Artificial Intelligence : Foundations & Applications [AI61005]
[Problem - 3]

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Introduction

In this assignment we are exposed to this idea of Optimal Multi-Agent Path finding, where the goal is to find the optimal path for all players such that a certain metric is optimized whilst taking care of all the certain constraints. For the purpose of solving the problem we have assumed certain things so as to make things a bit more clear.
In the following sections we would be discussing some of the State of Art algorithms out there to solve a particular problem, with and without using any heuristic as such and also would present steps to solve the problem.

Multi - Agent Path Finding Problem

The multi agent Path Finding Problem is a very fundamental problem for planning paths for Multiple Agents and they can interact, and there are some constraints which they have to abide by. And there is an Objective which we need to optimize. Applications of **MAPF** include automated warehouses and autonomous vehicles. Research on **MAPF** has been flourishing in the past couple of years. Different **MAPF** research papers make different assumptions, e.g., whether agents can traverse the same road at the same time, and have different objective functions.
In this problem, we are to plan paths for some EVs and they are somewhat charged initially, and while travelling the charge shall dissipate and there is exactly one charge point in a certain city. So, if an EV reaches a certain city whilst another one is being charged, it has to wait for a certain time, until the former gets charged. Here the other thing is that the EVs can decide how much charge they need. We need to minimize the Max [Time required to reach the destination for all EVs].
So, clearly it’s a Multi-Agent Path Finding problem since the structure of the problem is also similar as well.

Problem Formulation

There are n EVs. Each Ev can be represented as a tuple of 8 different fields.
Kth EV : (S_k, D_k, B_k, c_r, d_r, M_r, s_r)
S_k = Starting Point
D_k = Destination Point
B_k = Battery Charge Status Initially
c_k - charging rate for battery at a charging station (energy per unit time)
d_k - discharging rate of battery while traveling (distance travel per unit charge)
M_k - maximum battery capacity
s_k - average traveling speed (distance per unit time).

We need to route each of them to their Destination and Minimize [Max[time to reach to Destination among all EVs]]

Algorithms

There are certain State-Of-Art algorithms based on different scenarios especially in a Probably Approximately Correct Scenario, or Stochastic Scenario. These are based on cutting edge research based on Motion and Path Planning.
Initial Assumption:

a. Whenever an EV is charged , it is to be fully charged.

It is to be noted, the code is entirely designed by us, and we haven;t used any library as such [and special purpose modules some of them which are produced by MIT and other leading universities based on cutting edge research.

a. First find All Pairs Shortest path [Floyd Warshall Algorithm], then divide each by corresponding speed which shall be our Heuristic Estimate for applying A* algorithm.
b. Then apply A* algorithm, and keep track of EVs in each City, then assign that EV in the Charging station which has the minimum Heuristic Estimate.

Without Heuristic:

a. For each EV individually, we shall create tuples (time, city , charge), and initialize a min-heap, and perform a BFS with priority queue.
b. Each time pop the element on the top of the heap, and iterate over those adjacent to present node and if the charge while reaching those if >0, then add push 2 new elements to the heap one with fully charged at that point and the other one not at all charged [according to our assumption initially].

c. Whilst finding the optimal path, trace and store the cities one by one in an array.
d. Lastly, iterate over that again and then perform similar steps as that for the Heuristic Algorithm.

Limitations of our Algorithm :

a. Time Complexity : O(2^n) , so n must be less otherwise our algorithm would take huge time.
b. Our assumption in a very practical situation is actually valid, but from a theoretical perspective it's a serious drawback for the algorithm.
c. Our algorithm [With / Without heuristic is actually follows a greedy approach in assigning a particular EV to the charging point when multiple EV is in a queue for a particular city, which might not be the best thing to do], in that case, the algorithm we proposed is not essentially 'Optimal' but is a pretty 'Sub-Optimal' approach.

Conclusion:

In this assignment, we were exposed to this problem of Optimal Multi-Agent Path planning which has been applied to a very simple situation where we have to deal with routing some EVs and as we have seen in our algorithm thi problem essentially is having exponential time complexity.
There are certain other techniques in more complex stochastic scenarios where we address the problem, through Simulation modelling and Queuing theory as such.