IN PARTNERSHIP WITH:
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Université Nice - Sophia Antipolis

Activity Report 2019

Project-Team COATI

Combinatorics, Optimization and Algorithms for Telecommunications

IN COLLABORATION WITH: Laboratoire informatique, signaux systèmes de Sophia Antipolis (I3S)

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Networks and Telecommunications

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Creation of the Team: 2013 January 01, updated into Project-Team: 2013 January 01

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1. Team, Visitors, External Collaborators

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External Collaborator

Nathann Cohen [CNRS, until Sep 2019]

2. Overall Objectives

2.1. Overall Objectives

COATI is a joint team between Inria Sophia Antipolis - Méditerranée and the I3S laboratory (Informatique Signaux et Systèmes de Sophia Antipolis) which itself belongs to CNRS (Centre National de la Recherche Scientifique), UNS (Univ. Nice Sophia Antipolis) and Univ. Côte d'Azur. Its research fields are Algorithmics, Discrete Mathematics, and Combinatorial Optimization, with applications mainly in telecommunication networks.

The main objectives of the COATI project-team are to design networks and communication algorithms. In order to meet these objectives, the team studies various theoretical problems in Discrete Mathematics, Graph Theory, Algorithmics, and Operations Research and develops applied techniques and tools, especially for Combinatorial Optimization and Computer Simulation. In particular, COATI used in the last years both these theoretical and applied tools for the design of various networks, such as SDN (software defined networks), WDM, wireless (radio), satellite, and peer-to-peer networks. This research has been done within various industrial and international collaborations.

COATI also investigates other application areas such as bio-informatics and transportation networks.

The research done in COATI results in the production of advanced software such as GRPH, and in the contribution to large open source software such as Sagemath.

3. Research Program

3.1. Research Program

Members of COATI have a strong expertise in the design and management of wired and wireless backbone, backhaul, broadband, software defined and complex networks. On the one hand, we cope with specific problems such as energy efficiency in backhaul and backbone networks, routing reconfiguration in connection oriented networks (MPLS, WDM), traffic aggregation in SONET networks, compact routing in large-scale networks, survivability to single and multiple failures, etc. These specific problems often come from questions of our industrial partners. On the other hand, we study fundamental problems mainly related to routing and reliability that appear in many networks (not restricted to our main fields of applications) and that have been widely studied in the past. However, previous solutions do not take into account the constraints of current networks/traffic such as their huge size and their dynamics. COATI thus puts a significant research effort in the following directions:

- **Service Function Chains (SFC):** we study the placement of Service Function Chains within the network considering the ordering constraints. Then, we focus firstly on energy efficiency and secondly on reliability and protection mechanisms. In a last step, we study reconfiguration of the SFCs in case of dynamic traffic with a make-before-break approach.
- **Larger networks:** Another challenge one has to face is the increase in size of practical instances. It is already difficult, if not impossible, to solve practical instances optimally using existing tools. Therefore, we have to find new ways to solve problems using reduction and decomposition methods, characterization of polynomial instances (which are surprisingly often the practical ones), or algorithms with acceptable practical performances.

- **Stochastic behaviors:** Larger topologies mean frequent changes due to traffic and radio fluctuations, failures, maintenance operations, growth, routing policy changes, etc. We aim at including these stochastic behaviors in our combinatorial optimization process to handle the dynamics of the system and to obtain robust designs of networks.

The methods and tools used in our studies come from discrete mathematics and combinatorial optimization, and COATI contributes to their improvements. Also, COATI works on graph-decomposition methods and various games on graphs which are essential for a better understanding of the structural and combinatorial properties of the problems, but also for the design of efficient exact or approximate algorithms. We contribute to the modelling of optimization problems in terms of graphs, study the complexity of the problems, and then we investigate the structural or metric properties of graphs that make these problems hard or easy. We exploit these properties in the design of algorithms in order to find the most efficient ways for solving the problems.

COATI also focuses on the theory of *directed graphs*. Indeed, graph theory can be roughly partitioned into two branches: the areas of undirected graphs and directed graphs. Even though both areas have numerous important applications, for various reasons, undirected graphs have been studied much more extensively than directed graphs. It is worth noticing that many telecommunication problems are modelled with directed graphs. Therefore, a deeper understanding of the theory of directed graphs will benefit to the resolution of telecommunication networks problems. For instance, the problem of finding disjoint paths becomes much more difficult in directed graphs and understanding the underlying structures of actual directed networks would help us to propose solutions.

Last, we have recently started investigating how tools from multi-agents based systems and machine learning theory could help solving some optimization problems in networks. The arrival of Emanuele Natale as a Junior Researcher (CNRS) in the team and of two new PhD students (Franceso D'Amore and Hicham Lesfari) will foster these investigations.

4. Application Domains

4.1. Telecommunication Networks

COATI is mostly interested in telecommunications networks but also in the network structure appearing in social, molecular and transportation networks.

We focus on the design and management of heterogeneous physical and logical networks. The project has kept working on the design of backbone networks (optical networks, radio networks, IP networks). However, the fields of Software Defined Networks and Network Function Virtualization are growing in importance in our studies. In all these networks, we study routing algorithms and the evolution of the routing in case of any kind of topological modifications (maintenance operations, failures, capacity variations, etc.).

4.2. Other Domains

Our combinatorial tools may be well applied to solve many other problems in various areas (transport, biology, resource allocation, chemistry, smart-grids, speleology, etc.) and we collaborate with experts of some of these domains.

For instance, we collaborate with project-team ABS (Algorithms Biology Structure) from Sophia Antipolis on problems from Structural Biology (co-supervision of a PhD student). In the area of transportation networks, we collaborate with SMEs Benomad and Instant-System on dynamic car-pooling combined with multi-modal transportation systems in the context of ANR project Multimod started in January 2018. Last, we have started a collaboration with GREDEG (Groupe de Recherche en Droit, Economie et Gestion, Univ. Nice Sophia Antipolis) on the analysis of collaboration networks.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

- Julien Bensmail: “Jeunes Talents France-Chine” funding for one travel to China in 2019;
- Christelle Caillouet: UCA Excellence award;
- Emilio Cruciani: recipient of a 2019 Testing and Verification research award;
- François Dross: recipient of an accessit to the PhD prize Graphes "Charles Delorme" 2019 for his PhD entitled *Vertex partition of sparse graphs* [87];
- William Lochet: recipient of the PhD prize Graphes "Charles Delorme" 2019 for his PhD entitled *Substructures in digraphs* [92];
- Emanuele Natale: awarded the "Best Italian Young Researcher in Theoretical Computer Science" by the Italian Chapter of the EATCS.

5.1.2. Promotions

- Patricia Riveill: promoted to Administrative Engineer.

BEST PAPER AWARD:

[47]
C. CAILLOUET, T. RAZAFINDRALAMBO, D. ZORBAS. *Optimal placement of drones for fast sensor energy replenishment using wireless power transfer*, in "WD 2019 - Wireless Days 2019", Manchester, United Kingdom, April 2019, Best Paper Award, https://hal.inria.fr/hal-02043123

6. New Software and Platforms

6.1. GRPH

The high performance graph library for Java

KEYWORDS: Graph - Graph algorithmics - Java

FUNCTIONAL DESCRIPTION: Grph is an open-source Java library for the manipulation of graphs. Its design objectives are to make it portable, simple to use/extend, computationally/memory efficient, and, according to its initial motivation: useful in the context of graph experimentation and network simulation. Grph also has the particularity to come with tools like an evolutionary computation engine, a bridge to linear programming solvers, a framework for distributed computing, etc.

Grph offers a very general model of graphs. Unlike other graph libraries which impose the user to first decide if he wants to deal with directed, undirected, hyper (or not) graphs, the model offered by Grph is unified in a general class that supports mixed graphs made of undirected and directed simple and hyper edges. Grph achieves great efficiency through the use of multiple code optimization techniques such as multi-core parallelism, caching, adequate data structures, use of primitive objects, exploitation of low-level processor caches, on-the-fly compilation of specific C/C++ code, etc. Grph attempts to access the Internet in order to check if a new version is available and to report who is using it (login name and hostname). This has no impact whatsoever on performance and security.

- Participants: Aurélien Lancin, David Coudert, Issam Tahiri, Luc Hogie and Nathann Cohen
- Contact: Luc Hogie
- URL: http://www.i3s.unice.fr/~hogie/grph/

6.2. BigGraphs

KEYWORDS: Graph algorithmics - Distributed computing - Java - Graph processing

FUNCTIONAL DESCRIPTION: The objective of BigGraphs is to provide a distributed platform for very large graphs processing. A typical data set for testing purpose is a sample of the Twitter graph : 240GB on disk, 398M vertices, 23G edges, average degree of 58 and max degree of 24635412.

We started the project in 2014 with the evaluation of existing middlewares (GraphX / Spark and Giraph / Hadoop). After having tested some useful algorithms (written according to the Bulk Synchronous Parallel (BSP) model) we decided to develop our own platform.

This platform is based on the existing BIGGRPH library and we are now working on improving the quality of the code. In particular we have designed strong test suites and some non trivial bugs have been fixed. We also have solved problems of scalability, in particular concerning the communication layer with billions of messages exchanged between BSP steps. We also have implemented specific data structures for BSP and support for distributed debugging. This comes along with the implementation of algorithms such as BFS or strongly connected components that are run on the NEF cluster.

In 2017 we have developed a multi-threaded shared-memory parallel version of the BSP framework. This new version uses advanced synchronization mechanisms and strategies to minimize the congestion of multiple threads working on the same graph. Using the NEF cluster (Inria Sophia Antipolis), this parallel version exhibits speed-ups up to 6.5 using 8 nodes (16 cores each) when computing a BFS on the 23 G edges Twitter graph sample.

- Participants: Luc Hogie, Michel Syska and Nicolas Chleq
- Partner: CNRS
- Contact: Luc Hogie
- URL: http://www.i3s.unice.fr/~hogie/software/?name=biggrph

6.3. JMaxGraph

KEYWORDS: Java - HPC - Graph algorithmics

FUNCTIONAL DESCRIPTION: JMaxGraph is a collection of techniques for the computation of large graphs on one single computer. The motivation for such a centralized computing platform originates in the constantly increasing efficiency of computers which now come with hundred gigabytes of RAM, tens of cores and fast drives. JMaxGraph implements a compact adjacency-table for the representation of the graph in memory. This data structure is designed to 1) be fed page by page, à-la GraphChi, 2) enable fast iteration, avoiding memory jumps as much as possible in order to benefit from hardware caches, 3) be tackled in parallel by multiple-threads. Also, JMaxGraph comes with a flexible and resilient batch-oriented middleware, which is suited to executing long computations on shared clusters. The first use-case of JMaxGraph allowed F. Giroire, T. Trolliet and S. Pérennes to count K2,2s, and various types of directed triangles in the Twitter graph of users (23G arcs, 400M vertices). The computation campaign took 4 days, using up to 400 cores in the NEF Inria cluster.

- Contact: Luc Hogie
- URL: http://www.i3s.unice.fr/~hogie/software/?name=jmaxgraph

6.4. Sagemath

SageMath

KEYWORDS: Graph algorithmics - Graph - Combinatorics - Probability - Matroids - Geometry - Numerical optimization

SCIENTIFIC DESCRIPTION: SageMath is a free open-source mathematics software system. It builds on top of many existing open-source packages: NumPy, SciPy, matplotlib, Sympy, Maxima, GAP, FLINT, R and many more. Access their combined power through a common, Python-based language or directly via interfaces or wrappers.

FUNCTIONAL DESCRIPTION: SageMath is an open-source mathematics software initially created by William Stein (Professor of mathematics at Washington University). We contribute the addition of new graph algorithms along with their documentations and the improvement of underlying data structures.

RELEASE FUNCTIONAL DESCRIPTION: See http://www.sagemath.org/changelogs/

NEWS OF THE YEAR: 1) Improvement of shortest path computation algorithms. Done in the context of Google Summer of Code 2019. 2) Main contributor for making the graph module (more than 100,000 lines of code) of SageMath compatible with Python3. Version 9.0 of Sagemath, released on January 1st, 2020, is 100% Python3 compliant.

- Participant: David Coudert
- Contact: David Coudert
- URL: http://www.sagemath.org/

7. New Results

7.1. Network Design and Management

Participants: Julien Bensmail, Jean-Claude Bermond, Christelle Caillouet, David Coudert, Frédéric Giroire, Frédéric Havet, Nicolas Nisse, Stéphane Pérennes, Joanna Moulierac, Foivos Fioravantes, Adrien Gausseran, Andrea Tomassilli.

Network design is a very wide subject which concerns all kinds of networks. In telecommunications, networks can be either physical (backbone, access, wireless, ...) or virtual (logical). The objective is to design a network able to route a (given, estimated, dynamic, ...) traffic under some constraints (e.g. capacity) and with some quality-of-service (QoS) requirements. Usually the traffic is expressed as a family of requests with parameters attached to them. In order to satisfy these requests, we need to find one (or many) paths between their end nodes. The set of paths is chosen according to the technology, the protocol or the QoS constraints.

We mainly focus on the following topics: Firstly, we study Software Defined Networking (SDN) and Network Function Virtualization (NFV) and how to exploit their potential benefits. We propose algorithms for the Provisioning Service Function Chains (SFC) and algorithms to reconfigure the SFC in order to improve the network operational costs without any interruption (with a *make-before-break approach*) and Virtual Network Functions (VNF) placement algorithms to address the mono- and multi-tenant issues in edge and core networks. We also propose algorithms for distributed Mininet [1] in order to improve the performance, and also bandwidth-optimal failure recovery scheme for robust programmable networks. Secondly, we study optimization problems within optical networks: wavelength reconfiguration for seamless migration and spectrum assignment in elastic optical tree-networks. Thirdly, we study the scheduling of network tasks within a data center while taking into account the communication between the network resources. We also study distributed link scheduling in wireless networks. Finally, we investigate on the placement of drones for maximizing the coverage of a landscape by drones in order to localize targets or collect data from sensors.

7.1.1. Software Defined Networks and Network Function Virtualization

Recent advances in networks such as Software Defined Networking (SDN) and Network Function Virtualization (NFV) are changing the way network operators deploy and manage Internet services. On the one hand, SDN introduces a logically centralized controller with a global view of the network state. On the other hand, NFV enables the complete decoupling of network functions from proprietary appliances and runs them as software applications on general purpose servers. In such a way, network operators can dynamically deploy Virtual Network Functions (VNFs). SDN and NFV, both separately, bring to network operators new opportunities for reducing costs, enhancing network flexibility and scalability, and shortening the time-to-market of new applications and services. Moreover, the centralized routing model of SDN jointly with the possibility

[1] Mininet provides a virtual test bed and development environment for software-defined networks (SDN). See http://mininet.org.

of instantiating VNFs on demand may open the way for an even more efficient operation and resource management of networks. For instance, an SDN/NFV-enabled network may simplify the Service Function Chain (SFC) deployment and provisioning by making the process easier and cheaper. We addressed several questions in this context.

In [15], we aim at investigating how to leverage both SDN and NFV in order to exploit their potential benefits. We took steps to address the new opportunities offered in terms of network design, network resilience, and energy savings, and the new problems that arise in this new context, such as the optimal network function placement in the network. We show that a symbiosis between SDN and NFV can improve network performance and significantly reduce the network's Capital Expenditure (CapEx) and Operational Expenditure (OpEx).

In [50], [57], [58], we consider the problem of reconfiguring SFC with the goal of bringing the network from a sub-optimal to an optimal operational state. We propose optimization models based on the *make-before-break* mechanism, in which a new path is set up before the old one is torn down. Our method takes into consideration the chaining requirements of the flows and scales well with the number of nodes in the network. We show that, with our approach, the network operational cost defined in terms of both bandwidth and installed network function costs can be reduced and a higher acceptance rate can be achieved, while not interrupting the flows.

In [59], we consider the placement of functions in 5G networks in which functions must not only be deployed in large central data centers, but also in the edge. We propose an algorithm that solves the Virtual Network Function Chain Placement Problem allowing a fine management of these rare resources in order to respond to the greatest number of requests possible. Because networks can be divided into several entities belonging to different tenants who are reluctant to reveal their internal topologies, we propose a heuristic that allows the NFV orchestrator to place the function chains based only on an abstract view of the infrastructure network. We leverage this approach to address the complexity of the problem in large mono- or multi-tenant networks. We analyze the efficiency of our algorithm and heuristic with respect to a wide range of parameters and topologies.

In [53], [80], [69], we rethink the network dimensioning problem with protection against Shared Risk Link Group (SLRG) failures in the SDN context. We propose a path-based protection scheme with a global rerouting strategy, in which, for each failure situation, there may be a new routing of all the demands. Our optimization task is to minimize the needed amount of bandwidth. After discussing the hardness of the problem, we develop a scalable mathematical model that we handle using the Column Generation technique. Through extensive simulations on real-world IP network topologies and on random generated instances, we show the effectiveness of our method. Finally, our implementation in OpenDaylight demonstrates the feasibility of the approach and its evaluation with Mininet shows that technical implementation choices may have a dramatic impact on the time needed to reestablish the flows after a failure takes place.

Finally, in [49], [78], [79], we consider the problem of performing large scale SDN networks simulations in a distributed environment. Indeed, networks have become complex systems that combine various concepts, techniques, and technologies. Hence, modelling or simulating them is now extremely complicated and researchers massively resort to prototyping techniques. Among other tools, Mininet is the most popular when it comes to evaluate SDN propositions. It allows to emulate SDN networks on a single computer. However, under certain circumstances experiments (e.g., resource intensive ones) may overload the host running Mininet. To tackle this issue, we propose Distrinet [49], [78], [79], a way to distribute Mininet over multiple hosts. Distrinet uses the same API than Mininet, meaning that it is compatible with Mininet programs. Distrinet is generic and can deploy experiments in Linux clusters or in the Amazon EC2 cloud. Thanks to optimization techniques, Distrinet minimizes the number of hosts required to perform an experiment given the capabilities of the hosting infrastructure, meaning that the experiment is run in a single host (as Mininet) if possible. Otherwise, it is automatically deployed on a platform using a minimum amount of resources in a Linux cluster or with a minimum cost in Amazon EC2.

7.1.2. Optimization of optical networks operation

7.1.2.1. Wavelength Defragmentation for Seamless Migration

Dynamic traffic in optical networks leads to spectrum fragmentation, which significantly reduces network performance, i.e., increases blocking rate and reduces spectrum usage. Telecom operators face the operational challenge of operating non-disruptive defragmentation, i.e., within the make-before-break paradigm when dealing with lightpath rerouting in wavelength division multiplexed (WDM) fixed-grid optical networks. In [39], we propose a make-before-break (MBB) Routing and Wavelength Assignment (RWA) defragmentation process, which provides the best possible lightpath network provisioning, i.e., with minimum bandwidth requirement. We tested extensively the models and algorithms we propose on four network topologies with different GoS (Grade of Service) defragmentation triggering events. We observe that, for a given throughput, the spectrum usage of the best make-before-break lightpath rerouting is always less than 2.5% away from that of an optimal lightpath provisioning.

7.1.2.2. On spectrum assignment in elastic optical tree-networks

To face the explosion of the Internet traffic, a new generation of optical networks is being developed; the Elastic Optical Networks (EONs). EONs use the optical spectrum efficiently and flexibly, but that gives rise to more difficulty in the resource allocation problems. In [31], we study the problem of Spectrum Assignment (SA) in Elastic Optical Tree-Networks. Given a set of traffic requests with their routing paths (unique in the case of trees) and their spectrum demand, a spectrum assignment consists in allocating to each request an interval of consecutive slots (spectrum units) such that a slot on a given link can be used by at most one request. The objective of the SA problem is to find an assignment minimizing the total number of spectrum slots to be used. We prove that SA is NP-hard in undirected stars of 3 links and in directed stars of 4 links, and show that it can be approximated within a factor of 4 in general stars. Afterwards, we use the equivalence of SA with a graph coloring problem (interval coloring) to find constant-factor approximation algorithms for SA on binary trees with special demand profiles.

7.1.3. Scheduling

7.1.3.1. When Network Matters: Data Center Scheduling with Network Tasks

We consider in [51] the placement of jobs inside a data center. Traditionally, this is done by a task orchestrator without taking into account network constraints. According to recent studies, network transfers represent up to 50% of the completion time of classical jobs. Thus, network resources must be considered when placing jobs in a data center. In this paper, we propose a new scheduling framework, introducing network tasks that need to be executed on network machines alongside traditional (CPU) tasks. The model takes into account the competition between communications for the network resources, which is not considered in the formerly proposed scheduling models with communication. Network transfers inside a data center can be easily modeled in our framework. As we show, classical algorithms do not efficiently handle a limited amount of network bandwidth. We thus propose new provably efficient algorithms with the goal of minimizing the makespan in this framework. We show their efficiency and the importance of taking into consideration network capacity through extensive simulations on workflows built from Google data center traces.

7.1.3.2. Distributed Link Scheduling in Wireless Networks

In [55], we investigate distributed transmission scheduling in wireless networks. Due to interference constraints, “neighboring links” cannot be simultaneously activated, otherwise transmissions will fail. Here, we consider any binary model of interference. We use the model described by Bui, Sanghavi, and Srikant in [85], [93]. We assume that time is slotted and during each slot there are two phases: one control phase which determines what links will be activated and a data phase in which data are sent. We assume random arrivals on each link during each slot, so that a queue is associated to each link. Since nodes do not have a global knowledge of the network, our aim (like in [85], [93]) is to design for the control phase a distributed algorithm which determines a set of non-interfering links. To be efficient the control phase should be as short as possible; this is done by exchanging control messages during a constant number of mini-slots (constant overhead). In this paper, we design the first fully distributed local algorithm with the following properties: it works for any arbitrary binary interference model; it has a constant overhead (independent of the size of the network and the values of the queues), and it does not require any knowledge of the queue-lengths. We prove that this algorithm gives a maximal set of active links, where in each interference set there is at least one active link. We also establish sufficient conditions for stability under general Markovian assumptions. Finally, the performance of our algorithm (throughput, stability) is investigated and compared via simulations to that of previously proposed schemes.

7.1.3.3. Backbone colouring and algorithms for TDMA scheduling

We investigate graph colouring models for the purpose of optimizing TDMA link scheduling in Wireless Networks. Inspired by the BPRN-colouring model recently introduced by Rocha and Sasaki, we introduce a new colouring model, namely the BMRN-colouring model, which can be used to model link scheduling problems where particular types of collisions must be avoided during the node transmissions.

In [25], we initiate the study of the BMRN-colouring model by providing several bounds on the minimum number of colours needed to BMRN-colour digraphs, as well as several complexity results establishing the hardness of finding optimal colourings. We also give a special focus on these considerations for planar digraph topologies, for which we provide refined results. Some of these results extend to the BPRN-colouring model as well. We notably prove that every planar digraph can be 8-BMRN*-coloured, while there exist planar digraphs for which 8 colours are needed in a BMRN*-colouring [72]. We also proved that the problem of deciding whether a planar digraph can be k-BMRN*-coloured is NP-hard for every $k \in \{3, ..., 6\}$.

7.1.4. Optimizing drone coverage

7.1.4.1. Self-organized UAV-based Supervision and Connectivity

The use of drones has become more widespread in recent years. Many use cases have been developed involving these autonomous vehicles, ranging from simple delivery of packages to complex emergency situations following catastrophic events. The miniaturization and very low cost of these machines make it possible today to create large meshes to ensure network coverage in disaster areas, for instance. However, the problems of scaling up and self-organization are necessary to solve problems in these use cases.

In the position paper [45], we first present different new requirements for the deployment of unmanned aerial vehicles (UAV) networks, involving the use of many drones. Then, we introduce solutions from distributed algorithms and real-time data processing to ensure quasi-optimal solutions to the raised problems.

In [44], [65], we propose VESPA, a distributed algorithm using only one-hop information of the drones, to discover targets with unknown location and auto-organize themselves to ensure connectivity between them and the sink in a multi-hop aerial wireless network. We prove that connectivity, termination and coverage are preserved during all stages of our algorithm, and we evaluate the algorithm performances through simulations. Comparison with a prior work shows the efficiency of VESPA both in terms of discovered targets and number of used drones.

7.1.4.2. Optimal placement of drones for fast sensor energy replenishment using wireless power transfer

Lifetime is the main issue of wireless sensors networks. Since the nodes are often placed in inaccessible places, the replacement of their battery is not an easy task. Moreover, the node maintenance is a costly and time consuming operation when the nodes are high in numbers. Energy harvesting technologies have recently been developed to replenish part or all of the required energy that allows a node to function. In [47], [48], we use dedicated chargers carried by drones that can fly over the network and transmit energy to the nodes using radio-frequency (RF) signals. We formulate and optimally solve the Optimal Drone Placement and Planning Problem (OD3P) by using a given number of flying drones, in order to efficiently recharge wireless sensor nodes. Unlike other works in the literature, we assume that the drones can trade altitude with coverage and recharge power, while each drone can move across different positions in the network to extend coverage. We present a linear program as well as a fast heuristic algorithm to meet the minimum energy demands of the nodes in the shortest possible amount of time. Our simulation results show the effectiveness of our approaches for network scenarios with up to 50 sensors and a 50×50m terrain size.

7.1.4.3. Efficient Data Collection and Tracking with Flying Drones

Data collection is an important mechanism for wireless sensor networks to be viable. In [34], we address the Aerial Data Collection Problem (ADCP) from a set of mobile wireless sensors located on the ground, using a fleet of flying devices. The objective is i) to deploy a set of UAVs in a 3D space to cover and collect data from all the mobile wireless sensors at each time step through a ground-to-air communication, ii) to send these data to a central base station using multi-hop wireless air-to-air communications through the network of UAVs, iii) while minimizing the total deployment cost (communication and deployment) over time. The Aerial Data Collection Problem (ADCP) is a complex time and space coverage, and connectivity problem. We first present a mixed-integer linear program solving ADCP optimally for small instances. Then, we develop a second model solved by column generation for larger instances, with optimal or heuristic pricing programs. Results show that our approach provides very accurate solutions minimizing the data collection cost. Moreover, only a very small number of columns are generated throughout the resolution process, showing the efficiency of our approach.

7.1.5. Other results

7.1.5.1. The Structured Way of Dealing with Heterogeneous Live Streaming Systems

In peer-to-peer networks for video live streaming, peers can share the forwarding load in two types of systems: unstructured and structured. In unstructured overlays, the graph structure is not well-defined, and a peer can obtain the stream from many sources. In structured overlays, the graph is organized as a tree rooted at the server and parent-child relationships are established between peers. Unstructured overlays ensure robustness and a higher degree of resilience compared to the structured ones. Indeed, they better manage the dynamics of peer participation or churn. Nodes can join and leave the system at any moment. However, they are less bandwidth efficient than structured overlays. In [54], we propose new simple distributed repair protocols for video live streaming structured systems. We show, through simulations and with real traces from Twitch, that structured systems can be very efficient and robust to failures, even for high churn and when peers have very heterogeneous upload bandwidth capabilities.

7.1.5.2. Optimal SF Allocation in LoRaWAN Considering Physical Capture and Imperfect Orthogonality

In [46], we propose a theoretical framework for maximizing the long range wide-area networks (LoRaWAN) capacity in terms of the number of end nodes, when they all have the same traffic generation process. The model optimally allocates the spreading factor to the nodes so that attenuation and collisions are optimized. We use an accurate propagation model considering Rayleigh channel, and we take into account physical capture and imperfect spreading factors (SF) orthogonality while guaranteeing a given transmission success probability to each served node in the network. Numerical results show the effectiveness of our SF allocation policy. Our framework also quantifies the maximum capacity of single cell networks and the gain induced by multiplying the gateways on the covered area. We finally evaluate the impact of physical capture and imperfect SF orthogonality on the SF allocation and network performances.

7.2. Graph Algorithms

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COATI is interested in the algorithmic aspects of Graph Theory. In general we try to find the most efficient algorithms to solve various problems of Graph Theory and telecommunication networks. We use Graph Theory to model various network problems. We study their complexity and then we investigate the structural properties of graphs that make these problems hard or easy.

7.2.1. Complexity of graph problems

7.2.1.1. Fully Polynomial FPT Algorithms for Some Classes of Bounded Clique-width Graphs.

Recently, hardness results for problems in P were achieved using reasonable complexity theoretic assumptions such as the Strong Exponential Time Hypothesis. According to these assumptions, many graph theoretic problems do not admit truly subquadratic algorithms. A central technique used to tackle the difficulty of the above mentioned problems is fixed-parameter algorithms with polynomial dependency in the fixed parameter (P-FPT). Applying this technique to clique-width, an important graph parameter, remained to be done. In [35], we study several graph theoretic problems for which hardness results exist such as cycle problems, distance problems and maximum matching. We give hardness results and P-FPT algorithms, using clique-width and some of its upper bounds as parameters. We believe that our most important result is an algorithm in $O(k^4 \cdot n + m)$-time for computing a maximum matching where k is either the modular-width of the graph or the P_4-sparseness. The latter generalizes many algorithms that have been introduced so far for specific subclasses such as cographs. Our algorithms are based on preprocessing methods using modular decomposition and split decomposition. Thus they can also be generalized to some graph classes with unbounded clique-width.

7.2.1.2. *Explicit Linear Kernels for Packing Problems*

During the last years, several algorithmic meta-theorems have appeared (Bodlaender et al. [83], Fomin et al. [88], Kim et al. [90]) guaranteeing the existence of linear kernels on sparse graphs for problems satisfying some generic conditions. The drawback of such general results is that it is usually not clear how to derive from them constructive kernels with reasonably low explicit constants. To fill this gap, we recently presented [89] a framework to obtain explicit linear kernels for some families of problems whose solutions can be certified by a subset of vertices. In [37], we enhance our framework to deal with packing problems, that is, problems whose solutions can be certified by collections of *subgraphs* of the input graph satisfying certain properties. $\mathcal{F}$-Packing is a typical example: for a family $\mathcal{F}$ of connected graphs that we assume to contain at least one planar graph, the task is to decide whether a graph G contains k vertex-disjoint sub-graphs such that each of them contains a graph in $\mathcal{F}$ as a minor. We provide explicit linear kernels on sparse graphs for the following two orthogonal generalizations of $\mathcal{F}$-Packing: for an integer $\ell \geq 1$, one aims at finding either minor-models that are pairwise at distance at least ℓ in G (ℓ-$\mathcal{F}$-Packing), or such that each vertex in G belongs to at most ℓ minors-models ($\mathcal{F}$-Packing with-Membership). Finally, we also provide linear kernels for the versions of these problems where one wants to pack *subgraphs* instead of minors.

7.2.1.3. *Low Time Complexity Algorithms for Path Computation in Cayley Graphs.*

We study the problem of path computation in Cayley Graphs (CG) from an approach of word processing in groups. This approach consists in encoding the topological structure of CG in an automaton called Diff, then techniques of word processing are applied for computing the shortest paths. In [17], we present algorithms for computing the K-shortest paths, the shortest disjoint paths and the shortest path avoiding a set of nodes and edges. For any CG with diameter D, the time complexity of the proposed algorithms is $O(KD|\mathrm{Diff}|)$, where $|\mathrm{Diff}|$ denotes the size of Diff. We show that our proposal outperforms the state of art of topology-agnostic algorithms for disjoint shortest paths and stays competitive with respect to proposals for specific families of CG. Therefore, the proposed algorithms set a base in the design of adaptive and low-complexity routing schemes for networks whose interconnections are defined by CG.

7.2.1.4. *Convex hull in graphs.*

In [40], we prove that, given a closure function the smallest preimage of a closed set can be calculated in polynomial time in the number of closed sets. This implies that there is a polynomial time algorithm to compute the convex hull number of a graph, when all its convex subgraphs are given as input. We then show that deciding if the smallest preimage of a closed set is logarithmic in the size of the ground set is LOGSNP-hard if only the ground set is given. A special instance of this problem is to compute the dimension of a poset given its linear extension graph, that is conjectured to be in P.

The intent to show that the latter problem is LOGSNP-complete leads to several interesting questions and to the definition of the isometric hull, i.e., a smallest isometric subgraph containing a given set of vertices S. While for $|S| = 2$ an isometric hull is just a shortest path, we show that computing the isometric hull of a set of vertices is NP-complete even if $|S| = 3$. Finally, we consider the problem of computing the isometric hull number of a graph and show that computing it is Σ_2^P complete.

7.2.2. Combinatorial games in graphs

7.2.2.1. *Graph searching and combinatorial games in graphs.*

The Network Decontamination problem consists of coordinating a team of mobile agents in order to clean a contaminated network. The problem is actually equivalent to tracking and capturing an invisible and arbitrarily fast fugitive. This problem has natural applications in network security in computer science or in robotics for search or pursuit-evasion missions. Many different objectives have been studied: the main one being the minimization of the number of mobile agents necessary to clean a contaminated network.

Many environments (continuous or discrete) have also been considered. In the book chapter [61], we focus on networks modeled by graphs. In this context, the optimization problem that consists of minimizing the number of agents has a deep graph-theoretical interpretation. Network decontamination and, more precisely, *graph searching* models, provide nice algorithmic interpretations of fundamental concepts in the Graph Minors theory by Robertson and Seymour.

For all these reasons, graph searching variants have been widely studied since their introduction by Breish (1967) and mathematical formalizations by Parsons (1978) and Petrov (1982). The book chapter [61] consists of an overview of the algorithmic results on graph decontamination and graph searching. Moreover, [19] is the preface to the special issue of TCS on the 8th Workshop on GRAph Searching, Theory and Applications, Anogia, Crete, Greece, April 10 - April 13, 2017.

In [52], we focus on another game with mobile agents in a graph. Precisely, in the eternal domination game played on graphs, an attacker attacks a vertex at each turn and a team of guards must move a guard to the attacked vertex to defend it. The guards may only move to adjacent vertices on their turn. The goal is to determine the eternal domination number γ_{all}^{∞} of a graph which is the minimum number of guards required to defend against an infinite sequence of attacks. [52] continues the study of the eternal domination game on strong grids $P_n \boxtimes P_m$. Cartesian grids $P_n \square P_m$ have been vastly studied with tight bounds existing for small grids such as $k \times n$ grids for $k \in \{2,3,4,5\}$. It was recently proven that $\gamma_{all}^{\infty}(P_n \square P_m) = \gamma(P_n \square P_m) + O(n+m)$ where $\gamma(P_n \square P_m)$ is the domination number of $P_n \square P_m$ which lower bounds the eternal domination number [91]. We prove that, for all $n, m \in \mathbb{N}^*$ such that $m \geq n$, $\lfloor \frac{nm}{9} \rfloor + \Omega(n+m) = \gamma_{all}^{\infty}(P_n \boxtimes P_m) = \lceil \frac{nm}{9} \rceil + O(m\sqrt{n})$ (note that $\lceil \frac{nm}{9} \rceil$ is the domination number of $P_n \boxtimes P_m$). Our technique may be applied to other “grid-like" graphs.

In [66], we adapt the techniques of [91] to prove that the eternal domination number of strong grids is upper bounded by $\frac{mn}{7} + O(m+n)$. While this does not improve upon a recently announced bound of $\lceil \frac{m}{3} \rceil \lceil \frac{n}{3} \rceil + O(m\sqrt{n})$ [52] in the general case, we show that our bound is an improvement in the case where the smaller of the two dimensions is at most 6179.

7.2.2.2. The Orthogonal Colouring Game

In [18], we introduce the Orthogonal Colouring Game, in which two players alternately colour vertices (from a choice of $m \in N$ colours) of a pair of isomorphic graphs while respecting the properness and the orthogonality of the colouring. Each player aims to maximize her score, which is the number of coloured vertices in the copy of the graph she owns. Our main result is that the second player has a strategy to force a draw in this game for any $m \in N$ for graphs that admit a strictly matched involution. An involution σ of a graph G is strictly matched if its fixed point set induces a clique and any non-fixed point $v \in V(G)$ is connected with its image $\sigma(v)$ by an edge. We give a structural characterization of graphs admitting a strictly matched involution and bounds for the number of such graphs. Examples of such graphs are the graphs associated with Latin squares and sudoku squares.
In [62], we prove that recognising graphs that admit a strictly matched involution is NP-complete.

7.2.2.3. Complexity of Games Compendium

Since games and puzzles have been studied under a computational lens, researchers unearthed a rich landscape of complexity results showing deep connections between games and fundamental problems and models in computer science. Complexity of Games (CoG, https://steven3k.gitlab.io/isnphard-test/) is a compendium of complexity results on games and puzzles. It aims to serve as a reference guide for enthusiasts and researchers on the topic and is a collaborative and open source project that welcomes contributions from the community.

7.2.3. Algorithms for social networks

7.2.3.1. KADABRA, an ADaptive Algorithm for Betweenness via Random Approximation

In [32], we present KADABRA, a new algorithm to approximate betweenness centrality in directed and undirected graphs, which significantly outperforms all previous approaches on real-world complex networks. The efficiency of the new algorithm relies on two new theoretical contributions, of independent interest. The first contribution focuses on sampling shortest paths, a subroutine used by most algorithms that approximate betweenness centrality. We show that, on realistic random graph models, we can perform this task in time $|E|^{\frac{1}{2}+o(1)}$ with high probability, obtaining a significant speedup with respect to the $\Theta(|E|)$ worst-case performance. We experimentally show that this new technique achieves similar speedups on real-world complex networks, as well. The second contribution is a new rigorous application of the adaptive sampling technique. This approach decreases the total number of shortest paths that need to be sampled to compute all betweenness centralities with a given absolute error, and it also handles more general problems, such as computing the k most central nodes. Furthermore, our analysis is general, and it might be extended to other settings.

7.2.3.2. Distributed Community Detection via Metastability of the 2-Choices Dynamics

In [56], we investigate the behavior of a simple majority dynamics on networks of agents whose interaction topology exhibits a community structure. By leveraging recent advancements in the analysis of dynamics, we prove that, when the states of the nodes are randomly initialized, the system rapidly and stably converges to a configuration in which the communities maintain internal consensus on different states. This is the first analytical result on the behavior of dynamics for non-consensus problems on non-complete topologies, based on the first symmetry-breaking analysis in such setting. Our result has several implications in different contexts in which dynamics are adopted for computational and biological modeling purposes. In the context of Label Propagation Algorithms, a class of widely used heuristics for community detection, it represents the first theoretical result on the behavior of a distributed label propagation algorithm with quasi-linear message complexity. In the context of evolutionary biology, dynamics such as the Moran process have been used to model the spread of mutations in genetic populations [Lieberman, Hauert, and Nowak 2005]; our result shows that, when the probability of adoption of a given mutation by a node of the evolutionary graph depends super-linearly on the frequency of the mutation in the neighborhood of the node and the underlying evolutionary graph exhibits a community structure, there is a non-negligible probability for species differentiation to occur.

7.2.3.3. On the Necessary Memory to Compute the Plurality in Multi-Agent Systems

Consensus and Broadcast are two fundamental problems in distributed computing, whose solutions have several applications. Intuitively, Consensus should be no harder than Broadcast, and this can be rigorously established in several models. Can Consensus be easier than Broadcast?

In models that allow noiseless communication, we prove in [60] a reduction of (a suitable variant of) Broadcast to binary Consensus, that preserves the communication model and all complexity parameters such as randomness, number of rounds, communication per round, etc., while there is a loss in the success probability of the protocol. Using this reduction, we get, among other applications, the first logarithmic lower bound on the number of rounds needed to achieve Consensus in the uniform GOSSIP model on the complete graph. The lower bound is tight and, in this model, Consensus and Broadcast are equivalent.

We then turn to distributed models with noisy communication channels that have been studied in the context of some bio-inspired systems. In such models, only one noisy bit is exchanged when a communication channel is established between two nodes, and so one cannot easily simulate a noiseless protocol by using error-correcting codes. An $\Omega(\epsilon^{-2}n)$ lower bound on the number of rounds needed for Broadcast is proved by Boczkowski et al. [82] in one such model (noisy uniform PULL, where ϵ is a parameter that measures the amount of noise). In such model, we prove a new $\Theta(\epsilon^{-2}n\log n)$ bound for Broadcast and a $\Theta(\epsilon^{-2}\log n)$ bound for binary Consensus, thus establishing an exponential gap between the number of rounds necessary for Consensus versus Broadcast.

7.2.3.4. How long does it take for all users in a social network to choose their communities?

In [30], we consider a community formation problem in social networks, where the users are either friends or enemies. The users are partitioned into conflict-free groups (i.e., independent sets in the conflict graph $G^-=(V,E)$ that represents the enmities between users). The dynamics goes on as long as there exists any set of at most k users, k being any fixed parameter, that can change their current groups in the partition simultaneously, in such a way that they all strictly increase their utilities (number of friends i.e., the cardinality of their respective groups minus one). Previously, the best-known upper-bounds on the maximum time of convergence were $O(|V|\alpha(G^-))$ for $k\leq 2$ and $O(|V|^3)$ for $k=3$, with $\alpha(G^-)$ being the independence number of G^-. Our first contribution consists in reinterpreting the initial problem as the study of a dominance ordering over the vectors of integer partitions. With this approach, we obtain for $k \leq 2$ the tight upper-bound $O(|V| \min \left\{\alpha(G^-), \sqrt{|V|}\right\})$ and, when G^- is the empty graph, the exact value of order $\frac{(2|V|)^{3/2}}{3}$. The time of convergence, for any fixed $k \geq 4$, was conjectured to be polynomial. In this paper we disprove this. Specifically, we prove that for any $k \geq 4$, the maximum time of convergence is in $\Omega(|V|\Theta(\log |V|))$.

7.2.3.5. A Comparative Study of Neural Network Compression

There has recently been an increasing desire to evaluate neural networks locally on computationally-limited devices in order to exploit their recent effectiveness for several applications; such effectiveness has nevertheless come together with a considerable increase in the size of modern neural networks, which constitute a major downside in several of the aforementioned computationally-limited settings. There has thus been a demand of compression techniques for neural networks. Several proposal in this direction have been made, which famously include hashing-based methods and pruning-based ones. However, the evaluation of the efficacy of these techniques has so far been heterogeneous, with no clear evidence in favor of any of them over the others. In [70], we address this latter issue by providing a comparative study. While most previous studies test the capability of a technique in reducing the number of parameters of state-of-the-art networks, we follow [86] in evaluating their performance on basic architectures on the MNIST dataset and variants of it, which allows for a clearer analysis of some aspects of their behavior. To the best of our knowledge, we are the first to directly compare famous approaches such as HashedNet, Optimal Brain Damage (OBD), and magnitude-based pruning with L1 and L2 regularization among them and against equivalent-size feed-forward neural networks with simple (fully-connected) and structural (convolutional) neural networks. Rather surprisingly, our experiments show that (iterative) pruning-based methods are substantially better than the HashedNet architecture, whose compression doesn't appear advantageous to a carefully chosen convolutional network. We also show that, when the compression level is high, the famous OBD pruning heuristics deteriorates to the point of being less efficient than simple magnitude-based techniques.

7.3. Graph and digraph theory

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COATI studies theoretical problems in graph theory. If some of them are directly motivated by applications, others are more fundamental.

We are putting an effort on understanding better directed graphs (also called *digraphs*) and partitioning problems, and in particular colouring problems. We also try to better the understand the many relations between orientations and colourings. We study various substructures and partitions in (di)graphs. For each of them, we aim at giving sufficient conditions that guarantee its existence and at determining the complexity of finding it.

To ease the reading, we split our results in this section into several subsections dedicated to particular topics.

7.3.1. Graph and digraph colourings

7.3.1.1. Distinguishing labellings and the 1-2-3 Conjecture

We are interested in several distinguishing labelling (or edge-weighting) problems, where the general aim, given a graph, is to label the edges in such a way that certain properties are fulfilled. The main problem we have been considering is the **1-2-3 Conjecture**, which claims that every connected graph different from K_2 admits a labelling with $1, 2, 3$ such that no two adjacent vertices are incident to the same sum of weights. Some of our latest results provide evidence towards the 1-2-3 Conjecture. We also investigated questions inspired from the conjecture, such that the role of the weights $1, 2, 3$ in the statement of the conjecture, the deep connection with proper vertex-colourings and other standard notions of graph theory.

7.3.1.2. A 1-2-3-4 result for the 1-2-3 Conjecture in 5-regular graphs

To date, the best-known result towards the 1-2-3 Conjecture is due to Kalkowski, Karoński and Pfender, who proved that it holds when relaxed to 5-edge-weightings. Their proof builds upon a weighting algorithm designed by Kalkowski for a total version of the problem. In [23], we present new mechanisms for using Kalkowski's algorithm in the context of the 1-2-3 Conjecture. As a main result we prove that every 5-regular graph admits a 4-edge-weighting that permits to distinguish its adjacent vertices via their incident sums.

7.3.1.3. On $\{a,b\}$-edge-weightings of bipartite graphs with odd a,b

For any $S \subset \mathbb{Z}$ we say that a graph G has the S-property if there exists an S-edge-weighting $w : E(G) \to S$ such that for any pair of adjacent vertices u,v we have $\sum_{e \in E(v)} w(e) \neq \sum_{e \in E(u)} w(e)$, where $E(v)$ and $E(u)$ are the sets of edges incident to v and u, respectively. In general, deciding if a graph G has the $\{a,b\}$-property is NP-complete for every a,b. This question is open for bipartite graphs however. The only known results of this sort are that bipartite graphs without the $\{1,2\}$-property can be recognized easily, and similarly for 2-connected bipartite graphs without the $\{0,1\}$-property. In [28], we focus on $\{a,a+2\}$-edge-weightings where $a \in \mathbb{Z}$ is odd. We show that a 2-connected bipartite graph has the $\{a,a+2\}$-property if and only if it is not a so-called odd multi-cactus. In the case of trees, we show that only one case is pathological. That is, we show that all trees have the $\{a,a+2\}$-property for odd $a \neq -1$, while there is an easy characterization of trees without the $\{-1,1\}$-property.

7.3.1.4. 1-2-3 Conjecture in Digraphs: More Results and Directions

When arc-weighting a digraph, there are, at each vertex, two sums of incident weights: the in-coming sum σ^- and the out-going sum σ^+. Thus, there are many ways for generalizing the 1-2-3 Conjecture to digraphs. In the recent years, four main variants have been considered, where, for every arc $\overrightarrow{uv}$, it is required that one of $\sigma^-(u), \sigma^+(u)$ is different from one of $\sigma^-(v), \sigma^+(v)$. All of these four variants are well understood, except for the one where, for every arc $\overrightarrow{uv}$, it is required that $\sigma^-(u) \neq \sigma^+(v)$. Regarding this version, Horňak, Przybyło and Woźniak recently proved that almost every digraph can be 4-arc-weighted so that, for every arc $\overrightarrow{uv}$, the sum of weights incoming to u is different from the sum of weights outgoing from v. They conjectured a stronger result, namely that the same statement with 3 instead of 4 should also be true. We verify this conjecture in [73]. This work takes place in a recent "quest" towards a directed version of the 1-2-3 Conjecture, the variant above being one of the last introduced ones. We take the occasion of this work to establish a summary of all results known in this field, covering known upper bounds, complexity aspects, and choosability. On the way we prove additional results which were missing in the whole picture. We also mention the aspects that remain open.

7.3.1.5. Edge Weights and Vertex Colours: Minimizing Sum Count

Put differently, the 1-2-3 Conjecture asks whether, via weights with very low magnitude, we can "encode" a proper vertex-colouring of any graph. Note, however, that we do not care about whether such a result colouring is optimal, i.e., whether its number of colours is close to the chromatic number. In [22], we investigate the minimum number of distinct sums/colours we can produce via a neighbour-sum-distinguishing edge-weighting of a given graph G, and the role of the assigned weights in that context. Clearly, this minimum number is bounded below by the chromatic number $\chi(G)$ of G. When using weights of $\mathbb{Z}$, we show that, in general, we can produce neighbour-sum-distinguishing edge-weightings generating $\chi(G)$ distinct sums, except in the peculiar case where G is a balanced bipartite graph, in which case $\chi(G)+1$ distinct sums can be generated. These results are best possible. When using k consecutive weights $1, ..., k$, we provide both lower and upper bounds, as a function of the maximum degree Δ, on the maximum least number of sums that can be generated for a graph with maximum degree Δ. For trees, which, in general, admit neighbour-sum-distinguishing 2-edge-weightings, we prove that this maximum, when using weights 1 and 2, is of order $2\log_2 \Delta$. Finally, we also establish the NP-hardness of several decision problems related to these questions.

7.3.1.6. On Minimizing the Maximum Color for the 1-2-3 Conjecture

In the line of the previous investigation, one way to get some sort of progress is to design proper labellings where the maximum color of a vertex is as small as possible. In [64], we investigate the consequences of labeling graphs as in the 1-2-3 Conjecture when it is further required to make the maximum resulting color as small as possible. We first investigate the hardness of determining the minimum maximum color by a labeling for a given graph, which we show is NP-complete in the class of bipartite graphs but polynomial-time solvable in the class of graphs with bounded treewidth. We then provide bounds on the minimum maximum color that can be generated both in the general context, and for particular classes of graphs. Finally, we study how using larger labels permits to reduce the maximum color.

7.3.1.7. Decomposing degenerate graphs into locally irregular subgraphs

A (undirected) graph is locally irregular if no two of its adjacent vertices have the same degree. A decomposition of a graph G into k locally irregular subgraphs is a partition $E_1, ..., E_k$ of $E(G)$ into k parts each of which induces a locally irregular subgraph. Not all graphs decompose into locally irregular subgraphs; however, it was conjectured that, whenever a graph does, it should admit such a decomposition into at most three locally irregular subgraphs. This conjecture was verified for a few graph classes in recent years. It was introduced because it was noticed that, in some contexts, there are connections between locally irregular decompositions and the 1-2-3 Conjecture. In [63], we consider the decomposability of degenerate graphs with low degeneracy. Our main result is that decomposable k-degenerate graphs decompose into at most $3k + 1$ locally irregular subgraphs, which improves on previous results whenever $k \leq 9$. We improve this result further for some specific classes of degenerate graphs, such as bipartite cacti, k-trees, and planar graphs. Although our results provide only little progress towards the leading conjecture above, the main contribution of this work is rather the decomposition schemes and methods we introduce to prove these results.

7.3.1.8. A general decomposition theory for the 1-2-3 Conjecture and locally irregular decompositions

In [21], we propose an approach encapsulating locally irregular decompositions and proper labelings. As a consequence, we get another interpretation of several existing results related to the 1-2-3 Conjecture. We also come up with new related conjectures, to which we give some support.

7.3.1.9. Decomposability of graphs into subgraphs fulfilling the 1-2-3 Conjecture

In particular, one of the side problems we run into is decomposing graphs into subgraphs verifying the 1-2-3 Conjecture. In [29], we prove that every d-regular graph, $d \geq 2$, can be decomposed into at most 2 subgraphs (without isolated edges) fulfilling the 1-2-3 Conjecture if $d \notin \{10, 11, 12, 13, 15, 17\}$, and into at most 3 such subgraphs in the remaining cases. Additionally, we prove that in general every graph without isolated edges can be decomposed into at most 24 subgraphs fulfilling the 1–2–3 Conjecture, improving the previously best upper bound of 40. Both results are partly based on applications of the Lovász Local Lemma.

7.3.1.10. On the 2-edge-coloured chromatic number of grids

The oriented (2-edge-coloured, respectively) chromatic number $\chi_o(G)$ ($\chi_2(G)$, respectively) of an undirected graph G is defined as the maximum oriented (2-edge-coloured, respectively) chromatic number of an orientation (signature, respectively) of G. Although the difference between $\chi_o(G)$ and $\chi_2(G)$ can be arbitrarily large, there are, however, contexts in which these two parameters are quite comparable. In [24], we compare the behaviour of these two parameters in the context of (square) grids. While a series of works has been dedicated to the oriented chromatic number of grids, we are not aware of any work dedicated to their 2-edge-coloured chromatic number. We investigate this throughout this paper. We show that the maximum 2-edge-coloured chromatic number of a grid lies between 8 and 11. We also focus on 2-row grids and 3-row grids, and exhibit bounds on their 2-edge-coloured chromatic number, some of which are tight. Although our results indicate that the oriented chromatic number and the 2-edge-coloured chromatic number of grids are close in general, they also show that these parameters may differ, even for easy instances.

7.3.1.11. From light edges to strong edge-colouring of 1-planar graphs

A strong edge-colouring of an undirected graph G is an edge-colouring where every two edges at distance at most 2 receive distinct colours. The strong chromatic index of G is the least number of colours in a strong edge-colouring of G. A conjecture of Erdős and Nešetřil, stated back in the 80's, asserts that every graph with maximum degree Δ should have strong chromatic index at most roughly $1.25\Delta^2$. Several works in the last decades have confirmed this conjecture for various graph classes. In particular, lots of attention have been dedicated to planar graphs, for which the strong chromatic index decreases to roughly 4Δ, and even to smaller values under additional structural requirements. In [26], we initiate the study of the strong chromatic index of 1-planar graphs, which are those graphs that can be drawn on the plane in such a way that every edge is crossed at most once. We provide constructions of 1-planar graphs with maximum degree Δ and strong chromatic index roughly 6Δ. As an upper bound, we prove that the strong chromatic index of a 1-planar graph with maximum degree Δ is at most roughly 24Δ (thus linear in Δ). In the course of proving the latter result, we prove, towards a conjecture of Hudák and Šugerek, that 1-planar graphs with minimum degree 3 have edges both of whose ends have degree at most 29.

7.3.1.12. Pushable chromatic number of graphs with degree constraints

Pushable homomorphisms and the pushable chromatic number χ_p of oriented graphs were introduced by Klostermeyer and MacGillivray in 2004. They notably observed that, for any oriented graph $\overrightarrow{G}$, we have $\chi_p(\overrightarrow{G}) \leq \chi_o(\overrightarrow{G}) \leq 2\chi_p(\overrightarrow{G})$, where $\chi_o(\overrightarrow{G})$ denotes the oriented chromatic number of $\overrightarrow{G}$. This stands as first general bounds on χ_p. This parameter was further studied in later works.

In [71], we consider the pushable chromatic number of oriented graphs fulfilling particular degree conditions. For all $\Delta \geq 29$, we first prove that the maximum value of the pushable chromatic number of an oriented graph with maximum degree Δ lies between $2^{\frac{\Delta}{2}-1}$ and $(\Delta-3)\cdot(\Delta-1)\cdot 2^{\Delta-1}+2$ which implies an improved bound on the oriented chromatic number of the same family of graphs. For subcubic oriented graphs, that is, when $\Delta \leq 3$, we then prove that the maximum value of the pushable chromatic number is 6 or 7. We also prove that the maximum value of the pushable chromatic number of oriented graphs with maximum average degree less than 3 lies between 5 and 6. The former upper bound of 7 also holds as an upper bound on the pushable chromatic number of planar oriented graphs with girth at least 6.

7.3.2. Graph and digraph decompositions

7.3.2.1. Edge-partitioning a graph into paths: beyond the Barát-Thomassen conjecture

In 2006, Barát and Thomassen conjectured that there is a function f such that, for every fixed tree T with t edges, every $f(t)$-edge-connected graph with its number of edges divisible by t has a partition of its edges into copies of T. This conjecture was recently verified in [81] by, in particular, some members of COATI. In [27], we further focus on the path case of the Barát-Thomassen conjecture. Before the aforementioned general proof was announced, several successive steps towards the path case of the conjecture were made, notably by Thomassen [94], [95], [96], until this particular case was totally solved by Botler, Mota, Oshiro and Wakabayashi [84]. Our goal in this work was to propose an alternative proof of the path case with a weaker hypothesis: Namely, we prove that there is a function f such that every 24-edge-connected graph with minimum degree $f(t)$ has an edge-partition into paths of length t whenever t divides the number of edges. We also show that 24 can be dropped to 4 when the graph is eulerian.

7.3.2.2. Constrained ear decompositions in graphs and digraphs.

Ear decompositions of graphs are a standard concept related to several major problems in graph theory like the Traveling Salesman Problem. For example, the Hamiltonian Cycle Problem, which is notoriously NP-complete, is equivalent to deciding whether a given graph admits an ear decomposition in which all ears except one are trivial (i.e. of length 1). On the other hand, a famous result of Lovász states that deciding whether a graph admits an ear decomposition with all ears of odd length can be done in polynomial time. In [38], we study the complexity of deciding whether a graph admits an ear decomposition with prescribed ear lengths. We prove that deciding whether a graph admits an ear decomposition with all ears of length at most ℓ is polynomial-time solvable for all fixed positive integer ℓ. On the other hand, deciding whether a graph admits an ear decomposition without ears of length in $\mathcal{F}$ is NP-complete for any finite set $\mathcal{F}$ of positive integers. We also prove that, for any $k \geq 2$, deciding whether a graph admits an ear decomposition with all ears of length $0 \mod k$ is NP-complete.

We also consider the directed analogue to ear decomposition, which we call handle decomposition, and prove analogous results : deciding whether a digraph admits a handle decomposition with all handles of length at most ℓ is polynomial-time solvable for all positive integer ℓ; deciding whether a digraph admits a handle decomposition without handles of length in $\mathcal{F}$ is NP-complete for any finite set $\mathcal{F}$ of positive integers (and minimizing the number of handles of length in $\mathcal{F}$ is not approximable up to $n(1-\epsilon)$); for any $k \geq 2$, deciding whether a digraph admits a handle decomposition with all handles of length $0 \mod k$ is NP-complete. Also, in contrast with the result of Lovász, we prove that deciding whether a digraph admits a handle decomposition with all handles of odd length is NP-complete. Finally, we conjecture that, for every set $\mathcal{A}$ of integers, deciding whether a digraph has a handle decomposition with all handles of length in $\mathcal{A}$ is NP-complete, unless there exists $h \in \mathbb{N}$ such that $\mathcal{A} = \{1, \cdots, h\}$.

7.3.3. Substructures in graphs and digraphs

7.3.3.1. Subdivisions in Digraphs of Large Out-Degree or Large Dichromatic Number

In 1985, Mader conjectured the existence of a function f such that every digraph with minimum out-degree at least $f(k)$ contains a subdivision of the transitive tournament of order k. This conjecture is still completely open, as the existence of $f(5)$ remains unknown. In this paper, we show that if D is an oriented path, or an in-arborescence (i.e., a tree with all edges oriented towards the root) or the union of two directed paths from x to y and a directed path from y to x, then every digraph with minimum out-degree large enough contains a subdivision of D. Additionally, we study Mader's conjecture considering another graph parameter. The dichromatic number of a digraph D is the smallest integer k such that D can be partitioned into k acyclic subdigraphs. We show in [16] that any digraph with dichromatic number greater than $4m(n-1)$ contains every digraph with n vertices and m arcs as a subdivision.

7.3.3.2. Bipartite spanning sub(di)graphs induced by 2-partitions

For a given 2-partition (V_1, V_2) of the vertices of a (di)graph G, we study properties of the spanning bipartite subdigraph $BG(V_1, V_2)$ of G induced by those arcs/edges that have one end in each $V_i, i \in \{1, 2\}$. In [20], we determine, for all pairs of non-negative integers k_1, k_2, the complexity of deciding whether G has a 2-partition (V_1, V_2) such that each vertex in V_i (for $i \in \{1, 2\}$) has at least k_i (out-)neighbours in V_{3-i}. We prove that it is NP-complete to decide whether a digraph D has a 2-partition (V_1, V_2) such that each vertex in V_1 has an out-neighbour in V_2 and each vertex in V_2 has an in-neighbour in V_1. The problem becomes polynomially solvable if we require D to be strongly connected. We give a characterization of the structure of NP-complete instances in terms of their strong component digraph. When we want higher in-degree or out-degree to/from the other set the problem becomes NP-complete even for strong digraphs. A further result is that it is NP-complete to decide whether a given digraph D has a 2-partition (V_1, V_2) such that $BD(V_1, V_2)$ is strongly connected. This holds even if we require the input to be a highly connected eulerian digraph.

7.3.3.3. Metric Dimension: from Graphs to Oriented Graphs

The metric dimension $MD(G)$ of an undirected graph G is the cardinality of a smallest set of vertices that allows, through their distances to all vertices, to distinguish any two vertices of G. Many aspects of this notion have been investigated since its introduction in the 70's, including its generalization to digraphs.

In [42], [43], we study, for particular graph families, the maximum metric dimension over all strongly-connected orientations, by exhibiting lower and upper bounds on this value. We first exhibit general bounds for graphs with bounded maximum degree. In particular, we prove that, in the case of subcubic n-node graphs, all strongly-connected orientations asymptotically have metric dimension at most $\frac{n}{2}$, and that there are such orientations having metric dimension $\frac{2n}{5}$. We then consider strongly-connected orientations of grids. For a torus with n rows and m columns, we show that the maximum value of the metric dimension of a strongly-connected Eulerian orientation is asymptotically $\frac{nm}{2}$ (the equality holding when n, m are even, which is best possible). For a grid with n rows and m columns, we prove that all strongly-connected orientations asymptotically have metric dimension at most $\frac{2nm}{3}$, and that there are such orientations having metric dimension $\frac{nm}{2}$.

7.3.4. Bio-informatics motivated problems

7.3.4.1. Overlaying a hypergraph with a graph with bounded maximum degree

A major problem in structural biology is the characterization of low resolution structures of macro-molecular assemblies. One subproblem of this very difficult question is to determine the plausible contacts between the subunits (e.g. proteins) of an assembly, given the lists of subunits involved in all the complexes. This problem can be conveniently modelled by graphs and hypergraphs. Let G and H be respectively a graph and a hypergraph defined on a same set of vertices, and let F be a fixed graph. We say that G F-overlays a hyperedge S of H if F is a spanning subgraph of the subgraph of G induced by S, and that it F-overlays H if it F-overlays every hyperedge of H. Motivated by structural biology, we study in [68] the computational complexity of two problems. The first problem, $(\Delta \leq k)$ F-Overlay, consists in deciding whether there is a graph with maximum degree at most k that F-overlays a given hypergraph H. It is a particular case of the second problem Max $(\Delta \leq k)$ F-Overlay, which takes a hypergraph H and an integer s as input, and consists in deciding whether there is a graph with maximum degree at most k that F-overlays at least s hyperedges of H. We give a complete polynomial/NP-complete dichotomy for the Max $(\Delta \leq k)$ F-Overlay problems depending on the pairs (F, k), and establish the complexity of $(\Delta \leq k)$ F-Overlay for many pairs (F, k).

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

8.1.1. Oui!Greens, 2019

Participant: Joanna Moulierac.

Duration: January 2019 - February 2019

Coordinator: Joanna Moulierac

Other partners: Dorian Mazauric from EP ABS

Abstract: Supervision of an InriaTech engineer for the development of the algorithm proposed in a previous collaboration with Oui!Greens.

The aim of the algorithm is to propose to clients the adequate products (fruits or vegetables) that are almost out-of-date with the objective of maximizing the satisfaction of the clients, and the diminution of the wastage. During one month, this algorithm has been implemented into the mobile application pepino, owned by Oui!Greens.

8.1.2. MillionRoads, 2019-2020

Participants: David Coudert, Frédéric Giroire, Luc Hogie, Nicolas Nisse, Michel Syska.

Duration: October 2019 - April 2020

Project title: HumanRoads

Coordinator: Nicolas Nisse

Other partners: SME MillionRoads; EP Zenith (Didier Parigot)

Abstract: HumanRoads uses a graph database, in the Neo4j environment, to store and structure its data. This database is already large and is regularly enriched with new data. However, to date, response times to queries are not satisfactory. This Project aims at identifying the limiting factors and to propose alternatives. More precisely, we will work on analyzing the data structure in the graph database to optimize queries, in the Neo4j environment, and on graph algorithms to speed up queries.

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. SNIF, 2018-2021

Participants: David Coudert, Frédéric Giroire, Nicolas Nisse, Stéphane Pérennes.

Program: Innovation project of IDEX UCA$^{\text{JEDI}}$.

Project acronym: SNIF

Project title: Scientific Networks and IDEX Funding

Duration: September 2018 - August 2021

Coordinator: Patrick Musso

Other partners: GREDEG, SKEMA, I3S (SigNet) and Inria (COATI), all from UCA.

Abstract: Scientific collaboration networks play a crucial role in modern science. This simple idea underlies a variety of initiatives aiming to promote scientific collaborations between different research teams, universities, countries and disciplines. The recent French IDEX experience is one of them. By fostering competition between universities and granting few of them with a relatively small amount of additional resources (as compare to their global budget), public authorities aim to encourage them to deeply reshape the way academic activities are organized in order to significantly increase the quality of their research, educational programs and innovative activities. The development of new collaboration networks is one of the factors at the heart of this global reorganization. Promoting new international and/or interdisciplinary collaborations is supposed to increase researchers' productivity and industry partnerships. This project aims to question the validity of this line of thought.

9.2. National Initiatives

9.2.1. DGA/Inria Brainside, 2019-2023

Participants: Francesco d'Amore, Emanuele Natale.

Program: DGA/Inria

Project acronym: Brainside

Project title: Algorithms for simplifying neural networks

Duration: October 2019 - March 2023

Coordinator: Emanuele Natale

Other partners: Inria Paris, EP GANG

Abstract: The widespread use of neural networks on devices with computationally-low capabilities, demands for lightweight and energy-efficient networks. Despite such need, and despite the strategies employed to prevent overfitting by removing a substantial part of their edges, the question of how to reduce their size in terms of the number of neurons appears largely unexplored. The aim of the project is to investigate algorithmic procedures to reduce the size of neural networks, in order to improve the speed with which they can be evaluated and to shed light on how much information about the computational problem at hand can be encoded within neural networks of small size.

9.2.2. ANR-17-CE22-0016 MultiMod, 2018-2022

Participants: Mohammed Amine Ait Ouahmed, Ali Al Zoobi, David Coudert, Nicolas Nisse, Michel Syska.

Program: ANR

Project acronym: MultiMod

Project title: Scalable routing in Multi Modal transportation networks

Duration: January 2018 - December 2022

Coordinator: David Coudert

Other partners: Inria Paris, EP GANG; team CeP, I3S laboratory; SME Instant-System; SME Benomad

Abstract: The MultiMod project addresses key algorithmic challenges to enable the fast computation of personalized itineraries in large-scale multi-modal public transportation (PT) networks (bus, tram, metro, bicycle, etc.) combined with dynamic car-pooling. We will use real-time data to propose itineraries with close to real travel-time, and handle user-constraints to propose personalized itineraries. Our main challenge is to overcome the scalability of existing solutions in terms of query processing time and data-structures space requirements, while including unplanned transportation means (car-pooling), real-time data, and personalized user constraints. The combination of car-pooling and PT network will open-up areas with low PT coverage enable faster itineraries and so foster the adoption of car-pooling. We envision that the outcome of this project will dramatically enhanced the mobility and daily life of citizens in urban areas.

Web: https://project.inria.fr/multimod/

9.2.3. PICS DISCO

Program: PICS

Project acronym: DISCO

Project title: DIsjoint Structures and Coverings in Oriented graphs

Duration: January 2018 -December 2020.

Coordinator: Stéphane Bessy (LIRMM)

Other partners: CNRS LIRMM (Montpellier), Syddansk universitet (Odense, Danemark)

Abstract: Directed graphs (digraphs) are much less understood than undirected graphs. Many, seemingly very simple questions remain unsolved for digraphs while the analogous problem for undirected graphs is trivial. At the same time digraphs are a very important modelling tool for practical applications and so a better undestanding of their structure is important. The purpose of DISCO is to advance knowledge on fundamental problems on digraphs, including splitting a digraph into smaller pieces with given properties, problems regarding disjoint paths and trees, finding small certificates for given properties, such as strong spanning subdigraphs with few arcs. The later is important for speeding up certain algorithms.

Through a concerted effort we expect to obtain important results which will lead to a better undestanding of fundamental questions about the structure of digraphs. The participants will meet regularly both in France and in Denmark to work on carefully selected problems.

9.2.4. GDR Actions

9.2.4.1. GDR RSD, ongoing (since 2006)

Members of COATI are involved in the working group RESCOM (*Réseaux de communications*) of GDR RSD, CNRS (http://gdr-rsd.cnrs.fr/pole_rescom). In particular, David Coudert is co-chair of this working group since 2017.

We are also involved in the working group "Energy" of GDR RSD (http://gdr-rsd.cnrs.fr/action_green). In particular, Frédéric Giroire is co-hair of this working group.

9.2.4.2. GDR IM, ongoing (since 2006)

Members of COATI are involved in the working group "Graphes" of GDR IM, CNRS. (http://gtgraphes.labri.fr/). In particular, Frédéric Havet is member of the steering committee.

9.2.4.3. GDR MADICS, ongoing (since 2017)

Members of COATI are involved in the working group GRAMINEES (GRaph data Mining in Natural, Ecological and Environnemental Sciences) of GDR MADICS (Masses de Données, Informations et Connaissances en Sciences). (http://www.madics.fr/actions/actions-en-cours/graminees/).

9.3. International Initiatives

9.3.1. Inria Associate Teams Not Involved in an Inria International Labs

9.3.1.1. EfDyNet

Title: Efficient Dynamic Resource Allocation in Networks

International Partner (Institution - Laboratory - Researcher):

Concordia University (Canada) - Department of Electrical Engineering - Brigitte Jaumard

Start year: 2019

See also: https://team.inria.fr/coati/projects/efdynet/

Networks are evolving rapidly in two directions. On the one hand, new network technologies are developed for different layers, and in particular flexible optical technologies (enabling to allocate a fraction of the optical spectrum rather than a fixed wavelength), Software Defined Networks, and Network Function Virtualization. On the other hand, the traffic patterns evolve and become less predictable due to the increase of cloud and mobile traffic. In this context, there are new possibilities and needs for dynamic resource allocations. We will study this problem mainly in two directions: network reconfiguration and the allocation of virtualized resources. The associated team will build on an already fruitful collaboration between COATI and Concordia. The two teams address design and management optimization problems in networks (WDM, wireless, SDN) with complementary tools and expertise.

9.3.2. Inria International Partners

9.3.2.1. Informal International Partners

Apart from formal collaboration COATI members maintain strong connections with the following international teams, with regular visits of both sides.

Universidade Federal do Ceará (Fortaleza, Brazil), ParGO team;

Universidade Estadual do Ceará (Fortaleza, Brazil), Prof. Leonardo Sampaio;

Univ. of Southern Denmark (Odense, Denmark), Prof. Jørgen Bang-Jensen.

9.3.3. Participation in Other International Programs

9.3.3.1. International Initiatives

GALOP

Program: STICAmSud

Title: Graphs ALgorithms for Optimization Problems

International Partners (Institution - Laboratory - Researcher):

Universidad Diego Portales (Chile) - Facultad de Ingeniería y Ciencias - Karol Suchan

Universidade Federal do Ceará (Brazil) - ParGo team - Julio Araujo

Duration: 2019 - 2020

Start year: 2019

See also: https://team.inria.fr/coati/projects/sticamsud-galop/

This project aims at allowing to continue the fruitful and long-standing collaboration between Inria and UFC and between Inria and UAI. Another goal is to reinforce the collaboration between UFC and UAI that has been recently initiated. Our goal is to study the Computational Complexity of several important problems arising in networks (routing, resources assignment...). In particular, we will focus on the computation of metric or structural properties and parameters of large networks (e.g., transportation and social networks...). We plan to design efficient exact algorithms for solving these problems or to theoretically prove that such algorithms cannot exist. In the latter case, we will then design approximation algorithms, or prove that none exists. In all cases, we aim at implementing our algorithms and use them on real-world instances such as large road networks or huge social networks.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- Hossein Baktash: Sharif Institute of Technology, Tehran, Iran. July 15 - September 15, 2019.
- Joergen Bang-Jensen: Southern Denmark University, Odense, Denmark, January 7-11 2019.
- Brigitte Jaumard: Concordia University, Montréal, Québec, Canada. June 17-28 and December 7-21, 2019.
- Malgorzata Sulkowska: Faculty of Fundamental Problems of Technology, Wroclaw University of Science and Technology, Wroclaw, Poland. September 23-27th, 2019.
- Karol Suchan: Universidad Diego Portales, Santiago, Chile. December 8-22th, 2019.
- Julio-Cesar Silva Araújo: Universidad do Ceara, Fortaleza, Brazil. December 5-28th, 2019.
- Karol Maia de Oliveira: Universidad do Ceara, Fortaleza, Brazil. December 5-28th, 2019.
- Claudia Linhares Sales: Universidad do Ceara, Fortaleza, Brazil. December 5-28th, 2019.
- Leonardo Sampaio Rocha: Universidad do Ceara, Fortaleza, Brazil. until June 2019.
- Xavier Defago: Tokyo Institute of Technology, Tokyo, Japan. January 7-11, 2019.
- Takako Kodate: Tokyo Woman's Christian University, Tokyo, Japan. March 18-31, 2019.

9.4.2. Visits to International Teams

9.4.2.1. Research Stays Abroad

- Julien Bensmail :

  Indian Statistical Institute, Kolkata, India. January 26-February 9, 2019.

  Universidade Federal do Ceará, Fortaleza, Brazil. May 4-May 17, 2019.

  Xidian University, Xi'an, China. August 31-September 14, 2019.

  Northwestern Polytechnical University, Xi'an, China. October 19-November 2, 2019.
- David Coudert :

  Concordia University, Montréal, Québec, Canada. July 12-27, 2019.
- Adrien Gausseran :

  Concordia University, Montréal, Québec, Canada. September 2 - December 2, 2019.
- Frédéric Giroire :

  Concordia University, Montréal, Québec, Canada. October 8-18th, 2019.
- Joanna Moulierac :

  Concordia University, Montréal, Québec, Canada. October 8-18th, 2019.
- Emanuele Natale :

  Max Planck Institute for Informatics, Sarrebruck, Germany. January 19 - February 28, 2019.

  University of Melbourne, Melbourne, Australia & University of Otago, Dunedin, New Zealand. October 1-30, 2019.

  University of Rome Tor Vergata, Rome, Italy. 1 November 2019 - 31 January 2020.
- Nicolas Nisse :

  Univ. Federal do Ceara, Fortaleza, Brazil, May 4-18th, 2019.

  Xidiang University, Xi'an, China. September 1-15th, 2019.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events: Selection

10.1.1.1. Member of the Conference Program Committees

- Christelle Caillouet :

  MiSARN'19: International Mission-Oriented Wireless Sensor, UAV and Robot Networking in conjunction with IEEE INFOCOM 2019.

  Wi-DroIT'19: 1st International Workshop on Wireless sensors and Drones in Internet of Things in conjunction with DCOSS 2019

  AlgoTel'19: 21ème Rencontre Francophone sur les Aspects Algorithmiques de Télécommunications, Saint Laurent de la Cabrerisse, France, June 4-7, 2019.

- David Coudert :

  ONDM'19: 23rd Conference on Optical Network Design and Management, Athens, Greece, May 13-16, 2019.

  IEEE ICC'19: IEEE International Conference on Communications, Shangai, China, May 20-24, 2019.

  IEEE Globecom'19: IEEE Global Communications Conference, Waikoloa, Hi, USA, December 9-13, 2019.

- Frédéric Giroire :

  Algotel'19: 21ème Rencontre Francophone sur les Aspects Algorithmiques de Télécommunications, Saint-Laurent-de-la-Cabrerisse, France, June 4-7, 2019.

- Frédéric Havet :

  LAGOS'19: X Latin and American Algorithms, Graphs and Optimization Symposium, Belo Horizonte, Brazil, June 2-7 2019.

  JGA'19: Journées Graphes et Algorithmes, Brussels, Belgium, November 15-17 2019.

- Joanna Moulierac :

  CoRes'19: Rencontres Francophones sur la Conception de Protocoles, l'Evaluation de Performance et l'Expérimentation des Réseaux de Communication, Saint Laurent de la Cabrerisse, France, June 3-4, 2019.

- Emanuele Natale :

  SPAA'19: 31st ACM Symposium on Parallelism in Algorithms and Architectures, Phoenix, AZ, USA, June 22-24, 2019 .

- Nicolas Nisse :

  CIAC'19: 11th International Conference on Algorithms and Complexity, Roma, Italy, May 27-29th, 2019.

  LAGOS'19: X Latin and American Algorithms, Graphs and Optimization Symposium, Belo Horizonte, Brazil, June 2-7, 2019.

  WG'19: 45th International Workshop on Graph-Theoretic Concepts in Computer Science, Vall de Núria, Catalonia, Spain, June 19-21, 2019.

10.1.1.2. Reviewer

Members of COATI have reviewed numerous manuscripts submitted to national and international conferences, including:

AlgoTel 2019, CoRes 2019, CSR 2019, EvoApplications 2019, IEEE ICC 2019, IPDPS 2019, IEEE Globecom 2019, LAGOS 2019, MFCS 2019, ONDM 2019, OPODIS 2019, IEEE PIMRC 2019, SPAA 2019, WG 2019.

10.1.2. Journal

10.1.2.1. Member of the Editorial Boards

Jean-Claude Bermond :

Computer Science Reviews, Discrete Mathematics, Discrete Applied Mathematics, Journal of Graph Theory, Journal of Interconnection Networks (Advisory Board), Mathématiques et Sciences Humaines, Networks, Parallel Processing Letters, the SIAM book series on Discrete Mathematics, Transactions on Network Optimization and Control, Algorithms and Applications.

Christelle Caillouet :

Guest Editor of the Special Issue "Optimization and Communication in UAV Networks" of MDPI Sensors Journal with Nathalie Mitton.

Alexandre Caminada :

Sensors — Open Access Journal, MDPI editor, Basel.

Soft Computing, Springer.

Journal of Traffic and Transportation Engineering, Elsevier.

Transactions on Mobile Computing, IEEE.

Transactions on Vehicular Technology, IEEE.

David Coudert :

Discrete Applied Mathematics (Elsevier).

Networks (Wiley).

Frédéric Giroire :

Journal of Interconnection Networks (World Scientific).

Frédéric Havet :

Discrete Mathematics and Theoretical Computer Science.

10.1.2.2. Reviewer - Reviewing Activities

Members of COATI have reviewed numerous manuscripts submitted to international journals, including:

IEEE Access, The American Mathematical Monthly, ACM Journal of Experimental Algorithmics (JEA), Elsevier Ad Hoc Networks, Ars Combinatorica, Computer Communications (ComCom) Computer Networks (COMNET), Computers & Operations Research (COR), Discrete Applied Mathematics (DAM), Discrete Mathematics, Discrete Mathematics and Theoretical Computer Science (DMTCS), Discussiones Mathematicae Graph Theory, European Journal of Combinatorics, European Journal of Operational Research (EJOR), Graphs and Combinatorics, Journal of Computer and System Sciences (JCSS), Journal of Combinatorial Theory, Series B (JCTB), IEEE/OSA Journal of Lightwave Technology (JLT), Opuscula Mathematica, SIAM Journal on Discrete Mathematics (SIDMA), IEEE Transactions on Mobile Computing (TOMC), IEEE/ACM Transactions on Networking (ToN), IEEE Transactions on Network and Service Management (TNSM), IEEE Transactions on Parallel and Distributed Systems (TPDS), IEEE Transaction on Services Computing, Theoretical Computer Science (TCS), Theory of Computing Systems (TOCS), Utilitas Mathematica.

10.1.3. Invited Talks

- Julien Bensmail :

  Sequential Metric Dimension (in trees). Meeting of IFCAM project, Indian Statistical Institute, Kolkata, India. February 2019.

  On the "quest" towards a directed variant of the 1-2-3 Conjecture. Seminar of the Department of Applied Mathematics, Northwestern Polytechnical University, Xi'an, China. October 2019.

  On the "quest" towards a directed variant of the 1-2-3 Conjecture. Seminar of the School of Mathematics and Statistics, Xidian University, Xi'an, China. September 2019.

  On partitioning graphs into connected subgraphs. Seminar of the Department of Applied Mathematics, Northwestern Polytechnical University, Xi'an, China. September 2019.

  A Decompositional Approach to the 1-2-3 Conjecture. Seminar of the Departamento de Matemática, Universidade Federal do Ceará, Fortaleza, Brazil. May 2019.

- David Coudert :

  Scientific objectives of ANR project MULTIMOD. Workshop "Complexité et algorithmes" of GDR IM, Roscoff, France, April 3-5, 2019.

  On the Flinders Hamiltonian Cycle Problem Challenge. Keynote speaker at "21ème Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications" (AlgoTel 2019), Saint Laurent de la Cabrerisse, France, June 3-7, 2019.

  On the Flinders Hamiltonian Cycle Problem Challenge. Department of Computer Science & Software Engineering, Concordia University, Québec, Canada, July 25, 2019.

- Frédéric Giroire :

  Placement de services réseaux virtuels dans le cloud et au-delà. Journées Cloud https://www.irit.fr/journeescloud2019/, Toulouse, France. September, 12, 2019.

  Overview of Networking Challenges for the Placement of Cloud Services. Team seminar. Concordia University, Montréal, Canada.

  Sobriété énergétique des réseaux informatiques. Journée Scientifique "Concilier numérique et environnement ?" de l'Académie RISE / EUR DS4H de l'Université Côte d'Azur, France. December 2, 2019.

- Frédéric Havet :

  Unavoidability and universality of digraphs, WG 2019, Vall de Núria, Catalonia, Spain, June 2019.

  On the unavoidability of trees in tournaments, A tribute to Frédéric Maffray, Grenoble, France, September 2-4, 2019.

- Emanuele Natale :

  From Distributed Computing to Natural Algorithms and Beyond, invited talk at the 20th Italian Conference on Theoretical Computer Science (ICTCS'19) as a recipient of the IC-EATCS Young Researcher Award, Como, Italy, September 9-11, 2019.

- Nicolas Nisse :

  Recovery of disrupted airline operations, seminar team ParGO, Univ. federal do Ceara, Fortaleza, Brazil, May 10th, 2019

  Eternal domination in grid-like graphs, seminar of Northwestern Polytechnical University, Xi'an, China, Sept. 9th, 2019

  Localization GameS in graphs, seminar of Xidian University, Xi'an, China, Sept. 5th, 2019

10.1.4. Leadership within the Scientific Community

Alexandre Caminada :

Member of the administrative board of the Sophia Club Entreprise (club of more than 200 Sophia companies).

David Coudert :

Co-chair of *Pôle RESCOM of GDR RSD of CNRS* since 2017 and member of the steering committee since 2005.

Frédéric Giroire :

Member of the steering committee of *GT Energy of the GDR RSD of CNRS*.

Frédéric Havet :

Member of the steering committee of *GT Graphes of the GDR IM of CNRS*.

Nicolas Nisse :

Member of the "bureau" of the GT CoA of the GDR IM.

10.1.5. Scientific Expertise

- Jean-Claude Bermond :

  Expert for DRTT-MESR Crédit impôt recherche (CIR et agréments).
- Alexandre Caminada :

  Expert for HCERES evaluation of UMR5157 SAMOVAR (Services répartis, Architectures, MOdélisation, Validation, Administration des Réseaux), Telecom Sud Paris.

  Expert for CTI of ENSEA, graduate school on economy and statistics, Abidjan, Côte d'Ivoire.
- David Coudert :

  Expert for ANR
- Frédéric Havet :

  Expert for The Fund for Scientific Research - FNRS, Belgium.
- Nicolas Nisse :

  Expert for ESF (European Science Foundation).

  Expert for National Science Centre, OPUS (Poland)

10.1.6. Research Administration

- Jean-Claude Bermond :

  Responsible for the cooperation between Inria and Greece : setting of grants for master 2 students co-financed by Inria Sophia Antipolis Méditerranée and the French Embassy in Greece (in 2019 the grant was given to Foivos Fioravantes who did his internship in Coati) and getting financial support for internships via the Bodossakis Fundation.
- Christelle Caillouet :

  Elected member of CPRH (Comité Permanent de Ressources Humaines) University of Nice Sophia Antipolis;

  Elected member of I3S laboratory committee since December 2016.
- Alexandre Caminada :

  Head of the graduate school of engineering Polytech Nice Sophia which includes the EA7498 lab (Polytech Lab) of the French Ministry for Education, Research and Innovation, in charge of research in civil engineering and smart building at Université Côte d'Azur.

Member of the executive board of the Sophia Interdisciplinary Institute of Artificial Intelligence started in 2019.

Manager of the Chinese Scholarship Council PhD program for the Polytech network (70 Phd subjects proposed in 2019 by the 15 graduate schools).

Member of the selection committee of the tenure professor position nr552 (section 27, machine learning) at Université Côte d'Azur.

- David Coudert :

  Nominated member for Inria at the doctoral school STIC, since September 2017;

  Head (since December 2019) and member (since 2009) of the "Comité de Suivi Doctoral" of Inria;

  Nominated member for Inria at the steering committee of Academy 1 RISE (Networks, Information, Digital Society) of UCA^{JEDI} since February 2018;

  Nominated member for Inria at the steering committee of EUR DS4H since February 2018;

  Nominated member for Inria at the steering committee of Labec UCN@Sophia since February 2018;

  Member of the steering committee of seminar Forum Numerica of Academy 1 RISE of UCA^{JEDI} since 2018;

  Member of the "Bureau du comité des équipe-projets" of Inria research center Sophia Antipolis - Méditerranée since 2018.

- Frédéric Giroire :

  In charge of the internships of stream UbiNet of Master 2 IFI, UNS.

- Frédéric Havet :

  Head of COMRED team of I3S laboratory.

- Luc Hogie :

  Member of the CUMI (comité des utilisateurs des moyens informatiques) of Inria Sophia Antipolis Méditerranée;

  Elected member of I3S laboratory committee since December 2016.

- Joanna Moulierac :

  Member of selection committee MCF 775, IUT Arles, 2019.

- Nicolas Nisse :

  Elected member of "Comité de centre", Inria, Sophia Antipolis.

  Member of "Comité Scientifique et Pédagogique" (CSP) EUR DS4H.

- Michel Syska :

  Elected member of CPRH (Comité Permanent de Ressources Humaines) University of Nice Sophia Antipolis.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching Responsibilities

Julien Bensmail :

2019: In charge of the internships of the 1st-year students of Département QLIO of IUT Nice Côte d'Azur.

Since September 2019: Head of the Licence Professionnelle "Managements des Processus Logistiques" (MPL) of Université Nice-Sophia Antipolis.

Christelle Caillouet :

Elected member of Conseil de département IUT Informatique since September 2017.

Alexandre Caminada :

Head of the graduate school of engineering Polytech Nice Sophia (1500 master grade students, 100 faculty members, 50 staffs).

Member of the executive board of the Polytech network, national network of public graduate school of engineering.

Member of the executive board of Université Côte d'Azur.

Joanna Moulierac :

"Directrice d'études" for the 1st-year students of "Département Informatique" of IUT Nice Côte d'Azur (since September 2017).

Head of the "Conseil de Département Informatique" of IUT Nice Côte d'Azur (since September 2017).

10.2.2. Teaching

IUT: Julien Bensmail, *Recherche opérationnelle*, 90h ETD, Level L2, Département QLIO of IUT Nice Côte d'Azur, UNS, France;

IUT: Julien Bensmail, *Systèmes de gestion de bases de données*, 70h ETD, Level L2, Département QLIO of IUT Nice Côte d'Azur, UNS, France;

IUT: Julien Bensmail, *Sécurité des échanges de données inter-entreprises*, 30h ETD, Level LP, LP MPL of IUT Nice Côte d'Azur, UNS, France;

IUT: Christelle Caillouet, *Object Oriented Programming*, 150h ETD, Level L1, IUT Nice Côte d'Azur, UNS, France;

IUT: Christelle Caillouet, *Introduction to Networks*, 21h ETD, Level L1, IUT Nice Côte d'Azur, UNS, France;

IUT: Christelle Caillouet, *Algorithmics*, 21h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Adrien Gausseran, *Bases de la conception orientée objet*, 64h ETD, Level L1, IUT Nice Côte d'Azur, UNS, France;

IUT: Adrien Gausseran, *Introduction à l'algorithmique et à la programmation*, 6h ETD, Level L1, IUT Nice Côte d'Azur, UNS, France;

IUT: Luc Hogie, *Distributed programming*, 28h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Hicham Lesfari, *Réseaux d'opérateurs et réseaux d'accès*, 48h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Joanna Moulierac, *Introduction à l'algorithmique*, 30h ETD, Level L1, IUT Nice Côte d'Azur, UNS, France;

IUT: Joanna Moulierac, *Introduction aux Réseaux*, 36h ETD, Level L1, IUT Nice Côte d'Azur, UNS, France;

IUT: Joanna Moulierac, *Réseaux avancés*, 60h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Joanna Moulierac, *Compléments d'algorithmique*, 30h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Thibaud Trolliet, *Database*, 64h ETD, Level L1, IUT Nice Côte d'Azur, UNS, France;

IUT: Michel Syska, *Tutored Project: Introduction*, Level L1, IUT Nice Côte d'Azur, UNS, France;

IUT: Michel Syska, *Operating Systems: Advanced Programming*, 40h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Michel Syska, *Data Structures and Algorithms*, 44h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Michel Syska, *Introduction to Artificial Intelligence*, 40h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Michel Syska, *Algorithmics*, 52h ETD, Level L2, IUT Nice Côte d'Azur, UNS, France;

IUT: Michel Syska, *Web Security*, 13h ETD, Level L3, IUT Nice Côte d'Azur, UNS, France;

MPSI: Nicolas Nisse, *Option informatique, MPSI*, 24h ETD, classe préparatoire MPSI, Lycée International de Valbonne, France;

Licence: Frédéric Giroire, *Probability and statistics*, 50h ETD, 1st year (L3), Engineer School Polytech Nice;

Licence: Thi Viet Ha Nguyen, *TDs Theoretical computer science 2 (Formal langages and automata)*, 22h ETD, L3, Polytech Nice Sophia, France;

Master: Alexandre Caminada, *Radio location systems*, 20h ETD, Master 2 (in english), Polytech Nice Sophia, France

Master: Alexandre Caminada, *Artificial intelligence*, 40h ETD, Master 2 (in english), Polytech Nice Sophia, France

Master: Alexandre Caminada, Master grade student's internship supervision and assesment, 10h ETD, Master 2, Polytech Nice Sophia, France

Master: David Coudert, *Algorithms for Telecoms*, 36h ETD, M2, Université Nice Sophia Antipolis, France;

Master: Frédéric Giroire, *Graph Algorithms*, 15h ETD, Master 2, International Track Ubinet, Université Côte d'Azur, Nice;

Master: Frédéric Giroire, *Machine learning for networks*, 15h ETD, Master 2, International Track Ubinet, Université Côte d'Azur, Nice;

Master: Emanuele Natale, *Natural Distributed Algorithms*, 20h, Laurea Magistrale, University of Rome Tor Vergata, Italy.

Master: Nicolas Nisse, *Graphes*, 36 ETD, M1 Informatique, UNS/UCA, France;

Master: Nicolas Nisse, *Graphes avancés*, 36 ETD, M2 Informatique, UNS/UCA, France;

Master: Nicolas Nisse, *Algorithmes et Optimisation*, 15 ETD, M2 IFI, Parcours Ubinet, UNS/UCA, France;

Master: Nicolas Nisse, *Algorithmique*, 10 ETD, Formation professeurs de lycée, DIU, UCA, France;

Master: Stéphane Pérennes, *Algorithmes et complexité*, 10h ETD, M1 SI4, Polytech Nice Sophia, France

10.2.3. Supervision

10.2.3.1. PhD thesis

PhD: Brieuc Berruet, *Application des techniques de Machine Learning à la géolocalisation "indoor" des objets connectés dans le contexte de la future 5G*, doctorale school SPIM, Université de Belfort Franche Comté, December 17, 2019. Supervisor: Alexandre Caminada and Oumaya Baala (Orange).

PhD: Emilio Cruciani, *Simple Randomized Distributed Algorithms for Graph Clustering*, Gran Sasso Science Institute, December 19, 2018. Co-supervisors: Gianlorenzo D'Angelo (GSSI), Luca Becchetti (Sapienza University of Rome) and Emanuele Natale.

PhD: Mehdi Katranji, *Utilisation des méthodes de Machine Learning pour apprendre les modèles de mobilité humaine selon leurs attibuts socio-démographiques et géographiques*, doctorale school SPIM, Université de Belfort Franche Comté, December 16, 2019. Supervisor: Alexandre Caminada and Fouad Hadjselem (Orange).

PhD: Fionn McInerney, *Domination and Identification Games in Graphs* [14], Université Côte d'Azur, July 8, 2019. Supervisor: Nicolas Nisse.

PhD: Andrea Tomassilli, *Towards Next Generation Networks with SDN and NFV* [15], June 24, 2019. Supervisors: Stéphane Pérennes and Frédéric Giroire.

PhD in progress: Ali Al Zoobi, *Algorithms for shared on demand public transportation system in the city*, since October 2018. Co-supervisors: David Coudert and Nicolas Nisse.

PhD in progress: Francesco D'Amore, *Dynamics for multi-agent system coordination in noisy and stochastic environments*, since October 2019. Co-supervisors: Emanuele Natale and Nicolas Nisse.

PhD in progress: Giuseppe Di Lena, *Resilience of virtualized networks*, since April 2018. Co-supervisors: Thierry Turletti (DIANA), Chidung Lac (Orange Labs Lannion) and Frédéric Giroire. CIFRE grant with Orange.

PhD in progress: Foivos Fioravantes, *Distinguishing labellings of graphs*, since October 2019. Co-supervisors: Julien Bensmail and Nicolas Nisse.

PhD in progress: Adrien Gausseran, *Optimization Algorithms for Network Slicing for 5G*, since October 2018. Supervisors: Joanna Moulierac and Nicolas Nisse.

PhD in progress: Hicham Lesfari, *Machine learning for dynamic network resource allocation*, since October 2019. Supervisor: Frédéric Giroire.

PhD in progress: Zhejiayu Ma, *Learning problem for the diffusion of multimedia contents*, since October 2018. Co-Supervisors: Guillaume Urvoy-Keller, Frédéric Giroire, Soufiane Rouiba (Easy-broadcast, Nantes). CIFRE grant with Easybroadcast.

PhD in Progress: Thi-Viet-Ha Nguyen, *Graph Algorithms techniques for (low and high) resolution model of large protein assemblies.*, since October 2018. Co-supervisors: Frédéric Havet and Dorian Mazauric (ABS).

PhD in progress: Thibaud Trolliet, *Exploring Trust on Twitter*, since October 2017. Co-supervisors: Arnaud Legout (DIANA) and Frédéric Giroire.

10.2.3.2. Internships

Licence: Paul Bastide, *Density Estimation via Random Walks with Limited Communication*, ENS Rennes, France, from 20 May 2019 until 12 July 2019. Supervisor: Emanuele Natale.

Licence: Gabriel Djebbar, *Collapse and graphs problems*, SI3, Polytech Nice Sophia, France, from July 2018 until August 2018. Co-supervisors: Frédéric Havet and Dorian Mazauric (ABS).

Licence: Solal Gaudin, *Compromis temps-espace dans l'énumération des paires éloignés par distances décroissantes*, L3 ENS Cachan, France, from June 2019 until July 2019. Supervisor: David Coudert.

Licence: Emile Sorci, *Oblivious metric dimension*, L3, ENS Lyon, France, from June 2019 until July 2019. Co-supervisors: Julien Bensmail and Nicolas Nisse.

Licence: Zoé Varin, *Constrained matchings*, L3, ENS Lyon, France, from June 2019 until July 2019. Co-supervisors: Julien Bensmail and Nicolas Nisse.

Master 1 (tutorship): Nitha Sagar Jayanna, *Shortest Path in Multimodal Public Transportation Networks*, M1 Computer Science, Digital Systems for Humans (DS4H) Graduate school - Université Côte d'Azur, France, from October 2018 until June 2019. Supervisor: Michel Syska

Master 1 (tutorship): Shamprikta Mehreen, *Multi Objective Shortest Path Problem*, M1 Computer Science, Digital Systems for Humans (DS4H) Graduate school - Université Côte d'Azur, France, from October 2018 until June 2019. Supervisor: Michel Syska

Master 2 (TER): Haoran Ding, *Machine learning for dynamic network resource allocation*, Master 2 IFI, international track Ubinet, Université Côte d'Azur, France, from October 2019 until December 2019. Co-supervisors: Frédéric Giroire and Hicham Lesfari.

Master 2 (TER): Thomas Dissaux, *Computing treelength*, M2 IFI, Université Côte d'Azur, France, from October 2019 until December 2019. Supervisor: Nicolas Nisse

Master 2 (TER): Igor Dias Da Silva, *Computation and analysis of drone trajectories for effective surveillance and data collection*, Master IFI, Université Côte d'Azur, France, from November 2019 until December 2019. Supervisor: Christelle Caillouet.

Master 2 (TER): Arno Gobbin, *Computational Complexity of Puzzles and Games*, SI5 Polytech Nice Sophia, Université Côte d'Azur, France, from November 2019 until December 2019. Supervisor: Emanuele Natale

Master 2 (TER): Siwar Helaoui, *Distributed simulation of algorithms for the deployment of self-organized UAVs*, SI5 Polytech Nice Sophia, Université Côte d'Azur, France, from November 2019 until March 2020. Supervisor: Christelle Caillouet and David Coudert.

Master 2 (TER): Noueman Khalikine, *Algorithms for studying the evolution over time of the structure of social graphs*, stream Ubinet of M2 IFI, Université Côte d'Azur, France, from November 2019 until December 2019. Supervisor: David Coudert and Frédéric Giroire.

Master 2 (TER): Abdelkrim El Merss, *Algorithms for studying the evolution over time of the structure of social graphs*, stream Ubinet of M2 IFI, Université Côte d'Azur, France, from November 2019 until December 2019. Supervisor: David Coudert and Frédéric Giroire.

Master 2 (TER): Victor Tapissier, *Evolution over time of the structure of social graphs*, SI5 Polytech Nice Sophia, Université Côte d'Azur, France, from November 2019 until December 2019. Supervisor: David Coudert and Frédéric Giroire.

Master 2 (TER): Bruno Tarbes, *Evolution over time of the structure of social graphs*, SI5 Polytech Nice Sophia, Université Côte d'Azur, France, from November 2019 until December 2019. Supervisor: David Coudert and Frédéric Giroire.

Master 2 (apprentissage): Théo Qui, *Implementation and study of Graphs' decompositions*, M2 IFI, Université Côte d'Azur, France, from September 2019 until August 2020. Supervisor: Nicolas Nisse.

Master 2: Athanasia Farmaki, *Implementaiton of algorithms for the dial-a-ride problem with time windows*, in the context of ANR MULTIMOD, Master 2, National Technical University of Athens, Greece, from January 2019 until June 2019. Co-supervisors: David Coudert and Nicolas Nisse.

Master 2: Foivos Fioravantes, *BMRN*-colouring of planar digraphs*, Master 2 IFI, international track Ubinet, Université Côte d'Azur, France, from March 2019 until August 2019. Supervisor: Julien Bensmail.

Master 2: Hicham Lesfari, *Network Anomaly Detection Using Graph Kernels*, Master 2 IFI, international track Ubinet, Université Côte d'Azur, France, from March 2019 until August 2019. Supervisor: Frédéric Giroire.

Master 2: Bai Xin, *Optimization of Drones Trajectory for Optimal Sensor Coverage and Data Collection*, M2 Ubinet, Université Côte d'Azur, France, from March 2019 until August 2019. Supervisor: Christelle Caillouet.

Google Summer of Code: Ritesh K, *Improvement of methods for computing distances in the graph module of Sagemath*, Bachelor of Technology at the Department of Computer Science and Engineering of National Institute of Technology Karnataka, India. from May 2019 until August 2019. Mentor: David Coudert.

Google Summer of Code: Rajat Mittal, *Implementation of algorithms for enumeration of k-shortests simple paths and contribution to the improvement of graph module of Sagemath*, Master at Indian Institute of Technology (BHU) Varanasi, India. from May 2019 until August 2019. Mentor: David Coudert.

Google Summer of Code: Georgios Giapitzakis Tzintanos, *Implementation of new graph traversals (LexBFS, LexDFS, etc.) and contribution to the improvement of graph module of Sagemath*, Bachelor of Science at the National and Kapodistrian University of Athens, Greece. from May 2019 until August 2019. Mentor: David Coudert.

10.2.4. Juries

Jean-Claude Bermond :

President of the PhD prize committee *prix de thèse Graphes "Charles Delorme"* http://gtgraphes.labri.fr/pmwiki/pmwiki.php/PrixTheseDelorme/PrixTheseDelorme;

Christelle Caillouet :

Member of PhD committee of Dorin Rautu, Université de Toulouse, October 1, 2019;

Alexandre Caminada :

Referee for the PhD thesis of Shen Peng, Paris-Sud university, June 17, 2019, Chance Constrained Problem and Its Applications;

Referee for the Pierre Lafitte Price, supported by the Doctoral Schools SFA (Basic and Applied Sciences) and STIC (Sciences and Technologies of Information and Communication) of Université Côte d'Azur and Mines Paris, to enhance the quality of the research work of 2nd year PhD students;

David Coudert :

Referee and member of PhD committee of Valentin Pollet, Université de Montpellier, October 3, 2019;

Referee and member of PhD committee of Francesca Fossati, Sorbonne Université, November 29, 2019;

President of PhD committee of Paul Beaujean, Université Paris Dauphine, December 16, 2019;

Frédéric Havet :

Member of PhD committee Jocelyn Thiébaut, Université de Montpellier, November 19, 2019;

Joanna Moulierac :

Member of PhD committee of Chaopeng Guo, Université de Toulouse, June 14, 2019;

Nicolas Nisse :

Referee and member of PhD committee Valentin Gledel, Université de Lyon (LIRIS), September 24th, 2019;

Referee and member of PhD committee Sébastien Ratel, Université Aix-Marseille (LIS), November 8th, 2019.

10.3. Popularization

10.3.1. Internal or external Inria responsibilities

- Jean-Claude Bermond, Frédéric Havet, Joanna Moulierac, and Nicolas Nisse are involved in Terra Numerica which brings together several popularization groups in order to create a museum of digital sciences.
- Frédéric Havet: Vice-president and member of the scientific committee of the association Institut Esope 21 (https://lewebpedagogique.com/institutesope21/).

10.3.2. Education

- Frédéric Havet, Joanna Moulierac and Nicolas Nisse (responsable) : Participation to Galejade project "Graphes et ALgorithmes : Ensemble de Jeux À Destination des Ecoliers... (mais pas que)" https://galejade.inria.fr/.

  Design of pedagogical resources introducing graphs and algorithms to primary school students.

Training of primary school teachers, ESPE, Nice (March 22, 2019), Lyon (April 10th, 2019).

Intervention Lycée Carnot (Cannes, March 14, 2019), Lycée Sydney Bechet (Antibes, March 13, 2019), Lycée au Cannet (April 5, 2019)

- Frédéric Havet :

  Training of secondary school teachers on graphs and algorithms. April 23, 2019.

10.3.3. Interventions

- Fête de la Science (Frédéric Havet, Nicolas Nisse, Ali Al Zoobi) :

  Villeneuve-Loubet, October 5, 2019;

  Colline du Château de Nice (stands Inria and I3S laboratory), October 4-6, 2019;

  Collège Lycée Vinon-sur-Verdon, October 8-11, 2019;

  Palais des Congrès de Juan-Les-Pins, October 19-20, 2019.

- Ali Al Zoobi :

  Presentation of posters and combinatorial games during the "Fête des Sciences", Collège Emile Roux, June 5, 2019.

- David Coudert :

  Presentation of the *Flinders Hamiltonian Cycle Problem Challenge* to a group of students from classe préparatoire MPSI, Lycée International de Valbonne, June 24, 2019.

- Frédéric Giroire :

  Accueil de la mission locale de Grasse pour une session de médiation scientifique, 26 avril 2019.

- Frédéric Havet :

  Animation of the exhibition “Animals of the Mediterranean sea” 6 classes, Ecole la Tauriac, Toulon, January 24, 2019.

  Conferences “Birds of Var”, 6 classes, Ecole élémentaire de Rians, February 1, 2019.

  Conference “Be a mathemagician”, Ecole des Pallières, February 2, 2019.

  Animation “Birds of Var”, 6 classes Ecole de la Tauriac and 2 classes Ecole de la Beaucaire, Toulon, Mars 07 2019.

  3 conferences “Les pavages”, “La science du ballon de football”, “Mathémagie” for 10 classes in total. Collège Daudet Nice, April 15, 2019.

  “La magie du binaire”. Conference for six classes in Manosque for the “Jeux fabriqués” day organised by DANE 04. April 2, 2019.

  Training of primary school teachers.

- Frédéric Havet, Joanna Moulierac, and Nicolas Nisse participated to the supervision of twelve schoolchildren (3ème) in internship.

- Nicolas Nisse :

  MathC2+, Sophia Antipolis, June 14, 2019

- Michel Syska :

  Member of the organization of the code competition "*Retro Gaming pico-8*" (55 teams of 3 students), April, 2019.

  Organization and supervision of the local site IUT for the national code competition "*La nuit de l'info*" (156 students = 3.7% of participants), December 5-6, 2019.

10.3.4. Internal action

- Frédéric Havet and Nicolas Nisse participated to the Cafe'In presenting Galejade. April 29, 2019.

11. Bibliography

Major publications by the team in recent years

[1] D. AGARWAL, C. CAILLOUET, D. COUDERT, F. CAZALS. *Unveiling Contacts within Macro-molecular assemblies by solving Minimum Weight Connectivity Inference Problems*, in "Molecular and Cellular Proteomics", April 2015, vol. 14, pp. 2274-2284 [*DOI :* 10.1074/MCP.M114.047779], https://hal.inria.fr/hal-01245401

[2] J. BENSMAIL, A. HARUTYUNYAN, T.-N. LE, S. THOMASSÉ. *Edge-partitioning a graph into paths: beyond the Barát-Thomassen conjecture*, in "Combinatorica", April 2019, vol. 39, n^o 2, pp. 239-263 [*DOI :* 10.1007/S00493-017-3661-5], https://hal.archives-ouvertes.fr/hal-01744515

[3] C. CAILLOUET, F. GIROIRE, T. RAZAFINDRALAMBO. *Efficient Data Collection and Tracking with Flying Drones*, in "Ad Hoc Networks", 2019, vol. 89, n^o C, pp. 35-46 [*DOI :* 10.1016/J.ADHOC.2019.01.011], https://hal.inria.fr/hal-02043136

[4] N. COHEN, F. HAVET, W. LOCHET, N. NISSE. *Subdivisions of oriented cycles in digraphs with large chromatic number*, in "Journal of Graph Theory", April 2018, vol. 89, n^o 4, pp. 439-456 [*DOI :* 10.1002/JGT.22360], https://hal.archives-ouvertes.fr/hal-01834779

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[7] E. CRUCIANI, E. NATALE, G. SCORNAVACCA. *Distributed Community Detection via Metastability of the 2-Choices Dynamics*, in "AAAI 2019 - 33th AAAI Conference Association for the Advancement of Artificial Intelligence", Honolulu, United States, January 2019, https://hal.archives-ouvertes.fr/hal-02002462

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