Structure-based Instance Generation

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Outline

1. Motivation
2. Structures in SAT/Max-SAT Problems
3. The structure-based instance generation approach
4. Application to SAT/Max-SAT
5. Computational results
6. Conclusion

Motivation

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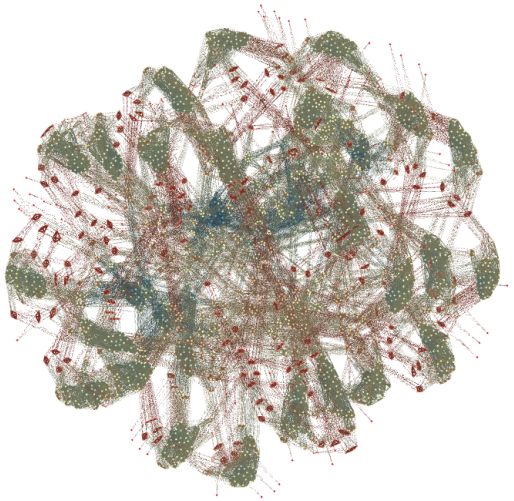
Solution: Generate new instances based on the instances we already have!

Novelty of this work

The first instance generation paradigm that...

- Analyzes the structure of existing instances based on their features and transports structures between instances
- Uses instance features as a criteria for accepting/rejecting an instance
- Shows that instances generated are effective within a selection approach

Variable graph visualizations



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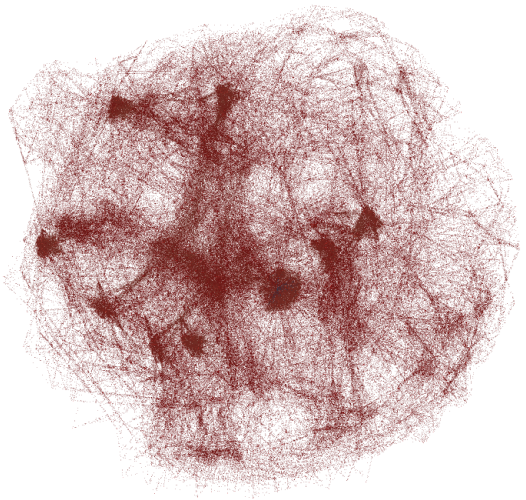

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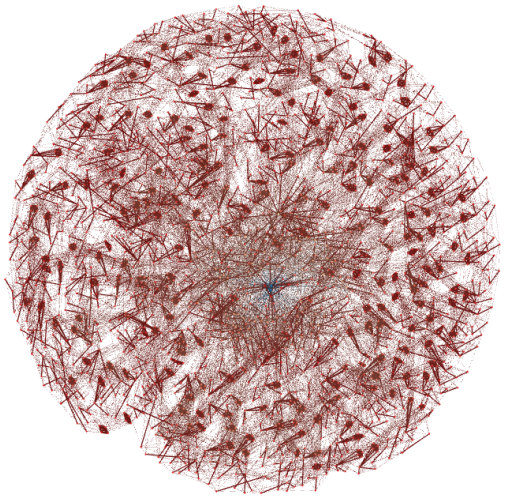

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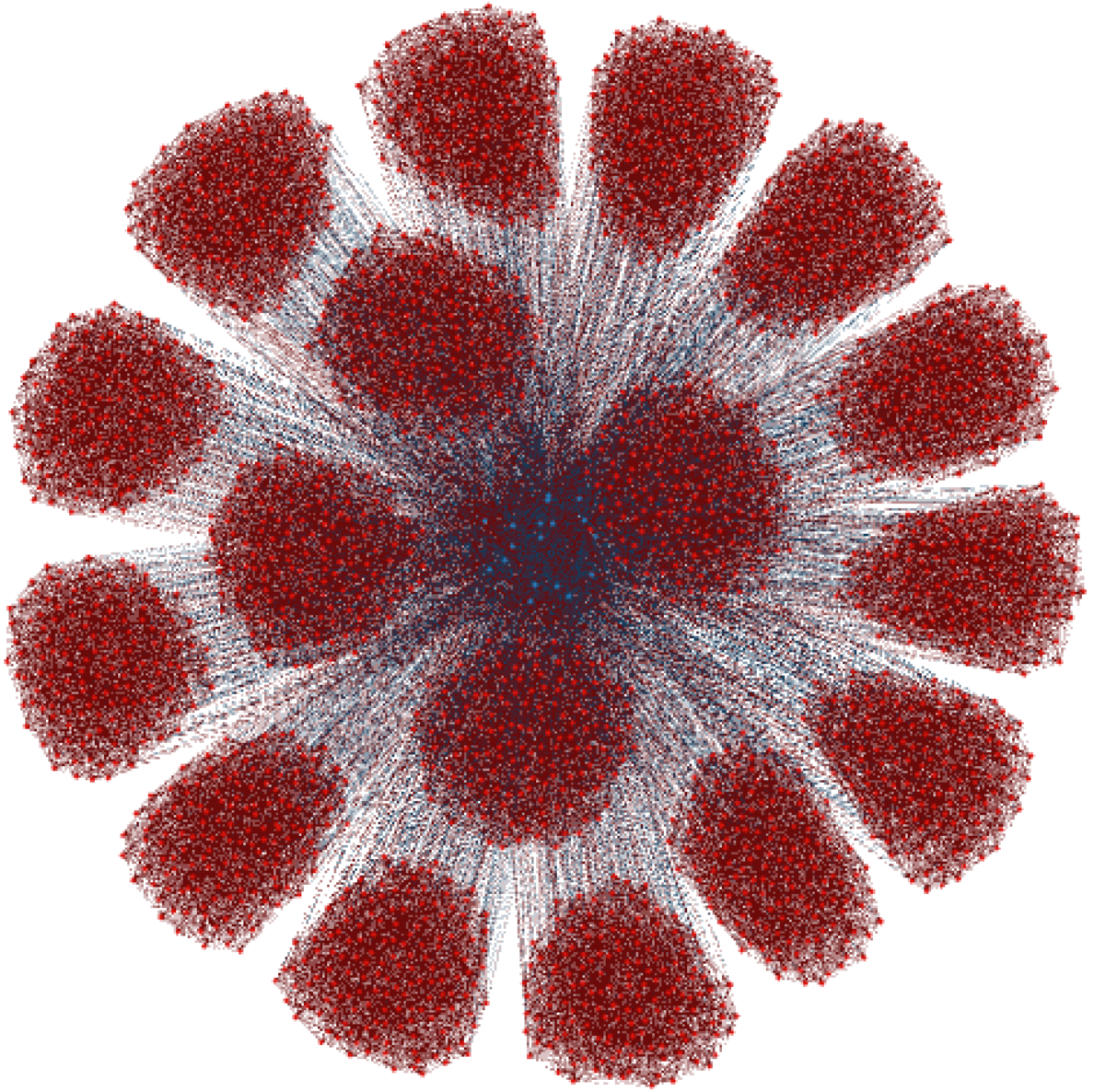
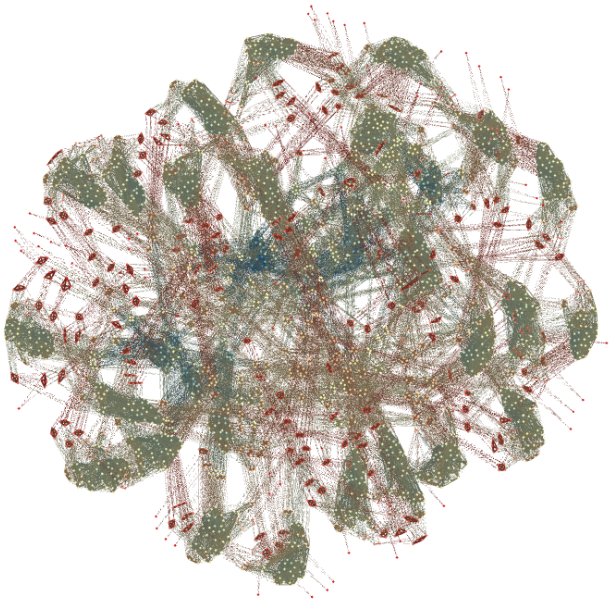
The "SAT Flower": counting-harder-php- reshuffled-07



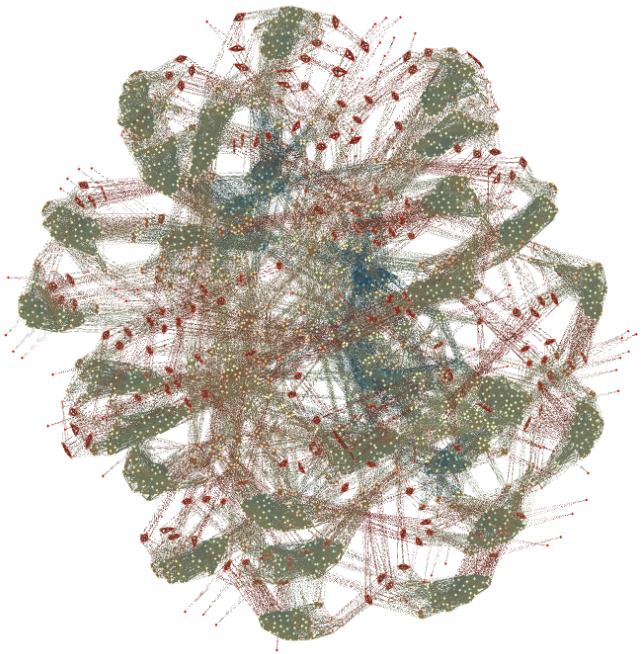
The Structure-based Instance Generation Approach

Instance generation example

Receiver

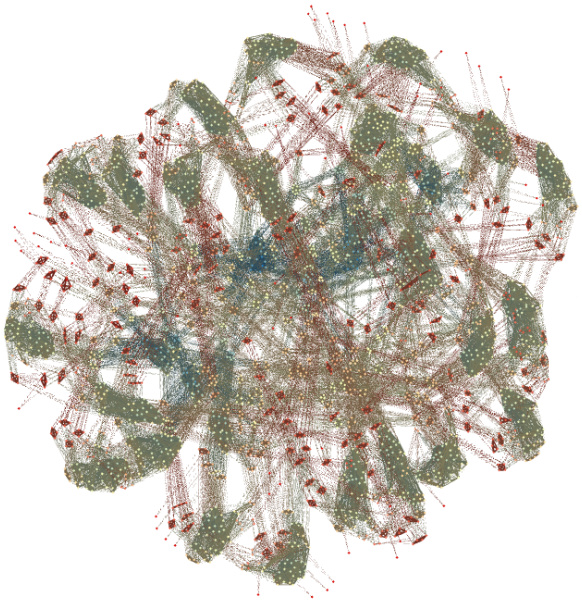


Giver



Instance generation example

Receiver (1 Destroy)



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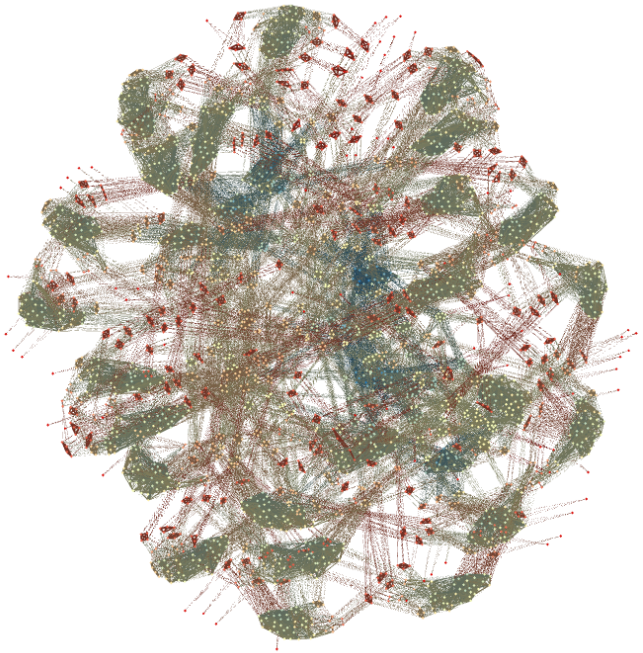

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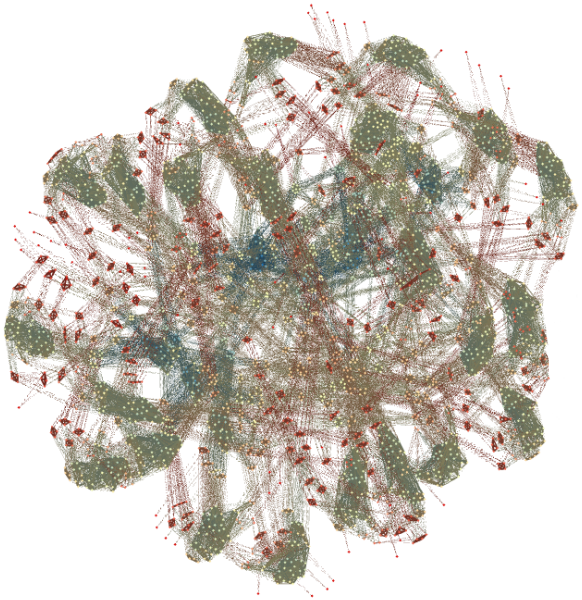
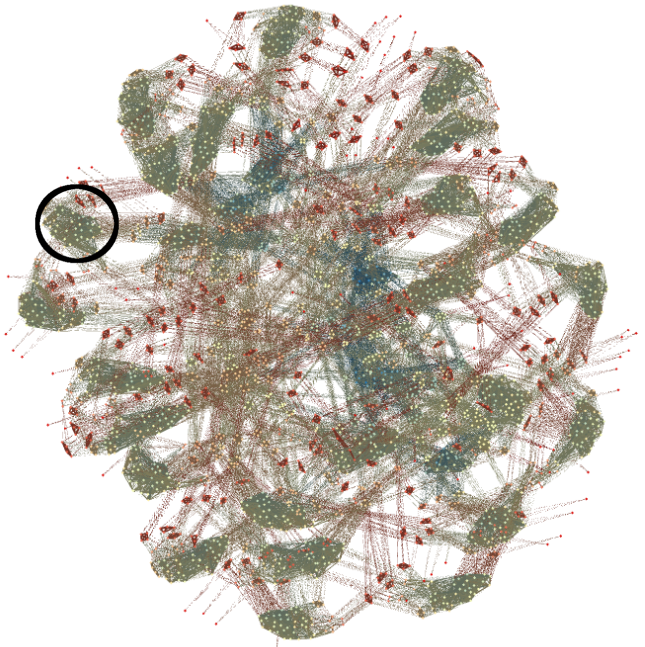
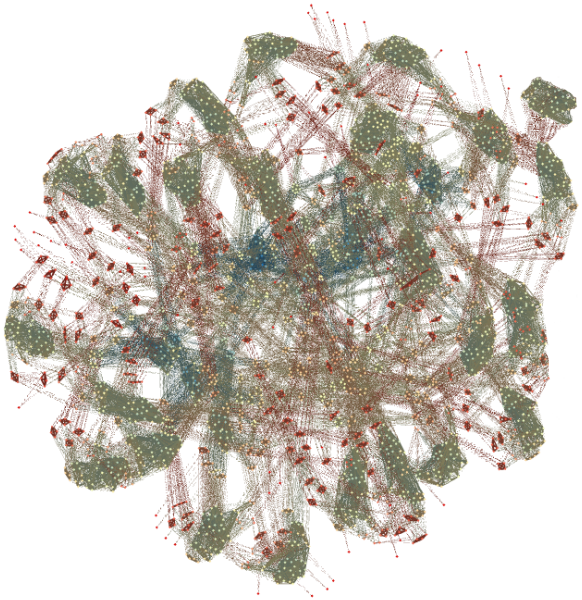


Giver (Identify structure)



Instance generation example

Receiver (Repair with structure)



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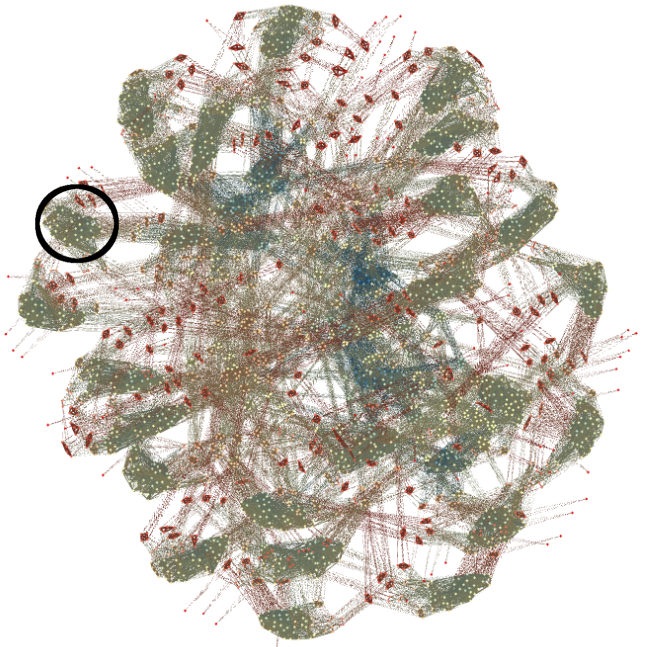
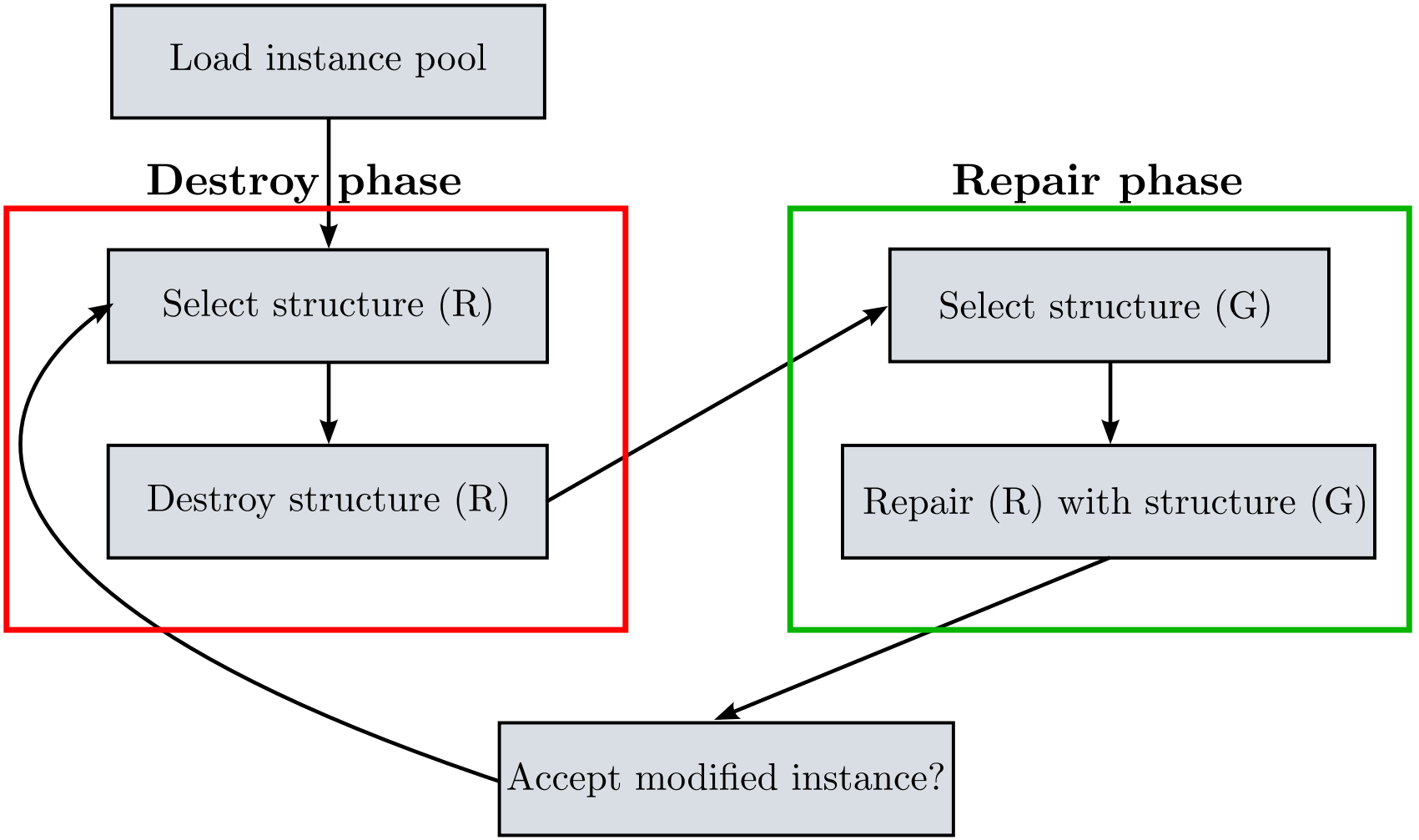


Instance generation algorithm



Reliance on instance features

Structure detection

- Structures should be connected to the instance features

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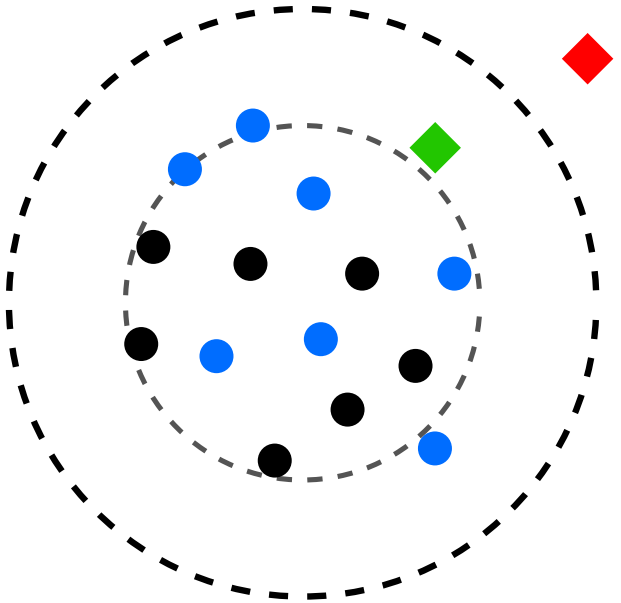
Instance acception

- Ensure the distance of the new instance is not “too far” away from the pool of instances it was created from.



Related work

Numerous SAT/Max-SAT Instance generators:

- Too many to list them all; most generate instances based on probability distributions fine tuned to try to make the instances more industrial-like.

Main related work:

Morphing (Gent, Hoos, Prosser, Walsh. AAAI 1999):

- Goal is to "connect" the structures of two instances; it is a much more invasive process
- Through our destroy/repair process, we modify the underlying instance differently

Why SAT/Max-SAT

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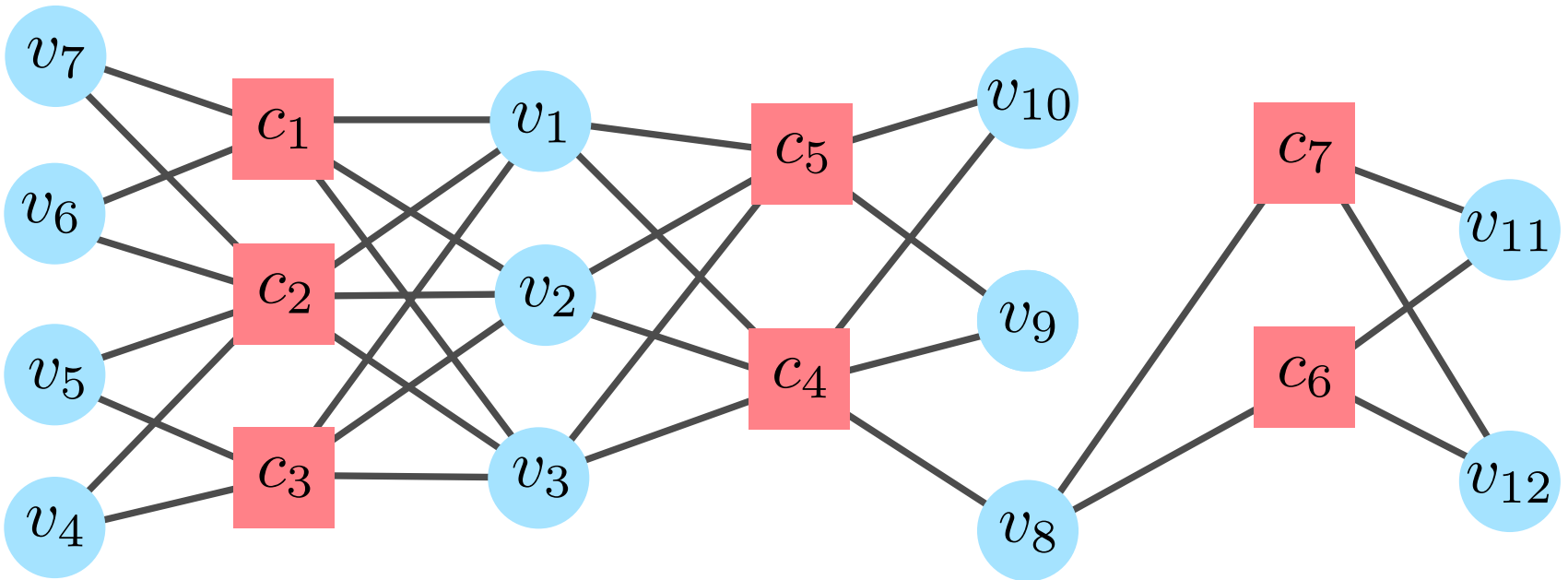
- Dearth of real-world data, especially for Max-SAT
- Well-known and studied instance features

Application to SAT/Max-SAT

Variable based heuristic

- Identifies variables in sub-components of the instance
- Uses the average number of clauses each variable is in and selects a variable with a number of clauses near this value



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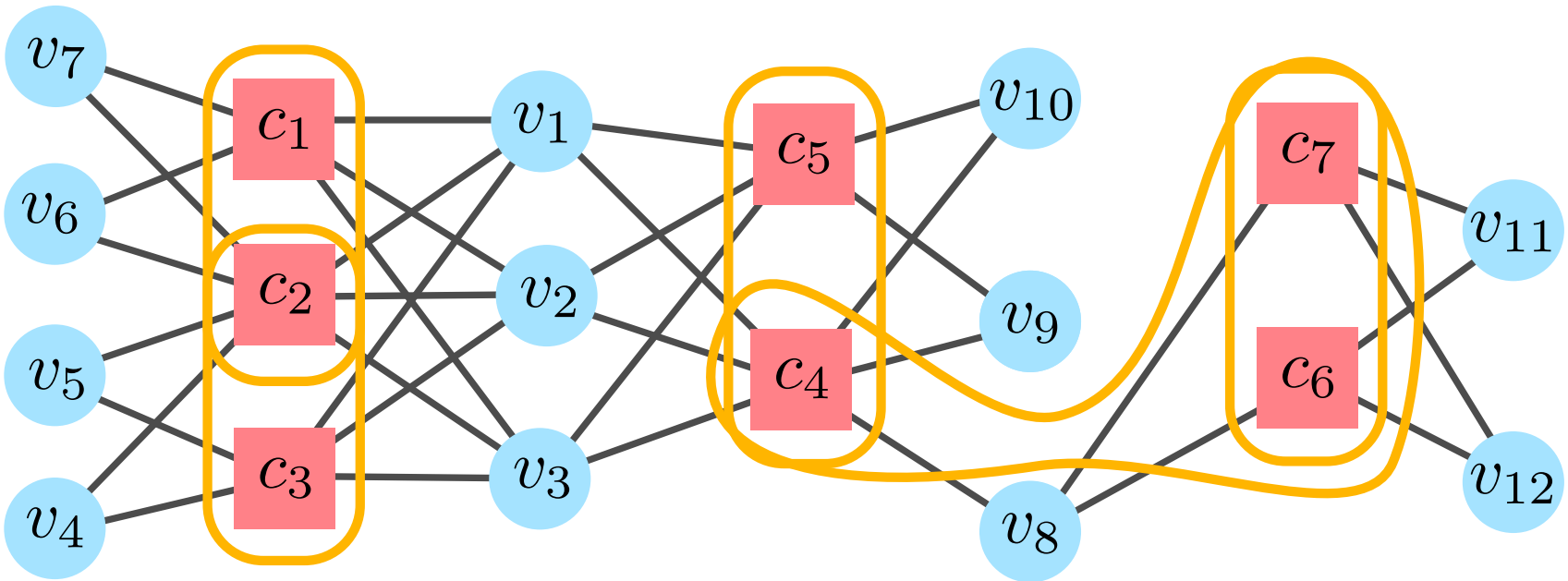

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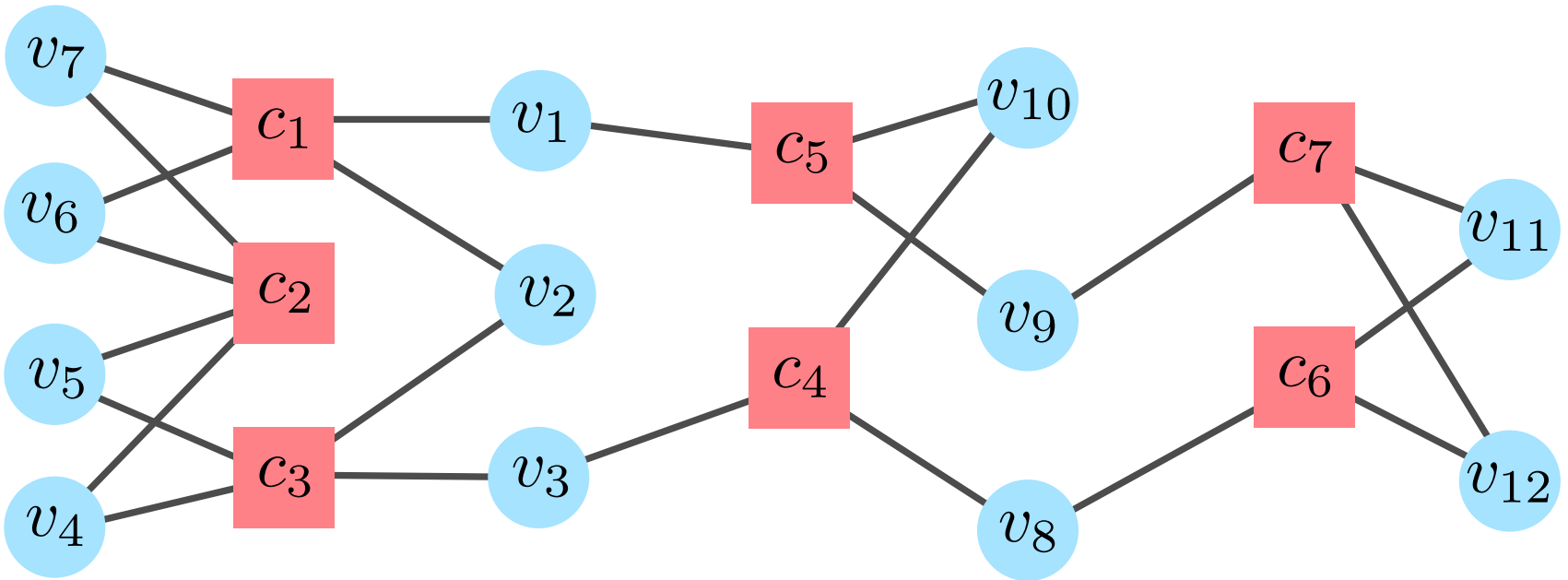

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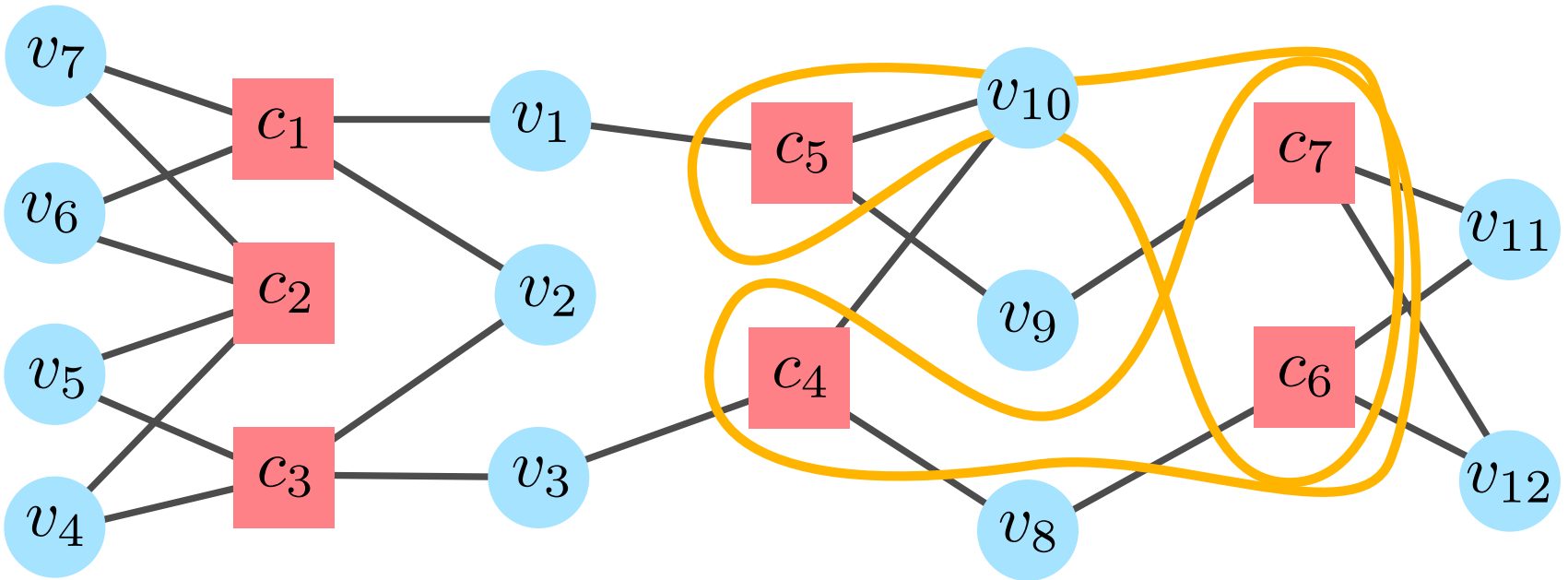

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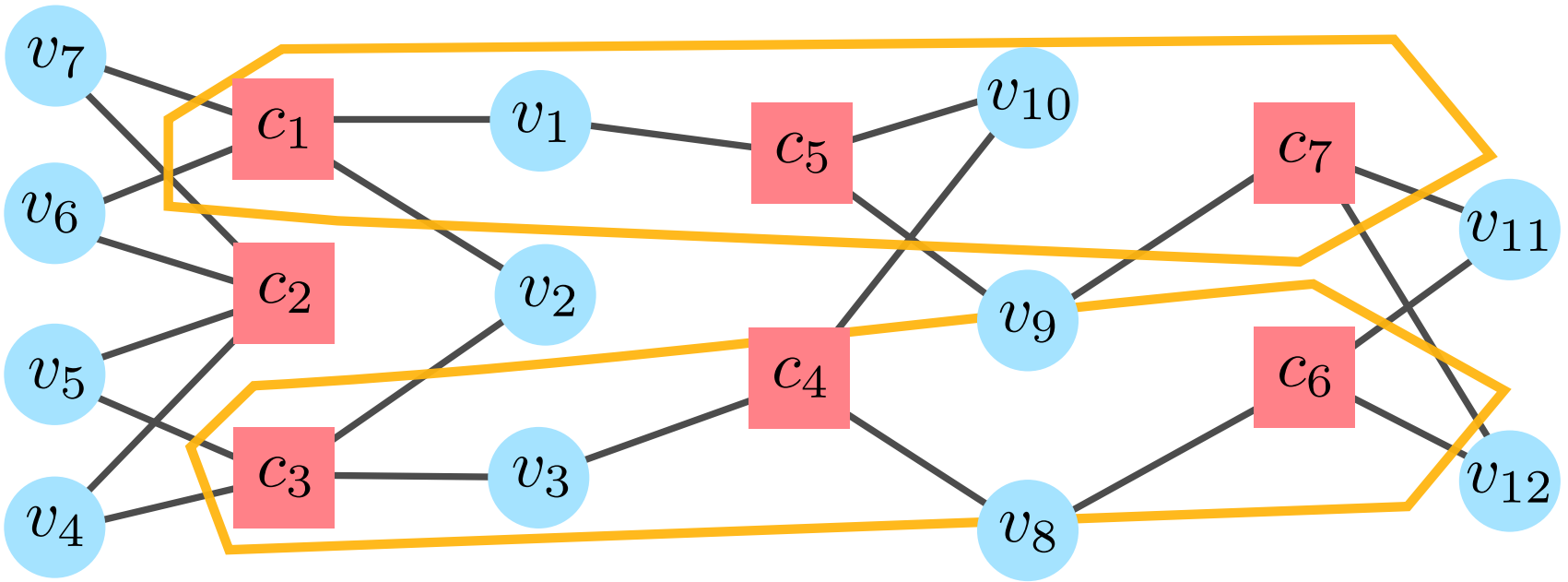

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Application to SAT/Max-SAT

Destroy

- Destroying is simple:
  1. Remove all of the selected clauses
  2. Perform bookkeeping

Application to SAT/Max-SAT

Repair

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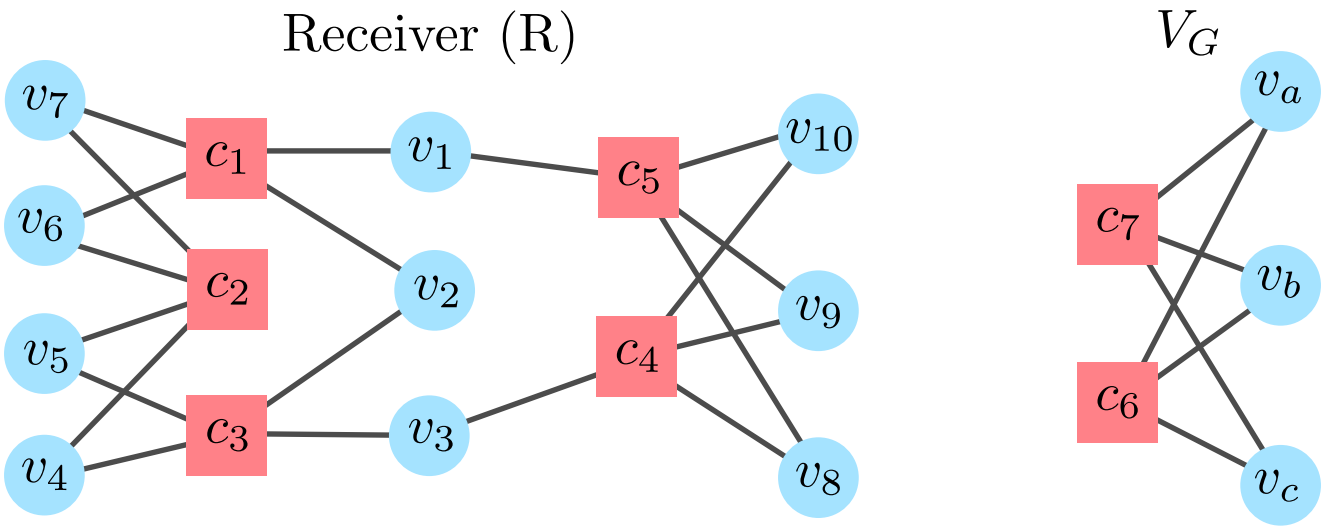

Then, map variables in V_G to variables with similar features, or with small probability, make it a new variable.

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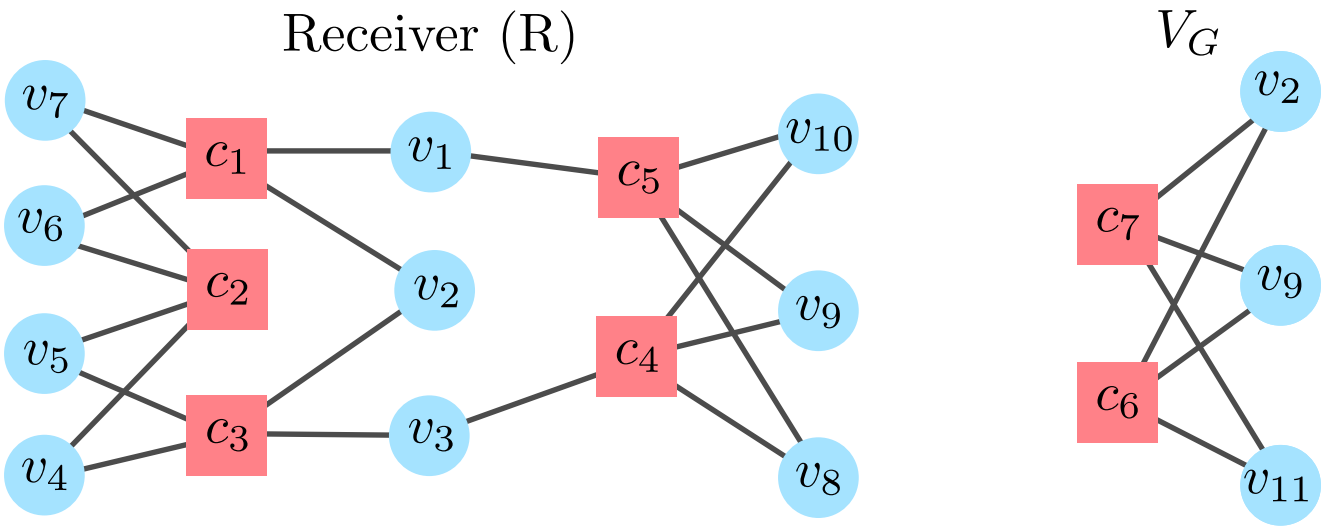

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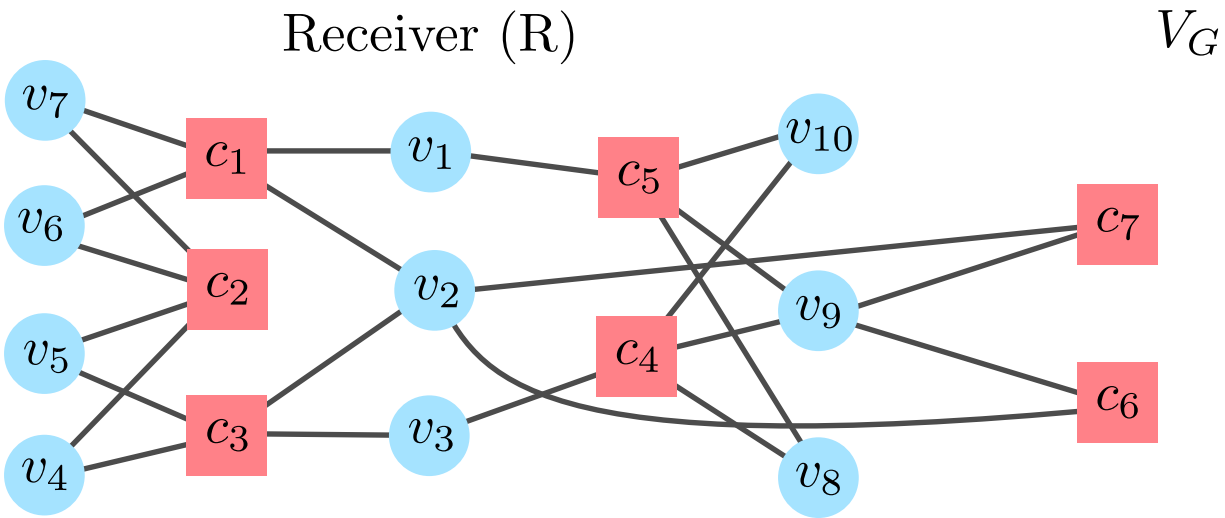

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Application to SAT/Max-SAT

Acceptance criterion

Max-SAT & SAT

- Compute instance features and check if the distance to the cluster center is within 3 standard deviations of the mean for each feature

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Application to SAT/Max-SAT

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Max-SAT & SAT

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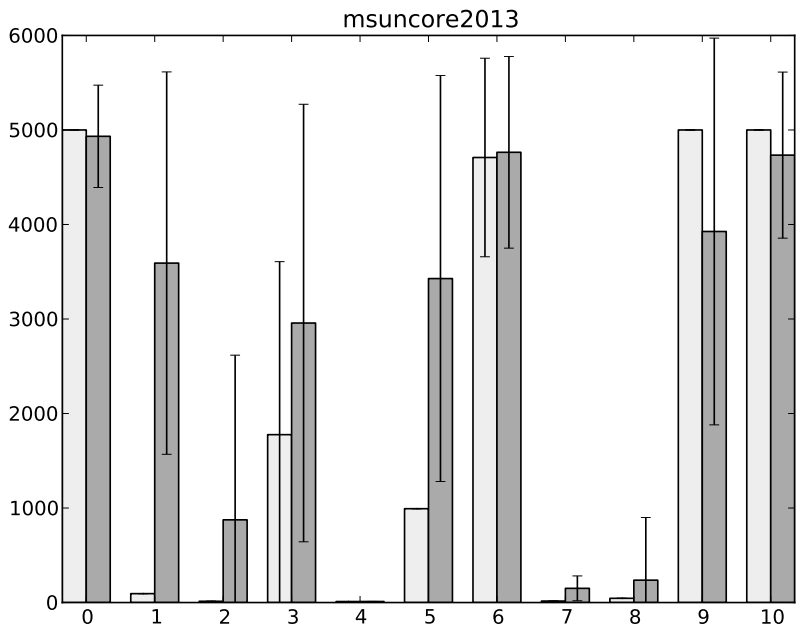
SAT

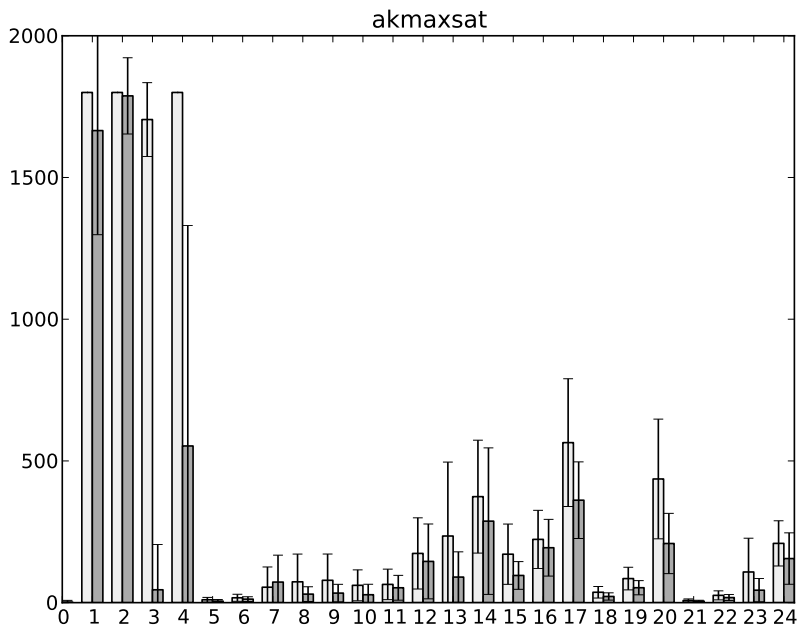
- Potential problem with SAT: Small changes to the instance can make it trivial to solve
- Solution: Run a SAT solver for 30 seconds; if the instance is solved, reject it.

Computational results

Max-SAT

We generated Max-SAT instances using the industrial instances in the Max-SAT 2013 competition.





Above: Average runtime (s) for an industrial solver and random solver on clusters of generated instances from the industrial and random instances, respectively.

Computational results

Max-SAT (2)

Model	Original		Generated	
	Avg. (s)	# Unsolved	Avg. (s)	# Unsolved
Best Single	735	2	735	2
Random Forest	988	5	599	2
SVM (radial)	734	2	591	1
VBS	184	0	184	0

Several selection techniques training a portfolio of industrial Max-SAT solvers (10-fold cross validation).

Computational results

SAT

	Average	PAR10	Solved
Best Single	453	3,872	157
Random (300)	541	5,107	144
Crafted (300)	386	4,090	154
Industrial (46)	348	3,426	161
Generated (300)	502	3,463	162
Generated (1,500)	437	3,049	166
VBS	364	364	195

Conclusion and future work

- We generate industrial-like instances from a pool of existing instances
- Currently, this is possible for the SAT and Max-SAT problems
- We intend to expand this work to mixed-integer programming and possibly other problems