Project Deliverable D

Conceptual Design

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GNG1103 Project Group 6
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Abstract

On Halifax-class frigates, the Department of National Defence has a need for a robotic arm that uses inverse kinematics to paint surfaces. The robot must also scan and clean areas to identify and remove defects. To design the robot, a design process with several steps will be followed. Thus far, raw data about the product has been gathered from one of the users and interpreted to identify user needs and design criteria. At this stage in the design process, concepts must be designed for a meeting with the client. This report presents a set of subsystems that were broken down into smaller sections and conceptual designs. The design ideas were then analysed based on the design criteria created in Deliverable C, and the design that best satisfies the criteria was chosen to be developed in future work.

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1.0 Introduction

The Department of National Defence expressed the need for a robotic arm with three degrees of freedom to paint areas on Halifax-class frigates. Raw data was collected from the client and analysed to identify the needs of the user. The needs were then prioritised, and design criteria were produced from the interpreted needs. Conceptual designs were created based on the design criteria produced.

2.0 Subsystems

The subsystems of the design are smaller sections of the robot that are different from one another. Categorizing the project into smaller components makes the design process more structured. After discussion within the group, three subsystems were unanimously identified:

1. Software
2. Hardware
3. End-effector

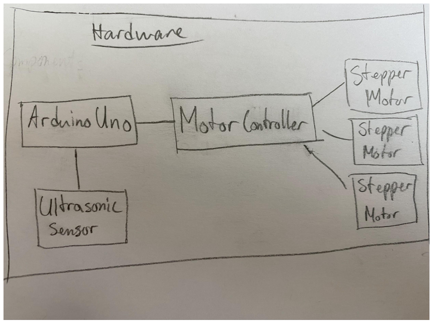
With the aim of finding the best structure for the subsystems, each team member designed a concept for each subsystem and presented it to the rest of the team. With multiple design ideas, the team then discussed the positive and negatives aspects of the designs, based on the design criteria, and created a new design that takes the best ideas from the individual designs.

It is important for the boundaries between the three subsystems to be defined because if one subsystem is changed later in the design process, it will not change the conceptual design of the other subsystems.

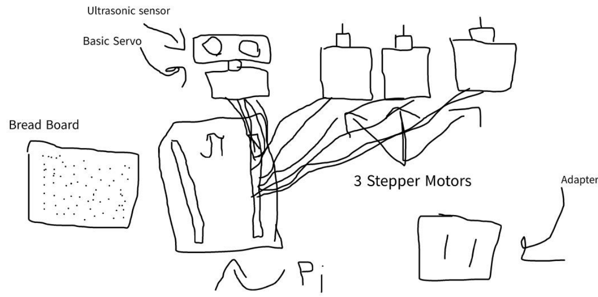
3.0 Hardware

The hardware subsystem encapsulates the physical components of the entire system, excluding the end-effector. Conceptual designs of this subsystem consist of different combinations of hardware parts.

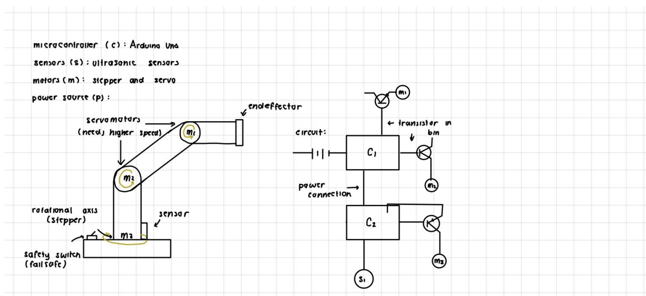
Paul:



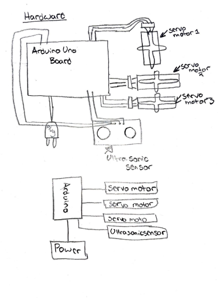
Ani:



Christy:



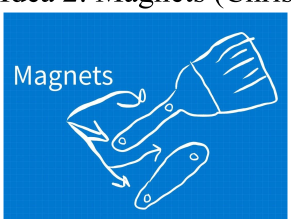
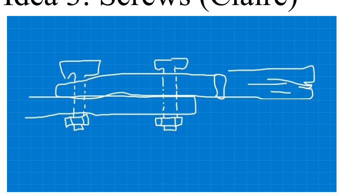
Claire:



Microcontroller	Arduino Uno Pros: - Familiar with Arduino - Lots of resources and large community online - Easier to use and more user friendly Cons: - Less powerful and has limitations	Raspberry Pi Pros: - More powerful and has more capabilities within one microcontroller Cons: - Group members not familiar with Raspberry Pi (requires more research)
Sensors	Ultrasonic Pros: - Can detect areas within distances Cons: - May interact with other electronics	IR Pros: - Able to detect movements and objects in area Cons: - Detects movements
Motors	Stepper - Less expensive - Cannot be maintained at high speeds	Servo - Can be maintained at high speeds - More expensive - Less prone to error due to internal feedback system - Large in size (heavier) - Requires an encoder and gearbox for more accurate control - Pulsates and vibrates in standstill position

4.0 End-Effector

The end-effector subsystem designs explore different ideas of possible end-effectors. In this section, sketches of different end-effectors are tabulated with several brief comments on advantages and disadvantages of each idea.

Idea 1: Clamp (Ani)  In this system, a clamp is used to hold down both sides of the brush and attached to the arm	Pros: - Simple - Brushes are interchangeable - Inexpensive	Cons: - Constant clamping force required to avoid dropping brush
Idea 2: Magnets (Christy)  Similar to a screwdriver with switchable heads, a magnet is attached to the paint brush and to the end of the arm	Pros: - Easy for user to place brush in end-effector	Cons: - Effect of gravity on the brush (weight vs strength) - Equipping paint brush with magnet
Idea 3: Screws (Claire)  Holes are drilled into the paint brush and attached to a rod that is attached to the arm	Pros: - Strong mechanism to hold paint brush in place	Cons: - Not interchangeable for different ends - Requires tools to change different brushes/ends
Idea 4: Pressurised Nozzle (Paul)	Pros: - Covers a larger surface area - Faster than painting with a	Cons: - Expensive - Requires different amounts

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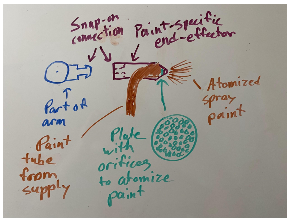
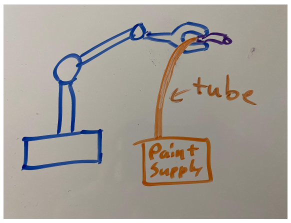
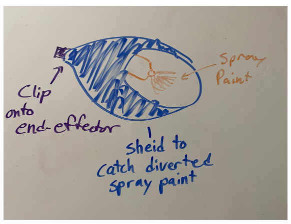
<td>





A clamp attached to the end of the arm is used to apply pressure to the nozzle</td>
<td>brush
- More consistent painting</td>
<td>of pressure from the clamp holding the nozzle</td>
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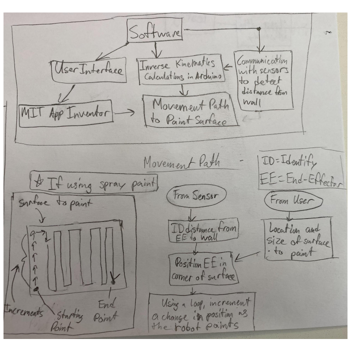
5.0 Software

The software subsystem is responsible for a lot of the characteristics of the robot. Since it is difficult to create concrete designs of code, the designs in this section are more conceptual and discuss important functions that the software must be able to accomplish.

Paul:



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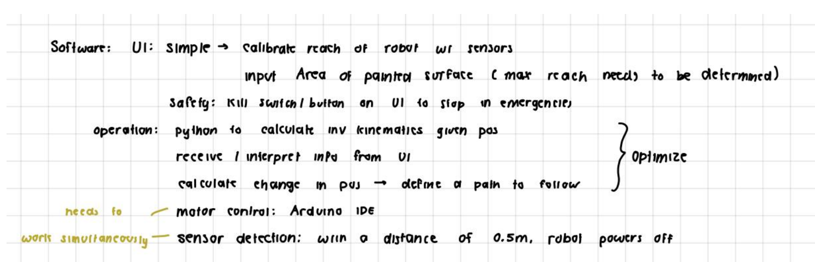
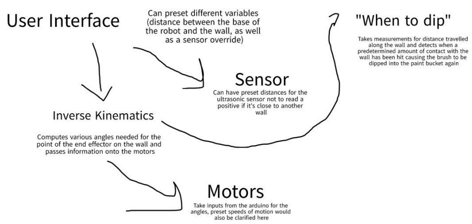
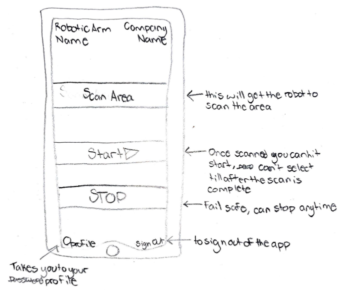


Ani:



Claire:



6.0 Selection Matrix

	Arduino Uno	Raspberry Pi	Ultrasonic Sensors	IR sensors	Stepper Motor	Servo Motor	Clamp	Magnet	Screws	Pressurized Nozzle
Light for transport										
Ease of use										
Compact ($1m^2$)										
Safety sensors										
Supports a maximum of 1 kg										
Can withstand 8 bar of pressure										
Budget of $100										

7.0 Analysis

In this section, the selection matrix will be used to consider design ideas for each subsystem and produce three solutions for a final design. Further analysis will be done to identify the best of the three solutions.

7.1 Solution One

Software-

- Use of python for calculations
- Kill switch
- Easy user interface

Hardware-

- Stepper motors
- 2 x Arduino Uno
- Ultrasonic Sensor

End Effector-

- Clamp

One arduino has few pegs and may not be able to provide enough power to all the hardware components. This solution avoids those problems by using a second arduino.

The use of an ultrasonic sensor would reduce the amount of interaction required from the user because the robot would position itself at a specified distance from the wall to paint properly. Without an ultrasonic sensor, the robot would not have information about the location of the wall and would rely on the user to position it correctly.

The clamp end-effector is the simplest solution because it does not require much setup from the user and there are few parts that could cause errors or need maintenance.

Stepper motors are effective at low speeds, which is sufficient for this project. Stepper motors are also relatively inexpensive compared to other direct current (DC) motors.

A kill switch is a safety feature that is useful in case of emergencies because someone can manually turn off the robot if it is malfunctioning, or if a person gets stuck in close proximity to the robot.

7.2 Cost-Effective Solution

Software-

- Arduino for inverse kinematics
- Code for infrared sensors

Hardware-

- Stepper motors
- Use of a single arduino
- No ultrasonic sensor to detect difference from the wall

End Effector-

- Screws

This solution uses the most cost-effective materials. One arduino is used instead of two and stepper motors are included instead of the alternative servo motors. With this design sensors to detect the difference from the wall are not included to further decrease the cost. The end effector would be simple to use and effective, since it only uses two screws. While still using arduino for inverse kinematics and code for infrared sensors this solution is the most cost effective.

7.3 Solution Three

Software-

- Use of python for calculations
- Kill switch
- Easy user interface

Hardware-

- Servo
- Infrared sensors
- Adapter
- Raspberry Pi

End Effector-

- Spray nozzle

This solution offers variety in case the User prefers the spray nozzle end effector option. This solution also uses Raspberry Pi which is a more powerful motherboard, and the group will have an easier time using python for the inverse kinematics equations over coding the kinematics in Arduino. The servos would be more sensitive to small changes in movement allowing for greater control and precise movements over the stepper motors.

7.4 Final Solution

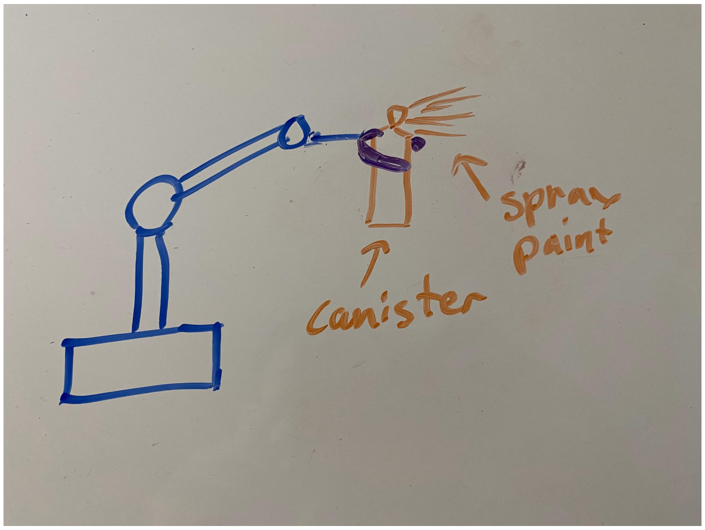
The final solution chosen is Solution One. While it may be more expensive than solution 2, from a technical aspect, solution one is the ideal choice. It uses two Arduino Uno microcontrollers to ensure that enough power is supplied to the parts of the robotic arm, while the cost-effective solution only uses one Arduino board. Solution One also utilises ultrasonic sensors to guarantee the safety of those around the robot and to detect objects within the vicinity of the robot, while Solution Two does not have any sensors. The end effectors on both solutions are similar in cost, however, the clamp is a better option, since

it is simpler to set up and does not require the use of other tools, such as a screwdriver when compared to Solution Two.
When comparing solutions one and three, solution three is also a feasible option that uses a more powerful microcontroller and the spray nozzle end effector. However, Solution One uses ultrasonic sensors that are able to detect objects within a distance, while Solution Three uses infrared sensors which are able to detect individuals, but unable to detect distances and other nearby objects. Solution One is also more cost effective than Solution Three.

8.0 Conclusion

The Department of National Defence has a need for a robotic arm that uses inverse kinematics to paint surfaces. In this deliverable, design criteria identified in Deliverable C were used to formulate conceptual designs for separate subsystems. The designs for the subsystems were analysed and combined to create a final design for the robotic arm. Moving forward with the project, a cost analysis will be performed on the finalised system.

Appendix: Other Design Ideas



This end-effector design uses a canister of spray paint. This design is simpler than a nozzle, but more wasteful.