CNRS Audition

Alexandre Vigny

Universität Bremen, Germany

March 21, 2023

Alexandre Vigny

→ 31 years old, born in 1992.

→ PhD defense September 2018 *(5 years ago)*.

→ Living in Bremen, Germany.

→ Master in University Paris Diderot, 2015.
Logique Mathématique et Fondement de l'Informatique (LMFI).

→ PhD in University Paris Diderot. (3 years)
With Arnaud Durand & Luc Segoufin

→ Post-doc in Warsaw. (1 year)
With Szymon Toruńczyk & Mikołaj Bojańczyk

→ Post-doc in Bremen. (3 years)
With Sebastian Siebertz

Summary

Area of Research

→ Logic

→ Graph theory

→ Distributed computing

Highlights

→ Publication in J.ACM

→ 2 Upcoming journal papers

→ 9 Conference papers

→ Co-organizer of a workshop

PODC-DARe: Distributed Algorithms on REalistic network models

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PODC-DARe: Distributed Algorithms on REalistic network models

Teaching

- → In Paris (3 years) $\sim$ 180h
- → In Bremen (3 years) $\sim$ 270h

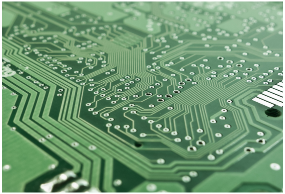
Highlights

- → Creation of syllabuses
- → Responsible for two courses
- → Including master level

Algorithmic graph theory

Given a graph G and a property P: “Does G satisfy P?”

$\rightarrow$ Is G planar?

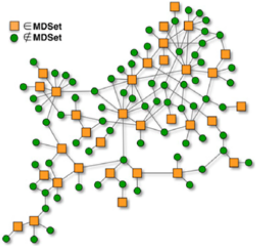


Algorithmic graph theory

Given a graph G and a property P: "Does G satisfy P?"

$\rightarrow$ Is G planar?

$\rightarrow$ Does G have a k-dominating set?



Algorithmic graph theory

Given a graph G and a property P: “Does G satisfy P?”

→ Is G planar?

→ Does G have a k-dominating set?

→ Is G connected?

Goal: Efficient algorithms ...

... at least for restricted graph classes and/or simple properties.

Logic

First-order (FO) logic

- $\rightarrow$ Can express k-independent set: *There are k vertices, that are not adjacent*

$$\exists x_1 \ldots \exists x_k \bigwedge_{i<j} (\neg E(x_i, x_j) \wedge x_i \neq x_j)$$

- $\rightarrow$ Cannot express : connectivity, planarity, 2-colorability, ...

Logic

First-order (FO) logic

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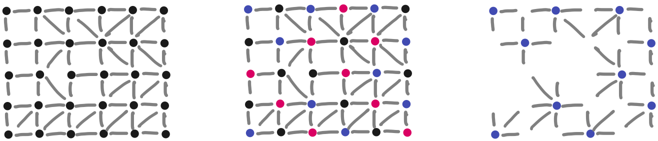
→ Cannot express : connectivity, planarity, 2-colorability, ...

Monadic second-order (MSO) logic

→ More general than FO

→ Can express : 3-colorability:
$\exists X_1 \exists X_2 \exists X_3 \; (\forall x \bigvee_{i<3} x \in X_i) \wedge (\forall x \forall y \; E(x,y) \rightarrow \bigwedge_{i<3} (x \notin X_i \vee y \notin X_i))$



Logic & Meta theorems

Problems can be expressed in logic. (FO, MSO,...)

The $\mathcal{L}$, $\mathcal{C}$ model-checking problem:
Given $\varphi \in \mathcal{L}$ and $G \in \mathcal{C}$, does $G \models \varphi$?

Goal: fixed parameter tractable algorithms $O(f(\varphi) \cdot |G|^c)$

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Goal: fixed parameter tractable algorithms $O(f(\varphi) \cdot |G|^c)$

Courcelle's Theorem (1990):
for $\varphi \in \mathrm{MSO}$ and treewidth$(G) \leq k$, in time $O(f(\varphi, k) \cdot |G|)$

$\rightarrow$ Generalize many known results, ex:
Arnborg, Proskurowski 1989:
independent sets, dominating sets, graph coloring, Hamiltonian, ...
are linear on partial k-tree.

Distributed Computing

Previously, computation with Turing machine. There are others!

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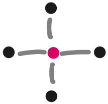
Local model

$\rightarrow$ Different notion of efficient

$\rightarrow$ Time needed VS Information needed



Distributed Computing

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Local model

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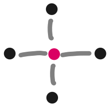
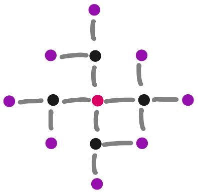




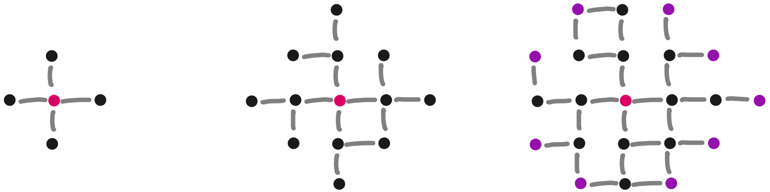
Distributed Computing

Previously, computation with Turing machine. There are others!

Local model

→ Different notion of efficient

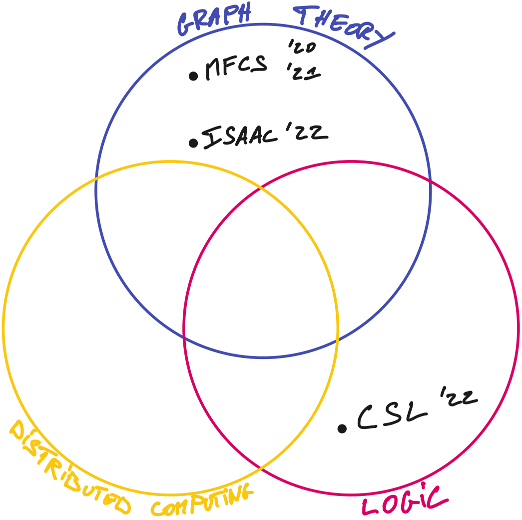
→ Time needed VS Information needed



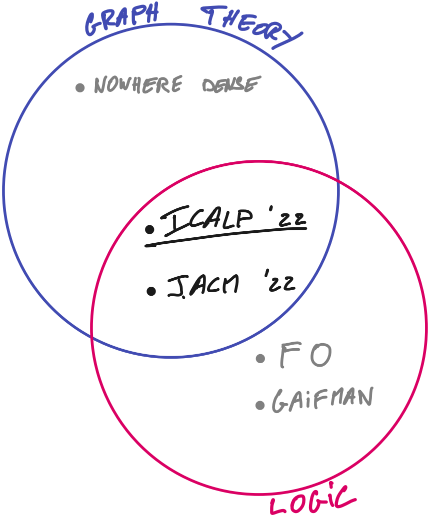
→ Can you decide locally?

→ Still reaching for meta theorems

Result overview



Result overview



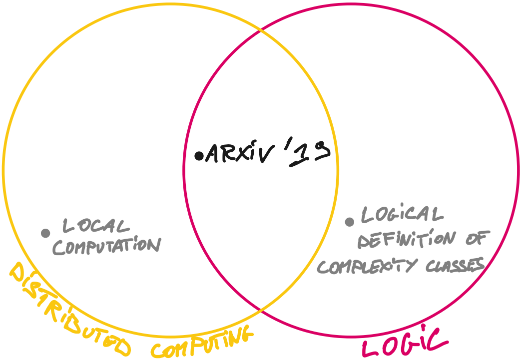
• ENUMERATION FO QUERIES

-> PODS 2018
JACM 2022

Result overview

- ENUMERATION FO QUERIES
  - -> PODS 2018
    JACM 2022
- DISTRIBUTED DOMINATION ON SPARSE GRAPH CLASSES
  - -> SIROCCO 2021/2022
  - -> EUR. J. COMB. (TO APPEAR)

Result overview



- ENUMERATION FO QUERIES
  -> PODS 2018
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- DISTRIBUTED DOMINATION ON SPARSE GRAPH CLASSES
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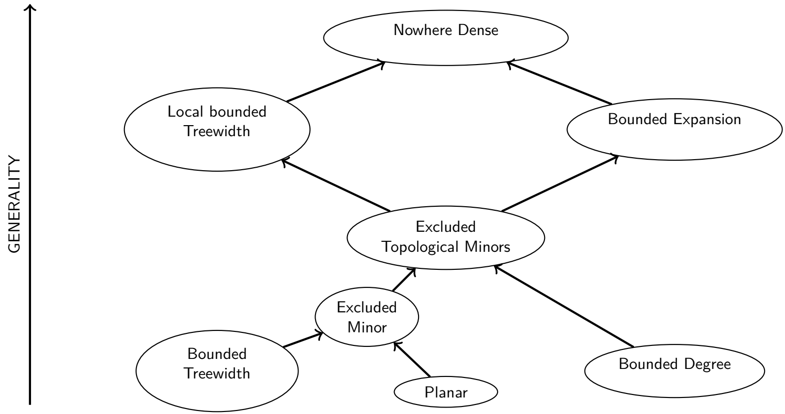
- PARAMETERIZED DISTRIBUTED COMPLEXITY THEORY : A LOGICAL APPROACH
  -> ARXIV

Monotone graph classes



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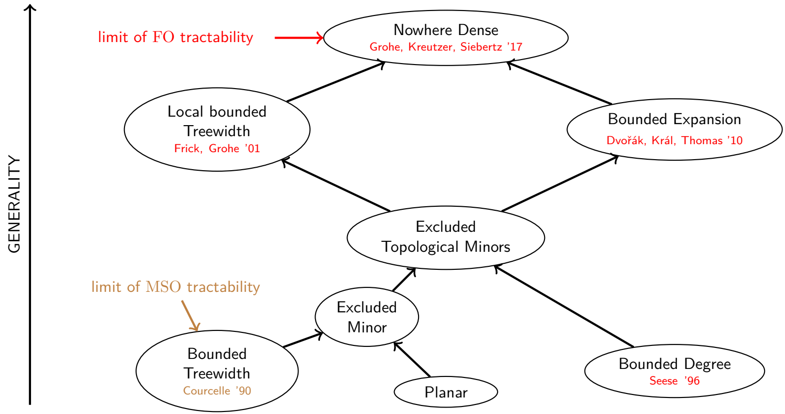
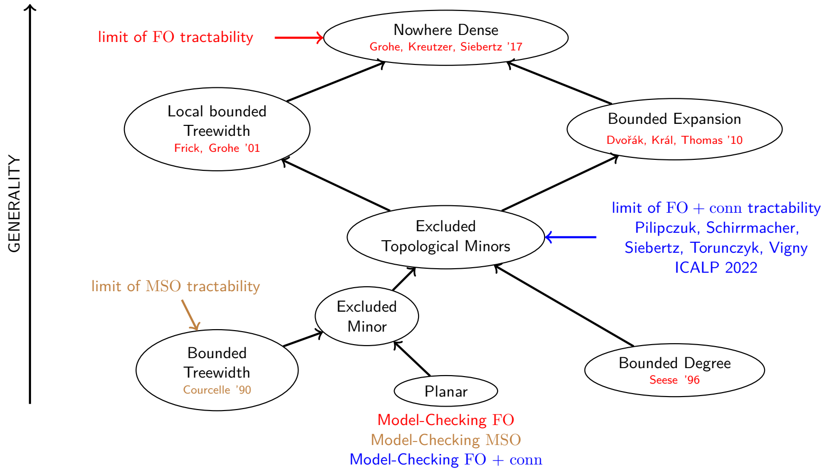


Model-Checking FO
Model-Checking MSO

Monotone graph classes



FO + conn

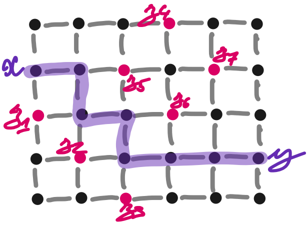
Schirrmacher, Siebertz, Vigny '21 and Bojanczyk '21

Syntax

→ Uses : FO and $\mathbf{conn}_k(x, y, z_1, \ldots, z_k)$

Meaning

→ x and y are connected after the deletion of $z_1, \ldots, z_k$.



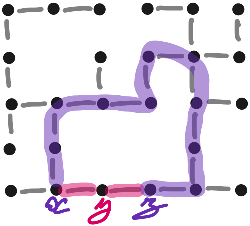
Expressive power of $\mathrm{FO} + \mathrm{conn}$

→ connectivity

$$\forall x \forall y \; \mathrm{conn}_0(x, y)$$

→ cycle

$$\varphi_{cycle} := \exists x \exists y \exists z (E(x, y) \wedge E(y, z) \wedge z \neq x \wedge \mathrm{conn}_1(z, x, y))$$



→ Not expressible

planarity, bipartiteness, Hamiltonicity, . . .

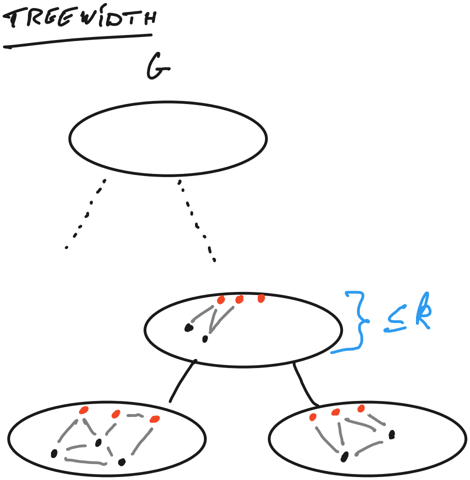
Main result

Theorem: Pilipczuk, Schirrmacher, Siebertz, Torunczyk, Vigny

→ Model-checking for properties in $\mathrm{FO} + \mathrm{conn}$ over graph classes excluding a topological minor is solvable in time FPT.

→ Model-checking is not FPT for more general graph classes.
Under complexity assumptions

Logic tools



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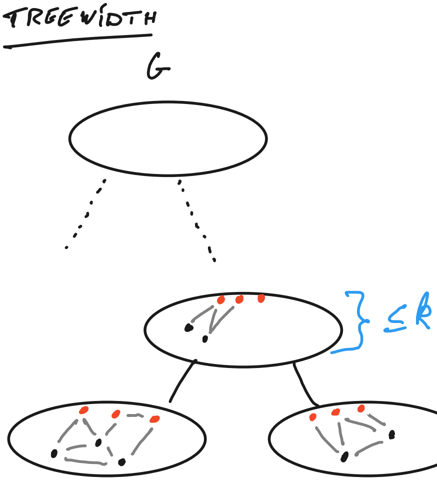

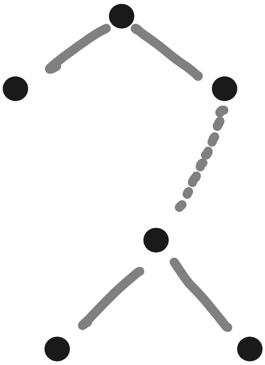

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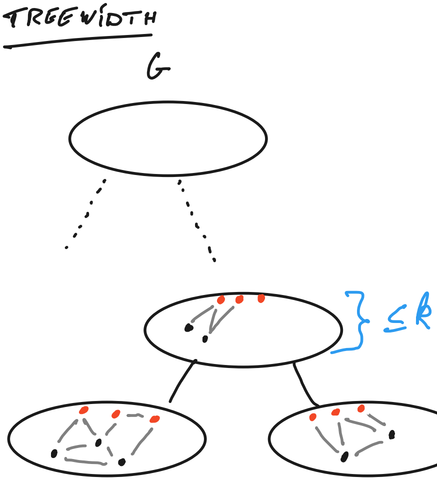

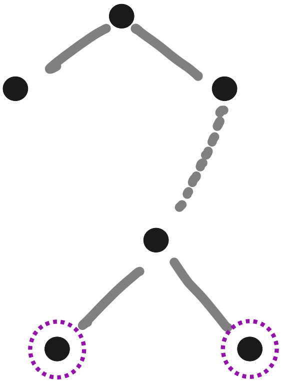

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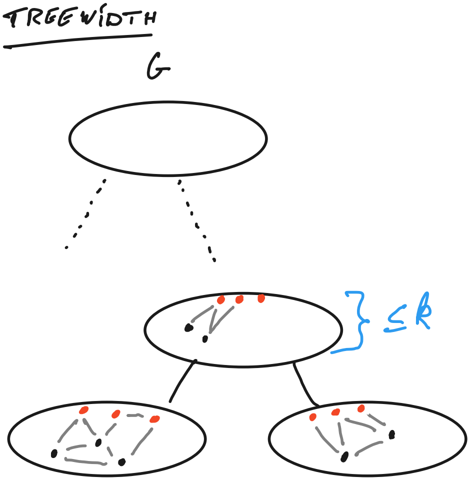

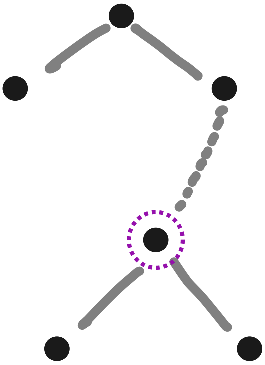

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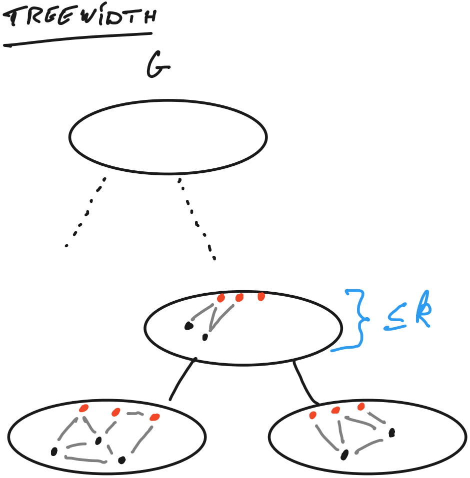

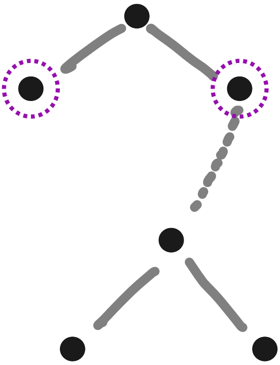

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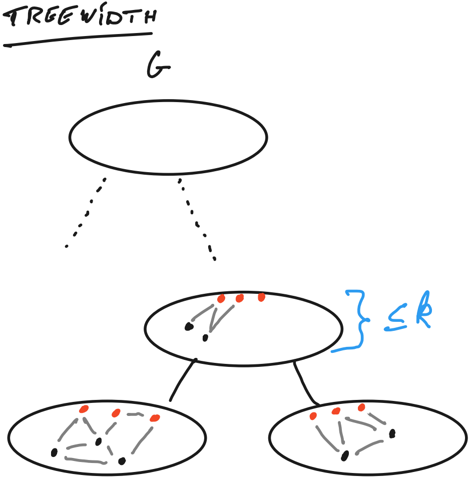
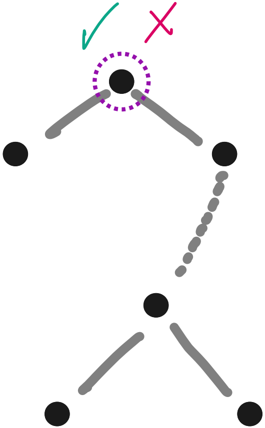




Graph theory tools

Cygan, Lokshtanov, Pilipczuk, Pilipczuk, Saurabh '19:

For every G there is a tree decomposition of G such that:

$\rightarrow$ Adjacent bags have "small" intersections.

$\rightarrow$ Every bag is unbreakable.

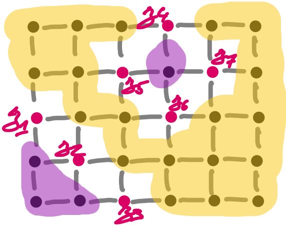
Unbreakable

→ A graph G is (q, k)-unbreakable if for all sets S with $|S| \leq k$:

$$\text{for all separations } A, B \text{ of } G \setminus S \text{ either } |A| \leq q \text{ or } |B| \leq q$$

→ Example 1: Cliques

→ Example 2: $m \times m$ grids are (k^2, k)-unbreakable.



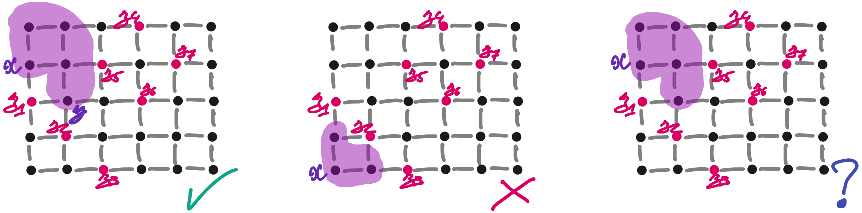
What we do with conn_k and unbreakability

If G is (q,k)-unbreakable, then $\mathrm{conn}_k()$ solvable in time $O(q+k)$.

Take $x, y, z_1, \dots, z_k$:

$\rightarrow$ Depth-first search in $G \setminus \{z_1, \dots, z_k\}$ around x:

- $\rightarrow$ Stop after $q+1$ new vertices.
- 1) Found y?
- 2) Explored the whole component of x?
- 3) Then x is in "The big component".



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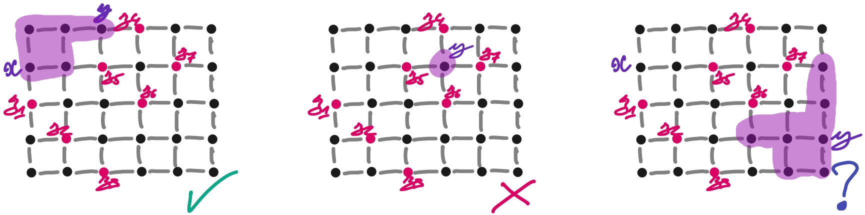

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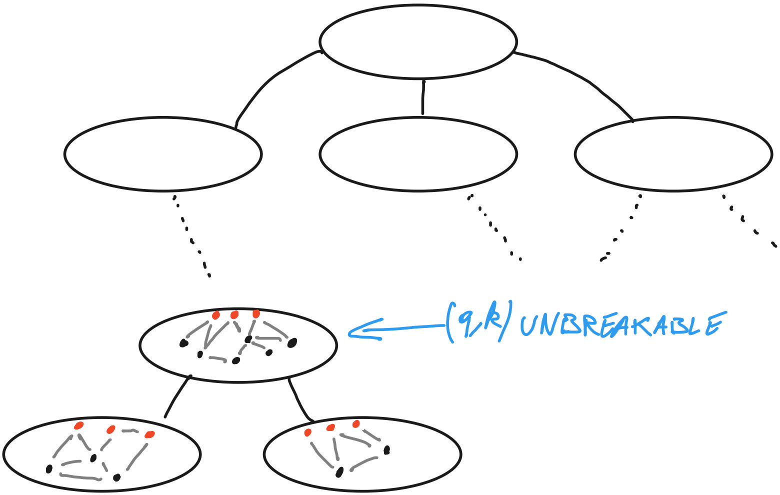
$\rightarrow$ We can conclude $\mathrm{conn}_k(x, y, z_1, \ldots, z_k)$

What we do with conn_k and unbreakability



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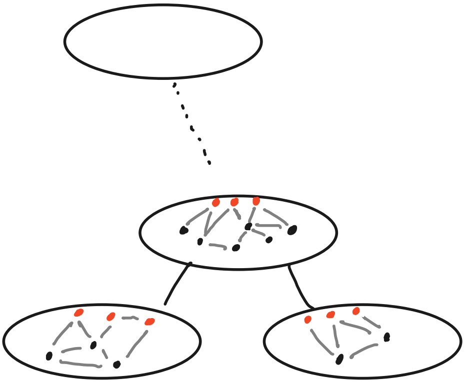
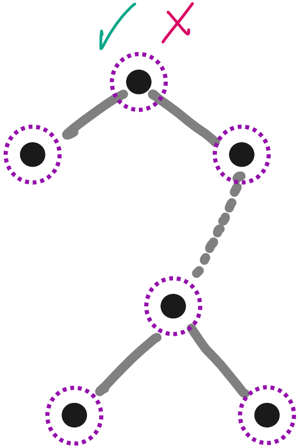




Research project

Research project

First *(short term)* goal: new logics

Beyond $\mathrm{FO} + \mathrm{conn}$

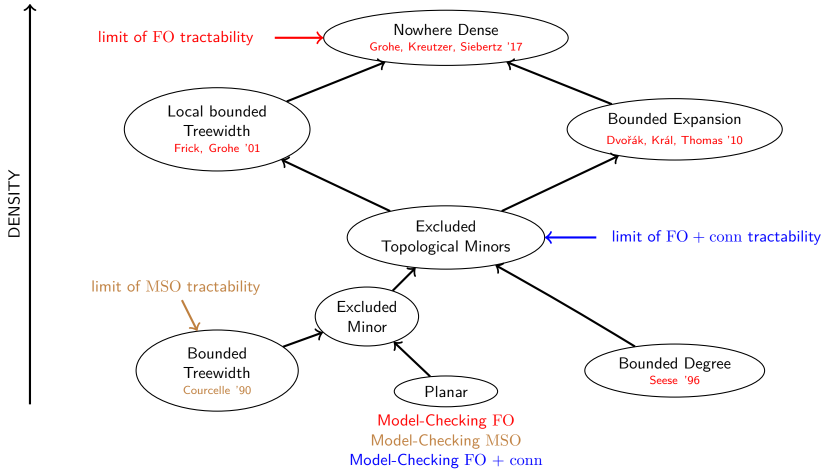
$\rightarrow$ What can be added?

$\rightarrow$ What do we want to express?

$\rightarrow$ Example: a path of even length, using only blue nodes, ...

Keeping in mind algorithmic applications

Characterization of graph classes



Directed graphs

Direction on edges

$\rightarrow$ More general

$\rightarrow$ Problems are harder
E.g. Directed Dominating Set is NP-complet on DAGs

$\rightarrow$ Some problems do not care about orientation

Reconfiguration problems

$\rightarrow$ No need to find a set

$\rightarrow$ Here, the orientation matters!

Distributed computing & Certification

Local computing

→ Other notion of efficient

→ Still looking for meta theorems

Compact certification

→ Feuilloley, Bousquet, Pierron
What Can Be Certified Compactly? Compact local certification of MSO properties in tree-like graphs. In PODC'22

→ Fraigniaud, Montealegre, Rapaport, Todinca
A Meta-Theorem for Distributed Certification. In SIROCCO'22

Integration

Bordeaux *(LaBRI, UMR 5800)*

→ Combinatoire et Algorithmique
M. Bonamy, A. Casteigts, C. Gavoille

→ Méthodes et Modèles Formels
J. Ochremiak, D. Figueira

Lyon *(LIRIS, UMR 5205)*

→ Graphes, algOrithmes et AppLications (GOAL)
N. Bousquet, L. Feuilloley and T. Pierron

Montpellier *(LIRMM, UMR 5506)*

→ Algorithmes, Graphes et Combinatoire (AlGCo)
D. Thilikos, I. Sau, G. Stamoulis

Thank you!

→ 2019-2023: Postdoc, University of Bremen. With Sebastian Siebertz

→ 2018-2019: Postdoc, University of Warsaw. With Szymon Toruńczyk & Mikołaj Bojańczyk

→ 2015-2018: Thesis, University Paris Diderot. With Arnaud Durand & Luc Segoufin

Info:

→ 1 Journal: J.ACM (TOCL & Eur. J. Comb. to appear)

→ 9 Conferences: ICDT, PODS, MFCSx2, SIROCCOx2, ISSAC, CSL, ICALP.

→ 1 Workshop (co-organizer): `https://podc-dare.github.io/`.

→ 1 Popularization: La gazette du GDR-IM.