

Informatics 2D: Reasoning and Agents

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Lecture 19b: Planning and acting in the real world
Hierarchical Planning

Where are we?

- Actions are often non-deterministic
 - Bounded non-determinism: **when** clauses; contingent planning
 - Unbounded non-determinism: execution monitoring and re-planning
- Now: **Hierarchical Planning**

Hierarchical decomposition in planning

- **Hierarchical decomposition** seems a natural idea to improve planning capabilities.
- **Key idea**: at each level of the hierarchy, activity involves only small number of steps (i.e. small computational cost)
- **Hierarchical task network** (HTN) planning: initial plan provides only high-level description, refined by **action refinements**
- Refinement process continued until plan consists only of **primitive actions**

Representing action decompositions

- Each **high level action (HLA)** has (at least) one **refinement** into a sequence of actions.
- The actions in the sequence may be HLAs or primitive.
 - So HLAs form a hierarchy!
- If they're all primitive, then that's an **implementation** of the HLA.

Example: Go to SF Airport

*Refinement(Go(Home, SFO),
Precond: At(Car, Home)
Steps: [Drive(Home, SFO LongTermParking)
 Shuttle(SFO LongTermParking, SFO)])*

*Refinement(Go(Home, SFO),
Precond: Cash, At(Home)
Steps: [Taxi(Home, SFO)])*

Refinements can be Recursive

Refinement(Navigate([a, b], [x, y]),

Precond: $a = x, b = y$

Steps: [])

Refinement(Navigate([a, b], [x, y]),

Precond: *Connected*([a, b], [a - 1, b])

Steps: [*Left*, *Navigate*([a - 1, b], [x, y])])

Refinement(Navigate([a, b], [x, y]),

Precond: *Connected*([a, b], [a + 1, b])

Steps: [*Right*, *Navigate*([a + 1, b], [x, y])])

High-Level Plans

- High-Level Plans (HLP) are a sequence of HLAs.
- An implementation of a High Level Plan is the concatenation of an implementation of each of its HLAs.
- A HLP achieves the goal from an initial state if **at least one** of its implementations does this.
- **Not all implementations of an HLP have to reach the goal state!**
- The agent gets to decide which implementation of which HLAs to execute.

Summary

- Natural to think of actions at different levels of granularity.
- Can achieve this through *refinements* of high-level actions (HLAs)
- Different refinements of an HLA can have differing preconditions and effects.
- A refinement that consists entirely of primitive or executable actions is an *implementation* of the HLA.
- You can choose which implementation of an HLA to execute.
- Next time: **searching for valid HLP**