# The Third (Open) Answer Set Programming Competition

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Dipartimento di Matematica, Università della Calabria

11th International Conference on Logic Programming and Nonmonotonic Reasoning

presented by G. Ianni, F. Ricca

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# Outline



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# The Third ASP Competition

## An event gaining momentum and maturity

- Two tracks: the System Competition Track and the Model and Solve Competition Track
- Host institution: the Dipartimento di Matematica at Università della Calabria (one of the proud homes of the DLV System)

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- System Track: 11 Participants + 7 Non-competing
- M&S Track: 6 Teams
- The host institution stood neutral

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# Benchmark Selection - I

- 35 problems (of which 18 for the System track only):

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## Field of provenance

- **Database/Information extraction**: Grammar-BasedInformationExtraction, Weight-AssignmentTree
- **Planning/Routing**: AirportPickup, HanoiTower, Sokoban, FastFood, Solitaire, KnightTour, Hydraulic Planning
- **Classic graph problems**: Reachability, MaximalClique, GraphColouring, CrossingMinimization, StableMarriage
- **Biology/Academy**: PartnerUnits, MinimalDiagnosis, ReverseFolding
- **Scheduling/Packing**: DisjunctiveScheduling, IncrementalScheduling, Packing
- **Puzzle inspired**: Tangram, MagicSquareSets, MazeGeneration, Numberlink, GeneralizedSlitherlink, Tomography

# Benchmark Selection - II

## Difficulty level

- Some problems (20) came from the 2nd Competition: harder instances and/or harder variant introduced whenever necessary;

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Polynomial, NP, Beyond-NP ($\Sigma_2^P$), Optimization (Model Track only):

## Complexity/Type

- (Pure) Polynomial (5 problems). Natural declarative encoding is polynomial: mostly measures efficiency of grounders;
- (Known) Polynomial (2 problems). Natural declarative encoding includes guessing. Measures 'convergence' capabilities of systems (StableMarriage, PartnerUnitsPolynomial)
- NP (19 problems): the "core" class.
- Beyond-NP/Optimization (2 + 6 problems).

# Scoring

Each participant is awarded the sum of scores per each benchmark domain, naturally weighing NP (>50%) more than P (20-25%) and Beyond-NP/Opt ( 20-25% ).

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## Instance Quota

$$S_{solve}(P) = \frac{N_S}{N}$$

$N_S$ = number of solved instances for problem $P$, $N$ = total number of instances for problem $P$.

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## Instance Quota

$$S_{solve}(P) = \frac{N_S}{N}$$

$N_S$ = number of solved instances for problem $P$, $N$ = total number of instances for problem $P$.

## Time Quota

$$S_{time}(P) = \frac{1}{N} \sum_{i=1}^{N} \left(1 - \left(\frac{\log(t_i + 1)}{\log(t_{out} + 1)}\right)\right)$$

$t_{out}$ = maximum allowed time, $t_i$ on instance $i$, $N$ as above.

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# More on the time quota

Awards faster systems logarithmically. For $t_{out} = 600$ and $S_{time}$ normalized to 50:

| Time (sec) | Score (0-50) |
|---|---|
| 0 | 50.00 |
| 0.9 | 45.00 |
| 2.6 | 40.00 |
| 5.8 | 35.00 |
| 11.9 | 30.00 |
| 23.5 | 25.00 |
| 45.4 | 20.00 |
| 87.1 | 15.00 |
| 166.1 | 10.00 |
| 315.9 | 5.00 |
| 527.8 | 1.00 |
| 562.7 | 0.50 |

Similar as the log-based score proposed for SAT Competition 2009: naturally tends to award significant time score only to very fast systems.

# Optimization Quota

$S_{opt} =$

- Inconsistent instances: a flat score of $\frac{1}{2N}$ for detecting it;
- Satisfiable instances:
  - A flat reward of $\frac{1}{4N}$ for finding a witness;
  - A flat reward of $\frac{1}{4N}$ for finding an optimal witness;
  - A quality reward of

$$\frac{1}{2N} e^{\frac{B_i - Q_i}{Q_i}}$$

depending on the distance of the solution cost $Q_i$ from the best solution cost $B_i$ for instance $i$.

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# More on Optimization Quota

Some additional score awarded to solutions within 3% of the *measured* optimal solution. Finding an optimum is strongly rewarded. For $N = 1$ and $S_{opt}$ normalized within 0 and 50:

| Quality Gap (%) | Score (0-50) |
|---|---|
| 0 | 50 |
| 1 | 22 |
| 2 | 16 |
| 3 | 14 |
| >4 | 13 |

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# Driving Principles of the System Track

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## Language standardization

- Try to enlarge the number of acknowledged common constructs of ASP systems;

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- Try to enlarge the number of acknowledged common constructs of ASP systems;

## Compare systems in fixed conditions

- Fixed input problem encoding;
- Fixed default heuristics and internal settings;

# From driving principles to rules

## Rules

- Language fixed to ASP-Core (larger ASP-RfC draft as a proposal);
- Organizers provide ASP-Core encodings for each benchmark;
- Forbidden to look for syntactic aspects of problem encodings in order to trigger ad-hoc heuristics (e.g. predicate names).

# From driving principles to rules

## Rules

- Language fixed to ASP-Core (larger ASP-RfC draft as a proposal);
- Organizers provide ASP-Core encodings for each benchmark;
- Forbidden to look for syntactic aspects of problem encodings in order to trigger ad-hoc heuristics (e.g. predicate names).

## Scoring

For benchmark $P$, a participant is awarded $S(P)$ according to:

$$S(P) = \alpha S_{solve}(P) + (100 - \alpha) S_{time}$$

Where $\alpha = 50$. Note that the logarithmic behavior of $S_{time}$ naturally weighs this term less than $S_{solve}(P)$.

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# Participants

- **claspd**, **claspfolio** and **clasp**, Potassco team at University of Potsdam
- **CModels** and **SUP**, University of Kentucky
- **IDP**, KRR Group at KU-Leuven
- **lp2*** systems and **smodels**, AAlto University, former Helsinki UT

# Polynomial Problems

# Polynomial Problems

| System | P | P-inst | P-time |
|---|---|---|---|
| **clasp** | 213 | 150 | 63 |
| **claspfolio** | 209 | 150 | 59 |
| **claspd** | 206 | 145 | 61 |
| **sup** | 195 | 140 | 55 |
| **lp2sat2gminisat** | 185 | 140 | 45 |
| **cmodels** | 184 | 130 | 54 |
| **idp** | 184 | 130 | 54 |
| **smodels** | 180 | 130 | 50 |
| **lp2sat2minisat** | 179 | 135 | 44 |
| **lp2diffz3** | 178 | 135 | 43 |
| **lp2sat2lminisat** | 171 | 130 | 41 |

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# NP Problems

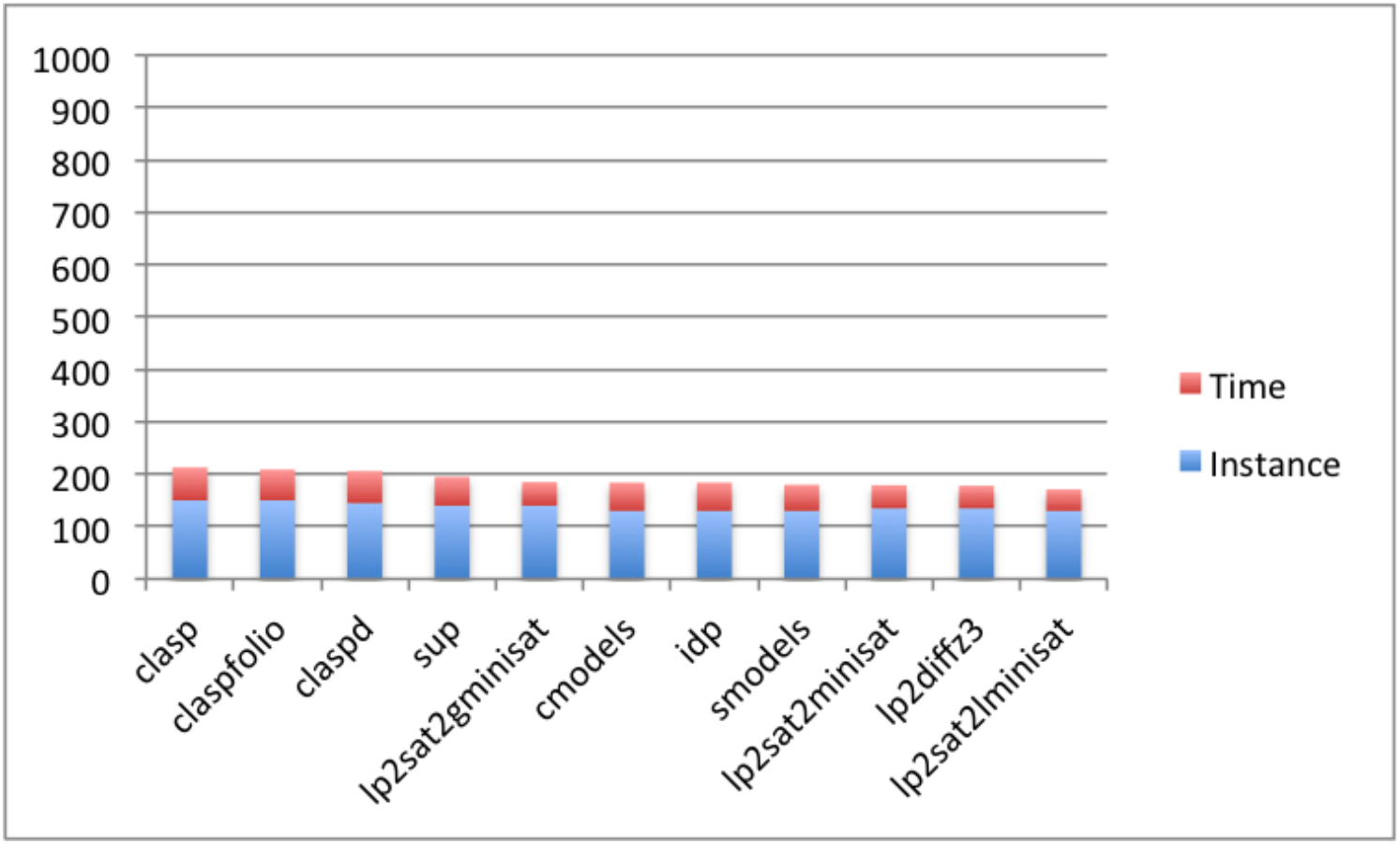
# NP Problems

| System | NP | NP-inst | NP-time |
|---|---|---|---|
| **claspfolio** | 609 | 385 | 224 |
| **clasp** | 597 | 370 | 227 |
| **idp** | 597 | 370 | 227 |
| **claspd** | 552 | 355 | 197 |
| **cmodels** | 510 | 335 | 175 |
| **lp2diffz3** | 394 | 270 | 124 |
| **sup** | 346 | 240 | 106 |
| **lp2sat2gminisat** | 310 | 225 | 85 |
| **lp2sat2minisat** | 302 | 220 | 82 |
| **lp2sat2lminisat** | 301 | 220 | 81 |
| **smodels** | 269 | 165 | 104 |

# Beyond NP Problems

# Beyond NP Problems

| System | Beyond NP | Beyond NP-inst | Beyond NP-time |
|---|---|---|---|
| **claspd** | 103 | 60 | 43 |
| **cmodels** | 72 | 45 | 27 |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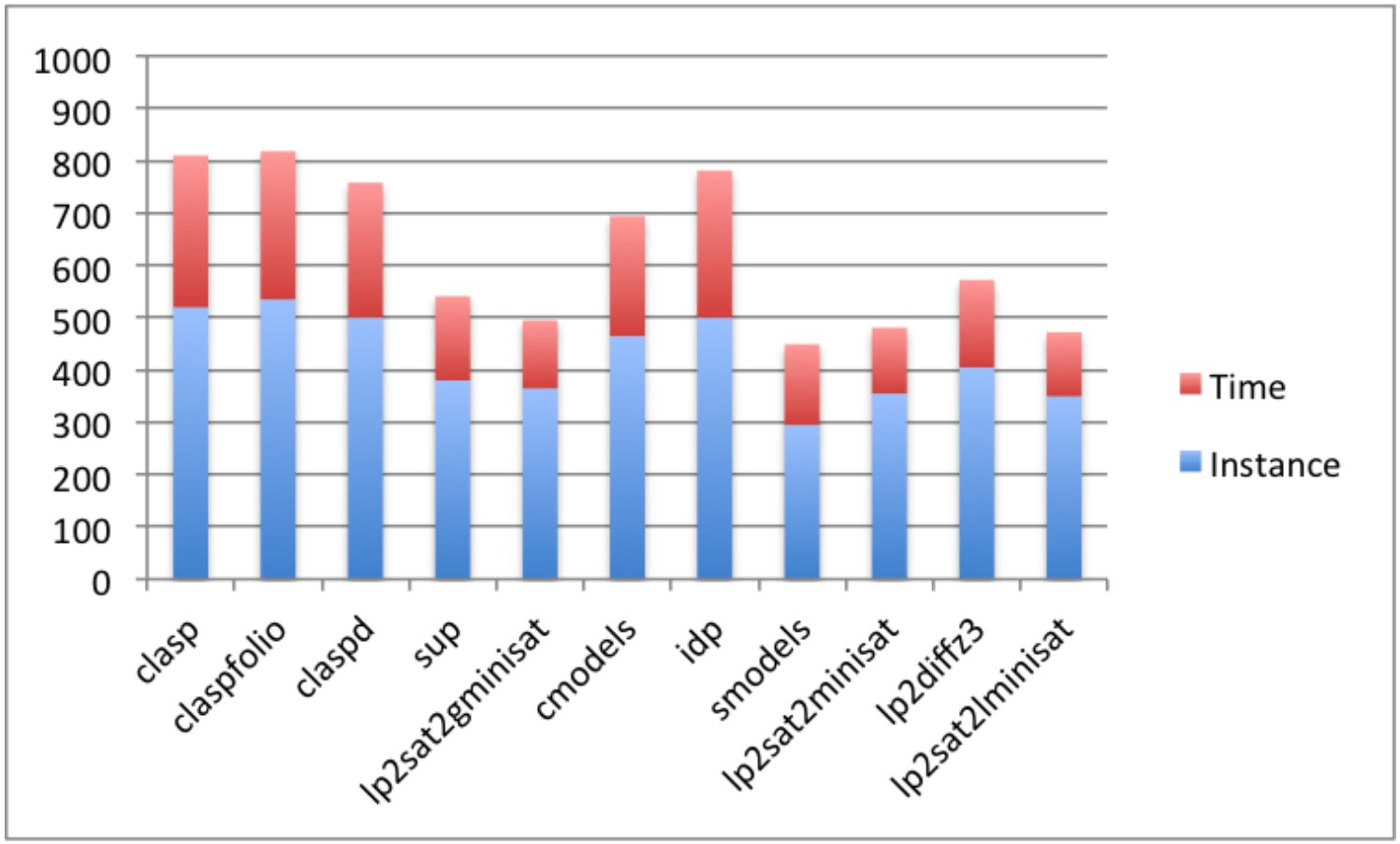
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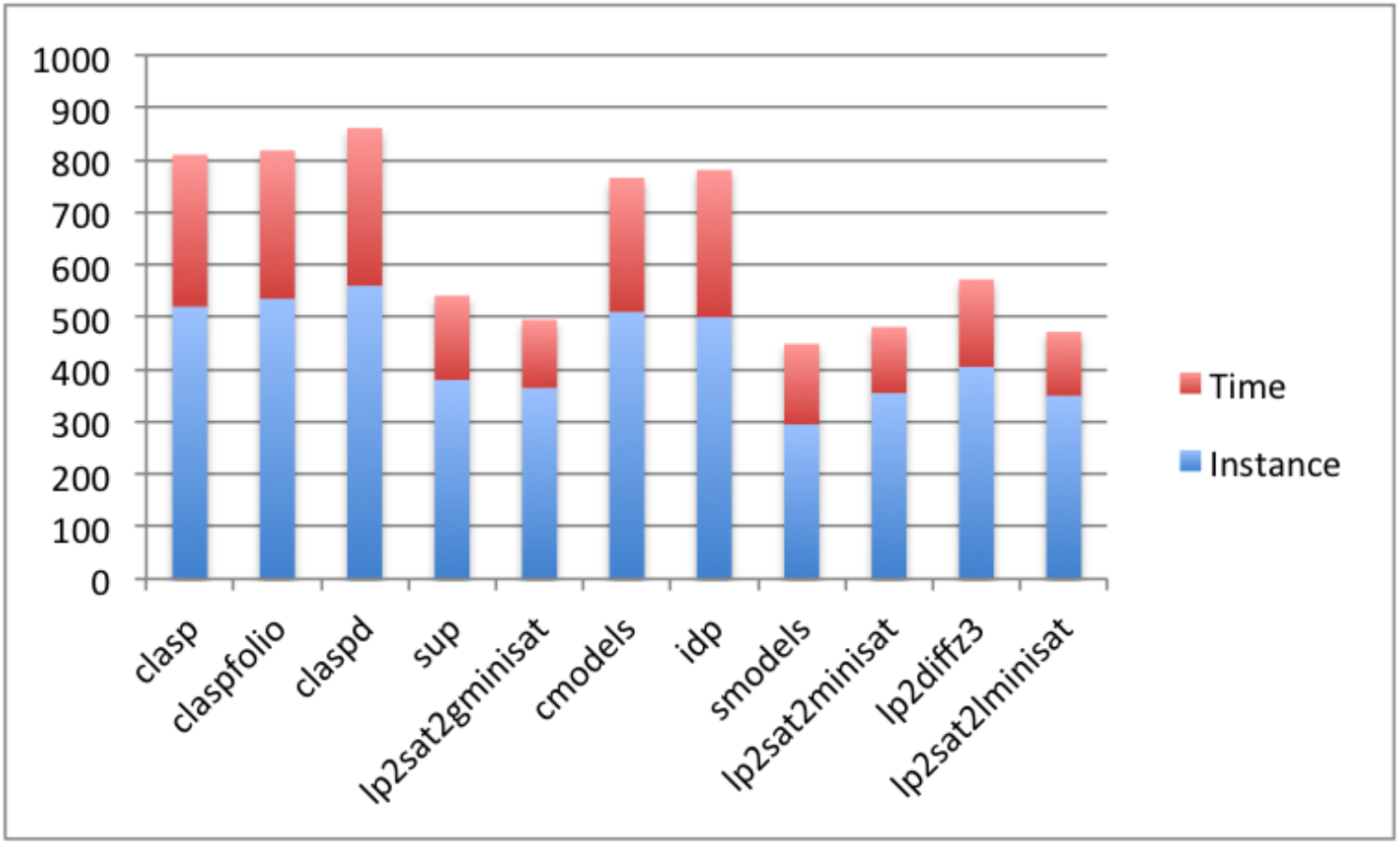
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lp2sat2lminisat
Time
Instance

# Overall Scoring

# Overall Scoring

| System | Total | Inst | Time |
|---|---|---|---|
| **claspd** | 861 | 560 | 301 |
| **claspfolio** | 818 | 535 | 283 |
| **clasp** | 810 | 520 | 290 |
| **idp** | 781 | 500 | 281 |
| **cmodels** | 766 | 510 | 256 |
| **lp2diffz3** | 572 | 405 | 167 |
| **sup** | 541 | 380 | 161 |
| **lp2sat2gminisat** | 495 | 365 | 130 |
| **lp2sat2minisat** | 481 | 355 | 126 |
| **lp2sat2lminisat** | 472 | 350 | 122 |
| **smodels** | 449 | 295 | 154 |

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# Driving Principles of the Model and Solve track

**To foster open comparison with any other declarative paradigm**

Competition open to any "declarative"-based system

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**To foster development of new linguistic constructs**

No restriction on language. Participants develop their own problem specifications

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**To foster open comparison with any other declarative paradigm**

Competition open to any "declarative"-based system

**To foster development of new linguistic constructs**

No restriction on language. Participants develop their own problem specifications

**To foster development of new heuristics and/or algorithms**

No restrictions in fine-tuning, on a per benchmark basis.

# From driving principles to rules

## Rules

Participants submit a "solution" on a per benchmark basis.
Knowledge of the benchmark domain can be exploited (yet not the knowledge of the instance family)

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## Rules

Participants submit a "solution" on a per benchmark basis. Knowledge of the benchmark domain can be exploited (yet not the knowledge of the instance family)

## Scoring

- **Search and Query problems**: same as in the System track;
- **Optimization problems**: for problem $P$, a participant team is awarded $S(P)$, where

$$S(P) = \alpha S_{opt}(P) + (100 - \alpha) S_{time}$$

for $\alpha = 50$.

# Participants

- **aclasp**, Potsdam University
- **BPSolver**, CU - New York, University of Udine, Texas Tech University
- **Ezcsp**, Eastman Kodak Company, University of Kentucky
- **fastdownward**, Universitaet Freiburg, Universidad Carlos III de Madrid, Technion Univ. NICTA, University of British Columbia
- **IDP**, KRR Group at KU-Leuven
- **Potassco** team at University of Potsdam

# Polynomial Problems

| System | P | P-inst | P-time | (Pure) - P |
|---|---|---|---|---|
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# Polynomial Problems

| System | P | P-inst | P-time | (Pure) - P |
|---|---|---|---|---|
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# Polynomial Problems

| System | P | P-inst | P-time | (Pure) - P |
|---|---|---|---|---|
| | | | | |
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| | | | | |
| | | | | |
| | | | | |
| **idp** | 175 | 117 | 58 | 148 |

# Polynomial Problems

| System | P | P-inst | P-time | (Pure) - P |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| **fastdownward** | 181 | 100 | 81 | 181 |
| **idp** | 175 | 117 | 58 | 148 |

# Polynomial Problems

| System | P | P-inst | P-time | (Pure) - P |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| **ezcsp** | 320 | 173 | 147 | 285 |
| **fastdownward** | 181 | 100 | 81 | 181 |
| **idp** | 175 | 117 | 58 | 148 |

# Polynomial Problems

| System | P | P-inst | P-time | (Pure) - P |
|---|---|---|---|---|
| | | | | |
| | | | | |
| **aclasp** | 404 | 240 | 164 | 365 |
| **ezcsp** | 320 | 173 | 147 | 285 |
| **fastdownward** | 181 | 100 | 81 | 181 |
| **idp** | 175 | 117 | 58 | 148 |

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# Polynomial Problems

| System | P | P-inst | P-time | (Pure) - P |
|---|---|---|---|---|
| | | | | |
| **bpsolver** | 459 | 253 | 206 | 459 |
| **aclasp** | 404 | 240 | 164 | 365 |
| **ezcsp** | 320 | 173 | 147 | 285 |
| **fastdownward** | 181 | 100 | 81 | 181 |
| **idp** | 175 | 117 | 58 | 148 |

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# Polynomial Problems

| System | P | P-inst | P-time | (Pure) - P |
|---|---|---|---|---|
| **clasp** | 497 | 290 | 207 | 459 |
| **bpsolver** | 459 | 253 | 206 | 459 |
| **aclasp** | 404 | 240 | 164 | 365 |
| **ezcsp** | 320 | 173 | 147 | 285 |
| **fastdownward** | 181 | 100 | 81 | 181 |
| **idp** | 175 | 117 | 58 | 148 |

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# NP Problems

| System | NP | NP-inst | NP-time |
|---|---|---|---|
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# NP Problems

| System | NP | NP-inst | NP-time |
|---|---|---|---|
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| | | | |
| | | | |
| **fastdownward** | 105 | 70 | 35 |

# NP Problems

| System | NP | NP-inst | NP-time |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| **bpsolver** | 1126 | 607 | 519 |
| **fastdownward** | 105 | 70 | 35 |

# NP Problems

| System | NP | NP-inst | NP-time |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| **idp** | 1127 | 680 | 447 |
| **bpsolver** | 1126 | 607 | 519 |
| **fastdownward** | 105 | 70 | 35 |

# NP Problems

| System | NP | NP-inst | NP-time |
|---|---|---|---|
| | | | |
| | | | |
| **aclasp** | 1224 | 680 | 544 |
| **idp** | 1127 | 680 | 447 |
| **bpsolver** | 1126 | 607 | 519 |
| **fastdownward** | 105 | 70 | 35 |

# NP Problems

| System | NP | NP-inst | NP-time |
|---|---|---|---|
| | | | |
| **ezcsp** | 1419 | 786 | 633 |
| **aclasp** | 1224 | 680 | 544 |
| **idp** | 1127 | 680 | 447 |
| **bpsolver** | 1126 | 607 | 519 |
| **fastdownward** | 105 | 70 | 35 |

# NP Problems

| System | NP | NP-inst | NP-time |
|---|---|---|---|
| **clasp** | 1481 | 848 | 633 |
| **ezcsp** | 1419 | 786 | 633 |
| **aclasp** | 1224 | 680 | 544 |
| **idp** | 1127 | 680 | 447 |
| **bpsolver** | 1126 | 607 | 519 |
| **fastdownward** | 105 | 70 | 35 |

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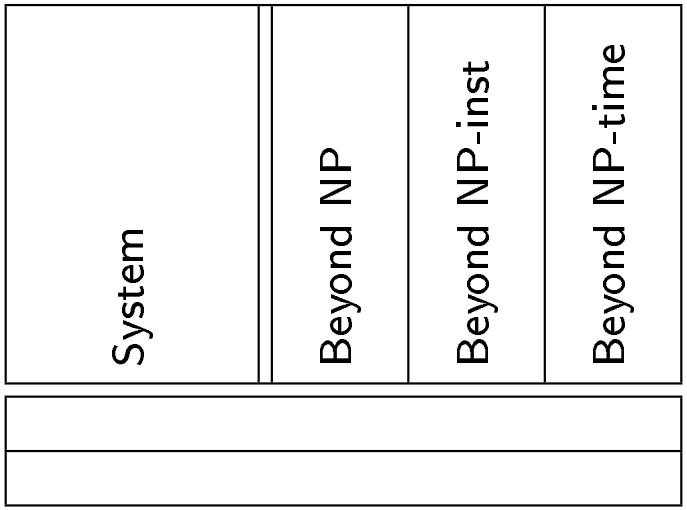
# Beyond NP



# Beyond NP

| System | Beyond NP | Beyond NP-inst | Beyond NP-time |
|---|---|---|---|
| **bpsolver** | 86 | 43 | 43 |

# Beyond NP

| System | Beyond NP | Beyond NP-inst | Beyond NP-time |
|---|---|---|---|
| **clasp** | 110 | 60 | 50 |
| **bpsolver** | 86 | 43 | 43 |

# Optimization Problems

| System | Opt | Opt-opt | Opt-time |
|---|---|---|---|
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# Optimization Problems

| System | Opt | Opt-opt | Opt-time |
|---|---|---|---|
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| | | | |
| | | | |
| **ezcsp** | 34 | 34 | 0 |

# Optimization Problems

| System | Opt | Opt-opt | Opt-time |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| **fastdownward** | 81 | 47 | 34 |
| **ezcsp** | 34 | 34 | 0 |

# Optimization Problems

| System | Opt | Opt-opt | Opt-time |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| **idp** | 140 | 121 | 19 |
| **fastdownward** | 81 | 47 | 34 |
| **ezcsp** | 34 | 34 | 0 |

# Optimization Problems

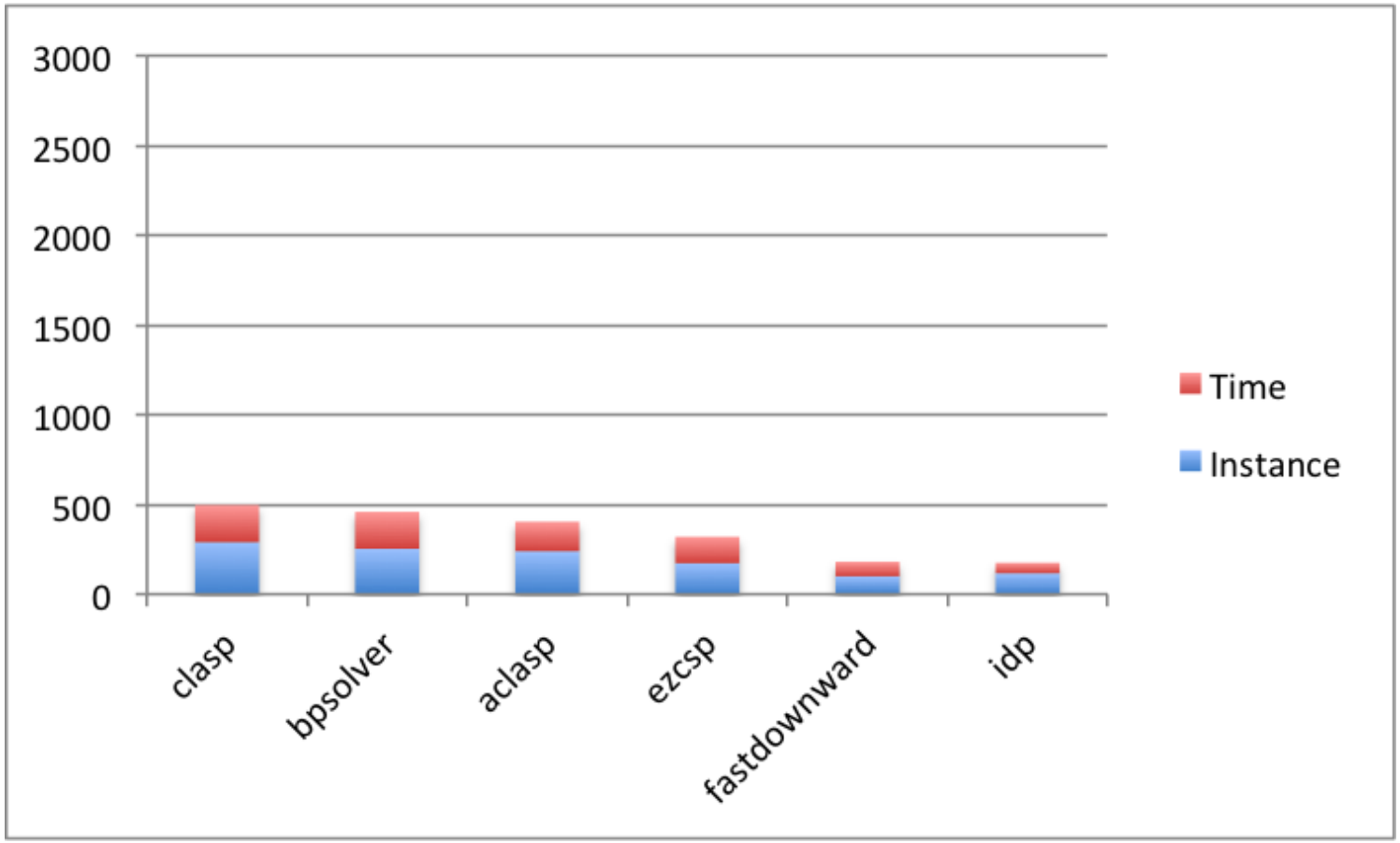
| System | Opt | Opt-opt | Opt-time |
|---|---|---|---|
| | | | |
| | | | |
| **bpsolver** | 207 | 161 | 46 |
| **idp** | 140 | 121 | 19 |
| **fastdownward** | 81 | 47 | 34 |
| **ezcsp** | 34 | 34 | 0 |

# Optimization Problems

| System | Opt | Opt-opt | Opt-time |
|---|---|---|---|
| **aclasp** | 325 | 220 | 105 |
| **bpsolver** | 207 | 161 | 46 |
| **idp** | 140 | 121 | 19 |
| **fastdownward** | 81 | 47 | 34 |
| **ezcsp** | 34 | 34 | 0 |

# Optimization Problems

| System | Opt | Opt-opt | Opt-time |
|---|---|---|---|
| **clasp** | 343 | 234 | 109 |
| **aclasp** | 325 | 220 | 105 |
| **bpsolver** | 207 | 161 | 46 |
| **idp** | 140 | 121 | 19 |
| **fastdownward** | 81 | 47 | 34 |
| **ezcsp** | 34 | 34 | 0 |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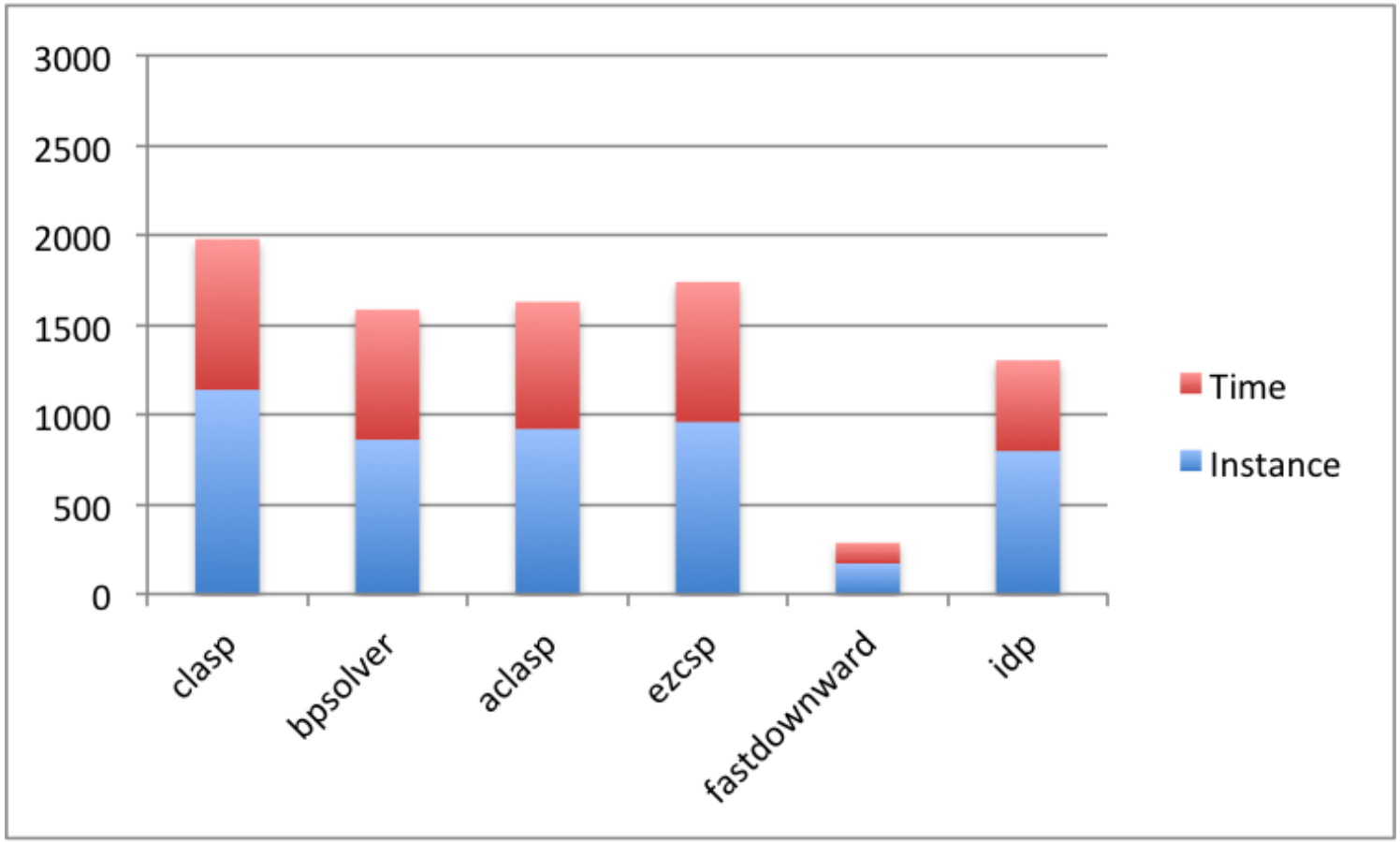
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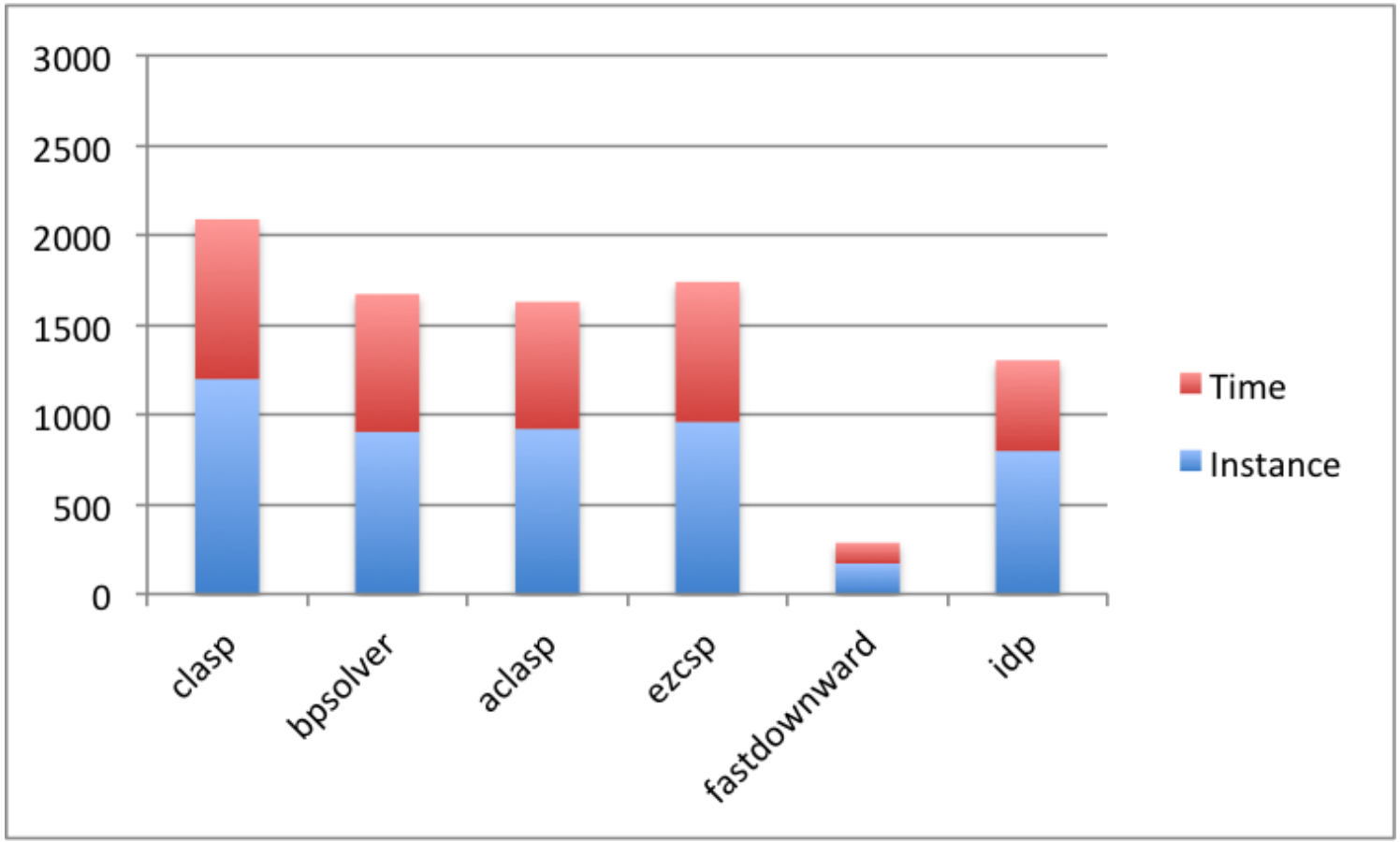
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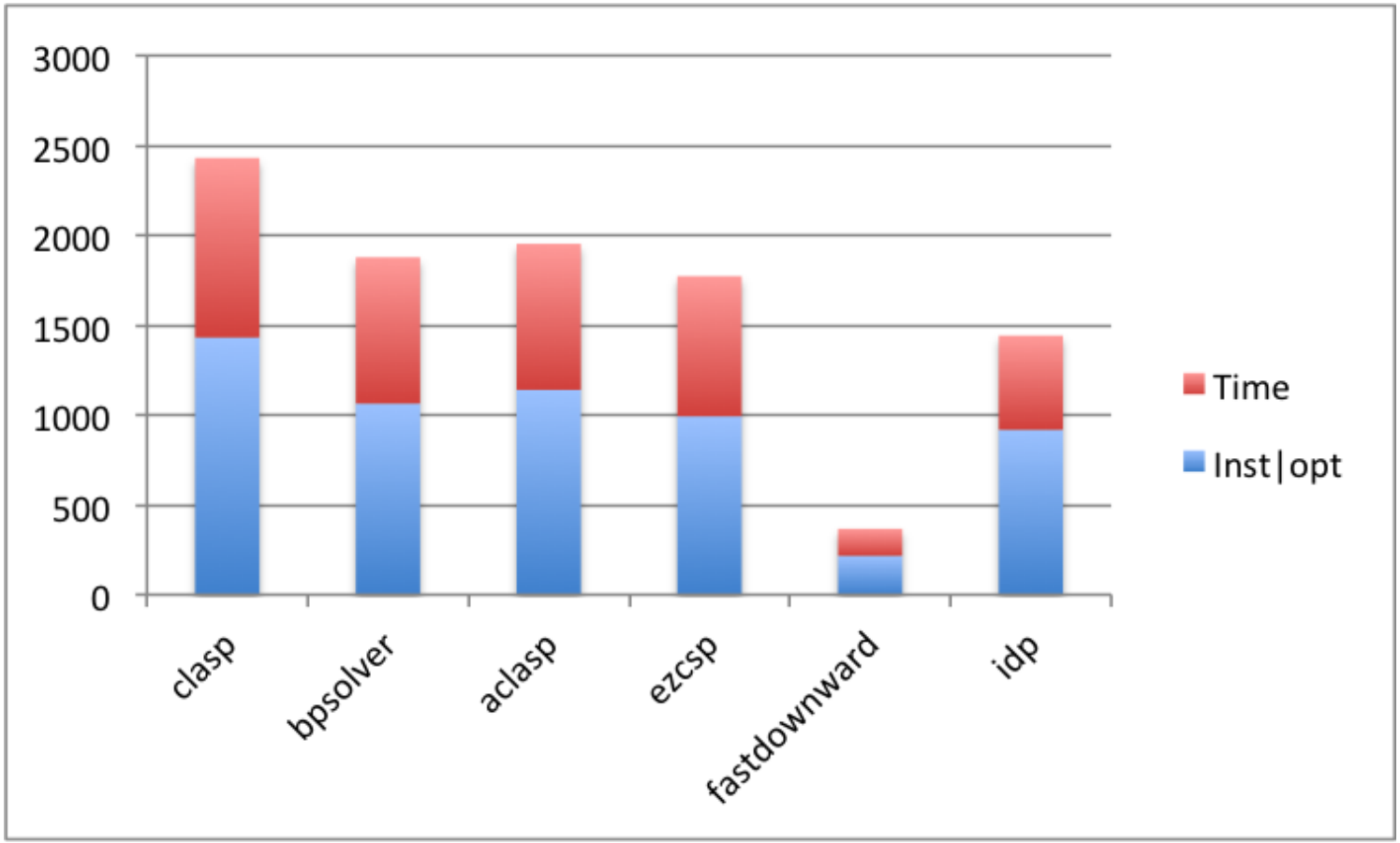
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# Overall Ranking

| System | Total | Inst | Time |
|---|---|---|---|
| | | | |
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# Overall Ranking

| System | Total | Inst | Time |
|---|---|---|---|
| | | | |
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| | | | |
| **fastdownward** | 367 | 217 | 150 |

# Overall Ranking

| System | Total | Inst | Time |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| **idp** | 1442 | 918 | 524 |
| **fastdownward** | 367 | 217 | 150 |

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# Overall Ranking

| System | Total | Inst | Time |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| **ezcsp** | 1773 | 993 | 780 |
| **idp** | 1442 | 918 | 524 |
| **fastdownward** | 367 | 217 | 150 |

# Overall Ranking

| System | Total | Inst | Time |
|---|---|---|---|
| | | | |
| | | | |
| **bpsolver** | 1878 | 1064 | 814 |
| **ezcsp** | 1773 | 993 | 780 |
| **idp** | 1442 | 918 | 524 |
| **fastdownward** | 367 | 217 | 150 |

# Overall Ranking

| System | Total | Inst | Time |
|---|---|---|---|
| | | | |
| **aclasp** | 1953 | 1140 | 813 |
| **bpsolver** | 1878 | 1064 | 814 |
| **ezcsp** | 1773 | 993 | 780 |
| **idp** | 1442 | 918 | 524 |
| **fastdownward** | 367 | 217 | 150 |

# Overall Ranking

| System | Total | Inst | Time |
|---|---|---|---|
| **clasp** | 2431 | 1432 | 999 |
| **aclasp** | 1953 | 1140 | 813 |
| **bpsolver** | 1878 | 1064 | 814 |
| **ezcsp** | 1773 | 993 | 780 |
| **idp** | 1442 | 918 | 524 |
| **fastdownward** | 367 | 217 | 150 |

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# Outline

# A few comparisons

| REACHABILITY | | Grammar-Based I | | GRAPH COLORING | | CROSSING MIN | | FastFoodOpt | | Maximal Clique | | overall VS Sys | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | clasp | 1198 |
| | | | | | | | | | | | | ezcsp | 1069 |
| bpsolver | 90 | bpsolver | 98 | | | | | | | | | bpsolver | 1030 |
| clasp | 87 | aclasp | 85 | idp | 66 | | | clasp | 83 | clasp | 64 | aclasp | 949 |
| idp | 76 | clasp | 85 | clasp | 51 | | | aclasp | 83 | aclasp | 64 | idp | 885 |
| XSB 3.2 | 65 | Clasp 2009 | 80 | Clasp 2009 | 38 | CPLEX 12 | 83 | Clasp 2009 | 77 | Clasp 2009 | 64 | clasp (System) | 701 |
| | | | | | | Minisat+ | 52 | | | Cliquer 2.1 | 62 | | |
| | | | | aclasp | 28 | clasp | 17 | idp | 64 | idp | 58 | fastdownward | 302 |
| | | | | ezcsp | 23 | idp | 13 | bpsolver | 48 | bpsolver | 50 | | |
| | | | | bpsolver | 15 | aclasp | 13 | | | | | | |
| | | | | | | bpsolver | 13 | | | | | | |

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- Manpower: 3 Chairs, 16 among Ph.D. Students, Professors, Webmasters, Sysadmins

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# Competition figures

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- Resource allocation: 1 Million Marble blocks; 2 Triremes; 4 Miles steel chains; More than 600 wooden oars; 20 wasted weekends;