

# On the Number of Conditional Independence Tests in Constraint-based Causal Discovery

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\* Equal contribution

AISTATS 2026 Spotlight

## Joint work with



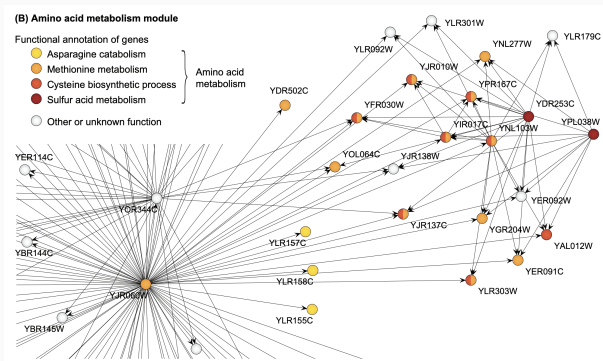
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# Constraint-based causal discovery

Recover a causal graph from observational data using conditional independence tests.

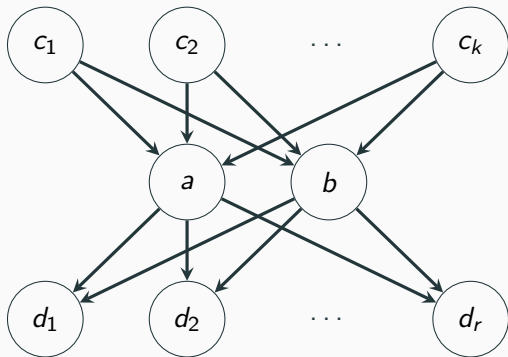


**Figure 1:** An example gene regulatory network.<sup>1</sup>

<sup>1</sup>Marbach et al. 2009

## Why previous algorithms pay for degree

Previous algorithms condition on all subsets of  $c_1, \dots, c_k$  to identify that  $a$  and  $b$  are not adjacent.



# Complexity depends on clique size

## Theorem (Upper Bound)

*GAS recovers the essential graph using  $p^{\mathcal{O}(s)}$  CI tests.*

## Theorem (Lower Bound)

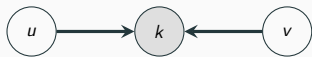
*Any algorithm must perform at least  $2^{\Omega(s)}$  CI tests.*

$p$ : variables     $s$ : max undirected clique size in the essential graph

# GAS learns ancestry during adjacency search

- Learn ancestry during adjacency search.
- Track when conditioning creates dependencies.

Collider / descendant



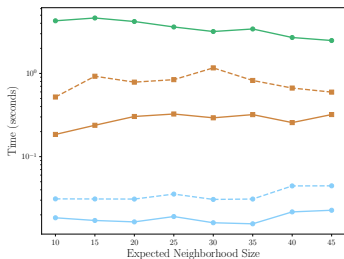
$u \perp v$  and  $u \not\perp v \mid k$

Meek rule 1

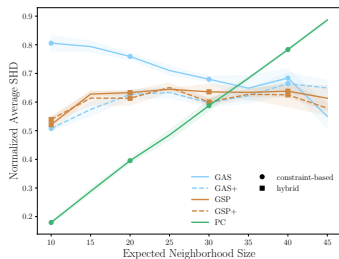


$u \not\perp k$  and  $u \perp k \mid v$

# GAS scales better as neighborhoods grow



Runtime gap grows.

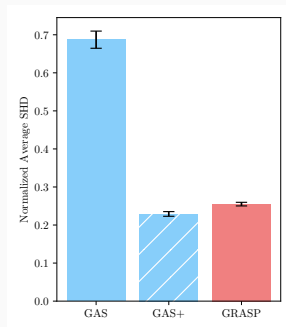
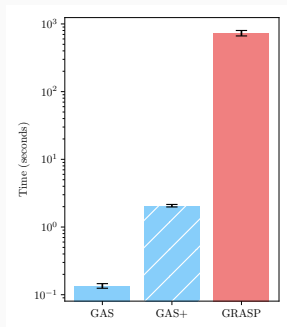


Accuracy stays competitive.

50-node Erdős–Rényi graphs; 100 runs.

# Gene-expression simulations show the same trend

GAS is fastest; GAS+ improves structural error.



Semi-synthetic data from SERGIO.<sup>2</sup> Results are averaged over 5 runs.

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<sup>2</sup>Dibaeinia and Sinha 2020

# Thank you

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Jiaqi Zhang and Caroline Uhler

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