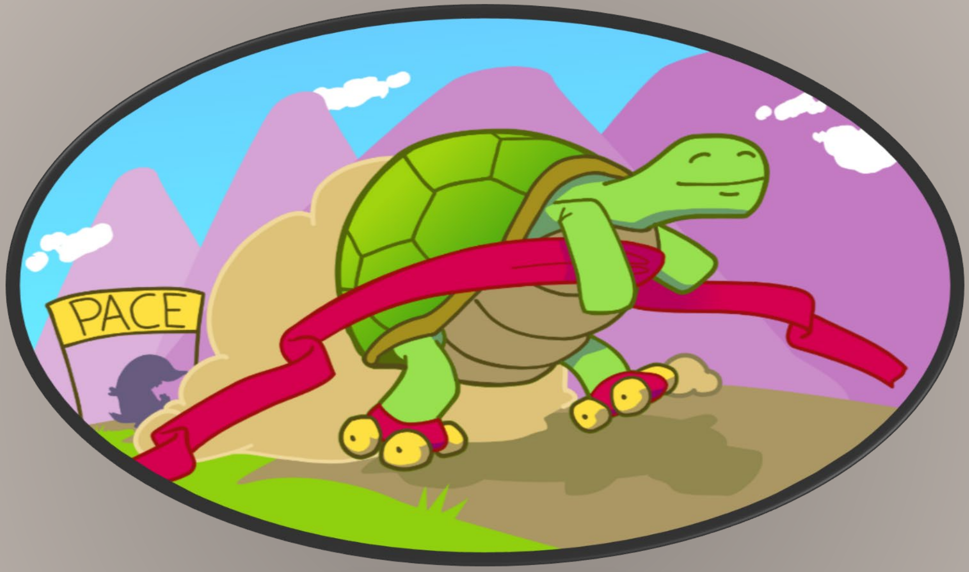
Parameterized Algorithms & Computational Experiments Challenge

www.pacechallenge.org



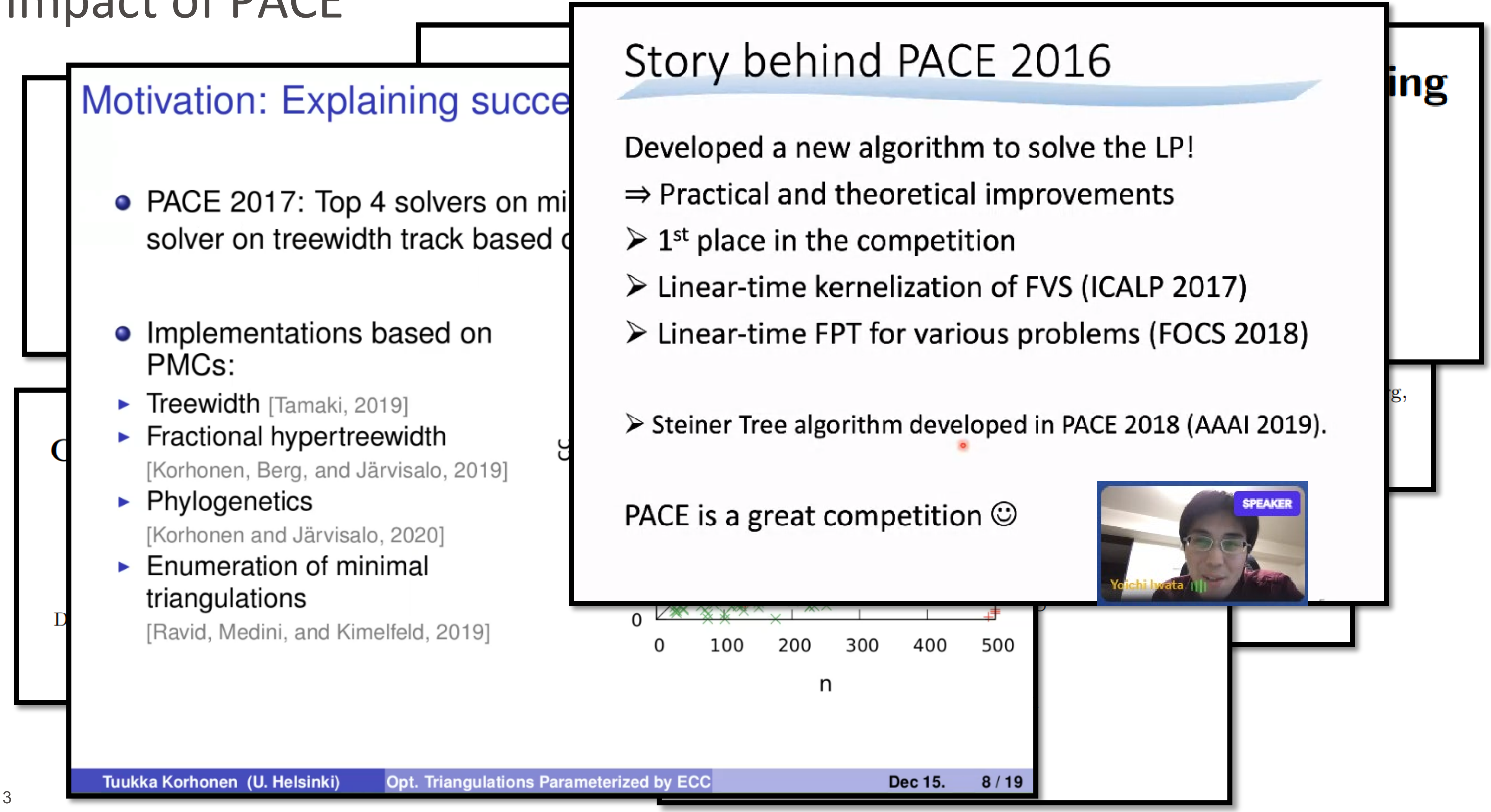
December 16th, IPEC 2020, Hong Kong

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



The history of PACE

2015 – Idea for PACE born @ *Simons Institute* meeting

"parameterized algorithmics should have a greater impact on practice"

2016 –
1. Treewidth
2. Feedback Vertex Set

First PACE challenge

[Holger Dell & Christian Komusiewicz]

2017 –
1. Treewidth
2. Minimum Fill-in

[Holger Dell & Christian Komusiewicz]

2018 – Steiner Tree

[Édouard Bonnet & Florian Sikora]

2019 –
1. Vertex Cover
2. Hypertree width

Poster session

[Johannes Fichte & Markus Hecher]

2020 – Treedepth

Implementation reports in proceedings

[Lukasz Kowalik]

2021 – Cluster Editing

[André Nichterlein]

2022

PACE 2021: Cluster Editing

Challenge tracks:

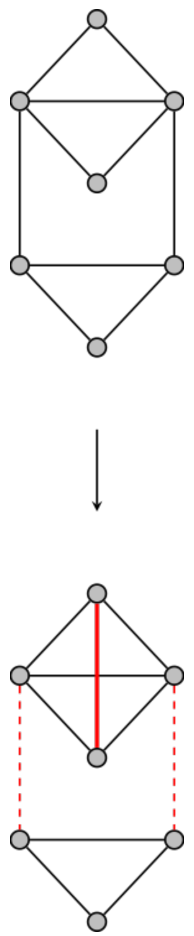
1. Exact algorithms
2. Heuristic algorithms
3. Kernelization algorithms

https://pacechallenge.org/2021/tracks/

Program Committee:

Leon Kellerhals
Tomohiro Koana
André Nichterlein*
Philipp Zschoche

Technical University of Berlin



PACE 2022: We need your help!

Wanted:
researcher with experience in theory & practice of parameterized algorithms, to be the program chair of PACE 2022

- Set up challenge tracks in discussion with the steering committee
- Assemble a program committee to help with selection of instances, setting up the evaluation platform, handling submissions, evaluating implementation reports
- Publish an article summarizing the challenge in the IPEC proceedings

Potentially interested? Contact the steering committee!

Steering committee

Édouard Bonnet	LIP, ENS Lyon
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
Marcin Pilipczuk	University of Warsaw
Manuel Sorge	Technische Universität Wien

Former members

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

PACE 2020 Award Ceremony

Łukasz Kowalik

UNIVERSITY OF WARSAW

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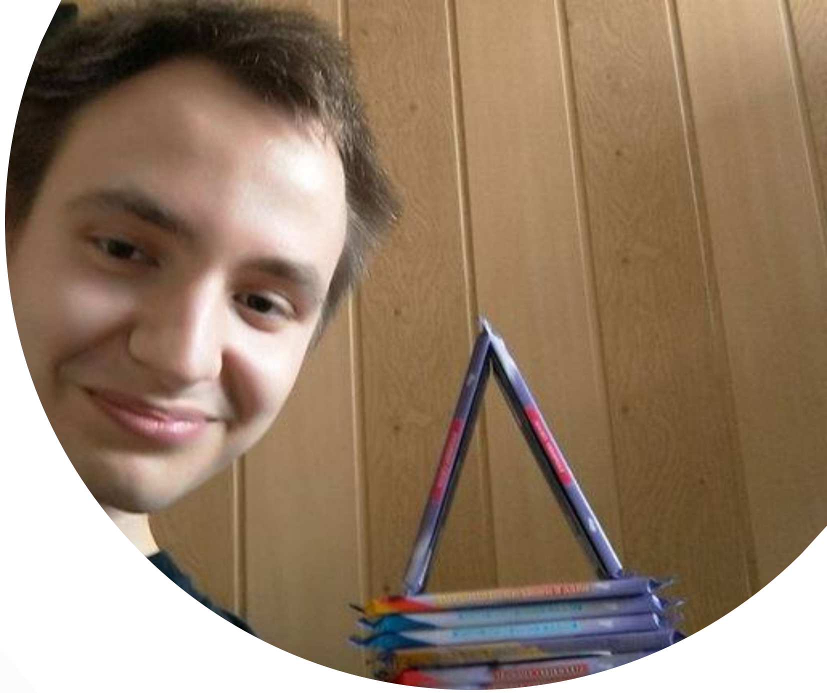
Outline

1. PACE 2020 organization
2. Treedepth
3. Dataset
4. Exact track
   - Results
   - Short summary
   - Presentations of five winning teams
5. Heuristic track (11:15 CET, 18:15 HKT)
   - Results
   - Short summary
   - Presentations of five winning teams

Program Comittee

- Łukasz Kowalik (chair)
- Marcin Mucha
- Wojciech Nadara
- Marcin Pilipczuk
- Manuel Sorge
- Piotr Wygocki



Thanks go to

- Networks
  for sponsoring the prizes
- Optil.io team, in particular to Jan Badura
  for hosting PACE'20 on their on-line judge system
- Felix Reidl
  for the PACE'20 poster

… and to the participants!

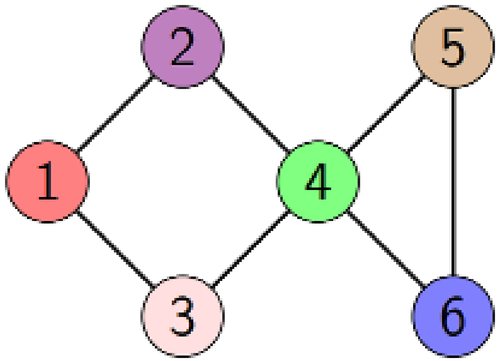
Country	Number of teams
Germany	4
Netherlands	4
Japan	2
United Kingdom	2
Brazil	1
Finland	1
France	1
India	1
Kosovo	1
Poland	1
Russia	1
Ukraine	1

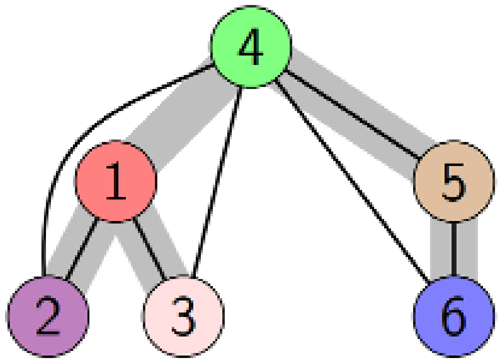
- 20 teams officialy submitted
- 38 more registered users in the online judge system
- 51 participants
- 12 countries
- 3 continents

Treedepth

A *treedepth decomposition* of a connected graph **G=(V,E)** is a rooted tree **T**, V(T)=V, such that every edge of **G** connects a pair of nodes that have an ancestor-descendant relationship in **T**.

Treedepth of **G** = minimum depth of such **T**

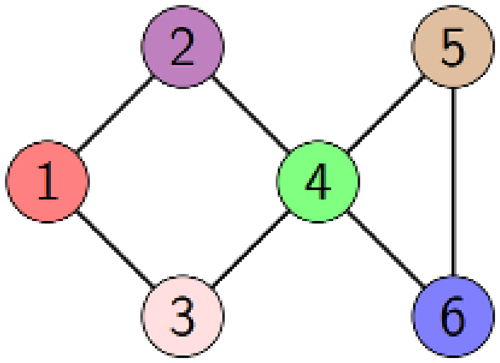


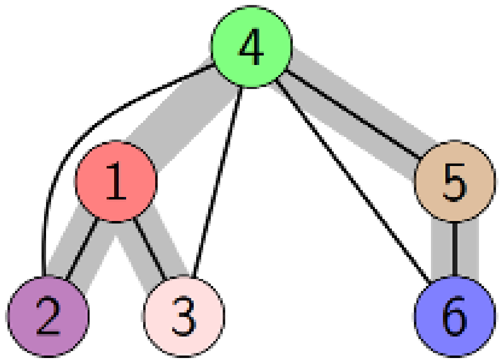


Why treedepth?

A natural and useful notion in

- structural graph theory (sparsity),
- logic,
- FPT algortihms

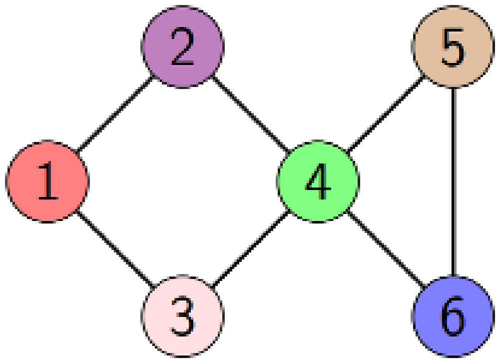


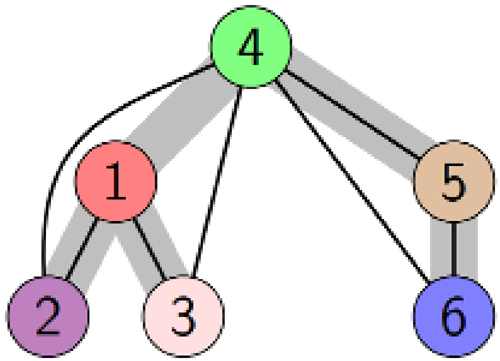


What do we know about computing treedepth?

- DP over subsets of V, O(2^n) [folklore]
- DP over tree decomposition of width t O(2^{td(G)*t} poly(n) [Reidl et al. 2014]
- O(t*log^1.5 t)-approximation [Czerwiński et al. 2019, Kawarabayashi et al. 2018]
- in **P** for trees

- Computing treedepth of graphs up to 24 vtcs: reduction to ILP [Ganian et al. 2019]



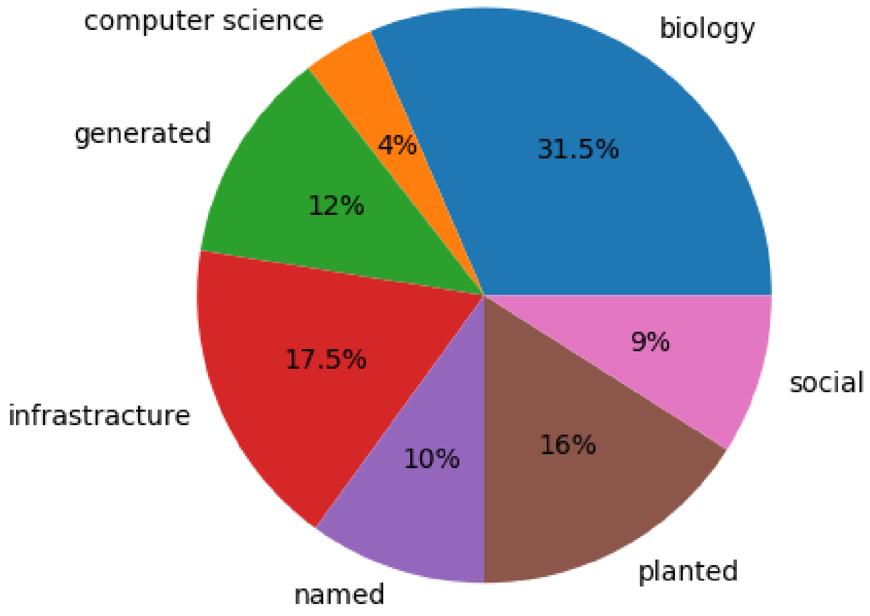


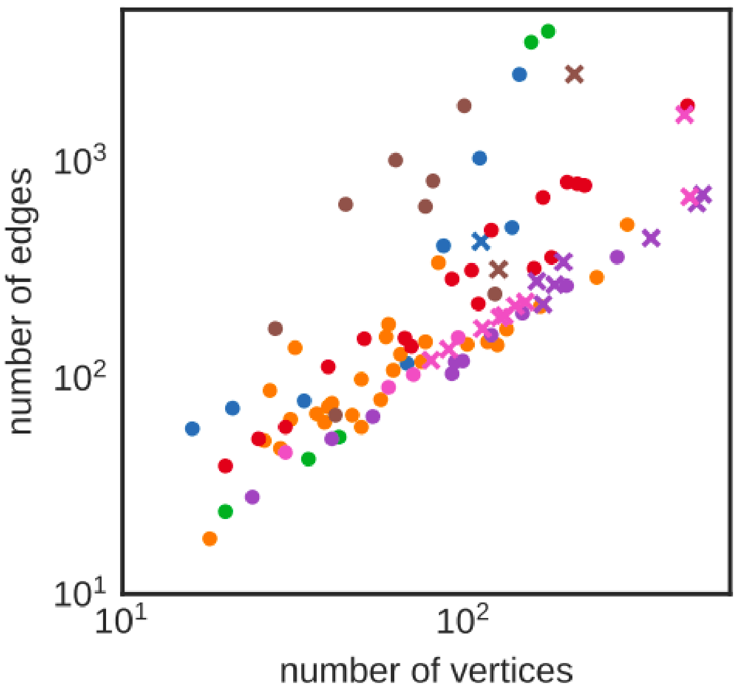
Track A: Exact

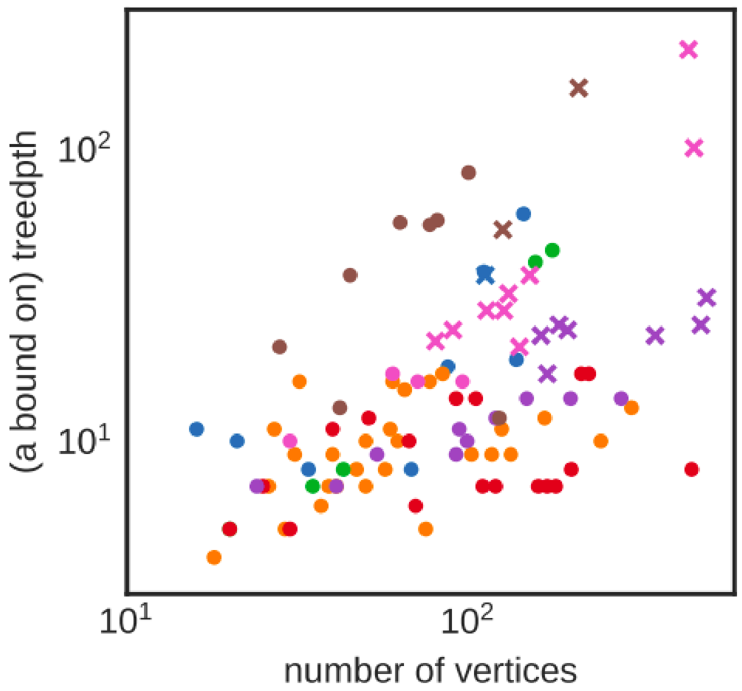
Rules:

- Compute a tree decomposition of minimum depth in 30 minutes or give up.
- No formal proof of optimality required...
- ...but if your decomposition is suboptimal on any instance, you get disqualified.
- You are given 100 public instances.
- You are evaluated on 100 private instances.
- Score: number of instances solved; time as a tiebreaker

Our dataset for exact track







https://github.com/lkowalik/Treedepth-PACE-2020-instances

Results

Rank	Team	Institute	#pts	time
1	James Trimble	University of Glasgow (United Kingdom)	78	6503
2	Tuukka Korhonen	University of Helsinki (Finland)	77	5599
3	Ruben Brokkelkamp, Mees de Vries, Raymond van Venetië, Jan Westerdiep	CWI, U. Amsterdam, KdVI (Netherlands)	72	3149
4	Max Bannach, Sebastian Berndt, Martin Schuster, Marcel Wienöbst	Universität zu Lübeck, Universität Kiel (Germany)	72	4267
5	Dejun Mao, Vorapong Suppakitpaisarn, Zijian Xu	The University of Tokyo (Japan)	68	8794
6	Narek Bojikian, Alexander van der Grinten, Falko Hegerfeld, Laurence Alec Kluge, Stefan Kratsch	Humboldt-Universität zu Berlin (Germany)	64	4515
7	Tom van der Zanden	Maastricht University (Netherlands)	44	6304
8	Dmitry Sayutin (cdkrot)	ITMO University (Russia)	37	11465
9	Philip de Bruin, Erik Jan van Leeuwen (PhiliPdB)	Utrecht University (Netherlands)	27	4470
10	Jun Kawahara, Toshiki Saitoh, Akira Suzuki, Toshiyuki Takase, Katsuhisa Yamanaka (t-saitoh)	Kyoto University, Kyushu Institute of Technology, Tohoku University, Iwate University (Japan)	6	198

Closer look at the results

- The winning solver solved 78 instances
- 81 instances solved in total
- All instances up to 80 vertices solved
- The smallest treedepth of an **unsolved** instance is 17 (a 170 vertex road network)
- The largest treedepth of a **solved** instance was 83 (the 100 vertex Hall-Janko graph)

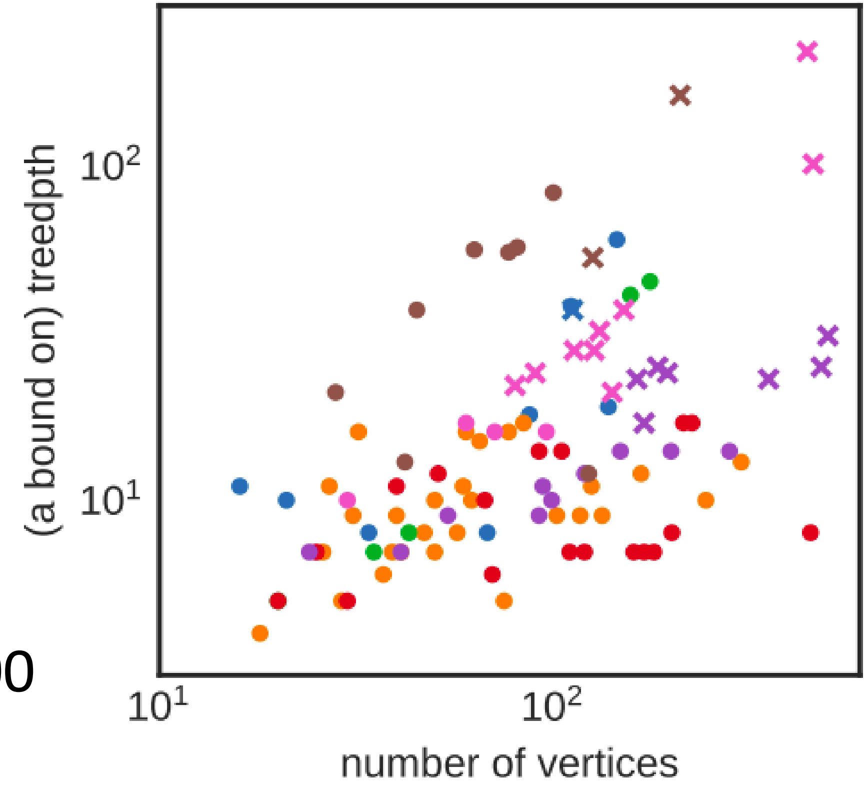


Table 2 Differences between the top five teams in the exact track (columns contain instances).

Name	068	074	084	088	090	094	108	112	120	148	150	174	180	182	186
Trimble	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	
Korhonen	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓		✓	
Brokkelkamp et al.		✓		✓						✓			✓	✓	✓
Bannach et al.				✓			✓		✓	✓			✓	✓	
Mao et al.		✓									✓				

Methods used

- **Bottom-up** (leaves to root):
  for increasing $k=0,1,2...$ generate depth k tree decompositions of induced subgraphs of G
  (places 1,4,6,7)

- **Top-down** (root to leaves):
  list minimal separators, branch, memoize.
  (places 2,3,5,9,10)

- None of the approaches crushes the other

- The best solvers used a combination of **many** new and existing ideas

Talks of the five winning teams

5th Parameterized Algorithms and Computational Experiments Challenge (PACE)

Uniting FPT and practice

IPEC 2020 December 14 – 16 Hongkong

This is to certify that the 2020 PACE Program Committee has selected

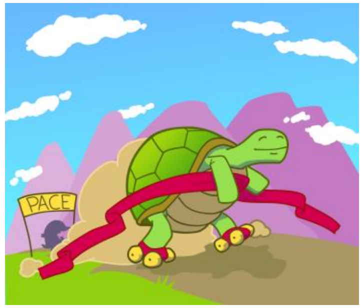
James Trimble

University of Glasgow

as the

First Place Winner in the Exact Track of the Treedepth Challenge

750 €



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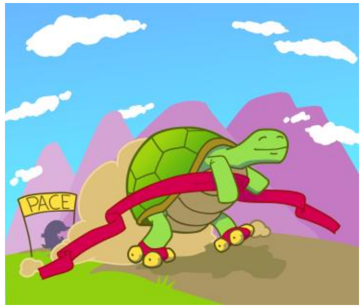
Tuukka Korhonen

University of Helsinki

as the

2nd Place Winner in the Exact Track of the Treedepth Challenge

450 €



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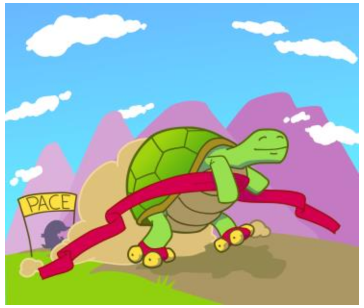
Ruben Brokkelkamp*, Raymond van Venetië, Mees de Vries** , Jan Westerdiep****

*CWI, **U. Amsterdam

as the

3rd Place Winners in the Exact Track of the Treedepth Challenge

350 €



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This is to certify that the 2020 PACE Program Committee has selected

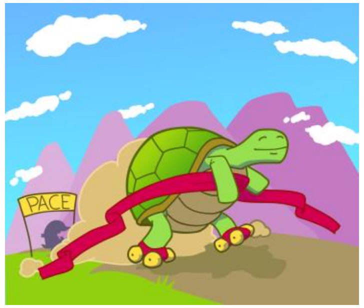
Max Bannach*, Sebastian Berndt*, Martin Schuster, Marcel Wienöbst***

*Universität zu Lübeck, **Kiel University

as the

4th Place Winner in the Exact Track of the Treedepth Challenge

250 €



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5th Parameterized Algorithms and Computational Experiments Challenge (PACE)

Uniting FPT and practice

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This is to certify that the 2020 PACE Program Committee has selected

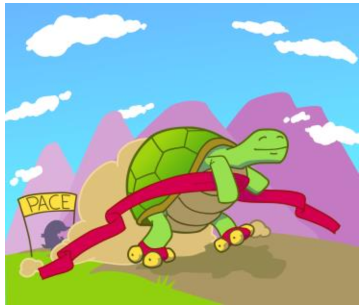
Dejun Mao, Vorapong Suppakitpaisarn, Zijian Xu

The University of Tokyo

as the

5th Place Winner in the Exact Track of the Treedepth Challenge

200 €



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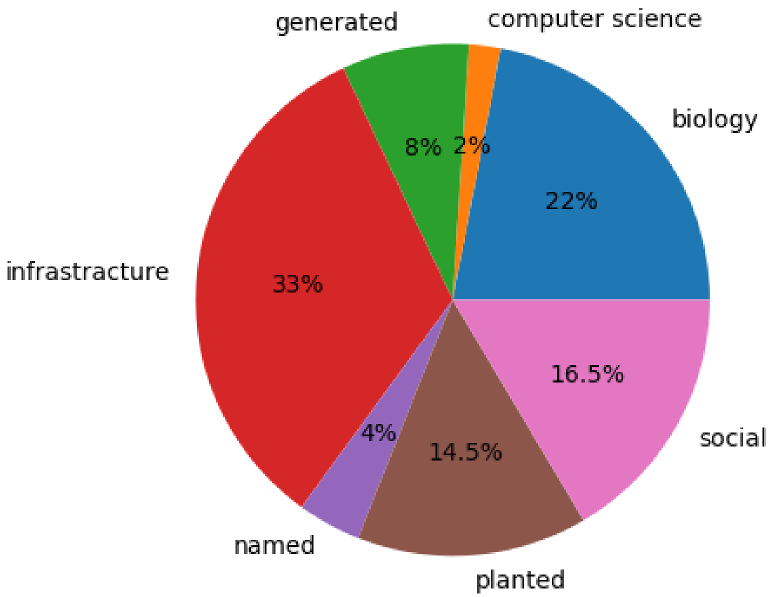
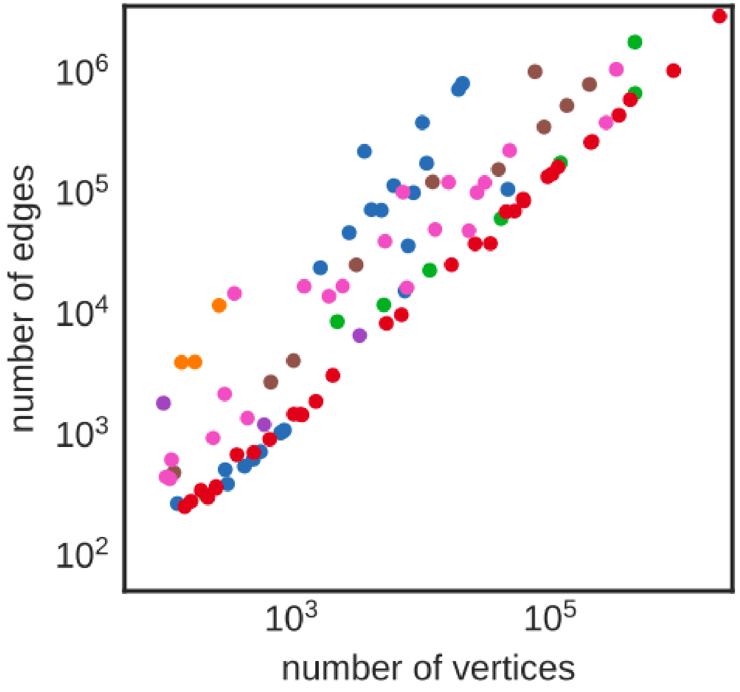
Track B: Heuristic

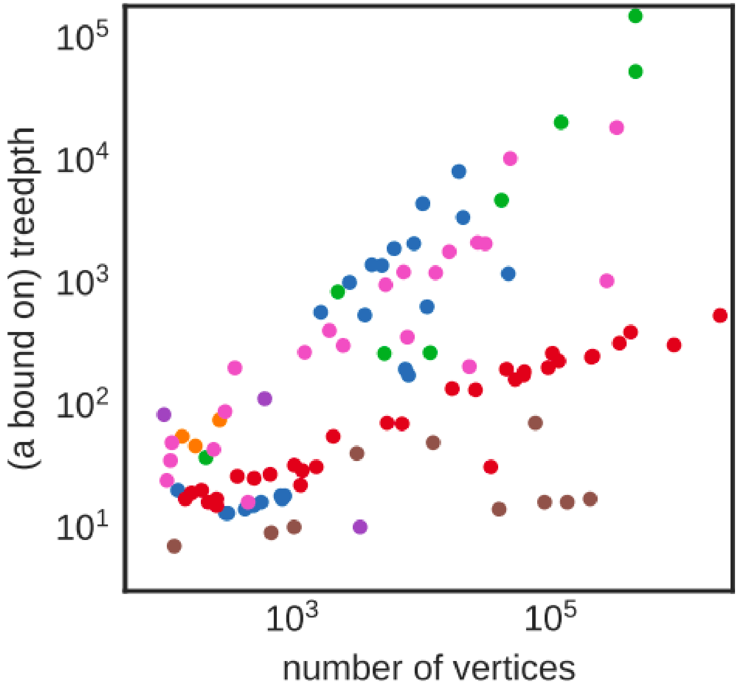
Rules:

- Compute a tree decomposition of **small** depth in 30 minutes.
- You are given 100 public instances.
- You are evaluated on 100 private instances.
- Score: 100***min/d** for depth **d**
  - Does not award minor improvements much
  - Score is within (0,100]

Our dataset for heuristic track





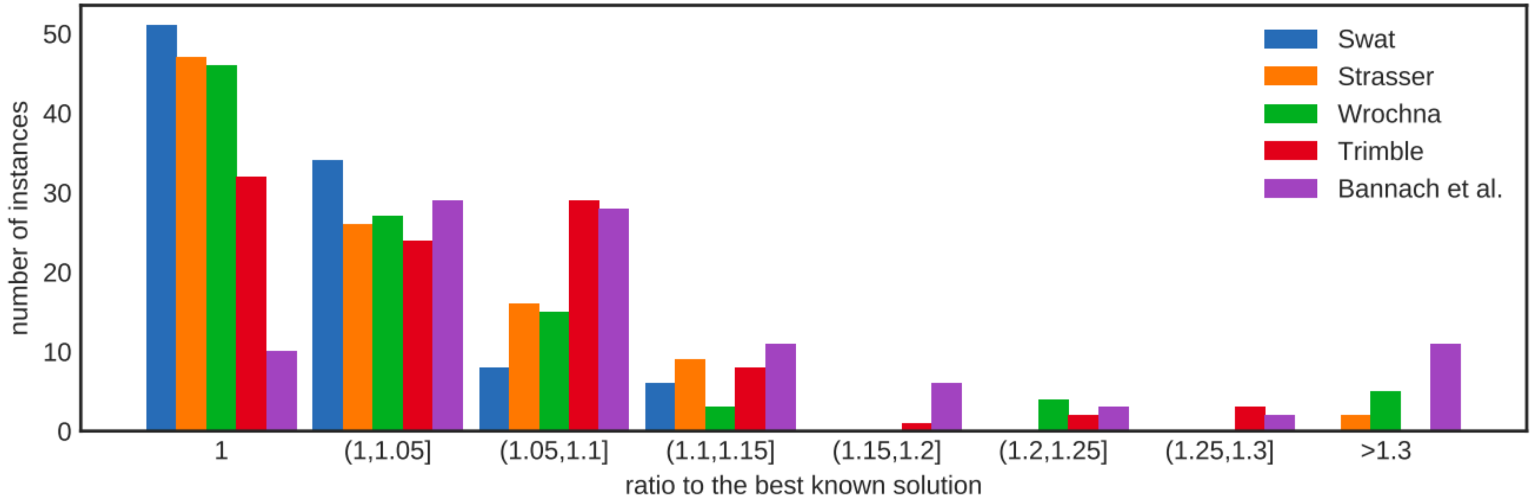


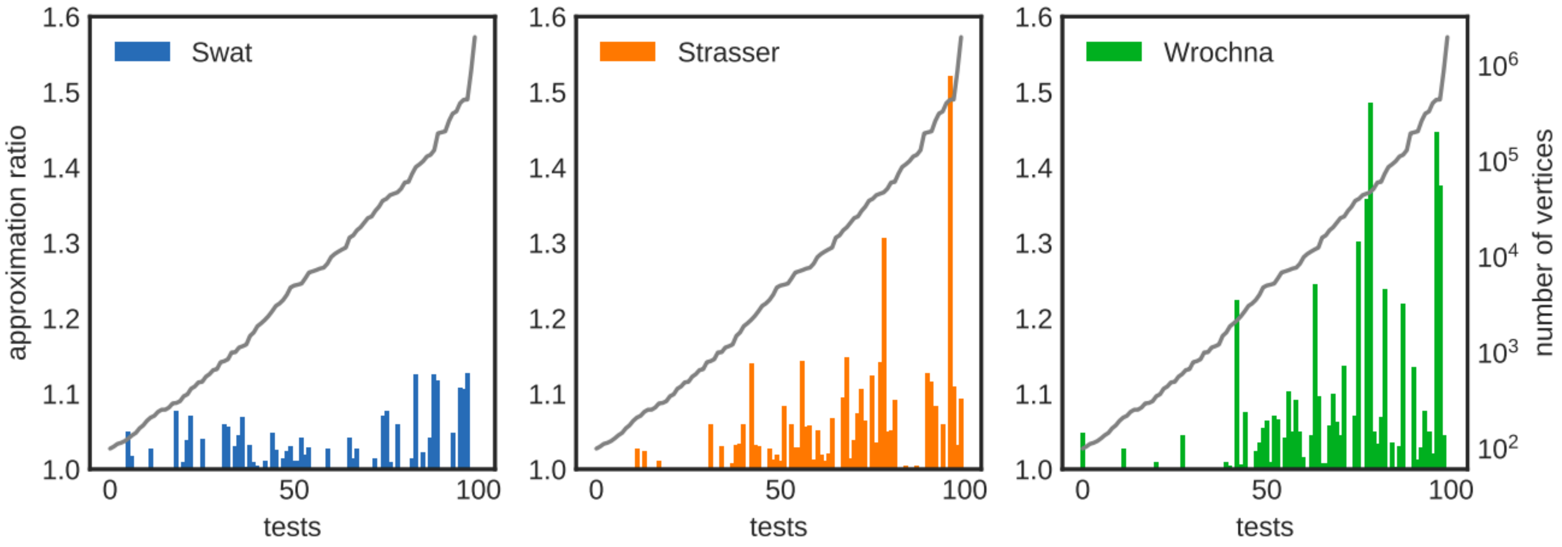
https://github.com/lkowalik/Treedepth-PACE-2020-instances

Results

Rank	Team	Institute	#pts
1	Sylwester Swat	Poznań University Of Technology (Poland)	9710,9
2	Ben Strasser	— (Germany)	9684,1
3	Marcin Wrochna	University of Oxford (United Kingdom)	9591,2
4	James Trimble	University of Glasgow (United Kingdom)	9448
5	Max Bannach, Sebastian Berndt, Martin Schuster, Marcel Wienöbst	Universität zu Lübeck, Universität Kiel (Germany)	8935,6
6	Stéphane Grandcolas	LIS (France)	8880,6
7	Miguel Bosch Calvo, Giorgia Carranza Tejada, Dominik Jeurissen, Steven Kelk, Zhuoer Ma, Alexander Reisach, Borislav Slavchev	Maastricht University (Netherlands)	6320,2
8	Gabriel Duarte, Uéverton Souza, Samuel Silva	Fluminense Federal University (Brazil)	5068,5
9	Aman Singal	Indian Institute of Technology Dharwad (India)	4254,9
10	Oleg Evseev, Igor Kozin, Alexander Zemlyanskiy	Zaporizhzhya National University (Ukraine)	1071,7

Closer look at the results





- The winning solver was always within the **ratio of 1.13** to the output of any other solver
- But each of the top 5 teams had an instance solved better than others

Methods used

- **Bottom-up** (leaves to root):
  pick a vertex *v* (according to a heuristic measure), connect its neighbors to a clique, get a decomposition of *G-v,* add *v* to it (as a leaf).
  (places 2,3)

- **Top-down** (root to leaves):
  find a *nice* separator *S*, decompose each component of *G-S* recursively
  (places 2,5,7,8,9)

- Many solvers used a **portfolio of approaches** and output the best outcome

- Preprocessing not very popular, but 3 teams used **postprocessing** (simple imrovements in the resulting tree).

- Again, the best solvers used a combination of **many** ideas

Talks of the five winning teams

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Uniting FPT and practice

IPEC 2020 December 14 – 16 Hongkong

This is to certify that the 2020 PACE Program Committee has selected

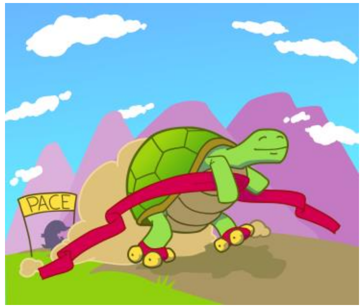
Sylwester Swat

Poznań University Of Technology

as the

First Place Winner in the Heuristic Track of the Treedepth Challenge

750 €



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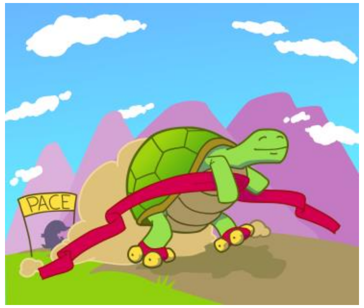
Ben Strasser

as the

2nd Place Winner in the Heuristic Track of the Treedepth Challenge

450 €



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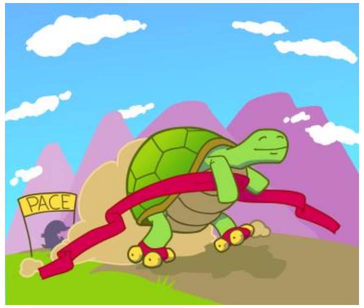
Marcin Wrochna

University of Oxford

as the

3rd Place Winners in the Heuristic Track of the Treedepth Challenge

350 €



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This is to certify that the 2020 PACE Program Committee has selected

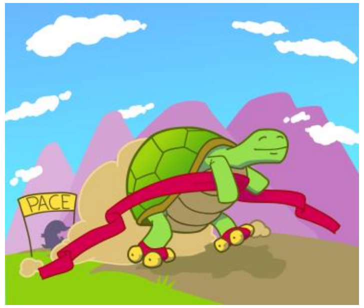
James Trimble

University of Glasgow

as the

4th Place Winner in the Heuristic Track of the Treedepth Challenge

250 €



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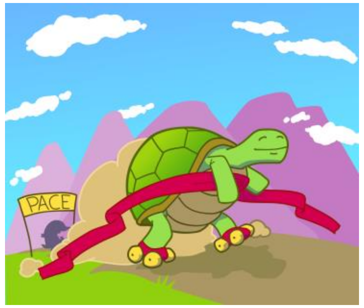
Max Bannach*, Sebastian Berndt*, Martin Schuster, Marcel Wienöbst***

*Universität zu Lübeck, **Kiel University

as the

5th Place Winner in the Heuristic Track of the Treedepth Challenge

200 €



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