

SUNNY-CP: A Multicore Tool for Constraint Solving

Jacopo Mauro

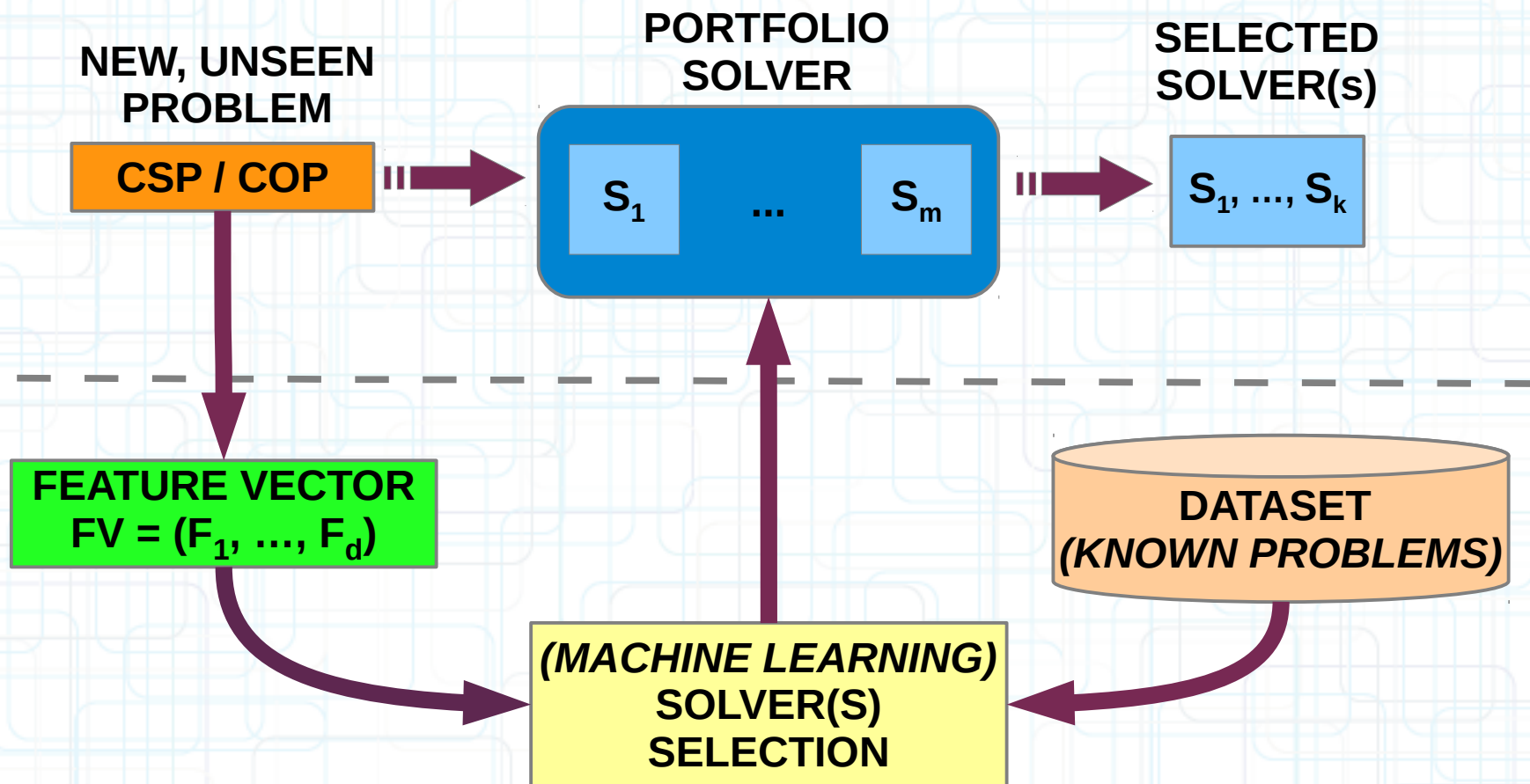
University of Oslo

NordConsNet

Uppsala, May 2017

Portfolio Approaches in CP

IDEA: combine different CP solvers to get an overall better **Portfolio Solver**



Motivations

- **SAT** portfolio solvers → effective in competitions
- Lack of **CP** portfolio solvers
 - **sunny-cp** only portfolio entrant since MiniZinc Challenge 2014 (first version sequential)
- **GOAL**: provide an effective, usable, and *Parallel CP Portfolio Solver*

sunny-cp

- **Parallel** – many cores exploited
- **Dynamic** – solvers selection on-line
- **Cooperative** – bounds communication
- **Configurable** – different user options
- **Modern** – contains *state-of-the-art* solvers

SUNNY

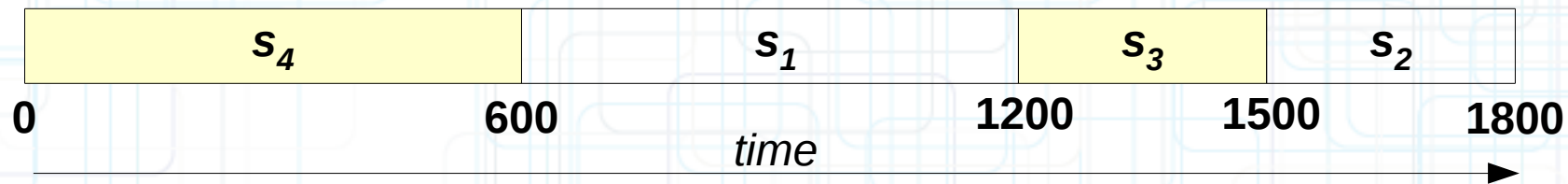
- Minimizing the **probability** of choosing the wrong solver(s)
- **SUB-portfolio**: only a subset of solvers is scheduled
- **k-NN algorithm**: solvers selection relies on the k -NN algorithm
- **LazY approach**: no explicit ML model learned off-line (like RF, SVM, ...)

Scheduling

- Solve instance with 4 solvers s_i , timeout $T = 1800$ s, backup solver $BK = s_3$, $k = 5$, neighborhood $\{p_1, \dots, p_5\}$,

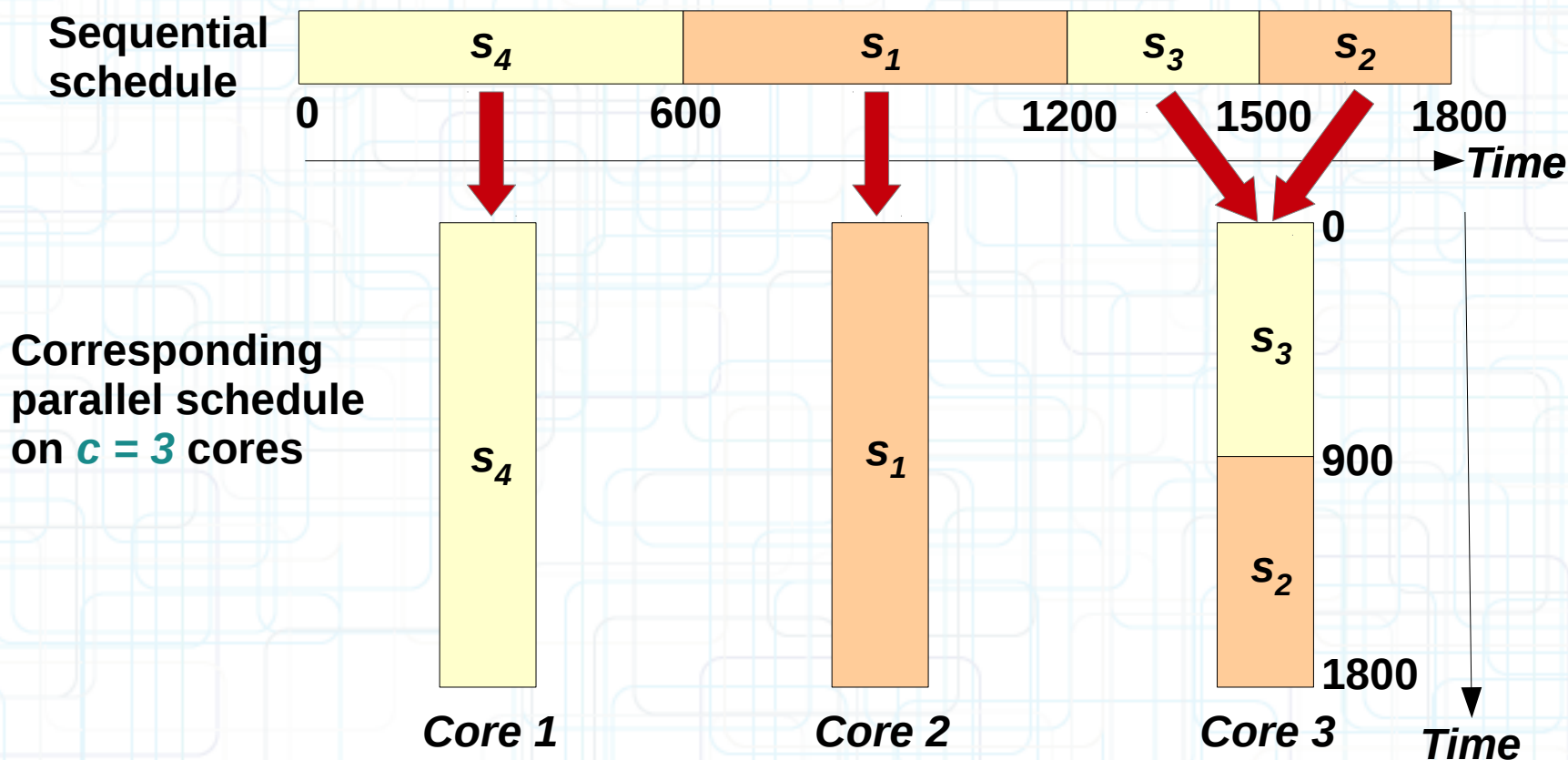
	p_1	p_2	p_3	p_4	p_5	AST
s_1	T	T	3	T	278	1136.2
s_2	T	593	T	T	T	1558.6
s_3	T	T	36	1452	T	1377.6
s_4	T	T	T	122	60	1116.4

- Best sub-portfolios:** $\{s_1, s_2, s_3\}$, $\{s_1, s_2, s_4\}$, $\{s_2, s_3, s_4\}$
- $[0, T]$ is divided in $2 + 1 + 2 + 1 = 6$ **slots** of $T/6 = 300$ s:
 - 2 assigned to s_1 , 1 to s_2 , 2 to s_4 , 1 to $BK = s_3$
- After sorting slots by AST, the **resulting schedule** is:

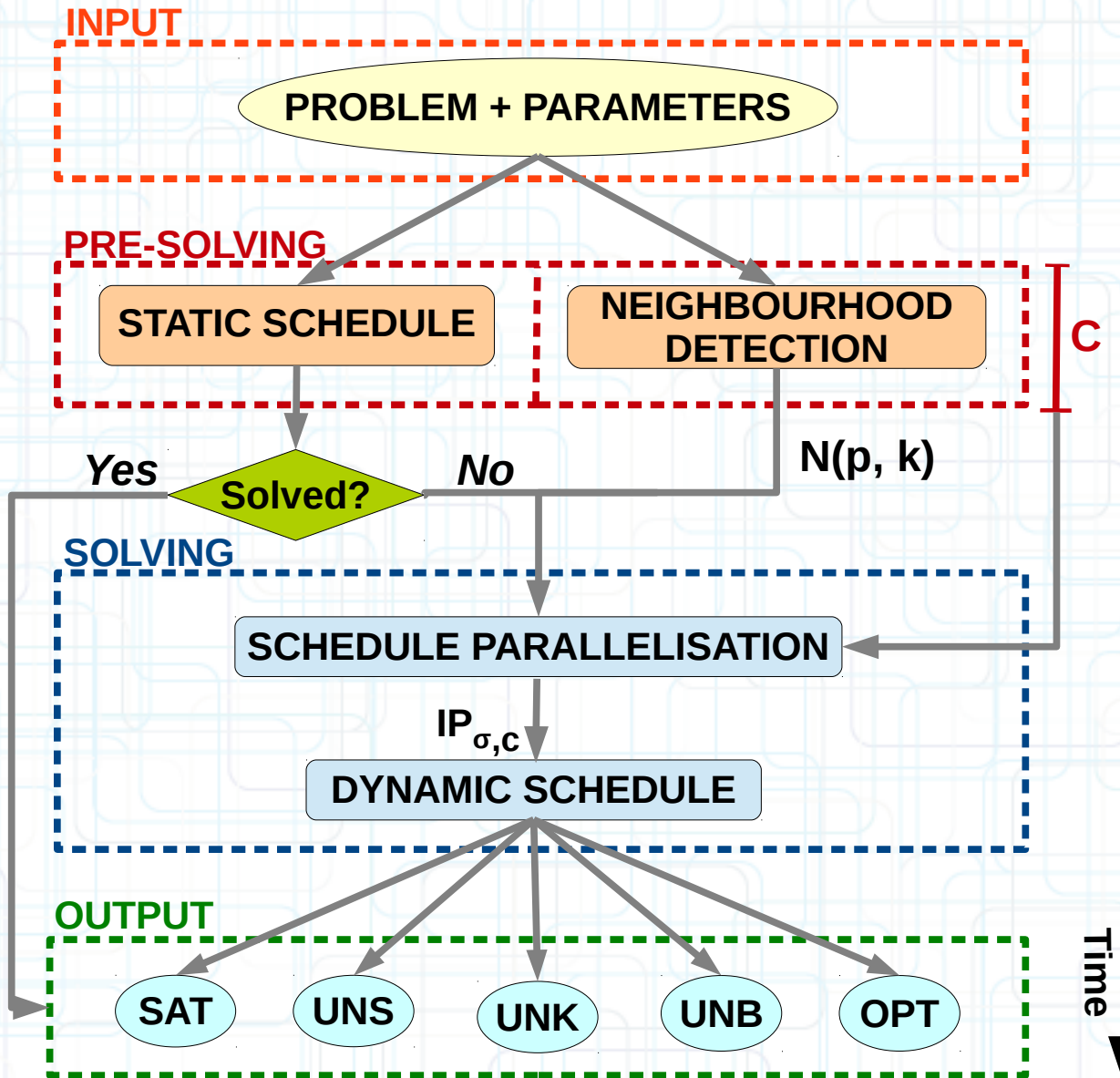


Parallel schedule

- How to *parallelise* SUNNY sequential schedule on $c > 1$ cores?
 - **IDEA:** First $c - 1$ solvers on $c - 1$ cores, the remaining solvers on the last core



Architecture



Technicalities

- Input problem defined in *MiniZinc*
- Default portfolio of 12 solvers:
 - Chuffed, *MZN/Gurobi*, G12/FD, G12/LazyFD, Choco, Gecode, HaifaCSP, iZplus, MinisatID, *Opturion CPX*, OR-Tools, JaCoP, Mistral, and Picat-SAT
- **mzn2feat** extracts 95 features from
 - scaled in range $[-1, 1]$, constant features are removed
- k usually square root of knowledge base

Bounds Communication

- COP schedule takes into account quality
- COPs execution is **cooperative**
- Best objective bound \mathbf{z} found by solver \mathbf{S} is obsolete \mathbf{S} is restarted
- Injecting a better bound \mathbf{z}^*
- can speed up the search → even **outperform** the Virtual Best Solver

Validation

- *10-fold cross validation exploiting 1, 2, 4, 8 cores on:*

– 5524 CSPs

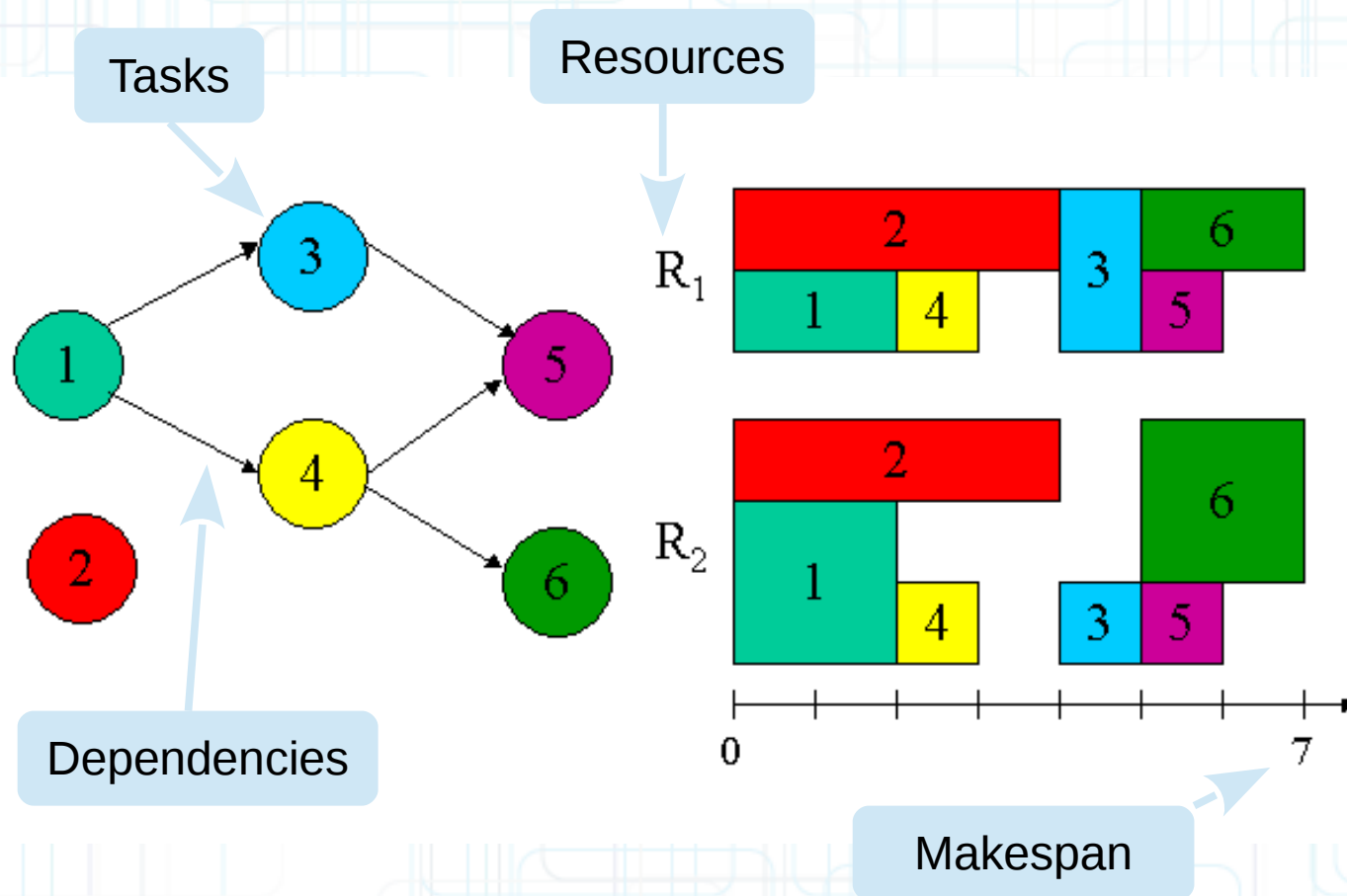
Metric	sunny-cp	sunny-cp2				VPS				VBS
		1 core	2 cores	4 cores	8 cores	1 core	2 cores	4 cores	8 cores	
proven (%)	83.26	95.26	99.11	99.38	99.35	89.04	93.51	95.19	99.24	100
time (s)	504.10	223.21	136.04	112.60	112.32	297.30	211.13	176.81	68.52	54.30

– 4864 COPs

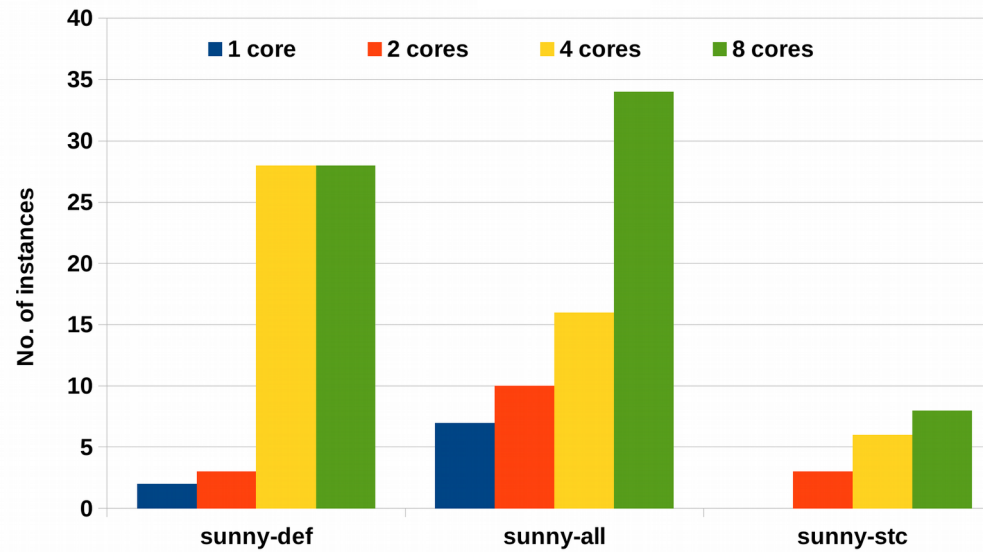
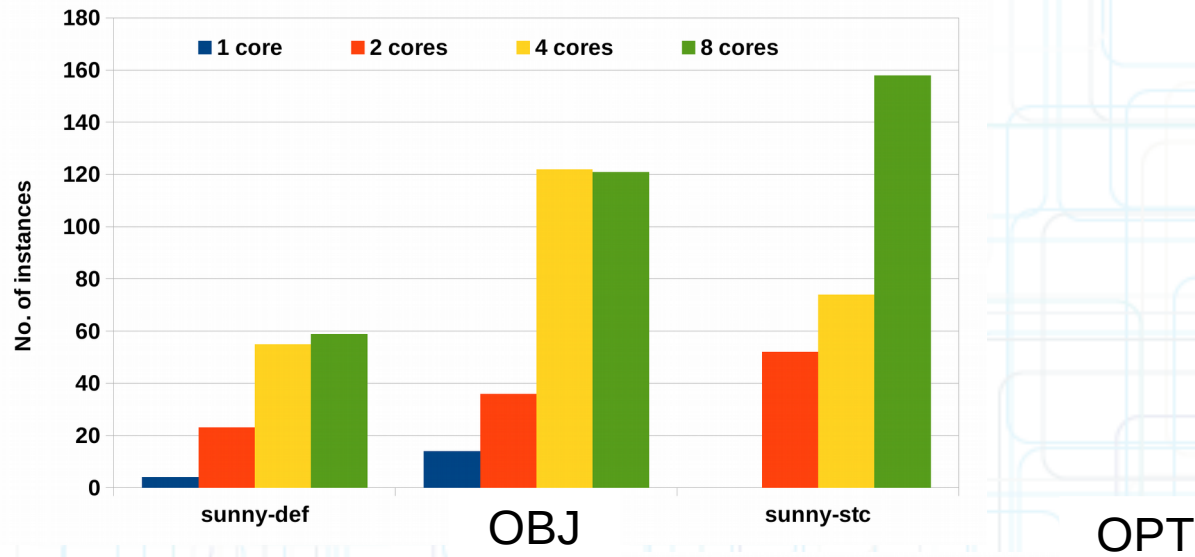
Metric	sunny-cp	sunny-cp2				VPS				VBS
		1 core	2 cores	4 cores	8 cores	1 core	2 cores	4 cores	8 cores	
proven (%)	71.55	74.40	74.94	75.68	76.34	61.33	63.45	65.60	75.86	76.30
time (s)	594.79	501.35	482.95	469.74	454.54	718.86	682.35	645.68	463.63	457.00
score × 100	90.50	92.26	93.00	93.45	93.62	82.80	85.99	89.53	90.79	93.63
area (s)	257.86	197.44	149.33	138.94	130.53	314.07	266.11	188.20	178.81	132.28

RCPSP Example

- **Resource-Constrained Project Scheduling Problem** (2904 instances in MiniZinc benchmark → 647 hard)



Better than VBS



MiniZinc Challenge

- Use Borda Count to rank
- Sequential version for 2014 → honorable mention
- Winner and gold medalist in 2015
- Gold medalist in 2016

MiniZinc Challenge 2015

Solver	Score	Incomplete
<i>sunny-cp</i> *	1351.13	1175.2
<i>Chuffed</i>	1342.37	1118.16
<i>sunny-cp</i> ⁻ *	1221.88	1156.25
OR-Tools *	1111.83	1071.67
Opturion CPX	1094.09	1036.65
<i>Gecode</i> *	1049.49	979.05
Choco *	1027.65	989
iZplus *	1021.13	1082.92
JaCoP	914.97	865.64
Mistral *	872.35	878.53
MinisatID	835.01	793.74
<i>MZN/CPLEX</i> *	799.92	686.64
<i>MZN/Gurobi</i> *	774.3	697.12
Picat SAT	744.53	626.61
MinisatID-MP	637.14	700.35
<i>G12/FD</i>	629.94	664.79
Picat CP	617.22	654.81
Concrete	533.42	657.2
YACS *	404.01	553.51
OscAR/CBLS	403.61	536.17

* → parallel solver

MiniZinc Challenge 2016

Solver	Score	Incomplete
<i>LCG-Glucose</i>	1899.23	1548.2
<i>sunny-cp</i> *	1877.79	1616.19
<i>Chuffed</i>	1795.57	1486.8
<i>LCG-Glucose-UC</i>	1671.52	1306.26
<i>sunny-cp</i>⁻⁻ *	1620.82	1486.11
<i>MZN/Gurobi</i> *	1499.04	1308.18
HaifaCSP	1448.35	1343.54
<i>MZN/CPLEX</i> *	1436.05	1287.09
Picat SAT	1423.81	1336.36
iZplus *	1374.12	1446.36
<i>sunny-cp</i>⁻ *	1365.31	1205.73
Choco *	1342.41	1390.21
OR-Tools *	1115.8	1258.51
<i>Gecode</i> *	1110.19	1137.21
MinisatID *	992.12	1002.17
<i>MZN/SCIP</i>	985.37	1011.25
JaCoP	923.78	1041.03
Mistral *	826.61	935.8
<i>MZN/CBC</i>	754.77	827.06
SICStus Prolog	754.33	837.57
G12/FD	703.14	829.39
Concrete	583.9	627.36
Picat CP	475.47	651.63
OscAR/CBLS	468.5	708
Yuck *	316	412

* → parallel solver

Results updated (no bugs)

Solver	Score	Incomplete
<i>sunny-cp</i> *	1054.83	928.95
<i>LCG-Glucose</i>	1029.43	876.56
<i>Chuffed</i>	993.79	844.42
<i>sunny-cp</i> ⁻ *	982.7	893.39
<i>LCG-Glucose-UC</i>	929.28	748.17
<i>sunny-cp</i> ⁻⁻ *	899.47	875.6
<i>MZN/Gurobi</i> *	862.26	705.18
<i>MZN/CPLEX</i> *	829.12	704.59
<i>iZplus</i> *	779.88	778.98
<i>HaifaCSP</i>	777.91	775.48
<i>Picat SAT</i>	735.82	713.71
<i>Choco</i> *	700.46	765.13
<i>Gecode</i> *	633	639.35
<i>OR-Tools</i> *	560.5	659.38
<i>MZN/SCIP</i>	545.85	535.75
<i>MinisatID</i> *	498.33	539.69
<i>SICStus Prolog</i>	437.33	510.66
<i>JaCoP</i>	433.76	555.49
<i>MZN/CBC</i>	421.32	453.06
<i>Mistral</i> *	382.68	470.87
<i>G12/FD</i>	374.56	430.27
<i>Concrete</i>	291.42	327.7
<i>Picat CP</i>	260.79	334.13
<i>OscAR/CBLS</i>	216.5	286.5
<i>Yuck</i> *	171	181

* → parallel solver

ICON Challenge on Algorithm Selection (2015)

- ASlib → library to evaluate performances of algorithm selectors
- 13 scenarios
- We submitted SUNNY

	System	Average total score
1	zilla	0.38953
2	autofolio	0.38980
3	zillafolio	0.39572
4	ASAP_RF	0.41169
5	ASAP_kNN	0.43386
6	flexfolio	0.45371
7	sunny-presolv	0.48956
8	sunny	0.48998

New Findings (by others)

- Lindauer et al. → k matters: needs to be learned

	<i>flexfolio</i>	<i>AutoFolio</i>	<i>aspeed</i>	<i>Sunny</i>	<i>TSunny</i>	<i>ISA</i>
ASP-POTASSCO	0.78*	0.80*	0.34	0.69	0.81*	0.72
CSP-2010	0.80*	0.75*	0.05	0.68	0.77*	0.74*
MAXSAT12-PMS	0.67	0.90*	0.65	0.87	0.93*	0.94*
PREMAR-2013	0.70	0.74*	0.74*	0.71	0.62	0.78*
PROTEUS-2014	0.82	0.87	0.87	0.88	0.94*	0.91
QBF-2011	0.90	0.91	0.80	0.90	0.94*	0.92
SAT11-HAND	0.73*	0.71*	0.74*	0.54	0.52	0.69*
SAT11-INDU	0.29*	0.36*	0.06	0.19	0.37*	0.43*
SAT11-RAND	0.93*	0.95*	0.80	0.59	0.87	0.95*
SAT12-ALL	0.69*	0.69*	0.10	0.58	0.69*	0.71*
SAT12-HAND	0.68	0.71	0.46	0.57	0.72	0.78*
SAT12-INDU	0.39	0.46*	-0.22	0.01	0.53*	0.54*
SAT12-RAND	0.17	0.24*	-0.28	-0.14	0.32*	0.12
Average	0.66	0.70	0.39	0.54	0.69	0.71
Equal to Best	6	10	2	0	9	9

Future and Ongoing Work

- Understand the concurrent interaction of solver
 - What to share? When?
 - Impact on race conditions on memory
 - Need better solver support!
- Stochastic solvers into the picture
- Parallel execution of parallel solvers
- Other problems / other domains (ASLIB)
- What to do with buggy solvers?

sunny-cp

Open source and publicly available

<https://github.com/CP-Unibo/sunny-cp>

Welcome to play with it

***...Thanks
for your
attention!***