Universität Bremen

PACE 2025

Dominating Set and Hitting Set

Mario Grobler, Sebastian Siebertz

September 18, 2025

DATA SCIENCE CENTER

OPTIL.io

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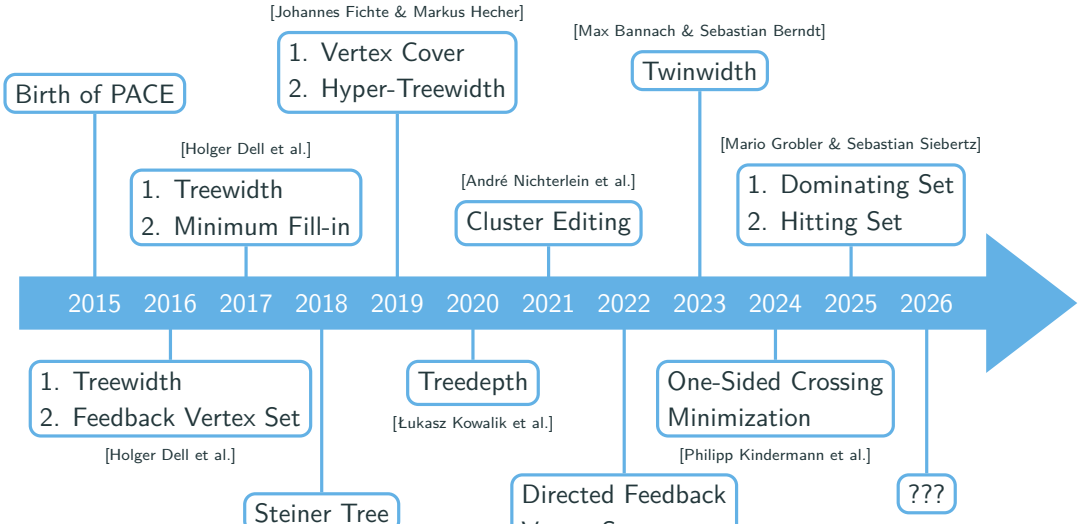
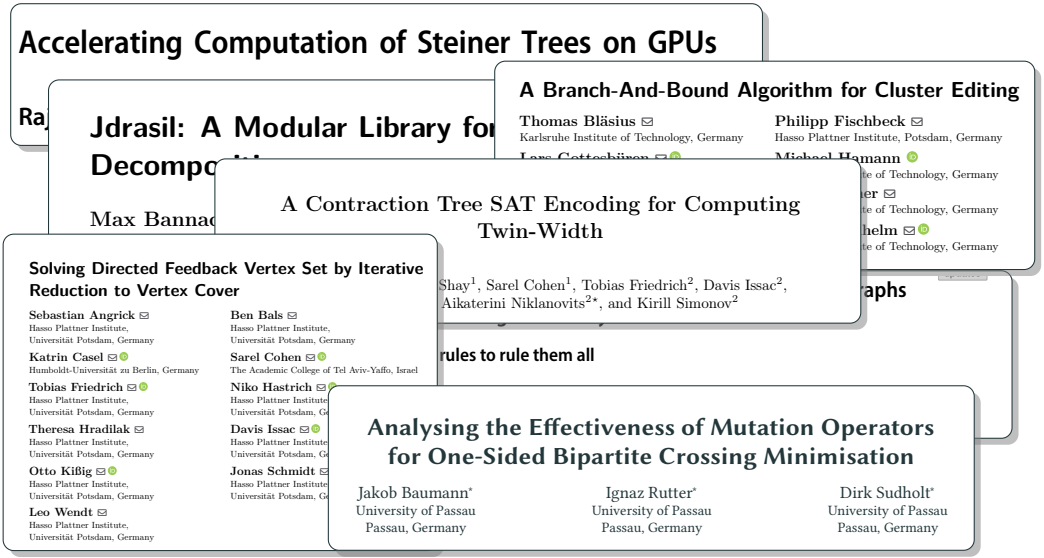
History of PACE



Impact of PACE



Steering Committee

Max Bannach	European Space Agency
Sebastian Berndt	Universität zu Lübeck
Holger Dell	Goethe University Frankfurt and IT University of Copenhagen
Bart M. P. Jansen*	Eindhoven University of Technology
Philipp Kindermann	Universität Trier
André Nichterlein	Technical University of Berlin
Christian Schulz	Universität Heidelberg
Soeren Terziadis	Eindhoven University of Technology

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Manuel Sorge	(2020-2024)	Petteri Kaski	(2016-2020)
Marcin Pilipczuk	(2021-2023)	Christian Komusiewicz	(2016-2020)
Johannes Fichte	(2020-2023)	Frances Rosamond	(2016-2019)
Markus Hecher	(2020-2023)	Thore Husfeldt	(2016-2019)
Édouard Bonnet	(2017-2021)		

Sponsors

We thank our sponsors for their generous support!

- Networks for sponsoring the PACE 2025 prize money (4000€ in total).

- Optil.io for providing the platform to run the challenge.

- Data Science Center for providing the evaluation infrastructure.

PACE 2025

Problems:

- Dominating Set
- Hitting Set

Tracks:

- Exact
- Heuristic

Program Committee:

Sebastian Siebertz
University of Bremen

Mario Grobler
University of Bremen

Change and Continuity

Changes for PACE 2025:

- These year's problems are *not* fpt in general (but on many restricted classes)
- Increased memory limit: 8GB $\rightarrow$ 16GB
- Predefined Docker container to ensure uniform environment
- Dedicated reviewing phase to ensure correctness of solvers
  - ▷ Additional test set (thanks to Manuel Penschuck for Stride!)

Continuity:

- Two tracks: Exact and Heuristic
- Dedicated student rankings

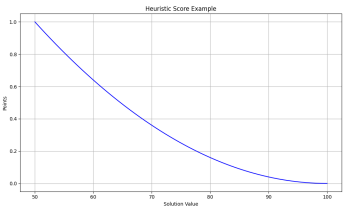
The Tracks

Exact:

- Find an optimal solution
- Time limit: 30 minutes, memory limit: 16GB
- Scoring based on number of solved instances and time

Heuristic:

- Find a good solution (not necessarily optimal)
- Time limit: 5 minutes, memory limit: 16GB
- Scoring function:



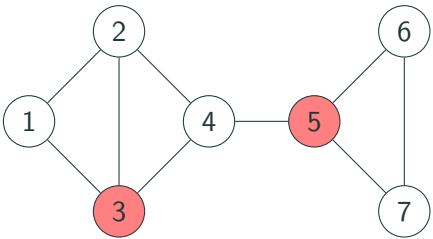
$$f(k) = \left(\frac{u-k}{u-k^*}\right)^2, \text{ where } u = \min\{n, 2k^*\},$$

k = solution size, k^* = best known solution size, n = number of vertices

Problems

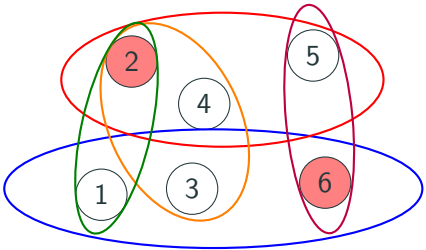
This year's iteration features **two problems**.

Dominating Set



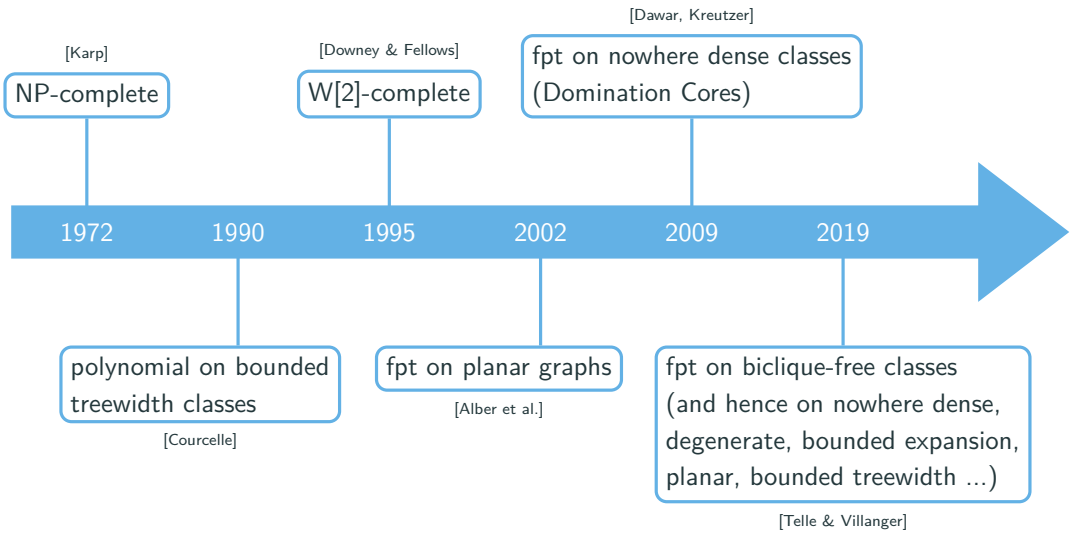
Set $D \subseteq V(G)$ such that for all $v \in V(G)$ we have $N[v] \cap D \neq \varnothing$

Hitting Set



Set $H \subseteq V(\mathcal{S})$ such that for all $S \in E(\mathcal{S})$ we have $S \cap H \neq \varnothing$

Known Results: Dominating Set

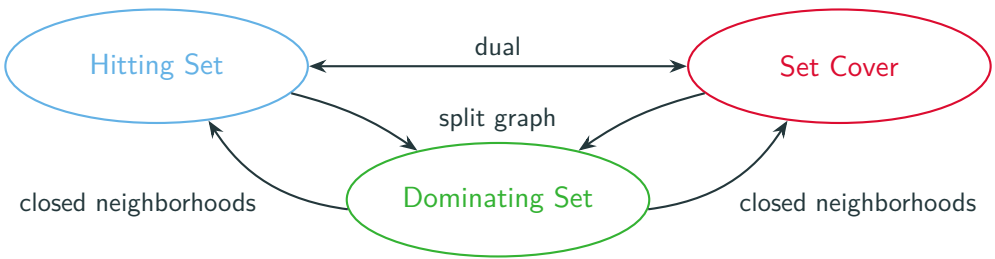


Known Results: Hitting Set

Hitting Set generalizes many problems, including

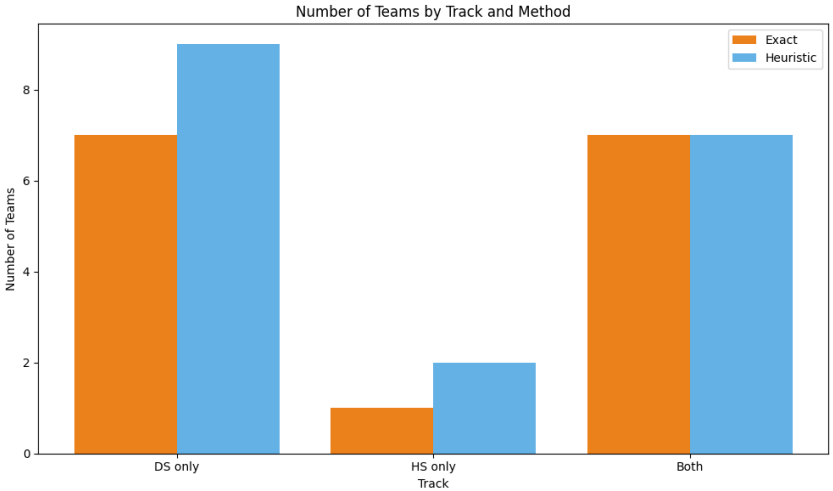
- Vertex Cover (sets have size 2)
- Dominating Set (sets are closed neighborhoods)
- Feedback Vertex Set (sets are cycles)

Still, Dominating Set, Hitting Set and Set Cover are in a sense the same problem



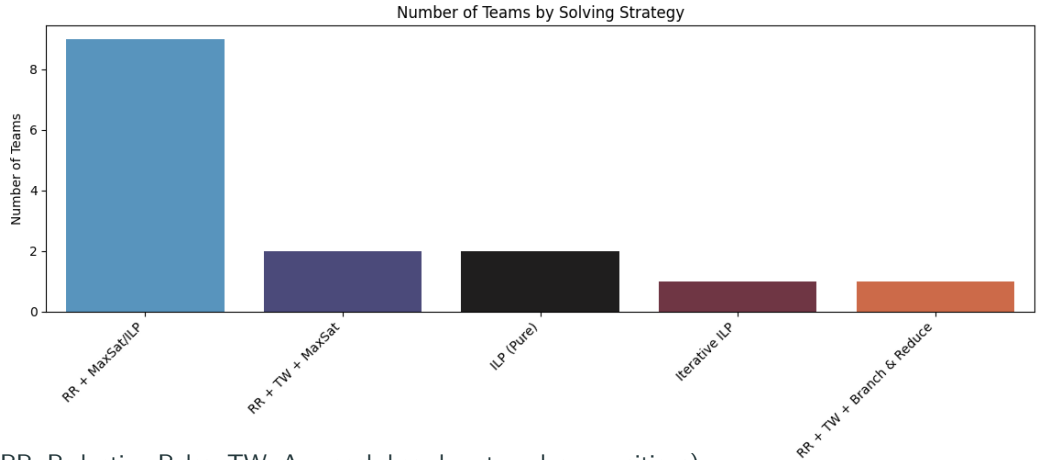
Number of Participants

PACE 2025: 71 participants from 25 teams, 13 countries, and 3 continents



Solving Strategies – Exact Solvers

Employed Solving Strategies of exact solvers (grouped into nearest fitting category)

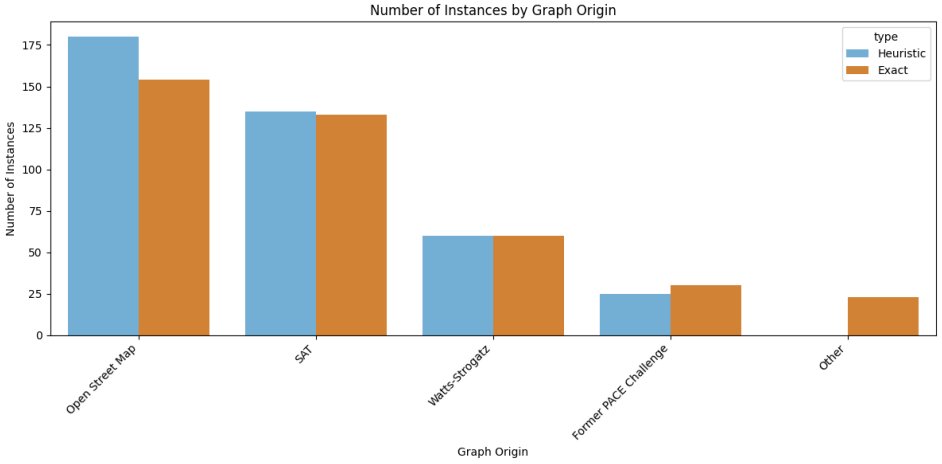


(RR: Reduction Rules, TW: Approach based on tree decompositions)

Employed Solving Strategies of heuristic solvers

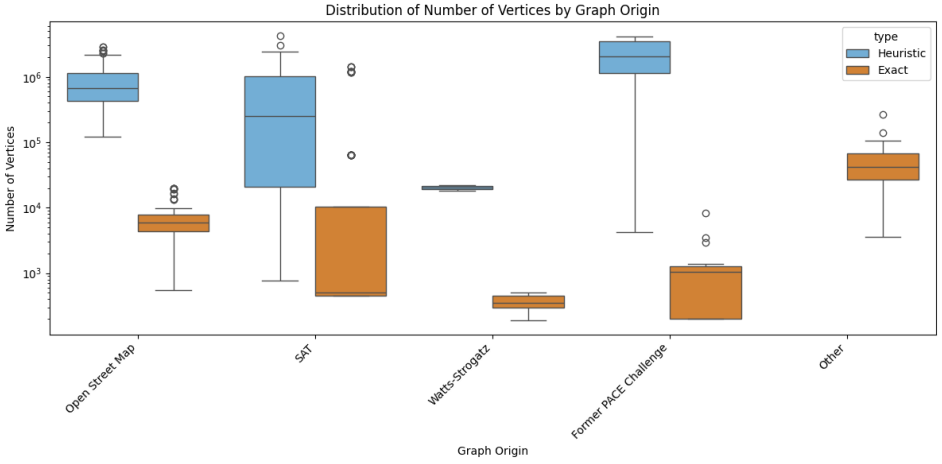
Graph Origins

Dominating Set and Hitting Set combined, grouped by Exact and Heuristic Tracks



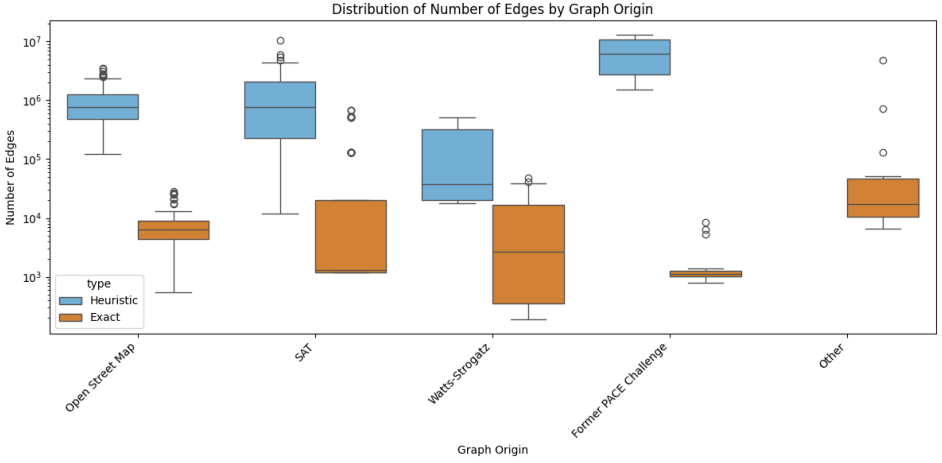
Graph Sizes by Origin

Number of vertices grouped by graph origin and track (logarithmic scale!)

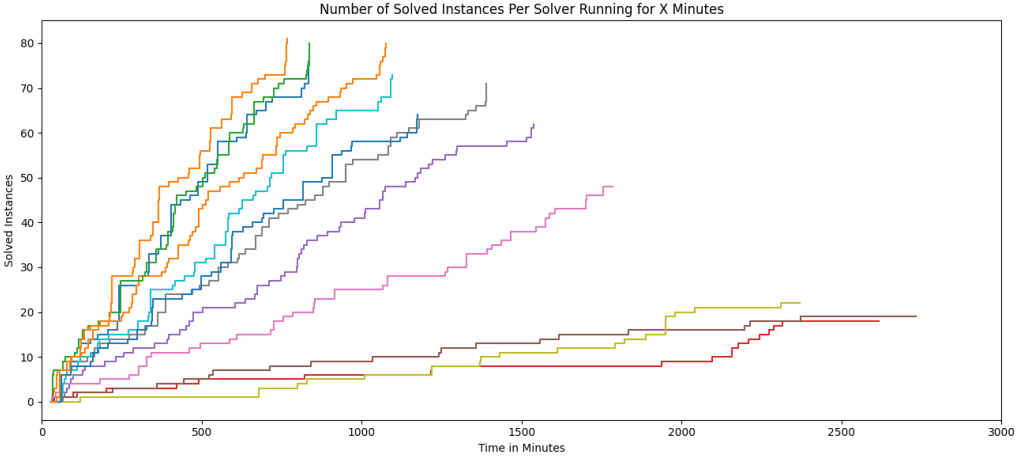


Graph Sizes by Origin

Number of edges grouped by graph origin and track (logarithmic scale!)

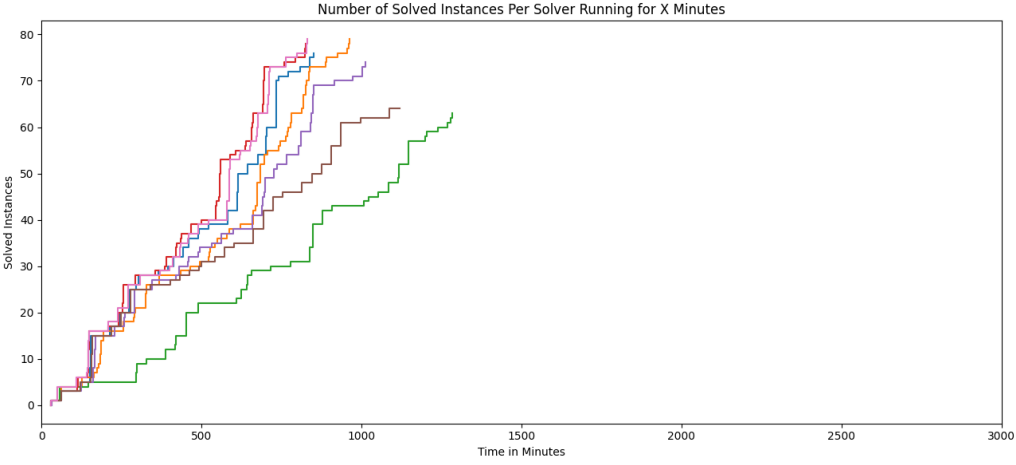


Solved Instances by Time – Dominating Set Exact



(Disqualified teams are not shown)

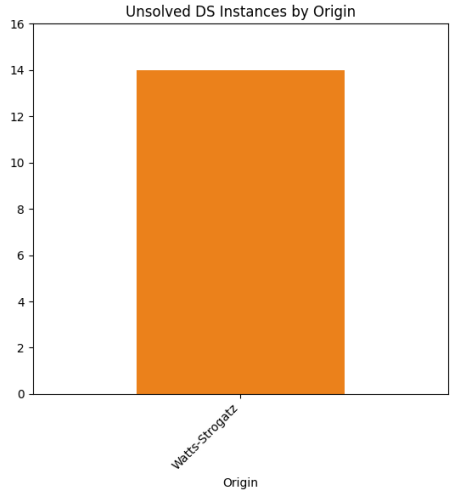
Solved Instances by Time – Hitting Set Exact

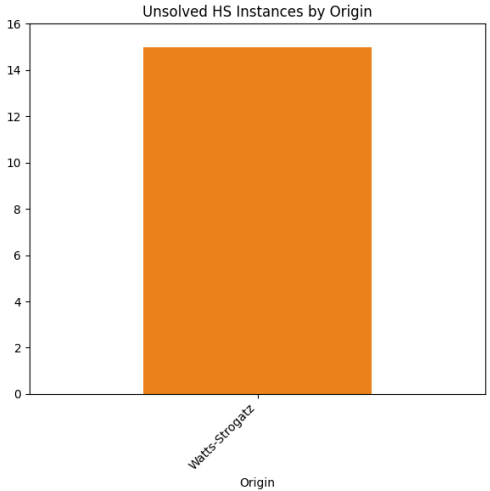


(Disqualified teams are not shown)

Unsolved Instances

Unsolved instances "grouped" by origin





DS Exact Track – Ranking

OBLX

Score: 80

Time: 64579 s

Members:

- Jona Dirks
- Enna Gerhard
- Victoria Kaial
- Lucas Lorieau

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Jona Dirks
Université Clermont-Auvergne

Enna Gerhard
University of Bremen

Victoria Kaial
Université Clermont-Auvergne

Lucas Lorieau
Université Clermont-Auvergne

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Third Place in the Dominating Set Exact Track

€ 100,-

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DS Exact Track – Ranking

Bad DS Maker

Score: 80

Time: 50254 s

Members:

- Alexander Dobler
- Simon D. Fink
- Mathis Rocton

OBLX

Score: 80

Time: 64579 s

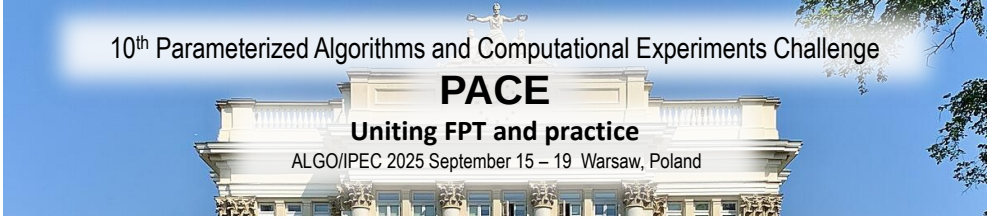
Members:

- Jona Dirks
- Enna Gerhard
- Victoria Kaial
- Lucas Lorieau

2.

1.

3.



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Alexander Dobler **Simon D. Fink** **Mathis Rocton**

Tu Wien

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DS Exact Track – Ranking

Bad DS Maker

Score: 80

Time: 50254 s

Members:

- Alexander Dobler
- Simon D. Fink
- Mathis Rocton

2.

UzL

Score: 81

Time: 46111 s

Members:

- Max Bannach
- Florian Chudigiewitsch
- Marcel Wienöbst

1.

OBLX

Score: 80

Time: 64579 s

Members:

- Jona Dirks
- Enna Gerhard
- Victoria Kaial
- Lucas Lorieau

3.

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Max Bannach
European Space Agency

Florian Chudigiewitsch
University of Lübeck

Marcel Wienöbst
University of Lübeck

for the

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PACE Steering Committee Chair

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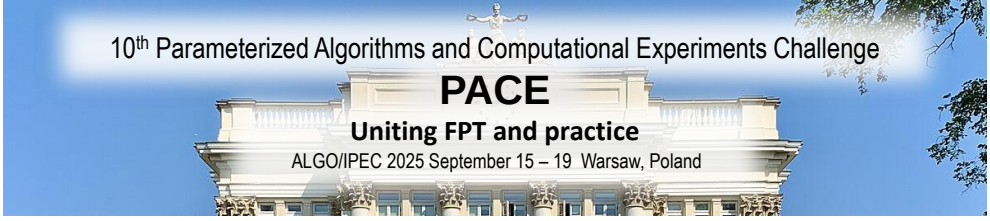
DS Heuristic Track – Ranking

Swats

Score: 99.35

Members:

- Sylwester Swat



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Sylwester Swat

Poznań University of Technology

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DS Heuristic Track – Ranking

Root

Score: 99.64

Members:

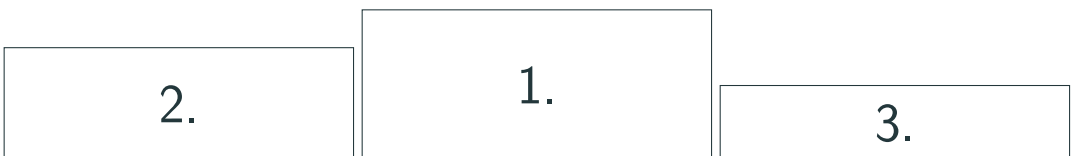
- Canhui Luo
- Zhipeng Lv
- Zhouxing Su
- Qingyun Zhang

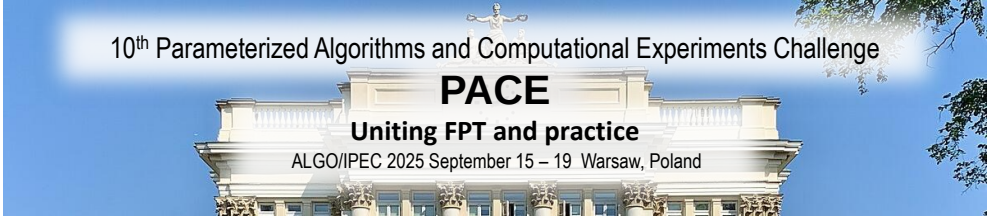
Swats

Score: 99.35

Members:

- Sylwester Swat





This is to certify that the 2025 PACE Program Committee recognizes

Canhui Luo **Zhipeng Lv** **Zhouxing Su** **Qingyun Zhang**

Huazhong University of Science and Technology

for the

Second Place in the Dominating Set Heuristic Track

€ 200,-

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2025 PACE Program Committee Chair

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PACE Steering Committee Chair

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DS Heuristic Track – Ranking

Root
Score: 99.64
Members:
- Canhui Luo
- Zhipeng Lv
- Zhouxing Su
- Qingyun Zhang

Florian & Guillaume
Score: 99.81
Members:
- Florian Fontan
- Guillaume Verger

Swats
Score: 99.35
Members:
- Sylwester Swat

2.

1.

3.

This is to certify that the 2025 PACE Program Committee recognizes

Florian Fontan **Guillaume Verger**

for the

First Place in the Dominating Set Heuristic Track

€ 300,-

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2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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HS Exact Track – Ranking

André Schidler

Score: 78

Time: 49566 s

Members:

- André Schidler

2.

1.

3.

This is to certify that the 2025 PACE Program Committee recognizes

André Schidler

Albert-Ludwigs-Universität Freiburg

for the

Third Place in the Hitting Set Exact Track

€ 100,-

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2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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HS Exact Track – Ranking

Bad DS Maker

Score: 79

Time: 57783 s

Members:

- Alexander Dobler
- Simon D. Fink
- Mathis Rocton

André Schidler

Score: 78

Time: 49566 s

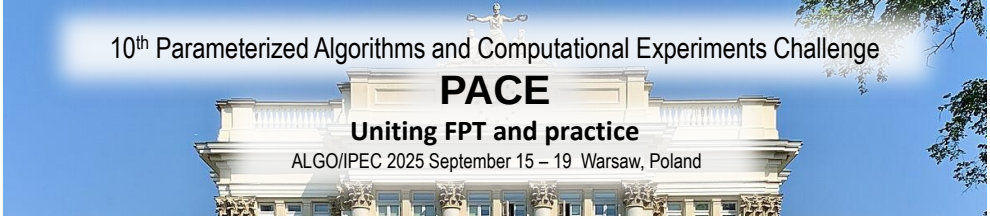
Members:

- André Schidler

2.

1.

3.



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Alexander Dobler **Simon D. Fink** **Mathis Rocton**

Tu Wien

for the

Second Place in the Hitting Set Exact Track

€ 200,-

Mario Grobler, Universität Bremen
2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

NET WORKS
THENETWORKCENTER.NL

HS Exact Track – Ranking

Bad DS Maker

Score: 79

Time: 57783 s

Members:

- Alexander Dobler
- Simon D. Fink
- Mathis Rocton

UzL

Score: 79

Time: 49854 s

Members:

- Max Bannach
- Florian Chudigiewitsch
- Marcel Wienöbst

André Schidler

Score: 78

Time: 49566 s

Members:

- André Schidler

2.

1.

3.

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Max Bannach
European Space Agency

Florian Chudigiewitsch
University of Lübeck

Marcel Wienöbst
University of Lübeck

for the

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€ 300,-

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2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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HS Heuristic Track – Ranking

Shadoks

Score: 99.21

Members:

- Guilherme D. da Fonseca
- Fabien Feschet
- Yan Gerard

This is to certify that the 2025 PACE Program Committee recognizes

Guilherme D. da Fonseca
Aix-Marseille Université

Fabien Feschet
Université Clermont-Auvergne

Yan Gerard
Université Clermont-Auvergne

for the

Third Place in the Hitting Set Heuristic Track

€ 100,-

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2025 PACE Program Committee Chair

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PACE Steering Committee Chair

NET WORKS
THENETWORKCENTER.NL

HS Heuristic Track – Ranking

Florian & Guillaume

Score: 99.73

Members:

- Florian Fontan
- Guillaume Verger

Shadoks

Score: 99.21

Members:

- Guilherme D. da Fonseca
- Fabien Feschet
- Yan Gerard

2.

1.

3.

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Florian Fontan **Guillaume Verger**

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Second Place in the Hitting Set Heuristic Track

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Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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HS Heuristic Track – Ranking

Florian & Guillaume

Score: 99.73

Members:

- Florian Fontan
- Guillaume Verger

2.

Root

Score: 99.79

Members:

- Canhui Luo
- Zhipeng Lv
- Zhouxing Su
- Qingyun Zhang

1.

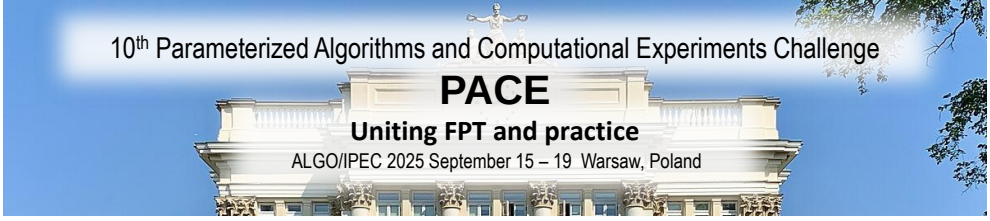
Shadoks

Score: 99.21

Members:

- Guilherme D. da Fonseca
- Fabien Feschet
- Yan Gerard

3.



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Canhui Luo **Zhipeng Lv** **Zhouxing Su** **Qingyun Zhang**

Huazhong University of Science and Technology

for the

First Place in the Hitting Set Heuristic Track

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Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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DS Exact Track – Student Ranking

Floris

Score: 62

Time: 92309 s

Members:

- Floris van der Hout

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Floris van der Hout

Utrecht University

for the

Third Student Place in the Dominating Set Exact Track

€ 100,-

Mario Grobler, Universität Bremen
2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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DS Exact Track – Student Ranking

Tobias Röhr

Score: 76

Time: 50057 s

Members:

- Tobias Röhr

Floris

Score: 62

Time: 92309 s

Members:

- Floris van der Hout

2.

1.

3.

This is to certify that the 2025 PACE Program Committee recognizes

Tobias Röhr

Hasso Plattner Institut

for the

Second Student Place in the Dominating Set Exact Track

€ 150,-

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Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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DS Exact Track – Student Ranking

Tobias Röhr
Score: 76
Time: 50057 s
Members:
- Tobias Röhr

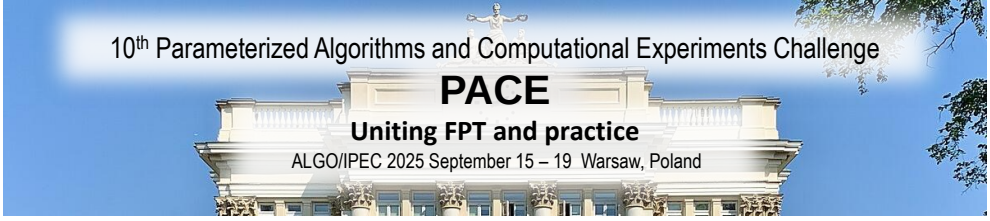
2.

OBLX
Score: 80
Time: 64579 s
Members:
- Jona Dirks
- Enna Gerhard
- Victoria Kaial
- Lucas Lorieau

1.

Floris
Score: 62
Time: 92309 s
Members:
- Floris van der Hout

3.



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Jona Dirks
Université Clermont-Auvergne

Enna Gerhard
University of Bremen

Victoria Kaial
Université Clermont-Auvergne

Lucas Lorieau
Université Clermont-Auvergne

for the

First Student Place in the Dominating Set Exact Track

€ 200,-

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2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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DS Heuristic Track – Student Ranking

Hui, Bo, Yexin, Xinyun

Score: 96.16

Members:

- Hui Kong
- Bo Peng
- Yexin Peng
- Xinyun Wu

This is to certify that the 2025 PACE Program Committee recognizes

Hui Kong
Hubei University of Technology

Bo Peng
Hubei University of Technology

Yexin Peng
Hubei University of Technology

Xinyun Wu
Southwestern U. of Financy and Economics

for the

Third Student Place in the Dominating Set Heuristic Track

€ 100,-

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2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

NET WORKS
THENETWORKCENTER.NL

DS Heuristic Track – Student Ranking

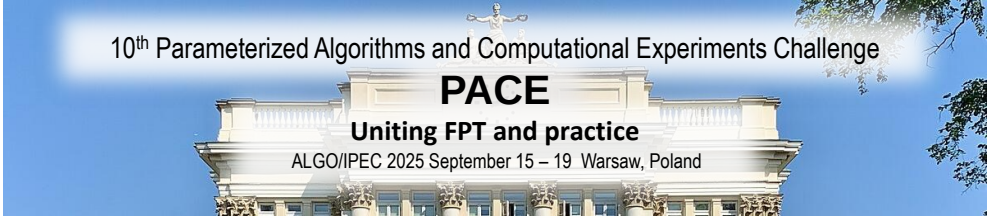
Hui, Bo, Yexin, Xinyun
Score: 96.16
Members:
- Hui Kong
- Bo Peng
- Yexin Peng
- Xinyun Wu

1.

Viacheslav
Score: 96.27
Members:
- Viacheslav Khrushchev

2.

3.



This is to certify that the 2025 PACE Program Committee recognizes

Viacheslav Khrushchev

HSE University Moscow

for the

Second Student Place in the Dominating Set Heuristic Track

€ 150,-

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2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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DS Heuristic Track – Student Ranking

Viacheslav
Score: 96.27
Members:
- Viacheslav Khrushchev

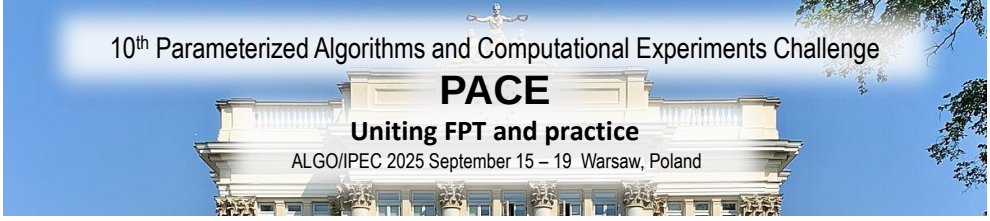
2.

Samuel
Score: 96.80
Members:
- Samuel Füßinger

1.

Hui, Bo, Yexin, Xinyun
Score: 96.16
Members:
- Hui Kong
- Bo Peng
- Yexin Peng
- Xinyun Wu

3.



This is to certify that the 2025 PACE Program Committee recognizes

Samuel Füßinger

Eberhard Karls Universität Tübingen

for the

First Student Place in the Dominating Set Heuristic Track

€ 200,-

Mario Grobler, Universität Bremen
2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

NET WORKS
THENETWORKCENTER.NL

HS Exact Track – Student Ranking

AEG Heidelberg

Score: 63

Time: 77045 s

Members:

- Adil Chhabra
- Marlon Dittes
- Ernestine Großmann
- Kenneth Langedal
- Henrik Reinstädtler
- Christian Schulz
- Darren Strash
- Henning Woydt

1.

This is to certify that the 2025 PACE Program Committee recognizes

Adil Chhabra
Heidelberg University

Marlon Dittes
Heidelberg University

Ernestine Großmann
Heidelberg University

Kenneth Langedal
Heidelberg University

Henrik Reinstädtler
Heidelberg University

Christian Schulz
Heidelberg University

Darren Strash
Hamilton College

Henning Woydt
Heidelberg University

for the

Second Student Place in the Hitting Set Exact Track

€ 150,-

Mario Grobler, Universität Bremen
2025 PACE Program Committee Chair

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PACE Steering Committee Chair

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- Henrik Reinstädtler
- Christian Schulz
- Darren Strash
- Henning Woydt

Tobias

Score: 76

Time: 50947 s

Members:

- Tobias Röhr

1.

This is to certify that the 2025 PACE Program Committee recognizes

Tobias Röhr

Hasso Plattner Institut

for the

First Student Place in the Hitting Set Exact Track

€ 200,-

Mario Grobler, Universität Bremen
2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

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THENETWORKCENTER.NL

HS Heuristic Track – Student Ranking

Sebastian, Mirza, Patrick & Mariette

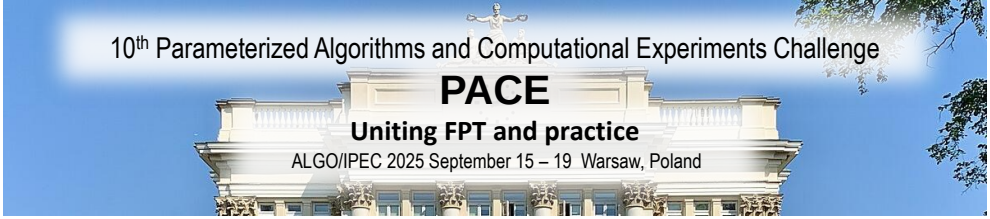
Score: 1.83

Members:

- Sebastian Angrick
- Mirza Redzic
- Patrick Steil
- Mariette Vasen

2.

1.



This is to certify that the 2025 PACE Program Committee recognizes

Sebastian Angrick **Mirza Redzic** **Patrick Steil** **Mariette Vasen**

Karlsruhe Institute of Technology

for the

Second Student Place in the Hitting Set Heuristic Track

€ 150,-

Mario Grobler, Universität Bremen
2025 PACE Program Committee Chair

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NET WORKS
THENETWORKCENTER.NL

HS Heuristic Track – Student Ranking

Sebastian, Mirza, Patrick & Mariette

Score: 1.83

Members:

- Sebastian Angrick
- Mirza Redzic
- Patrick Steil
- Mariette Vasen

Deepak, Syed, Kabir & Saurabh

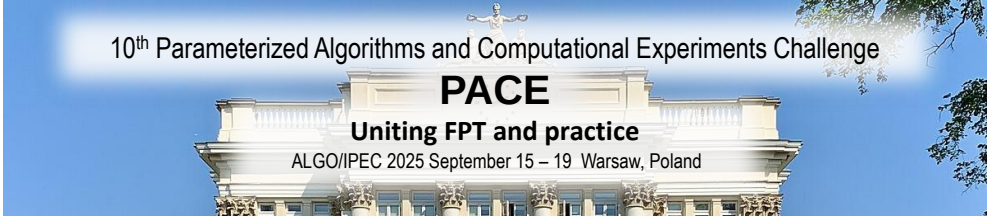
Score: 82.50

Members:

- Deepak Ajwani
- Syed Mahmudul
- Kabir Ratul
- Saurabh Ray

2.

1.



This is to certify that the 2025 PACE Program Committee recognizes

Deepak Ajwani
University College Dublin

Syed Mahmudul Kabir Ratul
New York University Abu Dhabi

Saurabh Ray
New York University Abu Dhabi

for the

First Place in the Hitting Set Heuristic Track

€ 200,-

Mario Grobler, Universität Bremen
2025 PACE Program Committee Chair

Bart M. P. Jansen, TU Eindhoven
PACE Steering Committee Chair

NET WORKS
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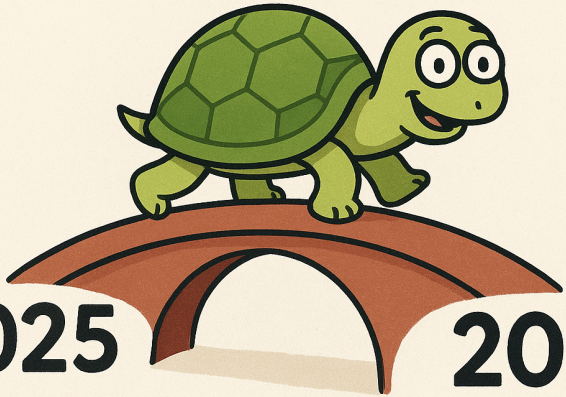
Lessons Learned

- Finding good benchmark instances is hard
- Discrepancy between preliminary and final test set
- Installing the solvers in Docker containers was time-consuming, but eventually worth the effort
- The reviewing phase helped to identify bugs in the solvers
- Making a schedule is easy, sticking to it is hard

PACE



2025 2026

Preview: PACE 2026

Alexander Leonhardt[1], Manuel Penschuck[2], Mathias Weller[3]

[1]Goethe-Universität Frankfurt, Germany
[2]University of Southern Denmark, Odense, Denmark
[3]CNRS, Université Gustave Eiffel, Paris, France
https://pacechallenge.org/

Scientific Topic: Agreement Forests

Definition

- A phylogenetic tree is a rooted, bijectively leaf-labelled out-branching.

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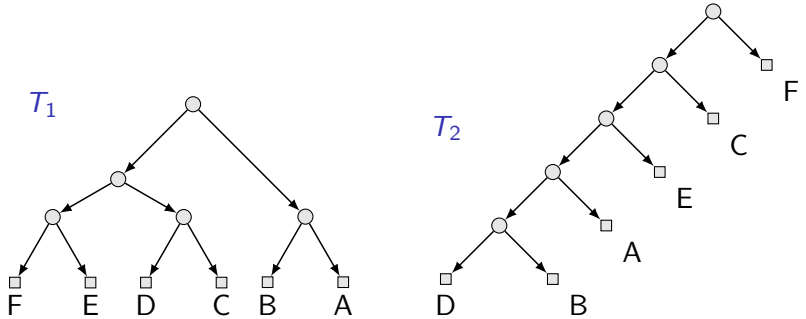

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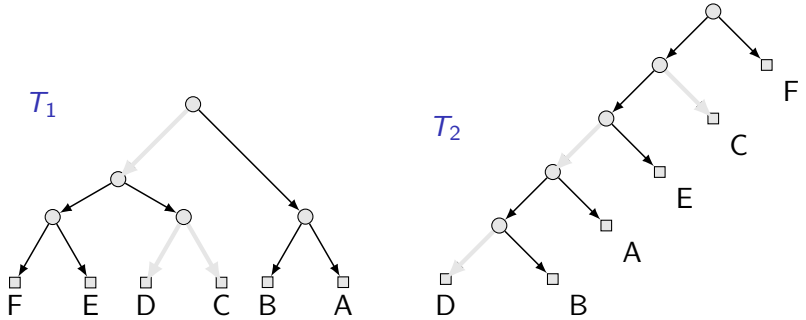

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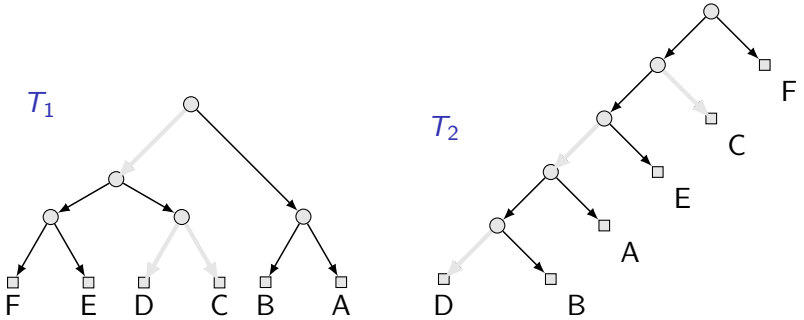

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Results for $t = 2$, $\mathrm{MAF}(T, T') = k$

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- $O(2.35^k n)$ time — Chen & Wang, '13
  ($O(2^k n)$ time claimed) — Whidden, '13
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Note: No other parameterization explored!

Organization and Data

Exact/Parameterized Track

- t trees
- **idea**: instances accompanied by parameters
  (with proof, e.g. decomposition)
- committee takes requests for parameters in the first months
- parameter statistics of hidden instances available in advance

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Real-World Data

expect few trees, small MAF, many leaves

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Generated Data

expect many trees, large MAF, many leaves

Timeline

mostly follows previous PACE-instances

September '25	Announcement of the challenge and tracks
October '25	Definition of input and output formats
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– good luck and an enjoyable competition –