Region STIC-AmSud

2018 Project Proposal (Research – Innovation)

Basic Form

- This form, and the associated CVs, must be filled in English. Before filling the form, please read carefully the bases published in the STIC-AmSud site (http://sticmathamsud.org/).
- This form must be sent in **.pdf** by email to the STIC-AmSud Secretariat (contacto@sticmathamsud.org) by the project's International Coordinator.

A. General Information

A1	**Project title**
	Graphs ALgorithms for Optimization Problems

A2	**Acronym**
	GALOP

A3	**Research domain**
	Graph Theory, Algorithms and Complexity, and Mathematical Programming

A4	**Project goals**
	Theoretical results on metric and structure of graphs and their use for various problems arising in telecommunication, transportation and social networks. Implementation of a set of efficient algorithms (in graph libraries as SageMath) and analysis of properties of real large-scale networks (urban networks, Twitter)

A5	**Abstract**
	This proposal aims at allowing to continue the fruitful and long-standing collaboration between Inria and UFC and between Inria and UAI. Another goal is to reinforce the collaboration between UFC and UAI that has been recently initiated. Our goal is to study the Computational Complexity of several important problems arising in networks (routing, resources assignment...). In particular, we will focus on the computation of metric or structural properties and parameters of large networks (e.g., transportation and social networks...). We plan to design efficient exact algorithms for solving these problems or to theoretically prove that such algorithms cannot exist. In the latter case, we will then design approximation algorithms, or prove that none exists. In all cases, we aim at implementing our algorithms and use them on real-world instances such as large road networks or huge social networks.

A6	Scientific coordinators at each institution			
	South America A		**South America B**	
	Institution	Universidade Federal do Ceará (UFC) Fortaleza, Brazil	Institution	Universidad Adolfo Ibáñez(UAI) Facultad de Ingeniería y Ciencias Santiago, Chile
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	Institution	Inria Sophia Antipolis COATI team project	Institution	
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A7	Other participating institutions	
	In South America	**In France**

A8	List of expected participants (name and affiliation and status : junior, senior)

COATI, common team, Inria, I3S (CNRS, Univ. Nice Sophia Antipolis), France

- Julien BENSMAIL, Maître de Conférence UNS (since 2016) (Graph Theory)
- David COUDERT, DR2 Inria, (Graph Algorithms, Networks, Operational Research)
- Frédéric HAVET, DR2 CNRS, (Combinatorics, Graph Theory, Computational Complexity)
- Frédéric GIROIRE, CR CNRS (since 2008) (Graph Algorithms, Probability, Networks)
- Fionn Mc INERNEY, PhD Student (since 2016) (Graph Algorithms)
- Nicolas NISSE, CR1 Inria (since 2009) (Computational Complexity, Graph Algorithms)

Universidade Federal do Ceará (UFC), Fortaleza, Brazil

- Julio ARAUJO, Professor (since 2014), Dept. de Matemática, (Graph theory, Graphs Algorithms)
- Fabricio Siqueira BENEVIDES, Professor (since 2011), Dept. Matemática, (Combinatorics, Probability)
- Victor CAMPOS, Professor (since 2011), Dept. de Computação, (Graph theory, Graphs Algorithms)
- Ana Karolinna MAIA de OLIVEIRA , Professor (since 2016), Dept. de Computação (Combinatorics, Graph theory)
- Rudini SAMPAIO, Professor (since 2009), Dept. de Computação (Combinatorics, Graph theory)
- Claudia Linhares SALES, Professor (since 1990), Dept. de Computação (Combinatorics, Graph theory)
- Ana Shirley Ferreira da SILVA, Professor (since 2011), Dept. Matemática, (Combinatorics, Graph theory)
- Ronan Pardo SOARES, Professor (since 2014), Dept. de Estatística e Matemática Aplicada, (Graph theory, Graphs Algorithms)

Universidad Adolfo Ibáñez (UAI), Santiago, Chile

- Hernán LESPAY, PhD Student (since 2017), (Operational Research)
- Pedro MONTEALEGRE, Professor (since 2017), Faculty of Science and Engineering, (Graph Algorithms)
- Eduardo MORENO, Professor (since 2007), Faculty of Science and Engineering, (Operational Research, Networks)
- Sebastián MUÑOZ, PhD Student (since 2018), (Operational Research)
- Karol SUCHAN, Professor (since 2008), Faculty of Science and Engineering, (Graph Algorithms, Operational Research)

A9	International Project Coordinator (to be chosen among the Scientific Coordinators mentioned in A6)
	Nicolas NISSE

B. Project Details

B1. Project guidelines

Our goal is to study the Computational Complexity of several important problems arising in networks. In particular, we will focus on the computation of metric or structural properties and parameters of large networks. We plan to design efficient exact algorithms for solving these problems or to theoretically prove that such algorithms cannot exist. In the latter case, we will then design approximation algorithms, or prove that none exists. In all cases, we aim at implementing our algorithms and use them on real-world instances such as large road networks or huge social networks.

In this project, we will mainly tackle three kinds of network problems that are naturally modeled as graph-theoretical problems.

- First, we will consider graph decompositions: how to efficiently compute "good" decompositions (e.g., tree-decompositions) and how such decompositions (e.g., decompositions with clique-separators) can be used to speed-up the actual running time of algorithms for computing various graph metrics. As an example of application, we will consider road-networks for which new usages (e.g. multi-modal transportation) require algorithms to compute shortest paths more efficiently and in a dynamic setting.

- Second, we will study combinatorial games in graphs because they naturally model many network problems in different contexts. For instance, localization games are a game-theoretic way to handle the detection of faults in multiprocessor networks (e.g., via identifying codes or metric dimension). Another example is the surveillance game that is a nice theoretical model for data prefetching.

- Last but not least, we will obtain new results in two graph optimization problems: graph colorings that naturally model various allocation problems (e.g., resource assignment, like channel assignment in radio networks, personnel assignment, etc.), and graph convexity that may be seen as a model of diffusion in a network (e.g., spreading opinions/innovations, propagating diseases/faults, logical inference, etc.). An objective of particular interest is to study propagation of information in real social networks.

Since all these problems are complex, we will start by considering simpler models or hypothesis (for instance, consider a problem on a more restricted graph class) and then obtain results in a more refined setting. For instance, we will first focus on the case of undirected graphs, which is generally easier than that of directed graphs. After getting some understanding of the undirected case, we will then consider the directed one.

In the sequel, we give more details on the problems and applications we will consider.

B2. Project description

Goals, motivation, methodology and contribution of each participating institution

I. Computing and Using Graph Decompositions

I.1 Tree-decompositions

During the last decades, much work has been dedicated to *tree-decompositions* of graphs because, on the one hand, many NP-hard problems can be solved in polynomial time in the class of graphs

admitting “good” tree-decompositions (i.e., with small *treewidth*) [CM93], and on the other hand, graphs with large treewidth have particular structure (e.g., large grid minor) which led to the bi-dimensionality theory and corresponding algorithmic results [DH08, CFK+15]. Therefore, one of the main challenges in this area is to design efficient algorithms to compute “good” tree-decompositions of graphs. This problem is NP-complete in general, existing Fixed Parameterized Tractable (FPT) algorithms [BK96] are not efficient in practice and no approximation algorithm is expected to exist (under the standard complexity hypothesis) [WAPL14]. To deal with the intractability of the computation of decompositions with small pieces (small *width*), researchers have investigated other properties of the pieces (called *bags*). In particular, tree-decompositions where the bags must satisfied some metric constraints (e.g., small diameter, small radius, etc.) have been widely studied during the last decade [DG07, Lok10, CDN16, DLN16].

More precisely, the *treelength* of a graph G is the minimum d such that G admits a tree-decomposition whose all bags have diameter at most d [DG07]. While treewidth and treelength are incomparable in general, several problems can be solved efficiently in the class of bounded treelength graphs (e.g., the Traveling Salesman Problem admits a PTAS). On the positive side, we proved that treelength approximates treewidth in large graph classes such as apex-minor free graphs [CDN16]. Since treelength can be efficiently approximated [DG07], this latter result offers many nice perspectives on the design of efficient/practical approximation algorithms for computing treewidth in large graph classes.

One of the objectives of this project concerns the design of exact (or better approximation) algorithms for computing the treelength and the treebreadth (where the radius of the bags must be minimized) of graphs. The class of planar graphs (and more generally of bounded genus graphs, or of graphs excluding a fixed graph as minor) will be targeted first. In particular, we proved that deciding if a graph excluding K_{3, 3} as a minor has treebreadth 1 can be solved in polynomial time (while it is NP-complete in general graphs) [DLN16]. It is not known whether deciding if a graph has treelength 2 can be solved in polynomial time in planar graphs (treelength 1 corresponds to chordal graphs and so is easy, and deciding if a graph has treelength 2 is NP-hard in general). A first step will be to study the computational complexity of computing treelength/treebreadth in series-parallel graphs and outerplanar graphs (as a first step toward planar graphs). Another challenging objective will be to design algorithms for turning decompositions with small length (that can be computed efficiently) into decompositions with small width (from [CDN16], we already know some cases when it may be possible).

The Ph.D. of Ronan Pardo Soares was mainly focusing on FPT algorithms for computing treewidth of graphs. Moreover, many members of this project (Julio Araujo, Nicolas Nisse, Ronan Soares, Karol Suchan, etc.) are well familiar with the use of tree-decompositions (they have developed many efficient algorithms for various problems in graphs with bounded treewidth). Therefore, we think this objective will take advantage of this collaboration.

I.2 Decomposing graphs to speed-up algorithms for metric properties

During the last decade, a lot of work has been dedicated to improving the practical efficiency of algorithms for “simple” problems. For instance, computing the diameter of graphs (which can be easily solved in quadratic time) has required new clever ideas to become tractable in huge networks such as Facebook [BCH+15, DHV18]. In the same vein, the current development of multimodal transportation in urban networks requires very efficient tools for online trip planning, dealing with a dynamic setting (current traffic, delay of metro and buses, etc.) and with many possibilities guided by customers’ preferences (no walk, few changes during the journey, etc.). Much work has been dedicated to design algorithms for answering quickly to requests, by using new data structures (e.g., hub labeling) for storing relevant information [BDG+16, AHN+14, KV17].

This part of the project is devoted to the theoretical study of some graph properties related with their metric structure, namely their eccentricity, reach, hyperbolicity, and centrality. We aim at using graph decompositions to derive efficient algorithms to compute these properties in large graphs.

The Gromov hyperbolicity of a graph is a parameter that is related to its metric (roughly, to the distribution of the distances in the graph) [Gromov87]. More precisely, the hyperbolicity of a graph G measures how the metric of G is close to the metric of a tree. It is well known that, in graphs with small hyperbolicity, very simple routing schemes (e.g., greedy routing) perform very well. Computing the hyperbolicity of a graph can be done in polynomial time. However, the best known algorithm has complexity $O(n^{3,69})$ which is far from being efficient for large scale networks. Hence, better algorithms dedicated to networks wih particular structural properties are needed [CD14]. Our preliminary work led to an efficient algorithm by decomposing the graphs using clique-separators [CCDL17]. Yet, this algorithm is still time-expensive for large graphs. More recently, we developed algorithms parameterized by the *modular-width* of the graph to further reduce the time complexity of computing hyperbolicity [CDP18]. Since the urban networks are almost planar, the next step is to use this specificity in our algorithm in order to speed it up. Another direction of research will be to understand whether a data structure such as a hub labeling may help in the computation of such a parameter. Reciprocally, can a hub-labeling be computed more efficiently in a graph with small hyperbolicity?

The centrality of a graph measures the importance of a vertex with respect to the shortest paths passing through it [Jackson14]. For instance, it may describe the impact of a person in a social network or the importance or attractiveness of a building or an intersection in an urban network. Many different definitions of centrality have been proposed for graphs and the corresponding parameters are generally polynomially solvable [NohR89, Brandes01]. However, the metric space associated to an urban network is more complex, because of the no-left, no-right and no U-turn signs. We have to deal with, so-called, forbidden transitions. In this setting, even the question of connectivity in a graph becomes NP-hard [KMMN15]. We aim at using Linear Programming techniques for handling this problem. Computing diffusion structures such as Steiner trees will also be useful in networks with forbidden transitions.

This part of the project is clearly oriented toward applications. In particular, all algorithms will be implemented (in Python using SageMath, or in C++ when more efficiency will be required) and tested on real networks. During previous collaborations between UAI and Inria, we have already worked on the urban and transportation networks of Santiago and Nice. Our experience with tools for handling such networks (OpenStreetMap to obtain data, QGIS to work on it, etc.) will clearly benefit the project. Moreover, this part of the project will allow to introduce a new area of expertise among the members of UFC. On the social networks side, members of COATI are currently working on the Twitter graph (a snapshot with 500 millions nodes) and this project will allow them to pursue their study of its structural properties.

II. Combinatorial Games in Graphs.

II.2 Pursuit-Evasion Games

Tree-decompositions of graphs have a nice algorithmic interpretation in terms of a *pursuit-evasion game* called *graph searching* [Bie89, FFN09]. Given a graph G, an omniscient visible arbitrarily fast fugitive is moving along the edges of G. Then, the minimum number of searchers required to capture the fugitive is exactly the treewidth of G plus one, and an optimal strategy basically consists in “following” any optimal tree-decomposition. This kind of games provide an elegant way of

modeling the problem of routing reconfiguration in WDM networks, which was one of the topics for which we got new interesting results during the Ph.D. thesis of Ronan Pardo Soares (UFC). Many interesting questions are still open in this area, such as: what happens if it is allowed to reroute requests more than once?

Turn-by-turn pursuit-evasion games have been widely investigated by many research groups. These games are 2-player games in which, at every turn, one of the two players places a token at some vertex of a graph, or moves a token along one (or several) edge(s) in a graph. Each of the two players has its own goal and, generally, it is asked what is the minimum number of "resources" that is required for one of the players to win.

The most famous such game is the *Cops and robber game* in graphs [BN11]. In this game, the first player has a team of k *cops* that are initially placed at some vertices of a graph G. Then, the second player places its robber at some vertex. Then, turn-by-turn, the Cop-player may move each of its cops along one edge of the graph G, and then the Robber-player may move its robber along one edge of G. The goal of the Cop-player is to eventually move one of its cops to the robber's location (to *capture* the robber). The main question is, given a graph G, what is the minimum number k of cops required to capture a robber, whatever it does. For instance, it is known that at most 3 cops are sufficient in any planar graph [AF84], and more generally, at most g*3/2+3 cops are sufficient in any graph with genus at most g [Sch01]. Many long-standing conjectures are still open: Meyniel's conjecture asks whether $O(\sqrt{n})$ cops are sufficient in any n-node graph [Fra87], Schroder's conjecture asks whether g+3 cops are sufficient in any graph with genus at most g [Sch01], etc. More simple questions are still open such that: is it true that 3 cops are sufficient in graphs with genus 1? Previous common work between UAI and Inria has been devoted to get further progress into these questions [FGK+10, KLNS15, FFNT16]. Another direction of research in this area is the case of directed graphs, for which almost no results are known. Several UFC members (R. Sampaio, N. Martins) are also interested in these questions.

To further investigate these questions, together with several researchers of UFC (R. Sampaio, N. Martins), we introduced a more general game, called *spy-game* [CMM18]. This game also generalizes the *eternal domination game* [KM12], and many problems remain open, such as the exact complexity of the problem, the minimum number of cops required to win the game in grids, the existence of an FPT algorithm for this problem, etc. In a recent work, we have designed the first algorithm using Linear Programming in this context [CMN17]. Hence, we have proved that it would be useful to tackle the problem using this approach. The expertise of the UFC and UAI members in Operational Research will significantly help in this direction.

This task will be a natural continuation of a fruitful collaboration on this topic by members of the three institutions.

II.2 Combinatorial Games as Models for Network Problems.

Localization games. Identifying problems by tests is very common in various domains such as pattern recognition, group test in biology, failure detection, localization, or key searching in databases [CM02, HM76, Kog95, PP80]. We are more specifically interested in a problem that models fault diagnosis in multiprocessor systems. This kind of problem is closely related to well-studied graph parameters such as the *metric dimension, locating dominating sets and identifyi*ng codes. Roughly, in identifying codes, we aim at selecting a small set S of vertices such that every set of at most k vertices of the graph can be distinguished by the closed neighborhood of the vertices in S.

In a recent work, members of the project used the discharging method (which we intensively used and develop in our work on graph colouring) to obtain optimal 1-identifying codes in the square

grid of height 3. The use of the discharging method for finding and proving (near) optimality of identifying codes seems very promising. We also used it a recent joint work between Inria and UFC [DHS17] to obtain (near) optimal 1-identifying codes in triangular grids of bounded height. We now plan to focus on k-identifying of those grids as well as other grids. We also would like to investigate directed variants of these problems. The first one is the very analogue of the undirected problems for directed graphs, where the closed neighborhood is replaced by the *closed out-neighbourhood*. The second one consists in finding an orientation of a given undirected graph which has an identifying code of smallest possible size. Hopefully, we would be able to find a general method, possibly computer-assisted, to find optimal identifying codes for large classes of (directed) graphs.

Another interesting approach initiated by members of the project is the study of the metric dimension via a game theoretical approach [BGG+18,BMM+18]. It would be interesting to extend it to identifying codes. In this context, a moving target must be located by probing a limited number of vertices at every step (while the target may move to an adjacent vertex at every step) and one possible objective is to locate the target in a minimum number of steps.

Surveillance game. To conclude this part, we should mention the surveillance game which is a game modeling pre-processing processes (prefetching) and that has been widely studied in the Ph.D. thesis of Ronan Pardo Soares (UFC) (e.g., see [GNPS13, GLM+15]). Several problems, such that the cost of connectivity, remain open and would be worth studying in this project. In particular, the approach using Linear Programming seems to be particularly well suited for this game [GNPS13] and the expertise of UFC and UAI in polytopes study will allow the project to obtain significant progress in this direction.

III. Optimization in Graphs

As already mentioned, the project aims at developing new algorithms and graph-theoretical results to be applied on several important problems arising in networks. We will also contribute to the study of two graph concepts, namely *convexity* and *coloring*, that have very important applications in this area.

III.1. Graph Convexity

In Euclidean space, computing the *convex hull* of a set of points X is a very classical problem. In any graph G=(V, E), this notion can be defined as: for any subset X of V, the convex hull h(X) of X is the smallest subset H of V such that H contains X and, for every x, y in H, every vertex in a shortest path between x and y belongs to H. Computing the convex hull of a set X of vertices can be seen as an infection process where the vertices in X are initially infected, and at every step, any vertex in a shortest path between two vertices already infected becomes infected. Natural questions then arise, such as, what is the minimum size of a set of vertices that will eventually infect the whole graph? Another question is what is the smallest size of a set of vertices sufficient to contaminate the graph in one step?

Many problems related to graph convexity have been investigated by Brazilian research groups (e.g., [DPRS12, CDS15, BCDS15]). Among others, the question of what is the smallest size of a vertex-set S of G such that h(S)=V(G). The size of such a *hull set* is called the *hull number* of G. We have proved that computing this graph parameter is NP-complete even in bipartite graphs, and that it can be computed in polynomial time in many graph classes [ACG+13]. This work has been further extended in [AK16], where it is proved that computing the hull number of partial cubes is NP-complete. Recently, this problem has been proved NP-complete in chordal graphs [BDDR17] (showing that a previous work announcing a polynomial-time algorithm for this problem was not correct). One of the main open questions in this area is whether this problem is FPT (in the size of

the solution) in general graphs or even in partial cubes [KN17].

Many variants of graph convexity have been studied, in particular because they model contamination spreading processes. For instance, the so-called P_3-convexity has been studied by UFC members in [CSSS15]. Cycle-convexity of graphs has been defined by Araujo et al., because it allows to model several applications in Knot Theory. Members of Inria, UFC and UAI recently have further investigated this problem in [ADNS18]. One interesting question is to determine how to apply our results to Knot Theory and how to generalize them.

As far as we know, the question of convexity has not been investigated in directed graphs.

III.2 Graph Coloring and Frequency Assignment

Graph coloring is one of the most important topics in graph theory. Given a graph, a proper coloring is an assignment of positive integers, i.e. *colors,* to vertices such that no two adjacent vertices receive the same color. The *chromatic number* chi(G) of a graph G is the minimum number of colors used in a proper coloring of G. There are several variations of the graph coloring defined in the literature to model different practical applications. We will focus on graph coloring problems modeling frequency assignment problems in networks. One of them, motivated by multicast in radio network, is the Backbone Coloring. Given a graph G and a subgraph H of G, a q-backbone k-coloring of (G,H) is a proper k-coloring of G such that, for every pair of adjacent vertices in H, their colors differ of at least q units. One important conjecture in the area is that for every planar graph G, and for every spanning tree T of G, there is a 2-backbone 6-coloring of (G,H) [BFG+07]. The members of COATI and UFC have been working on this problem in the last years and several contributions have been made [AHS18+, ACS17, HK14, HKL+14, CHS+13]. Many questions, alongside the above conjecture, remain open and will be studied during this project. We will also study some variant arising from several problems. For instance, motivated by the optimization of TDMA link in sensor networks, we recently started to investigate some directed variant of backbone coloring [BBC+18].

It is well-known that deciding if finding and even approximate the chromatic number of graph is NP-hard. In addition, in many applications, the coloring must be found or updated on-line. Therefore we are interested in on-line coloring heuristics. The easiest and most famous one is the *greedy heuristic*. The *grundy number* Gamma(G) is the maximum number of colors used after applying the greedy heuristic coloring [Grundy39]. It represents the worst case behavior of the greedy heuristic. Another heuristic, called the *b-heuristic* is used to improve coloring. It consists in recoloring all vertices of a given color class when it is possible (that is when each vertex of the color class has another available color). A *b-coloring* is a proper coloring such that, for every color class c, there is a vertex with color c that has a neighbor in every other color class. Computing such a b-coloring can be done greedily, and the *b-chromatic number* chi_b(G) is the maximum number of colors of a b-coloring [IM99]. Computing Gamma(G) or chi_b(G) is NP-complete [Zaker06, HSS12], and one open question studied by UFC and COATI members is to know whether chi_b(G) is FPT (in the size of the solution) and whether Gamma(G) is FPT for another parameter (it is known to be W[1]-hard when parameterized by the size of the solution).

In general, we are interested in better understanding the behavior of such heuristics for proper coloring and for the above-mentioned backbone colorings, in order to understand in which cases (on which class of graphs/networks) it is efficient. In particular, during the visits of Ana Shirley Silva and Claudia Linhares Sales to the COATI team in 2017, we have started working on several aspects of b-colorings of planar graphs.

Methodology

In the context of the theoretical objectives of the project, we will use our knowledge and skills from fields such as Graph Theory, Algorithms and Mathematical Programming to study problems of Computing and Using Graph Decompositions, Combinatorial Games in Graphs, and Optimization in Graphs, as described above.

We will study well known conjectures and propose new ones on relations between graph parameters under investigation and try to prove them. We will work to design efficient algorithms for exact or approximated computation of the parameters and prove their properties, or to prove that no such algorithms can exist.

As usual in the area of theoretical computer science, we do not fix a small number of research hypothesis and make a detailed work plan to follow – there is to much uncertainty about what might be achievable to do that. Instead, we only set a certain area of topics to be tackled, and fix the kind of conceptual tools to be used. The detailed work has to be highly adaptive: proposing new ideas or exposing flaws in the arguments made before.

Our approach consists of doing literature review in search of interesting results and techniques, individual work to develop certain ideas, small work meetings of tightly collaborating teams to quickly find the strong and weak points of each idea, and open seminars to share “best practices” and “success stories”, but also open questions, with the complete research group. These open meetings are sometimes an opportunity to get an “outsider’s” opinion that is crucial to get the research on the right track.

From what was exposed, the seminars and exchange visits of the members are crucial, since they are an opportunity to discuss both the theoretical and practical aspects of the project, coordinating the activities of the project and providing the desired exchanges between the distinct areas of expertise of the members.

Such visits and seminars will also be important to involve graduate students of the respective universities in the research being developed in the project. It is expected that the students shall profit of such meetings to interact with the foreign researchers and it will certainly contribute to the development of their thesis.

Project scope

This project has mostly a theoretical vein but also intends to apply the obtained results on real-world networks. It proposes the study of several problems arising in networks by modeling them with Graph Theory and Mixed Integer Programming and using adequate techniques to solve them, or even to show that no efficient algorithms computing optimal or approximating solutions shall exist. Moreover, it is also planned to implement the obtained solutions to be used on real-world networks.

All problems considered in this project are related to important STIC applications. In particular, we will focus on routing problems (mainly in telecommunications networks and in public transportation networks), on resources assignment (in telecommunications network) and more generally on information diffusion in large networks (social networks).

It is important to recall that the set of knowledge areas that will be used cover a large part of the techniques that are known in the literature on Theoretical Computer Science and Operational Research to study this kind of problems.

Expected results

The main outcome of this project will be a set of theoretical combinatorial results and graph algorithms, such as

- Theoretical results on treewidth and treelength and efficient algorithms to compute graph decompositions
- Efficient algorithms to compute graph metric parameters (reach, hyperbolicity, centrality) in large scale networks (such as big urban networks or huge social networks)
- A framework for studying Combinatorial games in graphs using Linear Programming
- Theoretical results on graph Convexity and Coloring, such as proofs of lower and upper bounds for the graph parameters in this context, as well as the study of the Computational (Parameterized) Complexity to determine them exactly and approximatively.

Theses results will be published in international conferences (ICALP, ESA, SEA, WG, etc.) and revues (JCTB, SIAM J. of Discrete Maths., Algorithmica, TCS, DAM, etc.).

Besides the theoretical outcome, we aim at implementing our algorithms and integrate them into graph libraries such as SageMath (http://www.sagemath.org/). Note that one project participant, David Coudert (Inria), is an active contributor of Sagemath. Moreover, we will use our algorithms on urban/transportation networks (such as Nice and Santiago) and on huge social networks (Twitter) in order to get new relevant information about their structural and metric properties. It is worse mentioning that both Inria and UAI have ongoing industrial collaborations in the field of transportation networks providing access to large data sets.

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B3. Schedule, with main execution stages

As described in detail in Section B2, this project proposed the study of different problems, with their corresponding applications. Each problem is a Combinatorial Optimization problem and different outcomes are expected, as described in Section B4. Some of the problems, like the study of reach, centrality, treelength, etc., although we expect theoretical results, we also plan to implement and test the performance of algorithms that will be proposed. Thus, for these problems, we will focus on the theoretical studies in the first 18 months of this project, alongside the beggining of the implementation of the proposed algorithms. In the last year, specially in the last semester, we will focus on the analysis of the performance of these algorithms under real-world instances.

The other proposed problems are strictly theoretical and for these problems we plan to work on all the duration of the project. Of course, the last 3 months will be mostly used to write all obtained results and submit them to international revues. The schedule is resumed in the following table :

Year	2019				2020			
Month	**1-3**	**4-6**	**7-9**	**10-12**	**1-3**	**4-6**	**7-9**	**10-12**
Theoretical results on graph structural/metric parameters (reach, centrality, treelength, treewidth...)								
Design of efficient algorithms to compute graph decompositions								
Implementation (e.g., using SageMath) of efficient Algorithms for computing structural and metric properties of large scale networks								
Analysis of theoretical parameters on real networks (Twitter, road-networks)								
Theoretical results on combinatorial games and related applications (identifying code...)								
Theoretical results on Graph Convexity								
Theoretical results on Graph Coloring								

Planned missions:

- Kick-off meeting. At UFC, May 2019
- At Sophia Antipolis, September 2019
- At UAI, December 2019
- At UFC, March 2020
- At UAI, June 2020
- At Sophia Antipolis, October 2020

B4. Contributions

Present contributions so as to highlight the role of each partner and the integration among partners.

The main contributions will be scientific papers published in international conferences and revues. We may summarize the main objectives and the role of each partners as follows.

O 1 : Establish relationship between graph parameters such as treewidth, treelength and hyperbolicity, in general graphs and in specific ones (bounded genus graphs).	Inria,UAI
O2: Implementation of efficient algorithms to compute structural/metric properties in large social or transportation networks	Inria, UAI
O3: Design of efficient approximation algorithms for computing tree-decompositions in various graph classes.	Inria,UAI, UFC
O4: Implementation of efficient algorithms to compute graph decompositions	Inria,UAI,UFC
O 5 : Use Linear Programming techniques to solve connectivity and centrality problems in networks.	Inria,UAI,UFC
O6: Study complexity of Convexity parameters in function of graph metric parameters.	Inria, UFC
O7: Study of graph coloring Problems	Inria,UFC
O8: Theoretical results on graphs combinatorial games	Inria,UAI,UFC

B5. Regional Aspects

Indicate how the activities will stimulate effective scientific interactions between all the participants.

This project is a continuation of more than 10 years of fruitful collaboration between several participants. On the one hand, COATI team-project and ParGO (UFC) collaborate since 2006 with the sabbatical of Claudia Linhares Sales in the MASCOTTE team project (most of the members of MASCOTTE form the COATI team now). Since them, two bilateral projects between the groups were funded by the associated teams EWIN (2009-14) and GAIATO (2014-16). This collaboration already led to more than 30 common publications in international conferences and journals. Moreover, five Brazilian students from UFC have done their Ph.D. thesis (partly or fully) in the COATI team-project and several other master students of UFC had few months of internship in the COATI team. Both teams also organized the two editions of the "French-Brazilian Workshop on Graphs and Combinatorial Optimization". On the other hand, the collaboration between members of COATI and of UAI started in 2007 when N. Nisse and K. Suchan were postdocs at Universidad de Chile. Since then, the collaboration has been formalized through the Associated Team Inria AlDyNet (2013-2018) and the project ECOS-Sud-Conicyt C12E03 (2013-2015). This collaboration has already given rise to more than 15 common publications in international conferences and journals.

This project aims at providing us with an opportunity to continue this fruitful collaboration and to reinforce it by establishing collaboration between UFC and UAI. Actually, this has already been initiated with the visit of J. Araujo in Santiago (December 1st-15th 2014) with the following accepted paper [ADNS18].

B6. Institutions and CVs of coordinators

Description of each participating institution, and curriculum vitae of each participant (maximum 2 pages per participant).

Here we present a description of the participating institutions. The CVs of each participant are available as attachments to this document.

Inria is a public science and technology institution placed under the supervision of the French ministries of research and industry. Currently 3,150 scientists compose its staff, including 900 researchers without Frech nationality. Its unit in Sophia Antipolis, a science park in the south of France, was founded in 1981, and includes research teams in other cities. COATI (Combinatorics, Optimization, and Algorithms for Telecommunications) is a joint project-team between Inria Sophia Antipolis – Méditerranée and the I3S laboratory, which itself belongs to CNRS and University of Nice-Sophia Antipolis (UNS). Inside I3S, COATI belongs to the “pôle COMRED”, and within Inria it belongs to the domain “Networks and Telecommunications”.

Universidad Adolfo Ibáñez (UAI) is a private university in Chile. It is ranked 1º Private University in Chile according to América Economía. It has over 10000 students, 300+ full time professors, of which 2400+ and 80+, respectively, correspond to Faculty of Engineering and Science (FES). FES is experiencing very dynamic growth in all respects: student enrollment, faculty, scientific publications and research grants awarded. iUAI Systems is an R&D center formed by 12 faculty members working in areas of computer science, mathematical programming, management science, economy and financial engineering. On the other hand, from the point of view of the industry, the experience of the professors associated to the center includes: natural resources, health, services, telecommunications, transport and logistics, public sector and design of public policies, energy,

production, education, finance, retail and airlines among others.

The **Universidade Federal do Ceará** (UFC) was founded in 1954 on the state of Ceará, located in the northeast of Brazil. In its more than 60 years, it maintains the commitment of serving the region, taking into account the universal needs of its production, and achieving nowadays nearly all knowledge fields represented on its 7 Campi. Its development over the last decade led UFC to a notorious position among the universities in Brazil. For instance, under different criteria and indices, UFC is recently been placed among the two best univesities in the north and northest regions of Brazil and among the 20 best universities in the country.

Currently, UFC has a over 2000 professors, among which around 1500 with PhD, and it has over 30000 students distributed in its 119 undergraduate courses and 94 graduation programs. Among such graduation programs, the "Pós-graduação em Matemática (PGMAT)" has been recently evaluated by CAPES-Brazil with their highest grade 7/7. Four of the researchers of this project belong such program, including its Brazilian coordinator Julio Araujo. Such grade emphasizes the relevance of the program in Brazil, and also its international insertion due to its several collaborations. The **ParGO** (parallelism, graphs and optimization) research group, created in 1999 by UFC researchers is a multidepartamental group, having researchers from the Mathematics, Computer Science and Statistics and Applied Mathematics departments. All researchers have as common interest the resolution of Combinatorial Optimization problems. This research group is nowadays a recognized research team, with an extensive bibliographic production (more than 500 papers, over 150 in journals), several financed projects and estabilished cooperations and it also has organized several events, including the Latin-American Graphs and Optimization Symposium in 2015. The group has currently 13 professors and over 30 graduate students. All the participants of this project belong to ParGO.

B7. Additional information

List all the complementary fundings expected or already obtained.

- ANR Mutimod (Scalable routing in Multi-Modal transportation networks), 2018-2021 https://project.inria.fr/multimod/
- Districting for consistent vehicle routing, Conicyt - Scholarship for PhD Thesis in the Industry, 2018 – 2019.
- FUNCAP-Brazil PRONEM Project PNE-0112-00061.01.00/16 - Problemas em grafos: complexidade e métodos, 2017-2020. Funded by Funcap-Brazil.
- CNPq-Brazil Universal Project 401519/2016-3 - Coloração backbone, coloração gulosa e convexidade cíclica, 2017-2020. Funded by CNPq-Brazil.

Experience of the coordinators in similar projects.

Julio Araujo (Dept. Matemática, UFC)

- Variações Recentes do Problema de Coloração de Grafos, CNPq-Universal, 2014-17, 21kR$~6k€

Nicolas Nisse (Inria, COATI)

- Coordinator of Inria Associated Team AlDyNet with Univ. Adolfo Ibáñez (Santiago, Chile) 2013-18, 15k€/year
- Coordinator of ECOS-Sud-Conicyt C12E03, with Univ. Adolfo Ibáñez, Santiago, Chile, 2013-15, 12k€/year

Karol Suchan (UAI, iUAI Systems)

- Coordinator / Scientific leader of the Chilean part of Inria Associated Team *AlDyNet* with COATI 2013-18, 12k€/year.
- Principal investigator of *The geography of education: a territorial intelligence platform to support the implementation and management of new public policies in education*, Fondef IT15I10010, 2016 – 2018, 202k€.
- Alternate director of *Prototype of a an analytic and interactive system to support desing, development and evaluation of public policies in education*, Fondef CA13i10023, 2014 – 2016, 162k€.
- Principal investigator of *Distributed Algorithms for Network Structure Analysis*, Ecos-Conicyt C12E03, 2013 – 2015, 4.2k€/year.
- Principal investigator of *Epidemic-Like Processes in Social and Communication Networks: Structures, Algorithms and Probabilistic Analysis*, FONDECYT 11090390, 2009 – 2012, 43k€.

Present main activities and their relationship with the project's main goal.

Perspectives of continuing collaboration after project financing is over.

As it was mentioned in the regional aspects, there are already strong collaborations between the groups in Chile and in France, and also between the groups in Brazil and in France. There is no doubt that the approval of this proposal will only strengthen these partnerships that are already well consolidated.

We believe that this project will also be the starting point of along term collaboration between Brazil and Chile as it has excellent chances of being established due to the common interest of both groups in similar problems.

B8. International referees

Suggest names of at least 3 international referees to evaluate the project. These researchers should not be connected to people in the project.

1- Jayme Luiz Szwarcfiter

2- Antonio Fernández Anta

3- Laurent Viennot

Names of referees who should not review this project in your opinion (optional)

1-

2-

B9. Public and private support obtained related to the project:

Participation in a previous STIC AmSud or MATH AmSud project?
NO

Other public support in the past (ECOS, COFECUB, CNRS, European Union, etc.):

Project ECOS-Sud C12E03 (2013-2015) between Inria (N. Nisse) and UAI (K. Suchan)

C. Project Budget

Project title: GALOP

Participating institutions: Inria Sophia Antipolis Méditerranée, Universidad Adolfo Ibanez (UAI) and Universidade Federal do Ceara (UFC).

The STIC-AmSud program **funds travel expenses** (air tickets and *per diem*) to researchers in research missions and workshops.

C1. First year (2019)
Planned missions – Year 1

Researcher	Status	Institution	Origin	Destination	Planned date	Duration	Estimated cost of the trip (€)	Estimate of total *per diem* (€)	Trip and Mission funding institution[1]	Mission objectives
J. Araujo	senior	UFC	Fortaleza	Santiago	December 2019	15	750,00 €	1 500,00 €	CAPES-BRAZIL	O5;O6
N. Nisse	senior	Inria	Nice-Sophia	Fortaleza	May 2019	15	1000€	1 500,00 €	Inria	O3;O8
K. Suchan	senior	UAI	Santiago	Fortaleza	May 2019	15	750,00 €	1 500,00 €	CONICYT	O3;O8
J. Bensmail	junior	UNS	Nice-Sophia	Fortaleza	May 2019	15	1000€	1 500,00 €	Inria	O3;O8
P. Montealegre	junior	UAI	Santiago	Nice-Sophia	September 2019	15	1000€	1 500,00 €	CONICYT	O1;O6
R. Soares	junior	UFC	Fortaleza	Nice-Sophia	September 2019	15	1000€	1 500,00 €	CAPES-BRAZIL	O1;O6

[1] **Each institution will pay for the trip and per diem of its own researchers.**

CONSOLIDATED BUDGET: Year 1

Funding requested to the STIC-AmSud Program
Estimated costs (€)

	A. Travel costs (air tickets)	B- Maintenance costs (*per diem)*	**TOTAL**
INRIA France	2000€	3000€	5000€
CAPES Brazil	1750€	3000€	4 750,00 €
CONICYT Chile	1750€	3000€	4 750,00 €
Total requested funding to STIC-AmSud	5 500,00 €	9 000,00 €	14500€
Other funding[2]			
TOTAL	5 500,00 €	9 000,00 €	14500€

Do you have additional funding sources for this project[3]? (if so please specify the amount and source (s)).

[2] Specify in additional page.
[3] Reserved for CNRS researchers

C2. Second year (2020)

Second year funding depends on approval of intermediate progress report.

Planned missions – Year 2

Researcher	Status (student, junior, senior)	Institution	Origin	Destination	Planned date	Duration (max. 30 days)	Estimated cost of the trip (€)	Estimate of total *per diem* (€)	Trip and Mission funding institution[4]	Mission objectives
V. Campos	senior	UFC	Fortaleza	Nice-Sophia	December 2020	15	1000€	1 500,00 €	CAPES-BRAZIL	O6;O7
F. Havet	senior	CNRS	Nice-Sophia	Fortaleza	May 2020	15	1000€	1 500,00 €	Inria	O1;O7
K. Suchan	senior	UAI	Santiago	Nice-Sophia	May 2020	15	1000€	1 500,00 €	CONICYT	O1;O7
N. Nisse	senior	Inria	Nice-Sophia	Santiago	May 2020	15	1000€	1 500,00 €	Inria	O1;O7
H. Lespay	student	UAI	Santiago	Fortaleza	September 2020	15	750€	1 500,00 €	CONICYT	O2;O4
F. Benevides	senior	UFC	Fortaleza	Nice-Sophia	September 2020	15	1000€	1 500,00 €	CAPES-BRAZIL	O6;O7

[4] **Each institution will pay for the trip and per diem of its own researchers.**

CONSOLIDATED BUDGET: Year 2

Funding requested to the STIC-AmSud Program
Estimated costs (€)

	A. Travel costs (air tickets)	B- Maintenance costs (*per diem)*	**TOTAL**
INRIA France	2000€	3000€	5000€
CAPES Brazil	2000€	3000€	5 000,00 €
CONICYT Chile	1750€	3000€	4 750,00 €
Total requested funding to STIC-AmSud	5 750,00 €	9 000,00 €	14500€
Other funding[5]			
TOTAL	5 750,00 €	9 000,00 €	14750€

Do you have additional funding sources for this project[6]? (if so please specify the amount and source (s)).

[5] Specify in additional page.
[6] Reserved for CNRS researchers

C3. BUDGET TOTALS

	Year 1	**Year 2**	**Total**
Funding requested to INRIA (France)	5000€	5000€	**10000**€
Funding requested to CAPES (Brazil)	4750€	5000€	**9750**€
Funding requested to CONICYT (Chile)	4750€	4750€	**9500**€
Matching funds from the partners	14500€	14750€	**29250**€
Other sources			
TOTAL	**14500**€	**14750**€	**29250**€

ANNEX: CV Nicolas Nisse (http://lattes.cnpq.br/1042258732882033)

1/ Personal data

Name: Nicolas NiSSE **Birth date:** 26/11/1980

Professional address (with telephone and e-mail): email:nicolas.nisse@inria.fr

Inria, 2004 route des Lucioles, BP 93, phone: +33 (0)4 97 15 53 28

06902 Sophia Antipolis, France http://www-sop.inria.fr/members/Nicolas.Nisse/

Current job title and size of the research group: Chargé de Recherche (CRCN) Inria, France

2/ Highest obtained degree (with indication of place and date)

- Habilitation thesis (HDR) from Univ. Nice Sophia Antipolis (May 26th 2014)
- PhD in Computer Science from Univ. Paris Sud 11 (July 2nd 2007)

3/ Professional activity in the last 5 years

Nicolas Nisse is a full time researcher at Inria since 2009 inside the joint team Coati between Inria and I3S (CNRS, University of Nice-Sophia Antipolis) laboratory. His research interests include **Graph Theory** and **Algorithms**. His work mainly focuses on information spreading problems in telecommunication networks (routing, virus spreading, etc.). His expertise concerns the design of algorithms using structural properties (e.g., **graph decompositions**) of networks. He is/has been the coordinator of several collaboration with Univ. Adolfo Ibanez (Associated team, project ECOS-Sud).

4/ Other duties/ positions

- Member of the Scientific Committee of Académie 1 of UCA Jedi
- Member of the Bureau of the GT CoA of the gdr IM (Informatique et Mathématiques)
- Member of Program Committee of LAGOS'15, Ad-Hoc Now'15, FCT'17, SEA'18, CIAC'19.
- Reviewers: SIAM J. on Discrete Maths., Distributed Computing, Transaction on Algorithms, Theoretical Computer Science, Discrete Applied Mathematics, etc., STOC, SODA, PODC, DISC, STACS, MFCS, WG...
- Teaching at master level in Univ. Nice Sophia Antipolis, and in classes préparatoires at Lycée International de Valbonne (Sophia Antipolis)

5/ Awards, fellowships and external recognition

6/ Ongoing funded research projects with dates, titles, sources of funding

- Coordinator / Scientific leader of the Inria Associated Team AlDyNet with Univ. Adolfo Ibanez (Santiago, Chile) 2013-18, 12k€/year

- Member of ANR Multimod, Scalable routing in Multi-Modal transportation networks, 2018-21

7/ Projects approved in the least 5 years

8/ Publications (names of members of the project are in bold)

8.1 – Highlight the most important publications related to the project theme

- N. Cohen, N. **Martins**, F. **McInerney**, N. **Nisse**, S. Pérennes and R. **Sampaio**. Spy-game on graphs: Complexity and simple topologies. *Theor. Comput. Sci*. 725: 1-15, 2018.
- D. **Coudert**, G. Ducoffe and N. **Nisse**, To approximate treewidth, use treelength! *SIAM Journal of Discrete Maths*, Volume 30(3), pages 1424-1436, 2016.
- **J. Araujo,** G. Ducoffe**, N. Nisse** and **K. Suchan**. On Interval Number in Cycle Convexity. To appear in *Discrete Mathematics and Theoretical Computer Science*.

- D. **Coudert**, D. Mazauric and N. **Nisse**. Experimental Evaluation of a Branch and Bound Algorithm for computing Pathwidth. *Journal of Experimental Algorithmics*, Volume 21:1, 2016.
- B. Bosek, P. Gordinowicz, J. Grytczuk, N. **Nisse**, J. Sokól, M. Sleszynska-Nowak. Localization game on geometric and planar graphs. To appear in *Discrete Applied Maths*.
- B. Li, F.Z. Moataz, N. **Nisse** and K. **Suchan**, Minimum Size Tree-Decompositions. To appear in *Discrete Applied Maths*.
- M.M. Kanté, F.Z. Moataz, B. Momège, N. **Nisse** Finding Paths in Grids with Forbidden Transitions. 41st Int. Workshop on Graph-Theoretic Concepts in Comp. Sc., Springer, 2015.
- A. Kosowski, B. Li, N. **Nisse** and K. **Suchan**. k-Chordal Graphs: from Cops and Robber to Compact Routing via Treewidth. *Algorithmica*, Volume 72(3), pages 758-777, 2015.
- J. **Araujo**, V. Campos, F. **Giroire**, N. **Nisse**, L. Sampaio and R.P. **Soares**, On the hull number of some graph classes. *Theoretical Comp. Science*, Vol. 475, pages 1-12, 2013.

8.2 – Other Publications in cooperation with the project partners

- N. **Nisse** and R.P. **Soares**. On the monotonicity of Process Number. *Discrete Applied Maths*, Volume 210, pages 103-111, 2016
- F. **Giroire**, I. Lamprou, D. Mazauric, N. **Nisse**, S. Pérennes and R. P. **Soares**. Connected Surveillance Game. *Theoretical Computer Science*, Volume 584, pages 131-143, 2015.
- G. D'Angelo, G. Di Stefano, A. Navarra, N. **Nisse**, K. **Suchan**. Computing on rings by oblivious robots: a unified approach for different tasks. *Algorithmica*, Vo. 72(4), pp 1055-1096, 2015.
- F. Becker, A. Kosowski, M. Matamala, N. **Nisse**, I. Rapaport, K. **Suchan**, and I. Todinca. Allowing each node to communicate only once in a distributed system: shared whiteboard models. *Distributed Computing*, Volume 28(3), pages 189-200, 2015.
- J. **Araujo**, N. **Nisse** and S. Pérennes. Weighted Coloring in Trees. Proceedings of STACS 2014. *SIAM Journal of Discrete Maths*, Volume 28(4), pages 2029-2041, 2014.
- N. **Nisse**, I. Rapaport and K. **Suchan**, Distributed computing of efficient routing schemes in generalized chordal graphs. *Theoretical Comp. Sc.,* Vol. 444(27), pages 17-27, 2012.
- N. Cohen, D. **Coudert**, D. Mazauric, N. **Nepomuceno** and N. **Nisse**, Tradeoffs in process strategy games with application in the WDM reconfiguration problem. *Theoretical Computer Science*, Volume 412(35), pages 4675-4687, 2011.
- F.V. Fomin, P. Golovach, J. Kratochvil, N. **Nisse** and K. **Suchan**, Pursuing a fast robber on a graph. *Theoretical Computer Science*, Volume 411(7-9), pages 1167-1181, 2010.

9/ Theses oriented and post-doctoral fellows supervised

- Fionn Mc Inerney, Combinatorial Games in Graphs, Ph.D. thesis, since Oct. 2016.

9.1 – Finished/defended in the last 5 years

- Ronan Pardo Soares, Pursuit-Evasion, Decompositions and Convexity on Graphs, Ph.D. thesis, Univ. Federal do Ceara and Univ. Nice Sophia Antipolis, November 12th, 2013.
- Bi Li, Tree Decompositions and Routing Problems, Ph.D. thesis, Univ. Nice Sophia Antipolis, defended on November 14th, 2014.

Julio ARAUJO

Curriculum Vitae

1/ Personal data

Name: Júlio César Silva Araújo **Birth date: 22 April 1985**

Professional address (with telephone and e-mail):

Universidade Federal do Ceará, Centro de Ciências, Departamento de Matemática. Bloco 914. Campus do Pici. 60.440-900 - Fortaleza, CE – Brasil.

Phone: +55 (85) 33669313 - Website URL: www.mat.ufc.br/~julio

Current job title and size of the research group:

Professor at Department of Mathematics of Universidade Federal do Ceará.

ParGO Research Group (13 researches, 17 PhD and 16 master students) www.lia.ufc.br/~pargo

2/ Highest obtained degree (with indication of place and date)

Ph.D. in Computer Science. Co-guardianship between Universidade Federal do Ceará (Advisor: Cláudia Linhares Sales), UFC, Brazil, and Université de Nice Sophia Antipolis (Advisors: Jean-Claude Bermond e Frederic Giroire). *Year of degree:* Septembre 2012.

3/ Professional activity in the last 5 years

Julio Araujo has been a professor at the Department of Mathematics of Universidade Federal do Ceará since February 2014. Before, he was a post-doctoral fellow in the COATI team at INRIA Sophia Antipolis, France, from September 2012 to October 2013. From 2009 to 2012 he was a PhD student in a co-guardianship between the Universidade Federal do Ceará (Advisor: Cláudia Linhares Sales), UFC, Brazil, and Université de Nice Sophia-Antipolis (Advisors: Jean-Claude Bermond and Frédéric Giroire).

4/ Other duties/ positions

Coordinator of the undergraduation course: Licenciatura em Matemática (2015-2016).

5/ Awards, fellowships and external recognition

- Research Productivity Grant – Level 2 – CNPq Brazil – Research grant to develop the project entitled “Novos parâmetros em Coloração e Convexidade em grafos”. Feb 2016- Feb 2019.

- Wilkes Award 2017 - ARAUJO, J.; GIROIRE, F.; LIU, Y.; MODRZEJEWSKI, R.; MOULIERAC, J. Energy Efficient Content Distribution. Computer Journal, vol. 59(2), 2016, pp. 192-207. URL: https://academic.oup.com/comjnl/pages/Wilkes_award

6/ Ongoing funded research projects with dates, titles, sources of funding

- PROBRAL Project - Graph Coloring: Extremal Combinatorics, Graph Theory and Algorithms, project member, 2018-2020. Funded by CAPES-Brazil and DAAD-Germany.

- PRONEM Project - Problemas em grafos: complexidade e métodos, project member, 2017-2020. Funded by Funcap-Brazil.

- Universal Project - Coloração backbone, coloração gulosa e convexidade cíclica, project member, 2017-2020. Funded by CNPq-Brazil.

7/ Projects approved in the least 5 years

- Variações Recentes de Coloração de Grafos, project coordinator, Universal Project 459466/2014-3, CNPq-Brazil, Nov 2014 - Mar 2018.

- Redes Sociais e Particionamento de Grafos, post-doctoral project, funded by CNPq-Brazil, Sep 2012 – Oct 2013.

8/ Publications

8.1 – Highlight the most important publications related to the project theme

Journals:

1. ARAUJO, J. ; MOREL, G. ; SAMPAIO, L. ; SOARES, R. ; WEBER, V. Hull number: P5-free graphs and reduction rules. Discrete Applied Mathematics, vol. 210, September 2016, pp. 171-175.
2. ARAUJO, J. ; CAMPOS, V. ; GIROIRE, F. ; NISSE, N. ; SAMPAIO, L. ; SOARES, R. On the hull number of some graph classes. Theoretical Computer Science, p. 1-12, 2013.
3. ARAUJO, J.; F.; CEZAR, A. A.; SILVA, A. On the Existence of Tree Backbones that Realize the Chromatic Number on a Backbone Coloring. Journal of Graph Theory, vol. 85(4), August 2017, pp. 808-813.
4. ARAUJO, J.; DUCOFFE, G.; NISSE, N.; SUCHAN, K. On interval number in cycle convexity. Discrete Mathematics and Theoretical Computer Science, 2018+, to appear.

8.2 – Publications in cooperation with the project partners

Journals:

1. ARAUJO, J.; F. HAVET; C. LINHARES SALES; A. SILVA. Proper orientation of cacti. Theoretical Computer Science, vol. 639, August 2016, pp. 14-25.
2. ARAUJO, J.; GIROIRE, F.; LIU, Y.; MODRZEJEWSKI, R.; MOULIERAC, J. Energy Efficient Content Distribution. Computer Journal, vol. 59(2), 2016, pp. 192-207.
3. ARAUJO, J.; COHEN, N.; DE REZENDE, S.F.; HAVET, F.; MOURA, P. On the proper orientation number of bipartite graphs. Theoretical Computer Science, vol. 566, February 2015, pp. 59-75.
4. Araujo, J. ; NISSE, N. ; PERENNES, S. Weighted Coloring in Trees. SIAM Journal on Discrete Mathematics (Print), v. 28, p. 2029-2041, 2014.
5. Araujo, Julio ; Bermond, Jean-Claude ; DUCOFFE, GUILLAUME. Eulerian and Hamiltonian Dycicles in Directed Hypergraphs. Discrete Mathematics, Algorithms and Applications, v. 06, Issue 01, 2013.
6. Araujo, J. ; Bermond, J-C. ; GIROIRE, F. ; HAVET, F. ; MAZAURIC, D. ; MODRZEJEWSKI, R. Weighted improper colouring. Journal of Discrete Algorithms, v. 16, p. 53-66, 2012.
7. Araujo, J. ; COHEN, N. ; GIROIRE, F. ; HAVET, F. Good edge-labelling of graphs. Discrete Applied Mathematics, v. 160, p. 2502-2513, 2012.

Due to space constraints, works in conferences and research reports are not listed.

See http://lattes.cnpq.br/7659965567201224 for more information.

ANNEX: CV Karol Suchan

1/ Personal data

Name: Karol SUCHAN **Birth date:** 21/11/1979

Professional address (with telephone and e-mail):

Universidad Adolfo Ibáñez, Av. Diagonal las Torres 2640, email:karol.suchan@uai.cl

7941169 Peñalolén, Santiago, Chile phone: +56 2 2331 1533

Current job title and size of the research group:

Associate Professor, iUAI Systems, UAI, Chile (http://ingenieria.uai.cl/centros/systems/): 12

2/ Highest obtained degree (with indication of place and date)

- PhD in Computer Science from Université d'Orléans (December 12, 2006)

3/ Professional activity in the last 5 years

Karol Suchan is an associate professor in the Faculty of Engineering and Sciences at the Universidad Adolfo Ibáñez. He has been a principal researcher in Fondecyt, Ecos-Conicyt, Inria Associated Team, Anillo, Fonide, and Fondef projects. He is dedicated to the study of graph theory and algorithms (sequential and distributed), and their applications in decision support systems. In his theoretical work, he is particularly interested in algorithms for analysis of graph structure, diffusion processes in graphs, and optimization problems like routing and assignment. As for applications, he works on topics in production, supply chain management (especially, distribution), and accessibility of public services.

4/ Other duties/ positions

- Reviewer for journals: Discrete Applied Mathematics, Information and Computation, Information Processing Letters, Optimization, SIAM Journal on Discrete Mathematics, Theoretical Computer Science.
- Reviewer for conferences: LAGOS, SODA, STACS, WG.

5/ Awards, fellowships and external recognition

6/ Ongoing funded research projects with dates, titles, sources of funding

- Coordinator / Scientific leader of the Chilean part of Inria Associated Team *AlDyNet* with COATI 2013-18, 12k€/year.
- PhD advisor of *Districting for consistent vehicle routing*, Conicyt - Scholarship for PhD Thesis in the Industry, 2018 – 2019, 48k€.
- Principal investigator of *The geography of education: a territorial intelligence platform to support the implementation and management of new public policies in education*, Fondef IT15I10010, 2016 – 2018, 202k€.

7/ Projects approved in the last 5 years

- Alternate director of *Prototype of a an analytic and interactive system to support desing, development and evaluation of public policies in education*, Fondef CA13i10023, 2014 – 2016, 162k€.
- Principal investigator of *Distributed Algorithms for Network Structure Analysis*, Ecos-Conicyt C12E03, 2013 – 2015, 4.2k€/year.
- Associated investigator of *Mathematical Modeling for Industrial and Management Science Applications: An Interdisciplinary Approach*, ANILLO ACT-88, 2010 – 2013, 202k€/year.

8/ Publications (names of members of the project are in bold)

8.1 – Highlight the most important publications related to the project theme

- **J. Araujo,** G. Ducoffe**, N. Nisse** and **K. Suchan**. On Interval Number in Cycle Convexity. *Discrete Mathematics and Theoretical Computer Science 20(1), 2018*.
- B. Li, F.Z. Moataz, N. **Nisse** and K. **Suchan**, Minimum Size Tree-Decompositions. *Discrete Applied Mathematics, https://doi.org/10.1016/j.dam.2017.01.030, online*.
- A. Kosowski, B. Li, N. **Nisse** and K. **Suchan**. k-Chordal Graphs: from Cops and Robber to Compact Routing via Treewidth. *Algorithmica*, Volume 72(3), pages 758-777, 2015.
- **N. Nisse**, I. Rapaport, **K. Suchan**, Distributed computing of efficient routing schemes in generalized chordal graphs,, Theoretical Computer Science 444: 17-27, 2012.
- I. Rapaport, **K. Suchan**, I. Todinca, J. Verstraete, On Dissemination Thresholds in Regular and irregular graph classes, Algorithmica, 59:16-34, 2011.

8.2 – Other Publications in cooperation with the project partners

- G. D'Angelo, G. Di Stefano, A. Navarra, **N. Nisse**, **K. Suchan**, Computing on rings by oblivious robots: a unified approach for different tasks, Algorithmica 72(4):1055-1096, 2015.
- F. Becker, A. Kosowski, M. Matamala, **N. Nisse**, I. Rapaport, **K. Suchan**, I. Todinca, Allowing each node to communicate only once in a distributed system: shared whiteboard models, Distributed Computing 28(3):89-200, 2015.
- F. V. Fomin, P. Golovach, J. Kratochvíl, **N. Nisse**, **K. Suchan**, Pursuing Fast Robber in a Graph, Theoretical Computer Science 411(7-9):1167-1181, 2010.

9/ Theses oriented and post-doctoral fellows supervised

- H. Lespay, On the problem of territory design for vehicle routing with consistency in service, Ph.D. in Industrial Engineering and Operations Research, Universidad Adolfo Ibáñez, Chile, in progress.
- S. Muñoz, Complexity considerations in Rich Vehicle Routing Problems, Ph.D. in Complex Systems Engineering, Universidad Adolfo Ibáñez, Chile, in progress.

9.1 – Finished/defended in the last 5 years

Nicolas Nisse
Tel: +33 (0)4 97 15 53 28
E-mail: nicolas.nisse@inria.fr

Sophia Antipolis, May 13, 2018

Object: *Project SticAmsud between UFC, Inria and UAI.*

By this letter, I confirm that I will be the international coordinator of the project "Graphs ALgorithms for Optimization Problems" (GALOP)

a collaboration between

- Inria Sophia Antipolis, France (coordinator: Nicolas Nisse)
- Universidade Federal do Ceara, Fortaleza, Brazil (coordinator: Julio Araujo)
- Universidad Adolfo Ibanez, Santiago, Chile (coordinator: Karol Suchan)

Nicolas Nisse
Chargé de recherche Inria
http://www-sop.inria.fr/members/Nicolas.Nisse/

INVENTORS FOR THE DIGITAL WORLD

To: STIC AmSud

Sophia Antipolis, 14th May 2018

Object : Letter of support for the proposal « GALOP » for STIC AmSud Program 2018.

To whom it may concern,

I, herewith, confirm the participation of the Inria Sophia-Antipolis Méditerranée research Center to the STIC-AmSud program with the proposal entitled « Graphs ALgorithms for Optimization Problems » (GALOP). For the French participation, the proposal will be coordinated by the Inria team project COATI under the scientific responsability of Dr. Nicolas Nisse.

The project throughout the STIC AmSud program would come to strengthen and develop the scientific partnerships of the COATI team project with both Brazil and Chile, in the continuation of some ongoing collaborations involving the three partners : Universidade Federal do Ceara (UFC), Fortaleza, Brazil and the Universidad Adolfo Ibanez (UAI), Santiago, Chile.

Centre de Recherche de Sophia-Antipolis Méditerranée
Inria

David Simplot

Director of Inria Research Center Sophia-Antipolis Méditerranée

UNIVERSIDADE FEDERAL DO CEARÁ

To:
STIC AmSud

Date :
Fortaleza, 14th May 2018

Object : Letter of support for the proposal « GALOP » for STIC AmSud Program.

To whom it may concern,

We, herewith, confirm the participation of the Federal University of Ceará (UFC) to the STIC-AmSud program with the proposal entitled « Graphs ALgorithms for Optimization Problems » (GALOP). For the Brazilian participation, the proposal will be coordinated by Prof. Dr. Júlio Araújo, member of the Mathematics Department of UFC, and the international coordination is under responsability of Dr. Nicolas Nisse, member of COATI team in the INRIA Sophia Antipolis research center.

The project throughout the STIC AmSud program would come to strengthen and develop the scientific partnerships of the Federal University of Ceará with both France and Chile, in the continuation of some ongoing collaborations involving the three partners : Federal University of Ceará, Fortaleza, Brazil, Université de Nice Sophia-Antipolis (UNS), Sophia Antipolis, France and the Universidad Adolfo Ibanez (UAI), Santiago, Chile.

Prof. Dr. Alexandre César Gurgel Fernandes
Coordinator of the Graduation Program in Mathematics
Federal University of Ceará

Marcelo Ferreira de Melo
Chefe do Departamento de Matemática
da UFC

Prof. Dr. Alexandre César Gurgel Fernandes
Coordenador da Pós-Graduação

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