Lab Section: 7
Project Group: 3
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Cpre 288 Final Project Proposal

Problem Statement:

A firefighter's job is very dangerous, so they need a way to make their job safer and more efficient for them. To be more specific, they need a robot that can do the job of a firefighter efficiently while keeping the firefighter/s at a safe distance away from the dangerous environment and conditions of a fire. When a firefighter goes into a fire, they are at risk of inhaling carcinogens and toxins from within the smoke, which can lead to bad health problems like cancer. It is also very unpredictable at times for how a fire will act. Having a robot that can put out a fire while being controlled a great distance away from the fire will greatly reduce the chances of a firefighter being affected by the dangerous effects caused by fires.

Application Narrative Story:

In the face of increasingly devastating wildfires, the development of an autonomous and manually-driven quick-response robot is not just an innovative endeavor but a paramount solution with far-reaching implications. This cutting-edge technology is not only pivotal for the safety and effectiveness of firefighters on the ground but also for the agencies supporting them and the taxpayers who fund disaster responses.

An autonomous response to putting out fires would be a game-changer, enabling firefighters to rapidly extinguish and limit the damage and spread of wildfires without exposing human lives to unnecessary risk. By deploying an autonomous-response bot, we would provide a powerful tool for the early containment of fires.

Beyond immediate fire suppression, the autonomous bot also serves as a valuable data collector. It provides real-time insights into the fire's location, intensity, and conditions on the ground. This data is especially critical in scenarios where standard aerial reconnaissance may be ineffective due to tree coverage or other limitations.

The robot's operational versatility is a key feature. It can function autonomously to extinguish fires, with its primary directive being to seek and contain the fire by creating a fire break around the initial blaze to limit and contain the spread. Furthermore, the response team coordinators can take control manually, allowing the robot to perform additional functions, such as assessing ground conditions.

To accomplish these tasks, our team will draw on our prior experience with the bot to develop a search function. This function will allow the robot to detect the fire's location, at which point it will begin creating a firebreak autonomously while skillfully navigating complex terrain.

Simultaneously, our team will work on creating an intuitive user interface that enables a remote operator to take control of the robot. This interface is essential for navigating and scoping through a complex environment. By taking this approach, our team aims to revolutionize wildfire response strategies, making them more efficient and safer for all involved. This project not only addresses an immediate need but also showcases the potential of autonomous technology to mitigate disaster impacts.

User Research:

For a fire search-and-rescue robot, the main users are:

- Fire departments/fire rescue teams
- Outdoor government departments
    - DNR
    - US Forest Service
    - US Fish and Wildlife Service
    - National Interagency Fire Center

Empathy Map:

Do	Think
● Extinguish fires that occur in cities and wildlife [1] ● Respond to fires, explosions, vehicular accidents, and natural disasters [1] ● Extract/evacuate people out of dangerous situations, like burning buildings, crashed vehicles, etc. [1] ● Thin trees out in wildlife areas to help suppress future fires and decrease the potential amount of fuel for a fire [7] ● Might breathe in toxic chemicals while fighting a fire and expose themselves to hazardous carcinogens	● Evaluate the best way for people to get out, given limited time and terrible conditions. [1] ● The first concern is safety. So how do we make sure that all people that are in help get out safely. [1] ● Sometimes, the fire areas can get too dangerous for firefighters to enter, so the Cybot can come in instead. [1] ● How to respond to any fire, rescue, hazard, or emergency. [1] ● How can we clear the way if we are surrounded by wildfire without us

that can cause cancer [2] ● Some fire rescue teams can control a robot that can remotely extinguish fires in extremely dangerous areas [4]	getting injuries? [1]
Say	**Feel**
● "Even though fire-fighting robot is no substitute for human firefighters, it does provide an alternative to sending people into extremely dangerous situations." [3] ● "I found out that I had a cancerous tumor in my kidney, where I needed to have my kidney removed. My doctor told me that the type of cancer that I had was normally found in people that are heavy smokers." [2] ● "A fire-fighting robot could assist during wildfires, pulling hoses up steep hillsides or protecting homes threatened by flames." [3] ● "The point [of a fire-fighting robot] is because we cannot afford to lose firefighters. We would much rather lose a piece of machinery, so we would put this into situations we would not put firefighters in due to significant hazards." [4] ● "In order to better control large forest fires, we need a better way of thinning out remote forest areas" [7]	● "How will we get out of this dangerous wildfire?" [1] ● "The way is blocked. How are we going to clear the way?" [1] ● There will be less room for any human error. [2] ● "There are people there that we need to help, but we can't help them due to the extremely dangerous conditions." [2] ● "If only there were a superhero fire-fighting robot that could come in and clear the way for us." [3]

Point-Of-View Statements:

Left side of Empathy Map	Right side of Empathy Map
● Needs a way to fight fires while avoiding the dangers of the smoke ● Needs a robot that can withstand the harsh environment of fires and/or natural disasters ● Needs a robot that can assist firefighters during fire rescues and putting out fires ● Needs a robot that can help prep wildlife areas to decrease the dangers of wildfires	● Need a way to get rescued without anyone getting injured. ● Need a fire-fighting robot that can rescue people from the wildfire. ● Need the fire-fighting robot to be able to analyze the given situation and find a rescue plan. ● Need a fire-fighting robot that can handle and survive in the given dangerous conditions.

[1] The user **needs** to be able to fight fires while avoiding the smoke **because** inhaling the smoke caused by fires contains toxic chemicals and hazardous carcinogens that can lead to cancer.

[2] The user **needs** a robot that can function properly while dealing with the harsh conditions that fires and natural disasters cause **because** the robot's purpose is to do all the jobs that firefighters do and be able to finish the job.

[3] The user **needs** a robot that can help assist firefighters **because** fighting fires and performing rescues is very dangerous, so it will be very useful and safer if firefighters can get as much help as they can.

[4] The user **needs** a robot that can help prep wildlife areas **because** it will make it much safer and more efficient for crews to thin out trees and reduce how fast fires spread in wildlife areas.

[5] The user **needs** a robot that can find a safe way to rescue people from the wildfire without any people getting injured **because** human safety is the number one priority for the robot.

[6] The user **needs** a robot to be able to analyze the given situation and find the most efficient and effective way to open up a pathway **because** it needs to get people to be safely exported.

IEEE Source Citations for Fire Rescue Teams:

[1]"What does a firefighter do?," *Career Explorer*. [Online]. Available: https://www.careerexplorer.com/careers/firefighter/. [Accessed Oct. 29, 2023].

[2] "How firefighters' life-saving work puts them at a higher risk of cancer," *Youtube*, Sep. 28, 2022. [Online]. Available: https://www.youtube.com/watch?v=s32rdSVqu88. [Accessed Oct. 29, 2023].

[3] D. Szondy, "Thermite fire-fighting robot removes firefighters from harm's way," *New Atlas*, Oct. 5, 2012. [Online]. Available: https://newatlas.com/thermite-robot/24445/. [Accessed Oct. 29, 2023].

[4] F. Giuliani-Hoffman, "The first firefighting robot in America is here – and it has already helped fight a major fire in Los Angeles," *CNN*, Oct. 21, 2020. [Online]. Available: https://www.cnn.com/2020/10/21/business/first-firefighting-robot-in-america-lafd-trnd/index.html. [Accessed Oct. 29, 2023].

IEEE Source Citations for Outdoor Government Departments:

[5] B. Plumer, "There's a better way to tame large forest fires. So why don't we do it?," *Vox*, Sep. 17, 2015. [Online]. Available: https://www.vox.com/2015/9/17/9347361/wildfire-management-prescribed-burn. [Accessed Oct. 29, 2023].

[6] M. North, S. Stephens, B. Collins, J. Agee, G. Aplet, J. Franklin, P. Fulé, "Reform forest fire management," *Science*, Sep. 18, 2015. [Online]. Available: https://www.science.org/doi/10.1126/science.aab2356. [Accessed Oct. 29, 2023].

[7] "Cutting edge technology being used for wildfire management," *Youtube*, Oct. 24, 2023. [Online]. Available: https://www.youtube.com/watch?v=zuXn8jvxjNI. [Accessed Oct. 29, 2023].

Functional Requirements:

Lotus Blossom Chart

Use the Cliff Sensors as Color Sensors	Use Ping Sensor	Use IR Sensor	Use Bump Sensors	Correction procedure to turn away from fires
Create an autonomous program that allows the Cybot to drive around the fire without any user input	Detect a fire while traversing the field (which will be denoted with tin foil)	Sense and detect multiple objects around the Cybot	Avoid bumping into objects, detecting a cliff edge, and detecting where the boundary is	Use a sensor to avoid getting stuck in holes
Use the servo to perform 180° sweeps	Have the Cybot look around and see what's around it	Put out a fire while avoiding objects and not leaving the field	Navigate through field to find trees that can be moved	Use wheels for movement
Create a map of the field that gets filled in as the Cybot navigates through the field	Communicate information from the sensors	Give off a message if Cybot gets close to a fire, rock, or the boundary	Give off a sound when the robot has created a path of clearance	The sound can be heard from remotely (by the driver)
Communicate between Putty and the Cybot's UART to display information	Display different messages for different objects the Cybot is close to, and what sensors get triggered	Use Putty to display that message	Use Putty to display what actions and movements the Cybot is performing	Use built-in speaker to create the noise?

Base Functionality

Base Functionality	Mapping to Application Narrative (in form of needs statements)
Cybot Communication	The Cybot will communicate with Putty to act as our User Interface. Putty will also allow a driver to drive the Cybot, see data from the IR and Ping sensors, get noticed whenever a cliff sensor detects a cliff, fire, or boundary, and to help navigate through the field overall.
Cybot Movement	The Cybot will navigate through a wooded area that contains a fire, where it will avoid hitting objects, going outside of the area, and not running off a cliff edge.
Object Detection	Use the raw IR values from the Cliff Sensors to detect when we are near a fire. Also use the Infrared Sensor, Ping Sensor, and Bump Sensors to collect data about the Cybot's surroundings and run an autonomous correctional procedure to avoid objects.
Object Avoidance	The information gathered from the Cliff Sensors will let the Cybot know when it has detected a fire, and should start moving around it to extinguish it. If the Cybot gets close to any objects, the Cybot will back up and notify the driver via Putty so that they can drive around the object/s.
Boundary Adherence	The Cybot will use the Cliff Sensors to determine if it is about to cross a boundary. When it does, the Cybot will back up a bit and not allow the driver to go forward so that they don’t try and cross the boundary.
Arrival at Destination (Completion of Goal)	The Cybot has completed our goal when it has traversed the field enough to find the fire, and has gone around the whole perimeter of the fire once, therefore extinguishing the fire.
User Interface	The Cybot will communicate with Putty, where Putty will display the current readings

	of the Infrared Sensor and Ping Sensor to help with the navigation of the Cybot. Putty will also display if any Bump Sensors were activated and if the fire or another object was detected, letting the driver of the Cybot know that the Cybot is running a correction procedure to avoid the fire. Putty will also show a map of the field and where the Cybot has gone so far in the field.
Application Specific Functionality (opportunities for bonus)	
Fire Detection (Cliff Sensors)	The raw IR values from the Cliff Sensors will be used to distinguish fires from other objects. This will then allow the Cybot to run an autonomous algorithm to extinguish the fire.

Cybot Capabilities

Base Capabilities Types	**Default Usage**	**Project Usage (can use defaults; opportunities for bonus)**
Open Interface	Robot Movement	The Cybot will navigate through a wooded area, avoiding running into any objects and circling around a fire.
Interrupts	Ping Sensor	The Ping Sensor will be used to determine how far an object is from the Cybot, where it'll generate an interrupt to run a correction procedure to avoid the object if it isn't a fire.
WiFi-UART	Cybot Communications	The Cybot's UART will communicate with Putty to allow us to move the Cybot, use the sensors, see what data

		the sensors are collecting, and see a map of the field.
Analog-to-Digital Conversion	Infrared Sensor	The Infrared Sensor will be used to determine the spread of objects surrounding the Cybot, where it will convert that data into readable information to be communicated with Putty for us to read.
Input Capture	Ping Sensor	The Ping Sensor will be used to gather information about how far objects are from the robot.
Pulse Wave Generation (PWM)	Servo Motor	The Servo Motor will be used to move the Ping Sensor and Infrared Sensor 0° - 180° to determine the distance and number of objects surrounding the Cybot.
Microcontroller Capabilities not Covered By Labs (opportunities for bonus)		
Input Capture	Cliff Sensors	To detect if the Cybot is near a fire, cliff edge, or boundary, we will use the raw IR values of the Cliff Sensors to distinguish between the three.

Mapping Test Field Elements to Application Narrative

Basic Test Field Objects and other Elements	Description of how Test Field Elements Map to Application Narrative
Tall wide objects	These will represent trees, so the Cybot will need to avoid bumping into these objects and instead go around them.
Short objects	These will represent rocks that will get in the way of the Cybot navigating through the area, so the Cybot will also need to avoid bumping into these objects.
Pillars (tall thin objects)	These will also represent present trees, so the Cybot will need to avoid bumping into these.
Holes	These will represent cliffs/an elevated dropoff in a wooded area, so the Cybot will have to avoid falling from these when it detects that it's near a cliff edge.
Out of bounds	The white tape surrounding the field will represent the boundary of the wooded area, and the Cybot will avoid going out of the wooded area since the fire is contained in the wooded area
Destination zone	There will be one fire in the area, and the Cybot will need to go around it and simulate putting fire retardant on the ground. Once the Cybot has fully gone around the perimeter of the fire, the fire will be extinguished.
Other Application-Specific Test Field Elements (opportunities for bonus; consult with TAs and Professor)	
Tin foil paper	There will be a 50 cm x 30 cm rectangle made of tin foil, which will represent the area that has been consumed by fire.

Bonus Points:

- **5 bonus points** for extinguishing the fire in 15 minutes, and an additional **5 bonus points** for extinguishing the fire in 10 minutes
    - In order to prevent the fire from spreading and becoming more dangerous, the Cybot needs to be able to extinguish the fire as quickly as possible

- **5 bonus points** for plotting the whole field onto the map
    - If the Cybot knows the entire layout of the wooded area, then it can navigate to new fires much easier and faster before the fire becomes a greater danger. Having the whole field mapped out would also let the Cybot know if there are any stray embers in the area

- **5 bonus points** for not making contact with any objects on the field
    - The Cybot can't waste time hitting objects and being thrown off course. The Cybot also shouldn't be destroying the wooded area and making it more difficult for firefighters and other first responders to get into the area

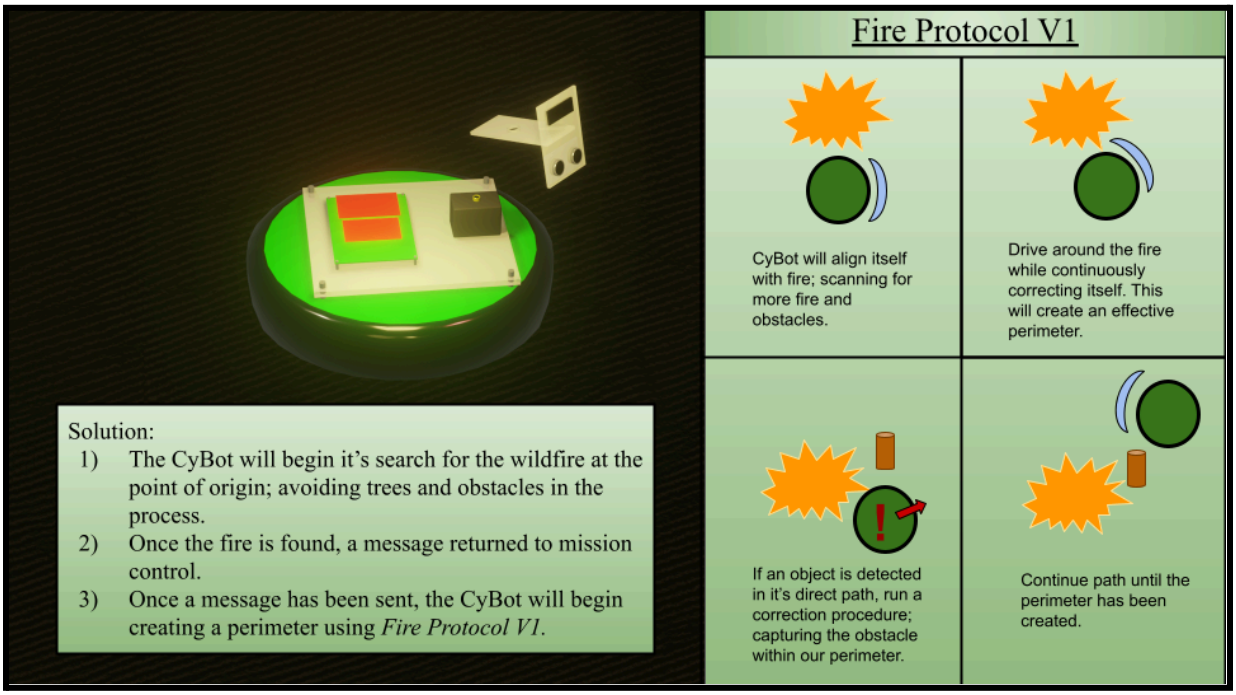
- **3 bonus points** for mapping 10 objects on the map
    - If the Cybot has a general idea of where obstacles (trees, rocks, etc.) are at in the wooded area, then it could generate a path to easily get to the fire and give first responders an easy-to-traverse way in

- **2 bonus points** for mapping the whole outline of the field onto the map
    - The Cybot should be able to secure the wooded area around the main fire to ensure no new fires pop up before extinguishing the fire.
    - The Cybot shouldn't be leaving the wooded area before extinguishing the fire

User-Centered Sketch:

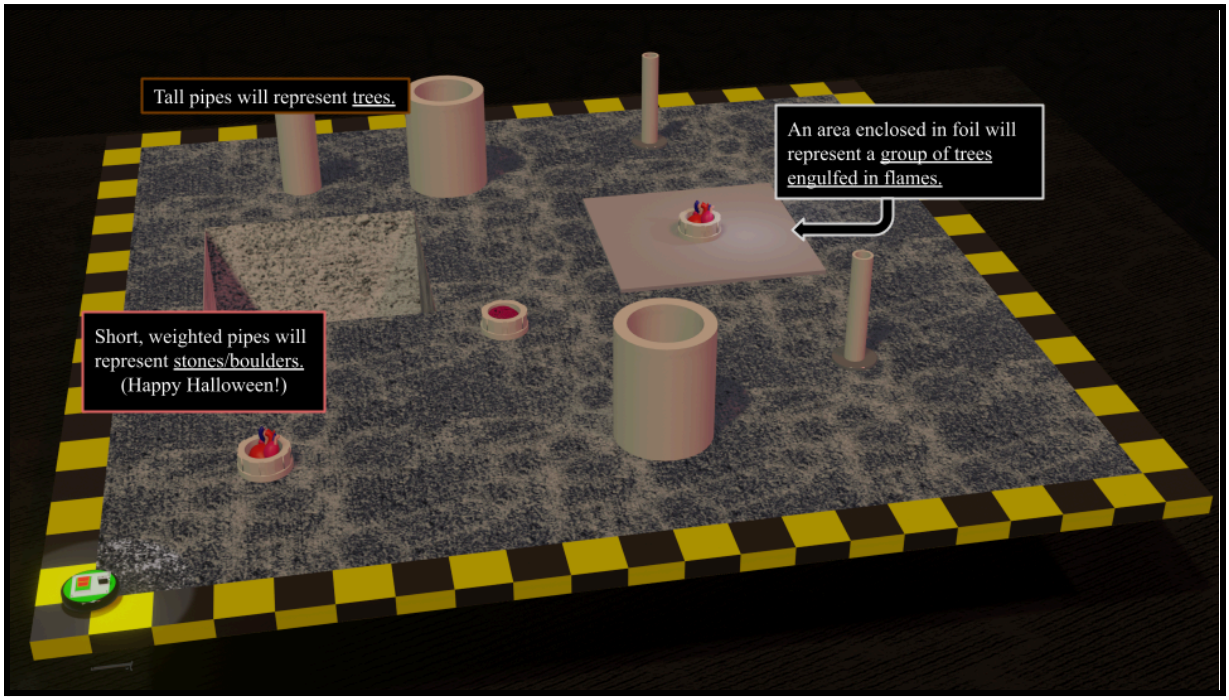
(Figure 1)

Technical-Centered Sketch:

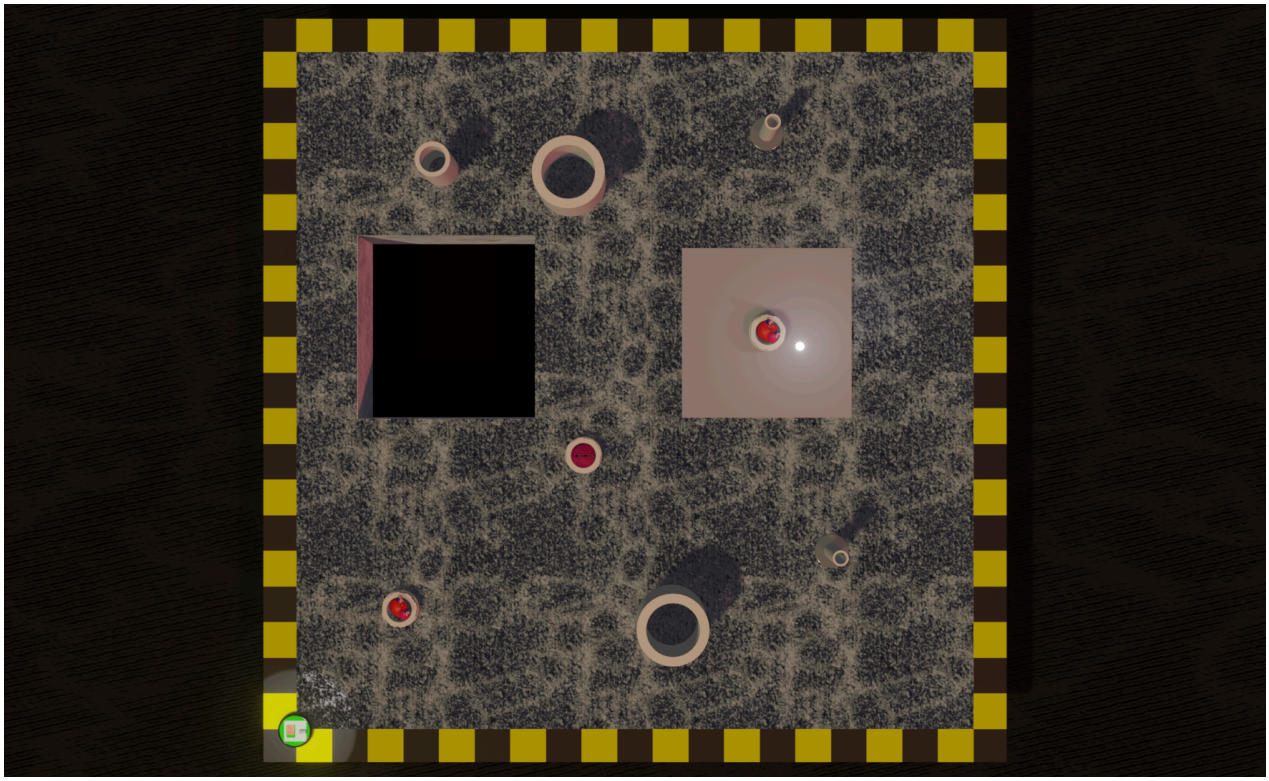


(Figure 2)

Test-Field:



(Figure 3)



(Figure 4)

Collaboration:

Team Member	Contributions
Caden Otis	Helped in narrowing down a final project idea that relates to a serious real-world issue, brainstormed the different types of users, helped create an empathy map with POV statements, made a problem statement, and planned out all of the functionality of the Cybot. Created an autonomous program for the robot to fully go around the fire to extinguish it. Also helped in creating a mapping feature to give the driver insight into what the Cybot is and has seen on the field.
Michael Hurley	Developed the application narrative story. Helped debug the autonomous program and was the main driver for the demo.
Ryan Foster	Created two prototype images, test field design, and developed a crude algorithm for our solution. Focused on writing the mapping code, and assisted in writing the fire detection and looping code.
Mina Khalil	Contributed to the project proposal by helping with the empathy map and POV statements, along with the problem statement as well. Also created a rectangle sheet made of tin foil to represent the fire zone within the field.
Angel Velez Villamil	Helped to come up with a final project idea and was the co-driver for the demo, helping to decipher the data received from the IR and Ping sensors and guide the driver. He also drew a physical map during the demo to help the driver know where they had been and a rough estimate of where objects, the cliff, and the boundaries were located.