GGTW 2019

Ghent Graph Theory Workshop on Structure and Algorithms

12-14 August 2019
Ghent University

GHENT UNIVERSITY

Contents

Welcome

Welcome to Ghent, and welcome to the third edition of the Ghent Graph Theory Workshop. This year, it is our pleasure to greet four distinguished main speakers, Professors Chudnovsky, Jackson, McKay, and Mohar, together with more than fifty participants from fifteen countries on four continents. This year we thank the Franqui Foundation for the financial support they provided for the organisation of this conference.

We hope everyone finds something interesting in this programme – or at least a good restaurant. Speaking of food: the conference dinner will be on Tuesday at 7 p.m. at the *Pakhuis*.

If you would like to join us on our visit to the beautiful town of Bruges on Thursday (we'll be back in the early afternoon), please inform us.

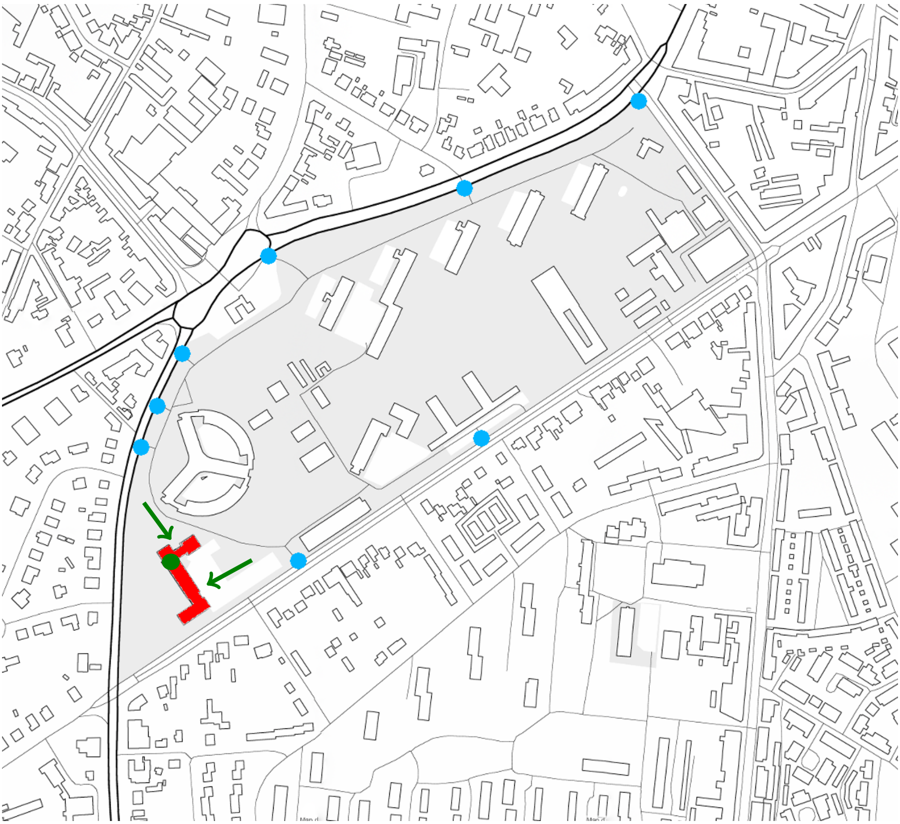
Finally, if you have any problems – mathematical or non-mathematical –, suggestions, or just want to chat, please do not hesitate to contact us.

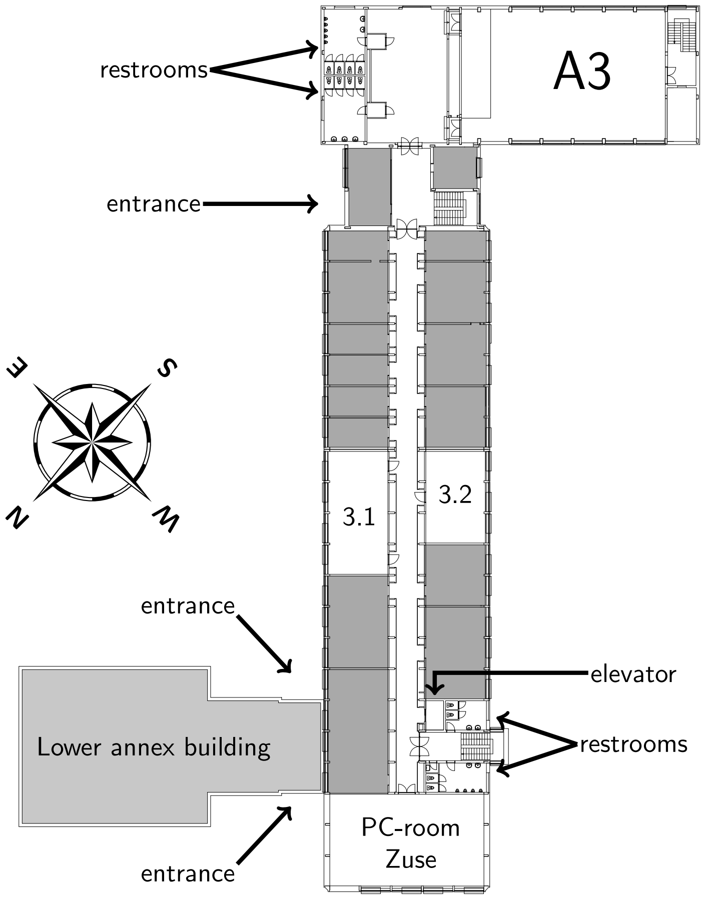
Wishing you an excellent time in Ghent,

Jan Goedgebeur • Nico Van Cleemput • Carol Zamfirescu

Venue

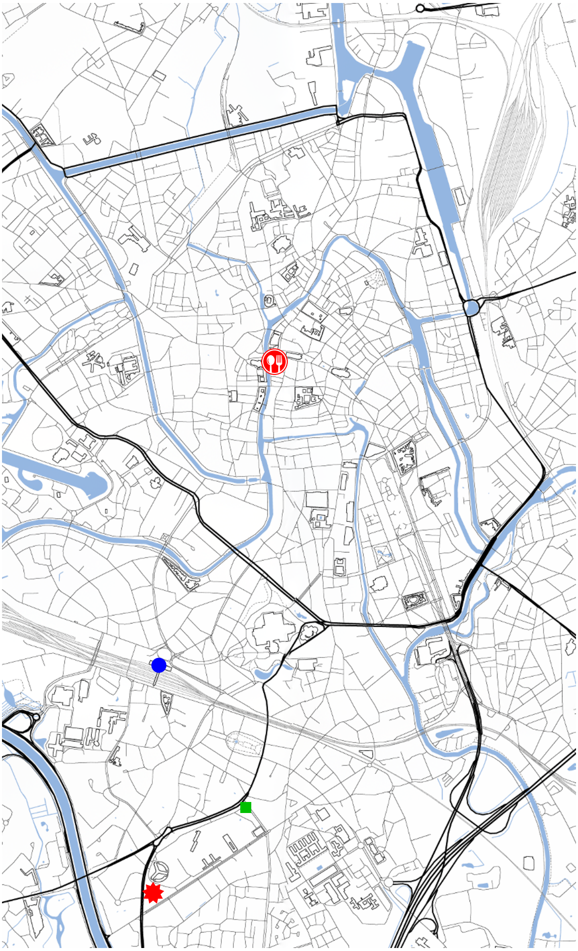
The scientific part of the Ghent Graph Theory Workshop takes place on the third floor in the S9 building of Campus De Sterre (Krijgslaan 281, 9000 Ghent). Below you can see the campus in grey. The access points to the campus are shown with blue dots. The S9 building is shown in red, and the green arrows show the entrances of the building. The elevator is located at the green dot.





All academic activities for the workshop will happen on the **third floor** of the S9 building. Above you see a map of that floor. The grey areas are offices which are not accessible for participants of the workshop.

All talks will be held in auditorium A3. The coffee breaks will be in room 3.1, and room 3.1 and 3.2 are available for discussions. PC-room Zuse is available as a silent working space. Eduroam is available on the whole floor.



- ✸ S9
- ■ Main campus entrance
- Pakhuis
- ● Gent-Sint-Pieters train station

This map situates the workshop venue (S9) in reference to the city centre. On Tuesday at 17h45 we will meet at the main campus entrance for a group walk to the restaurant *Pakhuis* for the conference dinner. You can either join this group walk, or come to the restaurant directly. The walk will take roughly 1 hour.

On Thursday at 9h we will meet in the main hall of Gent-Sint-Pieters train station for the survivors' excursion to Bruges. Of course, everybody is welcome to join.

Schedule

Monday August 12

Time	Talk	
09:00 - 09:30	*Badge pick-up*	
09:30 - 09:35	*Opening*	
09:35 - 10:20	**Detecting odd holes** Maria Chudnovsky	p. 9
10:20 - 10:35	*Coffee break*	
10:35 - 11:00	**Forbidden pairs and perfect graphs** Adam Kabela	p. 9
11:00 - 11:25	**Large independent sets in triangle-free subcubic graphs** Gwenaël Joret	p. 10
11:25 - 11:50	**The 1–2–3 Conjecture almost almost holds for regular graphs** Jakub Przybyło	p. 10
11:50 - 12:15	**Component factors of simple edge-chromatic critical graphs** Eckhard Steffen	p. 10
12:15 - 14:00	*Lunch*	
14:00 - 14:25	**4-connected polyhedra have at least a linear number of hamiltonian cycles** Gunnar Brinkmann	p. 11
14:25 - 14:50	**Using Tutte paths for finding long cycles in planar graphs** Andreas Schmid	p. 11
14:50 - 15:15	**Circumference of essentially 4-connected planar graphs** Igor Fabrici	p. 11
15:15 - 15:30	*Coffee break*	
15:30 - 15:55	**X-minors and X-spanning subgraphs** Samuel Mohr	p. 12
15:55 - 16:20	**Non-bipartite regular 2-factor isomorphic graphs: an update** Domenico Labbate	p. 12
16:20 - 16:45	**Faithful subgraphs and hamiltonian circles of infinite graphs** Binlong Li	p. 13

Tuesday August 13

Time	Talk	
09:30 - 10:15	**Graphs with specified degrees** Brendan McKay	p. 14
10:15 - 10:35	*Coffee break*	
10:35 - 11:00	**Diagonal Conjecture for classical Ramsey numbers** Stanisław Radziszowski	p. 14
11:00 - 11:25	**Generating graph and matroid minors** Sandra Kingan	p. 15
11:25 - 11:50	**Combinatorial generation via permutation languages** Torsten Mütze	p. 15
11:50 - 12:15	**Combinatorial objects as hereditarily finite sets and algorithmic applications** Pascal Schweitzer	p. 16
12:15 - 14:00	*Lunch*	
14:00 - 14:45	**Crossing-critical graphs** Bojan Mohar	p. 16
14:45 - 15:10	**Superposition of snarks revisited** Martin Škoviera	p. 17
15:10 - 15:35	**Lower bound on the length of a cycle cover of a cubic graph** Edita Máčajová	p. 17
15:35 - 16:00	**Reduction of the Berge-Fulkerson Conjecture to cyclically 5-edge-connected snarks** Giuseppe Mazzuoccolo	p. 18
19:00 - 22:00	*Conference dinner*	

The conference dinner will take place at the restaurant **Pakhuis** (Schuurkenstraat 4, 9000 Ghent). There is an optional group walk from the campus to the restaurant. This walk will leave at 17h45 and roughly take one hour. See page 5 for a map situating the start of the group walk and the restaurant.

Wednesday August 14

Time	Talk	
09:30 - 10:15	**The maximal abstract 3-rigidity matroid** Bill Jackson	p. 19
10:15 - 10:35	*Coffee break*	
10:35 - 11:00	**On the 4-color theorem for signed graphs** František Kardoš	p. 19
11:00 - 11:25	**3-coloring of claw-free graphs** Mária Maceková	p. 20
11:25 - 11:50	**Polynomial χ-binding functions and forbidden induced subgraphs – a survey** Ingo Schiermeyer	p. 20
11:50 - 12:15	**The stable set problem in graphs with bounded genus and bounded odd cycle packing number** Samuel Fiorini	p. 20
12:15 - 14:00	*Lunch*	
14:00 - 14:25	**Complete acyclic colorings** Raphael M. Steiner	p. 21
14:25 - 14:50	**Compact cactus representations of all non-trivial min-cuts** On-Hei Solomon Lo	p. 21
14:50 - 15:15	**Minimum leaf number of 2-connected cubic graphs** Márton Dücső	p. 22
15:15 - 15:40	**Extremal results on the eccentric connectivity index** Pierre Hauweele	p. 22
15:40 - 15:45	*Closing remarks*	

Abstracts

Monday August 12

Detecting odd holes

Maria Chudnovsky *Joint work with: Alex Scott, Paul Seymour, Sophie Spirkl*

A hole in a graph is an induced cycle of length at least four; and a hole is odd if it has an odd number of vertices. In 2003 a polynomial-time algorithm was found to test whether a graph or its complement contains an odd hole, thus providing a polynomial-time algorithm to test if a graph is perfect. However, the complexity of testing for odd holes (without accepting the complement outcome) remained unknown. This question was made even more tantalizing by a theorem of D. Bienstock that states that testing for the existence of an odd hole through a given vertex is NP-complete. Recently we were able to design a polynomial time algorithm to test for odd holes. In this talk we will survey the history of the problem and the main ideas of the new algorithm.

Forbidden pairs and perfect graphs

Adam Kabela *Joint work with: Petr Vrána*

We characterize pairs $\{X, Y\}$ of graphs such that all $\{X, Y\}$-free graphs (distinct from C_5) are perfect. Similarly, we characterize pairs such that all considered graphs are ω-colourable (that is, their chromatic number is equal to their clique number). Furthermore, we present such characterizations in relation to perfectness of all graphs with additional constraints of being connected, or being distinct from an odd cycle, or being of independence at least 3, or having at least n vertices, or satisfying a combination of these constraints. We use the results of Brause et al. (2019), Chudnovsky et al. (2006), Olariu (1988) and Ramsey (1930).

Large independent sets in triangle-free subcubic graphs

Gwenaël Joret *Joint work with: Wouter Cames van Batenburg and Jan Goedgebeur*

Every n-vertex planar triangle-free graph with maximum degree at most 3 has an independent set of size at least $\frac{3}{8}n$. This was first conjectured by Albertson, Bollobás and Tucker, and was later proved by Heckman and Thomas. Fraughnaugh and Locke conjectured that the planarity requirement could be relaxed into just forbidding a few specific nonplanar subgraphs: They described a family $\mathcal{F}$ of six nonplanar graphs (each of order at most 22) and conjectured that every n-vertex triangle-free graph with maximum degree at most 3 having no subgraph isomorphic to a member of $\mathcal{F}$ has an independent set of size at least $\frac{3}{8}n$. In this talk, I will present of proof of this conjecture, obtained in joint work with Wouter Cames van Batenburg and Jan Goedgebeur.

As a corollary, we also obtain that every 2-connected n-vertex triangle-free graph with maximum degree at most 3 has an independent set of size at least $\frac{3}{8}n$, with the exception of the six graphs in $\mathcal{F}$. This confirms a conjecture made independently by Bajnok and Brinkmann, and by Fraughnaugh and Locke.

The 1–2–3 Conjecture almost almost holds for regular graphs

Jakub Przybyło

The well-known 1–2–3 Conjecture asserts that the edges of every graph without isolated edges can be weighted with 1, 2 and 3 so that adjacent vertices receive distinct weighted degrees. This is open in general, while it is known to be possible from the weight set $\{1, 2, 3, 4, 5\}$. The conjecture also holds for 3-colourable graphs. Not much more is known in the case of regular graphs. We shall present a proof that for such a family of graphs it is sufficient to use weights 1, 2, 3, 4; and moreover discuss the cases when the 1–2–3 Conjecture truly holds.

Component factors of simple edge-chromatic critical graphs

Eckhard Steffen

There are many (open) conjectures on component factors of simple edge-chromatic critical graphs. The talk surveys the topic and presents some new results.

4-connected polyhedra have at least a linear number of hamiltonian cycles

Gunnar Brinkmann *Joint work with: Nico Van Cleemput*

Although polyhedra can have much fewer edges than triangulations, many results about hamiltonicity proven for triangulations also hold for polyhedra. The most famous of these results is surely Whitney's result from 1931 that 4-connected triangulations are hamiltonian, which was 25 years later generalised to 4-connected polyhedra by Tutte. Nevertheless the only known bounds for the number of hamiltonian cycles in 4-connected polyhedra are constant, though for triangulations a lower bound of $|V|/(\log_2 |V|)$ was already proven in 1979 and improved to a linear bound in 2018. In this talk we present the proof of a linear lower bound for 4-connected polyhedra.

Using Tutte paths for finding long cycles in planar graphs

Andreas Schmid *Joint work with: Jens M. Schmidt*

The question of whether a graph is *hamiltonian* is among the most fundamental graph problems. For planar graphs and graphs embeddable on higher surfaces, *Tutte paths* have proven to be one of the most successful tools for attacking hamiltonicity problems and problems on long cycles. For this reason, there is a wealth of existential results in which Tutte paths serve as the main ingredient. In the past very little was known about the complexity of actually finding a Tutte path. In this talk I will present a string of recent results on the computation of Tutte paths in planar graphs with different restrictions and highlight the algorithmic applications that follow.

Circumference of essentially 4-connected planar graphs

Igor Fabrici *Joint work with: Jochen Harant, Samuel Mohr, Jens M. Schmidt*

A 3-connected planar graph G is *essentially 4-connected* if for every 3-separator S, one of the two components of G–S is an isolated vertex. Let n denote the number of vertices of a graph. Jackson and Wormald (1992) proved that an essentially 4-connected planar graph contains a cycle of length at least $(2n+4)/5$. For a cubic essentially 4-connected planar graph, Grünbaum with Malkevitch (1976) and Zhang (1987) showed the existence of a cycle of length at least $3n/4$.

We prove that every essentially 4-connected planar graph contains a cycle of length at least $5(n+2)/8$ and every essentially 4-connected maximal planar graph contains a cycle of length at least $2(n+4)/3$; moreover the second bound is best possible.

X-minors and *X*-spanning subgraphs

Samuel Mohr *Joint work with: Thomas Böhme, Jochen Harant, Matthias Kriesell, Jens M. Schmidt*

Given a finite, undirected, and simple graph G and $X \subseteq V(G)$, let $\mathcal{H}$ be a partition of a subset of $V(G)$ into connected sets—called *bags*—such that each bag contains at most one vertex of X and X is a subset of the union of all bags. If M is a simple graph on the vertex set $\mathcal{H}$ such that there is an edge of G connecting two bags of $\mathcal{H}$ if these two bags are adjacent in M, then M is an X*-minor* of G.

We consider the problem whether G has a highly connected X-minor if X cannot be separated in G by removing a few vertices of G. As an application of the achieved results, statements on the existence of special X-spanning subgraphs of G are presented, where a subgraph H of G is X*-spanning* if $X \subseteq V(H)$.

Non-bipartite regular 2-factor isomorphic graphs: an update

Domenico Labbate *Joint work with: Marien Abreu, Martin Funk, Bill Jackson, John Sheehan et al.*

A 2–factor of a graph G is a 2–regular spanning subgraph of G. A graph with a 2–factor is said to be 2–factor hamiltonian if all its 2–factors are hamiltonian cycles, and, more generally, 2–factor isomorphic if all its 2–factors are isomorphic. Examples of such graphs are K_4, K_5, $K_{3,3}$, the Heawood graph (which are all 2–factor hamiltonian) and the Petersen graph (which is 2–factor isomorphic). Several papers have addressed the problem of characterizing families of graphs (particularly regular graphs) which have these properties. We give an updated survey on results and open problems on the structure of 2–factors in (non-bipartite) regular graphs obtained in the last few years by the author jointly with several other colleagues.

Faithful subgraphs and hamiltonian circles of infinite graphs

Binlong Li

A circle of an infinite locally finite graph G is the image of a homeomorphic map of the unit circle S^1 in $|G|$, the Freudenthal compactification of G. A circle of G is hamiltonian if it meets every vertex (and then every end) of G. In this paper, we study a method for finding hamiltonian circles of infinite graphs. We illustrate this by extending several results on finite graphs to infinite graphs. For example, we prove that the prism of every infinite 3-connected cubic graph has a hamiltonian circle, extending the result of the finite case by Paulraja.

Tuesday August 13

Graphs with specified degrees

Brendan McKay *Joint work with: Mikhail Isaev, Nicholas C. Wormald*

Graphs with specified degrees have a very wide range of applications. For mathematicians, the most important case is the *regular* graphs, where each vertex has the same degree. The immense literature concerns many questions ranging from very theoretical to very practical. We will be concerned with two problems, restricting ourselves to regular graphs of given order n and degree d for the sake of simplicity.

Our first problem is how to generate a regular graph at random. The simplest exact method was developed in the late 1970s by several independent researchers, but it is only useful for degree up to about 7 or 8. The speaker and Wormald extended this to $d = o(n^{1/3})$ using an accept-reject strategy, which was later improved to $d = o(n^{1/2})$ by Gao and Wormald. For higher degrees, all known practical methods guarantee only approximate uniformity; we will survey the main ideas.

Our second problem is to determine the number of regular graphs. Useful exact formulas are only available for $d \leq 4$, so we will mainly consider asymptotic formulas. The asymptotic counts for $d = o(n^{1/2})$ and $d \geq n/\log n$ were determined by McKay and Wormald in the 1980s, but until recently the large gap between these ranges was not filled. Now the full range is known, firstly using combinatorial means by Liebenau and Wormald, and secondly using analytical methods by Isaev and McKay.

Diagonal Conjecture for classical Ramsey numbers

Stanislaw Radziszowski *Joint work with: Meilian Liang, Xiaodong Xu*

Let $R(k_1, \cdots, k_r)$ denote the classical r-color Ramsey number for integers $k_i \geq 2$. The Diagonal Conjecture (DC) for classical Ramsey numbers poses that if $k_1, \cdots, k_r$ are integers no smaller than 3 and $k_{r-1} \leq k_r$, then $R(k_1, \cdots, k_{r-2}, k_{r-1} - 1, k_r + 1) \leq R(k_1, \cdots, k_r)$. We obtain some implications of this conjecture, present evidence for its validity, and discuss related problems.

Let $R_r(k)$ stand for the r-color Ramsey number $R(k, \cdots, k)$. It is known that $\lim_{r\to\infty} R_r(3)^{1/r}$ exists, either finite or infinite, the latter conjectured by Erdős. This limit is related to the Shannon capacity of complements of K_3-free graphs. We prove that if DC holds, and $\lim_{r\to\infty} R_r(3)^{1/r}$ is finite, then $\lim_{r\to\infty} R_r(k)^{1/r}$ is finite for every integer $k \geq 3$.

Generating graph and matroid minors

Sandra Kingan *Joint work with: Joao Paulo Costalonga and Robert Kingan*

Suppose that G is a simple 3-connected graph with a simple 3-connected minor H. The Splitter Theorem (Seymour 1980) states that, if G is not a wheel and H is not a 3-wheel, then up to isomorphism G can be obtained from H by a sequence of operations that consist of adding an edge between non-adjacent vertices or splitting a vertex. The Strong Splitter Theorem (Kingan and Lemos 2014) optimizes the Splitter Theorem to best possible by showing that at most two edges may be added before a vertex must be split, unless G and H have the same number of vertices. These are matroid results and this perspective on graphs comes from matroid theory. We say G is H-critical if removal of any edge either destroys 3-connectivity or the H-minor. H-critical graphs are useful because they are just barely outside the class of graphs with no H-minor. In this talk we will present an algorithm for generating H-critical graphs using the Strong Splitter Theorem and some additional results. A graph is a special type of binary matroid. The same algorithm works for H-critical matroids representable over finite fields (with appropriate changes for handling finite field arithmetic), even though projective geometries are exponentially larger than complete graphs. We use Brendan McKay's Nauty for graph isomorphism checking and Oid for matroid isomorphism checking. This is joint work with Joao Paulo Costalonga and Robert Kingan.

Combinatorial generation via permutation languages

Torsten Mütze *Joint work with: Liz Hartung, Hung P. Hoang, Aaron Williams*

In this talk I present a general and versatile algorithmic framework for exhaustively generating a large variety of different combinatorial objects, based on encoding them as permutations. This approach provides a unified view on many known results and allows us to prove many new ones. In particular, we obtain several classical Gray codes as special cases, including the Steinhaus-Johnson-Trotter algorithm and the binary reflected Gray code.

I will present two distinct applications for our new framework: The first is the generation of pattern-avoiding permutations, yielding new Gray codes for different families of permutations that are characterized by the avoidance of certain classical patterns, (bi)vincular patterns, barred patterns, Bruhat-restricted patterns, mesh patterns, monotone and geometric grid classes, and many others. We thus also obtain new Gray code algorithms for the combinatorial objects that are in bijection to these permutations, in particular for five different types of rectangulations.

The second main application of our framework are lattice congruences of the weak order on the symmetric group. Recently, Pilaud and Santos realized all those lattice congruences as polytopes, called quotientopes, which generalize hypercubes, associahedra, permutahedra etc. Our algorithm generates each of those lattice congruences, by producing a hamilton path on the skeleton of the corresponding quotientope. We thus obtain a provable notion of optimality for the Gray codes obtained from our framework: They translate into walks along the edges of a polytope.

Combinatorial objects as hereditarily finite sets and algorithmic applications

Pascal Schweitzer

The talk advocates that hereditarily finite sets are a generic and convenient way to encode finite combinatorial structures. In fact they can be readily used to model basic combinatorial objects such as partitions, hypergraphs, projective planes, more generally discrete geometries, and block designs. However, they can also be used to model colorings, tree decompositions, tree-like decompositions, coherent configurations, permutation groups, explicit codes, as well as various generalizations of such concepts. The talk will also give an overview over some recent algorithmic applications in the context of symmetry detection that exploit hereditarily finite sets.

Crossing-critical graphs

Bojan Mohar *Joint work with: Zdeněk Dvořák and Petr Hliněný*

A graph G is c-crossing-critical if $cr(G) \geq c$, but $cr(G - e) < c$ for every $e \in E(G)$, where $cr(.)$ denotes the crossing number of the corresponding graph. The speaker will present an overview about the "tile" structure and generation process of graphs that are c-crossing-critical.

Superposition of snarks revisited

Martin Škoviera *Joint work with: Edita Máčajová*

Superposition is generally regarded as one of the most powerful techniques for constructing snarks (cubic graphs admitting no proper 3-edge-colouring). Roughly speaking, superposition replaces the vertices and edges of a base snark G with certain subgraphs – supervertices and superedges – and puts them together in such a way that the resulting graph $\tilde{G}$ is cubic and keeps the 'shape' of G. The heart of the method is, however, the argument that, with a suitable choice of supervertices and superedges, $\tilde{G}$ is again a snark. A typical reasoning concludes that if $\tilde{G}$ was 3-edge-colourable, then so would be G. In this talk we propose a general approach to superposition, provide some old and new examples, and introduce an entirely new kind of superposition wherein $\tilde{G}$ is guaranteed to be a snark if and only if two graphs derived from G in a certain way are both snarks. We also mention an application of this method to constructing permutation snarks.

Lower bound on the length of a cycle cover of a cubic graph

Edita Máčajová *Joint work with: Martin Škoviera*

The well-known shortest cycle cover conjecture suggests that every bridgeless cubic G can have its edges covered with a collection of cycles of total length not exceeding $\frac{7}{5}|E(G)|$. This conjecture is particularly interesting for cubic graphs, where the largest known values of the ratio between the length of a shortest cycle cover and the number of edges occur. The covering ratio $7/5$ is best possible, being reached by the Petersen graph whose shortest cycle cover has length 21. There exist infinitely many cubic graphs with cyclic connectivity 2, as well as those with cyclic connectivity 3, whose covering ratio equals $7/5$. By contrast, all cyclically 4-edge-connected cubic graphs, where the length of a shortest cycle cover is known, have covering ratio close to $4/3$, which is a natural lower bound. In line with this observation, Brinkmannn et al. [J. Combin. Theory Ser. B **103** (2013), 468–488] made a conjecture that every cyclically 4-edge-connected cubic graph has a cycle cover of length at most $\frac{4}{3}m + o(m)$, where m is the number of edges. We disprove this conjecture by exhibiting an infinite family of cyclically 4-edge-connected cubic graphs G_n, $n \geq 1$, such that the length of a shortest cycle cover of each G_n is at least $(\frac{4}{3} + \frac{1}{69})|E(G_n)|$.

Reduction of the Berge-Fulkerson Conjecture to cyclically 5-edge-connected snarks

Giuseppe Mazzuoccolo *Joint work with: Edita Máčajová*

The Berge-Fulkerson Conjecture belongs to one of the most prominent open problems in graph theory. It suggests that the edges of any bridgeless cubic graph can be covered with six perfect matchings in such a way that each edge belongs to exactly two of them. Despite the fact that Berge and Fulkerson made this conjecture almost half a century ago, it has been verified only for several explicitly defined families of graphs. Moreover, in contrast to what happens for other outstanding conjectures (Cycle Double Cover Conjecture, Tutte 5-flow Conjecture), no additional restriction, except the trivial ones, is proved for a possible minimum counterexample. In the present talk, we prove that Berge-Fulkerson's conjecture can be reduced to cyclically 5-edge-connected cubic graphs.

Wednesday August 14

The maximal abstract 3-rigidity matroid

Bill Jackson *Joint work with: Katie Clinch and Shin-Ichi Tanigawa*

A d-*dimensional framework* (G,p) is a graph $G=(V,E)$ together with a map $p:V\to\mathbb{R}^d$. It is *rigid* if every continuous motion of the vertices which preserves the distance between *adjacent* pairs of vertices, preserves the distance between *all* pairs of vertices. It is known that, for 'generic' frameworks, rigidity in $\mathbb{R}^d$ depends only on the underlying graph. Graphs which are generically rigid in $\mathbb{R}^d$ have been characterised for $d=1,2$, but it is a major open problem in discrete geometry to extend this characterisation to any $d\geq 3$.

For fixed n and d, the edge sets of the spanning subgraphs of K_n which are minimally rigid in $\mathbb{R}^d$ form the set of bases of the d-*dimensional rigidity matroid* on $E(K_n)$. When $d=1$ the minimally rigid subgraphs are the spanning trees so this is just the well known *cycle matroid* of K_n. Graver defined an *abstract* d-*rigidity matroid* in 1991 as a matroid on $E(K_n)$ which satisfies two closure conditions (which hold for the d-dimensional rigidity matroid). He conjectured that there is a unique maximal abstract d-rigidity matroid for all n,d, and that this maximal matroid is the d-dimensional rigidity matroid on $E(K_n)$. Graver showed that both parts of his conjecture are true when $d=1,2$. Whiteley pointed out that the second part of the conjecture is false for $d\geq 4$ in 1996 by showing that the C_{d-1}^{d-2}-cofactor matroid is a counterexample.

We verify the first part of Graver's conjecture for $d=3$ by showing that the C_2^1-cofactor matroid on $E(K_n)$ is the maximal abstract 3-rigidity matroid and give a good characterisation of its rank function.

On the 4-color theorem for signed graphs

František Kardoš *Joint work with: Jonathan Narboni*

There are several ways to generalize graph coloring to signed graphs. Máčajová, Raspaud and Škoviera introduced one of them and conjectured that in this setting, for signed planar graphs four colors are always enough, generalising thereby the Four Color Theorem. We disprove the conjecture.

3-coloring of claw-free graphs

Mária Maceková *Joint work with: Frédéric Maffray*

Vertex coloring is the problem of determining the chromatic number of a graph; it is a well-known NP-hard problem. In fact, even determining if a graph is 3-colorable is NP-complete and it remains NP-complete also in the class of claw-free graphs in general.

In the talk we will focus on the computational complexity of the problem in the subclasses of claw-free graphs defined by forbidding additional subgraphs. We extend the results of Kamiński and Lozin, and prove the polynomial-time solvability of the 3-coloring problem in the class of (claw, Φ_2)-free and (claw, Φ_4)-free graphs.

Polynomial χ-binding functions and forbidden induced subgraphs - a survey

Ingo Schiermeyer *Joint work with: Bert Randerath*

A graph G with clique number $\omega(G)$ and chromatic number $\chi(G)$ is *perfect* if $\chi(H) = \omega(H)$ for every induced subgraph H of G. A family $\mathcal{G}$ of graphs is called χ-bounded with binding function f if $\chi(G') \leq f(\omega(G'))$ holds whenever $G \in \mathcal{G}$ and G' is an induced subgraph of G. In this talk we will present a survey on polynomial χ-binding functions. Especially we will address perfect graphs, hereditary graphs satisfying the Vizing bound ($\chi \leq \omega + 1$), graphs having linear χ-binding functions and graphs having non-linear polynomial χ-binding functions. Thereby we also survey polynomial χ-binding functions for several graph classes defined in terms of forbidden induced subgraphs, among them $2K_2$-free graphs, P_k-free graphs, $claw$-free graphs, and $diamond$-free graphs.

The stable set problem in graphs with bounded genus and bounded odd cycle packing number

Samuel Fiorini *Joint work with: Michele Conforti, Tony Huynh, Gwenaël Joret, Stefan Weltge*

Consider the family of graphs without k node-disjoint odd cycles, where k is a constant. Determining the complexity of the stable set problem for such graphs G is a long-standing problem. We give a polynomial-time algorithm for the case that G can be further embedded in a (possibly non-orientable) surface of bounded genus. Moreover, we obtain polynomial-size extended formulations for the respective stable set polytopes.

To this end, we show that 2-sided odd cycles satisfy the Erdős-Pósa property in graphs embedded in a fixed surface. This extends the fact that odd cycles satisfy the Erdős-Pósa property in graphs embedded in a fixed orientable surface (Kawarabayashi & Nakamoto, 2007).

Eventually, our findings allow us to reduce the original problem to the problem of finding a minimum-cost non-negative integer circulation of a certain homology class, which turns out to be efficiently solvable in our case.

Complete acyclic colorings

Raphael Steiner *Joint work with: Stefan Felsner, Winfried Hochstättler, Kolja Knauer*

We study two parameters that arise from the dichromatic number and the vertex-arboricity in the same way that the achromatic number comes from the chromatic number. The adichromatic number of a digraph is the largest number of colors its vertices can be colored with such that every color induces an acyclic subdigraph but merging any two colors yields a monochromatic directed cycle. Similarly, the a-vertex arboricity of an undirected graph is the largest number of colors that can be used such that every color induces a forest but merging any two yields a monochromatic cycle. We study the relation between these parameters and their behavior with respect to other classical parameters such as degeneracy and most importantly feedback vertex sets.

Compact cactus representations of all non-trivial min-cuts

On-Hei Solomon Lo *Joint work with: Jens M. Schmidt, Mikkel Thorup*

Recently, Kawarabayashi and Thorup presented the first deterministic edge-connectivity recognition algorithm in near-linear time. A crucial step in their algorithm uses the existence of vertex subsets of a simple graph G on n vertices whose contractions leave a multigraph with $\tilde{O}(n/\delta)$ vertices and $\tilde{O}(n)$ edges that preserves all non-trivial min-cuts of G, where δ is the minimum degree of G and $\tilde{O}$ hides logarithmic factors.

We present a simple argument that improves this contraction-based sparsifier by eliminating the poly-logarithmic factors, that is, we show a contraction-based sparsification that leaves $O(n/\delta)$ vertices and $O(n)$ edges, preserves all non-trivial min-cuts and can be computed in near-linear time $\tilde{O}(m)$, where m is the number of edges of G. We also obtain that every simple graph has $O((n/\delta)^2)$ non-trivial min-cuts.

Our approach allows to represent all non-trivial min-cuts of a graph by a cactus representation, whose cactus graph has $O(n/\delta)$ vertices. Moreover, this cactus representation can be derived directly from the standard cactus representation of all min-cuts in linear time. We apply this compact structure to show that all min-cuts can be explicitly listed in $\tilde{O}(m) + O(n^2/\delta)$ time for every simple graph, which improves the previous best time bound $O(nm)$ given by Gusfield and Naor.

Minimum leaf number of 2-connected cubic graphs

Márton Dücső

A natural generalisation of traceability, the minimum leaf number $m\ell(G)$ of a connected graph G is defined as the minimum number of leaves of spanning trees of G.

Goedgebeur, Ozeki, Van Cleemput and Wiener (2018) proved that if G is a 2-connected cubic graph of order n, then $m\ell(G) \leq \frac{n}{6.53}$. In the same paper, they presented an infinite family of such graphs with $m\ell(G) = \frac{n}{10}$, and conjectured that $\lceil \frac{n}{10} \rceil$ is the best bound possible.

In this talk we improve their result of $\frac{n}{6.53}$ to $\frac{n}{8}$ and discuss some related problems.

Extremal results on the eccentric connectivity index

Pierre Hauweele *Joint work with: Alain Hertz, Hadrien Mélot, Bernard Ries and Gauvain Devillez*

The eccentric connectivity index of a connected graph is the sum over all vertices of the product between eccentricity (maximum distance to any other vertex) and degree. Alternatively, it is the sum, over all edges, of the eccentricities of both their vertices.

We will present some known and new extremal results about this invariant. Especially, given two integers n and D with $D \leq n-1$, we characterize those graphs which have the largest eccentric connectivity index among all connected graphs of order n and diameter D. As a corollary, we also characterize those graphs which have the largest eccentric connectivity index among all connected graphs of a given order n.

Food options

Near the campus

As the group would be too large to go for lunch together, we encourage you to split up in smaller groups and have lunch in one of the restaurants near the campus. Feel free to speak to us about suggestions.

On page 24 you can see a map of the campus and its surroundings. The campus is shown in grey, all talks are in the red building (S9), and the access points to the campus are shown in blue.

Below is an overview of the restaurants/shops near the campus. For each one we note whether it is take-out (TO) or eat-in (EI). If you buy take-out, you can eat it in one of the rooms at the university, or – in case of good weather – there are several picnic tables in the garden behind the S9 building.

A. **Eetoile** *(Oudenaardsesteenweg 34, 9000 Gent)* TO/EI
Healthy foodbar: has salads, quiches, wraps, and soups.
www.eetoile.be

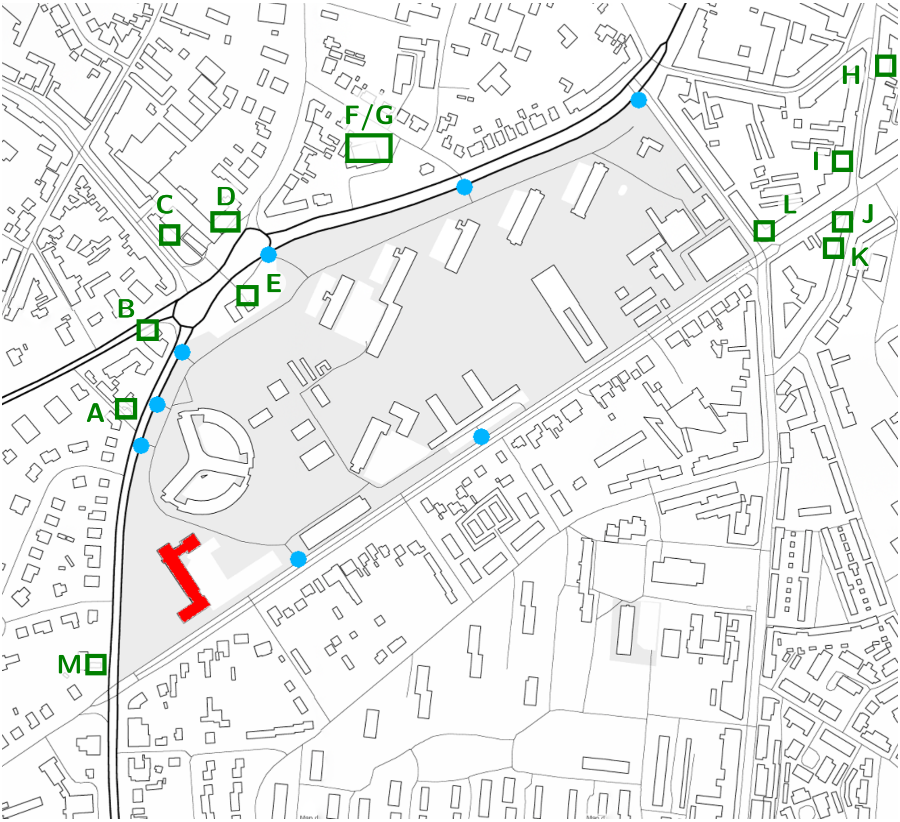
B. **Gran Gusto** *(Kortrijksesteenweg 857, 9000 Gent)* EI
Italian restaurant, but a bit more expensive than average.
grangusto.business.site

C. **De Fritoloog** *(Voskenslaan 413, 9000 Gent)* TO/EI
A Belgian-style friterie.
www.facebook.com/voskenslaan413gent

D. **Delhaize** *(Kortrijksesteenweg 906, 9000 Gent)* TO
A large supermarket that also sells sandwiches and salads to go.
www.delhaize.be

E. **Select Shop (Shell)** *(Kortrijksesteenweg 831, 9000 Gent)* TO
A gas-station shop that also sells sandwiches.

F. **Pizza Hut** *(Pacificatielaan 6, 9000 Gent)* TO/EI
American-style pizzas. At lunchtime they have an all-you-can-eat buffet.
www.pizzahut.be


F/G
H
I
C
D
L
J
E
K
B
A
M

G. **Lunch Garden** *(Pacificatielaan 6, 9000 Gent)* EI
A self-service restaurant offering lunch at a reasonable price.
www.lunchgarden.com

H. **Ocean Garden** *(Zwijnaardsesteenweg 399, 9000 Gent)* TO
Chinese take-out restaurant.
oceangarden.byethost3.com

I. **Bizar Cafe** *(Zwijnaardsesteenweg 454, 9000 Gent)* EI
Alcohol-free bar which offers snacks and desserts (also has a selection of gluten-free and lactose-free food).
www.bizarcafe.be

J. **Uniq** *(Zwijnaardsesteenweg 458, 9000 Gent)* TO/EI
Kebab and grill snack bar.
www.uniqkebab.be

K. **Pizza Carlo** *(Zwijnaardsesteenweg 462/1, 9000 Gent)* TO/EI
Very good Italian pizzas, but limited number of tables.
www.facebook.com/pizzacarlogent

L. **Sim Pizza** *(De Pintelaan 252, 9000 Gent)* TO/EI
Italian-style pizzas and some other snacks
www.sim-pizza.be

M. **Go (Texaco)** *(Oudenaardse Steenweg 77-89, 9000 Gent)* TO
A gas-station shop that also sells sandwiches.

For people with special dietary requirements (vegan, vegetarian, ...) or who are looking for a specific cuisine (Greek, Indian, ...), there are some options which are slightly further away, but still manageable for lunch. Please contact us for directions.

In the city centre

Belgians are Burgundian people, so you shouldn't have any problem finding restautants in the city center. Below we list some personal favorites and some restaurants for people with special dietary requirements. In the era of Google Maps, TripAdvisor, and the rest of the internet you shouldn't have any difficulty locating them, but please feel free to contact us to help you find them on a map.

Belgian food

The Belgian cuisine is hard to define, since it has many influences from neighbouring countries. Nevertheless for those willing to sample the local food, we list some restaurants which serve typical Belgian dishes.

De Frietketel The best place to get the typical Belgian fries, since it was elected best friterie of Flanders in 2017. They have a large range of home-made snacks to accompany the fries including a large selection of vegetarian options. Make sure to taste their "stoverijsaus" to dip your fries in together with mayonnaise for the ultimate Belgian experience.

www.facebook.com/De-Frietketel-34597147572

Balls & Glory Real comfort food for Belgians. You get a meatball (meat/chicken/veggie) with a liquid filling (the options change each day) together with mashed potatoes-and-vegetables ("stoemp") accompanied by a gravy and a creamy curry sauce. Or, if you don't like stoemp or aren't that hungry, you can choose a salad to go with your meatball. An ideal spot if you don't want to waste too much time eating. Also well-suited for larger groups.

ballsnglory.be

Het Pakhuis A classic "brasserie" with French and Belgian dishes as we would have them going out for dinner. When you're not looking for creative cooking, but like the classics well prepared, this is a good place to go. Also the venue is quite big, so you have a good chance of finding a spot. **This is also the venue for the conference dinner.**

www.pakhuis.be

Meme Gusta Food like our grandma would prepare it. All the classic flavours of the Belgian cuisine. You might need to make a reservation as we all love grandma's kitchen.

www.meme-gusta.be

Vegetarian/vegan

Ghent has several restaurants which are either completely vegetarian or vegan, or offer a vegetarian or vegan option. A more complete list can be found on the website www.evavzw.be/resto. Unfortunately, this website is only available in Dutch and French, so contact us if you need help navigating it. Below are some of our favourite places.

Greenway Burgers, wraps and salads that taste great. Not a place to wine and dine, but excellent if you want to have a quick meal.

greenway.be

Lokaal Charming place for honest food and delicious tea. Small choice of dishes, but prepared with lots of love.

www.facebook.com/LokaalGent

De Appelier You can get a daily special or a pasta over here. The special is a plate full of different veggies and grains and something like a homemade meat replacer or quiche. There's soup and a dessert of the day as well. Food is served fast here, so if you're in a hurry, this is very healthy fast food!

www.deappelier.be

Trendy places

Ghent is also a hip and happening city. If you want to be a part of this, then below are some places you should really visit.

Holy Food Market Housed in a former chapel there are food stalls here with food from all over the world. You can sit and have bits and pieces from different places. Choosing is the hard part.

holyfoodmarket.be

Mosquito Coast A travel café where you can have cocktails and tapas but also a decent meal. You might want to make a reservation.

www.mosquitocoast.be

De Superette The project of Michelin star chef Kobe Desramaults with an affordable and more simple menu. The atmosphere is easy going and you get to see bread and pizzas being baked in the oven which has a central place in the restaurant.

www.de-superette.be

Eat Love Pizza Trendy pizza place with quite expensive pizzas but some interesting flavours. You can also choose to have two halves of different flavours instead of picking just one. They also opened a new place Eat Love Lasagna which serves lasagnas.

eatlove.be

Exotic Ghent

You might have had enough of Belgian cuisine? We can't imagine how that is possible, but no worries: we have you covered. Belgians have a wide palate, and so you can find several restaurants in Ghent which serve non-Belgian cuisine.

Gado-Gado Hidden in the narrow streets of the trendy neighbourhood 'Patershol', you will find this Indonesian restaurant. Besides great Indonesian food, they also offer a long list of cocktails and mocktails.

gado-gado.gent

Le Baan Thai This well-established Thai restaurant is also located in 'Patershol'. From the outside you will only see a sign on the wall. After you pass the first two gates, you will have to cross a garden to get to the entrance.

www.lebaanthai.be

AYWA Beirut Streetfood A fine Lebanese streetfood restaurant for those who love to share food and taste a lot of different dishes. You can't make reservations here, but you can also order food for take-out.

aywabeirutstreetfood.business.site

Meat lovers

If you got an insatiable desire for meat, then one of the following restaurants might be ideal for you.

Amadeus This is an all-you-can-eat restaurant for ribs. They are prepared with a sweet marinade and come with a jacket-potato with some curried cream inside. There are different restaurants of this chain in Ghent. They have a charming interior, but service is usually more pragmatic.

amadeus-resto.be

De Gekroonde Hoofden This is another all-you-can-eat restaurant for ribs. They have different kind of preparations (honey, somewhat spicy, sweet-and-sour or without marinade) and serve them with Turkish pide bread, a hot tomato and some salad.

degekroondehoofden.be

Pampas This is an all-you-can-eat Brazilian grill restaurant. Giant skewers of meat are being grilled in the kitchen and the waiters go from table to table to slice off a piece for you. There's also fish and prawns on the skewers and grilled vegetables and fruit. This is served with a salad and fries or a jacket-potato.

www.pampas.be

Ankara This is a Turkish restaurant known for its "plateau du chef" which is a huge platter with a combination of different mezzes and grilled meats. Kudos to you if you manage to finish it! You can of course just order a simple dish as well.

www.ankararesto.be

Gastronomy & Co

You might have high standards when it comes to dining. Well, then these restaurants are ideal for you. Note that you will most likely need to make a reservation at least a day in advance, and that these restaurants tend to be quite pricey.

Vrijmoed Michelin star restaurant by young chef Michael Vrijmoed, former sous-chef of Michelin 3-star restaurant Hof van Cleve. There are two set menus from which you can choose: vegetarian or non-vegetarian. Each menu comes in either five, six, or seven courses.

www.vrijmoed.be

Karel de Stoute Located in the picturesque 'Patershol', this restaurant offers haute cuisine at an 'affordable' price. They only offer the set menu (ranging from two to five courses).

www.restkareldestoute.be

Publiek Publiek is the Michelin star restaurant of Flemish Foodie Olly Ceulenaere and Kelly Dehollander. At noon they serve a healthy lunch. In the evening you can either take the six course menu or just a part of it.

www.publiekgent.be

Beer

After all this food you might be thirsty, and looking to sample some Belgian beers.

Waterhuis aan de Bierkant Idyllically located next to the water, this bar has a large selection of Belgian beers. It can however get very crowded during the tourist season.

www.waterhuisaandebierkant.be

Het Trappistenhuis This bar lies outside of the historic center, and is therefore less visited by tourists. It has more than 170 special Belgian beers.

www.facebook.com/Trappistenhuis

Trollekelder A favourite both with tourists and locals. Ideal place to sample a Belgian beer and have a nice chat.

www.trollekelder.be

Participants

Florian Adriaens
Ghent University, Ghent, Belgium

Sam Adriaensen
Vrije Universiteit Brussel, Brussels, Belgium

Simon Apers
Inria, Paris, France

Gunnar Brinkmann
Ghent University, Ghent, Belgium

Stijn Cambie
Radboud University, Nijmegen, Netherlands

Wouter Cames van Batenburg
Université Libre de Bruxelles, Brussels, Belgium

Xiangfeng Chen
Ghent University, Ghent, Belgium

Reshma Chiryail Chandrasekharan
KU Leuven, Ghent, Belgium

Maria Chudnovsky
Princeton University, Princeton, USA

Jan De Beule
Vrije Universiteit Brussel, Brussels, Belgium

Gauvain Devillez
Université de Mons, Mons, Belgium

Márton Dücső
Budapest University of Technology and Economics, Budapest, Hungary

Igor Fabrici
P.J. Šafárik University, Košice, Slovakia

Samuel Fiorini
Université Libre de Bruxelles, Brussels, Belgium

Bernard Fortz
Université Libre de Bruxelles, Brussels, Belgium

Jan Goedgebeur
Ghent University, Ghent, Belgium

Pieter Goetschalckx
Ghent University, Ghent, Belgium

Krystal Guo
Université Libre de Bruxelles, Brussels, Belgium

Jochen Harant
TU Ilmenau, Ilmenau, Germany

Pierre Hauweele
Université de Mons, Mons, Belgium

Lisa Hernandez Lucas
Vrije Universiteit Brussel, Brussels, Belgium

Junqing Huang
Ghent University, Ghent, Belgium

Bill Jackson
Queen Mary University of London, London, UK

Gwenaël Joret
Université Libre de Bruxelles, Brussels, Belgium

Adam Kabela
Masaryk University, Brno, Czech Republic

František Kardoš
Bordeaux University, Bordeaux, France

Sandra Kingan
Brooklyn College, CUNY, Brooklyn, USA

Domenico Labbate
Università degli Studi della Basilicata, Potenza, Italy

Binlong Li
Northwestern Polytechnical University, Xi'an, China

On-Hei Solomon Lo
TU Ilmenau, Ilmenau, Germany

Edita Máčajová
Comenius University, Bratislava, Slovakia

Mária Maceková
P.J. Šafárik University, Košice, Slovakia

Tomáš Masařík
Charles University, Prague, Czech Republic
University of Warsaw, Warsaw, Poland

Sam Mattheus
Vrije Universiteit Brussel, Brussels, Belgium

Giuseppe Mazzuoccolo
University of Verona, Verona, Italy

Brendan McKay
Australian National University, Canberra, Australia

Bojan Mohar
SFU, Burnaby, Canada
IMFM, Ljubljana, Slovenia

Samuel Mohr
TU Ilmenau, Ilmenau, Germany

Dieter Mourisse
Ghent University, Ghent, Belgium

Torsten Mütze
University of Warwick, Warwick, UK
Charles University, Prague, Czech Republic

Jakub Przybyło
AGH University of Science and Technology, Krakow, Poland

Stanisław Radziszowski
Rochester Institute of Technology, Rochester, USA

Ingo Schiermeyer
TU Bergakademie Freiberg, Freiberg, Germany

Andreas Schmid
Aalto University, Espoo, Finland

Pascal Schweitzer
TU Kaiserslautern, Kaiserslautern, Germany

Martin Škoviera
Comenius University, Bratislava, Slovakia

Eckhard Steffen
Paderborn University, Paderborn, Germany

Raphael Steiner
TU Berlin, Berlin, Germany

Guillaume Valette
Université Libre de Bruxelles, Brussels, Belgium

Nico Van Cleemput
Ghent University, Ghent, Belgium

Heidi Van den Camp
Ghent University, Ghent, Belgium

Steven Van Overberghe
Ghent University, Ghent, Belgium

Mehmet Aziz Yirik
Friedrich-Schiller University Jena, Jena, Germany

Carol T. Zamfirescu
Ghent University, Ghent, Belgium

Peter Zeman
Charles University, Prague, Czech Republic

Tao Zhao
Ghent University, Ghent, Belgium

Monday August 12

09:00 - 09:30	*Badge pick-up*
09:30 - 09:35	*Opening*
09:35 - 10:20	**Chudnovsky**
10:20 - 10:35	*Coffee break*
10:35 - 12:15	**Kabela, Joret, Przybyło, Steffen**
12:15 - 14:00	*Lunch*
14:00 - 15:15	**Brinkmann, Schmid, Fabrici**
15:15 - 15:30	*Coffee break*
15:30 - 16:45	**Mohr, Labbate, Li**

Tuesday August 13

09:30 - 10:15	**McKay**
10:15 - 10:35	*Coffee break*
10:35 - 12:15	**Radziszowski, Kingan, Mütze, Schweitzer**
12:15 - 14:00	*Lunch*
14:00 - 14:45	**Mohar**
14:45 - 16:00	**Škoviera, Máčajová, Mazzuoccolo**
19:00 - 22:00	*Conference dinner*

Wednesday August 14

09:30 - 10:15	**Jackson**
10:15 - 10:35	*Coffee break*
10:35 - 12:15	**Kardoš, Maceková, Schiermeyer, Fiorini**
12:15 - 14:00	*Lunch*
14:00 - 15:40	**Steiner, Lo, Dücső, Hauweele**
15:40 - 15:45	*Closing remarks*