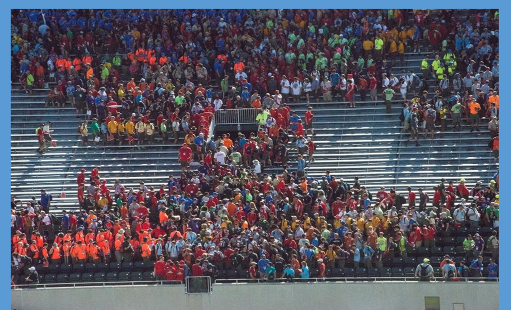
The Effects of Quad-copter Guidance in Crowd Emergency Evacuation Scenarios: Simulation and Analysis

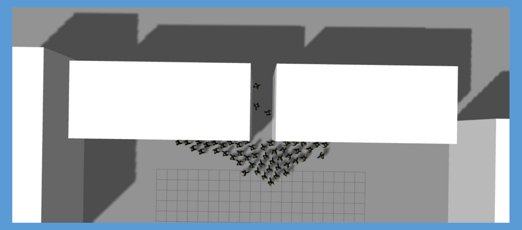
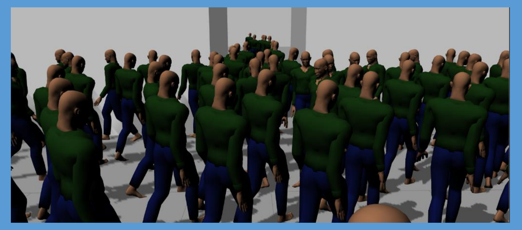
Michael Huang[1], Professor Nilanjan Chakraborty[2], Professor Minh Hoai Nguyen[3]
Westlake High School, Austin, TX[1]   Stony Brook Univ. Department of Computer Science[3], Department of Mechanical Engineering[2]

Motivations

In the case of a disasters like fires, explosions, shootings, earthquakes, a large amount of deaths can be attributed to inefficient evacuation of the area. Evacuation is often slowed down because information on surroundings or possible exits is either unavailable because of the suddenness of the disaster or difficult to communicate over possibly damaged terrain and limited time.

Because of the little information and low visibility a single crowd member may have, they will most likely choose to leave through the nearest exit. However, choosing the nearest exit is not the optimal way to evacuate; more accessible and visible exits are too popular and become congested, causing crowd buildup and a slower evacuation time.

To help solve this problem, we believe that using quadcopters, which are known for their versatility in diverse environments, will allow for better evacuation efficiency and a higher survival rate.

Objectives

- Create a framework for simulating robot-crowd interactions
- Collect and analyze data (% Agents Escaped vs. Time) from simulations of quadcopter and crowd interactions to form conclusions about the effectiveness of quadcopter guidance

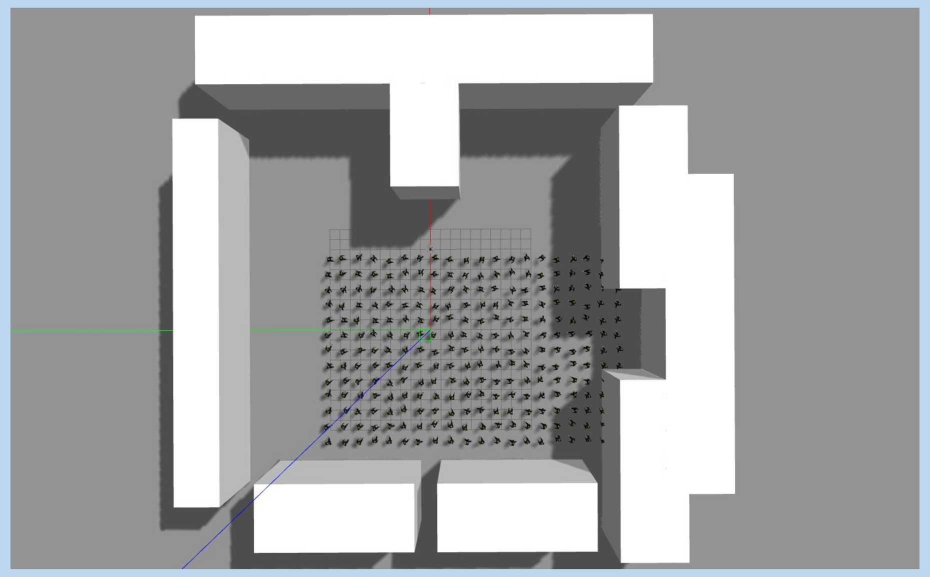
Methods

We decided to test the effectiveness of quad-copter guidance in evacuation scenarios using simulations because replicating disaster situations in real life would be both dangerous and costly. Although significant work has already been done on robot and crowd simulations separately, there were no preexisting general purpose robot-crowd interaction simulation tools. Therefore, it was necessary to combine components from both research fields to create a simulator that could serve the needs of this kind of study. In the end, we chose to use ROS(Robot Operating System)[2], Gazebo(3D simulator)[3], and Menge (Crowd simulator)[1] together to create a novel robot-crowd interaction simulator.

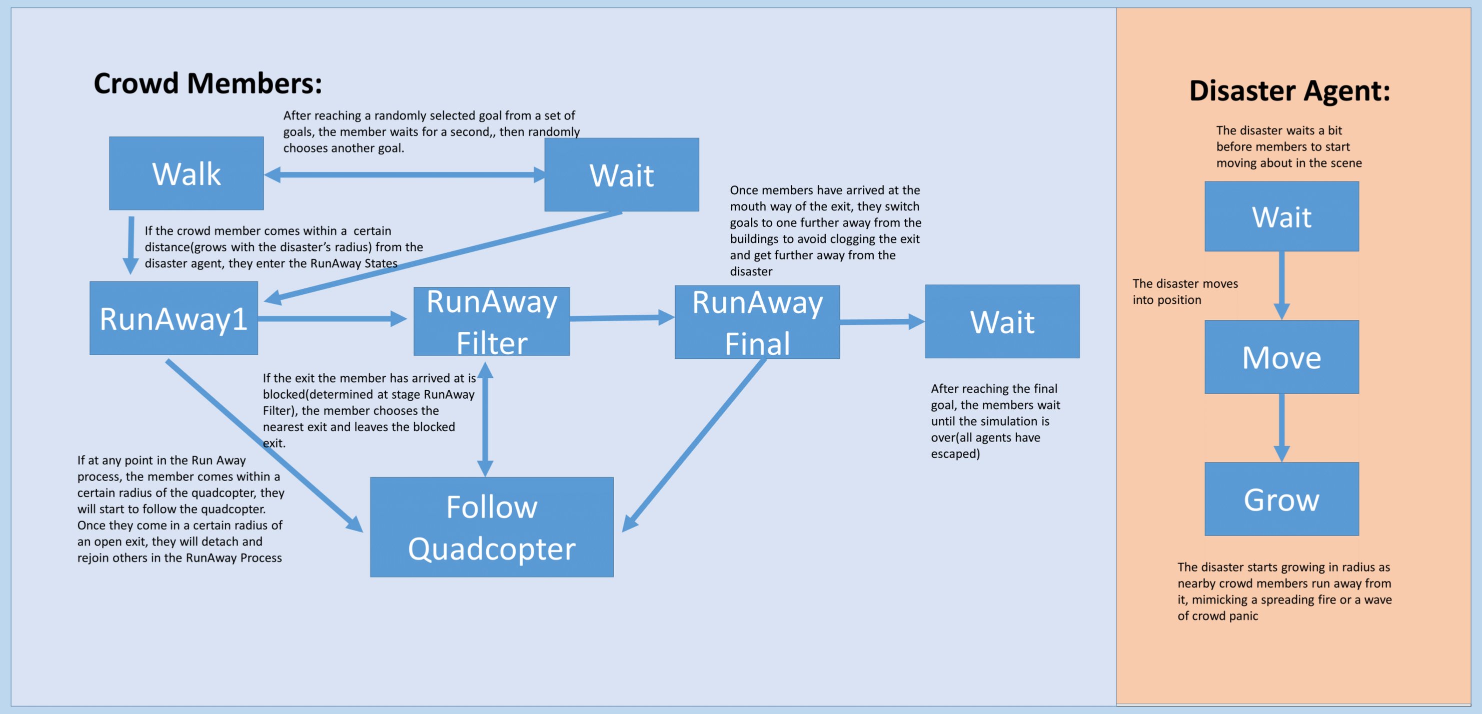
Discussion

Most of the results seem to support the usefulness of quadcopter guidance in evacuation scenarios. In the control case, the rate at which agents leave the disaster area with quadcopter help is noticeably steeper, and all of the members of the quadcopter case have escaped at an earlier time than the members of the "No Quadcopter" case. Similar benefits are displayed in two of the remaining cases. However, in the variation in which the middle exit is blocked, the quadcopter seems counter productive! This is because in the "Quadcopter" case, the members follow the quadcopter, which moves in a loosely snaking motion to attract the attention of as many members as possible; this slows the members following the quadcopter down. In the end, however, all crowd members have exited the area at roughly the same time.
Because of the large amount of adjustable variables, the four cases tested here cannot prove that quadcopter guidance is beneficial in every situation; further testing with other variables(multiple quadcopters, diverse crowd members…etc.) will need to be done in the future. However, these few cases demonstrate the feasibility and flexibility of the simulation, and it is easy to see the simulation framework being used in future, similar projects.

Scene

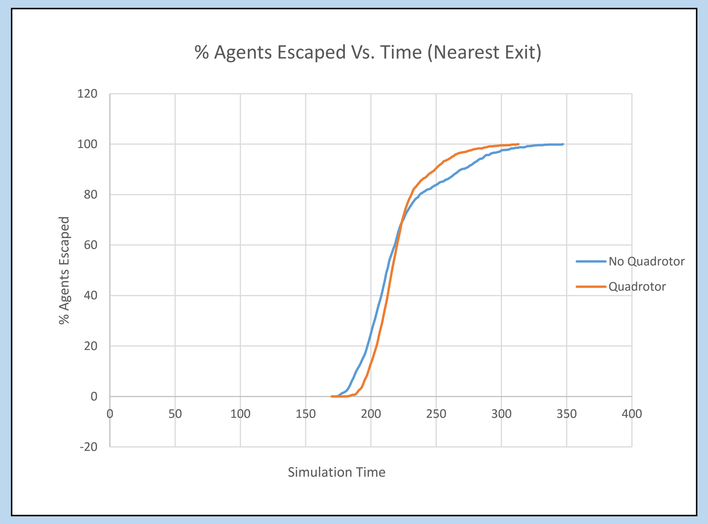


The scene is based off a "city square" type situation. People move about randomly, until a explosion goes of near the tip of the T-shaped building! As flames spread across the square, people must exit through one of the five exits around the square's perimeter. However, most people choose to exit through the narrow southern middle exit, because it is the nearest to them, which causes severe crowding problems and slows down evacuation.

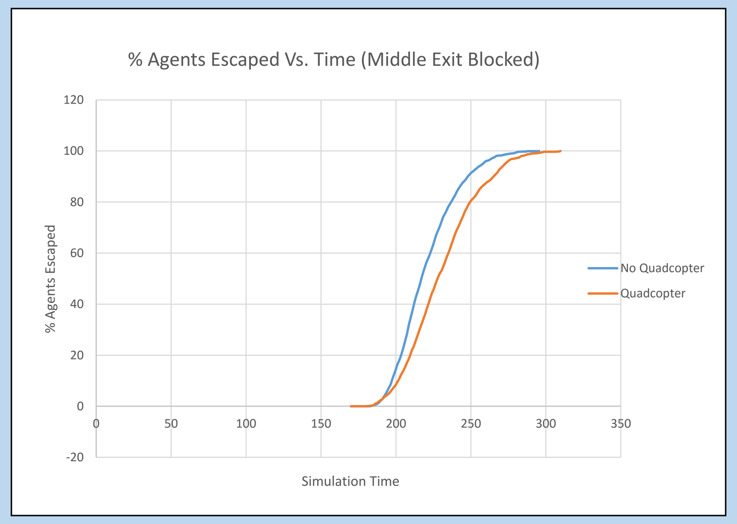


Results

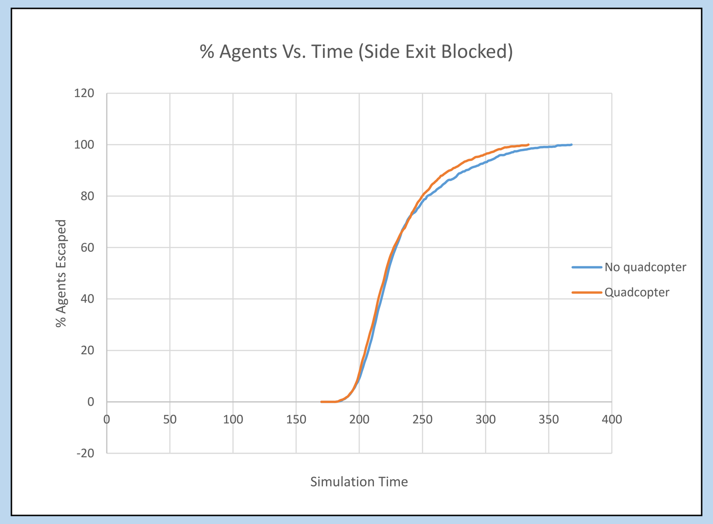
*Each curve is the average of data obtained from 5 repeated trials



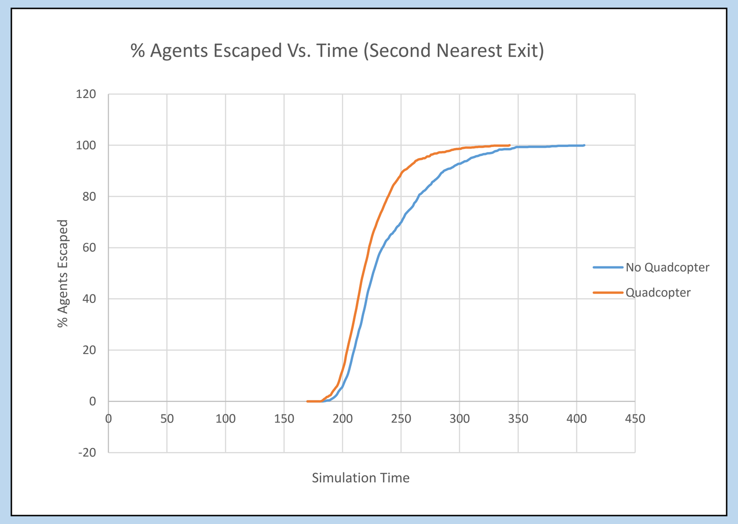
In the Control Group, Crowd Members choose the nearest exit as their goal, favoring the narrow middle exit. In this case, the tele-operator tries to direct crowd members to less crowded side exits.



In this variation, the middle exit is blocked, but the crowd members don't know before hand. In this case, the tele-operator tries to direct member away from the middle exit preemptively.

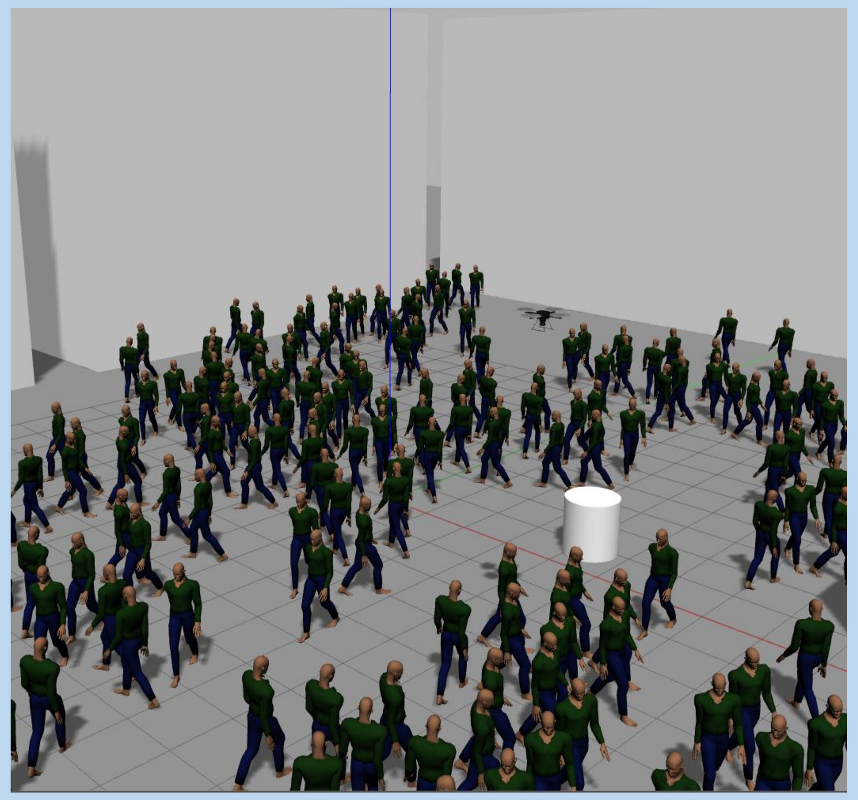


In this variation, a side exit is blocked. The tele-operator tries to direct people away from the side exit to the middle or remaining side exit.

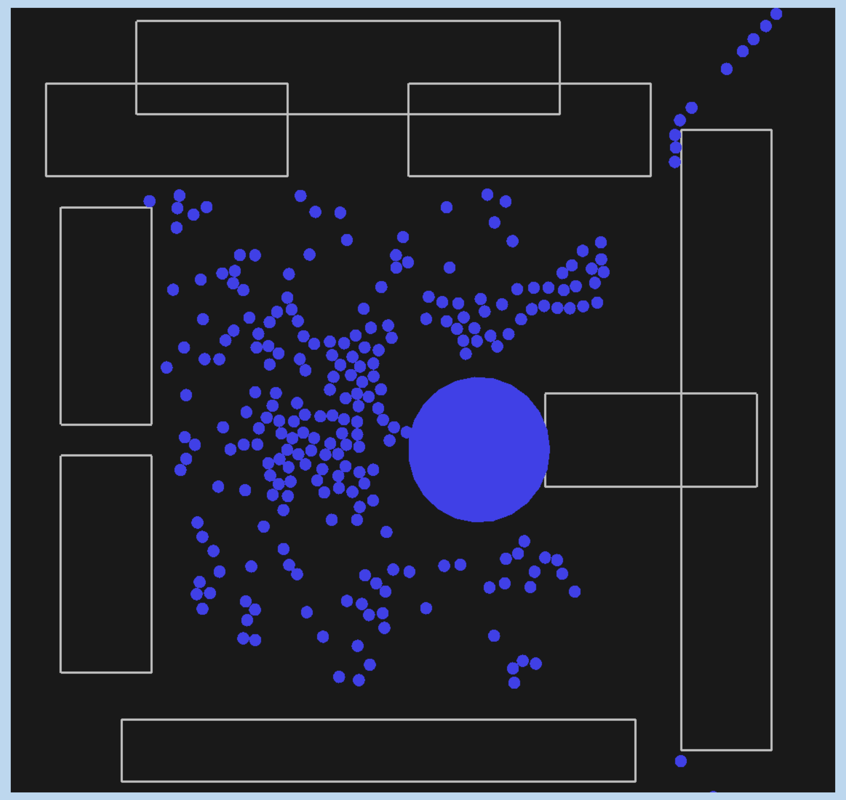


In this variation, there is a 50% chance a crowd member will choose the second nearest exit as their goal. This simulates people not knowing their nearest exit beforehand. The tele-operator tries to direct members toward less crowded side exits.

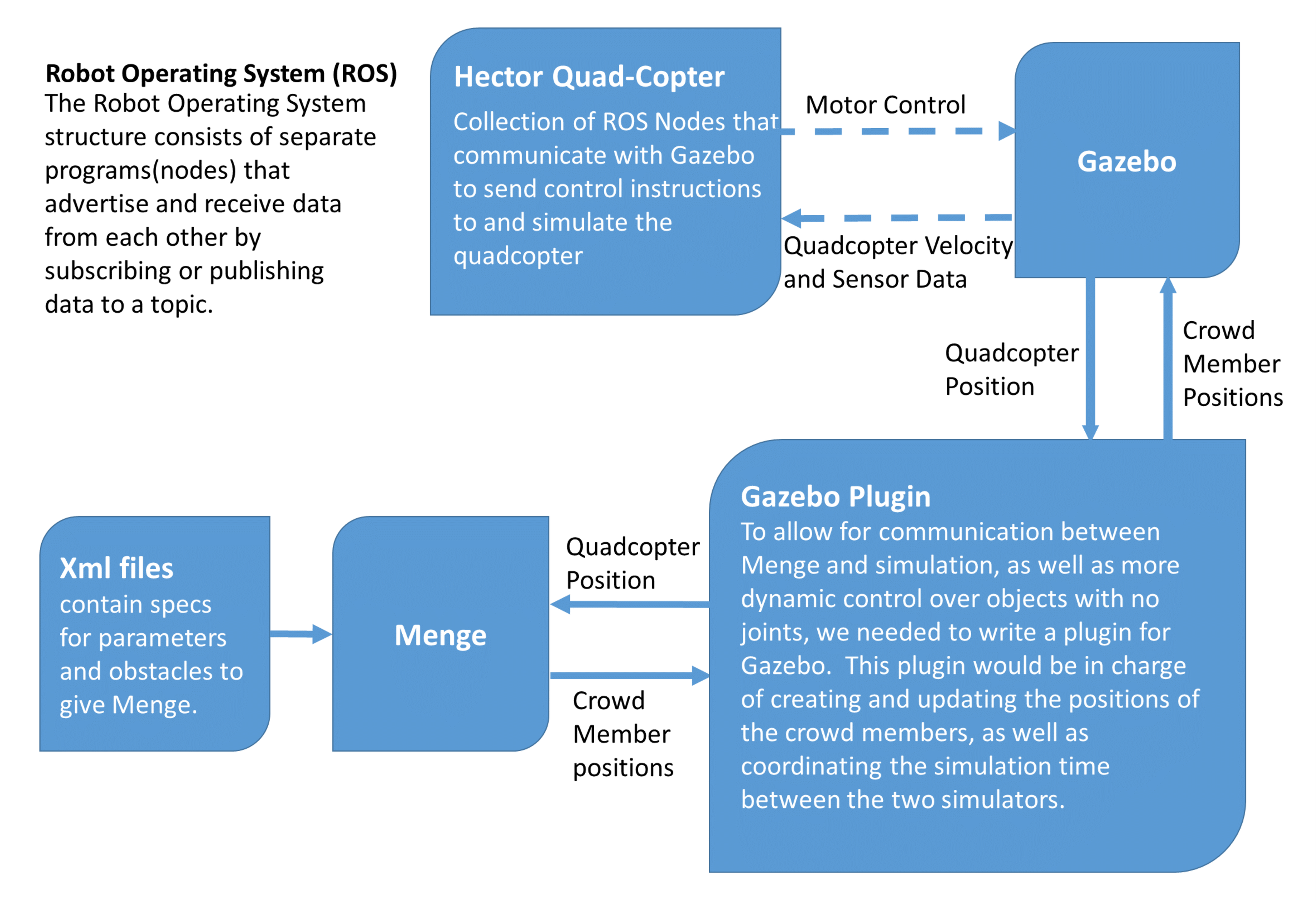
Simulator Architecture



Gazebo is a robot simulator that has "a robust physics engine, high-quality graphics, and convenient programmatic and graphical interfaces" as well as an active community. Gazebo is frequently used in combination with ROS, and its plugin capabilities allowed us to dynamically set the positions of crowd members and interact with the quadcopter.



Menge is a crowd simulator recently developed by researchers at the University of North Carolina, Chapel Hill. Given xml files containing parameters specifying crowd member behaviors and obstacles, Menge can generate positions of crowd members as they travel.



References and Acknowledgements

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Picture Sources:

Ferland, Catherine. Spartan Stadium Evacuation Drill. Digital image. *The State News*. The State News, n.d. Web.

Hydrogen gas explosion. Digital image. *The Sun*. The Sun, n.d. Web

Thanks to Le Hou for his help in giving me access to the lab's computer cluster and server room.

Stony Brook University