Visualizing and Designing Multi Agent Search Algorithms

David Bushta, Christopher Till
Rutgers University, Camden

Introduction

The purpose of our research is to study distributed search-and-evacuation 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.

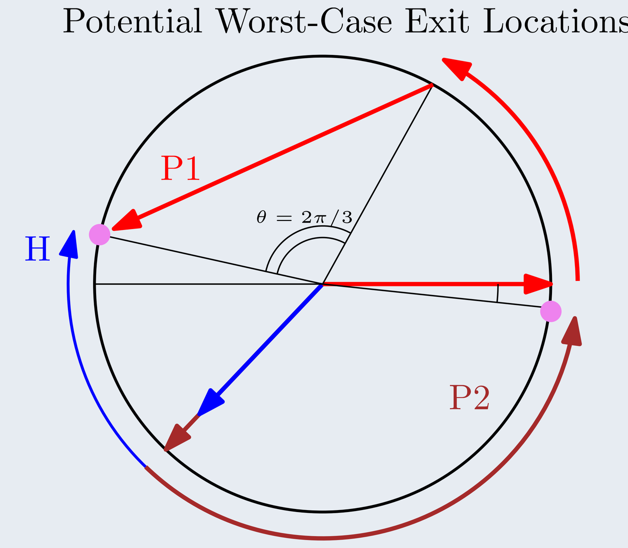
Definitions

- An Exit is a point unknown to the agents, that is located on the perimeter of a disk.
- Priority Agents P1 and P2.
- A Helper H, is an agent that simply assists the priority agents in finding the exit.
- Algorithm Termination occurs if either P1 or P2 reaches the exit.

Main Result

The purpose of our research is to propose an algorithm for two priority 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 in the worst case.

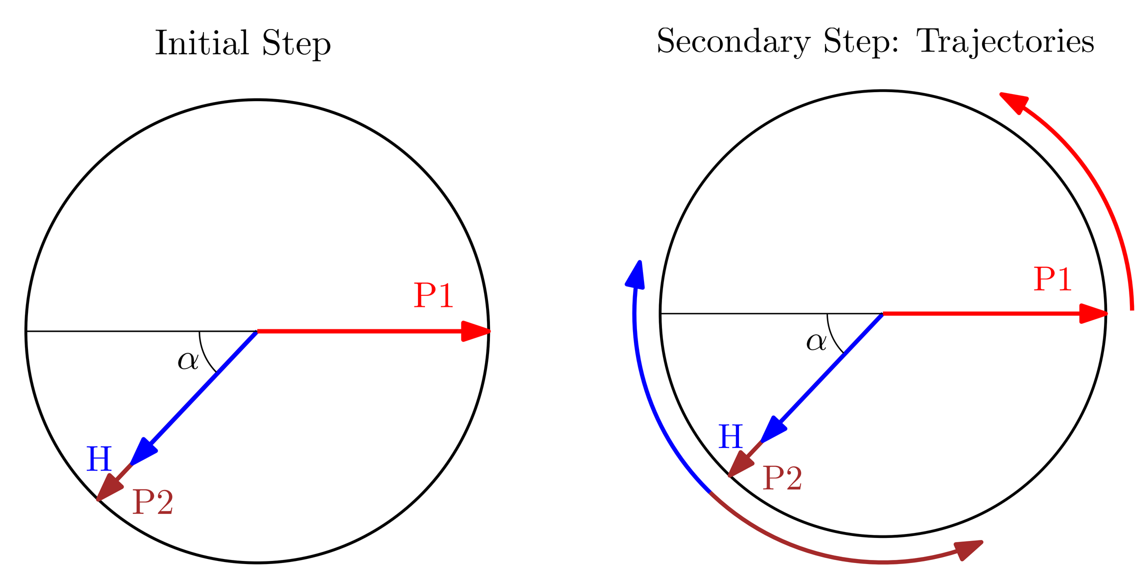
Potential Worst-Case Exit Locations



Algorithm Description

- The priority agents are **P1 and P2**. The helper agent is **H**.
- **P2** along with **H** go at angle α in the third quadrant to the perimeter. **H** travels clockwise, and **P2** travels counterclockwise.
- **P1** travels at angle 0 to the perimeter, and travels counterclockwise.
- The algorithm is required to ensure that between the agents, every part of the perimeter will potentially get searched before the exit is found.

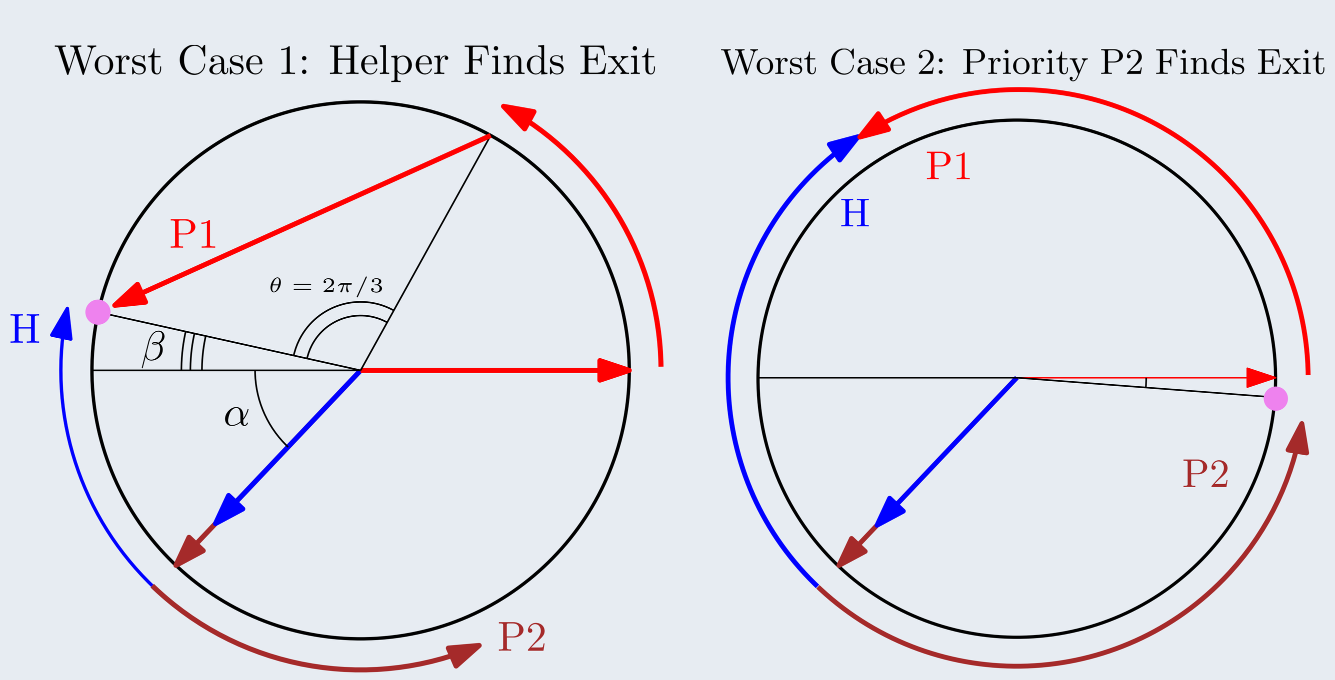
Algorithm Steps

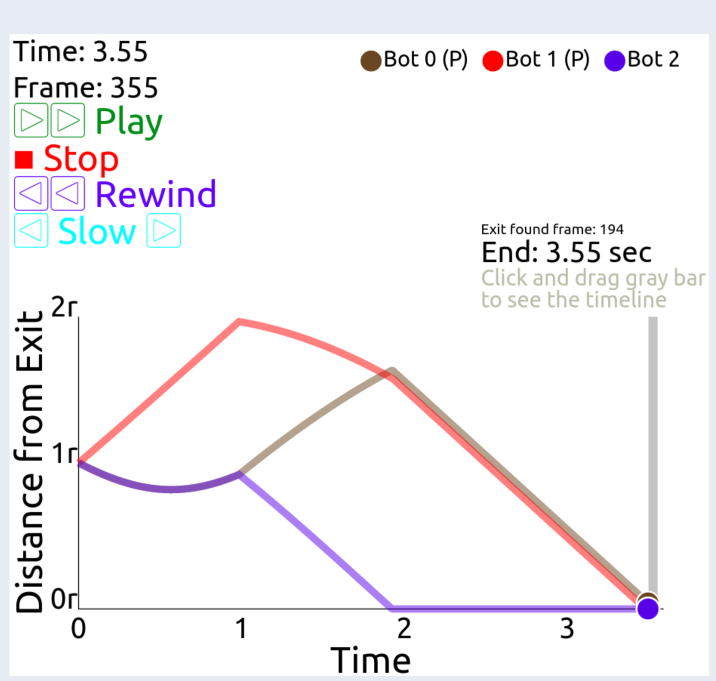


Our Analysis

In this algorithm, we observe two worst case situations. In one, **P2** travels the entire distance of its arc, until it reaches the exit a small distance before 0 radians. In the other, **H** finds the exit at a point such that the closest priority agent (**P1**) would have to travel along a chord to reach it.

We analyze the case in which **H** finds the exit in the second quadrant, at angle $\pi - \beta$. Say that there is an angle of θ between **P1** and **H**, such that the shortest distance between the two agents is $2\sin(\theta/2)$. The angle θ that would produce the longest distance between **P1** and **H**, is $\theta = 2\pi/3$. Therefore, the termination time for the algorithm in this case is $1 + (\alpha + \beta) + 2\sin(\theta/2)$ in the worst case, where $\alpha + \beta$ is the circumferential distance already traveled by each agent. By trading off this worst case with the one in which **P2** finds the exit at a very small angle below 0, we arrived at a solution for these angles α and β.





Conclusions

This algorithm has an upper bound of 3.55 time units in the worst case. We can achieve this time by sending **H** and **P2** out at an angle of $\alpha = 5\pi/9 - 2\sqrt{3}/3$, and $\beta = (\pi/3 - \alpha)/2$, so that both of the worst case time predictions are equal.

Future Work

This is an example of an algorithm that abstracts real world problems, where a specified subset of agents has to evacuate. In the future we will study further distributed algorithms of search and evacuate on lines and polygons, or even topologies such as arbitrary finite graphs. To analyze these, we have created a web app that shows visualizations and helpful data of all of the algorithms that we have studied. Link to website: **https://bit.ly/2Vv85OJ**

Acknowledgements

This research is supported by the National Science Foundation under grant # CCF-AF 1813940 (RUI: Search, Evacuation and Reconfiguration with Coordinated Mobile Agents).

Our faculty advisor is Dr. Sunil Shende.

References

[1] Jurek Czyzowicz, et. al., (2014). Evacuating Robots via Unknown Exit in a Disk. Proceedings of DISC 2014, LNCS 8784, pp. 122-136, 2014.

[2] Jurek Czyzowicz, et. al., (2015). Evacuating Robots From a Disk Using Face-To-Face Communication. Proceedings of CIAC, 2015 p. 140-152, 2015.

[3] Jurek Czyzowicz, et. al., Priority Evacuation from a Disk Using Mobile Robots, Proceedings of SIROCCO, pages 392-407, 2018.

[4] Jurek Czyzowicz, et. al., God Save the Queen. Fun with Algorithms, arXiv:1804.06011v1 [cs.MA] 17 Apr 2018.