COMMUNICATION DEVICES FOR HUMAN TRIAGE ROBOTS

FEDERAL EMERGENCY MANAGEMENT AGENCY'S RESPONSE TO HURRICANE MARIA IN PUERTO RICO

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By
Leila Troxell

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Technical Team Members: Kailey Brown, Shrinidhi Nadgouda, Amelia Nist

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.

ADVISORS

Ben Laugelli, Department of Engineering and Society

Adam Barnes, Department of Electrical and Computer Engineering

Introduction

During natural disasters, relief teams flood the area searching for and treating victims. However, this dual purpose for medics delays the location of potentially more urgent victims in the area, which is why robotic systems are being designed to search the area and report back about victim location and severity. Communication devices are necessary for robots' prompt conveyal of victim information with the medics and other robots, streamlining the workload for medics in a disaster zone.

In order to accomplish this effective communication, new devices need to be designed to meet all of the requirements introduced by a disaster zone. My team will create a compact communication system that utilizes the ZigBee antenna's mesh-network capability to allow the passing of messages indirectly through devices, eliminating the need for direct delivery by the sender. This enables more efficient exploration by the robots, lowering the time to treat victims, ultimately saving lives.

Just as communication devices are one component that can improve emergency response, multiple factors led to the Federal Emergency Management Agency's (FEMA) disappointing response to Hurricane Maria in Puerto Rico. To best understand why its response was so poor, it is necessary to evaluate how various factors, whether technical, social, economic, or environmental, work together to affect a project's success or failure. I will draw on the STS framework of actor-network theory (ANT) to investigate how these factors influenced FEMA's decision making during its support of Puerto Rico amidst the destruction. If governments and organizations only work to maximize efficiency in disaster zones and fail to acknowledge the misuse of tools and their employees' underlying biases, these issues could be perpetuated: medics in the field could choose to not best treat a victim due to biases or continue to misuse the tools provided. If medic workloads are not eased by robotic support, medics will continue to misuse their tools, further worsening issues. Because the challenge of streamlining the medics experience in a disaster zone is sociotechnical in nature, it requires attending to both its technical and social aspects to be accomplished successfully. In what follows, I set out two related research proposals: a technical project proposal for developing a communication device that allows robots to explore and remotely communicate their findings and an STS project proposal for examining the underlying biases and misuse of management tools in response to Hurricane Maria in Puerto Rico.

Technical Project Proposal

During natural disasters, time is of the essence - every second wasted could cost a victim their life. To help save time, Dr. Nicola Bezzo has been working with a group of students and professionals to design and implement a team of robots that could traverse the dangerous terrain after a disaster and report to nearby medics about victims and the urgency of their injuries. Currently, these robots use predictive modeling, detailed further in “Epistemic Planning for Heterogeneous Robotic Systems,” by L. Bramblett and N. Bezzo (2023), to assume the location of other robots and medics. Epistemic planning optimizes information dissemination in multi robot systems which lack constant communication. However, this method relies heavily on robots and humans following a logical, and thus predictable, path. When a human deviates from the range of expected actions, epistemic planning proves to be an incomplete solution without some method of updating the robots’ algorithms in the field.

While a communication device would prove useful, the existing methods introduce additional challenges as no option fulfills all of the requirements presented by a disaster zone.

The majority of robotic communication systems rely on WIFI or bluetooth to send messages (Zettascale, 2024). While this is convenient for at-home robotics, internet and cellular data are not reliable resources in a disaster. Other robotic transmission media are instead reliant on "implicit communication and self-organization through stigmergy" (Gielis et al.. 2022, 213-225). Stigmergy leaves traces in the environment so the robots can coordinate indirectly. However, in a disaster zone, this implementation becomes less useful, as the traces - alterations made to the environment - may become less recognizable (Beckers, 2000). Near-field communication has also been used for network-less robot communication and has proved to be more useful when the task requires performance guarantees (Gielis et al.. 2022, 213-225). This implementation best meets the needs of locating all victims in an area (a performance guarantee), but limits efficiency as all robots must then travel back into the limited range of the desired recipient before transmitting their data.

The aim of this technical project is to create a compact communication system that can attach to the robots so they can coordinate with other robots about their search progress and efficiently communicate the most pressing information with the medics. This will all be done while taking advantage of the various strengths and avoiding the network reliability issues of existing systems. The device will operate on a mesh network layout, allowing information to be passed through multiple devices for delivery at its destination, rather than the sender delivering it themselves. If this technique were not to be implemented, then robot efficiency would decrease, increasing the time it takes for a victim to receive aid, ultimately increasing the mortality rate of any natural disaster where these robots are present.

The project will be divided into two subsystems to be completed concurrently. The hardware subsystem team will construct a Printed Circuit Board (PCB) with a micro USB input, a Zigbee, a switch, and a CO2 sensor. The micro USB provides both power for and an information pathway into and out of the board; the ZigBee is an antenna communication device that has mesh network capabilities; the switch serves to allow the user to externally designate which type of robot the device is attached to; the CO2 sensor measures air quality as the robot explores. The other team's subsystem is responsible for integrating the robot and the ZigBee through code. The information pathway from the USB into the ZigBee microcontroller flows two ways and is how messages are sent to other devices, and how the instructions are sent back to the host system after messages are received. The code will be responsible for analyzing the host system's sensor information, interpreting received messages from Zigbee, and creating instructions for the host system. This team will also be responsible for coding the robots through the Robot Operating System (ROS) - this will be how the sensor data is output and where instructions will be received and converted into actions.

To demonstrate the functionality of the design, the following tasks will be performed and validated: 1) run the initial communication test through the computer, 2) wirelessly pass information from a medic's computer to robot A through robot B, 3) simulate finding an object of interest, determining its priority, and sending a message with the location and severity rating, 4) update robot tasks and target location after receiving a message, and finally 5) sort and filter robot messages on the medic's computer. If all of these tasks are completed, the project will be functionally complete. The time the robots take to locate and report back with, and without, the communication devices can be used as a quantitative measure of success for the system, illustrating the role this design plays in saving time, and lives, during disasters.

STS Project Proposal

In September 2017, Hurricane Maria struck Puerto Rico. Just two weeks after Hurricane Irma had ravaged the island, Maria swept through, knocking out the power for almost the entire island and marking the beginning of the longest power outage in American history ("The Longest Blackout", 2022). The Federal Emergency Management Agency (FEMA) is the point of contact for emergency response throughout the United States and was responsible for organizing the recovery of the island and ensuring the safety of all victims. However, despite FEMA's assistance, recovery in Puerto Rico was poorly managed, resulting in thousands dying and many more lacking proper access to food, water, and electricity for months (Cuffari, 2020).

The outpouring of analyses following this embarrassing response to Hurricane Maria attributed several factors as the cause, with most authors recognizing the concurrent landing of five hurricanes across different parts of American territories ("North Atlantic Ocean Statistics Compared With Climatology," n.d.), the underqualified FEMA staff going into hurricane season ("2017 Hurricanes and Wildfires," 2018), and the overall poor management skills shown by FEMA's leaders when put in a difficult situation. Other authors mention FEMA overlooking previous analyses of the Puerto Rican state, specifically the state of their electrical grid, as well as the "serious [financial] liquidity challenges" facing the bankrupt Puerto Rican government ("Puerto Rico's Current Fiscal Challenges," 2016).

While all of these factors certainly influenced the slow response and recovery in Puerto Rico, they do not provide a comprehensive explanation for why it happened, ultimately placing the majority of the blame on FEMA's overall unpreparedness and inadequate leadership. They all fail to acknowledge the underlying causes that lead to the listed factors. These underlying forces influenced the unique interactions between each of the separate actors, or pieces, in the overall system that came to Puerto Rico's rescue.

I argue that FEMA failed in its response to Hurricane Maria not because of individual leadership failures or because of the situational pressure, but rather because of both underlying biases toward the territory of Puerto Rico and the improper use of the Logistics Supply Chain Management System (LSCMS). Storms will continue to ravage America; if the United States continues to ignore the influence of ignorance and bias towards Puerto Rico and to not utilize its resources to the fullest extent, people will continue to die, extra money will continue to be spent, and every response to a storm will be just as ineffective.

To illustrate my analysis of the Puerto Rican emergency response, my argument draws on the framework of actor-network theory (ANT), developed by sociologists Michel Callon, Bruno Latour, and John Law. ANT claims that all technical projects are composed of human and non-human actors that are assembled into a network by a network builder to accomplish a particular goal. A main component of ANT is that the various actors of the system can only be fully understood when considered in respect to their overall system (Cressman, 2009). Michel Callon's translation, which describes the process of forming and maintaining an actor network, will also be incorporated into my analysis to explain the introduction of rogue actors and their pervasiveness within the system (Callon, 1986). Throughout my argument, I will draw upon evidence from government analyses of FEMA's failure, such as from the Office of the Inspector General and from FEMA itself, as well as new media articles, first-hand accounts, and academic research analyses of the catastrophe.

Conclusion

At the conclusion of this paper, I hope to have provided two things. Through analyzing the case study of FEMA's response to Hurricane Maria's impact on Puerto Rico, I hope to establish a greater understanding of how the underlying biases and misuse of key tools can influence all actors within a system. Over the course of this analysis, I too will gain a greater understanding of how different, unanticipated factors can influence the end result of the entire network. These insights can be applied to the second deliverable, a functional robot communication device that enables robots and medics to send and receive information while apart. This deliverable will include robotic movement logic, which decodes received messages to determine the robot's next action. This tool and the associated movement logic will decrease the time to locate victims, ultimately saving lives.

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