Algorithms for Very Large Scale Causal Discovery & Feature Selection

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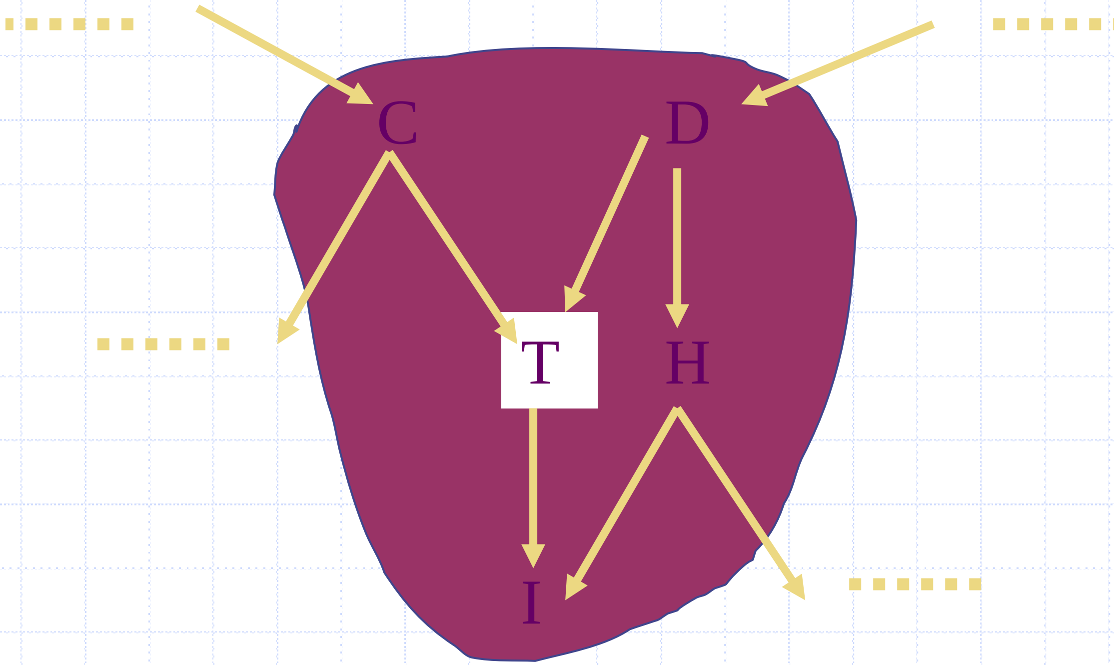
Algorithms for Discovery: Causal Neighborhood

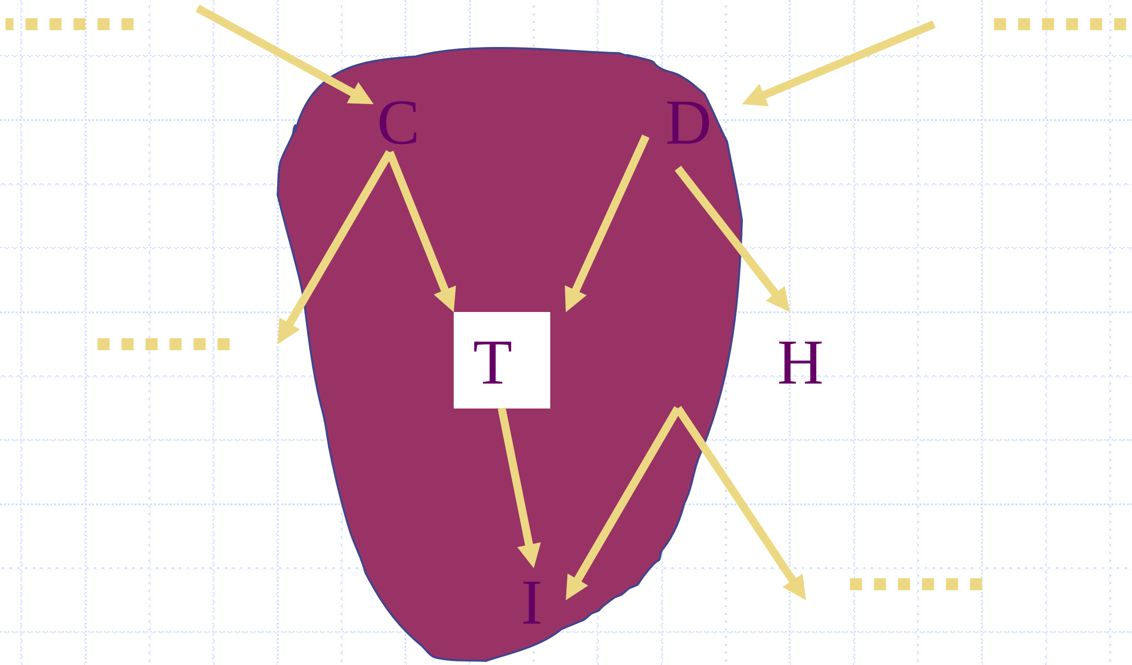
- Definition:
  - The Markov Blanket of some variable of interest **T** (“MB(T)”) is the set of the immediate causes, immediate effects, and immediate causes of the immediate effects of **T.**



Note: C causes T, T causes I ,etc.

Algorithms for Discovery : Causal Neighborhood

- Definition:
  - The Direct Causal Neighborhood can alternatively be defined as the set of Direct Causes and Effects of some variable of interest **T** (“DCE(T)”).



Note: C causes T, T causes I ,etc.

Algorithms for Discovery: Problem Statement

- Goal:
  - Given: Data (observations of **T** and a set of variables V)
  - Find: MB(T) or DCE(T)
- Why?

Algorithms for Discovery: Motivation

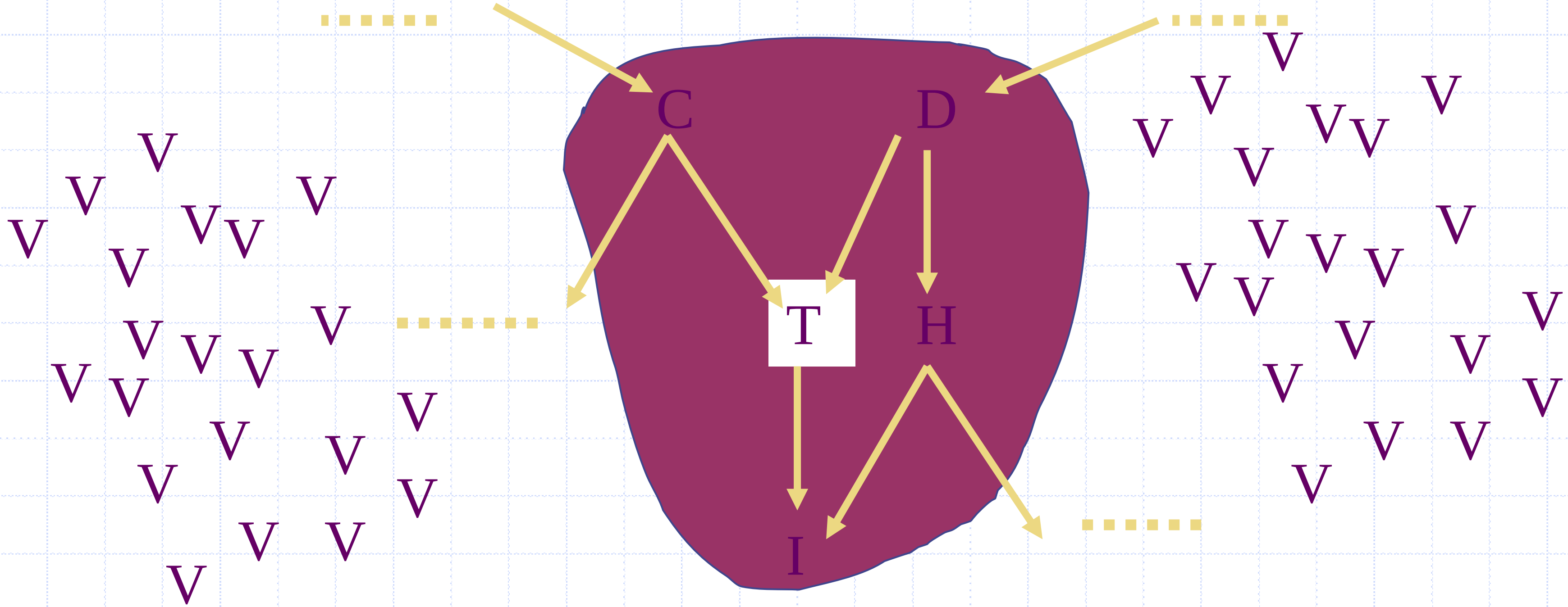
- Applications:
  - MB(T) is the minimal set of predictor variables needed for classification (diagnosis, prognosis, etc.) of the target variable **T**
  - MB(T) and DCE(T) help us discover immediate causes and effects of **T**
  - MB(T) and DCE(T) can be used to discover total causal structure of domain (what variable is causing/is caused by what other variables)
  - DCE(Ti) are specific/fine-grain“causal clusters” of variables Ti

DSL Algorithms for Discovery

- Previously MB(T) and DCE(T) could be discovered using a full-network induction algorithm, or various heuristic procedures
- Characteristics of newly-developed algorithms :
  - Sound given broad and well-defined assumptions
  - Scale up to hundreds of thousands of variables
  - Quality of output insensitive to errors in learning about the rest of the variables
  - Computational performance insensitive to structure beyond the target **T**
  - Behave well when confounders are not observed

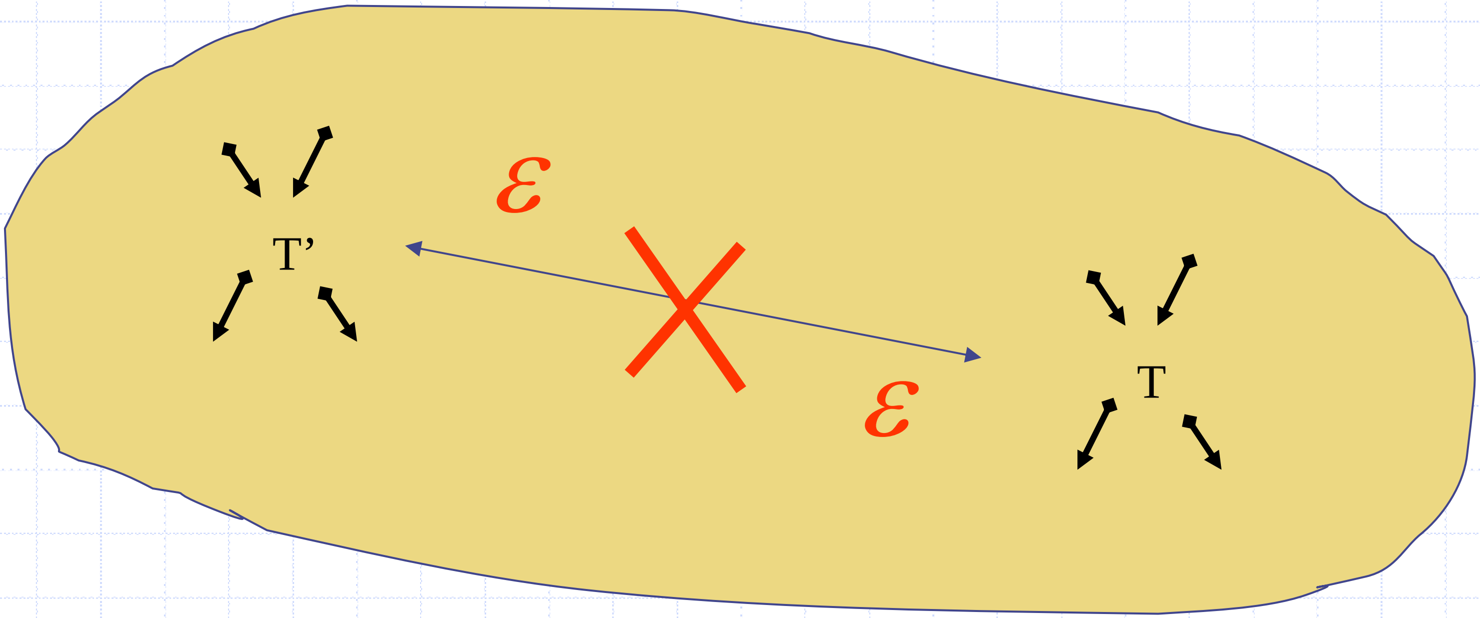
Scalability

- As long as MB(T)/DCE(T) is small relative to the available sample size, we can discover MB(T)/DCE(T) regardless of how many variables are present in the data; our methods scale up to extremely large numbers of total variables without sacrificing soundness;
- The state-of-the-art (full-network) algorithms try to learn the whole network and are not tractable for large networks



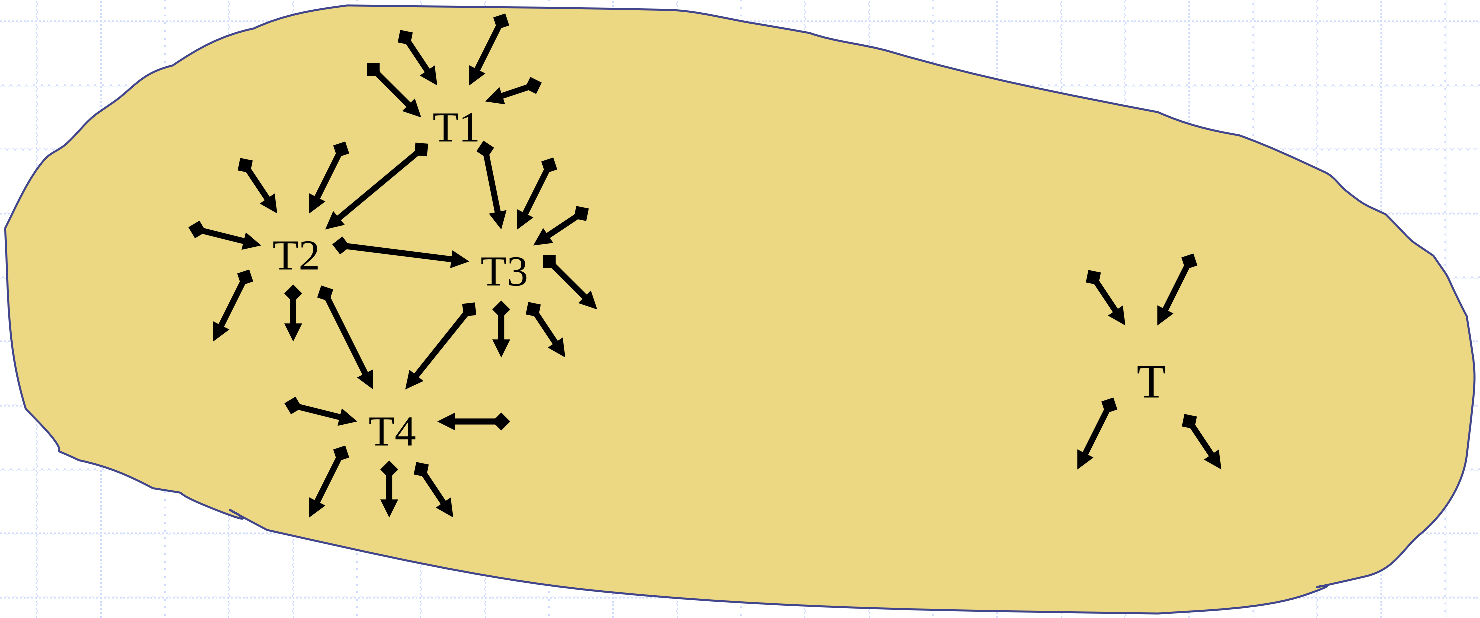
Insensitivity to errors in other parts of the network

- As long as MB(T)/DCE(T) is small relative to the available sample size, we can discover it regardless of how successfully one can infer the MB/DCE of other features (i.e., remote errors do not contaminate local discovery);
- The state-of-the-art full-network algorithms do not have this property.



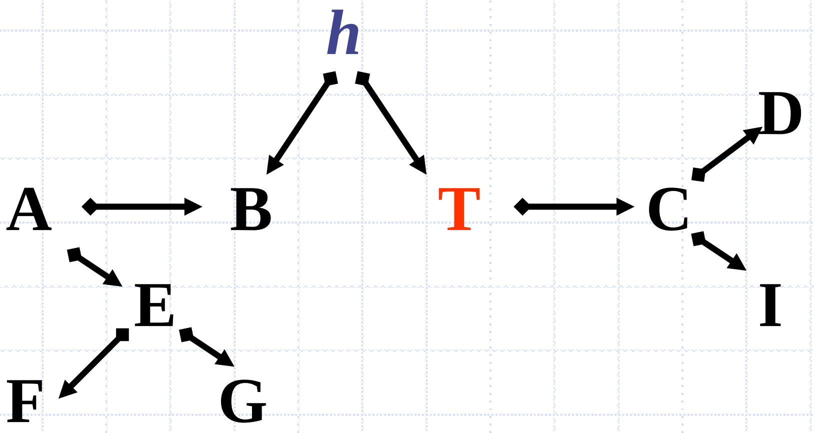
Insensitivity to variable relationships in other parts of the network

- As long as MB(T)/DCE(T) is small relative to the available sample size, we can discover it regardless of how complex is the rest of the process.
- The state-of-the-art full-network algorithms do not have this property.



Discovery "Monotonicity"

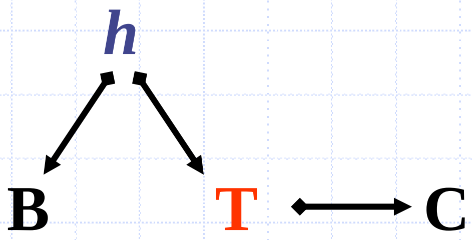
- Say true structure is:



- With *h* unobserved, any sound algorithm (including DSL algorithms) will return: DCE(T)= {B,C}

Discovery "Monotonicity"

- Say now that we can observe *h*.



- By analyzing *only* the previous DCE(T)= {B,C}, and *h* we get the new DCE(T)= *{h,*C}.
- State-of-the-art full-network algorithms either try to learn the hidden structure (an intractable and incomplete task) or have to re-analyze the full network (since local errors propagate as explained earlier)

Ongoing Work

- Forthcoming:
  - Discover total causal structure of domain
  - Discover generalized-XOR (Gx) and quasi-Gx functions (e.g., for multi-gene etiology) as well as non-faithful distributions of any kind
  - Filter causal hypotheses generated by application of other methods
  - Combine with clustering to identify new molecular disease types
  - Discover MB(T)/DCE(T) in dynamic domains/temporal data

  - **Problem-driven applications/evaluations**