Project Proposal

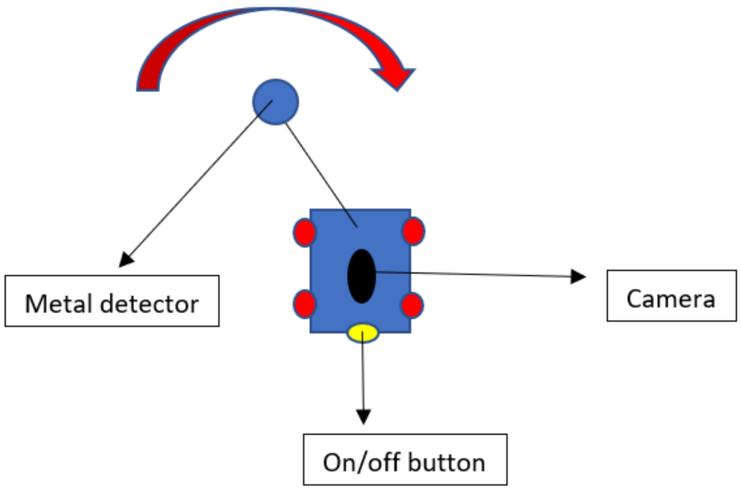
1. Introduction

1.1. Problem

Metal detection is designed to benefit humans in various aspects. In daily life, people usually lose something by accident, and it could be keys to houses or cars. However, sometimes these objects will be too difficult to find, and can take up a lot of free time if the task was to be performed manually. In industrial regions, metal detection is also important as to seek potential lost construction components. However, given the danger of the construction site, losing parts and seeking them will pose potential hazards for humans. Thus, robotics developed specifically for metal detection is in need. However, currently most robots used for metal detection implement manual control to search for objects, and it takes a long time if the field of interest is large, and it still requires human control or otherwise, it will not have directional searching progress. Thus, a new automated robot design with the function of searching for potential metallic objects efficiently will potentially be needed.

1.2. Solutions

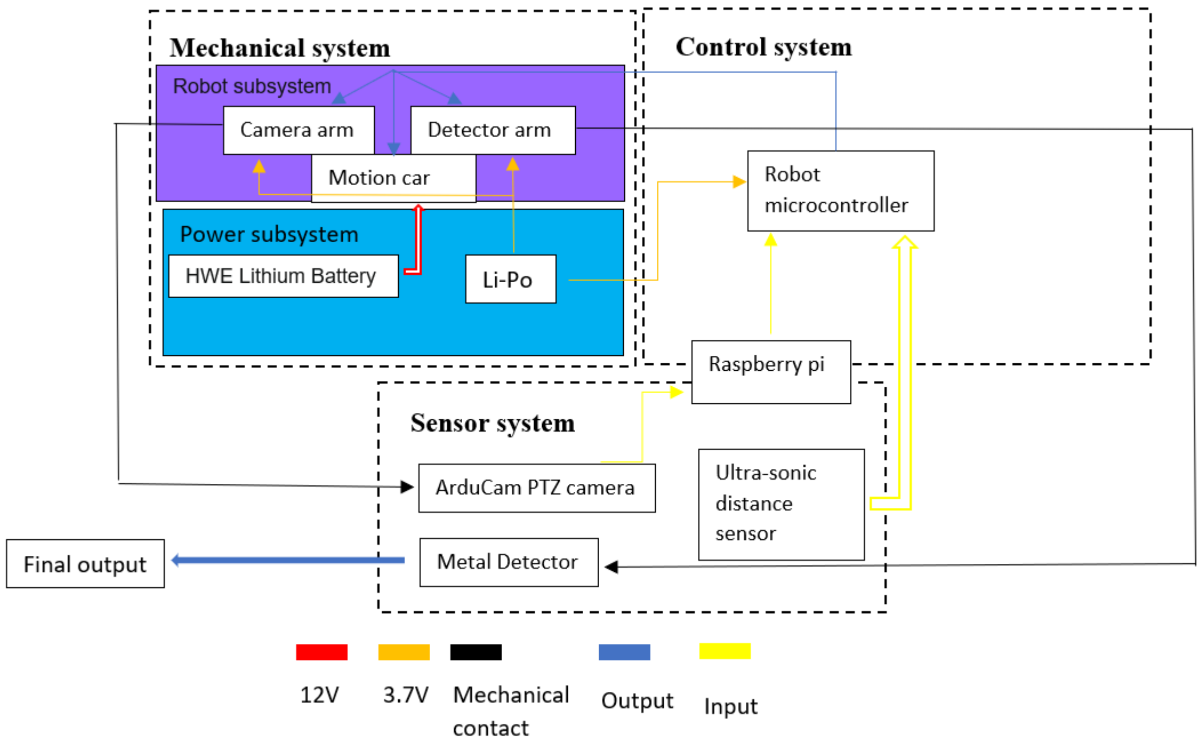
To design a robot that can search for metallic objects within a specific field without human control, we propose to use an optical camera as the eye to the robot which indicates potential candidate places (like blocks of stuff where small objects may hide). To be more specific, we will program the robot's movement using algorithms similar to random walk, but not exactly random. The optical camera serves as a way to capture essential spatial structures within the field of interest, by signal processing, we will afterwards use these signals to command how the robot will move. It thus uses the route determined to automatically search for the metallic object with a metal detector thoroughly within each of the regions divided within the field of interest. To be more specific, we want the robot to move towards places with the "most likelihood" being the host to the target metallic object. Finally, when it detects something, the optical camera again serves as a recognizer to eliminate some false positives. This solution requires signal processing, and essential programming to the robot to make it move, we may need some experiments to implement different algorithms. To reduce the manual control we will need for the robot, ideally, we will only need an on/off switch for the robot to change its operation.



Considering the solutions we have above, there are several high level requirements that are needed to successfully implement this project:
1. Robot's basics, including moving algorithms, robotic arms design, and sufficient power supply, should be accomplished. (mechanical functionality)
2. Having the ability to recognize images captured from the optical camera. (visual/determination functionality, or eye/brain functionality of the robot)
3. The metal detector should be able to detect the metal objects from a relatively reasonable distance (at least 15 cm). (sensing functionality).

2. Design

2.1. Block diagram of the design



2.2. Subsystem overview

The mechanical system includes power, robotic arms, motors, and actuators (which will be used mostly for the motion car). For the power subsystem, we will consider two parts which may require different power sources. For the robot itself, especially the robotic arms, we consider Lithium Polymer Batteries (Li-Po), which are lightweight, have good capacity, and sufficient voltage for most electronic components (3.7 Volts). For the carrier which we plan to use with a motion car, to have enough power for long term utilization, we plan to use HWE lithium battery to have enough power (420 Wh) and voltage (12 Volts) for motion. We can also consider the metal detector's power in this section, but depending on the type of detector we choose at last, we will have different preparations: for example, one cheap economic "9 Function Metal Detector With ArmRest" in Harbor Freight store uses 6 AA batteries, and some others use USB charging, therefore, we are not concerning them in this mechanical system. Overall, the choice of the metal detector will depend on our needs once we enter deep into the project. The optical camera may have its own power methods (like cable charging), so we will not consider them here as well. For the robotic subsystem, like robotic arms, motors, and actuators, we expect at least one robotic arm used for metal detector handling, and one small controller for our optical camera. Both parts should be able to rotate freely in the horizontal plane so that we have the control to search thoroughly within a flat region. Some vertical direction control may need further parts to gain advanced control. For this project, we mostly focus on the horizontal plane to gain initial implementation.

The control system is the heart of the design, which relies on our ability to translate the signals from the camera to control signals that will be sent to the robotic systems (the robotic sub-mechanical system above), and thus, we will need a microcontroller which is capable of processing data efficiently to perform the task afterwards. The microcontroller should have inputs associated with the angle of the robotic arms (angle information is needed to control the 2D movements), camera (signal processing to output a 1 or 0 signal, combining with angle signal to determine if the robot should move towards that direction). Considering 2D signal processing tasks to be performed, we will need a large enough memory for our microcontroller, or an extra external device having sufficient memory to process the images. Typically we have considered using AT32UC3A3256 for efficient and compact design for robot microcontroller and raspberry pi for the specific task of image processing which then generates signals for the microcontroller for integration. The alternative is to process data using other interfaces (computer), and send the processed and simplified data back to the microcontroller to perform tasks we desire. However, currently we prefer the idea of Raspberry pi combined with a microcontroller so as to minimize the external condition needed to operate the system.

The sensor system is the eye for the robotic system which consists of three components: Metal detector, optical camera, and an ultrasonic sensor for more refined control. Metal detector as we have described in the mechanical subsystem, uses the economic metal detector from Harbor Freight store (70 dollars). Since this detector has a small detection range, we may have to switch to a more advanced detector. But overall, this should not be a limiting factor for this project as we have the core to be the optimized route determination. The metal detector serves as one determination end to receive signals to trigger detection when the object is close enough. Optical camera assisted with an ultrasonic sensor is used for obtaining and transmitting data to the control subsystem to generate accurate control signals for the mechanical system. It also serves as the second determination end along with the metal detector to eliminate false positives. We have considered cameras similar to the ArduCam PTZ camera which is both economical (50 dollars), programmable, and flexible enough (apart from horizontal control, but also vertical direction to focus) to scan a reasonable amount of spatial information.

Overall, the entire design depends mostly on integrating the raspberry pi and microcontroller systems with multiple sensors. We plan to use the PCB to create connections between the microcontroller input and raspberry pi output using digital (High/Low signals) while simultaneously managing analog signals from the IR signal and the sonar which identifies metal detection. We would also need to manage the feedback loops, the microcontroller and different sensors to control the robot’s motion and orientation. This product is very difficult to simulate as it’s dependent on signals operating in tandem and solving the resulting mathematical calculations would take a few months at the undergraduate level. We can simulate parts of the project such as showing how the image classifier would work in real time using python modules like tensorflow on Jupyter notebook and simulate the power circuit on LTSpice.

3. Ethics and Safety

The design consists of multiple components that could pose hazards such as a powerful battery to support the motion and operation of the robot for a significant period of time. We are planning to use a lithium polymer battery combined with a typical lithium battery which could end up posing a chemical hazard in the remote and unlikely case that the robot crashes thereby damaging the battery.

In addition, as mentioned in the previous section, we plan to use an optical camera to generate control signals to support mobility and function. This could be viewed as an invasion of privacy in case the camera captures any object, image etc. that was meant to be private in residences as the camera we end up picking might have a 3D view of the surroundings which can be implemented by enhancing a servo to function as the rotating base upon which the camera will be placed. To mitigate this issue, we might(if time permits by the end of the project) design a machine learning algorithm to interrupt the recorded video frame by frame and identify any objects whose appearance on our recorded video might infringe the privacy of the resident or corporation whose building the drone is currently operating in and blur such objects frame by frame automatically before the video record is stored or transmitted beyond the camera so as to protect the privacy of residents.

As we're using a lithium ion based battery, we would like to confirm that we have read all the State, National and university regulations and safety procedures provided by the university at https://courses.engr.illinois.edu/ece445/documents/GeneralBatterySafety.pdf

Which contains instructions on how to identify faulty and dangerous situations where a lithium ion battery could malfunction and have also read and understood the safety procedures such as using an IC to regulate power and getting our charging circuit design approved by a "power centric TA's after getting a good simulation run on LTSpice. We are aware of the different situations and the appropriate response to each situation when a battery hazard occurs for example, in case the circuit breaker trips, the appropriate response would be to report it to the ECE-shop-repairs or call Casey Smith.

Our plan for the 12 V Lithium ion battery is to design a power circuit after consulting professor Schuh and then proceed to simulating it on LT spice and getting it approved by the TA before we actually connect our battery to any of the components.

Lastly, we have completed both the online safety training and have reviewed the instructions located in the link I've provided in the previous paragraph regarding Chemical spills(Cleaning it using the Chemical safety kit located in the back of the lab) , fire hazards (calling 911 immediately) and the appropriate method to dispose depleted/damaged batteries(Calling Casey Smith).