When Abstractions Met Landmarks

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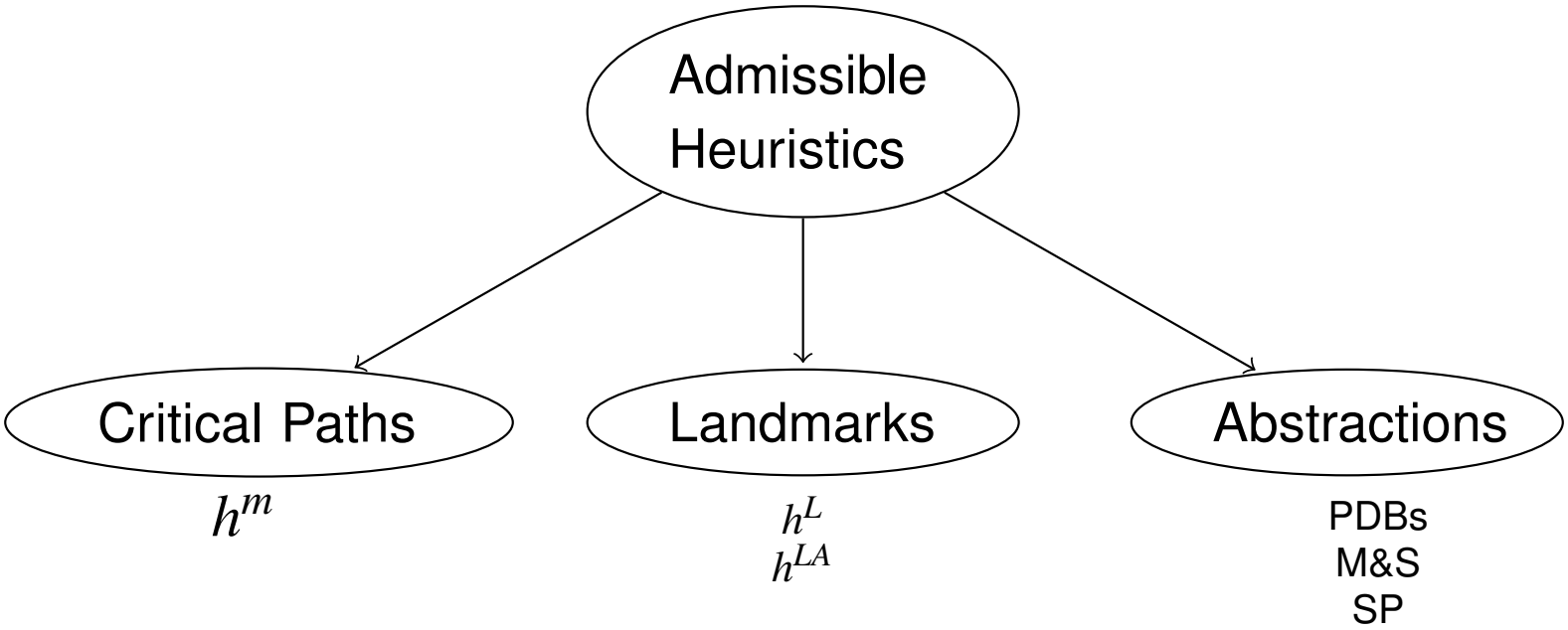
Context



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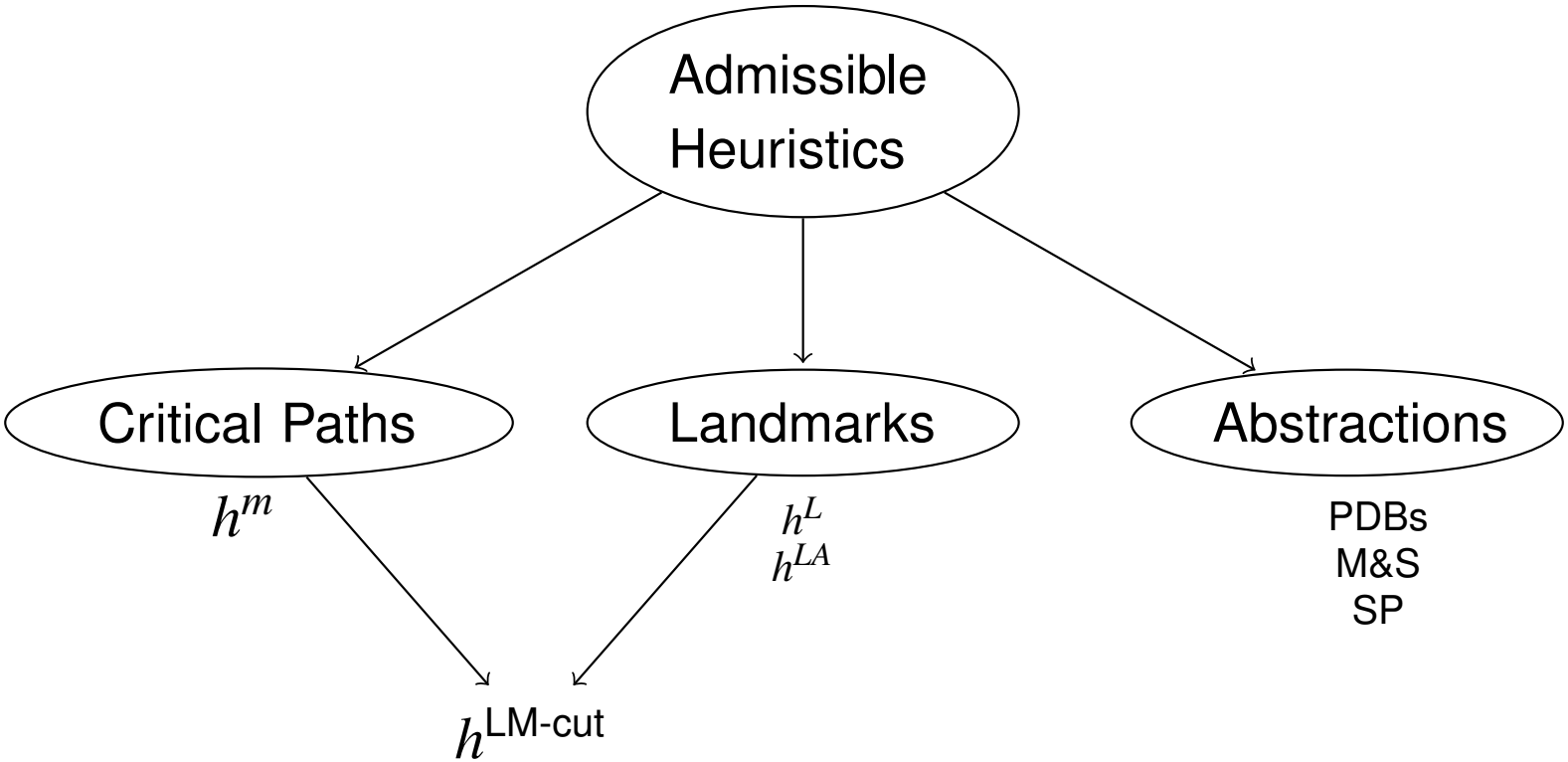

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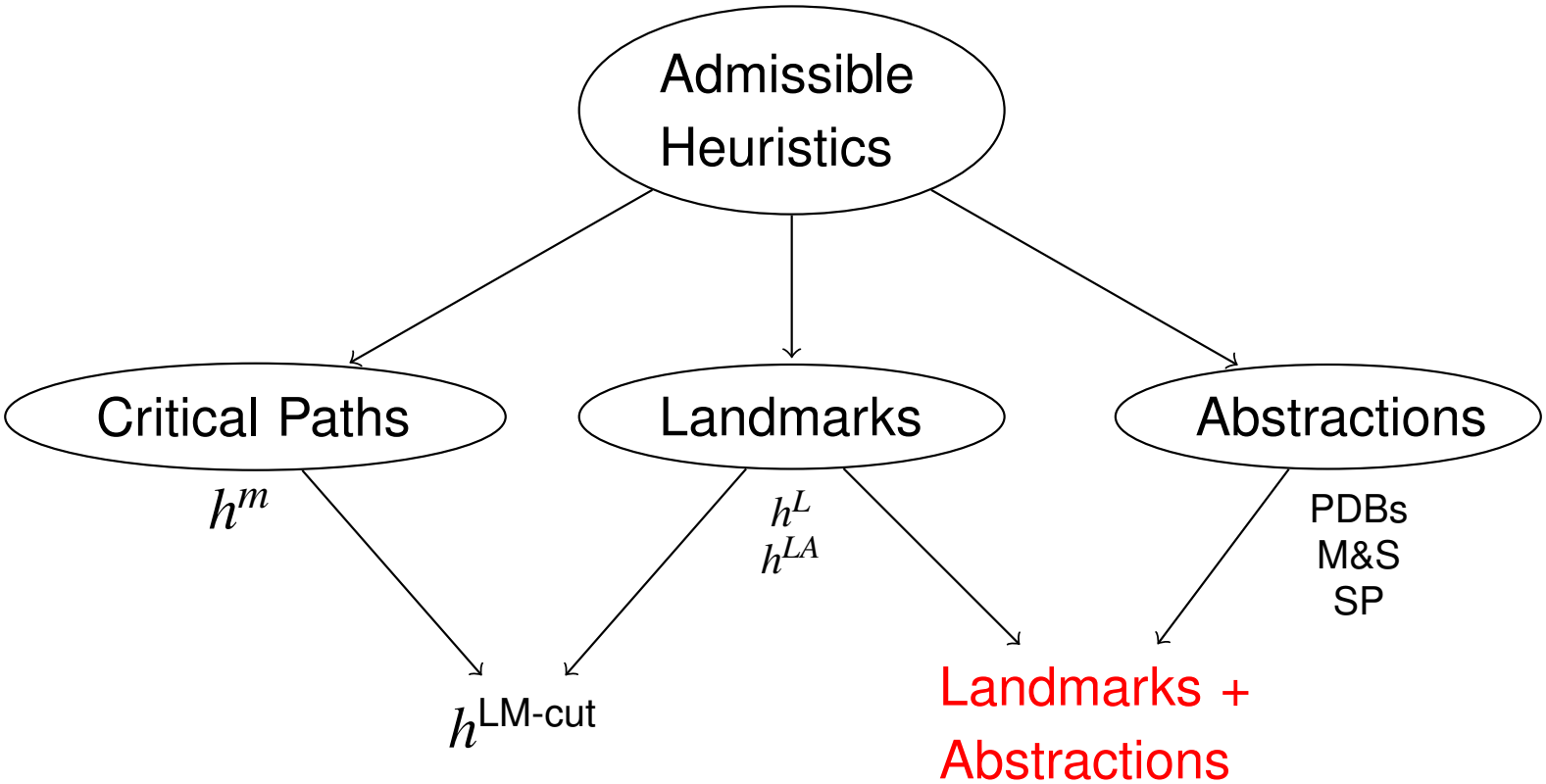

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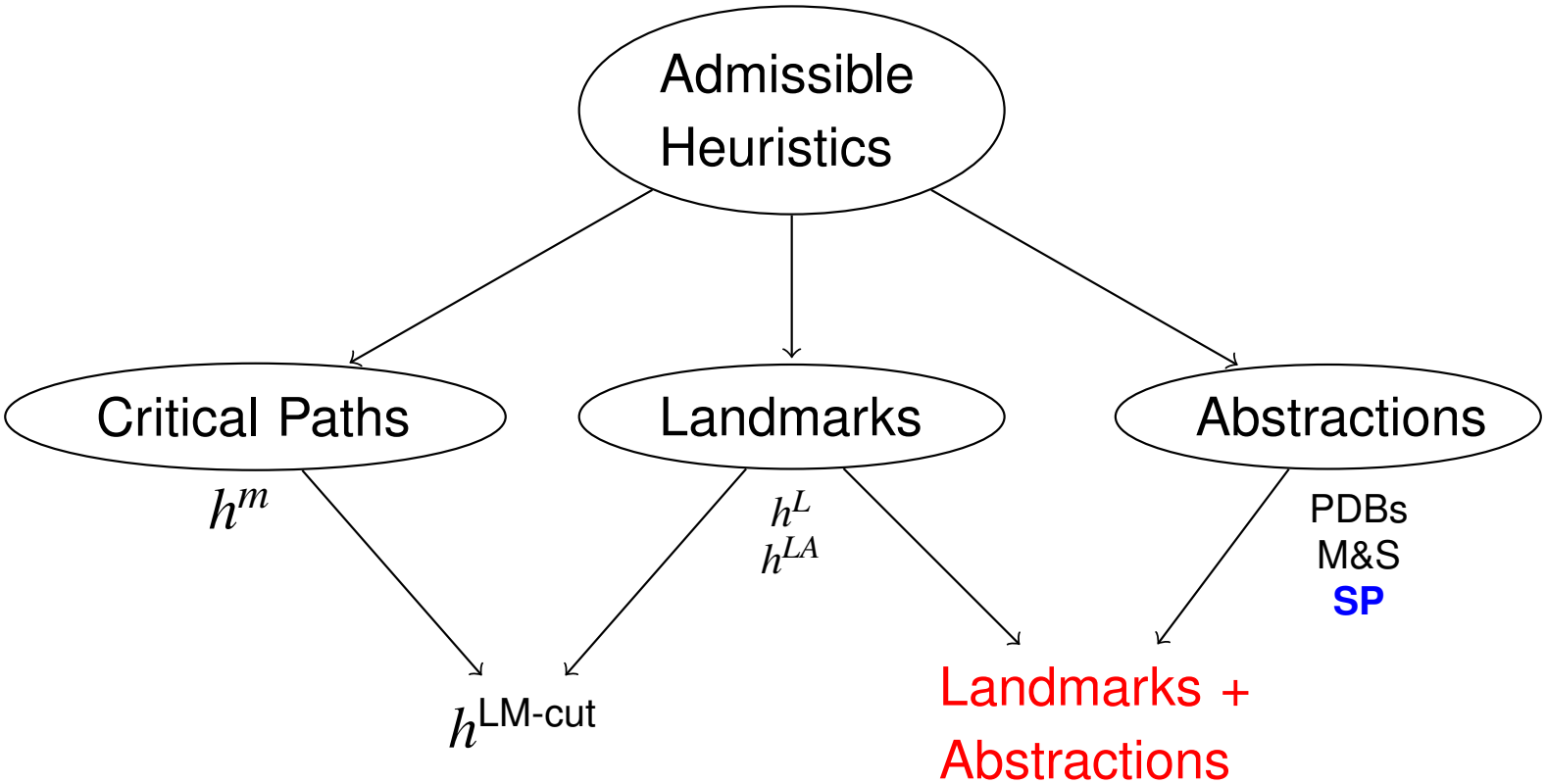
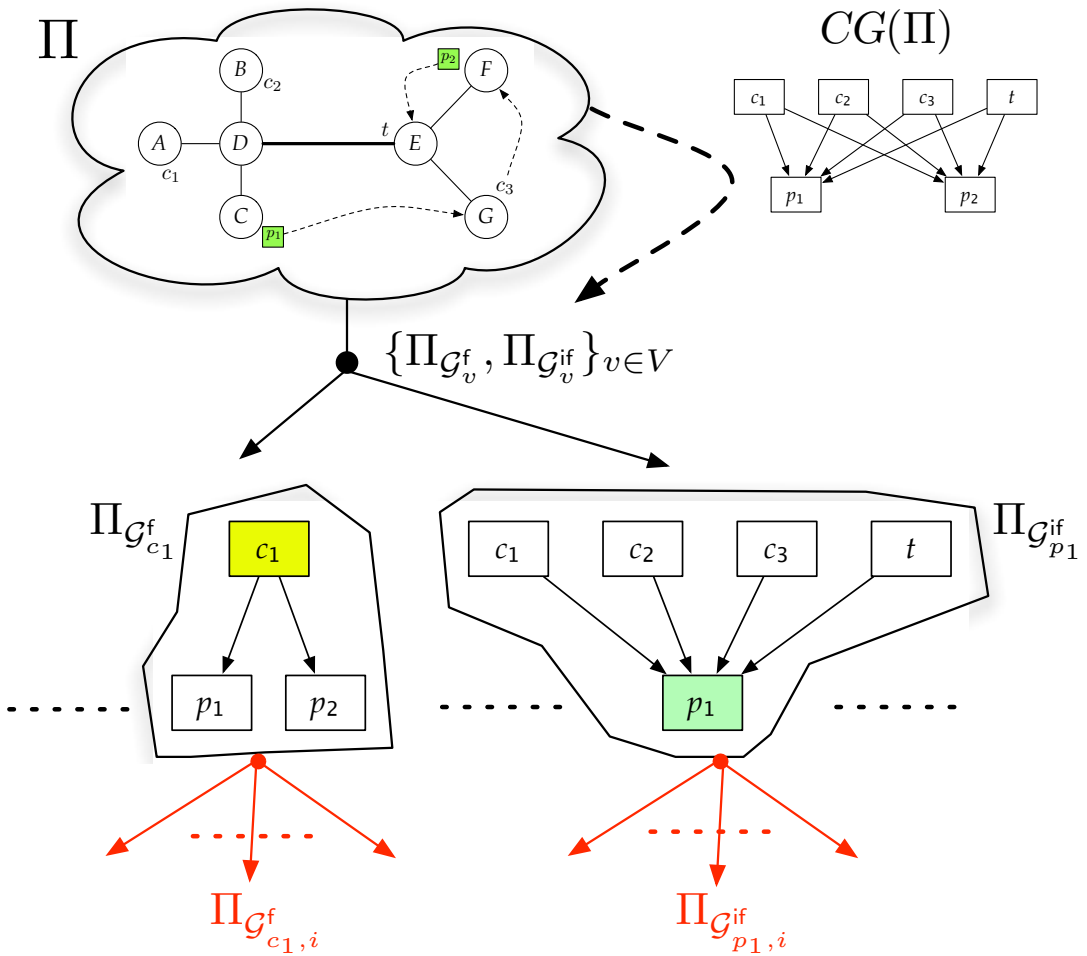


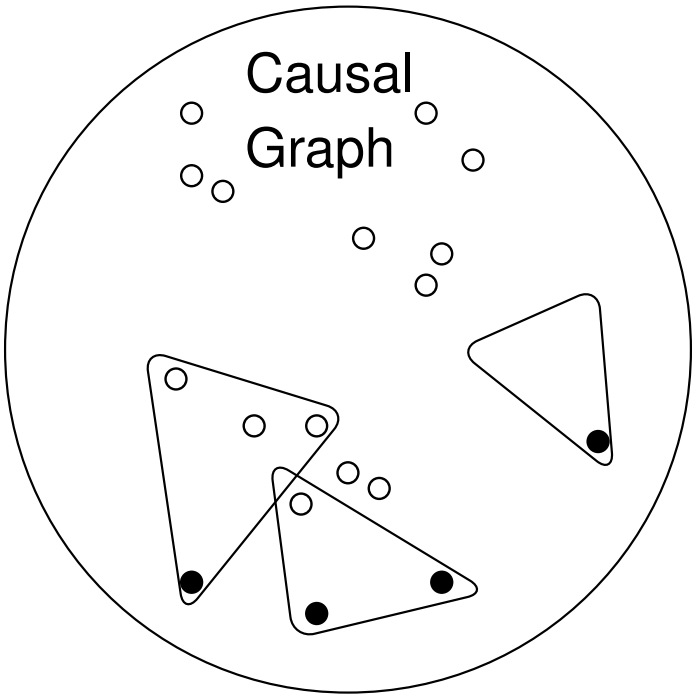
Implicit Abstractions - Fork Decomposition

(Katz & Domshlak, ICAPS08,09)

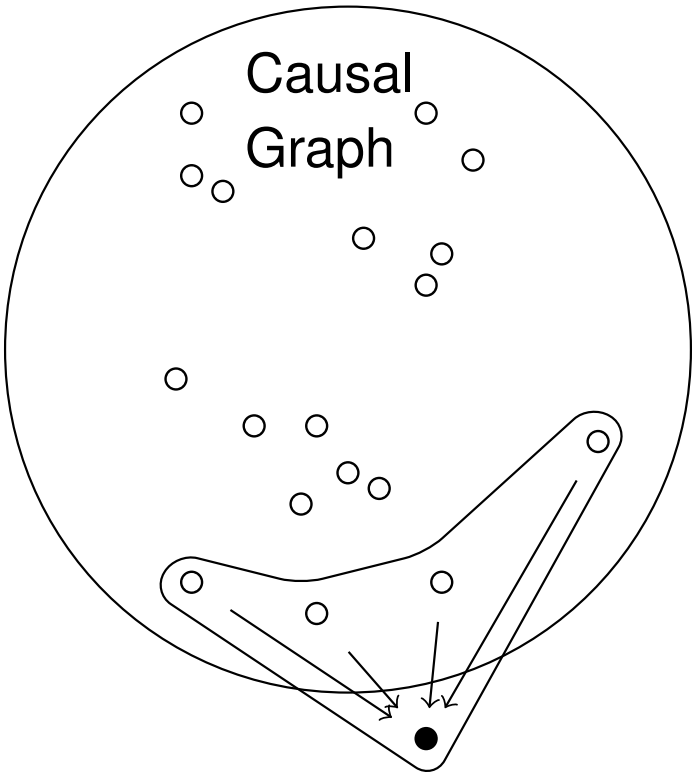


+ ensuring proper action cost partitioning

Goal Sensitivity



Goal Sensitivity



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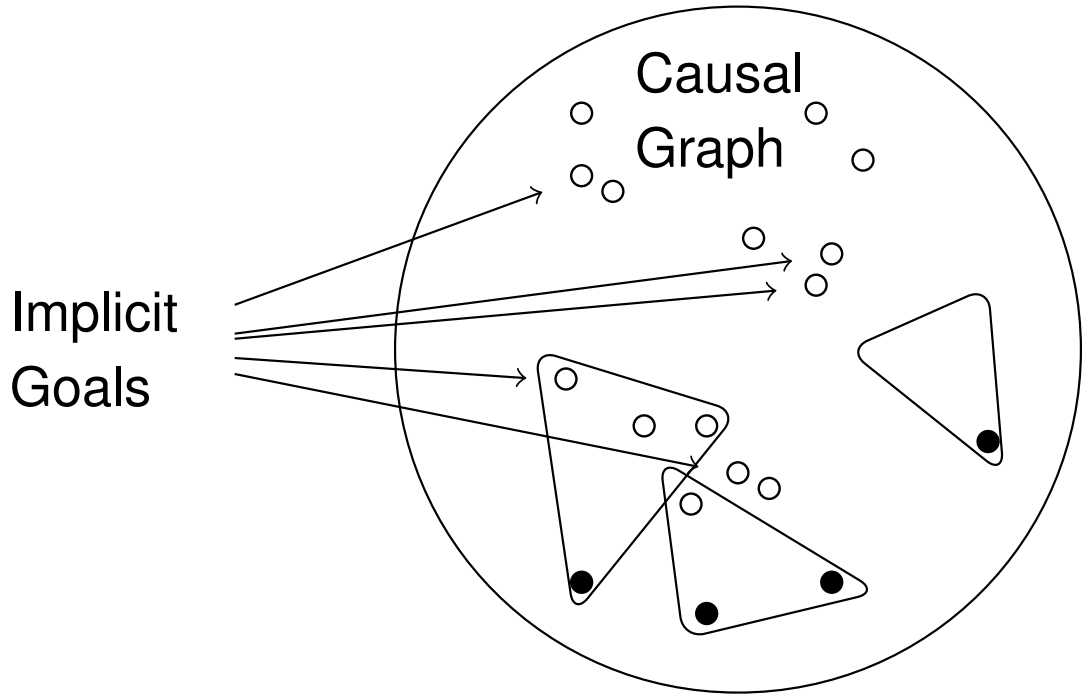
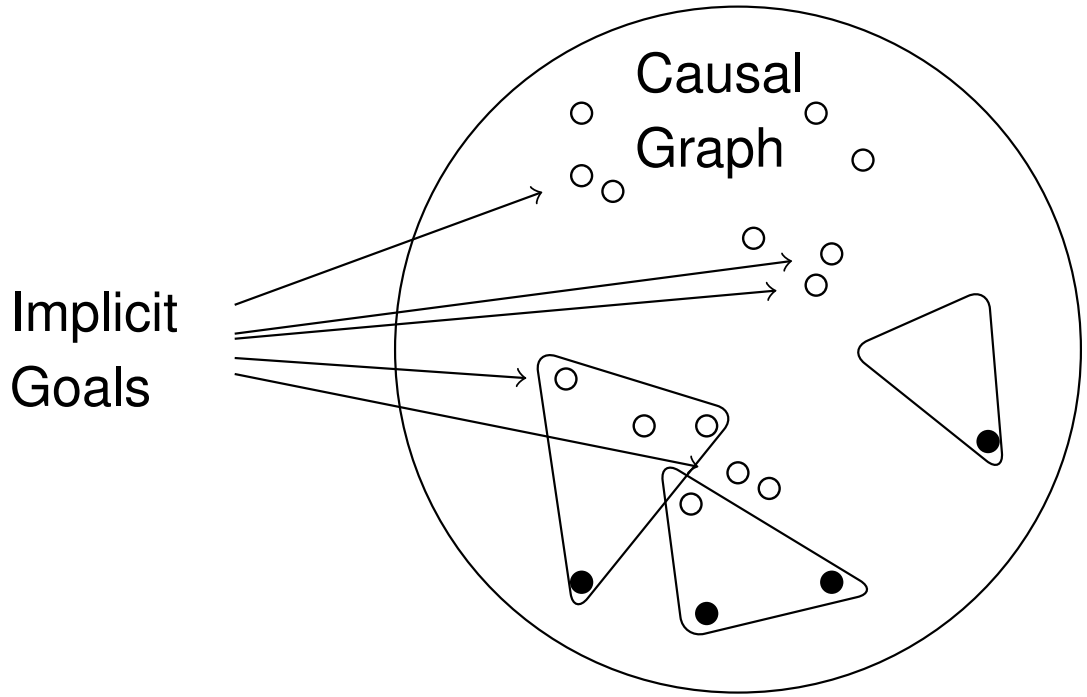


Landmark = Implicit Goal

Goal Sensitivity



Landmark = Implicit Goal

Landmarks

Landmark = Implicit Goal

- A landmark is a fact that must be true at some point in every valid plan (Hoffmann, Porteous and Sebastia 2004)
- *Some* landmarks can be discovered automatically
  - Hoffmann, Porteous, Sebastia 2004
  - Zhu, Givan 2005
  - Richter, Helmert, Westphal 2008
  - Helmert, Domshlak, 2009
  - ...

Enriching Planning Task

Classical Planning Task

$$\Pi = \langle V, A, I, G, C \rangle$$

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$\Longrightarrow$

Landmarks Set

$L = \{l_1 \ldots l_k\}$

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Landmark Enriched Task

$$\Pi^L = \langle V^L, A^L, I^L, G^L, C^L \rangle$$

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Landmark Enriched Task

$\Pi^L = \langle V^L, A^L, I^L, G^L, C^L \rangle$

1. Solve Π^L instead of solving Π

Landmark-based Heuristics

- Given state s, the number of "to be achieved from s" landmarks $|L(s)|$ can be used as an (inadmissible) estimate (Richter, Helmert, Westphal, 2008)

  ♠ used by $LAMA$ - a state of the art satisficing planner, and winner of the IPC-2008 sequential satisficing track

  ♠ proper cost partitioning between landmarks $\Rightarrow$ admissible estimate (Karpas & Domshlak, IJCAI09)

- multi-path-dependent search LM-A* (Karpas & Domshlak, IJCAI09) maintains the "to be achieved from s" landmark sets $L(s)$ well

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$\searrow$ $\swarrow$

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Landmark Enriched Task

$\Pi^L = \langle V^L, A^L, I^L, G^L, C^L \rangle$

1. Solve Π^L instead of solving Π
2. Solve Π while using Π^L for heuristic estimate
   - Run LM-A* on Π
   - Given state s of Π and "to be achieved from s" landmarks $L(s)$
     - map $(s, L(s))$ to the corresponding state s' of Π^L
     - compute $h^{\mathcal{F}}(s')$ [wrt Π^L]

Evaluation - Forks

domain ($\mathscr{D}$)	A^*/h on Π		A^*/h on Π^L		*LM-A**	
	s	E	s	E	s	E
airport-ipc4	20	13.86	18	14.96	17	17.00
blocks-ipc2	21	20.60	18	3.59	17	5.58
depots-ipc3	7	6.59	4	1.06	4	2.97
driverlog-ipc3	12	7.64	11	5.89	11	10.84
freecell-ipc3	5	1.32	5	4.58	5	4.83
grid-ipc1	2	0.20	2	0.39	2	2.00
gripper-ipc1	7	6.22	5	0.50	6	6.00
logistics-ipc1	6	2.35	6	2.44	5	3.81
logistics-ipc2	22	22.00	20	11.91	20	11.42
miconic-strips-ipc2	51	8.17	52	14.68	108	108.00
mprime-ipc1	23	9.87	22	15.38	23	18.21
mystery-ipc1	21	11.13	21	9.67	21	14.12
openstacks-ipc5	7	1.26	7	7.00	7	6.97
pathways-ipc5	4	3.99	4	4.00	4	3.99
pipes-notank-ipc4	16	10.61	15	7.79	15	15.00
pipes-tank-ipc4	10	6.75	10	5.20	10	10.00
psr-small-ipc4	49	48.56	49	48.07	48	47.98
rovers-ipc5	6	2.97	6	5.71	5	4.90
satellite-ipc4	6	1.01	7	3.08	7	7.00
schedule-strips	46	43.61	46	42.38	46	43.61
tpp-ipc5	6	6.00	6	5.48	5	4.49
trucks-ipc5	6	0.84	7	2.92	7	7.00
zenotravel-ipc3	11	7.31	9	5.05	9	9.00
	364	242.85	350	221.72	402	364.72

Evaluation - Cost Partition

LM-A* with Forks

domain ($\mathscr{D}$)	Optimal		Uniform		Optimal for I	
	s	E	s	E	s	E
airport-ipc4	7	6.77	17	16.52	17	16.52
blocks-ipc2	13	13.00	17	8.37	17	9.17
depots-ipc3	1	1.00	4	3.22	4	3.48
driverlog-ipc3	6	5.28	11	5.70	11	7.07
freecell-ipc3	2	2.00	5	3.07	5	3.87
grid-ipc1	0	0.00	2	2.00	2	2.00
gripper-ipc1	2	1.85	6	5.55	6	6.00
logistics-ipc1	2	2.00	5	3.42	5	3.97
logistics-ipc2	17	17.00	20	14.20	20	14.22
miconic-strips-ipc2	90	89.91	108	76.30	108	80.20
mprime-ipc1	9	8.89	23	15.32	23	19.30
mystery-ipc1	11	10.50	21	17.34	21	18.80
openstacks-ipc5	5	4.99	7	2.50	7	7.00
pathways-ipc5	4	4.00	4	2.36	4	3.98
pipes-notank-ipc4	3	3.00	15	10.00	15	14.19
pipes-tank-ipc4	2	2.00	10	6.52	10	9.62
psr-small-ipc4	40	40.00	48	34.96	48	27.29
rovers-ipc5	4	4.00	5	3.07	7	5.66
satellite-ipc4	5	5.00	7	3.59	7	3.27
schedule-strips	33	32.93	46	26.15	47	23.00
tpp-ipc5	5	5.00	5	4.02	5	5.00
trucks-ipc5	4	4.00	7	3.39	8	4.91
zenotravel-ipc3	7	7.00	9	3.36	11	7.79
	272	270.12	402	270.93	408	296.32

Evaluation - Merge & Shrink

domain ($\mathscr{D}$)	A^*/h on Π		A^*/h on Π^L		*LM-A**	
	s	E	s	E	s	E
airport-ipc4	17	14.90	15	12.91	16	16.00
blocks-ipc2	18	10.88	20	16.33	18	15.82
depots-ipc3	7	6.17	6	3.91	4	3.89
driverlog-ipc3	12	9.12	11	8.46	11	10.08
freecell-ipc3	4	2.67	4	3.99	4	2.81
grid-ipc1	2	1.12	2	0.76	1	1.00
gripper-ipc1	7	6.91	4	1.12	6	5.01
logistics-ipc1	4	2.67	3	0.49	3	2.12
logistics-ipc2	16	15.03	16	10.61	14	10.84
miconic-strips-ipc2	55	45.87	44	32.97	63	58.04
mprime-ipc1	21	13.85	17	12.14	20	16.31
mystery-ipc1	17	13.96	16	12.25	19	14.91
openstacks-ipc5	7	6.96	7	7.00	7	1.96
pathways-ipc5	4	4.00	4	3.08	4	4.00
pipes-notank-ipc4	21	18.68	16	12.28	15	12.44
pipes-tank-ipc4	13	11.77	12	7.68	13	10.97
psr-small-ipc4	50	49.09	50	49.40	49	43.42
rovers-ipc5	6	5.18	6	5.19	5	5.00
satellite-ipc4	6	3.25	5	3.17	7	7.00
schedule-strips	19	19.00	19	19.00	19	19.00
tpp-ipc5	6	5.37	6	5.78	6	6.00
trucks-ipc5	5	4.45	4	2.76	4	2.01
zenotravel-ipc3	11	9.36	9	7.58	9	9.00
	328	280.26	296	238.85	317	277.62

Summary and Future Work

Conclusions

1. (At least implicit) abstractions and landmarks can be friends
2. Want to use landmark-enriched abstraction heuristic?
   $\leadsto$ Try the "search here, evaluate there" scheme

Future Work

1. Successful dating between landmarks and explicit abstractions
2. Other methods for landmarks compilation, exploiting action landmarks, ...

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