Inria International program
Associate Team final report

Associate Team acronym: AlDyNet

Period of activity: *Indicate the 3-years or 6-years of activity of the team. For teams that were renewed for a second 3-years period, the rest of this report is only concerned with the last 3-years.*

2013-2015

Principal investigator (Inria): *Name and Inria project team of the principal investigator on the INRIA side.*

Nicolas NISSE, COATI

Principal investigator (partner): *Name and main affiliation (university, research center...) of the principal investigator on the partner side.*

Karol SUCHAN, Universidad Adolfo Ibáñez, Santiago, Chile

Other participants: *If the project involve other partners on either side name them here (Inria project team, university, research center...).*

We also have collaborated with colleagues from the Departemento de Ingeneria Informatica at the Universidad de Chile, Santiago: Marcos Kiwi, Martin Matamala, Ivan Rapaport and Mauricio Soto.

1 Overview of the activities

Outline the overall activity of the associate team over the 3-year period: visits, events organized, etc...

We summarize below the visits that have been organized:

- Chile to France
  - Eduardo Moreno: November 2nd to November 6th 2015. (1 week)
  - Esteban Roman Catafau (Ph.D. student), October 2015. (1 month)
  - Karol Suchan: September 7th to September 23th, 2014. (2 weeks)
  - Esteban Roman Catafau (Ph.D. student): May-July, 2014. (3 months)
  - Klaus Jaschan (Ms. student): internship December 2013- February 2014 (2 months)
  - Esteban Roman Catafau (Ph.D. Student): September 9th to October 6th, 2013. (1 month)
  - Karol Suchan: September 9th to September 25th, 2013. (2 weeks)
- France to Chile
  - David Coudert: November 21th to December 5th, 2015. (2 weeks)
  - Guillaume Ducoffe (Ph.D. Student): Nov. 21th to Dec. 5th, 2015. (2 weeks)
  - Nicolas Nisse: November 13th to November 27th, 2015. (2 weeks)
  - Frédéric Giroire: November 13th to November 27th, 2015. (2 weeks)
  - David Coudert: April 3rd to April 19th, 2015. (2 weeks)
  - Nicolas Nisse: November 14th to December 14th, 2014. (1 month)
  - Guillaume Ducoffe (Ph.D. Student): Nov. 14th to Dec.14th, 2014. (1 month)
  - David Coudert: November 14th to November 30th, 2014. (2 weeks)
  - Nicolas Nisse: November 14th to November 30th, 2013. (2 weeks)
  - Fatima Moataz (Ph.D. Student): Nov. 14th to Dec. 12th, 2013 (1 month)
  - Bi Li (Ph.D. Student): November 14th to December 12th, 2013. (1 month)
  - David Coudert: November 14th to November 30th, 2013. (2 weeks)

During the visit of COATI members in Santiago in November 2013, we have organized and participate to the AlDyNet Workshop on Algorithms and Randomness, UAI, Santiago, Chile November 21, 2013.

2 Scientific achievements

Briefly describe the scientific results obtained with the support of this associate team (including on-going research).

During the first year of the AlDyNet associated team between COATI and the Universidad Adolfo Ibáñez (Santiago, Chile), we have pursued ongoing research work on distributed computing through the coordination of mobile agents on graphs. We also have continued our work on particular graph decompositions (defined in a joint work in ICALP 2012), focusing on their algorithmic applications on planar graphs. Furthermore, we have started collaboration on new topics, namely the design of exact and heuristic algorithms for computing path-decompositions of graphs.

During the second year of AlDyNet, we have pursued ongoing research work on the design of exact and heuristic algorithms for computing path-decompositions of graphs. We have worked on the computation of other graph parameters such as the minimum size of a tree decomposition and the hyperbolicity of large graphs. We also have finalized our work on distributed computing through the coordination of mobile agents on graphs.

During the third year of AlDyNet, we have pursued our study of efficient algorithms for computing graph properties. In particular, we have designed an efficient approximation algorithm for the treewidth of graphs [9]. We also have initiated a collaboration with the Territorial Intelligence Center (TIC) of Universidad Adolfo Ibáñez on the transportation networks of Santiago. In collaboration with Chilean government, we have collected data on education, transportation, urban infrastructure, etc. The TIC uses a Geographical Information System software called ArcGIS to deal with this data. In a metropolitan area like that of Santiago de Chile, the model has to include information on some 40.000 blocks (set of buildings surrounded by streets) in a network with some 150.000 junctions. In this setting, ArcGIS takes hours to compute a complete origin-destination distance matrix for all blocks, a fundamental input to all further analysis. There is room for improvements here. We aim at using our expertise in graph algorithms in order to extract meaningful information about topological and metric structures of Santiago agglomeration. We then will be working on this data to develop decision support tools, for example, for improving quality education accessibility. We have initiated this work with the difficult task of correcting errors in the maps created by human users of ArcGIS and merging maps coming from different sources.

We expect to continue this work thanks to a prolongation of the AlDyNet associated team.

Below we detail further the main scientific achievements of AlDyNet.

- Distributed computing through the coordination of mobile agents on graphs [5,6,17,23].

  Consider a set of mobile robots with minimal capabilities placed over distinct nodes of a discrete anonymous ring (neither nodes nor edges are labeled). They operate on the basis of the so called Look-Compute-Move cycle. Asynchronously, each robot takes a snapshot of the ring, determining which nodes are either occupied by robots or empty. Based on the observed configuration, it decides whether to move to one of its adjacent nodes or to stay idle. In the first case, it performs the computed move, eventually. The computation also depends on the required task. We have proposed a unified approach to solve three important problems in the field: the exclusive perpetual exploration, the exclusive perpetual graph searching and the gathering problems. We investigate these tasks in the famous CORDA distributed computing model where the robots cannot communicate but can perceive the positions of other robots. Besides being a unified approach for the three different tasks, the given algorithms solve some open problems. Moreover, we provide some impossibility results for the perpetual graph searching problem. Then, we solved both the well-known Searching and Gathering tasks. In the literature, most contributions are restricted to a subset of initial configurations. Here, we design two different algorithms and provide a full characterization of the initial configurations that permit the resolution of the problems under minimal assumptions.

Our work on the coordination of mobile agents in graphs has been published in international conferences [17,23] and an international revue [5]. We also have worked on testing graph properties in a distributed setting. This work has been published in an international revue [6].

- Path-decomposition of graphs [15,21,22].

  Graph decompositions are a way to decompose graphs into small pieces (subsets of nodes) that are arranged in order to preserve the connectivity properties. They are widely used by dynamic programming algorithms (divide and conquer) in order to solve efficiently graph problems that are difficult in general. More precisely, many NP-hard problems (coloring, maximum independent set) can be solved in linear time in the class of graphs with small width (the size of the pieces). One prerequisite for running this kind of algorithms is the computation of good graph decompositions, which itself is a NP-hard problem. Our contribution here concerns the computation of good path-decompositions of graphs. Informally, a path-decomposition of a graph corresponds to a linear ordering of its vertices associated to a measure (its width). Since this is a NP-hard problem, we have focused on the design of an exact branch-and-bound algorithm and a set of heuristics. Our algorithm outperforms all previous work and it is able to compute the exact pathwidth of all graphs with up to 80 vertices [15]. During its internship in the COATI team (from December 2013 till February 2014), Klaus Jaschan has implemented other algorithms that will be used to evaluate the performance of our algorithm [21]. During its visit in the COATI team (May-July 2014), Esteban Roman has pursued these investigations [22]. Our work has been validated in an international conference [15].

- Graph searching games for the decompositions of directed graphs [24,25].

  Graph searching games involve a team of searchers that aims at capturing a fugitive in a graph. These games have been widely studied for their relationships with tree- and path-decomposition of graphs. In order to define decompositions for directed graphs, similar games have been proposed in directed graphs. In this paper, we consider such a game that has been defined and studied in the context of routing reconfiguration problems in WDM networks. Namely, in the processing game, the fugitive is invisible, arbitrary fast, it moves in the opposite direction of the arcs of a digraph, but only as long as it has access to a strongly connected component free of searchers. We prove that the processing game is monotone which leads to its equivalence with a new digraph decomposition.

  This work has been validated by an international publication [24].

- Tree-decompositions with small size. [7,9,14,19]

  Computing efficiently good tree-decomposition of graphs is a very challenging problem. To tackle this problem, we focus on tree-decompositions that must satisfy extra constraints. In [7], we designed an efficient polynomial-time algorithm that either find a large cycle in a graph or compute a tree-decomposition whose pieces have particular structural properties. We can use such structure to design efficient compact routing schemes. Then, during the visit of members of COATI in Santiago (Nov. 2013), we started investigating the problem of minimizing the size of tree-decompositions (minimizing the number of pieces with fixed size). Since then, we have obtained several complexity results and algorithms for this problem [9,14].

- Computation of hyperbolicity in large graphs [2,12,13,18].

  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). 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 (such as the Autonomous Systems network of the Internet), 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 $n^{3,69}$ which is far to be efficient for large scale networks. Hence, better algorithms are needed that are dedicated to networks with particular structural properties. First, we have applied the so-called clique-minimal decomposition to speed-up the computation of the parameter [18]. Our algorithm is now included in SageMath and has allowed to compute the exact hyperbolicity of large scale networks such as the AS network. We then improved the time complexity for the recognition of graphs with small hyperbolicity, and we proved our new algorithm is optimal under subcubic reductions [13]. Our lower bound relies on the fact that deciding whether a graph has hyperbolicity 1/2 is equivalent to find induced cycles of 4 nodes in graphs. This work is the starting point of one of our objectives for next year. Namely, we aim at relating metric properties of graphs (hyperbolicity) with their topological properties (treewidth). See Section 3. Part of this work has been published in an international revue [13]. The other part is currently submitted [18].

  We currently study the hyperbolicity of random graphs [2].

- Optimization in geographical networks [1,4].

  In view of our work on the transportation network of Santiago, we have worked on optimization problems in this context. In [4], we have studied the computational complexity of finding paths in a network with forbidden transitions (typically a city with no turn left/right signs...). We are also working on some modeling of spreading information in a network through the notion of convexity of graphs [1].

3 Production

List the scientific production that benefited from the support of the associate team: publications, software, manuscripts, PhD or master thesis, etc... Feel free to add any relevant information to appreciate the impact of these productions.

Members of the associated team are indicated in bold.

1. Julio Araujo, **Guillaume Ducoffe, Nicolas Nisse, and Karol Suchan**. Instantaneous cycle convexity. in preparation.

2. **David Coudert, Marcos Kiwi**, Dieter Mitsche. On the hyperbolicity of random hyperbolic graphs. In preparation.

3. **David Coudert, Guillaume Ducoffe, Nicolas Nisse, and Mauricio Soto**. Existence of a distance-preserving ordering is hard. In preparation.

4. Mamadou M. Kante, **Fatima Zahra Moataz**, Benjamin Momège and **Nicolas Nisse**, Finding Paths in Grids with Forbidden Transitions. In 41st International Workshop on Graph-Theoretic Concepts in Computer Science (WG), LNCS, Springer, 2015.

5. Gianlorenzo D'Angelo, Gabriele Di Stefano, Alfredo Navarra, **Nicolas Nisse** and **Karol Suchan**. Computing on rings by oblivious robots: a unified approach for different tasks. Algorithmica, Volume 72(4), pages 1055-1096, 2015.

6. Florent Becker, Adrian Kosowski, **Martin Matamala, Nicolas Nisse, Ivan Rapaport, Karol Suchan**, and Ioan Todinca. Allowing each node to communicate only once in a distributed system: shared whiteboard models. Distributed Computing, Volume 28(3), pages 189-200, 2015.

7. Adrian Kosowski, **Bi Li, Nicolas Nisse and Karol Suchan**. k-Chordal Graphs: from Cops and Robber to Compact Routing via Treewidth. Algorithmica, Volume 72(3), pages 758-777, 2015.

8. Serge Gaspers, Mathieu Liedloff, Maya Stein and **Karol Suchan**. Complexity of Splits Reconstruction for Low-Degree Trees. Discrete Applied Mathematics, Volume 180, pages 89-100, 2015.

9. **Bi Li, Fatima Zahra Moataz, Nicolas Nisse and Karol Suchan**, Minimum Size Tree-Decompositions. In 8th Latin-American Algorithms, Graphs and Optimization Symposium (LAGOS), 2015.

10. Julio Araujo, **Nicolas Nisse and Stéphane Pérennes**. Weighted Coloring in Trees. SIAM J. Discrete Math. 28(4): 2029-2041, 2014

11. **Fatima Zahra Moataz**. Towards Efficient and Fault-Tolerant Optical Networks: Complexity and Algorithms. Ph.D. thesis, Univ. Nice Sophia Antipolis, October 30th, 2015.

12. **David Coudert, Guillaume Ducoffe and Nicolas Nisse**, Diameter of Minimal Separators in Graphs. Research Report, INRIA-RR-8639, HAL, Sophia Antipolis, France, Nov. 2014.

13. **David Coudert, Guillaume Ducoffe**. On the recognition of C4-free and 1/2-hyperbolic graphs. SIAM J. Discrete Math. 28(3): 1601-1617 (2014)

14. **Bi Li, Fatima Zahra Moataz, Nicolas Nisse and Karol Suchan**, Minimum Size Tree-Decompositions. Extended abstract in 9th International colloquium on graph theory and combinatorics (ICGT), 2014 (no Proceedings). [Research Report], 2014, pp. 23. hal-01074177

15. **David Coudert**, Dorian Mazauric and **Nicolas Nisse**. Experimental Evaluation of a Branch and Bound Algorithm for computing Pathwidth. In 13rd Symposium on Experimental Algorithms (SEA), LNCS, Springer, pages 46-58, 2014.

16. Julio Araujo, **Nicolas Nisse and Stéphane Pérennes**. Weighted Coloring in Trees. 31st Symposium on Theoretical Aspects of Computer Science (STACS), Schloss Dagstuhl, pages 75-86, 2014.

17. Gianlorenzo D'Angelo, Alfredo Navarra and **Nicolas Nisse**. Gathering and Exclusive Searching on Rings under Minimal Assumptions. In Proceedings of the 15th International Conference on Distributed Computing and Networking (ICDCN), LNCS, Springer, pages 149-164, 2014.

18. Nathann Cohen, **David Coudert, Guillaume Ducoffe**, and Aurélien Lancin. Applying clique-decomposition for computing Gromov hyperbolicity. [Research Report], 2014, pp. 30. RR-8535

19. **Bi Li**, Tree Decompositions and Routing Problems. Ph.D. thesis, Univ. Nice Sophia Antipolis, November 12th, 2014.

20. **Nicolas Nisse**, Algorithmic complexity: Between Structure and Knowledge How Pursuit-evasion Games help. HDR, Univ. Nice Sophia Antipolis, May 26th, 2014.

21. **Esteban Roman Catafau**, Analysis of a Branch and Bound algorithm for pathwidth, internship report, May-July 2014.

22. **Klaus Jaschan**, Implementing a Vertex Separation algorithm for trees in Sagemath, internship report, Dec. 2013- Feb. 2014.

23. Gianlorenzo D'Angelo, Gabriele Di Stefano, Alfredo Navarra, **Nicolas Nisse and Karol Suchan**. A unified approach for different tasks on rings in robot-based computing systems. In Proceedings of the 15th Workshop on Advances in Parallel and Distributed Computational Models (APDCM), IEEE, 2013.

24. **Nicolas Nisse and Ronan Soares**. On the monotonicity of Process Number. In Proceedings of 7th Latin-American Algorithms, Graphs and Optimization Symposium (LAGOS), Elsevier, to appear in Electronic Note Discrete Maths, 2013.

25. **Ronan Pardo Soares**, Pursuit-evasion, decompositions and convexity on graphs. Ph.D. thesis, Univ. Nice Sophia Antipolis, November 8th, 2013.

4 Future of the partnership

Common activities foreseen/ expected, will the collaboration pursue after the end of the Associate Team?

We hope to pursue the collaboration and have asked for a prolongation of the associated team AlDyNet. During these 3 years, we have established new contacts with researchers from Universidad de Chile (Santiago). In particular, David Coudert has initiated a collaboration with Marcos Kiwi (full professor, Departamento de Ingeniera Matemtica, Universidad de Chile). We have included Marcos Kiwi in the proposal for the prolongation of the associated team.

The continuation of the collaboration will mainly focus on the public transportation problem that we have initiated during 2015. In particular, we have started collaborating with members of the Territorial Intelligence Center (TIC) of Universidad Adolfo Ibáñez, namely Ricardo Truffello (Assistant Professor, TIC) and John Treimun (GIS expert, TIC) who have also been included in the proposal for the prolongation of the associated team.

Karol Suchan has applied for a Project Team Decision Support Systems for Industrial Problems (of UAI), at CIRIC - Inria Chile.