~~Playing with AVATAR~~
How to play with AVATAR

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The 1st Vampire Workshop

Overview

1. Introduction
2. Reviewing AVATAR
3. The variables
4. How to evaluate
5. Results
6. Conclusion

Introduction

In this talk we will:

- Briefly recall what the AVATAR architecture is
- List the parameters that control its behaviour
  - (and what effects they have)
- Discuss how we should evaluate these kinds of frameworks
- Present results of our experimental evaluation

Work in progress!

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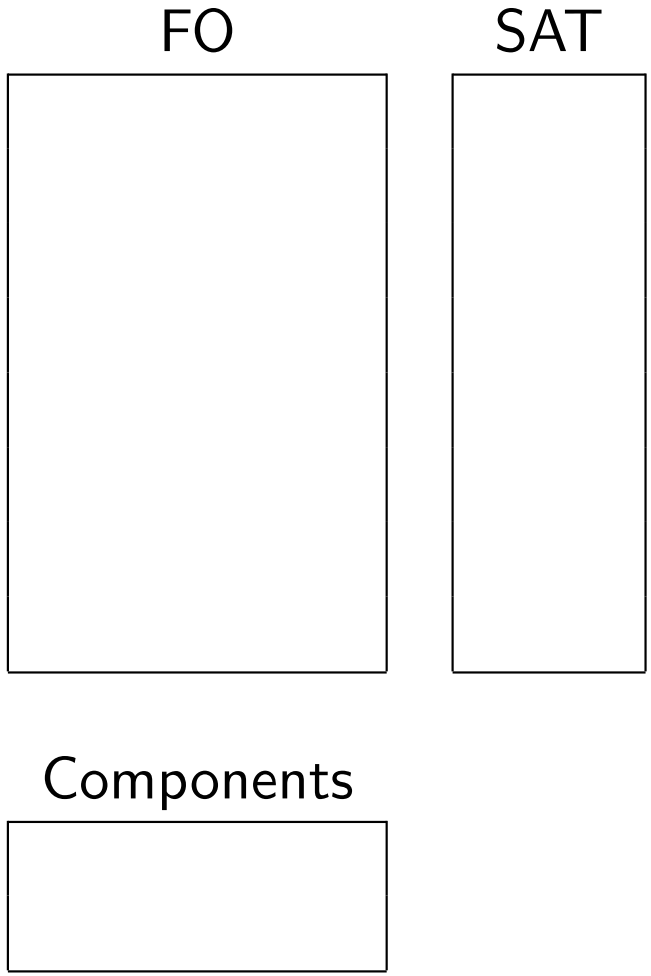

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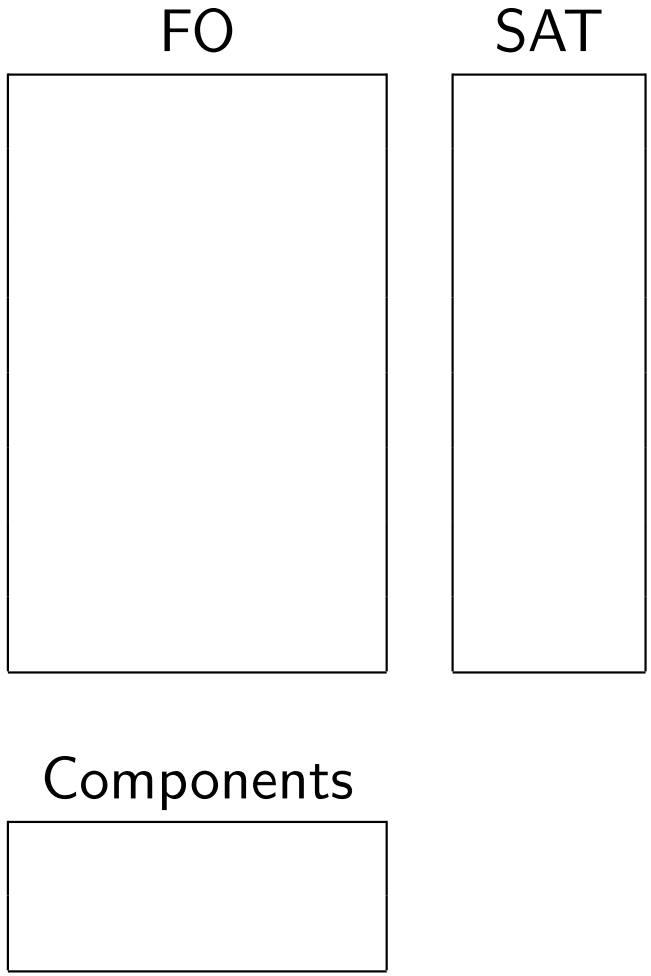

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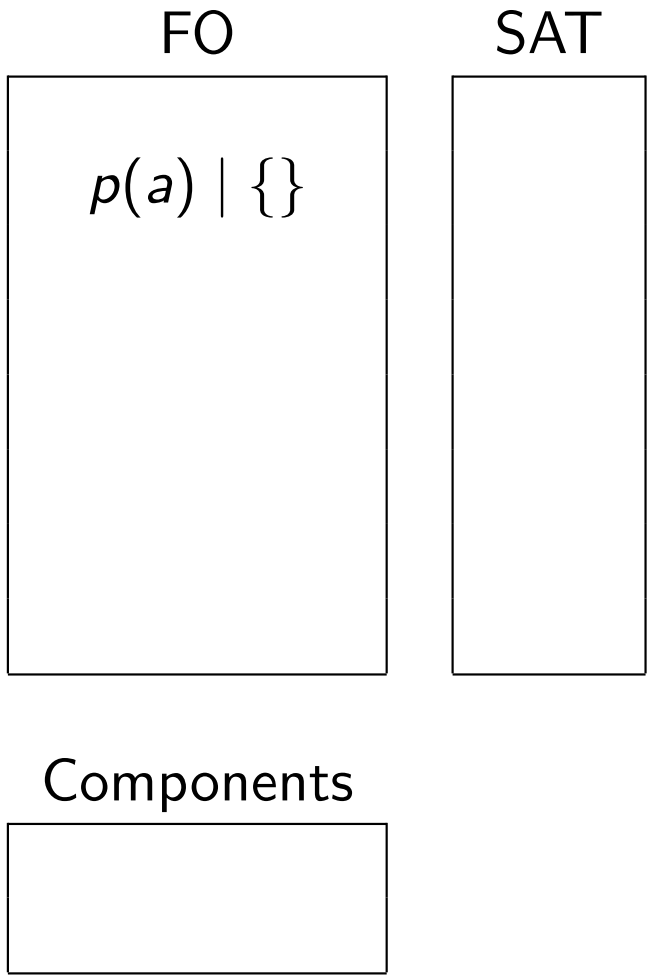

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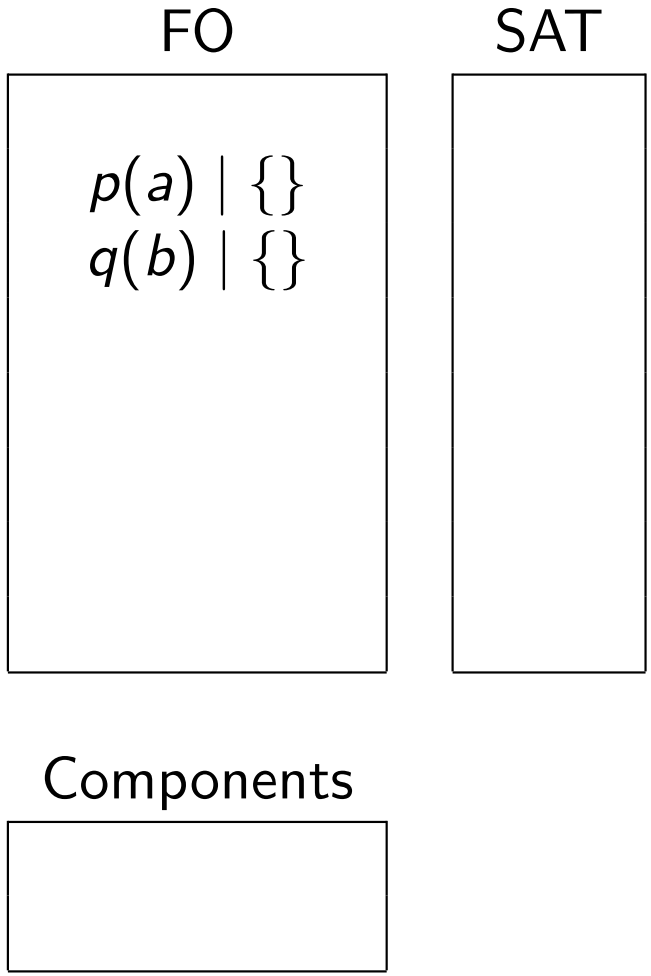

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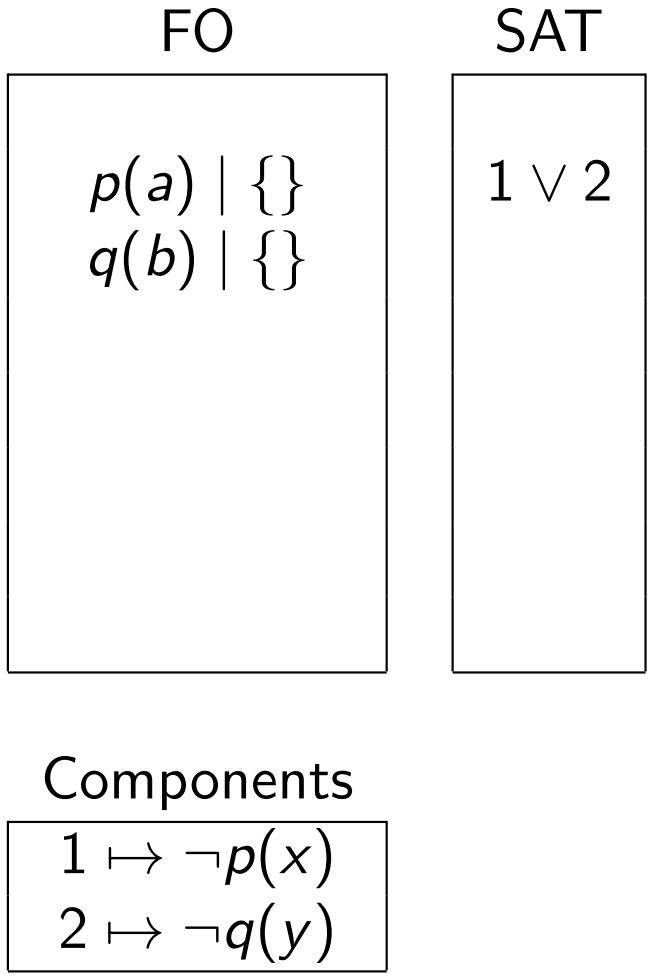

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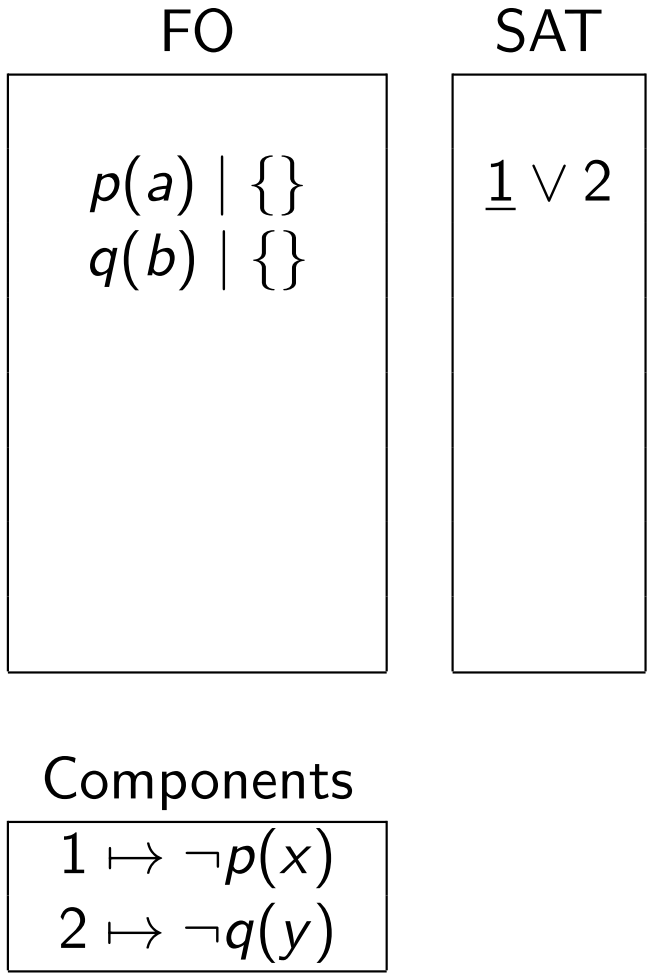

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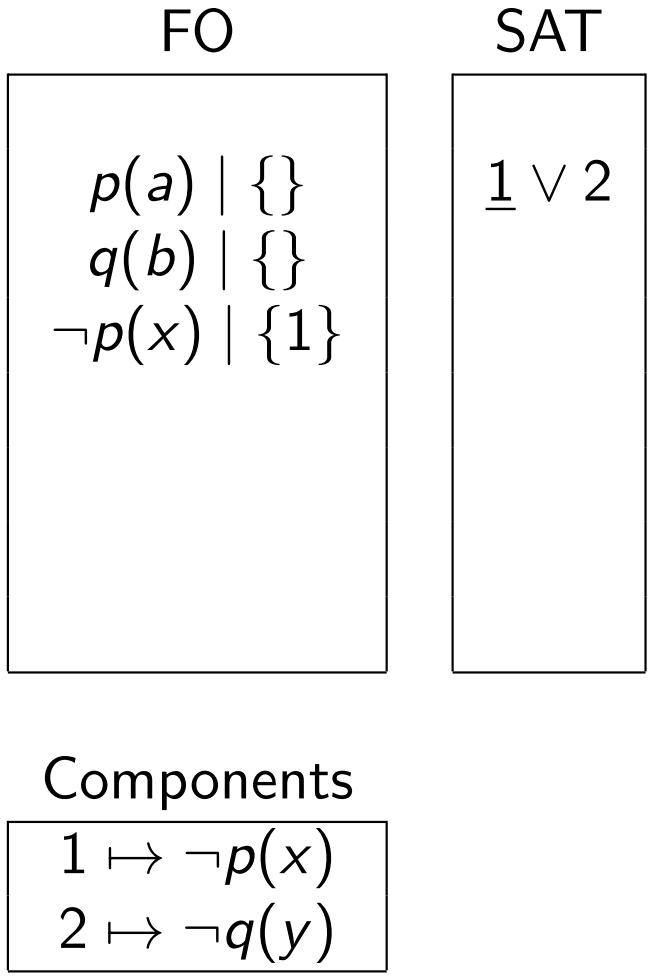

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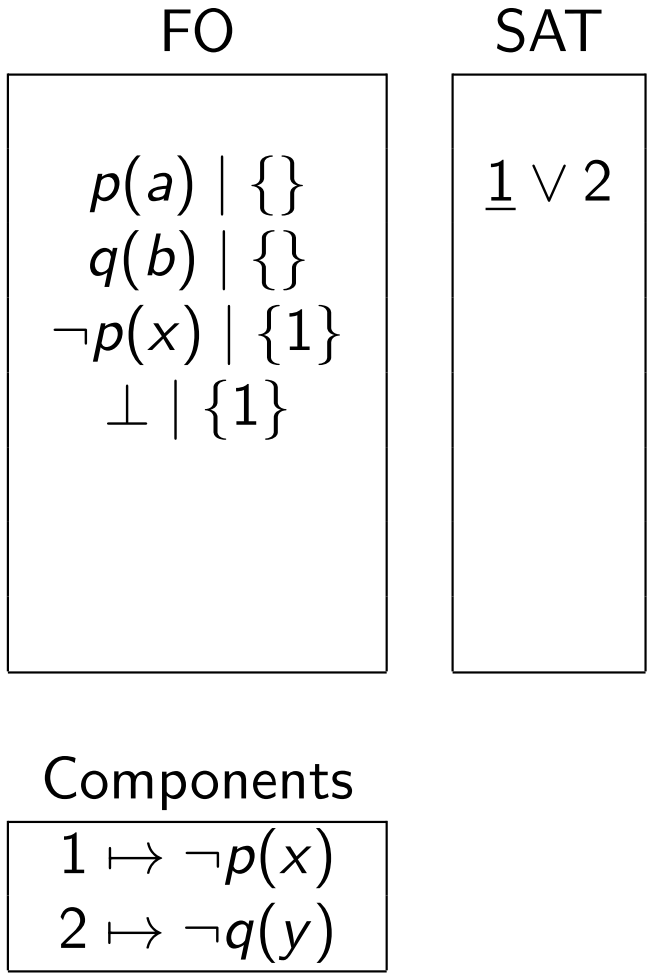

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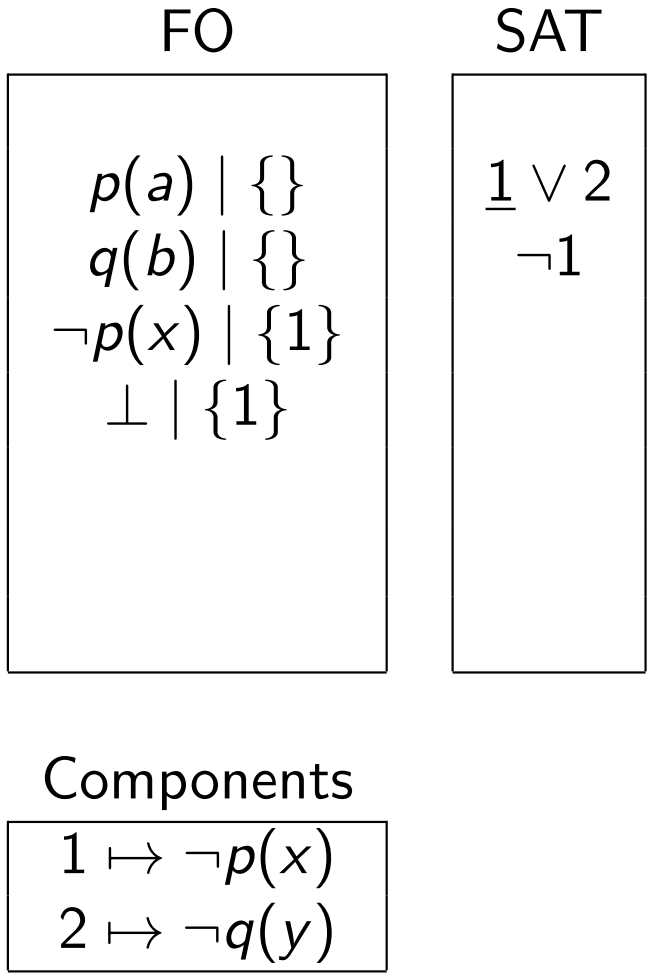

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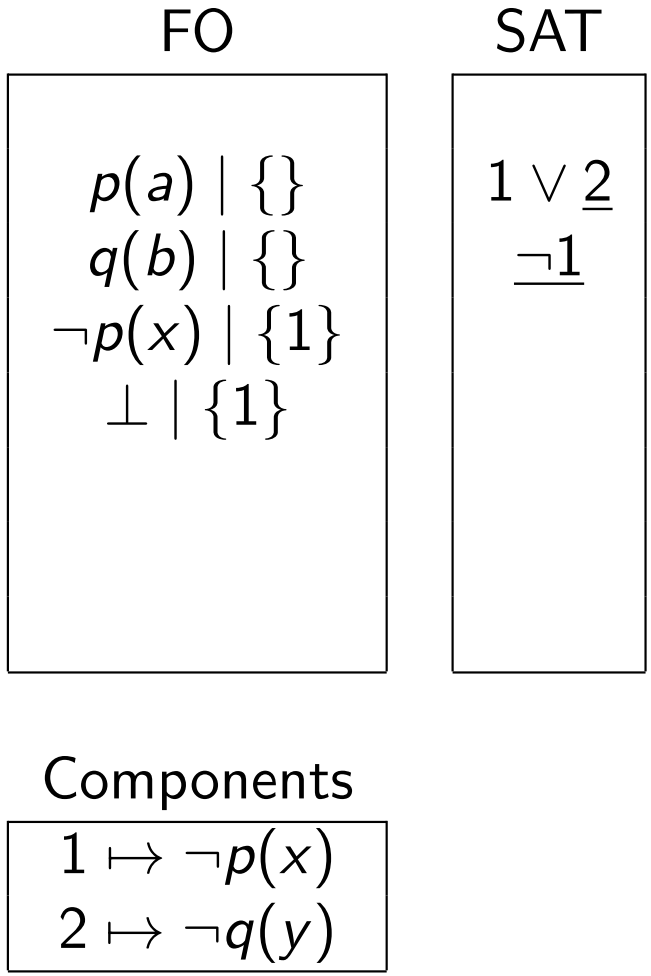

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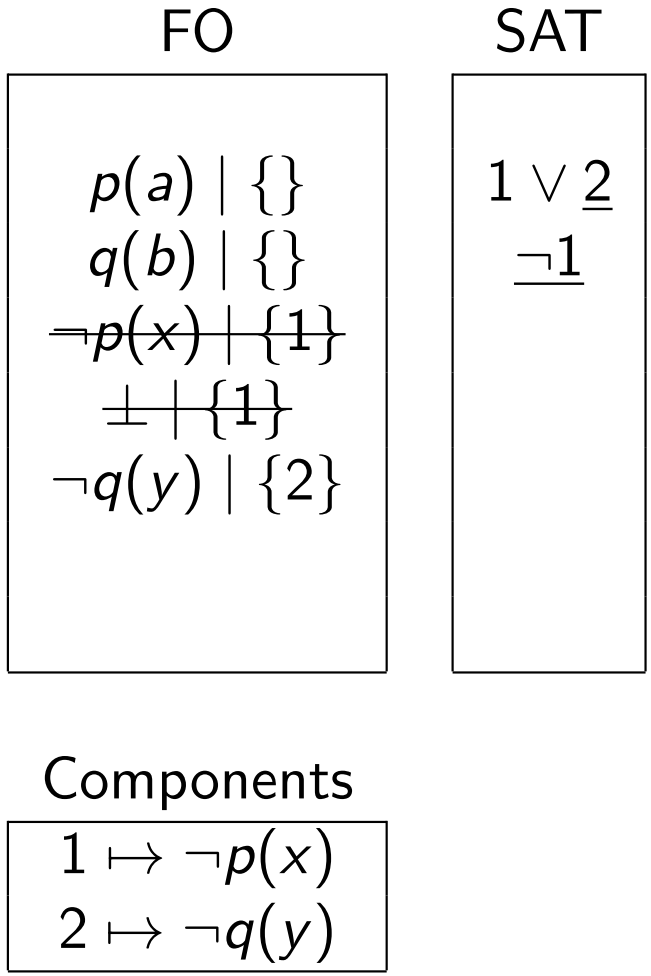

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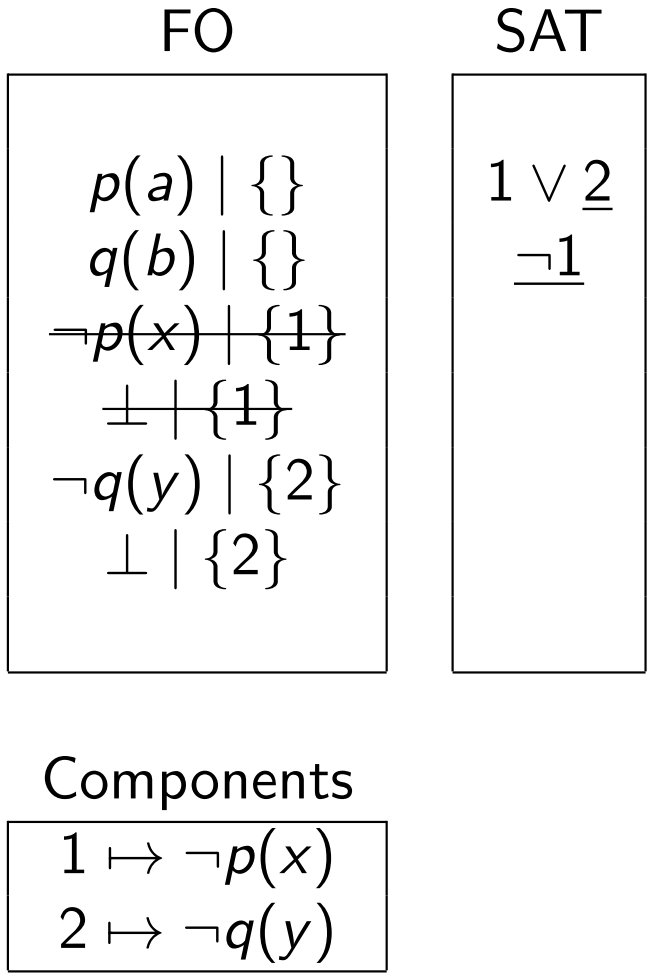

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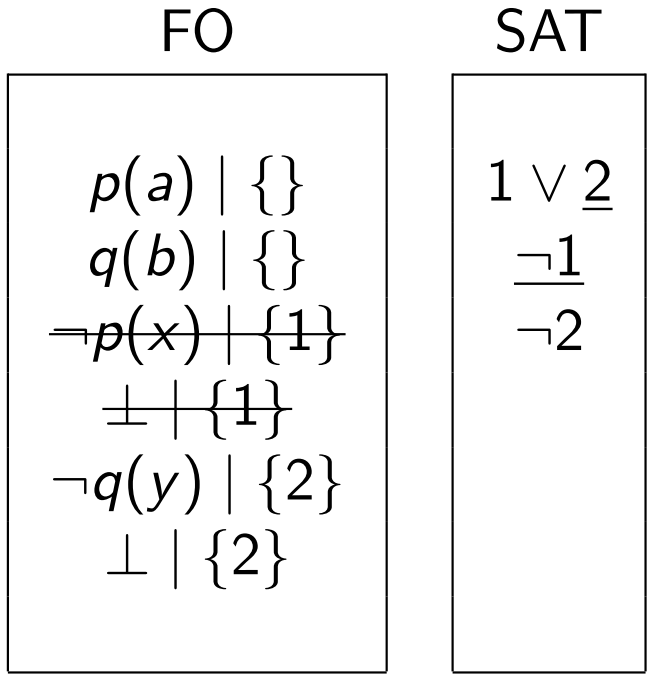

Components

$1 \mapsto \neg p(x)$
$2 \mapsto \neg q(y)$

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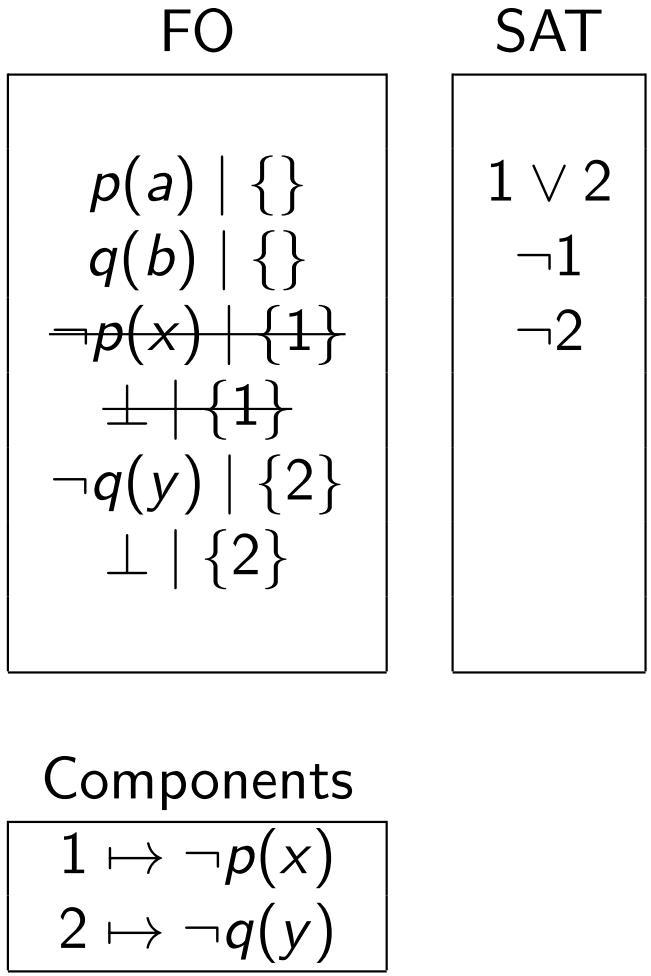

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- Refutation
  - From the SAT solver as we cannot construct a model

FO

$p(a) \mid \{\}$
$q(b) \mid \{\}$
~~$\neg p(x) \mid \{1\}$~~
~~$\bot \mid \{1\}$~~
$\neg q(y) \mid \{2\}$
$\bot \mid \{2\}$

SAT

$1 \vee 2$
$\neg 1$
$\neg 2$

Components

$1 \mapsto \neg p(x)$
$2 \mapsto \neg q(y)$

Important points

- Components are always named consistently (up to variants)
- An inference between two clauses with assertions takes the union of those assertions:

$$\frac{c_1 \mid a_1 \qquad c_2 \mid a_2}{d \mid (a_1 \cup a_2)}$$

- Removal of redundant clauses is conditional in general:
  - assume that c_2 is subsumed by c_1 for clauses $c_1 \mid a_1$ and $c_2 \mid a_2$
  - If $a_1 \subseteq a_2$
    - ★ Then whenever $c_1 \mid a_1$ is backtracked, then $c_2 \mid a_2$ must be also, as an assertion in a_1 is retracted, which must also be in a_2
    - ★ Therefore, we can remove $c_2 \mid a_2$
  - otherwise ($a_1 \not\subseteq a_2$)
    - ★ Later, if an assertion in a_2/a_1 is retracted then $c_1 \mid a_1$ would be backtracked, but $c_2 \mid a_2$ would not be
    - ★ Therefore, we conditionally remove (freeze) $c_2 \mid a_2$
    - ★ Then, if $c_1 \mid a_1$ is later removed we must add (unfreeze) $c_2 \mid a_2$

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Adding components (nonsplittable clauses)

- If we cannot split a clause into components what do we do?
  - Just add it anyway - it might be useful later!
  - Only add it as a component if it has assertions (dependencies) i.e.
    - ★ If we derive $q(x) \vee p(x)|\{2,4\}$ we would add $\neg 2 \vee \neg 4 \vee 8$ (for fresh 8)
    - ★ Helps if 8 is derived again later
  - Only add it as a component if it is a known component i.e.
    - ★ We previously added $2 \vee 4$ for $r(y) \mapsto 2$ and $q(x) \vee p(x) \mapsto 4$
    - ★ We then derive $q(x) \vee p(x)$ and add 4
    - ★ The SAT solver must always choose 4 - simplifying $2 \vee 4$
  - Don't add it

Adding components (ground components)

- If a component is ground it is safe to introduce a name for its negation (not safe for non-ground)
- If we have $p(x) \vee q(a)$ and $\neg p(x) \vee \neg q(a)$ we can add

$$1 \vee 2 \text{ and } 3 \vee 4$$

but it is better to add

$$1 \vee 2 \text{ and } 3 \vee \neg 2$$

- This is something we do not play with, as previous experiments showed that it was consistently a good idea
- Note that a ground component will be a literal

Constructing a model

- In AVATAR the SAT solver is a black box that is allowed to construct any valid model. There are two things we can consider
  - How quickly a model can be constructed
  - What model is constructed
- It is obvious that the model produced has a very large effect on the exploration of the search space.

- We consider two SAT solvers:
  - A native (two watched literals) solver
  - lingeling (with relatively default options)

- We also consider a buffering optimisation that buffers a clause if, either
  - it contains a fresh variable that can be made true, or
  - it is already true in the model

  This may lead to fewer calls to the SAT solver, but will also lead to a different model

Using a model

- As mentioned above, we do not need the whole model
- If we use a partial model we
  - Have to pay to minimise the model
  - But, we potentially add fewer FO clauses and do less freezing/unfreezing
- Choices:
  - Total model
  - Minimised model - a partial model that satisfies all added clauses
  - Minimised model for split clauses - satisfy split clauses only
- Note - partial model is a sub-model of the total one
- If a component was previously asserted, but is now don't care (not in the partial model) we can either
  - eagerly remove it, or
  - leave it there... it might be asserted again later

An overview of the relevant options

- Adding components
  - `ssplitting_nonsplittable_components`
    - When to add a component that is not splittable
    - `known`, `all`, `all_dependent`, `none`
- Constructing a model
  - `sat_solver`
    - Which sat solver is used to construct the model
    - `lingeling` or `vampire`, with `buffering` or not
- Using a model
  - `ssplitting_model`
    - We can minimise the model to reduce the number of components asserted in the FO part
    - `total`, `min_all`, `min_sco`
  - `ssplitting_eager_removal`
    - When using a non-total model we can eagerly remove components no longer mentioned by the model
    - `on`, `off`

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How should we evaluate?

- CASC mode makes use of 47 different (still valid) options
- Many of these have multiple values (some are continuous)
- If we stick only to values selected in CASC mode we have 493,748,224 possible combinations (some of which will not be valid)

- TPTP v6.0.0 has 16,004 FOF and CNF problems

- Giving one minute per experiment that takes 1,500 millennia per value we want to compare
  - That's 144,000 millennia for the experiments here...
  - To finish now we should have started at the end of the Jurassic period

- We need to consider what we are looking for...

Directly comparing options

- If we want to generally compare different values for an option we need to systematically run through the same experiments for each value.

- Massive search space requires us to select a subset of options or problems
  - Select subset of options
    - ⋆ May miss the best strategies
  - Select subset of problems
    - ⋆ May miss the easy/hard problems
  - Probably need to do both to have a reasonable search space

- Alternatively, we could use the CASC-mode approach that attempts multiple strategies, but
  - This suffers from similar restrictions i.e. the results are not generalisable from the chosen strategies.
  - Additionally it is biased as the default values for all of these options were included in the CASC-mode training... so are more likely to be successful.

Searching for improvements

- Observation: A CASC-mode-like approach makes use of many strategies. Therefore, if a strategy can be shown to perform well for some problems, its performance on other problems does not matter.
- If our aim is to solve new problems or solve problems faster then we want to identify cases where new options lead to these interesting cases.
- We can randomly select a strategy, a problem and an option to experiment with. We then vary the values for this option and check whether the result is interesting.
- However, our results are not generalisable.

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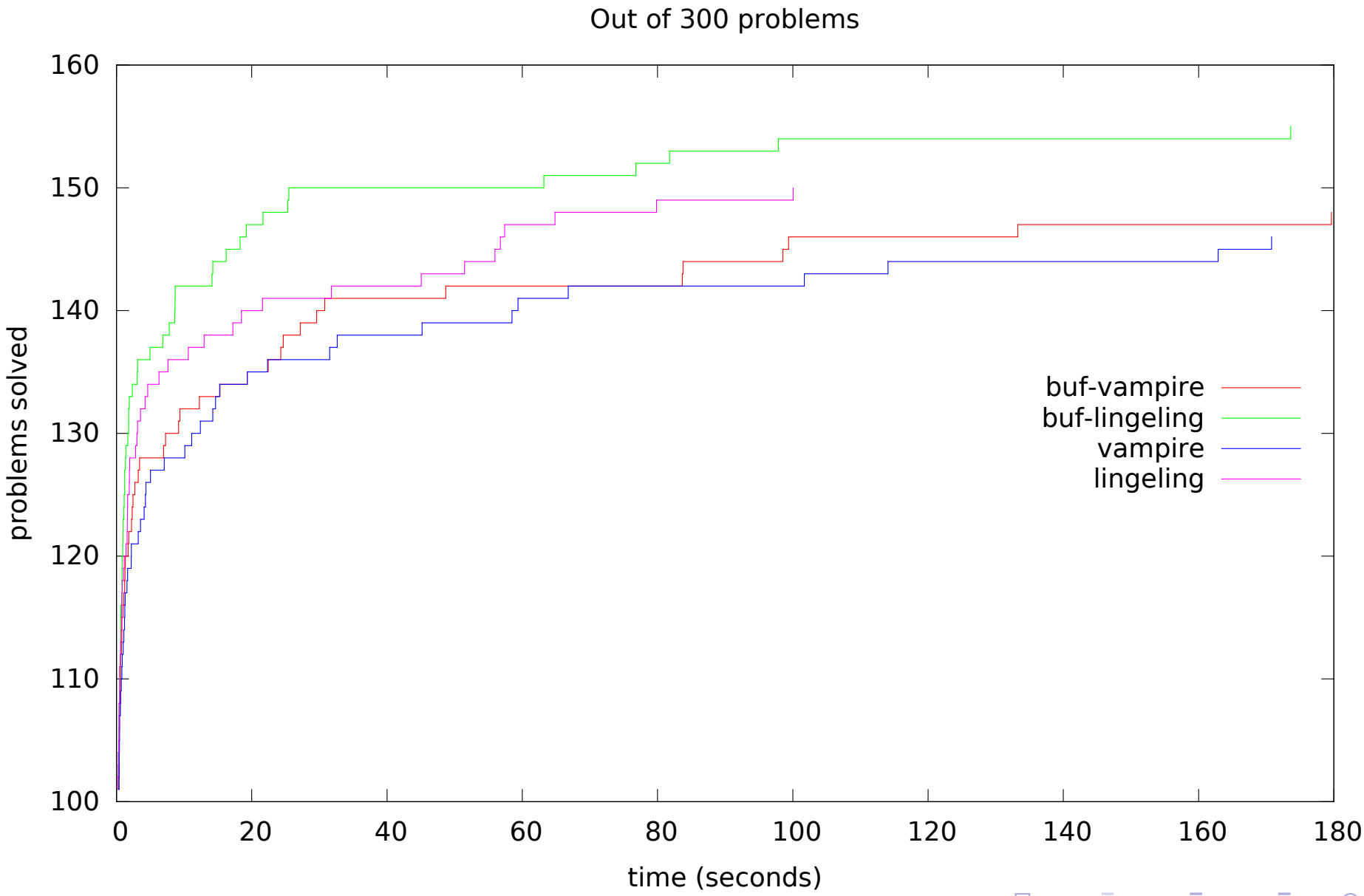
Our experiments

- Systematic
  - Use CASC13 problems
  - Use default options
- Random
  - Construct an experiment by randomly selecting
    - ★ A problem
    - ★ A set of options
    - ★ An experimental option
  - Vary the value for the experimental option
  - However - currently keep other experimental options as default

- These results
  - are not complete
  - can only be generalised within a certain context
  - are not very exciting

SAT solver


Out of 300 problems
problems solved
time (seconds)
100
110
120
130
140
150
160
0
20
40
60
80
100
120
140
160
180
buf-vampire
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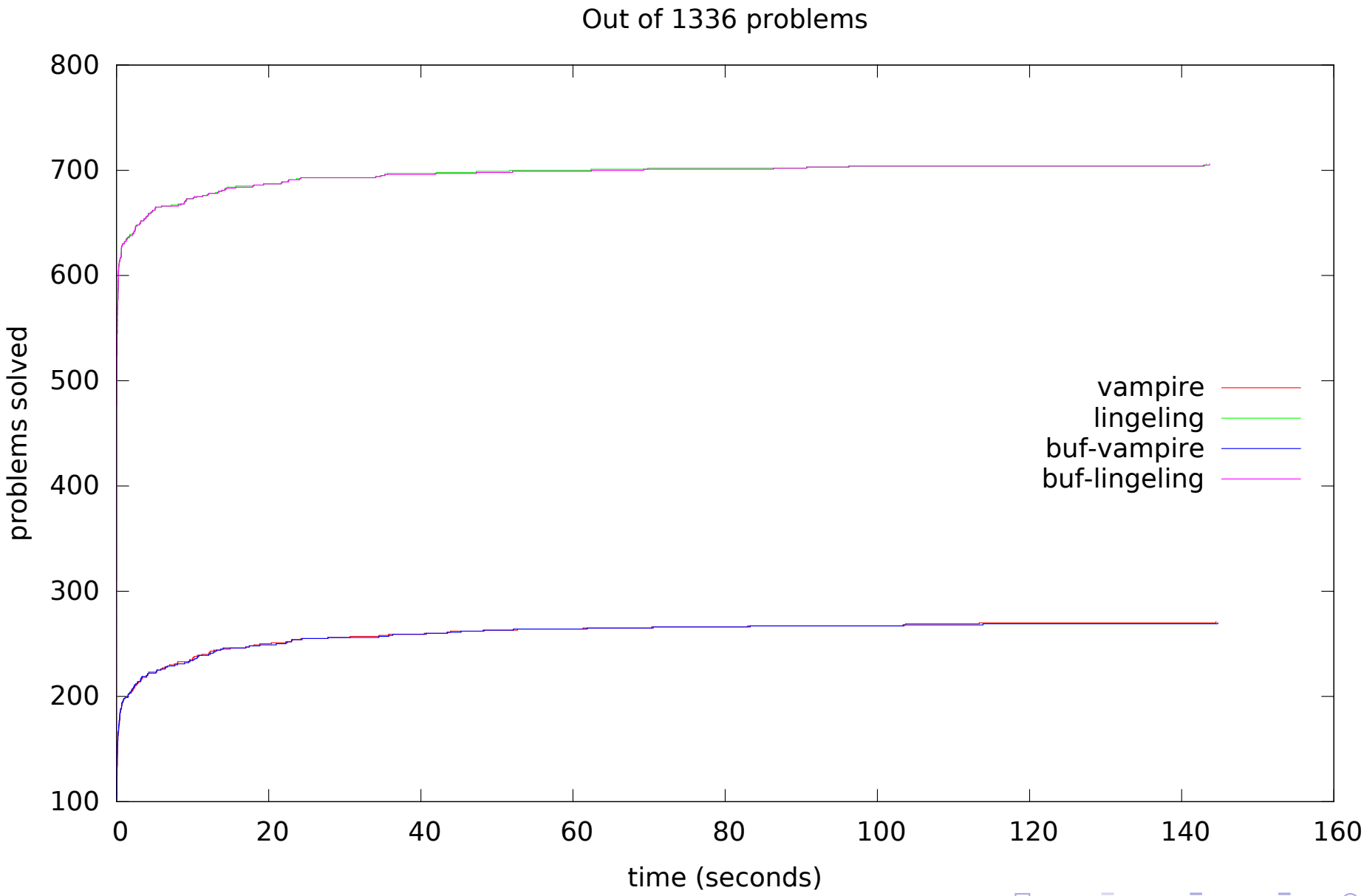
Out of 1336 problems
problems solved
time (seconds)
100
200
300
400
500
600
700
800
0
20
40
60
80
100
120
140
160
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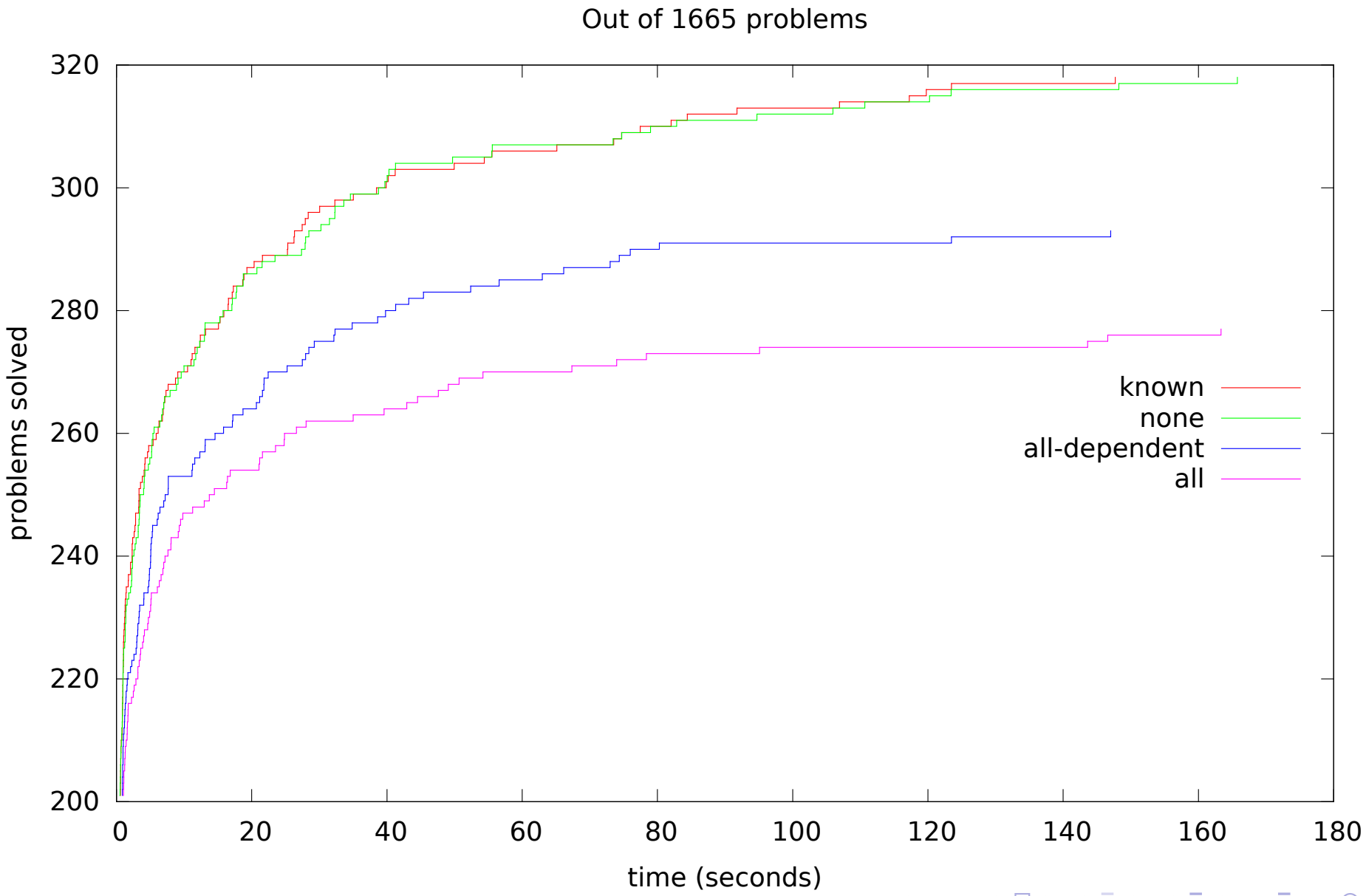
Nonsplittable Components



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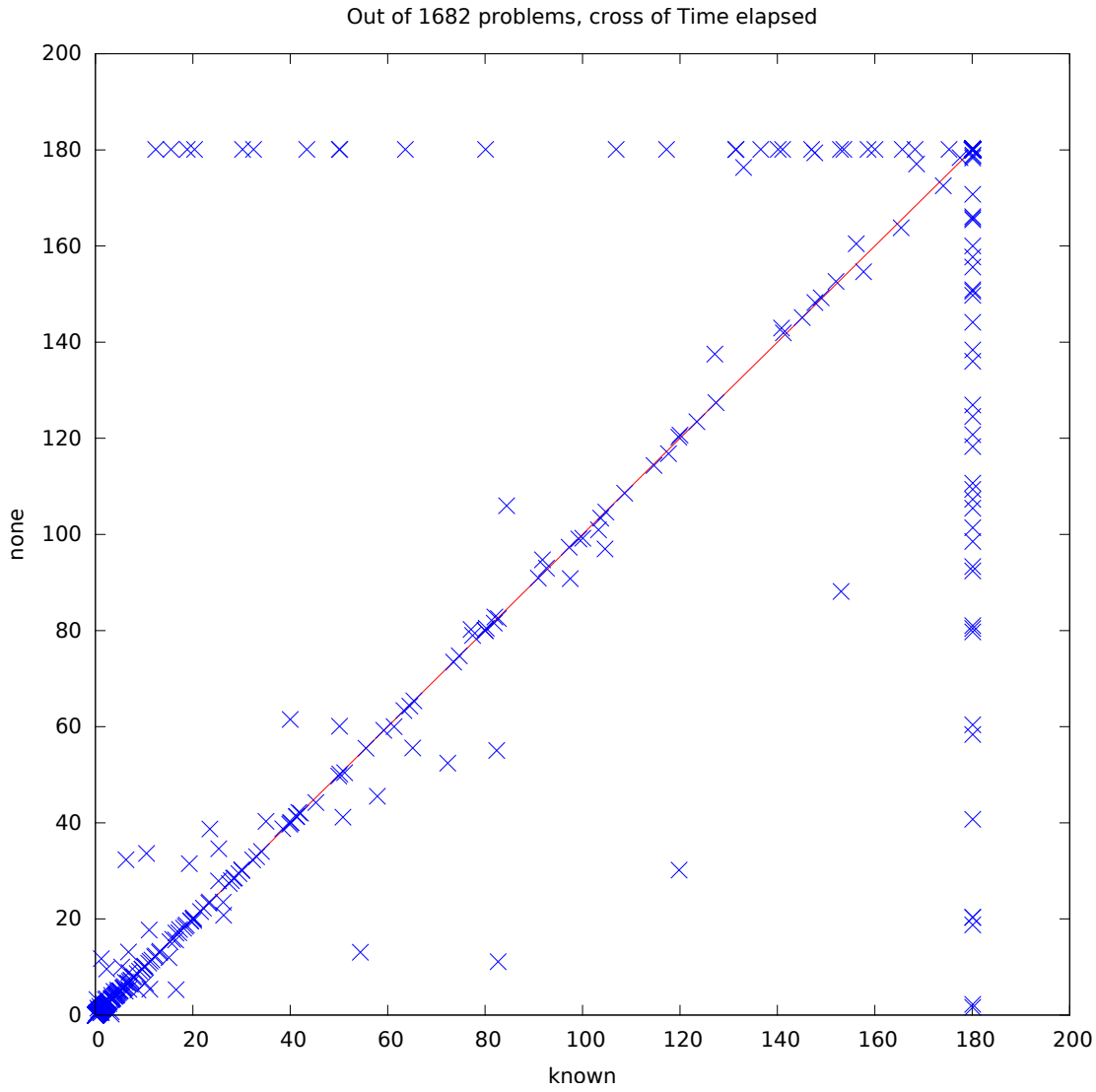

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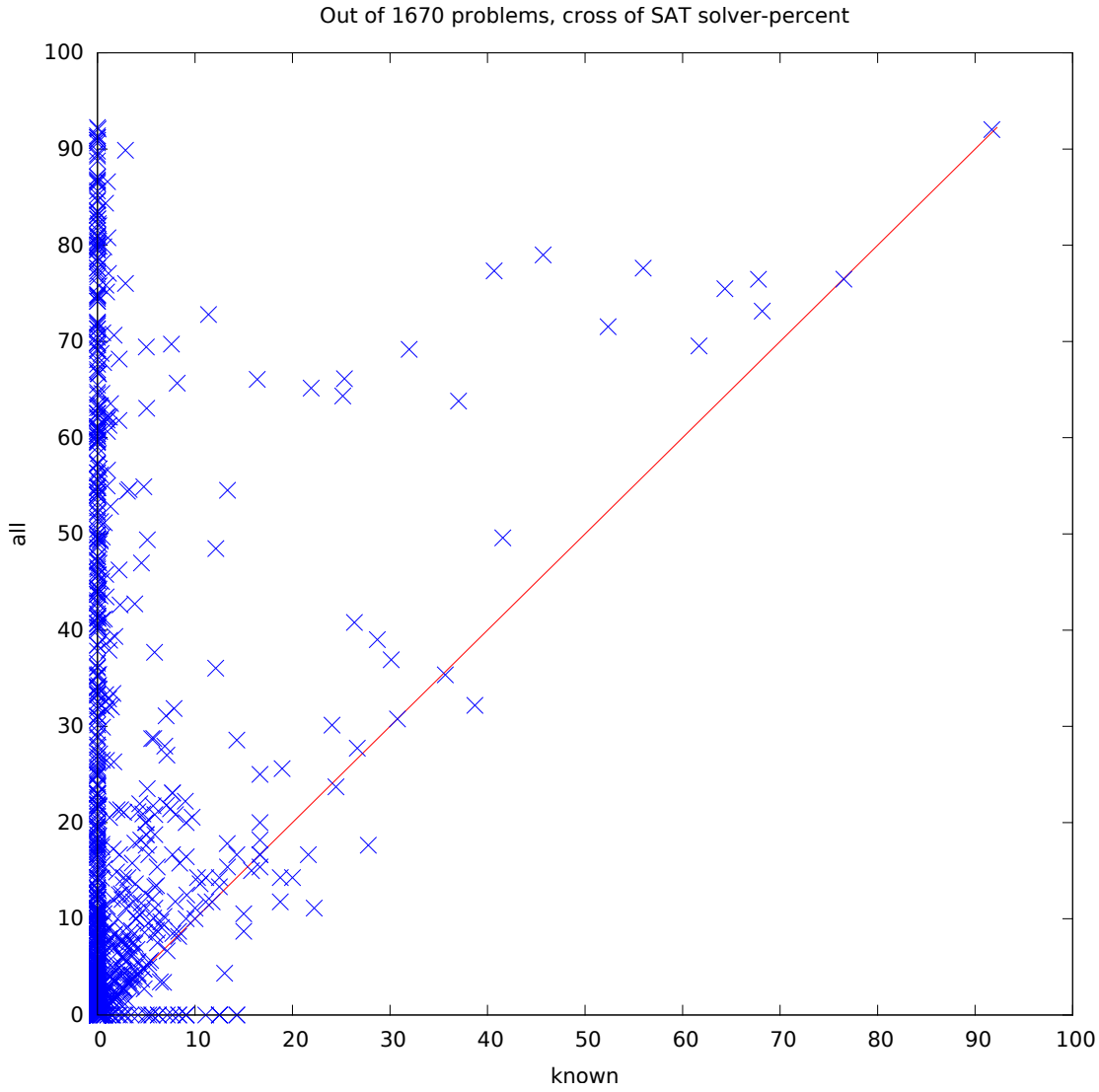
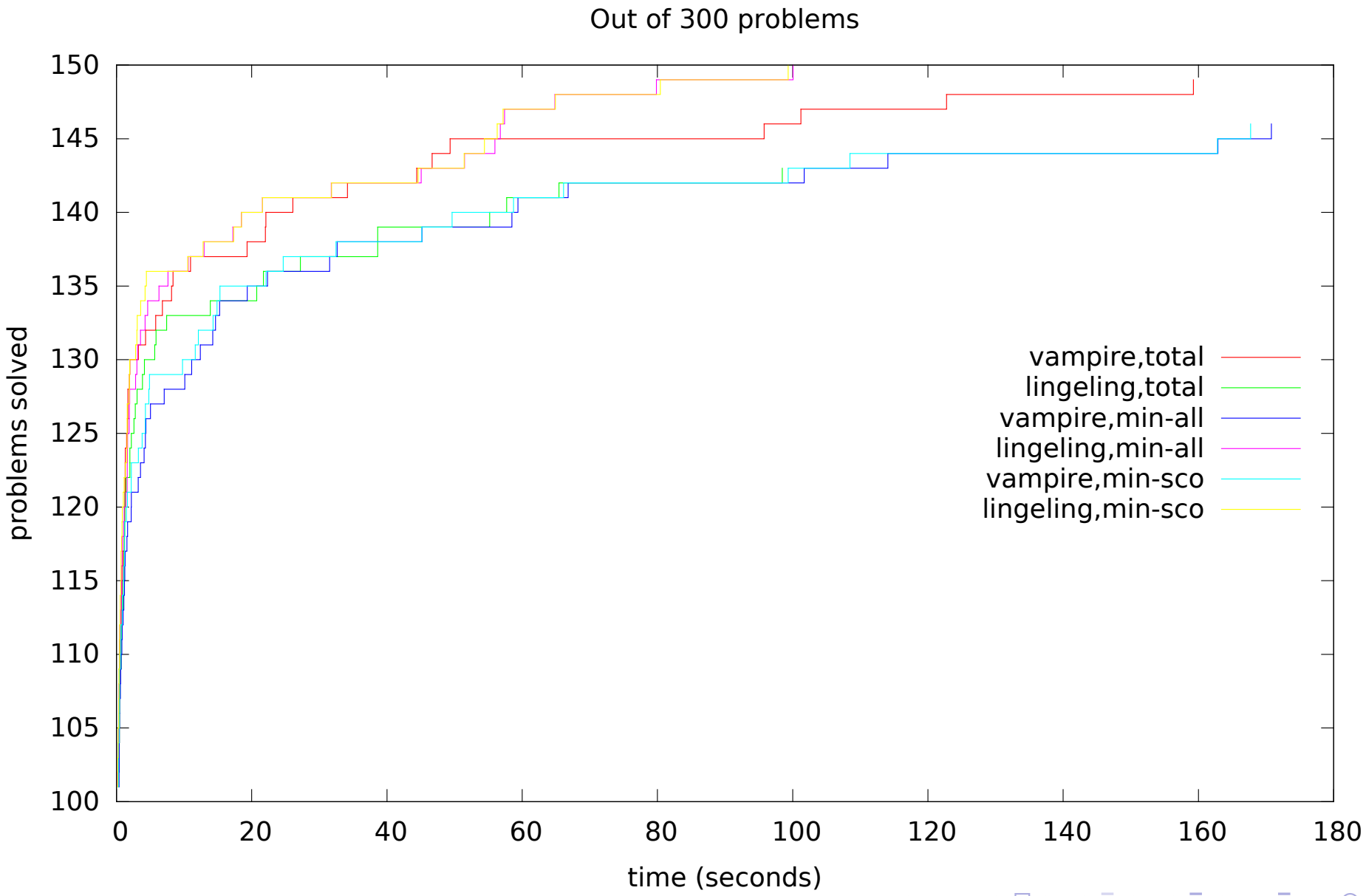


Model minimisation



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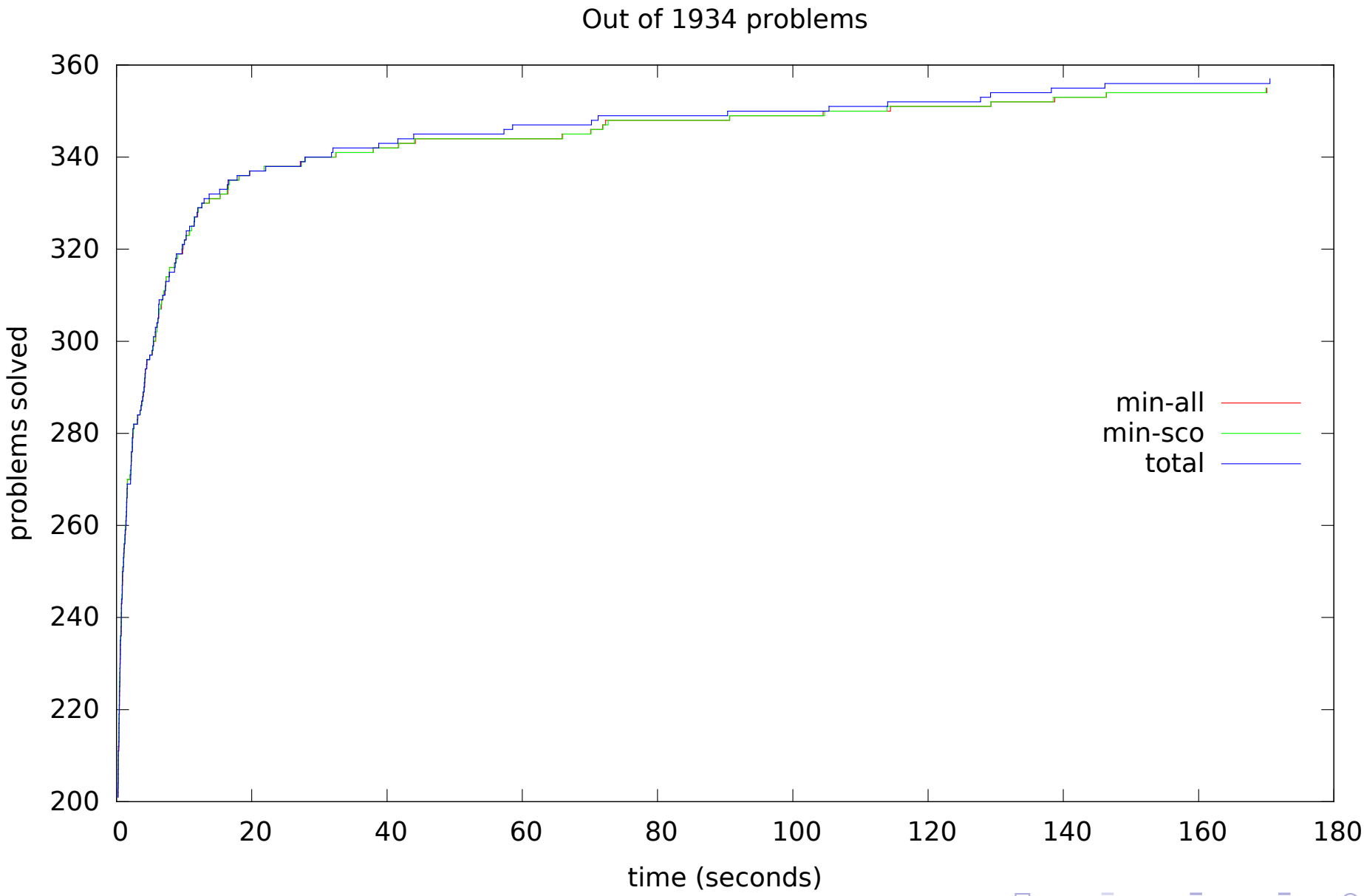
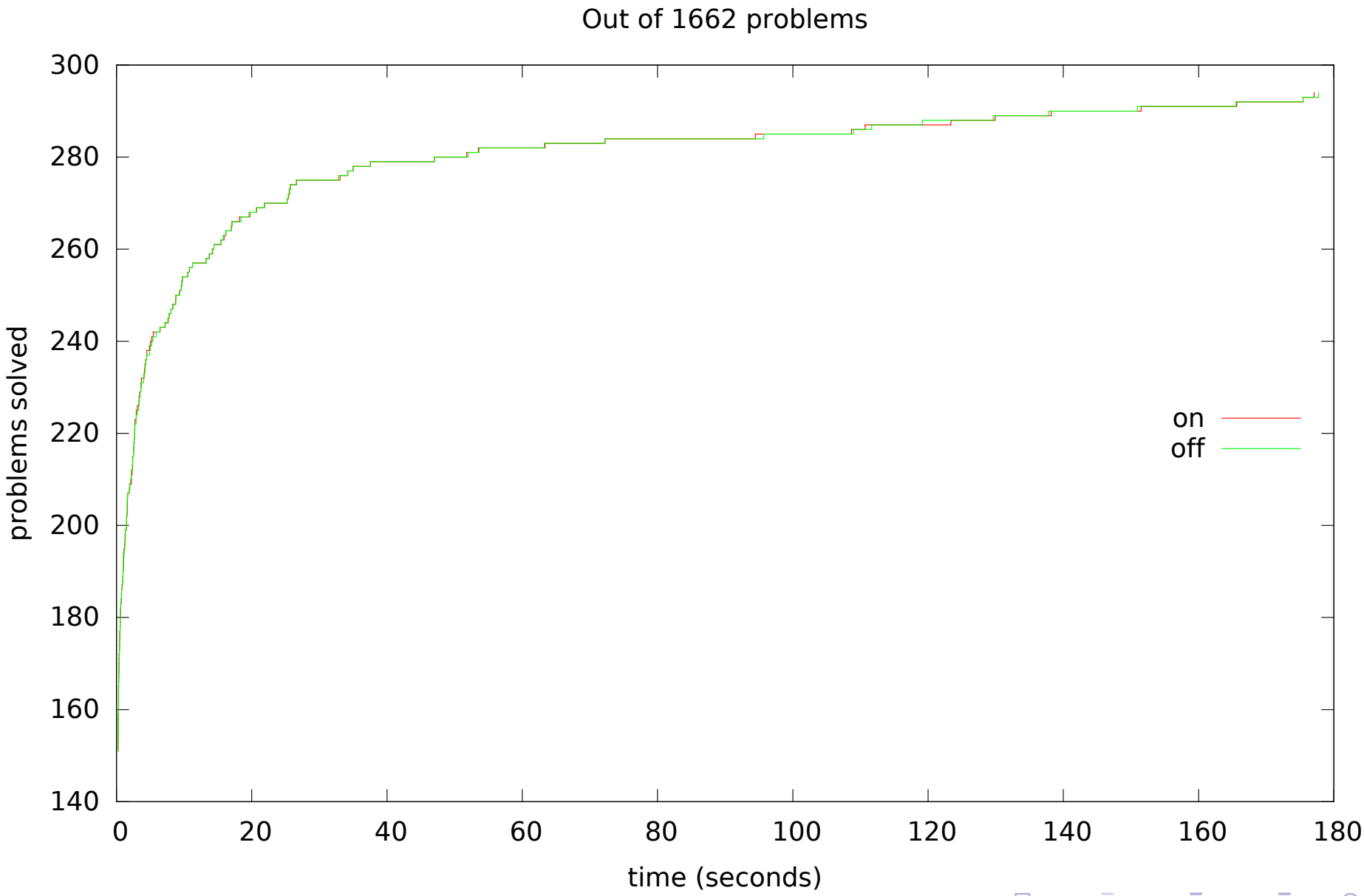


Eager removal



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Unanswered questions

- Can we encourage the SAT solver to construct a model that leads to 'nice' clauses being added to the FO part?
  - i.e. light, small clauses rather than heavy, long ones
- What makes a nice model?
  - How constrained is the model (can we make any difference?)
  - How does the constructed model interact with selection?
- Can we encourage the SAT solver to construct a model with a minimal difference from the previous model?
  - Beyond phase saving and Vampire's backtrack-to-last-valid-choice
- Would giving the SAT solver more information help?
  - i.e. add a clause if one component subsumes another
- Can we do more from a refutation with assumptions?
  - i.e. minimise them, collect multiple refutations in one FO run

Conclusions

- AVATAR is fun
- There are lots of things we can tweak
- Running experiments is difficult
- Our results were not interesting - maybe we asked the wrong questions