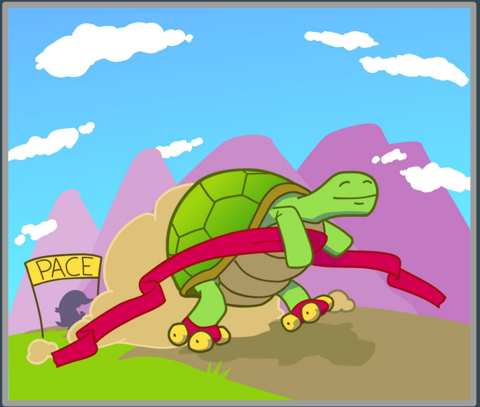
PACE 2019: The 4th Iteration

…

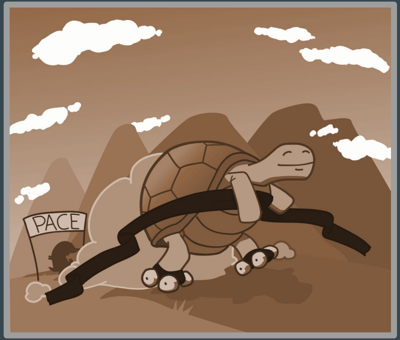


Johannes K. Fichte, TU Dresden
Markus Hecher, TU Wien & Univ. of Potsdam

IPEC 2019, TU Munich, Germany

History & Mission of PACE

Bart M.P. Jansen



History

- Conceived in fall 2015

  parameterized algorithmics should have a greater impact on practice
- First iteration: 2015/16
  - Track A: **Treewidth**
  - Track B: **Feedback Vertex Set**
- Second iteration: 2016/17
  - Track A: **Treewidth**
  - Track B: **Minimum Fill-In**
- Third iteration: 2017/18
  - Track 1: **Steiner tree exact with few terminals**
  - Track 2: **Steiner tree exact with low treewidth**
  - Track 3: **Steiner tree heuristic**
- Currently: Fourth iteration

Mission

Investigate ***applicability*** *of algorithmic ideas from parameterized complexity*

1. **Bridge gap** between theory and practice
2. Inspire new **theoretical developments**
3. **Investigate theoretical algorithms** in practice
4. Produce **accessible implementations** & benchmarks
5. Encourage dissemination in scientific **papers**

Outcome

- Previous iterations **inspired** long list of follow-up works
- Follow-up **Applications and Frameworks**
- Increased **awareness** of Parameterized Complexity
  - SAT community was particularly interested (this year)
- Usage of **Benchmark instances**
  - Almost 12,000 publicly available, citable instances published (this year)
- Scientific **Papers**

Outcome

- Previous iterations **inspired** long list of follow-up works
- Follow-up **Applications and Frameworks**
- plexity
  ear)
-
  published (this year)
-

Finding Hamiltonian Cycle in Graphs of Bounded Treewidth: Experimental Evaluation

Michał Ziobro
Theoretical Computer Science Department, Faculty of Mathematics and Computer Science, Jagiellonian University, Kraków, Poland
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Marcin Pilipczuk
Institute of Informatics, University of Warsaw, Poland
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Outcome

- Previous iterations **inspired** lon
- Follow-up **Applications and Fra**

published (this year)

An Improved GPU-Based SAT Model Counter

Johannes K. Fichte[1](✉), Markus Hecher[2,3], and Markus Zisser[2]

[1] TU Dresden, Dresden, Germany
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Finding Hamiltonian Cycle in Graph Treewidth: Experimental Evaluatio

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An Improved GPU-Based SAT Model Counter

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algorithms

MDPI

Article

Practical Access to Dynamic Programming on Tree Decompositions †

Max Bannach [1] and Sebastian Berndt [2,*]

1 Institute for Theoretical Computer Science, Universität zu Lübeck, 23562 Lübeck, Germany
2 Department of Computer Science, Kiel University, 24103 Kiel, Germany
* Correspondence: seb@informatik.uni-kiel.de

† This paper is an extended version of our paper published in ESA 2018.

Received: 18 July 2019; Accepted: 13 August 2019; Published: 16 August 2019

check for updates

Outcome

- Previou
- Follow

ed (this year)

An Improved GPU-Based SAT Model Counter

, Markus Hecher[2,3], and Markus Zisser[2]

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An Experimental Study of the Treewidth of Real-World Graph Data

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Suraj Jog
University of Illinois at Urbana–Champaign, Urbana-Champaign, USA
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algorit

Article

Practical Ac Tree Decom

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check for updates

Outcome

- Previou
- Follow

An Improved GPU-Based SAT Model Counter

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An Experimental Study of the Treewidth of Real-World Graph Data

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check for updates

Proceedings of the Twenty-Eighth International Joint Conference on Artificial Intelligence (IJCAI-19)

Enumerating Potential Maximal Cliques via SAT and ASP

Tuukka Korhonen, **Jeremias Berg** and **Matti Järvisalo**
HIIT, Department of Computer Science, University of Helsinki, Finland

Outcome

- Previou
- Foll

An Improved GPU-Based SAT Model Counter

Markus Hecher[2,3] and Markus Zisser[2]

An Experimental Study of the Treewidth of Real-World Graph Data

On the Relevance of Optimal Tree Decompositions for Constraint Networks

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Article

Practical Tree Dec

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check for updates

tificial Intelligence (IJCAI-19)

via SAT and ASP

Tuukka Korhonen, **Jeremias Berg** and **Matti Järvisalo**

HIIT, Department of Computer Science, University of Helsinki, Finland

Outcome

- Previou
- Foll

An Improved GPU-Based SAT Model Counter

An Experimental Study of the Treewidth of Real-World Graph Dat

Optimizing Answer Set Computation via Heuristic-Based Decomposition *

Zisser[2]

On the Relevance of ... for Co

alg

Article

Practical ... Tree Dec

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ce (IJCAI-19)

via SAT and ASP

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Received: 18 July 2019; Accepted: 13 August 2019; Published: 16 August 2019

check for updates

Outcome

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An Improved GPU-Based SAT
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An Experimental Study of the Treewidth of
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Optimizing Answer Set Computation via
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Zisser[2]

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Article
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* Correspondence: s
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Francesco Calimeri, Simona Perri and Jessica Zangari
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ce (IJCAI-19)

lis-lab.fr

via SAT and ASP

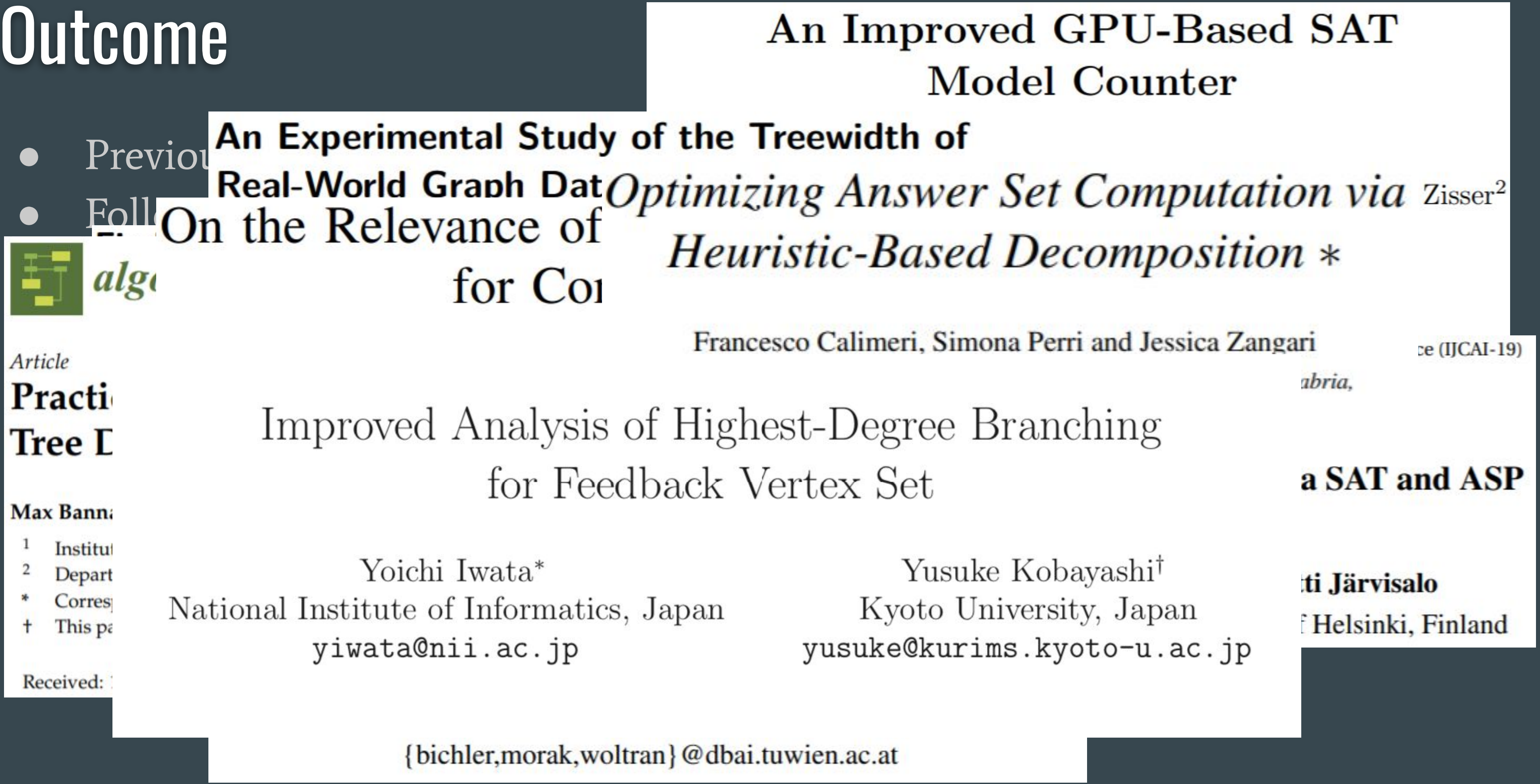
ias Berg and **Matti Järvisalo**
ience, University of Helsinki, Finland

Single-Shot Epistemic Logic Program Solving

Manuel Bichler, Michael Morak, and **Stefan Woltran**
TU Wien, Vienna, Austria
{bichler,morak,woltran}@dbai.tuwien.ac.at

Outcome

- Previou
- Foll



Outcome

An Improved GPU-Based SAT Model Counter

The Thirty-Third AAAI Conference on Artificial Intelligence (AAAI-19)

Article

Pract

Tree

Max Bar

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2 Dep

* Corres

† This pa

Received:

Separator-Based Pruned Dynamic Programming for Steiner Tree

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PACE 2019

Program and Steering Committee

- **Program Committee**

Johannes K. Fichte	TU Dresden
Markus Hecher	TU Wien, University of Potsdam

Intern:

Muhammad A. Dzulfikar	University of Indonesia @TU Dresden

- **Steering Committee**

Édouard Bonnet	Middlesex University
Holger Dell	IT University of Copenhagen
Bart M. P. Jansen	Eindhoven University of Technology
Thore Husfeldt	IT University of Copenhagen and Lund University
Petteri Kaski	Aalto University
Christian Komusiewicz	Philipps-Universität Marburg
Frances A. Rosamond	University of Bergen
Florian Sikora	LAMSADE, Université Paris Dauphine

We would like to thank our Sponsors...

- ... for prizes

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University of Amsterdam
Eindhoven University of Technology
Leiden University
Center for Mathematics and
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NET WORKS

data experts

Systemberatung
Softwareentwicklung
Informationsverarbeitung

- ... for computing resources

ZIH
Zentrum für Informationsdienste
und Hochleistungsrechnen

OPTIL.io

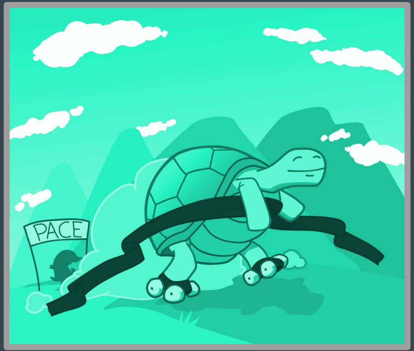
Thanks go to

- All the **participants of PACE**!

- Intern **Muhammad A. Dzulfikar** from the University of Indonesia
  - Performing instance selection
  - Support for validating results
  - ....
- **Jan Badura** at **optil.io**, who quickly implemented our requests
  - Using results of several runs for the final results
  - Customizing our judges for optil.io
  - ...

Tracks of PACE 2019

Track 1: Vertex Cover



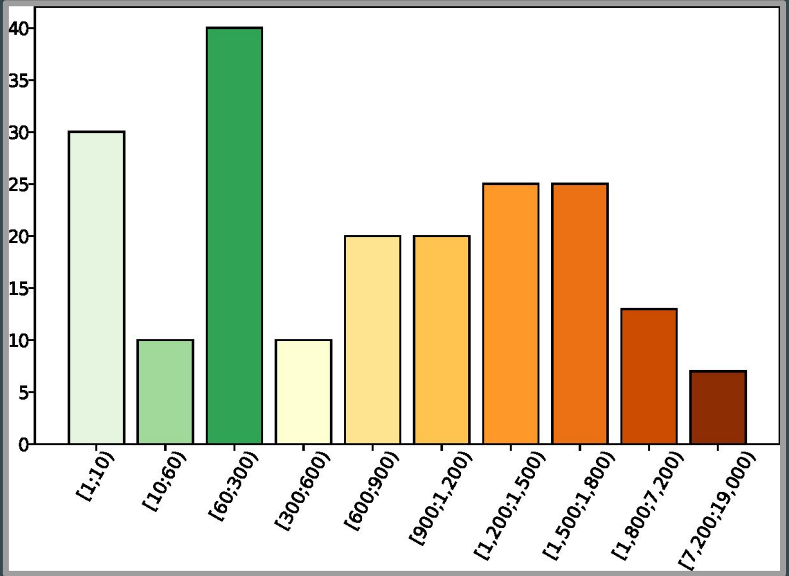
- Among the famous **21 first NP-complete** problems by Karp
- One of the famous, if not the most famous, graph problems
- Great **tradition** in parameterized complexity
  - Well studied problem variants
  - Different parameters
  - Kernelizations
  - Applications
  - ...

- Track 1a: Compute a Minimum Vertex Cover (Exact)

Problem:	MinVertexCover
Input:	Graph G
Task:	Output a minimum vertex cover for G.

Instance Selection for Vertex Cover

- 9,591 instances among 8 different origins
  - PACE 2016
  - TransitGraphs, Road-graphs
  - SNAP
  - frb
  - ASP Horn backdoors, SAT Horn backdoors
  - SAT2VC
- Classification by “Difficulty” (via Gurobi, numVC, Glucose) in intervals →



instances	$\lvert V_{\text{min}} \rvert$	$\lvert V_{\text{max}} \rvert$	$\lvert V_{\text{avg}} \rvert$	$\lvert V_{\text{med}} \rvert$	$\lvert E_{\text{min}} \rvert$	$\lvert E_{\text{max}} \rvert$	$\lvert E_{\text{avg}} \rvert$	$\lvert E_{\text{med}} \rvert$	$\text{tw}^{\text{ub}}_{\text{med}}$
public	198	138.14k	16.44k	14.69k	813	227.24k	30.95k	24.66k	105.0
private	153	98.13k	16.30k	13.59k	625	161.36k	30.50k	27.15k	103.5
all	153	138.14k	16.37k	13.59k	625	227.24k	30.73k	24.66k	107.0

Track 2: Hypertree Decompositions

- Motivation: Success of PACE 2016 & 2017 (Treewidth)
- Applications for (Hyper-)tree Decompositions
  - Databases
  - Constraint Programming
- Track 2a (EXACT): Compute a hypertree decomposition of **minimum width**

Problem:	MinHypertreeWidth
Input:	Hypergraph H
Task:	Output a hypertree decomposition of H of minimum width.

- Track 2b (HEUR): Heuristically compute a hypertree decomposition of **small width**

Problem:	HeurHypertreeWidth
Input:	Hypergraph H
Task:	Output a hypertree decomposition of H of small width.

Hypertree Decompositions

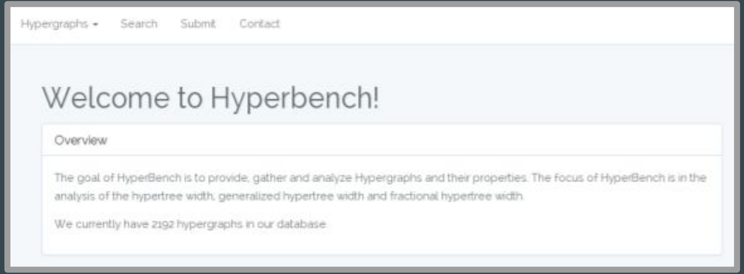
- Given: Hypergraph H (higher arity edges)

- A Hypertree Decomposition D of H is, roughly speaking,
  - A **Tree Decomposition** of H
  - + a bag covering function (***edge cover***) over hyperedges
  - + a certain monotonicity property (***Descendent Condition***) for the edge cover

- width(D) is size of the largest edge cover
- htw(H) smallest width over all Hypertree Decompositions of H

Instance Selection for Hypertree Decompositions

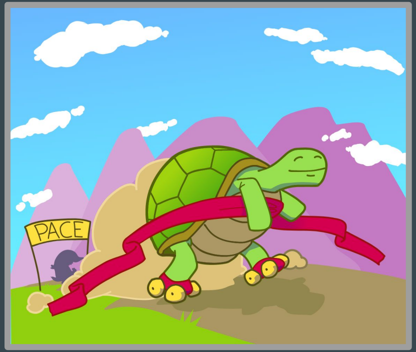
- 2,191 instances from hyperbench, originating from the area of CSP
  - DaimlerChrysler
  - Grid2D
  - MaxSAT, csp_application, csp_random, csp_other
  - CQ
- Classification of "Difficulty" by means of
  - htdecomp, kdetdecomp
  - Frasmt using the more generalized (fractional / generalized) hypertree decompositions



hyperbench.dbai.tuwien.ac.at

Track	instances	$\lvert V_{\min}\rvert$	$\lvert V_{\max}\rvert$	$\lvert V_{\text{med}}\rvert$	$\lvert E_{\min}\rvert$	$\lvert E_{\max}\rvert$	$\lvert E_{\text{med}}\rvert$
Track 2a	public	3	130	24.0	3	100	61.5
Track 2a	private	10	351	25.0	5	250	60.0
Track 2a	all	3	351	24.0	3	250	60.0
Track 2b	public	12	694	40.0	5	526	84.0
Track 2b	private	12	694	40.0	5	495	90.0
Track 2b	all	12	694	40.0	5	526	84.0

PACE 2019: Submission Requirements



Submission Requirements

1. Solvers + Dependencies have to be **open source**
2. Source code of solver is maintained on **public repository**
   + long term data library
3. *A dedicated **solver description** is required*
4. Solvers for Tracks 1a and 2a are **provably optimal**

Submission Limits

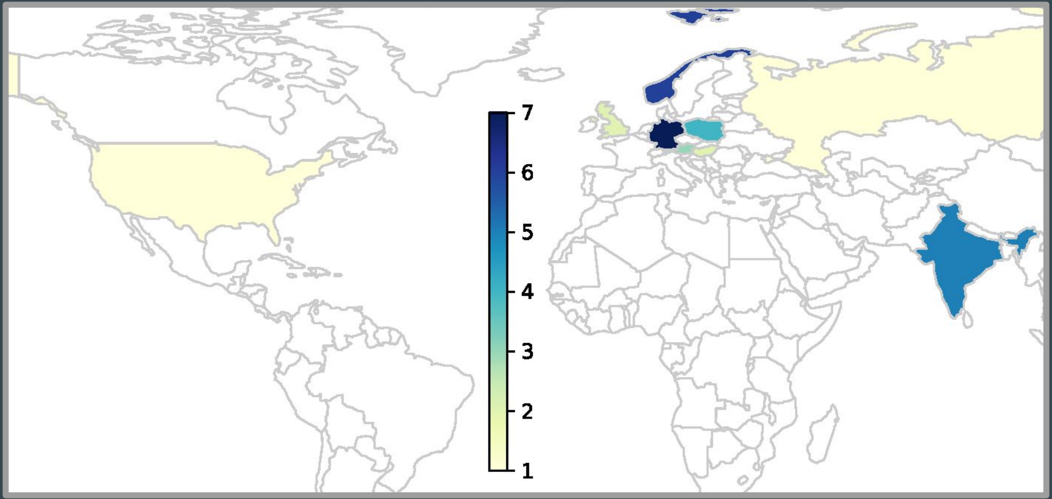
1. Submission on optil.io
2. 30 minutes per instance
3. 8 GB RAM per instance

Participants of PACE 2019

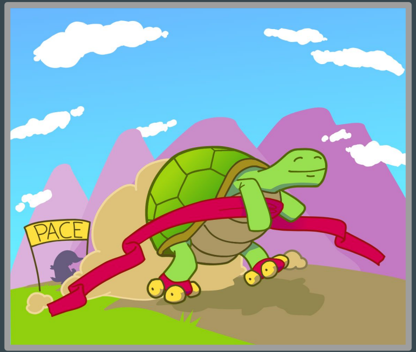
Participants

- 18 teams and 33 participants from 10 countries

Region	Country	Teams	Participants	Tracks
Europe	Austria	3	3	1a, 2a, 2b
	Germany	4	7	1a
	Hungary	1	2	1a
	Norway	2	6	1a
	Poland	2	4	1a
	Russia	1	1	1a
	Scotland	1	2	1a, 2a, b
Middle East	Lebanon	1	2	1a
North America	USA	1	1	1a
South Asia	India	2	5	1a
	10	18	33	

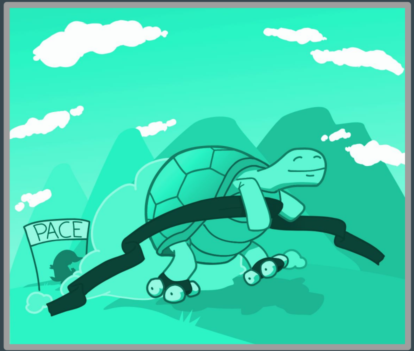


Results of PACE 2019



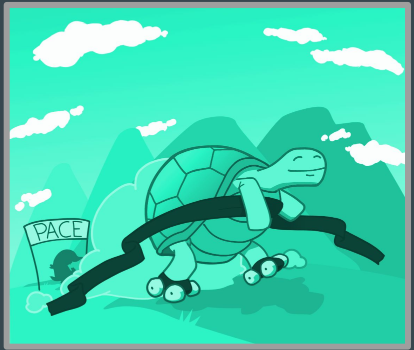
Results of Track 1: Vertex Cover

- Track 1a: Minimum Vertex Cover



POS	Team	#	$\#^{\text{all}}$	TLE	RTE	$t_{\text{sum}}[h]$	$t_{\text{avg}}[s]$
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1

Results of Track 1: Vertex Cover



- Track 1a: Minimum Vertex Cover

POS	Team	#	$\#^{all}$	TLE	RTE	$t_{sum}[h]$	$t_{avg}[s]$
8	hub	23	54	68	9	0.5	79.5
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1

4th Parameterized Algorithms and Computational Experiments Challenge

PACE

Uniting FPT and practice

ALGO/IPEC 2019 September 9 – 13 Munich, Germany

This is to certify that the 2019 PACE Program Committee recognizes

Falko Hegerfeld and Florian Nelles

Humboldt-Universität zu Berlin, Germany

for

Eighth Place in Track 1A: Vertex Cover

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

2019 PACE Program Committee Co-chairs

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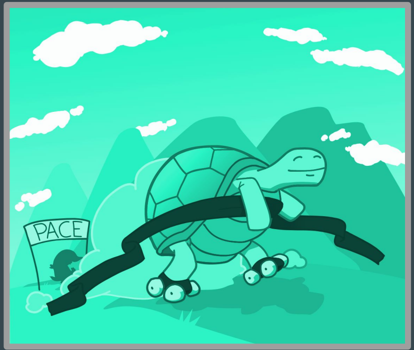
Results of Track 1: Vertex Cover

- Track 1a: Minimum Vertex Cover

POS	Team	#	$\#^{\text{all}}$	TLE	RTE	$t_{\text{sum}}[h]$	$t_{\text{avg}}[s]$
7	vasily_alferov	32	70	68	0	0.2	23.2
8	hub	23	54	68	9	0.5	79.5
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1



This is to certify that the 2019 PACE Program Committee recognizes

Vasily Alferov

National Research University Higher School of Economics, Russia

for

Seventh Place in Track 1A: Vertex Cover

225 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

2019 PACE Program Committee Co-chairs

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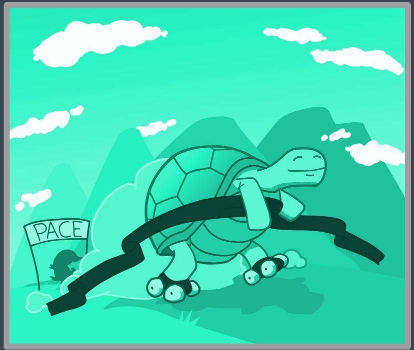
Results of Track 1: Vertex Cover

- Track 1a: Minimum Vertex Cover



POS	Team	#	$\#^{all}$	TLE	RTE	$t_{sum}[h]$	$t_{avg}[s]$
6	sfs	33	74	65	2	0.8	87.0
7	vasily_alferov	32	70	68	0	0.2	23.2
8	hub	23	54	68	9	0.5	79.5
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1

This is to certify that the 2019 PACE Program Committee recognizes

Jiehua Chen and **Sven Grottke**

University of Warsaw, Poland — TU Berlin, Germany

for

Sixth Place in Track 1A: Vertex Cover

250 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

2019 PACE Program Committee Co-chairs

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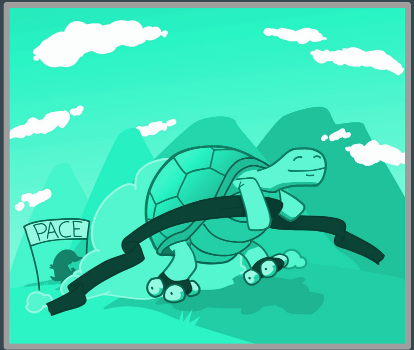
Results of Track 1: Vertex Cover



- Track 1a: Minimum Vertex Cover

POS	Team	#	$\#^{\text{all}}$	TLE	RTE	$t_{\text{sum}}[h]$	$t_{\text{avg}}[s]$
5	opm	33	75	67	0	0.4	47.8
6	sfs	33	74	65	2	0.8	87.0
7	vasily_alferov	32	70	68	0	0.2	23.2
8	hub	23	54	68	9	0.5	79.5
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1

This is to certify that the 2019 PACE Program Committee recognizes

Aleksander Figiel

TU Berlin, Germany

for

Fifth Place in Track 1A: Vertex Cover

275 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

2019 PACE Program Committee Co-chairs

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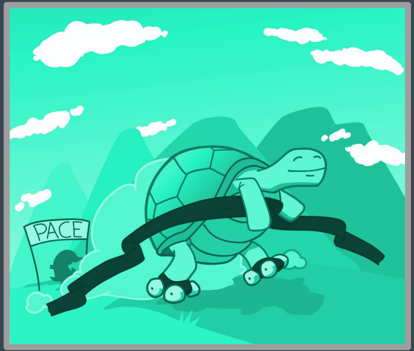
Informationsverarbeitung

Results of Track 1: Vertex Cover

- Track 1a: Minimum Vertex Cover



POS	Team	#	$\#^{all}$	TLE	RTE	$t_{sum}[h]$	$t_{avg}[s]$
4	ksimonov	34	73	64	2	1.0	102.1
5	opm	33	75	67	0	0.4	47.8
6	sfs	33	74	65	2	0.8	87.0
7	vasily_alferov	32	70	68	0	0.2	23.2
8	hub	23	54	68	9	0.5	79.5
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1

This is to certify that the 2019 PACE Program Committee recognizes

Christophe Crespelle, Eduard Eiben, and Kirill Simonov

University of Bergen, Norway

for

Fourth Place in Track 1A: Vertex Cover

300 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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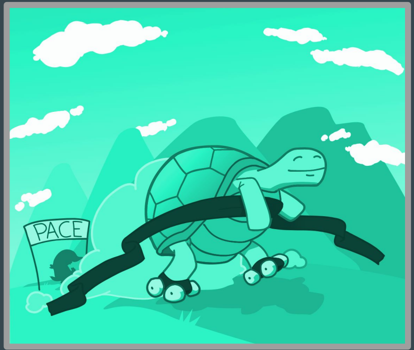
data experts Systemberatung Softwareentwicklung Informationsverarbeitung

Results of Track 1: Vertex Cover

- Track 1a: Minimum Vertex Cover

POS	Team	#	$\#^{all}$	TLE	RTE	$t_{sum}[h]$	$t_{avg}[s]$
3	bogdan	76	147	24	0	4.5	215.2
4	ksimonov	34	73	64	2	1.0	102.1
5	opm	33	75	67	0	0.4	47.8
6	sfs	33	74	65	2	0.8	87.0
7	vasily_alferov	32	70	68	0	0.2	23.2
8	hub	23	54	68	9	0.5	79.5
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1



4th Parameterized Algorithms and Computational Experiments Challenge

PACE

Uniting FPT and practice

ALGO/IPEC 2019 September 9 – 13 Munich, Germany

This is to certify that the 2019 PACE Program Committee recognizes

Sándor Szabó and **Bogdán Zaválnij**

University of Pecs, Hungary — Hungarian Academy of Sciences, Hungary

for

Third Place in Track 1A: Vertex Cover

450 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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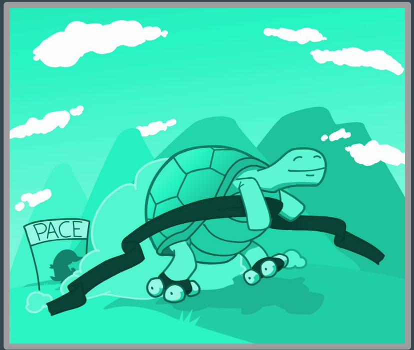
Results of Track 1: Vertex Cover



- Track 1a: Minimum Vertex Cover

POS	Team	#	$\#^{all}$	TLE	RTE	$t_{sum}[h]$	$t_{avg}[s]$
2	Peaty	77	157	23	0	0.4	20.6
3	bogdan	76	147	24	0	4.5	215.2
4	ksimonov	34	73	64	2	1.0	102.1
5	opm	33	75	67	0	0.4	47.8
6	sfs	33	74	65	2	0.8	87.0
7	vasily_alferov	32	70	68	0	0.2	23.2
8	hub	23	54	68	9	0.5	79.5
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1

This is to certify that the 2019 PACE Program Committee recognizes

Patrick Prosser and James Trimble

University of Glasgow, Scotland

for

Second Place in Track 1A: Vertex Cover

450 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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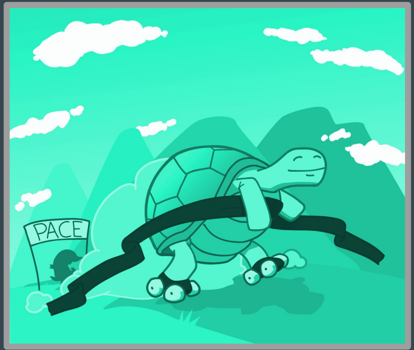
Results of Track 1: Vertex Cover

- Track 1a: Minimum Vertex Cover

POS	Team	#	$\#^{\text{all}}$	TLE	RTE	$t_{\text{sum}}[h]$	$t_{\text{avg}}[s]$
1	WeGotYouCovered	87	169	13	0	1.3	52.7
2	Peaty	77	157	23	0	0.4	20.6
3	bogdan	76	147	24	0	4.5	215.2
4	ksimonov	34	73	64	2	1.0	102.1
5	opm	33	75	67	0	0.4	47.8
6	sfs	33	74	65	2	0.8	87.0
7	vasily_alferov	32	70	68	0	0.2	23.2
8	hub	23	54	68	9	0.5	79.5
DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1



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This is to certify that the 2019 PACE Program Committee recognizes

Demian Hespe, Sebastian Lamm, Christian Schulz, and Darren Strash

Karlsruhe Institute of Technology, Germany University of Vienna, Austria Hamilton College, USA

for

First Place in Track 1A: Vertex Cover

750 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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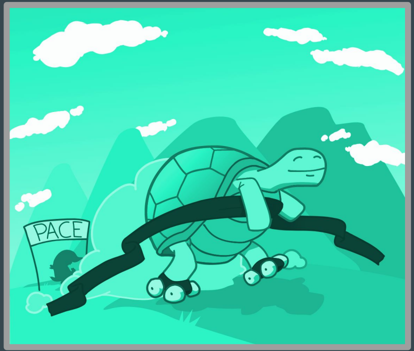
Results of Track 1: Vertex Cover



- Track 1a: Minimum Vertex Cover

POS	Team	#	$\#^{all}$	TLE	RTE	$t_{sum}[h]$	$t_{avg}[s]$
1	WeGotYouCovered	87	169	13	0	1.3	52.7
2	Peaty	77	157	23	0	0.4	20.6
3	bogdan	76	147	24	0	4.5	215.2
4	ksimonov	34	73	64	2	1.0	102.1
5	opm	33	75	67	0	0.4	47.8
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DSQ	Vertex_Cover_Solver	31	69	68	0	0.4	52.1

Results of Track 2: Hypertree Decompositions

Results of Track 2: Hypertree Decompositions

- Track 2a: MinHypertreeWidth

POS	#	$\#^{all}$	Team	t_{avg}	t_{sum}
3	1	6	heidi	0.14s	0.00h

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Patrick Prosser and James Trimble

University of Glasgow, Scotland

for

Third Place in Track 2A: Exact Hypertree Width

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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Results of Track 2: Hypertree Decompositions

- Track 2a: MinHypertreeWidth

POS	#	$\#^{all}$	Team	t_{avg}	t_{sum}
2	31	48	TULongo	95.96s	0.83h
3	1	6	heidi	0.14s	0.00h

This is to certify that the 2019 PACE Program Committee recognizes

225 €

Davide Mario Longo

TU Wien

for

Second Place in Track 2A: Exact Hypertree Width

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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Results of Track 2: Hypertree Decompositions

- Track 2a: MinHypertreeWidth

POS	#	$\#^{all}$	Team	t_{avg}	t_{sum}
1	69	144	asc	69.38s	1.32h
2	31	48	TULongo	95.96s	0.83h
3	1	6	heidi	0.14s	0.00h

This is to certify that the 2019 PACE Program Committee recognizes

André Schidler and Stefan Szeider

TU Dresden TU Wien

350 €

for

First Place in Track 2A: Exact Hypertree Width

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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Results of Track 2: Hypertree Decompositions

- Track 2a: MinHypertreeWidth

POS	#	$\#^{all}$	Team	t_{avg}	t_{sum}
1	69	144	asc	69.38s	1.32h
2	31	48	TULongo	95.96s	0.83h
3	1	6	heidi	0.14s	0.00h

- Track 2b: HeurHypertreeWidth

POS	Score	Team	#	PAR1	Δ_w
3	128.9	asc	30	27.5	11

This is to certify that the 2019 PACE Program Committee recognizes

André Schidler and Stefan Szeider

TU Dresden TU Wien

150 €

for

Third Place in Track 2B: Heuristic Hypertree Width

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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Results of Track 2: Hypertree Decompositions

- Track 2a: MinHypertreeWidth

POS	#	$\#^{all}$	Team	t_{avg}	t_{sum}
1	69	144	asc	69.38s	1.32h
2	31	48	TULongo	95.96s	0.83h
3	1	6	heidi	0.14s	0.00h

- Track 2b: HeurHypertreeWidth

POS	Score	Team	#	PAR1	Δ_w
2	14.1	TULongo	98	2.3h	20
3	128.9	asc	30	27.5	11

This is to certify that the 2019 PACE Program Committee recognizes

Davide Mario Longo

TU Wien

for

Second Place in Track 2B: Heuristic Hypertree Width

225 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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Results of Track 2: Hypertree Decompositions

- Track 2a: MinHypertreeWidth

POS	#	$\#^{all}$	Team	t_{avg}	t_{sum}
1	69	144	asc	69.38s	1.32h
2	31	48	TULongo	95.96s	0.83h
3	1	6	heidi	0.14s	0.00h

- Track 2b: HeurHypertreeWidth

POS	Score	Team	#	PAR1	Δ_w
–	na	htdecomp	100	na	na
1	5.0	hypebeast	100	0.1h	501
2	14.1	TULongo	98	2.3h	20
3	128.9	asc	30	27.5	11

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Patrick Prosser and James Trimble

University of Glasgow, Scotland

for

First Place in Track 2B: Heuristic Hypertree Width

350 €

Johannes K. Fichte, TU Dresden

Markus Hecher, TU Wien

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Conclusion & Future of PACE

Lessons Learned

- Solver description and public library essential
  - Maybe set solver description (abstract) deadline even at the beginning
- Selecting instances of moderate difficulty (vertex cover)
  - Possible, but not easy
  - Requires to collect numerous instances
- Problems and instances should be ready by the end of September
  - Some students lost attention due to late problem announcement
- Cluster resources essential
  - optil.io troubles during final submission phase
  - optil.io runtime difference was in some cases up to 7 minutes between same instance + solver
- Score hard to comprehend for submitters
  - limitation of optil.io: normalized scoreboard 0..1 depending
    on performance of individual solver and instance

Future Editions

- Next years PACE Deadline will be later
- Process of selecting new PCs ongoing

Problems?

- Subscribe to the newsletter
  and stay tuned!

pacechallenge.org

Hope we see you at PACE 2020.

The Winning Team of Track 1a (Vertex Cover)

Karlsruhe Institute of Technology

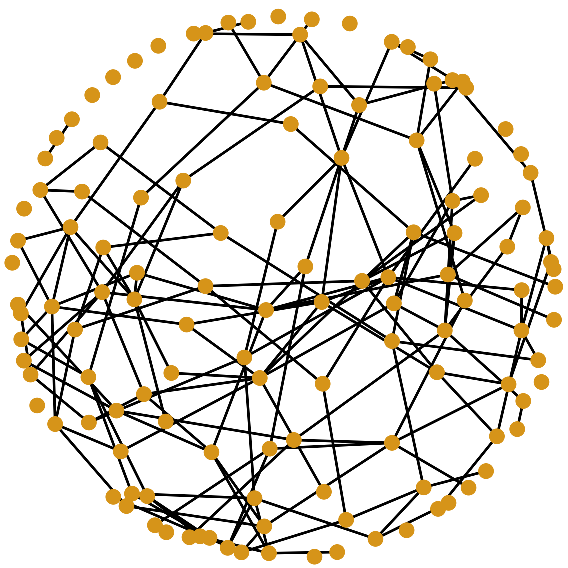
WeGotYouCovered

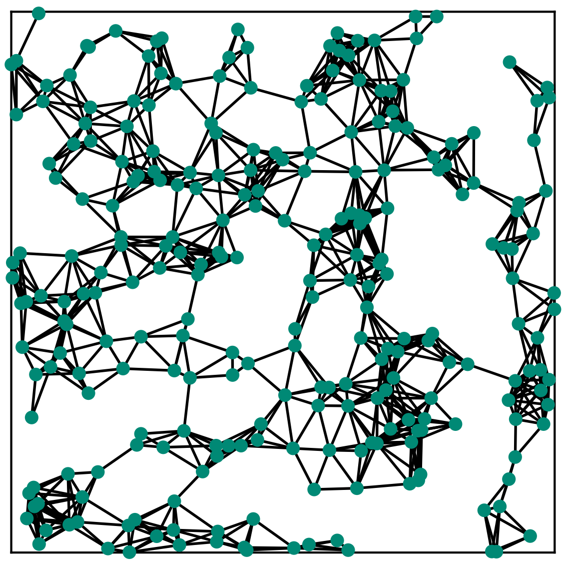
The Winning Solver from the PACE 2019 Implementation Challenge, Vertex Cover Track

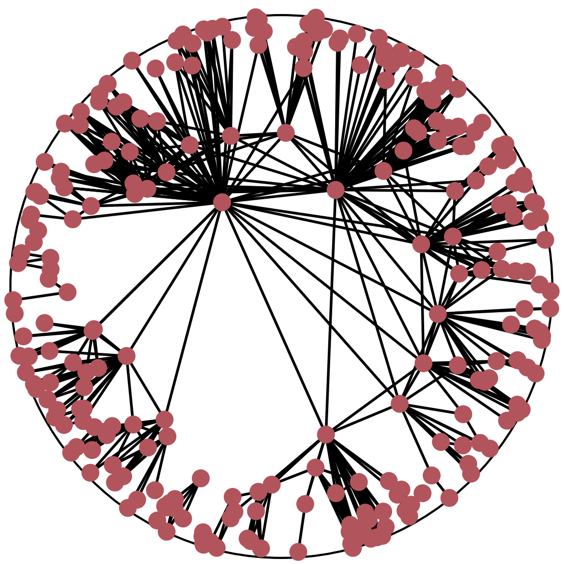
IPEC'19 · September 11, 2019

Demian Hespe, Sebastian Lamm, Christian Schulz, Darren Strash

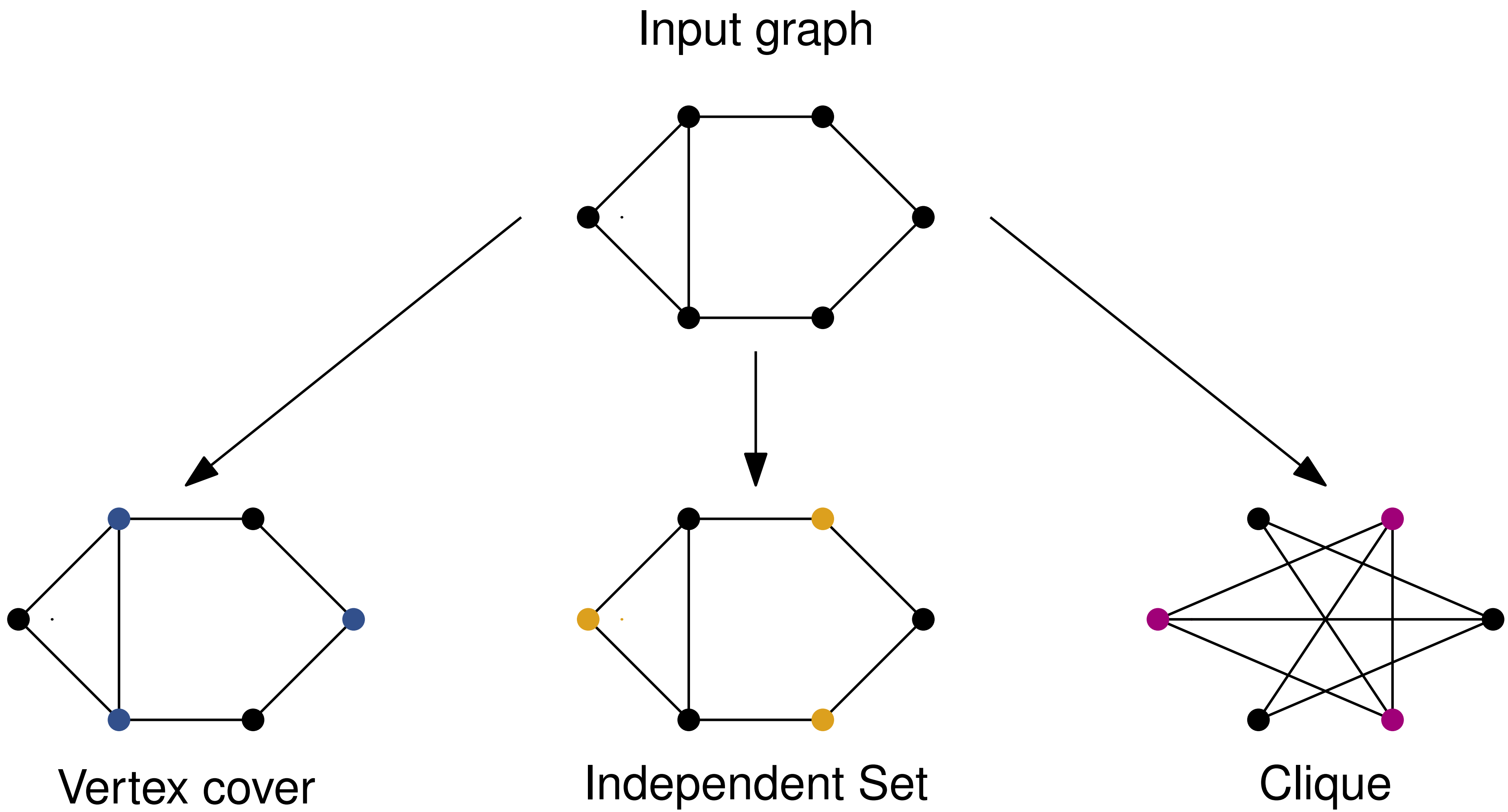
INSTITUTE OF THEORETICAL INFORMATICS · ALGORITHMICS GROUP





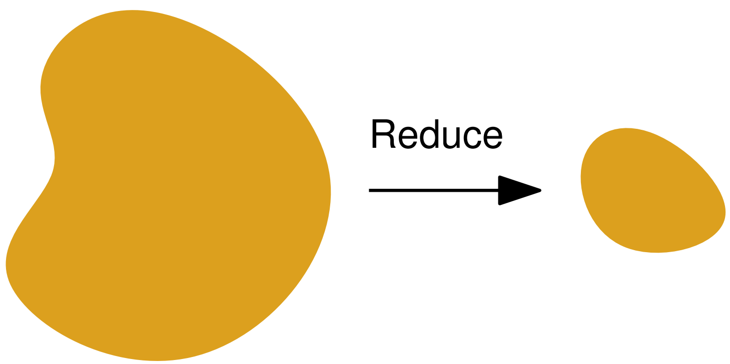


Vertex Cover and Complementary Problems

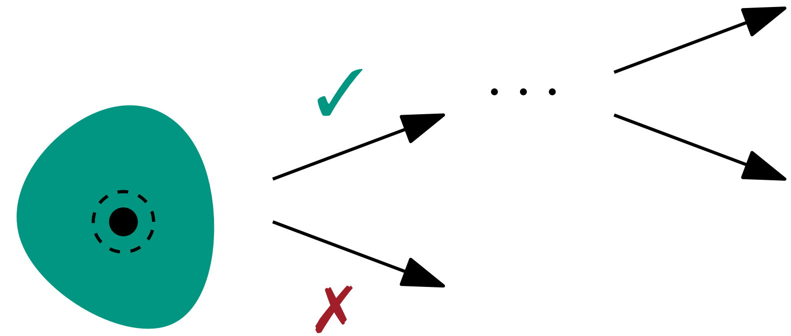


Techniques

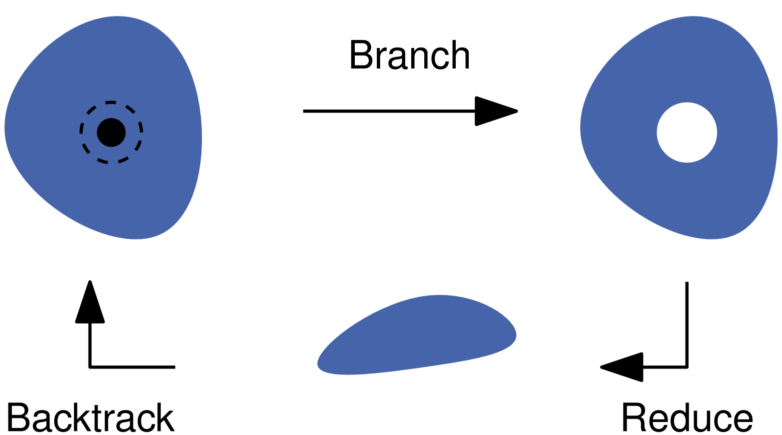
Kernelization



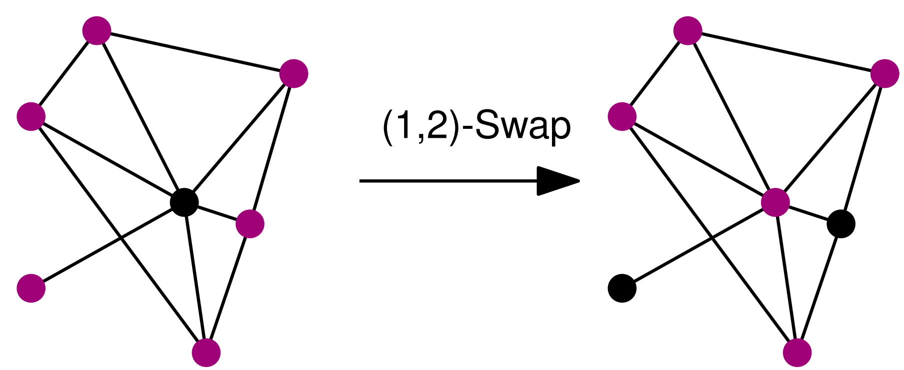
Branch-and-Bound



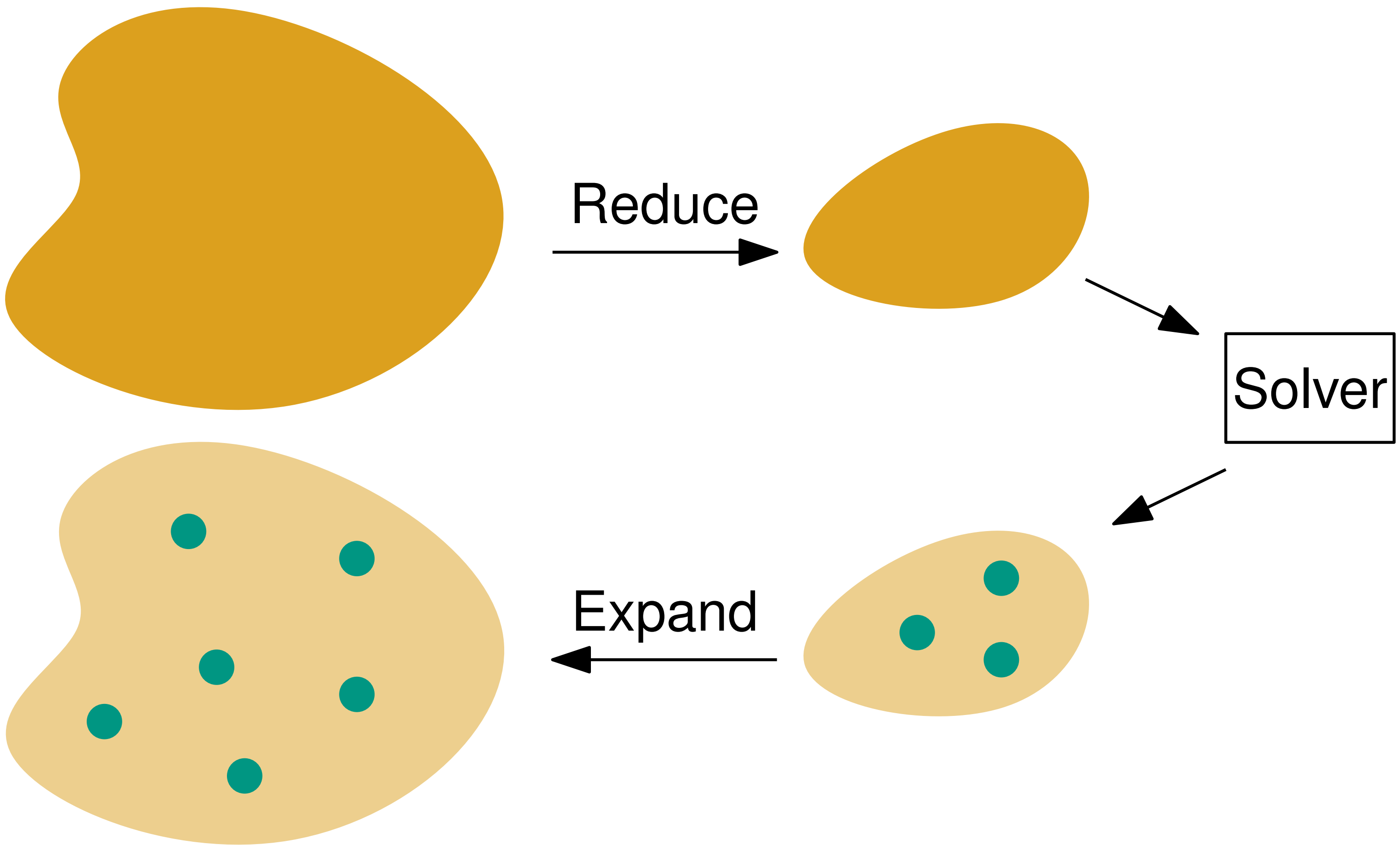
Branch-and-Reduce



Iterated Local Search

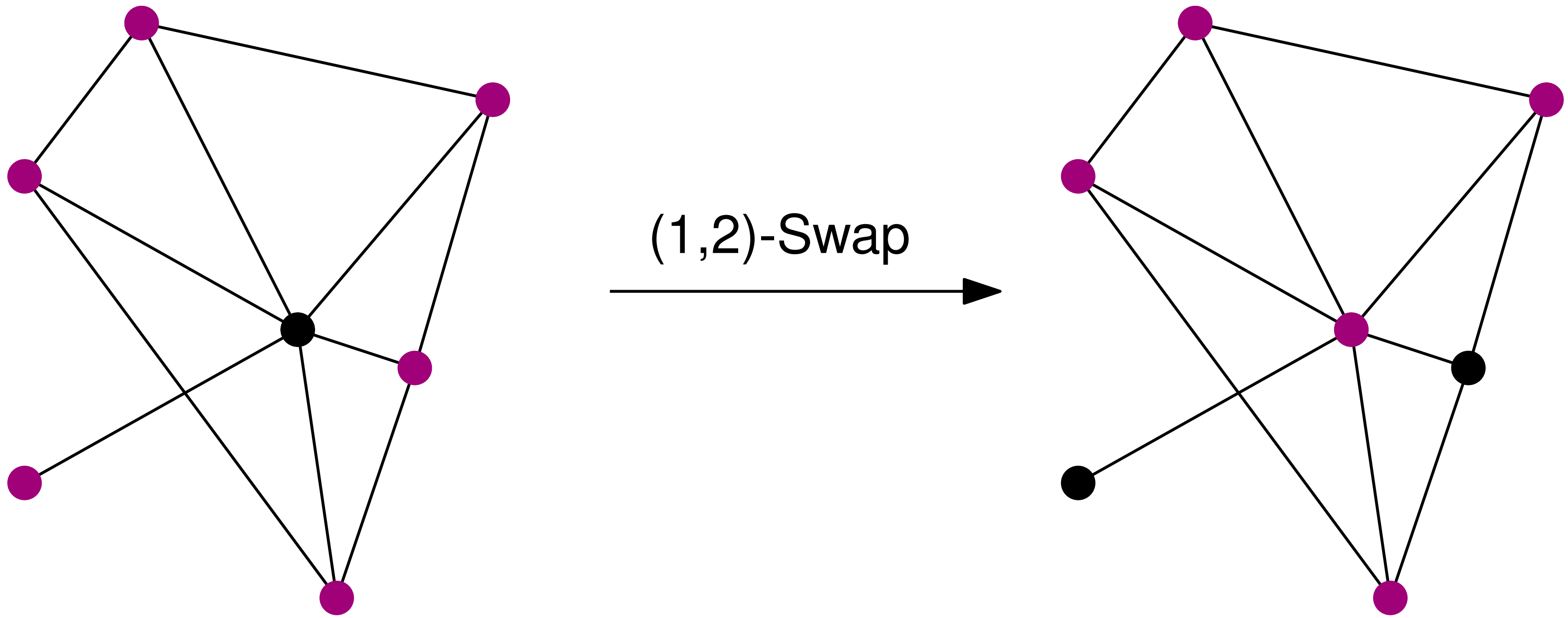


Kernelization [AI2016]



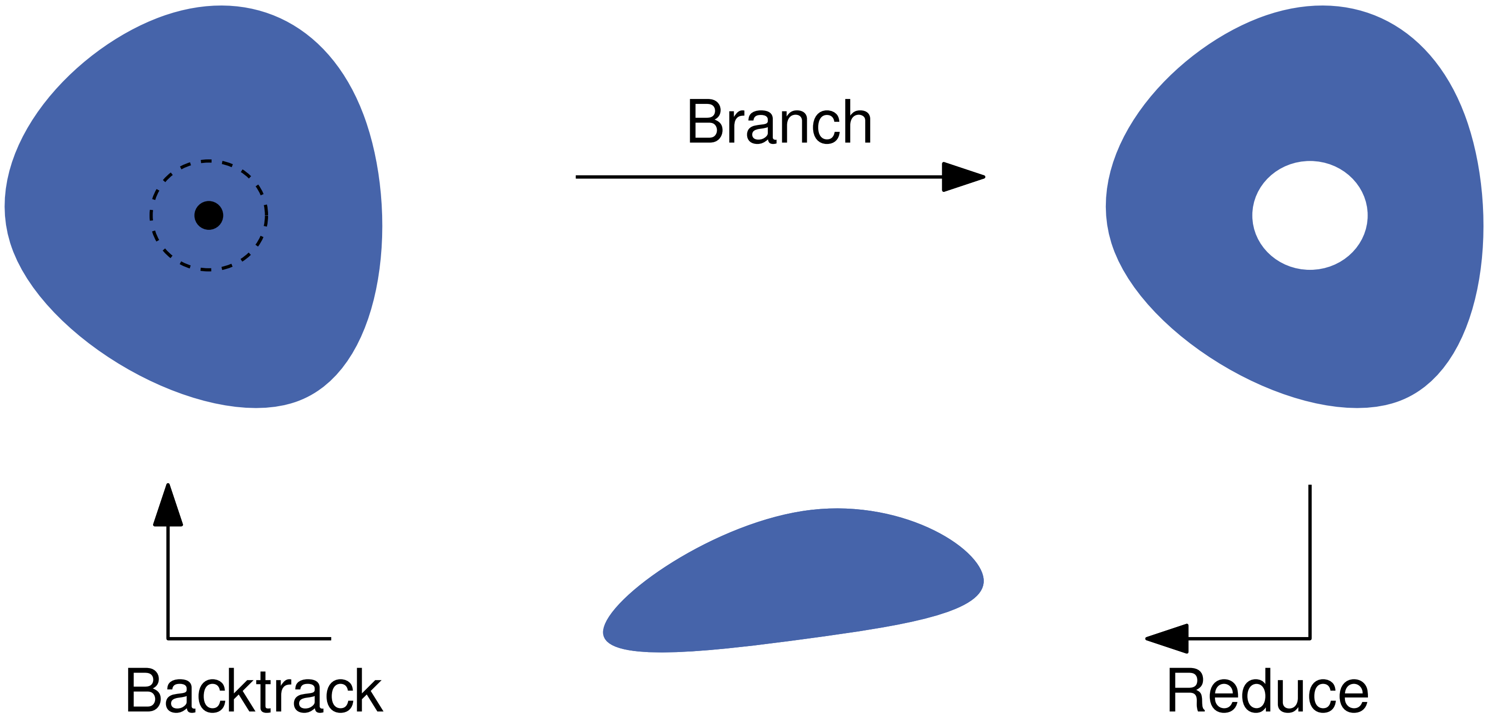
- Technique from FPT algorithms
- Applies rich set of reduction rules
- Significantly reduces graph size

Iterated Local Search [ARW2012]



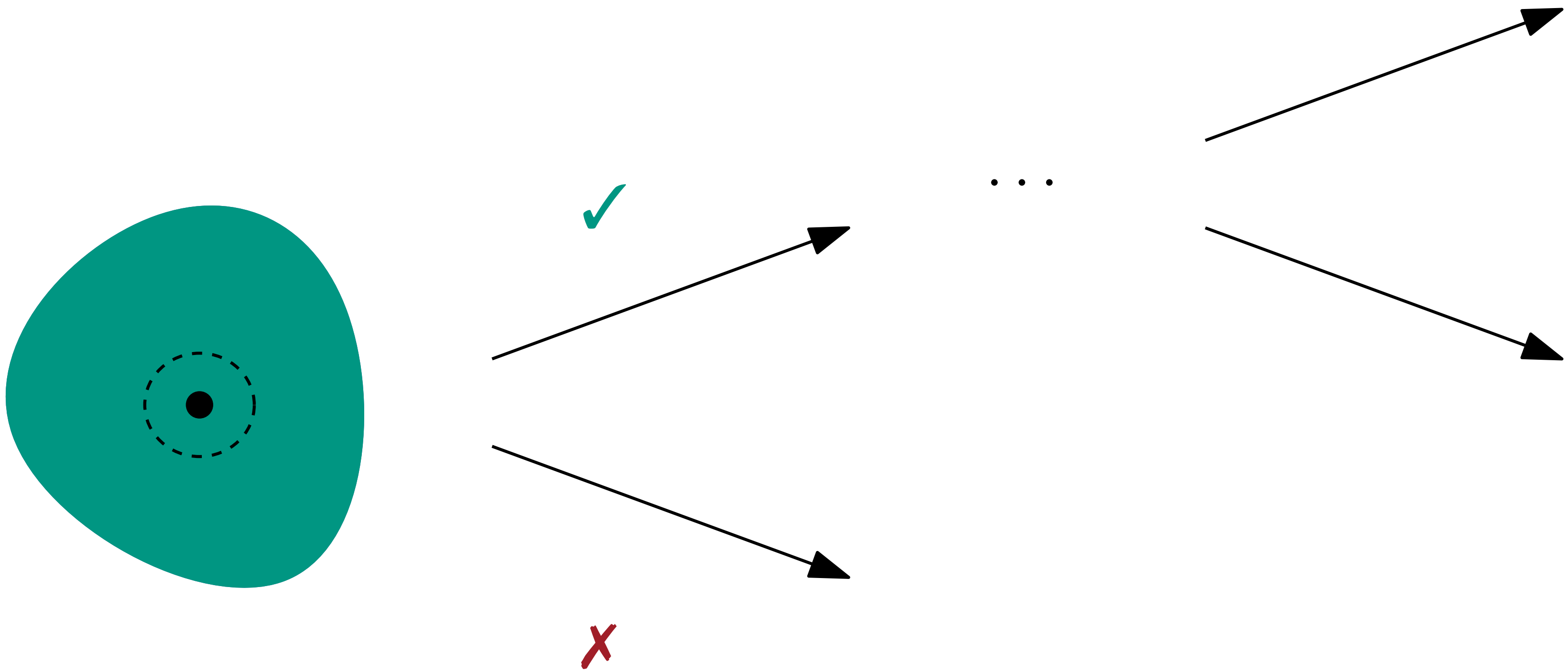
- Originally developed for independent sets
- Perturbation to escape local optima
- Can often find (near-)optimal solutions

Branch and Reduce [AI2016]



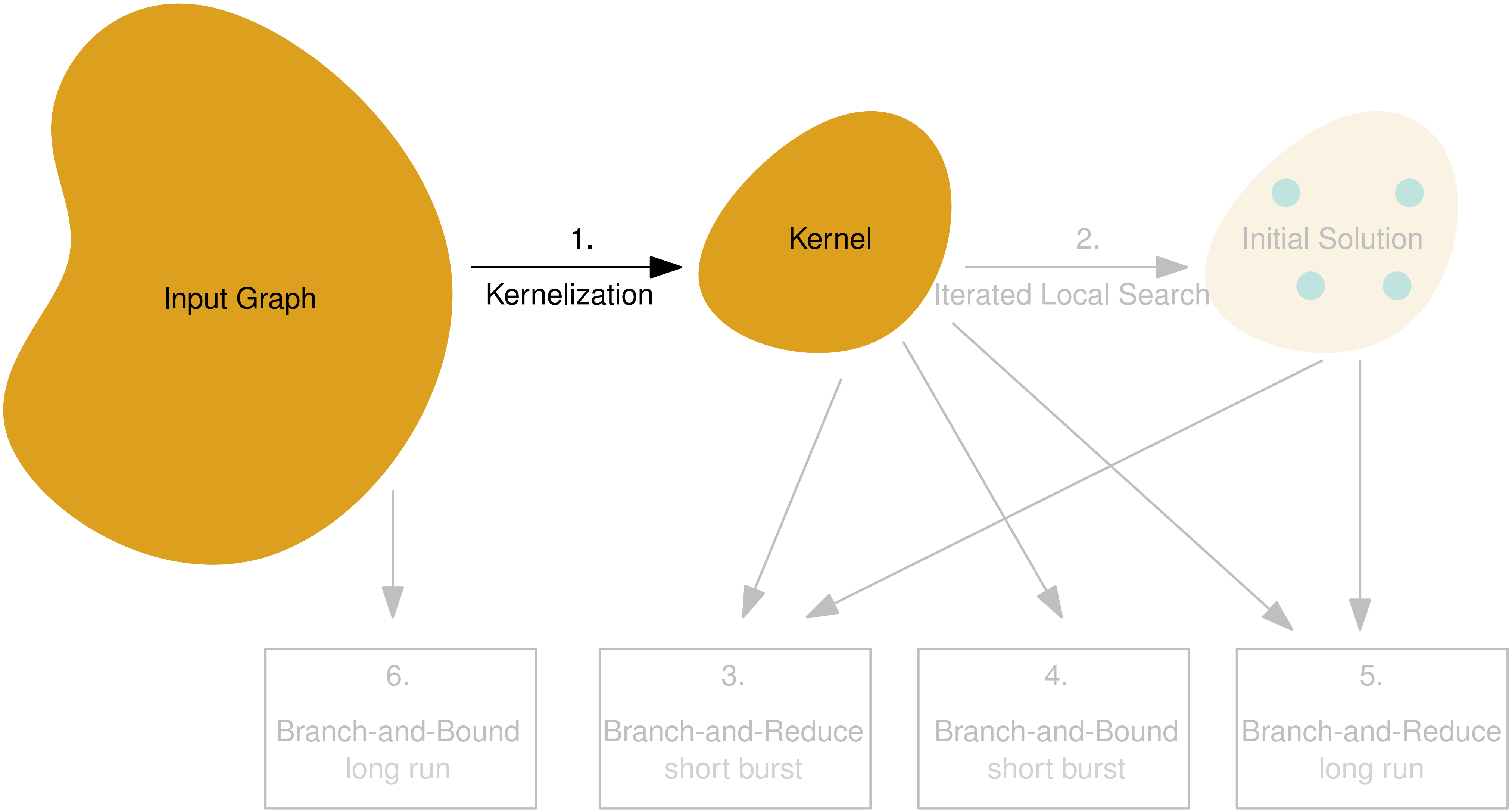
- Reduce graph after each branch
- Additional branching rules to reduce graph size
- Prune search based on lower bounds

Branch and Bound [LJM2017]

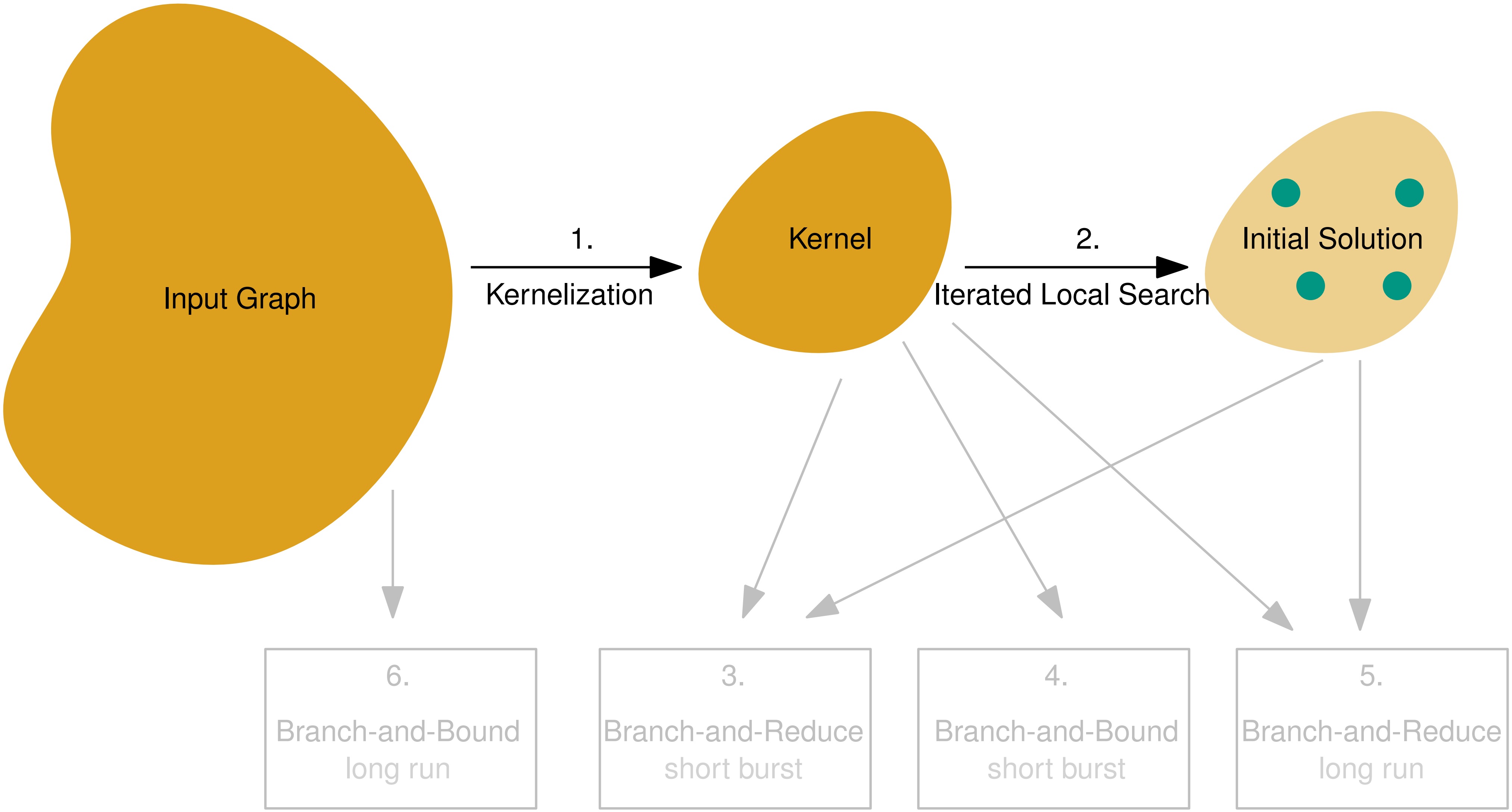


- Originally developed for maximum cliques
- Incremental MaxSAT reasoning to prune search
- Combination of static and dynamic vertex ordering

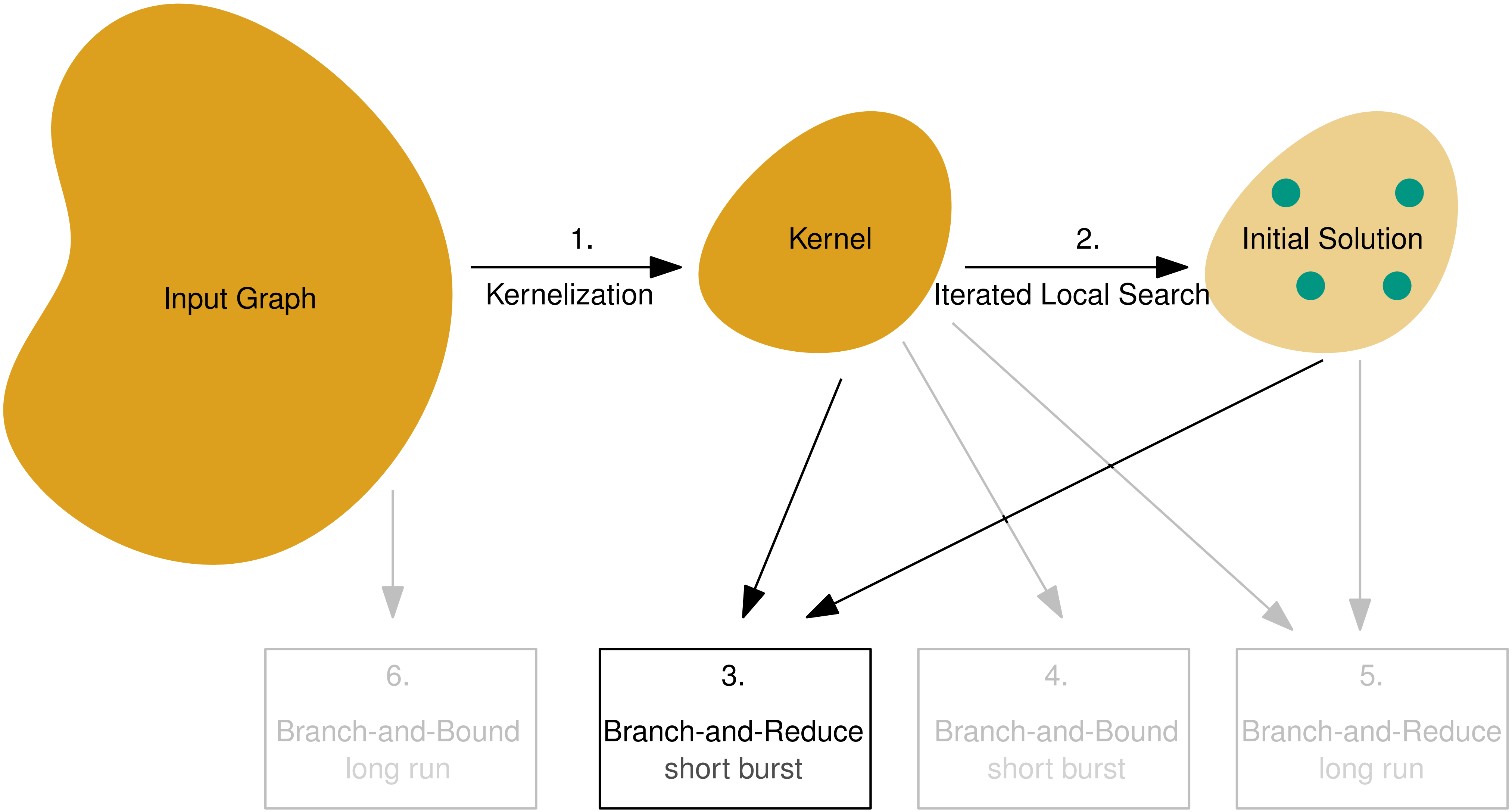
Algorithm Overview



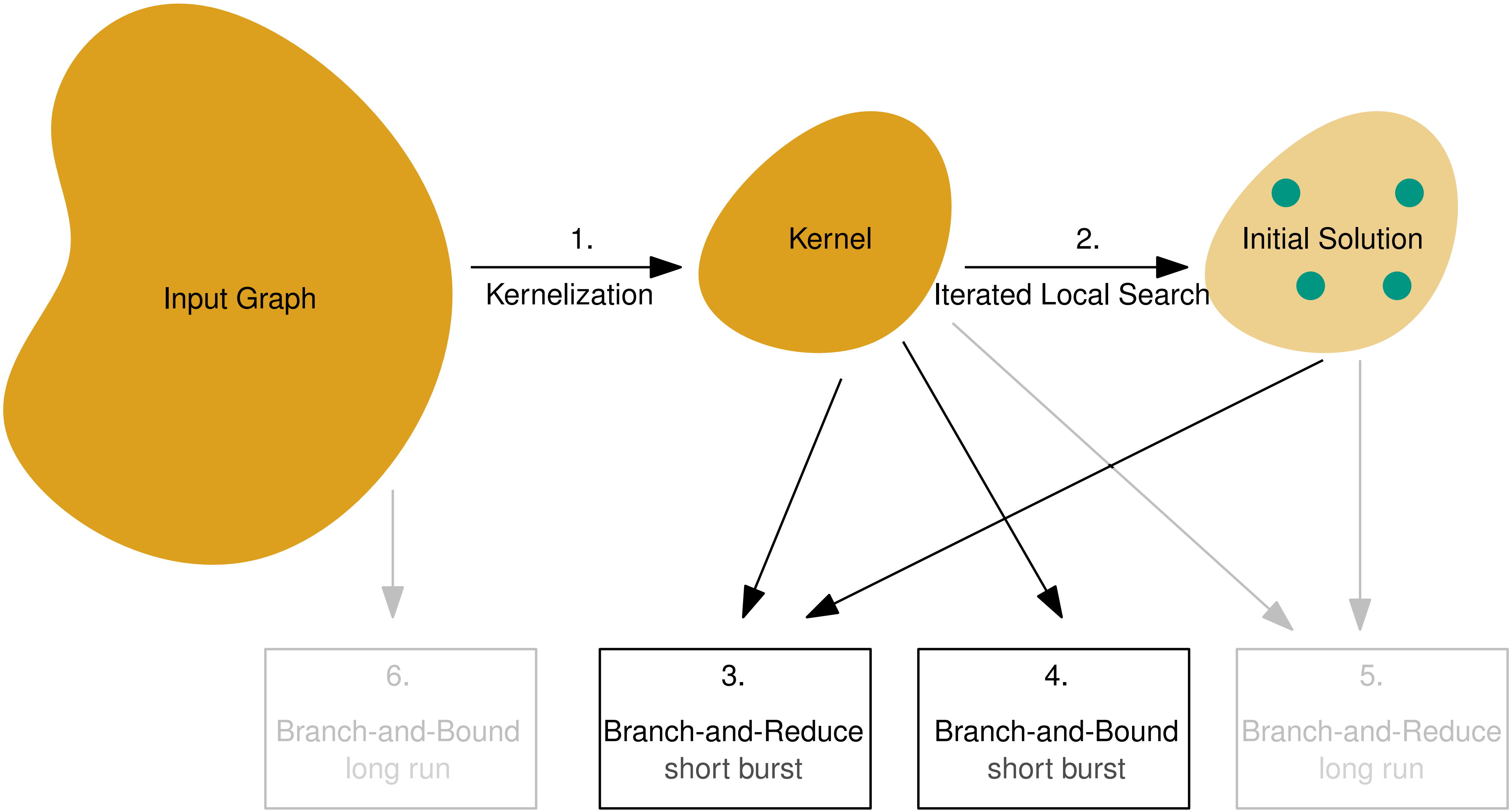
Algorithm Overview



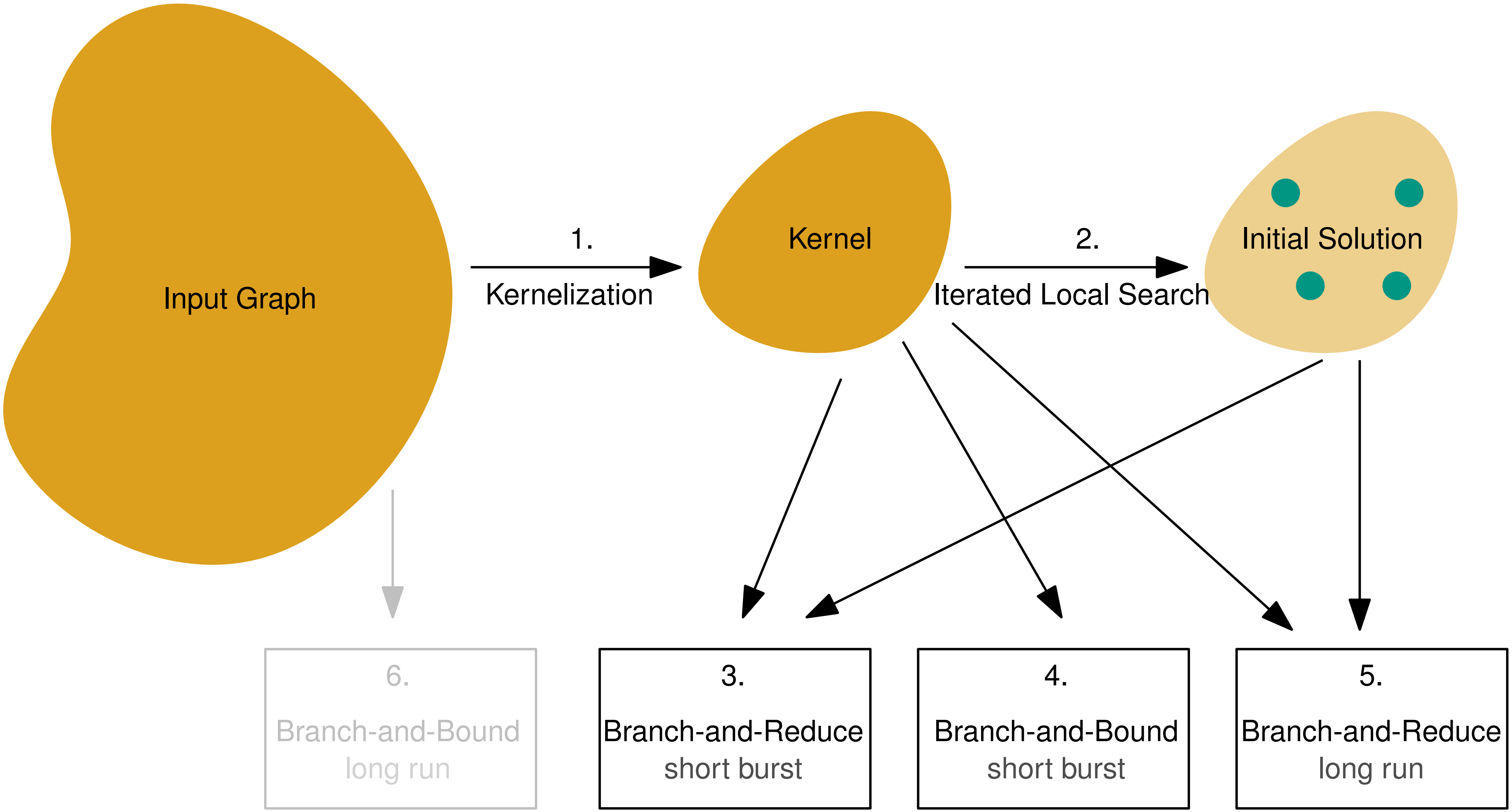
Algorithm Overview



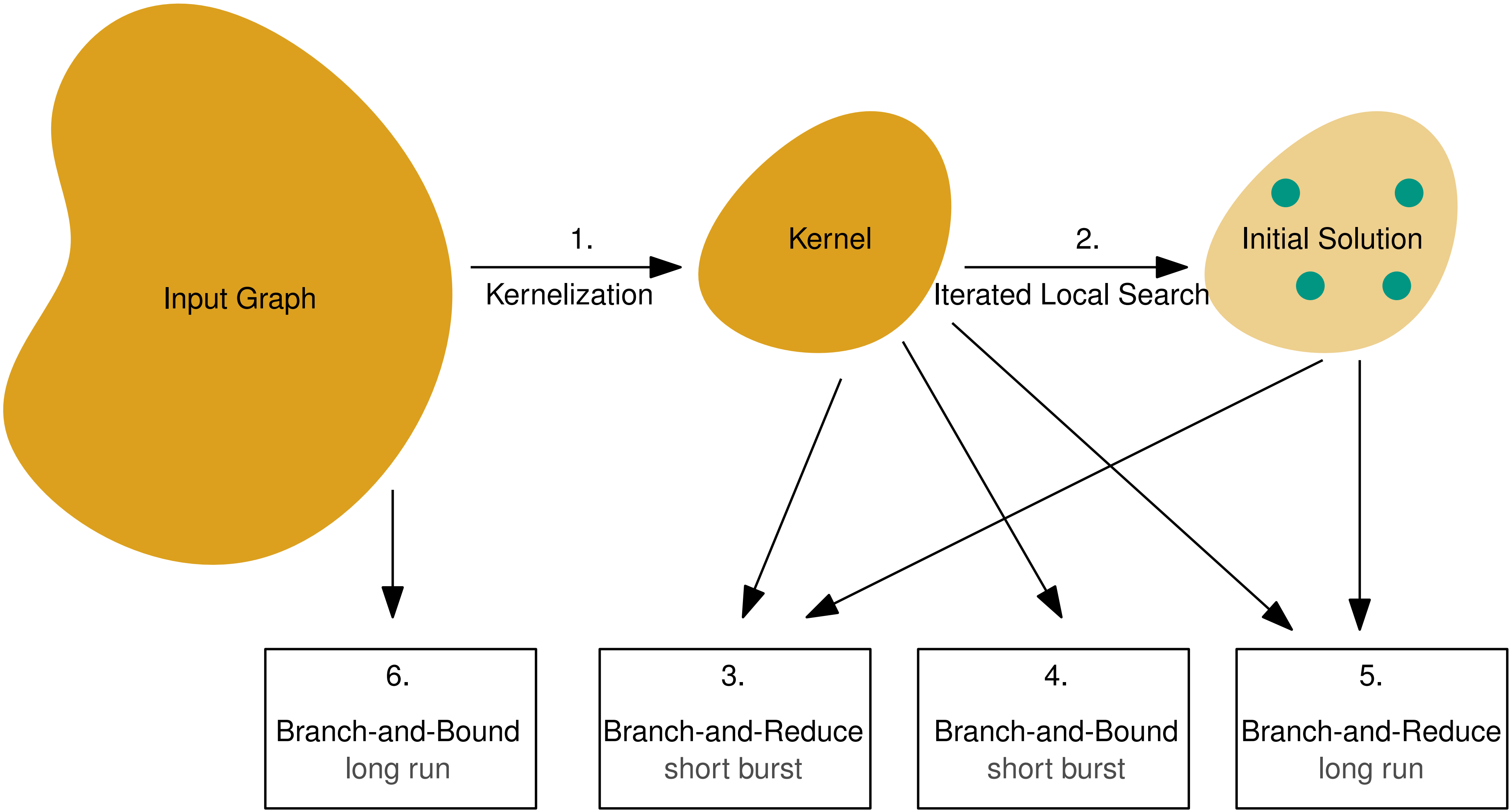
Algorithm Overview



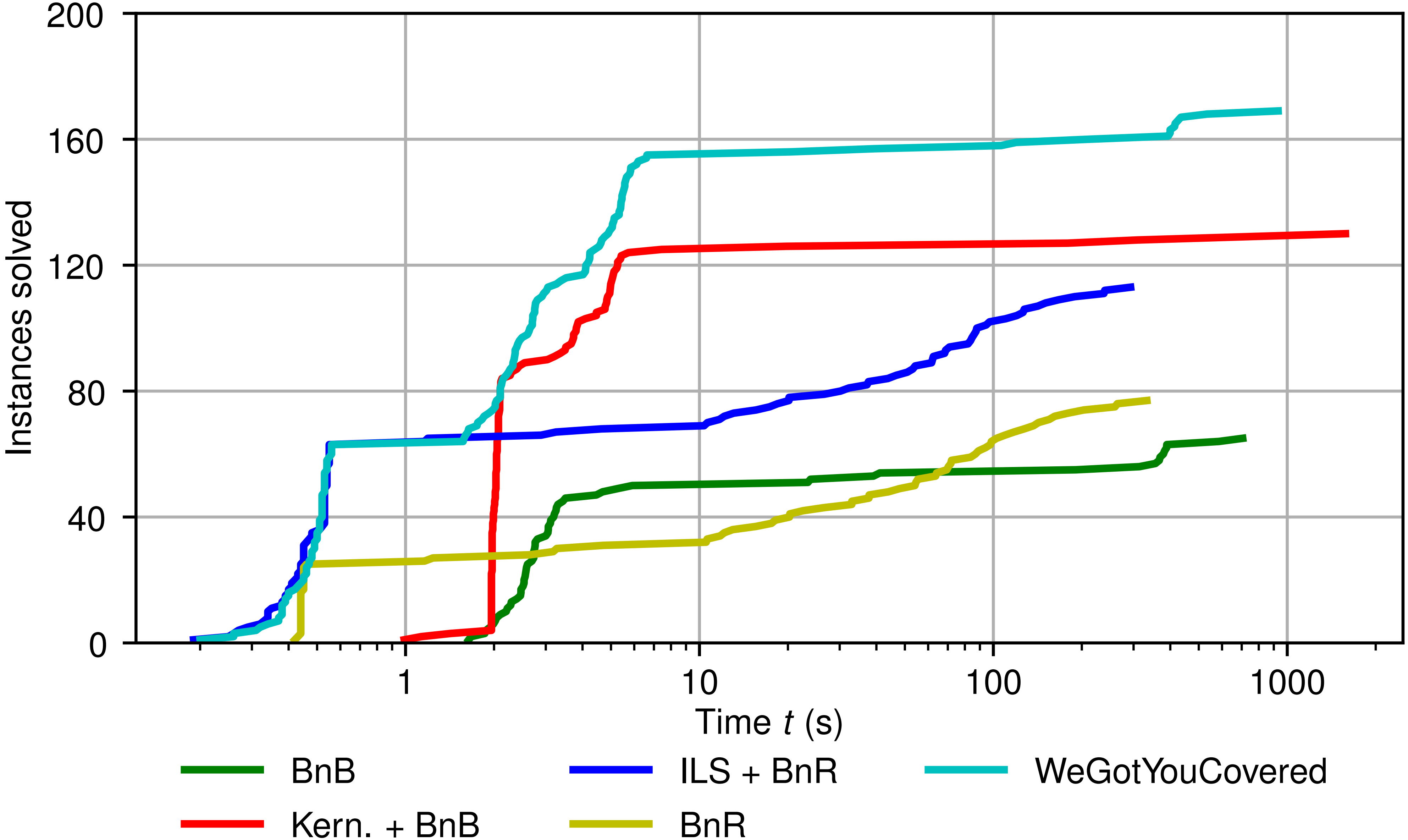
Algorithm Overview



Algorithm Overview



Instances Solved Over Time



References

- Akiba, Takuya, and Yoichi Iwata. “Branch-and-reduce exponential/FPT algorithms in practice: A case study of vertex cover.” Theoretical Computer Science 609 (2016): 211-225.
- Andrade, Diogo V., Mauricio G. C. Resende, and Renato F. Werneck. “Fast local search for the maximum independent set problem.” Journal of Heuristics 18.4 (2012): 525-547.
- Hespe, Demian, Sebastian Lamm, Christian Schulz and Darren Strash “WeGotYouCovered: The Winning Solver from the PACE 2019 Implementation Challenge, Vertex Cover Track.” arXiv preprint arXiv:1908.06795 (2019).
- Li, Chu-Min, Hua Jiang, and Felip Manyà. “On minimization of the number of branches in branch-and-bound algorithms for the maximum clique problem.” Computers & Operations Research 84 (2017): 1-15.

Thanks again for participating

See you outside at the Poster Session & PACE2020