AIDyNet 2013-2015
Algorithm for large and Dynamic Networks

Nicolas Nisse

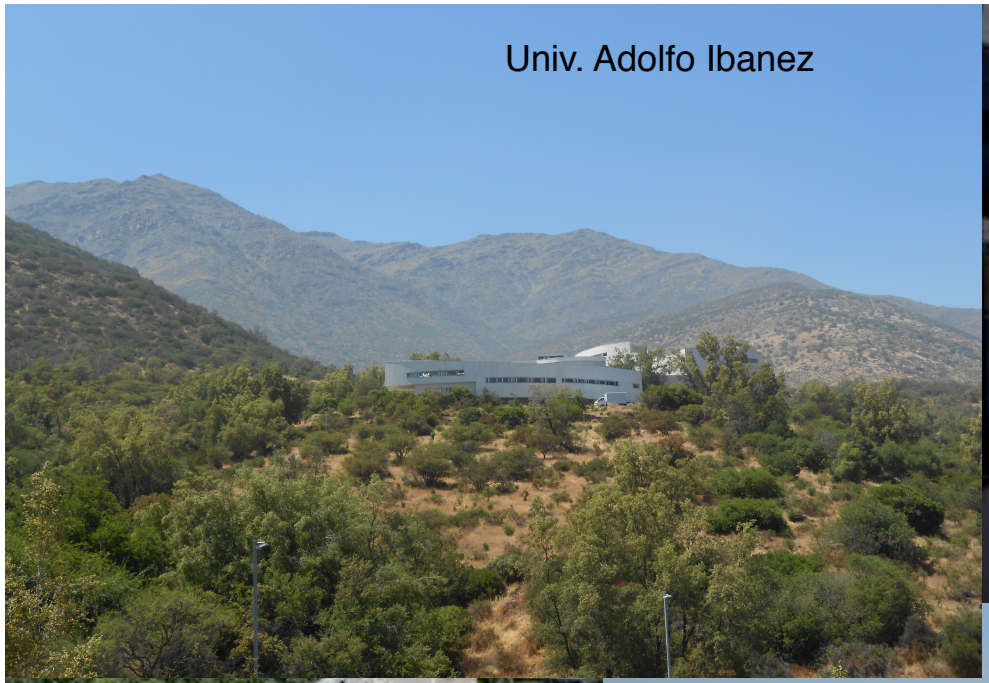
Inria, France

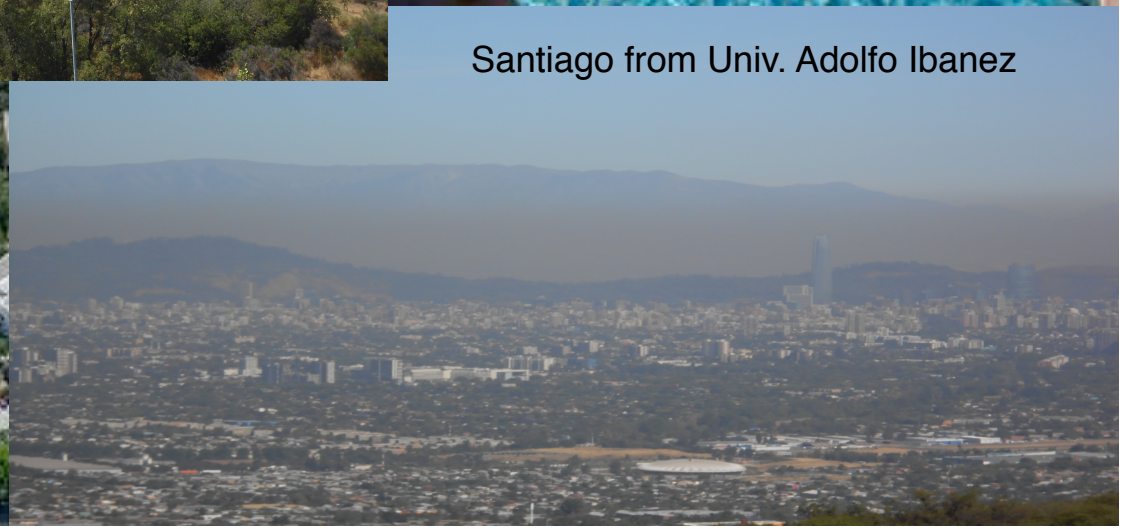
Univ. Nice Sophia Antipolis, CNRS, I3S, UMR 7271, Sophia Antipolis, France

Bilans Equipes Associées

October 15th, 2015

EPC COATI & Univ. Adolfo Ibáñez (UAI)





Santiago from Univ. Adolfo Ibanez

EPC COATI & Univ. Adolfo Ibáñez (UAI)

Nicolas Nisse (**coordinator**)
CR1 Inria

David Coudert
CR1 Inria, head of COATI

Guillaume Ducoffe
Ph.D. student, since 2014

Fatima Z. Moataz
Ph.D. student, till Oct. 2015

Bi Li
Ph.D. student, till Nov. 2014

Ronan P. Soares
Ph.D. student, till Nov. 2013

Karol Suchan (**coordinator**)
Associate Professor

Eduardo Moreno
Associate Professor

Esteban Roman
Ph.D. student, since 2013

John Treimun
Engineer, Territorial Intelligence Center

Ricardo Truffello
Assistant Prof., Territorial Intelligence Center

Main associated members: From Universidad de Chile, Santiago

Marcos Kiwi Associate Professor

Ivan Rapaport Associate Professor

Exchanges: Chile to France

2015
- Eduardo Moreno: Nov. 2nd to Nov. 6th. (1 week)
- Esteban Roman (Ph.D. student), Oct. (1 month)
- Marcos Kiwi: July 1st-7th (1 week)
- Mauricio Soto: March 1st-15th (2 weeks)

2014
- Karol Suchan: Sept. 7th to Sept. 23th. (2 weeks)
- Esteban Roman (Ph.D. student): May-July. (3 months)
- Klaus Jaschan (Ms. student): Dec. 2013- Feb. 2014 (2 months)

2013
- Esteban Roman (Ph.D. Student): Sept. 9th-Oct. 6th.(1 month)
- Karol Suchan: Sept. 9th to Sept. 25th. (2 weeks)

Exchanges: France to Chile

2015
- David Coudert: Nov. 21th to Dec. 5th. (2 weeks)
- Guillaume Ducoffe (Ph.D. Student): Nov.21th to Dec.5th. (2 weeks)
- Nicolas Nisse: Nov. 13th to Nov. 27th. (2 weeks)
- Frédéric Giroire: Nov. 13th to Nov. 27th. (2 weeks)
- David Coudert: April 3rd-19th. (2 weeks)

2014
- Nicolas Nisse: Nov. 14th to Dec. 14th. (1 month)
- Guillaume Ducoffe (Ph.D. Student): Nov.14th-Dec.14th. (1 month)
- David Coudert: Nov. 14th to Nov. 30th. (2 weeks)

2013
- Nicolas Nisse: Nov. 14th to Nov. 30th. (2 weeks)
- Fatima Moataz (Ph.D. Student): Nov.14th to Dec.12th (1 month)
- Bi Li (Ph.D. Student): Nov. 14th to Dec. 12th. (1 month)
- David Coudert: Nov. 14th to Nov. 30th. (2 weeks)

Scientific Workshop

AIDyNet Workshop on Algorithms and Randomness

organized by the dept. TI of the Facultad de Ingeniería y Ciencias of UAI with the collaboration of INRIA Sophia-Antipolis (Francia), **November 21st 2013.**

Funding

- AIDyNet, EA program

  2013: 15.000 €; **2014:** 12.000 €; **2015:** 10.000+3.000 €

- External Funding
  - **ECOS-Sud Chili C12E03**, 2 partners, **coordinator**: N. Nisse, 2013-2015
    $\approx$ 13.000 €(from France) + 13.000 €(from Chile)
  - ANR STINT (COATI, 2014-2017)
  - ANR AGAPE (COATI, 2010-2013)
  - FP7 (FIRE) european project EULER (COATI, 2010-2013)
  - FONDEF CA13i10023, **design, development and evaluation of public policies in education**, 2014-2016.
  - FONDECYT 1110674 (2011-2014)
  - CONICYT ACT-88 (IMSA, 2010-2013)
  - Proyecto Basal: CMM, Univ. de Chile (2008-2018)

Contributions of AIDyNet

Members of the associated team are indicated **in bold**. Joint publications in red.

On-going work

[ADNS] J. Araujo, **G. Ducoffe, N. Nisse, and K. Suchan**. Instantaneous cycle convexity. In preparation.

[CKM] **D. Coudert, M. Kiwi**, D. Mitsche. On the hyperbolicity of random hyperbolic graphs. In preparation.

[CDNS] **D. Coudert, G. Ducoffe, N. Nisse, and M. Soto**. Existence of a distance-preserving ordering is hard. In preparation.

2015

[BCCM15] M. Borassi, **D. Coudert**, P. Crescenzi, A. Marino: On Computing the Hyperbolicity of Real-World Graphs. ESA : 215-226, 2015

[KMMN15] M.M. Kante, **F.Z. Moataz**, B. Momège and **N. Nisse**, Finding Paths in Grids with Forbidden Transitions. In 41st Int. Workshop on Graph-Theoretic Concepts in Computer Science (WG), LNCS, Springer, 2015.

[ASN+15] G. D'Angelo, G. Di Stefano, A. Navarra, **N. Nisse** and **K. Suchan**. Computing on rings by oblivious robots: a unified approach for different tasks. Algorithmica, Volume 72(4), pages 1055-1096, 2015.

[BKM+15] 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.

[KLNS15] 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.

[GLSS15] S. Gaspers, M. Liedloff, M. Stein and **K. Suchan**. Complexity of Splits Reconstruction for Low-Degree Trees. Discrete Applied Mathematics, Volume 180, pages 89-100, 2015.

[LMNS15] **B. Li, F.Z. Moataz, N. Nisse and K. Suchan**, Minimum Size Tree-Decompositions. In 8th Latin-American Algorithms, Graphs and Optimization Symposium (LAGOS), 2015.

[Moataz15] **F.Z. Moataz**. Towards Efficient and Fault-Tolerant Optical Networks: Complexity and Algorithms. **Ph.D. thesis**, Univ. Nice Sophia Antipolis, October 30th, 2015.

Contributions of AIDyNet

2014

[ANP14] J. Araujo, **N. Nisse and S. Pérennes**. Weighted Coloring in Trees. SIAM J. Discrete Math. 28(4): 2029-2041, 2014

[CDN14] **D. Coudert, G. Ducoffe and N. Nisse**, Diameter of Minimal Separators in Graphs. Research Report, INRIA-RR-8639, HAL, Sophia Antipolis, France, Nov. 2014.

[CD14] **D. Coudert, G. Ducoffe**. On the recognition of C4-free and 1/2-hyperbolic graphs. SIAM J. Discrete Math. 28(3): 1601-1617 (2014)

[LMNS14] **B. Li, F.Z. Moataz, N. Nisse and K. Suchan**, Minimum Size Tree-Decompositions. Extended abstract in 9th International colloquium on graph theory and combinatorics (ICGT), 2014.

[CMN14] **D. Coudert**, D. Mazauric and **N. Nisse**. Experimental Evaluation of a Branch and Bound Algorithm for computing Pathwidth. 13rd Symp. on Experimental Alg. (SEA), LNCS, Springer, pages 46-58, 2014.

[ANP14] J. Araujo, **N. Nisse and S. Pérennes**. Weighted Coloring in Trees. 31st Symposium on Theoretical Aspects of Computer Science (STACS), Schloss Dagstuhl, pages 75-86, 2014.

[ANN14] G. D'Angelo, A. Navarra and **N. Nisse**. Gathering and Exclusive Searching on Rings under Minimal Assumptions. ICDCN 2014, LNCS, Springer, pp. 149-164, 2014.

[CDD14] N. Cohen, **D. Coudert, G. Ducoffe**, and A. Lancin. Applying clique-decomposition for computing Gromov hyperbolicity. [Research Report], 2014, pp. 30. RR-8535

[Li14] **B. Li**, Tree Decompositions and Routing Problems. **Ph.D. thesis**, UNS, Nov. 12th, 2014.

[Nisse14] **N. Nisse**, Algorithmic complexity: Between Structure and Knowledge How Pursuit-evasion Games help. **HDR**, Univ. Nice Sophia Antipolis, May 26th, 2014.

[Roman14] **E. Roman**, Analysis of a Branch and Bound algorithm for pathwidth, **internship report**, May-July 2014.

[Jaschan14] **K. Jaschan**, Implementing a Vertex Separation algorithm for trees in Sagemath, **internship report**, Dec. 2013- Feb. 2014.

2013

[ASN+13] G. D'Angelo, G. Di Stefano, A. Navarra, **N. Nisse and K. Suchan**. A unified approach for different tasks on rings in robot-based computing systems. APDCM 2013, IEEE.

[NS13] **N. Nisse and R. Soares**. On the monotonicity of Process Number. 7th Latin-American Algorithms, Graphs and Optimization Symp. (LAGOS), Elsevier, to appear in Electronic Note Discrete Maths, 2013.

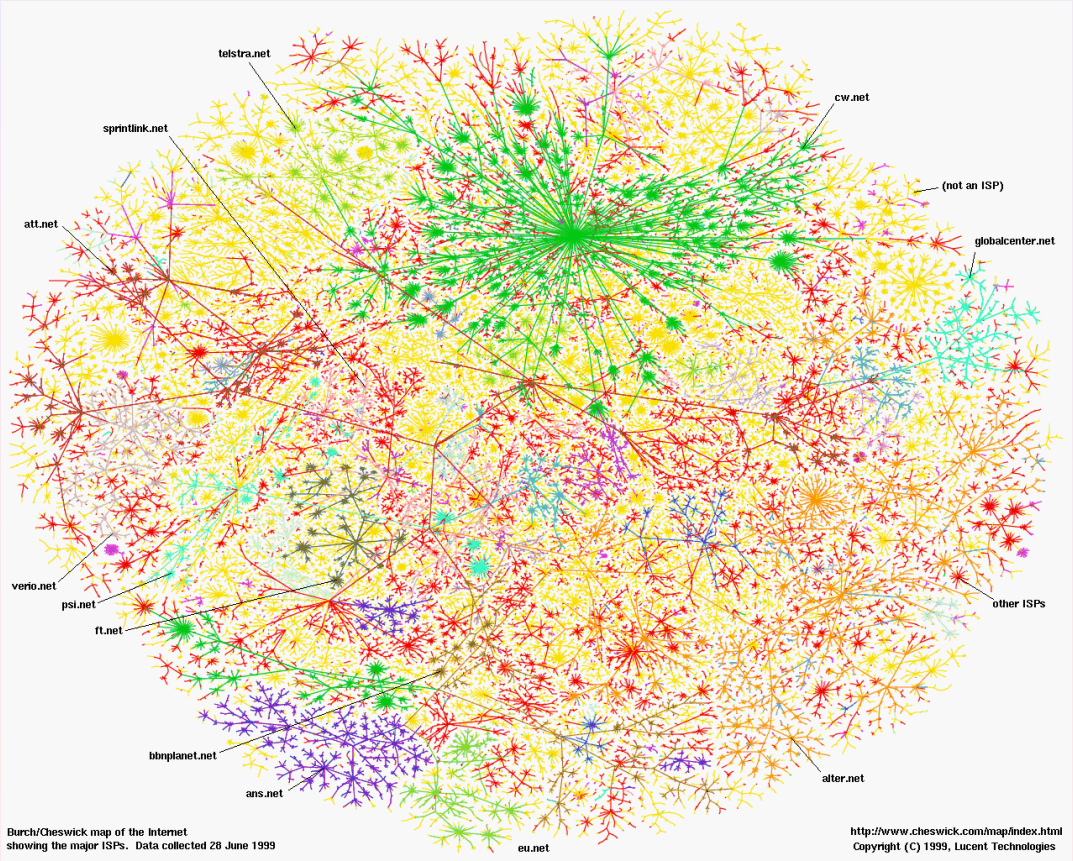
[Soares13] **R. Soares**, Pursuit-evasion, decompositions and convexity on graphs. **Ph.D. thesis**, Univ. Nice Sophia Antipolis, November 8th, 2013.

Distributed computation of network properties

Problem

Huge networks $\Rightarrow$ generic algorithms (even polynomial) are not efficient

Need to use structural properties



Distributed computation of network properties

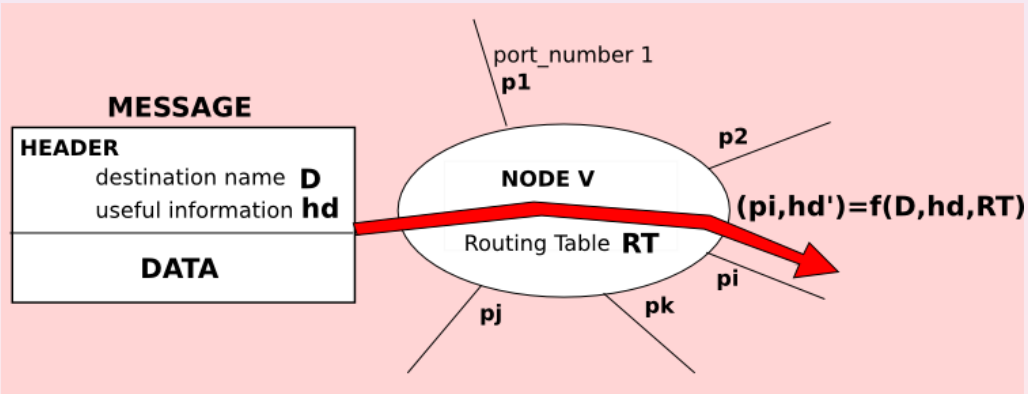
Problem

Huge networks ⇒ generic algorithms (even polynomial) are not efficient

Need to use structural properties

Example of compact routing

Goal: To deliver a message in a distributed way (i.e., direct the traffic in a network)



Distributed computation of network properties

Problem

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Need to use structural properties

Example of compact routing

network	**mult. stretch**	**routing table**	
		labelled	**name-independent**
arbitrary	shortest path	$O(n \log n)$ [folk]	$\Theta(n \log n)$ [Gavoille,Pérennes] (BGP)
$(k \geq 2)$	$O(k)$	$O(n^{1/k})$ [Thorup,Zwick]	$\Theta(n^{1/k})$ [TZ/Abraham et al.]
trees	shortest path	$O(\log n)$ [TZ/Fraigniaud,Gavoille]	$\Omega(\sqrt{n})$ [Laing,Rajaraman]
	$2^k - 1$		$\Theta(n^{1/k})$ [Laing/Abraham et al.]
chordality $\leq k$	$k \log \Delta$	$O(\log n)$ [K.,Li,Nisse,Suchan'15]	
doubling-α **dimension**	$O(1) + \epsilon$	$O(\log \Delta)$ [Talwar/Slivkins]	$O(\epsilon^{-\alpha} \log n)$ [Abraham et al.]
		$O(\log n)$ [Abraham et al.]	
planar	$1 + \epsilon$	$O(\log n)$ [Thorup]	
H**-minor free**	$1 + \epsilon$	$O(\lvert H \rvert ! \cdot 2^{\lvert H \rvert} \log n)$ [Abraham,Gavoille]	

BGP is generic $\Rightarrow$ large Routing Tables :(
but easy to compute and update :)

other schemes require structural information (e.g., decompositions) on the graph

Distributed computation of network properties

Problem

Huge networks $\Rightarrow$ generic algorithms (even polynomial) are not efficient

Need to use structural properties

Objectives

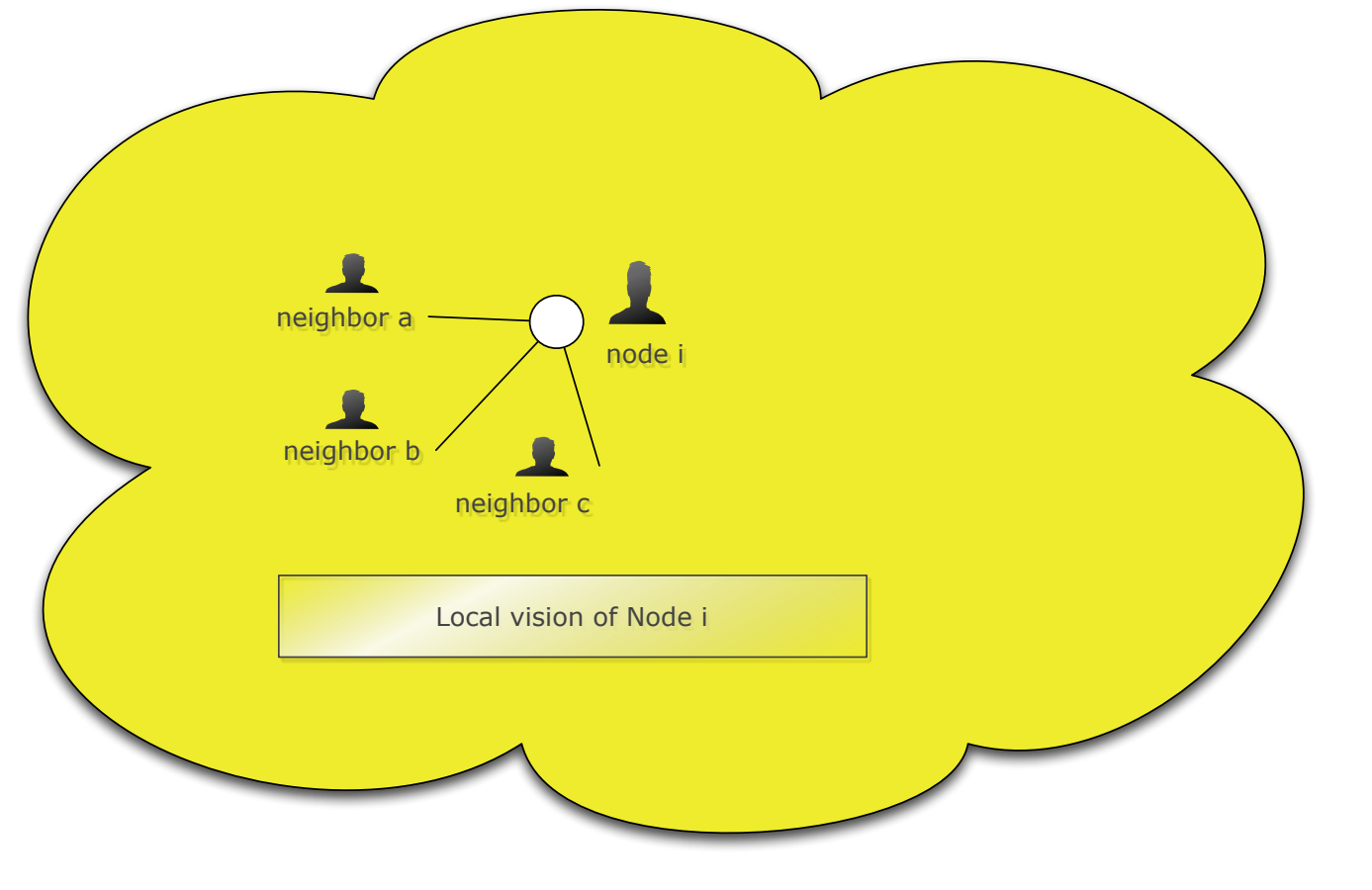
- Understand, compute, discover... structural Properties
- Distributed/Local computation
- Use it for algorithmic purposes (not only routing)
- Model/simulate such networks (static/dynamic behavior)

Questions

What hypothesis can we adopt for the computation?
What is feasible in a given model?

lot of recent works:
[Fraigniaud,Korman,Peleg FOCS'11, Frischknecht,Holzer,Wattenhofer, SODA'12,Feuilloley,Fraigniaud SPAA'15]...

Model of distributed computing

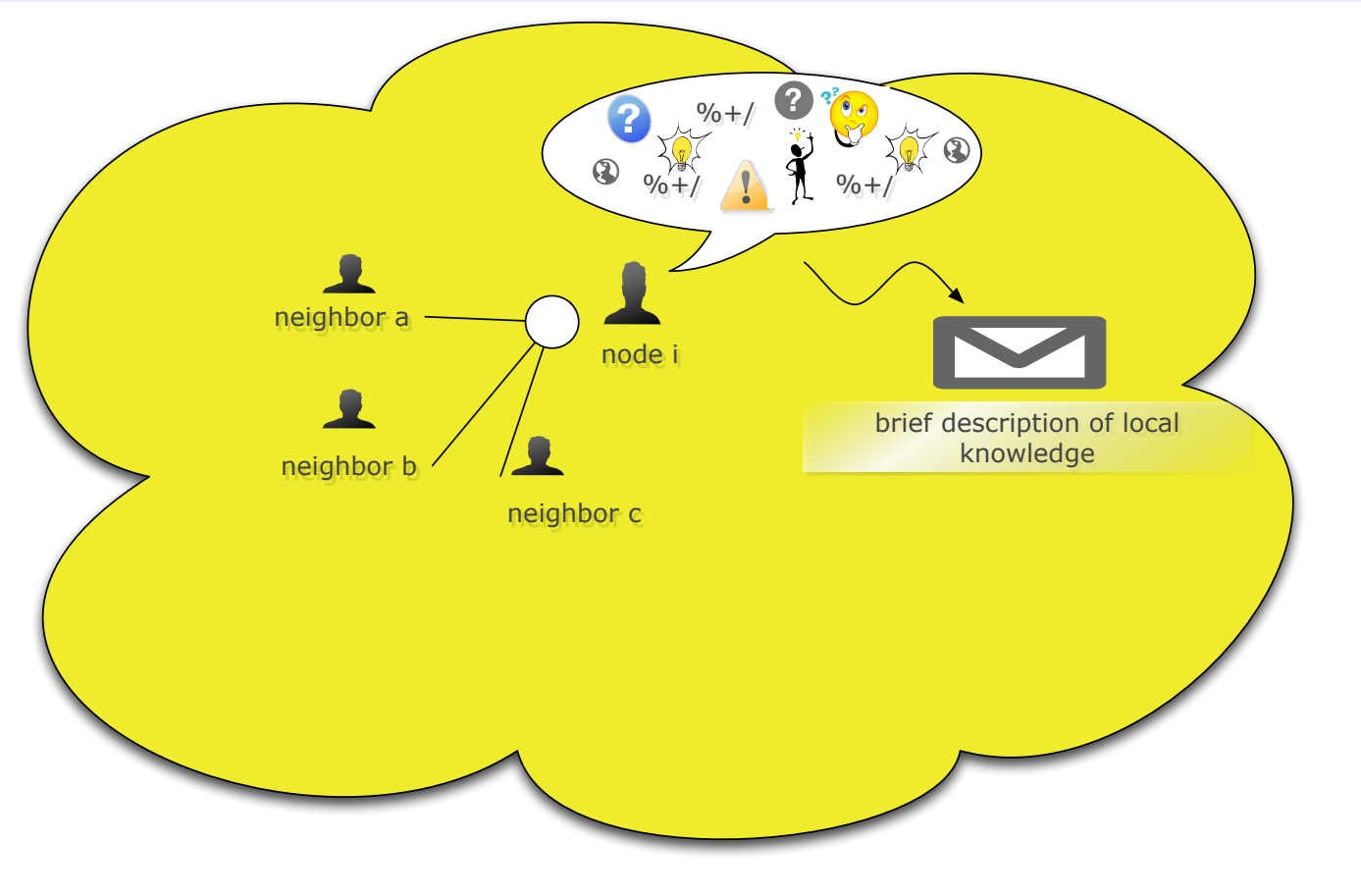


Graph with n nodes.

Nodes have distinct identifiers in $\{1, \cdots, n\}$.

A node knows: its ID and the IDs of its neighbors

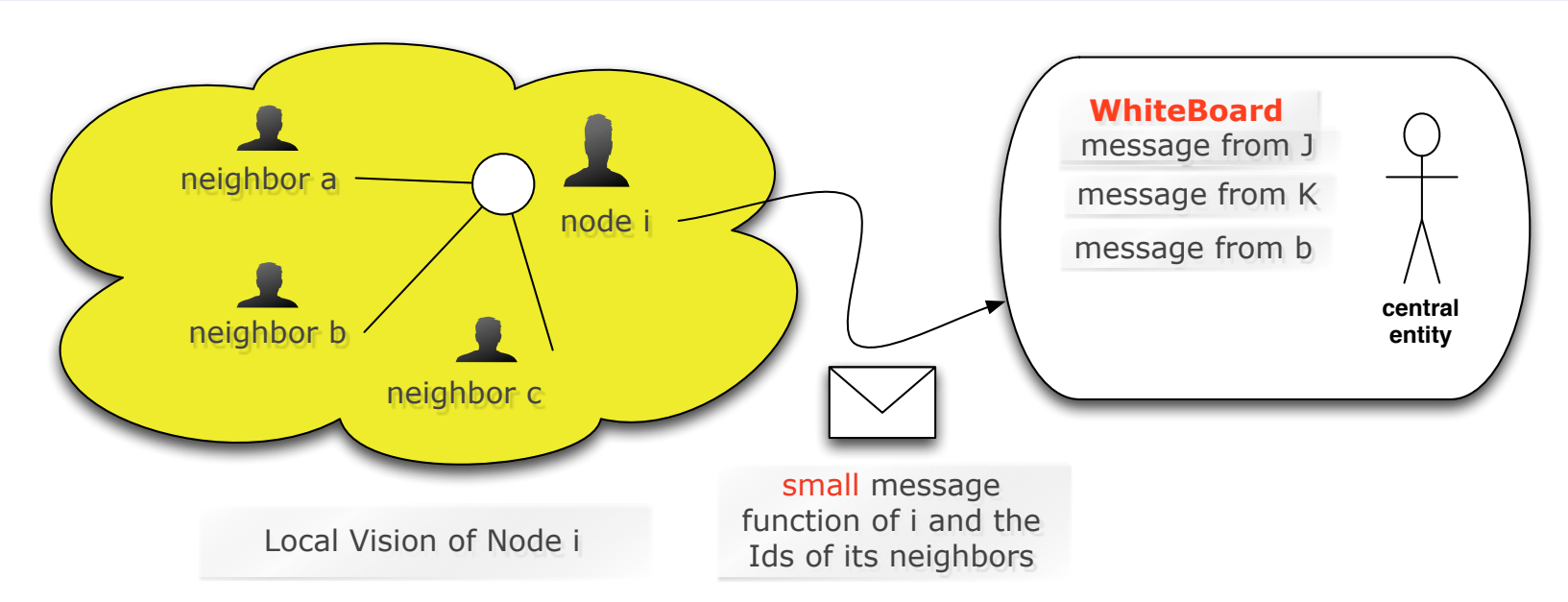
Model of distributed computing



A node has arbitrary computation power.

Goal: encode its local knowledge in a small message (typically $O(\log n)$)

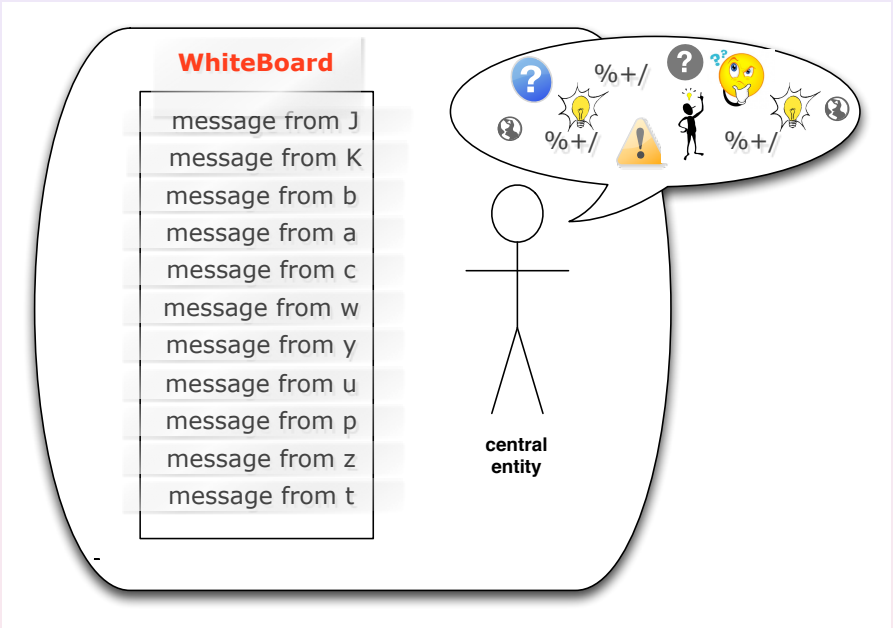
Model of distributed computing



Each node sends its (unique) message to a central entity

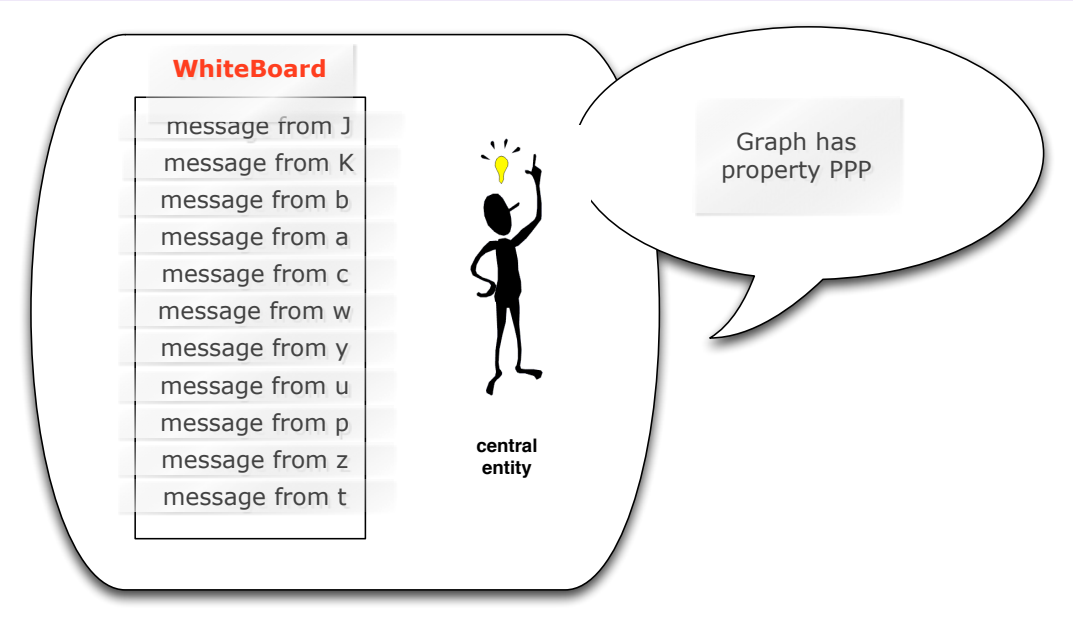
Remark: If $|message| = n$ bits, then node gives its whole neighboorhood

Model of distributed computing



The referee has arbitrary computation power and use the n messages to...

Model of distributed computing



... answer a question about the graph (typically: "does G has some property?")

What Can(not) Be Computed in One Round

[F. Becker, A. Kosowski, **M. Matamala, N. Nisse, I. Rapaport, K. Suchan***, and I. Todinca. Distributed Computing, 2015]*

Possible

Decide if a graph has bounded degeneracy (include planar graphs, bounded genus graphs, **bounded treewidth** graphs...). If yes, build their adjacency matrix.

Not possible

Decide if the graph **contains a triangle**, a (induced or not) square.
Decide if the graph has diameter at most 3

We don't know????

Decide if the graph is connected.

Practical Algorithms

Many "simple" problems are difficult to tackle in huge graphs
$\Rightarrow$ current effort to revisit polynomial-time solvable problems
in order to design better algorithms that work in practice

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Example: Computing the diameter (maximum distance) in Facebook ($n = 10^9$ nodes)

	requires	"time"
classical algorithm	n BFS (traversal)	$\geq 10^9$ seconds $\approx$ 31 years (on basic laptop)
iFub [Borassi,Crescenzi,Habib$^+$13]	17 BFS	few hours

Algorithm iFub has same worst-case complexity as classical algorithm
but work very well in practice

Practical Algorithms

Many "simple" problems are difficult to tackle in huge graphs
$\Rightarrow$ current effort to revisit polynomial-time solvable problems
in order to design better algorithms that work in practice

Example: Computing the diameter (maximum distance) in the world

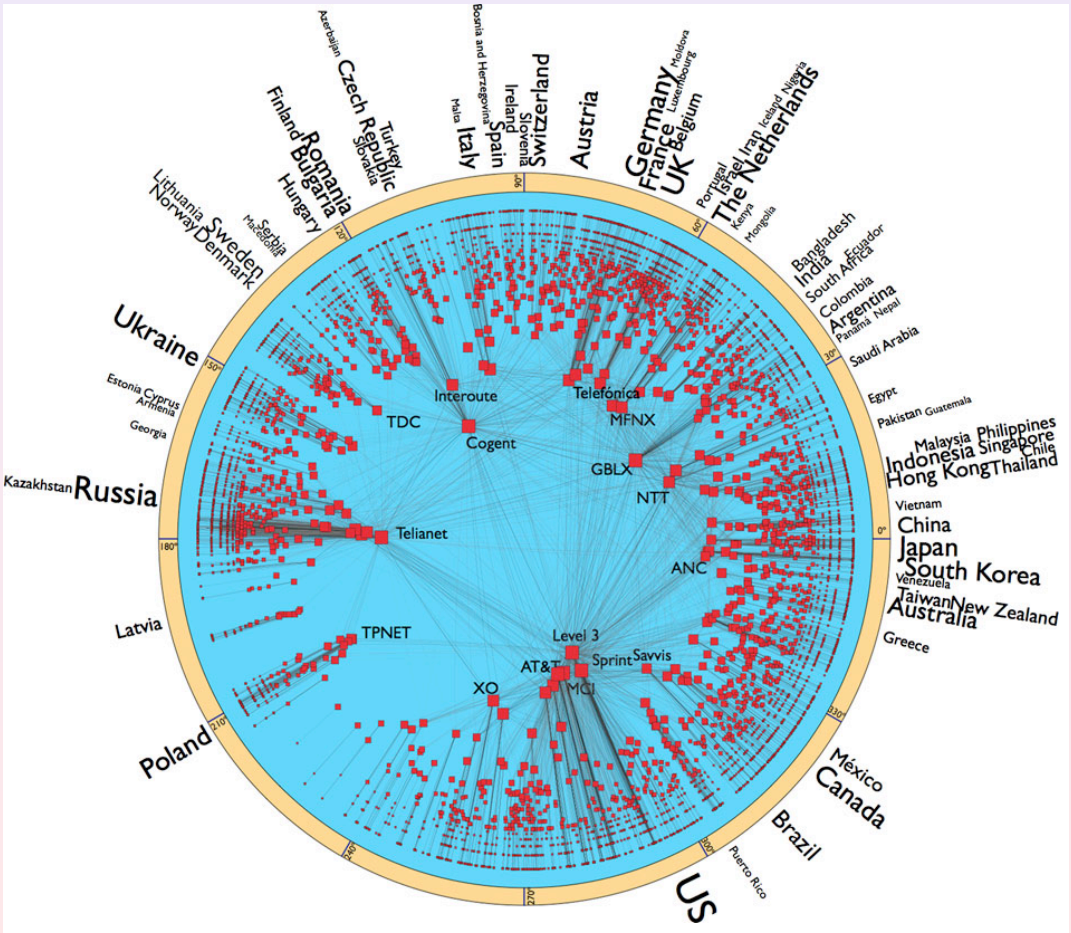
https://who.rocq.inria.fr/Laurent.Viennot/road/

Work of Kosowski, Habib, Rai, Shah, Viennot (GANG Inria team-project)

Practical Algorithms

We consider other topologic/metric parameters

Example: hyperbolicity (measure how close the metric of a graph is close to the metric of a tree) basic algo. $O(n^4)$, best known algo. $O(n^{3.69})$



- Efficient compact routing scheme in graphs with small hyperbolicity
- the Internet (AS network) has small hyperbolicity

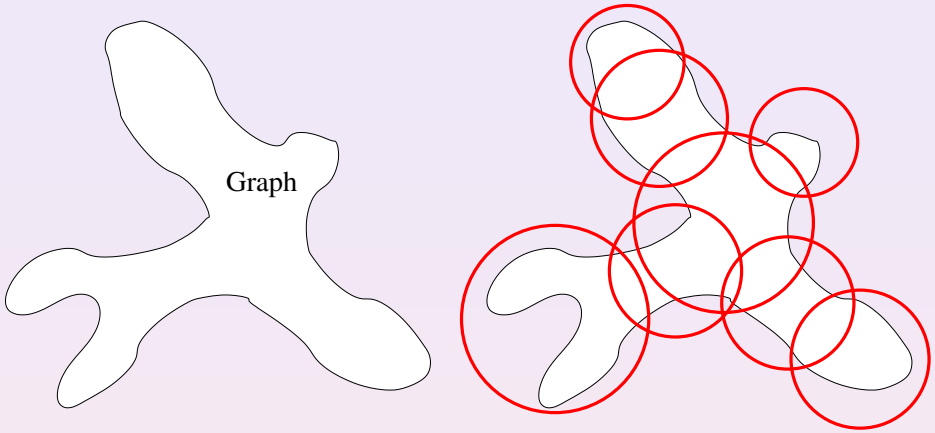
[Borassi,Coudert,Crescenzi,Marino'15]
[Coudert,Kiwi,Mitsche'15]
[Coudert, Ducoffe.'14]
[Cohen,Coudert,Ducoffe,Lancin'14]

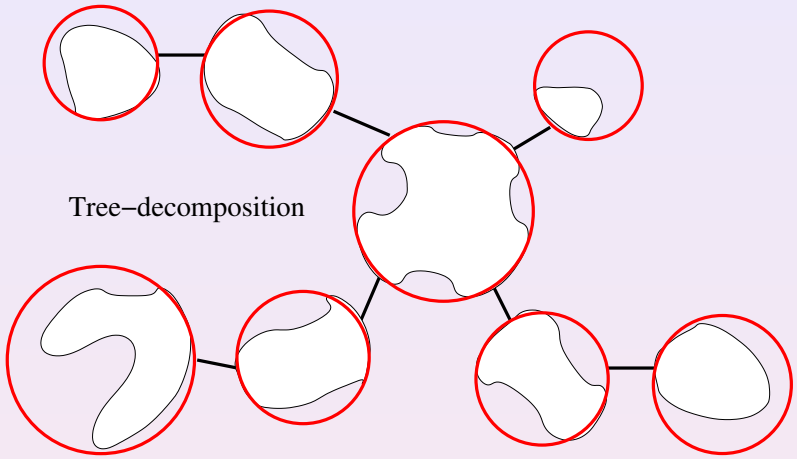
$\Rightarrow$ compute hyperbolicity of AS network ($n = 10^5$)

Tree-decomposition/treewidth (unformal)

Pieces (subgraphs) with tree-like structure

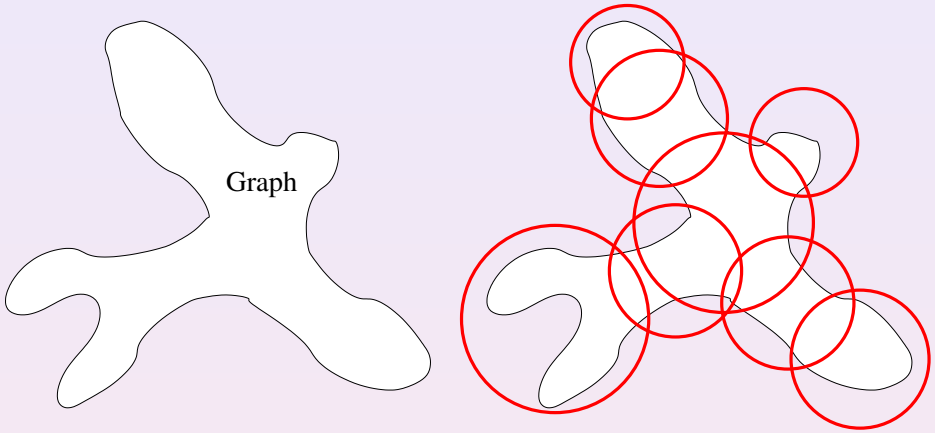
(bag=separator)

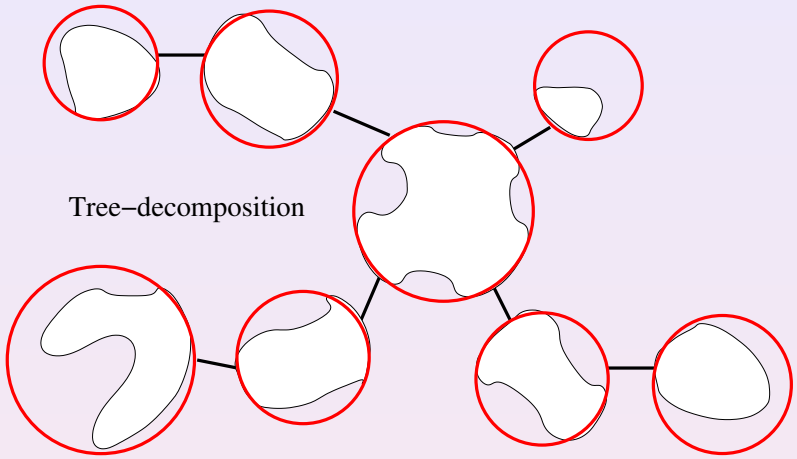




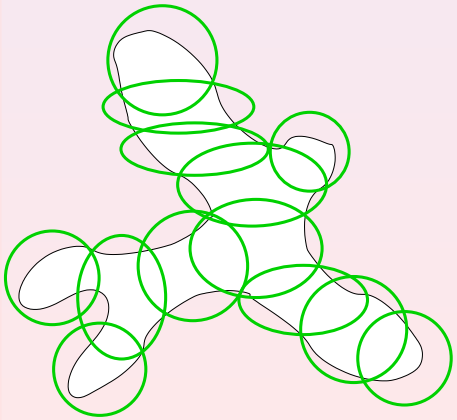
Tree-decomposition/treewidth (unformal)

Pieces (subgraphs) with tree-like structure (bag=separator)



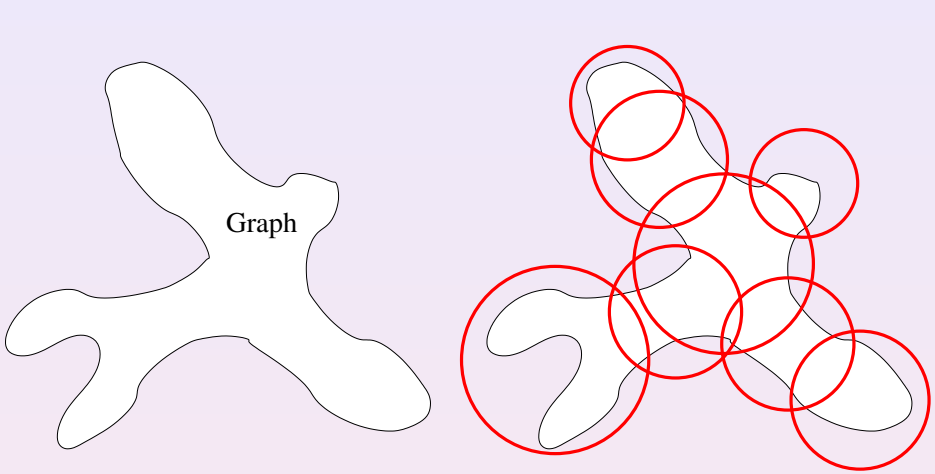


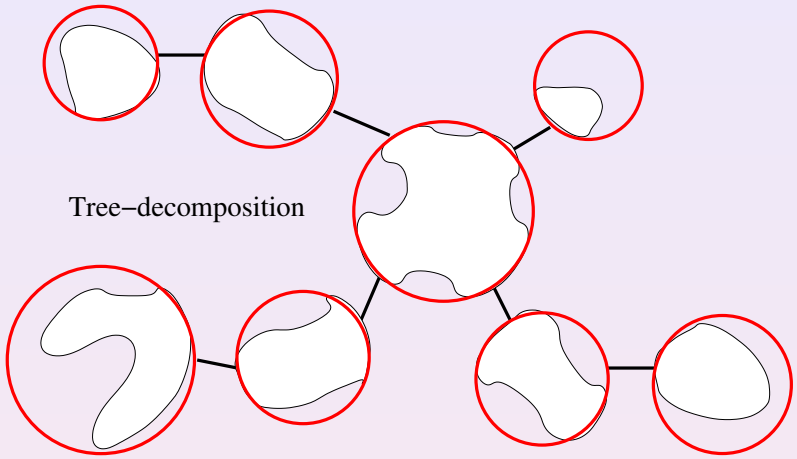
Usually, try to minimize the largest bag (treewidth)



Tree-decomposition/treewidth (unformal)

Pieces (subgraphs) with tree-like structure (bag=separator)





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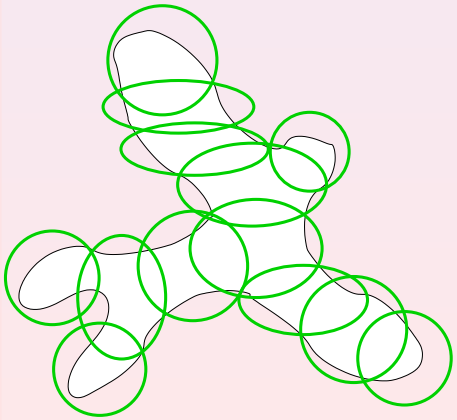


- Many NP-hard problems solvable in poly-time in graphs with bounded treewidth
- Bidimensionality theory (subexponential algo.)
- Parameterized complexity and Kernelization

$\Rightarrow$ need to compute decompositions but it is difficult !!!

AIDyNet contributions on Tree-decomposition/treewidth

We have focused on

Exact algorithms working well in practice

[Coudert,Mazauric,Nisse'14]

Computing decompositions with bags of specific structures

[Kosowski,Li,Nisse,Suchan. Algorithmica'15.]
[Li,Moataz,Nisse,Suchan LAGOS'15]

Designing approximation algorithms

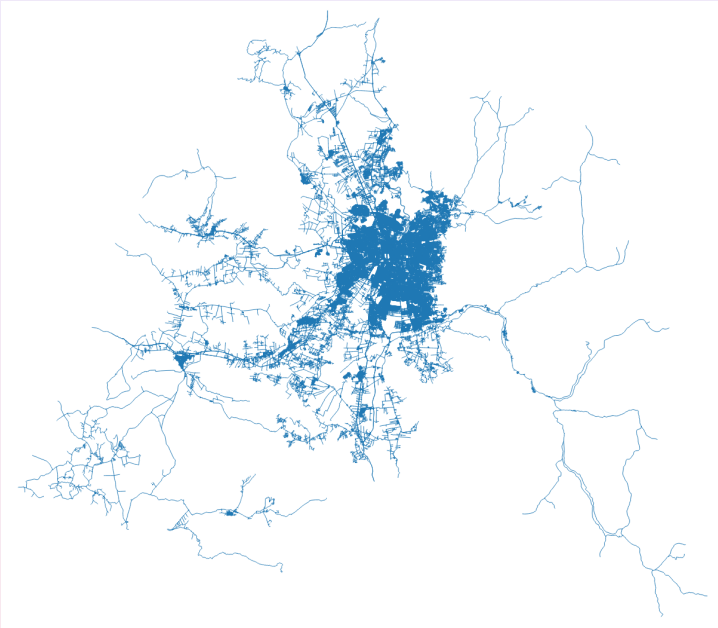
[Kosowski,Li,Nisse,Suchan. Algorithmica'15.]
[Coudert,Ducoffe,Nisse'14]

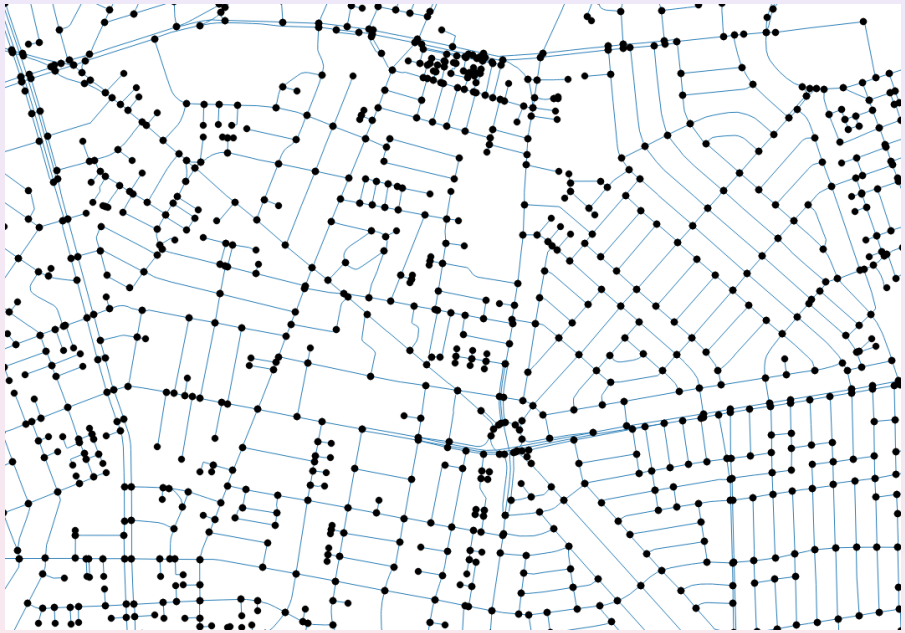
Next step: to implement our algorithms in large graphs and check their performance in practice

On-going work: Santiago agglomeration

Santiago transportation network + socio-economic data (school, student places, hospital,green areas, culture areas, criminality, etc.) $n > 10^5$

collected by Territorial Intelligence Center of UAI





Currently, we are cleaning the data

Next step: apply our (and other's) algorithms (diameter, hyperbolicity, etc.) to understand better the topology of Santiago

$\Rightarrow$ develop tools for decision support to improve the quality of life of citizens (transportation system, education and healthcare accessibility)

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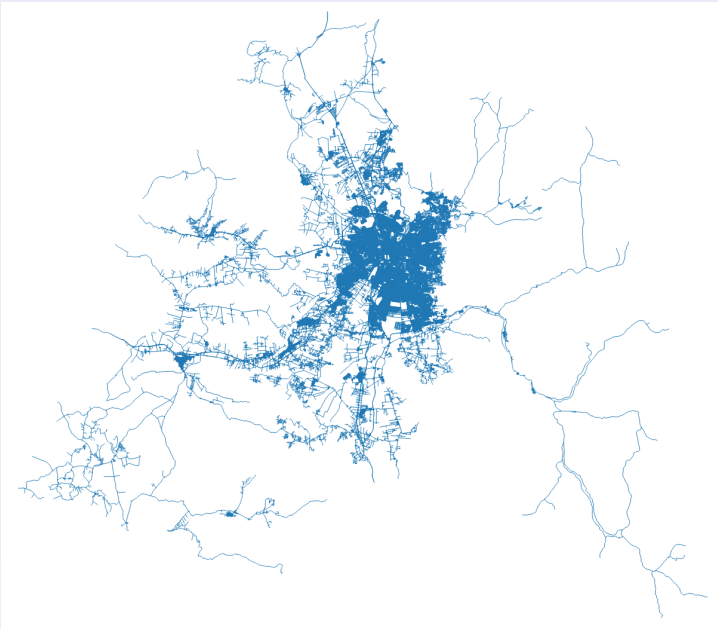

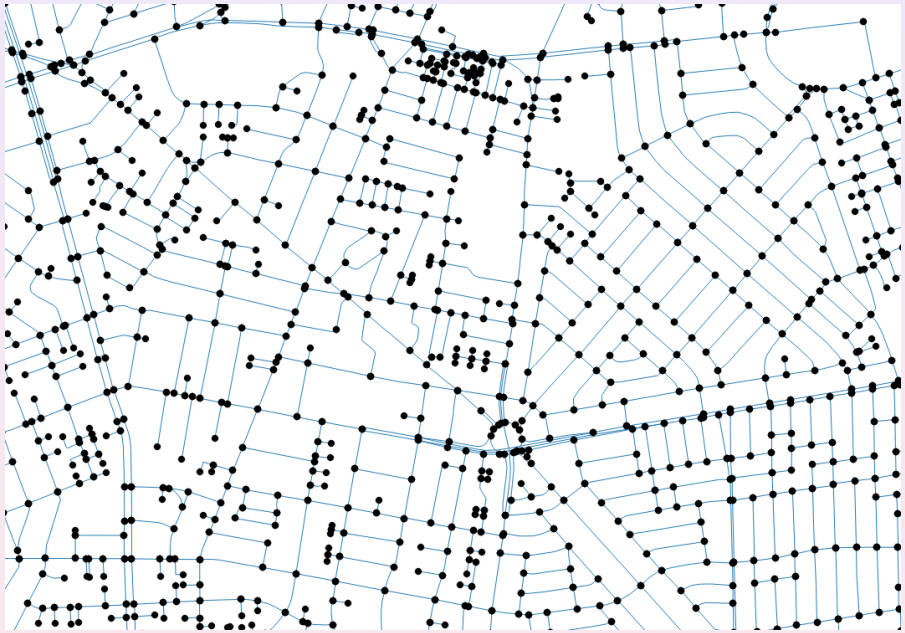

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Future of the partnership

Application to extend AIDyNet for 3 more years

- link with CIRIC
  - Project Team Decision Support Systems for Industrial Problems (of UAI), part of the second stage of CIRIC (Inria Chile)
- Attempt to extend the collaboration to Brazil
  - Julio Araujo (Univ. Federal Ceara) visited UAI in November 2015
  - project SticAmSud PUDDING (2 partners + Univ. Federal Ceara, Fortaleza, Brazil, applied in May 2015)
- Other projects applied or to be applied
  - FONDEF (applied in September 2015), The geography of education: a territorial intelligence platform to support the implementation and management of new public policies in education
  - FONDECYT (to apply in 2016), Algorithms for Large Scale Geographical Information Systems