Initial Project and Group Identification Document:

HeatSeekr

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Motivations

In our modern age of reinforced, synthetic materials, the threat of destructive fire remains a danger to residential, commercial, and industrial environments. Since the time of Ancient Rome, the ability to mobilize a response to unforeseen conflagration has been developed and engineered to minimize damage to property and life. Over time, these methods have increased in their efficacy and time response, culminating with the current four minute response times of firefighting personnel and the active fire sprinkler systems that seem to be ever-present in modern-day facilities which can activate in response to a fire's intense heat.

Modern fire protection systems are not without their faults. Firefighting personnel are summoned after a fire has reached uncontrollable levels, and given just a few minutes such a fire can cause enough damage to threaten any building. The philosophy behind manned fire protection is to contain the spread of fire, normally in units of households and office buildings. Such a philosophy is adequate, but not optimal. The household or office building that is lost doubtlessly holds incredible asset value in terms of technology, data, and in the worst case, lives that might be lost by the time a fire is detected and a response is elicited by external personnel. The same could be said of active fire sprinklers, as through normal operation they tend to cause damage to property and may destroy electrical devices and hard copy storages. Current incarnations of area treating fire sprinkling technology are frustrating solutions because of their lack of specificity: a kitchen fire in a hospital break room could lead to expensive MRI machines, chemical testing equipment, and other vulnerable technologies being doused in water and destroyed; the danger of moving critical or elderly patients in a panic scenario being present as well.

Given that response time and damage limitation are key aspects of fire prevention, an active system capable of on-the-spot fire retardation would be optimal. Such a system could be placed in fire prone areas of a building, such as a kitchen, or in areas where a fire or fire sprinkler system would prove disastrous for a company or residential area, such as any room where expensive technology is stored, or records are kept. An advantage to the active, specific fire protection system would be directed retardant on only emerging fires. Fires give off extremely strong infrared radiation in unique, flickering patterns that are, first, detectable without amplification by all cameras lacking infrared filters, and second, discernible with microcontroller-level processing. Through a system of actuators, a stream of fire retardant could be directed only at the source of the unique infrared signature. Thus the role of active, specific fire protection presents itself as realizable at low cost. Emerging building fires could be detected and eliminated without damage to, not only the rest of the building, but also to objects in the vicinity of the fire.

Technology that presents a specific, active solution to emerging fires is a natural continuation of our time-tested firefighting techniques. Affordable and effective on-the-spot fire protection could save millions in asset damage and potentially prevent human harm through the philosophy of fire retardation before such physical situations as intense heat and dense smoke present themselves to current fire prevention technologies. Careful and efficient design could result in a system that will eventually be as commonplace as smoke detectors and sprinkler heads in any fire-vulnerable facility; used in areas of high risk to prevent unneeded damage and loss.

Goals and Objectives

The primary goal of this robot is to detect a fire within a building and extinguish the flame before it turns into a larger situation. We intend to make this device fully independent and autonomous; however the few controls that is has will be intuitive and obvious for any reasonable human to operate. At this point we are still debating on a stationary, mounted design or a roaming "rover-type" design. Finally, since we are literally operating with fire, we are exploring various fireproofing techniques so the robot will be able to actually accomplish its job.

Fire gives off a very distinct infrared signature. We will be using a CMOS image sensor coupled with an IR filter to grab data from the external world. This data will then be fed into a microprocessor for image processing using the OpenCV libraries. Once enough thresholds are met, the microprocessor will determine it is in fact looking at a fire. The CMOS image sensor will work in conjunction with a forward-facing ultrasonic range finder to determine the base of the flame and the distance between the robot and the fire. Once this information is determined, the robot will angle the nozzle for the appropriate arc so the fire can be extinguished.

At this point we are unsure if we will use water or a gas like CO_2, although we are leaning heavily towards water. If we use water, we will have more explicit control of the extinguishing method since we can vary the pressure via a pump. Water is also easier to obtain and store, making the overall design and operation simpler. Unfortunately the amount of water we anticipate carrying will cause a weight concern that will need to be addressed. Additionally water is not a good option for all fires; grease and electrical fires can actually be made worse by trying to use water to extinguish them. If we utilize CO_2, our immediate plan is to equip the robot with a standard hand-held fire extinguisher and connect the hose to our aiming-system-nozzle. We would then have an apparatus to squeeze the extinguishers handle. The benefit of using a gas means we can extinguish a larger fire quicker. In addition, since a gas removes the oxygen of a fire, it will succeed on virtually all types of fires. One major drawback to using a gas is that our range is hampered considerably; in theory water can easily be shot across a room while a gas in the volume required won't go further than a couple yards. Using a gas also makes filling difficult since we'd have to partially disassemble the robot to retrieve the fire extinguisher so it may be refilled. This also creates substantially more downtime during refills and requires someone experienced with the robot to perform a refill, when compared to a simple water tank.

Ideally, our robot will have very minor controls. We intend to have a simple On/Off switch or button, a power LED, and an LED indicating the system has passed a self-test and the robot is ready to extinguish fires. We anticipate using Li-Ion batteries for power, which means we will also need a method of alerting humans of a low battery. The only real interaction that should be required is that human will need to turn the robot "On" and fill its reservoir, beyond that it should be fully autonomous. If we use a water system, the tank will have an obvious fill port and the robot will alert the human that it needs water before it can pass its self-test. If we use a gas system, it will likely be up to the human to ensure there is enough gas to operate.

When the robot detects a fire, it will sound a buzzer or siren alerting nearby humans of the fire. It will also call the front desk and play a pre-recorded message, alerting the main staff of the fire. If the fire is unable to be extinguished after a set amount of time, or the robot sees it has grown too big, it will dial 911 and play a pre-recorded message.

At this point we are unsure if the robot will be a mounted design that watches a set area like a hallway or a room, or if the robot will be a rover that can go to the location of the fire. A mounted design is simpler to implement but as it only watches a set area, its usefulness sharply drops. A rover is more versatile but we will need a system to notify the robot of the location of a fire. If we use a rover, we are pondering making it just roam the building. There are several ways to accomplish this roaming. It will have a range sensor on either side of itself and as it drives, it can center itself between two walls. Ideally, the robot will not need an internal map of the building, but rather will be able to cover the majority of a floor by simply roaming about. Pending research, if that system proves too troublesome to implement, the robot can patrol an area by following a line on the floor set down by a human. If we utilize a rover design, weight and size becomes major factors. Our robot will need to carry enough water to extinguish a fire, but not so much that it can't move itself. Additionally, the entire design needs to be compact enough to be unobtrusive and light enough that a human can pick it up. The moving rover design presents another challenge with power. At this point we're thinking the batteries will need to manually be disconnected by a human and charged; however we're exploring the possibility of a charge station to keep the human interaction to a minimum.

Our last major consideration is the environment we expect the robot to work in. Obviously this robot is meant to extinguish small fires before they become large fires, but it still requires some sort of fire protection. If we utilize the rover design, we're picturing the water tank making up the body of the rover, with the electronics situated in a depression in the middle of the tank, not in contact with the water. This should provide an adequate temperature control for the electronics. Additionally, the use of wood and plastic should be severely limited. Plastic may only be used if it is in direct contact with water, as the water will absorb heat faster than the plastic can.

System Function

We have a lot of ambitious expectations for our fire suppression system. Our first expected function of the system is to make it autonomous; in order to achieve that we have to figure out a way to design a navigation system for our robot. We are also considering making the robot stationary unless we can justify the reason for autonomy. In the center of our design we will have a microcontroller to receive information from different sub-systems. The microcontroller is responsible for sending signals to and receiving signals from the robot hardware. There will be a range finder communicating to the micro-controller to inform it on the robot's distance relative to its current location. This will be done using several sonar sensors. In order for the robot to determine its relative position, some kind of proximity sensing device is needed. After we considered all possible options, we chose an infrared system for its simplicity. We also considered other types of sensors that gives higher degrees of accuracy when measuring distance; however, infrared remains a simple and sufficient solution at a lower price tag. Once the range finder identifies its relative location the microcontroller will then be communicating with a drive system to help navigate through the office space in order to locate and extinguish the fire.

Our next function is fire detection; we are thinking of using a CMOS sensor to perform this task. We plan on performing some image processing by comparing different picture frames to tell us some information about the intensity and type of fire that needs to be extinguished. The CMOS sensor will convert the optical image into an electronic signal by capturing light and essentially turning the transistor on which will then be sending information to our micro-controller. An analog-to-digital converter will turn each pixel's value into a digital value so that our micro-controller can read and process the information. We chose the CMOS sensor because it can be implemented with fewer components, use less power, and also provide faster readout. Another feature that we wanted to add to our fire detection function is the ability to determine the four different types of fire before pursuing to extinguish the fire because our system would only be able to extinguish a type A fire which means we would have to know if the fire for example was an electrical fire; we hope to achieve this by recognizing the different heat range given off by the fire. We also thought about having a call alert system, in which 911 or the appropriate person would be alerted.

As far as the fire extinguishing mechanism, we contemplated on where the best placement would be, for our system. At the moment we went from using a CO_2 fire extinguisher to using water, which leads us to our robot design; A water tank. The idea is to make the body of the robot a water tank that would automatically pump water into our nozzle when it becomes low. The way we would find out when the tank is low, is by having some open circuitry going through the tank and once the water hits a certain level the circuitry would be close thus turning on and activating the pumping system. We plan on having servos connecting to our nozzle to help us with aiming and accuracy, servos are extremely small and light which would help in keeping our weight down, they are also very easy to control, the only downside is they are not fully rotational which means we are going to have to figure out a way to hack them, in order to get full rotation.

In order to make our system functional, we are going to evidently need power. Power is a critical part in our design. We need to be able to power the microcontroller, the servos, the range finder so on and so forth the tricky part is we need to achieve this task without overloading or supplying too little power to any components. We will need to add a heat sink and a regulator to prevent any possible overheating or overloading issues. We also might need several independent power supplies to isolate major components. With this separation it will allow us to run one component without worrying about affecting any other component. We also talked about using rechargeable batteries to help conserve our cost within the budget, not only will this be benefiting to our financial situation but keeping the batteries in rotation will give us the possibility to charge them constantly.

Specifications and Requirements

- Effective extinguish range of 1 to 20 feet with a detection area coverage of at least 90 degrees.
- Detection time under 30 seconds for fires appearing in set detection area.
- Ability to distinguish and disregard non-fire infrared sources.
- Initialization of fire-retardant dispenser within 3 seconds of fire detection.
- Operating time of at least 2-4 hours between fire events.
- Empty weight of no more than 25 pounds to facilitate transport and storage.
- Water capacity minimum of 2 gallons, with a potential 3.75 gallons for the rover design and 5.8 gallons for the stationary design.

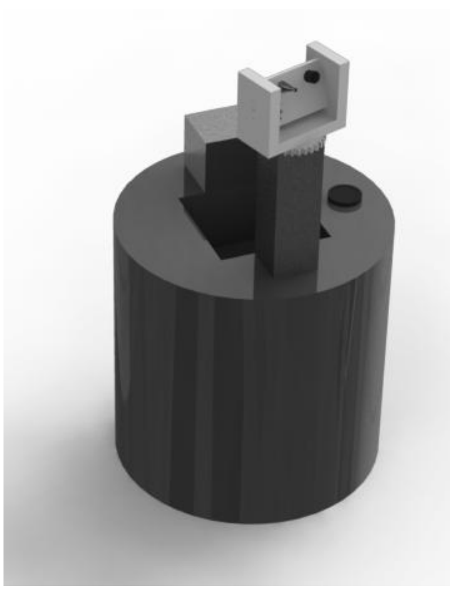

Figure 1: Stationary prototype render

Figure 2: Rover prototype render

Block Diagram

The block diagram shown in Figure 3 is the representation of all components that will be incorporated into the robot. The IR camera and range finder will be able to survey the area in front of the robot and send information regarding heat signatures and distance back to the microcontroller. The microcontroller will then process that information appropriately by using the aiming servos to aim at large heat signatures in accordance with the distance calculated by the range finder. Once properly calibrated, the extinguisher should emit a stream of water to neutralize any fires in the area. The power system will supply power to the microcontroller, and should light an LED so that any users can visibly see the power level available. Currently, the implementation of a drive system is under research. As shown in the dotted circle in Figure 3, the drive system would use information processed by the microcontroller from the range finder to estimate the distance needed to drive forward. Once the device is in a close proximity, the aiming servos can calibrate for the extinguisher to operate efficiently. All blocks are to be researched for further analysis and implementation.

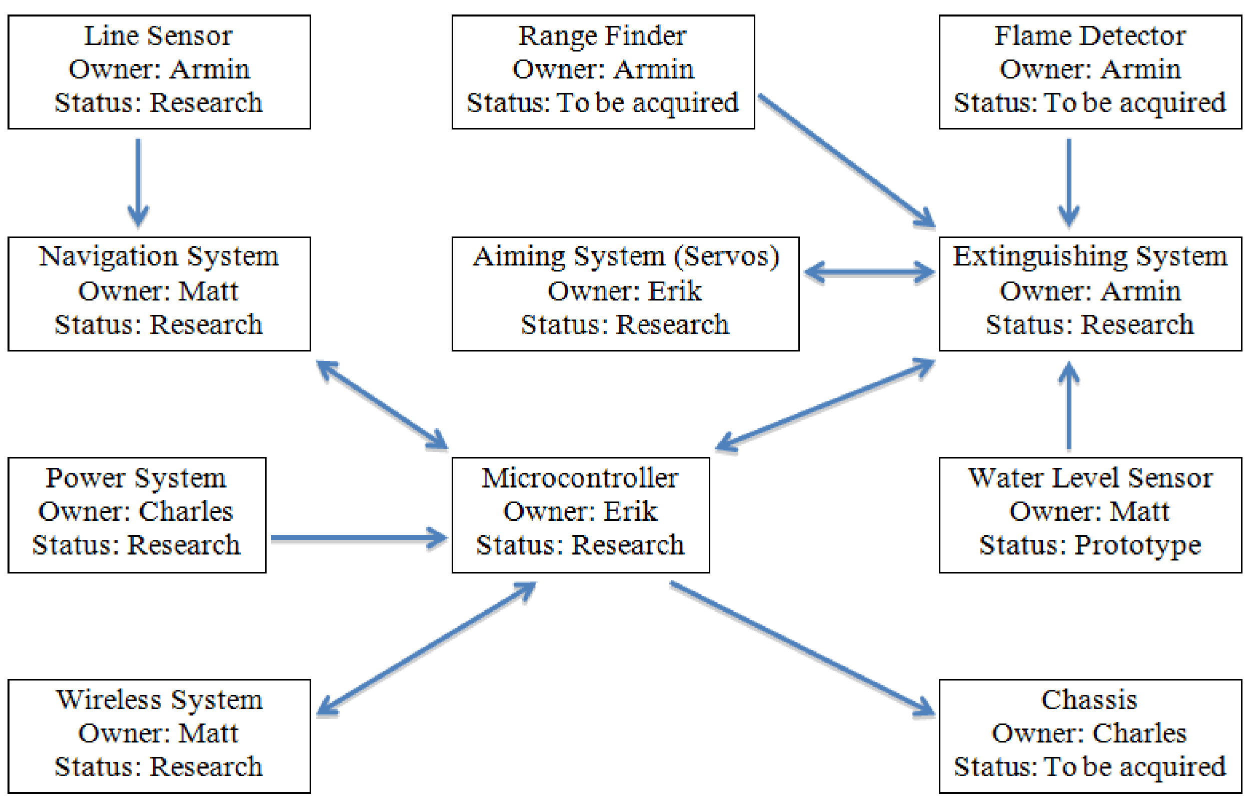

Figure 3

Budget and Financing

A calculated estimation for the projected budget is shown in Figure 4, and will be paid for by the primary members of group A. This projected budget has been created by selection of various parts that could be considered for a project prototype. Various optical sensors, such as the infrared camera and rangefinder, have been calculated to cost around $20.00 to $30.00 dollars each. A battery and power system will be further researched for possibility of creating an easy to charge power supply for less human interaction. The main component of the project will be the MSP430 microcontroller with connection points onto a custom board to be designed after further research. Should the robot require further processing power, a stronger microcontroller could be used instead. The LEDs will allow for notification of power supply and on or off status. The outer protective shell will be the main chassis of the robot, and also serve as the main storage component for water. If the water pump is not capable of creating a strong enough force to disrupt a small fire, then a fire extinguisher will become a necessary component. The aiming servos will be needed to adjust nozzles from the extinguisher to the correct location of a flame. The drive system controller and wheels are a desired ability; however, functional use is currently being further investigated. As it stands, the budget is projected to include a driving component.

Projected Budget	
Part	Estimated Cost
Infrared Camera	$30
Rangefinder	$30
Battery	$20
Power System	$30
MSP430 Microcontroller	$10
Custom Board	$200
LEDs	$10
Outer protective shell	$20
Fire Extinguisher // Water pump	$30
Aiming Servo	$20
Drive system controller (optional)	$10 (optional)
Wheels (optional)	$20 (optional)
Total	$400 ($430 with drive system)

Figure 4

Project Milestones

For this project to be successful, minimum project milestones are listed below:

1. Initial project design involving all basic requirements and level of control.
2. Selection and implementation of an IR camera subsystem.
3. Selection and implementation of a rangefinder subsystem.
4. Selection and implementation of a water system to be used as the fire extinguisher.
5. Implementation of a nozzle servo subsystem for accurate aiming.
6. Completion of a working interface connecting all subsystems to the microcontroller.
7. Ensure all coding is configured and subsystems can interact with each other.
8. Test the prototype and verify that all system requirements have been satisfied.
9. Create the finalized prototype.

All project millstones are subject to change over the course of further research and development.

Decision Matrix

	Stable version	**Drivable version**
Usefulness	3	2
Scalability	2	2
Budget	3	2
Feasibility	3	2
Amiable	2	2
Research	2	3
Market	2	2
Wow factor	1	3
Total scores	18	18

As mentioned throughout this document, a drivable rover represents a system with increased complexity and potential for design. For the purpose of fire prevention and extermination, it is hard to justify the increased power, budget, and computational considerations such a path would entail. A stationary platform is a more efficient solution to spontaneous fire, but objectively presents a less challenging set of features in terms of implementation and function. Further research into similar projects and stronger definitions of purpose, scope, and, in the end, desire, should lead to a decision on this design parameter.