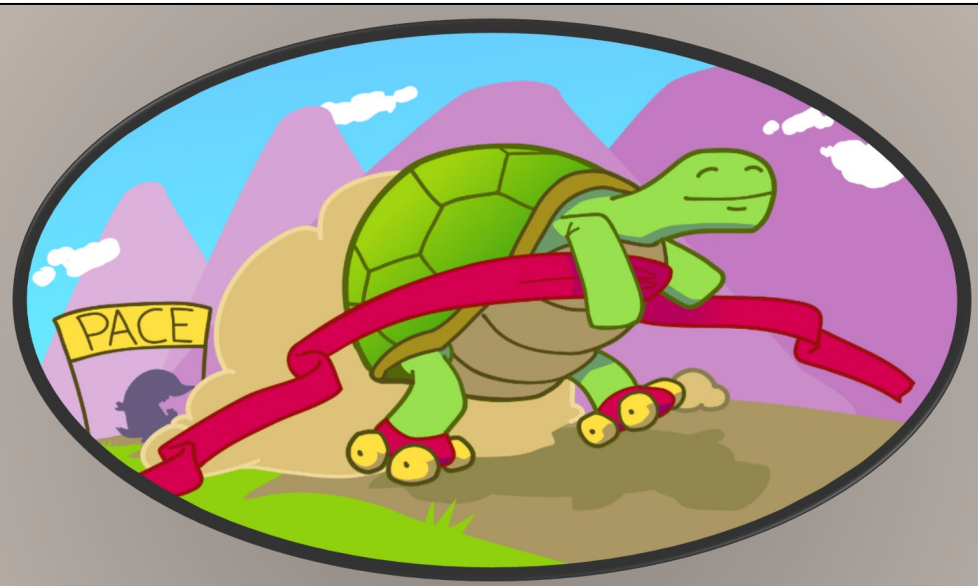
Parameterized Algorithms & Computational Experiments Challenge

www.pacechallenge.org



September 8th, IPEC 2021, Lisbon

Goals

Investigate the applicability of algorithmic ideas from parameterized algorithmics

1. provide bridge between algorithm theory and algorithm engineering practice
2. inspire new theoretical developments
3. investigate the competitiveness of analytical and design frameworks
4. produce universally accessible libraries of implementations & benchmark inputs
5. encourage dissemination of the findings in scientific papers

Impact of PACE

Story behind PACE 2016

Developed a new algorithm to solve the LP!

⇒ Practical and theoretical improvements

- 1st place in the competition
- Linear-time kernelization of FVS (ICALP 2017)
- Linear-time FPT for various problems (FOCS 2018)

Motivation: Explaining succe

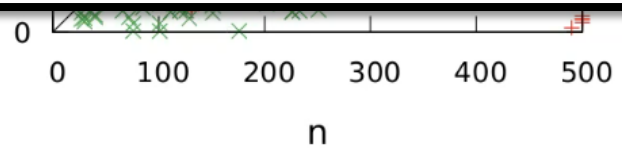
- PACE 2017: Top 4 solvers on mi
  solver on treewidth track based
- Implementations based on

triangulations

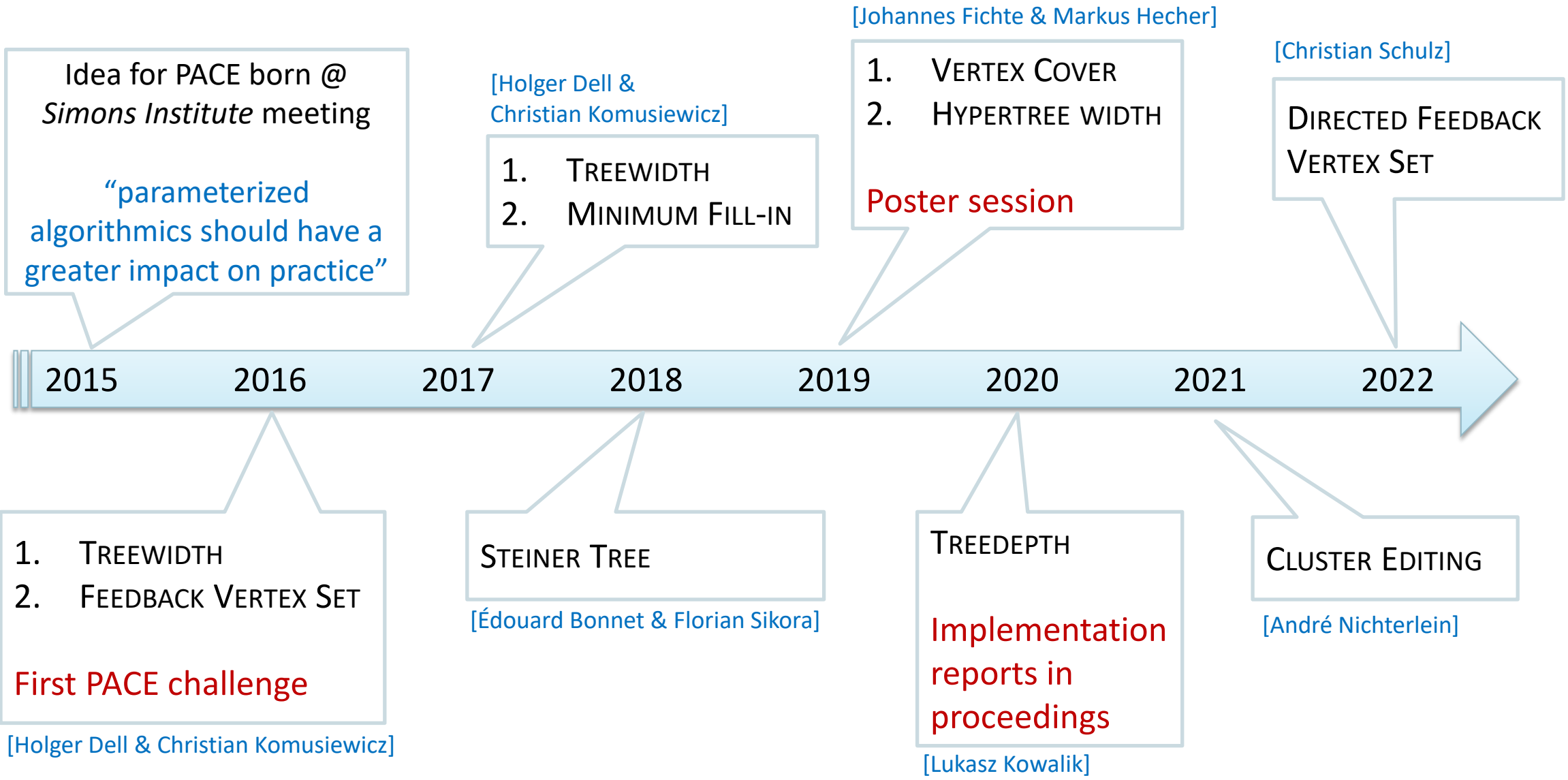
[Ravid, Medini, and Kimelfeld, 2019]

An Algorithm for the Exact Treedepth Problem

James Trimble
School of Computing Science, University of Glasgow, UK
j.trimble.1@research.gla.ac.uk



The history of PACE



PACE 2022: Directed Feedback Vertex Set

Challenge tracks:

1. Exact algorithms
2. Heuristic algorithms

https://pacechallenge.org/2022/

Program Committee:

Christian Schulz*	*Universität Heidelberg*
Darren Strash	*Hamilton College*
Ernestine Großmann	*Universität Heidelberg*
Tobias Heuer	*Karlsruher Institut für Technologie*

PACE 2022: Directed Feedback Vertex Set

Timeline

September 2021:	Announcement of the challenge (problem) and tracks
November 2021:	Announcement of additional information and ranking methods
December 2021:	Public instances are available
March 2022:	Submission via optil.io is open (for testing and unofficial leaderboard)
June 1st, 2022 (AoE):	Submission deadline for solver
June 15th, 2022 (AoE):	Submission deadline for solver description
July, 2022:	Announcement of the results
September 2022:	Award ceremony at IPEC 2022

Steering committee

Holger Dell	Goethe University Frankfurt and IT University of Copenhagen
Johannes Fichte	Technische Universität Dresden
Markus Hecher	Technische Universität Wien
Bart M. P. Jansen*	Eindhoven University of Technology
Łukasz Kowalik	University of Warsaw
Andre Nichterlein	Technical University of Berlin
Marcin Pilipczuk	University of Warsaw
Manuel Sorge	Technische Universität Wien

Former members

Édouard Bonnet	(2017-2021)
Thore Husfeldt	(2016-2019)
Petteri Kaski	(2016-2020)
Christian Komusiewicz	(2016-2020)
Frances Rosamond	(2016-2019)
Florian Sikora	(2017-2020)

PACE Award Ceremony

Parameterized Algorithms and Computational Experiments Challenge 2021

André Nichterlein

TU Berlin, Algorithmics and Computational Complexity

https://pacechallenge.org/

Table of contents

Organization & Sponsors

Program Committee:

Leon Kellerhals Tomohiro Koana André Nichterlein Philipp Zschoche

Thanks to sponsors:

Networks
for sponsoring the prizes

optil.io (especially Artur Laskowski and Jan Badura)
for their online judge system

Participants

Country	Participants	Submissions
Germany	39	15
Czechia	6	3
France	5	3 (1.5)
Australia	4	1
India	4	4
United States	3	2
Japan	1	1
Mexico	1	1
Netherlands	1	1
Poland	1	3
United Kingdom	1	3 (1.5)

- 11 countries & 3 continents
- 21 "distinct" teams
- 11 student teams
  (7 BSc / 1 MSc / 3 PhD)
  https://paraalgo.informatik.uni-bremen.de/

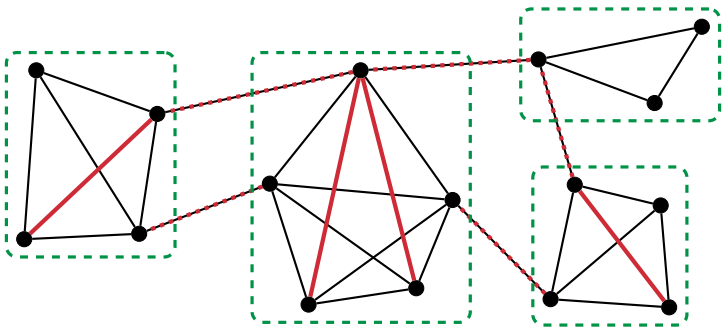
Language	Submissions
C++	21
Rust	4
Java	4
Python	3
C#	1

Cluster Editing I

Cluster Editing / Correlation Clustering

Input: An undirected graph $G = (V, E)$.

Task: Transform G into a cluster graph (each connected component is a clique) by a minimum number of edge insertions and deletions.



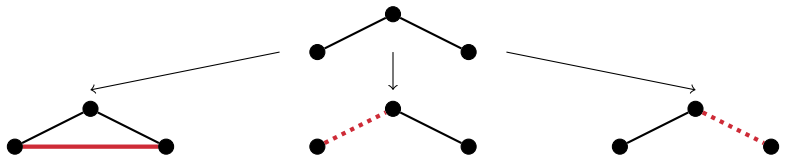
Applications: Bioinformatics, data mining, psychometrics, ...

Cluster Editing II

Observation

A graph G is a cluster graph $\iff$ G does not contain a P_3 as induced subgraph.

$\rightsquigarrow$ simple 3^k search tree ($k \mathrel{\widehat{=}}$ number of edge modifications):

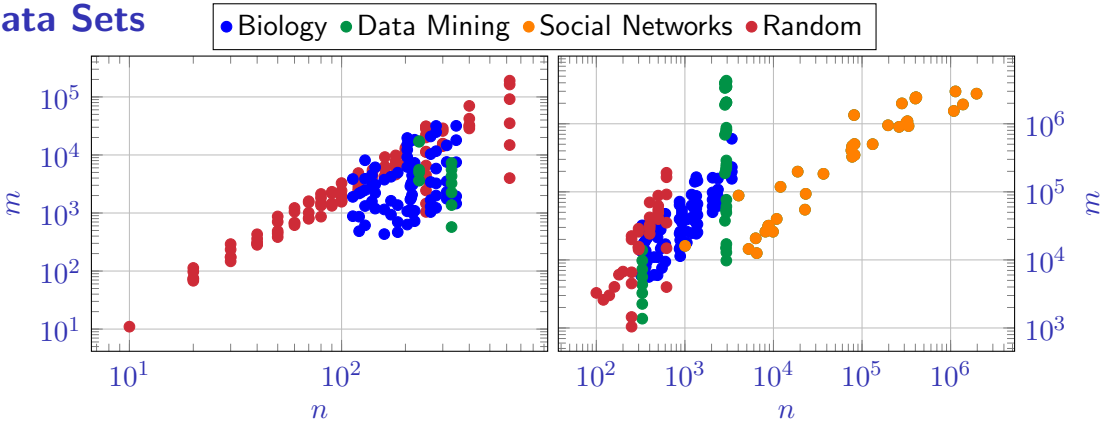


Cluster Editing well-studied in parameterized algorithmics:

- solvable in $O(1.62^k + n + m)$ time [Böcker, J. of Discrete Algorithms, 2012]
- no $2^{o(k)} \cdot n^{O(1)}$-time algorithm [Komusiewicz, Uhlmann, Discret. Appl. Math., 2012]
- problem kernel with $2k$ vertices [Chen, Meng, J. of Computer and System Sciences, 2011]

($n \mathrel{\widehat{=}}$ number of vertices; $m \mathrel{\widehat{=}}$ number of edges)

Data Sets



Description	$n_{\min}$	$n_{\max}$	$m_{\min}$	$m_{\max}$	instances
Left: Exact & Kernel Track	10	620	11	190,499	200
Right: Heuristic Track	10	1,965,206	31	4,295,123	200

https://github.com/PACE-challenge/Cluster-Editing-PACE-2021-instances

Tracks

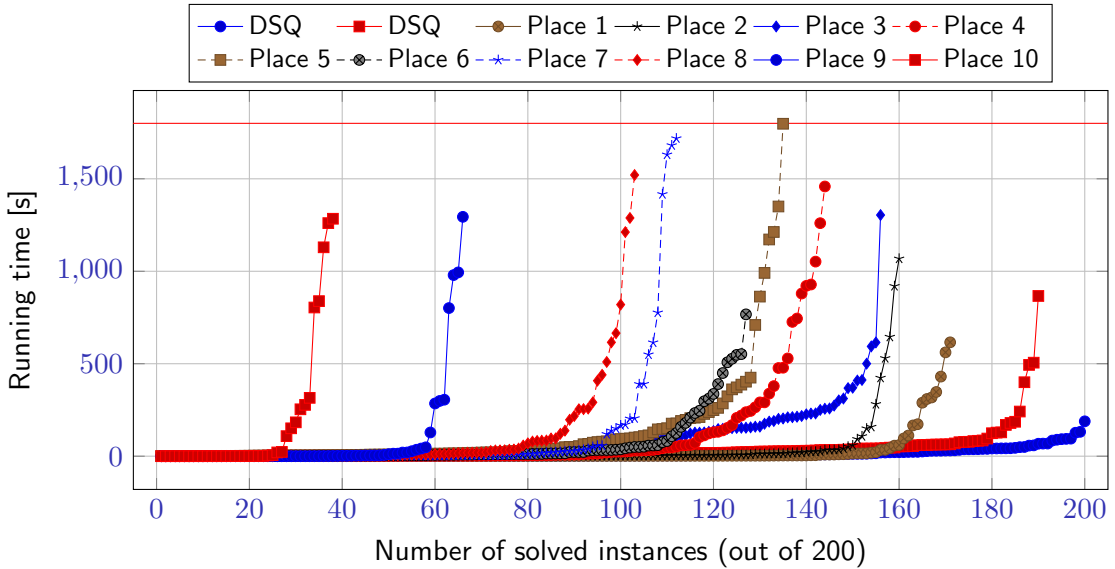
Input for all three tracks: graph $G = (V, E)$

Track	time limit	result of submission	ranking
Exact	30 min	optimal solution (list of vertex pairs)	number of solved instances
Heuristic	10 min	good solution (list S of vertex pairs)	size of S
Kernel	5 min	a small "kernel"	size of kernel

Prizes for:

- Best 3 submissions per track
- Best 3 student submissions per track
- At most one prize per submission (higher prize if applicable for top 3 and student prize)
- Tax may have to be paid if a single participant wins more than 450 euros.

Exact Track — Cactus Plot



Exact Track — Employed Techniques

Approach	number of teams
Branch & Bound	6
ILP	1
Combination of B&B and ILP	3
Data reduction and ILP	1

Test with standard ILP formulation, solved with Gurobi:

- 30 min time limit: **141** of the 200 instances solved
- 180 min time limit: **156** of the 200 instances solved

Exact Track — Results

	Team (Institute)	Points	Status
1	Lars Gottesbüren, Tobias Heuer, Thomas Bläsius, Philipp Fischbeck, Michael Hamann, Jonas Spinner, Christopher Weyand, Marcus Wilhelm (Karlsruhe Institute of Technology, Hasso Plattner Institut)	**87** (171)	—
2	Alexander Bille, Dominik Brandenstein, Emanuel Herrendorf (Philipps University of Marburg)	**81** (160)	MSc
3	Valentin Bartier, Gabriel Bathie, Nicolas Bousquet, Marc Heinrich, Théo Pierron, Ulysse Prieto (Grenoble INP, École Normale Supérieure de Lyon, Université de Lyon, University of Leeds)	**77** (156)	—
4	Jona Dirks, Mario Grobler, Tobias Meis, Roman Rabinovich, Yannik Schnaubelt, Sebastian Siebertz, Maximilian Sonneborn (University of Bremen, Technische Universität Berlin)	**71** (144)	BSc
5	Thorben Freese, Jakob Gahde, Mario Grobler, Roman Rabinovich, Fynn Sczuka, Sebastian Siebertz (University of Bremen, Technische Universität Berlin)	**67** (135)	BSc
6	Yosuke Mizutani (University of Utah)	**63** (127)	PhD
7	Václav Blažej, Radovan Červený, Dušan Knop, Jan Pokorný, Šimon Schierreich, Ondřej Suchý (Czech Technical University in Prague)	**59** (112)	PhD
8	Sachin Agarwal, Sahil Bajaj, Ojasv Singh, Srinibas Swain (IIIT Guwahati)	**52** (103)	BSc
9	Sebastian Paarmann (Technische Universität Hamburg)	**36** (66)	BSc
10	Tomoki Takayama (Osaka Prefecture University)	**17** (38)	—

6th Parameterized Algorithms and Computational Experiments Challenge

PACE

Uniting FPT and practice

ALGO/IPEC 2021, September 06 – 10 Lisbon, Portugal

This is to certify that the 2021 PACE Program Committee has selected

Yosuke Mizutani

University of Utah

as the

Third Student Prize Winner in the Exact Track of the Cluster Editing Challenge

175 €

André Nichterlein, TU Berlin
2021 PACE Program Committee Chair

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Thorben Freese[1], Jakob Gahde[1], Mario Grobler[1], Roman Rabinovich[2], Fynn Sczuka[1], Sebastian Siebertz[1]

[1]University of Bremen, [2]TU Berlin

as the

Second Student Prize Winners in the Exact Track of the Cluster Editing Challenge

225 €

André Nichterlein, TU Berlin
2021 PACE Program Committee Chair

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[1]University of Bremen, [2]TU Berlin

as the

First Student Prize Winners in the Exact Track of the Cluster Editing Challenge

300 €

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2021 PACE Program Committee Chair

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[1]Grenoble INP, [2]École Normale Supérieure de Lyon, [3]Université de Lyon, [4]University of Leeds

as the

Third Place Winners in the Exact Track of the Cluster Editing Challenge

200 €

André Nichterlein, TU Berlin
2021 PACE Program Committee Chair

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First Place Winners in the Exact Track of the Cluster Editing Challenge

500 €

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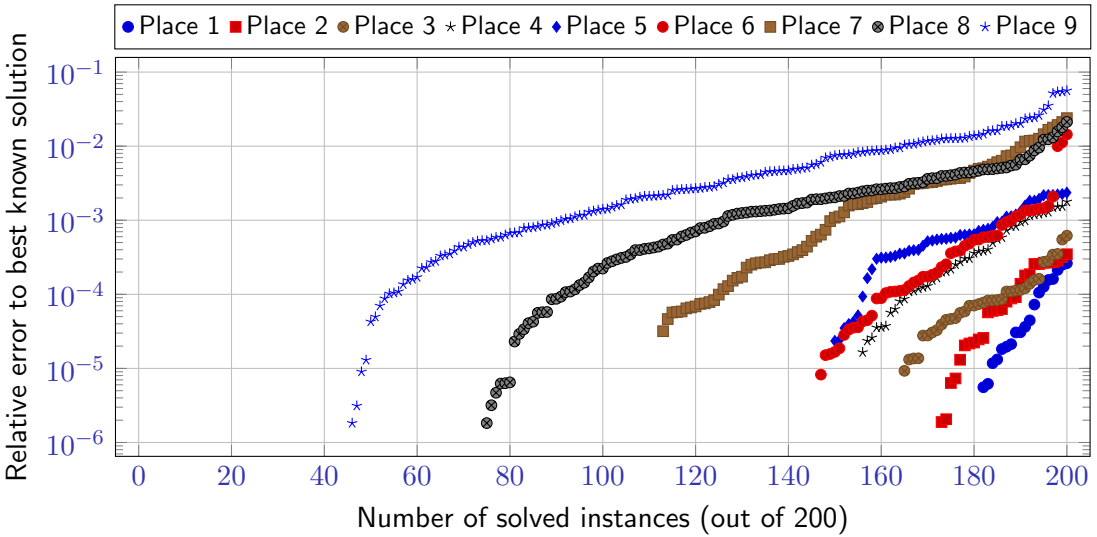
Heuristic Track — Cactus Plot



Heuristic Track — Results

Points: $\sum_{\text{instances}} 100 \cdot$ (best known solution size) / (submission solution size)

	Team (Institute)	Points	Status
1	Lars Gottesbüren, Tobias Heuer, Thomas Bläsius, Philipp Fischbeck, Michael Hamann, Jonas Spinner, Christopher Weyand, Marcus Wilhelm (Karlsruhe Institute of Technology, Hasso Plattner Institut)	**9999.89**	—
2	Sylwester Swat (Poznań University of Technology)	**9999.85**	PhD
3	Valentin Bartier, Gabriel Bathie, Nicolas Bousquet, Marc Heinrich, Théo Pierron, Ulysse Prieto (Grenoble INP, École Normale Supérieure de Lyon, Université de Lyon, University of Leeds)	**9999.75**	—
4	Martin Josef Geiger (University of the Federal Armed Forces Hamburg)	**9998.76**	—
5	Emir Demirović (Delft University of Technology)	**9997.86**	—
6	Ben Strasser	**9997.23**	—
7	Angus Ritossa, Paula Tennent, Tiana Tsang Ung, Akshay Valluru (UNSW Sydney)	**9986.56**	BSc
8	Sachin Agarwal, Sahil Bajaj, Ojasv Singh, Srinibas Swain (IIIT Guwahati)	**9967.39**	BSc
9	Václav Blažej, Radovan Červený, Dušan Knop, Jan Pokorný, Šimon Schierreich, Ondřej Suchý (Czech Technical University in Prague)	**9949.46**	PhD
10	Jona Dirks, Mario Grobler, Tobias Meis, Roman Rabinovich, Yannik Schnaubelt, Sebastian Siebertz, Maximilian Sonneborn (University of Bremen, Technische Universität Berlin)	**8900.09**	BSc

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UNSW Sydney

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300 €

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500 €

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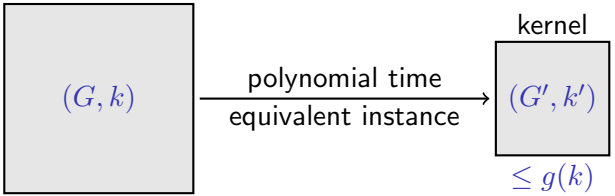
Kernel Track — Setup

Goal: Track for kernelization results

Issues:

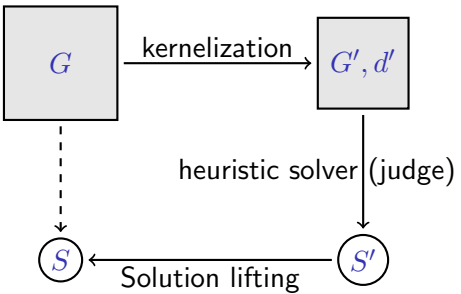
- Solution size k unknown
- Kernel itself not useful in practice
- Correctness hard to check
- Best exact solver is best kernel?



Track requirements: (input: graph $G = (V, E)$; $\mathrm{opt}(G)$: size of optimal solution of G)

1. Kernelization algorithm: return $d \in \mathbb{N}$ and $G' = (V', E')$ so that $\mathrm{opt}(G) = \mathrm{opt}(G') + d$
2. Solution lifting algorithm: given heuristic solution S' for G', compute solution S for G with $|S| \leq |S'| + d$

$\rightsquigarrow$ Practice orientated kernel track



Kernel Track — Results

Points: $\sum_{\text{instances}} 100 \cdot$ (best score) / (submission score)
score = (kernel size)/(parameter reduction)

	Team (Institute)	Points	Status
1	Sylwester Swat (Poznań University of Technology)	**6567.61**	PhD

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Sylwester Swat

Poznań University of Technology

as the

First Place Winner in the Kernel Track of the Cluster Editing Challenge

500 €

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2021 PACE Program Committee Chair

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Conclusion

Students prizes: Announce them for next iterations?

Exact & heuristic track: works well!

Issues with kernel track: Happy for any comments and feedback!

- 2-Phase setup suitable for practice but
  - not testable in optil.io
  - might exclude kernelizations (requiring optimal solutions for kernel)?
- Most frequently returned kernel: empty graph $\rightsquigarrow$ harder instances / shorter time limit for kernel track?
- Data reduction rules might insert edges $\rightsquigarrow$ kernel might be larger than input graph

Thank You!