Suboptimality in Hierarchical RL

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CS394R Reinforcement Learning

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Outline

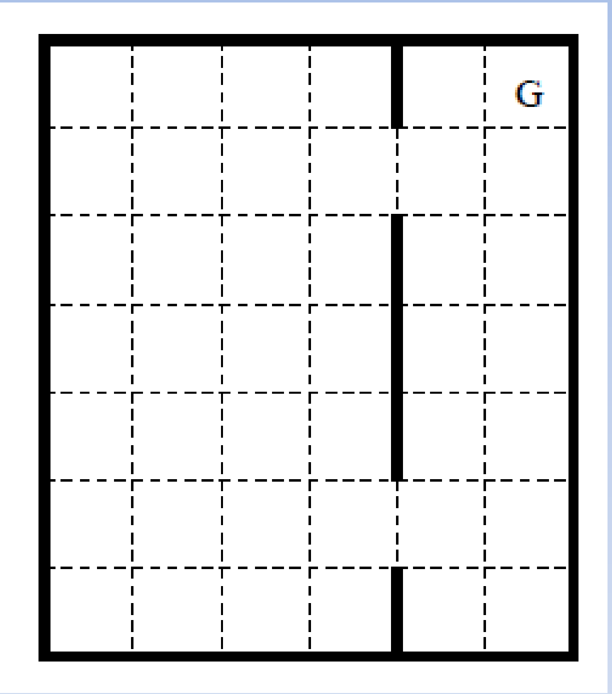
- Source of suboptimality in
  - Recursively optimal policy
  - Hierarchically optimal policy

- Solutions have been developed

Recall: Recursively vs. hierarchically optimal policy

- *Hierarchical optimality*: the final policy is the best policy consistent with given hierarchy.
- *Recursive optimality*: the final policy is optimal *given* the policies learned by its children.
- Source of suboptimality for each type?

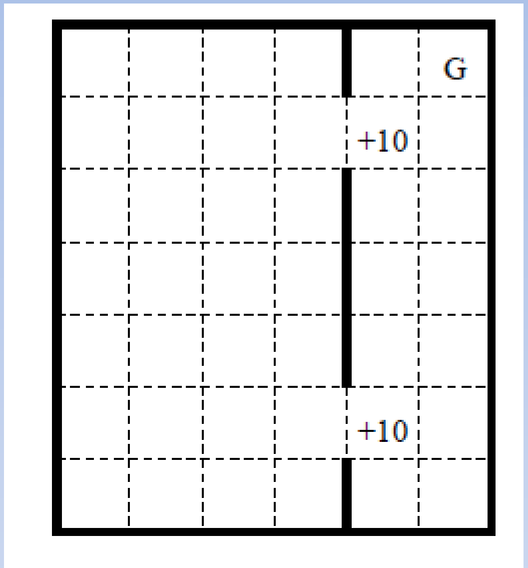
Domain (Dietterich)



- Grid world, start in the room on the left side, the Goal is located in the upper right corner.
- Actions: → ↓ ↑
- 2 doors
- Each action costs -1, goal gives reward 0.

Source of suboptimality

- What if we have the subtask as "exit by the nearest door?"
- What is the optimal policy, for the subtask?



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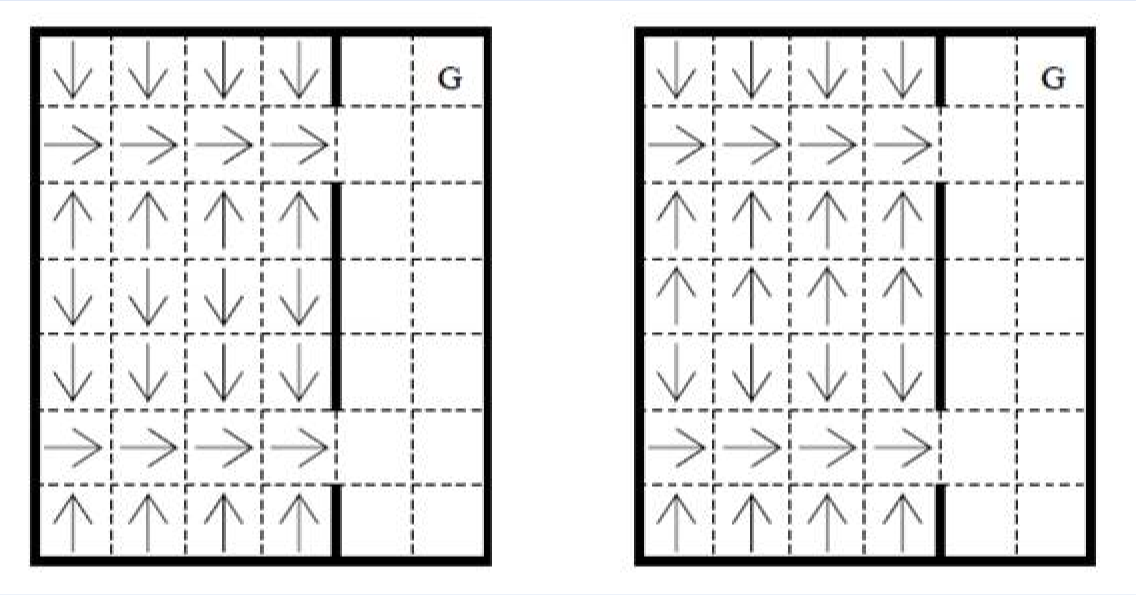
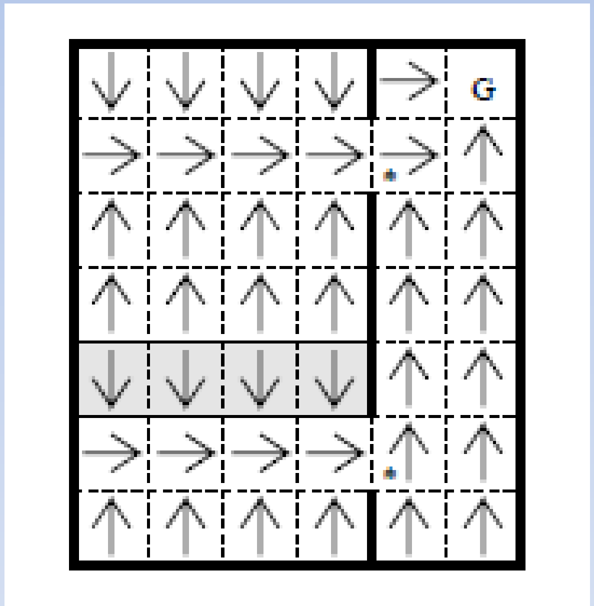


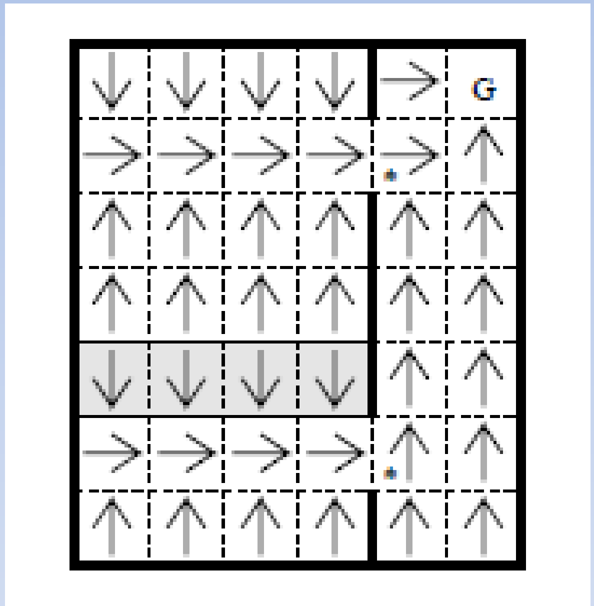
Source of suboptimality

- From the optimal policies of our subtask, we achieve this final policy.
- Is it recursively optimal?
- Is it hierarchically optimal?
- Is it globally optimal?



Source of suboptimality

- From the optimal policies of our subtask, we achieve this final policy.
- Is it recursively optimal?
- Is it hierarchically optimal?
- Is it optimal?
- This is a *recursively* optimal policy, but not *hierarchically* optimal nor *globally* optimal.

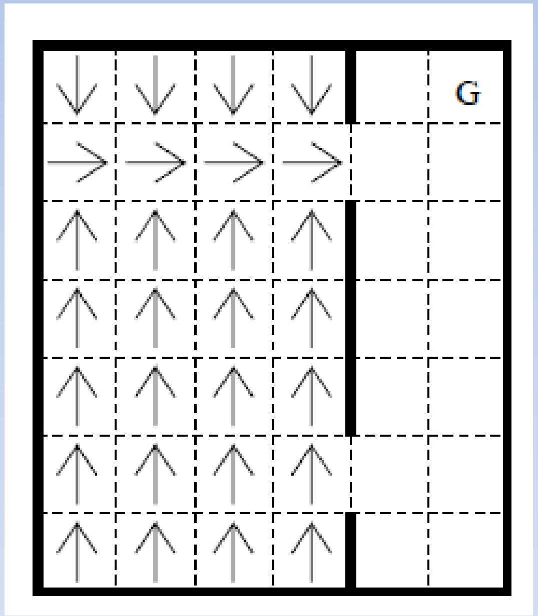


Source of suboptimality

- What would be a hierarchically optimal policy?
- We can always exit by upper

door.

- Is it recursively optimal?
- Is it globally optimal?



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Source of suboptimality

- One question we may ask is, is hierarchically optimal policy always optimal? What about in our example?
- *If we put a "landmark" at the lower door, and we always exit by the lower door.*
- The result is clearly hierarchically optimal, but not globally optimal.

Summary: source of suboptimality

- *Hierarchical optimality*: the imposed hierarchy constrains our policy.

- *Recursive optimality*: the policies learned from the subtasks are locally optimal, but we may have better policies for parent task.

Next…

- How do we deal with this problem?
  - Ideas?
  - There are helpful thoughts from our readings.

Solutions

- How do we deal with this problem?

- Approaches
  - Extend option set O to include A (primitive actions)
  - Redefine the reward of completing subtasks
  - Non-hierarchical execution

1. Extending O to include A

- Introduce primitive actions as special cases of options
  - Recall the hallway example and experimental results

- What is the cost?

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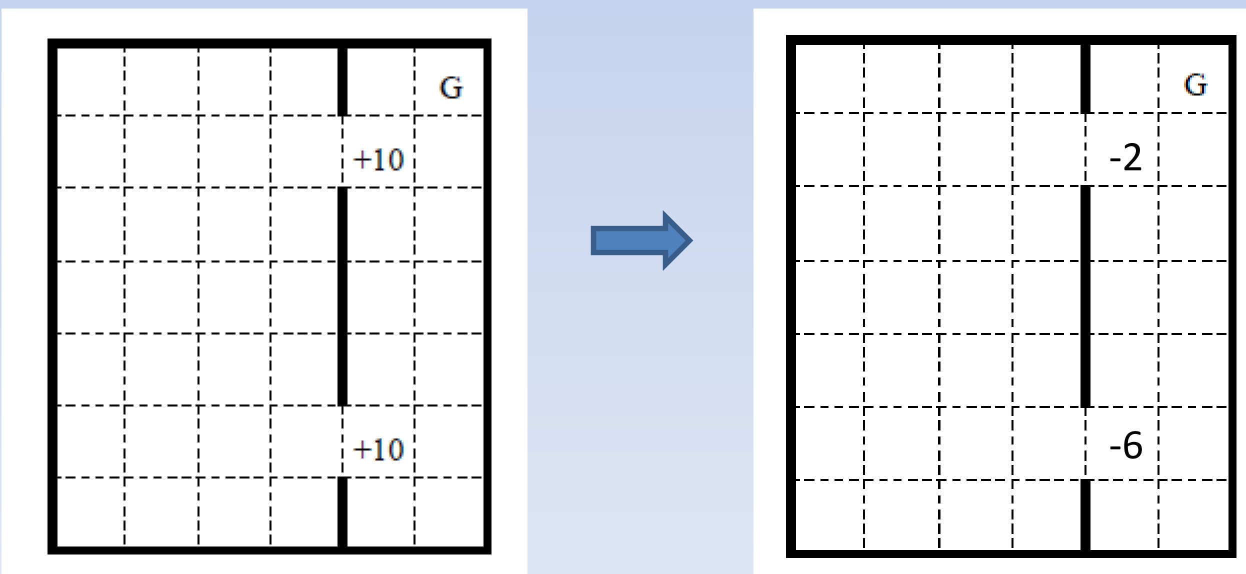
- Introduce primitive actions as special cases of options
  - Recall the hallway example and experimental results

- What is the cost?
  - Could it be even slower than non-hierarchical learning?

2. Redefine the subtasks

- What is the difference between subtask and option?
  - *Option: $<I, \pi, \beta>$*
  - *Subtask: $<I, R, \beta>$*
    - *R: pseudo reward function.*



2. Dynamically redefine the subtasks

- Denote the subgoal states for task *i* as *B(i)*
- Initialize *V'(s)* for all states in *B(i)*
- Repeat:
  - Define a Pseudo-reward functions
    - *R'(s)=V'(s),* for *s* that are in *B(i)*
    - 0, elsewhere
  - Apply hierarchical SMDP learning method to learn recursive optimal policy
  - Update *V'(s)*

3. Non-hierarchical execution

- $Q^{\pi}(s,a)$: function Q for learned hierarchical policy π, a is an option.
- At each time step, compute $a = argmax_a\ Q^{\pi}(s,a)$, then execute one primitive action according to a.
- We might terminate an option early.
- Similar to policy improvement in policy iteration, it always improves the policy.

3. Non-hierarchical execution

- An extreme case: what if we interrupt at every step (polling execution)? Do we still have advantage over non-hierarchical algorithms?

Thank you!