Parameterized Algorithms & Computational Experiments Challenge

www.pacechallenge.org
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

Motivation: Explaining success

- PACE 2017: Top 4 solvers on miniature solver on treewidth track based on PACE PMC:
  - Treewidth [Tamaki, 2019]
  - Fractional hypertreewidth [Korhonen, Berg, and Järvisalo, 2019]
  - Phylogenetics [Korhonen and Järvisalo, 2020]
  - Enumeration of minimal triangulations [Ravid, Medini, and Kimelfeld, 2019]

Implementations based on PMCs:

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)
  - Steiner Tree algorithm developed in PACE 2018 (AAAI 2019).

PACE is a great competition 😊

Tuukka Korhonen (U. Helsinki) Opt. Triangulations Parameterized by ECC Dec 15. 8 / 19
The history of PACE

Idea for PACE born @ Simons Institute meeting

“parameterized algorithmics should have a greater impact on practice”

First PACE challenge

1. TREEWIDTH
2. FEEDBACK VERTEX SET

First PACE challenge

[Holger Dell & Christian Komusiewicz]

1. TREEWIDTH
2. MINIMUM FILL-IN

[Holger Dell & Christian Komusiewicz]

STEINER TREE

[Édouard Bonnet & Florian Sikora]

1. VERTEX COVER
2. HYPERTREE WIDTH

[Johannes Fichte & Markus Hecher]

Poster session

TREEDEPTH

Implementation reports in proceedings

[Treewidth]

CLUSTER EDITING

[André Nichterlein]
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  
Holger Dell  
Johannes Fichte  
Markus Hecher  
Bart M. P. Jansen*  
Łukasz Kowalik  
Marcin Pilipczuk  
Manuel Sorge

LIP, ENS Lyon  
Goethe University Frankfurt and IT University of Copenhagen  
Technische Universität Dresden  
Technische Universität Wien  
Eindhoven University of Technology  
University of Warsaw  
University of Warsaw  
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
OPTIL.io
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 Committee

• 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!

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

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 $T$.

**Treethickness of** $G$ = minimum depth of such $T$
Why treedepth?

A natural and useful notion in
- structural graph theory (sparsity),
- logic,
- FPT algorithms
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 vtc: 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
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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).

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Methods used

• **Bottom-up** (leaves to root):
  for increasing $k=0,1,2\ldots$ 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
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 €
This is to certify that the 2020 PACE Program Committee has selected

Tuukka Korhonen
University of Helsinki

as the

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

450 €
This is to certify that the 2020 PACE Program Committee has selected

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 €
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 €
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 €
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/Treethedepth-PA CE-2020-instances
<table>
<thead>
<tr>
<th>Rank</th>
<th>Team</th>
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<td>Poznań University Of Technology (Poland)</td>
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<td>Ben Strasser</td>
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<td>Oleg Evseev, Igor Kozin, Alexander Zemlyanskiy</td>
<td>Zaporizhzhya National University (Ukraine)</td>
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</table>
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 improvements in the resulting tree).

• Again, the best solvers used a combination of many ideas
Talks of the five winning teams
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 €
This is to certify that the 2020 PACE Program Committee has selected

**Ben Strasser**

as the

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

450 €
This is to certify that the 2020 PACE Program Committee has selected Marcin Wrochna, University of Oxford, as the 3rd Place Winners in the Heuristic Track of the Treedepth Challenge.

350 €
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 €
This is to certify that the 2020 PACE Program Committee has selected Max Bannach*, Sebastian Berndt*, Martin Schuster**, Marcel Wienöbst* as the 5th Place Winner in the Heuristic Track of the Treedepth Challenge

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 €