Learning-Augmented Streaming Algorithms for Approximating Boolean Max-CSPs


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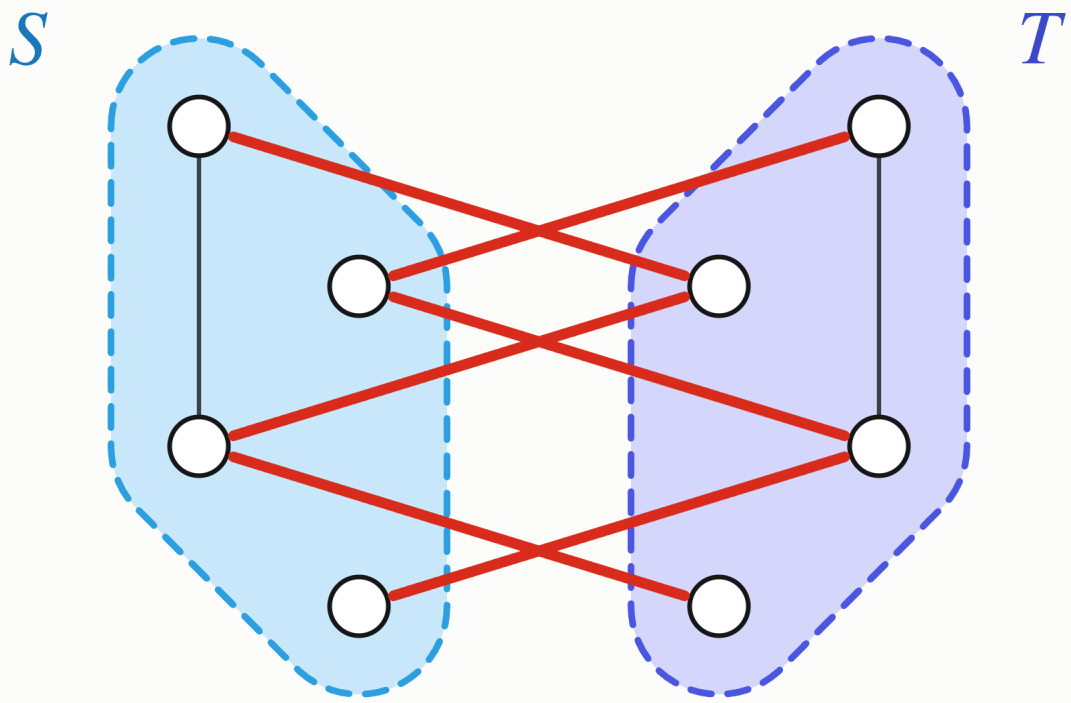
Max-Cut

Goal: split the vertices into two sides, to maximize the edges that cross



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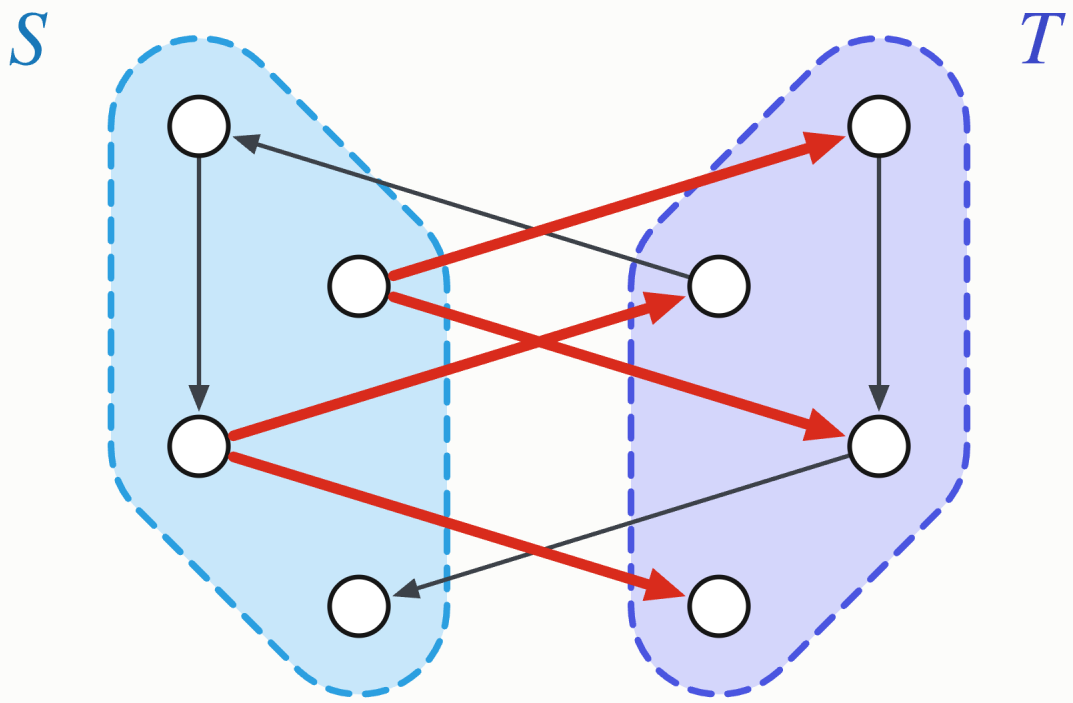
edges cross the cut

Max-DiCut

Goal: split the vertices into two sides, to maximize the edges directed from S to T



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edges go from S to T

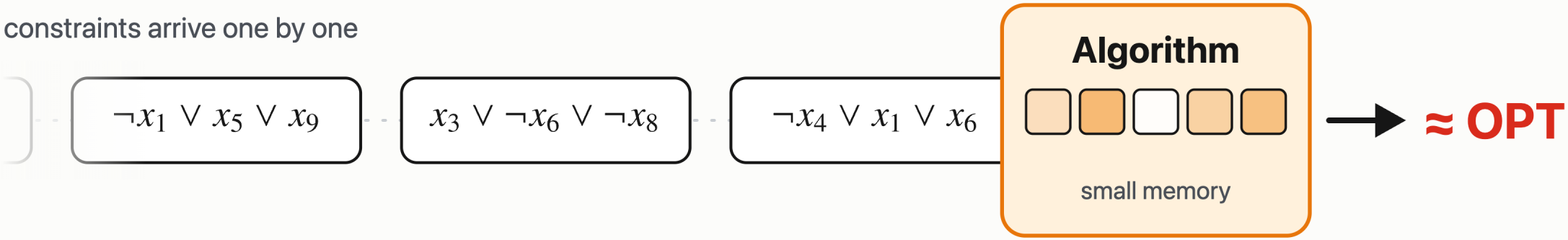
Boolean Max-CSPs

Input: n Boolean variables and constraints, each a predicate on k literals
Goal: satisfy as many constraints as possible

Max-Cut	**Max-DiCut**	**Max-*k*SAT**	**Max-*k*AND**
$x_u \neq x_v$	$x_u \wedge \neg x_v$	$\ell_1 \vee \cdots \vee \ell_k$	$\ell_1 \wedge \cdots \wedge \ell_k$
$k = 2$	$k = 2$	any fixed k	any fixed k

...and any other Boolean predicate $f : \{-1, 1\}^k \to \{0, 1\}$ **for any fixed** k

The Streaming Model



One pass

over the constraints

Small space

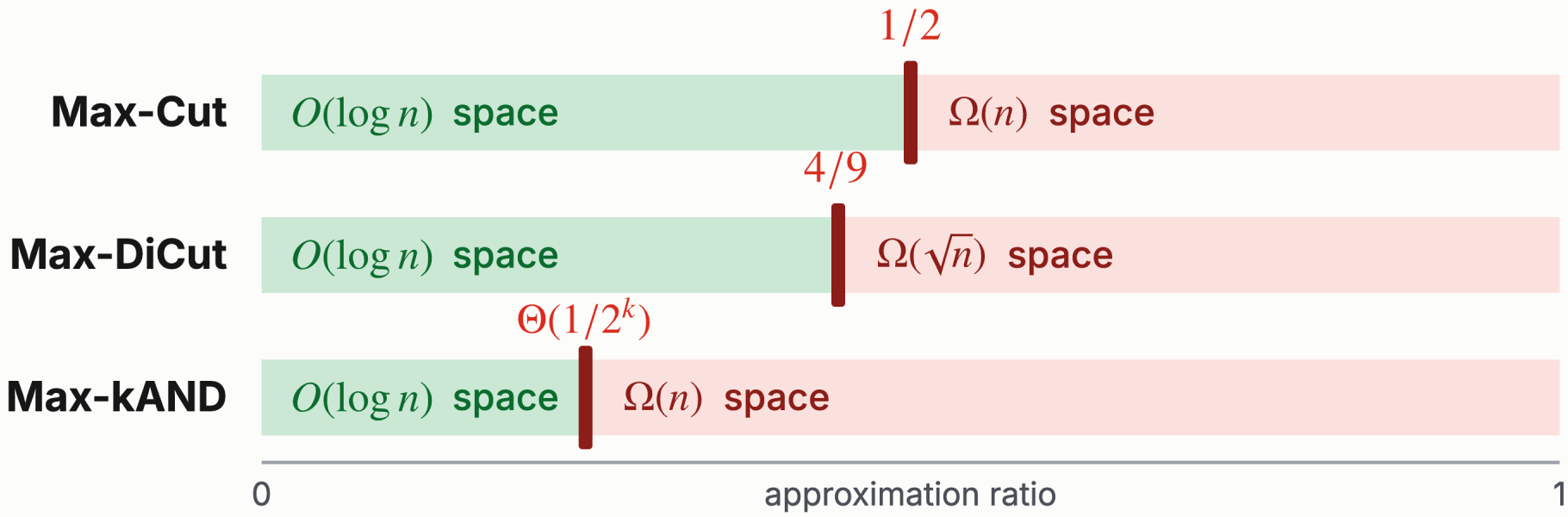
polylogarithmic in the number of variables

Estimate OPT

the value, not an assignment

Insertion-only streams, or dynamic streams with deletions.

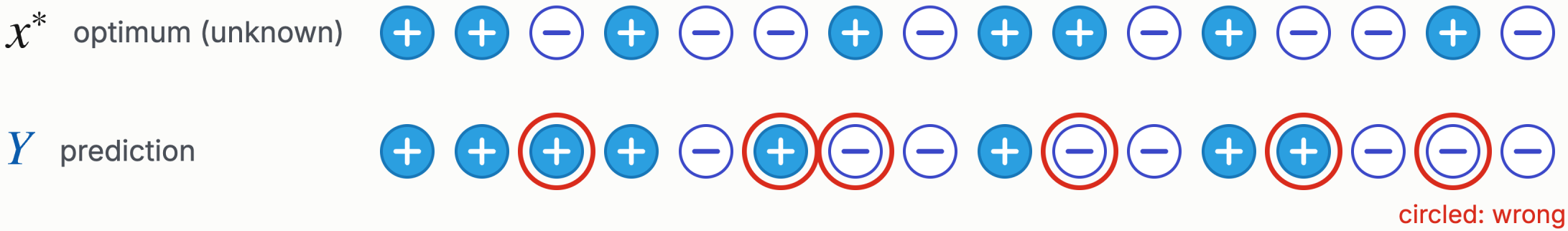
Streaming Without Predictions



Can machine-learned predictions bypass these barriers?

Max-Cut: Kapralov–Krachun '19 · Max-DiCut: Chou–Golovnev–Velusamy '20 · Max-kAND: Boyland et al. '22, Chou et al. '22

ε-Accurate Predictions



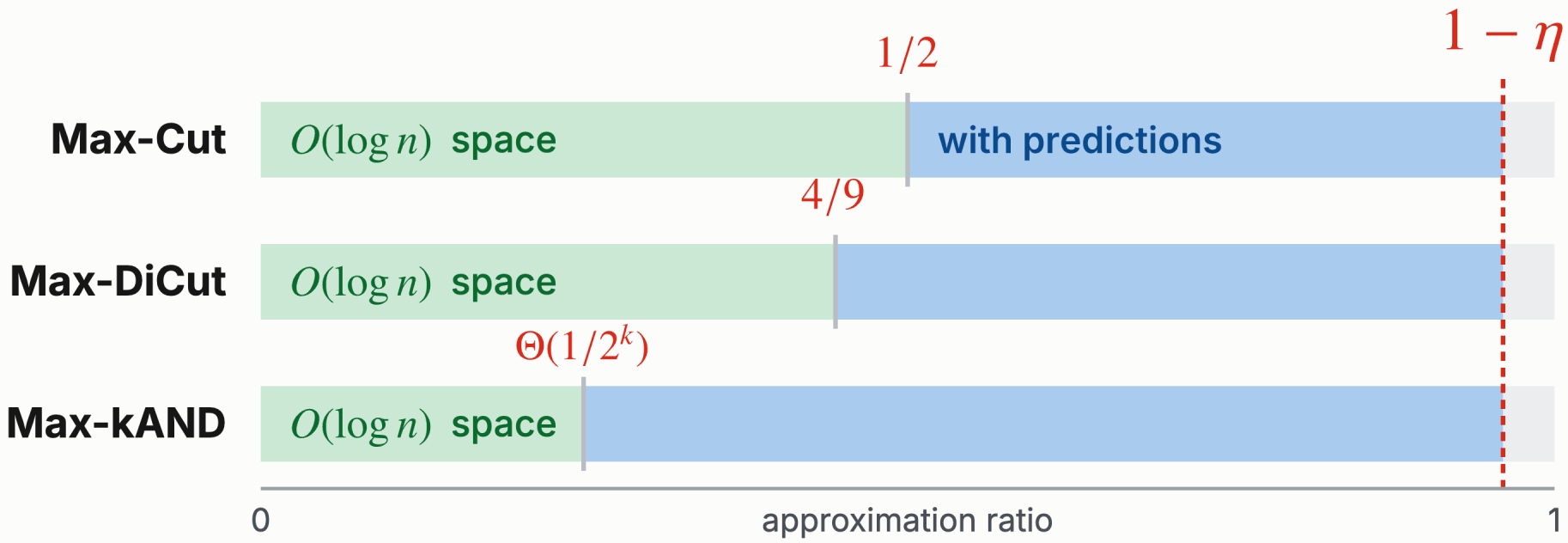
$$\Pr[Y_i = x_i^*] = \frac{1}{2} + \varepsilon$$

independently for every variable

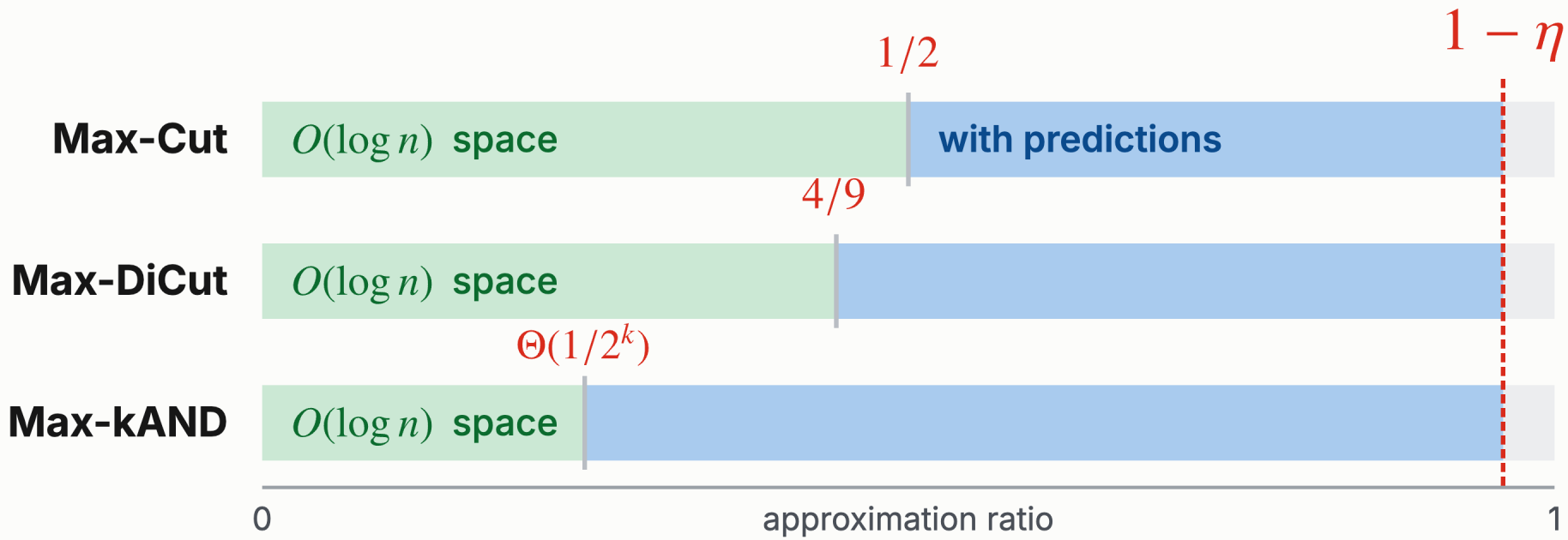
Barely better than a coin flip

Prediction model: Cohen-Addad et al. ’24 · Braverman et al. ’24 · Ghoshal, Makarychev, Makarychev ’25

Streaming With Predictions



Streaming With Predictions



Space (words)	**Insertion-only** · independent of n	**With deletions** · polylogarithmic in n
$k = 2$	$\mathrm{poly}(1/\varepsilon,\ 1/\eta)$	$\mathrm{poly}(1/\varepsilon,\ 1/\eta,\ \log n)$
$k \geq 3$	$\exp(\mathrm{poly}(k,\ 1/\varepsilon^k,\ 1/\eta))$	$\exp(\mathrm{poly}(k,\ 1/\varepsilon^k,\ 1/\eta)) \cdot \mathrm{poly}(\log n)$

Prior work with predictions: Max-Cut only, ratio ½ + Ω(ε²) (Dong, Peng, Vakilian '25)

Summary

ε-accurate predictions $\Longrightarrow$ $(1-\eta)$ **-approximation**

for every Boolean Max-CSP and every $\eta > 0$, in a single pass

Space independent of n

insertion-only streams

Space polylogarithmic in n

with deletions

Thank you!