf)

Some of the recent results on coalition formation games (in particular, on hedonic games) are surveyed in this talk. Hedonic games are cooperative games where the players have preferences on the coalitions they may join. Common stability notions (such as Nash stability or core stability) can be used to predict which coalition structure is likely to form.

The main focus of this talk is on the algorithmic aspects and computational complexity results for the existence and verification problem of such stability concepts in various types of hedonic games.

Resource Allocation

Haris Aziz (UNSW Sydney)

There are many problems in which both fairness and efficiency are important considerations. Recent examples from the operations research literature are scheduling, disaster relief, vehicle routing ambulance planning, and multi-portfolio optimization.
In this tutorial we focus on algorithms for allocating indivisible goods among agents. Such algorithms have broad impact in a number of areas including school choice, conference paper assignment, course allocation, warehouse delivery, and many others. Two often competing objectives are balancing the welfare of the allocation, defined as the sum of the utilities of the agents, with the fairness, which concerns the utility of each individual agent.

MINI–SYMPOSIUM

Kernelization and beyond

BART M. P. JANSEN

Day: Tuesday

Time: 14:00—16:00

Track: B

The mini-symposium consists of two parts. The first part is a 60-minute talk by Fedor Fomin, for which the details can be found below. The second part consists of an interactive session, chaired by Bart Jansen, in which the status of the most prominent open problems in kernelization is discussed based on experiences from people who have worked on them.

Kernelization: past, now and future.
FEDOR V. FOMIN

In this talk, we explore the historical origins and evolution of kernelization, a powerful technique in polynomial time preprocessing. We highlight advancements in kernelization algorithms and their relevance to practical applications. Additionally, we discuss open problems that could shape the future development of the area.

The current status of long-standing open problems
Chair: BART M. P. JANSEN

Interactive session based on material gathered from experts in the field.

MINI–SYMPOSIUM

Treewidth and relatives

Dimitrios M. Thilikos

Day: Thursday

Time: 10:30—12:30

Track: A

Dynamic treewidth
Tuukka Korhonen

We present a data structure that for a dynamic graph G that is updated by edge insertions and deletions, maintains a tree decomposition of G of width at most $6k+5$ under the promise that the treewidth of G never grows above k. The amortized update time is $\mathcal{O}_k(2^{\sqrt{\log n}\log\log n})$, where n is the vertex count of G and the $\mathcal{O}_k$-notation hides factors depending on k. In addition, we also obtain the dynamic variant of Courcelle's Theorem: for any fixed property φ expressible in the CMSO_2 logic, the data structure can maintain whether G satisfies φ within the same time complexity bounds. To a large extent, this answers a question posed by Bodlaender [WG 1993].

This is joint work with Konrad Majewski, Wojciech Nadara, Michał Pilipczuk, and Marek Sokołowski.

Threshold Treewidth and Hypertree Width
Stefan Szeider

The Constraint Satisfaction Problem (CSP) is XP-tractable but W[1]-hard for the parameters primal treewidth and hypertree width if the variables range over an unbounded domain of possible values. We introduce an enhancement of tree and hypertree width through a novel notion of thresholds, allowing the decompositions to consider information about the computational costs of solving the given CSP instance. Aside from introducing these notions, we obtain efficient theoretical and empirical algorithms for computing threshold treewidth and hypertree width and and show that these parameters give rise to fixed-parameter algorithms for CSP and other, more general problems. We also briefly report on experimental evaluations regarding heuristics and exact methods based on SAT/SMT encodings.

Joint work with Robert Ganian, Andre Schidler, and Manuel Sorge.

Chopping stuff up to decide things fast

Benjamin Merlin Bumpus

Structural graph theorists and algorithmicists alike know that it is usually a smart idea to decompose graphs into smaller and simpler parts before trying answer difficult questions. Tree decompositions are one of the best-known ways of chopping graphs up and they have been key tools for establishing deep results in many areas of discrete mathematics including graph minor theory and algorithmic meta-theorems. But what happens if we want to compute on other kinds of mathematical structures? In this talk I will explain how to use the recent, category-theoretic notion of a structured decomposition (a way of decomposing arbitrary mathematical objects, not just graphs) to solve any decision problem that is encoded as a sheaf in fixed-parameter tractable time.

This work is part of a large interdisciplinary project which so far has required a blend of structural graph theory, parameterized complexity, category theory and sheaf theory. As such you should consider it an invitation to get involved in the future!

Faster parameterized algorithms for modification problems to minor-closed classes

Laure Morelle

Let $\mathcal{G}$ be a minor-closed graph class and let G be an n-vertex graph. We say that G is a *k-apex* of $\mathcal{G}$ if G contains a set S of at most k vertices such that $G \setminus S$ belongs to $\mathcal{G}$. Our first result is an algorithm that decides whether G is a k-apex of $\mathcal{G}$ in time $2^{\mathsf{poly}(k)} \cdot n^2$. This algorithm improves the previous one, given by Sau, Stamoulis, and Thilikos [ICALP 2020, TALG 2022], whose running time was $2^{\mathsf{poly}(k)} \cdot n^3$. The *elimination distance* of G to $\mathcal{G}$, denoted by $\mathsf{ed}_{\mathcal{G}}(G)$, is the minimum number of rounds required to reduce each connected component of G to a graph in $\mathcal{G}$ by removing one vertex from each connected component in each round. Bulian and Dawar [Algorithmica 2017] provided an FPT-algorithm, with parameter k, to decide whether $\mathsf{ed}_{\mathcal{G}}(G) \leq k$. This algorithm is based on the computability of the minor-obstructions and its dependence on k is not explicit. We extend the techniques used in the first algorithm to decide whether $\mathsf{ed}_{\mathcal{G}}(G) \leq k$ in time $2^{2^{2^{\mathsf{poly}(k)}}} \cdot n^2$. This is the first algorithm for this problem with an explicit parametric dependence in k. In the special case where $\mathcal{G}$ excludes some apex-graph as a minor, we give two alternative algorithms, one running in time $2^{2^{\mathcal{O}(k^2 \log k)}} \cdot n^2$ and one running in time $2^{\mathsf{poly}(k)} \cdot n^3$.

This is joint work with Ignasi Sau, Giannos Stamoulis, and Dimitrios M. Thilikos

MINI–SYMPOSIUM

Scheduling

CÉLINE SWENNENHUIS

Day: Thursday

Time: 10:30—12:30

Track: B

In this mini–symposium, we will explore the application of parameterized complexity to scheduling. The talks by Danny Hermelin and Dušan Knop will showcase two notable results in this field. Additionally, Matthias Mnich will discuss some of the key challenges for parameterized scheduling. The remaining time of the mini–symposium will be an interactive session where we can collectively explore open problems.

Weighted Number of Tardy Jobs parameterized by $p_\#$
DANNY HERMELIN

In this talk we discuss the following open problem: What is the parameterized complexity of the weighted number of tardy jobs on a single machine problem, parameterized by the number of distinct processing times? We show that this problem can be resolved negatively when generalizing the problem to the batch scheduling with release times setting.

This is joint work with Matthias Mnich and Simon Omlor.

Makespan Minimization Parameterized by the Largest Processing Time
DUŠAN KNOP

Makespan minimization is arguably the most natural and studied scheduling problem. We study the makespan minimization problem and show fixed-parameter tractability for the parameter the maximum processing time $p_{\max}$).

Our main tool is n-fold integer programming, a variable dimension technique that we believe to be highly relevant for the parameterized complexity community. It follows that makespan minimization parameterized by the longest job processing time $p_{\max}$ has a kernelization yielding a reduced instance whose size is exponential in $p_{\max}$.

We give a polynomial kernel: Our algorithm first solves the Configuration LP and based on its solution constructs a solution for an intermediate problem, called HUGE N-FOLD INTEGER PROGRAMMING. This solution is further reduced in size by a series of steps until its encoding length is polynomial in the parameters. Then, we show that HUGE N-FOLD IP is in NP, which implies that there is a polynomial reduction back to our scheduling problem, yielding a kernel.

Joint work with Martin Koutecký.

Key Challenges in Parameterized Scheduling: Recent Progress and Future Directions

Matthias Mnich (by Danny Hermelin)

Scheduling is to process a large number of jobs under limited resources like machines as effectively as possible. Scheduling allows to model an abundance of human and computerized planning problems, which is to create a schedule that assigns the tasks to machines according to various types of constraints, e.g., limited capabilities of the machines, or precedence relations between the tasks. Since the 1960s, thousands of scheduling problems have been classified as being tractable or intractable by the classical one-dimensional theory which measures complexity of problems only in terms of the size of the large data sets that form the problem input.

The analysis of algorithms for scheduling problems is a fruitful and active research field since the 1960s. In the past decade, a new branch has spun off, that of designing parameterized algorithms and analyzing the parameterized complexity of scheduling problems. We present significant progress on characterizing the complexity of fundamental scheduling problems by analysing their parameterized complexity. We then highlight open problems and challenges that lie ahead. In particular, even for some of the most basic problems in scheduling it is still unknown whether they are fixed-parameter tractable for highly natural parameters such as the number of distinct processing times of the jobs in the input instance.

Open problems discussion

Chair: Céline Swennenhuis

During the open problems discussion, there will be the opportunity to present and discuss (other) open problems related to FPT in scheduling.

MINI–SYMPOSIUM

Fixed-Parameter Tractability in Machine Learning

Robert Ganian

Day: Thursday

Time: 14:00—16:00

Track: A

The mini-symposium is dedicated to the nascent role played by fixed-parameter tractability in the world of machine learning research. It will consist of three highlight talks followed by an open discussion, with each of the talks focusing on one area where the parameterized complexity paradigm has recently led to a deeper understanding of fundamental questions in machine learning.

> **Recent developments**
> Cornelius Brand
>
> The first of the three talks will be dedicated to some very recent developments in the intersection of parameterized and sample complexity. It will provide a basic overview of the PAC learning framework, introduce a parameterized generalization of efficient PAC-learnability and explain the connection between these frameworks and the parameterized complexity of consistency-checking problems.

> **Computing decision trees**
> Sebastian Ordyniak
>
> The second talk will be dedicated to the fundamental problem of computing "good" decision trees from provided data. It will include a parameterized complexity analysis of the problem and draw a detailed complexity map for the most natural parameters associated with the problem.

> **Bayesian network structure learning**
> Christian Komusiewicz
>
> The final of the three highlight talks will be dedicated to the parameterized complexity of Bayesian network structure learning, i.e., the problem of discovering a Bayesian network that optimally represents a given set of training data. It will outline the initial parameterized upper and lower bounds for the problem as well as some of the most recent advances in our understanding of the problem's complexity.

Open discussion

Chair: Robert Ganian

The mini-symposium will end with an open discussion which will focus on future developments in the field and other areas of machine learning research where the parameterized complexity paradigm has been (or perhaps could be) used to push beyond the state of the art. There will also be space for participants to mention their research in the area—either spontaneously in just a brief oral description, or via a short ($\leq$ 5 min.) mini-presentation.

MINI–SYMPOSIUM

Algorithmic meta-theorems and logic

Sebastian Siebertz

Day: Thursday

Time: 14:00—16:00

Track: B

Algorithmic meta-theorems provide general explanations when and why certain algorithmic problems can be solved efficiently. They are typically formulated in terms of logic (defining the descriptive complexity of the problems) and structural properties of their inputs. A prototypical algorithmic meta-theorem is Courcelle's Theorem, stating that every graph property definable in monadic second-order logic (MSO) can be decided in linear time on every graph class of bounded treewidth. Similarly, as shown by Grohe et al., every graph property definable in first-order logic (FO) can be tested efficiently on every nowhere dense graph class.

In the first talk of the mini-symposium, Szymon Toruńczyk will present an exciting new width measure, called *flip-width*. This measure has strong connections to first-order logic and we are excited to see if it can lead to new meta-theorems.

In the second talk, Ignasi Sau will present an algorithmic meta-theorem for compound logics for modification problems. This logic is sandwiched between FO and MSO and can express many interesting graph properties.

> **Flip-width**
> Szymon Toruńczyk (University of Warsaw)
> I will define a new graph parameter called flip-width. This parameter is defined in terms of a generalization of the Cops and Robber game, to dense graphs. Graph classes of bounded flip-width include classes of bounded expansion of Nešetřil and Ossona de Mendez, as well as classes of bounded twin-width of Bonnet, Kim, Thomassé, and Watrigant.

Compound Logics for Modification Problems

Ignasi Sau (LIRMM Montpellier)

We introduce a novel model-theoretic framework inspired from graph modification and based on the interplay between model theory and algorithmic graph minors. The core of our framework is a new compound logic operating with two types of sentences, expressing graph modification: the modulator sentence, defining some property of the modified part of the graph, and the target sentence, defining some property of the resulting graph. In our framework, modulator sentences are in counting monadic second-order logic (CMSOL) and have models of bounded treewidth, while target sentences express first-order logic (FOL) properties along with minor-exclusion. Our logic captures problems that are not definable in first-order logic and, moreover, may have instances of unbounded treewidth. Also, it permits the modeling of wide families of problems involving vertex/edge removals, alternative modulator measures (such as elimination distance or G-treewidth), multistage modifications, and various cut problems. Our main result is that, for this compound logic, model-checking can be done in quadratic time. All derived algorithms are constructive and this, as a byproduct, extends the constructibility horizon of the algorithmic applications of the Graph Minors theorem of Robertson and Seymour.

The proposed logic can be seen as a general framework to capitalize on the potential of the irrelevant vertex technique. It gives a way to deal with problem instances of unbounded treewidth, for which Courcelle's theorem does not apply. The proof of our meta-theorem combines novel combinatorial results related to the Flat Wall theorem along with elements of the proof of Courcelle's theorem and Gaifman's theorem. We finally prove extensions where the target property is expressible in FOL+DP, i.e., the enhancement of FOL with disjoint-paths predicates.

Joint work with Fedor V. Fomin, Petr A. Golovach, Giannos Stamoulis, Dimitrios M. Thilikos

MINI–SYMPOSIUM

SAT and CSPs

Stefan Szeider

Day: Friday

Time: 10:30—12:30

This mini-symposium features four talks on recent results on the parameterized complexity of the propositional satisfiability problem (SAT) and the constraint satisfaction problem (CSP). The talks will be given by Sebastian Ordyniak, Ramanujan M. S., Max Bannach, and George Osipov, respectively.

> **SAT Backdoors: Depth Beats Size**
> Sebastian Ordyniak
>
> For several decades, much effort has been put into identifying classes of CNF formulas whose satisfiability can be decided in polynomial time. Classic results are the linear-time tractability of Horn formulas and Krom (i.e., 2CNF) formulas. Backdoors, introduced by Williams, Gomes, and Selman (2003), gradually extend such a tractable class to all formulas of bounded distance to the class. Backdoor size provides a natural but rather crude distance measure between a formula and a tractable class. Backdoor depth, introduced by Mählmann, Siebertz, and Vigny (2021), is a more refined distance measure that admits using different backdoor variables in parallel. Bounded backdoor size implies bounded backdoor depth, but there are formulas of constant backdoor depth and arbitrarily large backdoor size.
>
> We propose FPT-approximation algorithms to compute backdoor depth into the classes Horn and Krom. This leads to a linear-time algorithm for deciding the satisfiability of formulas of bounded backdoor depth into these classes. We base our FPT approximation algorithm on a sophisticated notion of obstructions, extending Mählmann et al.'s obstruction trees in various ways, including adding separator obstructions. We develop the algorithm through a new game-theoretic framework that simplifies the reasoning about backdoors. Finally, we show that bounded backdoor depth captures tractable classes of CNF formulas not captured by any known method.
>
> Joint work with Jan Dreier and Stefan Szeider.

Backdoor Sets for Biclique-free SAT
Ramanujan M. S.

A central line of research in the work on FPT algorithms for SAT aims at delineating the tractability borders for the problem of detecting small weak backdoor sets to various tractable classes. Of interest to us in the context of this talk is the case where the tractable class under consideration is the class of bounded treewidth formulas (i.e., formulas whose incidence graphs have bounded treewidth). Results on this problem in the literature indicate that the sparsity of the incidence graph of the input formula impacts the parameterized complexity of this problem. In particular, the problem is W-hard in general, but FPT when the input is d-CNF. But where is the boundary? In this talk, we will discuss a recent advance on this topic, giving an algorithmic result for detecting small weak backdoor sets to bounded treewidth formulas for input formulas whose incidence graphs exclude $K_{d,d}$ as a subgraph.

Joint work with Daniel Lokshtanov, Fahad Panolan, and Saket Saurabh.

Advancing MaxSAT through Parallel Parameterized Approaches
Max Bannach

In this talk, we will discuss promising applications of parameterized complexity for the natural generalization of propositional satisfiability to optimization problems: MaxSAT, where the task is to find an assignment that maximizes the total weight of all satisfied clauses. As for most intractable optimization problems, obtaining parallel algorithms for MaxSAT with meaningful theoretical guarantees in the classical complexity-theoretic sense is tricky. The situation is, however, fundamentally different if we study the parallel parameterized complexity of the problem. We will give a gentle introduction to the underlying framework of parallel parameterized algorithms and, along the line, will motivate the definitions by pointing out how to achieve various levels of parallelization for MaxSAT for different parameters. In contrast, in a sequential world, all these results would collapse into the observation that MaxSAT is fixed-parameter tractable parameterized by any of these parameters.

Joint work with Malte Skambath and Till Tantau.

Parameterized Complexity of MinCSP: A Case Study of Interval Constraints

George Osipov

MinCSP is an optimization variant of CSP asking to minimize the number of unsatisfied constraints. Under the natural parametrization, MinCSP encompasses well-known problems like Directed Feedback Arc Set, Almost 2SAT, and Multicut. In this talk, we will introduce MinCSP, discuss some recent results, and focus on Allen's interval algebra (IA) as a case study. The domain of IA are closed intervals with rational endpoints, and it employs 13 basic comparison relations like "precedes" or "during" for relating intervals.

We establish an FPT vs. W[1]-hard dichotomy for all subsets of these relations. On the technical side, we prove hardness for simultaneous cuts or feedback arc set problems in directed graphs and solve tractable cases using flow augmentation.

Based on joint work with Konrad K. Dabrowski, Peter Jonsson, Sebastian Ordyniak, Marcin Pilipczuk, and Roohani Sharma.

Slots 3

Mike's day

$\mathcal{O}$ NO! Unfinished Business in Parameterized Complexity: A Radical Vision of the Future of PC That Comes From Its Roots

Michael R. Fellows

Day: Wednesday

Time: 10:30—11:30

Abstract. The theory of parameterized complexity had its motivational roots in the theory of graph minors and in earlier work of Tarjan, Williamson and others on the complexity of Graph Topological Containment based on depth–first search and on the k-Disjoint Paths problems.

The revolutionary results of Robertson and Seymour, announced at the British Combinatorial Conference in 1982, were largely ignored, repeatedly rejected and somewhat ridiculed at the top computer science theory conferences (FOCS, STOC and SODA) of the day, for the next six years.

The theory of algorithms and complexity really got off the ground with the emergence of the beautiful (!) amazing (!) and wonderful (!) theory of NP-completeness, that developed so rapidly that normal journal publication timeframes couldn't keep up! Hence David Johnson's famous NP-Completeness Column in the Journal of Algorithms in those days, with the most relevant of those Columns for this talk entitled: "On the P=NP Nightmare."

The modern theory of algorithms and complexity has been dominated for its first 50 years by a ("classical") framework that is:

· one-dimensional · worst-case · asymptotic

The theory of parameterized complexity has steadily emerged and developed over the last 35 years, in a way that could perhaps be compared to the emergence of Cartesian coordinatized geometry beyond the Geometry known to the Greeks. PC has gradually become a regular accepted theory, at a rate that could be compared to the gradual acceptance that the theory of plate tectonics enjoyed in Geology. It is a fundamentally two-dimensional framing, where one dimension of the time-costs is polynomial worst-case asymptotic (in the measurement n of the number of bits of a legal input), as in the classical framework notion of polynomial time. The second dimension is the time-costs $f(k)$, whatever they may be, associated with a vector k of relevant secondary measurements, the parameter.

The title of this talk refers to a 1999 unpublished manuscript of Downey and Fellows with the provocative title: "$\mathcal{O}$ No!" that was concerned with the finitism implicit in the PC framework. The perspective of finitism remains important, as expressed in the table of values of the ratio $2^k \cdot n^2/n^k$ that displays the typical advanges of FPT over XP complexities, even for quite moderate values of k and n.

Many computer applications are now being rapidly revolutionized by neural nets and similar algorithmic technologies which are NOT worst–case asymptotic frameworks. They are frameworks based on encountered instances and encountered difficulties.

FPT results based on well-quasi-ordering (wqo) with FPT order tests (such as provided off-the-shelf by graph minors theory) can usually be made constructive by employing encountered

obstructions, as first described in a STOC 1989 paper of Fellows and Langston. Michael Hallett has hypothesized ("Hallett's Hypothesis") that encountered obstruction algorithmics in well-quasi-ordered FPT frameworks might actually be practical. This is a radical surmise that is supported by a tiny amount of evidence. If Hallett's Hypothesis works out, it would be a cosmically humorous outcome, given the history of the subject. The talk will survey the technical route from problem-specific FPT-friendly wqos to possibly practical encountered-obstruction algorithmics. The route depends on the maturation of computer technology to be conceivable.

Panel discussion: The past, present, and future of FPT

Bart M. P. Jansen

Day: Wednesday

Time: 11:30—12:30

Panel discussion
Chair: Bart M. P. Jansen

This is a panel discussion about the past, present, and future of *parameterized algorithms and complexity*.

The goal of the discussion is to reflect on where the field of parameterized algorithms has come from, where it should be going, what problems and directions will be important in the coming decade; to provide advice for young researchers hoping to make a career in science; and to discuss what the role of FPT is within theoretical computer science and its relevance in an era that sometimes seems to be revolving around machine learning. The panel discussion will take roughly an hour.

The panel consists of

- Daniel Lokshtanov
- Dániel Marx
- Blair D. Sullivan
- Stefan Szeider

The discussion is moderated by Bart Jansen.

Computational Thinking–Computer Science Unplugged!

Frances A. Rosamond

Day: Wednesday

Time: 13:30—16:00

Abstract. CS Unplugged is a collection of free learning activities that teach Computer Science through engaging games and puzzles that use cards, string, crayons and lots of running around. We originally developed this so that young students could dive head-first into Computer Science, experiencing the kinds of questions and challenges that computer scientists experience, but without having to learn programming first. The collection was originally intended as a resource for outreach and extension, but with the adoption of computing and computational thinking into many classrooms around the world, it is now widely used for teaching. Many foundational ideas such as algorithm design and analysis, modeling, or clever information representation can be conveyed without using a keyboard. The material has been used in many contexts outside the classroom as well, including science museums, science shows, talks for senior citizens, and special events.

Additionally, the speakers will discuss some of the high-level university and government decisions they have influenced that impact the current and future generation's ability to understand, control and shape our technical landscape.

> **Sorting networks**
> Stefan Szeider (TU Wien)
>
> The Symposium begins at 13:30 in VilVite with a Sorting Network Race organized by Stefan Szeider, who created the world's largest Sorting Network with input size over fifty and 1225 comparator nodes!!
>
> See https://informatics.tuwien.ac.at/news/1759

The Symposium continues as follows.

> **Bringing computational thinking to schools**
> Juraj Hromkovič (ETH Zurich)
>
> Juraj Hromkovič has brought computational thinking to Swiss schools. In addition to research in theory, his focus is education for teachers of Computer Science and the illustration of basics of Computer Science to non–professionals. He has written 18 books/introductory guides to informatics. His most popular is *Algorithmic Adventures: From Knowledge to Magic*.
>
> See https://inf.ethz.ch/people/person-detail.hromkovic.html

Designing informatics curriculum for schools

Regula Lacher (ETH Zurich)

Regula Lacher is the Director of ABZ, a consortium of materials for teachers of all grades. Regula is co-author of 8 textbooks for computer science from kindergarten to maturity. She has worked on Bebras tasks and on designing informatics curriculum for K-12 education from concepts to implementations.

See https://abz.inf.ethz.ch/.

Bring computational thinking into your classes

Hon Wai Leong

Prof. Hon Wai Leong (National University of Singapore). In addition to active research in theoretical computer science, his focus is to find simple ways to explain complicated concepts and subject matters. He has created computational thinking courses that every student at the university is required to take. Additionally, Hon Wai shows K-12 teachers how to bring computational thinking into their classes.

See https://www.comp.nus.edu.sg/cs/people/leonghw/.

Community-wide computer science activities

Rudiger Reischuk (University of Luebeck)

Rudiger Reischuk has created many community-wide math/computer science activity days and he will share some of the activities.
He will present the idea of zero knowledge proofs using Sudoku.

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