Project Deliverable D - Conceptual Design

GNG 1103 Group C03

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Wrike Link: https://www.wrike.com/open.htm?id=824968763

Introduction

John Faurbo and the Royal Canadian Navy need a robotic arm that has the ability to detect, remove and paint over corroded areas to ensure proper maintenance on the Halifax class warships. Our team will be creating a solution to John's problem according to their conceptual needs and requirements.

In this deliverable, we will explore the different concepts belonging to 5 subsystems that will collectively join to form a final functional solution. We have divided our functional solution into five different subsystems including the user interface, the three end effectors, and the overall coding and programming of the robot. Each team member is responsible for generating ideas for each subsystem, discussing boundaries and relationships between the subsystems so the concepts are interchangeable in the final solution. From our individual ideas, our team created a selection matrix by discussing the requirements, similarities, and drawbacks and created three fully functional solutions and compared the global concepts with respect to our design criteria. The best solution is chosen, from which we will present to the client for feedback.

The end effectors are designed with respect to each task needed to be completed according to the design criteria. It is ideal for the arm to be able to translate efficiently and effectively from each position. Each position is then associated depending on the specific end-effector. To ensure portability and mobility, we have included "resting pose", where the arm will return in a compressed manner to help with transportability. These poses are achieved through inverse kinematics in a code later described in this deliverable. The inverse kinematics schemes are done in a 3D plane to achieve the three degrees of freedom in the x, y, z plane. Three rotational matrices can be calculated to define the precision in space associated with each end-effector pose.

Subsystem 1: User Interface

The user interface will be the screen the technician is looking at while they are operating the robotic arm. This will be made after the effectors and code are working and will ensure that it is simple and easy to learn and use.

Concept 1.1: Benoit Tremblay

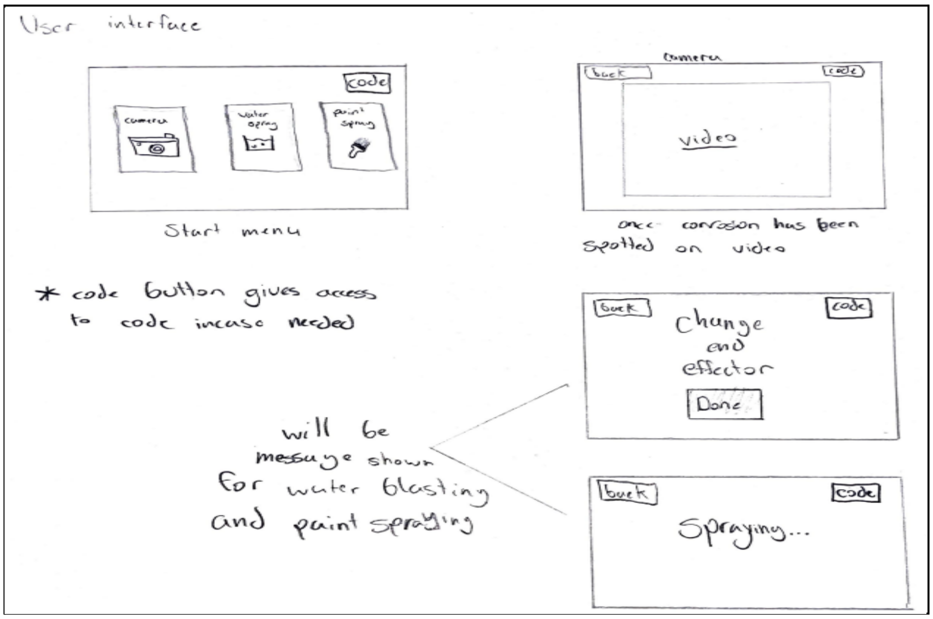


Figure 1. User interface with video and code access

Concept 1.2: Rebeca Poulin

The user will essentially need minimal action and will be able to choose an option from a different location than where the robot will be. There will be a USB serial connector that can input each option associated to a specific pin to a displayed option on the device.

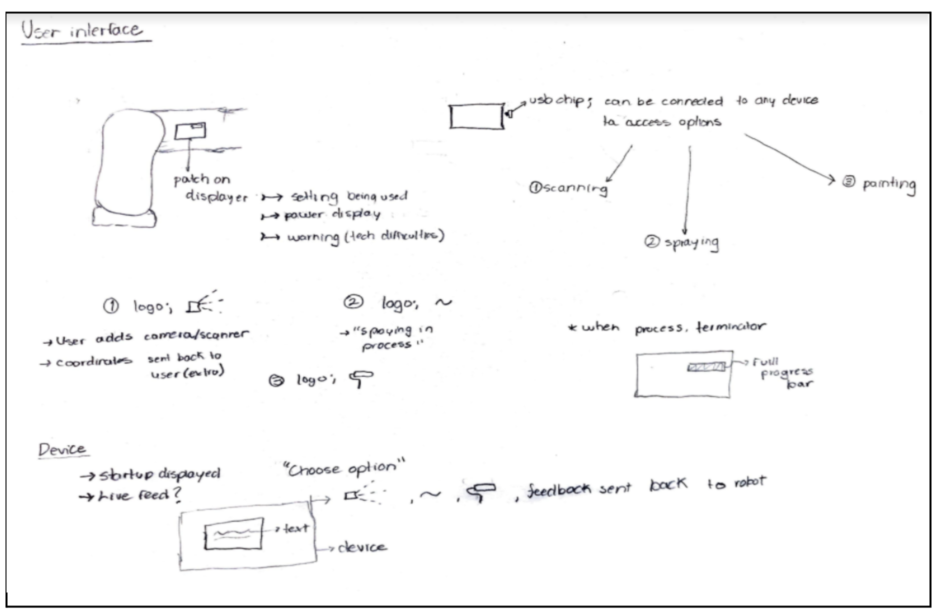


Figure 2. User interface with logo design and progress bar

Concept 1.3: Jess Beardshaw

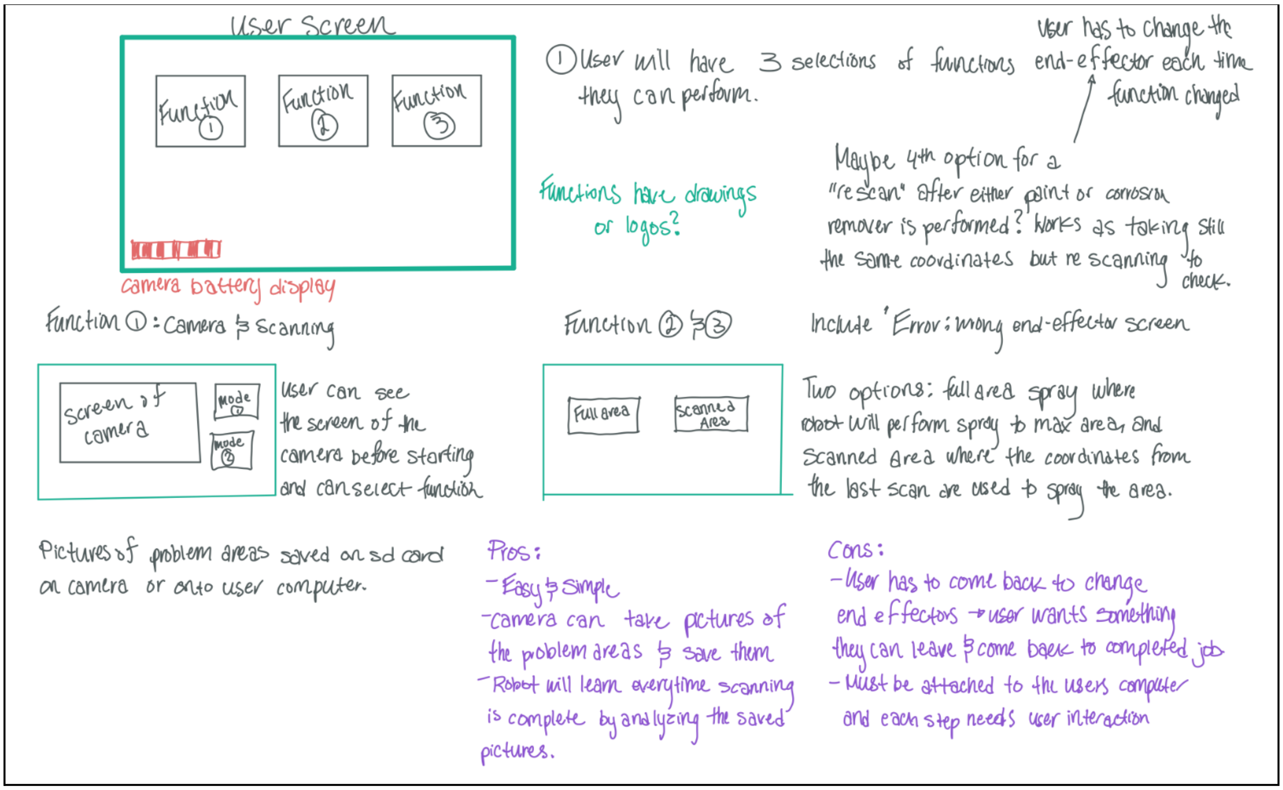


Figure 3. User interface with learning and rescaning ability

Concept 1.4: Isabelle Barrette

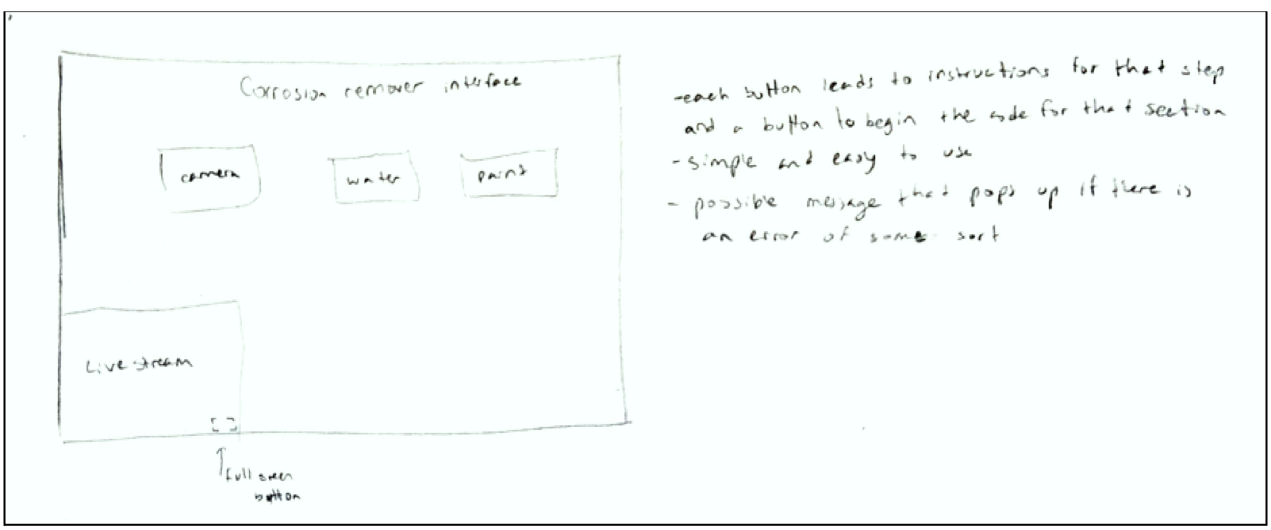


Figure 4. User interface with easy instructions and error message

Concept 1.5: Sarah Alkadri

This user interface contains three options upon turning on the robot being, camera, draw/paint, and water. These correspond to the various end effectors and tasks the robot should be able to complete. Upon clicking on the camera button, a video recording and a picture button will appear to allow for the user to view the corrosion and take pictures to allow for further analysis. Once the draw/paint button is chosen, the input screen will appear to allow the user to input the x,y,z coordinates as well as a simulation of the robots workspace and the maximum reach of the robot to allow the user to position it correctly. The following screen allows the user to understand when to change the end effector and when the robot is working.

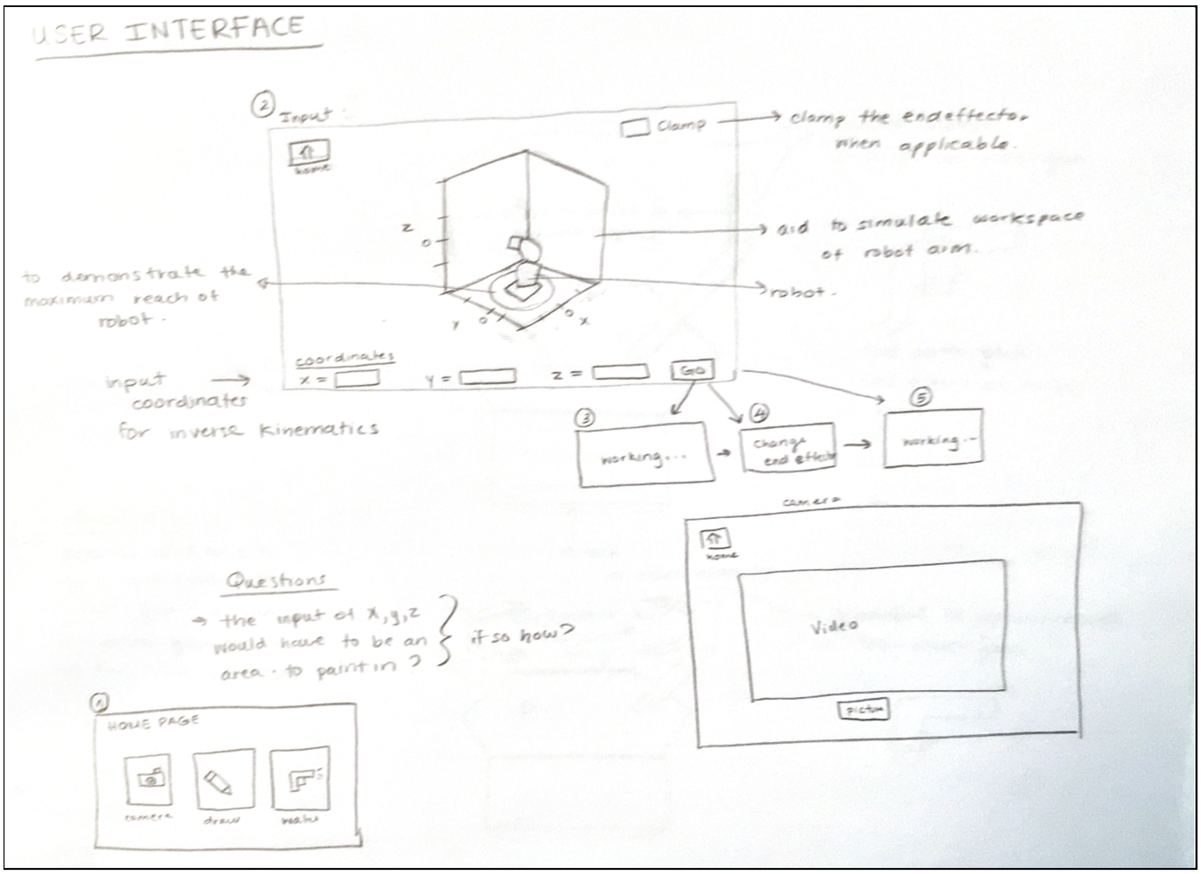


Figure 5. Visual user interface with coordinate input and video picture

Subsystem 2: End Effectors (Camera/sensor)

This subsystem is the ability to find/detect the rust with the use of a camera or a sensor endpoint. The code will enable the robot arm to move around looking at piping, walls, floor, ceiling, etc. and will be able to detect corrosion to then begin the process of removing corrosion as well as painting over the affected area with anti corrosion paint. Here are links to camera modules that are compatible with arduino uno online.

1. WaveShare OV9655 Camera Board (25.99$, ships March 7th-28th)
2. Arducam 2 Megapixels MT9D11 (35.26$, ships Feb 24th-March 8th)
3. Arducam Mini Module OV2640 2 Megapixels (25.99$, ships 4-6 weeks)

Some of these products might take longer to ship than what the time frame allows us so our decision will be based on cost of the module, availability and the quality/effectiveness of the module itself.

The sensors will be used to detect if there is someone in front of the robot arm to stop the process for safety precautions. Most likely each endpoint (or atleast the paint and water one) will contain sensors which will stop moving to keep the user/person in area safe whilst not wasting materials (water and paint) Below are 2 sensors found that are directly compatible with arduino and do not require any saultering to connect either, they are pin connected.

1. Onyehn IR Pyroelectric Infrared PIP Motion Sensor (10.89$ for 2 sensors, amazon prime 1 day shipping)
2. XINGYHENG 5Pcs HC-SR505 Micro Body Sensing Module PIP Motion Detector (16.35$ for 5 sensors, amazon prime 1 day shipping)

Concept 2.1: Benoit Tremblay

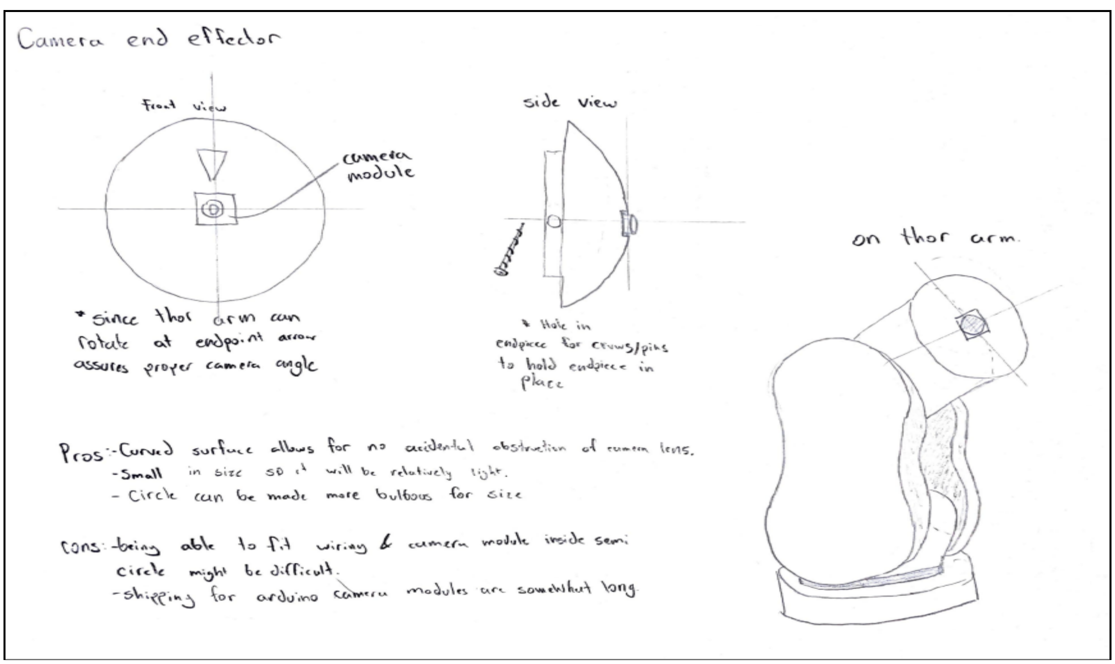


Figure 6. Curved camera end effector with screw connection

Concept 2.2: Rebeca Poulin

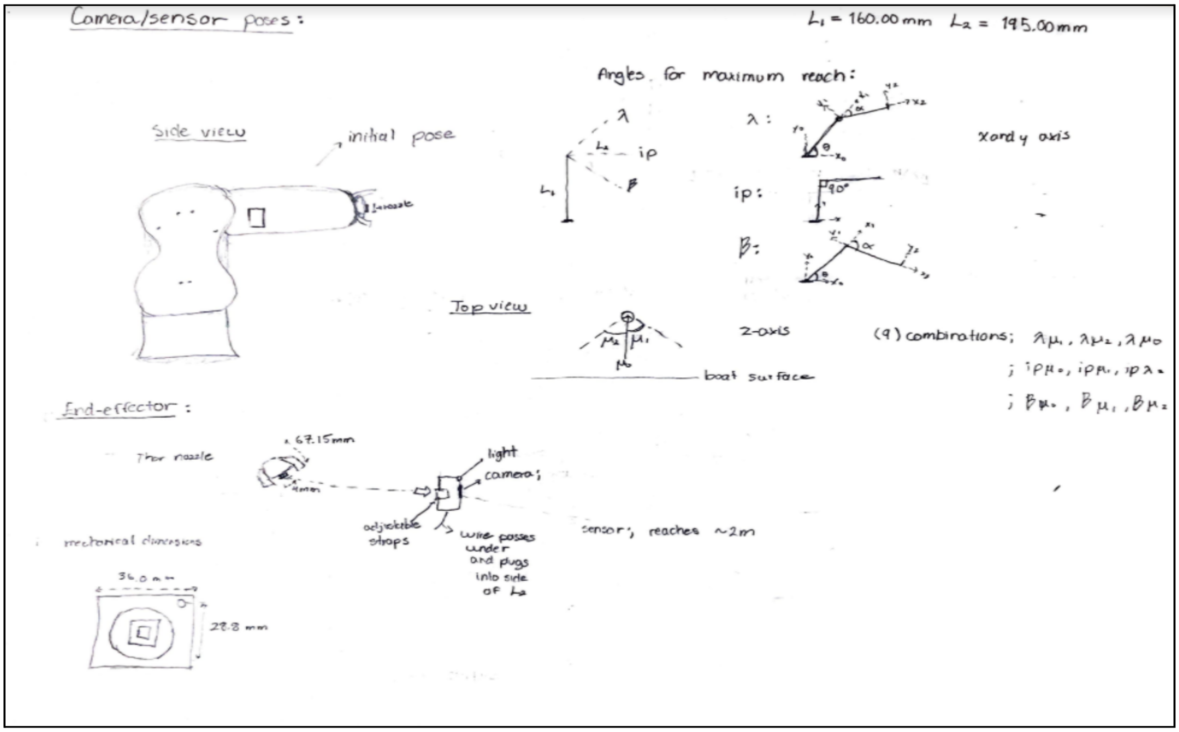


Figure 7. Multi-combination camera position end effector with dimensions

Concept 2.3 : Jess Beardshaw

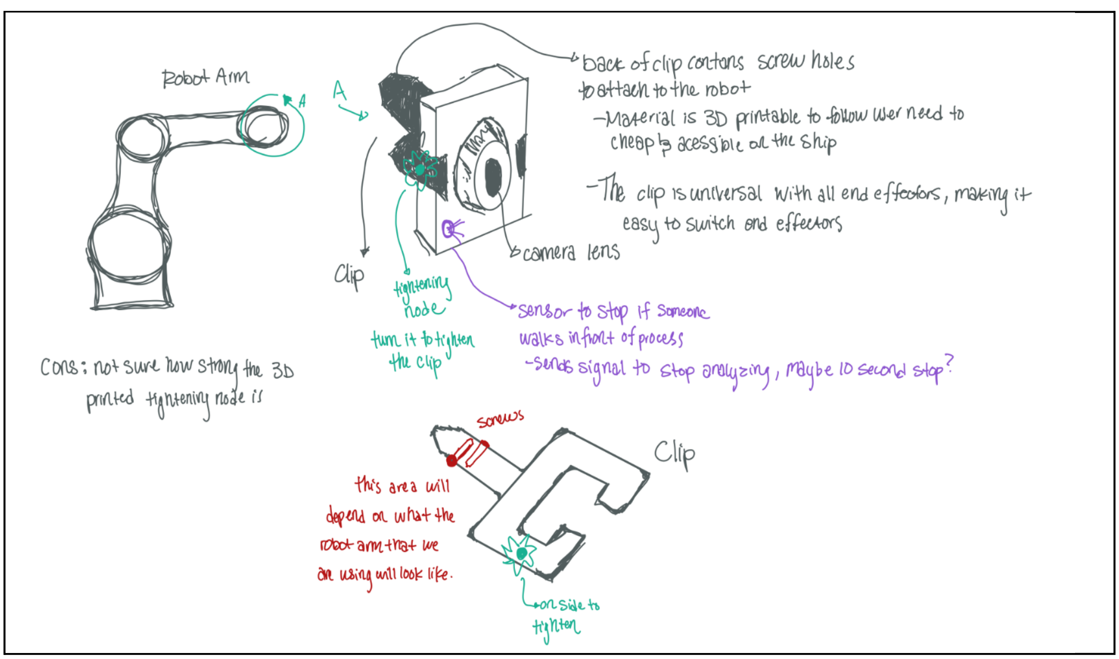


Figure 8. Camera end-effector with universal clip attachment

Concept 2.4 : Isabelle Barrette

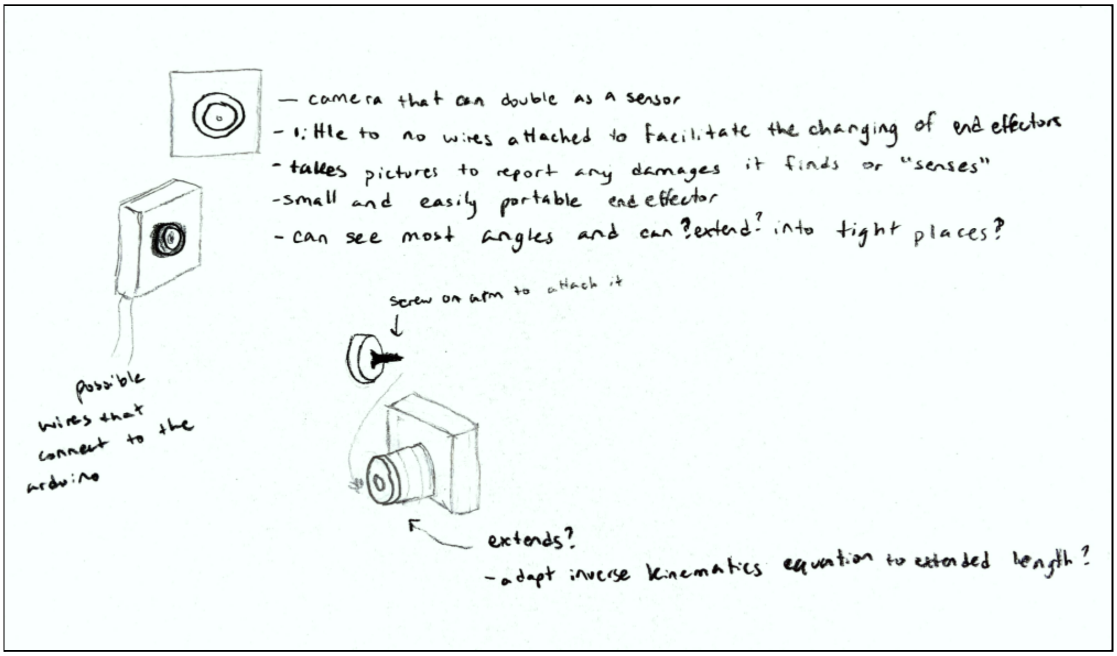
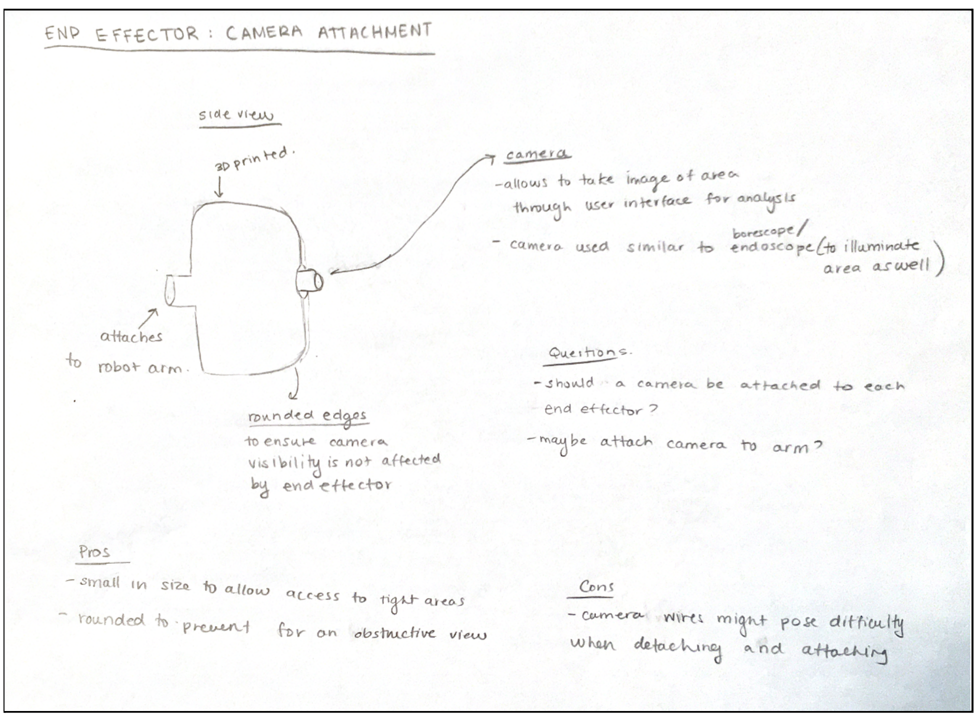


Figure 9. Portable camera and sensor with extendable lens

Concept 2.5: Sarah Alkadri



The camera will be attached within the 3D printed end effector. The advantages to this approach would be to small size to allow access to hard to reach areas; a disadvantage would be the wires that would have to connect to the arduino to power the camera.

Figure 10. Round endoscope camera end effector

Subsystem 3: End Effectors (Corrosion remover (water))

Concept 3.1: Benoit Tremblay

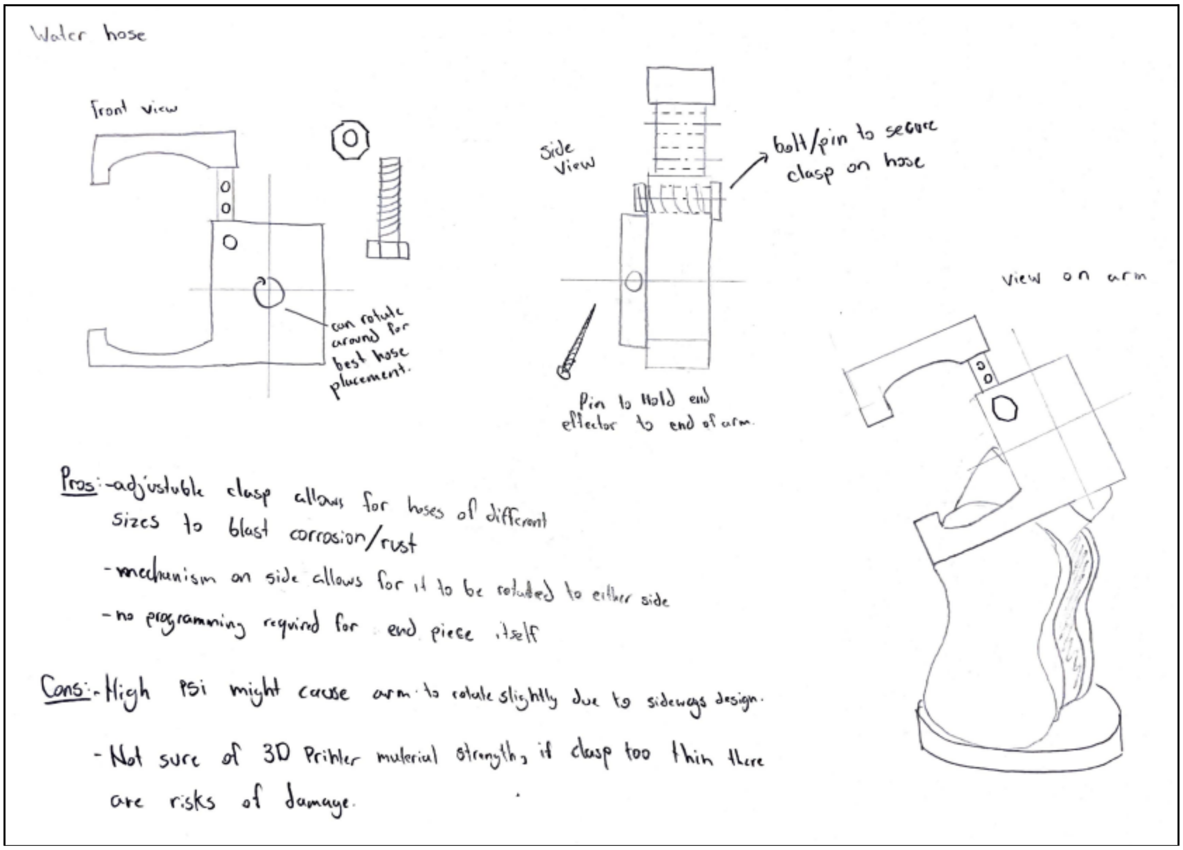


Figure 11. Adjustable modifiable clasp for corrosion remover

Concept 3.2: Rebeca Poulin

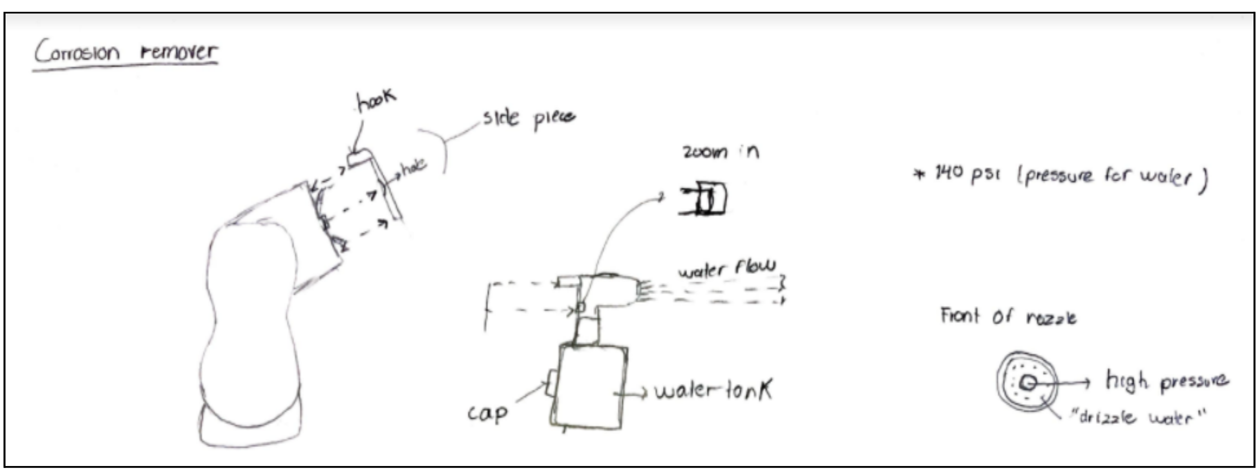


Figure 12. Hook attachment nossel with water tank for water

Concept 3.3: Jess Beardshaw

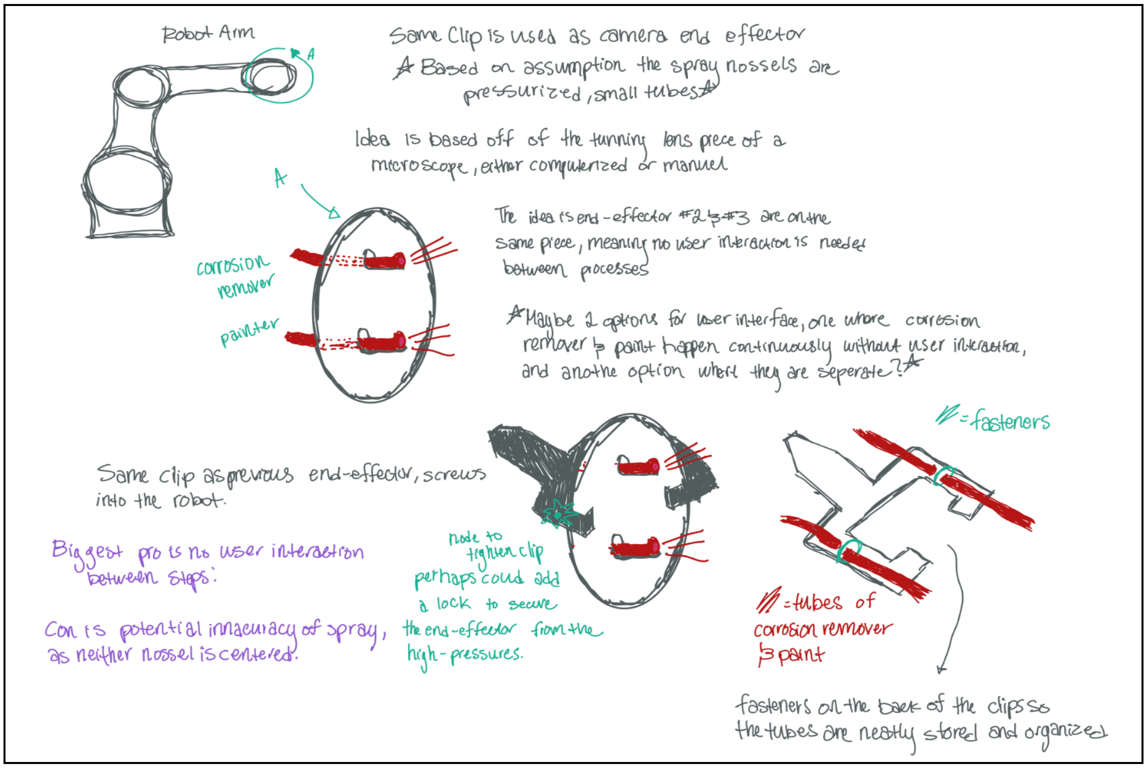


Figure 13. Dual-effector with corrosion remover and painting ability with clamp

Concept 3.4: Isabelle Barrette

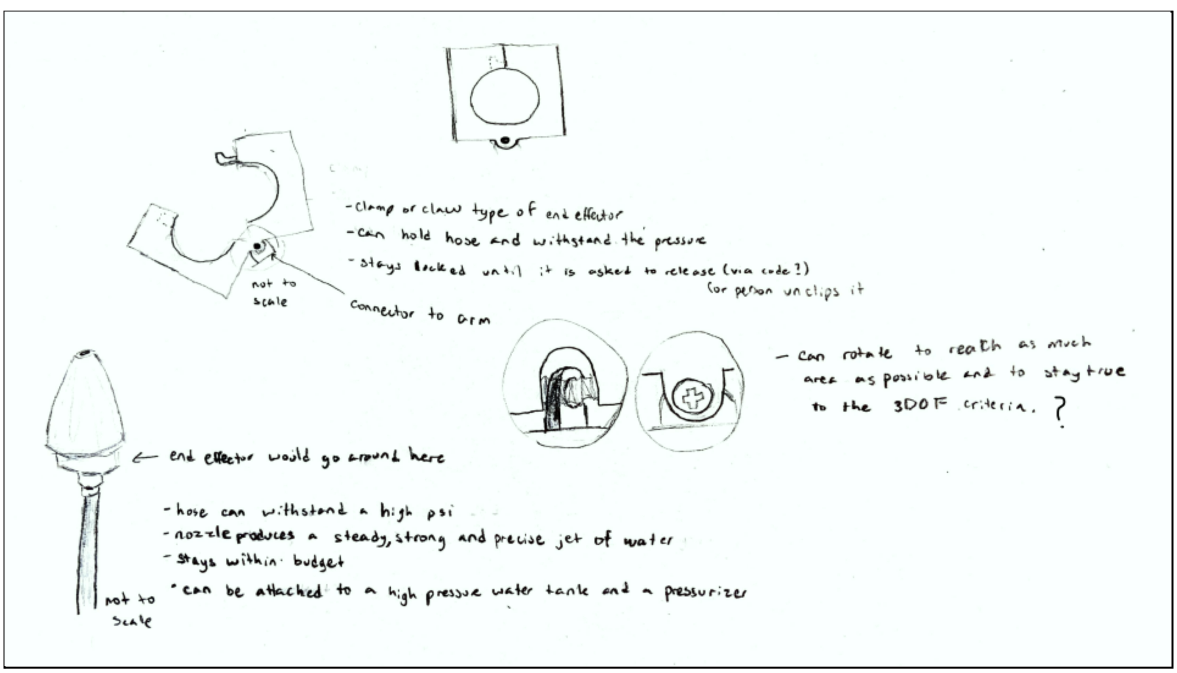


Figure 14. Lockable clamp for high-pressure spray

Concept 3.5: Sarah Alkadri

These designs will allow for the robot to grip steadily around the end of the water gun/ paint sprayer. It would be equipped with a silicone piece surrounding the water gun to prevent the water gun from slipping and to hold against the water pressure.

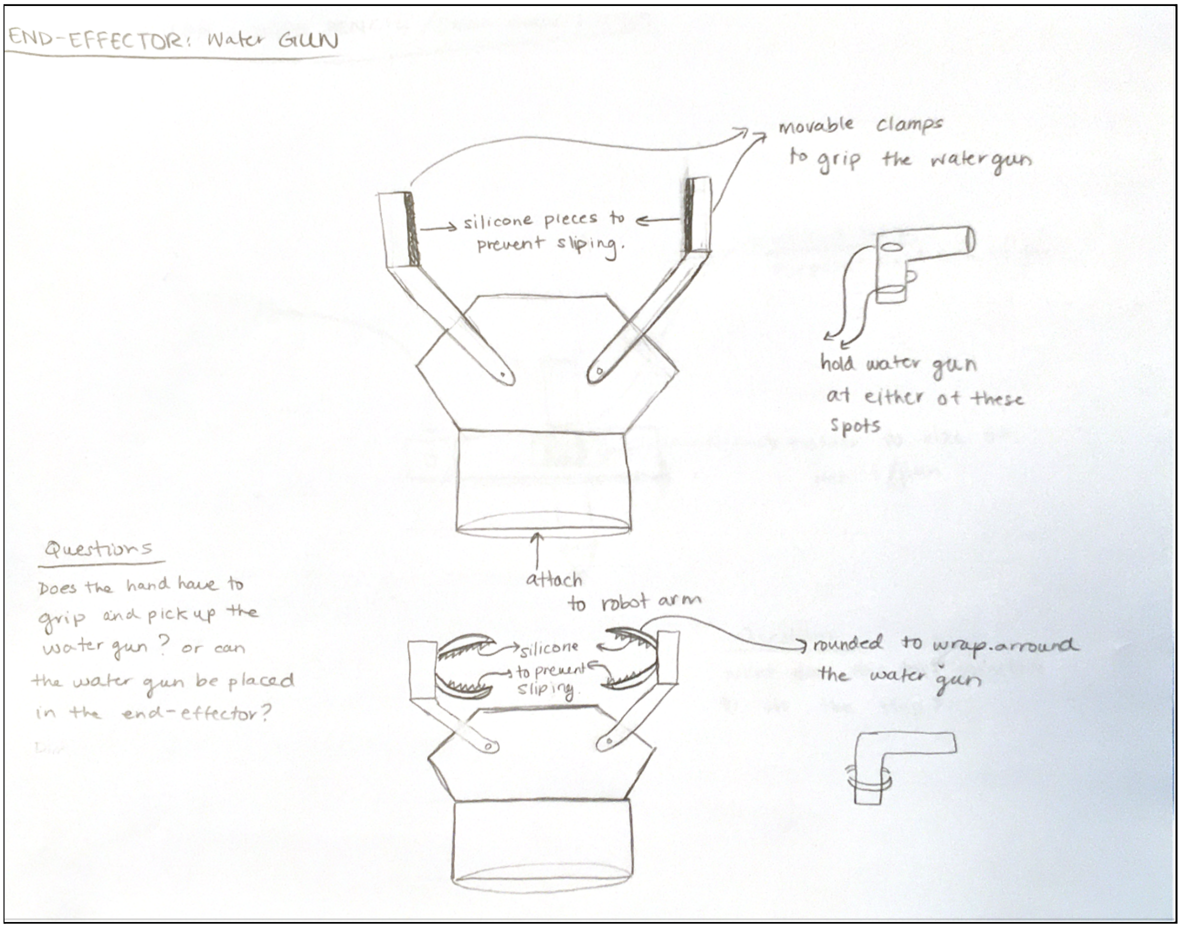


Figure 15. Movable clamps with silicone grips

Subsystem 4: End Effectors (Painter)

Concept 4.1: Benoit Tremblay

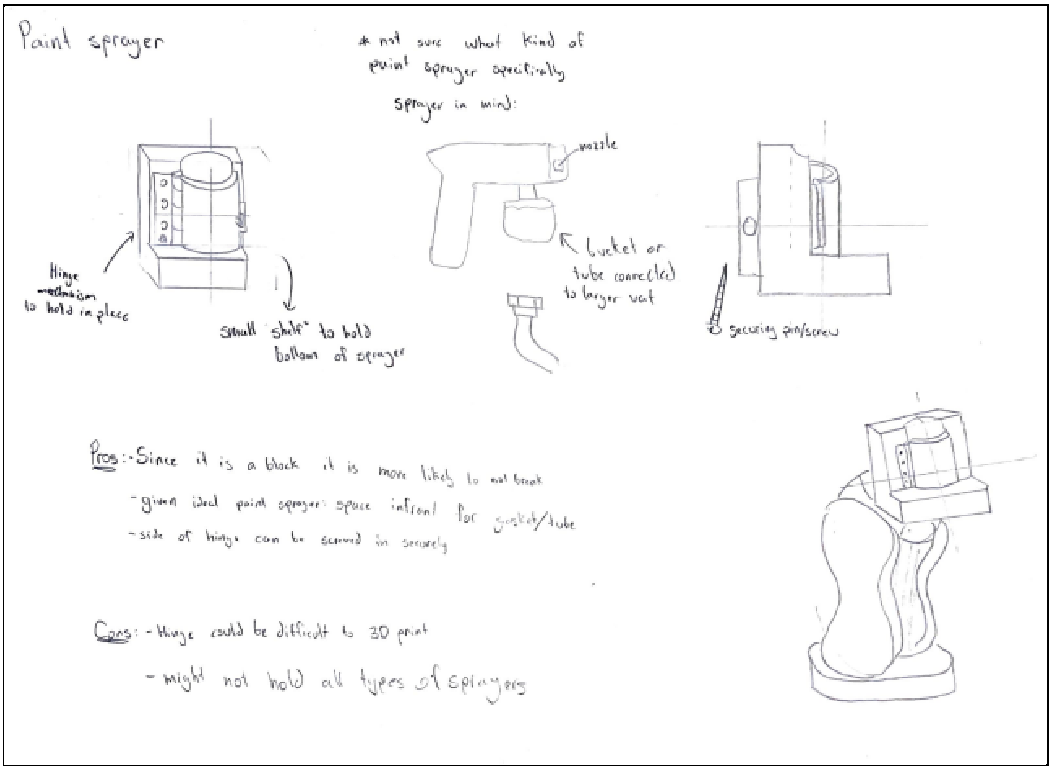


Figure 16. Hinge-connecting painting spray end effector

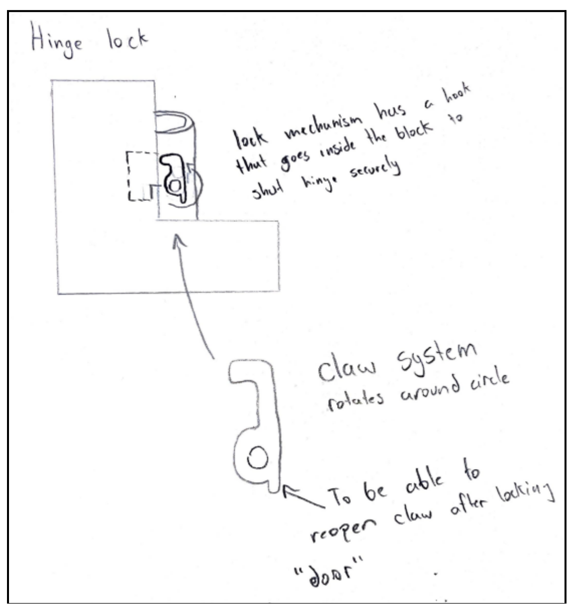


Figure 17. Hinge lock and claw system

Concept 4.2: Rebeca Poulin

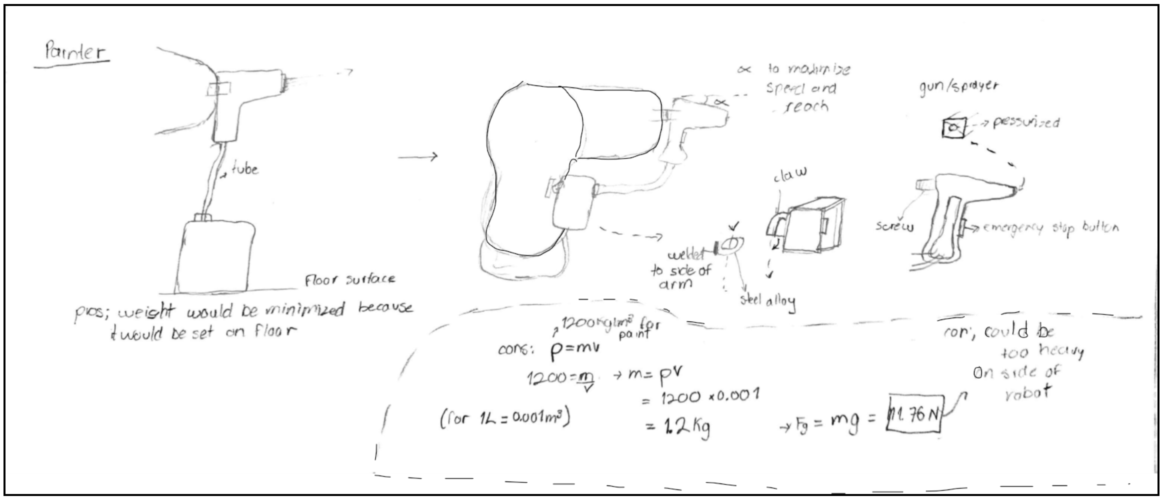


Figure 18. Paint attachment with floor contact and numerical approach

Concept 4.3: Jess Beardshaw

Refer to "Concept 3.3: Jess Beardshaw"

Concept 4.4: Isabelle Barrette

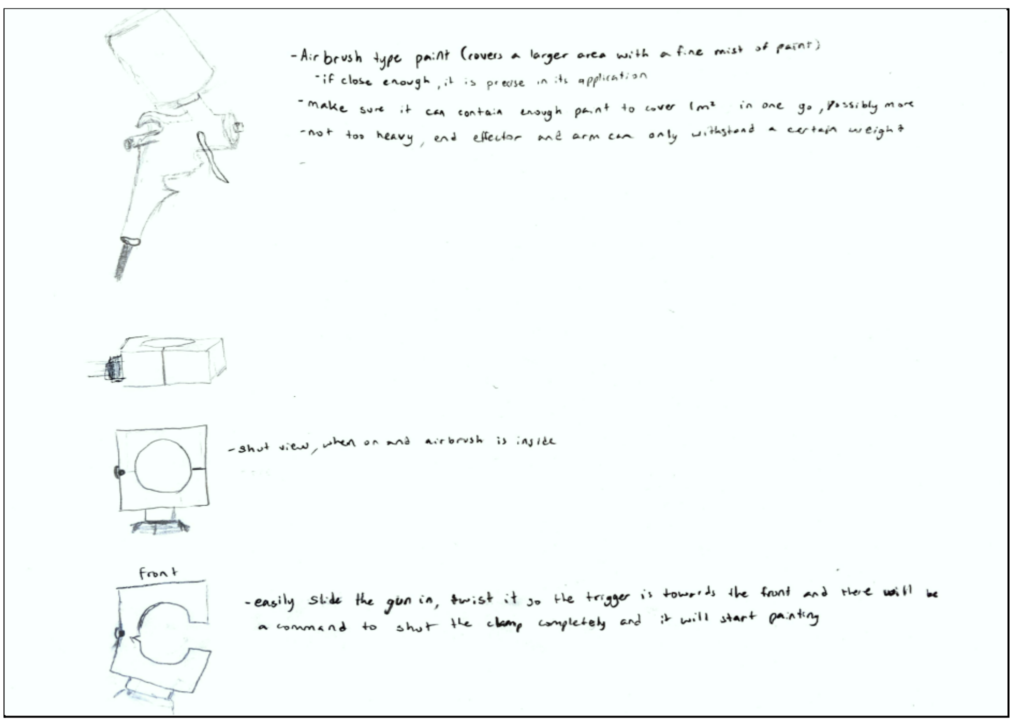


Figure 19. Light and effective clamp end effector

Concept 4.5: Sarah Alkadri

This design clamps around the paint sprayer to allow for optimal control of the position of paint being sprayed. There is a silicone backing to prevent slipping of the paint sprayer to allow for an accurate coverage.

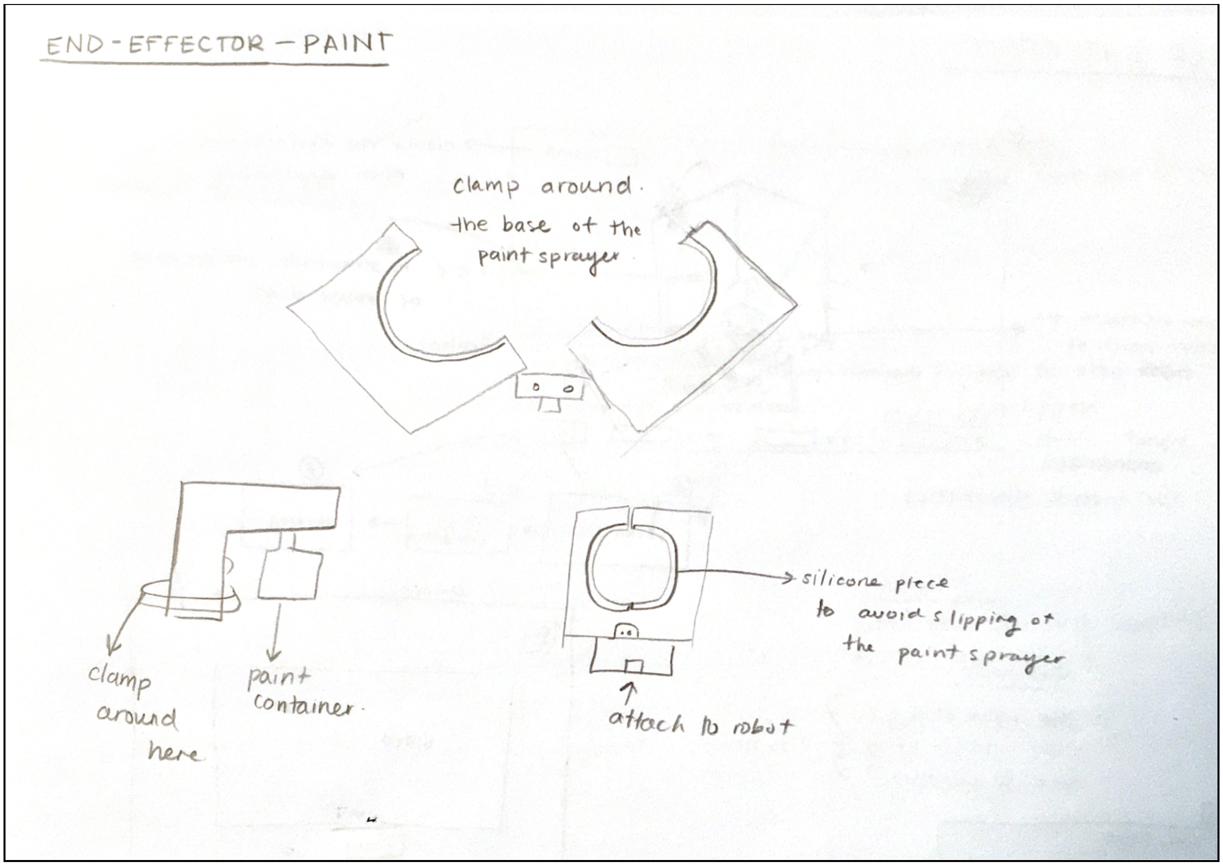


Figure 20. Clamp design for optimal control with silicone backing

Subsystem 5: Coding/Programming

Our code for the Thor arm will follow inverse kinematics calculations to ensure its tasks are done as precisely as possible. We will need to choose a language as well as think of programmable concepts for end goals that are needed to ensure the proper function of the robot.

Our approach includes using forward and inverse kinematics depending on the function required by the user. The main feature in the coding software includes using “Transfer Learning" using texture based features. This allows the program to be able to detect corrosion on the projected surface in our “scanning phase”, and will correspond to coordinates on a 2D plane. These coordinates will then be used for the next two steps – the corrosion removing and painting. The camera takes pictures based on where the software has detected corrosion, and saves it on an external drive for later analysis and data collection. Our approach is different from other solutions, as the software is able to learn and improve the accuracy of it’s detection with every scanning process with the pictures taken.

5.1 Design Criteria

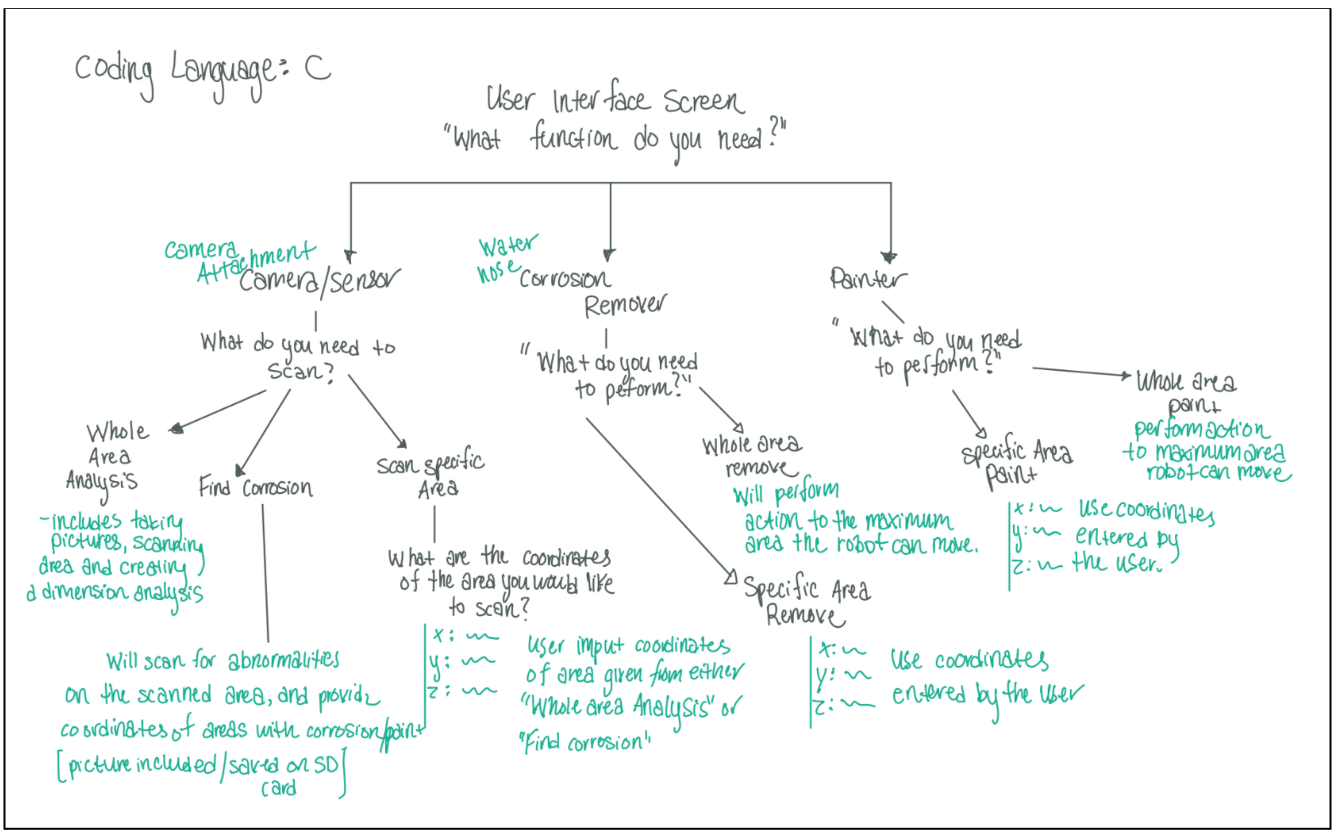


Figure 21. Coding logic with differentiation of required functions

The idea behind the code relates to the idea of the user interface. There will be three different paths the code can take depending on what the user needs – camera/scanning, corrosion remover, and painter. The needs of the user with respect to the design criteria are resolved as follows:

- “Simple/familiar code, files and hardware”: The coding language is in C.
- “Ability to move and complete the 3 tasks with inverse kinematics”: The code involves the user input of the desired function, either corrosion detecting, corrosion removing,

5.2 Ideas For Improvement/Drawbacks

- We will have to find a way for the robot to be able to detect if the wrong end effector is attached in correspondence to the function chosen (ex: print “Wrong end-effector chosen! Please attach the correct one”).
- We will need to implement a “waiting time” where the arm can wait a certain amount of time upon completion of spraying before alerting the user to change to painting end-effector.
- Rust detection programs might be difficult to implement, the program also needs to learn based on pictures of rust which leaves room for mistakes by the program itself.
- Could include another section of the code where after the corrosion removal is performed, the user could reattach the camera and sensor to re-evaluate the same corrosion area to verify the corrosion is gone. (using the same coordinate inputs).
- Without knowing

5.3 Inverse Kinematics Code Concept and Logic

Forward kinematics is used to find the coordinates of problem areas using the camera, and inverse kinematics for the corrosion removal and painting. Since the length of the arms remains constant, the robot will scan the area with respect to the reference plane and store the range of values where there is corrosion. This will be performed by the robot starting at (0, 0, 0) on the x, y, z plane and translating horizontally up the reference plane in 2D with respect to z and x. The coordinate for the y direction is constant, and will be based on the user’s input of the distance they put the robot from the closest target surface.

Inverse kinematics is used for the corrosion removal with the water hose, and the painting hose. The system will hold the range of variables from the scanning step with the camera and sensor, and use those inputs as inputs for where the systems will perform their action. The length of the arms remain constant, the distance the user declares the robot to be away from the projected surface, and the coordinates of the target areas in 2D are used for the robot to move the arm in 3D.

5.4 Resources

- Dave Pagurek’s Blog on explaining simple inverse kinematics, with simple diagrams, mathematical explanations, and software approaches.
- Programming software able to detect corrosion through simple scanned images. This website talks about using the Java software program to be able to get the computer to detect corrosion on surfaces using “Textured Based Features” and Transfer Learning”.
- This article by the University of Pennsylvaia describes all the mathematics behind the motion of a robotic arm in 2D and 3D. The author describes the motion behind the kinematics of a moving arm using mathematical equations, as well as the forces applied on the system.

Analysis and Evaluation

6.1 Summary

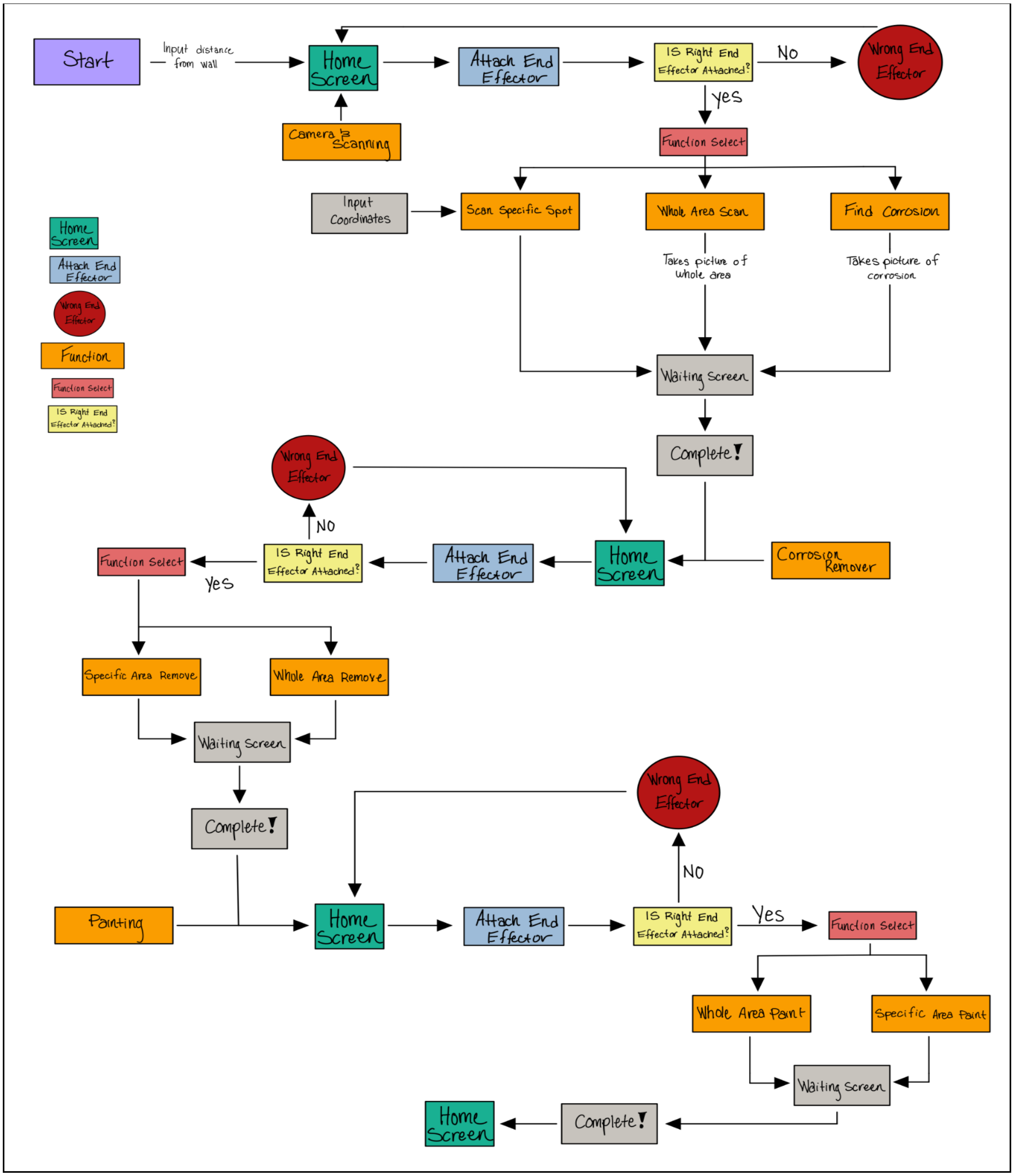


Figure 22. Block diagram of our functional solution showing the function decomposition

As displayed in Figure 22, our process has three main functions to perform during the process. The camera and sensor, the corrosion removing spray, and the painting spray. The user will have different options depending on which type of function they would like to perform. The key features include an error screen when the wrong end effector is attached, as well as collecting pictures of the corroded areas to store them on an external drive and for improving the AI.

The end effectors are designed to hold different types of objects. Our main concern regarding the end effectors, we are unsure which objects we will be holding (for removing corrosion for example – hose or water gun type objects). The client meeting will provide enlightenment as well as feedback on our different subsystems allowing us to improve the design of the arm to tailor to the clients needs.

6.2 Comparison

	Conceptual Design 1	Conceptual Design 2	Conceptual Design 3
Subsystem 1 : User Interface	Scans the whole area, and collects data points on spots of corrosion. These data points are returned to the user.	Detects IF there is corrosion, and paints the whole area. Alerts the user if the wrong effector is in.	User puts it down knowing there is corrosion, the robot scans the area to find where it is, and scans only that area. A live feed of the area is active on devices connected.
Advantages	- Corrosion spots are detected and corrected - Data collected and sent to user for analysis upon request	- Areas with corrosion are detected and corrected	- Area with corrosion detected - Users can monitor the process
Drawbacks	- No direct footage or monitoring available to user	- Paint could be wasted since areas that do not *require* correction are included in the process	

	Conceptual Design 1	Conceptual Design 2	Conceptual Design 3
Subsystem 2 : Camera/Scanner	Camera is in an end piece that can be screwed on to the end of THOR arm.	Camera is held by a clip that can be screwed into the end of the THOR arm	Camera is directly screwed into the THOR arm.

Advantages	- Affordable - Simple to use	- Easy to remove/add end effector	- Easy
Drawbacks	- Have to make a specific and very precise piece - Can take a little more time to remove	- Risk of clip breaking due to weight of camera	- Possible damages to the camera or would necessitate a more expensive one

	Conceptual Design 1	Conceptual Design 2	Conceptual Design 3
Subsystem 3 : Corrosion remover	Holds hose horizontally, points at predetermined points of corrosion.	Hose has a trigger to hold, is held vertically, and follows a zigzag pattern through the whole section.	Hose is held vertically, nozzle points at the found points and sprays to remove the corrosion.
Advantages	- Works great for a normal hose or a long attachment - Cheapest design	- Can cover a large area in one big pattern - More support from behind - Can press and hold a trigger while accurately pointing	- Can press and hold a trigger while accurately pointing - Precise with its targeted locations - More support than the horizontal hold
Drawbacks	- Lack of support from behind - Cannot press a trigger while pointing in the right direction	- No specific section being picked out, coordinates don't matter - More water waste than the others	- Coordinates may be hard to find/hit, could miss some areas - Weight may surpass the threshold

	Conceptual Design 1	Conceptual Design 2	Conceptual Design 3
Subsystem 4 : Painter	Tank of paint is attached to the top of the gun with a hinge lock.	Tank of paint attached to Thor arm	Tank of paint is on the ground beside the gun, with a tube feeding the paint into the sprayer gun

Advantages	- Paint flow into gun can be efficient	- Practical to put away and store sparayer	- Weight can be maintained under the maximum 750g requirement
Drawbacks	- Weight added to end-effector will probably exceed 750 g when tank is full	- Weight could surpass 750g and cause damage to arm or end-effector - Could pull weight on arm and break off	- Takes up more space around thor robot

Table 1. Comparison matrix of the subsystems

Final Functional Solution

Subsystem 1: User Interface

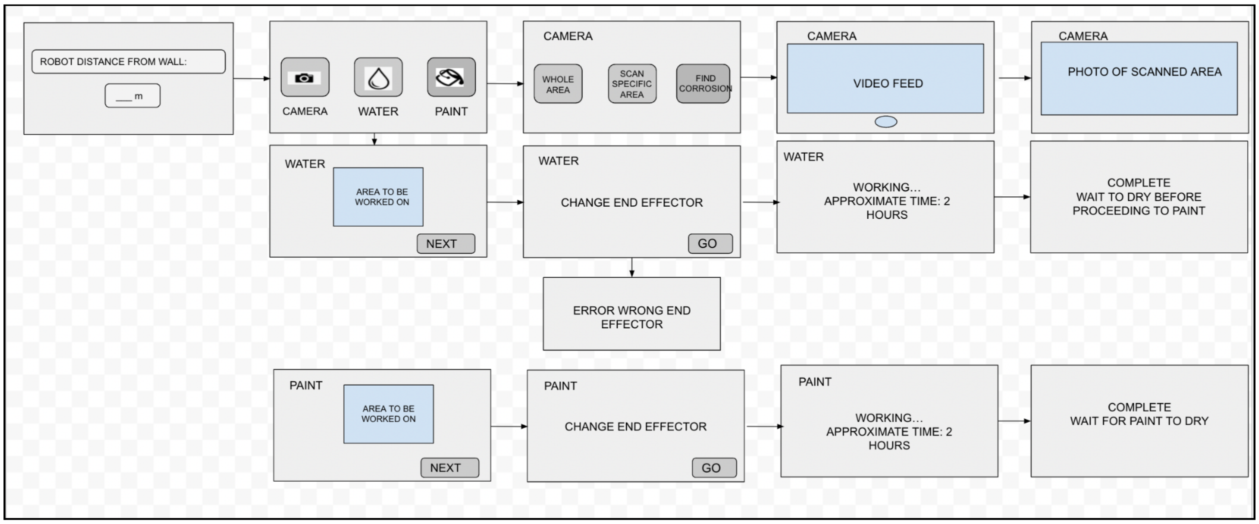


Figure 23. Final solution of user interface screen

Subsystem 2: End Effectors (Camera/sensor)

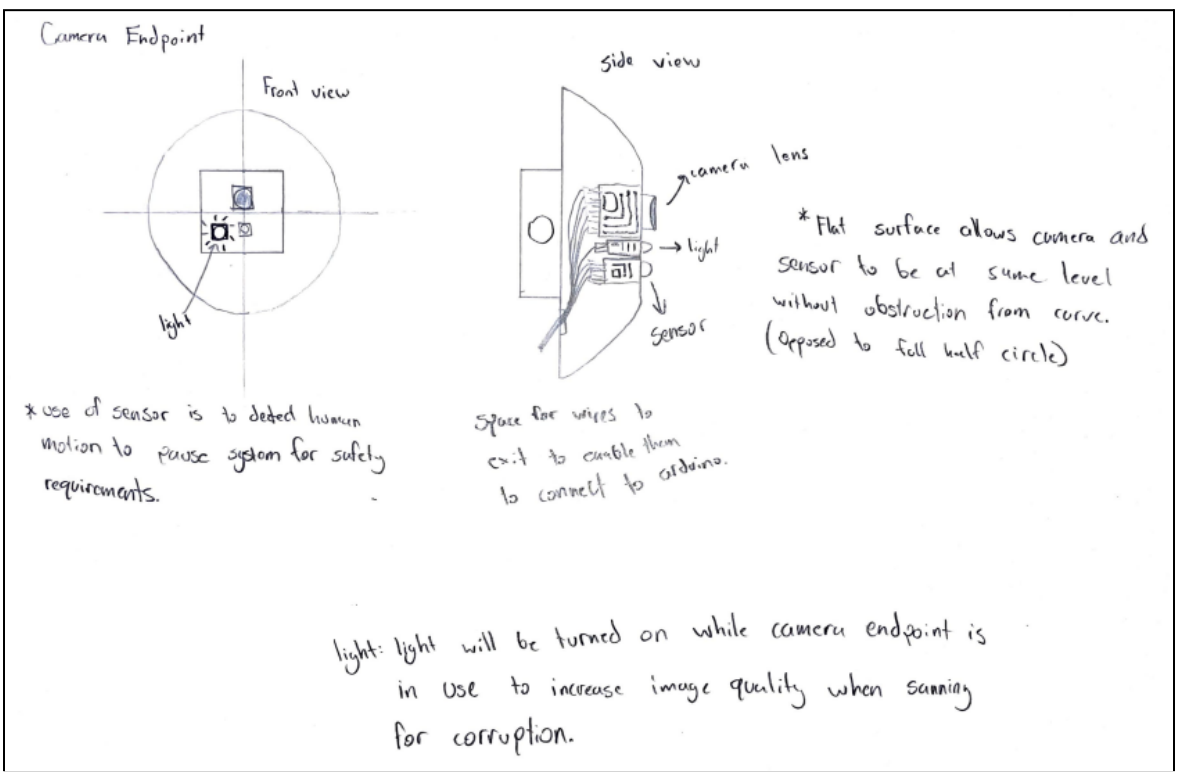
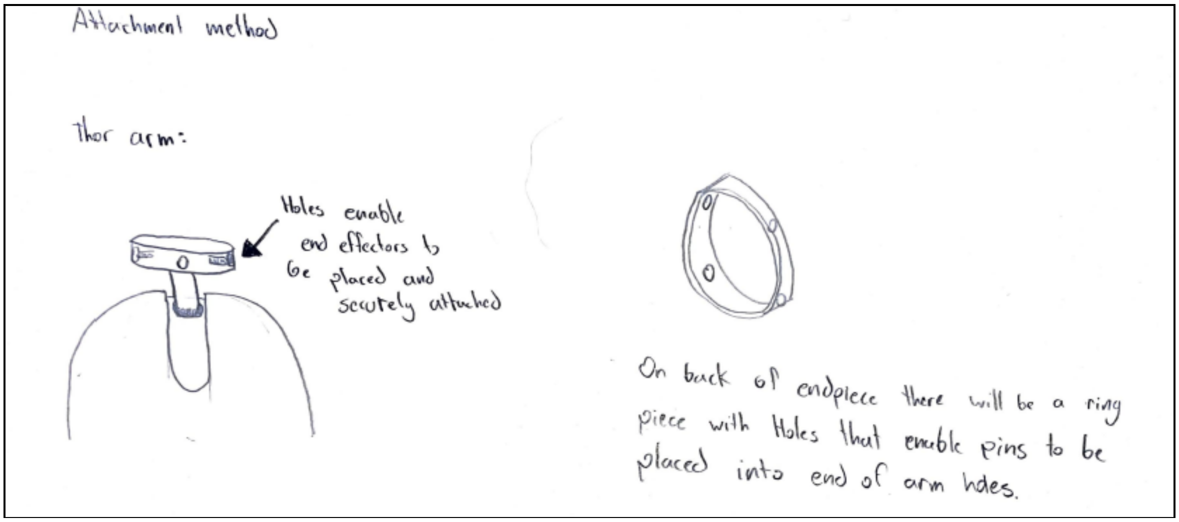


Figure 24. Final solution of camera and sensor end effector



Subsystem 3: End Effectors (Pressure Washer Gun)

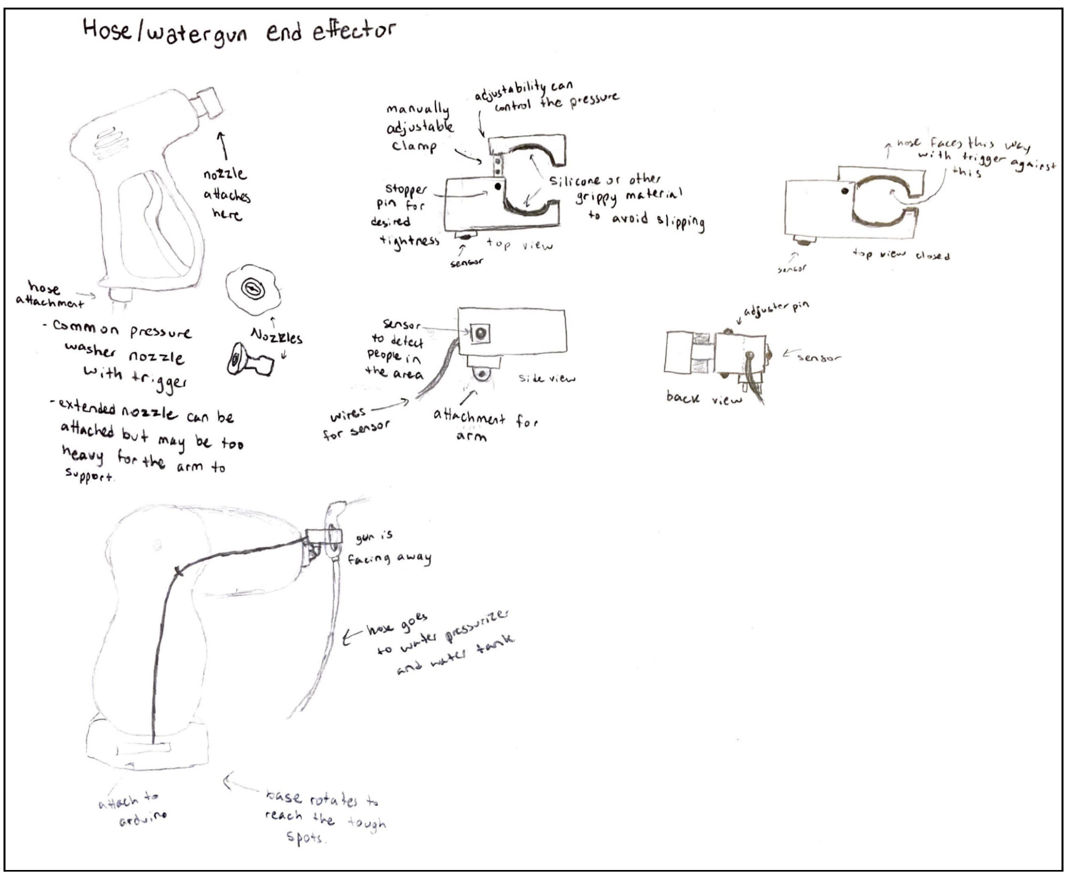


Figure 25. Final solution of pressure washer spray end effector

Subsystem 4: End Effectors (Paint Gun)

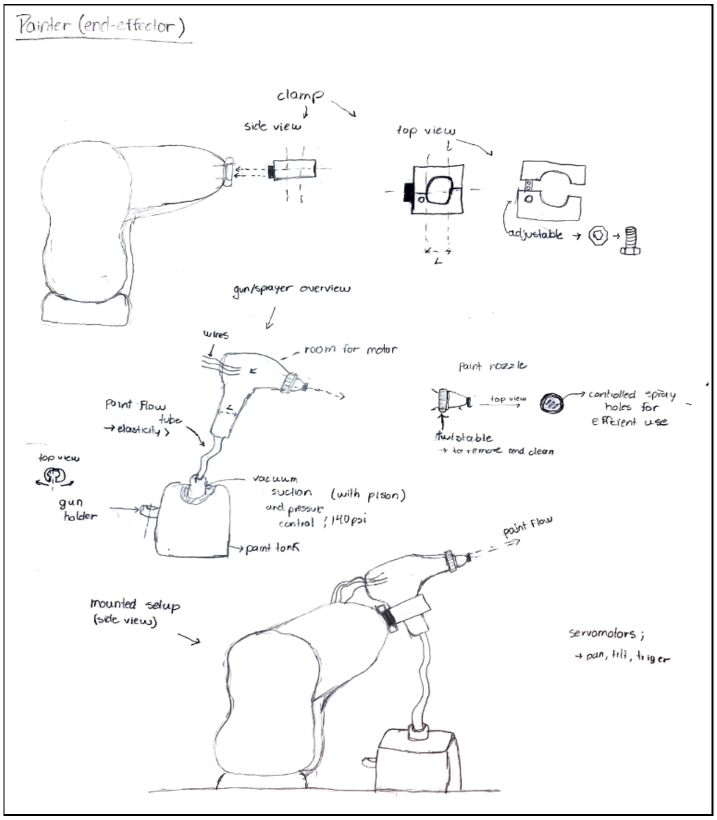


Figure 26. Final solution of paint gun end effector

Conclusion

After exploring different concepts from our five subsystems, we decided on a final functional solution analyzed and compared against the design criteria. Our solution contains plans for end-effectors, the user interface and the pseudo-code that encompasses our needs and desires for the final product of our project.

Upon completing sketches to demonstrate our ideas, we discussed and analyzed possible consequences for each conceptual design. This allowed us to idealize and combine the best of our collective ideas into five functional subsystems to our solution. Subsystem 1 describes the user interface, and the variety of screen displays and their respective functions. Subsystem 2 describes the first end effector, and the functionality of the camera and sensor with respect to the function of the code. The end effector is small and simple, ideal for saving materials for other bigger end effectors. Subsystem 3 – one of the bigger end effectors – is the water gun and pressure washer holder. Our idea defines a sensor system for an automatic shut off for safety, as well as being able to hold the gun and maintain a powerful pressure. Subsystem 4 is the last of our end effector subsystems, the paint spray holder. This subsystem is very similar in regards to subsystem 3, sharing a similar functionality and size. In subsystem 5, we collectively created the overall functionality of the robot, and included information about the mathematics and logic and the logic of our code.

Overall, we have a good idea of our project and all of its components. We have been able to successfully stay within our constraints and produce descriptive sketches of all of our ideas to eventually bring them to life.

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