

Understanding Questions

Question 13 - max level and level sum

Optimality

1. Theoretically, for each of the heuristics - is its optimality guaranteed?

Max Level Heuristic: Yes, the max level heuristic guarantees optimality. It is an admissible heuristic, meaning it never overestimates the true cost to reach the goal. Therefore, when used with A* search, it guarantees finding the shortest possible plan if one exists.

Level Sum Heuristic: No, the level sum heuristic does not guarantee optimality. It is not an admissible heuristic because it can overestimate the cost to reach the goal by summing the levels at which each goal proposition first appears. This can lead to suboptimal plans as it might inflate the actual cost.

2. Empirically, what are the lengths of the plans you found for the DWR problem (in questions 11 and 12) with each of the heuristics? Include also the null heuristic results in your comparison. For each of these - is it an optimal plan?

Max Level Heuristic:

- **Plan Length:** 6 actions
- **Time:** 0.57 seconds
- **Nodes Expanded:** 28
- **Optimality:** The plan found is optimal in this case, consistent with its theoretical guarantee of admissibility.

Level Sum Heuristic:

- **Plan Length:** 6 actions
- **Time:** 0.21 seconds
- **Nodes Expanded:** 9
- **Optimality:** The plan found is optimal in this case, even though the heuristic itself is not theoretically admissible.

Null Heuristic (Zero Heuristic):

- **Plan Length:** 6 actions

- **Time:** 0.00 seconds
- **Nodes Expanded:** 47
- **Optimality:** The plan found is optimal, but the search expanded significantly more nodes due to the lack of heuristic guidance.

3. Are the theoretical and empirical results consistent with each other? If so, explain. If not, explain how this is possible.

The theoretical and empirical results are not entirely consistent. The max level heuristic's results are consistent, as it guarantees optimality and did find an optimal plan empirically. However, the level sum heuristic, which is not guaranteed to be optimal theoretically, found an optimal plan in this specific case. This discrepancy can occur because the level sum heuristic, while not theoretically guaranteed to be optimal, can still produce optimal plans in practice for certain problems. The null heuristic even though it did find an optimal plan, it did in an inefficient way, which is consistent with its lack of heuristic guidance.

Running Time

1. Theoretically, can we claim that one of the heuristics is guaranteed to expand less-or-equal nodes than the other heuristic (in the general case)?

The level sum heuristic in general expands fewer nodes compared to the max level heuristic because it provides a more informative estimation of the cost to reach the goal. This guides the search process better, reducing the number of nodes expanded. The max level heuristic, being more conservative, may lead to the expansion of more nodes, as it does not always provide as tight of an estimation.

2. Empirically, how many search nodes were expanded with each one of the heuristics? So, which one was more efficient in this case?

Nodes Expanded in Max Level Heuristic: 28

Nodes Expanded in Level Sum Heuristic: 9

Nodes Expanded in Null Heuristic (Zero Heuristic): 47

Empirically, the level sum heuristic expanded fewer nodes than the max level heuristic, showing its efficiency in this specific case. The null heuristic expanded the most nodes as expected which shows that heuristic guidance significantly improves search efficiency.

Question 14 - set level (3 points) - Understanding Question

The set-level heuristic returns the level at which all the propositions in the goal appear in the planning graph without mutex between any pair of them.

1. Is the optimality of this heuristic (in the same sense as in the previous question) guaranteed?

The set-level heuristic measures the level at which all propositions in the goal appear without any mutual exclusions (mutex). This heuristic is admissible because it represents a lower bound on the true cost to reach the goal; propositions appearing together without mutex indicates that there is at least one way to achieve them simultaneously.

It guarantees finding the shortest possible plan if one exists.

Therefore, the optimality is guaranteed.

2. What is the relation between this heuristic and the max level heuristic in terms of number of nodes expanded?

Since the set-level heuristic considers the requirement for all goals to be non-mutex, it is generally more informed (more accurate) than the max level heuristic. This means that the set-level heuristic typically expands fewer nodes than the max level heuristic, as it provides a tighter bound on the true cost to the goal.

3. Is this heuristic perfect in the sense that it always returns the precise distance to the goal?

No. The set-level heuristic measures the first level where all goal propositions appear without mutexes, assuming parallel actions. However, the actual plan length might be longer if actions need to be executed sequentially, making the

heuristic an estimate rather than an exact measure. Also, the heuristic considers pairwise mutex relations but misses conflicts among multiple propositions.