Breaking Cycles in Noisy Hierarchies

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Outline

1. Motivation
2. Related Work
3. Our Framework: Breaking Cycles via Graph Hierarchies
4. Experiments
5. Conclusion

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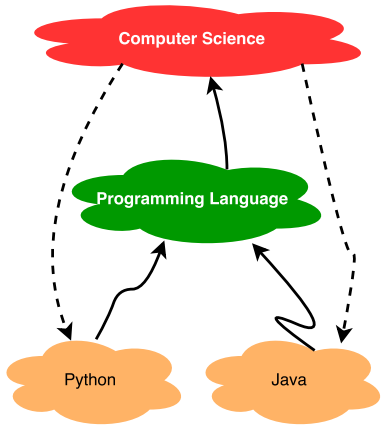
[0] Pic from Web

Motivation

- Taxonomy graphs that capture ”has a” or ”is a” relationships should be acyclic
- Ontological knowledge bases such as Wikipedia categories, created in crowd-sourced way, cause errors (cycles)
- Breaking Cycles to get a Directed Acyclic Graph (DAG) can benefit other applications such as job/dataflow scheduling



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Related Work

- Simple Heuristic Based on BFS or DFS
- Minimum Feedback Arc Set
- Domain-specific Algorithms

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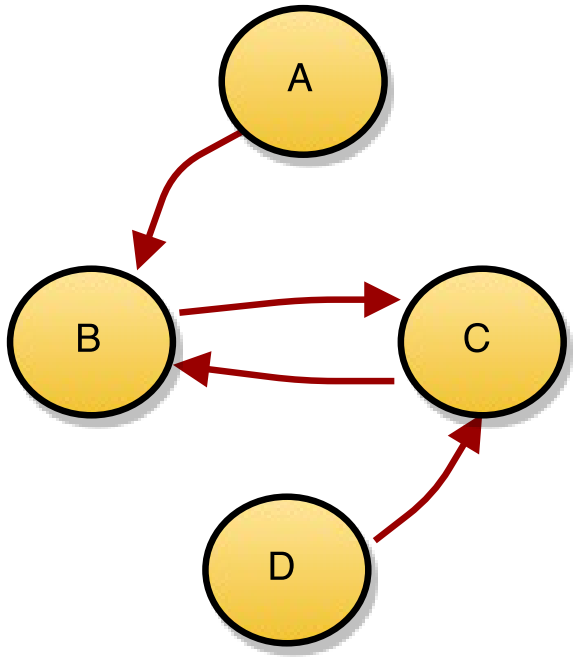
DFS & BFS: simple, domain independence

Depth-first Search

- detect and remove back edges randomly (un-deterministic)



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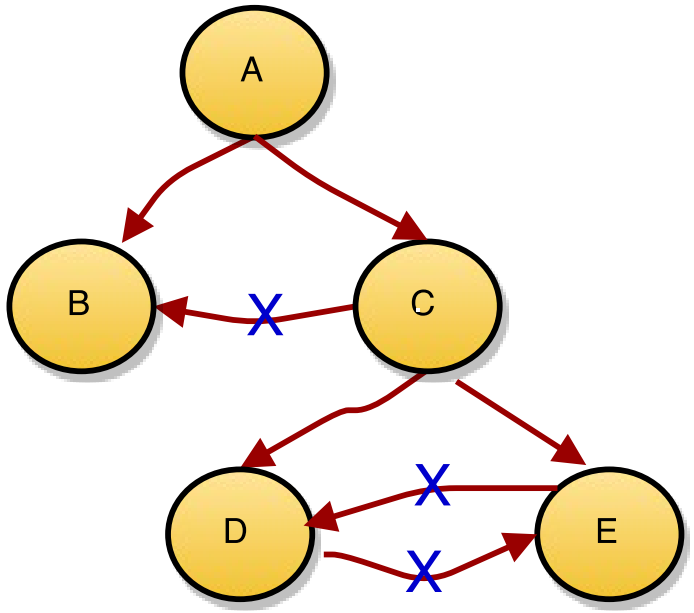
DFS & BFS: simple, domain independence

Breadth-first Search

- can remove non-cycle edges



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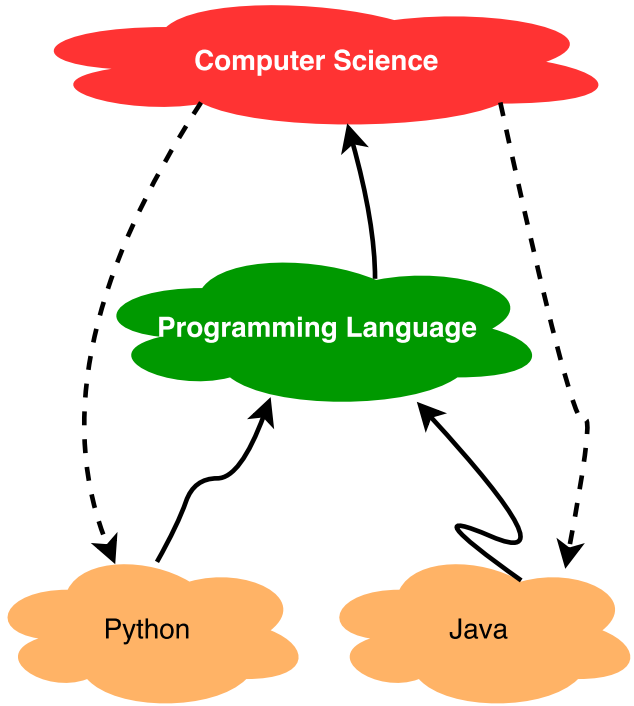
Minimum Feedback Arc Set

- Remove the least number of edges to break cycles
- NP-Hard Problem
- Cannot guarantee it preserves the logical hierarchy structure while minimizing the edges to remove



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Graph Hierarchy Based Framework

Goal: break cycles from a directed graph, while preserving the underlying hierarchy of the relationships as much as possible

1. Inferring graph hierarchy
   - TrueSkill
   - SocialAgony
2. Proposing strategies to select violation edges as candidates for removal based on graph hierarchy
   - Forward
   - Backward
   - Greedy

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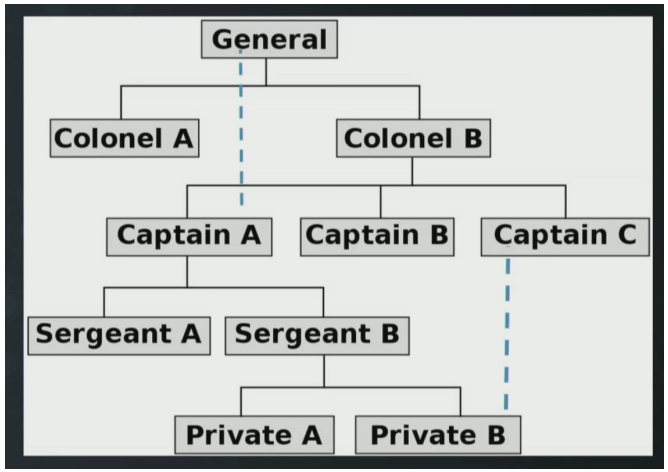
Finding a ranking function to infer graph hierarchy

- f assigns a ranking score to each node in the graph
- A higher ranking score indicates the corresponding node is higher up (or more general) in the hierarchy
- Edges violate the hierarchy (edges from a higher/general group to a lower/specific group) are potential edges for removal



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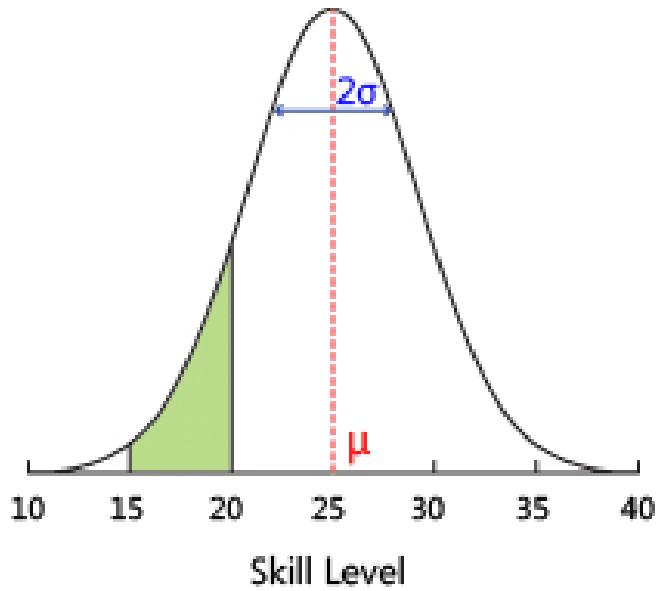
[0]Figure: `http://bit.ly/2sZTH3c`

Inferring Graph Hierarchy by TrueSkill

- TrueSkill ranking system is a skill based ranking system to rank Xbox players, developed by Microsoft Research
- Each player has two numbers
  - μ: average skill of the player
  - σ : degree of uncertainty in the player's skill



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View it as a competition graph

- a directed graph $G = (V, E) \Rightarrow$ a multi-player tournament with $|V|$ players and $|E|$ competitions
- an edge $(u, v) \in E \Rightarrow u$ loses the game between u and v

Updates of skill levels given an edge (u, v)

- If player v has a higher skill level than u, then the outcome of edge (u, v) is expected $\Rightarrow$ small updates in skill level μ and σ.
- If player u has a higher skill level than v, then the outcome of edge (u, v) is unexpected $\Rightarrow$ large updates in skill level μ and σ.

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Inferring Graph Hierarchy by TrueSkill

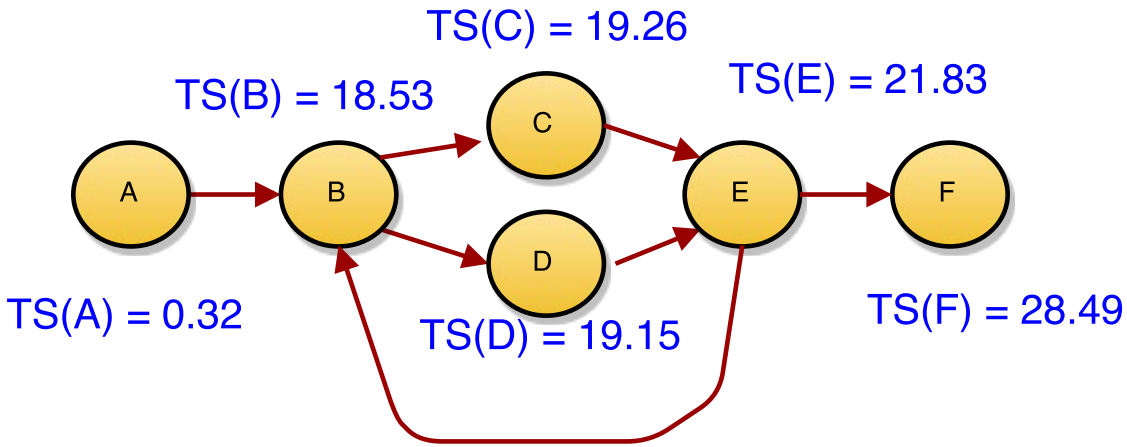

Figure: TrueSkill Compuation Demo

- As far as we know, we are the first researchers to consider **graph hierarchy inference as a competition problem**
- A node v's ranking score in the graph hierarchy: $f_{ts}(v) = \mu_v - 3\sigma_v$

Inferring Graph Hierarchy by Social Agony

- Social agony proposed by Gupte et al. assumes the existence of a link indicates a rank recommendation
  - A link $u \Rightarrow v$ indicates a recommendation of v from u
  - If there is no reverse link from v to u, it could indicate that v is higher up in the hierarchy than u
- In social networks such as Twitter, agony can be caused when people follow other people who are lower in the hierarchy

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[0]Figure: `http://bit.ly/2r7afHV`

Computation of Graph Agony

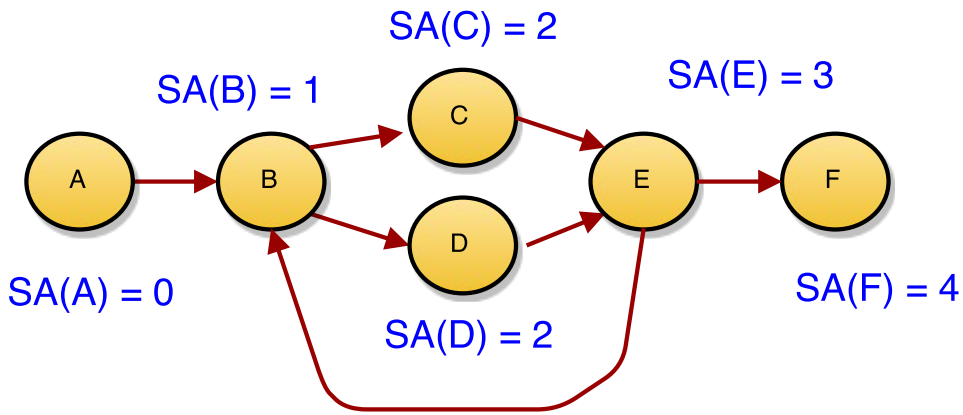
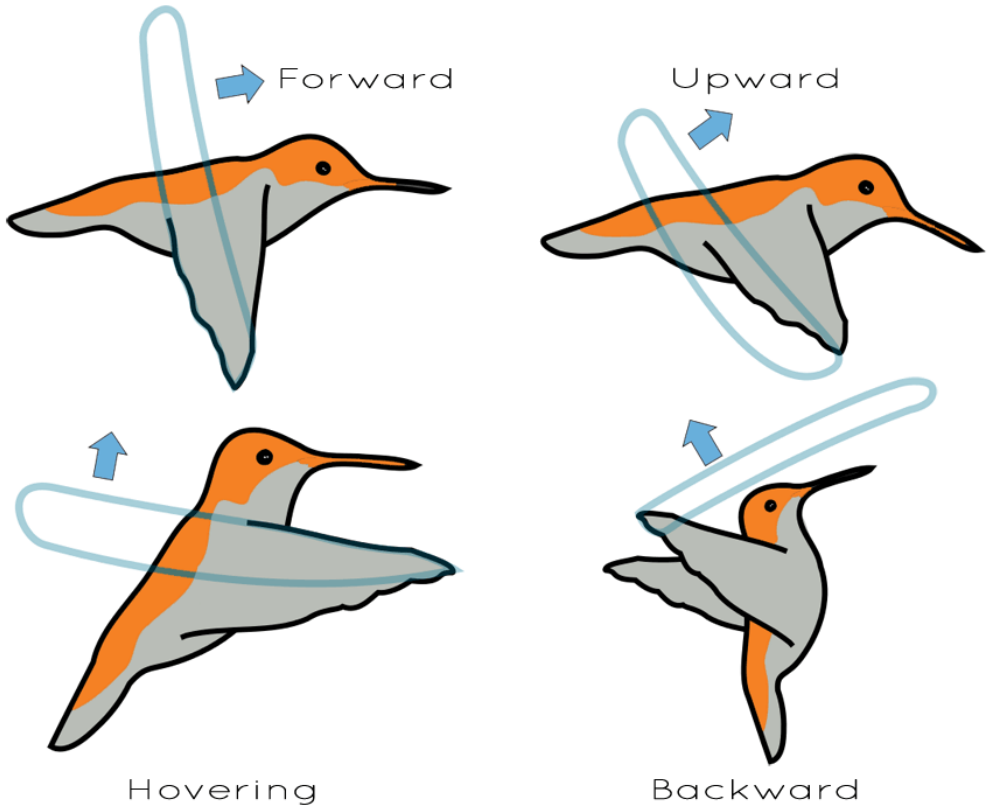


Figure: SocialAgony Compuation Demo

- Gupte et al., Tatti et al. proposed efficient algorithms to find a ranking r to minimize the agony of the graph
- A node v's ranking score in the graph hierarchy inferred by social agony: $f_{agony}(v) = r(v)$

We provide 3 solutions to select violation edges

- Forward
- Backward
- Greedy



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[0]Figure: http://bit.ly/2sCJNrf

Forward to select edges to remove and break cycles

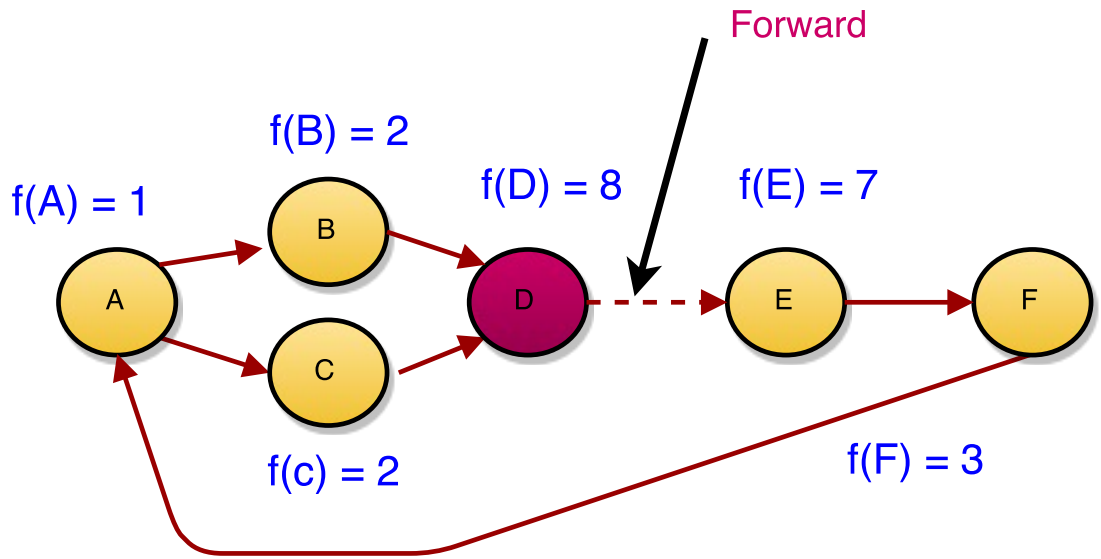

Figure: Strategy Forward to select violation edges

- *Forward*: Select the node which has the *highest* ranking score in the SCC and then remove its all *out* edges.

Backward to select edges to remove and break cycles

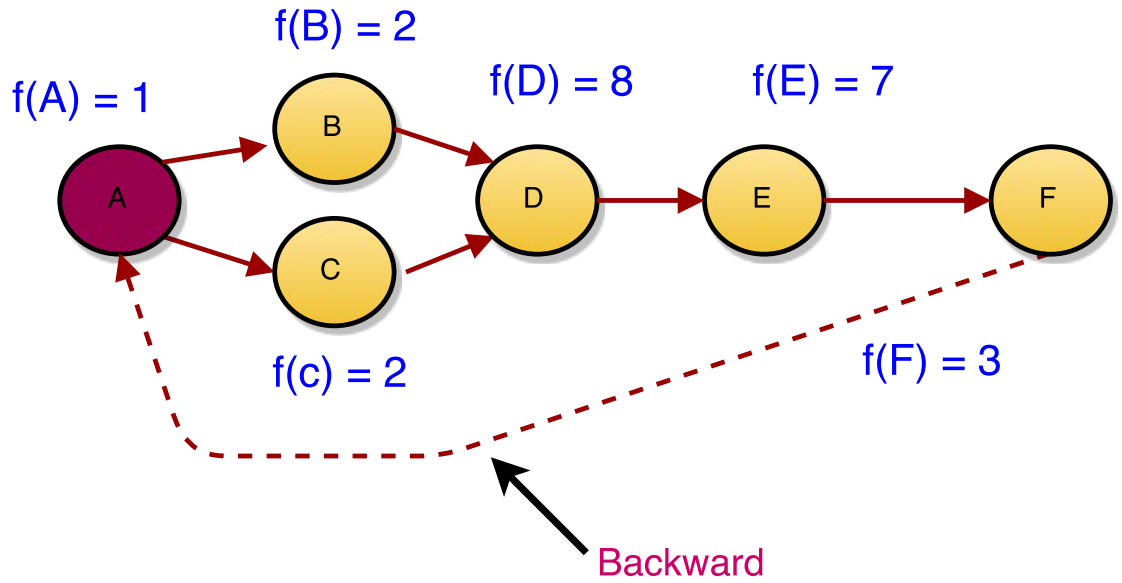

Figure: Strategy Forward to select violation edges

- *Backward*: Select the node which has the *lowest* ranking score in the SCC and then remove its all *in* edges.

Greedy to select edges to remove and break cycles

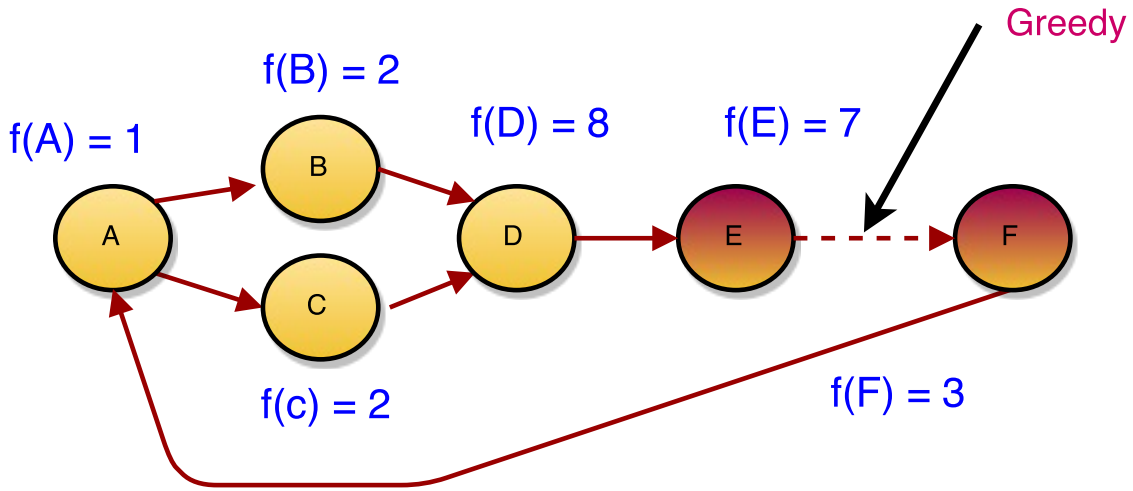

Figure: Strategy Forward to select violation edges

- *Greedy*: Select the edge which violates the hierarchy the *most* to remove.

Combine Them Toghether

- 2 ways to infer graph hierarchy: TrueSkill and SocialAgony
- 3 solutions to select edges: *Forward, Backward, Greedy*
- $\Rightarrow 6$ strategies to break cycles
  - TS_G, TS_B, TS_F
  - SA_G, SA_B, SA_F
- Assembled together: *H_Voting* selects the edge with the highest voting score for removal
  - voting score for an edge e: $\sum_m (I_m(e))$
  - $m \in \{TS\_G, TS\_F, TS\_B, SA\_G, SA\_F, SA\_B\}$
  - if edge e is removed by method m, $I_m(e) = 1$, otherwise $I_m(e) = 0$
  - remove the edge with the highest voting score first

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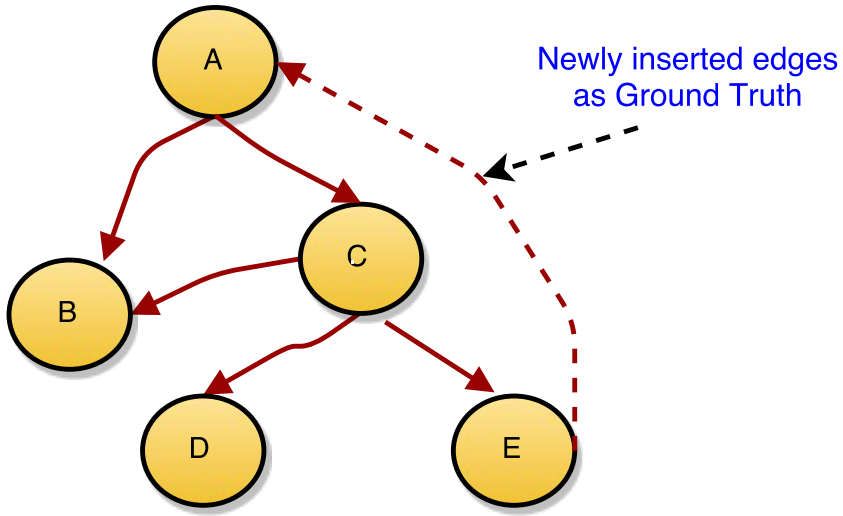
Experimental Setup

- Few large real taxonomy graphs have ground truth (edges are labeled as errors)
- Introduce cycles (randomly) to real and synthetic DAG
  - insert edges that violate the partial order



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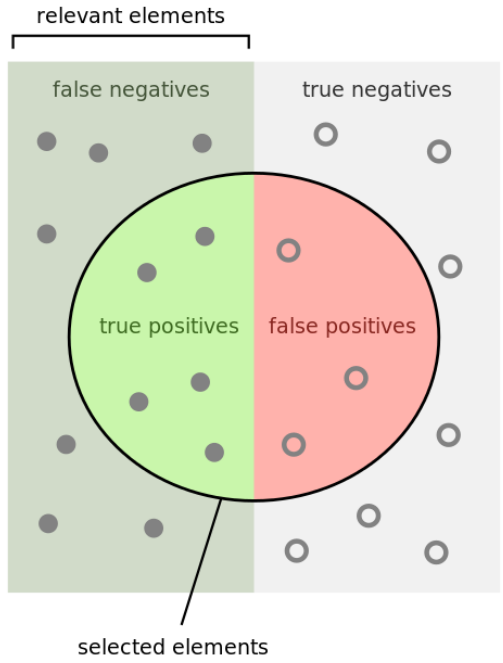
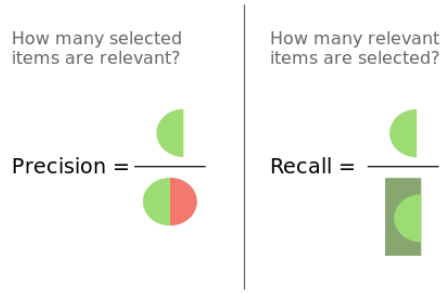
Evaluation Measures

- Ground truth edges T, edges removed by an approach T'
- Precision: $\frac{|T \cap T'|}{|T'|}$
- Recall: $\frac{|T \cap T'|}{|T|}$
- F Measure: $2*$(precision $*$ recall)/(precision + recall)





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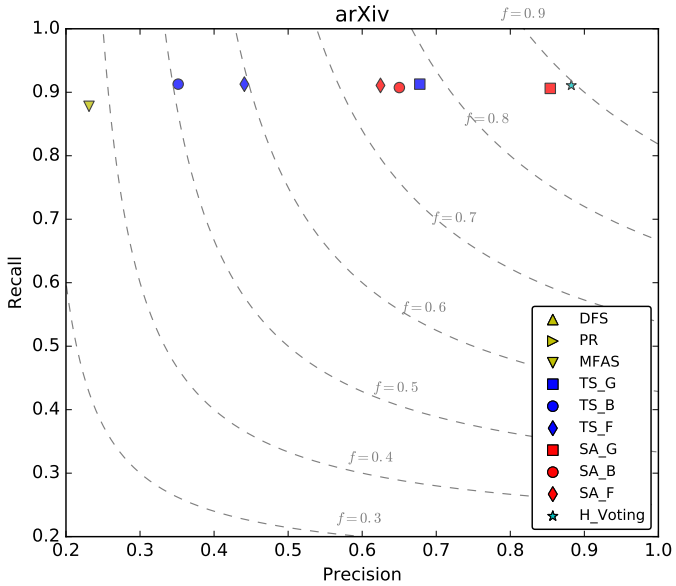
[0]Figure: http://bit.ly/2piTCZv

Performance on Real Graphs



- Results on more real datasets showing comparable results are available on our paper

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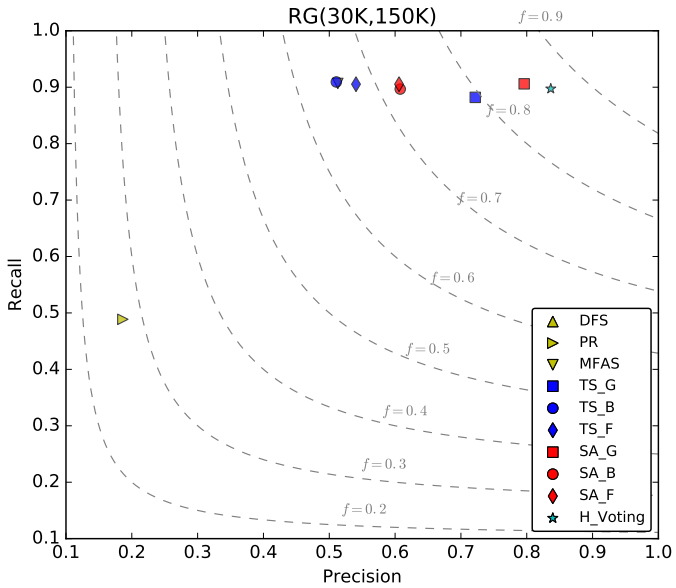
Performance on Synthetic Graphs



- Results on more synthetic datasets showing comparable results are available on our paper

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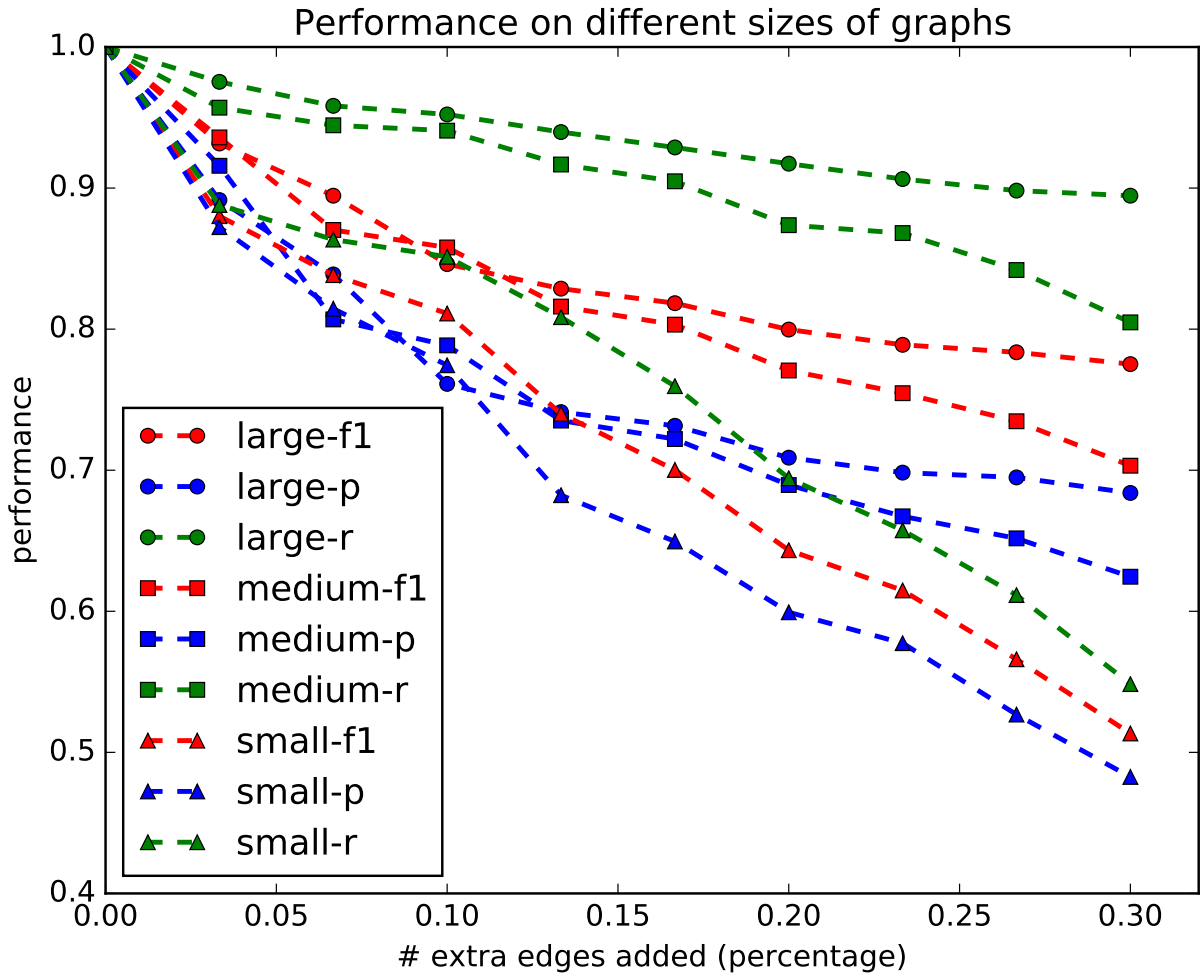
Sensitivity to Number of Noisy Edges



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Conclusion & Future Work

- Main Contribution
  - our approach addresses the problem of breaking cycles while preserving the graph hierarchy
  - we are the first researchers to infer graph hierarchy by viewing it as a competition problem
  - we propose several strategies and an ensemble approach to identify edges that should be removed
- Future Work
  - propose a model-based approach to predict which edge should be removed
- **Code is available on GitHub** [1]

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[1] https://goo.gl/491v7q

Q & A
Thanks

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