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Focus
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Future and integration
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Audition MCF 78

Alexandre Vigny

`https://alexandre-vigny.github.io/mcf78.pdf`

May 11, 2023

Alexandre Vigny

$\rightarrow$ 31 years old, born in 1992.

$\rightarrow$ PhD defense September 2018 *(5 years ago)*.

$\rightarrow$ Living in Bremen, Germany.

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

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

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

$\rightarrow$ 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

Summary

Area of Research

$\rightarrow$ Graph theory

$\rightarrow$ Logic

$\rightarrow$ Distributed computing

Highlights

$\rightarrow$ Publication in J.ACM

$\rightarrow$ 2 Upcoming journal papers

$\rightarrow$ 9 Conference papers

$\rightarrow$ Co-organizer of a workshop
    PODC-DARe: Distributed Algorithms on
        REalistic network models

Teaching

$\rightarrow$ In Paris (3 years)
    $\sim$ 180h

$\rightarrow$ In Bremen (3 years)
    $\sim$ 270h

Highlights

$\rightarrow$ Creation of syllabuses

$\rightarrow$ Responsible for two courses

$\rightarrow$ All level bachelor to master

$\rightarrow$ Both in French and English

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Algorithmic graph theory

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

$\rightarrow$ Is G planar?

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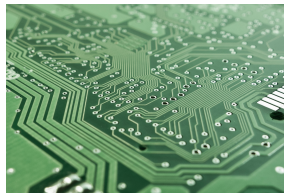
Algorithmic graph theory

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

$\rightarrow$ Is G planar?

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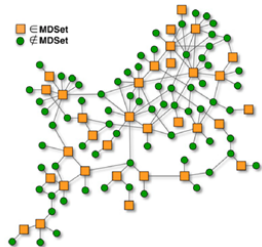
Algorithmic graph theory

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

$\rightarrow$ Is G planar?

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

$\rightarrow$ Is G connected?

Goal: Efficient algorithms ...

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

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Logic

First-order (FO) logic

→ Can express k-independent set: *There are k vertices, that are not adjacent*

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

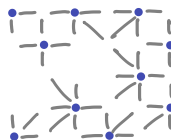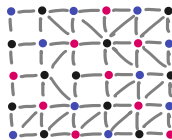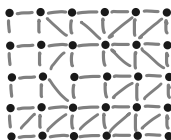→ Cannot express : connectivity, planarity, 2-colorability, ...

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, ...

Monadic second-order (MSO**) logic**

$\rightarrow$ More general than FO

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

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Distributed computing

Distributed Computing : Local model

$\rightarrow$ Different notion of efficient

$\rightarrow$ Time needed VS Information needed

Distributed computing

Distributed Computing : Local model

$\rightarrow$ Different notion of efficient

$\rightarrow$ Time needed VS Information needed

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Distributed computing

Distributed Computing : Local model

→ Different notion of efficient

→ Time needed VS Information needed

Distributed computing
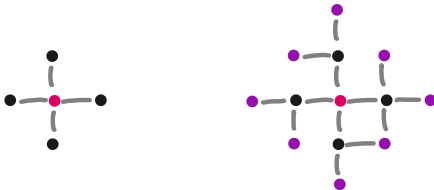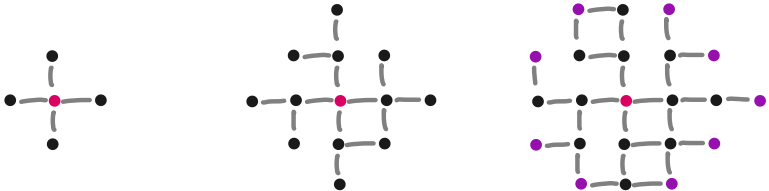
Distributed Computing : Local model

$\rightarrow$ Different notion of efficient

$\rightarrow$ Time needed VS Information needed

$\rightarrow$ Can you decide locally?

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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 $O(f(\varphi) \cdot |G|^c)$

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 $O(f(\varphi) \cdot |G|^c)$

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.

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Result overview

GRAPH THEORY

• MFCS '20 '21

• ISAAC '22

DISTRIBUTED COMPUTING

LOGIC

• CSL '22
• TOCL '23

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Result overview

GRAPH THEORY

• NOWHERE DENSE

• ICALP '22

• JACM '22

• FO

• GAIFMAN

LOGIC
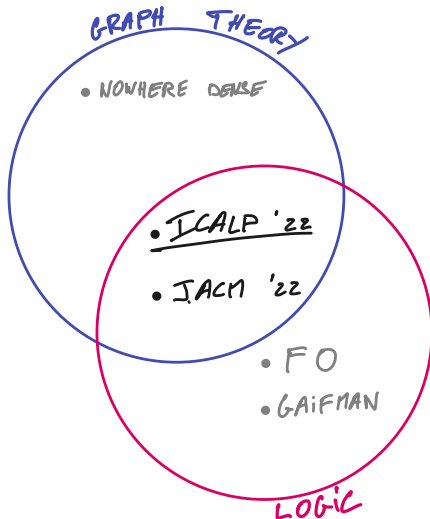
• ENUMERATION FO QUERIES
  -> PODS 2018
     JACM 2022
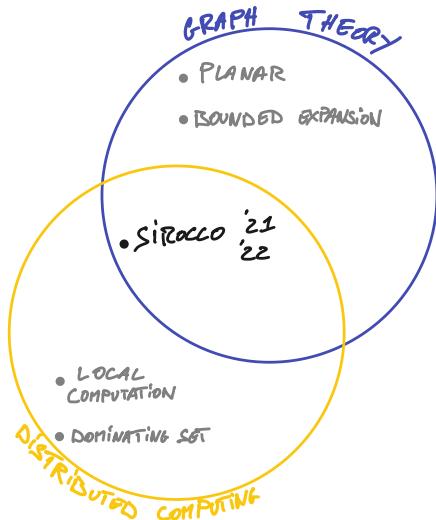
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Result overview

GRAPH THEORY

- PLANAR
- BOUNDED EXPANSION

• SIROCCO '21 '22

- LOCAL COMPUTATION
- DOMINATING SET

DISTRIBUTED COMPUTING

- ENUMERATION FO QUERIES
  - → PODS 2018
    SACM 2022

- DISTRIBUTED DOMINATION
  ON SPARSE GRAPH CLASSES
  - → SIROCCO 2021/2022
  - → EUR. J. COMB.
    (TO APPEAR)

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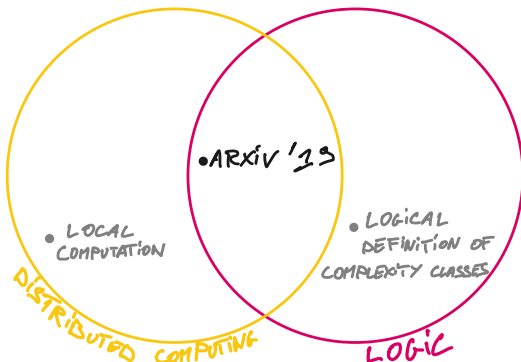
Result overview

- ENUMERATION FO QUERIES
  -> PODS 2018
     SACM 2022

- DISTRIBUTED DOMINATION
  ON SPARSE GRAPH CLASSES
  -> SIROCCO 2021/2022
  -> EUR. J. COMB.
     (TO APPEAR)

- PARAMETERIZED DISTRIBUTED
  COMPLEXITY THEORY:
  A LOGICAL APPROACH
  ->ARXIV

ARXIV '19

LOCAL
COMPUTATION

LOGICAL
DEFINITION OF
COMPLEXITY CLASSES

DISTRIBUTED COMPUTING

LOGIC

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Monotone graph classes

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Monotone graph classes

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Monotone graph classes

GENERALITY

limit of FO tractability →

Nowhere Dense
Grohe, Kreutzer, Siebertz '17

Local bounded
Treewidth
Frick, Grohe '01

Bounded Expansion
Dvořák, Král, Thomas '10

Excluded
Topological Minors

limit of FO + conn tractability
Pilipczuk, Schirrmacher,
Siebertz, Torunczyk, Vigny
ICALP 2022

limit of MSO tractability ↘

Excluded
Minor

Bounded
Treewidth
Courcelle '90

Planar

Bounded Degree
Seese '96

Model-Checking FO
Model-Checking MSO
Model-Checking FO + conn

FO + conn

Schirrmacher, Siebertz, Vigny '21 and Bojanczyk '21

Syntax

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

Meaning

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

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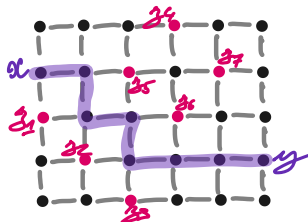
Expressive power of $\mathrm{FO} + \mathrm{conn}$

$\rightarrow$ connectivity

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

$\rightarrow$ cycle

$$\varphi_{cycle} := \exists x \exists y \exists z (E(x, y) \wedge E(y, z) \wedge z \neq x \wedge \mathrm{conn}_1(z, x, y))$$
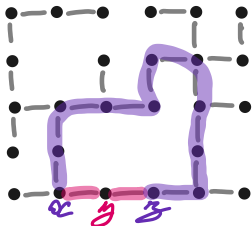
$\rightarrow$ Not expressible

    planarity, bipartiteness, Hamiltonicity, . . .

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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

Research project

Research project

First *(short term)* goal: new logics

Beyond $FO + conn$

$\rightarrow$ 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

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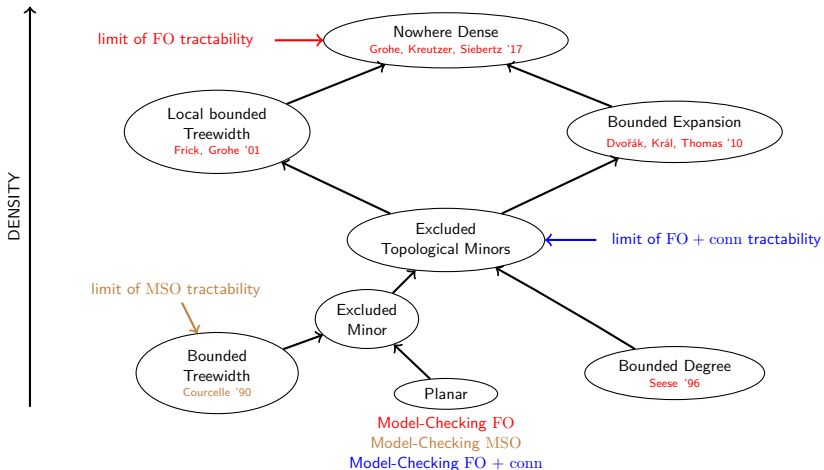
Directed graphs

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!

Presentation   Past Research   Focus   Future and integration   Teaching
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Distributed computing & Certification

Local computing

$\rightarrow$ Other notion of efficient

$\rightarrow$ Still looking for meta theorems

Complexity classes

$\rightarrow$ Hard problems may not be equally hard

$\rightarrow$ Define complexity classes through logic

Compact certification

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

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

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Integration

Axe MAAD : Modèles et Algorithmes de l'Aide à la Décision
Algorithmics, Graphs, Complexity

$\rightarrow$ M. Kanté, JF. Raymont, L. Nourine, B. Guillon

$\rightarrow$ Workshop Generalized coloring numbers (JF. Raymont)

$\rightarrow$ ANR GraphEn (M. Kanté, L. Nourine)

$\rightarrow$ Create a logic working group with B. Guillon and M. Kanté

$\rightarrow$ Distributed computing is new.

$\rightarrow$ Compact certification vs Labelling scheme (M. Kanté)

Past teaching in Paris

Around 180h

→ Mainly Bachelor level

→ Similar to topics in ISIMA

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
- $\rightarrow$ In French, in English
- $\rightarrow$ All levels
- $\rightarrow$ Physical and remote

Various responsibilities
- $\rightarrow$ Creation of the content
- $\rightarrow$ Fully in charge of a lecture

Takeaway
- $\rightarrow$ Polls
- $\rightarrow$ Online white boards

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Future

Responsibilities

$\rightarrow$ Responsable d'années

$\rightarrow$ Stages

$\rightarrow$ . . .

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Thank you!

$\rightarrow$ 2019-2023: Postdoc, University of Bremen. With Sebastian Siebertz

$\rightarrow$ 2018-2019: Postdoc, University of Warsaw. With Szymon Toruńczyk

& Mikołaj Bojańczyk

$\rightarrow$ 2015-2018: Thesis, University Paris Diderot. With Arnaud Durand

& Luc Segoufin

Info:

$\rightarrow$ 1 Journal: J.ACM   (TOCL & Eur. J. Comb. to appear)

$\rightarrow$ 9 Conferences: ICDT, PODS, MFCSx2, SIROCCOx2, ISSAC, CSL, ICALP.

$\rightarrow$ 1 Workshop (co-organizer): https://podc-dare.github.io/.

$\rightarrow$ 1 Popularization: La gazette du GDR-IM.

tinyurl.com/short-polls