GLUCOSE 2.1
Aggressive – but Reactive – Clause Database Management, Dynamic Restarts

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POS – 16 june 2012

A short history of GLUCOSE

- **2009 – Version 1.0**
  - Built on top of MINISAT 2.0
  - Learnt clause measure usefulness: LBD
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    - More agressive cleaning strategy
    - Dynamic
    - Protect promising clauses
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Litteral Block Distance

An observation

- Before CDCL solvers: solvers implement ideas (lookahead, Mom's heuristics...)

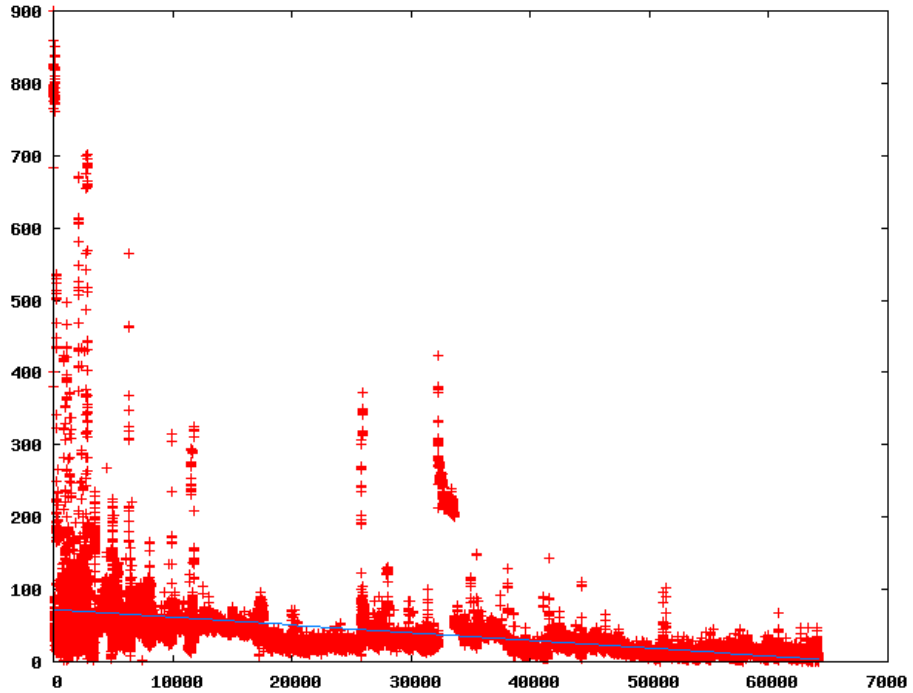
  explaining performances was simple

- With CDCL: lookback solvers (VSIDS heuristics, learning,...)

  explaining performances is hard

We need strong empirical studies in order to understand and improve performances

Some plots . . .



een-pico-prop05-50 – UNSAT – 13,000 vars and 65,000 clauses

- For each conflict, we store the decision level where it occurs
- We also compute the linear regression on these points
- Gives an idea of the global behavior of the computation

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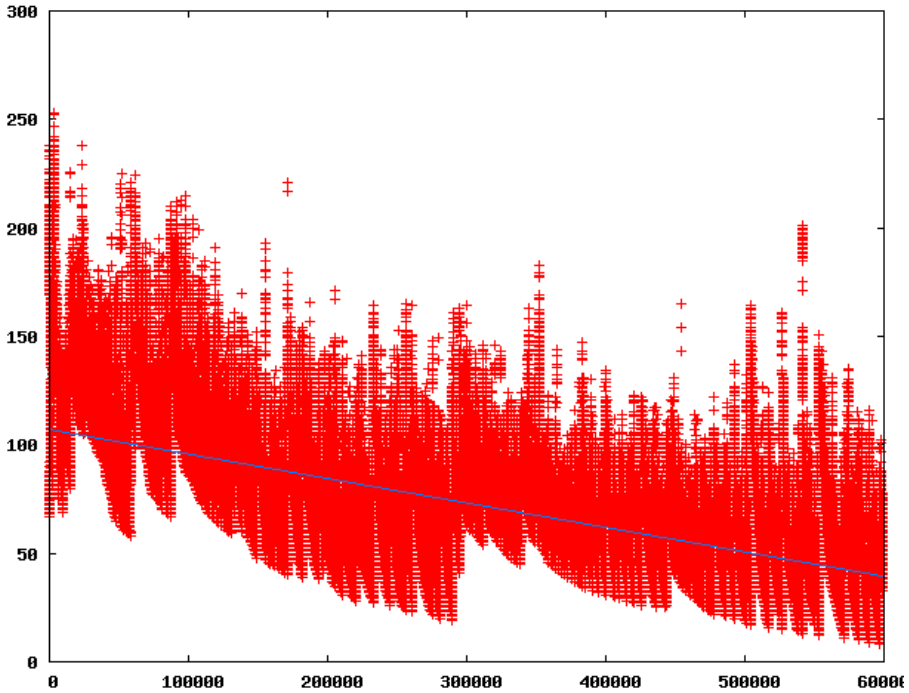

grieu-vmpc-s05-25 – SAT – 625 vars and 76,000 clauses

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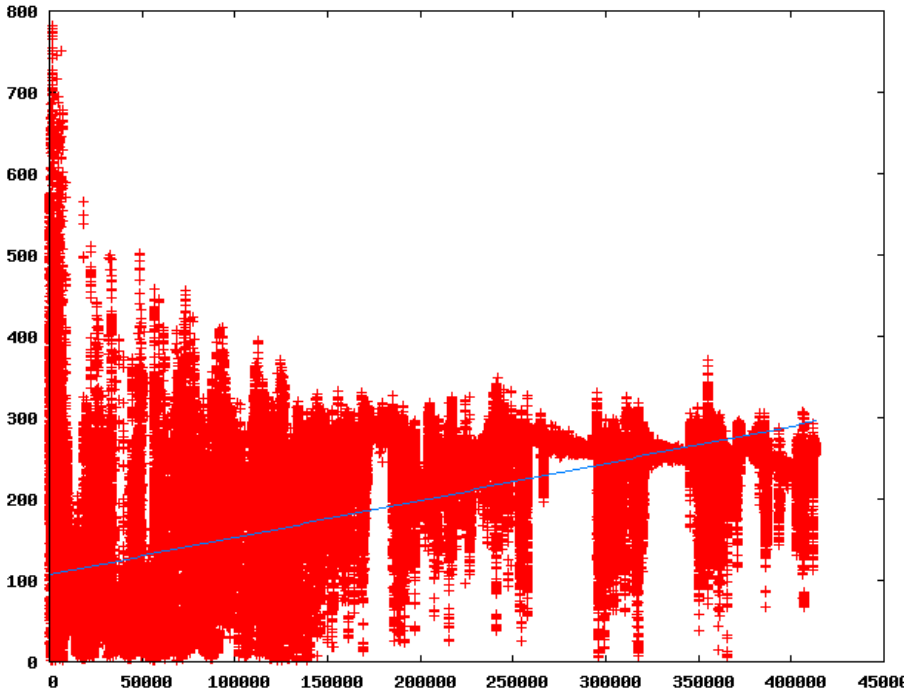

mizh-sha0-35-3 – SAT – 20,000 vars and 120,000 clauses

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- We also compute the linear regression on these points
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Remarks

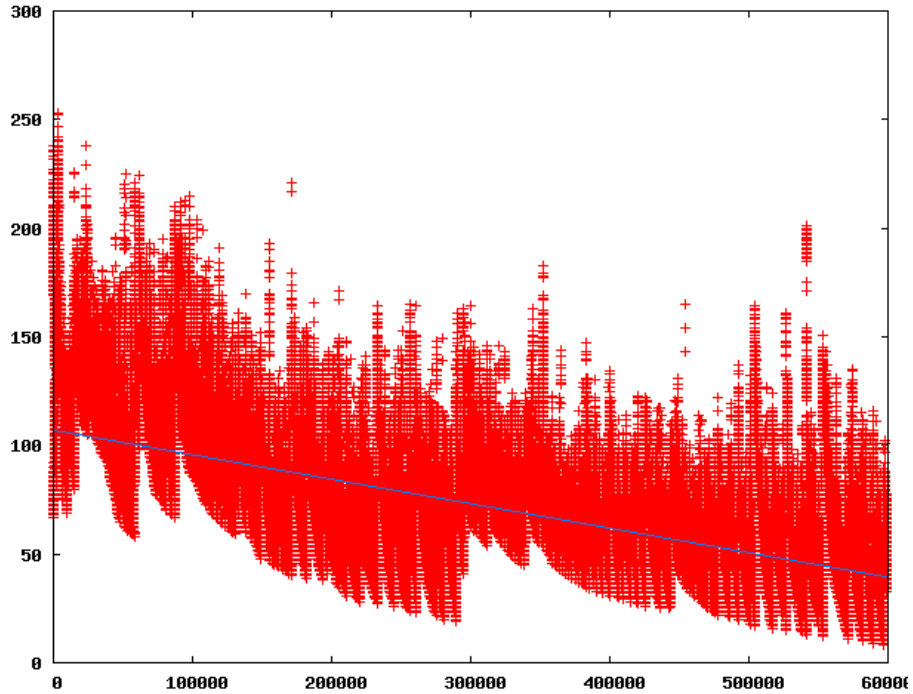
- Of course, we do not expect to feet curves
- We try to make observations of the behavior of a CDCL solver

AND...

Decreasing appear in a lot of problems

Series	#Benchs	% Decr.
een	8	62%
goldb	11	100%
grieu	7	71%
hoons	5	100%
ibm-2002	7	71%
ibm-2004	13	92%
manol-pipe	55	91%
miz	13	0%
schup	5	80%
simon	10	90%
vange	3	66%
velev	54	92%
all	199	83%

The goal



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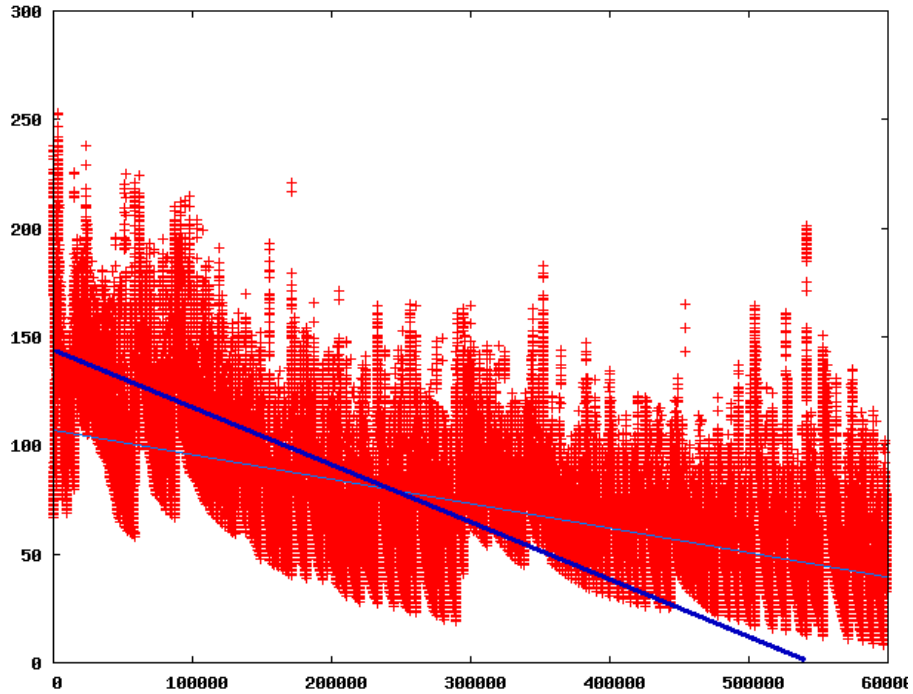

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Intuitions

- A lot of dependencies between variables

  During search those variables will probably be propagated together inside blocks of propagations
- One needs to collapse independent blocks of propagated literals in order to reduce the decision level

The LBD score of a nogood is the number of different blocks of propagated literals

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- LBD=2
  - Only one literal from the last decision level (the assertive one)
  - This literal will be **glued** to the other block
  - binary clauses have LBD equal to 2
- VSIDS + progress saving: this should occurs a lot!!!

Good clauses are GLUE clauses

Managing Learnt Clauses

Previous works

- Before GLUCOSE , managing learnt clauses was not considered as an important component of CDCL solvers
- Previous measures were not so accurate
- Clause database size followed a geometric progression
- Dependent of the size of the input formula: No cleaning are performed for huge formulas

Use the LBD measure

Agressive strategies

- Small LBD are good ones
- In case of equality, prefer clauses with recent activity (VSIDS like)
- No matter the size of the initial formula
- Remove half of learnt clauses every :
  - GLUCOSE 1.0 (2009): $20000 + 500 \times x$ conflicts
  - GLUCOSE 2.X (2011): $4000 + 300 \times x$ conflicts

A first step towards a dynamic management

- Performances of GLUCOSE heavily depends on the quality of LBD
- A very good indicator on many instances
- However, it may not be discriminating enough
- A special case:
  - Half of clauses have a LBD less than 3 (we are going to remove potentially good clauses)
  - Too much good clauses
- We need to keep more of them
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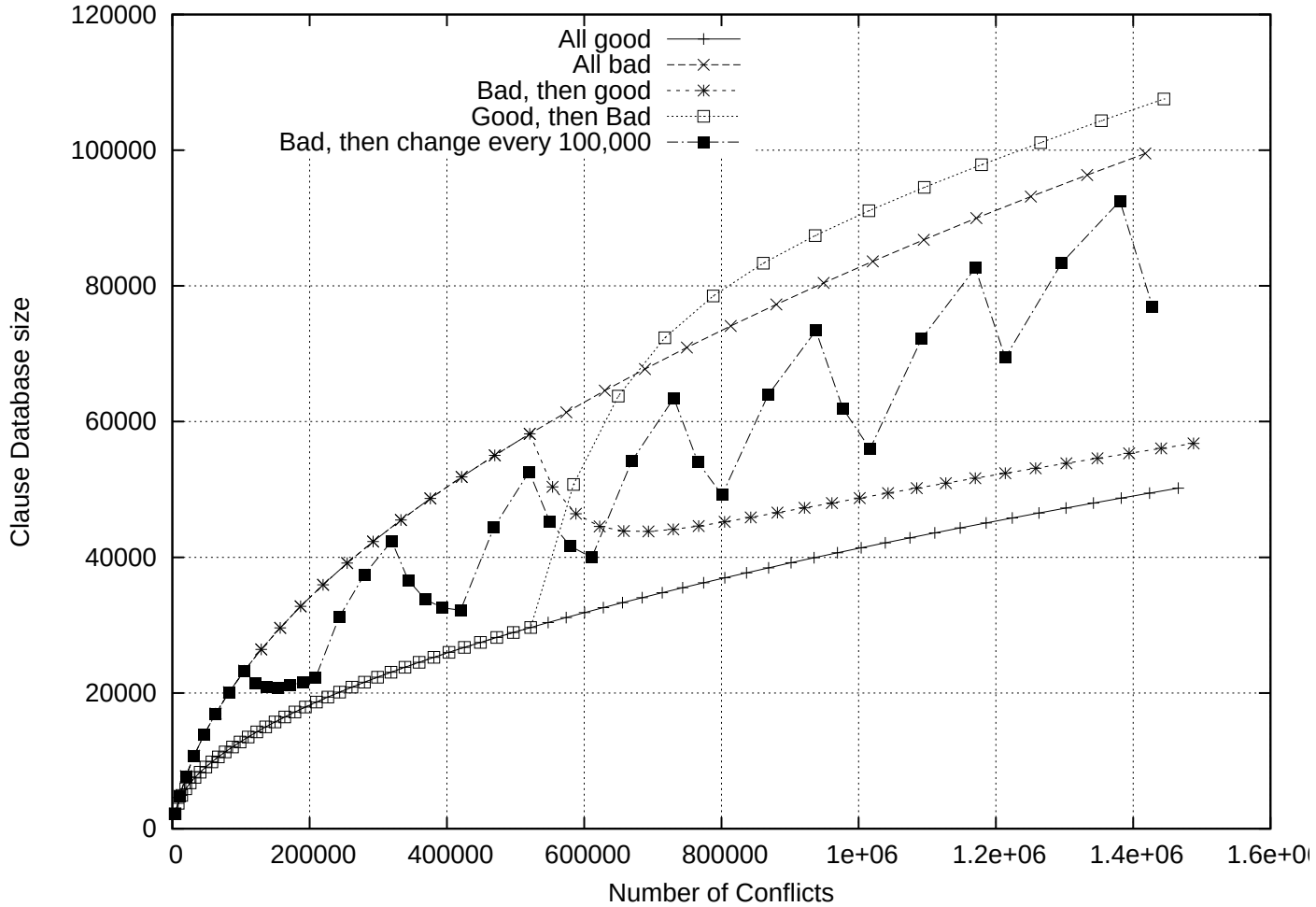
When performing cleaning??

Behavior


All good
All bad
Bad, then good
Good, then Bad
Bad, then change every 100,000
Clause Database size
Number of Conflicts
0
20000
40000
60000
80000
100000
120000
0
200000
400000
600000
800000
1e+06
1.2e+06
1.4e+06

Protect promising clauses

- Reminder: LBD is computed when the clause is learnt
- We computed it again it when a clause is used during BCP
- We change it, if it becomes smaller
- Such clauses seem interesting
- They are protected for one round

Restarts

Introduction

- Initially, restarts were introduced to prevent trashing
- Now, restarts must be seen as dynamic rearrangements of variables dependencies
- Restarts are more and more frequent
- GLUCOSE uses a dynamic restart strategy

Targetting UNSAT

- GLUCOSE aims to produce glue clauses
- If recent learnt clauses are bad (big LBD) a restart is performed
- We use
  - bounded queue (of size X) called `queueLBD`
  - the sum of all LBD clauses `sumLBD`

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compute learnt clause c;
sumLBD+=c.lbd();
queueLBD.push(c.lbd());
if(queueLBD.isFull() && queueLBD.avg()*K>sumLBD/nbConflicts) {
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    restart();
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- Average over last X LBD become too big wrt total average

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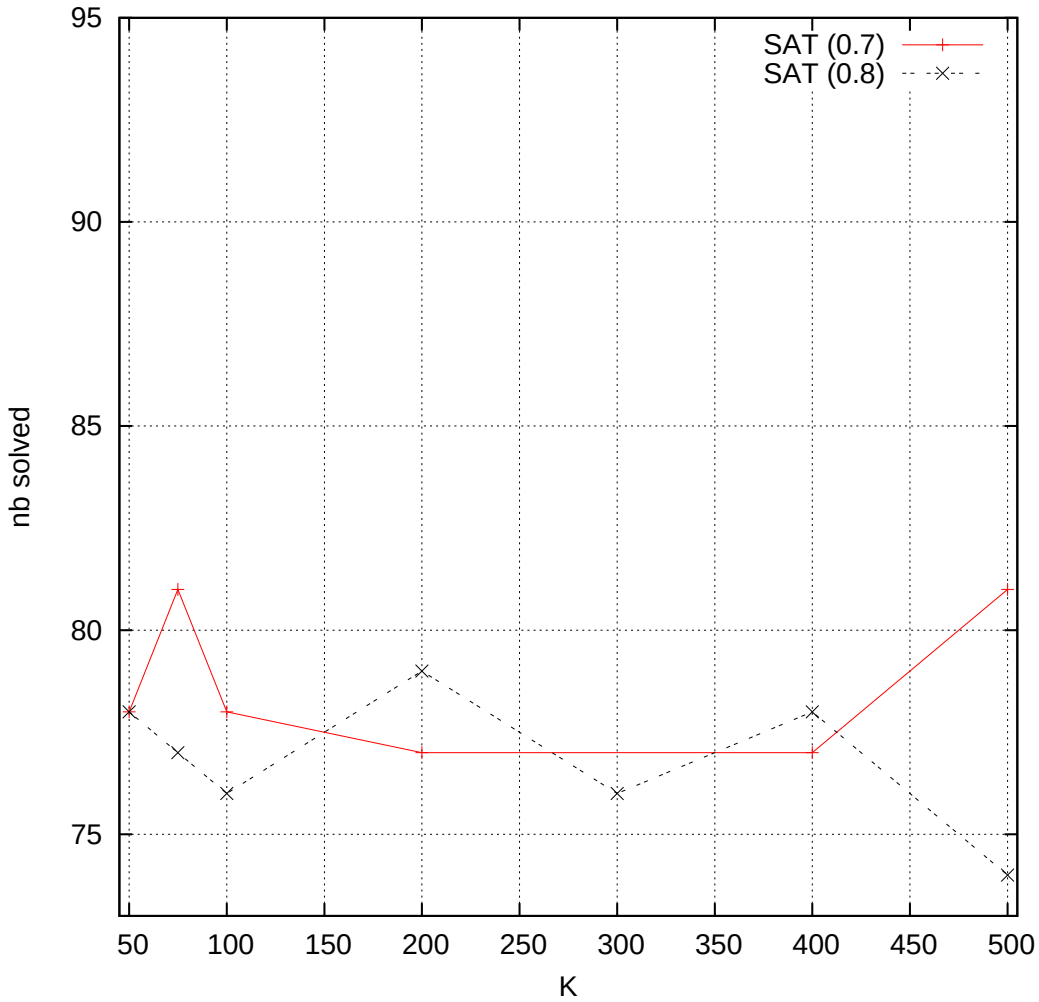
- GLUCOSE 1.0 and 2.0: X=100 and K=0.7
- GLUEMINISAT and GLUCOSE 2.1 : X=50 and K=0.8

Impact of different K and X



SAT 2011 Application benchmarks (limit 900 seconds)

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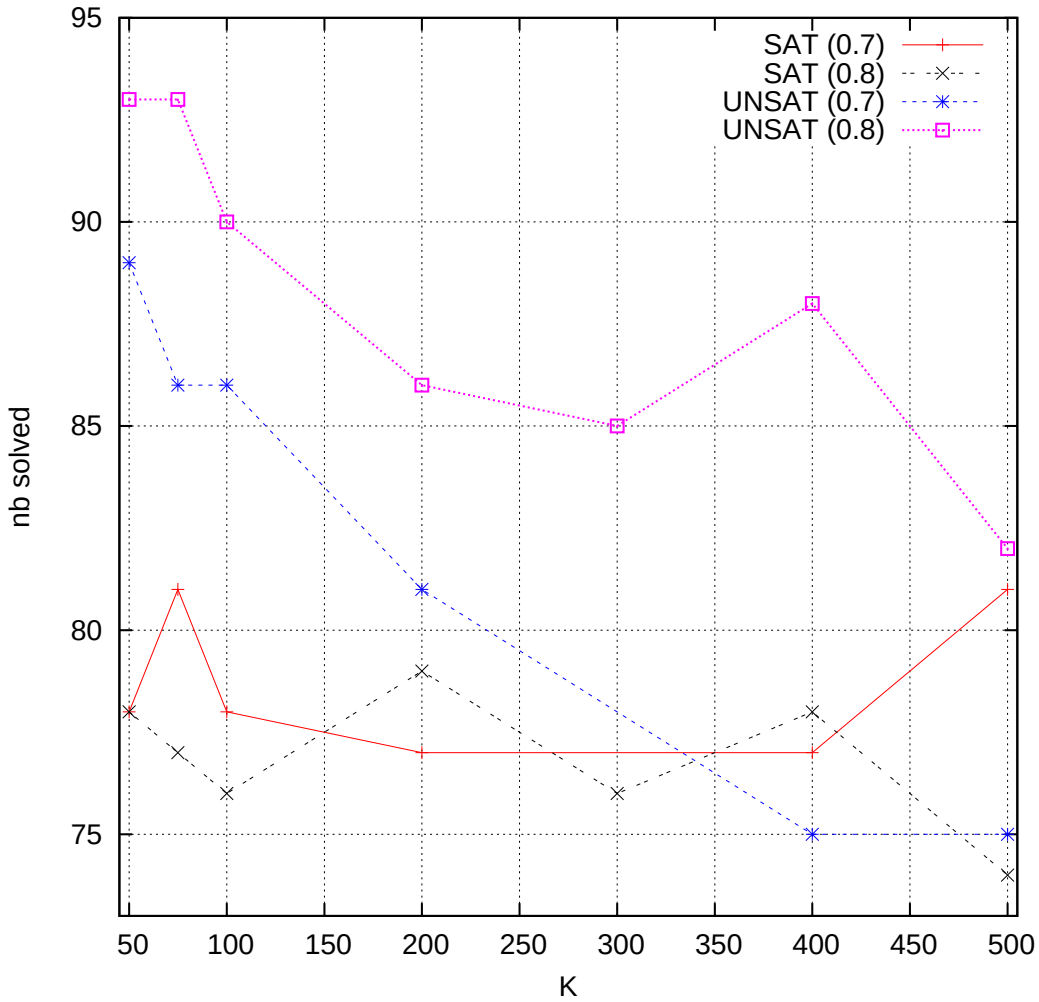

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Targeting SAT too (NEW in GLUCOSE 2.1)

- Frequent restarts seems not very good in case of SAT instances
- Some lessons of SAT 2011 competition – Second Phase, SAT instances
  - CONTRASAT: 1^{st} with 99 instances
  - GLUCOSE : 10^{th} with 94 instances
  - 6 of first ten solvers come from minisat hack (luby restarts)
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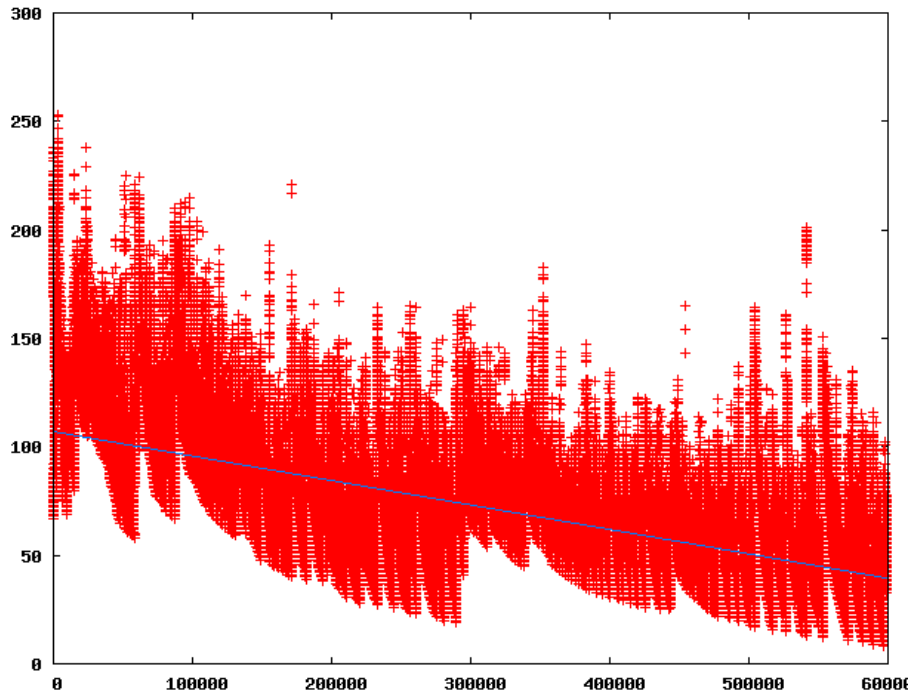
  - 18 instances separate 1^{st} and 10^{th} in UNSAT
- Agressive clauses deletion: some clauses may be bad for UNSAT but good for SAT
- Agressive restarts: some global assignments can be dropped!!

Delay restarts if total of assignments suddenly increase

Example

- Now, suppose dots represent trail stack assignment size



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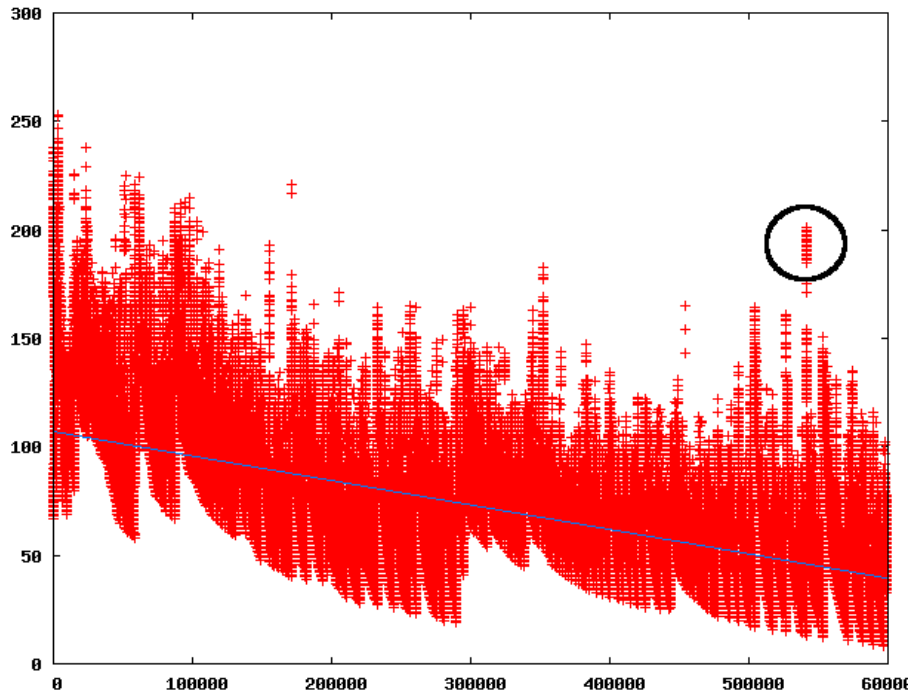

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- GLUCOSE is unlucky, a restart is performed!

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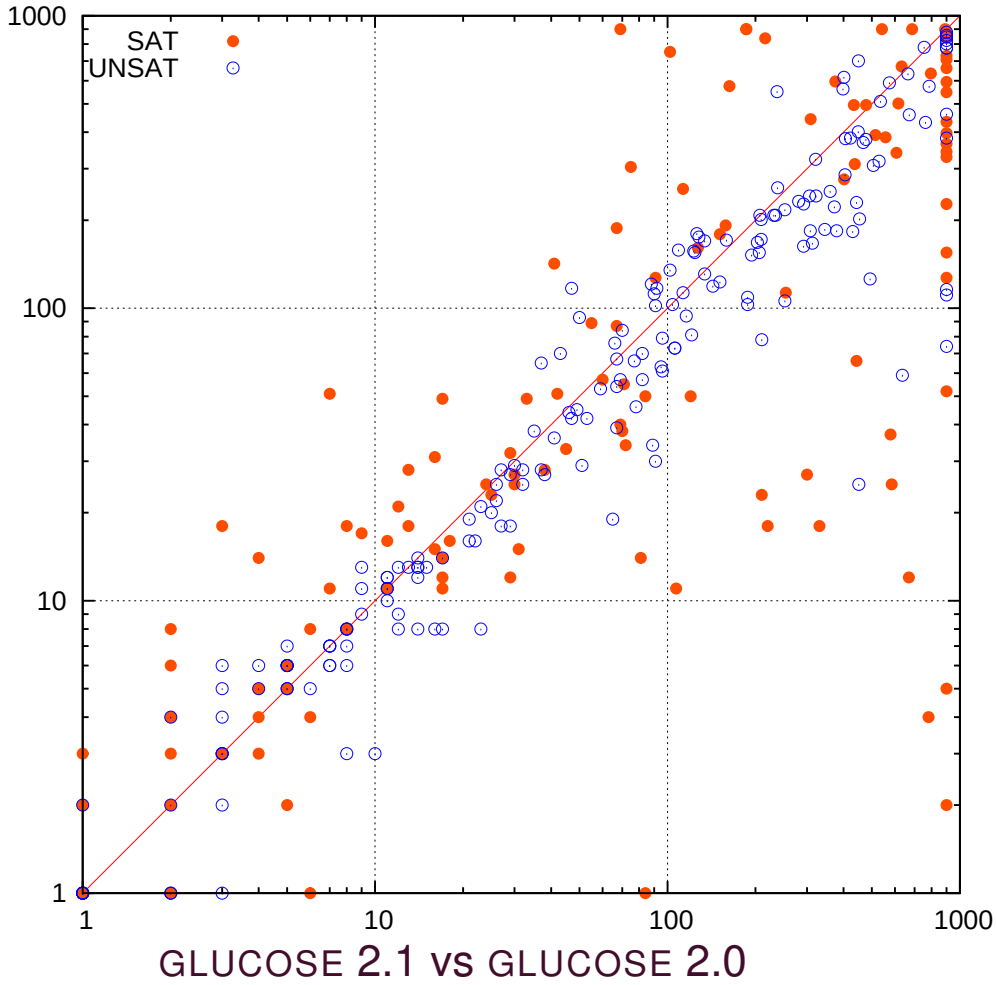
- Y=5000 and T=1.4 appears to be good

Conclusion

Evolution of GLUCOSE



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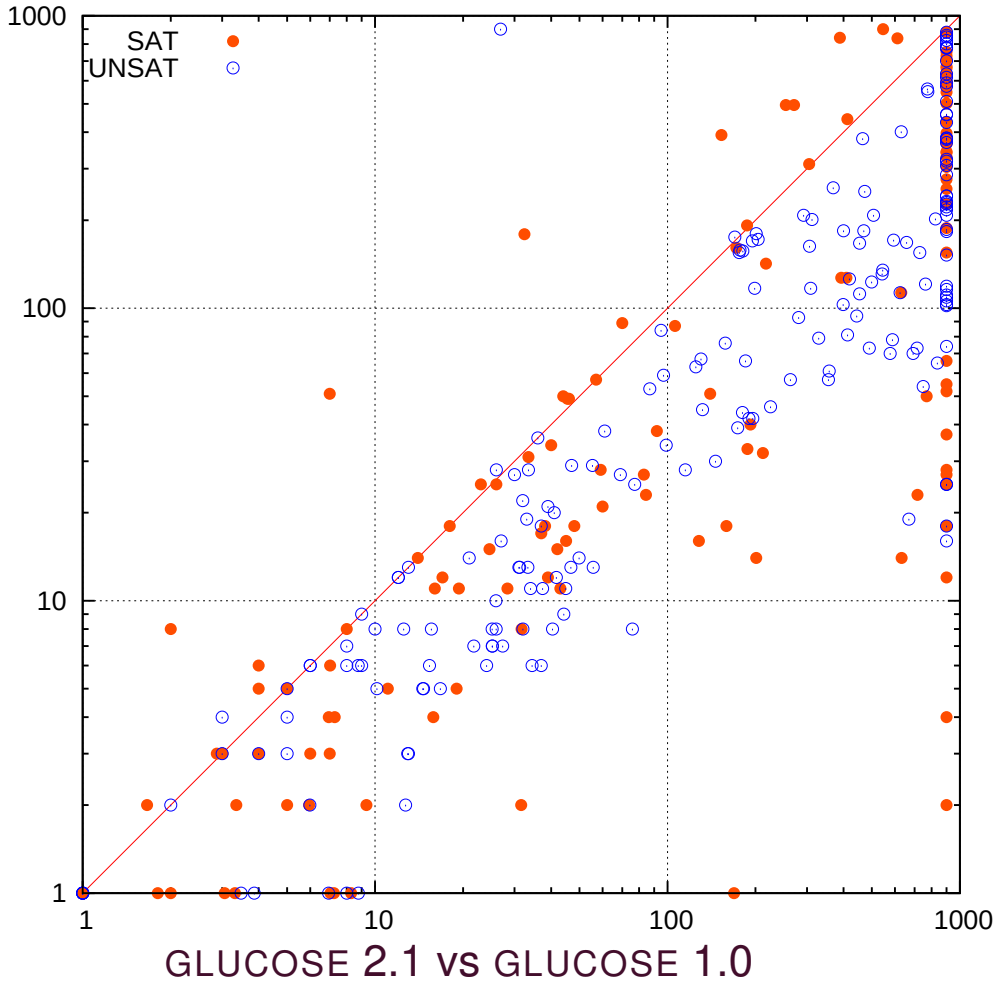

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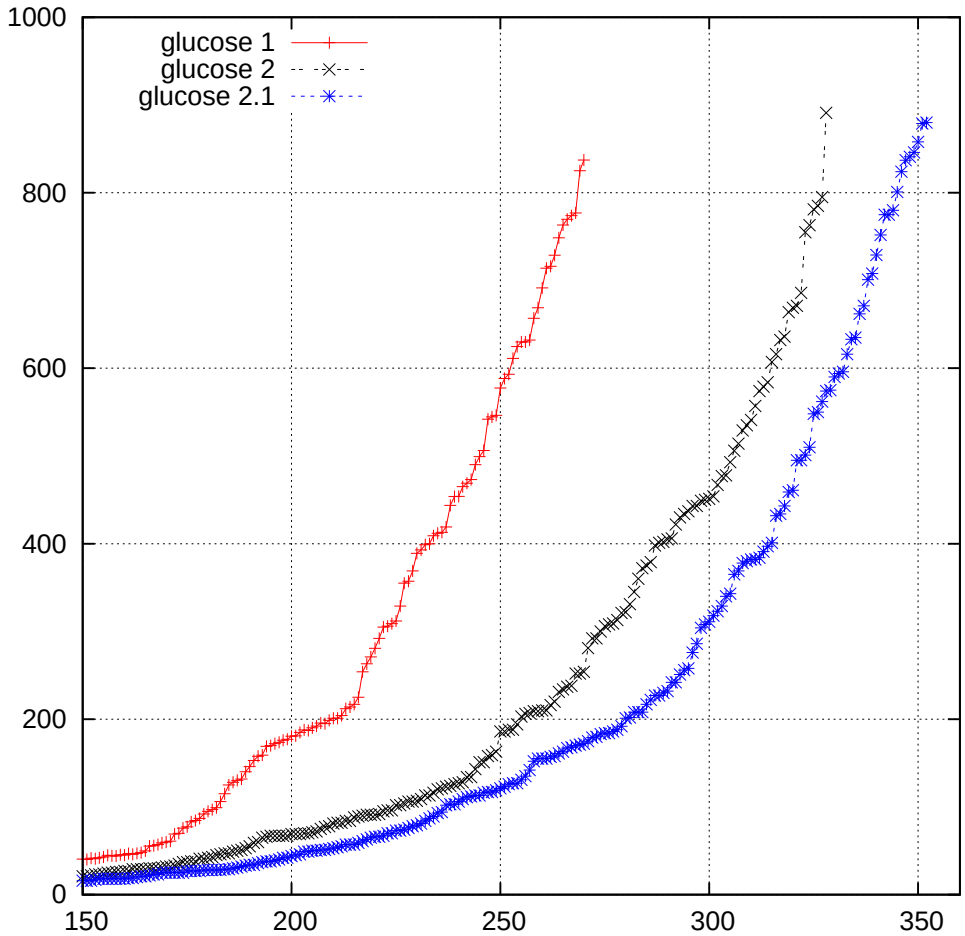

SAT 2009 + SAT 2011 application benchmarks (536, non redundant)

Evolution of GLUCOSE

Version	SAT	UNSAT	TOTAL
1.0	113	157	270
2.0	136	192	328
2.1	**148**	**204**	**352**

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- A possible controversy
  - Are CDCL solvers still complete?
    - Very frequent restarts
    - Many deleted clauses (more than 93% for GLUCOSE (total for SAT 2011 Application benchmarks))
  - Are CDCL solvers closer to DPLL62 or local search??