Thesis Project Portfolio

Toward Robotic Triage: A Distributed Task and Motion Planning Framework for Efficient Human-Robot Emergency Response

(Technical Report)

Using Actor-Network Theory to Make a Case for Human-Robot Triage for Disaster Management

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Abigail Manalang

Spring 2025

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Table of Contents

Sociotechnical Synthesis

When disasters occur, first responders are limited by time and resources to explore disaster areas to locate and triage victims. My technical report introduces the human-robot triage, which allows a system of heterogeneous, autonomous robots to explore a disaster site and perform basic triage on victims, leaving more advanced medical intervention to a human medic. These robots work in tandem with the human medic, allowing for faster exploration of environment with less required manpower. My STS research applies Actor Network Theory (ANT) to a case study focused on poor first responder safety and aims to remediate lack of protocol by defining disaster response as a utilitarian process.

My STS research examines the 9/11 attacks on the World Trade Center as a case study for poor disaster response through the lens of ANT. Immediately after the 9/11 tragedy, the Environmental Protection Agency (EPA) declared that the air surrounding the World Trade Center site was safe to breathe, which led to first responders not wearing respiratory protective equipment (RPE). However, the EPA had no basis for their claim, and in the years following the disaster, there have been various health complications, such as respiratory illness and cancer, in first responders who did not wear RPE. Through examination of this case study, the most important aspects of disaster response are utilitarianism. By endangering first responders, the EPA failed to follow utilitarian principles, which aim to save the greatest number of people; many first responders have died from inhaling toxic debris at the World Trade Center site.

My technical project provides a potential solution to the problems outlined in my STS research. It introduces a human-robot triage system, which includes three unmanned ground vehicles (UGVs), an unmanned aerial vehicle (UAV), and a human medic. My work was to design various simulations to determine the best algorithmic methods for human-robot triage.

The final design includes an algorithm that equally divides the environment between the UGVs, with the UAV serving as a relay positioned in the middle of the environment. When a UGV locates a low priority victim, it adds it to a list and continues exploring. However, when a UGV discovers a high priority task, it reports to the UAV, who in turn reports to the medic. The medic calculates an optimized path to travel between victims using a priority Traveling Salesman Problem (TSP), which sorts the victims into various lists and performs the TSP on each list individually before concatenating them together, with high priority victims visited first, followed by lower priority victims. This solution provides a low exploration and triage time, second only to the simulated "ideal" solution.

Since my technical project is in the early stages of development, my STS research provided real-world context to the human-robot triage. It is easy to make decisions that feel unimportant in a line of code; however, when it comes to decisions related to disaster response, every decision is a question of ethics and is therefore important. Decisions made in a line of code have the potential to be life or death in a real-world implementation. From the beginning of my capstone, my team researched different methods for triage to determine what decisions are acceptable for robots to decide, and what decisions should be left to human medics. By reflecting on ethical frameworks learned in class, such as utilitarianism, our team incorporated ethical thinking into our code.