Optimistic Best-First Search with Goal-preferred Actions in Fast Downward

Bachelor's Thesis by Lisette Maureira -- Supervisor: Remo Christen

UNIBAS AI Group HS2025

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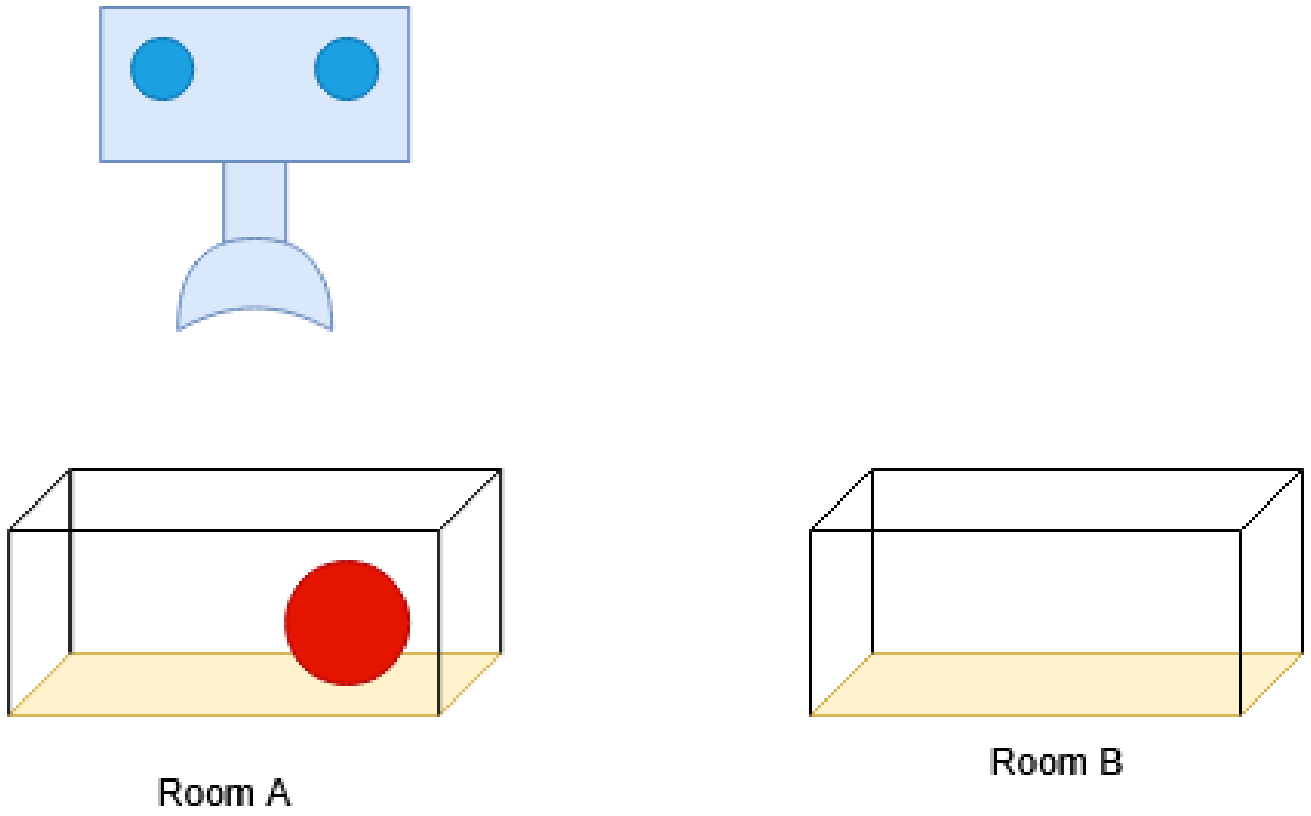
Searching…

Planning in Artificial Intelligence is the search for a sequence of applicable actions to reach a given goal from the initial state.

STRIPS Gripper: Initial state

State Variables:

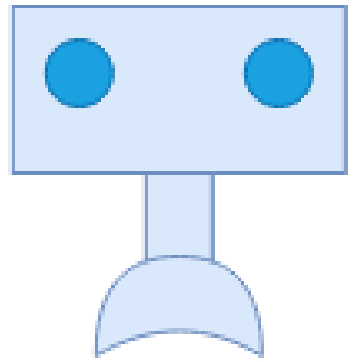
Robot at room A: **at_gA**
Ball at room A: **at_1A**
Robot arm free: **free**

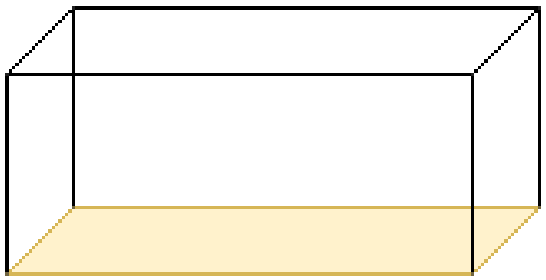


STRIPS Gripper: Goal state

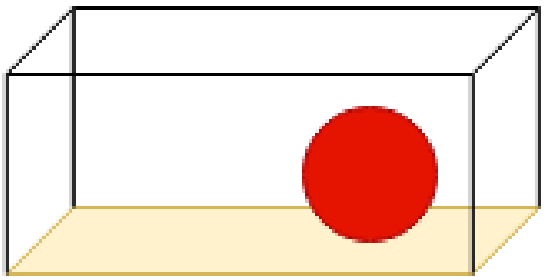
State Variables:

Robot at room B: **at_gB**
Ball at room B: **at_1B**





Room A

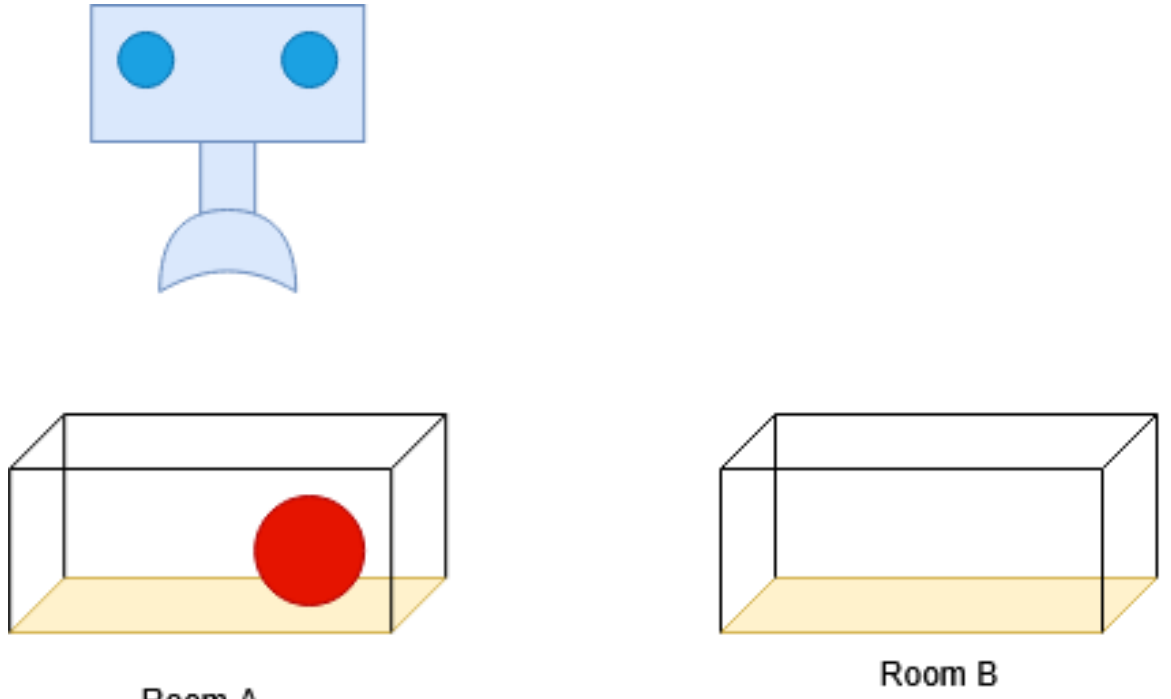


Room B

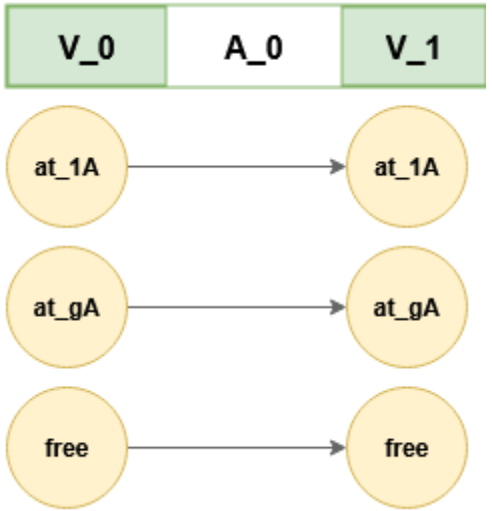
STRIPS Gripper: Actions

	Move		Pick		Drop	
Action	move_AB	move_BA	pick_1A	pick1B	drop_1A	drop_1B
Preconditions	at_gA	at_gB	at_gA, at_1A, free	at_gB, at_1B, free	at_gA, at_1A, in	at_gB, at_1B, in
Add effects	at_gB	at_gA	in	in	at_1A	at_1B
Delete effects	at_gA	at_gB	at_1A, free	at_1B, free	in	in
Cost	2		3		1	

Delete-relaxation: Initial state

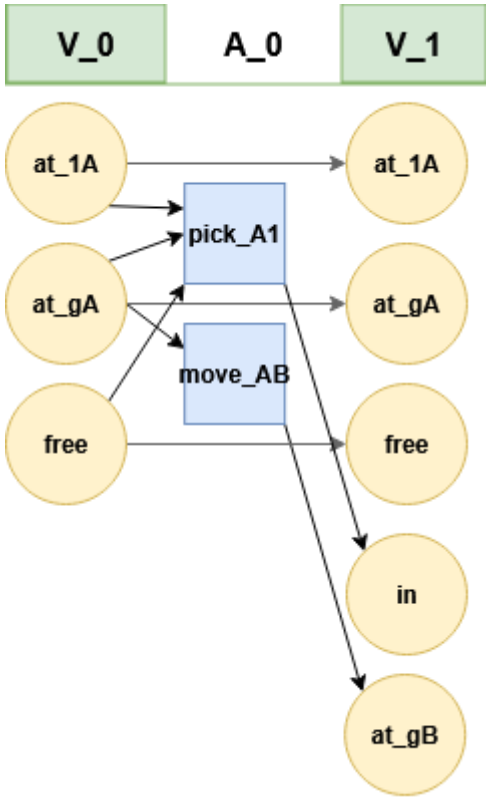


Delete-relaxation: Vertices



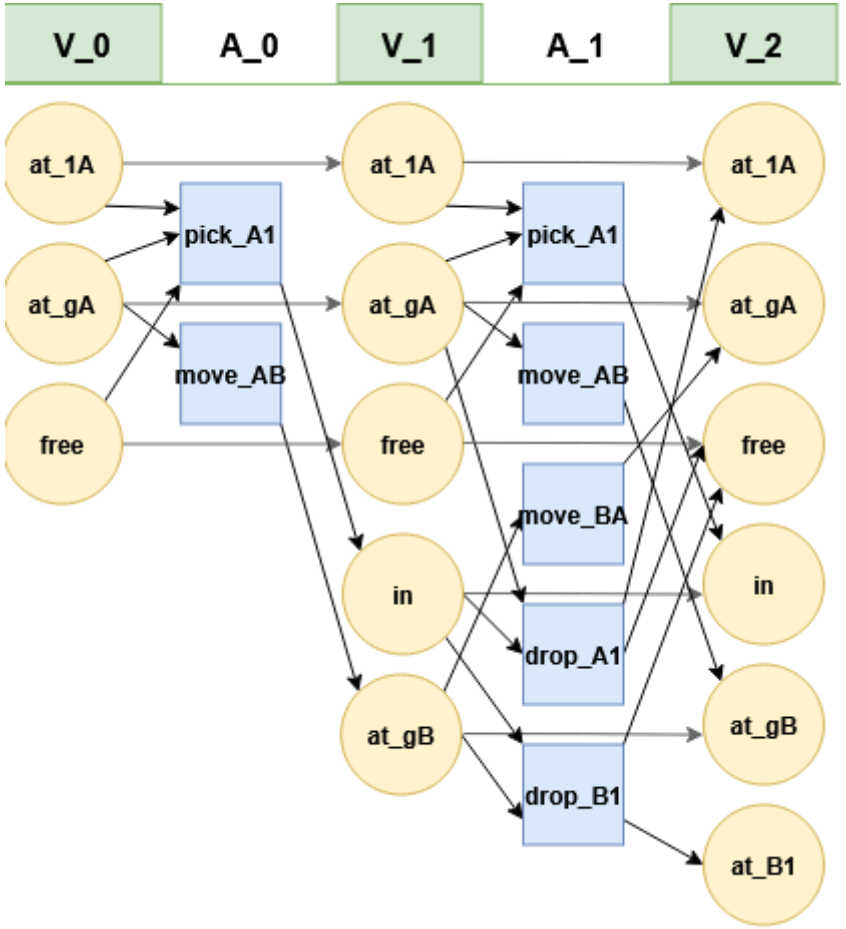
- No delete effects: vertices stay

Delete-relaxation: Action Layer

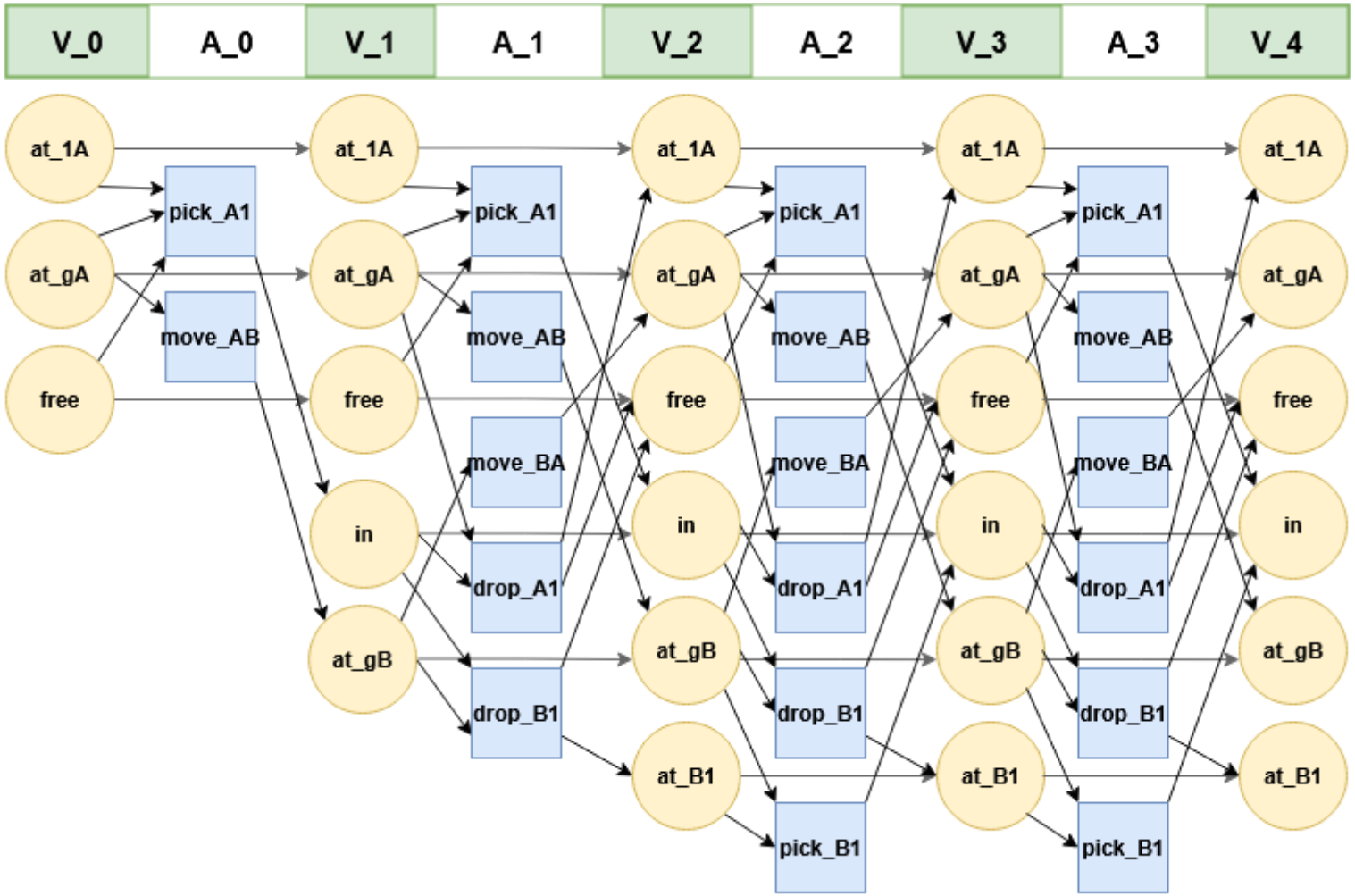


- Preconditions to pick the ball from Room A fulfilled
- Preconditions to move the robot from room A to room B fulfilled

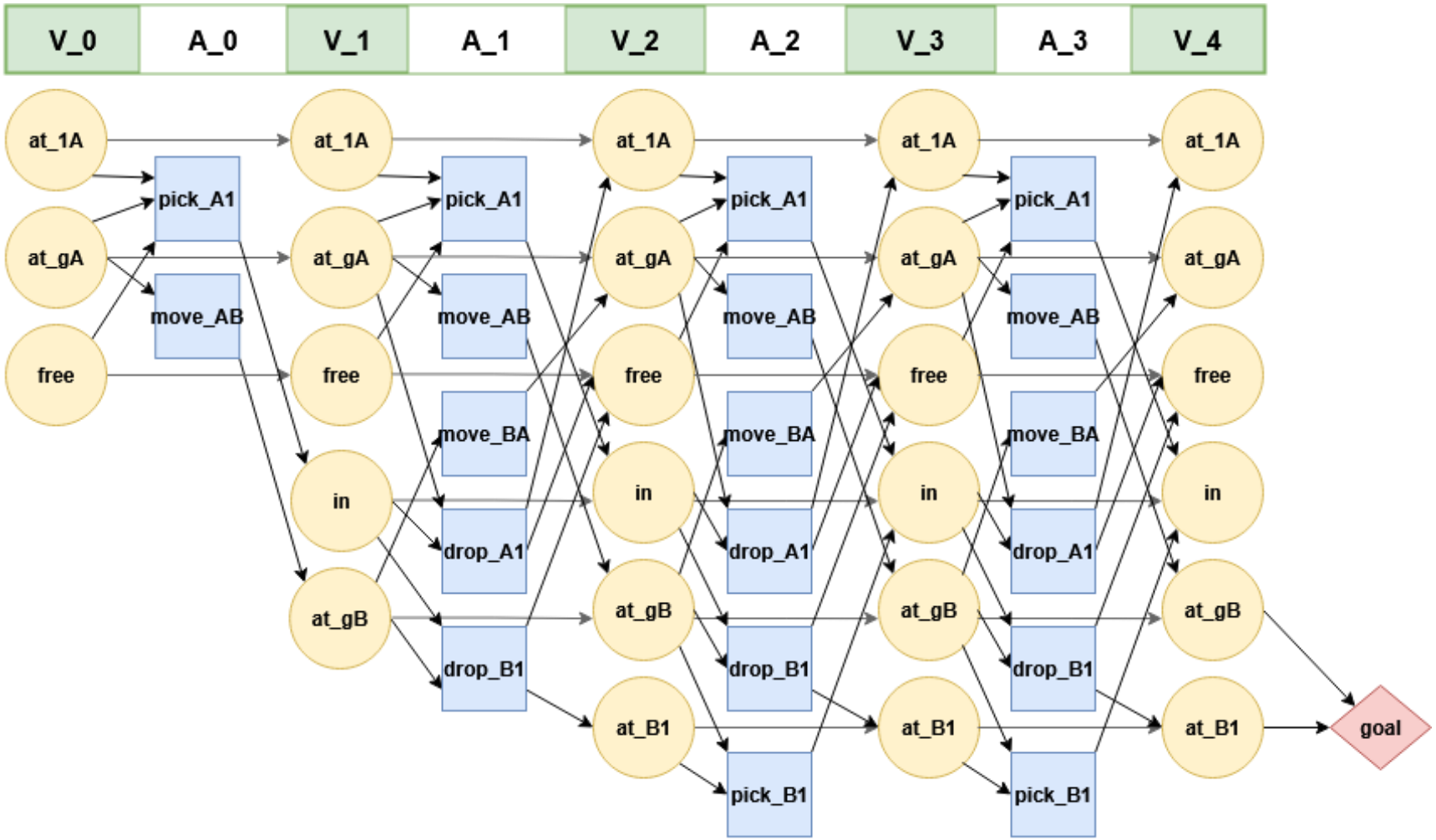
Delete-relaxation



Delete-relaxation: Termination



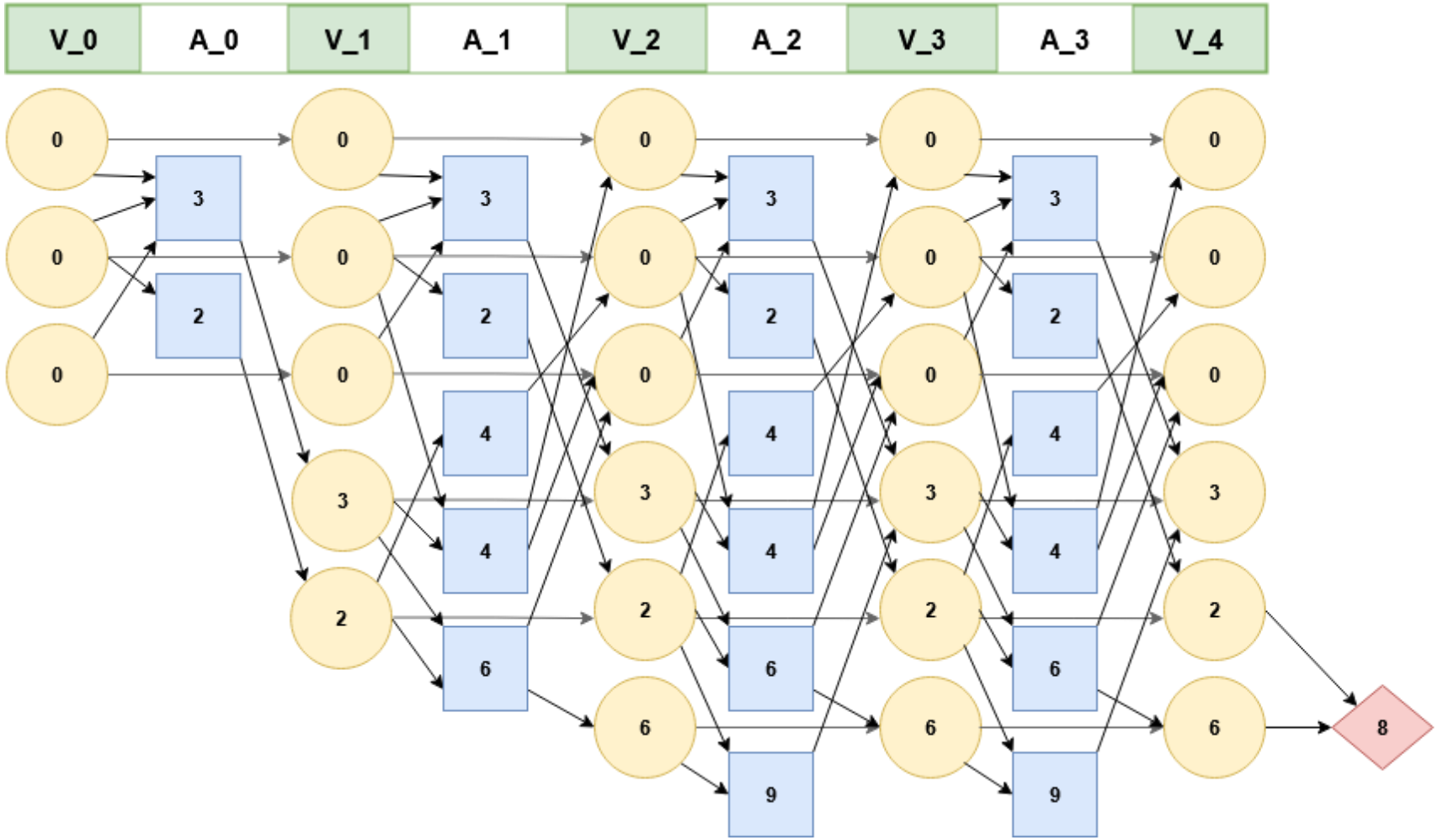
Delete-relaxation: Goal



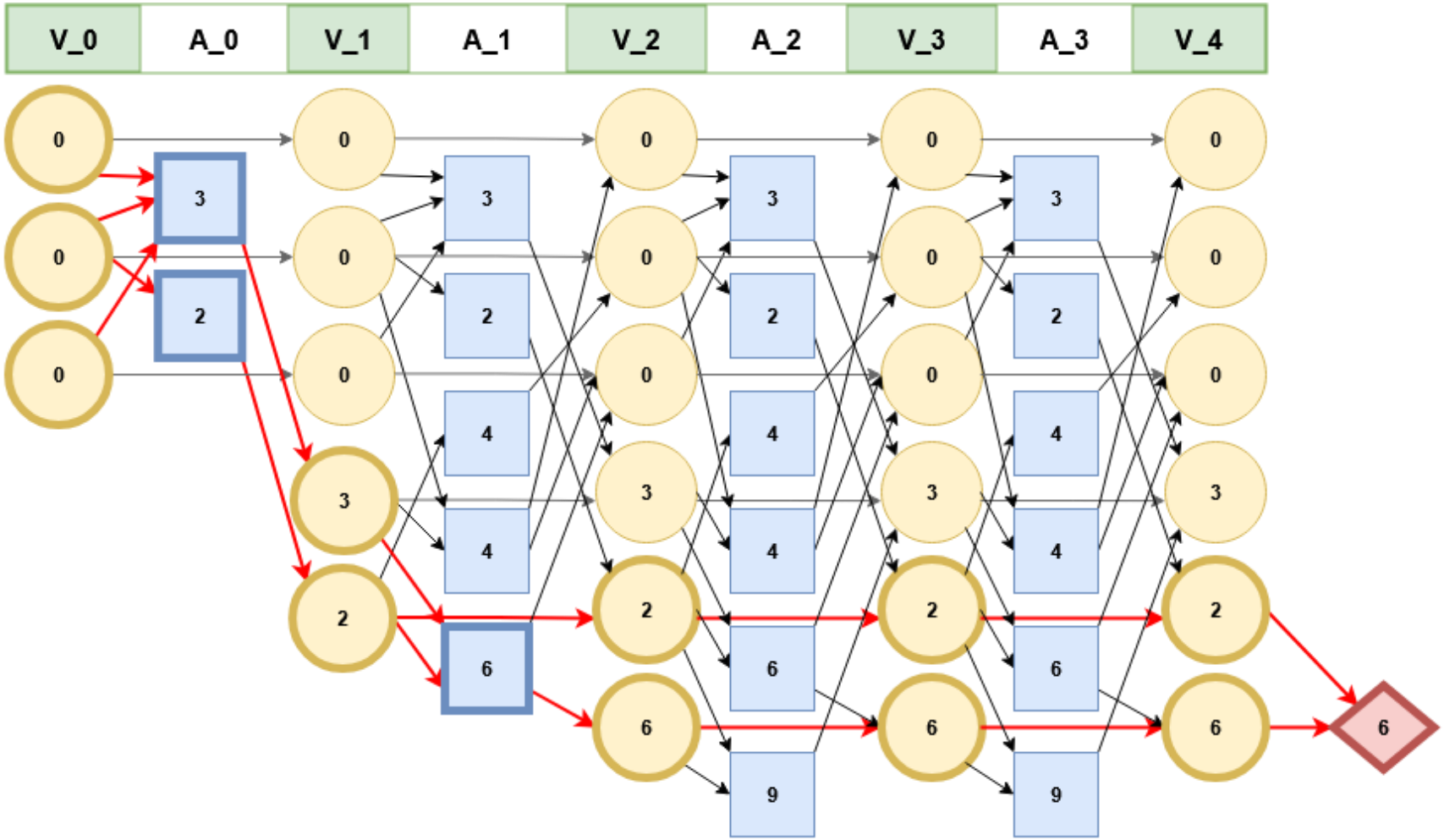
Heuristics

How do we estimate how far we are from the goal from a given node from the delete-relaxation graph?

hadd Heuristic



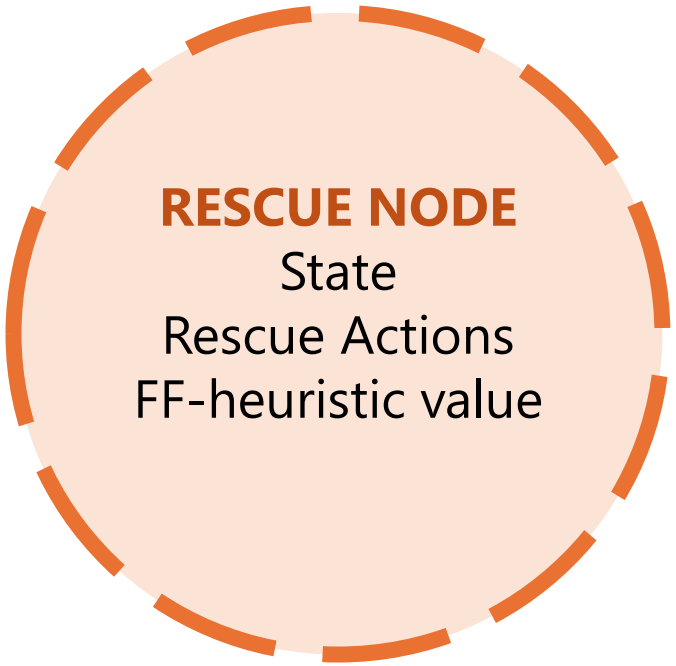
FF-heuristic: Helpful Actions & Nodes



Relaxed plan

Rescue Actions & Nodes

- Not helpful applicable actions
- Helpful Actions U Rescue Actions = All applicable actions
- Completeness
- Node stores state, Rescue Actions, heuristic value



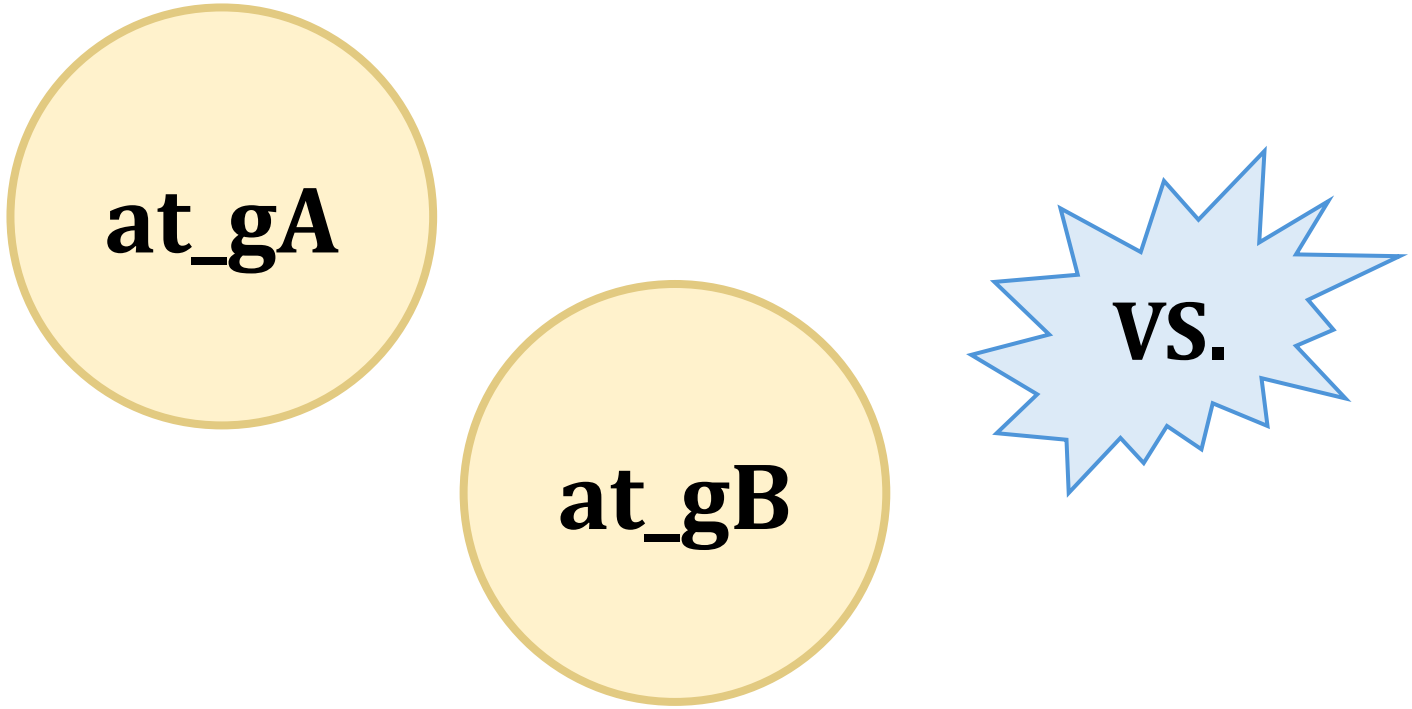
Goal-preferred Actions

«Actions that do not delete a state variable that belongs to the goal and do not belong in the initial state» *-Vincent Vidal*

- Goal-preferred actions….
  - Are free to delete any state variables present in the initial state, regardless of whether they too are in the goal
  - Otherwise cannot delete state variables present in the goal

Delete-Effects: STRIPS vs. SAS+

- Delete effects, Add effects vs. Effects
- Reassignment of variables, erasure of value



Goal-preferred Actions Algorithm

Naive Algorithm:

- Effect variable, value pair not in initial state
- Effect variable in the goal
- Effect value not the goal value

-> Not goal-preferred action

Goal-preferred Actions Algorithm

Naive Algorithm:

- Effect variable, value pair not in initial state
- Effect variable in the goal
- Effect value not the goal value

-> Not goal-preferred action

Reworked Algorithm:

- Effect variable, value pair not in initial state
- Effect variable in the goal
- Effect value not the goal value
- Goal variable not in preconditions
  or goal variable, value pair in preconditions

-> Not goal-preferred action

What does OBFS with goal-pref do?

Store expansion candidates:

1. Build a relaxed plan with only Goal-preferred Actions
2. If it succeeds, store Helpful Node & Rescue Node
3. If it fails, build relaxed plan and store as Rescue Node

Search Expansion Criteria:

1. Helpful Nodes preferred over Rescue Nodes
2. Low FF-heuristic value preferred

Results

Comparison of performance against related benchmarks

Results: What are we looking for?

- For suboptimal algorithms, if possible:
  - Few expansions
  - Memory efficiency
  - Fast search

- Further analysis:
  - Completeness
  - % of goal-preferred actions

Results: What are we comparing?

- Related planners:
  - Eager greedy FF
  - Greedy FF with preferred actions

- Our implementation:
  - Naive goal-preferred algorithm
  - Reworked goal-preferred algorithm

Results: Implementation differences

Sum	Naive Goalpref	Goalpref
Goal-preferred actions	22’143’251	35’433’194
Goal-preferred ratio arithmetic average %	64%	92%

What does this mean for the behavior of the search?

- Possibility that goal-preferred actions only relaxed plan fails less with more goal-preferred actions
- Thus FF-heuristic value tie-breaker comes less into play

Results: Completeness

Sum	Eager Greedy FF	Greedy FF with pref	Naive Goalpref	Goalpref
Error: Search unsolveable	4	4	119	97

Implementation is incomplete

Results: Coverage, 1st run

Sum	Eager Greedy FF	Greedy FF with pref	Naive Goal-pref	Goal-pref
Out of memory	87	70	829	760
Out of time	506	393	0	0
Other errors	5	6	4	9
Coverage	1117	1246	882	946
Coverage %	65.13%	72.65%	51.4%	55.16%

Implementation is memory inefficient

Can we be more memory efficient?

Store expansion candidates:

1. Build a relaxed plan with only Goal-preferred Actions
2. If it succeeds, store Helpful Node & Rescue Node
3. If it fails, build relaxed plan and store all as Rescue Node

Search Expansion Criteria:

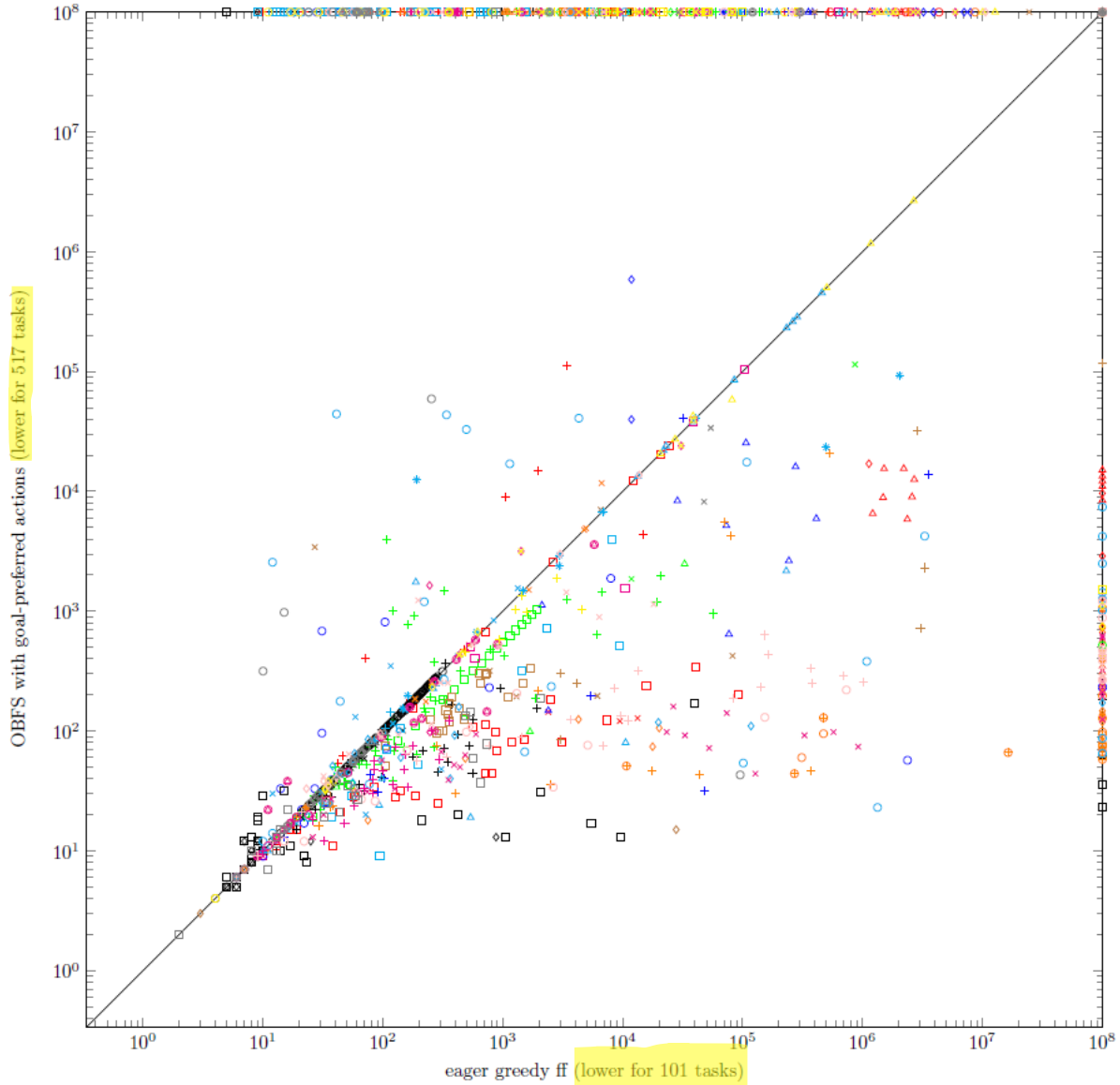
1. Helpful Nodes preferred over Rescue Nodes
2. Low FF-heuristic value preferred

Results: Coverage, Take 2

Sum	Eager Greedy FF	Greedy FF with pref	Naive Goal-pref	Goal-pref
Out of memory	85	68	661	301
Out of time	513	399	67	363
Other errors	7	4	8	8
Coverage	1227	1361	981	1067
Unsolveable	4	4	119	97

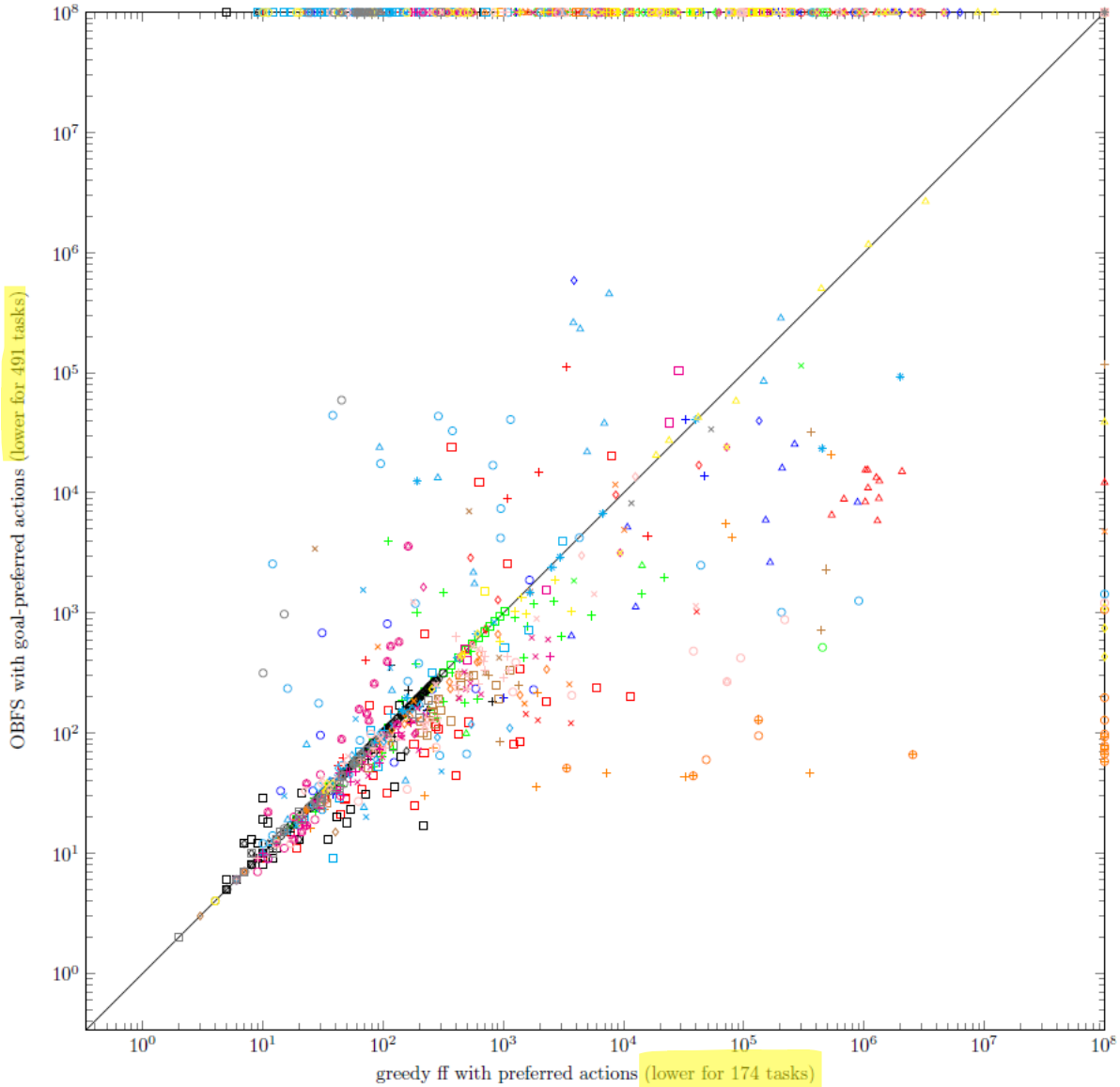
Implementation is less memory inefficient

Results: Expansions (Eager Greedy FF)



× agricola-sat18-strips	+ airport	○ barman-sat11-strips
△ barman-sat14-strips	□ blocks	◇ childsnack-sat14-strips
× data-network-sat18-strips	+ depot	○ driverlog
△ elevators-sat08-strips	□ elevators-sat11-strips	◇ floortile-sat11-strips
× floortile-sat14-strips	+ freecell	○ ged-sat14-strips
△ grid	□ gripper	◇ hiking-sat14-strips
× logistics00	+ logistics98	○ miconic
△ movie	□ mprime	◇ mystery
× nomystery-sat11-strips	+ openstacks-sat08-strips	○ openstacks-sat11-strips
△ openstacks-sat14-strips	□ openstacks-strips	◇ organic-synthesis-sat18-strips
× organic-synthesis-split-sat18-strips	+ parcprinter-08-strips	○ parcprinter-sat11-strips
△ parking-sat11-strips	□ parking-sat14-strips	◇ pathways
× pegsol-08-strips	+ pegsol-sat11-strips	○ pipesworld-notankage
△ pipesworld-tankage	□ psr-small	◇ quantum-layout-sat23-strips
× rovers	+ satellite	○ scanalyzer-08-strips
△ scanalyzer-sat11-strips	□ snake-sat18-strips	◇ sokoban-sat08-strips
× sokoban-sat11-strips	+ spider-sat18-strips	○ storage
△ termes-sat18-strips	□ tetris-sat14-strips	◇ thoughtful-sat14-strips
× tidybot-sat11-strips	+ tpp	○ transport-sat08-strips
△ transport-sat11-strips	□ transport-sat14-strips	◇ trucks-strips
× visitall-sat11-strips	+ visitall-sat14-strips	○ woodworking-sat08-strips
△ woodworking-sat11-strips	□ zenotravel	

Results: Expansions (Greedy FF with pref)



× agricola-sat18-strips	+ airport	○ barman-sat11-strips
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× data-network-sat18-strips	+ depot	○ driverlog
△ elevators-sat08-strips	□ elevators-sat11-strips	◇ floortile-sat11-strips
× floortile-sat14-strips	+ freecell	○ ged-sat14-strips
△ grid	□ gripper	◇ hiking-sat14-strips
× logistics00	+ logistics98	○ miconic
△ movie	□ mprime	◇ mystery
× nomystery-sat11-strips	+ openstacks-sat08-strips	○ openstacks-sat11-strips
△ openstacks-sat14-strips	□ openstacks-strips	◇ organic-synthesis-sat18-strips
× organic-synthesis-split-sat18-strips	+ parcprinter-08-strips	○ parcprinter-sat11-strips
△ parking-sat11-strips	□ parking-sat14-strips	◇ pathways
× pegsol-08-strips	+ pegsol-sat11-strips	○ pipesworld-notankage
△ pipesworld-tankage	□ psr-small	◇ quantum-layout-sat23-strips
× rovers	+ satellite	○ scanalyzer-08-strips
△ scanalyzer-sat11-strips	□ snake-sat18-strips	◇ sokoban-sat08-strips
× sokoban-sat11-strips	+ spider-sat18-strips	○ storage
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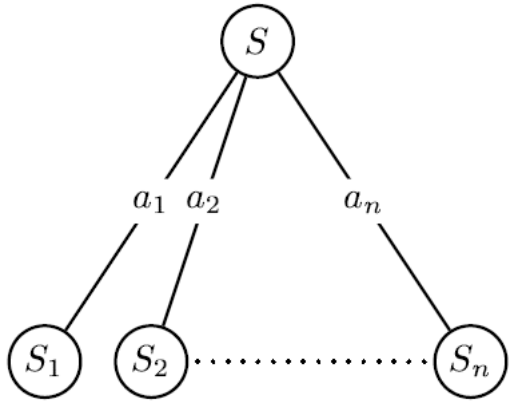
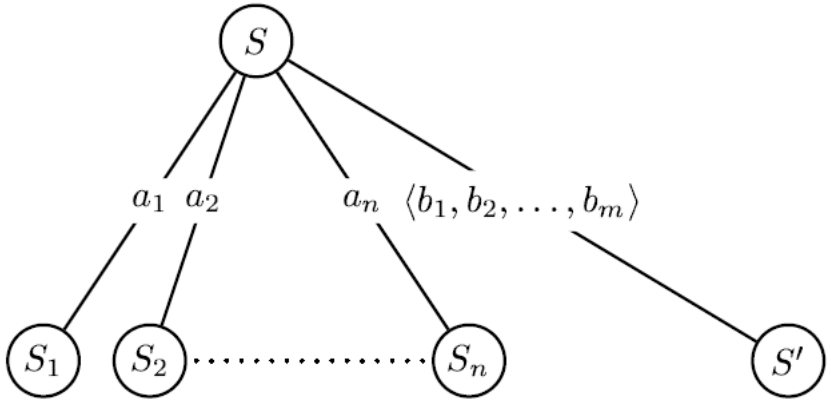
× tidybot-sat11-strips	+ tpp	○ transport-sat08-strips
△ transport-sat11-strips	□ transport-sat14-strips	◇ trucks-strips
× visitall-sat11-strips	+ visitall-sat14-strips	○ woodworking-sat08-strips
△ woodworking-sat11-strips	□ zenotravel	

Conclusion

- Results:
  - Incomplete
  - Memory inefficient
  - Few expansions
  - Reworked version more faithful & better

- Possible additions:
  - Achieve completeness
  - Lookahead algorithm
  - 3rd expansion tiebreaker
  - YAHSP2 & 3





lookahead-node development, YAHSP Vincent Vidal

Backup

STRIPS Gripper: Goal-preferred Actions

	Move		Pick		Drop	
Action	move_AB	move_BA	pick_A1	pickB1	drop_A1	drop_B1
Preconditions	at_gA	at_gB	at_gA, at_1A, Free	at_gB, at_1B, free	at_gA, at_1A, in	at_gB, at_1B, in
Add effects	at_gB	at_gA	in	in	at_1A	at_1B
Delete effects	at_gA	at_gB	at_1A, free	at_1B, free	in	in
Cost	2		3		1	

SAS+ Gripper: Goal-preferred Actions

Initial state: Gripper ↦at_A, Arm ↦ Free, Ball ↦ at_A

Goal: Gripper ↦at_B, Ball ↦ at_B

Action	pick_A1
Preconditions	Gripper ↦at_A, Ball ↦ at_A, Arm ↦ Free
Effects	Ball ↦in

Naive Algorithm:

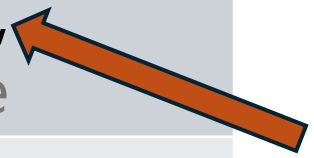
- Effect variable, value pair not in initial state
- Effect variable in the goal
- Effect value not the goal value

-> Not goal-preferred action

SAS+ Gripper: Goal-preferred Actions

Initial state: Gripper ↦at_A,, Arm ↦ Free, Ball ↦ at_A
Goal: Gripper ↦at_B, Ball ↦ at_B

Action	pick_A1
Preconditions	Gripper ↦at_A, Ball ↦ at_A, Arm ↦ Free
Effects	Ball ↦in

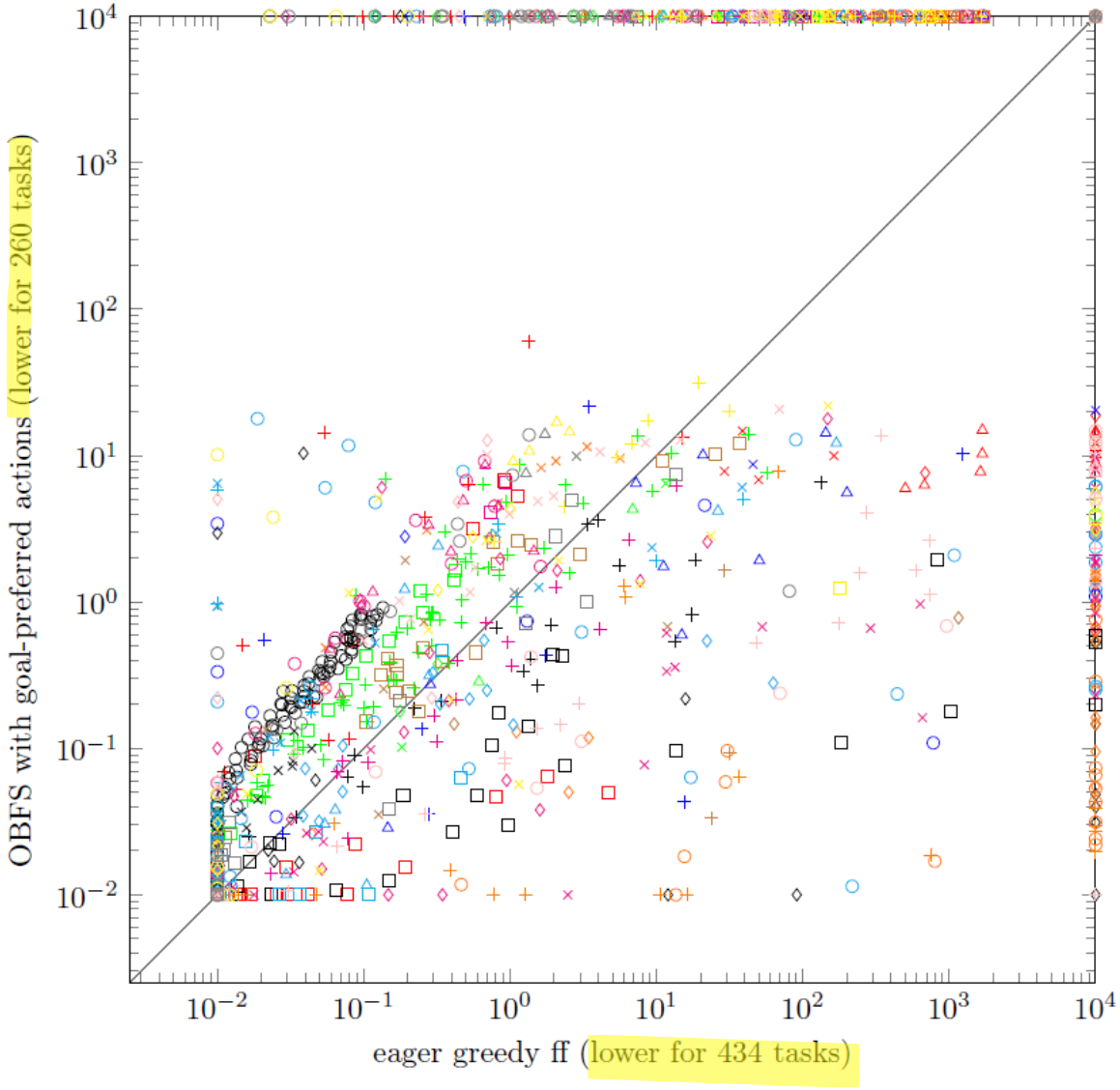


Reworked Algorithm:

- Effect variable, value pair not in initial state
- Effect variable in the goal
- Effect value not the goal value
- Goal variable not in preconditions or goal variable value pair in preconditions

-> Not goal-preferred action

Results: Search Time (Eager Greedy FF)



- agricola-sat18-strips
- barman-sat14-strips
- data-network-sat18-strips
- elevators-sat08-strips
- floortile-sat14-strips
- grid
- logistics00
- movie
- nomystery-sat11-strips
- openstacks-sat14-strips
- organic-synthesis-split-sat18-strips
- parking-sat11-strips
- pegsol-08-strips
- pipesworld-tankage
- rovers
- scanalyzer-sat11-strips
- sokoban-sat11-strips
- termes-sat18-strips
- tidybot-sat11-strips
- transport-sat11-strips
- visitall-sat11-strips
- woodworking-sat11-strips
- airport
- blocks
- depot
- elevators-sat11-strips
- freecell
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- parking-sat14-strips
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- satellite
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- spider-sat18-strips
- tetris-sat14-strips
- tpp
- transport-sat14-strips
- visitall-sat14-strips
- zenotravel
- barman-sat11-strips
- childsnack-sat14-strips
- driverlog
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- ged-sat14-strips
- hiking-sat14-strips
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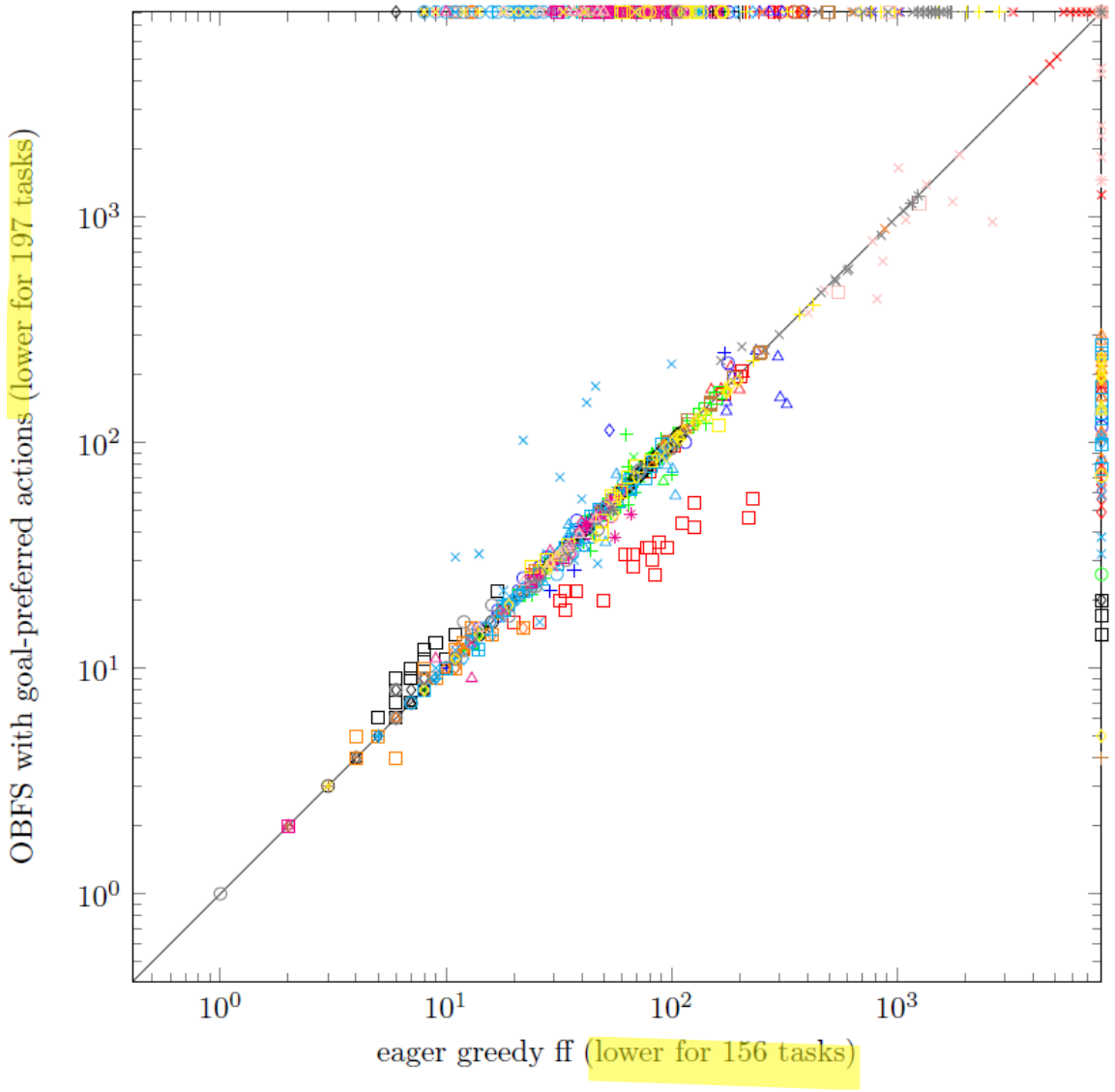
- scanalyzer-08-strips
- sokoban-sat08-strips
- storage
- thoughtful-sat14-strips
- transport-sat08-strips
- trucks-strips
- woodworking-sat08-strips

Results: Cost (Eager Greedy FF)



agricola-sat18-strips	airport	barman-sat11-strips
barman-sat14-strips	blocks	childsnack-sat14-strips
data-network-sat18-strips	depot	driverlog
elevators-sat08-strips	elevators-sat11-strips	floortile-sat11-strips
floortile-sat14-strips	freecell	ged-sat14-strips
grid	gripper	hiking-sat14-strips
logistics00	logistics98	miconic
movie	mprime	mystery
nomystery-sat11-strips	openstacks-sat08-strips	openstacks-sat11-strips
openstacks-sat14-strips	openstacks-strips	organic-synthesis-sat18-strips
organic-synthesis-split-sat18-strips	parcprinter-08-strips	parcprinter-sat11-strips
parking-sat11-strips	parking-sat14-strips	pathways
pegsol-08-strips	pegsol-sat11-strips	pipesworld-notankage
pipesworld-tankage	psr-small	quantum-layout-sat23-strips
rovers	satellite	scanalyzer-08-strips
scanalyzer-sat11-strips	snake-sat18-strips	sokoban-sat08-strips
sokoban-sat11-strips	spider-sat18-strips	storage
termes-sat18-strips	tetris-sat14-strips	thoughtful-sat14-strips
tidybot-sat11-strips	tpp	transport-sat08-strips
transport-sat11-strips	transport-sat14-strips	trucks-strips
visitall-sat11-strips	visitall-sat14-strips	woodworking-sat08-strips
woodworking-sat11-strips	zenotravel	

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