A Portfolio Approach for Enforcing Minimality in a Tree Decomposition

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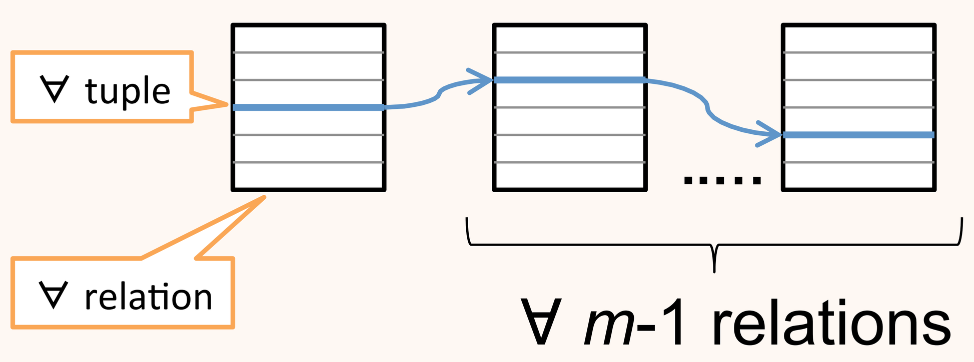
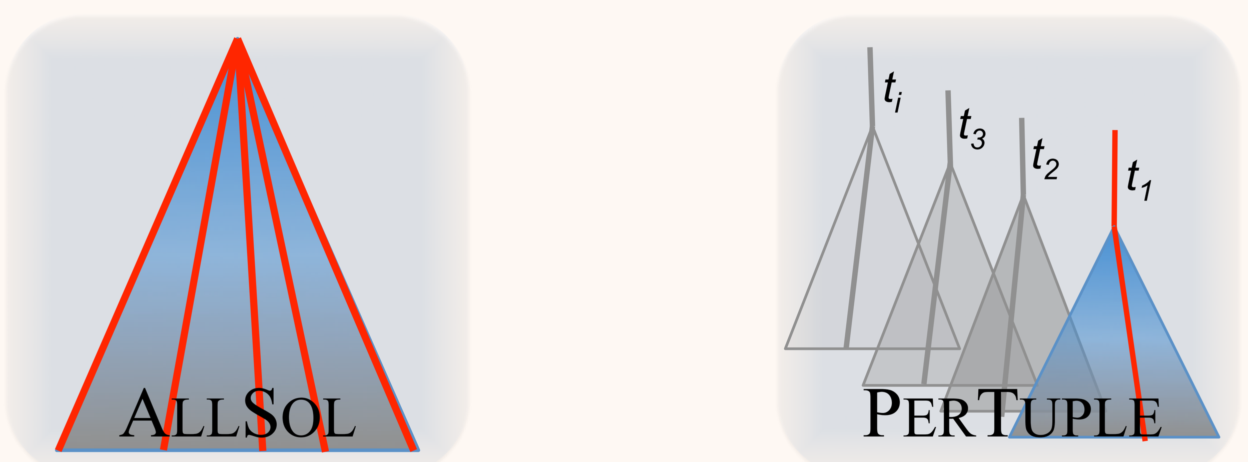
We advocate the use of an algorithm **portfolio** for enforcing minimality on the **clusters** of a tree decomposition during **lookahead** in a backtrack search for solving CSPs.

Minimal network: A global consistency property

- Minimal domains: Every *value* in a *domain* appears in a solution
- Minimal relations: Every *tuple* in a *relation* appears in a solution (i.e., the constraints are as tight as possible)



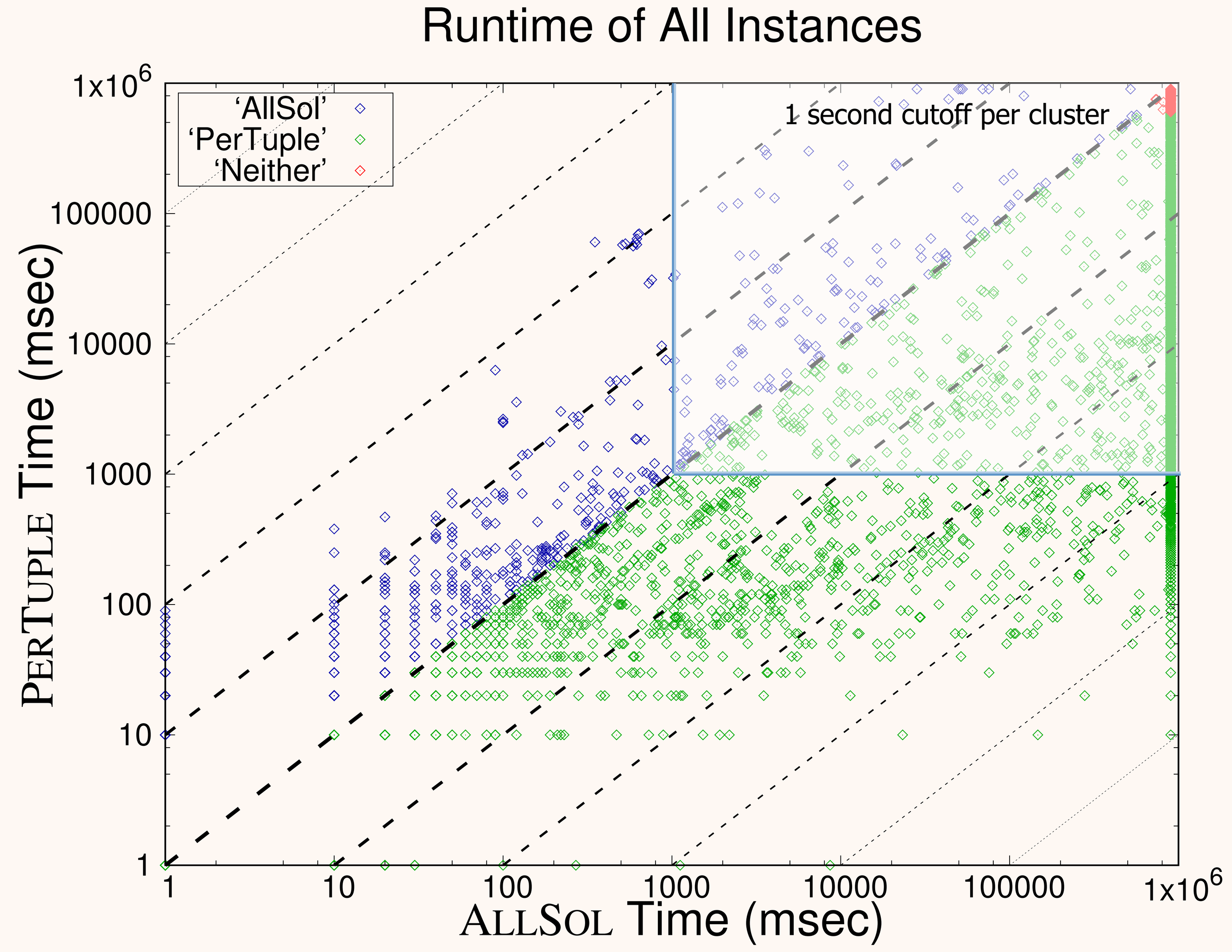
Two algorithms for enforcing minimality [Karakashian, PhD 2013]



AllSol
- Better when there are many 'almost' solutions
- One search explores the entire search space
- Finds all solutions without storing them, keeps tuples that appear in at least one solution

PerTuple
- Better when many solutions are available
- For each tuple, finds one solution where it appears
- Many searches that stop after the first solution

Runtime of All Instances



Classifier training

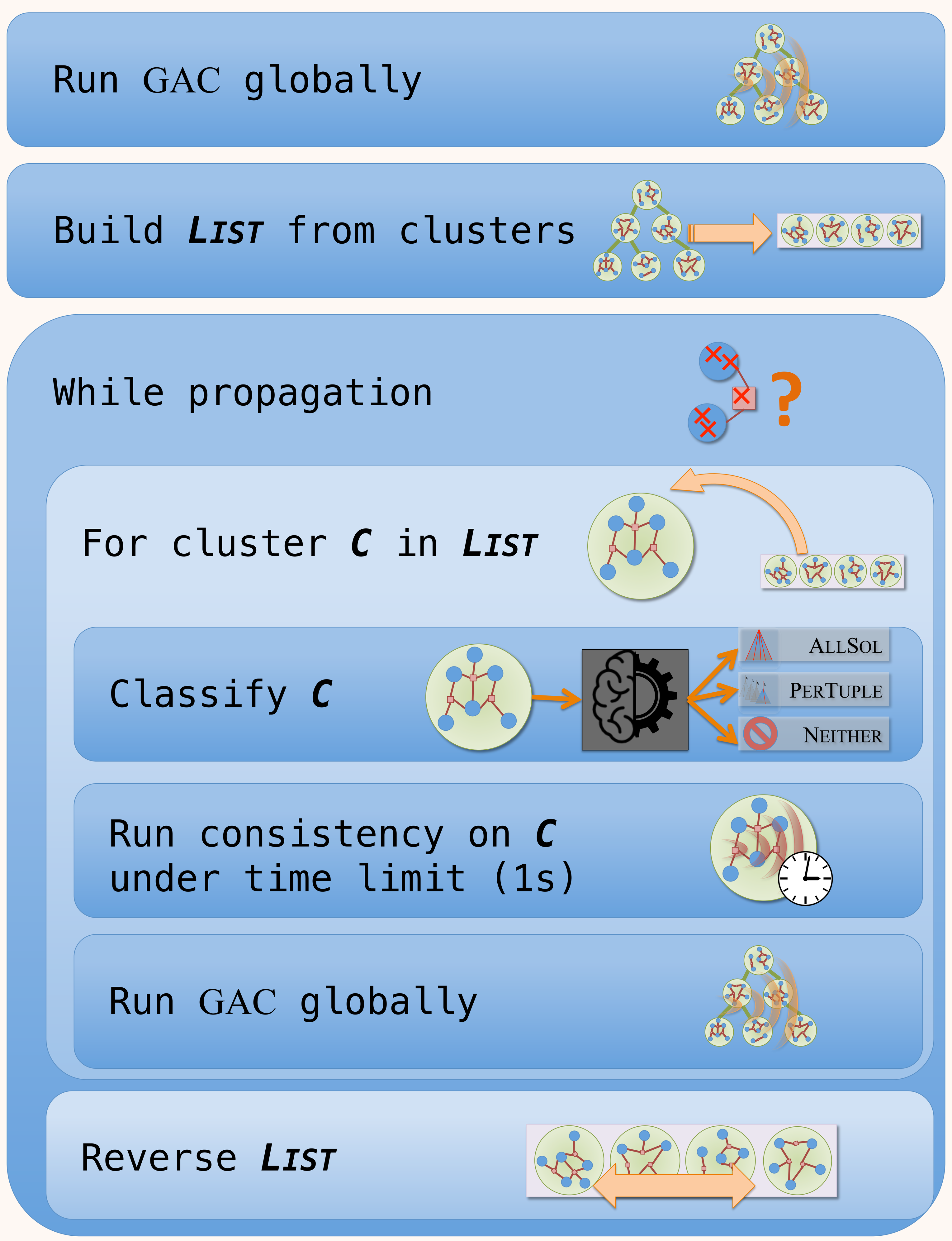
- Trained on 9362 individual clusters taken from 175 benchmarks
- Instances labeled: 'AllSol', 'PerTuple', or 'Neither' (more than 10 minutes)
- Used 73 separate features including: #tuples in relations, constraint tightness, relational linkage, features of incidence graph
- Computed descriptive statistics including: mean, min, max, coefficient of variation, entropy
- Weighted instances according to the function:

$$weight(i) = \begin{cases} w(allSol(i), perTuple(i)) & label(i) = \text{'}AllSol\text{'} \| \text{'}PerTuple\text{'} \\ 20 & label(i) = \text{'}Neither\text{'} \end{cases}$$

$$w(a,p) = \left\lceil \left| \log_{10}\left(\frac{a}{p}\right) \right| \cdot \left| \log_{10}\left(|a-p| + 0.01\right) \right| \right\rceil$$

- Used 10-fold cross validation
- The trained decision tree achieved 90.8% weighted accuracy

FilterClusters algorithm

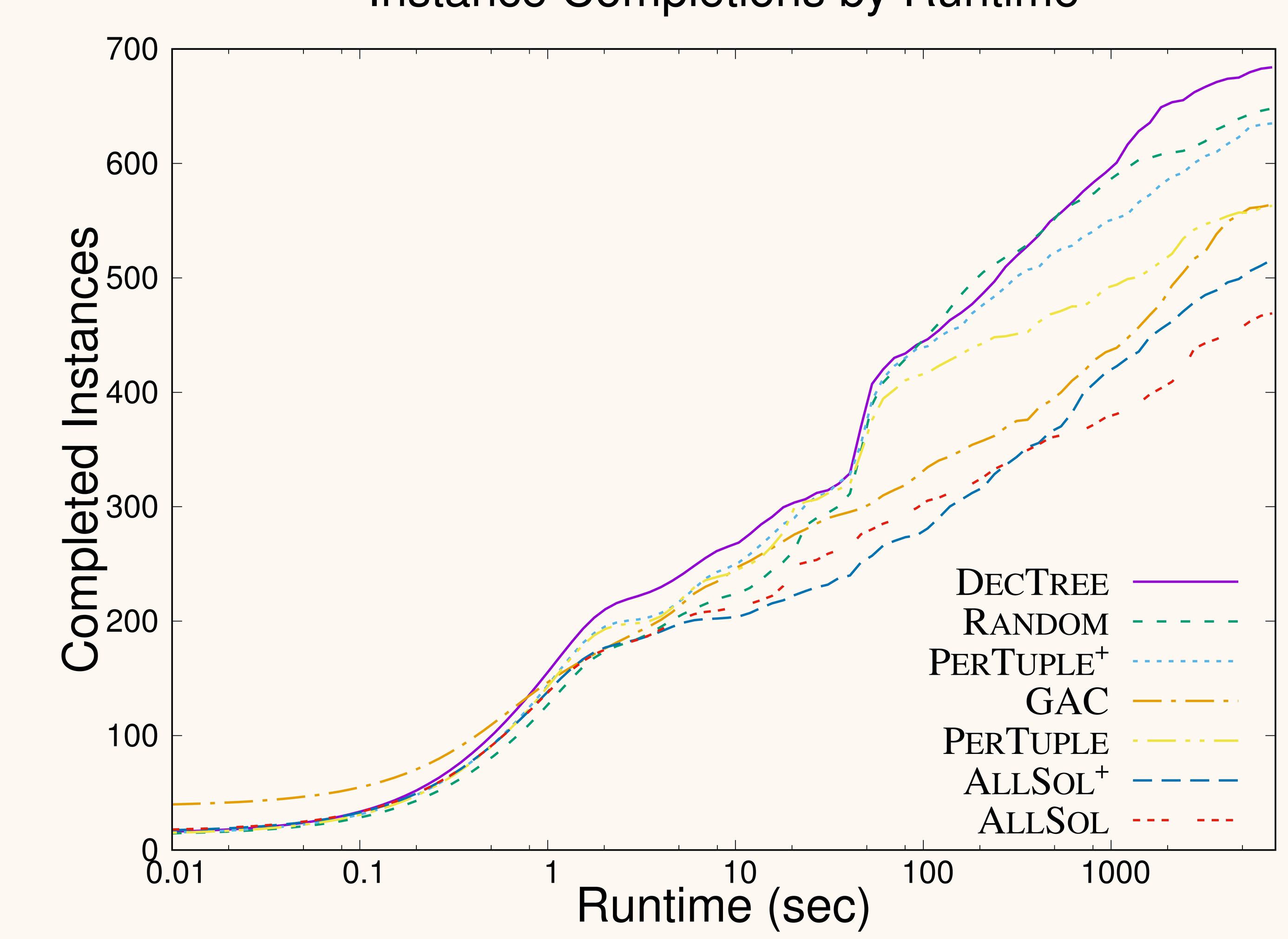


Experiments

- Used 1055 instances from 42 benchmarks
- Intel Xeon E5-2650 v3 2.30GHz processors with 12 GB memory
- 2 hour timeout per instance, 1 second timeout per cluster
- Backtrack search, dynamic dom/deg ordering
- Compared seven strategies for real-full lookahead
  - GAC, AllSol, PerTuple: basic algorithms
  - AllSol+, PerTuple+: AllSol/PerTuple with timeout and GAC interleave
  - Random: timeout, GAC interleave, and random classifier
  - DecTree: timeout, GAC interleave, and trained decision tree classifier

	GAC	AllSol	PerTuple	AllSol+	PerTuple+	Random	DecTree
Instances Completed	550	472	567	514	633	643	**685**
Average Time (s)	2,471	3,075	2,081	2,789	1,622	1,427	**1,121**

Instance Completions by Runtime



Conclusions

- A portfolio at the cluster level and during search is not only feasible but also a winner
- Enforcing a timeout on cluster consistencies prevents getting stuck on one part of the problem

Future work

- Use the classifier to dynamically set the timeout based on the anticipated filtering

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