Visualizing and Designing Multi Agent Search Algorithms

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Introduction

The purpose of our research is to study distributed search-and-escape algorithms. These algorithms involve mobile agents (or robots) searching in geometric domains, such as a closed disk or a convex polygon. By working together and communicating with one another, the mobile agents search for an exit hidden on the perimeter. The goal of our research is to create and study exit strategies that terminate as quickly as possible.

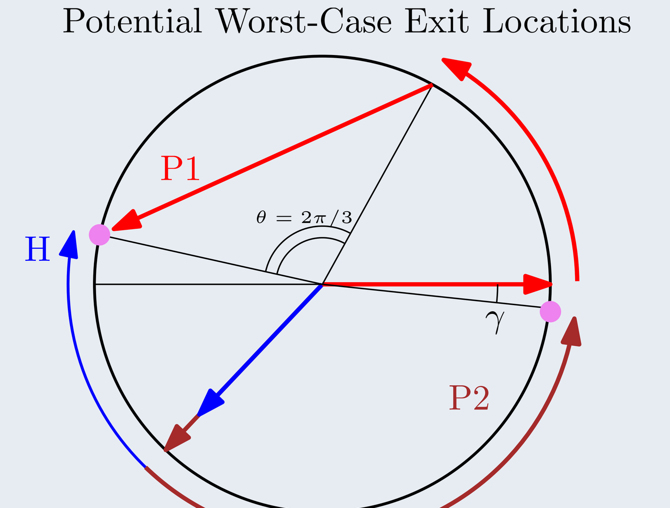
Definitions

- An exit is a point unknown to the agents, that is located on an perimeter on the domain. The agents must find the exit for the algorithm to finish.
- A priority agent is one that must reach the exit for the algorithm to terminate.
- A helper agent is one that simply assists the priority agent(s) in finding the exit.
- Algorithm termination occurs if a specified subset of agents shares a position with the exit.

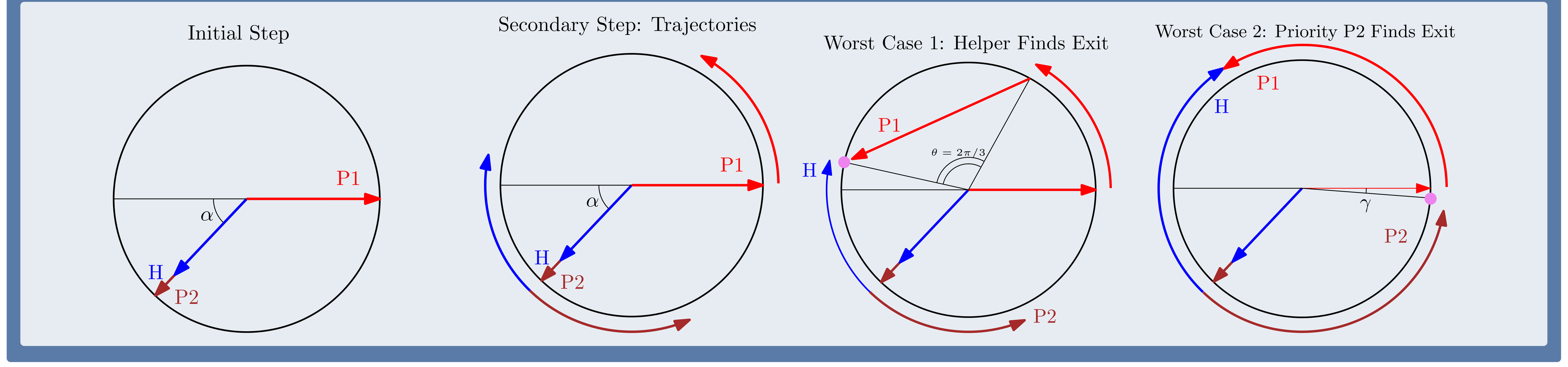
Main Result

The purpose of our research is to propose an algorithm for two distinguished agents and a helper agent to find an unknown exit on a disk. We show that this can be achieved in no more than 3.55 time units. This result does not represent all algorithms using 3 agents, nor does it represent all algorithms using distinguished agents.

Potential Worst-Case Exit Locations



Figures



Algorithm Description

In our algorithm, we use two **priority** agents and one **helper** agent. The termination condition in our algorithm is reached when either one of the two priority agents reaches the exit. We send one priority and one helper to some angle α on the perimeter of the shape, in the third quadrant. The priority agent travels counter-clockwise, and the helper travels clockwise. The other priority agent travels to 0 radians and travels counter-clockwise.

Algorithm Description (Cont)

We may compare this method of sending two agents out together and separating them with a more naive method of sending the agents out at equal distances. If we were to send all agents out at an angle of $2\pi/3$ and having them all travel in the same direction, we see that in the worst case, the helper will find the exit and the very end of its searched area and both agents will be equally close to it. This will result in a time of $1 + 2\pi/3 + 2\sin\pi/3$, or **4.826 time units.** This is significantly longer than our solution of **3.55 time units**.

Our Conjectures and Analysis

In this algorithm, we observe two worst case situations. In one, the priority robot assigned to the third and fourth quadrant travels the entire distance of its arc, until it reaches the exit a small distance before 0 radians (Fig. 3 above). In the other, the helper agent finds the exit at a point such that the closest priority agent would have to travel along a chord to reach it (Fig. 4 above).

We analyze the case in which the helper agent finds the exit in the second quadrant. Say that there is an angle of θ between the closest priority and the helper agent, so that the shortest distance between the two agents is $2\sin(\theta/2)$. The angle θ that would produce the longest distance between the priority agent along the top and the helper, is $\theta = 2\pi/3$. Therefore, the termination time for the algorithm in this case is $1 + \alpha + 2\sin(\theta/2)$, where α is the circumfrential distance already traveled by each robot. We can set this result equal to the termination time of the agent that explores the bottom part of the circle, which is $1 + \delta$, where δ is a distance traveled by the priority agent such that it finds the exit a small distance γ before angle 0 (Fig. 4 Above.).

Conclusions

This algorithm has an upper bound of 3.55 time units, being faster than an algorithm of one distinguished and two helpers with an upper bound of 3.83 time units. We can achieve this time by sending our Helper and Distinguished agents out at an angle of $(\pi + 5\pi/9 - 2\sqrt{3})$, so that both of the worst case time predictions are equal. This algorithm and many other like it have real world applications, such as having robots or drones be able to search for a safe exit in a room to evacuate humans in the event a disaster. By using this algorithm we can for example, quickly evacuate 1 of 2 doctors from an area in order to be able to get medical help to others as quickly as possible.

Future Work

Later on we will study further distributed algorithms of search and escape, such as lines or triangles.

Acknowledgements

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References

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