Automatically Configuring Multi-objective Local Search using Multi-objective Optimisation

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Context

Choosing and using the best algorithm

Algorithm Selection

- Multiple different algorithms
- Associate algorithm performance with instance features

Algorithm Configuration

- Single algorithm, various parameters
- Learn the best configuration for a given instance class

Context

Automatic Algorithm Configuration (AAC)

(Single-objective) AAC Configurators

- irace [López-Ibáñez *et al.*, 2016]
- SMAC [Hutter *et al.*, 2010]
- ParamILS [Hutter *et al.*, 2009]
- GGA++ [Ansótegui *et al.*, 2015]

Multi-objective AAC Configurators

- SPRINT-Race [Zhang *et al.*, 2015]
- MO-ParamILS [Blot *et al.*, 2016]

Motivation: Multi-objective Algorithms

Problematic

- How to define the best configuration?
  - Multiple performance indicators
- How to automatically configure multi-objective algorithms?

Possible Answers

- AAC using a single indicator
- AAC using aggregation of multiple indicators
- Multi-objective AAC

Automatically Configuring Multi-objective Local Search using Multi-objective Optimisation

- Question
  - Which AAC approach should we use for multi-objective algorithms?
- Target Algorithm
  - Multi-objective local search (MOLS)

Multi-objective Local Search

Why?

MOLS Algorithms

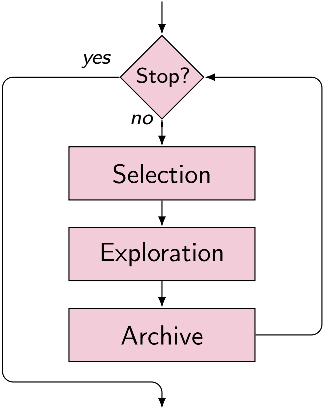
- Efficient metaheuristics
- Used on many problems (*e.g.*, scheduling, routing, assignment)
- Many combinations of parameters/strategies

MOLS Principles

- Iteratively improve a set of solutions
- Using a neighbouring relation

Multi-objective Local Search

Core MOLS

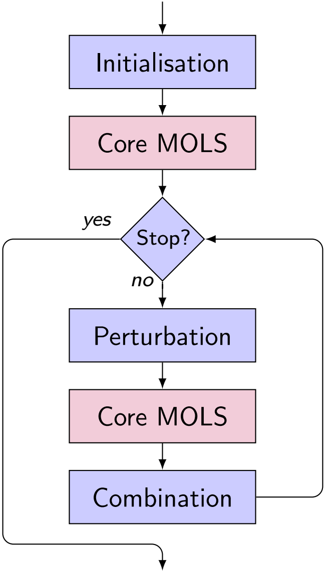


Core MOLS

- Termination
- Selection
- Exploration
- Archive

Multi-objective Local Search

Iterated MOLS



Iterated MOLS

- Initialisation
- Perturbation
- Combination

Multi-objective Local Search

Considered parameters

Phase	Parameter	Parameter values
Initialisation	initStrat	rand
	initSize	10
Selection	selectStrat	{all, rand, newest, oldest}
	selectSize	$\{1, 2, 3\}$
Exploration	explorStrat	{all, all_imp, imp, imp_ndom, ndom}
	explorRef	{sol, select, arch}
	explorSize	$\{1, 2, 3\}$
Perturbation	perturbStrat	{restart, kick, kick_all}
	perturbSize	$\{1, 2, 3\}$
	perturbStrength	$\{3, 5\}$

Total: 2790 configurations

Multi-objective Local Search

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Initialisation	initStrat	rand
	initSize	10
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Multi-objective Local Search

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Phase	Parameter	Parameter values
Initialisation	`initStrat`	`rand`
	`initSize`	10
Selection	`selectStrat`	{`all`, `rand`, `newest`, `oldest`}
	`selectSize`	$\{1, 2, 3\}$
Exploration	`explorStrat`	{`all`, `all_imp`, `imp`, `imp_ndom`, `ndom`}
	`explorRef`	{`sol`, `select`, `arch`}
	`explorSize`	$\{1, 2, 3\}$
Perturbation	`perturbStrat`	{`restart`, `kick`, `kick_all`}
	`perturbSize`	$\{1, 2, 3\}$
	`perturbStrength`	$\{3, 5\}$

Total: 2790 configurations

AAC Configurators

ParamILS [Hutter *et al.*, 2009]

- Prominent, state-of-the-art configurator
- Many successful applications
- ILS on the configuration space

MO-ParamILS [Blot *et al.*, 2016]

- Extension of ParamILS for multiple performance indicators
- Iterated MOLS on the configuration space

AAC Scenario

Application

- MOLS Algorithms
- Bi-objective Permutation Flowshop Scheduling Problem (PFSP)
  - Makespan & flowtime
  - Classical Taillard instances (20 and 50 jobs, 5 to 20 machines)

Performance Indicators

- Hypervolume (as convergence indicator)
- Δ spread (as diversity indicator)

AAC Approaches

HV: AAC with a single indicator

- Configure using only the hypervolume
- ParamILS

HV+Δ: AAC with an aggregation

- Configure using an aggregation $(0.75HV + 0.25\Delta)$
- ParamILS

HV||Δ: Multi-objective AAC

- Configure using Pareto dominance
- MO-ParamILS

Experimental Protocol

Training (30 times)

- 80 randomly generated Taillard-like PFSP instances
- Scenario 1 (20-jobs instances): 12 hours
- Scenario 2 (50-jobs instances): 24 hours

Validation

- Only non-dominated training configurations
- 30 original Taillard PFSP instances
- 5 runs / instance

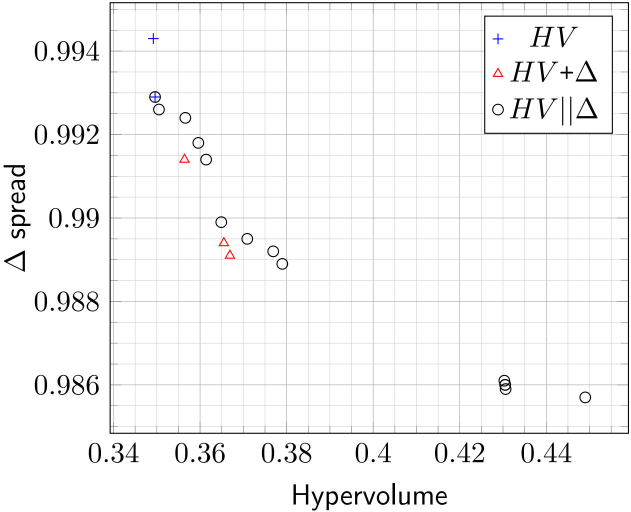
Results

Final configurations (50-jobs instances)

Approach	Selection		Exploration			Perturbation				HV	Δ
HV	newest	1	ndom	sol	2	kick	2	3	+	0.3492	0.9943
HV	newest	1	ndom	sol	1	kick_all	.	3	+	0.3496	0.9929
HV+Δ	all	.	ndom	arch	1	kick_all	.	3	△	0.3564	0.9914
HV+Δ	newest	1	ndom	arch	3	kick	2	3	△	0.3655	0.9894
HV+Δ	newest	1	ndom	arch	2	kick_all	.	3	△	0.3669	0.9891
$HV\|\|\Delta$	newest	1	ndom	sol	2	kick_all	.	3	○	0.3496	0.9929
$HV\|\|\Delta$	newest	1	ndom	sol	1	kick	1	5	○	0.3505	0.9926
$HV\|\|\Delta$	newest	3	ndom	arch	2	kick_all	.	3	○	0.3566	0.9924
$HV\|\|\Delta$	newest	2	ndom	arch	2	kick_all	.	3	○	0.3596	0.9918
$HV\|\|\Delta$	newest	3	ndom	arch	1	kick_all	.	3	○	0.3614	0.9914
$HV\|\|\Delta$	newest	1	ndom	arch	3	kick	3	3	○	0.3649	0.9899
$HV\|\|\Delta$	newest	1	ndom	arch	2	kick_all	.	3	○	0.3669	0.9891
$HV\|\|\Delta$	newest	1	ndom	arch	1	kick	1	3	○	0.379	0.9889
$HV\|\|\Delta$	all	.	all	.	.	kick	3	3	○	0.4303	0.9861
$HV\|\|\Delta$	all	.	all	.	.	kick	1	5	○	0.4305	0.986
$HV\|\|\Delta$	all	.	all	.	.	kick	3	5	○	0.4305	0.986
$HV\|\|\Delta$	all	.	all	.	.	kick	1	3	○	0.4306	0.9859
$HV\|\|\Delta$	all	.	imp_ndom	arch	2	restart	.	.	○	0.449	0.9857

Results

Test performance (50-jobs instances)



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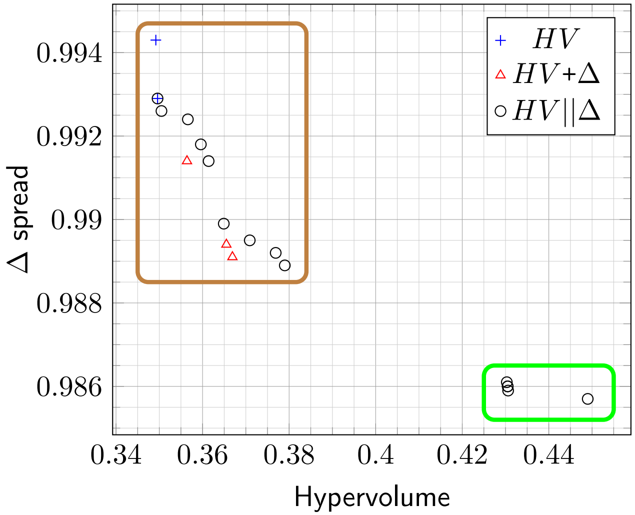

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$HV\|\|\Delta$	all	.	all	.	.	kick	3	3	○	0.4303	0.9861
$HV\|\|\Delta$	all	.	all	.	.	kick	1	5	○	0.4305	0.986
$HV\|\|\Delta$	all	.	all	.	.	kick	3	5	○	0.4305	0.986
$HV\|\|\Delta$	all	.	all	.	.	kick	1	3	○	0.4306	0.9859
$HV\|\|\Delta$	all	.	imp_ndom	arch	2	restart	.	.	○	0.449	0.9857

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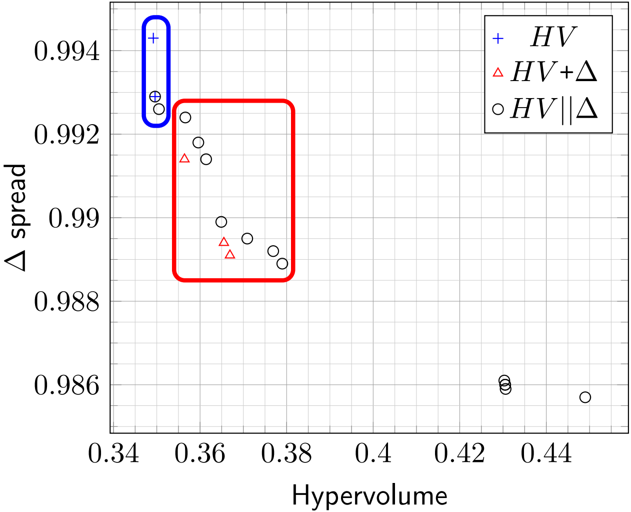

Results

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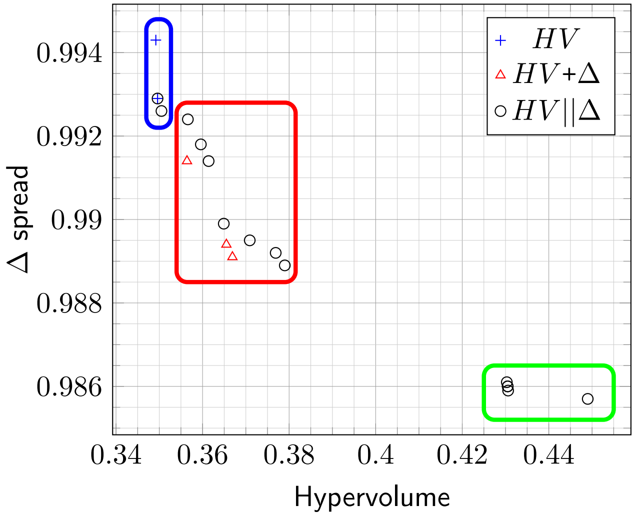

Results

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Results

Interpretation

HV

- Disregards diversity entirely

HV+Δ

- Only in the aggregation direction
- Requires costly indicator normalisation

HV||Δ

- Wide, diverse covering

Conclusion

Take-home Message

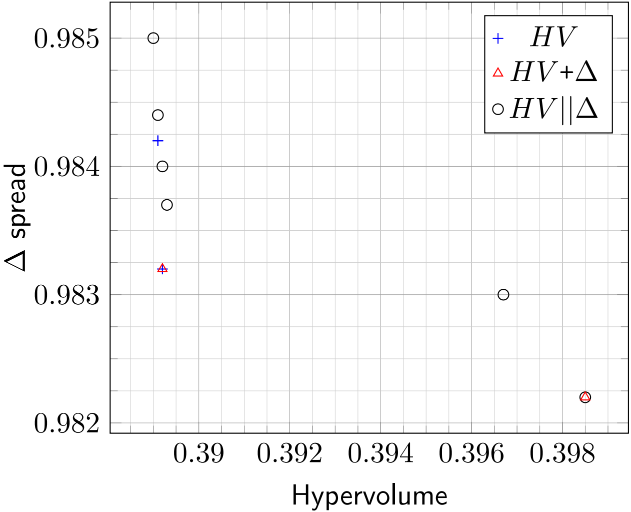
- Comparing the performance of MO algorithms is a MO problem
- Use multi-objective AAC!
  - No loss of performance
  - Way better diversity

Perspectives

- Extend to different problems
- Extend to different algorithms
- Fine-tune MO-ParamILS?

Results

Test performance (20-jobs instances)



Results

Final configurations (20-jobs instances)

Approach	Selection		Exploration			Perturbation		
HV	rand	2	imp_ndom	select	1	kick	1	5
HV	oldest	2	imp_ndom	sol	1	restart	.	.
HV	all	.	imp_ndom	select	1	kick_all	.	5
HV+Δ	all	.	imp_ndom	select	1	kick_all	.	5
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$HV\|\|\Delta$	all	.	ndom	arch	1	kick	1	3
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