SPEEDING UP MULTI-OBJECTIVE OPTIMIZATION VIA CORES

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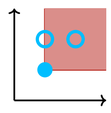
MULTI-OBJECTIVE OPTIMIZATION

- Many real-world problems have multiple conflicting objectives
- Aim: **Pareto-optimal** solutions
- Need for provably optimal solutions
- Linear combination of objectives not sufficient



AUTOMATED REASONING

- Programs to draw logical conclusions from given facts
- Suited for declarative problem solving

MAXIMUM SATISFIABILITY

- Constraints: propositional formula

$$(x_1 \vee \overline{x_2} \vee x_3) \wedge (x_1 \vee \overline{x_2} \vee x_4) \wedge (\overline{x_2} \vee x_3 \vee x_5) \wedge (x_3 \vee x_4 \vee x_5)$$

- Objective(s): linear function(s) to minimize

$$\mathrm{O}_1 = 3\overline{x_2} + 4x_3 + 2x_4 + 5x_5$$
$$\mathrm{O}_2 = 7x_1 + 4\overline{x_2} + 1x_3 + 2x_4$$

- Efficient for real-world optimization problems

MOTIVATION

- Core-guided search common in MaxSAT but not yet in multi-objective setting
- Building large objective encodings constitutes botteleneck for MO-MaxSAT algorithms

CONTRIBUTIONS

- Preprocessing/reformulation technique for MO-MaxSAT
- Open-source implementation
- Empirical evaluation

MULTI-OBJECTIVE CORE BOOSTING

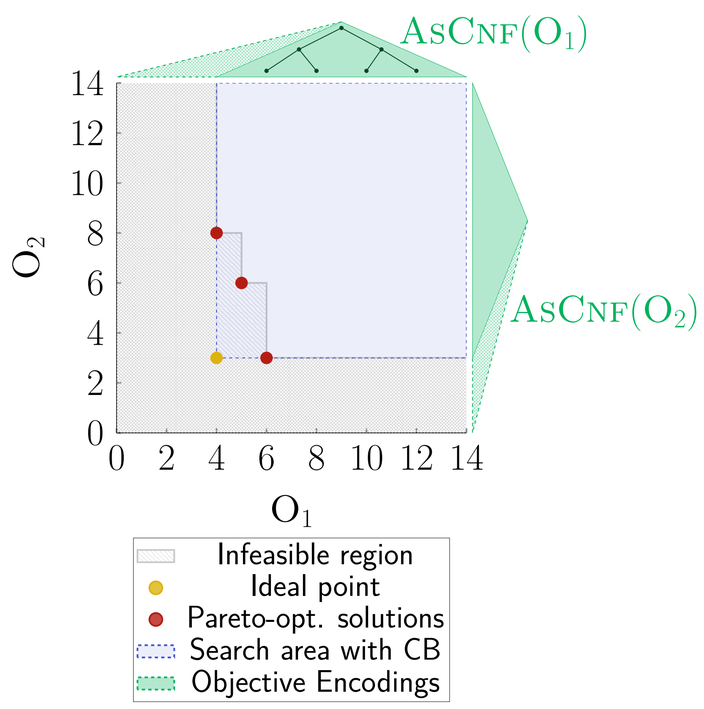
CORE-GUIDED SEARCH

- Iteratively relaxes inconsistencies over objective
- Reformulates objective

$$\mathrm{O}_1 = 3\overline{x_2} + 4x_3 + 2x_4 + 5x_5, \quad \text{into}$$
$$\mathrm{O}_1^{\mathrm{Ref}} = x_4 + 2x_5 + 3a_2 + 3a_3 + b_2 + b_3 + 4$$

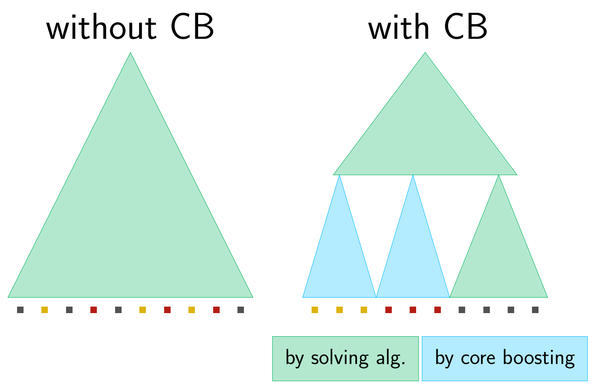
CORE BOOSTING

- Reformulate each objective via core-guided search
- Build objective encodings over reformulated objectives



EFFECTS OF CORE BOOSTING

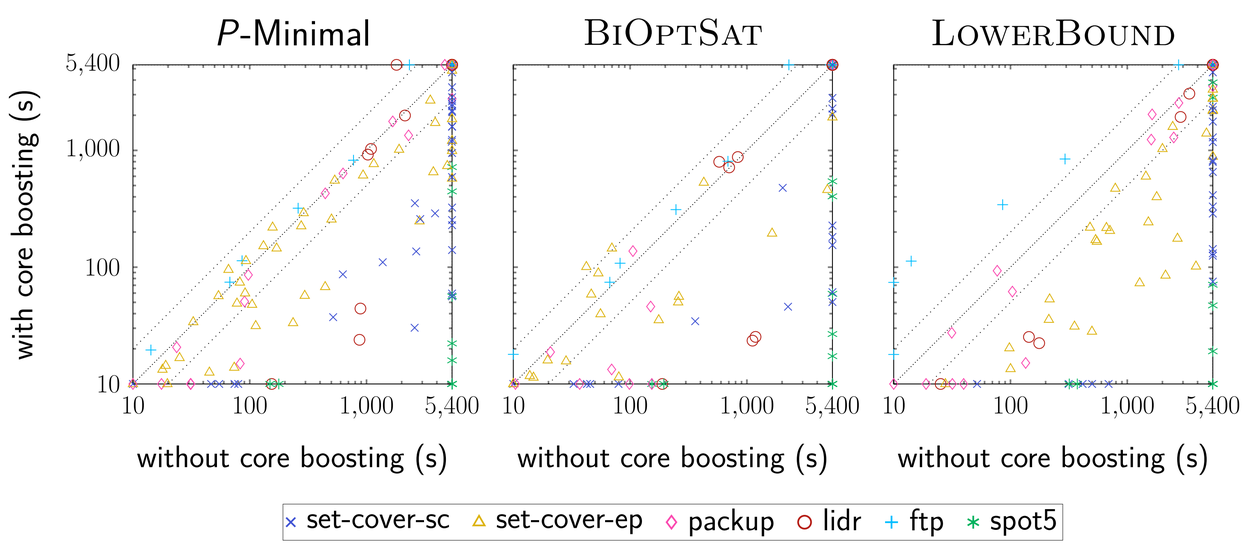
- Moves search anchor to ideal point: shrinks search space
- Restructures objective Encodings



EMPIRICAL EVALUATION

RESULTS

PER-INSTANCE RUNTIME



COMPARISON TO OTHER PREPROCESSING

Change in number of solved instance ($\Delta\#$) through core boosting (CB) and preprocessing with MaxPre [Jabs et al. CP'23].

Algorithm	Prepro.	set-cover-sc $\Delta\#$	set-cover-ep $\Delta\#$	packup $\Delta\#$	lidr $\Delta\#$	ftp $\Delta\#$	spot5 $\Delta\#$
P-minimal	CB	$\mathbf{+20}$	$\mathbf{+5}$	$\mathbf{\pm0}$	-1	-1	$\mathbf{+11}$
	MaxPre	$+1$	-1	-1	$\mathbf{\pm0}$	$\mathbf{+3}$	$+1$
BiOptSat	CB	$\mathbf{+8}$	$\mathbf{+1}$	$\mathbf{\pm0}$	$\mathbf{\pm0}$	-2	$\mathbf{+11}$
	MaxPre	±0	±0	$\mathbf{\pm0}$	$\mathbf{\pm0}$	$\mathbf{+2}$	$+1$
LowerBound	CB	$\mathbf{+16}$	$\mathbf{+6}$	$\mathbf{+1}$	±0	-1	$\mathbf{+11}$
	MaxPre	$+1$	±0	-1	$\mathbf{+1}$	$\mathbf{+1}$	±0

Paper & Code available at
`christophjabs.info/aiday24`

IMPLEMENTATION

Open-source Scuttle MO-MaxSAT solver
`bitbucket.org/coreo-group/scuttle`

THREE ALGORITHMS

- *P*-Minimal [Soh et al. CP'17]
- BiOptSat [Jabs et al. JAIR'24]
- LowerBound [Cortes et al. TACAS'23]

BENCHMARKS

- Learning Interpretable Decision Rules [Malioutov et al. CP'18]
- Set covering (2 variants)
- Package upgradeability [Janota et al. JSAT'12]
- Flying tourist problem [Marques et al. ESWA'19]
- Reverse engineered single-objective MaxSAT instances

REFERENCES

C. Jabs, J. Berg, and M. Järvisalo: "*Core Boosting in SAT-Based Multi-objective Optimization*", CPAIOR 2024.

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