CubeScrub

A compact robotic arm designed for efficient, gentle cleaning, housed within a sleek, cube-like base — ideal for the cleaning of fragile, small-scale items.

Michelle Ren Zhang
Department of Computer and Information Science
Cornell University
Ithaca, New York
mr897@cornel.edu

Marie Williams
Department of Computer and Information Science
Cornell University
Ithaca, New York
mcw242@cornell.edu

Lili Mkrtchyan
Department of Computer and Information Science
Cornell University
Ithaca, New York
lm688@cornell.edU

INTRODUCTION

Cleaning, while a necessary task, can often be tedious and time-consuming. Though some may find the process relaxing or even therapeutic, many would prefer to delegate this responsibility, either to other people or, as technological advancements have made possible in recent years, to machines. Robotic vacuum cleaners and other autonomous devices have gained popularity for their ability to save time and reduce the physical effort involved in maintaining a clean environment. Drawing inspiration from these technological trends, our project aims to create a specialized robotic arm designed for cleaning tasks.

Our robotic arm was conceived to assist in the cleaning of glasses, a fragile item that demands careful handling and thorough cleaning. From this inspiration, we aim to develop a robotic system that is not only precise but also adaptable to a wide variety of cleaning tasks. While our design is optimized for smaller-scale projects, it should prove effective on other objects as well.

We had initially planned to create a robotic arm built with three segments, each containing at least one motor, to achieve this level of precision. After consulting with the professor, however, we have scaled down our project so that our final deliverable will include an arm made of just one segment that will be extended from the top of a cube-like box. This arm will still have the ability to move along all three dimensions, which will provide it with the flexibility needed to access every corner of the object it intends to clean. At the end of the arm, a rotating cleaning disk will allow users to attach different types of cloths, such as microfiber cloths, disinfecting wipes, or rags, depending on the task at hand. This customizable design ensures that the robotic arm can be adapted for different types of surfaces and cleaning materials. Our robotic arm will also be equipped with remote control functionality via a mobile app, allowing users to guide the arm's movements to their liking.

RELATED WORK

Simple & Smart Robotic Arm: This project involved the creation of a simple, lightweight, Arduino-based robotic arm. What is most interesting about the design is how one controls the movements of the arm — users are meant to manipulate a separate arm as they want the robotic arm to move, and then the robotic arm moves accordingly (master-slave relationship). This "mirroring" control system was not particularly effective, especially paired with the lightweight materials used. Learning from this project, we plan to utilize a different controlling mechanism paired with sturdier parts. Despite its flaws, this DIY project provides a helpful, simplified breakdown of the components that go into building a robotic arm.

https://www.instructables.com/Simple-Smart-Robotic-Arm-Using-Arduino-/

Smart Cleaning Robot: Like most robot cleaners available, this one utilizes a body on wheels. Provided the time, we may add wheels to our robotic arm,

though it is not our priority. Having said that, this project provides a great piece-by-piece breakdown of a pretty simple cleaning robot. Some of the pieces are even 3D printed, so we could borrow from this project and print our own components. This design also utilizes the rotating "sweeper" technology we are hoping to implement in our robotic arm, so we will definitely be using this design as a guide in developing our own version of the same feature. Another interesting feature is a water dispenser on the body of the robot that allows it to squirt out some water to wet the cleaning cloth. We would be interested in incorporating a similar feature into our robot as an added benefit. Finally, this robot is smartphone controlled via a mobile app, like we plan for ours to be, so it will provide guidance in that regard as well.

https://ai.thestempedia.com/project/diy-smart-cleaning-robot/

CleanSweep: This robotic floor cleaner is very similar to the one described in the project above, in that it also uses rotational disks for floor cleaning, operates on wheels, and includes a water dispenser. There are some additional components of it that distinguish it from the project above, but we likely will not be using them in our project. Most helpful are the in-depth video tutorials that provide a step-by-step guide on how to build the entire robot; we will at minimum be able to utilize the videos on assembling the rotational disks in the building of our project.

https://www.instructables.com/CleanSweep-the-Floor-Cleaning-Robot/

How to Build Your Own Floor Cleaning Robot: Although centered around creating a floor cleaning machine, this article is a great reference of a step-by-step setup and materials on how to approach designing a cleaning robot. It has useful information on comparing different motors and sensors, given the goal of cleaning. Servo motors would be the best suit, considering the points made in the article, and the precision and flexibility needed for this task. Additionally, the article makes a great point of using ultrared sensors to detect dirt and dust, which we will consider implementing as an additional feature.

https://floorbotics.com.au/commercial-floor-cleaning-robot/how-to-build-your-own-floor-cleaning-robot-a-step-by-step-guide

How to Build a Robot at Home: This article provides a set of components that we would consider using in our design. Although it does not directly reference any cleaning, it is a visual and step-by-step tutorial on how to assemble a complex robot. Additionally, the article mentions that servo motors are used for robotic arms, which is what we intend to create, hence we will be using servo motors. Additionally, the article made us consider the need for a battery pack.

https://www.wikihow.com/Build-a-Robot-at-Home

Research on Design and Control of a Curtain Wall Cleaning Robot: In this research paper the authors are analyzing the design of a robot that is supposed to clean the glass curtain walls in China. We will be implementing a robot to clean more delicate smaller objects. There's a scale and potentially material difference, such as the huge curtain walls are tougher material and can resist more pressure than fragile glass-made objects. The robot described in the paper has four functional units: "adsorption force generating unit, a cleaning execution unit, an anti-collision protection unit, and a control hardware platform unit". We consider using swipes attached to the robotic arms instead of the adsorption force generating unit. Since our robot will be controlled by the users and will not be self-moving, there is no need for an anti-collision protection unit. For our reference, the paper also contains a useful sketch with all the parts labeled.

https://dl.acm.org/doi/abs/10.1145/3366194.3366277

A New Type Design: Glass Curtain Wall Cleaning Robot: The example discussed in this paper uses remote control through an Android interface to control the robot. Since we aim for our robotic arm to

be controlled in real life by the user, it is a potential idea to explore how to incorporate a remote control into our design. Additionally, they discuss features such as controlling the speed of the motion and the choice given to the users between an automatic cleaning system and a manual cleaning system. It gave us a potential idea for exploration in how we can automate the cleaning or add a feature to change the speed of the robotic arm, as additional features.

https://dl.acm.org/doi/abs/10.1145/3469213.3470307

How to Build a Robotic Arm: This article makes a useful analogy between the parts of the human arm and the hardware components that we will need to design and assemble our robotic arm. This provides us with a good starting framework through which we can analyze our design. The article mentions that actuators – motors or servos – act as the muscles of the arm, ensuring the movement. Hence, we will ensure to have motors corresponding to the number of movements we want our robotic arm to perform. The article mentions the importance of joints in the design for flexibility – this has come up during our discussion on how parts of the arm we want to move and in which direction. Additionally, the article mentions end effectors for specialized tasks, which in our case will be an attachment for different cleaning cloth materials.

https://dorna.ai/blog/how-to-build-a-robotic-arm/#building-the-arm-structure

Science Buddies: Build a Robotic Arm: This article has a tutorial on how to build robotic arms using arduino which could be useful for our project. It details the motors and materials needed in order to enable arm movement and also shows various examples of possible arm designs that could be useful when building our final machine. In addition to movement, it also provides instructions on how to build the arm using materials found at home – this intuition can be helpful on how we can build the actual arm.

https://www.sciencebuddies.org/science-fair-projects/project-ideas/Robotics_p050/robotics/arduino-robotic-arm

DIY - Robotic Arm With Servo Motors: This article showcases how to make an automated programmable robotic arm. It highlights the steps to control servo motors while communicating with a computer via a USB cable. This intuition might be useful for our project since our machine has a software component where users will be able to control robot hardware movement through a computer.

https://roboticsandenergy.com/projects/arduino-projects/robotic-arm/

DESIGN OVERVIEW

The initial design of our cleaning machine consists of a robotic arm that moves along three axes, providing full-range flexibility for various cleaning tasks. At the end of the arm, there is a rotating disk designed to accommodate various cleaning materials such as sponges, paper towels, or wipes. The arm is mounted on a platform which serves as a base of the structure. The machine will have a base motor at the bottom to rotate the entire structure in 360 degrees, motors at key joints to enable arm-like movements, and an additional motor at the head dedicated to spinning the attached cleaning material to ensure through scrubbing/polishing. We're planning to purchase the required amount of motors and 3D print various of the arm's components. Aside from hardware, there will be an additional software component where users will be able to control the cleaning machine's movement through a GUI that will detect cursor movement and key presses.

An additional feature we're looking to explore is an automatic water sprinkler. The base will have a container with water attached to it and a tube along the arm of the machine that connects the water container to the disk. We would also need to implement a water pump mechanism that can push water through the tube, which can end in a nozzle

position where the disk is. The spraying motion can be activated at intervals based on cleaning requirements and surface types. We are also looking into the possibility of replacing the static base by a platform with wheels that can be remote controlled—this can prove to be difficult since an additional software component would be needed to control the wheels' movement.

UPDATE: After talking to the professor we have updated the design of our machine to be a cleaning box as opposed to the initial robotic arm, since the robotic arm would require knowledge of physics and mathematics that is outside of the scope of the class and of our expertise. The idea of the machine is still to clean various objects presented by its users. The main component of the machine is a box which would have an "arm" with a cleaning cloth. The segment would be able to move in 3 directions, x, y, and z axis, powered by 3 motors, however, it would consist of only one segment. Additionally, the cloth would also be able to spin to accommodate the cleaning, requiring an additional motor. All the motions will be controlled by a remote controller.

We are planning to do 3D printing to create the segment inside the box, and do laser cutting to assemble the box itself. We will be using a transparent material to be able to see and show the process of the object being cleaned. This design should ideally accommodate for flat and curved objects placed inside the box.

EXPECTED COMPONENTS

We expect to need the following components in the building of our CubeScrub:

1. Glass/clear thick plastic for the sides of the box (will laser cut to needed measurements)
2. 4 motors (3 for each axes movement of the arm, 1 for spinning movement of disk)
3. Tracks along x, y, and z axis to enable 3D movement of the arm segment at the top of the box
4. 3D printed arm
5. Flexible joint for disk movement
6. Velcro attachments for cleaning materials

PRIORITY RANKING OF FEATURES

<u>Basic Features, ranked in order of importance</u>

1. 3D range of the cleaning arm (x, y, and z-axis separately enabled)
2. User-input-based controller for motion of the robotic arm
3. Spinning cleaning disk attached to a soft, flexible, joint that will allow it to clean at an angle as required for curved surfaces
4. Attachment/detachment mechanism for different cloth materials on the spinning disk

<u>Additional Features (Optional)</u>

- Mechanism to dispense/spray water on surface to be cleaned
- Sensors, such as ultrared sensors at the bottom of the box to detect dirt
- Provided the time, we would want to try and allow users to control the movement of the arm via an app; we would allow them to control movements along the x, y, and z axis

SKETCHES

Figure 1: Initial Robotic Arm Design

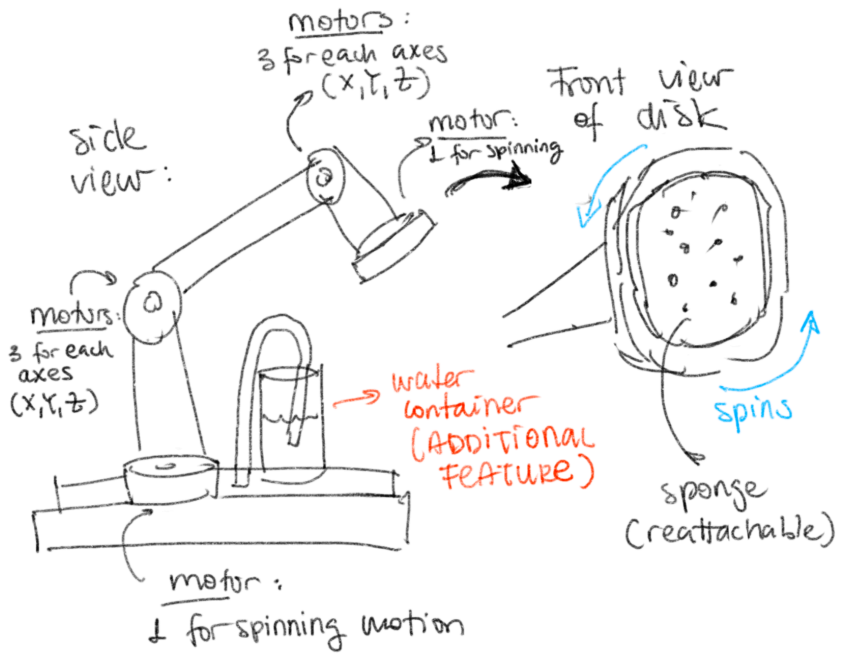

Figure 2: Final Design of CubeScrub