PDDL 2.1 – Time and concurrency

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Automated Planning

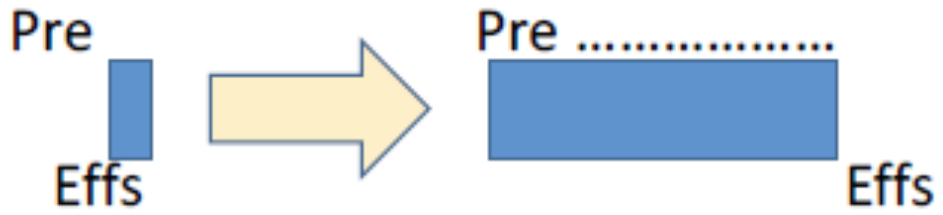
Introduction

- Classic planning is sequential and ignores time
  - It assumes actions are performed in sequence, one after the previous
  - It assumes only one action is being executed at the same time
  - It assumes the same unique agent performs all the actions

- Time is a factor that must be considered in real world scenarios
  - To perform multiple actions in parallel
  - To distribute the work between multiple actors
  - To optimize the plan execution time
    - Not only the plan total cost, which doesn't help with parallelization

Conservative time model

- A simple idea is to assign a duration time to each action
  - Preconditions must be met before the action starts
  - Actions effects are applied once the action is completed
  - The problem arises while the actions is being performed
    - ¿Preconditions need to be met only at the start of the action?
    - ¿The effects are only applied at the end?



Conservative time model

- Example: ¿what happens when a box is picked up?
  - Precondition is that the box is on the table
  - The effect is that the box is at the gripper
  - During the action, ¿we keep the box on the table?
    - Another actor could try to pick it, which would be an error

Non conservative time model

- Time is considered in preconditions and effects
  - Preconditions at the start, during or at the end of the action
  - Effects at the start or at the end of the action

- This model makes it posible to create logic to parallelize actions
  - It could be a single agent performing multiple actions at the same time
  - Or multiple agents doing actions in parallel

“Durative actions”

- PDDL 2.1 adds “durative actions”
  - Actions with a duration time
    - The duration can be constant or depend on *fluents*
  - Preconditions change to more general “conditions”
    - That can be required at the start, during the action or at the end
  - Effects can be applied at the start or at the end of the action

- It makes it possible for a planner to create parallelizable plans
  - The cost of two actions is the same in sequence or in parallel
  - But the time taken by both actions in parallel is less than in sequence

Durative actions - Domain

```
(define (domain rover-domain)
    (:requirements :durative-actions :fluents)
    ...
    (:durative-action move
        :parameters (?r - rover ?f ?t - waypoint)
        :duration (= ?duration 5)
        :condition (and
            (at start (and
                (at ?r ?f)
                (> (battery-amount ?r) 8))
            )
            (over all (and
                (can-move ?f ?t)
            ))
        )
        :effect (and
            (at start (and
                (not (at ?r ?f))
                (decrease (battery-amount ?r) 8)
                (decrease (fuel-level ?r) (* 2 #t))
            ))
            (at end (and
                (at ?r ?t)
                (been-at ?r ?t)
                (increase (distance-travelled) 5)
            ))
        )
```

- Requirement added :durative-actions
- Action declared as :durative-action
  - Duration is set
- Conditions (no preconditions)
  - at start → must be met at the action start
  - over all → must be met during the whole action
  - at end → must be met at the end of the action
- Efectos
  - at start → are applied when the action starts
  - at end → are applied when the action ends

Durative actions - Problem

- Action costs and durative actions should be used at the same time
  - Both are similar concepts, differing in the concurrency
  - Fluents can still be used for the problem logic, if required

- Not all the planners support metrics
  - Optimizing a metric while satisfying temporal restrictions is much harder

Temporal planners

- Temporal planners generate parallelizable plans
  - They indicate the start time and duration of each action
  - Actions are planned to be performed in parallel
    - When it is possible based on temporal logic set for each action
    - Possible conflicts between each action conditions and effects must be reviewed with care

Inicio (s) Acción Duración (s)

```
10.000: (move-helicopter heli3 depot loc3)  [81.000]
10.000: (move-helicopter heli4 depot loc2)  [177.000]
91.000: (drop-crate-with-content heli1 loc3 crate1 person2 food)  [10.000]
91.000: (drop-crate-with-content heli3 loc3 crate3 person2 medicine)  [10.000]
101.000: (move-helicopter heli1 loc3 depot)  [81.000]
101.000: (move-helicopter heli3 loc3 depot)  [81.000]
182.000: (pick-up-crate-with-content heli1 depot crate5 medicine)  [10.000]
187.000: (drop-crate-with-content heli4 loc2 crate4 person3 medicine)  [10.000]
```

Example – Airport Domain

- Fly actions will have a duration based on the travel distance, other actions will have a fixed duration.
- Two people can’t go into or out from the plane at the same time.
- Planes can take off, fly and land in any airport in parallel without restrictions.
- Planes cannot take fly while anyone is going into or out of it.