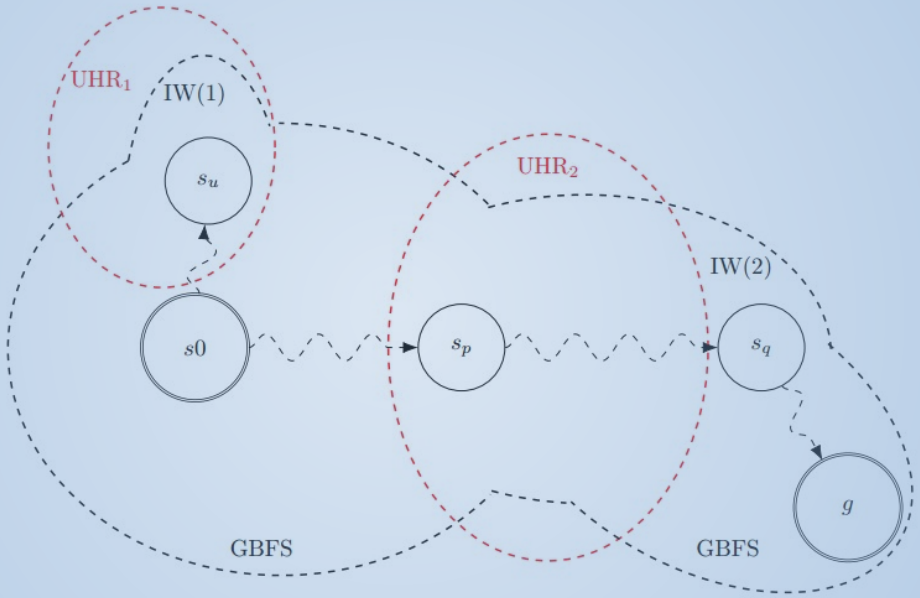
Combining Novelty-Guided and Heuristic-Guided Search



Master Thesis

Artificial Intelligence Group

Dario Maggi 29th July 2016

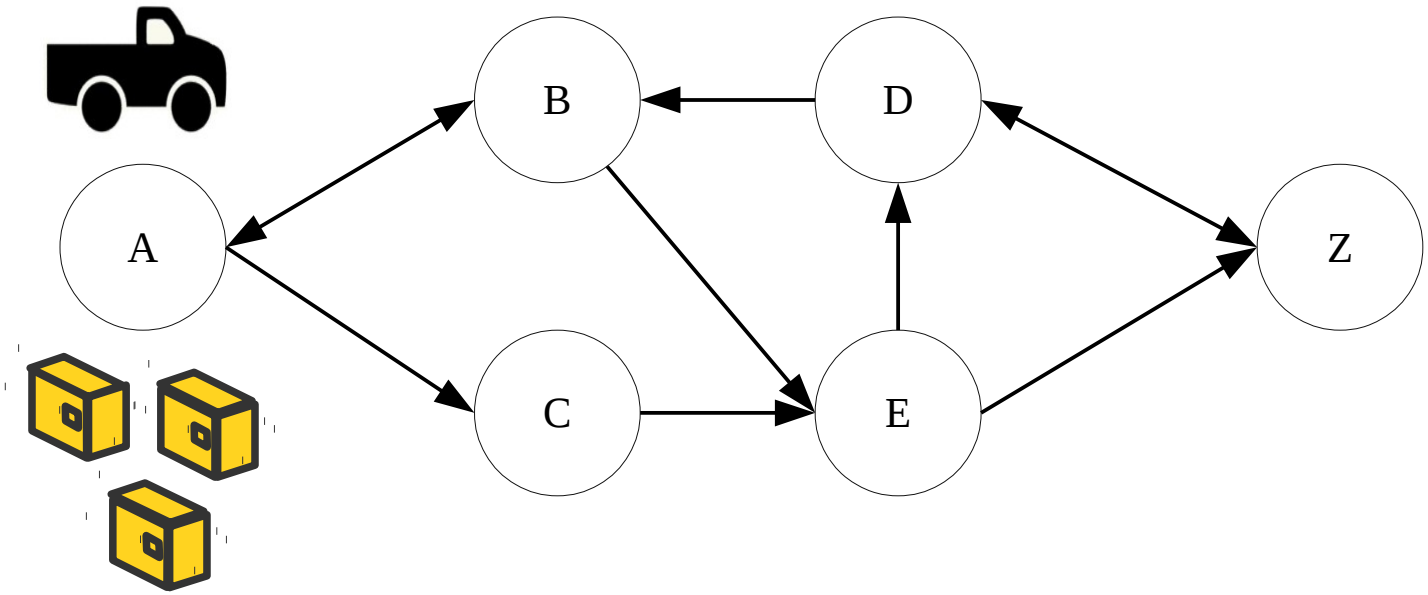
Examiner: Prof. Dr. Malte Helmert

Supervisor: Dr. Thomas Keller

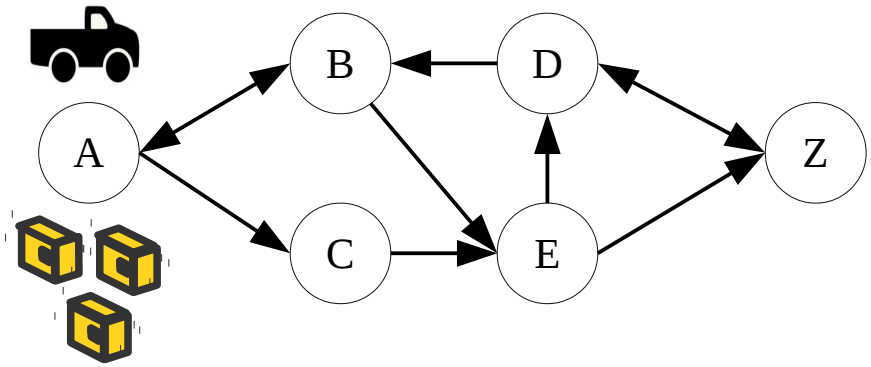
Overview

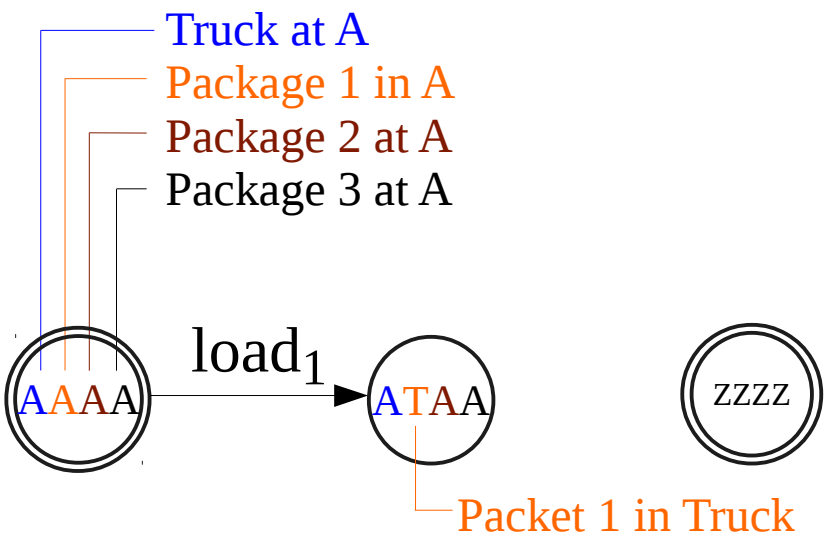
- 1. Introduction
  - Planning Task
  - Heuristic Guided Search: Greedy Best-First Search
- 2. Novelty
  - What is novel?
  - Iterated Width
- 3. Heuristic- and Novelty- Guided Search
- 4. Experiments
- 5. Conclusion

1. Introduction



Planning Task





- Variables

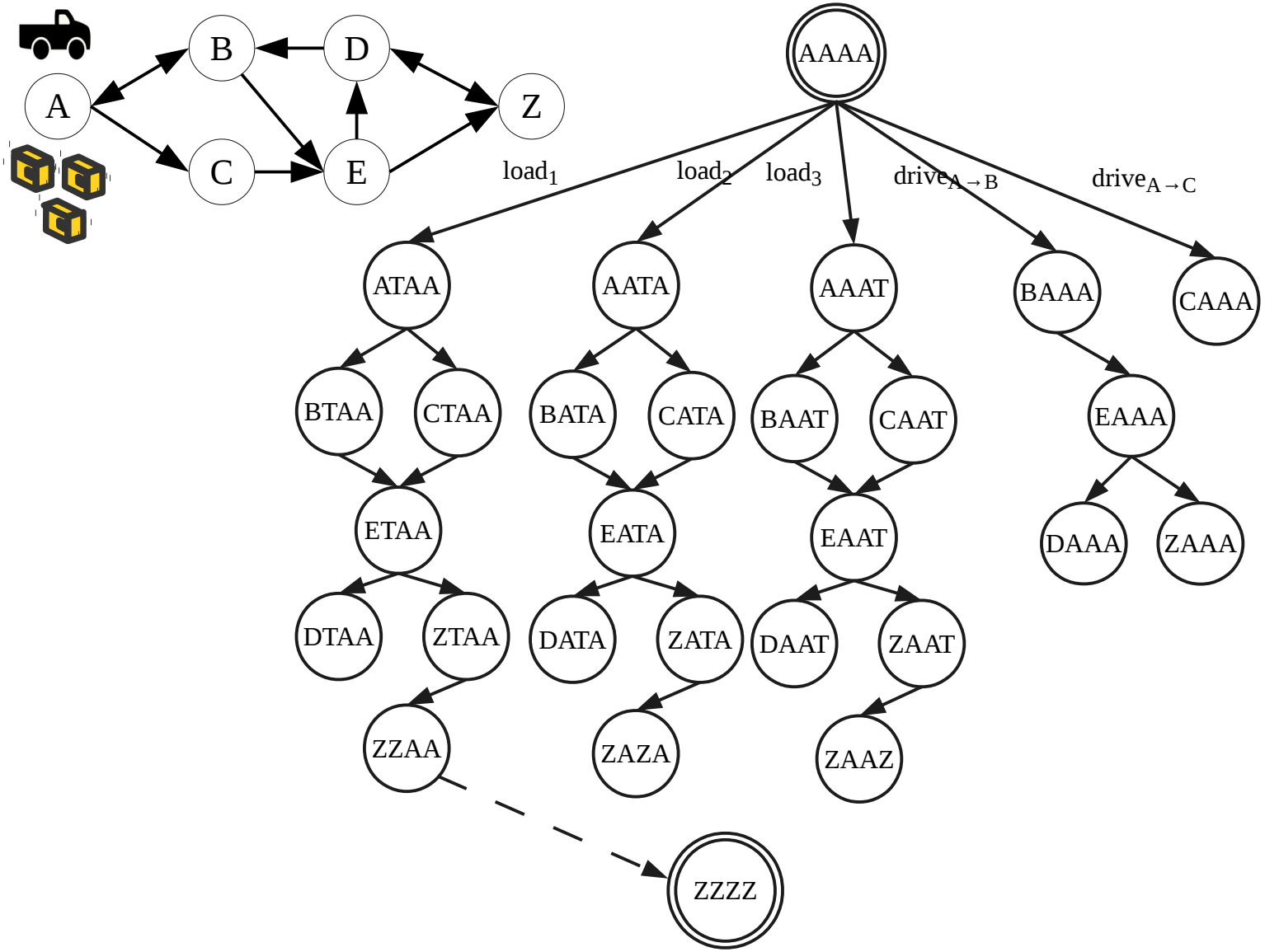
  Truck: A, B, C, D, E, Z
  Package 1: A, Truck, Z
  ...

- Operators

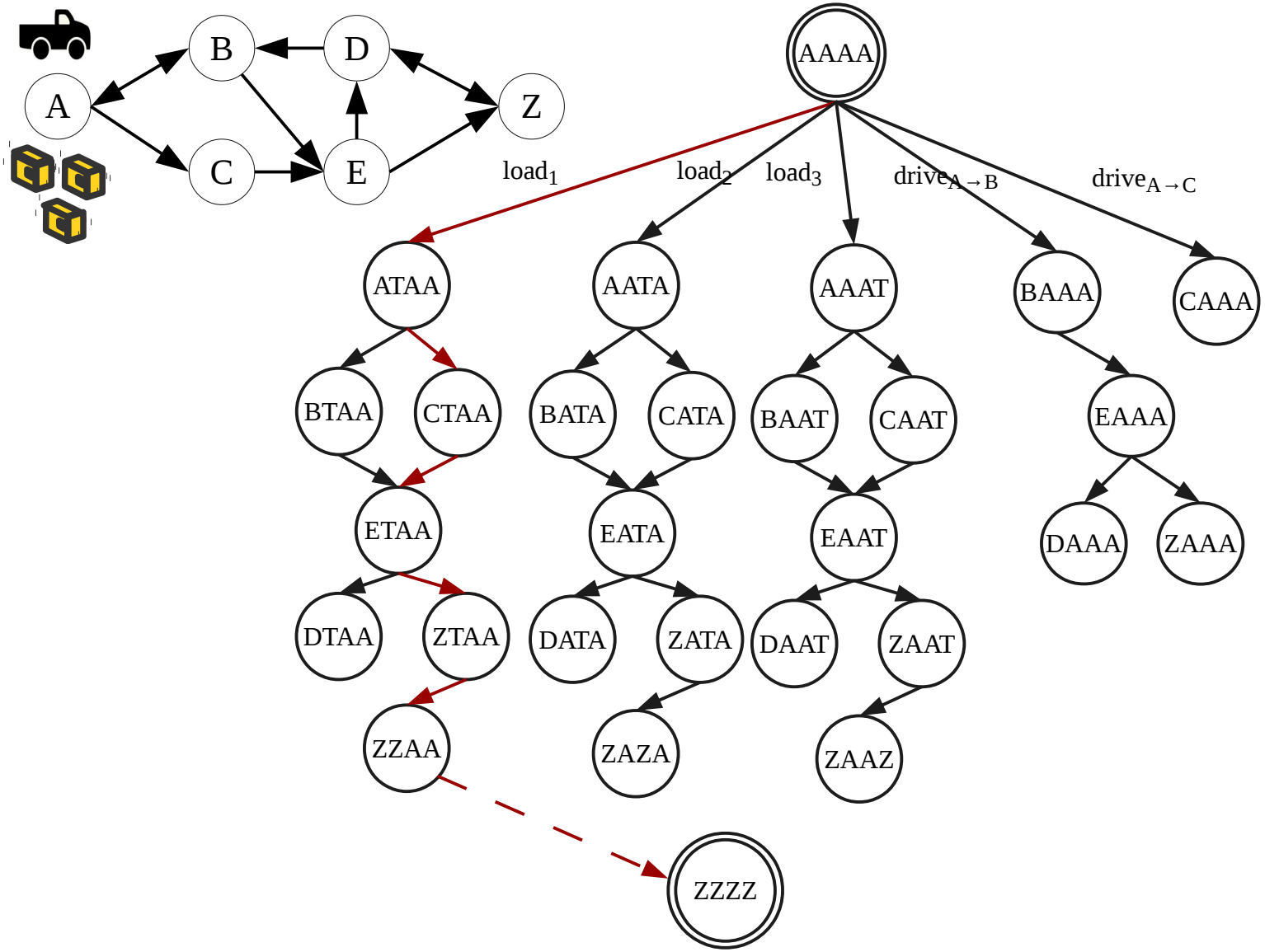
  $drive_{A \to B}$, $drive_{A \to C}$ ...
  $load_1$, $load_2$, $load_3$
  $unload_1$, $unload_2$, $unload_3$

- Initial State
- Goal State

Breadth-First Search



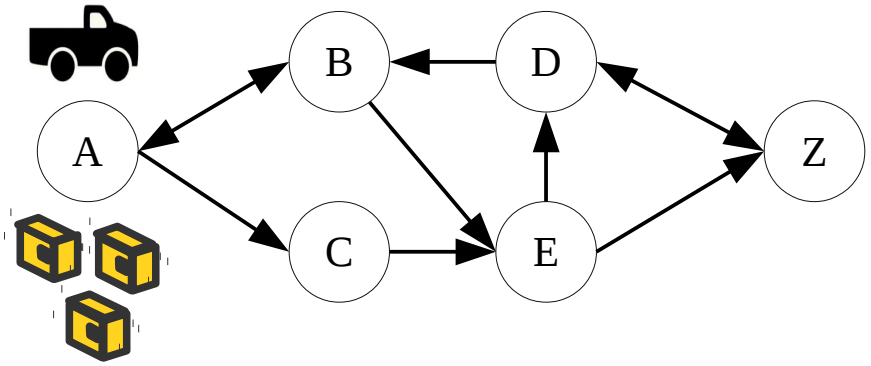
Breadth-First Search



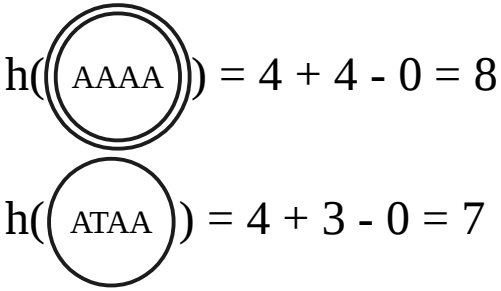
Plan:
load$_1$,
drive$_{A \to C}$,
drive$_{C \to E}$,
drive$_{E \to Z}$,
unload$_1$,
...

Heuristic Guided Search

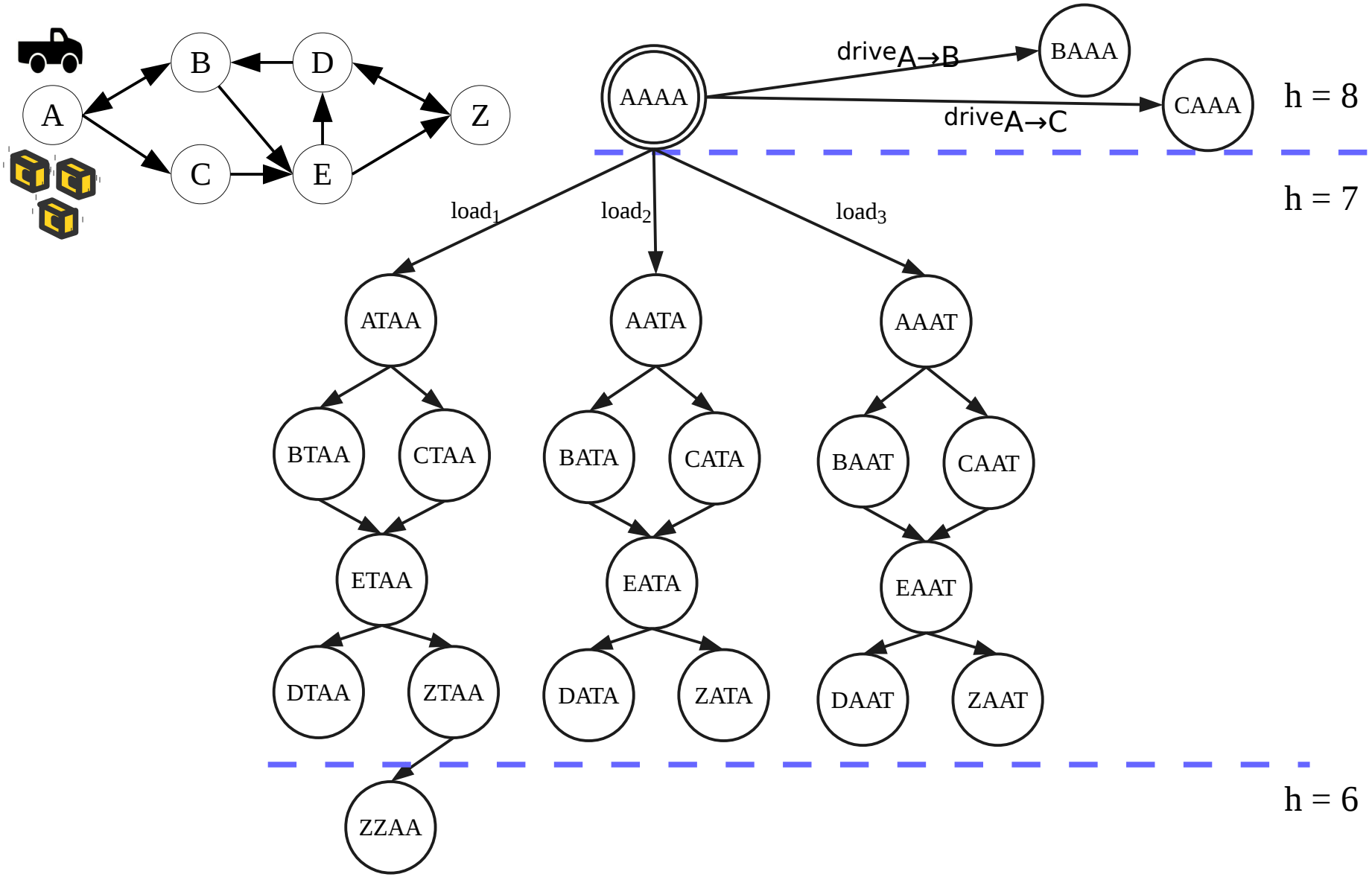
- Heuristic h: Distance to Goal Estimator



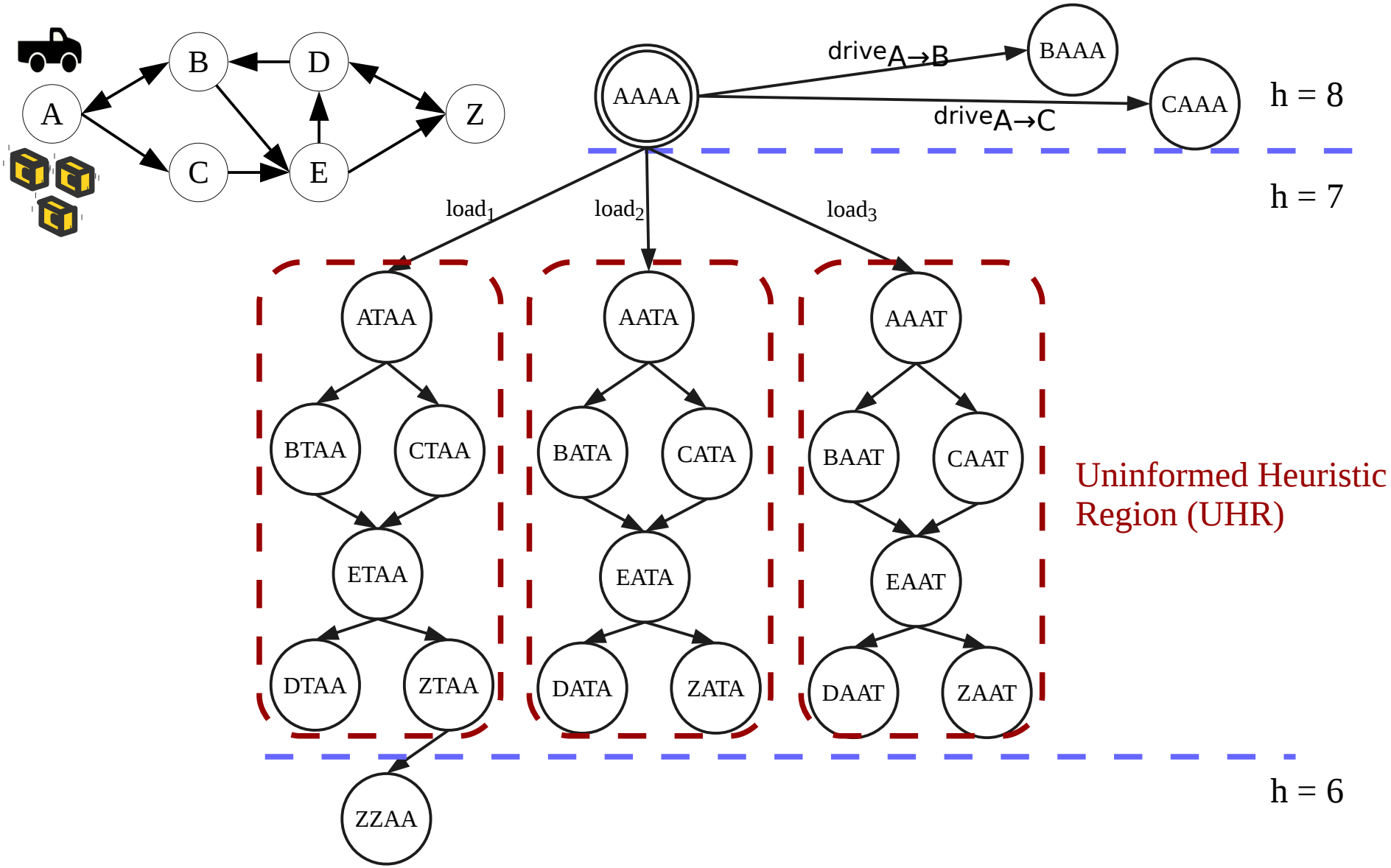
- h: #Packets + #Packets in A - #Packets in Z



Greedy Best-First Search (GBFS)



Greedy Best-First Search (GBFS)



GBFS and UHRs

- Two Problems:
  - No Guidance in UHRs
  - GBFS might expand multiple UHRs simultaneously

- What do we do?

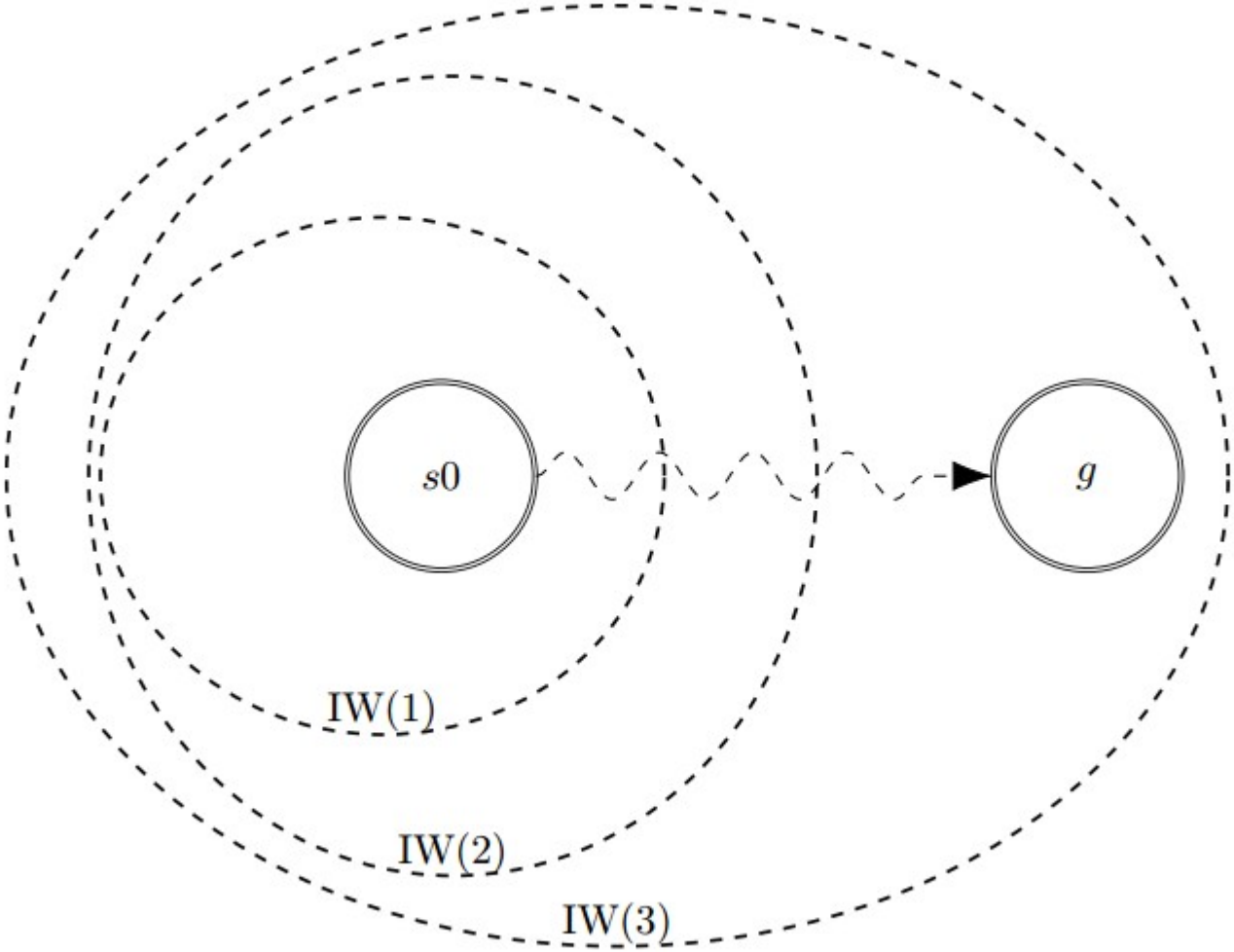
Change the approach in UHRs

2. Novelty

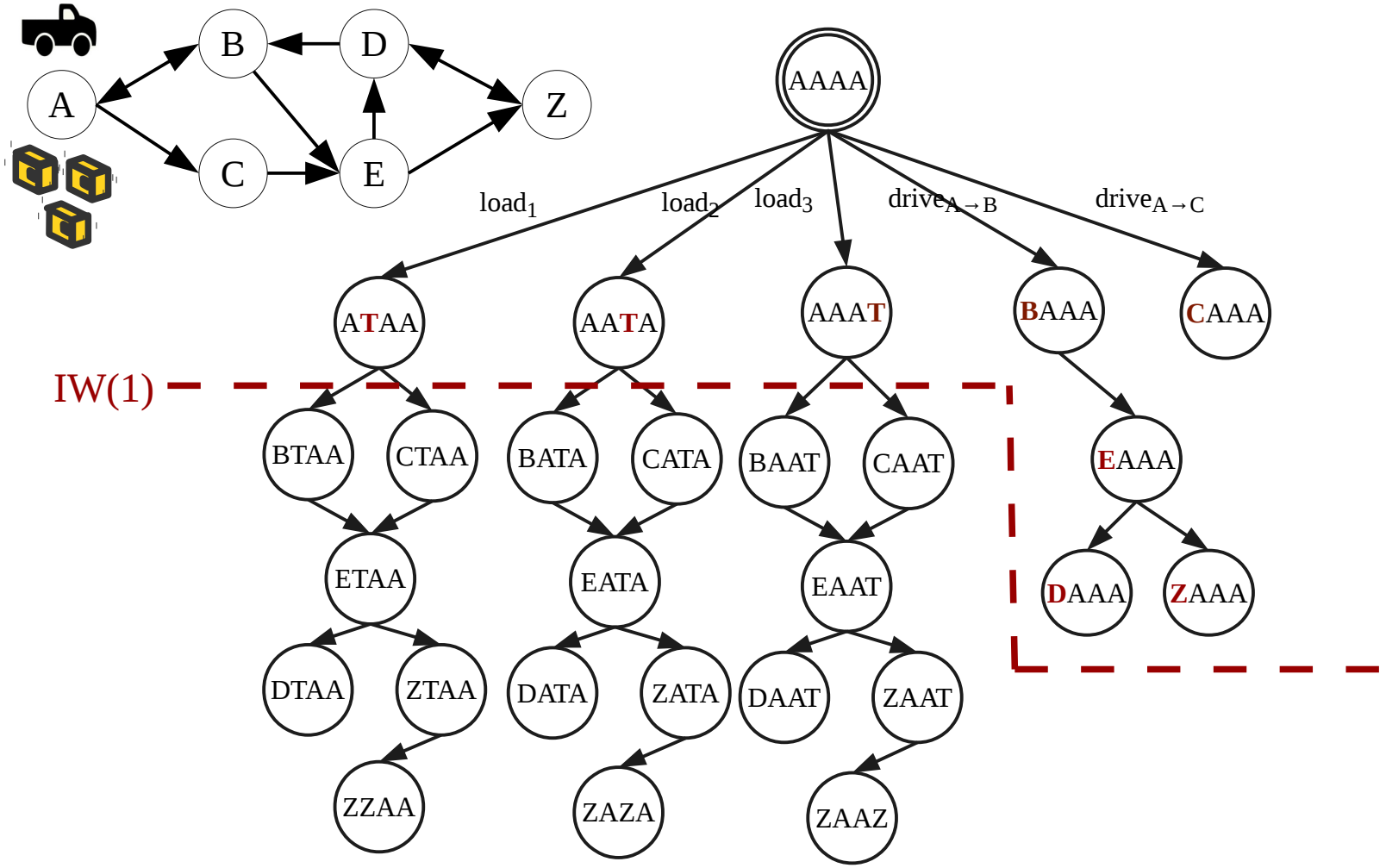
- How "new" is a state?

Truck	Package 1	Package 2	Package 3	Novelty
A	A	A	A	1
A	T	A	A	1
A	A	T	A	1
A	A	A	T	1
B	T	A	A	1
B	A	T	A	2
A	A	A	A	5

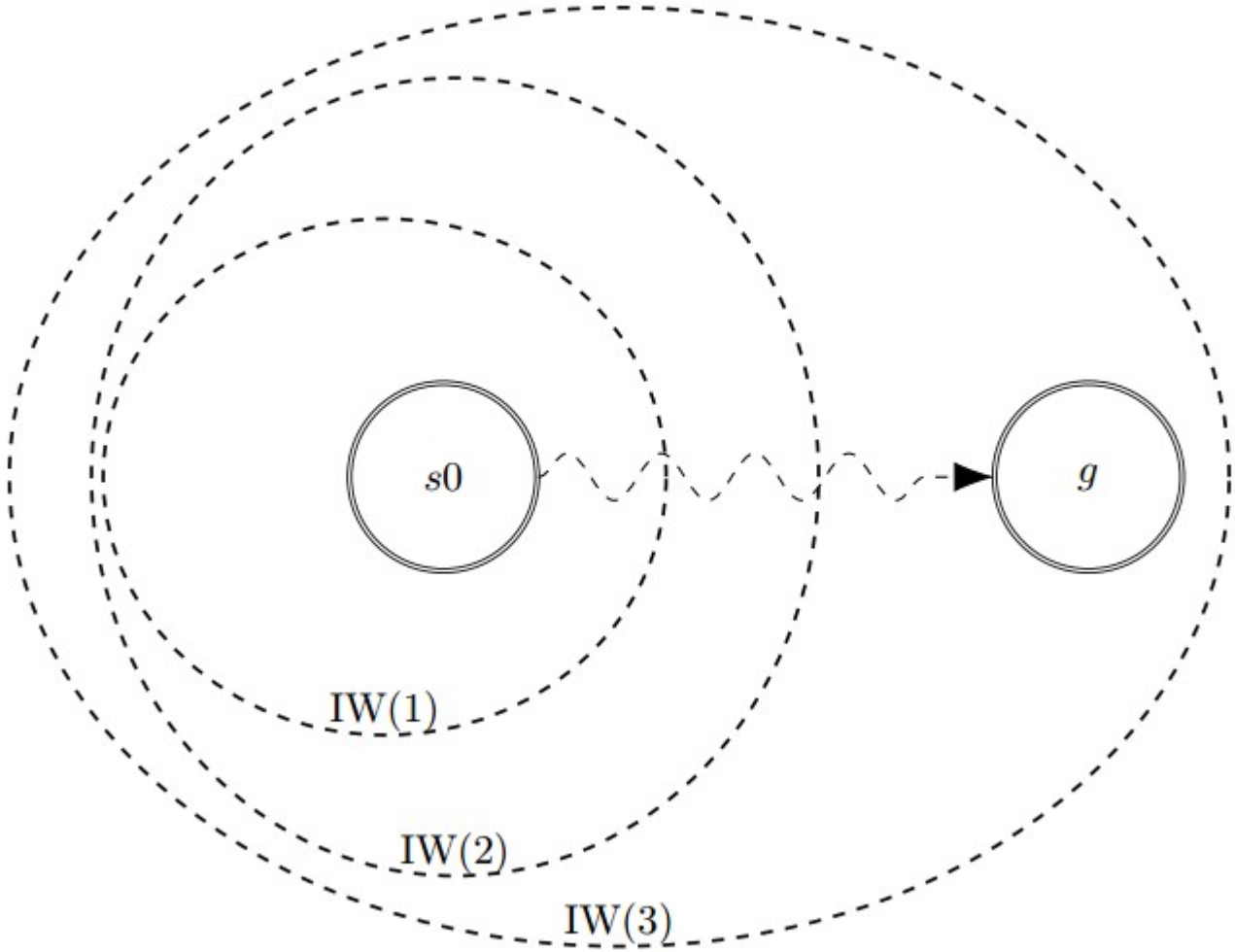
Iterated Width



Iterated Width



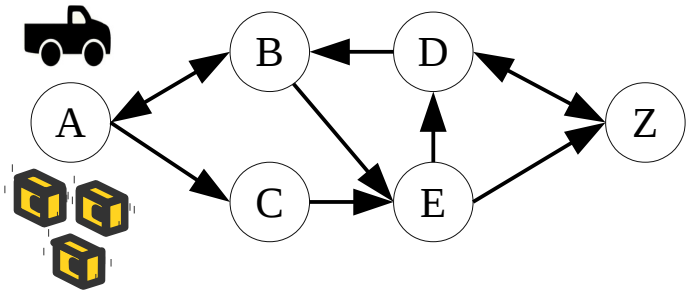
Iterated Width



Iterated Width +

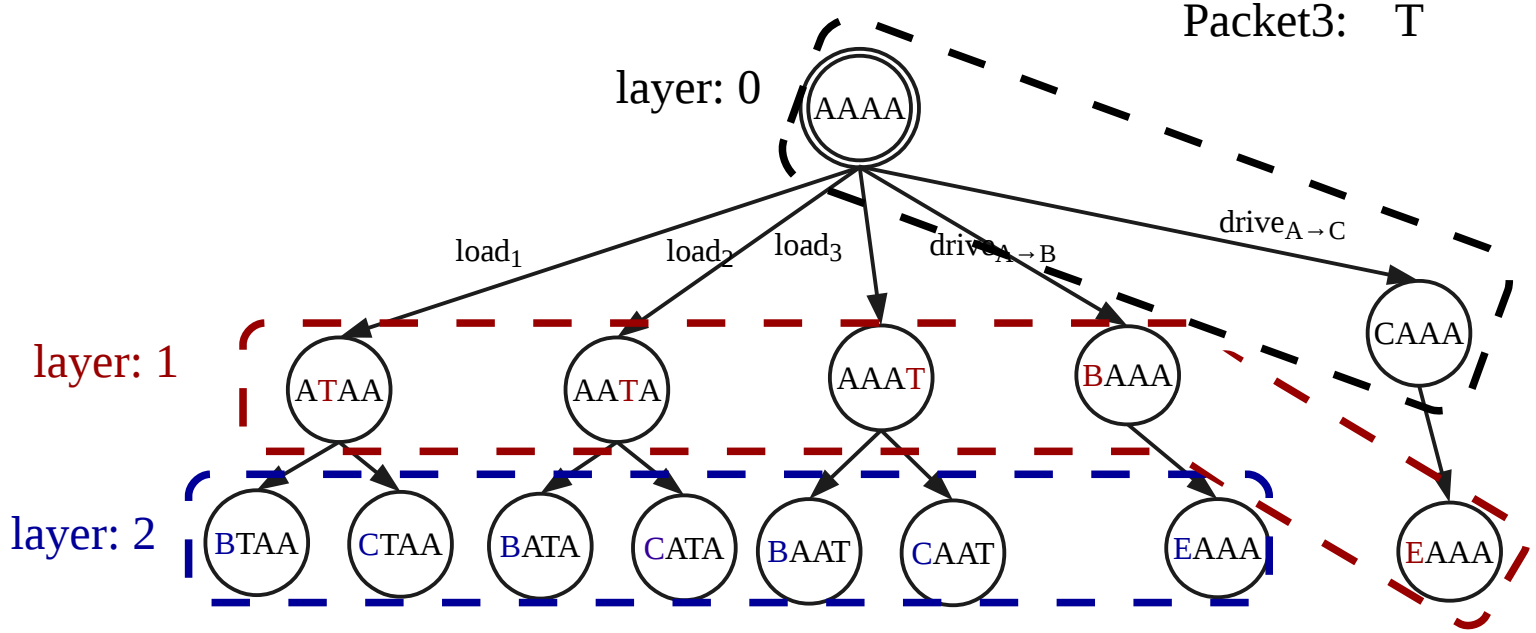
- Extension for IW
- Compute relaxed plan
- Novelty Check on different Layers
- Layer is the number of the relaxed plan facts that were made true on a path

Iterated Width +



Relaxed Plan:

Truck: B, E, D, Z
Packet1: T
Packet2: T
Packet3: T

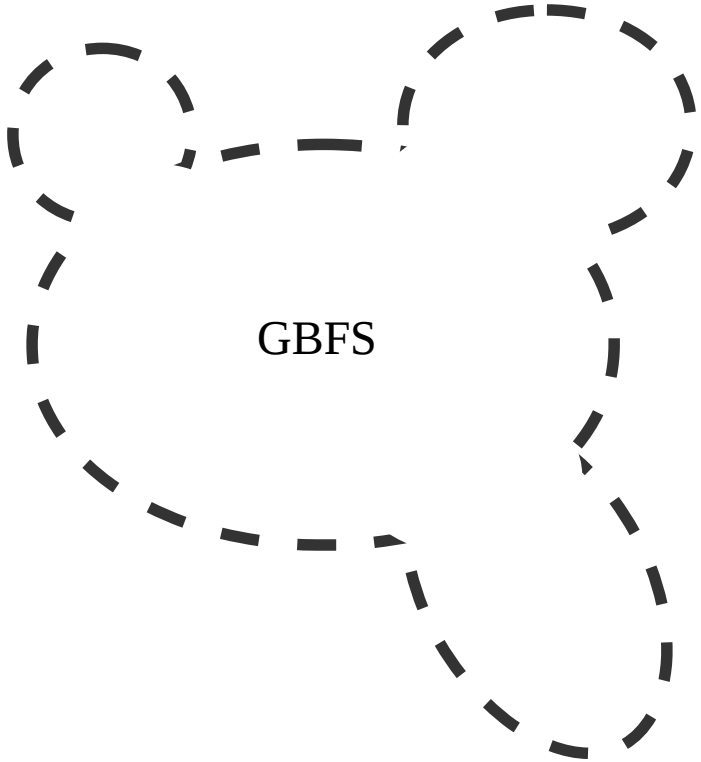


3. Heuristic- and Novelty- Guided Search

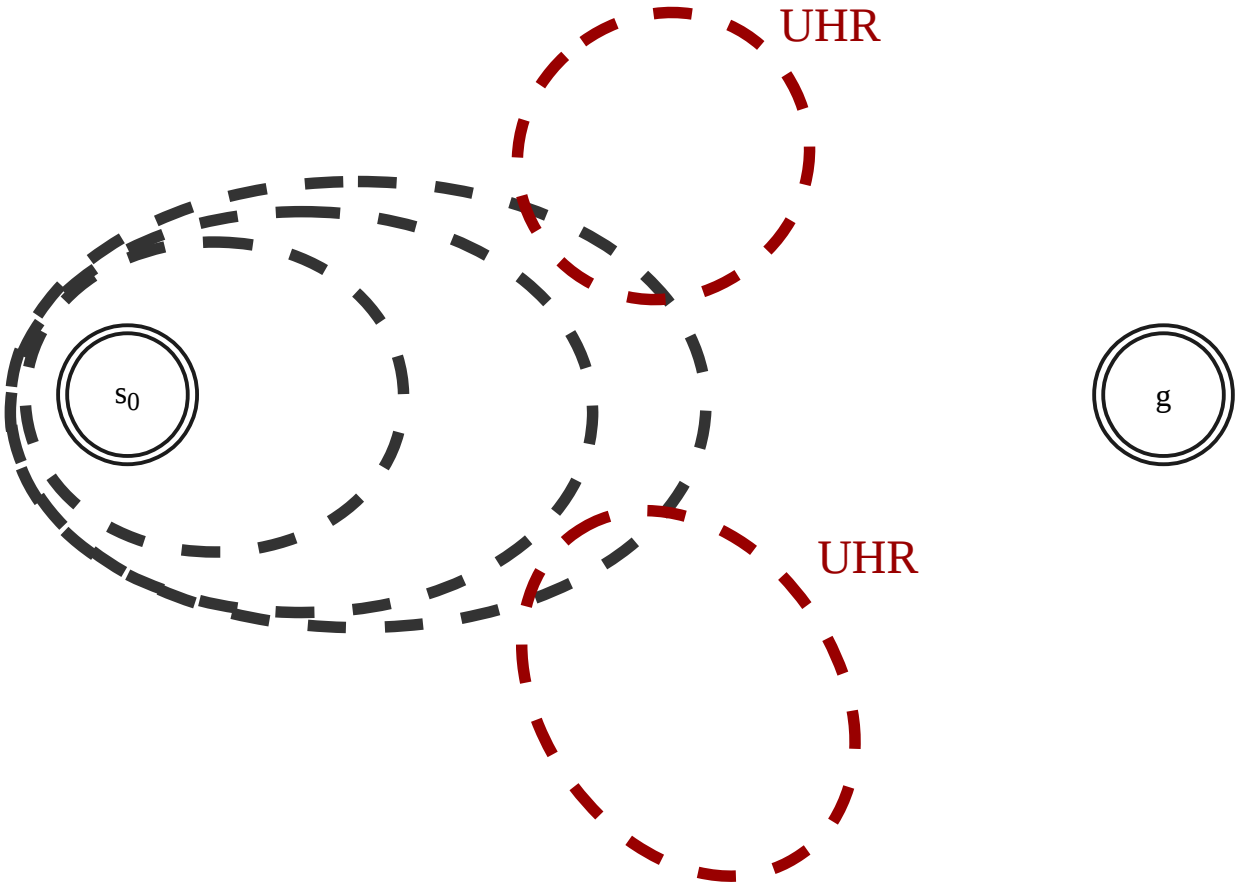
- Detect UHRs → UHR Threshold
- In UHR: Start local IW
- Expand nodes at maximum once

3. Heuristic- and Novelty- Guided Search

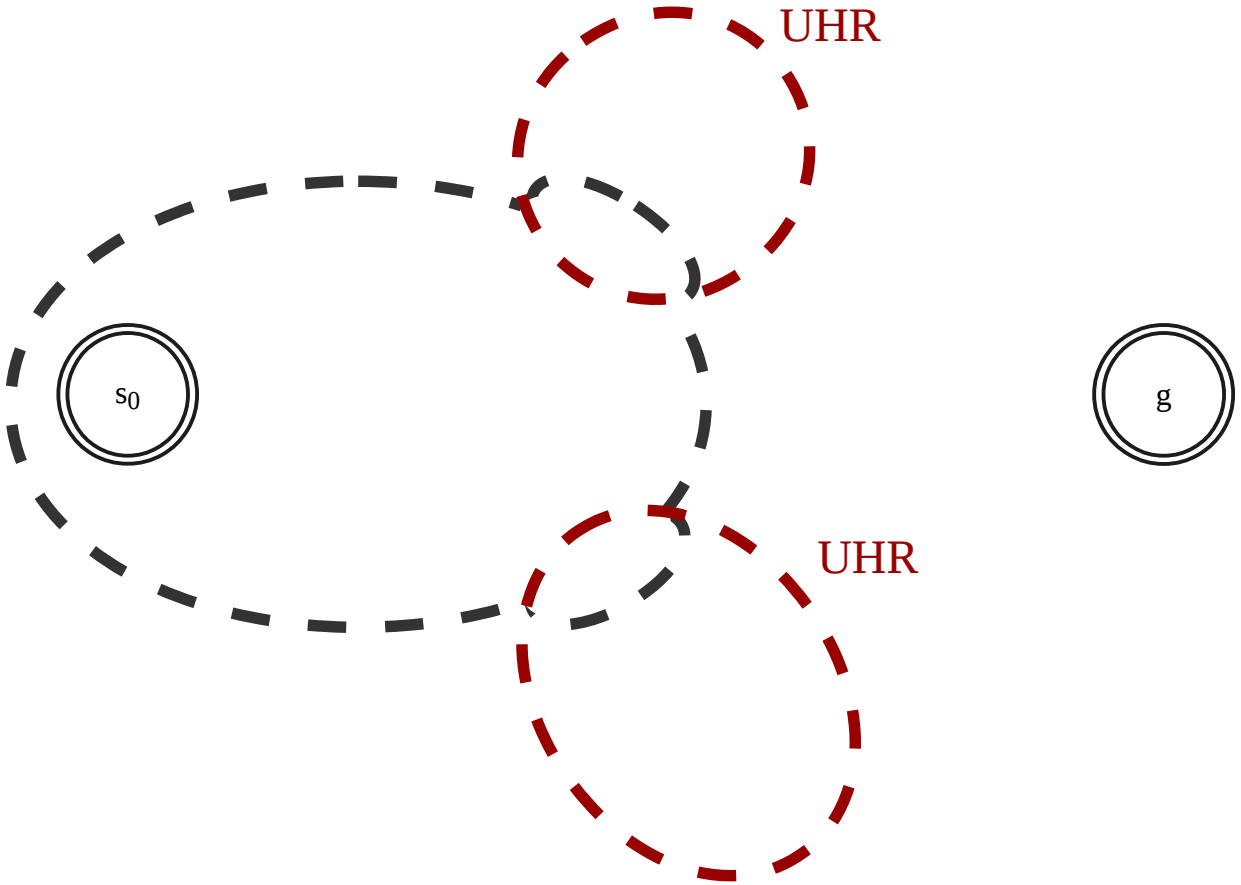
- Detect UHRs
- In UHR: Start local IW
- Expand nodes at maximum once
- Star Approach



Star Approach

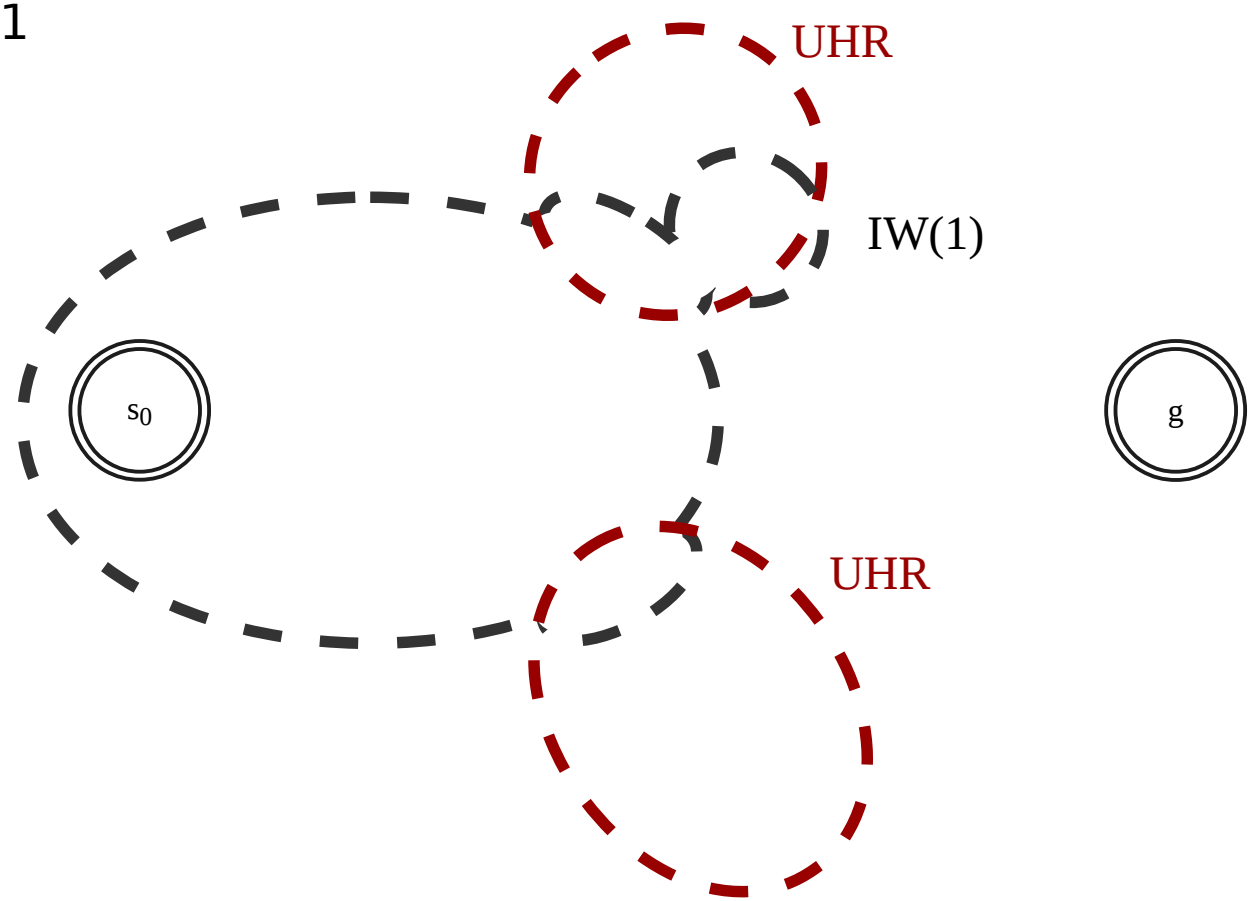


Star Approach



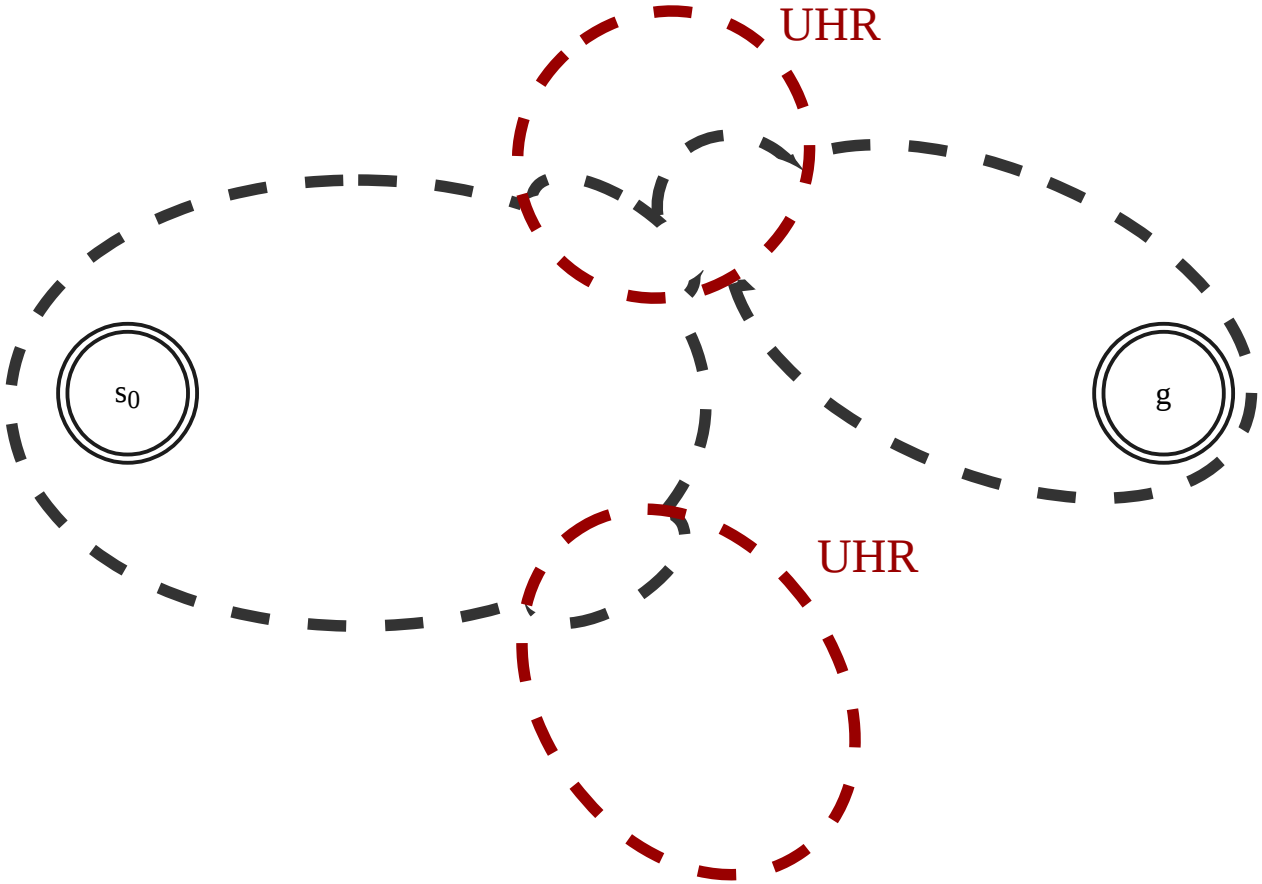
Star Approach

Szenario 1



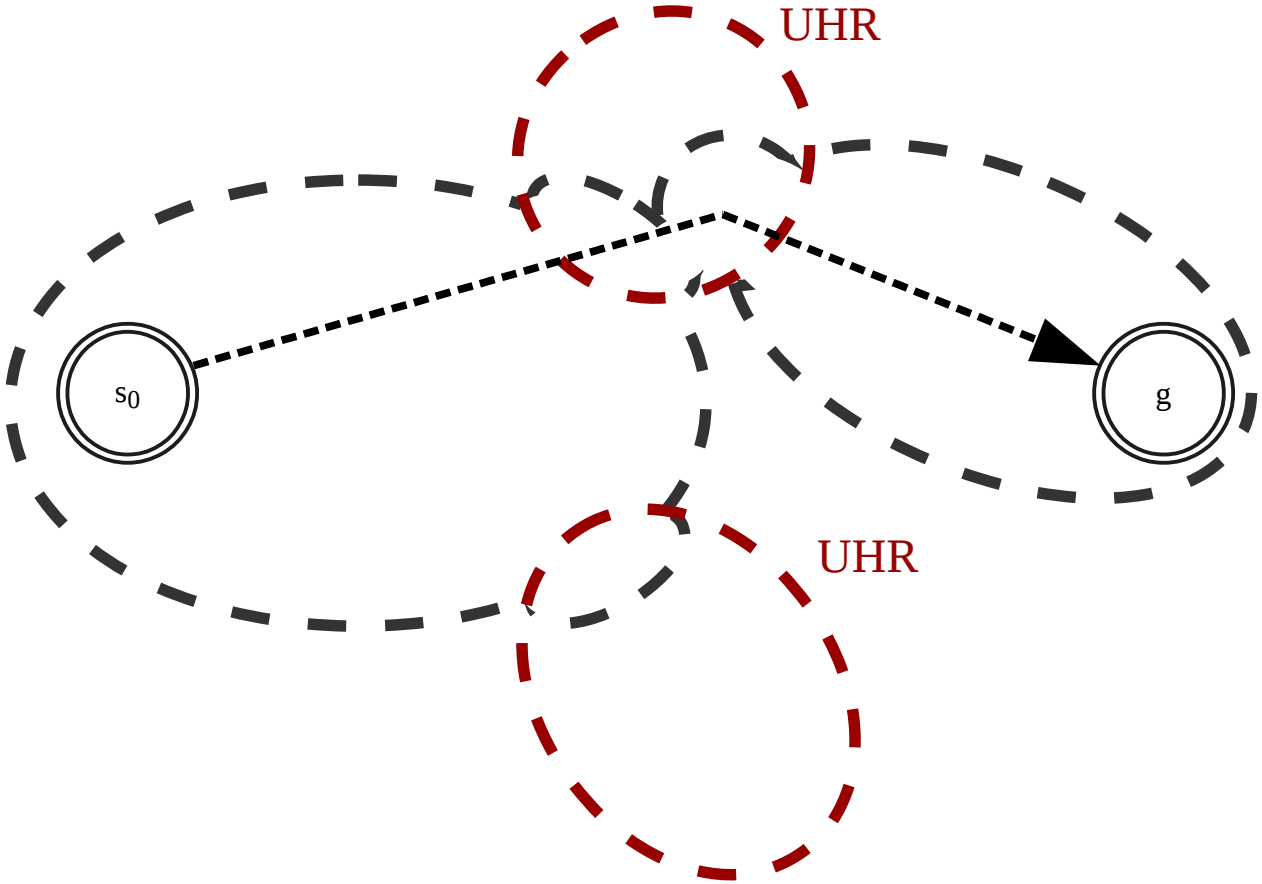
Star Approach

Szenario I



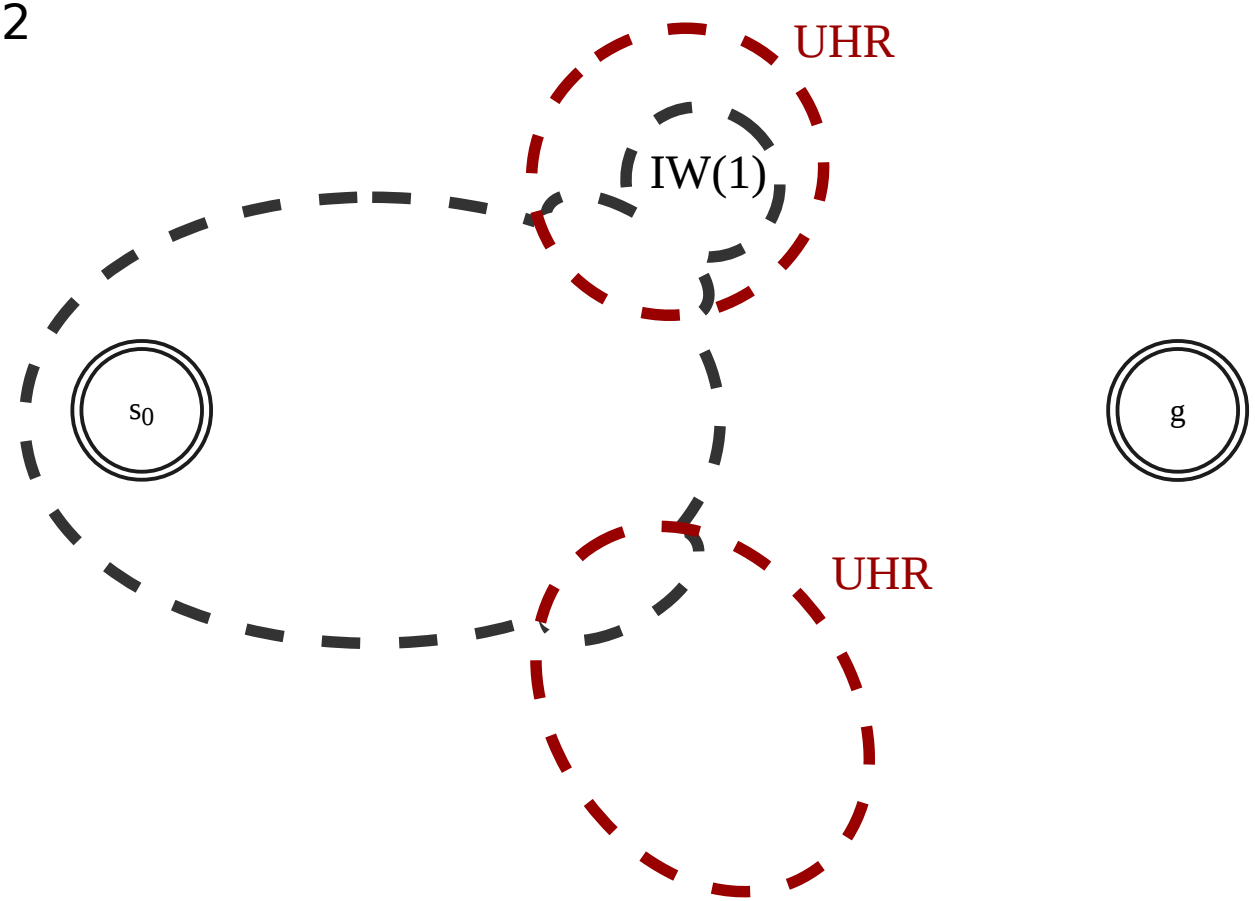
Star Approach

Szenario I



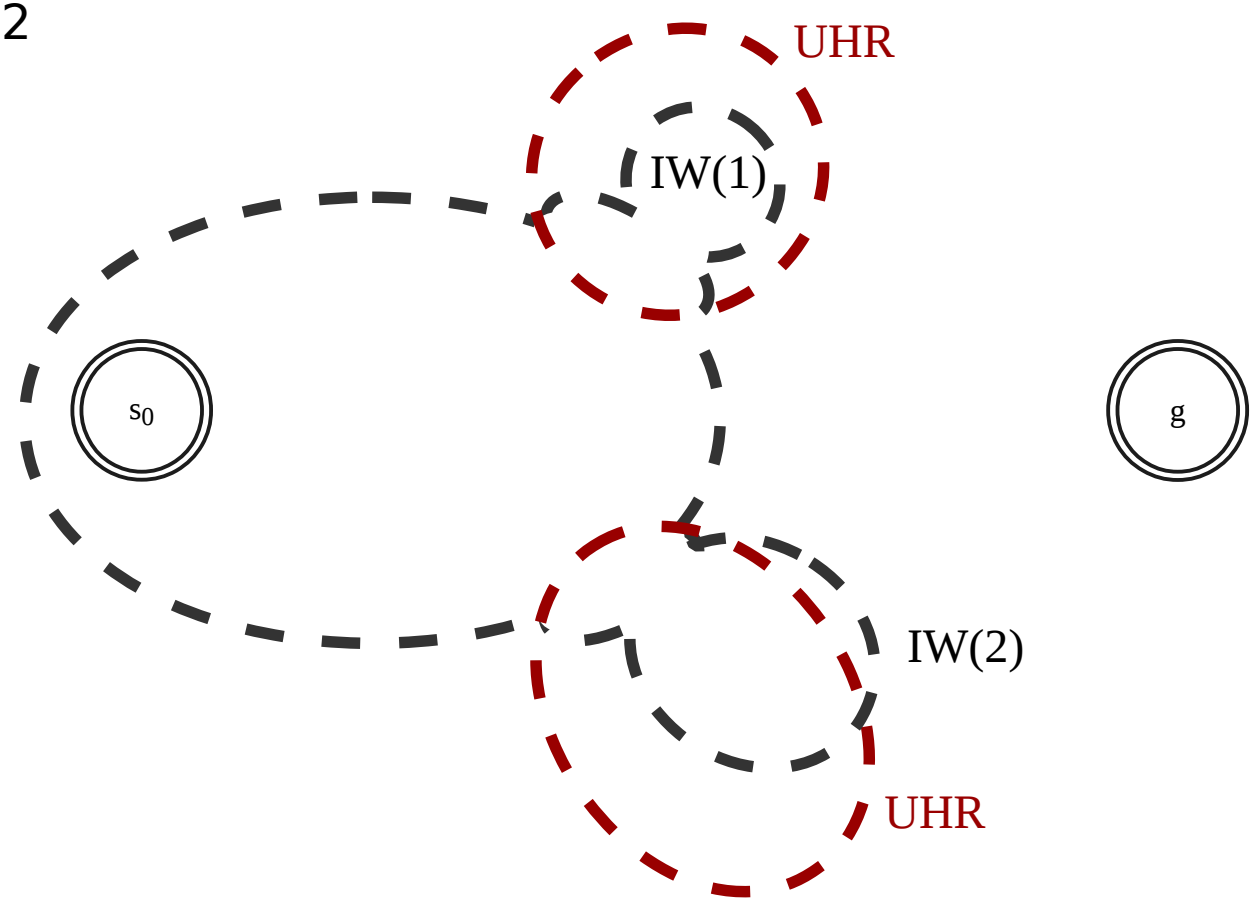
Star Approach

Szenario 2



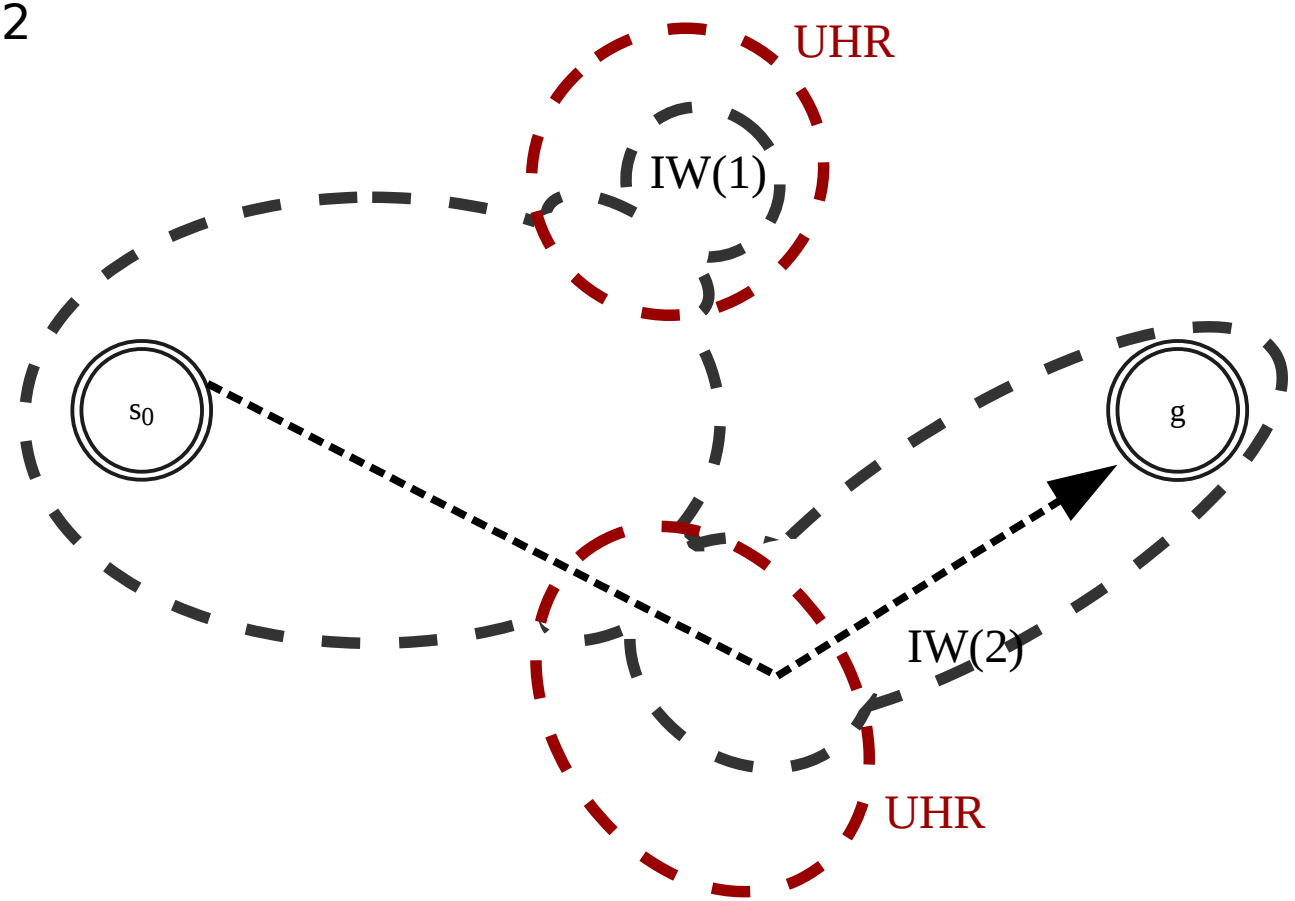
Star Approach

Szenario 2



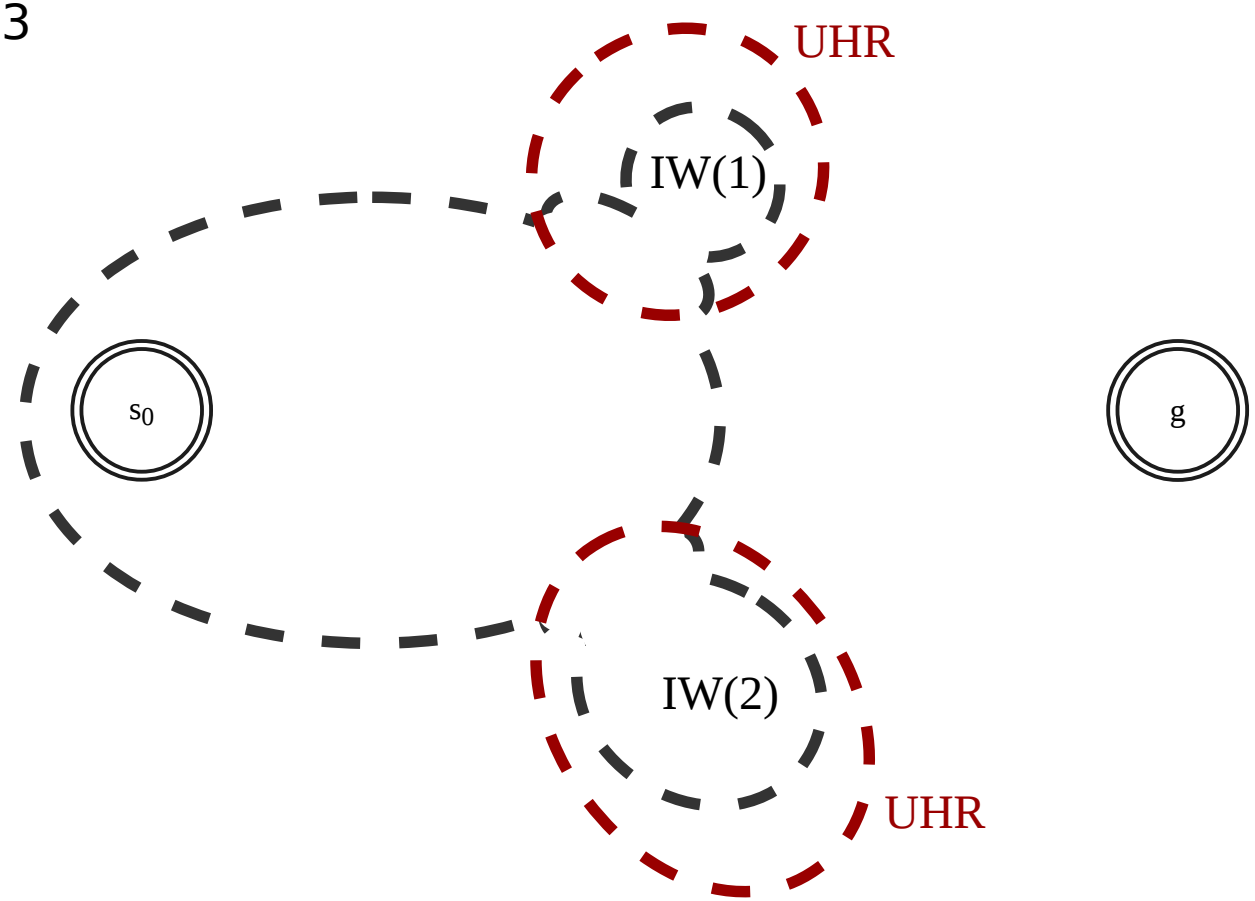
Star Approach

Szenario 2



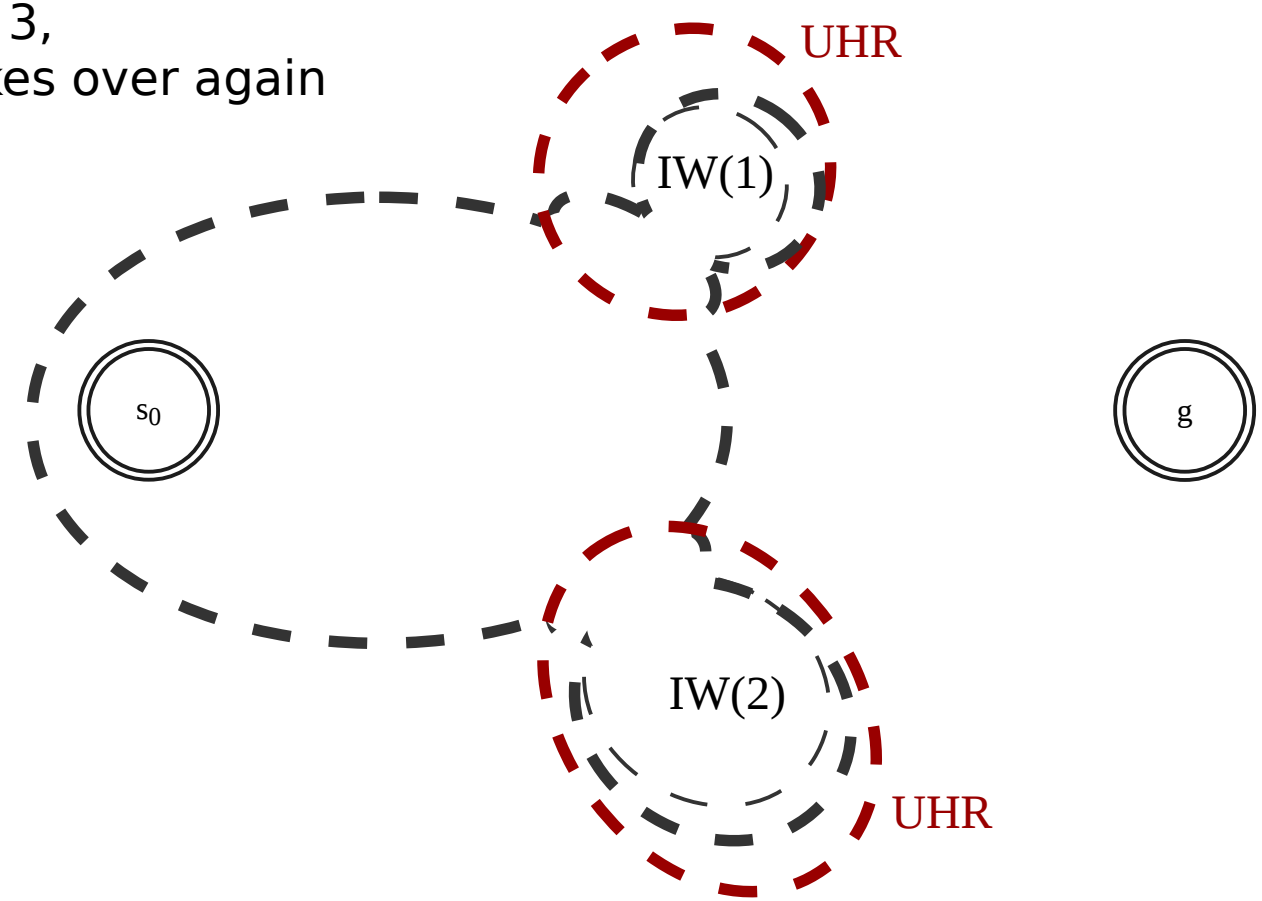
Star Approach

Szenario 3



Star Approach

Szenario 3,
GBFS takes over again



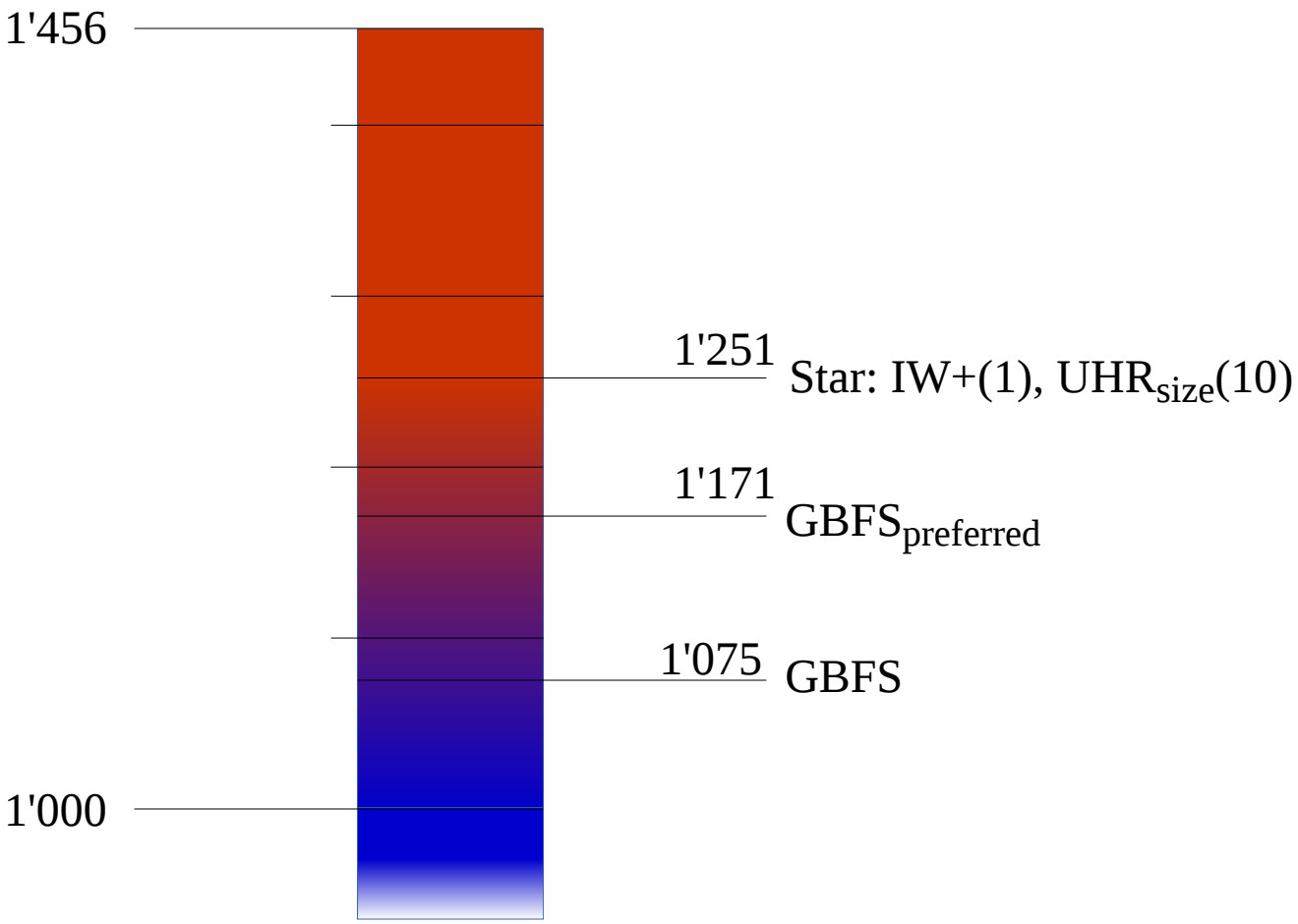
4. Experiments

- Implemented in Fast Downward
- 46 Domains, total of 1456 Problems
- Star Approach
- vs GBFS and $GBFS_{preferred}$ (ff-heuristic)

Coverage: Star Approach

Local Planner	Novelty-Bound	UHR threshold				
		10	50	100	500	1000
IW	1	1157	1151	**1161**	1144	1140
	2	1139	1136	1151	1152	1161
	3	1105	1112	1115	1133	1150
	∞	1059	1075	1086	1108	1126
IW+	1	**1251**	1236	1232	1222	1219
	2	1209	1214	1209	1205	1206
	3	1178	1187	1195	1200	1200
	∞	1149	1171	1183	1189	1201

Comparison


1'456
1'251
Star: IW+(1), UHR$_{size}$(10)
1'171
GBFS$_{preferred}$
1'075
GBFS
1'000

5. Conclusion

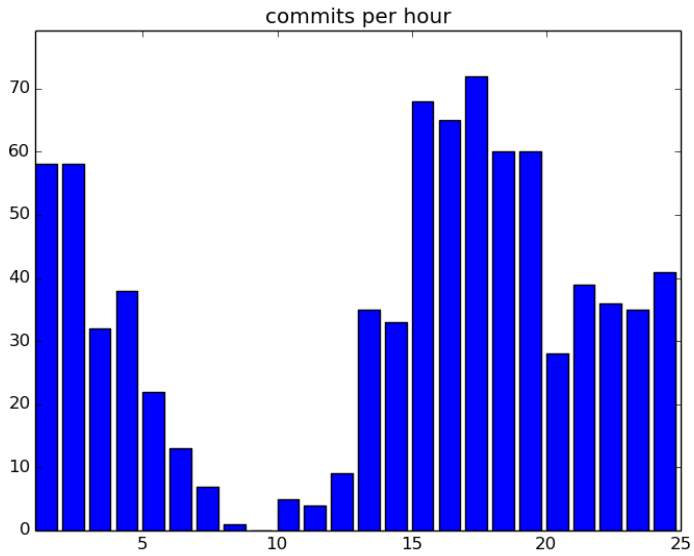
- Helpful to switch to IW
- Start more, smaller local searches

- Even Closer Coupling by only using IW to escape UHRs?

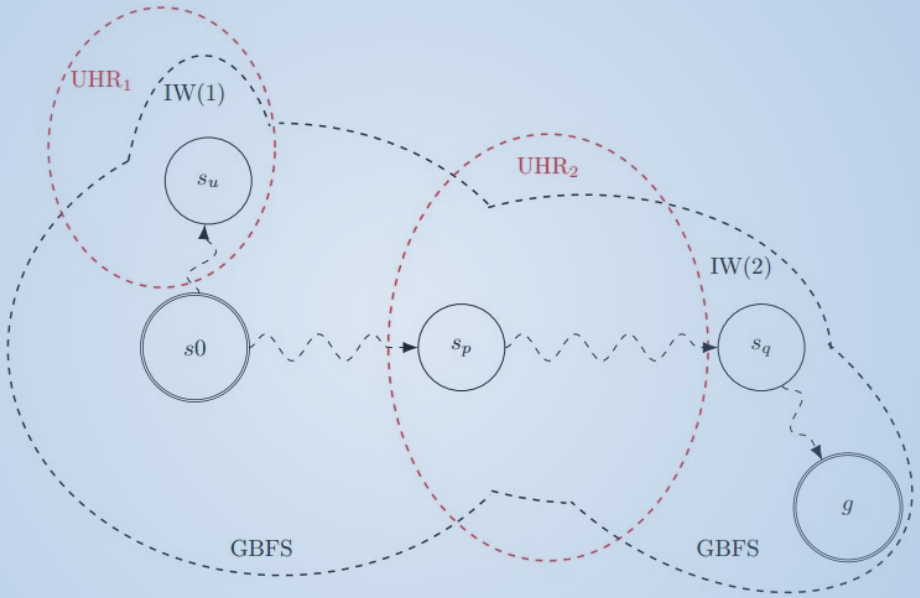
Lessons Learned

- Fast Downward, Novelty, Data Structure

- Lessons I wish I had finally learned
  - Branching Strategy
  - Setup Testing Environment
  - Carefulness
  - Don't Panic
  - Daily Routine



Thank You



Thank You for your attention