Implementing centralized coordination

Intelligent Agents Course

Pickup and Delivery Problem

- A company owns V vehicles
- Initially there are T tasks that need to be delivered
- Our goal is to build a plan for delivering all the packages with the available vehicles
- The total weight of tasks carried in each moment should not exceed the capacity of the vehicle
- Two variations
  - The vehicle can carry only one task at a time
  - The vehicle can carry more than one task at a time

Approach

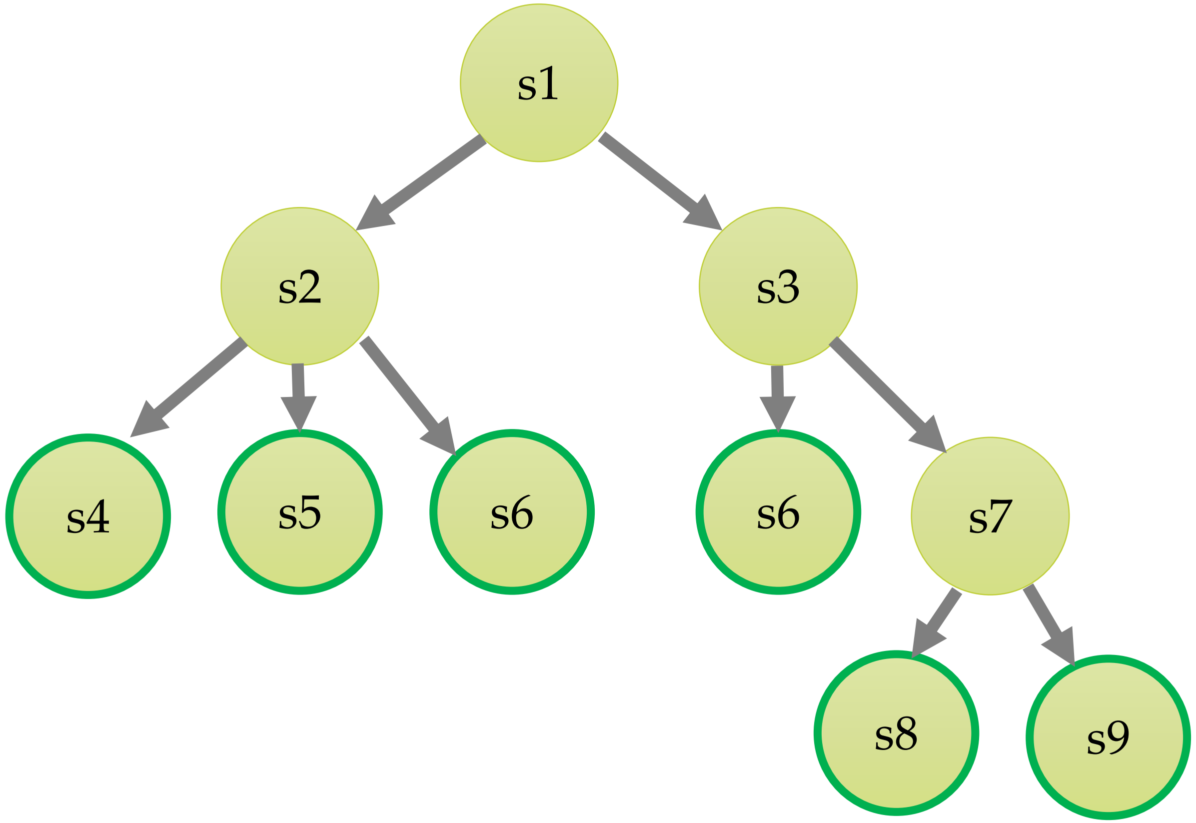
- We can assume that the company is deliberative agent, however, this is very inefficient approach
- Vehicles need to coordinate actions to achieve common goals
- The company can implement centralized coordination and build an optimal plan for delivering all tasks using all vehicles
- Vehicles execute the plan assigned to them

How to build the plan

- Central planner needs complete information about the vehicles (positions, costs, capacity)
- State-based algorithms are not adequate:
  - Would have a too large number of states
- Instead, the problem should be solved using a Stochastic Local Planner.

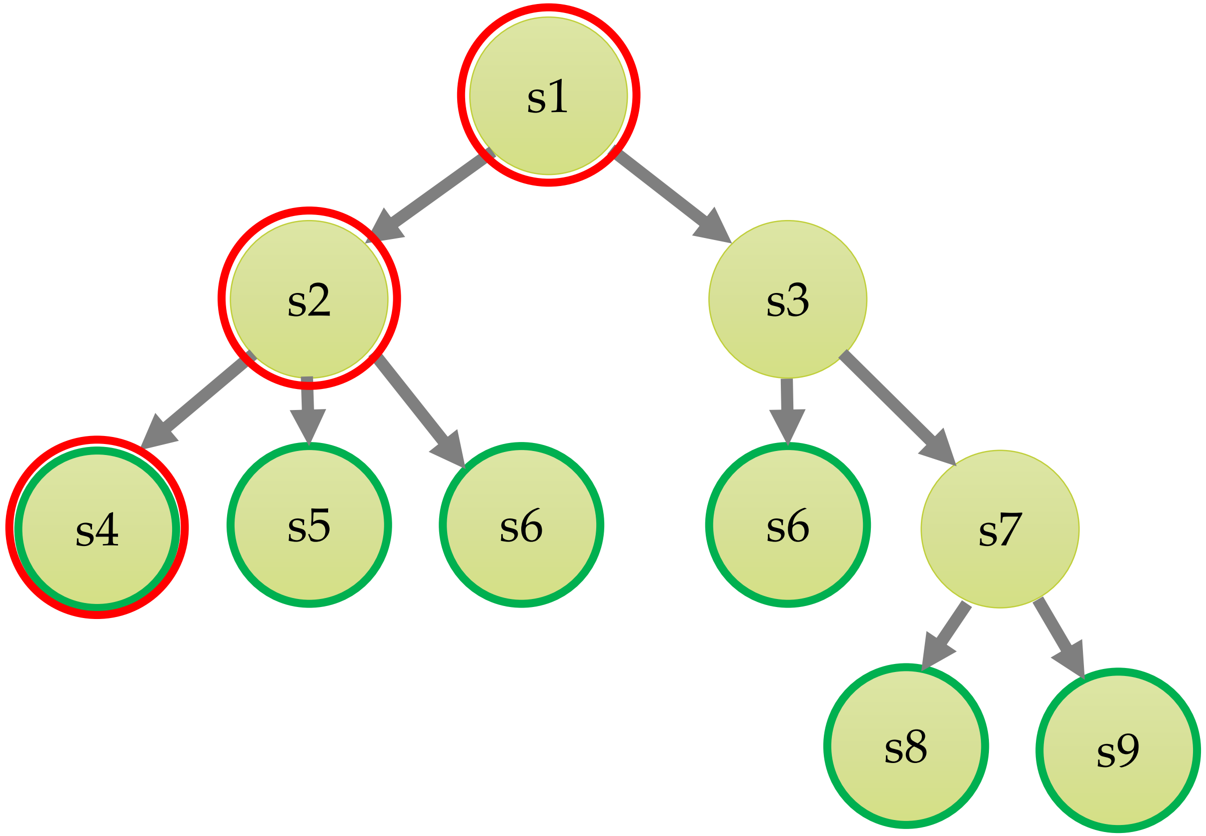
Deliberative agent vs. centralized coordination

- Deliberative agent
  - Searches in state-space



Deliberative agent vs. centralized coordination

- Centralized coordination
  - Searches in solution-space



The goal of this exercise

- Implement the local search algorithm "Stochastic Local Search" to solve a COP description of the PDP, allow a vehicle to carry multiple packages.

Constraint optimization problem

A discrete constraint optimization problem (COP) is a tuple $< X, D, C, f >$ where:

- $X = \{x_1, .., x_n\}$ is a set of variables.
- $D = \{d_1, .., d_n\}$ is a set of domains of the variables, each given as a finite set of possible values.
- $C = \{c_1, .., c_p\}$ is a set of constraints, where a constraint c_i is a function $d_{i1} \times .. \times d_{il} \rightarrow \{0, 1\}$ that returns 1 if the value combination is allowed and 0 if it is not.
- $f : d_1 \times ... \times d_n \rightarrow \Re$ is the objective function that we want to minimize (or maximize).

The optimal solution of a COP is an assignment of values to all variables that satisfies all constraints and minimizes the objective function.

Stochastic Local Search Algorithm

Algorithm 1 *SLS algorithm for COP*

procedure *SLS(X,D,C,f)*
    $A \leftarrow SelectInitialSolution(X, D, C, f)$
    repeat
        $A^{old} \leftarrow A$
        $N \leftarrow ChooseNeighbours(A^{old}, X, D, C, f)$
        $A \leftarrow LocalChoice(N, f)$ choose the best one
    until termination condition met
    return A
end procedure

p: proba of picking new A, stochastic to avoid stuck in local minima

Example solution

- We present solution of the pickup and delivery problem when the vehicle can carry only one task at a time
  - Vehicles carry tasks sequentially (this restriction lifted for SLS)
  - Total revenue of the company is maximized
- Solution representation

Vehicle 1: Task 1 Task 3 Task 4

Vehicle 2: Task 2 Task 5

Each task is assigned to one vehicle

A vehicle cannot carry a task whose weight exceeds his capacity

The order of delivery is important

Encoding the solution

- Three types of variables
  - nextTask: array of $T + V$ variables
  - time: array of T variables
  - vehicle: array of T variables

nextTask(t1) = t2
nextTask(t3) = t4
nextTask(t4) = NULL

nextTask(v1) = t1 Vehicle 1: Task 1 Task 3 Task 4

nextTask(v2) = t2 Vehicle 2: Task 2 Task 5

nextTask(t2) = t5
nextTask(t5) = NULL

Encoding the solution

- Three types of variables
  - nextTask: array of $T + V$ variables
  - time: array of T variables
  - vehicle: array of T variables

	time(t1) = 1	time(t3) = 2	time(t4) = 3
Vehicle 1:	Task 1	Task 3	Task 4
Vehicle 2:	Task 2	Task 5	
	time(t2) = 1	time(t5) = 2	

Encoding the solution

- Three types of variables
  - nextTask: array of $T + V$ variables
  - time: array of T variables
  - vehicle: array of T variables

vehicle(t1) = 1 vehicle(t3) = 1 vehicle(t4) = 1

Vehicle 1: Task 1 Task 3 Task 4

Vehicle 2: Task 2 Task 5

vehicle(t2) = 2 vehicle(t5) = 2

PDP as COP - Constraints

1. $nextTask(t) \neq t$: the task delivered after some task t cannot be the same task; $\boxed{\text{not same twice}}$
2. $nextTask(v_k) = t_j \Rightarrow time(t_j) = 1$: already explained;
3. $nextTask(t_i) = t_j \Rightarrow time(t_j) = time(t_i) + 1$: already explained;
4. $nextTask(v_k) = t_j \Rightarrow vehicle(t_j) = v_k$: already explained;
5. $nextTask(t_i) = t_j \Rightarrow vehicle(t_j) = vehicle(t_i)$: already explained;
6. all tasks must be delivered: the set of values of the variables in the $nextTask$ array must be equal to the set of tasks T plus N_V times the value $NULL$.
7. the capacity of a vehicle cannot be exceeded: if $load(t_i) > capacity(v_k) \Rightarrow vehicle(t_i) \neq v_k$

PDP as COP – Objective function

minimize cost

$$C = \sum_{i=1}^{N_T} \Big(dist(t_i, nextTask(t_i)) + length(nextTask(t_i)) \Big) \cdot cost(vehicle(t_i))$$

$$+ \sum_{k=1}^{N_V} \Big(dist(v_k, nextTask(v_k)) + length(nextTask(v_k)) \Big) \cdot cost(v_k);$$

special case for the first task

Example solution

- 2 vehicles located in Zurich and Lausanne
- 3 tasks:
  - <Task id="T1" load="10" pickup="Geneva" delivery="Fribourg"/>
  - <Task id="T2" load="15" pickup="Bern" delivery="Basel"/>
  - <Task id="T3" load="10" pickup="Aarau" delivery="St-Gallen"/>
- Optimal plan:
  - the vehicle v1 delivers the task T3, and
  - the vehicle v2 delivers the tasks T1 and T2 in this order

Example solution

- $nextTask(v1) = T3$, $nextTask(v2) = T1$;
- $nextTask(T1) = T2$, $nextTask(T2) = NULL$, $nextTask(T3) = NULL$;
- $time(T1) = 1$, $time(T2) = 2$, $time(T3) = 1$;
- $vehicle(T1) = v2$, $vehicle(T2) = v2$, $vehicle(T3) = v1$

Solving the PDP

have to find it oyurself

- Initial solution
  - Give all the tasks to the biggest vehicle
- Choose neighbors
  - Define a set of transformations that can be used to move from one to another close solution

Transformations

- Move task from one to another vehicle

Vehicle 1:	Task 1	Task 3	Task 4
Vehicle 2:	Task 2	Task 5	

Vehicle 1:	Task 3	Task 4	
Vehicle 2:	Task 1	Task 2	Task 5

- Choose a vehicle and change the order of any pair of two tasks

Vehicle 1:	Task 1	Task 3	Task 4
Vehicle 2:	Task 2	Task 5	

Vehicle 1:	Task 1	Task 4	Task 3
Vehicle 2:	Task 2	Task 5	

TO DO

- Implement the local search algorithm on PDP where each vehicle can carry more than one task at a time
- Use the stochastic planner :
  - Run simulations for different task sets

Deliverable

- Deadline as specified in the Moodle
- Report of maximum of 3 pages
- 100 points