Triangle Search in Planning

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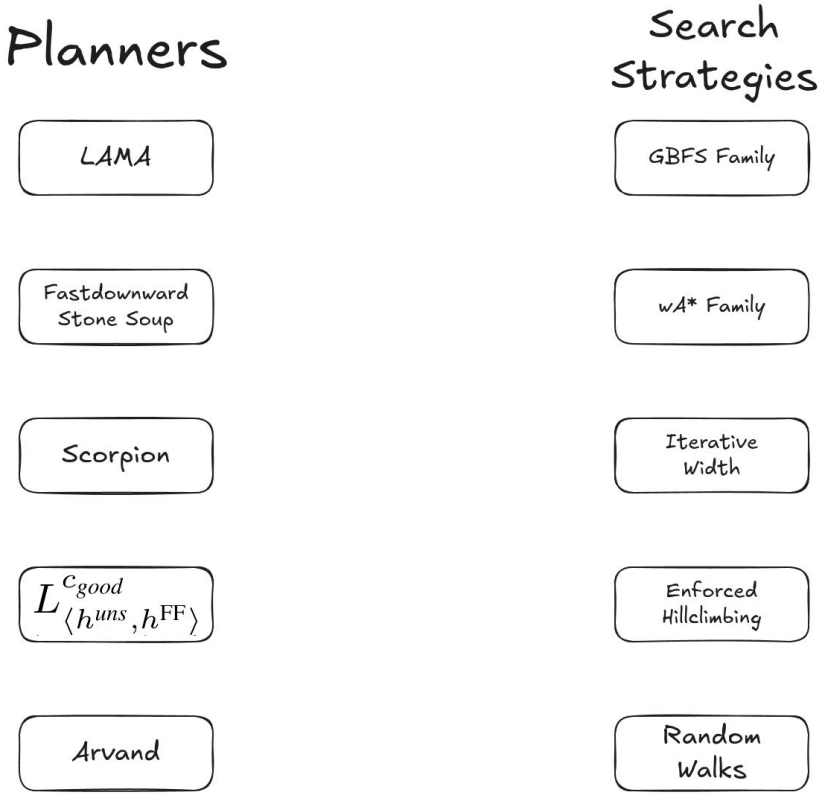
If the Building Catches Fire During the Talk...

- Triangle Search performs well in classic heuristic search benchmarks
- It also performs extremely well in planning
  - better than our usual base strategies
  - Not as well as algorithms with planning-specific enhancements
- This points to two opportunities:
  - Exporting planning-specific search enhancements to general search problems
  - Importing those enhancements to Triangle Search to improve planners

Planning Systems Use Search Under the Hood



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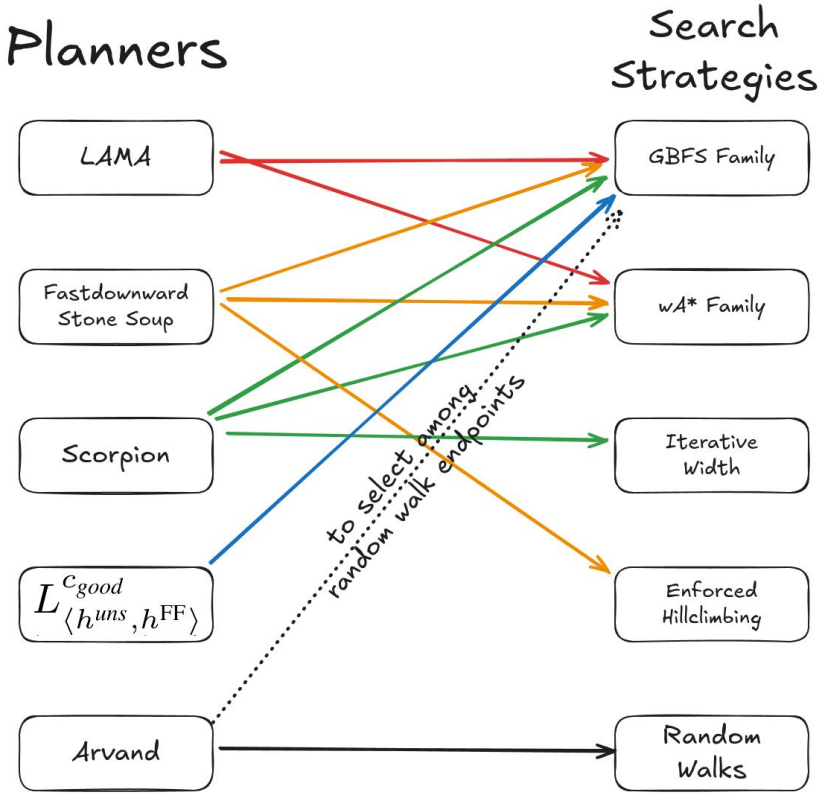

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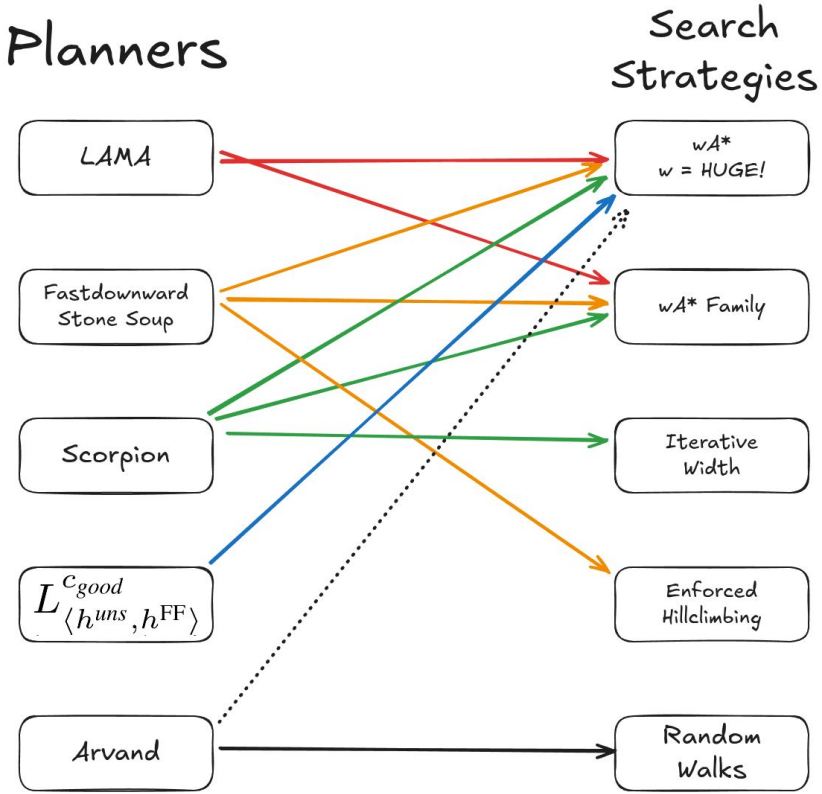

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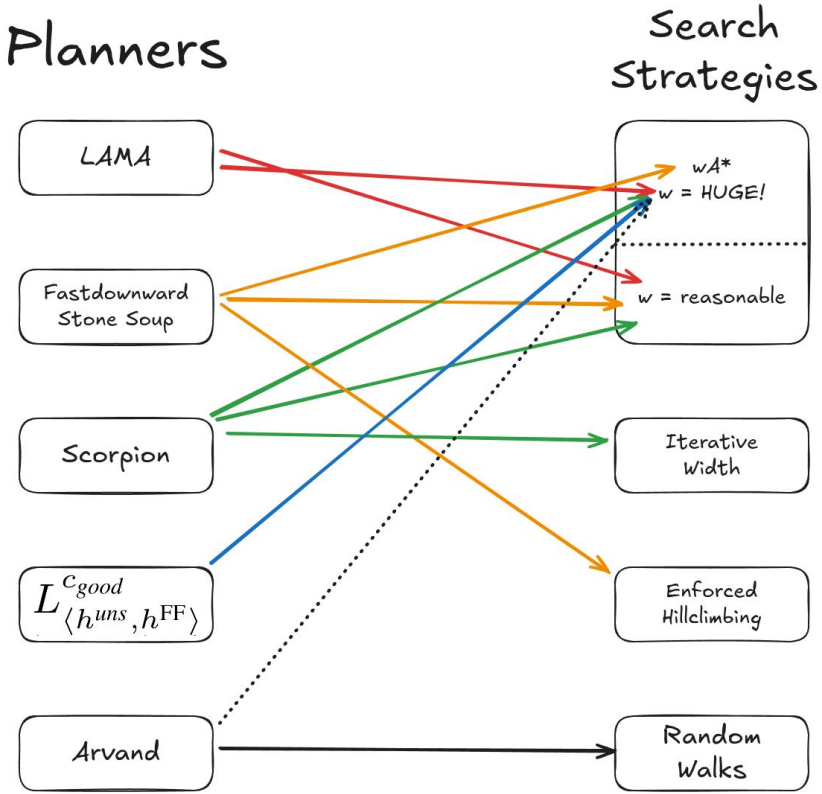
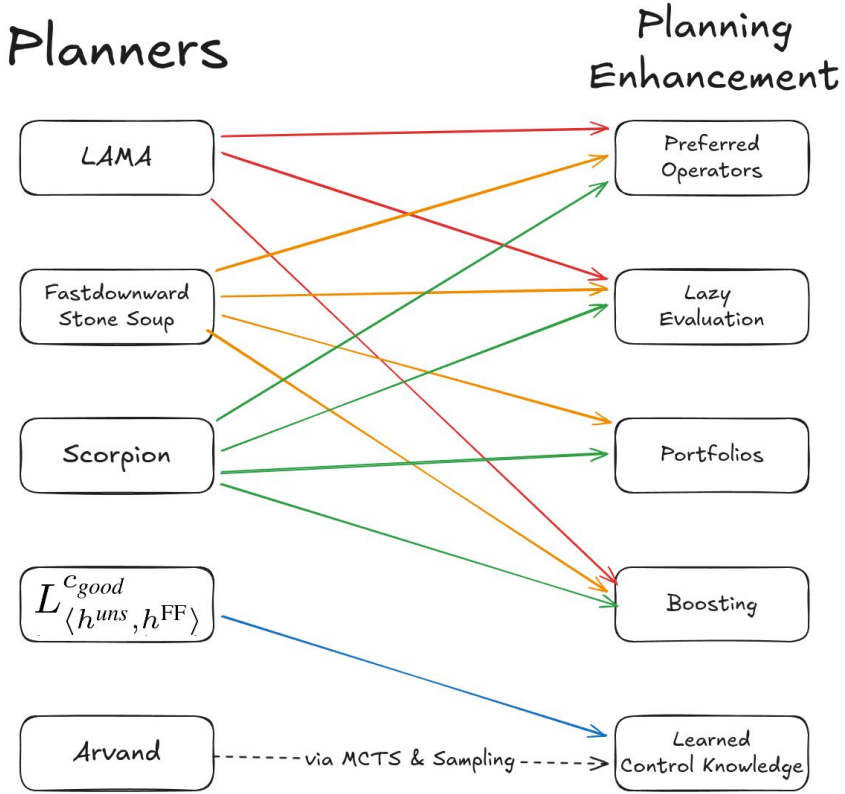
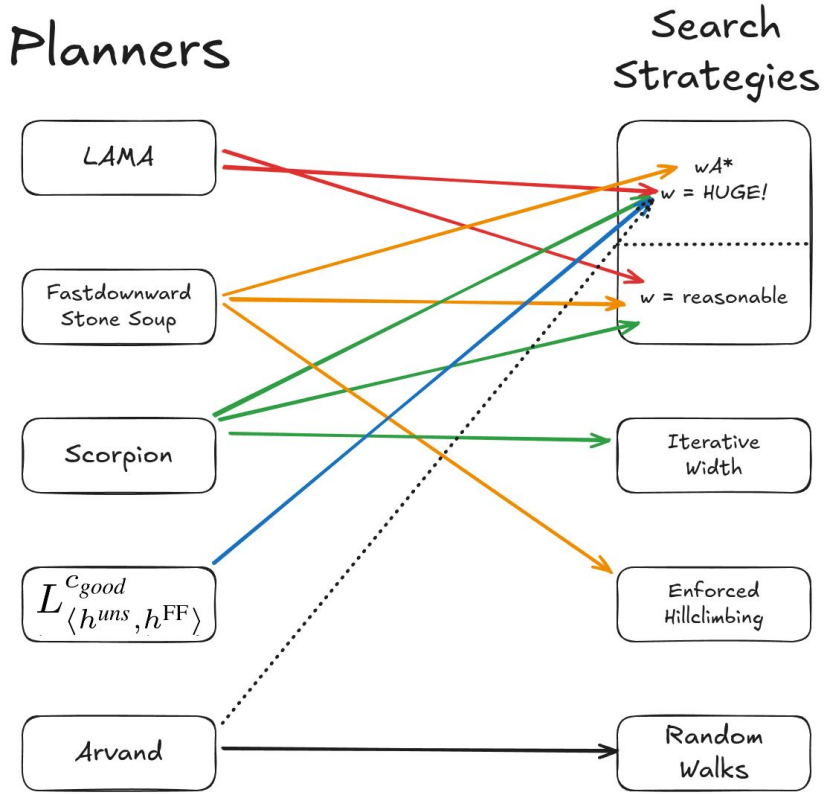


Planning Progress is Uneven

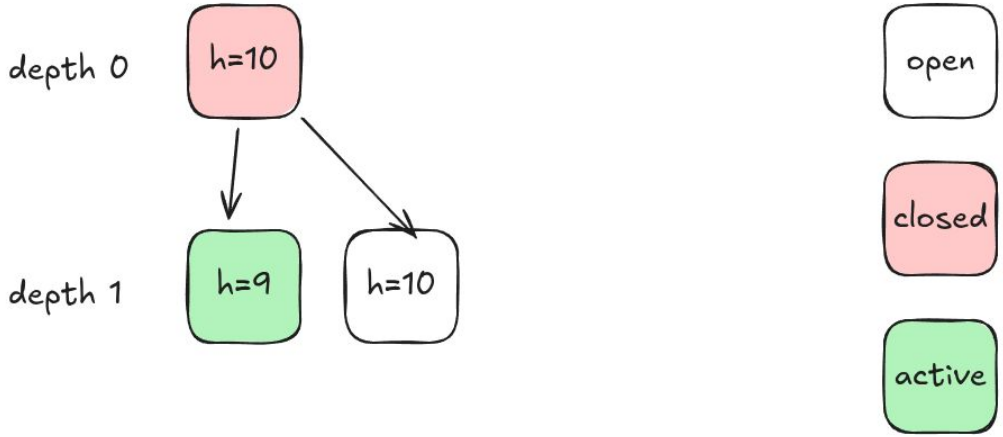




Triangle Search

Triangle search feels a lot like
Enforced hill climbing

We expand a node at each depth,
Starting with the shallowest



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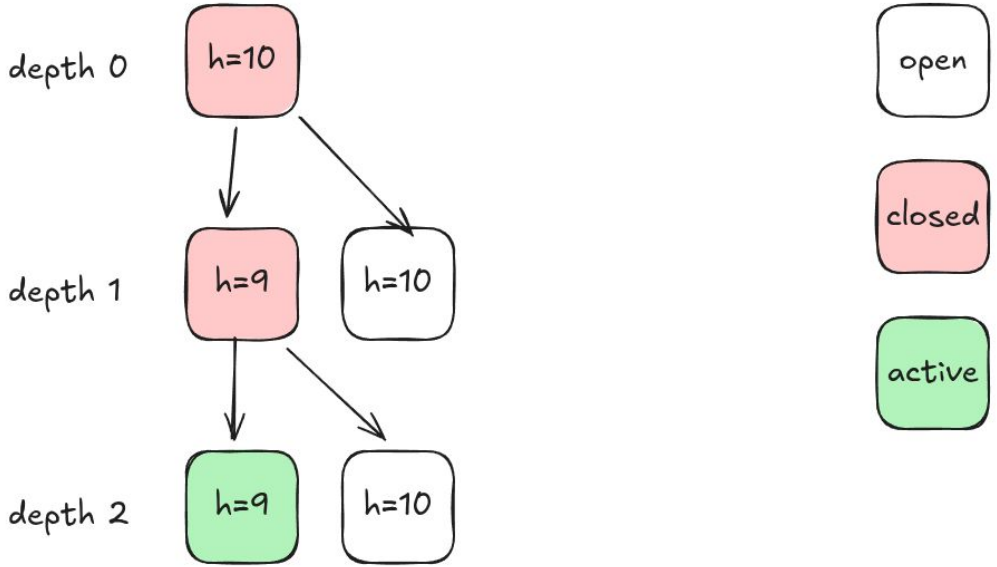

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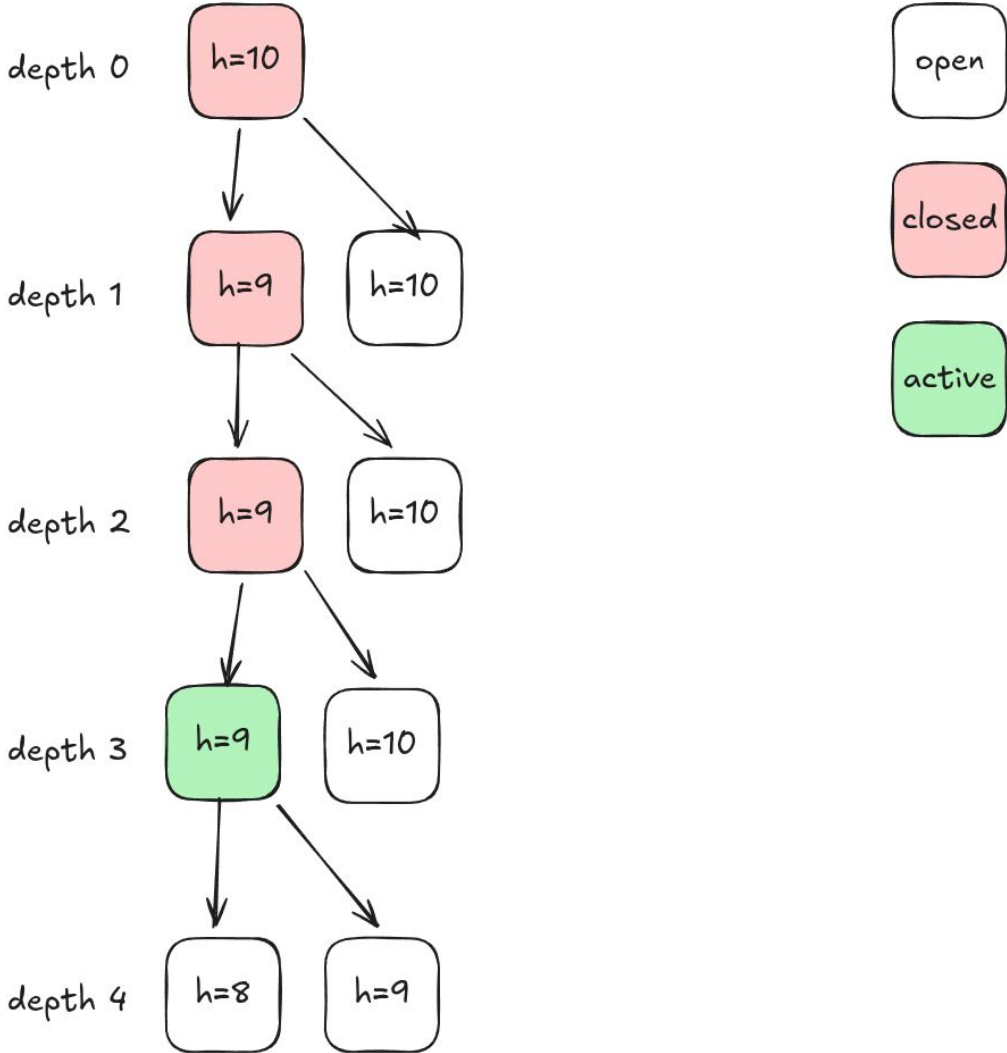

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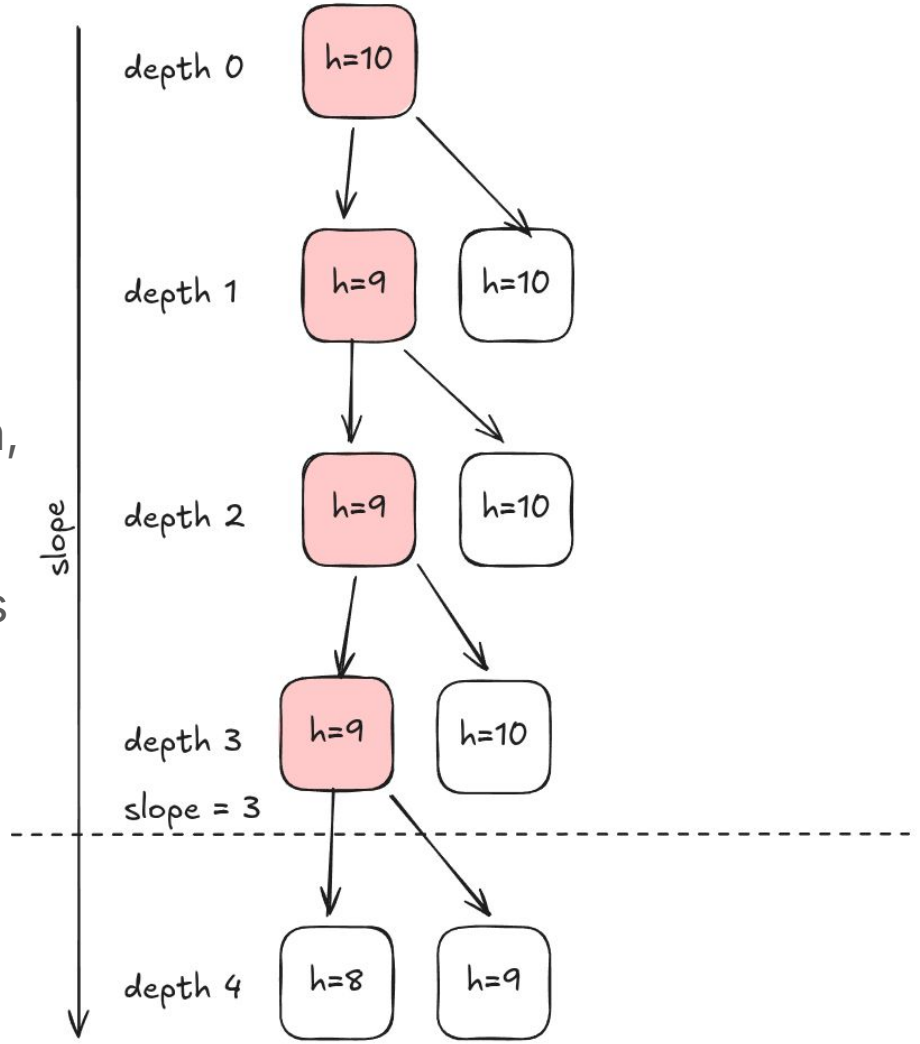
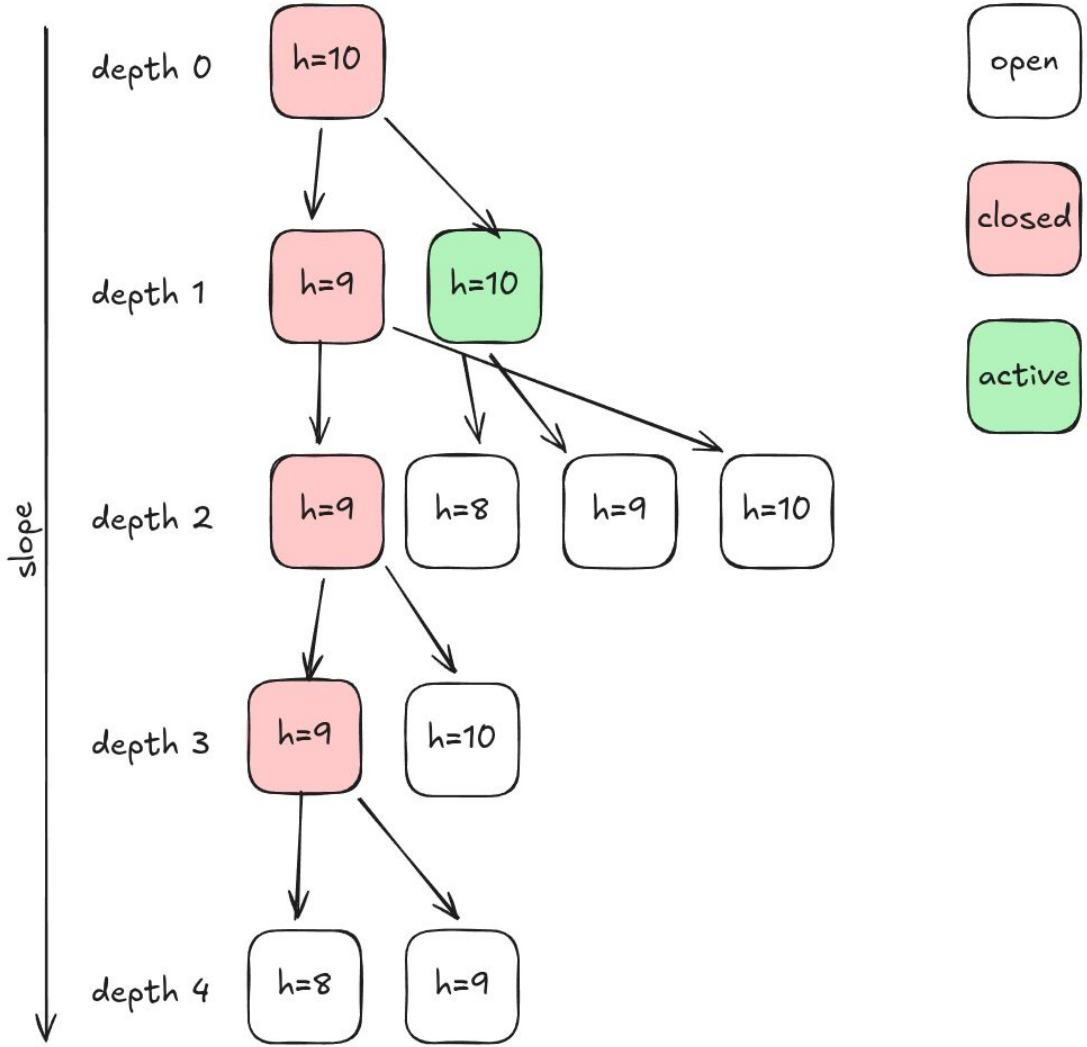
We run forward *SLOPE* steps,
Which is a parameter



Triangle Search

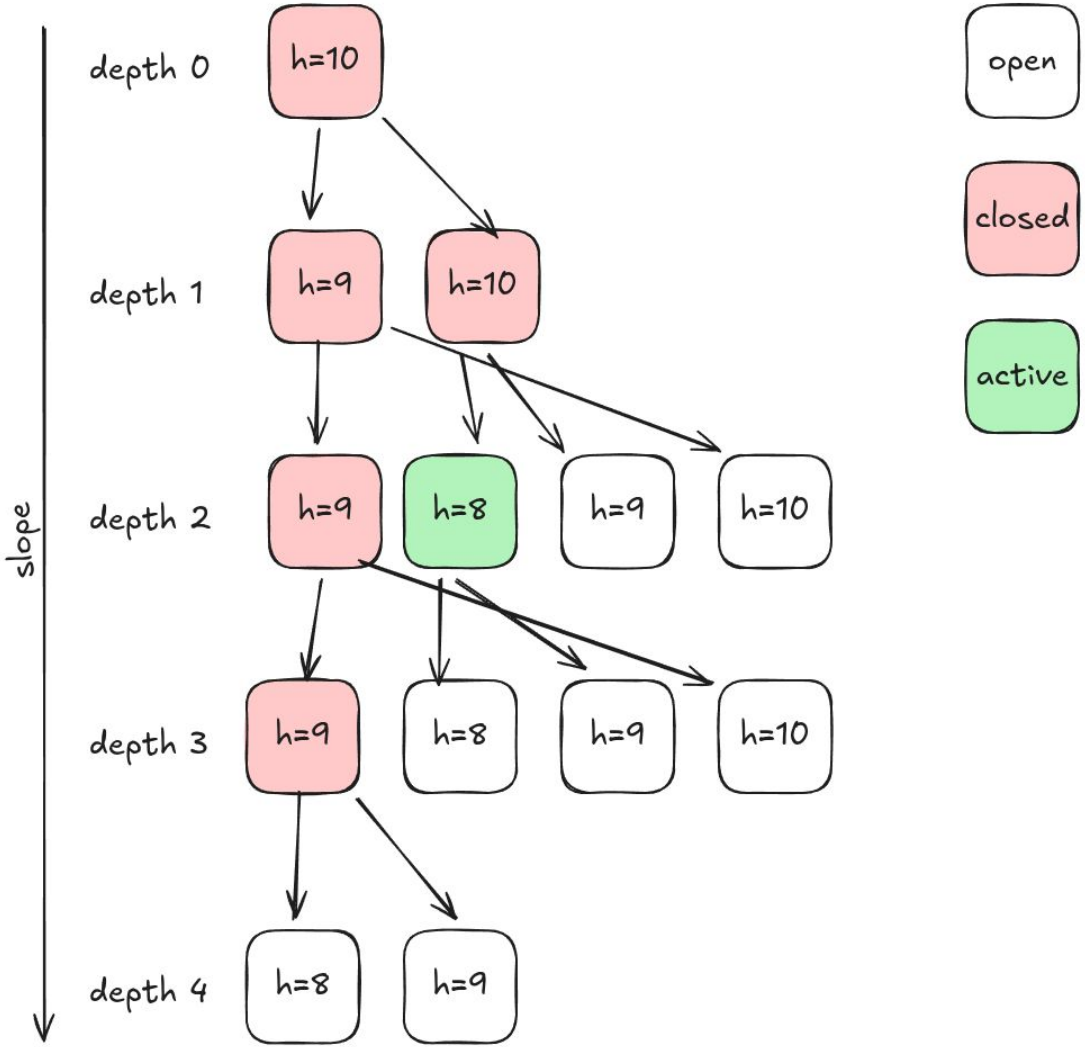
We restart from the shallowest depth with open nodes every iteration



Triangle Search

We restart from the shallowest depth with open nodes every iteration

We can prune shallow layers Where all nodes are closed



Triangle Search

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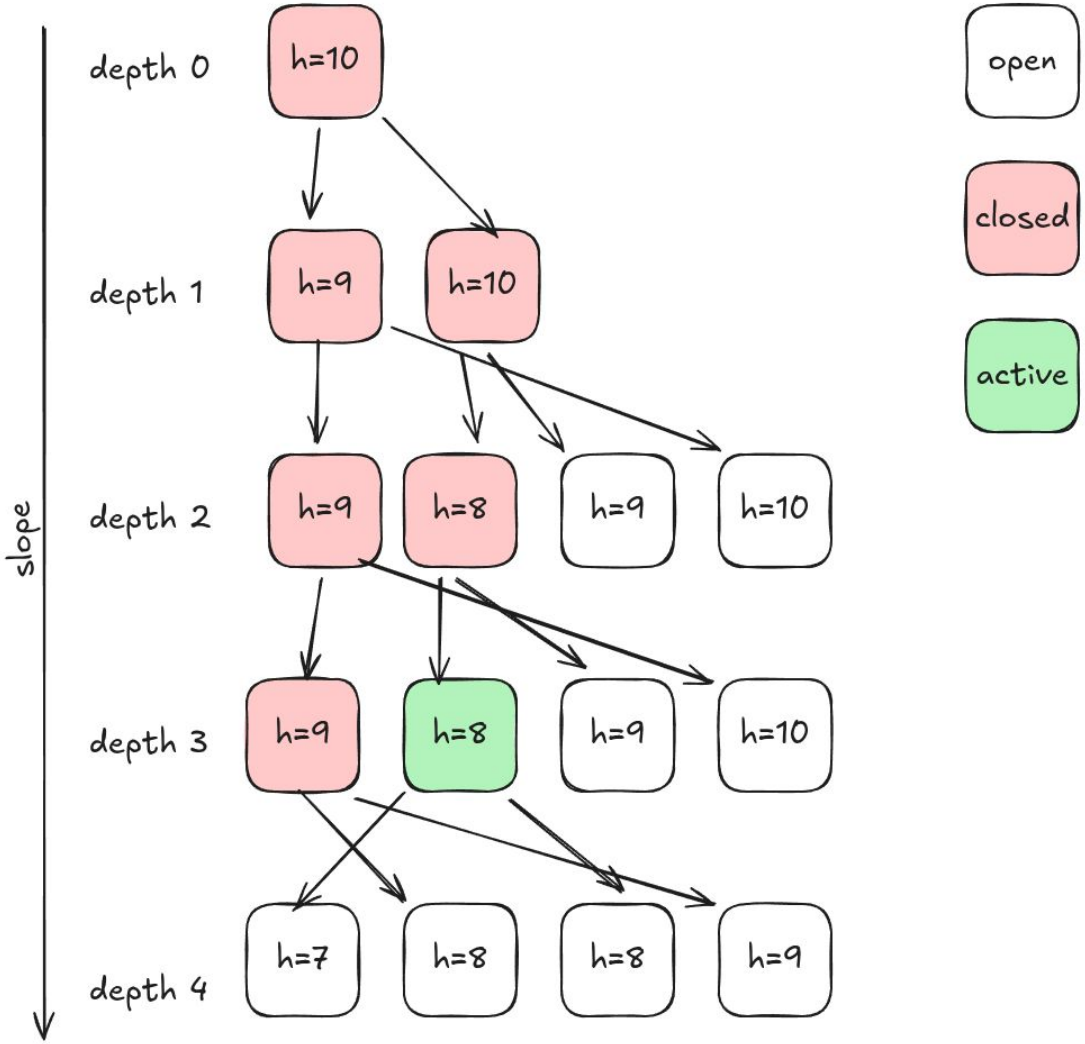
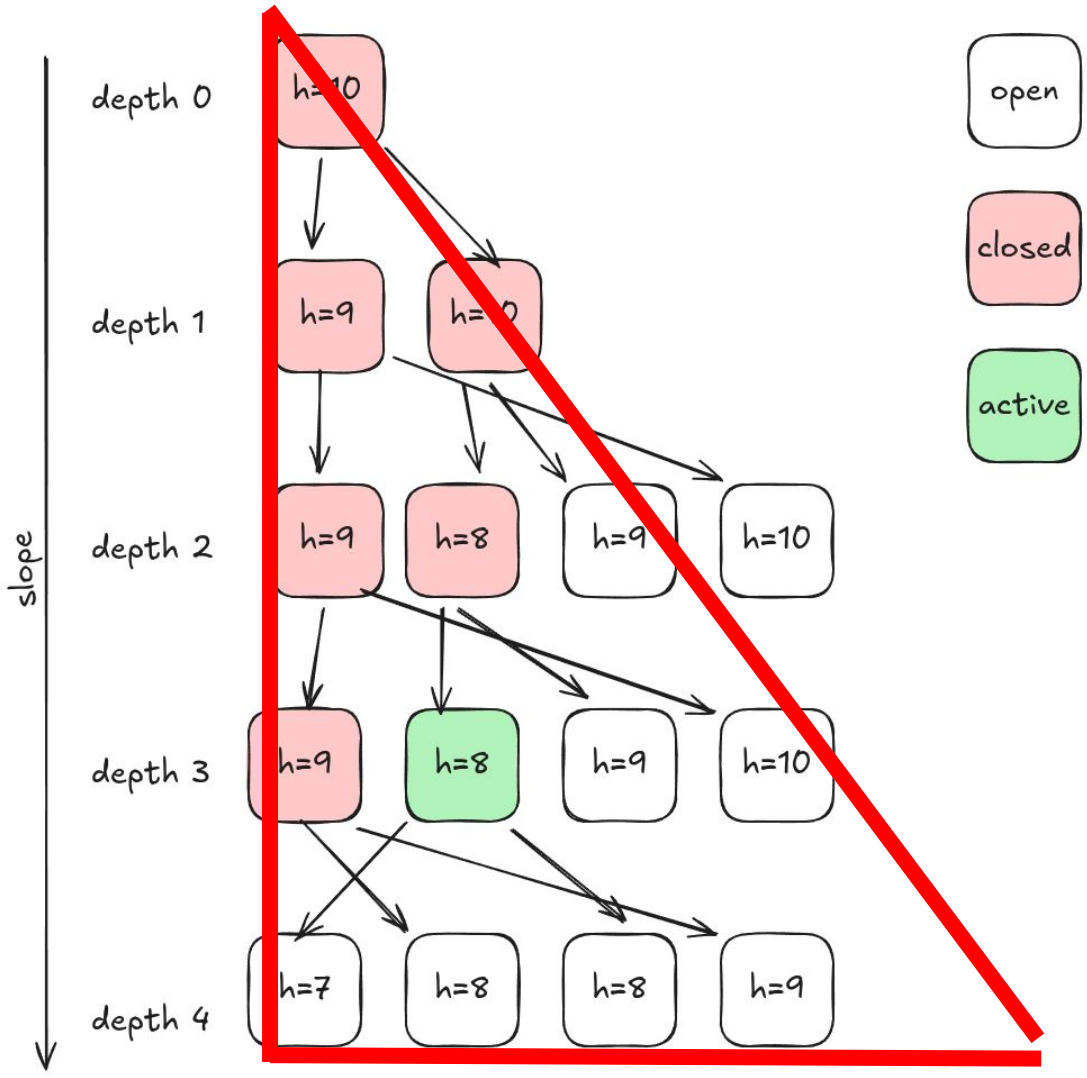
Going shallow to deep gives us a chance to ‘compete’ with children of siblings at a shallower layer



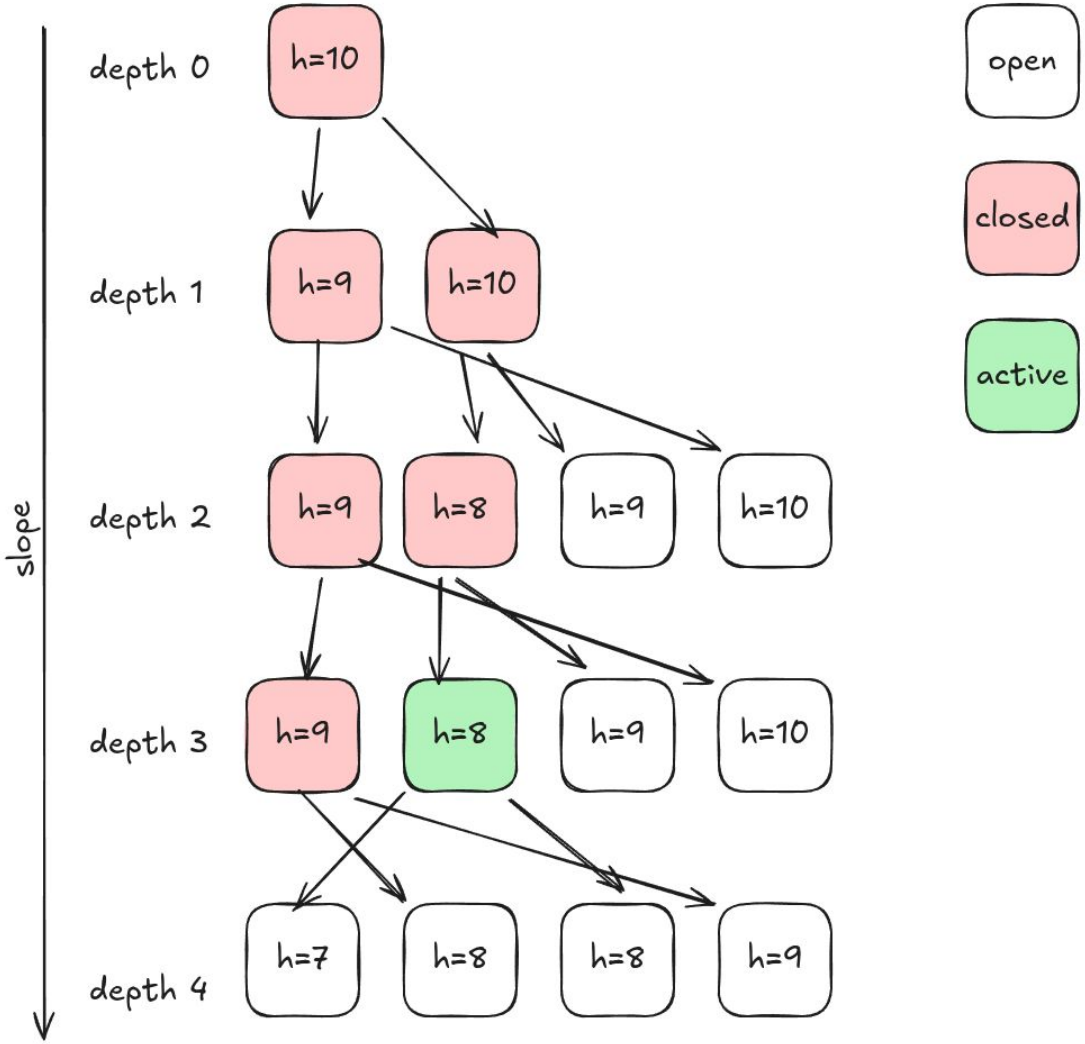
Triangle Search

Why Triangle?
Evocative of the search frontier



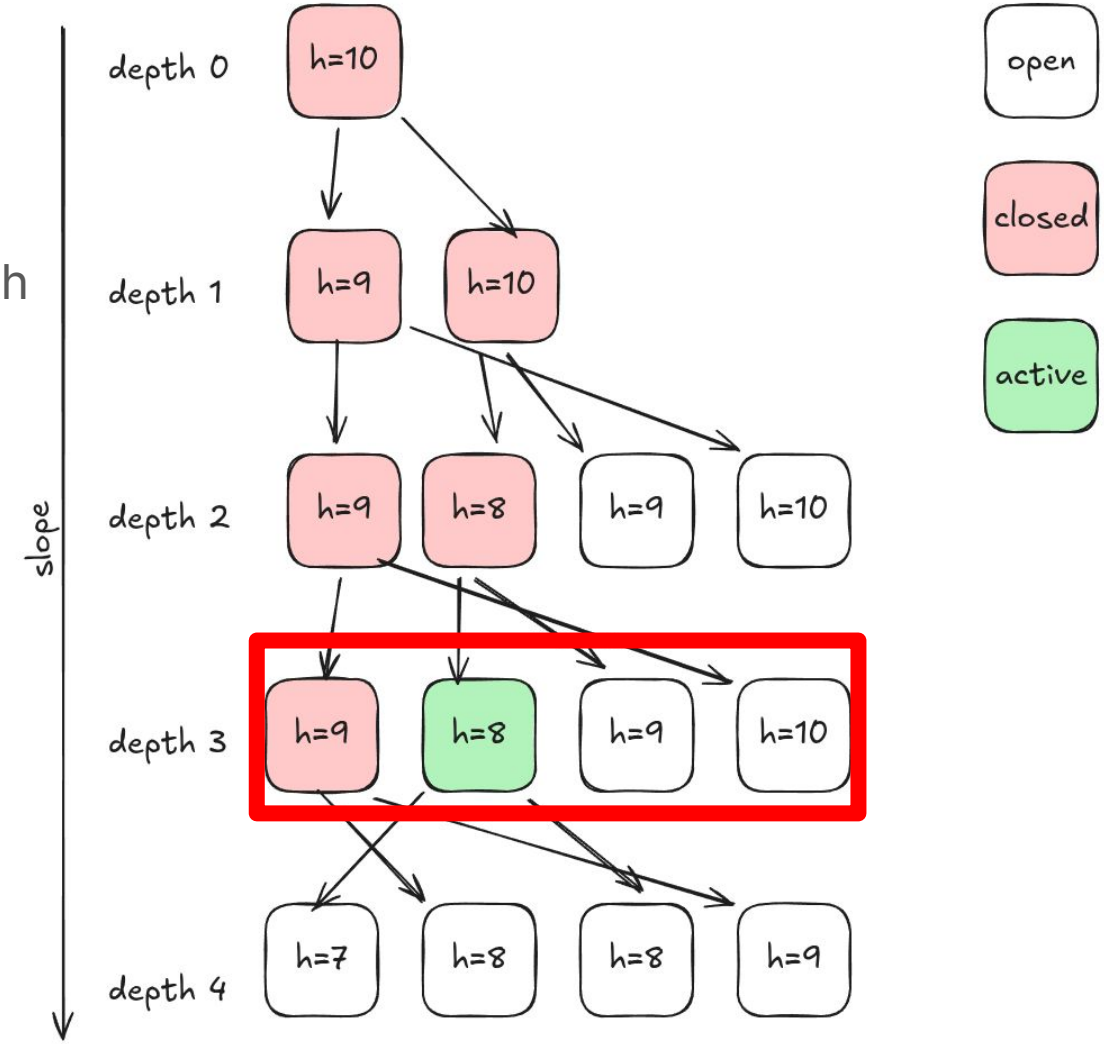
Triangle Search

I think ‘bead curtain’ is more accurate to behavior



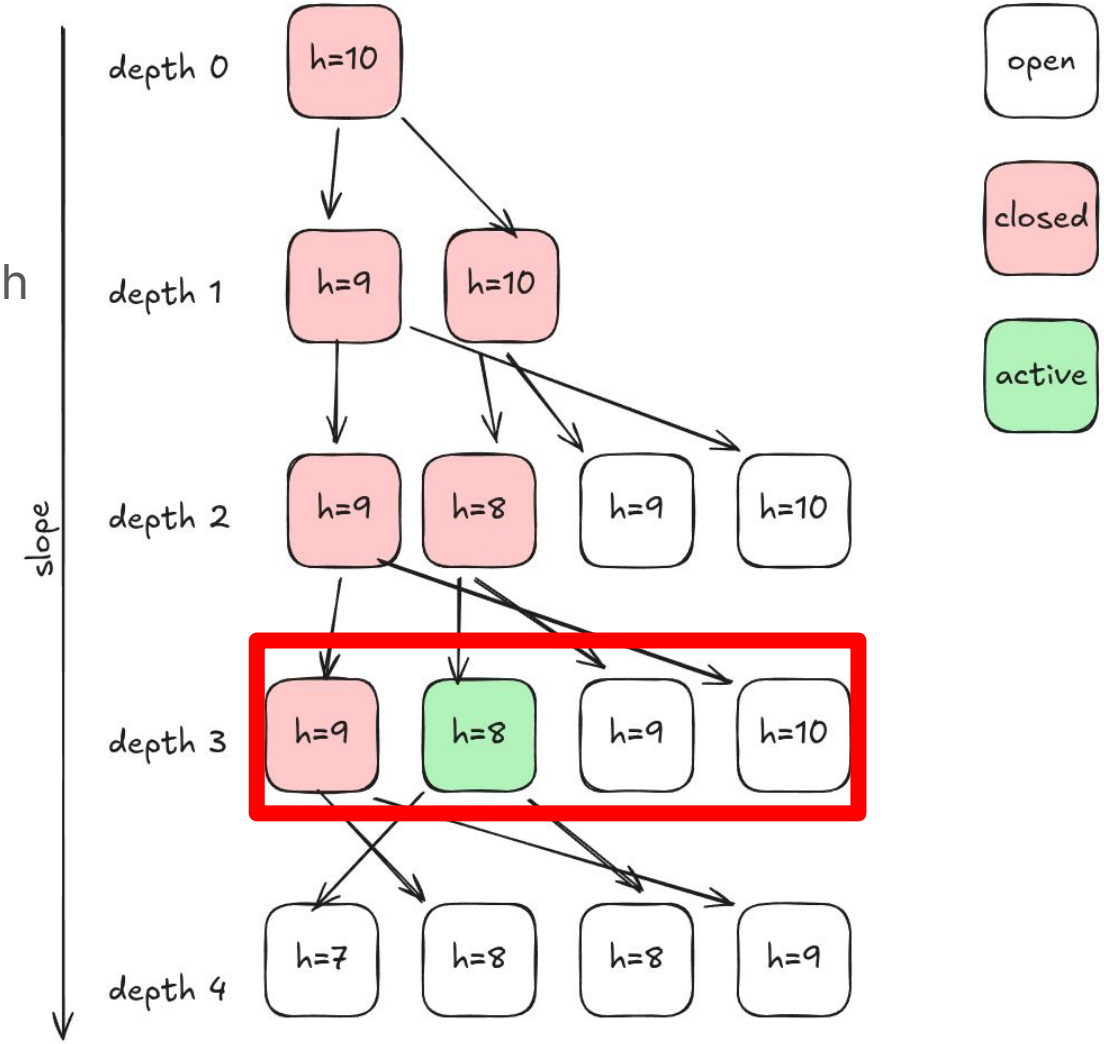
Triangle Search

- Nodes competing at fixed depth



Triangle Search

- Nodes competing at fixed depth
  - A* Epsilon-ish
  - Beam Search-ish
  - Tree Search-ish



Triangle Search

- Nodes competing at fixed depth
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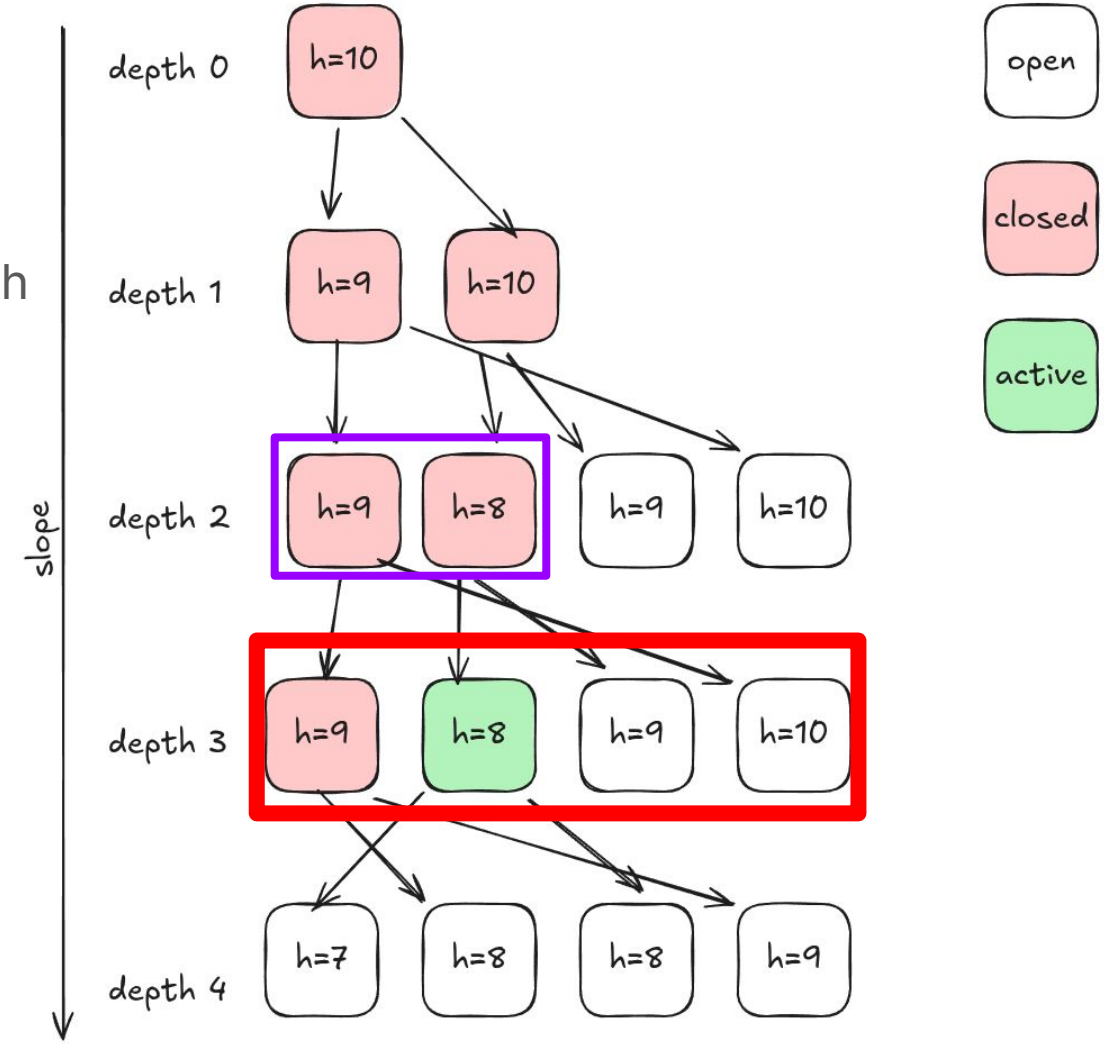
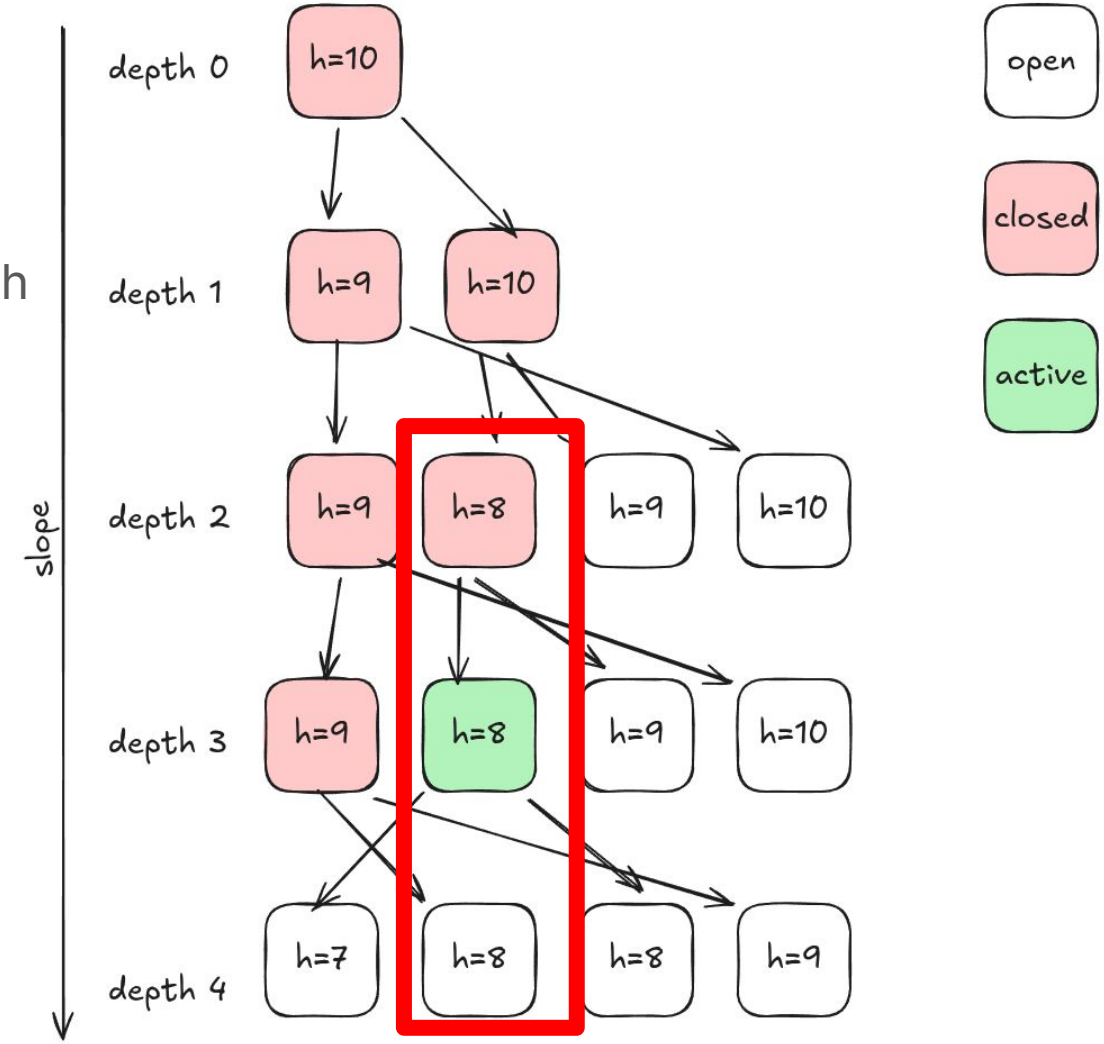


Triangle Search

- Nodes competing at fixed depth
  - A* Epsilon-ish
  - Beam Search-ish
  - Tree Search-ish
- Depth Search Control
  - Window A*
  - d-fenestration



Triangle Search Works Pretty Good! - h_ff

Algorithm	Cov.	Exp. (100k)	Gen. (100k)	Sec.
TRI	576	0.85	14.15	0.04
RECT	470	5.08	40.10	1.64
GBFS	458	2.49	36.71	0.05

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Algorithm	Cov.	Exp. (100k)	Gen. (100k)	Sec.
LAMA	878	0.42	4.24	0.06
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LAZY-GBFS	464	2.63	44.36	0.05
GBFS-PO	622	0.65	5.60	0.05
LAZY-GBFS-PO	682	0.56	4.67	0.04

Triangle Search Works Pretty Good! - lm count

Algorithm	Cov.	Exp. (100k)	Gen. (100k)	Sec.
LAMA	878	0.42	4.24	0.06
TRI	688	2.15	31.28	0.04
RECT	486	4.03	23.76	4.58
GBFS	605	4.09	26.36	0.05
GBFS-PO	593	3.18	19.04	0.07
LAZY-GBFS	597	4.67	66.07	0.06
LAZY-GBFS-PO	603	4.46	44.03	0.06

Triangle Search Works Pretty Good!

Algorithm	Δ Cov.	Improving Dom.	Improving Inst.
TRI-LM	-190	10	96
TRI-FF	-302	7	40
GBFS-FF	-420	1	4
LAZY-GBFS-FF	-414	1	2
GBFS-FF-PO	-256	4	6
LAZY-GBFS-FF-PO	-196	5	8
GBFS-LM-PO	-285	9	31
LAZY-GBFS-LM-PO	-275	9	33

Triangle Search Works Pretty Good!

Algorithm	Snake	NoMystery	Tidybot	Thoughtful	Parking
TRI-FF	21	18	13	10	9
RECT-FF	0	-11	-2	-6	12
GBFS-FF	0	2	2	11	12
LAZY-GBFS-FF	0	7	4	8	13
GBFS-FF-PO	0	0	2	3	12
LAZY-GBFS-FF-PO	0	7	8	4	13
TRI-LM	6	14	3	10	-6
RECT-LM	-19	-11	-13	-6	-4
LAZY-GBFS-LM-PO	2	8	3	5	7

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Material for Questions I Think You Might Ask!

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Ok, But Why Does It Work Pretty Good?

- Compare to Random Walks to Escape Plateaus
  - Slope length random walk
- Compare to Greedy Policy Following
  - Slope length greedy h following
  - Bypassing global search order with useful fallback
- Compare to LAMA
  - Slope similar to boost
  - Multiple queues hoping to drive fairer comparison

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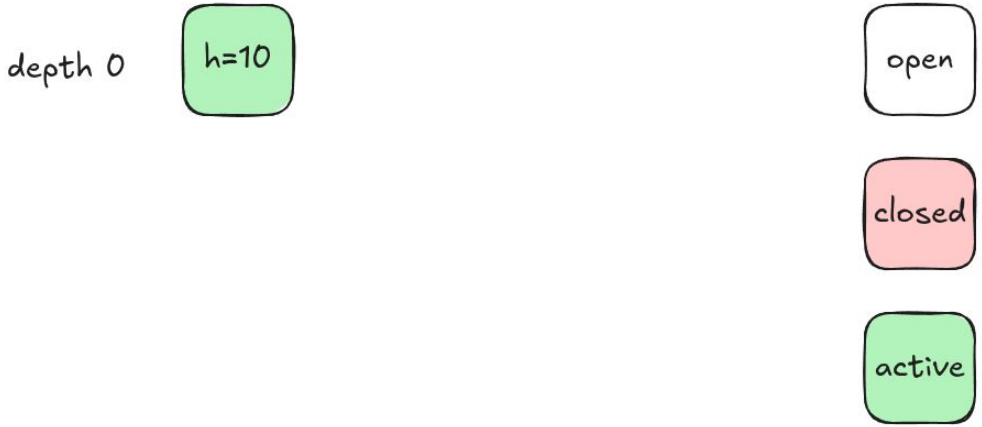

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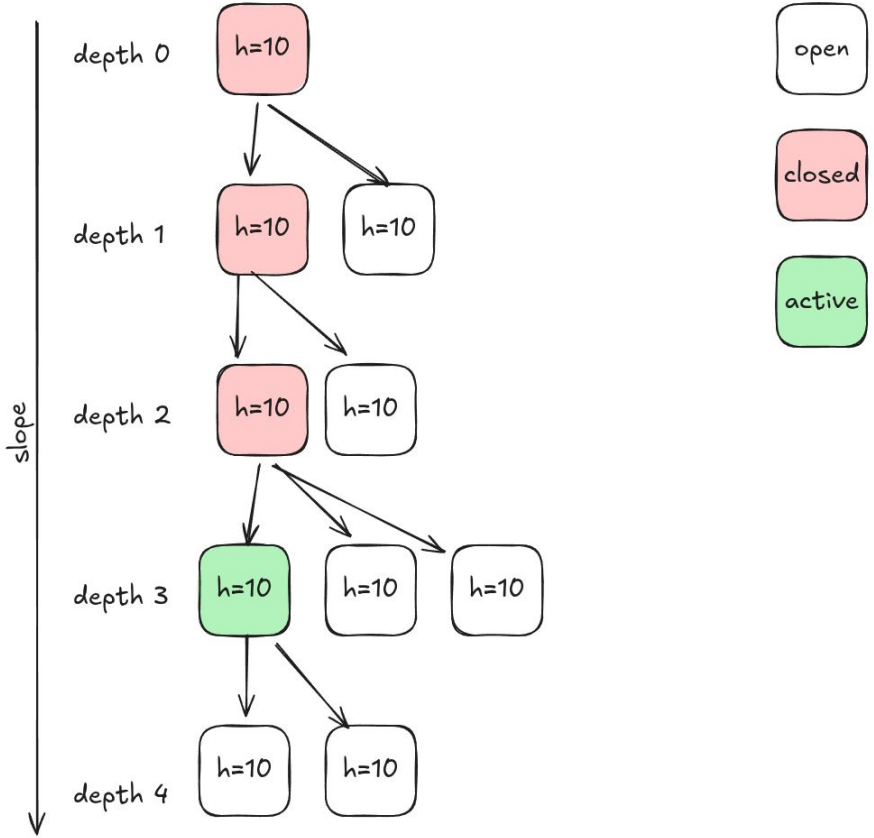
Random Walk



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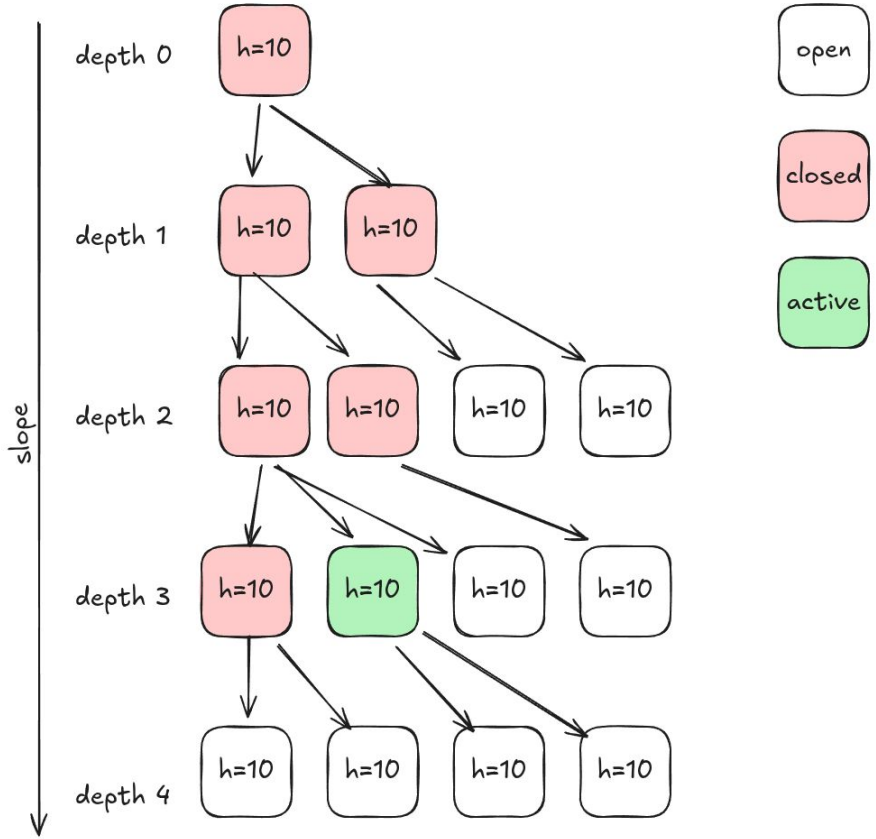

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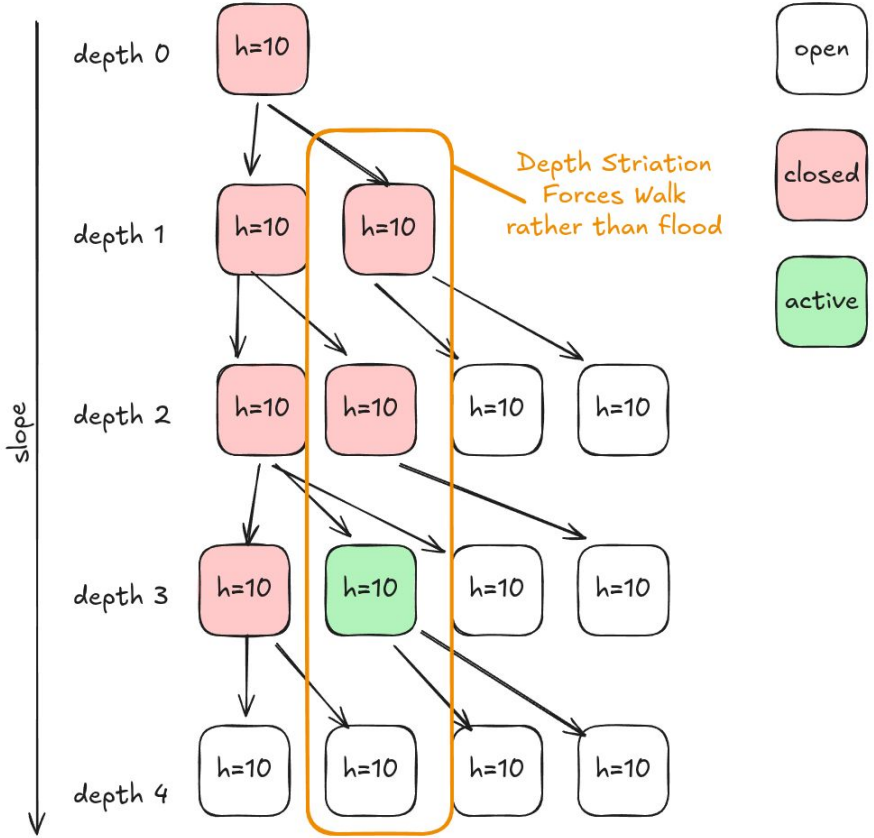

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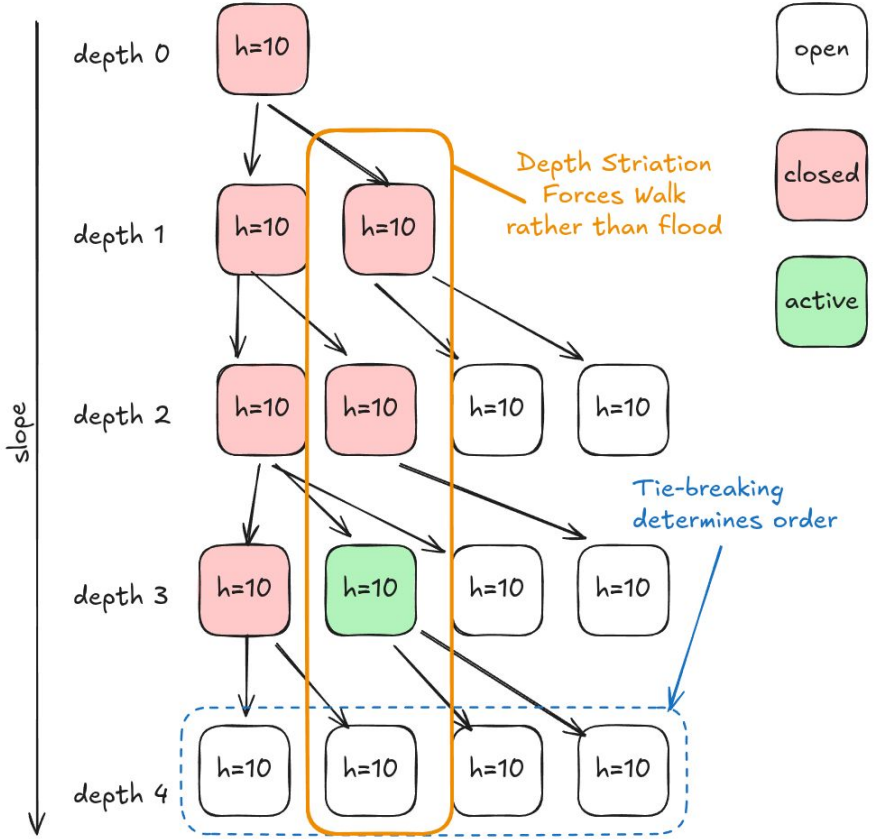

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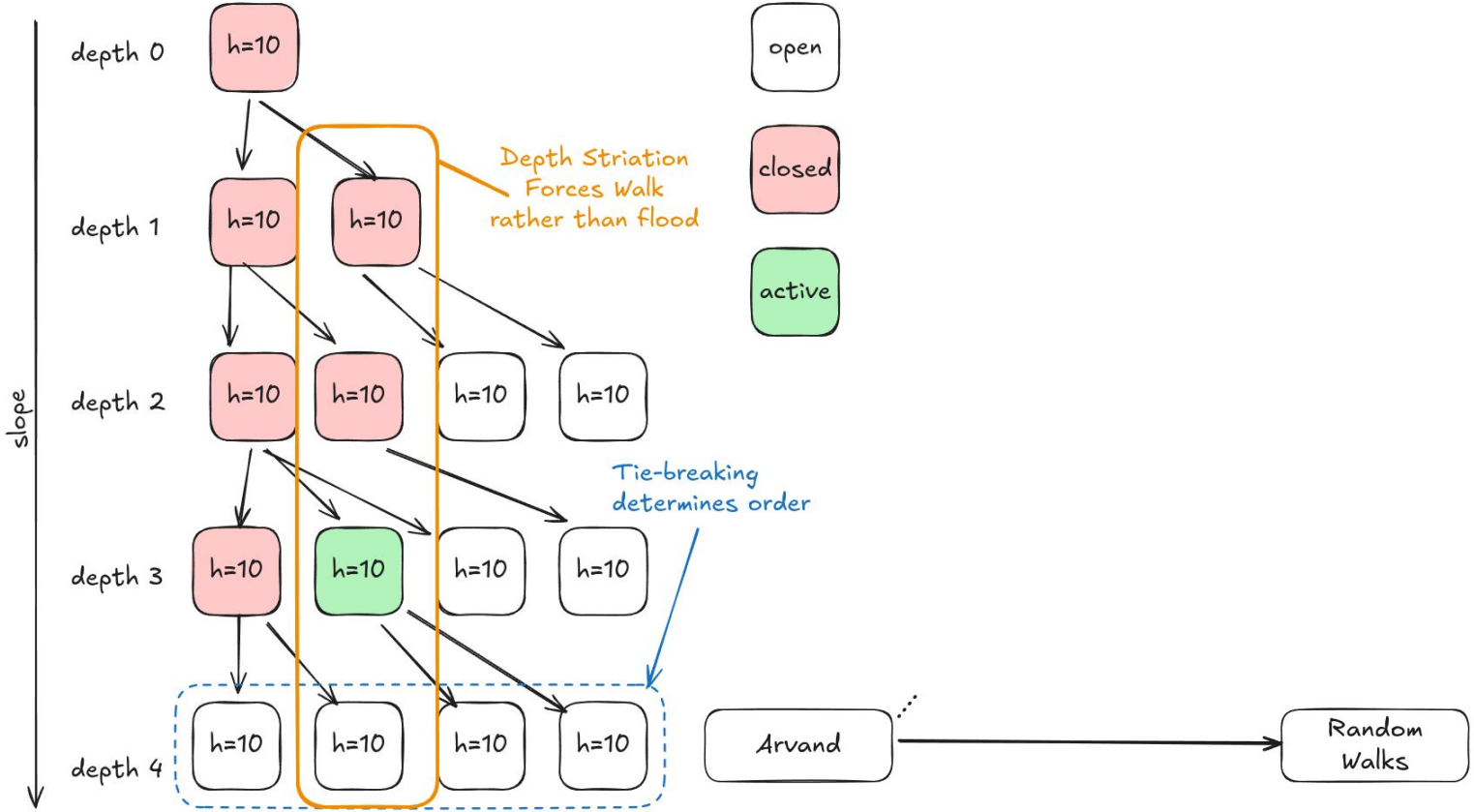

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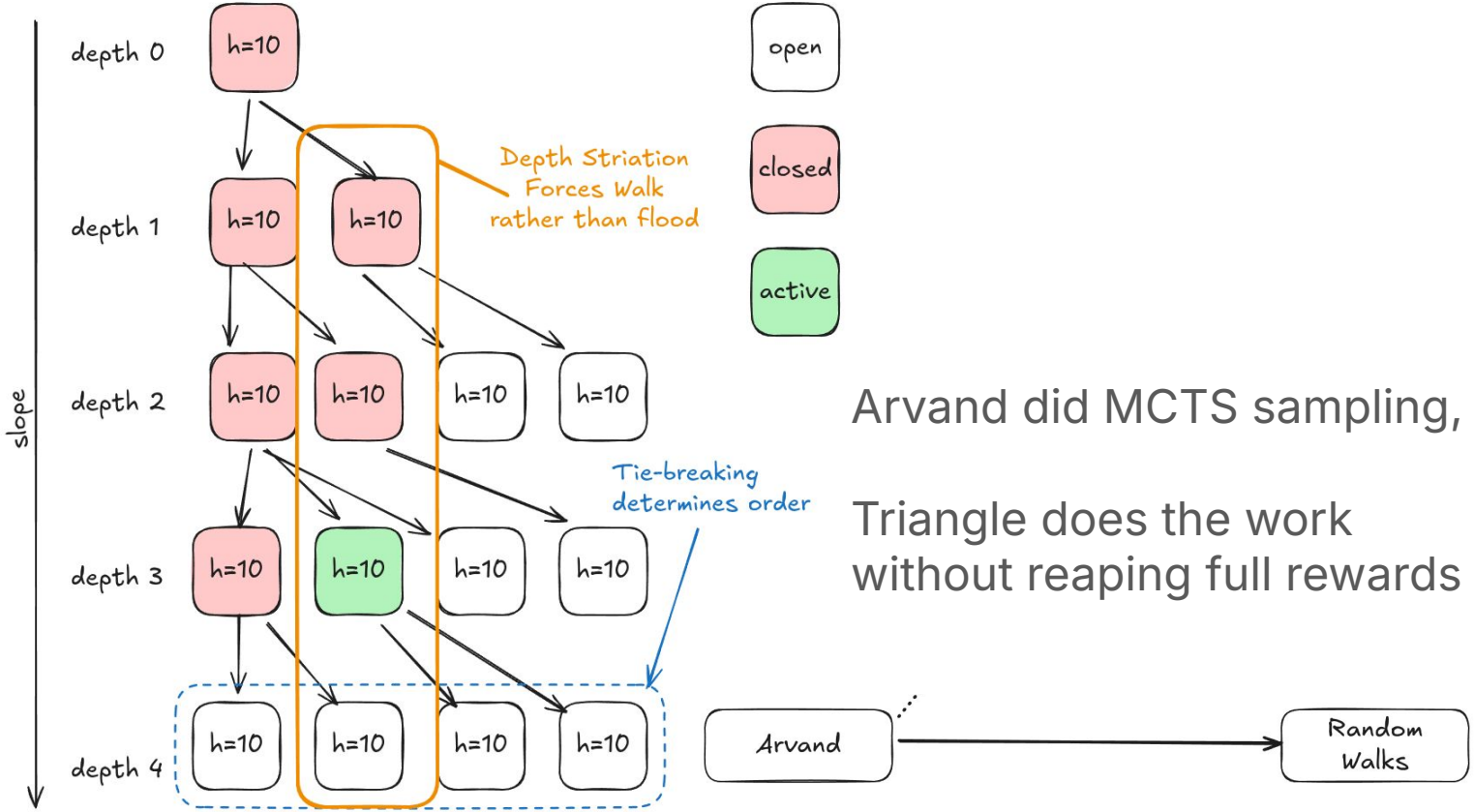

Arvand did MCTS sampling,

Triangle does the work without reaping full rewards

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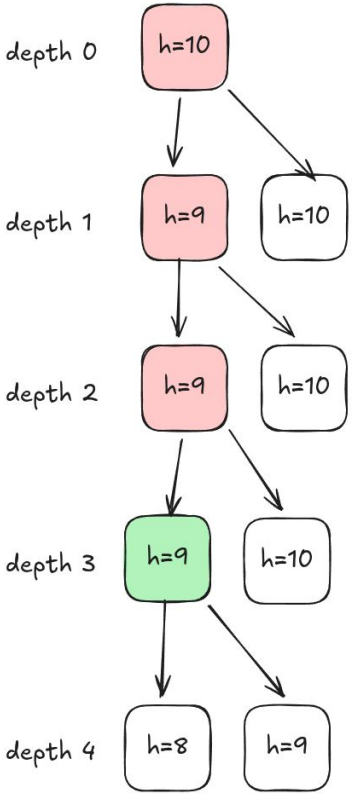

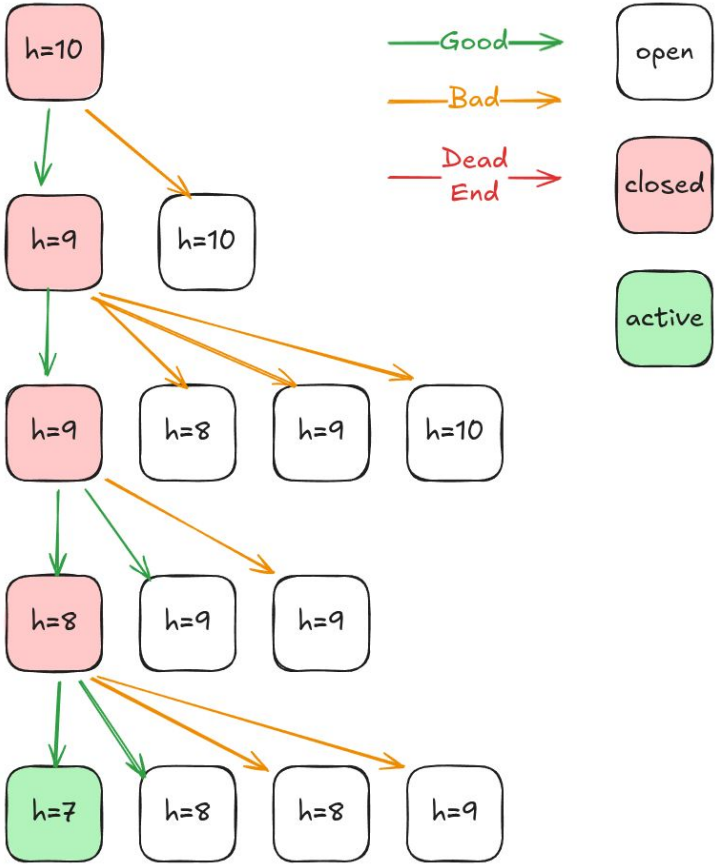

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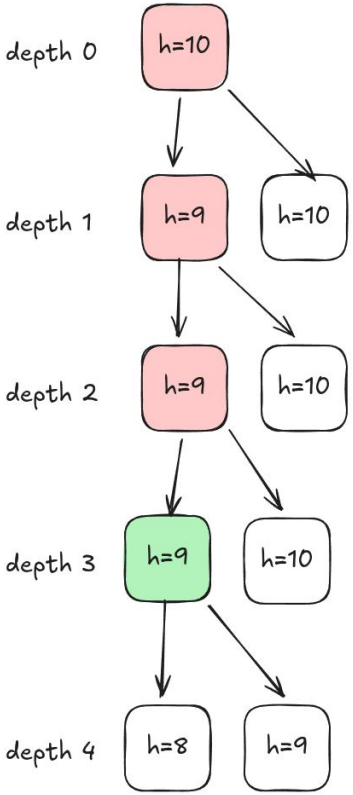

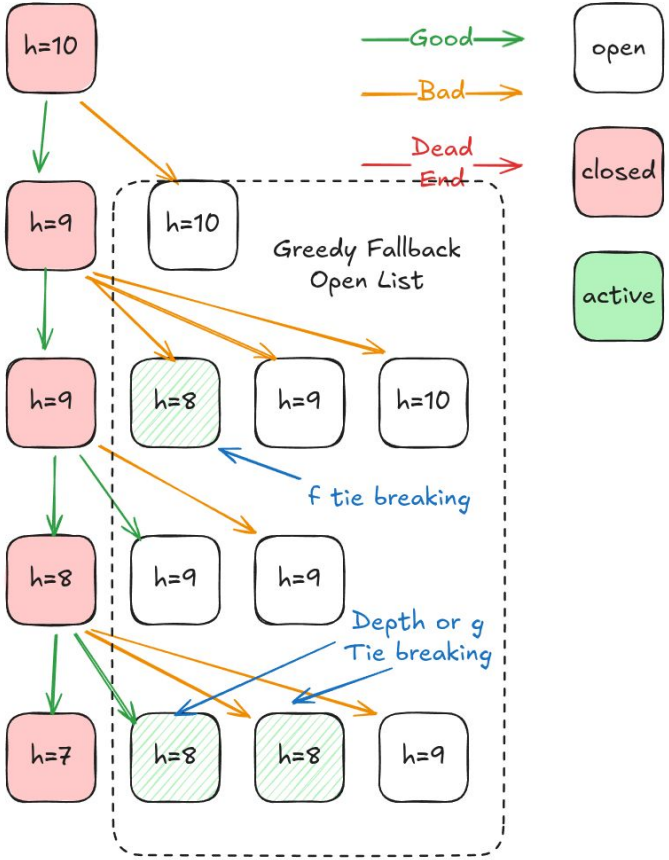

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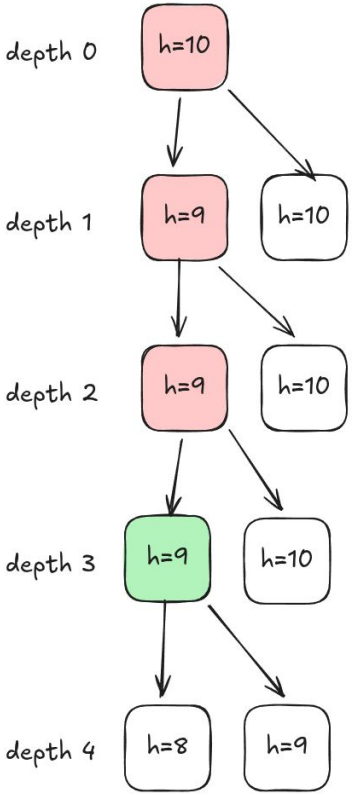
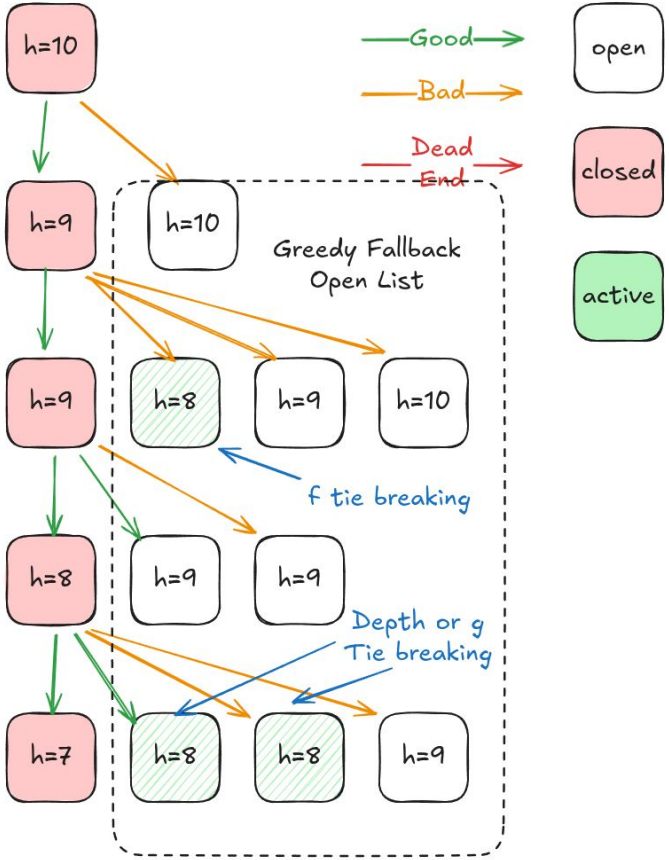
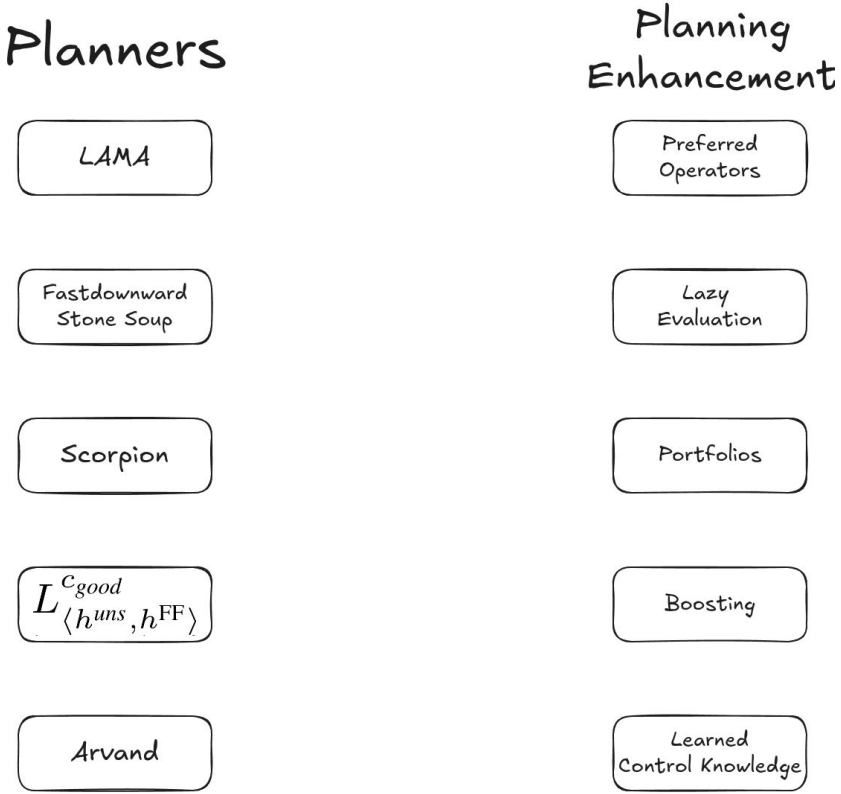




Planners Enhance Basic Search Techniques



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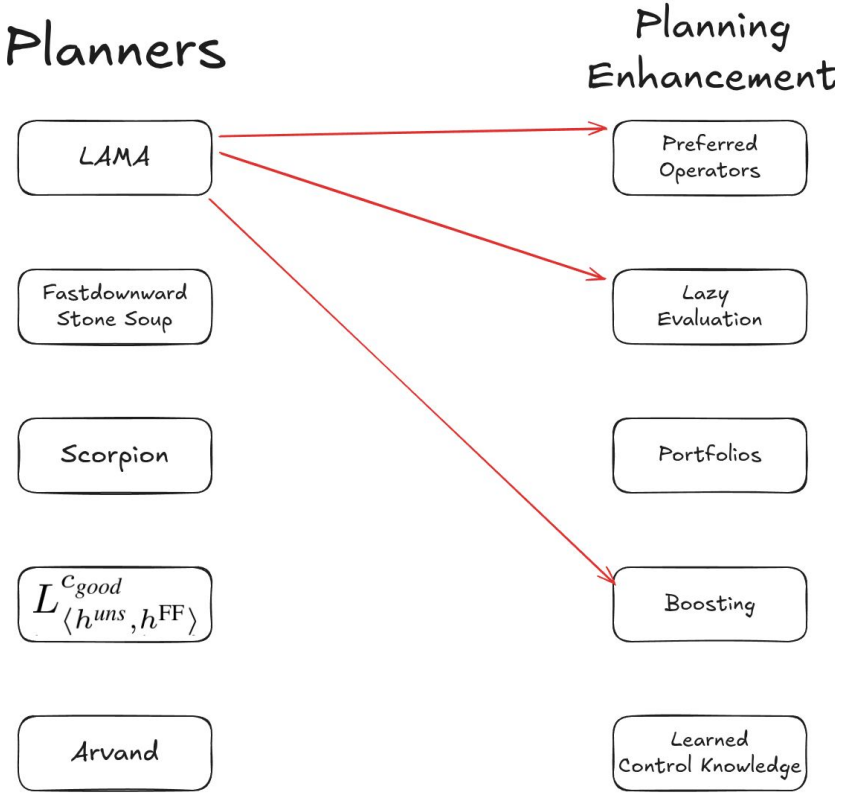

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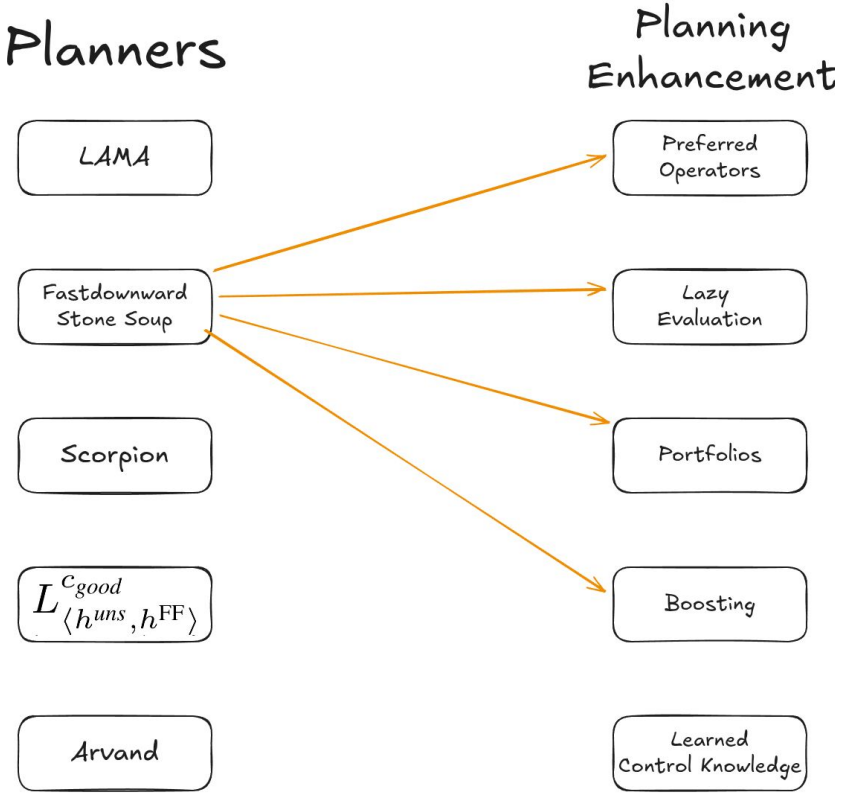

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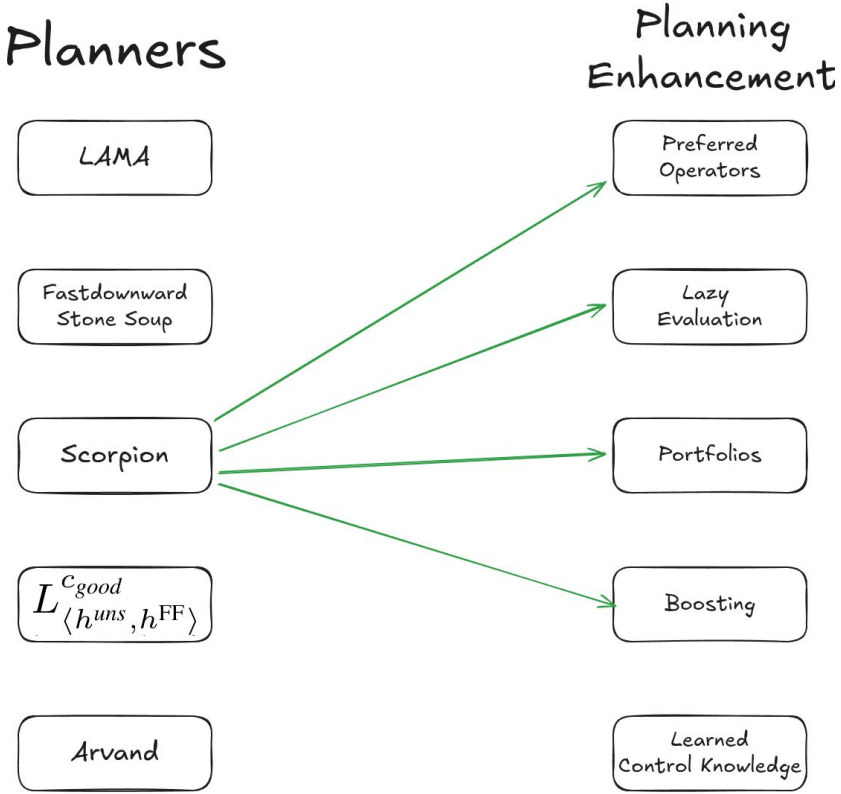

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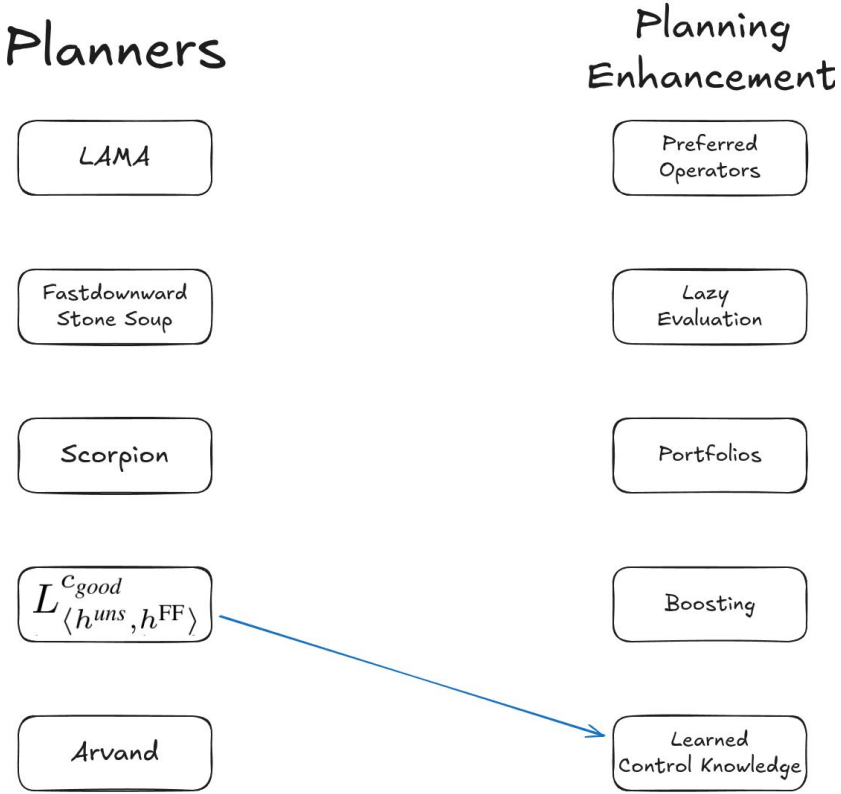

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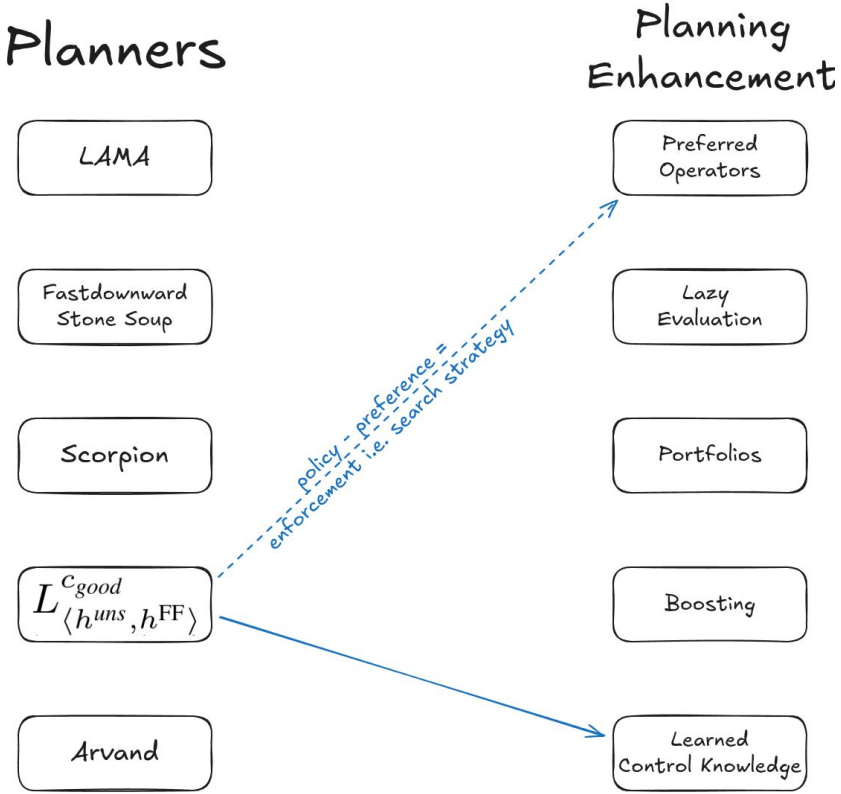

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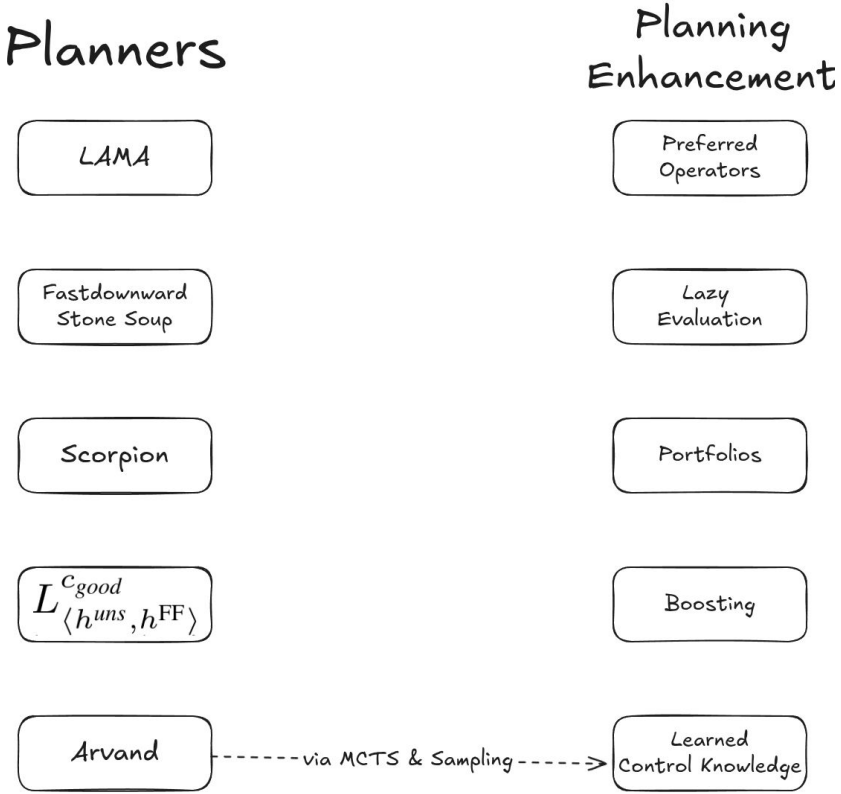

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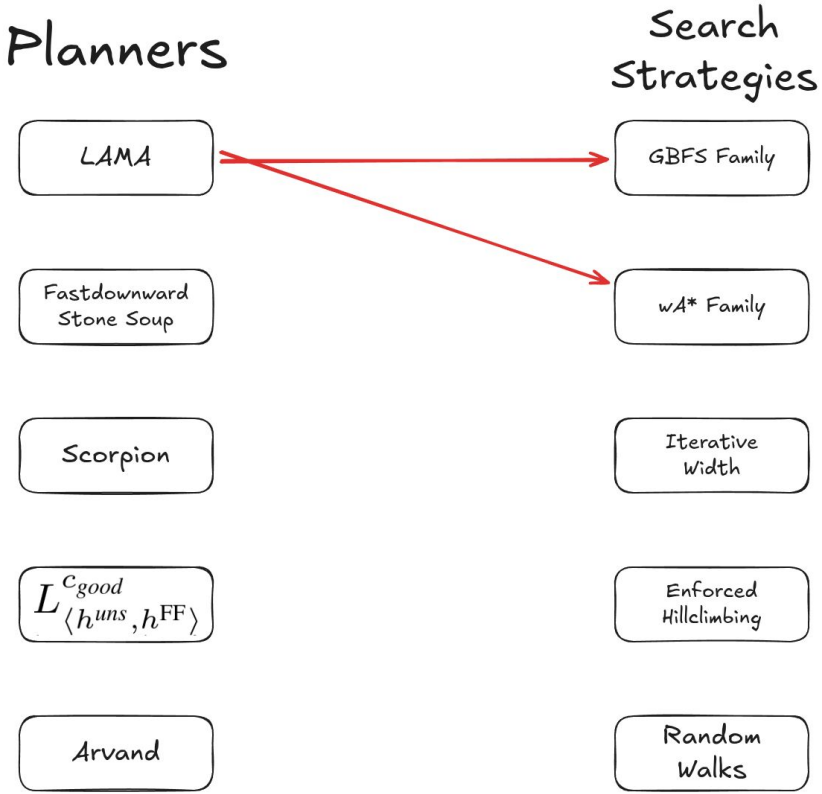

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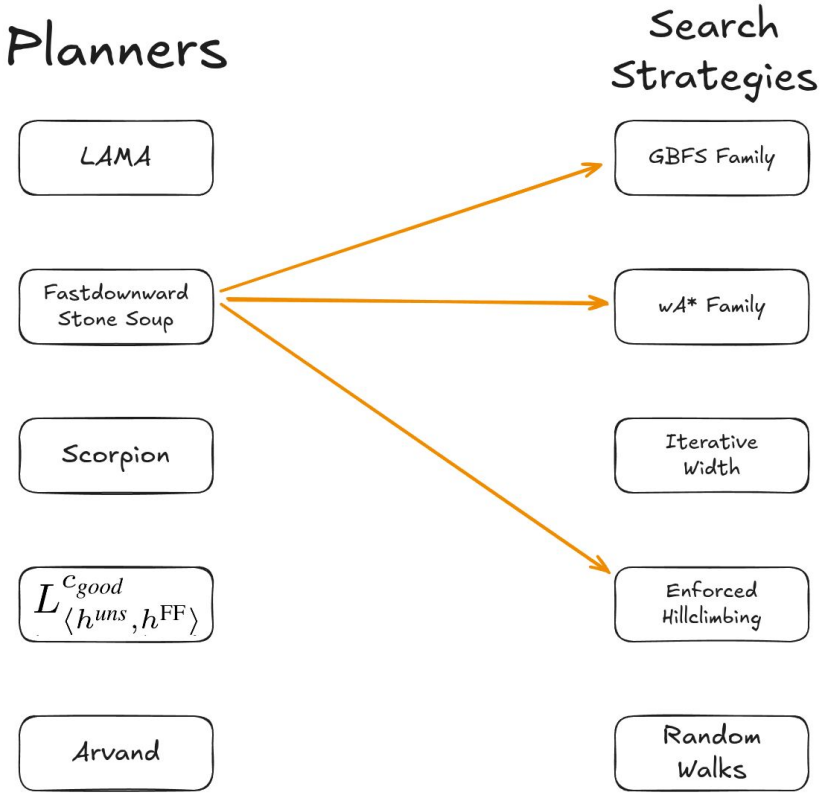

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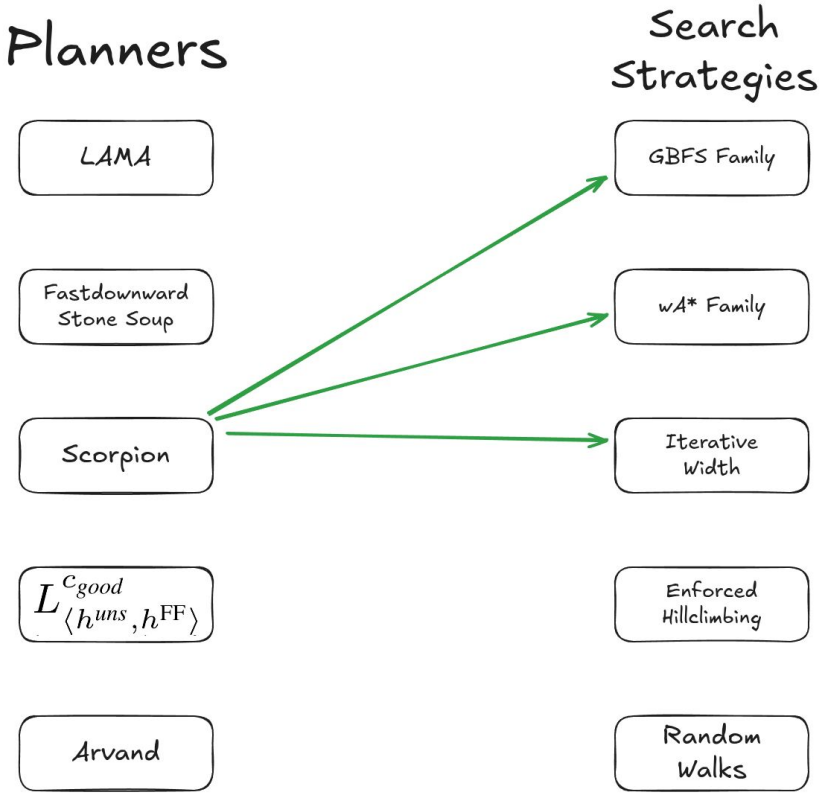

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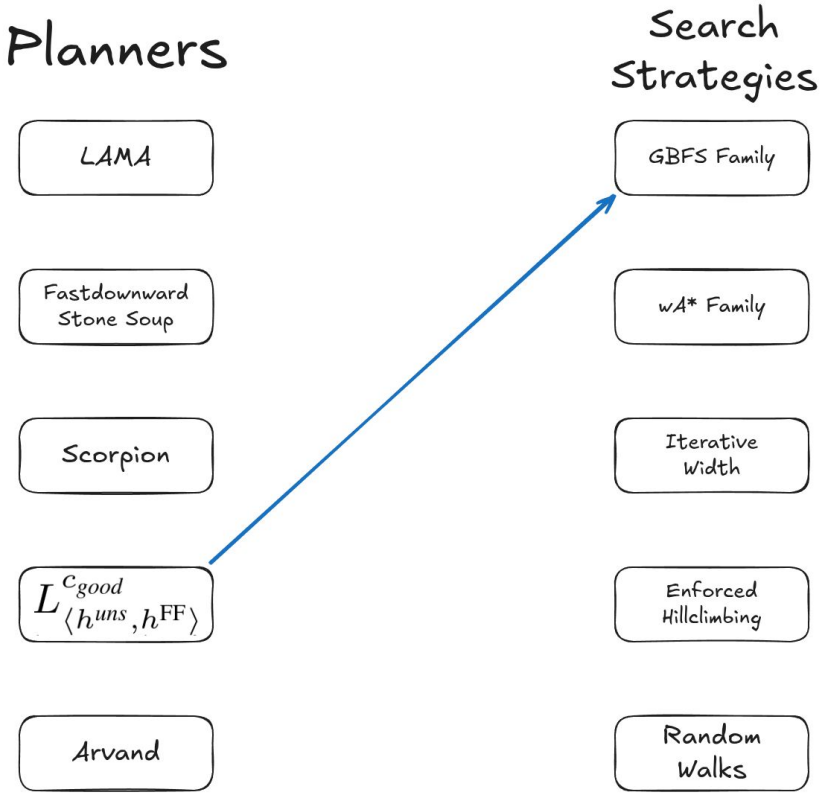

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