

# Audition MCF 144

Alexandre Vigny

<https://alexandre-vigny.github.io/mcf144.pdf>

May 22, 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

- Graph theory
- Logic
- 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)  
~ 180h
- In Bremen (3 years)  
~ 270h

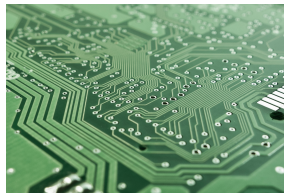
### Highlights

- Creation of syllabuses
- Responsible for two courses
- All level bachelor to master
- Both in French and English

## Algorithmic graph theory

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

→ Is  $G$  planar?

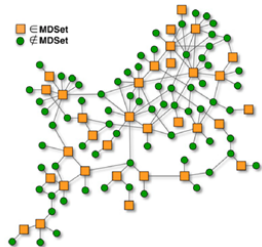


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→ Is  $G$  planar?

→ 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

- Can express  $k$ -independent set: *There are  $k$  vertices, that are not adjacent*  
$$\exists x_1 \dots \exists x_k \bigwedge_{i < j} (\neg E(x_i, x_j) \wedge x_i \neq x_j)$$
- Cannot express : connectivity, planarity, 2-colorability, ...



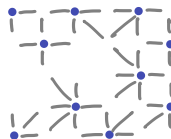
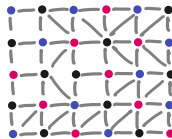
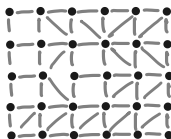
# Logic

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## Monadic second-order (MSO) logic

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



# Distributed computing

## Distributed Computing : Local model

- Different notion of **efficient**
- Time needed VS Information needed

# Distributed computing

## Distributed Computing : Local model

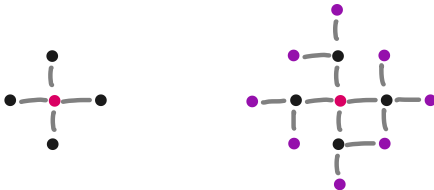
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# Distributed computing

## Distributed Computing : Local model

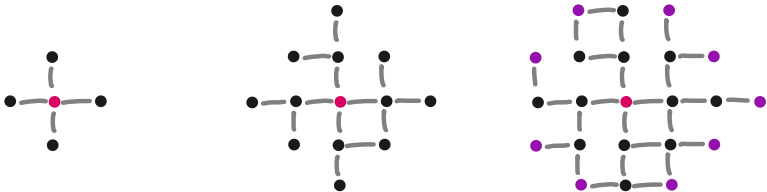
- Different notion of **efficient**
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# Distributed computing

## Distributed Computing : Local model

- Different notion of **efficient**
- Time needed VS Information needed



- Can you decide locally?

## 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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**Courcelle's Theorem (1990):**

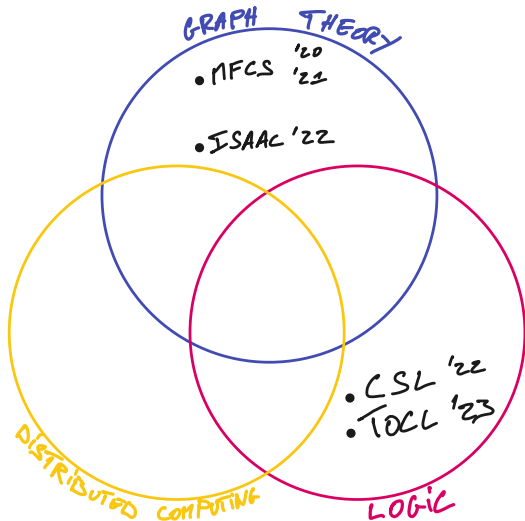
for  $\varphi \in \text{MSO}$  and  $\text{treewidth}(G) \leq k$ , in time  $O(f(\varphi, k) \cdot |G|)$

→ Generalize many known results, ex:

Arnborg, Proskurowski 1989:

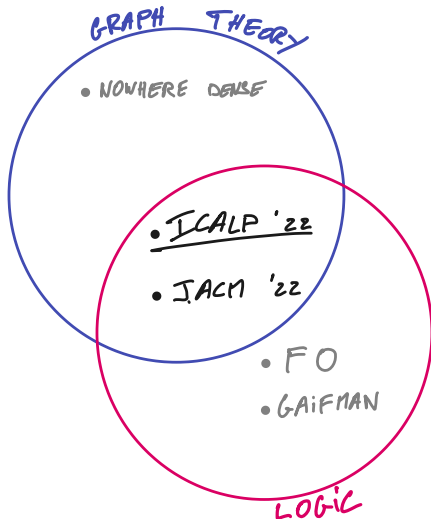
**independent sets, dominating sets, graph coloring, Hamiltonian, ...**  
are **linear** on **partial  $k$ -tree**.

## Result overview





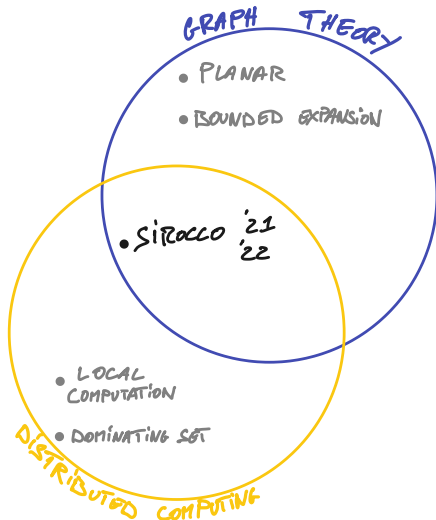
## Result overview



- ENUMERATION FO QUERIES

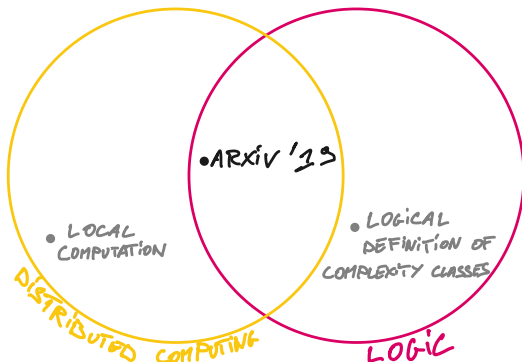
→ PODS 2018  
JACM 2022

## Result overview



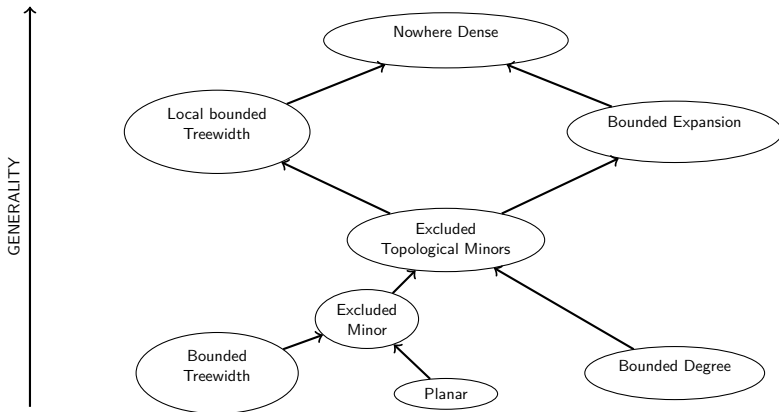
- ENUMERATION FO QUERIES
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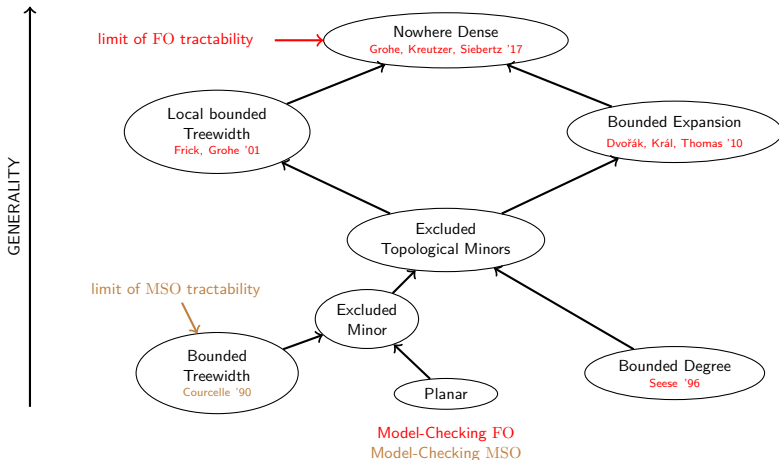


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- PARAMETERIZED DISTRIBUTED  
COMPLEXITY THEORY:  
A LOGICAL APPROACH  
→ ARXIV

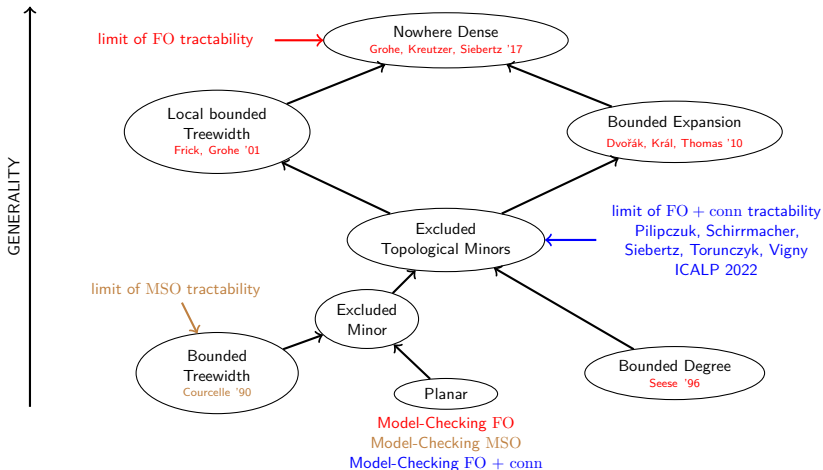
# Monotone graph classes



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# FO + conn

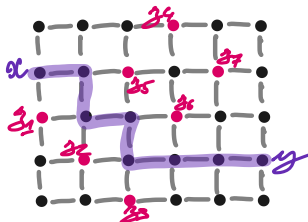
Schirrmacher, Siebertz, Vigny '21 and Bojanczyk '21

## Syntax

→ Uses : FO and **conn<sub>k</sub>**( $x, y, z_1, \dots, z_k$ )

## Meaning

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



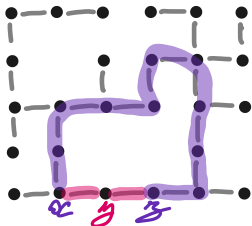
## Expressive power of FO + conn

→ connectivity

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

→ cycle

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



→ Not expressible

planarity, bipartiteness, Hamiltonicity, ...



## Main result

Theorem: Pilipczuk, Schirrmacher, Siebertz, Torunczyk, Vigny

- Model-checking for properties in  $\text{FO} + \text{conn}$  over graph classes excluding a topological minor is solvable in time  $\text{FPT}$ .
- Model-checking is *not*  $\text{FPT}$  for more general graph classes.  
*Under complexity assumptions*

Presentation  
○○

Past Research  
○○○○  
○○○○

Focus  
○○○○

Future and integration  
●○○○

Teaching  
○○○  
○○○

# Research project

## Research project

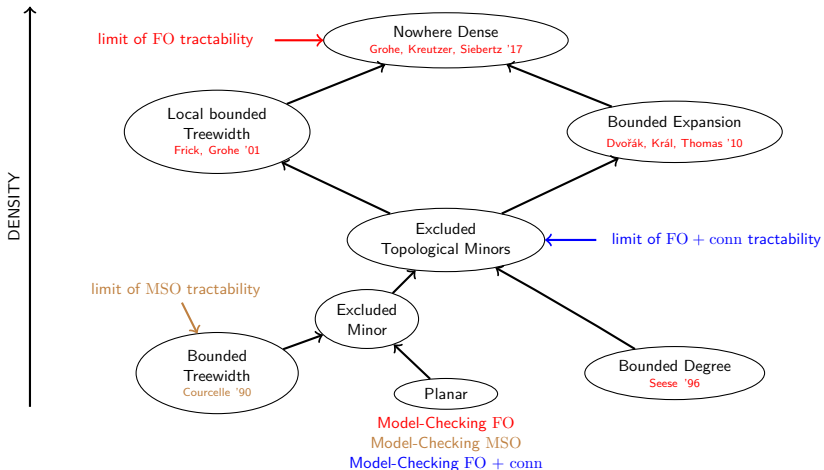
First (*short term*) goal: new logics

### **Beyond** FO + conn

- What can be added?
- What do we want to express?
- Example: a path of even length, using only blue nodes, ...

Keeping in mind algorithmic applications

# Characterization of graph classes



# Directed graphs

## Direction on edges

- More general
- Problems are harder  
*E.g. Directed Dominating Set is NP-complet on DAGs*
- Some problems do not care about orientation

## Reconfiguration problems

- No need to find a set
- Here, the orientation matters!

# Distributed computing & Certification

## Local computing

- Other notion of **efficient**
- Still looking for meta theorems

## Complexity classes

- Hard problems may not be equally hard
- Define complexity classes through logic

## 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

## LINKS (Linking Dynamic Data)

- S. Salvati, C. Paperman, I. Boneva, F. Capelli, M. Monet
- Tree-like structures & MSO (S. Salvati)
- Connections computation-logic (S. Salvati and C. Paperman)
- Graph databases (I. Boneva)
- Knowledge compilation & tree-like structures (F. Capelli, M. Monet)
- Distributed computing is new
- Adding a solid background on graph theory

## Past teaching in Paris

### Around 180h

- Mainly Bachelor level
- Similar to topics in Faculté des Sciences et Technologies

Subject	Years	Level	Activity
Initiation à la Programmation	2015-2016	L1	TP
Langages et Automates	2015-2016	L2	TD
Éléments d'Algorithmique	2016-2017	L2	TD
Base de données	2016-2017 2017-2018	L3 M1	TP & TD
Concepts Informatique	2017-2018	L1	TD



## Past teaching in Bremen

### Around 250h

- Master level
- Creation of syllabuses
- Fully in charge of a lecture

Subject	Years	Level	Activity
Finite Model Theory	2019-2020	Master	TD
Sparsity	2019-2020	Master	TD
Parametrized Complexity	2019-2020	Master	TD
Set and Model Theory	2020-2021	Master	TD
Databases, Graphs, Algorithms	2020-2021 2021-2022	Master	Cours & TD
Set and Model Theory	2021-2022	Master	Cours & TD

## Highlight

### Various settings

- In French, in English
- All levels
- Physical and remote

### Various responsibilities

- Creation of the content
- Fully in charge of a lecture

### Takeaway

- Polls
- Online white boards

# Future 1

## L1:

- Outils pour l'informaticien·ne
- Initiation à la programmation
- Algorithmes et programmation

## L2:

- Algorithmique et les structures de données
- Programmation orientée objet
- Programmation en C

## L3:

- Programmation objet
- Bases de données
- Algorithmique et structures de données

## Future 2

### Master

- Parcours Machine Learning
  - Algorithmique avancée,
  - Bases de données avancées

### Responsibilities

- Responsable d'années
- Stages
- ...

# 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.

[tinyurl.com/short-polls](https://tinyurl.com/short-polls)

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