Multi-Objective AI Planning: Evaluating DaE on a tunable benchmark

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AGENCE NATIONALE DE LA RECHERCHE ANR
DESCARWIN

An AI Planning problem

- Domain:
  - State space *S* (set of predicates)
  - Set of actions *A* with preconditions and effects
- Instance:
  - List of objects (instanciate predicates)
  - Initial state *I*
  - Goal state *G*

Find an optimal sequence of actions mapping *I* to *G*

Teaser: MiniZeno (best makespan 8)

- Domain: unique predicate at

```
(:action fly  :duration (= ?duration (time ?c1 ?c2))
  :precond ((at ?a ?c1) (at ?p ?c1))
  :effect ((at ?a ?c2) (not(at ?a ?c1)) (at ?p ?c2) (not(at ?p ?c1))))
(:action flyVide  :duration (= ?duration (time ?c1 ?c2))
  :precond ((at ?a ?c1)) :effect ((at ?a ?c2) (not (at ?a ?c1))))
```

- Instance: 3 cities, 2 planes, 3 passengers

```
(:objects plane1 plane2, person1 person2 person3 city0 city1 city2)
(= (time city0 city1) 2)(= (time city1 city2) 2)
(= (time city1 city0) 2)(= (time city2 city1) 2)
(:init (at plane1 city0) (at plane2 city0) (at person1 city0)
  (at person2 city0) (at person3 city0))
(:goal (at person1 city2) (at person2 city2) (at person3 city2))
```

Agenda

- AI Planning
- Multi-objective AI Planning and benchmarks
- Divide-and-Evolve (DaE)
- Multi-objective DaE
- Experiments
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AI Planning

- Yearly ICAPS conference since 1990
- Biennal IPC (International Planning Competition)
  - Since 1998 (7th in 20...11)
  - Drive for PDDL design/improvements
- Lots of exact or satisficing **single-objective** planners
- Either cost-based (purely sequential) or temporal (actions can be run in parallel)

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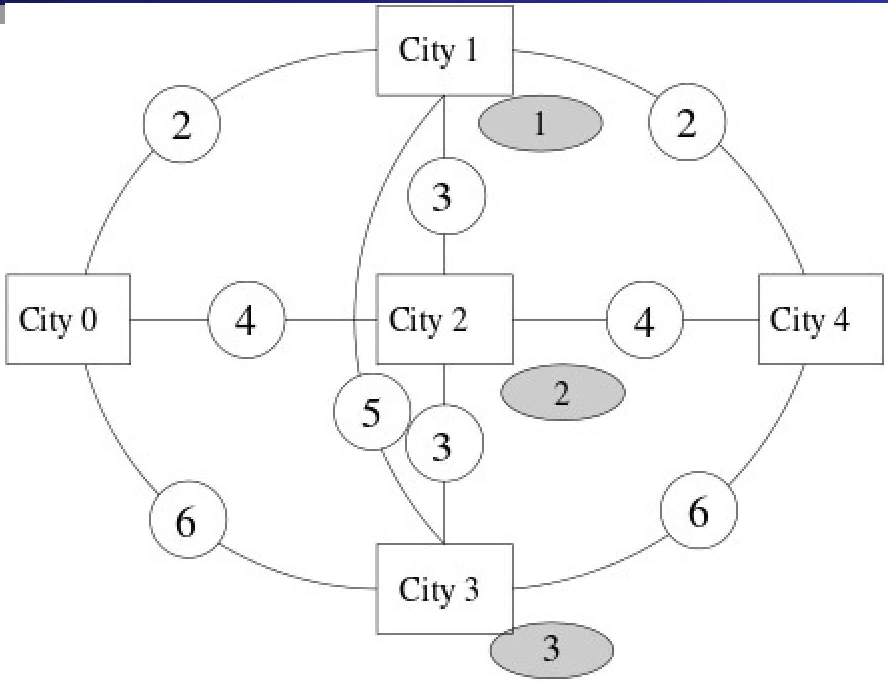
Multi-objective AI Planning

- PDDL 3.0 (2006) allows for several objectives
- But existing strategies/heuristics not applicable
- → aggregation of objectives

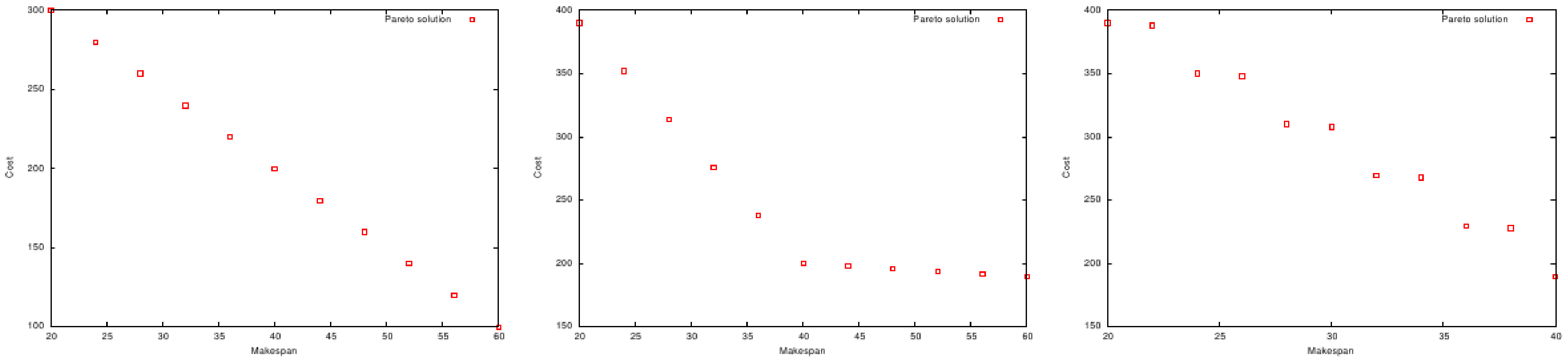
- A multi-objective track in IPC 5 and IPC 6 … not in IPC 7
- + recent approach [Sroka & Long, STAIRS 2012] using LPG [Geverini et al., AI 08]

Multi-objective Zeno Benchmark

- 3n passengers
- 2 planes
- from city0
- to city 4



Pareto fronts for 6 passengers and varying cost/durations values



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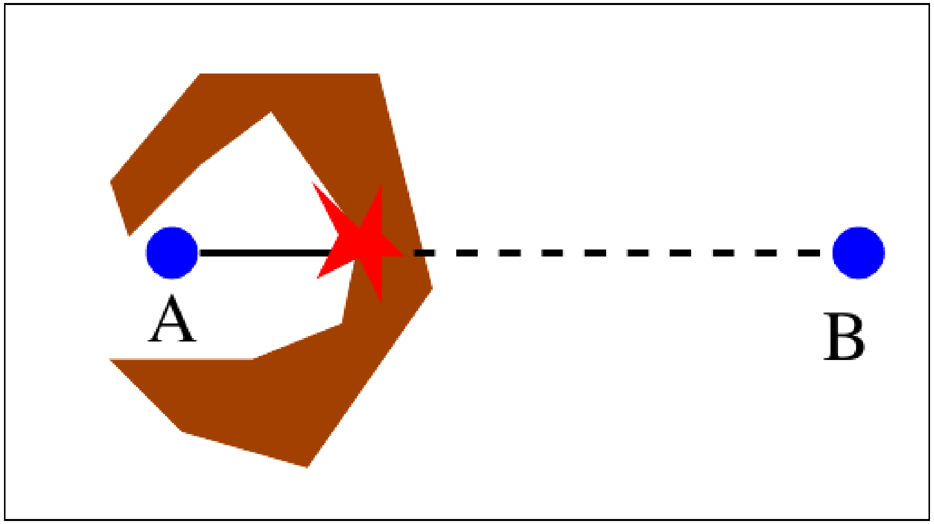
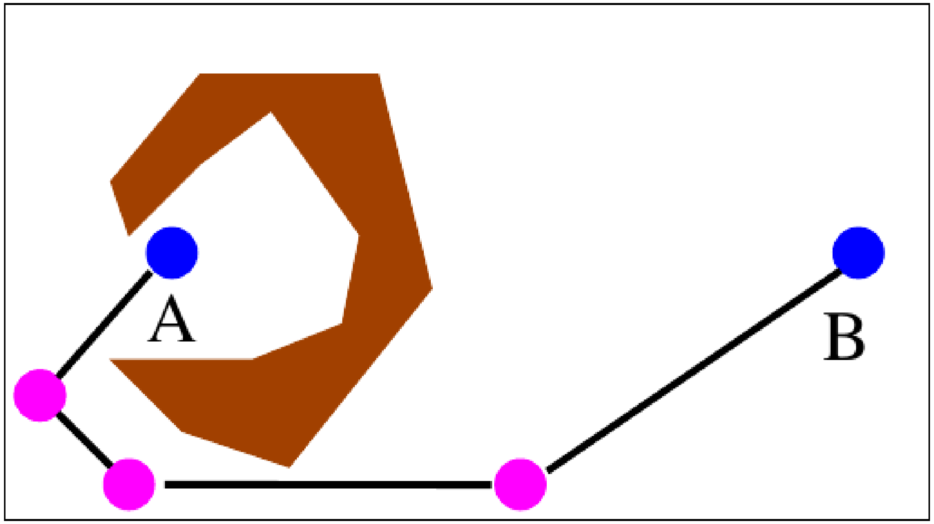
DaE: the Paradigm

- Slicing the original problem into a series of (hopefully simpler) sub-problems
- Using a 'dumb' solver on each sub-problem





(Variable length) Genotype = (●1,●2,●3)

DaE-YAHSP

Problem

$<S, A, I, G> = P_{D(I,G)}$

Representation

Ordered list of partial states $S_0 = I, S_1, \ldots, S_n, S_{n+1} = G$

Evaluation

Solve consecutive sub-problems $P_D(S_k, S_{k+1}) / k \in [0,n]$

with embedded single-objective planner YAHSP [Vidal, ICAPS 04]

Fitness

All problems solved: concatenate partial plans

Fails solving $P_D(S_l, S_{l+1})$: Penalization

Crossover: One-point crossover

Mutations : AddGoal, delGoal, addAtom, delAtom

Single-objective DAE-YAHSP

- An original (intricate) memetization strategy
- A very noisy fitness

but

- YAHSP is both cost- and temporal planner
- DAE-YASHP: state-of-the-art performance in both domains [Bibai et al., ICAPS 2010]
- Silver medal, Humies Awards 2010
- Ranked 1st, temporal satisficing, IPC 2011

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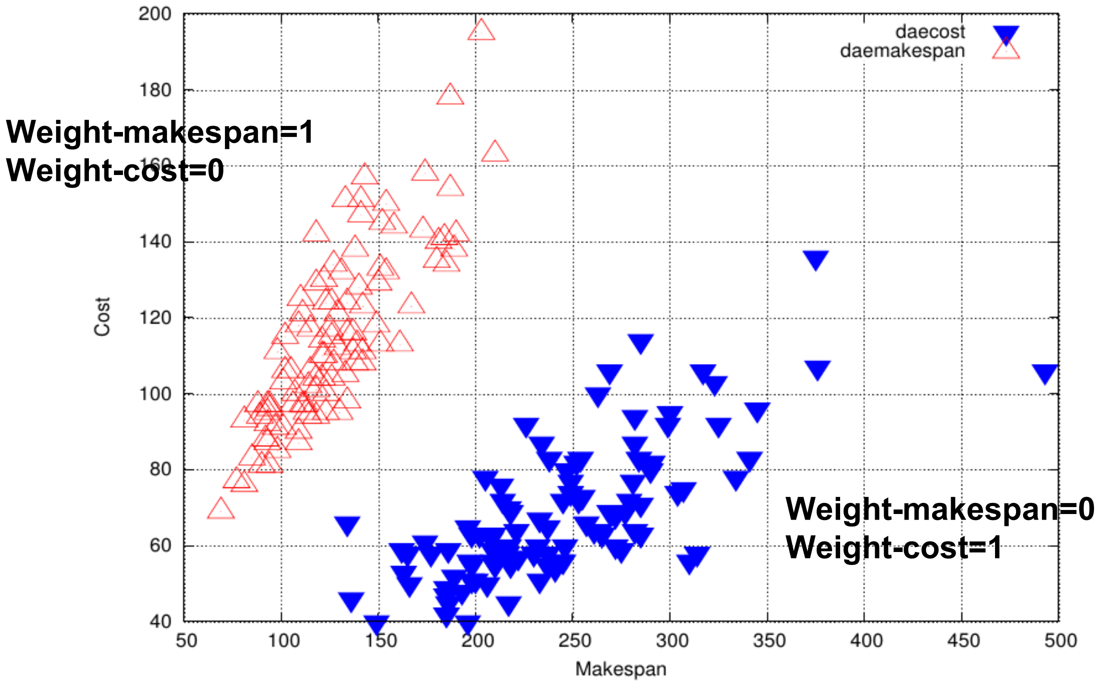
Multi-objective DAE-YAHSP

- YAHSP is both cost- and temporal planner

  … can compute one while optimizing the other (since 2010)
- « Only » need to change the EC engine !
  [Schoenauer, Saveant, Vidal, EvoCOP'06]
- Two problems
  - Cost: additive (tax at every landing)
  - Risk: max (only highest value matters)

YAHSP strategy

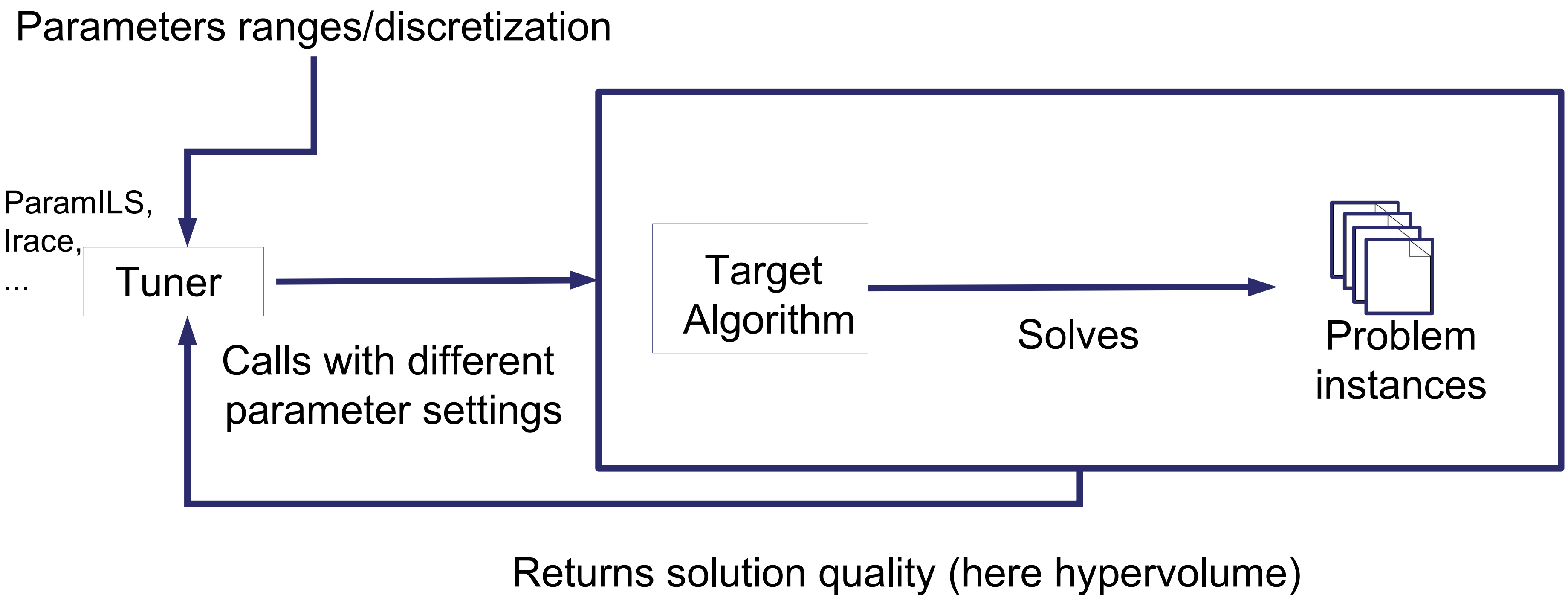
- Optimize cost or makespan?



Noisy fitness : objectives of a single individual computed by YAHSP with both pure strategies

→ randomize, and use weights (individual level)

Parameter Tuning



UBC ParamILS [Hutter et al., JAIR 2009]

Parameter Tuning (2)

Parameters	Range	Description
W-makespan W-cost	0,1,2,3,4,5	Weighting for optimizing makespan during the search Weighting for optimizing cost during the search
Pop-size	30,50,100,200,300	Population Size
Proba-cross Proba-mut	0.0,0.1,0.2,0.5,0.8,1.0	Probability (at population level) to apply crossover Probability (at population level) to apply one mutation
w-addAtom w-addGoal w-delAtom w-delGoal	0,1,3,5,7,10	Relative weight of the addAtom mutation Relative weight of the addGoal mutation Relative weight of the delAtom mutation Relative weight of the delGoal mutation
Proba-change Proba-delatom	0.0,0.1,0.2,0.5,0.8,1.0	Probability to change an atom in addAtom mutation Average probability to delete an atom in delAtom mutation
Radius	1,3,5,7,10	Number of neighbour goals to consider in addGoal mutation

⟶ $1.5 * 10^9$ Possible configurations

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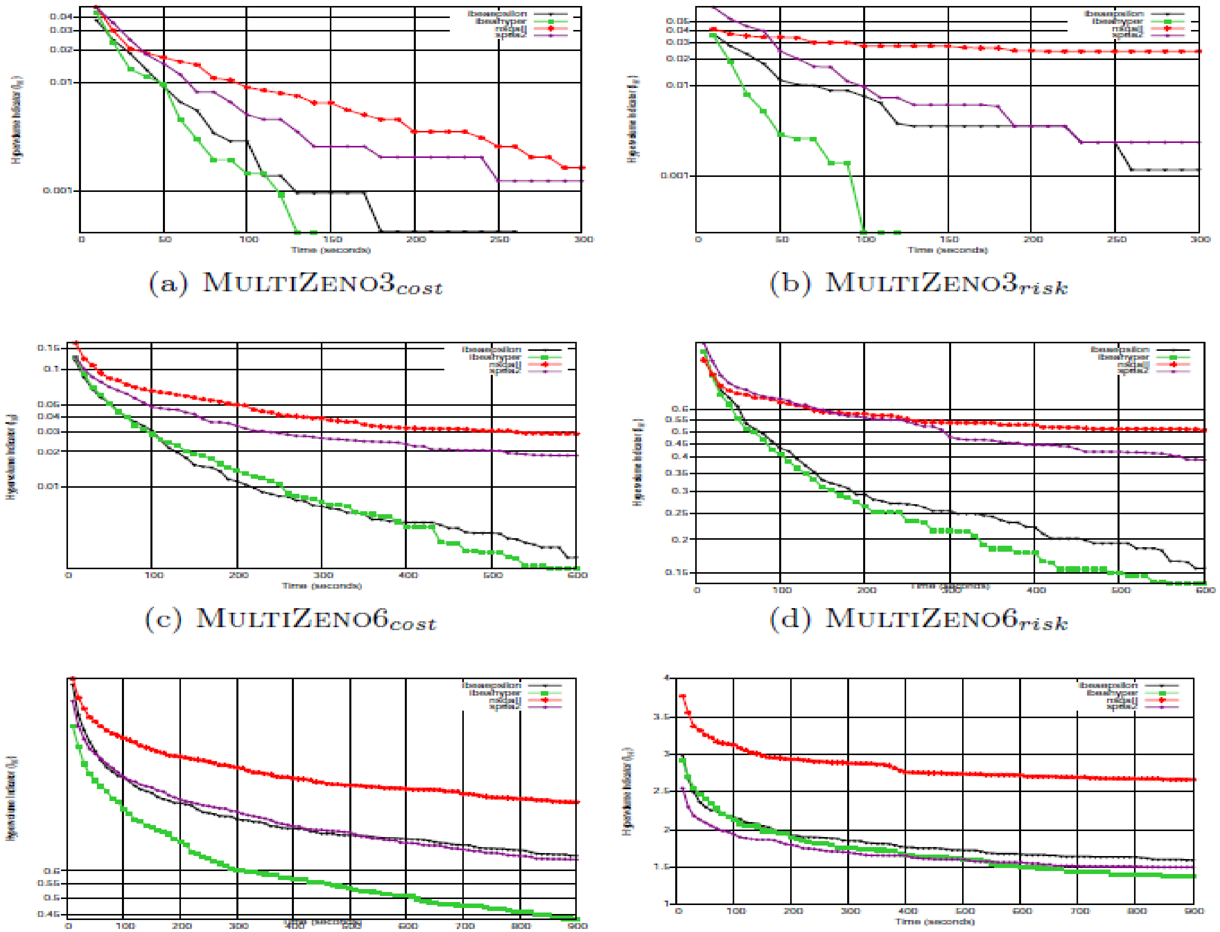
Experimental Conditions

- EC engines NSGA-II, SPEA2, IBEA-ε, IBEA-Hv
- Implementation ParadisEO
- Instances Zeno3, Zeno6, Zeno9
- 11 independent runs (also within ParamILS)
- Stopping criterion
  - ParamILS 48h (zeno3 and 6), 72h (zeno9)
  - Optimization 300, 600 and 900s
- Statistical tests Wilcoxon signed rank test with 95% confidence

Comparative Results



(a) MultiZeno3$_{cost}$ (b) MultiZeno3$_{risk}$

(c) MultiZeno6$_{cost}$ (d) MultiZeno6$_{risk}$

(e) MultiZeno9$_{cost}$ (f) MultiZeno9$_{risk}$

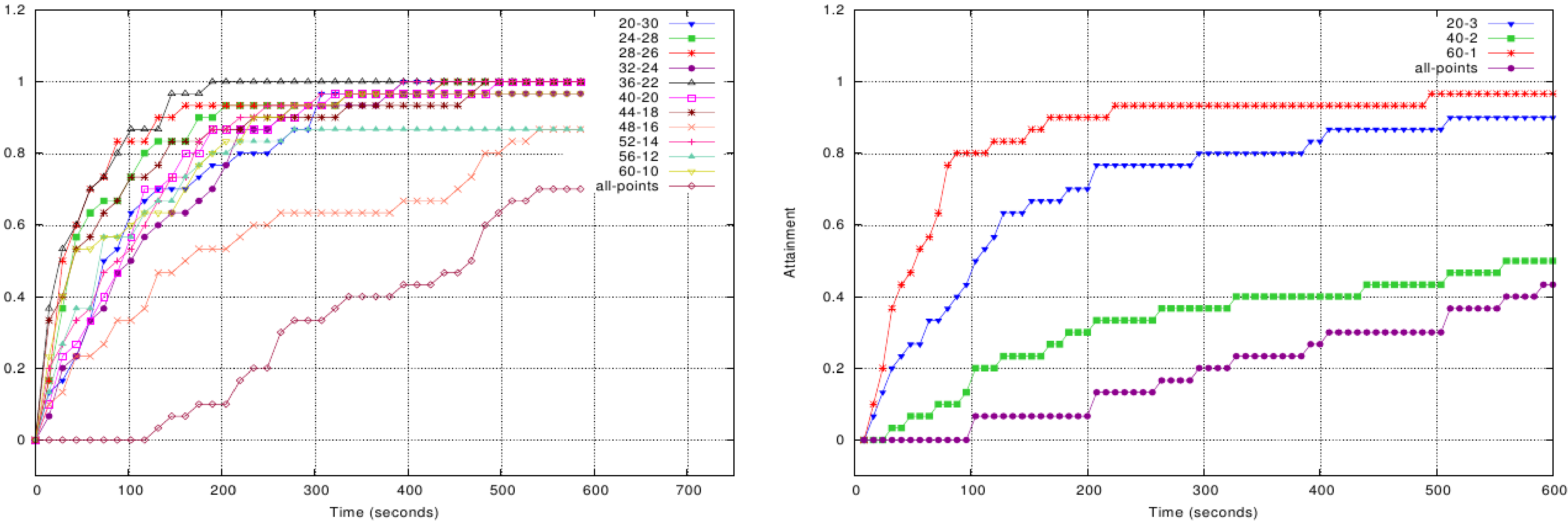
Evolution of hypervolume / reference set for all 4 MOEAs

Statistical tests

Instances	Algorithms	Algorithms			
		$NSGAII$	$IBEA_{\varepsilon+}$	$IBEA_{H-}$	$SPEA2$
$Zeno3_{cost}$	$NSGAII$	–	≡	≡	≡
	$IBEA_{\varepsilon+}$	≡	–	≡	≡
	$IBEA_{H-}$	≡	≡	–	≡
	$SPEA2$	≡	≡	≡	–
$Zeno3_{risk}$	$NSGAII$	–	≡	≡	≡
	$IBEA_{\varepsilon+}$	≡	–	≡	≻
	$IBEA_{H-}$	≡	≡	–	≻
	$SPEA2$	≡	≺	≺	–
$Zeno6_{cost}$	$NSGAII$	–	≺	≺	≺
	$IBEA_{\varepsilon+}$	≻	–	≡	≡
	$IBEA_{H-}$	≻	≡	–	≡
	$SPEA2$	≻	≡	≡	–
$Zeno6_{risk}$	$NSGAII$	–	≺	≺	≡
	$IBEA_{\varepsilon+}$	≻	–	≻	≻
	$IBEA_{H-}$	≻	≺	–	≻
	$SPEA2$	≡	≺	≺	–
$Zeno9_{cost}$	$NSGAII$	–	≺	≺	≺
	$IBEA_{\varepsilon+}$	≻	–	≺	≡
	$IBEA_{H-}$	≻	≻	–	≡
	$SPEA2$	≻	≡	≡	–
$Zeno9_{risk}$	$NSGAII$	–	≺	≺	≺
	$IBEA_{\varepsilon+}$	≻	–	≺	≡
	$IBEA_{H-}$	≻	≻	–	≡
	$SPEA2$	≻	≡	≡	–

Ibea-Hv performs significantly better

Pareto Front Attainability

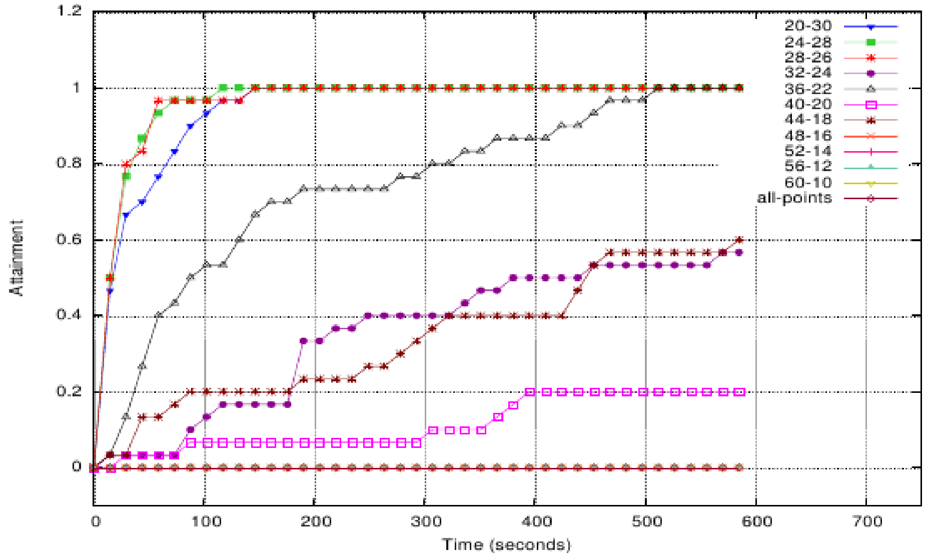


(a) $\textsc{MultiZeno6}_{cost}$

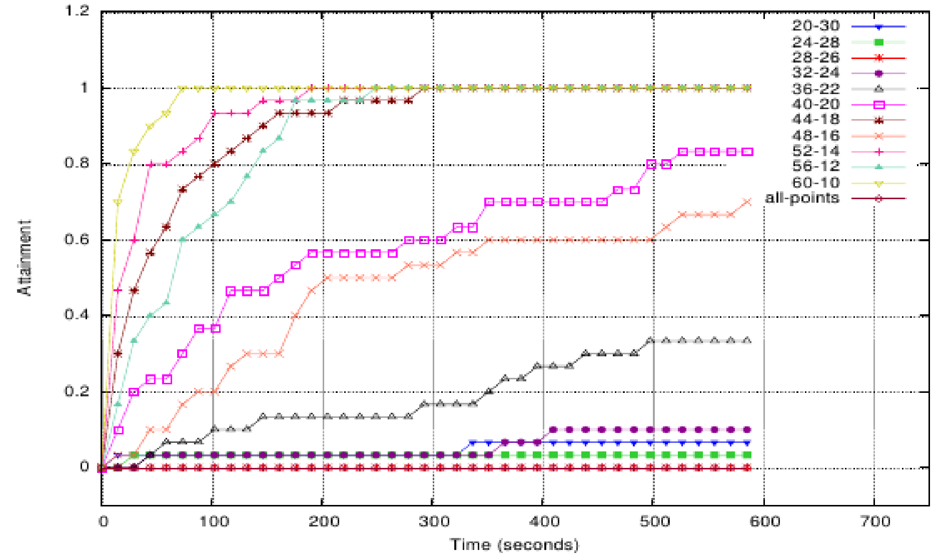
(b) $\textsc{MultiZeno6}_{risk}$

Hitting plots for Ibea-Hv on Zeno6 (Cost and Risk)

Influence of YAHSP strategy



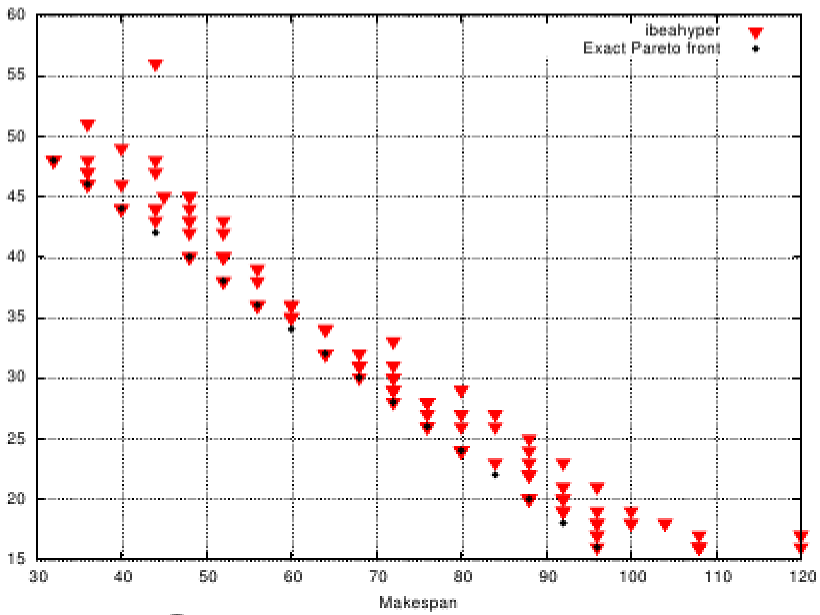
(a) YAHSP optimizes makespan



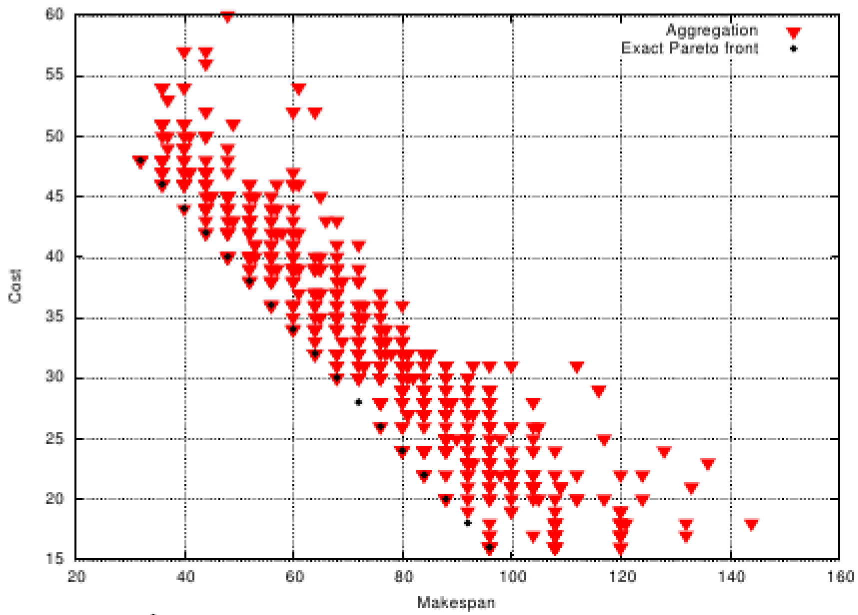
(b) YAHSP optimizes cost

Hitting plots for Ibea-Hv on Zeno6 for the 2 'pure' strategies

Comparison with aggregation



MO-DaE$_{\text{YAHSP}}$ on MultiZeno9



Agg-DaE$_{\text{YAHSP}}$ on MultiZeno9

Pareto Fronts (from 11 runs) for Zeno9 (scales are different)

See [EvoCOP'13]

Summary

- MO-DAE-YAHSP : a multi-objective evolutionary planner based on a single-objective classical planner
- A simple MO benchmark for AI Planning
- Randomized YAHSP strategy (confirmed:-)
- IBEA-Hv best choice (on Zeno benchmarks)
- Outperforms aggregation
  - Both DAE [EvoCop'13] and LPG [submitted]

Perspectives

- Comparison with LPG-based approach
  - [submitted]
- Extended benchmarks from IPC domains
  - [submitted] in parts
- Adaptive choice of YAHSP strategy
  - Individual or sub-goal level?
- On-line parameter setting
  - Adaptive operator selection/tuning
- Better handling of risk