Our research on Logic and Algorithms
Intro & Overview

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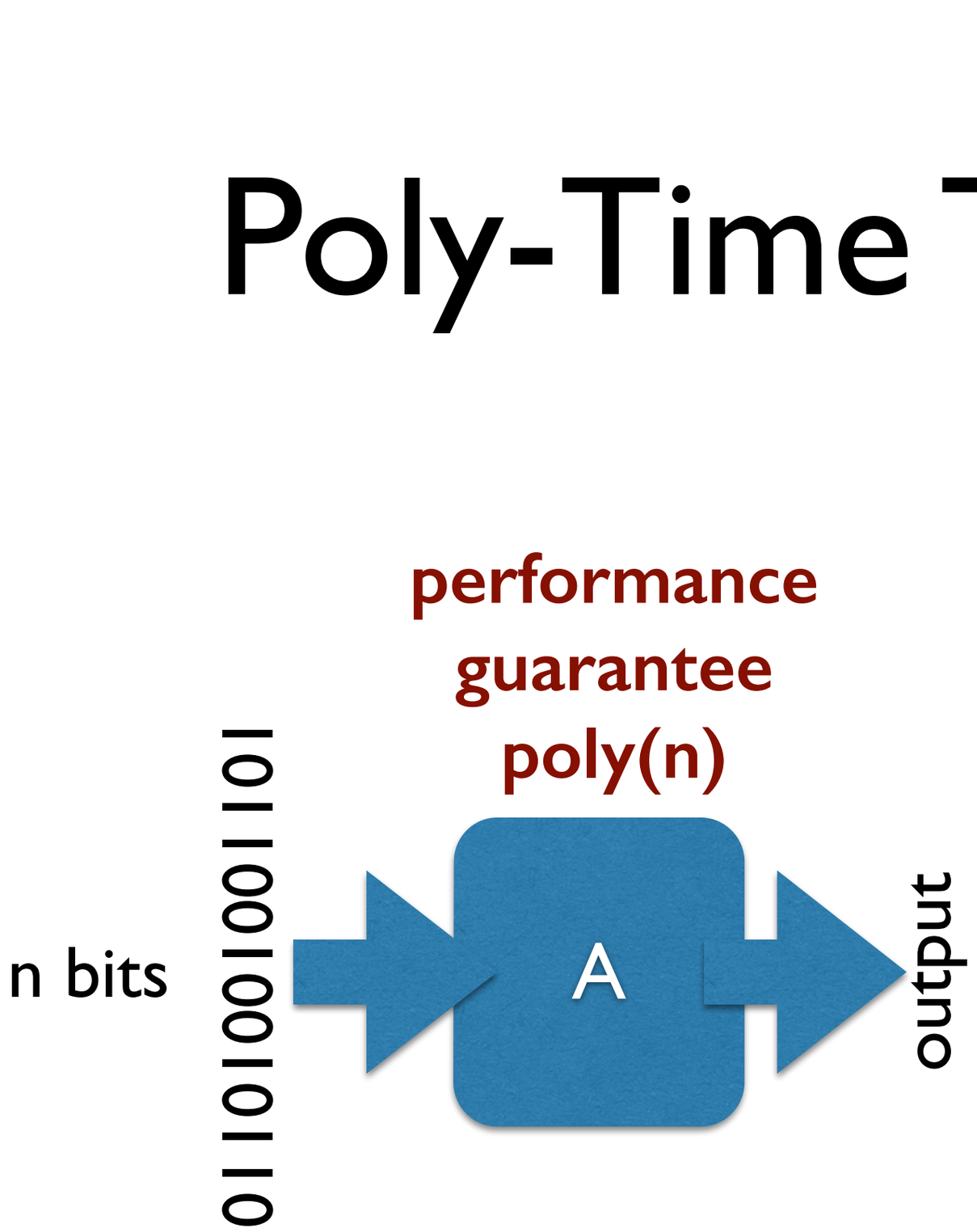
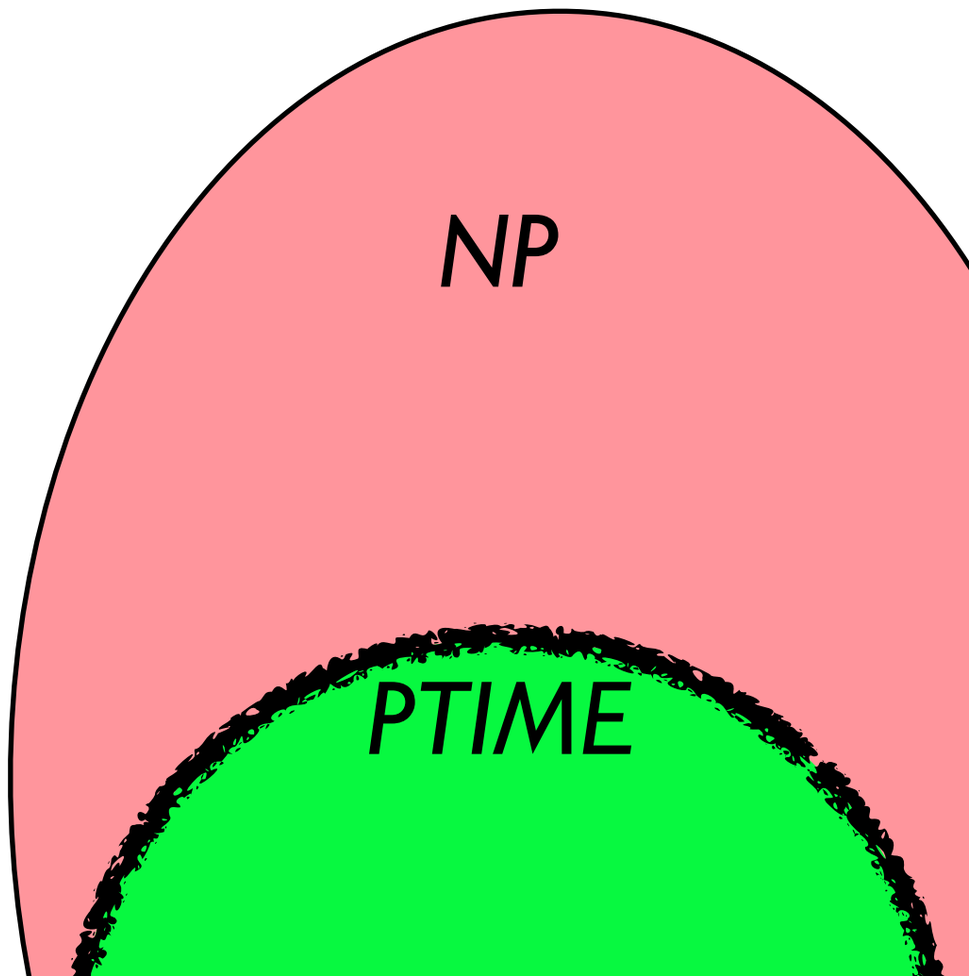
Poly-Time Tractability

performance guarantee

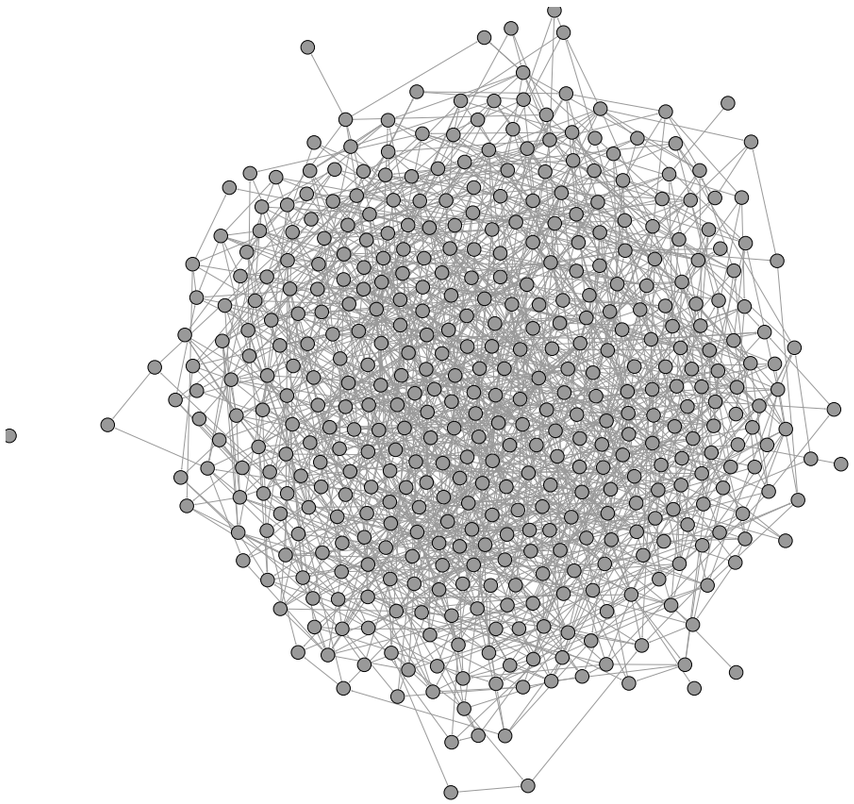
poly(n)



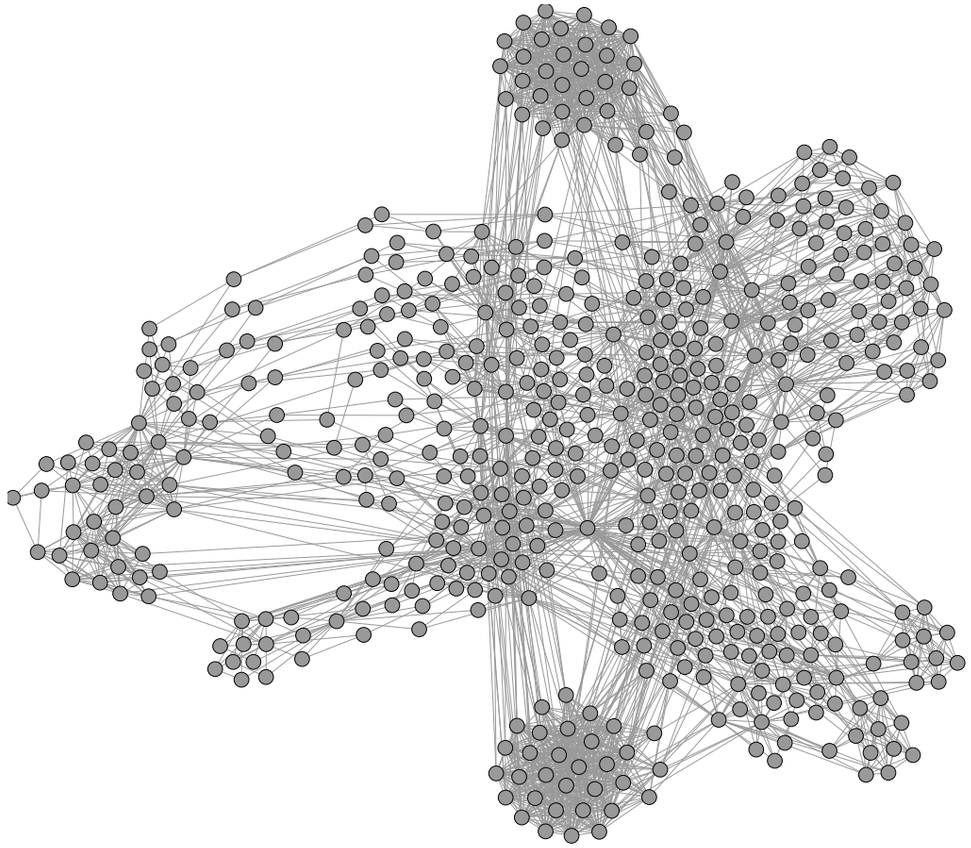
Most problems of practical relevance are NP-hard!



Structure Matters!

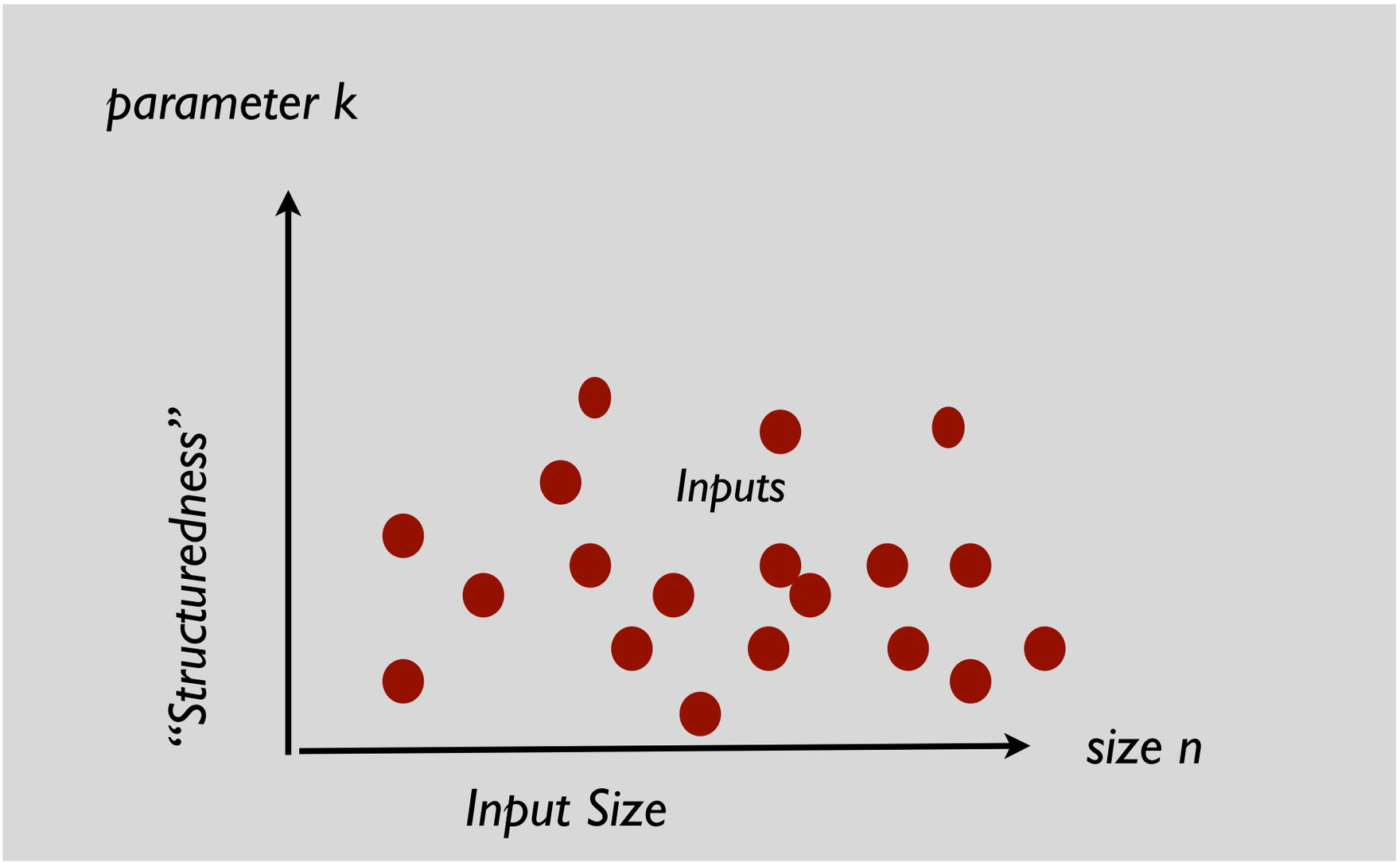


random input



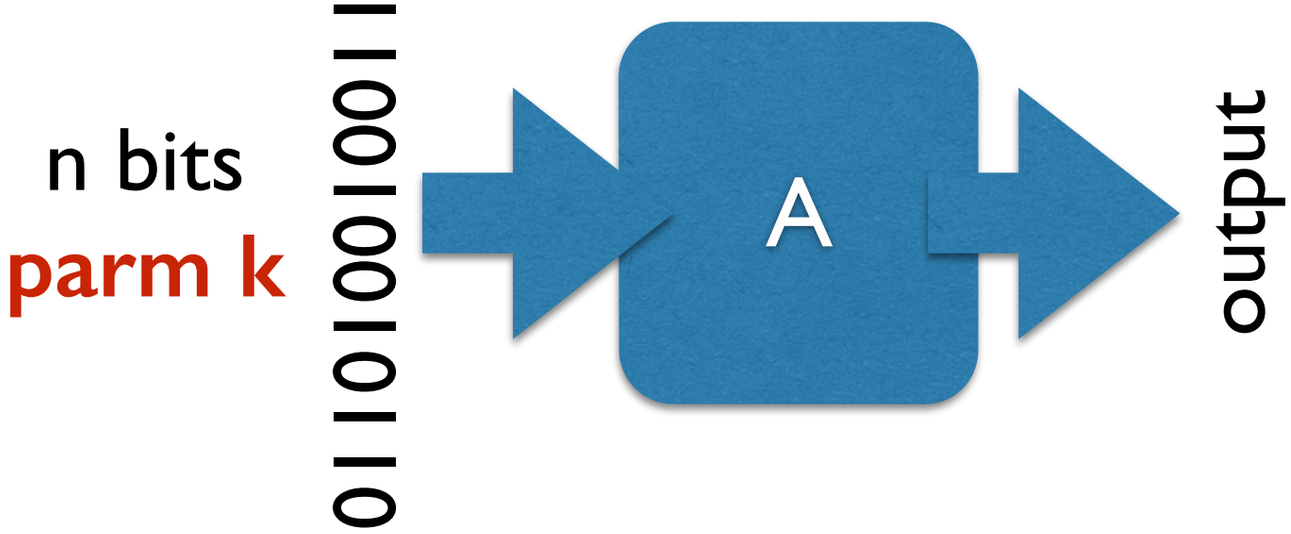
real-world input

Two-Dimensional Model!

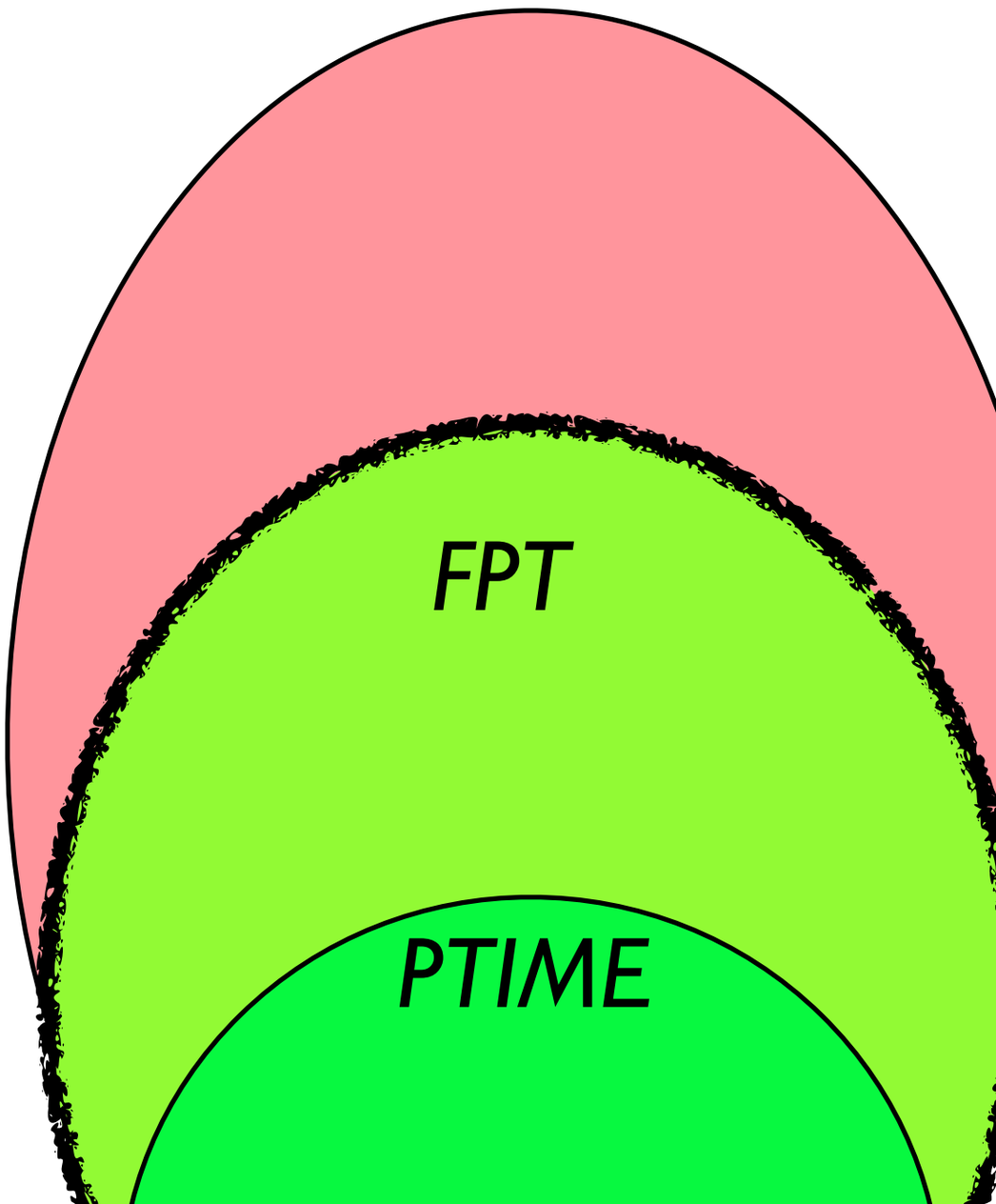


Fixed-Parameter Tractability (FPT)

performance guarantee
f(k) · poly(n)

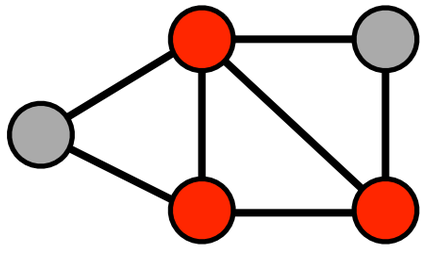


[Downey and M. Fellows 1999]



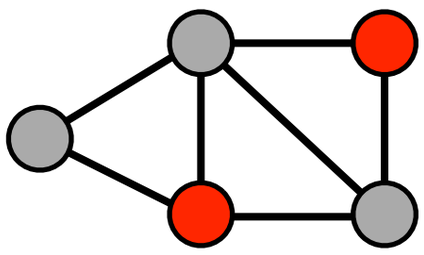
Famous Examples

VC



find a VC of size k

IS



find an IS of size k

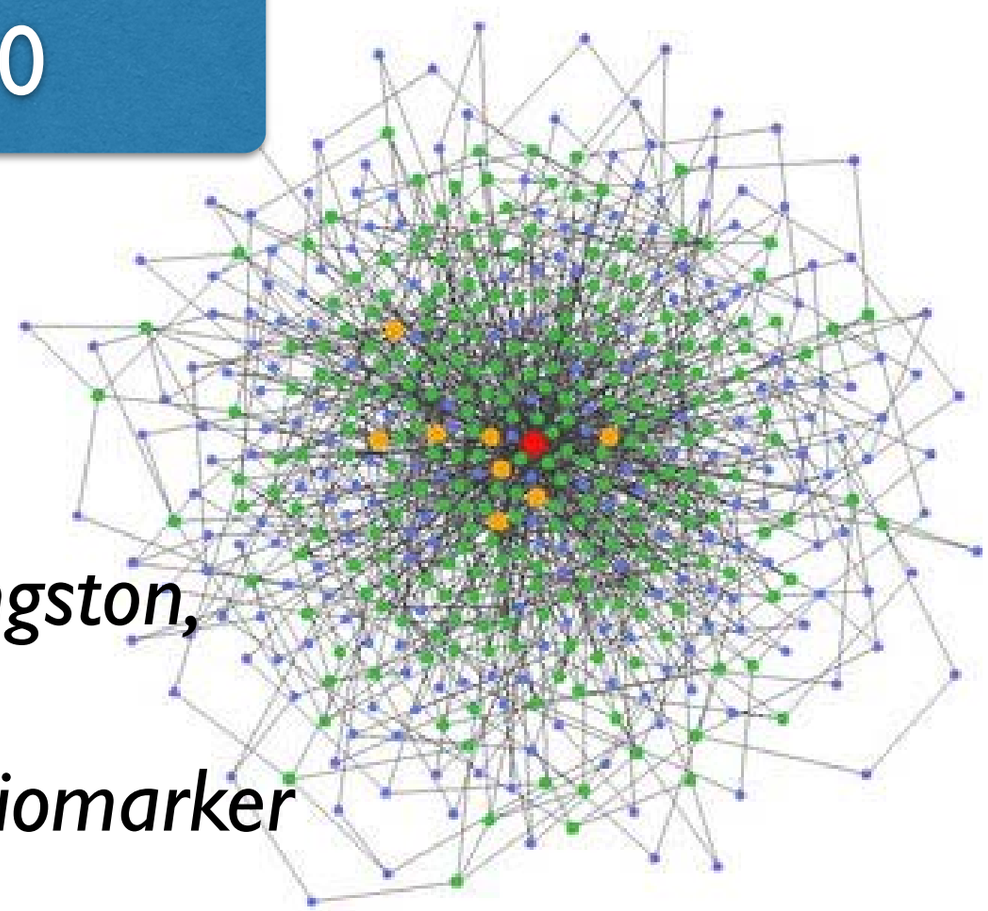
- both problems are NP-complete
- both problems can be solved in time $\mathbf{n^k}$
- VC can be solved in time $\mathbf{2^k m}$
- IS apparently cannot
- [What do we known about a graph with a small VC or IS?]

Vertex Cover Problem

trajectory of fixed-parameter algorithms

1993	$O(2^k k^{2k+2} kn)$
1995	$O(2^k k^2 + kn)$
1998	$O(1.324718^k k^2 + kn)$
1999	$O(1.31951^k k^2 + kn)$
2000	$O(1.2906^k + kn)$
2010	$O(1.2738^k + kn)$

practically feasible for k=300

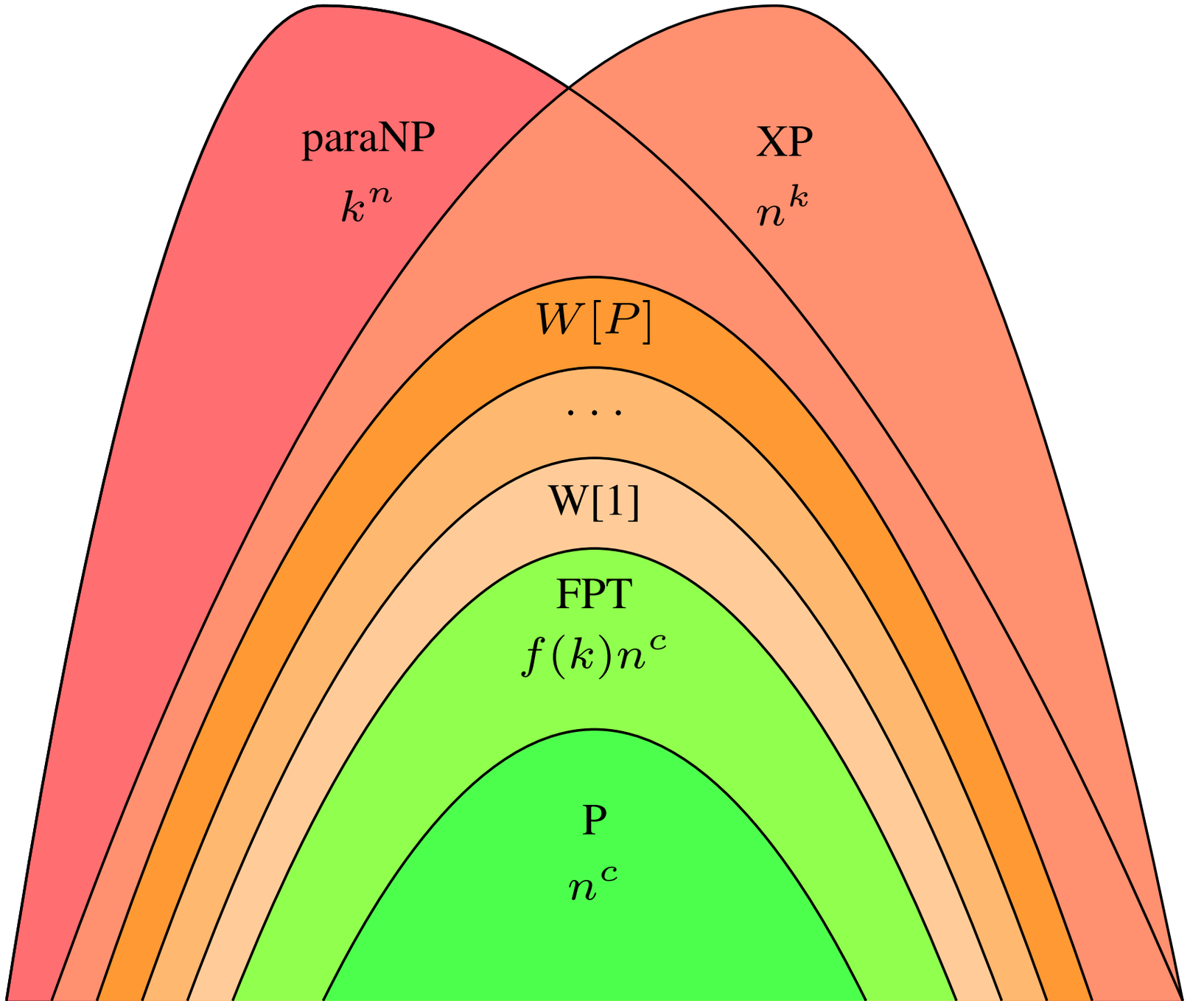


High performance comp (Langston, Knoxville)
VC as backend problem for biomarker discovery, etc

Hardness Theory

- class **XP**: Problems that can be solved in time $\mathbf{n^k}$
- Many problems outside **FPT** are not complete for **XP**
- Intermediate complexity classes

  FPT ⊆ **W[1]** ⊆ **W[2]** ⊆ **W[3]** ⊆ … ⊆ **XP**
- IS and CLIQUE are **W[1]**-complete (and 100s others)
- DS and 3HS are **W[2]**-complete (and 100s others)
- k-COL is not even in **XP**, it is complete for the class **para-NP**.
- (all via **fpt-reductions**)


paraNP
k^n
XP
n^k
$W[P]$
...
W[1]
FPT
$f(k)n^c$
P
n^c

Methods and Tools

Hardness Tools

W[i]-hardness

kernel lower bounds

Exponential Time Hypothesis

bounded search trees

logic meta-theorems

color coding

kernelization

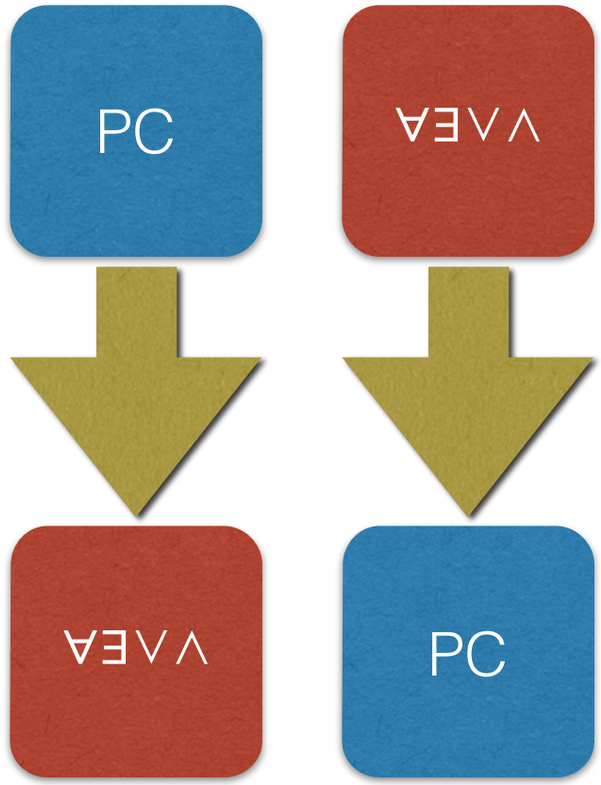
Algorithmic Tools

Upper Bounds
Lower Bounds

- our research often focuses on the **border between tractability and hardness**
- draw a detailed **complexity landscape**
- how far can we **push the border to intractability?**

Topics

- Many of our topics are related to **Logic** (either methods or problems)
- Often parameters are not solution size but **structural parameters** like treewidth
- **Discrete** combinatorics and algorithms



Topics

structural decomp	X	X	**X**	X	X	X	X	X
backdoors / modulators	X	**X**	**X**	X	X	X	X	X
SAT	X	X	X	**X**	**X**	X	X	X
QBF				X			**X**	X
Bayesian Nets						**X**		X
Model counting			X				**X**	X
Kernelization		X	X			**X**	X	X
Planning				X		**X**		X
Knowledge Compilation	**X**			X	X		X	X
Subexponential Time				**X**				X
model checking	**X**	X	X	X		X	X	X
CSP	X	X	X	X		X		X
ASP				X				X
Abstract Argumentation						X		X
. . .	X	X	X	X	X	X	X	

Thanks!

Parameterized LS

- Traveling Salesman *[E. Balas, 1999] [D. Marx, 2008] [Guo, Hartung, Niedermeier, Súchy, 2011]*
- r-Center, Vertex Cover, Odd Cycle Transversal, Max Cut, Min Bisection *[Fellows, Fomin, Lokshtanov, Rosamond, Saurabh, Villanger, 2009]*
- Feedback Arc Set on Tournaments *[Fomin, Lokshtanov, Raman, Saurabh, 2010]*
- Stable Marriage *[Marx and Schlotter, 2001]*
- Boolean Constraint Satisfiability *[Krokhin and Marx, 2012]*
- Satisfiability *[S. Szeider, 2011]*
- Cluster problems *[Dörnfelder, Guo Komusiewicz, Weller, 2011]*
- String problems *[Guo, Hermelin, Komusiewicz, 2012]*