GO 2023, Spa, Belgium

Program

June 21, 2023

Program at a glance

	Monday July 3	Tuesday July 4	Wednesday July 5	Thursday July 6
09:00 - 09:15	**Opening session**			
09:15 -10:45	**Graphs 1** Huang Schindl Korenblit	**Graphs 2** Hauweele Dusolier Devillez	**Combinatorial Optimization 3** Stern Callebaut Spieksma	**Graph Coloring** Sasaki Mann Cameron
10:45 - 11:15	Coffee break	Coffee break	Coffee break	Coffee break
11:15 - 12:15	**Keynote** Crama	**Healthcare and bioinformatics** Swiercz Baratto	**Keynote** Preissmann	**Matchings** Bonte Lucke
12:15 - 14:00	Lunch	Lunch	Lunch on your own Free afternoon Thermal baths	**Closing session**
14:00 - 15:30	**Combinatorial Optimization 1** Hertz Pelayo Felici	**Graphs 3** Hoang Picouleau Golumbic		
15:30 - 16:00	Coffee break	Coffee break		
16:00 - 17:30	**Combinatorial Optimization 2** Marin De Boeck Espejo	**Scheduling** Brunod Indrigo Stützle Carlier		
17:30 - 19:00	Free time	Free time		
from 19:00	Dinner	Dinner	Banquet	

Monday, 9:00-9:15

■ MA-01

Monday, 9:00-9:15

Opening session

Chair: *Bernard Fortz*
Chair: *Hadrien Mélot*

Monday, 9-15-10:45

■ MB-01

Monday, 9-15-10:45

Graphs 1

Chair: *Bernard Ries*

1 - Strong Cocomparability Graphs and Slash-free Orderings of Matrices
Jing Huang

We introduce the class of strong cocomparability graphs, as the class of reflexive graphs whose adjacency matrix can be rearranged by a simultaneous row and column permutation to avoid the submatrix with rows $01,10$, which we call em Slash.

We provide an ordering characterization, a forbidden structure characterization, and a polynomial-time recognition algorithm, for the class. These results complete the picture in which in addition to, or instead of, the $Slash$ matrix one forbids the em $Gamma$ matrix (which has rows $11,10$). It is well known that in these two cases one obtains the class of interval graphs, and the class of strongly chordal graphs, respectively.

By complementation, we obtain the class of strong comparability graphs, whose adjacency matrix can be rearranged by a simultaneous row and column permutation to avoid the two-by-two identity submatrix. Thus our results give characterizations and algorithms for this class of irreflexive graphs as well. In other words, our results may be interpreted as solving the following problem: given a symmetric $0,1$-matrix with 0-diagonal, can the rows and columns of be simultaneously permuted to avoid the two-by-two identity submatrix?

2 - Finding k-community structures in special graph classes
David Schindl, Narmina Baghirova, Clément Dallard, Bernard Ries

For a fixed integer k >= 2, a k-community structure in an undirected graph is a partition of its vertex set into k sets (called communities), each of size at least two, such that every vertex of the graph has proportionally at least as many neighbours in its own community as in any other community. In this paper, we present the following results. We give a necessary and sufficient condition for a forest to admit a k-community structure, for any integer k >= 2. Furthermore, if such a k-community structure exists, it can be found in quadratic time. If communities are allowed to have size one, we show that every forest on n >= k >= 2 vertices admits a k-community structure, that can also be found in quadratic time. We then consider threshold graphs and show that every connected threshold graph on n vertices and m edges admits a 2-community structure if and only if it is not isomorphic to a star. If such a 2-community structure exists, it can be found in linear time. We also introduce two infinite families of disconnected threshold graphs, containing exactly one isolated vertex, not admitting any 2-community structure. Finally, we present a new infinite family of connected graphs that do not admit any 2-community structure, even if communities are allowed to have size one. Such a family was presented in [Bazgan et al., Information Processing Letters, 155:105877, 2020], but its graphs all contained an even number of vertices. The graphs in our new family may contain an even or an odd number of vertices.

3 - Complexity of Algebraic Expressions Motivated by Graphs
Mark Korenblit, Vadim Levit

The focus of this research is to explore the relationship between algebraic expressions and graphs, with the ultimate goal of simplifying graph expressions and finding their shortest representations. Through

our research, we have proven monotonicity results that allow us to assert that the length of a shortest expression for any subgraph of a given graph is no greater than the length of a shortest expression for the graph itself. We have also described a decomposition method for generating expressions of complete st-dags (two-terminal directed acyclic graphs) and estimated their corresponding expression complexities. Based on these findings, we have presented a quasi-polynomial upper bound for the length of a shortest expression for every n-vertex st-dag.

Monday, 11:15-12:15

■ MC-01

Monday, 11:15-12:15

Keynote: Yves Crama

Chair: *Yasemin Arda*

1 - Graph and optimization models for kidney exchanges
Yves Crama

Nowadays, the preferred treatment option offered to patients with an end-stage renal disease is to receive a kidney transplant from a living donor. This option is primarily used when the patient has a relative who is willing to donate a healthy kidney. However, in many situations, the transplantation cannot take place due to immunological incompatibility between the patient and the healthy donor. Kidney exchange programs (KEPs) try to alleviate this limitation by enlisting a large number of incompatible patient-donor pairs (P_i,D_i), each one made up of a patient P_i and a donor D_i, where P_i is incompatible with D_i but P_i is typically compatible with a few donors D_k different from D_i. Considering such a pool makes it potentially feasible to perform sequences of transplantations in cyclic fashion across several pairs.

Kidney exchange programs typically try to maximize the number of cyclic exchanges performed in the pool by matching as many compatible individuals as possible. This optimization problem can be modeled as the problem of covering a maximum number of vertices of a compatibility digraph G = (V,A) by disjoint cycles, where V is the set of patient-donor pairs and there is an arc from pair k to pair i if the donor of pair k is compatible with the patient of pair i.

In this talk, I present some work I have done in recent years, together with several collaborators, on different models obtained by introducing uncertainty or stability considerations into the basic kidney exchange model. In particular, I will show how these models lead to new graph theoretic concepts and optimization problems.

The talk is based on joint work with Marie Baratto, Valentin Bartier, João Pedro Pedroso, Bart Smeulders, Frits Spieksma and Ana Viana.

Monday, 14:00-15:30

■ MD-01

Monday, 14:00-15:30

Combinatorial Optimization 1

Chair: *Marino Widmer*

1 - Hypercubes for the cold start problem in recommender systems
Alain Hertz

The initial interaction of a user with a recommender system is problematic because, in such a so-called cold start situation, the recommender system has very little information about the user, if any. Moreover, in collaborative filtering, users need to share their preferences with the service provider by rating items while in content-based filtering there is no need for such information sharing. We describe a content-based model that uses hypercube graphs to determine user preferences with a very limited number of ratings while better preserving user privacy. Experiments with more than 1,000 users in the restaurant and movie domains show that the proposed method outperforms standard machine learning algorithms when the number of available ratings is at most 10, which often happens, and is competitive with larger training sets. In addition, training is simple and does not require large computational efforts.

2 - Strong locating sets in Pseudotrees
Ignacio m. Pelayo

Given a connected graph G=(V,E), a vertex v is said to strong resolve two vertices x and y if there exists either a geodesic joining v and x that contains y, or a geodesic joining v and y that contains x.

A set of vertices S of G is called strong locating if every pair of distinct vertices x and y of G is strong resolved by a vertex v of S.

A significant characterization of these sets is the following one: A proper subset of vertices S of G=(V,E) is strong locating if and only if the graph G is uniquely determined by the matrix of distances between the vertices of S and the vertices of V.

A strong locating set of minimum cardinality is called a strong metric basis of G. The strong metric dimension of G, denoted by sdim(G), is the cardinality of a strong metric basis.

This parameter was formally introduced by András Sëbo and Eric Tannier In: [On metric generators in graphs, Math. Oper. Res. 29 (2004), no. 2, 383-393.]

If T is a tree with l leaves, then sdim(T) is equal to l-1, which is a consequence of the fact that every strong metric basis of T consists of a set of all leaves except one.

If C is a cycle of order n, then sdim(C) is equal to the ceiling of half its order. Moreover, every strong metric basis consists of k+1 consecutives vertices of C if n=2k+1 is odd, meanwhile if n=2k is even, then a set S is a strong metric basis of C if and only if its complementary V-S contains no antipodal pair.

If G is an unicyclic graph with l leaves and its unique cycle is C, then sdim(G) is at least l-1 and at most l+c, being c the floor of half the number of vertices of C of degree 2. Moreover, we have been able to characterize, for every integer h between both bounds, the set of unicyclic graphs whose strong metric dimension is h.

3 - MIP models for Simultaneous Feature Selection and Outlier Detection in Linear Regression
Giovanni Felici

High-dimensional linear regression models are nowadays pervasive in most research domains. However, as studies become larger, the likelihood of having redundant features or contaminated data (outlying values) increases, which can create serious challenges. To address these issues, researchers have focused on developing efficient methods for sparse estimation in the presence of outliers. We contribute to this area considering high-dimensional models contaminated by multiple mean-shift outliers affecting both the response and the design matrix - leading to the exclusion of out- lying cases from the fit. Our novel framework leverages mixed-integer programming techniques to simultaneously perform feature selection and outlier detection with provably optimal guarantees (i.e., the global optimum of the underlying "double" combinatorial problem is indeed achievable) [1]. We also prove theoretical properties for our approach, such as a necessary and sufficient condition for the robustly strong oracle property, where the number of features can increase exponentially with the sample size, and the breakdown point of the resulting estimates. Moreover, we provide computationally efficient procedures to tune integer constraints and warm-start the algorithm. Our extensive simulations and real-world applications demonstrate the superiority of our proposal over existing heuristic methods. Additionally, we discuss its extensions to a broader class of models, as well as the use of down-weighting schemes and adaptive procedures for outlier detection.

Monday, 16:00-17:30

■ ME-01

Monday, 16:00-17:30

Combinatorial Optimization 2

Chair: *Frits Spieksma*

1 - Comparing formulations of The Ordered Travelling Salesman Problem
Alfredo Marín, Ivana Ljubic, Justo Puerto, Francisco Temprano Garcia

The OTSP is to find a Hamiltonian cycle in a network with minimum weighted cost. The costs of the edges of the cycle have to be sorted in decreasing order before multiplying them times the given weights. When all weights are equal and positive, the TSP is obtained as a particular case. When the unique non-null weight (positive) is the first one, the bottleneck TSP is obtained. Positive weights in the first positions and negative weights in the last positions will provide us with balanced cycles. Many other particular cases of interest exist, and the aim of the problem is to study all of them as a whole. In this preliminary work we study and compare different integer programming formulations of reduced size for the OTSP, paying special attention to the sorting part of the models.

2 - Iterative Price-and-Branch for railway crew scheduling
Jérôme De Boeck

Railway scheduling problems have been studied for decades and are large-scale combinatorial optimization problems. Most mathematical methods for crew scheduling rely on a set covering formulation and column generation methods such as price-and-branch. Price-and-branch methods solve the column generation of the linear relaxation of the problem to optimality before using the columns obtained in a MILP solver. Also, some legal constraints are often not considered in the literature, allowing to use state-of-the-art methods to solve the set covering formulation of the problem. Ignoring these constraints leads to solutions that need to be manually corrected.

We propose a formulation for the crew scheduling problem of the Swiss Federal Railways, integrating a high level of detail regarding physical and legal constraints. The resulting formulation is very large, and price-and-branch methods tend to generate too many columns for commercial MILP solvers, the solution quality degrading when more columns are considered. An Iterative Price-and-Branch (IPB) matheuristic is developed to deal with a large number of columns. Feasible solutions are iteratively improved by considering a limited number of columns in a local neighborhood of the current best integer solution. Unlike for the full MILP formulation in price-and-branch, the performance of the IPB improves when considering more columns with a minor increase in the solving time. A generic IPB for problems solved with price-and-branch is proposed as well as a fine tuned version for our problem. The solution quality of the IPB improves the best solution of the price-and-branch by 10%.

3 - Upgrading arcs to p-median problem in a bi-network
Inmaculada Espejo, Alfredo Marín

We analyze the upgrading of arcs in the p-median problem on a bi-network. Both travel times and transportation costs are associated with each arc. Our goal consists of simultaneously finding p medians, allocating each node to the median of minimum travel time and distributing a known budget among the arcs of the network to reduce their transportation cost, in order to minimize the total transportation cost of the system. We formulate it in two different ways as an integer programming problem, derive some properties of any optimal solution, develop valid inequalities and present computational results.

Tuesday, 9-15-10:45

■ TA-01

Tuesday, 9-15-10:45

Graphs 2

Chair: *Kathie Cameron*

1 - A new web interface to PHOEG, a tool that Helps to Obtain Extremal Graphs
Pierre Hauweele, Sébastien Bonte, Gauvain Devillez, Hadrien Mélot

PHOEG is an acronym for "PHOEG Helps to Obtain Extremal Graphs". This discovery system is based on a large database of small graphs, invariant values and graph transformation effects. It uses a geometric approach to discover inequalities between graph invariants and hints for proofs by transformation. PHOEG provided tight bounds for several graph invariants, including the number and average number of non-equivalent colorings and the eccentric connectivity index. In this talk, we present a new web interface that allows graph theorists to query PHOEG and manipulate and visualize the outputs, without the need for programming. Also, we will give examples of results and open problems that were obtained with the help of PHOEG.

2 - About a conjecture on the number of non-equivalent colorings of graphs
Valentin Dusollier

We will present some results regarding a conjecture on the number of non-equivalent colorings of a graph, also known as the graphical Bell number. This conjecture establishes the lower bound on this invariant for graphs with fixed order and size. It was first mentioned in 2014 at GO IX (Sirmione) by Hadrien Mélot and Alain Hertz. Specifically, we will provide a proof for graphs of large size, and we will reduce the conjecture to another statement, which seems more accessible than the original one.

3 - Extremal results on the Arithmetic Geometric Index
Gauvain Devillez, Hadrien Mélot, Alain Hertz, Sébastien Bonte, Pierre Hauweele

The arithmetic geometric index, noted AG, is a graph invariant defined in 2015 by V. Shegehalli and R. Kanabur. AG is a topological index designed to improve the prediction capacity of the well known Randic index in QSPR/QSAR studies. However, the two have different extremal properties. Despite its objective of improving the Randic index, AG has not been widely studied in extremal graph theory.

We present results on the extremal properties of AG as well as the theoretical and practical methods we developed to work with invariants defined as sums of weights on the edges.

Tuesday, 11:15-12:15

■ TB-01

Tuesday, 11:15-12:15

Healthcare and bioinformatics

Chair: *Jacek Blazewicz*

1 - Graph theory in the context of DNA de novo assembly
Aleksandra Swiercz, Jacek Blazewicz

Graphs are often used to solve bioinformatics problems. Here we present different types of graphs used for solving de novo assembly problem. The problem of reading a DNA sequence involves assembling many shorter sequences into a longer one. The process is complicated due to the huge amount of data that needs to be processed. Short DNA fragments are represented as vertices in graphs. Vertices are connected with an arc if there is an overlap of corresponding DNA fragments. In such a graph, we are looking for a path that passes through all vertices, which corresponds to finding a genome sequence composed of all DNA fragments.

Difficulties such as repeats in the DNA sequence of the studied genome and uneven coverage of fragments that make it impossible to obtain one path in the graph will also be discussed.

2 - Local stability in kidney exchange programs
Marie Baratto, Yves Crama, João Pedro Pedroso, Ana Viana

When each patient of a kidney exchange program has a preference ranking over its set of compatible donors, questions naturally arise surrounding the stability of the proposed exchanges. We extend recent work on stable exchanges by introducing and underlining the relevance of a new concept of locally stable, or L-stable, exchanges. We show that locally stable exchanges in a compatibility digraph are exactly the so-called local kernels (L-kernels) of an associated blocking digraph (whereas the stable exchanges are the kernels of the blocking digraph). Based on these insights, we propose several integer programming formulations for computing an L-stable exchange of maximum size. We conduct numerical experiments to assess the quality of our formulations and to compare the size of maximum L-stable exchanges with the size of maximum stable exchanges. It turns out that nonempty L-stable exchanges frequently exist in digraphs which do not have any stable exchange.

Tuesday, 14:00-15:30

■ TC-01

Tuesday, 14:00-15:30

Graphs 3

Chair: *Myriam Preissmann*

1 - A closure lemma for tough graphs and Hamiltonian ideals
Chinh Hoang

The closure of a graph G is the graph G obtained from G by repeatedly adding edges between pairs of non-adjacent vertices whose degree sum is at least n, where n is the number of vertices of G. The well-known Closure Lemma proved by Bondy and Chvatal states that a graph G is Hamiltonian if and only if its closure G is. This lemma can be used to prove several classical results in Hamiltonian graph theory. We prove a version of the Closure Lemma for tough graphs. A graph G is t-tough if for any set S of vertices of G, the number of components of G S is at most t|S|. A Hamiltonian graph must necessarily be 1-tough. Conversely, Chvatal conjectured that there exists a constant t such that every t-tough graph is Hamiltonian. The t-closure of a graph G is the graph Gt obtained from G by repeatedly adding edges between pairs of non-adjacent vertices whose degree sum is at least n t. We prove that, for t 2, a ((3t1)/2)-tough graph G is Hamiltonian if and only if its t-closure Gt is. Hoang conjectured the following: Let G be a graph with degree sequence d1 d2 . . . dn; then G is Hamiltonian if G is t-tough and, i < n/2, if di i then dni+t ni. This conjecture is analogous to the well known theorem of Chvatal on Hamiltonian ideals. Hoang proved the conjecture for t 3. Using the closure lemma for tough graphs, we prove the conjecture for t = 4. This is joint work with Cleophee Robin.

2 - On the complexity of the Minimum Dominating Set in claw-free graphs with Diameter two
Christophe Picouleau, Valentin Bouquet

Given a graph G a dominating set is a subset of vertices S such that each vertex not in S has a neighbor in S. Dominating Set is the problem of deciding, given a graph G and a positive integer k, if G has a dominating set of size at most k. This problem is NP-complete for claw-free graphs, and for graphs with diameter two. We give a polynomial-time algorithm to compute a minimum dominating set for claw-free graphs with diameter two. For that, in a first step, we show that the we can compute, in polynomial-time, a minimum maximal matching in the class of (two independent edges)-free graphs. This last problem is equivalent to find a minimum dominating set for the class of line graphs. Then we show how to compute a a minimum dominating set for the claw-free graphs that are not line graphs.

3 - The Zeroth Book of Graph Theory (An after dinner speech)
Martin Golumbic

In this informal talk, I will present highlights from my annotated translation of the 1926 manuscript Les Réseaux (ou Graphes) by André Sainte-Laguë, published by Springer this past year. Many of the concepts treated were still in their infancy, and others more developed offering a wealth of mathematical challenges, providing a 'snapshot' of what was already known about graph theory in the same year Claude Berge was born! and 10 years before Konig's book appeared. Sainte-Laguë had a reputation for integrating humor and personality into his presentations, during his years of high school teaching, and later at the university attracting a thousand listeners at a time. He was ahead of his time in the use of illustrative slides, pictures and films in lectures at the Conservatoire National des Arts et Métiers (CNAM). He continued carrying this message of making mathematics popular, creating and employing visual representations for the public at large. For example, he was entrusted by Émile Borel with the organization of the mathematics rooms in the Palais de la Découverte for the 1937 Paris Exposition Internationale de Arts et Techniques dans la Vie Moderne (World's Fair). Myriam Preissmann provided invaluable help on all aspects of translating the manuscript, reading the entire translation several times. We spent many hours at a time, deliberating the intentions of the author, understanding terminology which is often mathematically unclear, and the subtleties of presentation. Her dedicated scholarly assistance is greatly appreciated. Alain Hertz provided many comments on the last two chapters and clarified several aspects of the original manuscript, and I also thank him for this. Finally, I wish to acknowledge discussions we had with Frederic Maffray.

Tuesday, 16:00-17:30

■ TD-01

Tuesday, 16:00-17:30

Scheduling

Chair: *Antoine Jouglet*

1 - Algorithms and complexity results for resource leveling problems

Luca Brunod Indrigo, *Pascale Bendotti*, *Philippe Chrétienne*, *Bruno Escoffier*

In many scheduling problems, jobs require resources such as workers or specific equipment in order to be executed. It is usually assumed that those resources are subject to hard capacity constraints, as in the widely studied Resource Constrained Project Scheduling Problem (RCPSP). In practice however, it is often possible to obtain additional resources when needed but at a significant cost, e.g. by hiring extra workforce. The field of scheduling known as resource leveling aims to obtain regularity in resource use by modeling such costs. The corresponding literature uses different leveling objective functions and mostly provides heuristics and MIP-based approaches.

The aim of this work is to study computational complexity and devise algorithmic solutions for resource leveling problems under classical scheduling constraints. The considered resource leveling criterion is the total overload cost : given an integer resource level, the resource use exceeding this level is minimized. As for scheduling constraints, makespan deadline, precedences, release and due dates as well as preemption are investigated.

Polynomial-time algorithms are found for several special cases. A special case with a tree precedence graph and unit processing times is solved by adapting a classical list algorithm. Another special case with arbitrary precedence graph, resource level equal to two and unit processing times is solved relying on elaborated matching arguments in graphs. NP-hardness results are also given.

2 - Automated Design for Permutation Flow-shop Problems

Thomas Stützle, *Federico Pagnozzi*

The design and development algorithms can be time-consuming and difficult for a number of reasons including the complexity of the problems being tackled, the large number of degrees of freedom when designing an algorithm and setting its numerical parameters, and the difficulties of algorithm analysis due to heuristic biases and stochasticity. Still very often this design is done manually, mainly guided by the expertise and intuition of the algorithm designer. However, the advancement of automatic algorithm configuration methods offers new possibilities to make this process more automatic, avoid some methodological issues, and at the same time improve the performance of algorithms.

In this talk, I will highlight the advantages of addressing algorithm design and configuration by algorithmic techniques; describe the main existing automatic algorithm design techniques; and discuss some of the main successful applications of automatic design we have in our own work. In particular, I will show how flexible algorithm frameworks can support the automatic design of high-performing hybrid stochastic local search algorithms. In fact, even for problems that have received very high attention in the literature new state-of-the-art algorithms can be obtained automatically, that is, without manual algorithm tuning. I will conclude arguing that automatic algorithm design will also have the power to transform the way algorithms for difficult problems are designed in the future.

3 - More powerful energetic reasoning for the Cumulative Scheduling Problem

Jacques Carlier, *Kristina Kumbria*, *Antoine Jouglet*, *Abderrahim Sahli*

An instance of the Cumulative Scheduling Problem (CuSP) consists of (1) one single resource with a given capacity and (2) a set of tasks, each of which is characterized by a release date r_i, a processing time p_i, a deadline d_i, and a resource capacity requirement c_i. The objective is to assign to each task a starting time such that all timing constraints are satisfied, and such that the capacity of the resource is never exceeded. Erschler and Lopez proposed the concept of energetic reasoning which gives a necessary condition for solution existence. This necessary condition, which has to be checked, is based on the energy balance over all intervals relying on the fact that tasks cannot be interrupted. Different checkers have been proposed in the literature. The aim of this paper is to propose a new definition of the energy balance of intervals. The idea is to take into account the fact that at any time t, the total demand for on line processed tasks is smaller that the availability of the resource. This remark will permit to improve the evaluation of any interval by solving a tripartition problem by Dynamic Programming. Next, we build a new checker more performent than the previous ones. By taking into account the integrity of c_i, we loose some previous nice properties, and the global complexity resolution will increase. But our new checker becomes much more powerful as it is confirmed by the numerical results.

Wednesday, 9-15-10:45

■ WA-01

Wednesday, 9-15-10:45

Combinatorial Optimization 3

Chair: *Jérôme De Boeck*

1 - Insertions for feasibility of clustered trees on grid intersection graphs
Michal Stern, Nili Beck

The problem we address is Clustered Spanning Tree problem, denoted by CST. In this problem we are given a hypergraph H=, where V is a set of vertices and S is a set of clusters, not necessarily disjoint. The problem aims to find whether, in a complete graph induced on the vertices of V, there exists a spanning tree, such that each cluster induces a subtree. If no feasible solution tree exists, we consider inserting vertices to clusters from S to gain feasibility, by finding feasible vertices insertion lists with minimum cardinality. We find those lists for hypergraphs whose intersection graphs are n*m grid graphs, constructed of chordless cycles, each cycle contains four nodes, and every two cycles intersect in at most one edge. For these hypergraphs we present the Convert to Clique method, which creates a feasible vertices insertion list for any given hypergraph. This method inserts vertices to ensure that one vertex is contained in every cluster of the graph, thus changing the intersection graph into a clique. Surprisingly, this method yields a minimum cardinality feasible vertices insertion list, for hypergraphs whose original intersection graphs are grids. Our problem is applicable to organizational networks. The idea is to consider the organizational network as a graph. People working in the various departments of the organization are represented as vertices. Groups of people assigned to certain projects are represented as clusters. Our goal is to enable a fast and secure flow of information inside each cluster. Therefore, we demand that each subgraph induced by a cluster has to be a subtree.

2 - Leveraging preprocessing for optimal Segment Routing
Hugo Callebaut, Jérôme De Boeck, Bernard Fortz

In this talk we introduce a preprocessing technique to solve the Segment Routing Traffic Engineering Problem optimally using much less computational resources than previously introduced methods. Segment Routing is a recently developed interior gateway protocol that introduces more flexibility in traffic engineering. In practice, segment routing allows to deviate traffic from its original path by specifying a list of intermediate nodes or links, called segments, to visit before going to its destination. The issue we tackle in this article is that the number of segments paths increases exponentially with the maximum number of segments allowed leading to scalability issues in mathematical formulations. This talk introduces the concept of dominated segment paths, these are paths that can be eliminated from an optimal solution. We propose a dynamic programming algorithm eliminating dominated paths for any number of segments. Numerical results show that respectively 50%, 90% and 97% of paths are dominated when considering up to 2, 3 and 4 segments on benchmark network topologies. Finally using a heuristic based on the total length of the segment paths, with respect to shortest path routing weights, we manage to remove respectively 47% and 84% of the non dominated segment paths for 2 and 3 segments.

3 - Stable Approximation Algorithms for a Range-Assignment Problem
Frits Spieksma, Mark de Berg, Arpan Sadhukhan

The broadcast range-assignment problem can informally be described as follows. Let P be a set of points in Rd, including a source node s. When associating a range r(p) to each point p in P, a communication graph G results: this graph has a node for each point in P, and there is an arc from point p to point q iff |pq| is at most r(p). The goal is to assign ranges to the points in P such that (i) the communication graph G contains an arborescence rooted at the source node s, and (ii) total cost, which is measured by the sum of the squared ranges, is minimized. We study the dynamic version of this problem, ie, points can be inserted and removed from P. In particular, we are interested in trade-offs between the stability of the solution, defined as the number of ranges that are modified when a point is inserted into or deleted from P, and its approximation ratio. To this end we employ so-called k-stable algorithms, which are algorithms that modify the range of at most k points when they update the solution. We also introduce the concept of a stable approximation scheme, or SAS for short. A SAS is an update algorithm that, for any given positive fixed parameter epsilon, is k-stable and that maintains a solution with approximation ratio 1+epsilon. We describe the following results: (i) when the points in P are on the line, we provide a SAS, (ii) when the points in P lie on a circle, we prove that no SAS exists, (iii) we also present 1-, 2-, and 3-stable algorithms with constant approximation ratio when the points in P are on the line.

Wednesday, 11:15-12:15

■ WB-01

Wednesday, 11:15-12:15

Keynote: Myriam Preissmann

Chair: *Martin Golumbic*

1 - About the structure of the graphs whose holes all have the same length
Myriam Preissmann

In a graph, a hole is an induced chordless cycle of length at least four. Several well-known classes can be defined by forbidding holes : - chordal graphs (containing no hole at all), - even-hole-free graphs (containing no hole of even length), - perfect graphs (containing no hole of odd length and no complement of a hole of odd length ; by the Strong Perfect Graph Theorem). Several characterizations are known for the graphs in the first class and they imply a lot of nice algorithmic properties. For the graphs in the two other classes, despite some decomposition theorems, it is not yet known how to construct them all. For a given integer l, a graph is said to be l-holed if its holes all have length l ; we denote by Cl the set of l-holed graphs. Note that Cl is a subclass of even-hole-free graphs when l is odd, and Cl is a subclass of perfect graphs when l is even and greater than four. In this talk I will describe the structure of l-holed graphs for any odd l 7 and any even l 8. This is a joint work with Jake Horsfield, Cléophée Robin, Ni Luh Dewi Sintiari, Nicolas Trotignon and Kristina Vuˇskovi c. A similar description has been obtained independently by Linda Cook and Paul Seymour.

Thursday, 9-15-10:45

■ HA-01

Thursday, 9-15-10:45

Graph Coloring

Chair: *Kathie Cameron*

1 - On the equitable total coloring of snarks
Diana Sasaki, Rieli Araújo

A k-total coloring of G is an assignment of k colors to the vertices or edges of G, so that adjacent or incident elements have different colors. The total chromatic number of G is the smallest k for which G has a k-total coloring. The well known Total Coloring Conjecture (TCC) states that the total chromatic number of a graph G is at least the maximum degree of G plus 1 (graphs called Type 1), and at most the maximum degree of G plus 2 (graphs called Type 2). The total chromatic number of a cubic graph was proved to be either 4 or 5 by Rosenfeld and Vijayaditya. An equitable total coloring is a total coloring such that the difference between the cardinalities of any two color classes is at most one. The equitable total chromatic number of G is the smallest number for which G admits an equitable total coloring. The Equitable Total Coloring Conjecture (ETCC) was posed by Wang in 2002, and states that the equitable total chromatic number of a graph G is at most the maximum degree of G plus 2. The ETCC was proved for cubic graphs, and it implies that if a cubic graph is Type 2, then both the total chromatic number and the equitable total chromatic number are equal to 5; if a cubic graph is Type 1, then the equitable total chromatic number is either 4 or 5. Gardner introduced the name Snark for cyclically 4-edge-connected cubic graph that does not allow a 3-edge-coloring. Dantas et al. in 2016 proposed the question about the existence of a Type 1 cubic graph with girth at least 5 and equitable total chromatic number 5. In this work, we establish that all members of the second infinite family of Loupekine snarks have equitable total chromatic number 4, contributing to the question as a negative evidence, since they are Type 1 and have girth at least 5.

2 - On d-stable locally checkable problems on graphs of bounded mim-width
Felix Mann

A locally checkable problem is a vertex colouring problem which is characterised by a so called check function: For each vertex v, this function receives the colouring of the neighbourhood of v as input and outputs True or False. If a colouring evaluates to True on its restriction to every neighbourhood, we call the colouring proper. Amongst the problems which fall into this family are Chromatic Number and Dominating Set. We continue the study of locally checkable problems under the framework introduced by Bonomo-Braberman and Gonzalez in 2020, by focusing on graphs of bounded mim-width. We study which restrictions on a locally checkable problem are necessary in order to be able to solve it efficiently on graphs of bounded mim-width. To this end, we introduce the concept of d-stability of a check function and show that we can solve d-stable locally checkable problems on graphs of bounded mim-width. We further explore the relation between d-stable locally checkable problems and the recently introduced DN-logic (Bergougnoux, Dreier and Jaffke, 2022), and show that they both model the same family of problems. We give examples of d-stable locally checkable problems whose complexity on graphs of bounded mim-width was open so far.

3 - Reconfiguration of Vertex Colourings and Forbidden Induced Subgraphs
Kathie Cameron, Manoj Belavadi, Owen Merkel

The reconfiguration graph of the k-colourings of a graph G, denoted R(k)(G), is the graph whose vertices are the k-colourings of G and two colourings are adjacent if they differ in colour on exactly one vertex. We investigate the connectivity and diameter of R(k+1)(G) for k-colourable graphs in classes restricted by forbidden induced subgraphs. We show that R(k+1)(G) is connected for every k-colourable H-free graph G if and only if H is an induced subgraph of the path on four vertices or of the path on three vertices together with an isolated vertex. We also start an investigation into this problem for (F,H)-free graphs, where F and H are 4-vertex graphs different from the two previously mentioned graphs. We show that if G is a k-colourable graph without the 4-cycle or its complement as an induced subgraph, R(k+1)(G) is connected and has diameter at most 4n, where n is the number of vertices of G. Furthermore, we show that if R(k+1)(G) is connected for every (F,H)-free graph, then one of F and H is the complement of the 4-cycle.

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■ HB-01

Thursday, 11:15-12:15

Matchings

Chair: *Jan Goedgebeur*

1 - The average size of maximal matchings in graphs
Sébastien Bonte, Alain Hertz, Hadrien Mélot, Gauvain Devillez

We investigate the ratio I(G) of the average size of a maximal matching to the size of a maximum matching in a graph G. If many maximal matchings have a size close to ν(G), this graph invariant has a value close to 1. Conversely, if many maximal matchings have a small size, I(G) approaches 1/2.

We propose a general technique to determine the asymptotic behavior of I(G) for various classes of graphs. To illustrate the use of this technique, we first show how it makes it possible to find known asymptotic values of I(G) which were typically obtained using generating functions, and we then determine the asymptotic value of I(G) for other families of graphs, highlighting the spectrum of possible values of this graph invariant between 1/2 and 1.

2 - Matching Cuts in H-free graphs
Felicia Lucke

The problem Matching Cut asks for an edge set of a graph which is both an edge cut and a matching. An edge cut is a set of edges whose deletion disconnects the graph and a matching is a set of edges in which no two edges share an endpoint. In the last years several variants of the problem have been considered: for a Disconnected Perfect Matching problem the matching cut is contained in a perfect matching, while in the Perfect Matching Cut problem the matching cut is a perfect matching. Another recent variant is the optimisation problem Maximum Matching Cut which asks for a matching cut with the maximum number of edges. We consider the complexity of the four variants in different graph classes, especially in H-free graphs, which are the graphs that do not contain a graph H as an induced subgraph. We give an overview of recent complexity results and point out some interesting differences between the variants. This is joint work with Carl Feghali, Daniel Paulusma and Bernard Ries.

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■ HC-01

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Closing session

Chair: *Bernard Fortz*
Chair: *Hadrien Mélot*

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