Home Cleaning Robots

Project Report

Team Pacific Standard Random

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1. Introduction

Many people are living increasingly busy lives. Household cleaning is a large time commitment especially for people already preoccupied balancing demanding careers and busy personal lives. The average American spends nearly 2 hours per day doing household tasks ranging from cooking (and the clean up that comes with it), to household cleaning and laundry [1]. The average American also spends over 300 hours annually on household cleaning which takes up nearly 40% of their week [2]. In addition "half of Americans admit to falling behind in cleaning their home" [2]. Americans also spend a significant amount of time indoors. The Environmental Protection Agency notes that Americans will spend about 90% of their time indoors [4], where concentrations of pollutants are anywhere from two to five times higher than they are outdoors [3]. This can be cause for major health concerns, especially for those with allergies or sensitivities. The aforementioned factors mark a clear need for a reliable and efficient solution that can autonomously manage housekeeping.

A multi-functional cleaning system offers an innovative solution, which allows individuals to maintain a cleaner and healthier living environment without constant manual labor. We propose a robotic system that can handle floor cleaning, window cleaning, toilet cleaning and air purification. The primary customer for this system is anyone looking for a time-saving, efficient cleaning solution, such as families, pet owners, busy professionals between the ages of 25-55, and elderly individuals. Individuals who live in suburban and urban areas alike can use this system as it's ideal for fast-paced lifestyles and those looking for a space efficient. Secondary stakeholders include: investors in home automation, developers in home technology, policymakers in government who handle smart home standards, and the general public that will benefit from this sustainable, smart home solution.

Customers currently rely on a variety of robots that act as standalone solutions for specific home cleaning tasks. Popular products include Roomba robotic vacuums and mops, which provide floor cleaning solutions in a variety of models [5]. Other products include air purifiers from brands like Dyson that aim to improve indoor air quality by capturing pollutants. These products function well in helping to remedy some of the burdens surrounding home cleaning but are usually only aimed towards one specific function, which leaves gaps within the overall cleaning process.

Many current products lack an integrated, multi-functional approach to home cleaning, which requires users to manage a number of different devices manually or through various applications to maintain a comprehensive cleaning routine. Our proposed robotic system aims to address these shortcomings by integrating various specialized robots that work collaboratively to cover several cleaning tasks including: floor and window cleaning, air purification, and toilet cleaning. By filling these gaps, our system aspires to deliver a more seamless, easy, and complete solution for household cleaning, enhancing efficiency for users while also addressing health and lifestyle needs holistically.

2. Formal Problem Definition

2.1 Problem Statement

The goal of this project is to develop a robotic solution that manages various home cleaning tasks including floor cleaning, window cleaning, air purification, and toilet cleaning. This autonomous system aims to address the gaps in current cleaning solutions by offering an integrated approach that enhances indoor cleanliness and air quality within the home.

2.2 Robot Types

Our system will contain four distinct robots that cover different home cleaning needs. FloorBot functions as a floor sweeper, vacuum cleaner, and mop. It is designed to recognize and work on different floor types such as hardwood, tile, and carpet. AirBot's primary purpose is as an air purifier and however it can also function as a scent diffuser. It monitors and purifies the air throughout various rooms, diffusing scent as the customer desires. WindowBot autonomously cleans windows. Finally ToiletBot cleans the inside of the toilet bowl, and uses powerful UV light to sanitize the seat and interior of the bowl.

2.3 Design Requirements

FloorBot Requirements:

1) FloorBot must clean at least 90% of the floor surface in a standard sized room (up to 300 sq ft) within 20 minutes.
2) FloorBot must hold at least 0.5 liters of dry debris before requiring disposal.
3) FloorBot must have a dual tank system for clean and dirty water respectively, each with a capacity of at least 0.3 liters.
4) FloorBot must both have an automatic detection system to differentiate between floor types in order to provide the most efficient cleaning and to prevent damage to the floor.
5) FloorBot must automatically dock at the charging station when the battery is below 10%.

AirBot Requirements:

1) AirBot should be able to measure and display real-time air quality levels that are updated every 5 minutes.
2) AirBot should cover an area up to 500 sq ft, filtering at least 99% of airborne particles.

WindowBot Requirements:

1) WindowBot must be able to autonomously navigate and clean 90% of a window's surface.
2) WindowBot must be able to clean windows and glass surfaces to a streak-free shine and be able to function on a variety of sized glass surfaces without user monitoring.

ToiletBot Requirements:

1) ToiletBot must be able to dispense cleaning solution and scrub the interior of the bowl removing debris and preventing buildup.
2) ToiletBot must be able to sanitize the seat and interior of the bowl.
3) ToiletBot must be able to operate autonomously.

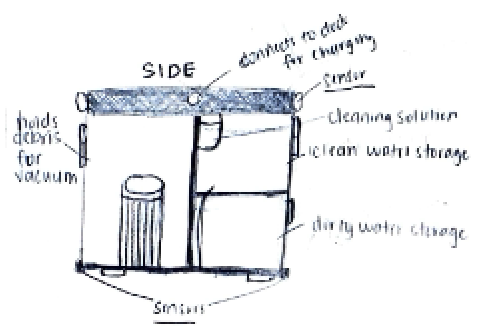
2.4 Project Schedule

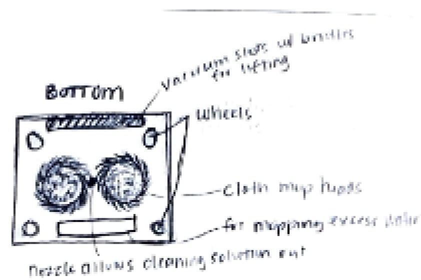
In order to complete this report, we'll need to brainstorm and develop our individual robots along with their descriptions and algorithm flowcharts. Following that, we'll need to work together and complete the collaborative work. To finalize our video, we'll first need to pitch our ideas and develop the storyboard. Through iteration (numerous recording attempts, editing, and revision) we'll have our completed product. For a more detailed schedule, see the Gantt chart located in Appendix A.

3. Individual Ideation

3.1 Robot Ideas by Alyssa Simonson

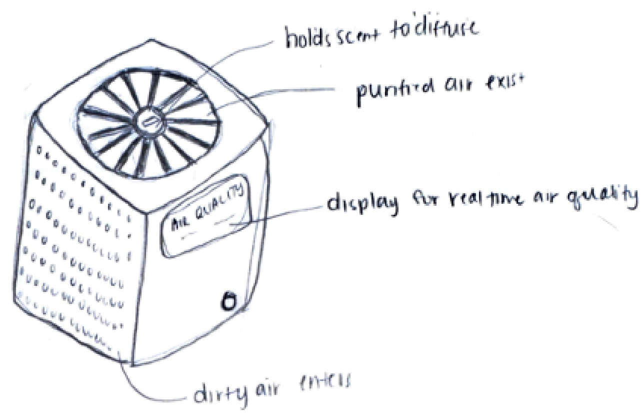
FloorBot





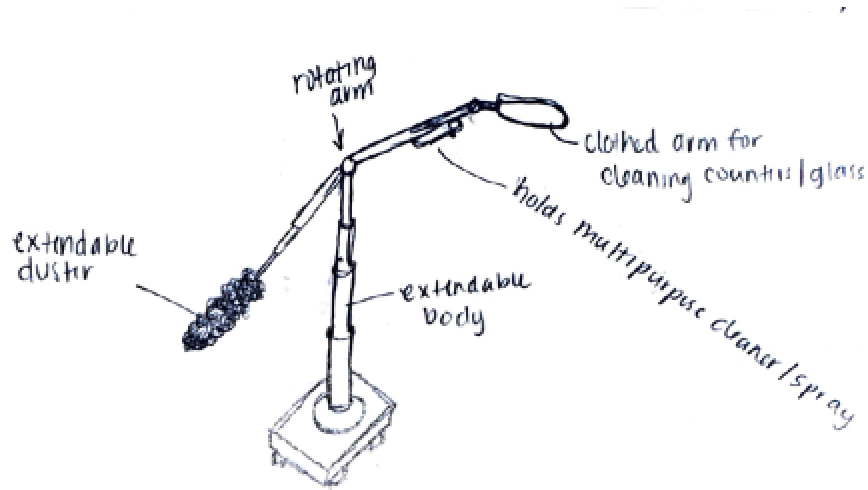
The FloorBot will be designed as a cube. One half will hold a filter and store debris picked up by the vacuum component. The other half will be divided into two stacked containers. The bottom container will hold dirty water as it gets pulled up by a cloth that will pick up excess water. The top container will hold clean water as well as a smaller container of cleaning solution that will be dispersed into the water as necessary. On the outside, there will be sensors on the bottom corners to detect objects as well as to distinguish floor type. On the bottom of the robot will be spinning mop heads for scrubbing as well as a small nozzle to release the cleaner/water solution. The robot itself will move on four wheels.

AirBot



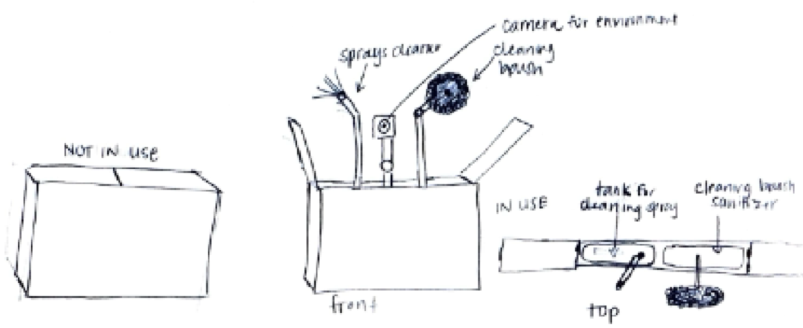
The AirBot is made into a cubic form. The sides and back of the robot will pull the air in and the top of the robot pushes the purified air back into the room. In the center of the top of the Airbot will be a small compartment where the user can add in essential oils or other scents to diffuse in the room. On the front of the robot will be a sensor to detect air quality. This sensor has a display on the robot itself.

WindowBot



The WindowBot will have a sturdy, low to the ground base and four wheels. The body WindowBot consists of an extendable part that leads to rotating arms. The WindowBot will have two arms. The first arm will have an extendable duster attached to the end. The second arm will have a clothed hand attached to the end. Just before the end of this hand, there will be a small automatic sprayer that can hold a multipurpose cleaning solution. This second arm will be used to clean counters, windows, tables, etc. Inside both hands there will be sensors for detecting how much resistance is met/how much force to use when cleaning.

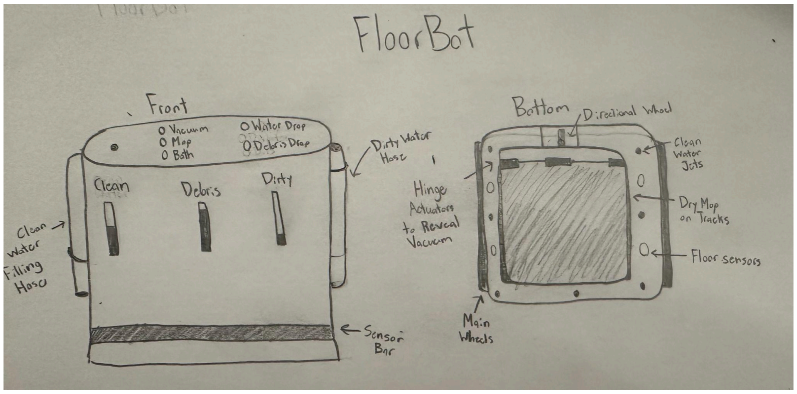
ToiletBot



The ToiletBot will be contained within a box. This box can be wall mounted for ease of use. When not in use, the parts of the robot will be stored inside of the container. When it is in use, three arms will extend out of the box: a camera for sensing the environment and visually detecting what needs to be cleaned; a mechanical hand with the dual function of lifting the lid or seat, and spraying cleaner in and around the toilet; finally an extendable brush with a bristled head for cleaning the inside of the bowl, and a cloth for cleaning the other parts of the toilet. The different cleaning heads will move according to whichever part of the toilet is being cleaned (i.e. if the seat is being cleaned, the bristle head will be moved back into a “resting” position).

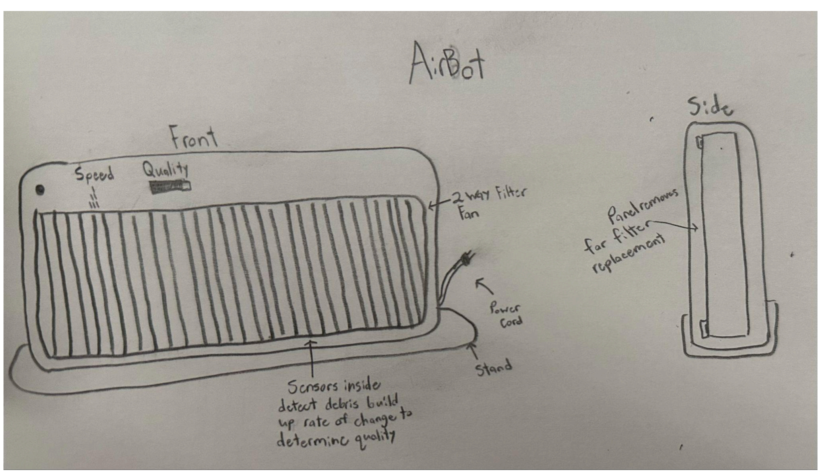
3.2 Robot Ideas by Landon Carroll

FloorBot



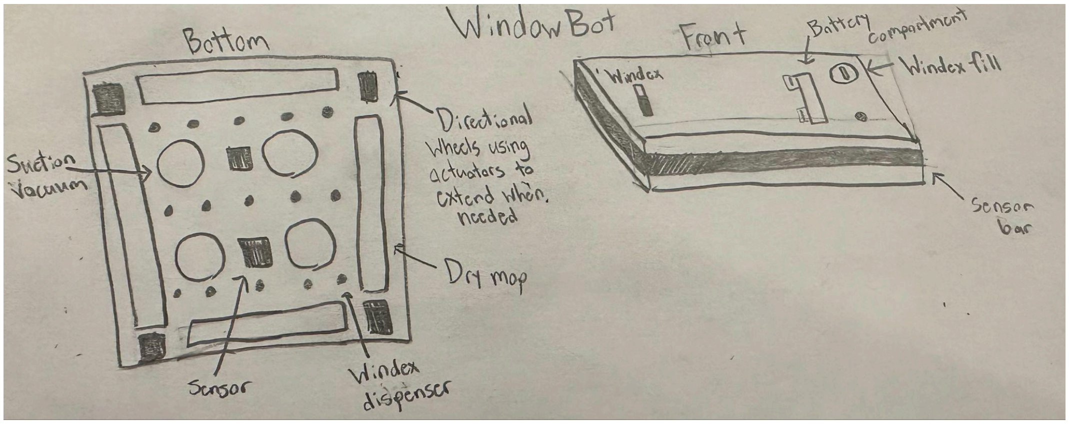
My FloorBot design is a compact, Roomba-inspired, vacuum and mopping robot. The rover uses sensors and wheels to navigate a space and provide optimal cleaning. Clean water can be filled up using the left hose, and dirty water can be disposed of through the right hose. The dry mop on the bottom extends while the robot is mopping and retracts when vacuuming. FloorBot is approximately 2ft tall with a diameter of 1.5ft. (drawing isn't to scale). It fulfills our criteria by being able to hold over 0.5 liters of water, having sensors to detect floor types, and having large wheels to quickly traverse rooms while cleaning.

AirBot



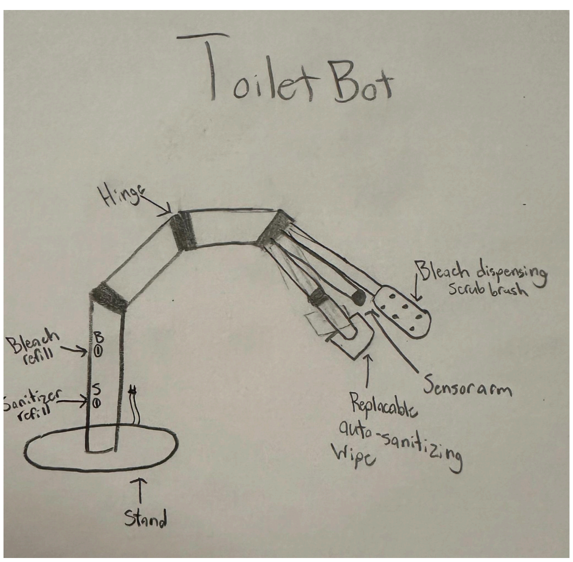
My AirBot design is a two-way fan that takes in air, runs it through a filter, and dispenses it out the other side. It has a removable panel on its left side that allows the filter to be replaced. Sensors inside the fan observe the filter and how fast it's catching debris. Based on its observations, it determines the overall quality of the air in a room. It sits at 2ft tall, 4ft long, and 10in wide. It fulfills our criteria by displaying the current air quality and by being big enough to filter larger-sized rooms.

WindowBot



My WindowBot design horizontally moves along windows and sprays them with Windex. It utilizes precisely calibrated vacuums to suction itself to surfaces. To get over ledges on windows, the directional wheels extend and allow it to horizontally climb. The sensors on the side and bottom allow it to visualize the surface it's cleaning. It fulfills our criteria by being able to navigate and clean all sections of a window's surface.

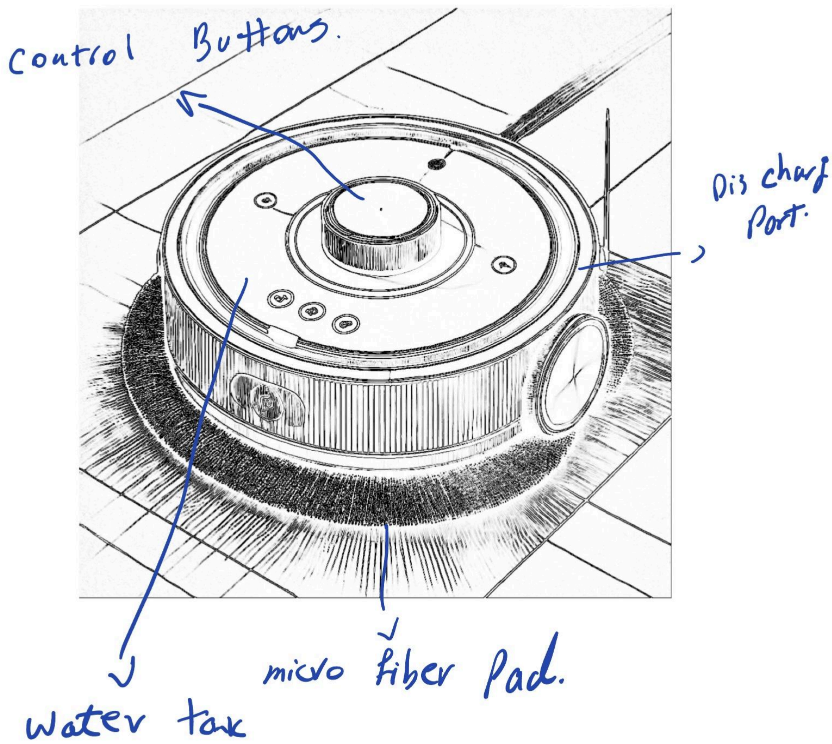
ToiletBot



My ToiletBot is a large, stationary arm with 3 sub-arms designed to optimally clean toilets. The main arm contains a camera that navigates the toilet, and creates a 3D map of the surfaces. The brush arm dispenses bleach and scrubs the interior of the bowl. Finally, the third arm holds an auto-sanitizing wipe that can be replaced when needed. It fulfills our criteria of being able to both scrub the bowl and sanitize the seat without user input.

3.3 Robot Ideas by Sajjad Sheykhi

FloorBot

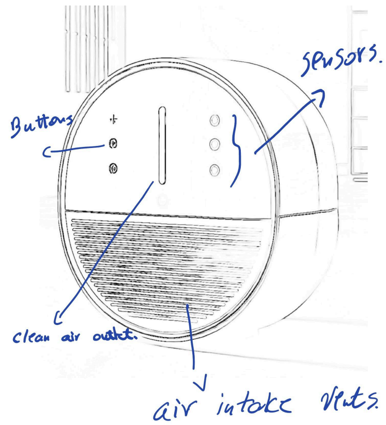


The FloorBot is an advanced cleaning robot designed to efficiently mop and polish hard floor surfaces. It features a compact, circular design with a rotating microfiber pad underneath for thorough cleaning. The robot includes a dual-tank system: a clean water tank for mopping and a dirty water tank for collecting wastewater.

The FloorBot docks on a ramp-based station that uses gravity to empty the dirty water tank and refill the clean water tank. If connected to a drainage system, the dirty water flows away automatically, and the clean water tank can be replenished from a freshwater supply. The dock also has an internal vacuum system to collect dust and debris from the robot, ensuring minimal maintenance.

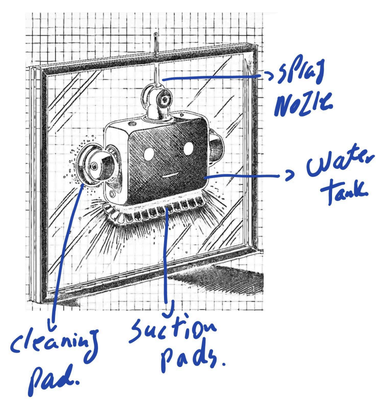
Equipped with intuitive control buttons, LED indicators, and built-in sensors, the FloorBot can navigate obstacles and clean efficiently in various environments. Optional settings allow users to add cleaning solutions for enhanced performance. The FloorBot simplifies floor cleaning, combining functionality with a user-friendly design to support a fully automated smart home.

AirBot



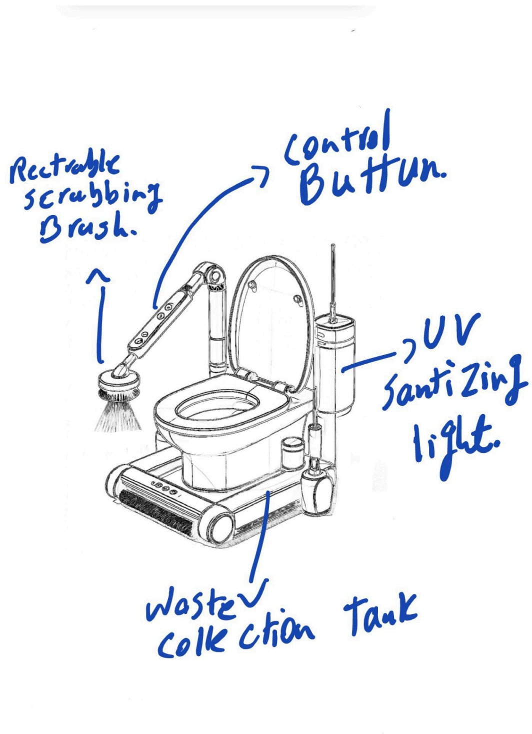
The AirBot features a sleek cylindrical design with a compact base, making it suitable for various room sizes. Air is drawn in through the side vents surrounding the body, where it undergoes purification. Clean air is released through the top vent, ensuring consistent air circulation throughout the space. At the center of the top surface, there is a discreet compartment for adding essential oils or scent capsules, allowing the user to diffuse fragrances. The front of the bot houses an advanced air quality sensor with a digital display that shows real-time air quality readings, providing users with immediate feedback on their environment.

WindowBot



The WindowBot is a compact, automated robot designed for cleaning windows and other glass surfaces such as mirrors. It features a square design with strong suction pads to securely attach to vertical and horizontal glass surfaces. A rotating cleaning pad on the front effectively scrubs and polishes glass while a built-in spray nozzle applies cleaning solution as needed. The robot has an integrated water reservoir and a simple control panel with a power button and indicator lights to show operational status. With its ability to navigate surfaces autonomously, the WindowBot ensures streak-free, spotless glass with minimal user effort.

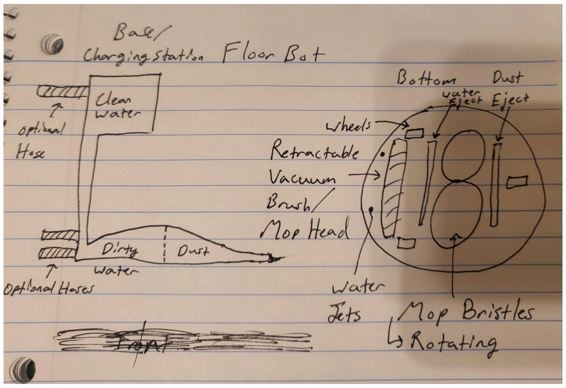
ToiletBot



The ToiletBot is a compact, stationary robot designed for efficient and thorough toilet cleaning. It features a main body equipped with a retractable scrubbing brush arm that navigates the inner bowl, ensuring a deep clean. A second arm dispenses disinfectant spray to sanitize the seat and surrounding surfaces. The robot also incorporates a UV sanitizing light for added hygiene, eliminating germs without the need for harsh chemicals. With built-in sensors, the ToiletBot maps the toilet's surface for precise cleaning and operates autonomously, requiring minimal user input. Its replaceable cleaning components ensure long-term usability and hygiene maintenance.

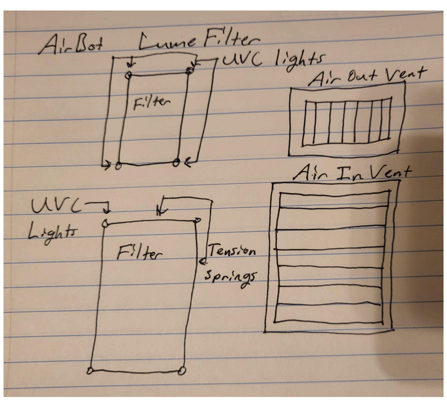
3.4 Robot Ideas by Tristan Van Cleave

FloorBot



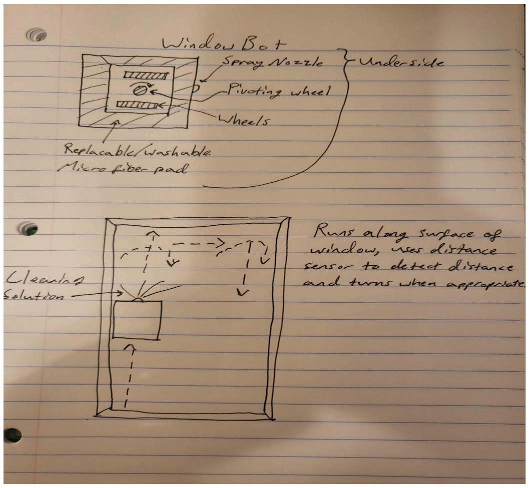
The base uses a ramp design allowing gravity to assist in filling and flushing away dirt and debris. A second vacuum (located in the base) will draw dust into the base receptacle. FloorBot includes optional hoses that connect to a central vacuum system, drain, and freshwater. If fully connected: the central vacuum will pull away dirt, water will drain into the ordinary plumbing of the home and fresh water flows from above, through the FloorBot, and away into the drain, cleaning the internal components of both the base and the FloorBot. Chemicals can be either manually or automatically added to the freshwater tank located either in the base/charging station or the FloorBot itself.

AirBot



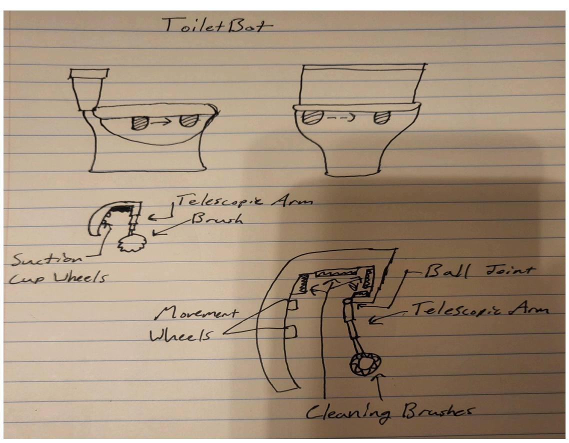
My AirBot functions alongside standard HVAC systems. It's a modular system and features multiple filters fitted for the air intake and air return vents. The filters are fitted to the inside of the vents by collapsing the tension springs that double as the frame for the filters. At the corners of each filter is a small but powerful UVC light that shines into the vent. Air is filtered entering the intake vents purified with UVC light, purified a second time leaving the return vents, and filtered a second time through the air return filters exiting the return vents. Scent diffusion is handled by scented filter inserts, and air quality is monitored by small computers located in the frame.

WindowBot



My WindowBot uses independently rotating suction cup wheels and a central retractable suction wheel that rotates 360 degrees, ensuring it's never stuck in a corner, and allowing omnidirectional movement. The WindowBot has an internal cleaning solution and water reservoir. The window bot can be used on any smooth surface such as glass or mirrored ceilings, and smooth tile. It has collision and distance sensors allowing it to map the surface and adjust its movement pattern.

ToiletBot



The ToiletBot attaches to the bowl of a standard toilet with four brushes for cleaning the rim of the toilet (including the underside of the inner rim), and an extendable brush arm with a ball joint that allows it to reach every surface of the inner bowl and dispenses it's own cleaning solution. The ToiletBot moves horizontally along the bowl, cleaning both the inside of the bowl, and the top of the rim. It operates on a programmable timer and is space saving allowing it to be easily removed when not in use.

4. Robot Selection

In this section, each team member individually selected the robot they wanted to take the lead creating, and created a decision matrix for their favorite of the designs put forth by the team. A single AHP chart was used for the whole team, that reflects our collectively agreed upon design principles, given that all robots share some design requirements, though their specific function may vary.

4.1 Decision Matrix for FloorBot

See table 4.1.1 for the decision matrix and table 4.1.2, its corresponding AHP chart.

Table 4.1.1 Decision Matrix to rate various designs of FloorBot

Criteria	**Weight**	**Alyssa's Design**		**Landon's Design**		**Sajjad's Design**		**Tristan's Design**	
		Rating	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**
Efficiency	**0.4**	**4**	**1.6**	**3**	**1.2**	**4**	**1.6**	**4**	**1.6**
Cleaning Quality	**0.3**	**4**	**1.2**	**4**	**1.2**	**3**	**1.2**	**4**	**1.2**
Adaptability	**0.2**	**5**	**1.0**	**5**	**1.0**	**3**	**0.6**	**5**	**1.0**
Independence	**0.1**	**3**	**0.3**	**4**	**0.4**	**5**	**0.5**	**5**	**0.5**
Total			**4.1**		**3.8**		**3.9**		**4.3**

Table 4.1.2 FloorBot AHP Chart

	Efficiency	Cleaning Quality	Adaptability	Independence	Total	Weight
Efficiency	1	4/3	2	4	25/3	0.4
Cleaning Quality	¾	1	3/2	3	25/4	0.3
Adaptability	½	2/3	1	2	25/6	0.2
Independence	¼	1/3	½	1	25/12	0.1
					125/6	

4.2 Decision Matrix for AirBot

See table 4.2.1 for the decision matrix and table 4.2.2, its corresponding AHP chart.

Table 4.2.1 Decision Matrix to rate various designs of AirBot

Criteria	**Weight**	**Alyssa's Design**		**Landon's Design**		**Sajjad's Design**		**Tristan's Design**	
		Rating	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**
Efficiency	**0.4**	**4**	**1.6**	**3**	**1.2**	**3**	**1.2**	**5**	**2.0**
Cleaning Quality	**0.3**	**5**	**1.5**	**5**	**1.5**	**5**	**1.5**	**4**	**1.2**
Adaptability	**0.2**	**4**	**0.8**	**2**	**0.4**	**3**	**0.6**	**5**	**1.0**
Independence	**0.1**	**4**	**0.4**	**4**	**0.4**	**4**	**0.4**	**4**	**0.4**
Total			**4.3**		**3.5**		**3.7**		**4.6**

Table 4.2.2 AirBot AHP Chart

	Efficiency	Cleaning Quality	Adaptability	Independence	Total	Weight
Efficiency	1	4/3	2	4	25/3	0.4
Cleaning Quality	¾	1	3/2	3	25/4	0.3
Adaptability	½	2/3	1	2	25/6	0.2
Independence	¼	1/3	½	1	25/12	0.1
					125/6	

4.3 Decision Matrix for WindowBot

See table 4.3.1 for the decision matrix and table 4.3.2, its corresponding AHP chart.

Table 4.3.1 Decision Matrix to rate various designs of WindowBot

Criteria	Weight	Alyssa's Design		Landon's design		Sajjad's design		Tristan's design	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score
Efficiency	0.4	4	1.6	4	1.6	4	1.6	5	2.0
Cleaning Quality	0.3	4	1.2	4	1.2	3	0.9	4	1.2
Adaptability	0.2	5	1.0	3	0.6	3	0.6	4	0.8
Independence	0.1	4	0.4	5	0.5	4	0.4	5	0.5
Total			4.2		3.9		3.5		4.5

Table 4.3.2 WindowBot AHP Chart

	Efficiency	Cleaning Quality	Adaptability	Independence	Total	Weight
Efficiency	1	4/3	2	4	25/3	0.4
Cleaning Quality	¾	1	3/2	3	25/4	0.3
Adaptability	½	2/3	1	2	25/6	0.2
Independence	¼	1/3	½	1	25/12	0.1
					125/6	

4.4 Decision Matrix for ToiletBot

See table 4.4.1 for the decision matrix and table 4.4.2, its corresponding AHP chart.

Table 4.4.1 Decision Matrix to rate various designs of ToiletBot

Criteria	Weight	Alyssa's Design		Landon's Design		Sajjad's Design		Tristan's Design	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score
Efficiency	0.30	3	0.90	3	0.90	4	1.20	2	0.60
Cleaning Quality	0.30	3	0.90	3	0.90	4	1.20	2	0.60
Adaptability	.05	2	0.10	2	0.10	1	0.05	2	0.10
Independence	.35	3	1.05	2	0.70	4	1.40	3	1.05
TOTAL	**1.00**		**2.95**		**2.60**		**3.85**		**2.35**

Table 4.3.2 ToiletBot AHP Chart

	Efficiency	Cleaning Quality	Adaptability	Independence	Total	Weight
Efficiency	1	4/3	2	4	25/3	0.4
Cleaning Quality	¾	1	3/2	3	25/4	0.3
Adaptability	½	2/3	1	2	25/6	0.2
Independence	¼	1/3	½	1	25/12	0.1
					125/6	

5. Proposed Designs

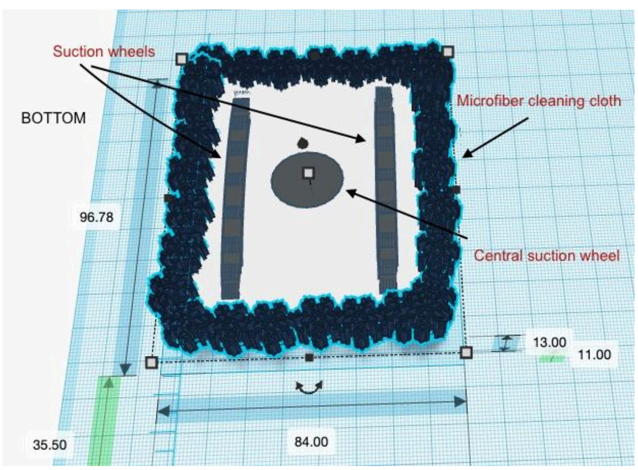
Based on the scores from the decision matrix, and further brainstorming, the group decided on the following designs.

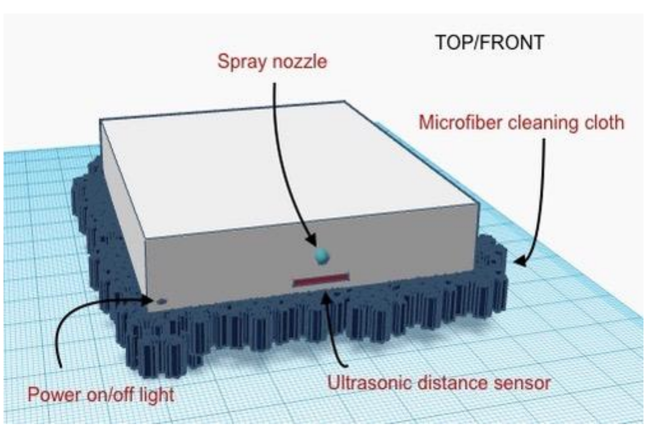
5.1 WindowBot by Alyssa Simonson

5.1.1 WindowBot Description

The WindowBot is designed to move along the surface of the window, cleaning the entire surface. It is designed to function independently using ultrasonic distance sensors that map the surface, prevent collision, and detect lingering dust or dirt on the window, ensuring a thorough cleaning. The WindowBot moves using three suction wheels on the bottom of the device. The two primary wheels are connected to DC motors which move the robot forward and backward while the third wheel is connected to a servo motor that allows for multi directional rotation. This third, central suction wheel lifts the device off the window and helps in turning the device to the correct angle for navigating around the corners of the window. Surrounding the outer edges of WindowBot is a microfiber cleaning cloth that is used to wipe down the surface of the window. It is removable for easy washing and replacing. Lastly, the WindowBot contains a compartment connected to an external spray nozzle that can easily be filled with water or cleaning solution.

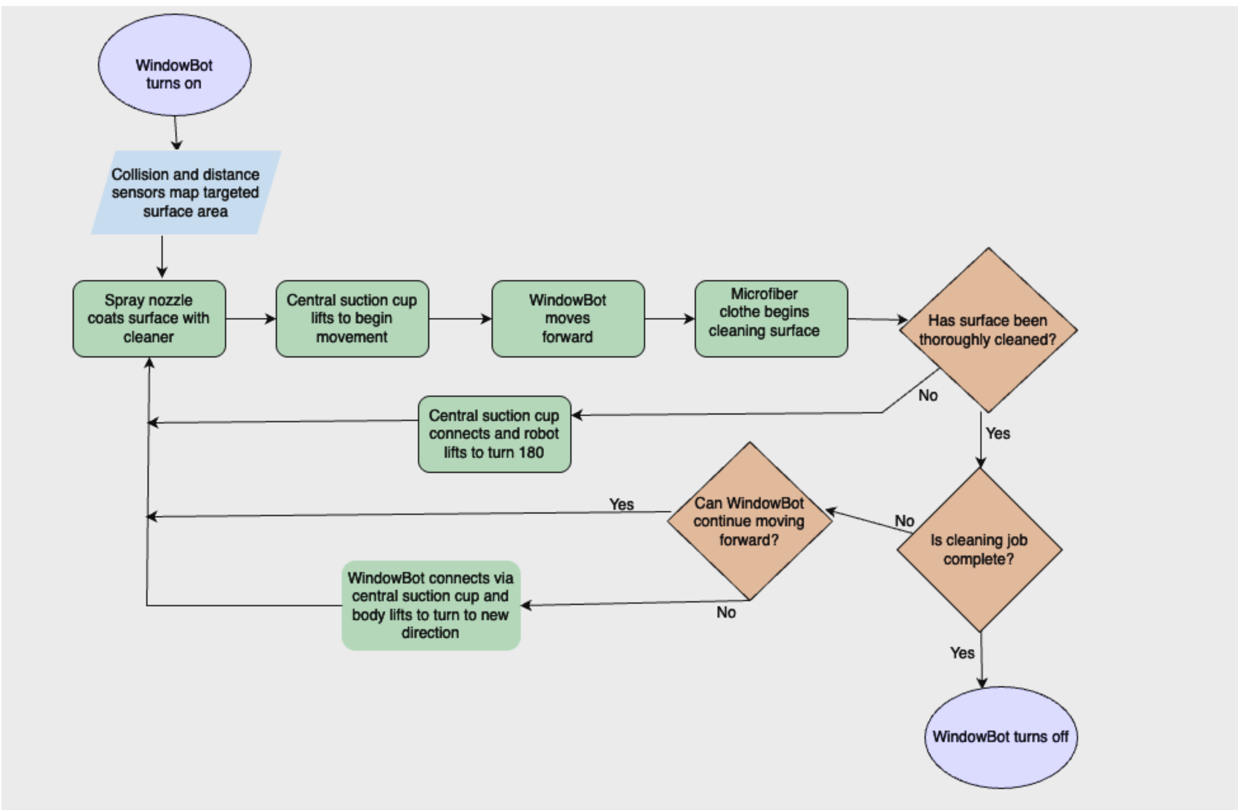
5.1.1 WindowBot CAD Model





5.1.2 WindowBot Algorithm
The WindowBot will first need to be directly turned on for use. The robot will use collision and distance sensors to gain a sense of where it is in relation to its surroundings and to map the window or targeted surface. The WindowBot will begin by using its spray nozzle on the front of the unit to spray with glass or window cleaner. It will then move forward on its suction cup wheels to wipe the surface with its body that contains microfiber clothes. The sensors will continuously be used to ensure it is thorough in its cleaning without going out of the desired environment. As needed, the robot, directed by the sensors, will use the inner pivoting wheel to turn the robot in different directions and ensure the entire surface is clean. Once it has detected the entirety of the surface is cleaned, it will turn off automatically.

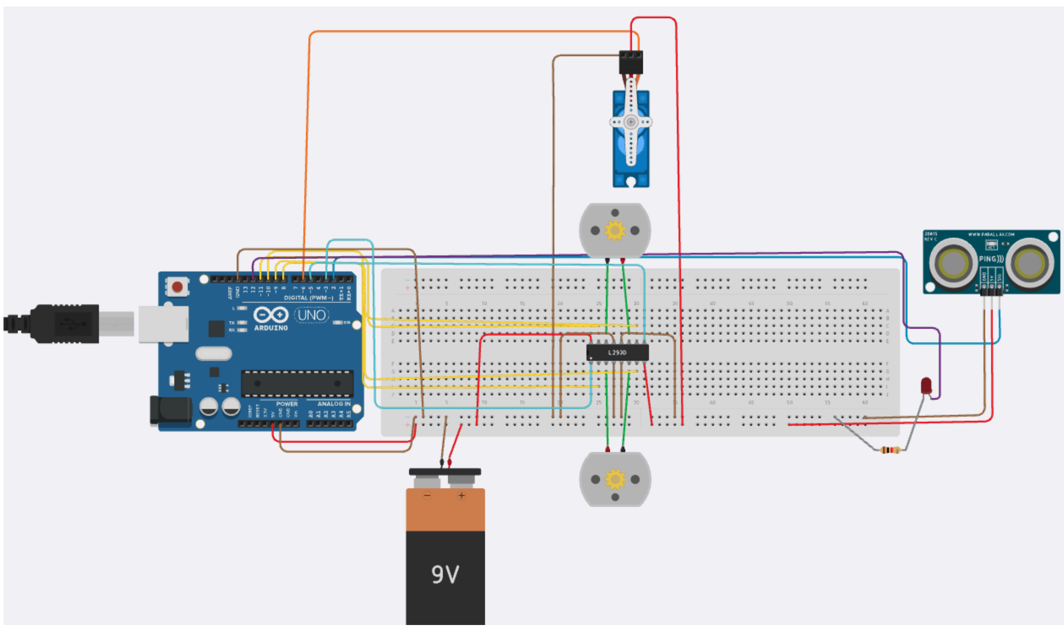
5.1.2 WindowBot Algorithm FlowChart



5.1.3 WindowBot TinkerCAD Simulation

A TinkerCAD circuit was made for this robot to simulate the algorithm described in the previous subsection. The circuit's snapshot is shown in the Figure 5.1.3 below and the TinkerCAD link for that circuit can be accessed at https://www.tinkercad.com/things/8d1ue0EzIDA-windowbot?sharecode=to5OcAbjda9HzoPHzNgq94WbaXeE8OnARLQPd43OUzo . A short video demonstrating the working circuit and the algorithm can be viewed at this link: https://youtu.be/nrLIB_vqrYA .

Figure 5.1.3 WindowBot TinkerCad Circuit

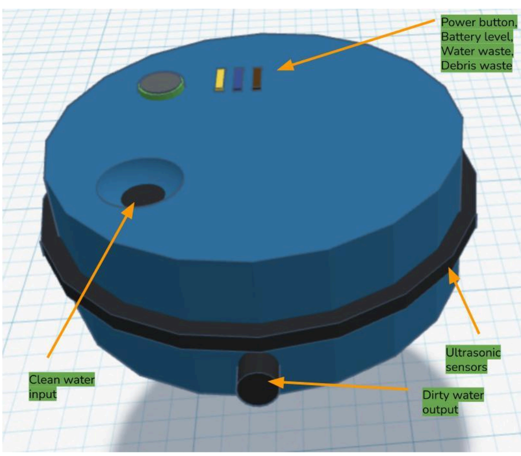


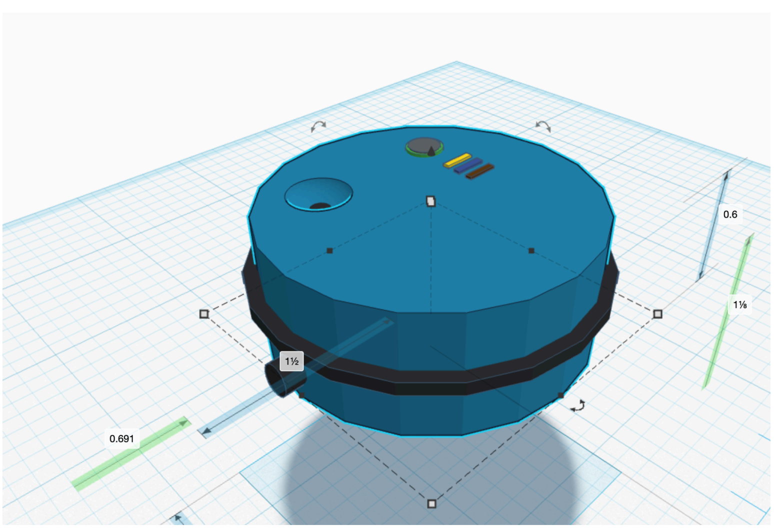
5.2 FloorBot by Landon Carroll

5.2.1 FloorBot Description

The FloorBot is designed to independently drive itself around the house and change its cleaning method based on the floor's surface. It features both a mop and a vacuum that can be cycled between based on input from vibration sensors along the bottom. The mop water itself is dispensed through jets on the bottom of the device. It can be filled up with clean water through a hole on top. Ultrasonic sensors along the sides allow the FloorBot to map out a room and prevent itself from driving into walls or furniture. Dirty water and debris picked up by the vacuum are held in tanks and have the option to be dispensed manually or automatically into an accommodating dock. The FloorBot can also charge itself via an accommodating charging dock. The actuators included in the design are the vacuum, water jets, front wheels, and rotating dry mop.

5.2.1 FloorBot CAD Model



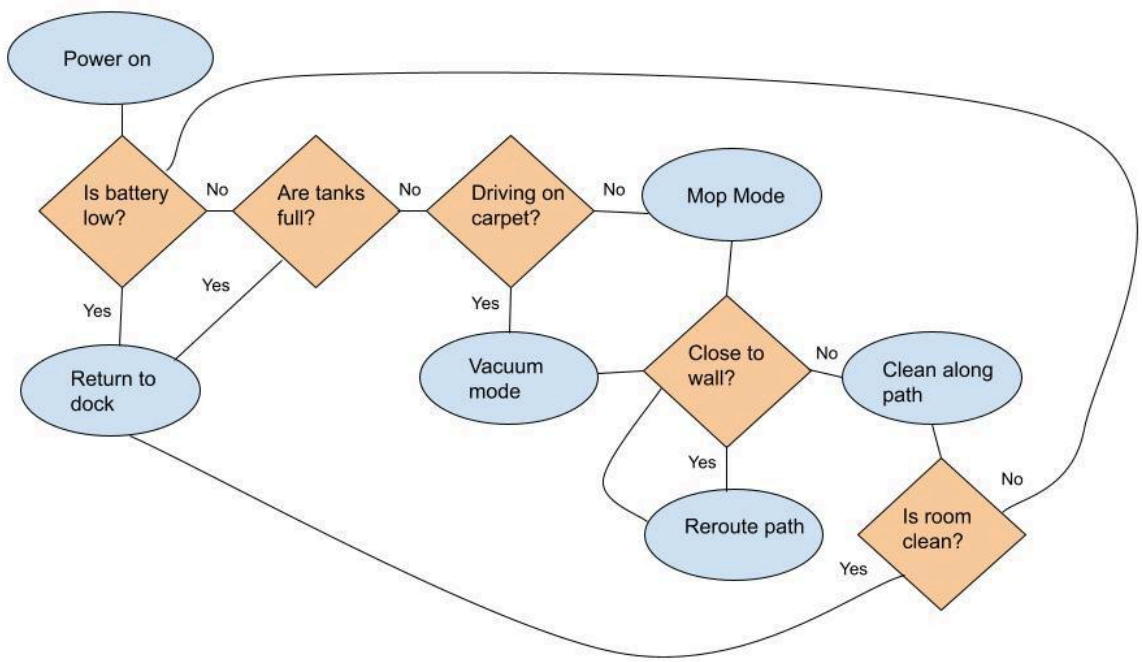


*Dimensions are in feet

5.2.2 FloorBot Algorithm

When the FloorBot is turned on, it first checks the status of its battery life, water waste, and debris waste. If it's low on battery or either of the waste tanks is full, it navigates itself back to its dock. It continues to constantly check this. When it's ready to start cleaning, it activates its vibration sensors to detect what type of floor it's cleaning. The vibration sensors detect whether it's on carpet or hardwood flooring and activate either the vacuum or the mopping mechanism. When in mopping mode, the FloorBot first loops around the room dispensing mop water through the jets. Following that loop, the dry mop will be deployed and the FloorBot will dry the floor. In vacuum mode, the FloorBot retracts the dry mop and deploys a small vacuum head in its place. The robot navigates the room via its ultrasonic sensors. The sensors loop and the device's distance from the nearest wall is constantly updated. The wheels are redirected if the FloorBot gets too close to a wall.

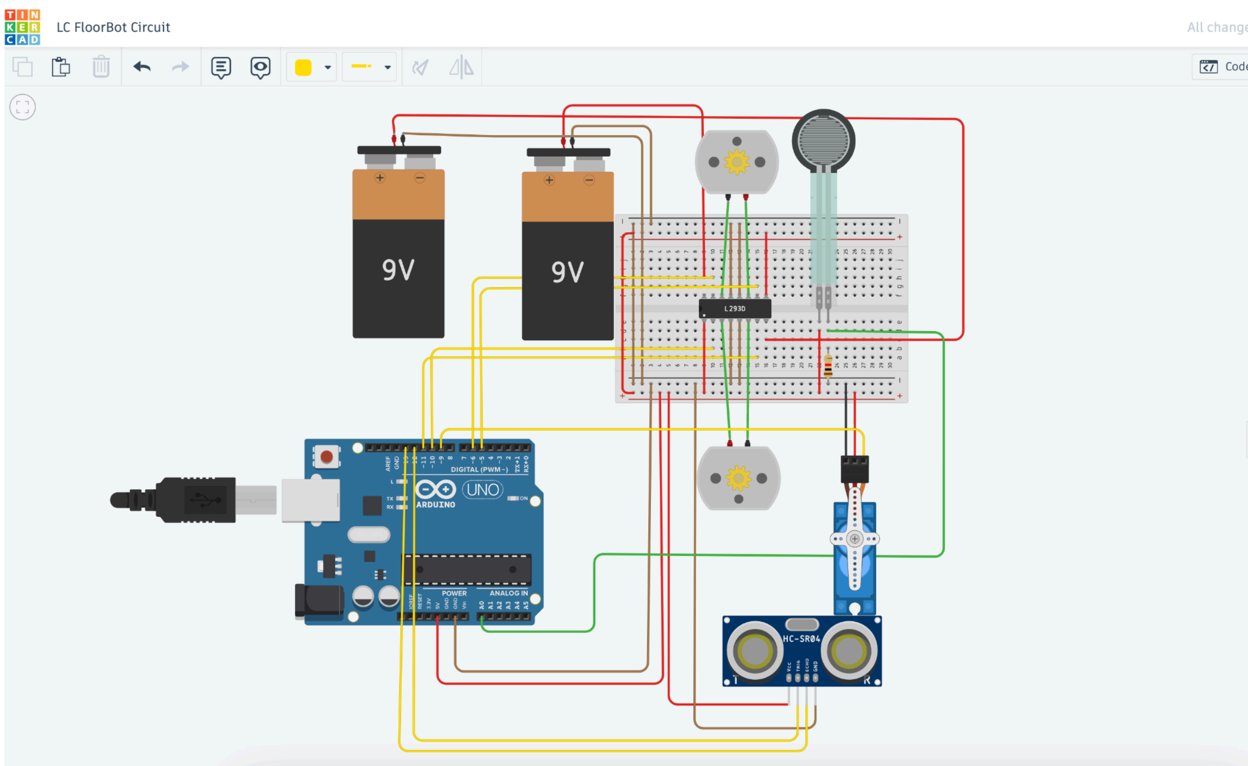
5.2.2 FloorBot Algorithm Flowchart



5.2.3 FloorBot TinkerCAD Simulation

A TinkerCAD circuit was made for this robot to simulate the algorithm described in the previous subsection. The circuit's snapshot is shown in the Figure 5.2.3 below and the TinkerCAD link for that circuit can be accessed at https://www.tinkercad.com/things/6gRidc3Rn7X-lc-floorbot-circuit?sharecode=yMPK_shULzNPW3NTuaxRbCFmn30--_6MS37LeeEyb9c A short video demonstrating the working circuit and the algorithm can be viewed at this link: https://youtu.be/rovRIOS1aE8

5.2.3 FloorBot TinkerCAD Circuit



5.3 ToiletBot by Tristan Van Cleave

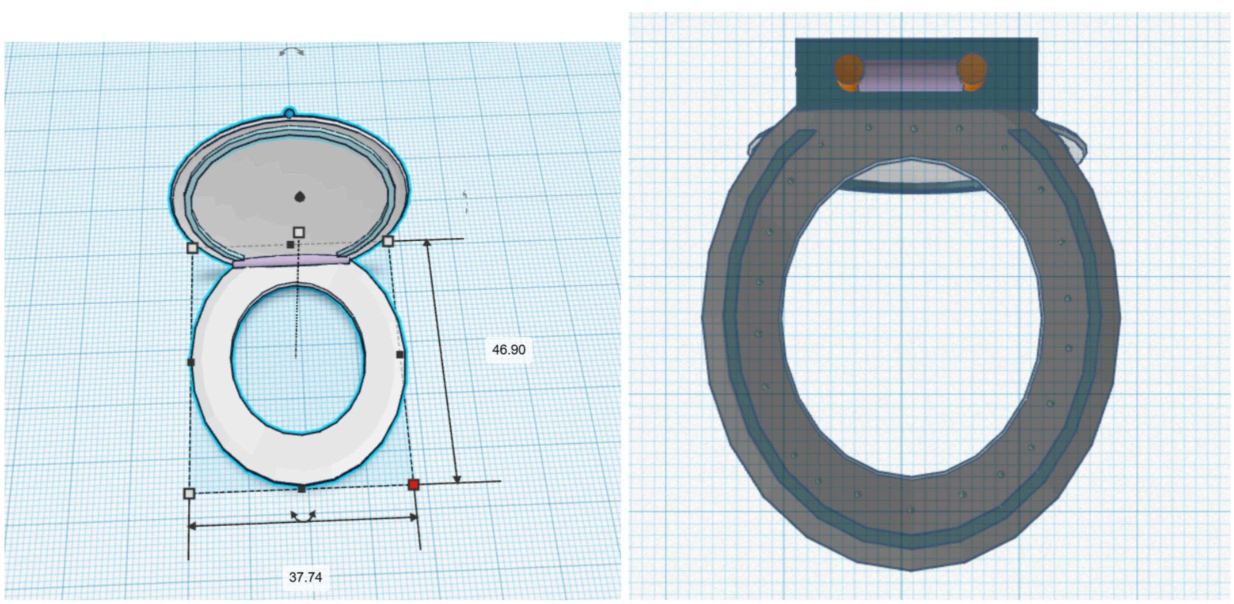
5.3.1 Description

The ToiletBot will be a smart, light activated toilet seat that cleans and sanitizes the interior of the bowl and sanitizes the seat after each use. It features a refillable sanitizing solution reservoir, high pressure water jets, and powerful UV lights located on the underside of the seat and lid. When activated, the lid will open automatically ready for use. When the lights are turned off, the servos will close the lid and return the seat to the down position–if it was raised during use.

When not in use, the ToiletBot will automatically enter a cleaning cycle. Water, fed from the standard plumbing system, mixed with sanitizing solution will be sprayed from the water jets at high pressure, removing any debris from the inside of the bowl. UV lights located under the seat and in the lid will activate, sanitizing the seat, and the bowl.

The prototype will be powered by an arduino housed within the rear compartment of the seat, use light activated servo motors to lift and lower the lid and seat (servo motors, photoresistor), contain UV sanitizing lights housed under the seat and lid (neopixel LED strips for prototype) that will activate, and contain water jets housed under the seat for washing away debris (DC motor for prototype).

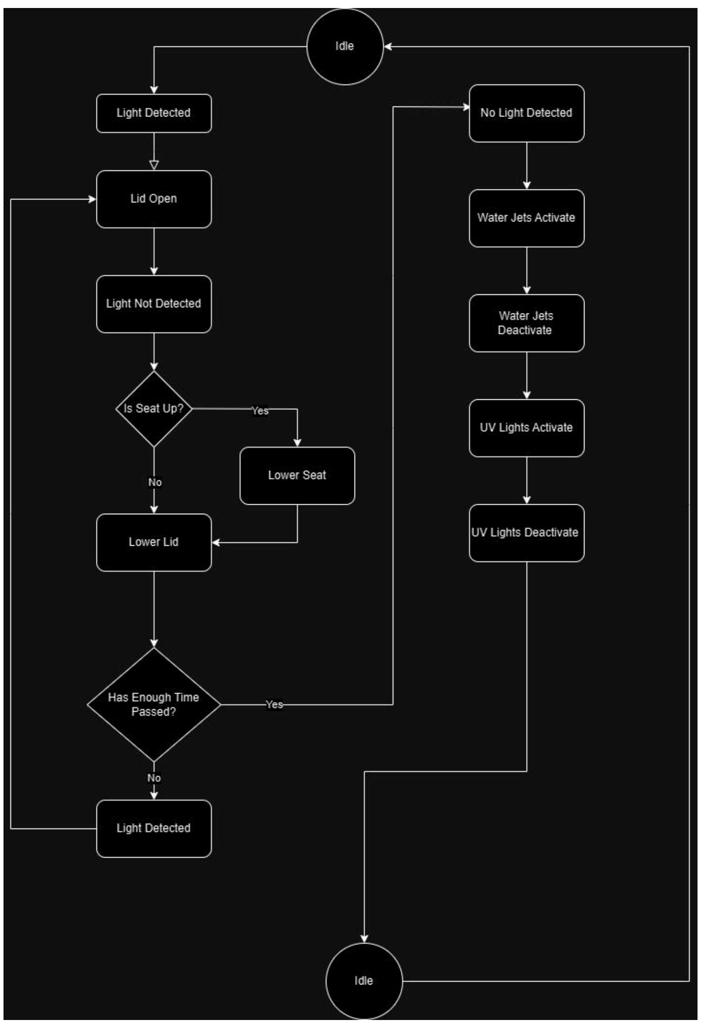
5.3.1 ToiletBot CAD Model



5.3.2 ToiletBot Algorithm

The ToiletBot will function from light detected by standard bathroom lighting. When no light is detected, the ToiletBot will sit in an idle state. When the overhead lights are detected, it will automatically raise the lid. The seat may or may not be manually raised by the user. When use has finished and light is not detected, the ToiletBot will check to see if the seat has been raised, this will be accomplished mechanically. The whole mechanism will be run with a single servo, if the seat is raised, then the servo will “catch” the seat, lowering it alongside the lid. if so it will lower the seat first and then the lid. The lid will lower regardless. It will then rest for a period of time before the cleaning process begins. If light is detected again in the waiting period, it will lift the lid and resume that branch of the program. If the time condition has been met, it will first activate the water jets that will clean the interior of the bowl, turn them off, then activate the UV lights under the seat and lid for a period of time. When the lights deactivate, cleaning is finished, and it will return to it’s idle state, ready to be used again.

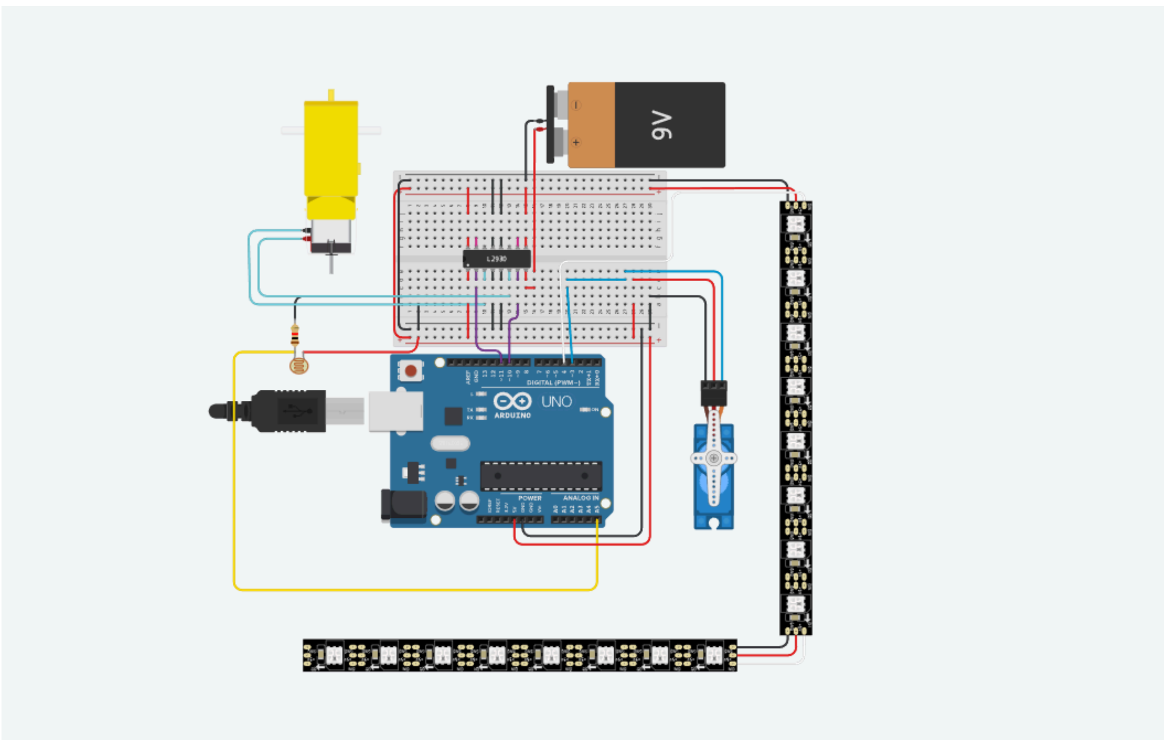
5.3.2 ToiletBot Algorithm Flowchart



5.3.3 ToiletBot TinkerCAD Simulation

A TinkerCAD circuit was made for this robot to simulate the algorithm described in the previous subsection. The circuit's snapshot is shown in the Figure 5.3.3 below and the TinkerCAD link for that circuit can be accessed at https://www.tinkercad.com/things/8eOgHjg0bh8-working-copy-of-final-project-arduino-circuit-2?sharecode=JyGfJF7Y_PjJkv2V8dOqnK7S_ZRsinpx3HpTmRR-MrI A short video demonstrating the working circuit and the algorithm can be viewed at this link: https://www.youtube.com/watch?v=QKe8PA91ITY

5.3.3 ToiletBot TinkerCAD Circuit



5.4 Airbot by Sajjad Sheykhi

5.4.1 Description

The AirBot is designed to autonomously monitor and improve air quality in indoor environments while optionally diffusing pleasant scents. It features air intake vents on the sides that draw in surrounding air, passing it through an internal purification system equipped with HEPA and activated carbon filters. The purified air is released through a clean air outlet at the top of the device.

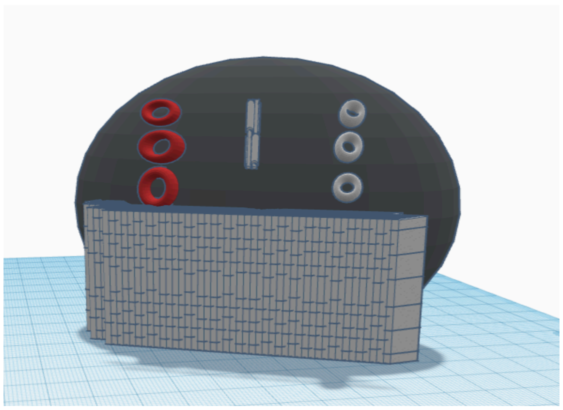
For scent diffusion, the AirBot includes a dedicated compartment on the top where users can insert essential oils or scent capsules. The diffusion system is integrated into the airflow mechanism, allowing for consistent scent dispersion when activated. The air quality sensor, located on the front of the AirBot, constantly monitors particulate levels and adjusts fan speed accordingly to maintain optimal air quality.

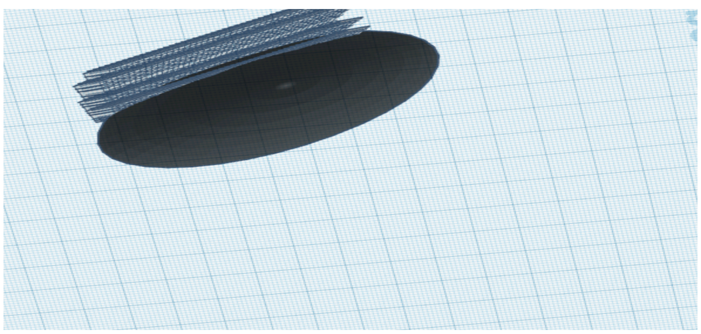
Ultrasonic sensors on the front and sides prevent the AirBot from colliding with obstacles if mobility features are enabled. The device also displays real-time air quality data and operational status on an LED panel, providing clear feedback to the user.

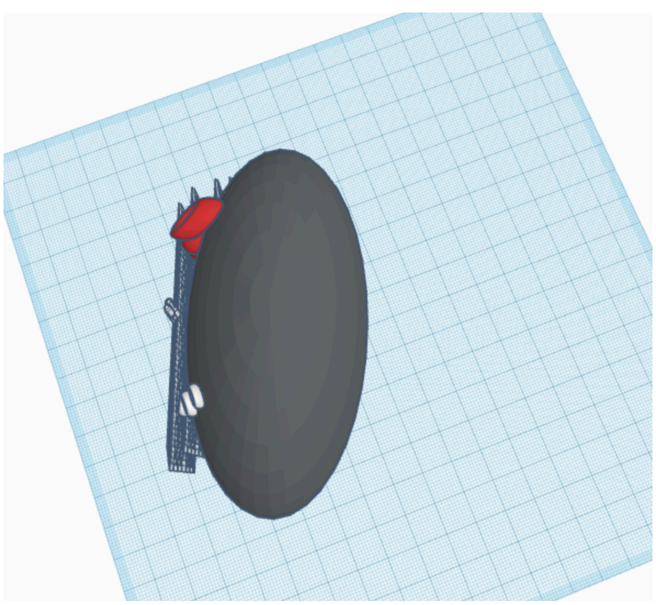
The AirBot is equipped with actuators for the fan, scent diffuser, and air quality monitoring adjustments. It can be manually operated or set to automated cleaning and scent modes, making it a versatile solution for maintaining a healthy and pleasant indoor environment.

5.4.1 AirBot CAD Model

The CAD model includes detailed representations of the air intake vents, air quality sensor, LED panel, and actuators. All components are shown integrated within a compact and sleek housing designed for maximum efficiency and minimal footprint.





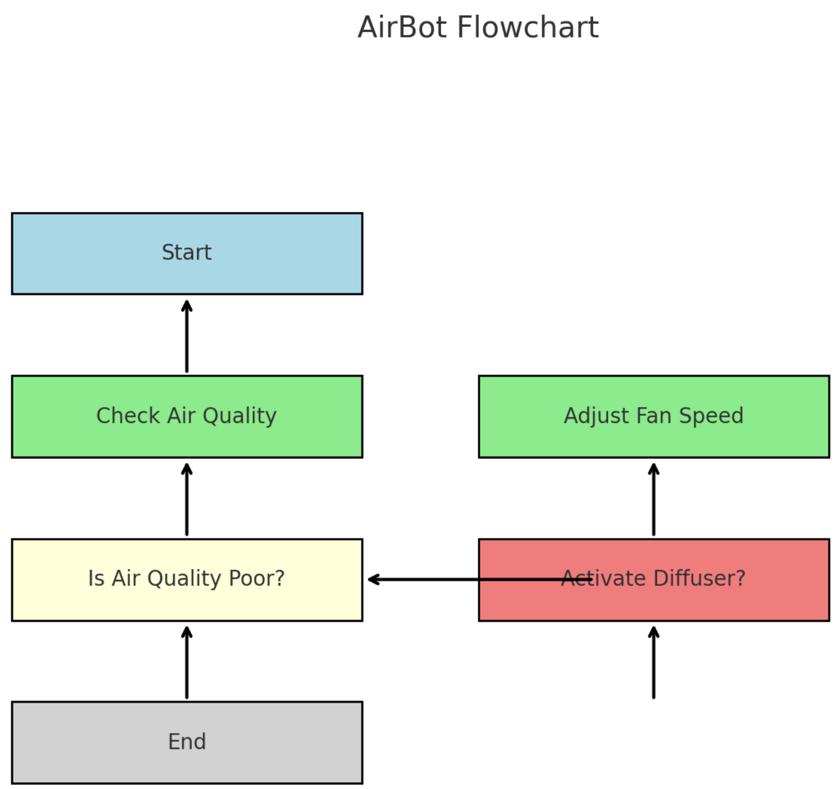


5.4.2 AirBot Algorithm

Below is a screenshot of the circuit simulation for the AirBot. The potentiometer simulates an air quality sensor, the motor represents the air purifier fan, and the LED indicates poor air quality. The circuit operates based on the input from the potentiometer, adjusting the fan speed dynamically and turning the LED on or off based on air quality thresholds.

The code simulates the AirBot running autonomously, continuously monitoring air quality and adjusting its components in real-time. The design is modular, making it easy to expand for additional features like a scent diffuser or advanced air quality monitoring.

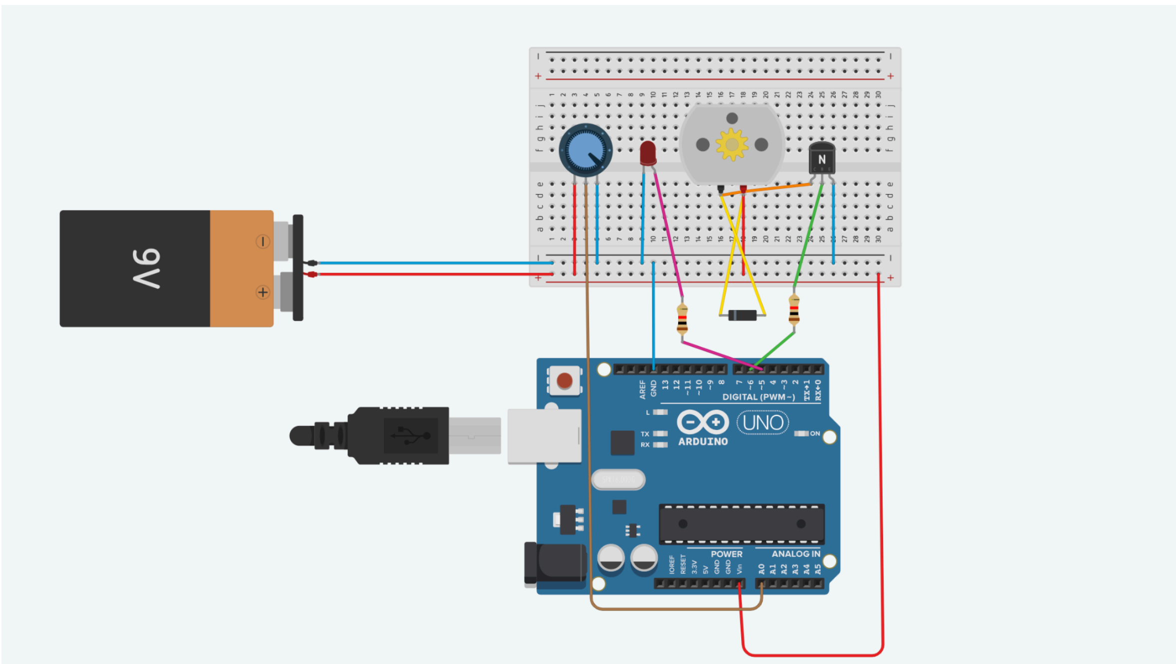
5.4.2 AirBot Algorithm Flowchart



5.4.3 AirBot TinkerCAD Simulation

A TinkerCAD circuit was made for this robot to simulate the algorithm described in the previous subsection. The circuit's snapshot is shown in the Figure 5.4.3 below and the TinkerCAD link for that circuit can be accessed at **< insert your shareable TinkerCAD link >**. A short video demonstrating the working circuit and the algorithm can be viewed at this link: https://youtu.be/ODDWjCETlYY.

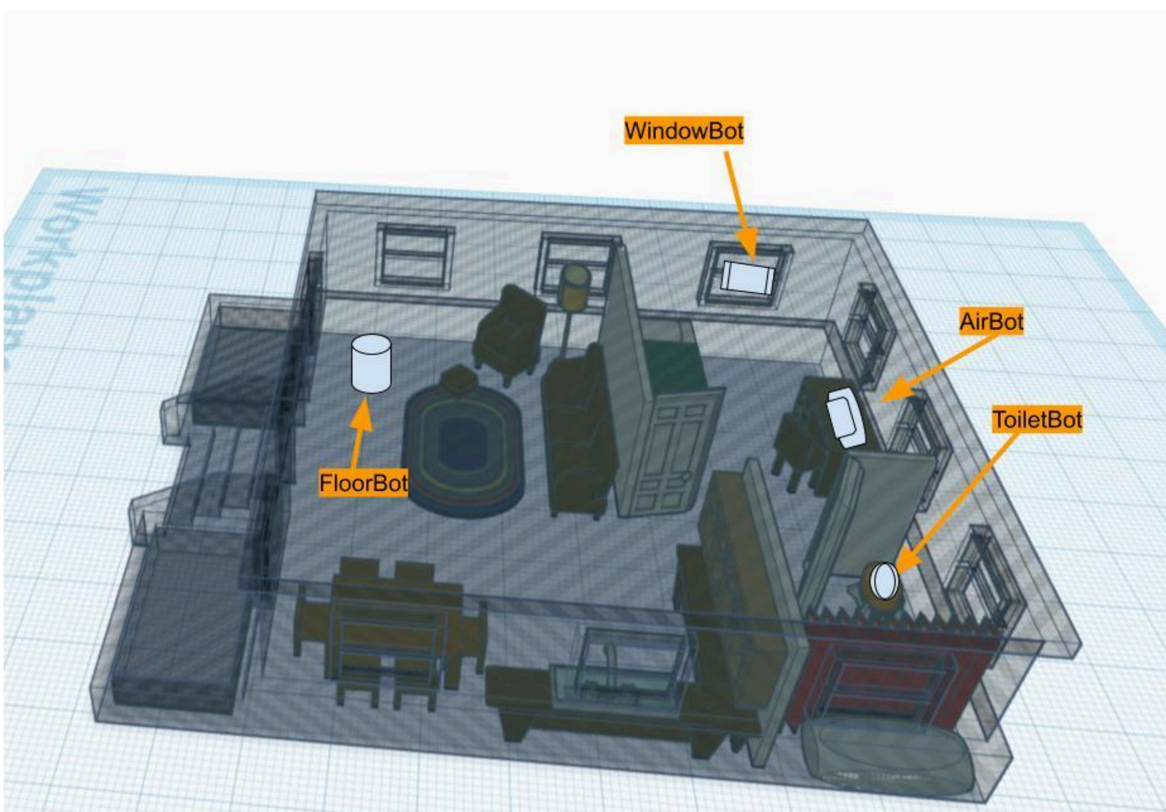
5.4.3 AirBot TinkerCAD Circuit



6. Robot Collaboration

This section describes how the individual robots work together to accomplish the team tasks of house cleaning including washing windows, mopping floors, scrubbing toilets, and purifying the air.

1. Operator places WindowBot on Window
2. Operator turns on WindowBot
3. Windows are washed by WindowBot
4. Operator turns off WindowBot
5. Operator turns on FloorBot
6. The floors are vacuumed and mopped by FloorBot
7. Operator turns off FloorBot
8. ToiletBot automatically cleans the toilet seat and bowl after each use via its light sensor.
9. Operator turns on AirBot
10. AirBot purifies the air automatically, navigated by ultrasonic sensors
11. Operator turns off Airbot



7. Conclusions

Our robot system utilizes cost-effective and time-efficient robots to automate several menial cleaning tasks. The robots fulfill our criteria by being able to not only accomplish their basic tasks well but also being cheap to assemble. A simple Arduino Uno runs each robot with the help of a few basic sensors and actuators. Their manageable designs even allow them to be tinkered with and built upon if desired.

This robotic cleaning system offers a multitude of advantages over current market solutions, Currently, products currently sold on the market as previously mentioned, are designed to perform only a single task. While they may be efficient solutions, they fail to provide an integrated solution for complete maintenance of the home. This reduces the need to search for individual devices for each task, providing a more economical and user-friendly solution. For example, a high-quality robotic vacuum can cost an average of around \$500-\$1,000 [5]; air purifiers and other specialized devices can add an additional cost of \$300-\$800 [7] each. With this proposed modular system, the total cost of ownership is projected to be significantly lower than purchasing individual devices for each task.The system provides time savings in addition to the cost savings. This system cuts the collective hours spent on home cleaning tasks since each robot focuses on a specific aspect and can be done simultaneously. This is an important aspect for dual-income households or busy professionals, where time is valued. Furthermore, the system reduces the need for user involvement by integrating automatic docking and maintenance, which adds convenience.

This report is the result of research and development by the entire team. **Section 1** introduces the problem that we set out to solve: designing an efficient and affordable solution for home cleaning, by automating some common household cleaning tasks. **Section 2** states our formal problem definition, outlines the design criteria which we would use for designing our robots, and presents a basic project time-line for us to follow. **Section 3** contains the individual robots designed by each team member and a brief explanation of how they are intended to function and how they solve the problem at hand. **Section 4** displays tables which each team member created where each design was ranked. **Section 5** is the result of the decision process that happened in the previous section. Each team member formalized a design proposal complete with a CAD model, a prototype circuit, and an algorithm which visually represents the intended functionality and operation of each robot. **Section 6** explains (with the help of the diagram) how the end user uses the system and how each robot works together to accomplish the collective goal of cleaning the home. **Section 7** is a conclusion to this report; followed by **References** which includes sources cited and consulted during research; **Appendix A** which displays a Gantt chart detailing the project timeline; finally **Appendix B** includes a video summarizing this project as a pitch to the customers.

If given the opportunity to do it over again, we would spend more time on TinkerCAD becoming familiar with the actuators and sensors available. Doing this would have informed the initial brainstorming process and likely would have likely changed the designs, and possibly led us to solve a different problem with a different swarm.

References

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https://www.cuimc.columbia.edu/news/new-type-ultraviolet-light-makes-indoor-air-safe-outdoors
[7]Dyson, “Air Purifiers | Pure Cool,” *Dyson.com*, 2022.
https://www.dyson.com/air-treatment/air-purifiers

Appendix A: Gantt Chart

Tasks	Start	End	Duration (weeks)	10/28 - 11/3	11/4 - 11/10	11/11 - 11/17	11/18 - 11/24	11/25 - 12/2
Decide problem	10/28	11/3	1					
Brainstorm robots	10/28	11/3	1	^				
Sketch robots	11/4	11/10	1		^			
Final designs	11/4	11/10	1		^			
Individual descriptions	11/4	11/17	2		^			
Individual algorithm flowcharts	11/4	11/17	2					
Initial CAD designs	11/11	11/17	1			^		
Robot collab	11/18	11/24	1				^	
Finalize Report	11/18	11/24	1				^	
Pitch Video	11/18	11/24	1				^	
Finalize Video	11/18	11/24	2				^	
Revision	11/25	12/2	1					^

Appendix B: Pitch Video

Due to conflicting work schedules, we were unable to do a Zoom meeting and collaboratively presented using captions instead. https://youtu.be/Z9KGgP3aIis