CNRS Application 06/02

LIPN & LIMOS

Sophie Huiberts

Travel

Bachelors	Math & CS	Utrecht	2012 - 2017
Master	Math	Utrecht	2016 - 2018
PhD	Centrum Wiskunde & Informatica	Amsterdam	2017 – 2022
Postdoc	Columbia, Data Science Institute	NYC	2022–

3-year fellowship — Simons Foundation

Visits

Tu Munich, spring 2020
Simons Institute, fall 2020
Hausdorff Institute, spring 2021
Hausdorff Institute, fall 2021

Plenary Talks

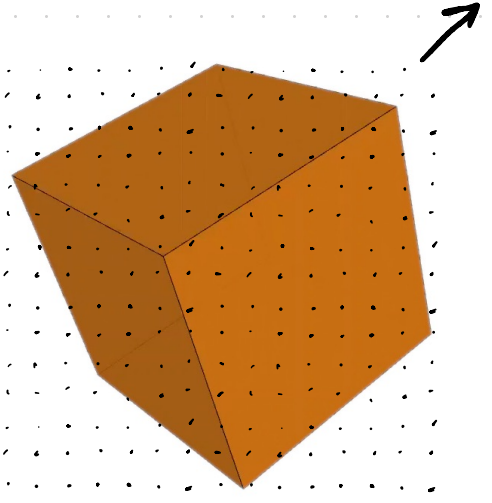
Cargese Optimization Workshop 2018, 2022
Aussois Optimization Workshop 2019, 2023
Mixed Integer Programming 2023

Integer Linear Program

$$\text{maximize } c^T x$$
$$\text{subject to } Ax \leq b$$
$$x \in \mathbb{Z}^d$$

we get $A \in \mathbb{R}^{n \times d}$
$b \in \mathbb{R}^n$
$c \in \mathbb{R}^d$

we compute $x \in \mathbb{Z}^d$



Pros	Cons
Versatile Practical	NP Hard

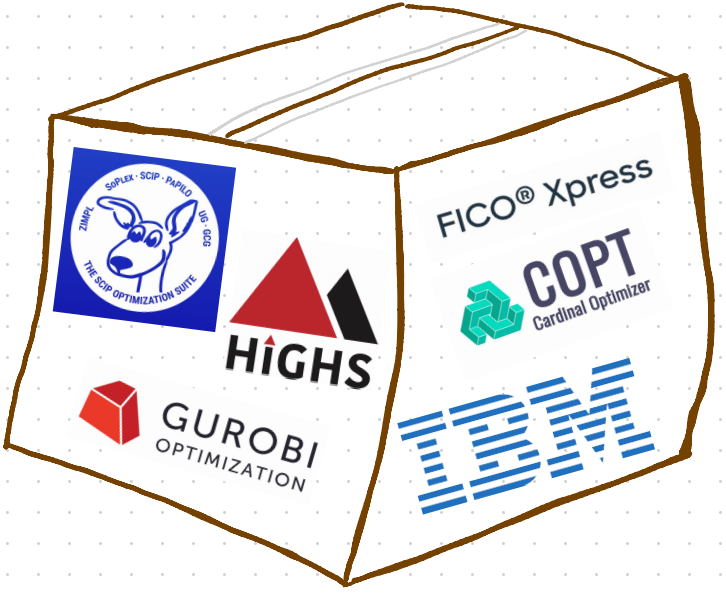
Solving Integer Linear Programs is NP Hard

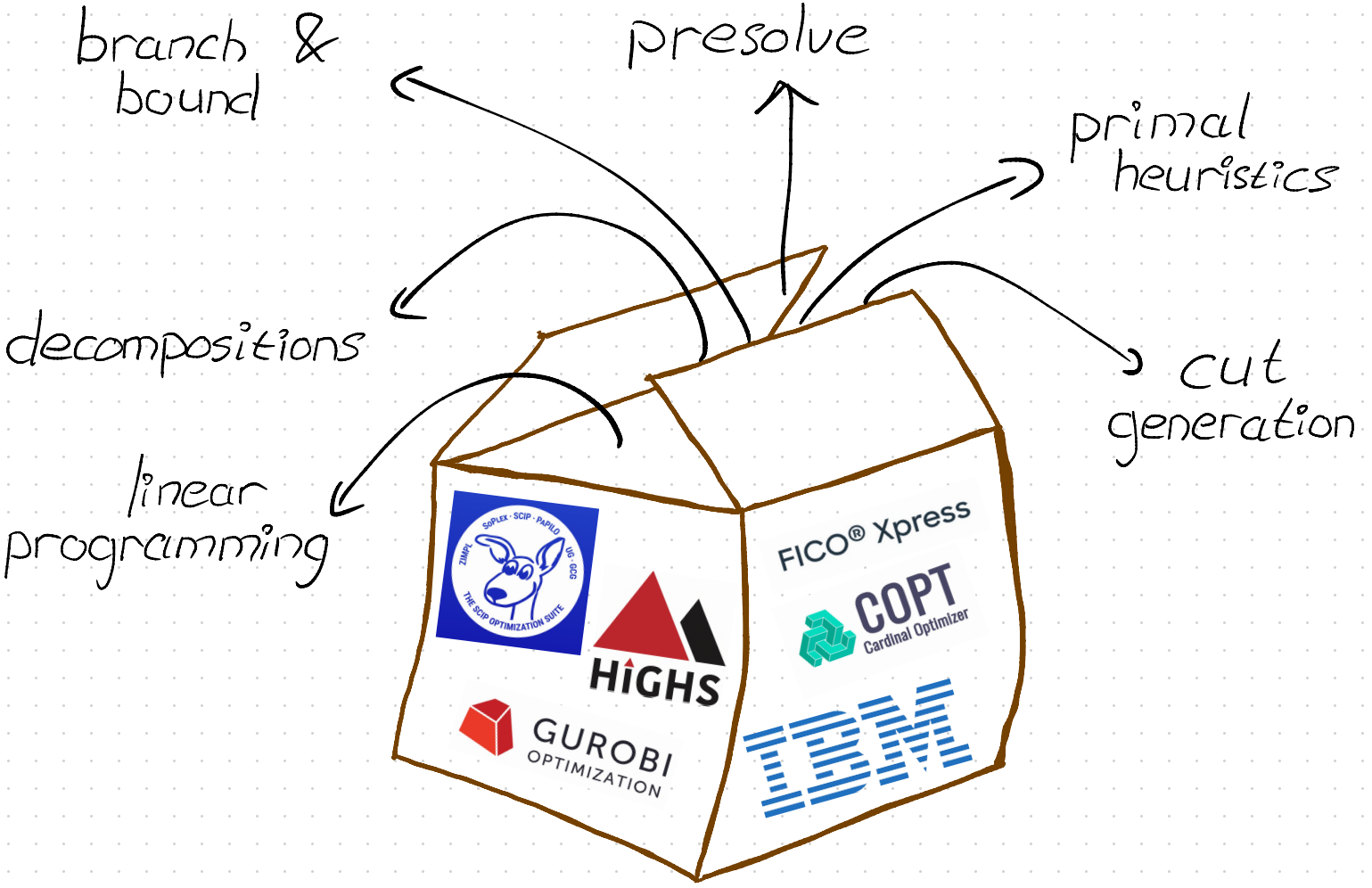
Widely believed that no polynomial time algorithm can exist.

All known algorithms take exponential time in the worst case.

Efficient Software Libraries Do Exist.

ILP's with tens of thousands of variables are solved regularly.




branch & bound
presolve
primal heuristics
decompositions
cut generation
linear programming
SoPLEX · SCIP · PaPILO
ZIMPL
UG · GCG
THE SCIP OPTIMIZATION SUITE
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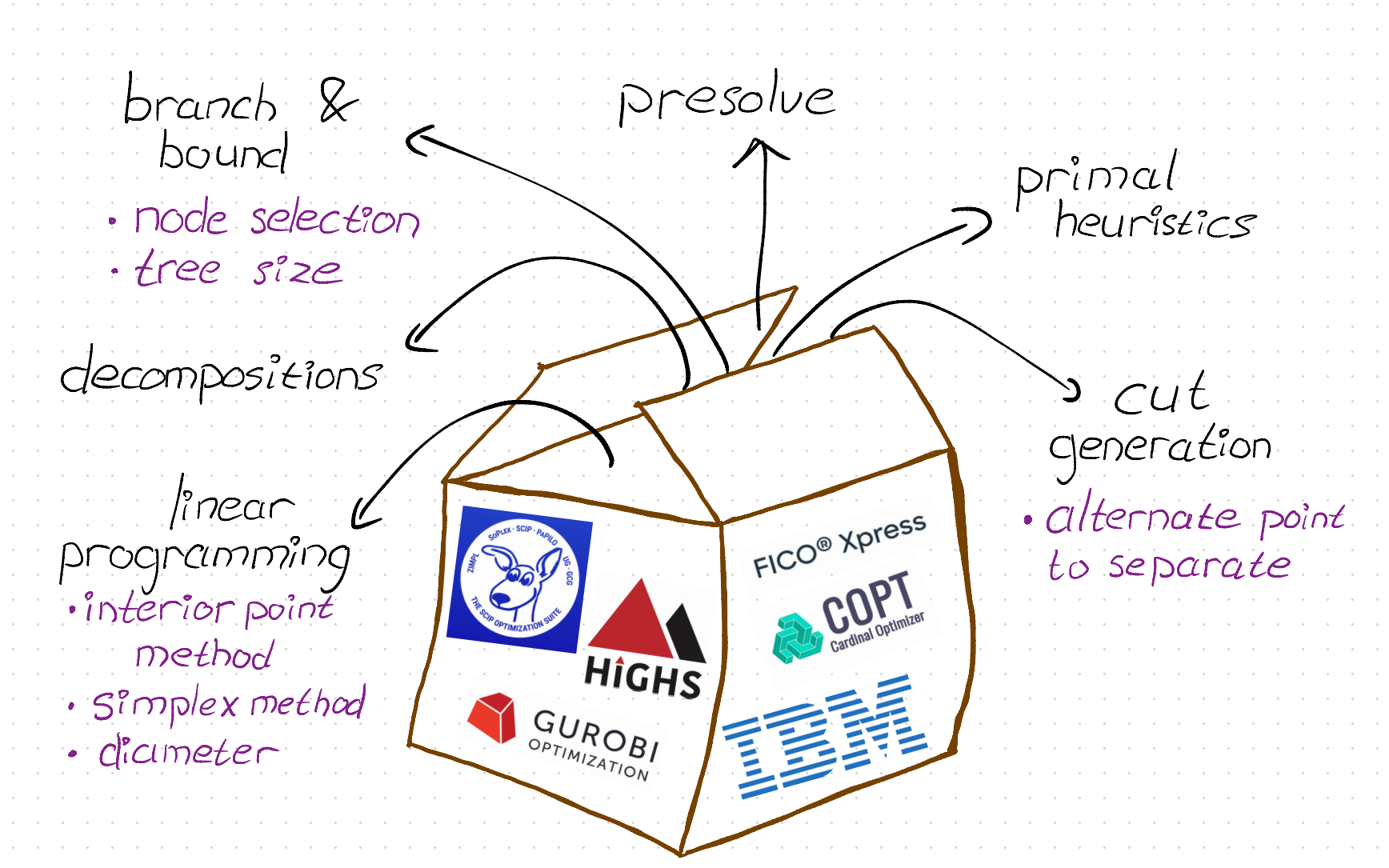
OPTIMIZATION
IBM


branch & bound
• node selection
• tree size
presolve
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• alternate point to separate
linear programming
• interior point method
• simplex method
• diameter
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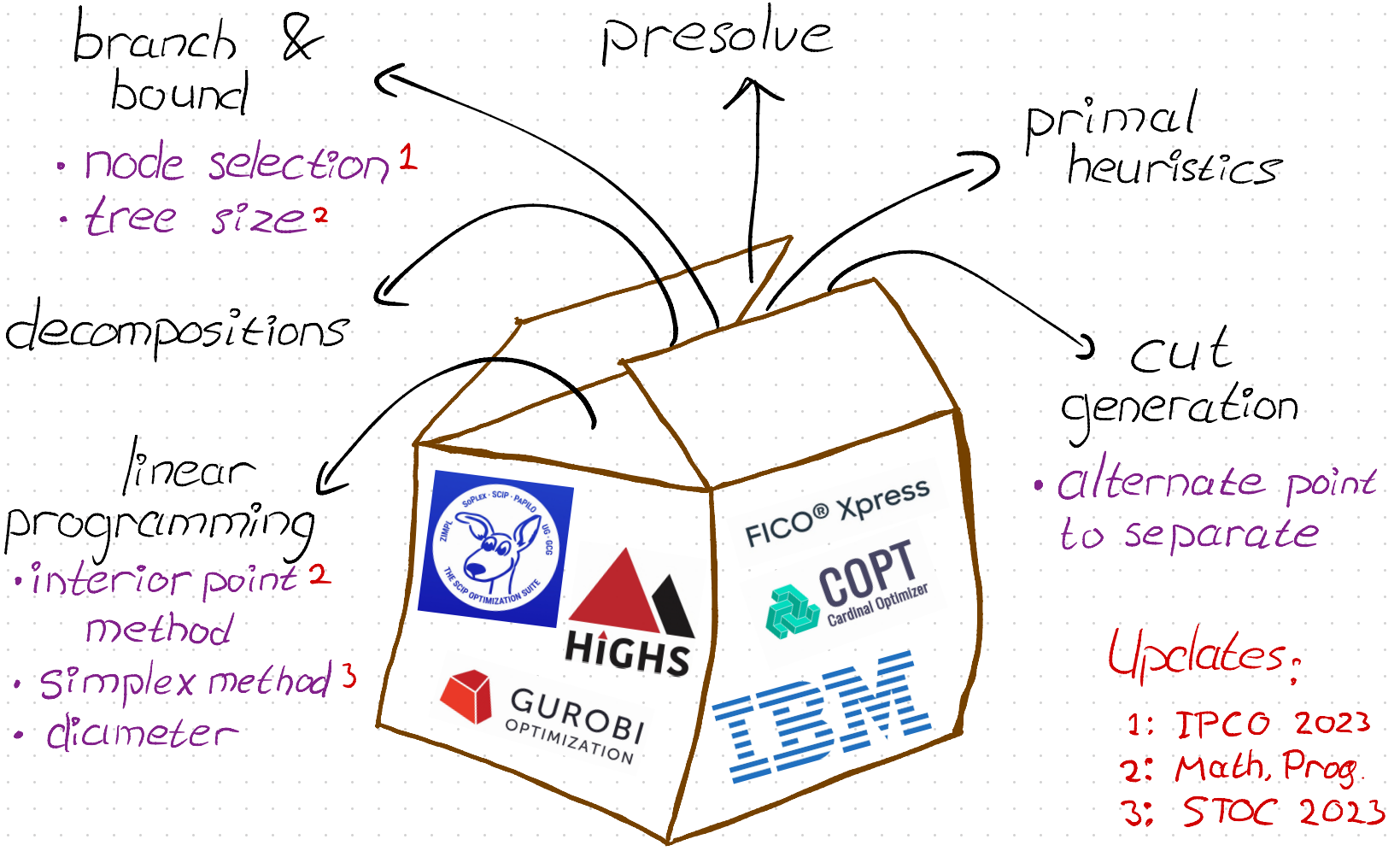
branch & bound
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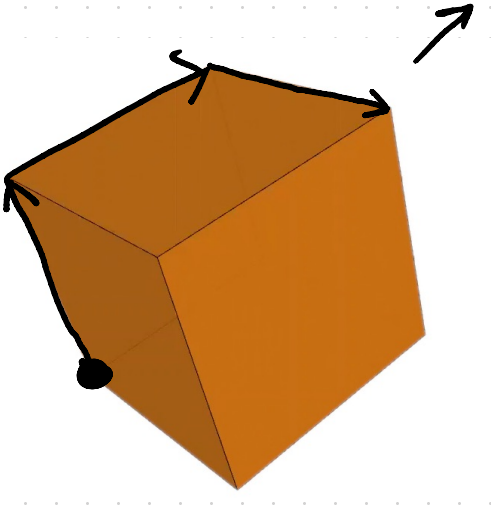
Updates:
1: IPCO 2023
2: Math. Prog.
3: STOC 2023

Case Study: the Simplex Method

maximize $c^T x$

subject to $Ax \leq b$

$x \in \mathbb{R}^d$



we get $A \in \mathbb{R}^{n \times d}$

$b \in \mathbb{R}^n$

$c \in \mathbb{R}^d$

we compute $x \in \mathbb{R}^d$

In Practice

The simplex method visits $\sim 2(n+d)$ vertices before reaching an optimal one

Only a few documented cases where $> 10(n+d)$ iterations were performed

In Theory

Theorem There exist input A, b, c, x°, $n = 2d$, such that the simplex method visits 2^d vertices

Klee Minty '72
Amenta Ziegler '98

How Realistic is Average Case?

Smoothed complexity

Let $\bar{A} \in \mathbb{R}^{n \times d}$ have rows of norm at most 1.

$\bar{b} \in [-1, 1]^n$, $c \in \mathbb{R}^d$

Let $\hat{A}$, $\hat{b}$ have iid $N(0, \sigma^2)$ entries.

The smoothed complexity is $\max_{\bar{A}, \bar{b}, c} \mathbb{E}_{\hat{A}, \hat{b}} [T(\bar{A} + \hat{A}, \bar{b} + \hat{b}, c)]$

where $T(A, b, c)$ is the time to solve $\max c^T x$ s.t. $Ax \leq b$

Spielman Teng '04

Results

	Expected Number of Pivots
Spielman, Teng '01	$O(n^{86} d^{55} \sigma^{-30})$
Vershynin '09	$O(d^3 \log^3 n\sigma^{-4})$
Dadush, Huiberts '18	$O(d^2 \sqrt{\log n}\sigma^{-2})$
Huiberts, Lee, Zhang '23	$O(d^{13/4} \log^{7/4} n\sigma^{-3/2})$
Borgwardt '87	$\Omega(d^{3/2}\sqrt{\log n})$
Huiberts, Lee, Zhang '23	$\Omega(\min(2^d, \frac{1}{\sqrt{\sigma d \sqrt{\log n}}}))$

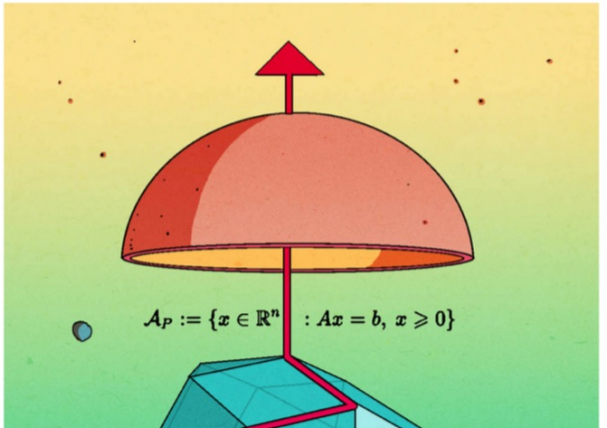
SCIENCES • MATHÉMATIQUES

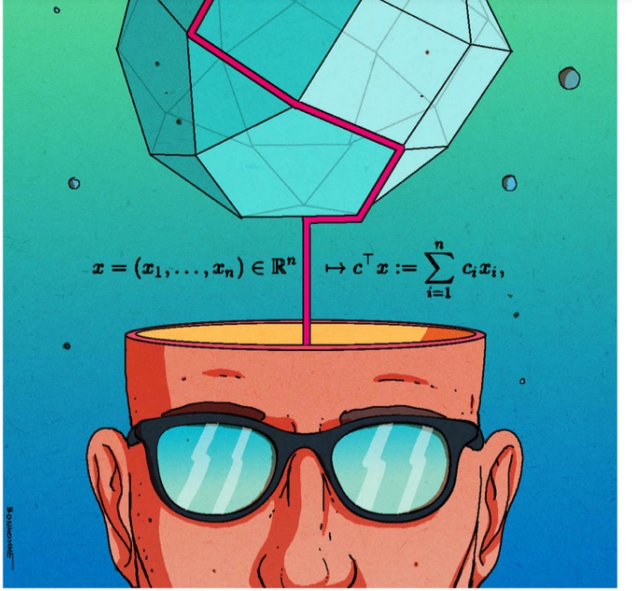
Mathématiques : lumière sur les étranges performances de l'algorithme du simplexe

Utilisé pour résoudre des problèmes très concrets d'optimisation, cet outil fonctionne généralement plus vite que prévu. Des travaux viennent d'expliquer ce paradoxe.

Par Clémentine Laurens

Publié le 04 octobre 2022 à 06h00, mis à jour le 04 octobre 2022 à 06h00 · Lecture 3 min.





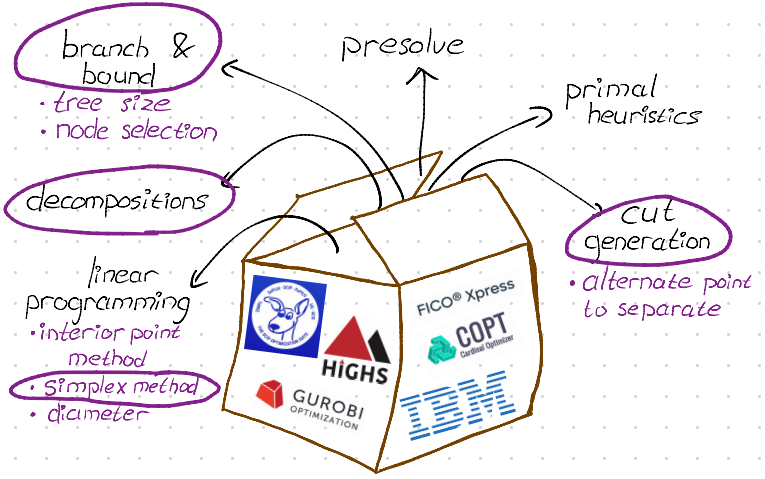
OLIVIER BONHOMME

C'est avec enthousiasme et presque soulagement que les chercheurs en informatique théorique évoquent les travaux de Sophie Huiberts et de son directeur de thèse, Daniel Dadush. Au sein du Centrum voor wiskunde en informatica, un centre national de recherche en informatique et en mathématiques aux Pays-Bas, ces deux informaticiens ont percé à jour les mystères de l'algorithme du simplexe. Si ce nom est inconnu du grand public, il fait pourtant partie intégrante de notre quotidien. Car ce programme informatique résout, en pratique, un grand nombre de problèmes très concrets. *« Il peut être utilisé partout, de la planification des tournois de base-ball à la gestion des plans de vol pour les avions, en passant par la logistique militaire ou la collecte des ordures ménagères »*, énumère Sophie Huiberts, maintenant postdoctorante à l'université Columbia, aux Etats-Unis.

Future direction I:

- More realistic theory
  - sparse perturbations
  - feasibility tolerances

- More solver components
  - reoptimization



Future direction II:

- Experiment to see which theoretical concepts have practical relevance
  - more stable extended formulations
  - cut selection using new point

Future direction III:

- New theoretical questions, assuming that ILP is easy in practice

  - interactive data collection for optimization
  - approximate TSP while minimizing measurement cost
  - currently solved ad-hoc in practice

Future directions

- More realistic theory, more solver components
- Experiment to see which theoretical concepts have practical relevance
- New theoretical questions, assuming that ILP is easy in practice

Integration:

I work on the theory of practical algorithms for combinatorial optimization.

LIPN and LIMOS are outstanding labs and house both practical expertise and deep theoretical knowledge.

Pierre Fouilhoux
Nabil Mustafa
Emiliano Traversi
Lucas Létocart

Roland Grappe
Lionel Pournin
Roberto Wolfler Calvo
Mathieu Lacroix

Mourad Baiou
Yan Gerard
Rodolphe Le Riche
Hervé Kérivin

Renaud Chicoisne
Mamadou Kante
Annegret Wagler
Fatiha Bendali

Peer Reviewed Conference Publications

A friendly smoothed analysis of the simplex method
Dadush, H., STOC 2018

A scaling-invariant algorithm for linear programming whose running time depends only on the constraint matrix
Dadush, H., Natura, Végh, STOC 2020

On the integrality gap of binary integer programs with Gaussian data
Borst, Dadush, H., Tiwari, IPCO 2021

A simple method for convex optimization in the oracle model
Dadush, Hojny, H., Weltge, IPCO 2022

Asymptotic bounds on the combinatorial diameter of random polytopes
Bonnet, Dadush, Grupel, H., Livshyts, SOCG 2022

A nearly optimal randomized algorithm for explorable heap selection
Borst, Dadush, H., Kasheav, IPCO 2023

Upper and lower bounds on the smoothed complexity of the simplex method
H., Lee, Zhang, STOC 2023

Journal Publications

A friendly smoothed analysis of the simplex method
Dadush, H., SIAM Journal of Computing, 2020

On the integrality gap of binary integer programs with Gaussian data
Borst, Dadush, H., Tiwari, Mathematical Programming, 2023

A scaling-invariant algorithm for linear programming whose running time depends only on the constraint matrix
Dadush, H., Natura, Végh, Mathematical Programming, 2023+

Invited Book Chapter

Smoothed analysis of the simplex method
Dadush, H., Beyond Worst Case Analysis, Cambridge University Press, 2021