Description of my Research

I study **algorithms in graphs**, maily applied to the **spreading of the information in telecommunications networks**.

I study the structure of graphs and some routing problems through graph searching games. In these games, a team of searchers aims at capturing a fugitive in a graph. The mobile agents follow the paths in the graph with bounded or unbounded speed and satisfying some constraints. The (NP-hard) problem is to minimize the number of searchers required to capture the fugitive. Two main variants have been studied: the **graph searching games** where mobile agents move simultaneously, and the **cos and robber games** where searchers and fugitive move by turns. These two variants are very different since they have not the same algorithmic applications, and the tools used for their study are completely different too.

My contributions have their applications mainly in routing problems in Wavelength-Division Multiplexing (WDM) networks, large scale networks (e.g., the Internet) and wireless networks. All these networks are facing difficult problems, e.g., either NP-complete problems or problems that become difficult to be handled because of networks size. To deal with this, my approach consists into **taking advantage of specific structural properties of real instances for the design of efficient algorithms**.

My objectives are twofold. On the one hand, I want to understand which structural properties can help to solve problems relative to the spreading of the information in networks, and for this prurpose, I am interested in determining which properties are shared by real networks. On the other hand, I want to develop (*via* the graph searching paradigm) new algorithmic tools to use these properties efficiently.

My main contributions deal with:

- the characterization of graphs with specific structures. My study of graph searching allowed to generalize some duality results of tree-decompositions. My study of cops and robber games allowed me to obtain new characterizations of several graphs classes;
- the design of efficient algorithms using the proposed characterizations. For instance, I am working on compact routing schemes in graphs with bounded chordality or hyperbolicity;
- the study of the routing reconfiguration problem inWDM networks. To model this problem in terms of digraph searching game allows to take advantage of the structure of these networks to obtain efficient solutions;
- in distributed and dynamic environments, it is important to use simple data structures that can be updated easily. I am interested in the amount of local information needed to design efficient distributed algorithm.

I use various tools of discrete mathematics, probabilities and combinatorial optimization. My publications are the result of collaborations with students I supervise, members of MASCOTTE and researchers from other universities.

Research Project

Current evolution of telecommunications' networks leads to new algorithmic challenges. Indeed, solutions that have been proposed are mainly generic and centralized (e.g., linear programs). These solutions do not take any advantage from the structure of the networks that are considered. Moreover, such solutions generally do not scale up the growing of current networks and cannot be (easily) adapted to the dynamicity of both topologies and traffic. For instance, the routing protocol (BGP) of the Autonomous Systems (AS) network of the Internet requires that any AS stores routing tables containing all paths toward all possible destinations. This global information (relative to a network with several thousands of nodes) must be updated regularly when topology changes (failures, changes in the routing policy of the AS, etc.) or to be adapted to the traffic (to deal with congestion). This requires an important amount of traffic of control and, moreover, such an updating takes time (several minutes) which affects the expected quality of service. However, the AS network (as well as large-scale networks) satisfies specific structural properties (small diameter – logarithmic in the network size –, high clustering coefficient, power law distribution degree, etc.). These structural information are not taken into account in the design of the routing protocol. One question is thus to know how to use them to get a more efficient protocol, i.e., using smaller routing tables that can be updated easier and faster.

Similar problems appear in various contexts like in Wavelength-Division Multiplexing (WDM) networks or large scale networks. My research project focuses on this question, mainly considering **routing applications** in both these two kind of networks. To deal with these problems, my goals are **to point out structural properties** of real networks, **to propose new characterizations** to model these networks, and to use considered structures **to design distributed algorithms** (or localized algorithms) that are both efficient and simple enough to handle dynamicity.

Desired solutions must not satisfy the same constraints depending on the applications considered. Solutions could be approximation algorithms to solve the (NP-hard) problems (traffic grooming, routing reconfiguration, multi-flow, etc.) that occur in WDM networks. On the other hand, in large scale networks (e.g., the Internet), desired solutions should be optimal (for instance, we want datas to reach their destination whatever happens) even if the whole topology of the network is not known.

My project aims at answering the following three complementary questions.

"Which properties?" We already mentioned that large-scale networks share common properties. In a similar way, WDM networks share structural characteristics: low density, well connected, almost planar (roughly, they look like grids). Hence, it is a natural question to ask what are other properties that are shared by these networks, and which of these properties have an algorithmic interest. This aims at **proposing new models** for real networks, in order to use them as benchmark for our algorithms. One question of interest is to understand **how these properties evolve with the dynamicity** of the networks. **For any property or combination of properties, it will be crucial to design algorithms to check whether a graph satisfies it, and to design algorithms to generate families of graphs satisfying it.** For this purpose, new algorithmic tools are needed to deal with dynamicity.

As part of the European project FP7 STREP EULER, we have initiated this study by considering two parameters (chordalit and hyperbolicity) with good perspectives in the context of routing.

The challenge here is to propose algorithms that are efficient in huge networks, i.e., looking for polynomiality is not sufficient but linear or quadratic algorithms are expected. This framework is also part of the so called "Science Network" initiative that aims at understanding the structure of large networks and their dynamicity. Other applications are considered like community detection, virus spreading, etc.

"Which structures?" Therefore, understanding networks characteristics for algorithmic purposes is a crucial challenge which is the goal of numerous current research studies. For instance, the study of parametrized complexity aims at determining from which structures the hardness of various NP-complete problems comes (e.g., *kernelization*). With another point of view of this generic approach, I propose to study structural properties of graphs with two main guidelines: to focus on **specific graphs' classes** and to keep in mind the **algorithmic applications** of the considered properties. Expected results would be global structures that could be computed easily (by greedy or localized algorithms) and that would allow the design of efficient algorithms. For this purpose, I want:

- **to continue the study of graphs decompositions:** in particular, it is important to design simple algorithm to compute (or approximate) decompositions in particular graphs classes: for instance, graphs with small *treewidth* (generic algorithms of Bodlaender and Kloks being not efficient even in such graphs classes), subclasses of planar graphs (the complexity of computing treewidth of planar graphs is still open);

- **to generalize this study to directed graphs:** currently several groups of researchers (e.g., [Ganian *et al.*2010]) aim at designing "good" decompositions for directed graphs, i.e., having the same algorithmic performances as tree-decompositions in the undirected case. This study is part of my work on routing reconfiguration in WDM networks and of its modelization in terms of digraph searching games. Since, nov. 2010, I am supervising the Ph.D. thesis of Ronan P. Soares on this topic. We have obtained some preliminary results that are promising. This work on directed graphs is also part of the collaboration with the Univ. of Fortaleza in which I am involved (EA EWIN, project FUNCAP).

- **to propose new structures that are more specific and dedicated to applications:** in the case of tree-decompositions, the size of the "pieces" of the decomposition is important to obtain efficient and generic algorithms using dynamic programming. However, when we are interested to specific problems, it would be more relevant to consider the structure of the pieces instead of their size. For instance, I proved that graphs with bounded chordality admit tree-decompositions where each bag induces a caterpillar. Moreover, such decomposition can be computed by a greedy algorithm and have interesting applications for compact routing. I will continue this study of graphs decompositions ("between" tree-decompositions and decompositions into paths [Gavoille *et al.*]) by considering other parameters like hyperbolicity. From oct. 2011, I will supervise the Ph.D. thesis of Bi Li on this topic. This study is also part of the European project FP7 STREP EULER that is interestd in compact routing in the Internet.

"Which Algorithms?" My choice to focus on specialized algorithms in specific graphs classes should allow to design algorithms satisfying constraints of current networks. In particular, solutions should handle the dynamicity of both the topology and the traffic. In this context, I want to design distributed algorithms and give good garanties for their performances (approximations, result with high probablity, etc.). I am particularly interested in developing new techniques allowing **to obtain global structural information from local (partial) views of the network**. We have started this study in the case of static networks and it should be extended in order to include dynamicity. This requieres to understand this dynamic and **to propose models of dynamicity**. For this purpose, new algorithmic tools that take into account the time must be develop.