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Project-Team GANG

Networks, Graphs and Algorithms

IN COLLABORATION WITH: Institut de Recherche en Informatique Fondamentale

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THEME
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Table of contents

Project-Team GANG

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Keywords:

Computer Science and Digital Science:

A1.2. - Networks
A1.2.3. - Routing
A1.2.9. - Social Networks
A1.3. - Distributed Systems
A3.5. - Social networks
A3.5.1. - Analysis of large graphs
A6.1.3. - Discrete Modeling (multi-agent, people centered)
A7.1. - Algorithms
A7.1.3. - Graph algorithms
A8.1. - Discrete mathematics, combinatorics
A8.2. - Optimization
A8.7. - Graph theory
A8.8. - Network science

Other Research Topics and Application Domains:

B1.1.8. - Evolutionnary biology
B1.1.11. - Systems biology
B6.3.2. - Network protocols
B6.3.4. - Social Networks
B7.2. - Smart travel

1. Personnel

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2. Overall Objectives

2.1. Overall Objectives

GANG focuses on algorithm design for large scale networks using structural properties of these networks. Application domains include the development of optimized protocols for large dynamic networks such as mobile networks or overlay networks over Internet. This includes for instance peer-to-peer applications, or the navigability of social networks. GANG tools come from recent advances in the field of graph algorithms, both in centralized and distributed settings. In particular, this includes graph decomposition and geometric properties (such as low doubling dimension, low dimension embedding, etc.). Today, the management of large networks, Internet being the reference, is best effort. However, the demand for mobility (ad hoc networks, wireless connectivity, etc.) and for dynamicity (node churn, fault tolerance, etc.) is increasing. In this distributed setting, it becomes necessary to design a new generation of algorithms and protocols to face the challenge of large scale mobility and dynamicity. In the mean time, recent and sophisticated theoretical results have emerged, offering interesting new tracks for managing large networks. These results concern centralized and decentralized algorithms for solving key problems in communication networks, including routing, but also information retrieval, localization, or load balancing. They are mainly based on structural properties observed in most of real networks: approximate topology with low dimension metric spaces, low treewidth, low doubling dimension, graph minor freeness, etc. In addition, graph decomposition techniques have recently progressed. The scientific community has now tools for optimizing network management. First striking results include designing overlay networks for peer-to-peer systems and understanding the navigability of large social networks.

3. Research Program

3.1. Graph and Combinatorial Algorithms

We focus on two approaches for designing algorithms for large graphs: decomposing the graph and relying on simple graph traversals.

3.1.1. Graph Decompositions

We study new decompositions schemes such as 2-join, skew partitions and others partition problems. These graph decompositions appeared in the structural graph theory and are the basis of some well-known theorems such as the Perfect Graph Theorem. For these decompositions there is a lack of efficient algorithms. We aim at designing algorithms working in $O(nm)$ since we think that this could be a lower bound for these decompositions.

3.1.2. Graph Search

We more deeply study multi-sweep graph searches. In this domain a graph search only yields a total ordering of the vertices which can be used by the subsequent graph searches. This technique can be used on huge graphs and do not need extra memory. We already have obtained preliminary results in this direction and many well-known graph algorithms can be put in this framework. The idea behind this approach is that each sweep discovers some structure of the graph. At the end of the process either we have found the underlying structure (for example an interval representation for an interval graph) or an approximation of it (for example in hard discrete optimization problems). We envision applications to exact computations of centers in huge graphs, to underlying combinatorial optimization problems, but also to networks arising in biology.

3.1.3. Graph Exploration

In the course of graph exploration, a mobile agent is expected to regularly visit all the nodes of an unknown network, trying to discover all its nodes as quickly as possible. Our research focuses on the design and analysis of agent-based algorithms for exploration-type problems, which operate efficiently in a dynamic network environment, and satisfy imposed constraints on local computational resources, performance, and resilience. Our recent contributions in this area concern the design of fast deterministic algorithms for teams of agents operating in parallel in a graph, with limited or no persistent state information available at nodes. We plan further studies to better understand the impact of memory constraints and of the availability of true randomness on efficiency of the graph exploration process.

3.2. Distributed Computing

The distributed computing community can be viewed as a union of two sub-communities. This is also true in our team. Although they have interactions, they are disjoint enough not to leverage each others' results. At a high level, one is mostly interested in timing issues (clock drifts, link delays, crashes, etc.) while the other one is mostly interested in spatial issues (network structure, memory requirements, etc.). Indeed, one sub-community is mostly focusing on the combined impact of asynchronism and faults on distributed computation, while the other addresses the impact of network structural properties on distributed computation. Both communities address various forms of computational complexity, through the analysis of different concepts. This includes, e.g., failure detectors and wait-free hierarchy for the former community and compact labeling schemes, and computing with advice for the latter community. We have an ambitious project to achieve the reconciliation between the two communities by focusing on the same class of problems, the yes/no-problems, and establishing the scientific foundations for building up a consistent theory of computability and complexity for distributed computing. The main question addressed is therefore: is the absence of globally coherent computational complexity theories covering more than fragments of distributed computing, inherent to the field? One issue is obviously the types of problems located at the core of distributed computing. Tasks like consensus, leader election, and broadcasting are of very different nature. They are not *yes-no* problems, neither are they minimization problems. Coloring and Minimal Spanning Tree are optimization problems but we are often more interested in constructing an optimal solution than in verifying the correctness of a given solution. Still, it makes full sense to analyze the *yes-no* problems corresponding to checking the validity of the output of tasks. Another issue is the power of individual computation. The FLP impossibility result as well as Linial's lower bound hold independently from the individual computational power of the involved computing entities. For instance, the individual power of solving NP-hard problems in constant time would not help overcoming these limits, which are inherent to the fact that computation is distributed. A third issue is the abundance of models for distributed computing frameworks, from shared memory to message passing, spanning all kinds of specific network structures (complete graphs, unit-disk graphs, etc.) and/or timing constraints (from complete synchronism to full asynchronism). There are however models, typically the wait-free model and the LOCAL model, which, though they do not claim to reflect accurately real distributed computing systems, enable focusing on some core issues. Our research program is ongoing to carry many important notions of Distributed Computing into a *standard* computational complexity.

3.3. Network Algorithms and Analysis

Based on our scientific foundation on both graph algorithms and distributed algorithms, we plan to analyze the behavior of various networks such as future Internet, social networks, overlay networks resulting from distributed applications or online social networks.

3.3.1. Information Dissemination

One of the key aspects of networks resides in the dissemination of information among the nodes. We aim at analyzing various procedures of information propagation from dedicated algorithms to simple distributed schemes such as flooding. We also consider various models, e.g. where noise can alter information as it propagates or where memory of nodes is limited.

3.3.2. Routing Paradigms

We try to explore new routing paradigms such as greedy routing in social networks for example. We are also interested in content centric networking where routing is based on content name rather than content address. One of our target is multiple path routing: how to design forwarding tables providing multiple disjoint paths to the destination?

3.3.3. Beyond Peer-to-Peer

Based on our past experience of peer-to-peer application design, we would like to broaden the spectrum of distributed applications where new efficient algorithms can be designed and their analysis can be performed. We especially target online social networks as we see them as collaborative tools for exchanging information. A basic question resides in making the right connections for gathering filtered and accurate information with sufficient coverage.

3.3.4. SAT and Forwarding Information Verification

As forwarding tables of networks grow and are sometimes manually modified, the problem of verifying them becomes critical and has recently gained in interest. Some problems that arise in network verification such as loop detection for example, may be naturally encoded as Boolean Satisfiability problems. Beside theoretical interest in complexity proofs, this encoding allows one to solve these problems by taking advantage of the many efficient Satisfiability testing solvers. Indeed, SAT solvers have proved to be very efficient in solving problems coming from various areas (Circuit Verification, Dependency and Conflicts in Software distributions...) and encoded in Conjunctive Normal Form. To test an approach using SAT solvers in network verification, one needs to collect data sets from a real network and to develop good models for generating realistic networks. The technique of encoding and the solvers themselves need to be adapted to this kind of problems. All this represents a rich experimental field of future research.

3.3.5. Network Analysis

Finally, we are interested in analyzing the structural properties of practical networks. This can include diameter computation or ranking of nodes. As we mostly consider large networks, we are often interested in efficient heuristics. Ideally, we target heuristics that give exact answers and are reasonably fast in practice although fast computation time is not guaranteed for all networks. We have already designed such heuristics for diameter computation; understanding the structural properties that enable fast computation time in practice is still an open question.

4. Application Domains

4.1. Large scale networks

Application domains include evaluating Internet performances, the design of new peer-to-peer applications, enabling large scale networks, and developping tools for transportation networks.

5. New Software and Platforms

5.1. big-graph-tools

FUNCTIONAL DESCRIPTION: Gang is developping a software for big graph manipulation. A preliminary library offering diameter and skeleton computation is available at https://who.rocq.inria.fr/Laurent.Viennot/dev/big-graph-tools/. This library was used to compute the diameters of the worldwide road network (200M edges) and the largest strongly connected component of the Twitter follower-followee graph (23G edges).

- Contact: Laurent Viennot
- URL: https://who.rocq.inria.fr/Laurent.Viennot/dev/big-graph-tools/

5.2. 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.

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6. New Results

6.1. Graph and Combinatorial Algorithms

6.1.1. Induced Matching algorithms

In [21] we study the maximum induced matching problem on a graph G. Induced matchings correspond to independent sets in $L^2(G)$, the square of the line graph of G. The problem is NP-complete on bipartite graphs. In this work, we show that for a number of graph families with forbidden vertex orderings, almost all forbidden patterns on three vertices are preserved when taking the square of the line graph. That is, given a graph class $\mathcal{G}$ characterized by a vertex ordering, and a graph $G = (V, E) \in \mathcal{G}$ with a corresponding vertex ordering σ of V, one can produce (in linear time in the size of G) an ordering on the vertices of $L^2(G)$, that shows that $L^2(G) \in \mathcal{G}$. This result gives alternate closure proofs for the $L^2(\bullet)$ closure operation. Furthermore, these orderings on $L^2(G)$ can be exploited algorithmically to compute a maximum induced matching for graphs belonging to $\mathcal{G}$ faster. We illustrate this latter fact in the second half of the paper where we focus on cocomparability graphs, a large graph class that includes interval, permutation, and trapezoid graphs, and we present the first $O(mn)$ time algorithm to compute a maximum weighted induced matching on G; an improvement from the best known $O(n^4)$ time algorithm for the unweighted case.

6.1.2. The LexBFS cycle on cocomparability graphs

Since its introduction to recognize chordal graphs by Rose, Tarjan, and Lueker, Lexicographic Breadth First Search (LexBFS) has been used to come up with simple, often linear time, algorithms on various classes of graphs. These algorithms, called multi-sweep algorithms, compute a number of LexBFS orderings $\sigma_1, ..., \sigma_k$, where σ_i is used to break ties for σ_{i+1}, we write $LexBFS^+(\sigma_i) = \sigma_{i+1}$. For instance, Corneil et al. gave a linear time multi-sweep algorithm to recognize interval graphs [SODA 1998], Kratsch et al. gave a certifying recognition algorithm for interval and permutation graphs [SODA 2003]. Since the number of LexBFS orderings for a graph is finite, after some fixed number of $^+$ sweeps, we will eventually loop in a sequence of $\sigma_1, ..., \sigma_k$ vertex orderings such that $\sigma_{i+1} = LexBFS^+(\sigma_i)$ modulo k.

In [13] we introduce and study this new graph invariant, *LexCycle*(G), defined as the maximum length of a cycle of vertex orderings obtained via a sequence of LexBFS$^+$. In this work, we focus on graph classes with small LexCycle. We give evidence that a small LexCycle often leads to linear structure that has been exploited algorithmically on a number of graph classes. In particular, we show that for proper interval, interval, co-bipartite, domino-free cocomparability graphs, as well as trees, there exists two orderings σ and τ such that $\sigma = LexBFS^+(\tau)$ and $\tau = LexBFS^+(\sigma)$. One of the consequences of these results is the simplest algorithm to compute a transitive orientation for these graph classes.

It was conjectured by Stacho [2015] that LexCycle is at most the asteroidal number of the graph class, we disprove this conjecture by giving a construction for which the LexCycle(G) grows polynomially in the asteroidal number of G.

6.1.3. Approximation Strategies for Generalized Binary Search in Weighted Trees

In [15], we have considered the following generalization of the binary search problem. A search strategy is required to locate an unknown target node t in a given tree T. Upon querying a node v of the tree, the strategy receives as a reply an indication of the connected component of $T \setminus \{v\}$ containing the target t. The cost of querying each node is given by a known non-negative weight function, and the considered objective is to minimize the total query cost for a worst-case choice of the target.

Designing an optimal strategy for a weighted tree search instance is known to be strongly NP-hard, in contrast to the unweighted variant of the problem which can be solved optimally in linear time. Here, we show that weighted tree search admits a quasi-polynomial time approximation scheme: for any $0 < \varepsilon < 1$, there exists a $(1+\varepsilon)$-approximation strategy with a computation time of $n^{O(\log n/\varepsilon^2)}$. Thus, the problem is not APX-hard, unless $NP \subseteq DTIME(n^{O(\log n)})$. By applying a generic reduction, we obtain as a corollary that the studied problem admits a polynomial-time $O(\sqrt{\log n})$-approximation. This improves previous $\widehat{O}(\log n)$-approximation approaches, where the $\widehat{O}$-notation disregards $O(\text{poly} \log \log n)$-factors.

6.1.4. The Dependent Doors Problem: An Investigation into Sequential Decisions without Feedback

In [24] we introduce the *dependent doors problem* as an abstraction for situations in which one must perform a sequence of possibly dependent decisions, without receiving feedback information on the effectiveness of previously made actions. Informally, the problem considers a set of d doors that are initially closed, and the aim is to open all of them as fast as possible. To open a door, the algorithm knocks on it and it might open or not according to some probability distribution. This distribution may depend on which other doors are currently open, as well as on which other doors were open during each of the previous knocks on that door. The algorithm aims to minimize the expected time until all doors open. Crucially, it must act at any time without knowing whether or which other doors have already opened. In this work, we focus on scenarios where dependencies between doors are both positively correlated and acyclic.

The fundamental distribution of a door describes the probability it opens in the best of conditions (with respect to other doors being open or closed). We show that if in two configurations of d doors corresponding doors share the same fundamental distribution, then these configurations have the same optimal running time up to a universal constant, no matter what are the dependencies between doors and what are the distributions. We also identify algorithms that are optimal up to a universal constant factor. For the case in which all doors share the same fundamental distribution we additionally provide a simpler algorithm, and a formula to calculate its running time. We furthermore analyse the price of lacking feedback for several configurations governed by standard fundamental distributions. In particular, we show that the price is logarithmic in d for memoryless doors, but can potentially grow to be linear in d for other distributions.

We then turn our attention to investigate precise bounds. Even for the case of two doors, identifying the optimal sequence is an intriguing combinatorial question. Here, we study the case of two cascading memoryless doors. That is, the first door opens on each knock independently with probability p_1. The second door can only open if the first door is open, in which case it will open on each knock independently with probability p_2. We solve this problem almost completely by identifying algorithms that are optimal up to an additive term of 1.

6.2. Distributed Computing

6.2.1. Robust Detection in Leak-Prone Population Protocols

In [10], we aim to design population protocols for the problem of detecting a signal in the presence of faults, motivated by scenarios of chemical computation. In contrast to electronic computation, chemical computation is noisy and susceptible to a variety of sources of error, which has prevented the construction of robust complex systems. To be effective, chemical algorithms must be designed with an appropriate error model in mind. Here we consider the model of chemical reaction networks that preserve molecular count (population protocols), and ask whether computation can be made robust to a natural model of unintended "leak" reactions. Our definition of leak is motivated by both the particular spurious behavior seen when implementing chemical reaction networks with DNA strand displacement cascades, as well as the unavoidable side reactions in any implementation due to the basic laws of chemistry. We develop a new "Robust Detection" algorithm for the problem of fast (logarithmic time) single molecule detection, and prove that it is robust to this general model of leaks. Besides potential applications in single molecule detection, the error-correction ideas developed here might enable a new class of robust-by-design chemical algorithms. Our analysis is based on a non-standard hybrid argument, combining ideas from discrete analysis of population protocols with classic Markov chain techniques.

6.2.2. Minimizing Message Size in Stochastic Communication Patterns: Fast Self-Stabilizing Protocols with 3 bits

In [12] we consider the basic PULL model of communication, in which in each round, each agent extracts information from few randomly chosen agents. We seek to identify the smallest amount of information revealed in each interaction (message size) that nevertheless allows for efficient and robust computations of fundamental information dissemination tasks. We focus on the *Majority Bit Dissemination* problem that considers a population of n agents, with a designated subset of *source agents*. Each source agent holds an *input bit* and each agent holds an *output bit*. The goal is to let all agents converge their output bits on the most frequent input bit of the sources (the *majority bit*). Note that the particular case of a single source agent corresponds to the classical problem of *Broadcast* (also termed *Rumor Spreading*). We concentrate on the severe fault-tolerant context of *self-stabilization*, in which a correct configuration must be reached eventually, despite all agents starting the execution with arbitrary initial states. In particular, the specification of who is a source and what is its initial input bit may be set by an adversary.

We first design a general compiler which can essentially transform any self-stabilizing algorithm with a certain property that uses ℓ-bits messages to one that uses only $\log \ell$-bits messages, while paying only a small penalty in the running time. By applying this compiler recursively we then obtain a self-stabilizing *Clock Synchronization* protocol, in which agents synchronize their clocks modulo some given integer T, within $\widetilde{O}(\log n \log T)$ rounds w.h.p., and using messages that contain 3 bits only.

We then employ the new Clock Synchronization tool to obtain a self-stabilizing Majority Bit Dissemination protocol which converges in $\widetilde{O}(\log n)$ time, w.h.p., on every initial configuration, provided that the ratio of sources supporting the minority opinion is bounded away from half. Moreover, this protocol also uses only 3 bits per interaction.

6.2.3. The ANTS Problem

In [6] we introduce the *Ants Nearby Treasure Search (ANTS)* problem, which models natural cooperative foraging behavior such as that performed by ants around their nest. In this problem, k probabilistic agents, initially placed at a central location, collectively search for a treasure on the two-dimensional grid. The treasure is placed at a target location by an adversary and the agents' goal is to find it as fast as possible as a function of both k and D, where D is the (unknown) distance between the central location and the target. We concentrate on the case in which agents cannot communicate while searching. It is straightforward to see that the time until at least one agent finds the target is at least $\Omega(D + D^2/k)$, even for very sophisticated agents, with unrestricted memory. Our algorithmic analysis aims at establishing connections between the time complexity and the initial knowledge held by agents (*e.g.*, regarding their total number k), as they commence the search. We provide a range of both upper and lower bounds for the initial knowledge required for obtaining fast running time. For example, we prove that $\log\log k + \Theta(1)$ bits of initial information are both necessary and sufficient to obtain asymptotically optimal running time, *i.e.,* $O(D + D^2/k)$. We also we prove that for every $0 < \epsilon < 1$, running in time $O(\log^{1-\epsilon} k \cdot (D + D^2/k))$ requires that agents have the capacity for storing $\Omega(\log^{\epsilon} k)$ different states as they leave the nest to start the search. To the best of our knowledge, the lower bounds presented in this paper provide the first non-trivial lower bounds on the memory complexity of probabilistic agents in the context of search problems.

We view this paper as a "proof of concept" for a new type of interdisciplinary methodology. To fully demonstrate this methodology, the theoretical tradeoff presented here (or a similar one) should be combined with measurements of the time performance of searching ants.

6.2.4. Breathe before Speaking: Efficient Information Dissemination despite Noisy, Limited and Anonymous Communication

Distributed computing models typically assume reliable communication between processors. While such assumptions often hold for engineered networks, e.g., due to underlying error correction protocols, their relevance to biological systems, wherein messages are often distorted before reaching their destination, is quite limited. In this study we take a first step towards reducing this gap by rigorously analyzing a model of communication in large anonymous populations composed of simple agents which interact through short and highly unreliable messages.

In [9] we focus on the broadcast problem and the majority-consensus problem. Both are fundamental information dissemination problems in distributed computing, in which the goal of agents is to converge to some prescribed desired opinion. We initiate the study of these problems in the presence of communication noise. Our model for communication is extremely weak and follows the push gossip communication paradigm: In each round each agent that wishes to send information delivers a message to a random anonymous agent. This communication is further restricted to contain only one bit (essentially representing an opinion). Lastly, the system is assumed to be so noisy that the bit in each message sent is flipped independently with probability $1/2 - \epsilon$, for some small $\epsilon > 0$.

Even in this severely restricted, stochastic and noisy setting we give natural protocols that solve the noisy broadcast and the noisy majority-consensus problems efficiently. Our protocols run in $O(\log n/\epsilon^2)$ rounds and use $O(n \log n/\epsilon^2)$ messages/bits in total, where n is the number of agents. These bounds are asymptotically optimal and, in fact, are as fast and message efficient as if each agent would have been simultaneously informed directly by an agent that knows the prescribed desired opinion. Our efficient, robust, and simple algorithms suggest balancing between silence and transmission, synchronization, and majority-based decisions as important ingredients towards understanding collective communication schemes in anonymous and noisy populations.

6.2.5. Parallel Search with no Coordination

In [23] we consider a parallel version of a classical Bayesian search problem. k agents are looking for a treasure that is placed in one of finately many boxes according to a known distribution p. The aim is to minimize the expected time until the first agent finds it. Searchers run in parallel where at each time step each searcher can "peek" into a box. A basic family of algorithms which are inherently robust is *non-coordinating* algorithms. Such algorithms act independently at each searcher, differing only by their probabilistic choices. We are interested in the price incurred by employing such algorithms when compared with the case of full coordination.

We first show that there exists a non-coordination algorithm, that knowing only the relative likelihood of boxes according to p, has expected running time of at most $10 + 4(1 + \frac{1}{k})^2 T$, where T is the expected running time of the best fully coordinated algorithm. This result is obtained by applying a refined version of the main algorithm suggested by Fraigniaud, Korman and Rodeh in STOC'16, which was designed for the context of linear parallel search.

We then describe an optimal non-coordinating algorithm for the case where the distribution p is known. The running time of this algorithm is difficult to analyse in general, but we calculate it for several examples. In the case where p is uniform over a finite set of boxes, then the algorithm just checks boxes uniformly at random among all non-checked boxes and is essentially 2 times worse than the coordinating algorithm. We also show simple algorithms for Pareto distributions over M boxes. That is, in the case where $p(x) \sim 1/x^b$ for $0 < b < 1$, we suggest the following algorithm: at step t choose uniformly from the boxes unchecked in $\{1, ..., \min(M, \lfloor t/\sigma \rfloor)\}$, where $\sigma = b/(b + k - 1)$. It turns out this algorithm is asymptotically optimal, and runs about $2 + b$ times worse than the case of full coordination.

6.2.6. Wait-free local algorithms

When considering distributed computing, reliable message-passing synchronous systems on the one side, and asynchronous failure-prone shared-memory systems on the other side, remain two quite independently studied ends of the reliability/asynchrony spectrum. The concept of locality of a computation is central to the first one, while the concept of wait-freedom is central to the second one. In [2] we propose a new DECOUPLED model in an attempt to reconcile these two worlds. It consists of a synchronous and reliable communication graph of n nodes, and on top a set of asynchronous crash-prone processes, each attached to a communication node. To illustrate the DECOUPLED model, the paper presents an asynchronous 3-coloring algorithm for the processes of a ring. From the processes point of view, the algorithm is wait-free. From a locality point of view, each process uses information only from processes at distance $O(\log *n)$ from it. This local wait-free algorithm is based on an extension of the classical Cole and Vishkin's vertex coloring algorithm in which the processes are not required to start simultaneously.

6.2.7. Immediate t-resilient Snapshot

An immediate snapshot object is a high level communication object, built on top of a read/write distributed system in which all except one processes may crash. It allows each process to write a value and obtains a set of pairs (process id, value) such that, despite process crashes and asynchrony, the sets obtained by the processes satisfy noteworthy inclusion properties. Considering an n-process model in which up to t processes are allowed to crash, [14] is on the construction of t-resilient immediate snapshot objects.

6.2.8. Decidability classes for mobile agents computing

In [7], we establish a classification of decision problems that are to be solved by mobile agents operating in unlabeled graphs, using a deterministic protocol. The classification is with respect to the ability of a team of agents to solve decision problems, possibly with the aid of additional information. In particular, our focus is on studying differences between the decidability of a decision problem by agents and its verifiability when a certificate for a positive answer is provided to the agents (the latter is to the former what NP is to P in the framework of sequential computing). We show that the class MAV of mobile agents verifiable problems is much wider than the class MAD of mobile agents decidable problems. Our main result shows that there exist natural MAV-complete problems: the most difficult problems in this class, to which all problems in MAV are reducible via a natural mobile computing reduction. Beyond the class MAV we show that, for a single agent, three natural oracles yield a strictly increasing chain of relative decidability classes.

6.2.9. Distributed Detection of Cycles

Distributed property testing in networks has been introduced by Brakerski and Patt-Shamir (2011), with the objective of detecting the presence of large dense sub-networks in a distributed manner. Recently, Censor-Hillel et al. (2016) have shown how to detect 3-cycles in a constant number of rounds by a distributed algorithm. In a follow up work, Fraigniaud et al. (2016) have shown how to detect 4-cycles in a constant number of rounds as well. However, the techniques in these latter works were shown not to generalize to larger cycles C_k with $k \geq 5$. In [19], we completely settle the problem of cycle detection, by establishing the following result. For every $k \geq 3$, there exists a distributed property testing algorithm for C_k-freeness, performing in a constant number of rounds. All these results hold in the classical CONGEST model for distributed network computing. Our algorithm is 1-sided error. Its round-complexity is $O(1/\epsilon)$ where $\epsilon \in (0, 1)$ is the property testing parameter measuring the gap between legal and illegal instances.

6.2.10. What Can Be Verified Locally?

In [18], we are considering *distributed network computing*, in which computing entities are connected by a network modeled as a connected graph. These entities are located at the nodes of the graph, and they exchange information by message-passing along its edges. In this context, we are adopting the classical framework for *local distributed decision*, in which nodes must collectively decide whether their network configuration satisfies some given boolean predicate, by having each node interacting with the nodes in its vicinity only. A network configuration is accepted if and only if every node individually accepts. It is folklore that not every Turing-decidable network property (e.g., whether the network is planar) can be decided locally whenever the computing entities are Turing machines (TM). On the other hand, it is known that every Turing-decidable network property can be decided locally if nodes are running *non-deterministic* Turing machines (NTM). However, this holds only if the nodes have the ability to guess the identities of the nodes currently in the network. That is, for different sets of identities assigned to the nodes, the correct guesses of the nodes might be different. If one asks the nodes to use the same guess in the same network configuration even with different identity assignments, i.e., to perform *identity-oblivious* guesses, then it is known that not every Turing-decidable network property can be decided locally.

We show that every Turing-decidable network property can be decided locally if nodes are running *alternating* Turing machines (ATM), and this holds even if nodes are bounded to perform identity-oblivious guesses. More specifically, we show that, for every network property, there is a local algorithm for ATMs, with at most 2 alternations, that decides that property. To this aim, we define a hierarchy of classes of decision tasks where the lowest level contains tasks solvable with TMs, the first level those solvable with NTMs, and level k contains those tasks solvable with ATMs with k alternations. We characterize the entire hierarchy, and show that it collapses in the second level. In addition, we show separation results between the classes of network properties that are locally decidable with TMs, NTMs, and ATMs, and we establish the existence of completeness results for each of these classes, using novel notions of *local reduction*.

6.2.11. Certification of Compact Low-Stretch Routing Schemes

On the one hand, the correctness of routing protocols in networks is an issue of utmost importance for guaranteeing the delivery of messages from any source to any target. On the other hand, a large collection of *routing schemes* have been proposed during the last two decades, with the objective of transmitting messages along short routes, while keeping the routing tables small. Regrettably, all these schemes share the property that an adversary may modify the content of the routing tables with the objective of, e.g., blocking the delivery of messages between some pairs of nodes, without being detected by any node.

In [17], we present a simple *certification* mechanism which enables the nodes to locally detect any alteration of their routing tables. In particular, we show how to locally verify the stretch-3 routing scheme by Thorup and Zwick [SPAA 2001] by adding certificates of $\widetilde{O}(\sqrt{n})$ bits at each node in n-node networks, that is, by keeping the memory size of the same order of magnitude as the original routing tables. We also propose a new *name-independent* routing scheme using routing tables of size $\widetilde{O}(\sqrt{n})$ bits. This new routing scheme can be locally verified using certificates on $\widetilde{O}(\sqrt{n})$ bits. Its stretch is 3 if using handshaking, and 5 otherwise.

6.2.12. Error-Sensitive Proof-Labeling Schemes

Proof-labeling schemes are known mechanisms providing nodes of networks with *certificates* that can be *verified* locally by distributed algorithms. Given a boolean predicate on network states, such schemes enable to check whether the predicate is satisfied by the actual state of the network, by having nodes interacting with their neighbors only. Proof-labeling schemes are typically designed for enforcing fault-tolerance, by making sure that if the current state of the network is illegal with respect to some given predicate, then at least one node will detect it. Such a node can raise an alarm, or launch a recovery procedure enabling the system to return to a legal state. We introduce *error-sensitive* proof-labeling schemes. These are proof-labeling schemes which guarantee that the number of nodes detecting illegal states is linearly proportional to the edit-distance between the current state and the set of legal states. By using error-sensitive proof-labeling schemes, states which are far from satisfying the predicate will be detected by many nodes, enabling fast return to legality. In [20], we provide a structural characterization of the set of boolean predicates on network states for which there exist error-sensitive proof-labeling schemes. This characterization allows us to show that classical predicates such as, e.g., acyclicity, and leader admit error-sensitive proof-labeling schemes, while others like regular subgraphs don't. We also focus on *compact* error-sensitive proof-labeling schemes. In particular, we show that the known proof-labeling schemes for spanning tree and MST, using certificates on $O(\log n)$ bits, and on $O(\log^2 n)$ bits, respectively, are error-sensitive, as long as the trees are locally represented by adjacency lists, and not by a pointer to the parent.

6.2.13. Distributed Property Testing

In [16], we designed distributed testing algorithms of graph properties in the CONGEST model [Censor-Hillel et al. 2016], especially for testing subgraph-freeness. Testing a given property means that we have to distinguish between graphs having the property, and graphs that are ϵ-far from having it, meaning that one must remove an ϵ-fraction of the edges to obtain it. We established a series of results, among which:

- Testing H-freeness in a constant number of rounds, for any graph H that can be transformed into a tree by removing a single edge. This includes, e.g., cycle-freeness for any constant cycle, and K_4-freeness. As a byproduct, we give a deterministic CONGEST protocol determining whether a graph contains a fixed tree as a subgraph.
- For cliques K_k with $k \geq 5$, we show that K_k-freeness can be tested in $O((\frac{m}{\epsilon})^{\frac{1}{2}+\frac{1}{k-2}})$ rounds, where m is the number of edges in the network graph.
- We describe a general procedure for converting ϵ-testers with $f(D)$ rounds, where D denotes the diameter of the graph, to work in $O((\log n)/\epsilon) + f((\log n)/\epsilon)$ rounds, where n is the number of processors of the network. We then apply this procedure to obtain an ϵ-tester for testing whether a graph is bipartite.

These protocols extend and improve previous results of [Censor-Hillel et al. 2016] and [Fraigniaud et al. 2016].

6.3. Models and Algorithms for Networks

6.3.1. Analysis of Multiple Random Walks on Paths and Grids

In [22], we derive several new results on multiple random walks on "low-dimensional" graphs. First, inspired by an example of a weighted random walk on a path of three vertices given by Efremenko and Reingold, we prove the following dichotomy: as the path length n tends to infinity, we have a super-linear speed-up w.r.t. the cover time if and only if the number of walks k is equal to 2. An important ingredient of our proofs is the use of a continuous-time analogue of multiple random walks, which might be of independent interest. Finally, we also present the first tight bounds on the speed-up of the cover time for any d-dimensional grid with $d \geq 2$ being an arbitrary constant, and reveal a sharp transition between linear and logarithmic speed-up.

6.3.2. Decomposing a Graph into Shortest Paths with Bounded Eccentricity

In [11], we introduce the problem of hub-laminar decomposition which generalizes that of computing a shortest path with minimum eccentricity (MESP). Intuitively, it consists in decomposing a graph into several paths that collectively have small eccentricity and meet only near their extremities. The problem is related to computing an isometric cycle with minimum eccentricity (MEIC). It is also linked to DNA reconstitution in the context of metagenomics in biology. We show that a graph having such a decomposition with long enough paths can be decomposed in polynomial time with approximated guaranties on the parameters of the decomposition. Moreover, such a decomposition with few paths allows to compute a compact representation of distances with additive distortion. We also show that having an isometric cycle with small eccentricity is related to the possibility of embedding the graph in a cycle with low distortion.

6.3.3. Individual versus collective cognition in social insects

The concerted responses of eusocial insects to environmental stimuli are often referred to as collective cognition at the level of the colony. To achieve collective cognition, a group can draw on two different sources: individual cognition and the connectivity between individuals. Computation in neural networks, for example, is attributed more to sophisticated communication schemes than to the complexity of individual neurons. The case of social insects, however, can be expected to differ. This is because individual insects are cognitively capable units that are often able to process information that is directly relevant at the level of the colony. Furthermore, involved communication patterns seem difficult to implement in a group of insects as they lack a clear network structure. In [5] we discusses links between the cognition of an individual insect and that of the colony. We provide examples for collective cognition whose sources span the full spectrum between amplification of individual insect cognition and emergent group-level processes.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

7.1.1. Collaboration with Nokia Bell Labs

Gang has a strong collaboration with Bell Labs (Nokia). We notably collaborate with Fabien Mathieu who is a former member of GANG and Nidhi Hegde. An ADR (joint research action) is dedicated to content centric networks and forwarding information verification. The PhD thesis of Leonardo Linguaglossa was funded by this contract.

This collaboration is developed inside the Alcatel-Lucent and Inria joint research lab.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. Laboratory of Information, Networking and Communication Sciences (LINCS)

Gang is participating to the LINCS, a research centre co-founded by Inria, Institut Mines-Télécom, UPMC and Alcatel-Lucent Bell Labs, dedicated to research and innovation in the domains of future information and communication networks, systems and services. Gang contributes to work on online social networks, content centric networking and forwarding information verification.

8.2. National Initiatives

8.2.1. ANR DESCARTES

Participants: Carole Delporte-Gallet, Hugues Fauconnier, Pierre Fraigniaud, Adrian Kosowski, Laurent Viennot.

Cyril Gavoille (U. Bordeaux) leads this project that grants 1 Post-Doc. H. Fauconnier is the local coordinator (This project began in October 2016).

Despite the practical interests of reusable frameworks for implementing specific distributed services, many of these frameworks still lack solid theoretical bases, and only provide partial solutions for a narrow range of services. We argue that this is mainly due to the lack of a generic framework that is able to unify the large body of fundamental knowledge on distributed computation that has been acquired over the last 40 years. The DESCARTES project aims at bridging this gap, by developing a systematic model of distributed computation that organizes the functionalities of a distributed computing system into reusable modular constructs assembled via well-defined mechanisms that maintain sound theoretical guarantees on the resulting system. DESCARTES arises from the strong belief that distributed computing is now mature enough to resolve the tension between the social needs for distributed computing systems, and the lack of a fundamentally sound and systematic way to realize these systems.

8.2.2. ANR MultiMod

Participants: Adrian Kosowski, Laurent Viennot.

David Coudert (Sophia Antipolis) leads this project. L. Viennot coordinates locally. The project begins in 2018.

The MultiMod project aims at enhancing the mobility of citizens in urban areas by providing them, through a unique interface enabling to express their preferences, the most convenient transportation means to reach their destinations. Indeed, the increasing involvement of actors and authorities in the deployment of more responsible and cost-effective logistics and the progress made in the field of digital technology have made possible to create synergies in the creation of innovative services for improving the mobility in cities. However, users are faced with a number of solutions that coexist at different scales, providing complementary information for the mobility of users, but that make very complex to find the most convenient itinerary at a given time for a specific user. In this context, MultiMod aims at improving the mobility of citizens in urban areas by proposing contextualized services, linking users, to facilitate multimodal transport by combining, with flexibility, all available modes (planned/dynamic carpooling, public transport (PT), car-sharing, bicycle, etc.).

We consider the use of carpooling in metropolitan areas, and so for short journeys. Such usage enables itineraries that are not possible with PT, allows for opening up areas with low PT coverage by bringing users near PT (last miles), and for faster travel-time when existing PT itineraries are too complex or with too low frequency (e.g., one bus per hour). In this context, the application must help the driver and the passenger as much as possible. In particular, the application must propose the meeting-point, indicate the driver the detour duration, and indicate the passenger how to reach this meeting-point using PT. Here, the time taken by drivers and passengers to agree becomes a critical issue and so the application must provide all needed information to quickly take a decision (i.e., in one click).

In addition, the era of Smart City gathers many emerging concepts, driven by innovative technological players, which enables the exploitation of real-time data (e.g., delay of a bus, traffic jam) made available by the various actors (e.g., communities in the framework of Open Data projects, users via their mobile terminals, traffic supervision authorities). In the MultiMod project, we will use these rich sources of data to propose itineraries that are feasible at query-time. Our findings will enable the design of a mobility companion able not only to guide the user along her journey, including when and how to change of transportation mean, but also to propose itinerary changes when the current one exceeds a threshold delay. The main originality of this project is thus to address the problem of computing itineraries in large-scale networks combining PT, carpooling and real-time data, and to satisfy the preferences of users. We envision that the outcome of this project will significantly improve the daily life of citizens.

The targeted metropolitan area for validating our solutions is Ile-de-France. Indeed, Instant-System is currently developing the new application “Vianavigo lab” which will replace the current “Vianavigo” application for the PT network of Ile-de-France. Our findings will therefore be tested at scale and eventually be integrated and deployed in production servers and mobile applications. The smaller networks of Bordeaux and Nice will be used to perform preliminary evaluations since Instant System already operates applications in these cities (Boogi Nice, Boogi Bordeaux). An important remark is that new features and algorithms can contractually be deployed in production every 4 months, thus enabling Instant System to measure and challenge the results of the MultiMod project in continue. This is a chance for the project to maximize its impact.

8.2.3. ANR FREDDA

Participants: Carole Delporte-Gallet, Hugues Fauconnier, Pierre Fraigniaud.

Arnaud Sangnier (IRIF, Univ Paris Diderot) leads this project that grants 1 PhD. (This project began in October 2017).

Distributed algorithms are nowadays omnipresent in most systems and applications. It is of utmost importance to develop algorithmic solutions that are both robust and flexible, to be used in large scale applications. Currently, distributed algorithms are developed under precise assumptions on their execution context: synchronicity, bounds on the number of failures, etc. The robustness of distributed algorithms is a challenging problem that has not been much considered until now, and there is no systematic way to guarantee or verify the behavior of an algorithm beyond the context for which it has been designed. We propose to develop automated formal method techniques to verify the robustness of distributed algorithms and to support the development of robust applications. Our methods are of two kinds: statically through classical verification, and dynamically, by synthesizing distributed monitors, that check either correctness or the validity of the context hypotheses at runtime.

8.2.4. ANR Distancia

Participants: Pierre Charbit, Michel Habib, Laurent Viennot.

Victor Chepoi (Univ. Marseille) leads this project. P. Charbit coordinates locally. The project begins in early-2018.

The theme of the project is Metric Graph Theory, and we are concerned both on theoretical foundations and applications. Such applications can be found in real world networks. For example, the hub labelling problem in road networks can be directly applied to car navigation applications. Understanding key structural properties of large-scale data networks is crucial for analyzing and optimizing their performance, as well as improving their reliability and security. In prior empirical and theoretical studies researchers have mainly focused on features such as small world phenomenon, power law degree distribution, navigability, and high clustering coefficients. Although those features are interesting and important, the impact of intrinsic geometric and topological features of large-scale data networks on performance, reliability and security is of much greater importance. Recently, there has been a surge of empirical works measuring and analyzing geometric characteristics of real-world networks, namely the Gromov hyperbolicity (called also the negative curvature) of the network. It has been shown that a number of data networks, including Internet application networks, web networks, collaboration networks, social networks, and others, have small hyperbolicity.

Metric graph theory was also indispensable in solving some open questions in concurrency and learning theory in computer science and geometric group theory in mathematics. Median graphs are exactly the 1–skeletons of CAT(0) cube complexes (which have been characterized by Gromov in a local-to-global combinatorial way). They play a vital role in geometric group theory (for example, in the recent solution of the famous Virtual Haken Conjecture). Median graphs are also the domains of event structures of Winskel, one of the basic abstract models of concurrency. This correspondence is very useful in dealing with questions on event structures.

Many classical algorithmic problems concern distances: shortest path, center and diameter, Voronoi diagrams, TSP, clustering, etc. Algorithmic and combinatorial problems related to distances also occur in data analysis. Low-distortion embeddings into l1-spaces (theorem of Bourgain and its algorithmical use by Linial et al.) were the founding tools in metric methods. Recently, several approximation algorithms for NP-hard problems were designed using metric methods. Other important algorithmic graph problems related to distances concern the construction of sparse subgraphs approximating inter-node distances and the converse, augmentation problems with distance constraints. Finally, in the distributed setting, an important problem is that of designing compact data structures allowing very fast computation of inter- node distances or routing along shortest or almost shortest paths. Besides computer science and mathematics, applications of structures involving distances can be found in archeology, computational biology, statistics, data analysis, etc. The problem of characterizing isometric subgraphs of hypercubes has its origin in communication theory and linguistics. . To take into account the recombination effect in genetic data, the mathematicians Bandelt and Dress developed in 1991 the theory of canonical decompositions of finite metric spaces. Together with geneticists, Bandelt successfully used it over the years to reconstruct phylogenies, in the evolutional analysis of mtDNA data in human genetics. One important step in their method is to build a reduced median network that spans the data but still contains all most parsimonious trees. As mentioned above, the median graphs occurring there constitute a central notion in metric graph theory.

With this project, we aim to participate at the elaboration of this new domain of Metric Graph Theory, which requires experts and knowledge in combinatorics (graphs, matroids), geometry, and algorithms. This expertise is distributed over the members of the consortium and a part of the success of our project it will be to share these knowledges among all the members of the consortium. This way we will create a strong group in France on graphs and metrics.

8.2.5. ANR HOSIGRA

Participants: Pierre Charbit, Michel Habib.

This project starting in early-2018, led by Reza Naserasr, explores the connection between minors and colorings, exploiting the notion of signed graphs. With the four colour theorem playing a central role in development of Graph Theory, the notions of minor and coloring have been branded as two of the most distinguished concepts in this field. The geometric notion of planarity has given birth to the theory of minors among others, and coloring have proven to have an algebraic nature through its extension to the theory of graph homomorphisms. Great many projects have been completed on both subjects, but what remains mostly a mystery is the correlation of the two subjects. The four color theorem itself, in slightly stronger form, claims that if a complete graph on five vertices cannot be formed by minor operation from a given graph, then the graph can be homomorphically mapped into the complete graph on four vertices (thus a 4-coloring). Commonly regarded as the most challenging conjecture on graph theory, the Hadwiger conjecture claims that five and four in this theorem can be replaced with n and $n-1$ respectively for any value of n. The correlation of these two concepts has been difficult to study, mainly for the following reason: While the coloring or homomorphism problems roots back into intersections of odd-cycles, the minor operation is irrelevant of the parity of cycles. To overcome this barrier, the notion of signed graphs has been used implicitly since 1970s when coloring results on graphs with no odd-K4 is proved, following which a stronger form of the Hadwiger conjecture, known as Odd Hadwiger conjecture, was proposed by P. Seymour and B. Gerards, independently. Being a natural subclass of Matroids and a superclass of graphs, the notion of minor of signed graphs is well studied and many results from graph minor are either already extended to signed graphs or it is considered by experts of the subject. Observing the importance, and guided by some earlier works, in particular that of B. Guenin, we then started the study of algebraic concepts (coloring and homomormphisms) for signed graphs. Several results have been obtained in the past decade, and this project aims at exploring more of this topic.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

Amos Korman has an ERC Consolidator Grant entitled “Distributed Biological Algorithms (DBA)”, started in May 2015. This project proposes a new application for computational reasoning. More specifically, the purpose of this interdisciplinary project is to demonstrate the usefulness of an algorithmic perspective in studies of complex biological systems. We focus on the domain of collective behavior, and demonstrate the benefits of using techniques from the field of theoretical distributed computing in order to establish algorithmic insights regarding the behavior of biological ensembles. The project includes three related tasks, for which we have already obtained promising preliminary results. Each task contains a purely theoretical algorithmic component as well as one which integrates theoretical algorithmic studies with experiments. Most experiments are strategically designed by the PI based on computational insights, and are physically conducted by experimental biologists that have been carefully chosen by the PI. In turn, experimental outcomes will be theoretically analyzed via an algorithmic perspective. By this integration, we aim at deciphering how a biological individual (such as an ant) “thinks”, without having direct access to the neurological process within its brain, and how such limited individuals assemble into ensembles that appear to be far greater than the sum of their parts. The ultimate vision behind this project is to enable the formation of a new scientific field, called algorithmic biology, that bases biological studies on theoretical algorithmic insights.

8.3.2. LIA Struco

Pierre Charbit is director of the LIA STRUCO, which is an Associated International Laboratory of CNRS between IÚUK, Prague, and IRIF, Paris. The director on the Czech side is Pr. Jaroslav Nešetřil. The primary theme of the laboratory is graph theory, more specifically: sparsity of graphs (nowhere dense classes of graphs, bounded expansion classes of graphs), extremal graph theory, graph coloring, Ramsey theory, universality and morphism duality, graph and matroid algorithms and model checking.

STRUCO focuses on high-level study of fundamental combinatorial objects, with a particular emphasis on comprehending and disseminating the state-of-the-art theories and techniques developed. The obtained insights shall be applied to obtain new results on existing problems as well as to identify directions and questions for future work.

One of the main goals of STRUCO is to provide a sustainable and reliable structure to help Czech and French researchers cooperate on long-term projects, disseminate the results to students of both countries and create links between these students more systematically. The chosen themes of the project indeed cover timely and difficult questions, for which a stable and significant cooperation structure is needed. By gathering an important number of excellent researchers and students, the LEA will create the required environment for making advances, which shall be achieved not only by short-term exchanges of researchers, but also by a strong involvement of Ph. D students in the learning of state-of-the-art techniques and in the international collaborations.

STRUCO is a natural place to federate and organize these many isolated collaborations between our two countries. Thus, the project would ensure long-term cooperations and allow young researchers (especially PhD students) to maintain the fruitful exchanges between the two countries in the future years, in a structured and federated way.

8.4. International Initiatives

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

Carole Delporte-Gallet and Hugues Fauconnier are members of the Inria-MEXICO Equipe Associée LiDiCo (At the Limits of Distributed Computability, https://sites.google.com/site/lidicoequipeassociee/).

8.4.2. Inria International Partners

8.4.2.1. Informal International Partners

Ofer Feinerman (Physics department of complex systems, Weizmann Institute of Science, Rehovot, Israel), is a team member in Amos Korman's ERC project DBA. This collaboration has been formally established by signing a contract between the CNRS and the Weizmann Institute of Science, as part of the ERC project.

Rachid Guerraoui (School of Computer and Communication Sciences, EPFL, Switzerland) maintains an active research collaboration with Gang team members (Carole Delporte, Hugues Fauconnier).

Pierluigi Crescenzi (University of Florence, Italy) is a frequent visitor to the team and maintains an active research collaboration with Gang team members (Pierre Fraigniaud).

Sergio Rajsbaum (UNAM, Mexico) is a regular collaborator of the team, also involved formally in a joint French-Mexican research project (see next subsection).

Boaz Patt-Shamir (Tel Aviv University, Israel) is a regular collaborator of the team, also involved formally in a joint French-Israeli research project (see next subsection).

8.5. International Research Visitors

8.5.1. Visits of International Scientists

[chercheurs invités, profs invités (via université), Les internships sont à mettre dans la subsection suivante.]

Sergio Rajsbaum (UNAM-Mexico) was invited for two months (May-June).

Eli Gafni visited the team for one month (mid-June to mid-July).

Lalla Mouatadid visited the group for 2 weeks in 2017. She is finishing her PhD in computer. Science at University of Toronto, under the supervision of prof. Derek Corneil and Alan Borodin.

8.5.2. Visits to International Teams

Carole Delporte-Gallet and Hugues Fauconnier have visited 2x10 days Sergio Rajsbaum at UNAM (Mexico) in September and November 2017.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Selection

9.1.1.1. Member of Conference Program Committees

- Adrian Kosowski: ICALP 2017, MFCS 2018, SIROCCO 2018.
- Carole Delporte-Gallet: ICDCN 2017, PODC 2017, IPDPS 2017, OPODIS 2017
- Pierre Fraigniaud: WWW 2017, SPAA 2017, DISC 2017.
- Hugues Fauconnier: SSS 2017, Algotel 2017
- Michel Habib: WG 2018
- Amos Korman: ICALP 2017
- Laurent Viennot: FCT 2017

9.1.2. Journal

9.1.2.1. Member of Editorial Boards

- Pierre Fraigniaud is a member of the Editorial Board of Distributed Computing (DC).
- Pierre Fraigniaud is a member of the Editorial Board of Theory of Computing Systems (TOCS).
- Pierre Fraigniaud is a member of the Editorial Board of Fundamenta Informaticae (FI).
- Adrian Kosowski is a member of the Editorial Board of Mathematical Foundations of Computing (AIMS MFOC)

9.1.3. Invited Talks

Carole Delporte, The Basics of Distributed Computing: consensus. 9th edition of the International Spring School on Distributed Systems(METIS 2017), May 2017.

Hugues Fauconnier, The Basics of Distributed Computing: Shared Memory. 9th edition of the International Spring School on Distributed Systems (METIS 2017), May 2017.

Carole Delporte: Workshop IWDCMR 2017 in honor of Michel Raynal, Détecteurs de défaillance, May 2017.

Michel Habib: IPM Combinatorics and Computing Conference 2017 (IPMCCC2017), Téhéran, May 2017

Michel Habib: Journée Charles Hermite Complexité : Théorie des graphes et théorie des nombres, Nancy, November 2017.

Adrian Kosowski: ADGA 2017 workshop (co-located with DISC 2017), Vienna, October 2017.

9.1.4. Scientific Expertise

Adrian Kosowski was an expert panel member for grant panel PE6 of the National Science Center, Poland (Spring 2017).

Carole Delporte-Gallet was in the recruting jury of "Informaticien" at Assemblee Nationale.

Michel Habib was member of the COS (Comité d'Orientation Stratégique) of the Labex Archimede Marseille. One meeting in April 2017.

9.1.5. Research Administration

Pierre Fraigniaud is director of the Institute de Recherche en Informatique Fondamentale (IRIF).

Hugues Fauconnier is director of the UFR d'informatique of Université Paris Diderot.

Carole Delporte-Gallet is deputy director of the UFR d'informatique of Université Paris Diderot.

Michel Habib is member of the Administration Council of University Paris Diderot.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Master: Carole Delporte and Hugues Fauconnier, Algorithmique distribuée avec mémoire partagée, 6h, M2, Université Paris Diderot

Master: Hugues Fauconnier, Cours programmation répartie, 33h, M2, Univ. Paris Diderot

Master: Carole Delporte, Cours et TP Protocoles des services internet, 44h, M2, Univ. Paris Diderot

Master: Carole Delporte, Cours Algorithmes répartis, 33h, M2, Univ. Paris Diderot

Master: Carole Delporte and Hugues Fauconnier, Théorie et pratique de la concurrence, 48h, M1, Université Paris Diderot

Licence: Carole Delporte and Hugues Fauconnier, Sécurité informatique, 36h, L3, Univ. Paris Diderot

Licence: Carole Delporte and Hugues Fauconnier, Culture informatique, 16h, L2, Univ. Paris Diderot

Licence: Boufkhad Yacine, Algorithmique et Informatique, 132h, L1, IUT de l'Université Paris Diderot

Licence: Boufkhad Yacine, Programmation Orientée Objet, 60h, L2, IUT de l'Université Paris Diderot

Licence: Boufkhad Yacine, Traitement de données, 16h, L2, IUT de l'Université Paris Diderot

Master: Pierre Fraigniaud, Algorithmique avancée, 24h, Ecole Centrale Supélec Paris, M2

Master: Pierre Fraigniaud, Algorithmique parallèle et distribuée, 24h, Ecole Centrale Supélec Paris, M2

Master: Adrian Kosowski, Randomization in Computer Science: Games, Networks, Epidemic and Evolutionary Algorithms, 18h, M1, École Polytechnique

Licence: Adrian Kosowski, Design and Analysis of Algorithms, 32h, L3, École Polytechnique

Master: Pierre Fraigniaud and Adrian Kosowski, Algorithmique distribuée pour les réseaux, 24h, M2, Master Parisien de Recherche en Informatique (MPRI)

Master: Fabien de Montgolfier and Michel Habib, Grand Réseaux d'Interaction, 44h, M2, Univ Paris Diderot

Licence: Fabien de Montgolfier, Protocoles Réseau (TP/TD), 24h, M1, Univ Paris Diderot

Licence: Fabien de Montgolfier, Programmation avancée (cours/TD/projet, bio-informatique), 52h, L3, Univ. Paris Diderot

Master: Fabien de Montgolfier, Algorithmique avancée (bio-informatique), 26h, M1, Univ Paris Diderot

Licence: Fabien de Montgolfier, Algorithmique (TD), 26h, L3, Ecole d'Ingénieurs Denis Diderot

Master : Laurent Viennot, Graph Mining, 3h, M2 MPRI, Univ. Paris Diderot

Licence: Michel Habib, Algorithmique, 45h, L, ENS Cachan

Master: Michel Habib, Algorithmique avancée, 24h, M1, Univ. Paris Diderot

Master: Michel Habib, Mobilité, 33h, M2, Univ. Paris Diderot

Master: Michel Habib, Méthodes et algorithmes pour l'accès à l'information numérique, 16h, M2, Univ. Paris Diderot

Master: Michel Habib, Algorithmique de graphes, 12h, M2, Univ. Paris Diderot

Licence: Pierre Charbit, Elements d'Algorithmique, 24h, L2, Université Paris Diderot, France

Licence: Pierre Charbit, Automates finis, 36h, L2, Université Paris Diderot, France

Licence: Pierre Charbit, Internet et Outils, 52h, L1, Université Paris Diderot, France

Master: Pierre Charbit, Programmation Objet, 60h, M2Pro PISE, Université Paris Diderot, France

Master: Pierre Charbit, Algorithmique de Graphes, 12h, M2 MPRI, Université Paris Diderot, France

9.2.2. Supervision

PhD in progress: Simon Collet (co-advised by Amos Korman and Pierre Fraigniaud). Title of thesis is: "Algorithmic Game Theory Applied to Biology". Started September 2015.

PhD in progress: Lucas Boczkowski (co-advised by Amos Korman and Iordanis Kerenidis). Title of thesis is: "Computing with Limited Resources in Uncertain Environments". Started September 2015.

PhD in progress: Brieuc Guinard (advised by Amos Korman). Title of thesis is: "Algorithmic Aspects of Random Biological Processes". Started October 2016.

PhD in progress: Laurent Feuilloley (advised by Pierre Fraigniaud). Title of thesis is: "Synchronous Distributed Computing". Started September 2015.

PhD in progress: Mengchuan Zou (co-advised by Adrian Kosowski and Michel Habib). Title of thesis is: "Local and Adaptive Algorithms for Optimization Problems in Large Networks". Started October 2016.

PhD in progress: Léo Planche (co-advised by Étienne Birmelé and Fabien de Montgolfier). Title if thesis is : "Classification de collections de graphes". Started October 2015.

PhD in progress: Alkida Balliu and Dennis Olivetti (PhD students from L'Aquilla University and Gran Sasso Science Institute) are supervised by Pierre Fraigniaud.

PhD in progress: Lucas Hosseini (co-advised by Pierre Charbit, Patrice Ossona de Mendez and Jaroslav Nešetřil since Sept. 2014). Title : Limits of Structures.

Master internship (MPRI): Emmanuel Arrighi (advised by Laurent Viennot). (March-August 2017) Title of report: "Schéma d'étiquetage de graphe pour le pré-calcul de plus courts chemins".

9.2.3. Juries

Laurent Viennot was on the jury committee of the HDR thesis of Mauro Sozio (Telecom Paristech) "Algorithms for Making Sense of Massive Dynamic Graphs" at Paris-Saclay University, July 2017.

Michel Habib was referee and on the jury committee of the HDR thesis of Mauro Sozio (Telecom Paristech) "Algorithms for Making Sense of Massive Dynamic Graphs" at Paris-Saclay University, July 2017.

Michel Habib was on the jury committee of the HDR thesis of Reza Naserasr "Projective Cubes, a coloring point of view" at Paris Diderot University, july 2017.

Michel Habib was referee and on the jury of the PhD thesis of Kaoutar Ghazi "Heurisitques et conjectures à propos de la 2-dimension des ordres", Clermont-Ferrand, october 2017.

Michel Habib was referee and on the jury of the HDR thesis of Phan Thi Ha Duong "Chip Firing Game and related models: algebraic structures and enumerative combinatorics" at Paris Diderot University, december 2017.

Carole Delporte-Gallet was on the jury committee of the thesis of Florent Chevrou " Formalisation of Asynchronous Interactions" Toulouse University, november 2017.

Hugues Fauconnier was referee and on the jury of the PhD thesis of Matoula Petrolia "Distribuer Shared memory in failure prone message passing systèmes", Nantes University, october 2017.

9.3. Popularization

- Amos Korman wrote the atricle “Conseils d’une fourmi: Ne me prenez pas trop au sérieux !” published in the French journal *interstices* in 10.7.2017.
- An article about a paper by Amos Korman, Adrian Kosowski and Lucas Boczkowski was published in *CNRS news* in 10.1.2017.
- An article called “Les fourmis, génies de l’orientation” about a paper by Amos Korman, Adrian Kosowski and Lucas Boczkowski was published in *Le Monde* in 30.1.2017.
- Laurent Viennot is “commissaire d’exposition” for the permanent exposition on “Informatique et sciences du numérique” at Palais de la déécouverte in Paris (opening in February 2018).

10. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journals

[1] E. Bampas, L. Gąsieniec, N. Hanusse, D. Ilcinkas, R. Klasing, A. Kosowski, T. Radzik. *Robustness of the Rotor–Router Mechanism*, in "Algorithmica", July 2017, vol. 78, n° 3, pp. 869-895 [*DOI :* 10.1007/s00453-016-0179-y], https://hal.inria.fr/hal-01416012

[2] A. Castañeda, C. Delporte-Gallet, ·. Hugues Fauconnier, S. Rajsbaum, M. Raynal. *Making Local Algorithms Wait-Free: the Case of Ring Coloring*, in "Theory of Computing Systems", May 2017, pp. 1-22 [*DOI :* 10.1007/s00224-017-9772-y], https://hal.archives-ouvertes.fr/hal-01672723

[3] J. Czyzowicz, D. Dereniowski, L. Gąsieniec, R. Klasing, A. Kosowski, D. Pająk. *Collision-Free Network Exploration*, in "Journal of Computer and System Sciences", 2017, vol. 86, pp. 70-81 [*DOI :* 10.1016/j.jcss.2016.11.008], https://hal.inria.fr/hal-01416026

[4] J. Czyzowicz, L. Gąsieniec, A. Kosowski, E. Kranakis, D. Krizanc, N. Taleb. *When Patrolmen Become Corrupted: Monitoring a Graph Using Faulty Mobile Robots*, in "Algorithmica", 2017, vol. 79, n° 3, pp. 925-940 [*DOI :* 10.1007/s00453-016-0233-9], https://hal.inria.fr/hal-01416010

[5] O. Feinerman, A. Korman. *Individual versus collective cognition in social insects*, in "The Journal of Experimental Biology", 2017, vol. 220, pp. 73 - 82, https://arxiv.org/abs/1701.05080 [*DOI :* 10.1242/jeb.143891], https://hal.inria.fr/hal-01432718

[6] O. Feinerman, A. Korman. *The ANTS problem*, in "Distributed Computing", June 2017, https://arxiv.org/abs/1701.02555 [*DOI :* 10.1007/s00446-016-0285-8], https://hal.inria.fr/hal-01430372

[7] P. FRAIGNIAUD, A. PELC. *Decidability classes for mobile agents computing*, in "Journal of Parallel and Distributed Computing", November 2017, vol. 109, pp. 117-128 [*DOI :* 10.1016/J.JPDC.2017.04.003], https://hal.inria.fr/hal-01674623

[8] R. KLASING, A. KOSOWSKI, D. PAJĄK, T. SAUERWALD. *The multi-agent rotor-router on the ring: a deterministic alternative to parallel random walks*, in "Distributed Computing", 2017, vol. 30, n^o^ 2, pp. 127-148 [*DOI :* 10.1007/S00446-016-0282-Y], https://hal.inria.fr/hal-01416011

[9] A. KORMAN, O. FEINERMAN, B. HAEUPLER. *Breathe before speaking: efficient information dissemination despite noisy, limited and anonymous communication*, in "Distributed Computing", October 2017, vol. 30, n^o^ 5, pp. 339 - 355 [*DOI :* 10.1007/S00446-015-0249-4], https://hal.inria.fr/hal-01672280

International Conferences with Proceedings

[10] D. ALISTARH, B. DUDEK, A. KOSOWSKI, D. SOLOVEICHIK, P. UZNANSKI. *Robust Detection in Leak-Prone Population Protocols*, in "DNA 2017 - 23rd International Conference DNA Computing and Molecular Programming", Austin, TX, United States, DNA Computing and Molecular Programming, Springer, September 2017, vol. 10467, pp. 155-171, https://arxiv.org/abs/1706.09937 [*DOI :* 10.1007/978-3-319-66799-7_11], https://hal.inria.fr/hal-01669203

[11] E. E. BIRMELÉ, F. DE MONTGOLFIER, L. PLANCHE, L. VIENNOT. *Decomposing a Graph into Shortest Paths with Bounded Eccentricity*, in "28th International Symposium on Algorithms and Computation (ISAAC 2017)", Phuket, Thailand, December 2017 [*DOI :* 10.4230/LIPICS.ISAAC.2017.15], https://hal.inria.fr/hal-01671718

[12] L. BOCZKOWSKI, A. KORMAN, E. NATALE. *Minimizing Message Size in Stochastic Communication Patterns: Fast Self-Stabilizing Protocols with 3 bits*, in "ACM-SIAM Symposium on Discrete Algorithms (SODA17)", Barcelona, Spain, January 2017, https://arxiv.org/abs/1602.04419 - 28 pages, 4 figures, https://hal.inria.fr/hal-01447435

[13] P. CHARBIT, M. HABIB, L. MOUATADID, R. NASERASR. *A New Graph Parameter to Measure Linearity*, in "COCOA 2017 - 11th Annual International Conference on Combinatorial Optimization and Applications", Shanghai, China, International Conference on Combinatorial Optimization and Applications, Springer, December 2017, vol. 10628, pp. 154-168 [*DOI :* 10.1007/978-3-319-71147-8_11], https://hal.inria.fr/hal-01672521

[14] C. DELPORTE-GALLET, H. FAUCONNIER, S. RAJSBAUM, M. RAYNAL. *t-résilient snapshot immédiat* , in "ALGOTEL 2017 - 19èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications", Quiberon, France, Aspects Algorithmiques des Télécommunications, May 2017, https://hal.archives-ouvertes.fr/hal-01517320

[15] D. DERENIOWSKI, A. KOSOWSKI, P. UZNANSKI, M. ZOU. *Approximation Strategies for Generalized Binary Search in Weighted Trees*, in "ICALP 2017 - 44th International Colloquium on Automata, Languages, and Programming", Warsaw, Poland, LIPIcs, 2017, vol. 80, pp. 84:1–84:14, https://arxiv.org/abs/1702.08207 [*DOI :* 10.4230/LIPICS.ICALP.2017.84], https://hal.inria.fr/hal-01470935

[16] G. EVEN, O. FISCHER, P. FRAIGNIAUD, T. GONEN, R. LEVI, M. MEDINA, P. MONTEALEGRE, O. DENNIS, R. OSHMAN, I. RAPAPORT, I. TODINCA. *Three Notes on Distributed Property Testing*, in "DISC 2017 - 31st International Symposium on Distributed Computing", Vienna, France, October 2017, pp. 1-30, https://hal.inria.fr/hal-01674664

[17] P. FRAIGNIAUD, B. ALKIDA. *Certification of Compact Low-Stretch Routing Schemes*, in "DISC 2017 - 31st International Symposium on Distributed Computing", Vienna, Austria, October 2017, https://hal.inria.fr/hal-01674656

[18] P. FRAIGNIAUD, O. DENNIS, B. ALKIDA, G. D'ANGELO. *What Can Be Verified Locally?*, in "STACS 2017 - 34th International Symposium on Theoretical Aspects of Computer Science", Hannover, Germany, March 2017, pp. 1-13 [*DOI :* 10.4230/LIPIcs.STACS.2017.8], https://hal.inria.fr/hal-01674650

[19] P. FRAIGNIAUD, O. DENNIS. *Distributed Detection of Cycles*, in "SPAA 2017 - 29th ACM Symposium on Parallelism in Algorithms and Architectures", Washington, United States, July 2017, pp. 153-162 [*DOI :* 10.1145/3087556.3087571], https://hal.inria.fr/hal-01674646

[20] P. FRAIGNIAUD, L. FEUILLOLEY. *Error-Sensitive Proof-Labeling Schemes*, in "DISC 2017 - 31st International Symposium on Distributed Computing", Vienna, Austria, October 2017, pp. 1-15 [*DOI :* 10.4230/LIPIcs.DISC.2017.16], https://hal.inria.fr/hal-01674660

[21] M. HABIB, L. MOUATADID. *Maximum Induced Matching Algorithms via Vertex Ordering Characterizations*, in "ISAAC 2017 - 28th International Symposium on Algorithms and Computation", Phuket, Thailand, December 2017, pp. 1-12 [*DOI :* 10.4230/LIPIcs.ISAAC.2017.43], https://hal.inria.fr/hal-01672520

[22] A. IVASKOVIC, A. KOSOWSKI, D. PAJĄK, T. SAUERWALD. *Multiple Random Walks on Paths and Grids*, in "STACS 2017 - 34th Symposium on Theoretical Aspects of Computer Science", Hannover, Germany, March 2017, vol. 66, pp. 44:1–44:14 [*DOI :* 10.4230/LIPIcs.STACS.2017.44], https://hal.inria.fr/hal-01669223

[23] A. KORMAN, Y. RODEH. *Parallel Search with no Coordination*, in "24th International Colloquium on Structural Information and Communication Complexity (SIROCCO)", Porquerolles, France, June 2017, https://arxiv.org/abs/1705.05704 , https://hal.inria.fr/hal-01523506

[24] A. KORMAN, Y. RODEH. *The Dependent Doors Problem: An Investigation into Sequential Decisions without Feedback*, in "The 44th International Colloquium on Automata, Languages, and Programming (ICALP)", Warsaw, Poland, July 2017, https://arxiv.org/abs/1704.06096 , https://hal.inria.fr/hal-01511050

[25] A. KOSOWSKI, L. VIENNOT. *Beyond Highway Dimension: Small Distance Labels Using Tree Skeletons*, in "SODA 2017 - 28th ACM-SIAM Symposium on Discrete Algorithms", Barcelona, Spain, January 2017, https://arxiv.org/abs/1609.00512 , https://hal.inria.fr/hal-01359084

Scientific Popularization

[26] T. F. DRUMOND, L. VIENNOT, T. VIÉVILLE, V. FRANÇOIS. *Jouez avec les neurones de la machine*, Le Monde, October 2017, pp. 1-3, Le but de ce blog est de parler d'informatique, de communiquer sur ce qu'est vraiment l'informatique en tant que science et technique, ses définitions, ses progrès, ses dangers, ses questionnements, ses succès et impacts, ses enjeux, ses métiers, son enseignement..., https://hal.inria.fr/hal-01620451

[27] O. FEINERMAN, A. KORMAN. *Conseils d'une fourmi : Ne me prenez pas trop au sérieux !*, in "Interstices", July 2017, https://hal.inria.fr/hal-01616341

Other Publications

[28] E. E. BIRMELÉ, F. DE MONTGOLFIER, L. PLANCHE, L. VIENNOT. *Decomposing a Graph into Shortest Paths with Bounded Eccentricity*, September 2017, working paper or preprint, https://hal.archives-ouvertes.fr/hal-01511357

[29] B. DUDEK, A. KOSOWSKI. *Universal Protocols for Information Dissemination Using Emergent Signals*, November 2017, https://arxiv.org/abs/1705.09798 - working paper or preprint, https://hal.inria.fr/hal-01503359