ADVITIYA’20 INVENTO

Window Cleaning Robot

Team CADbury

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Problem Description

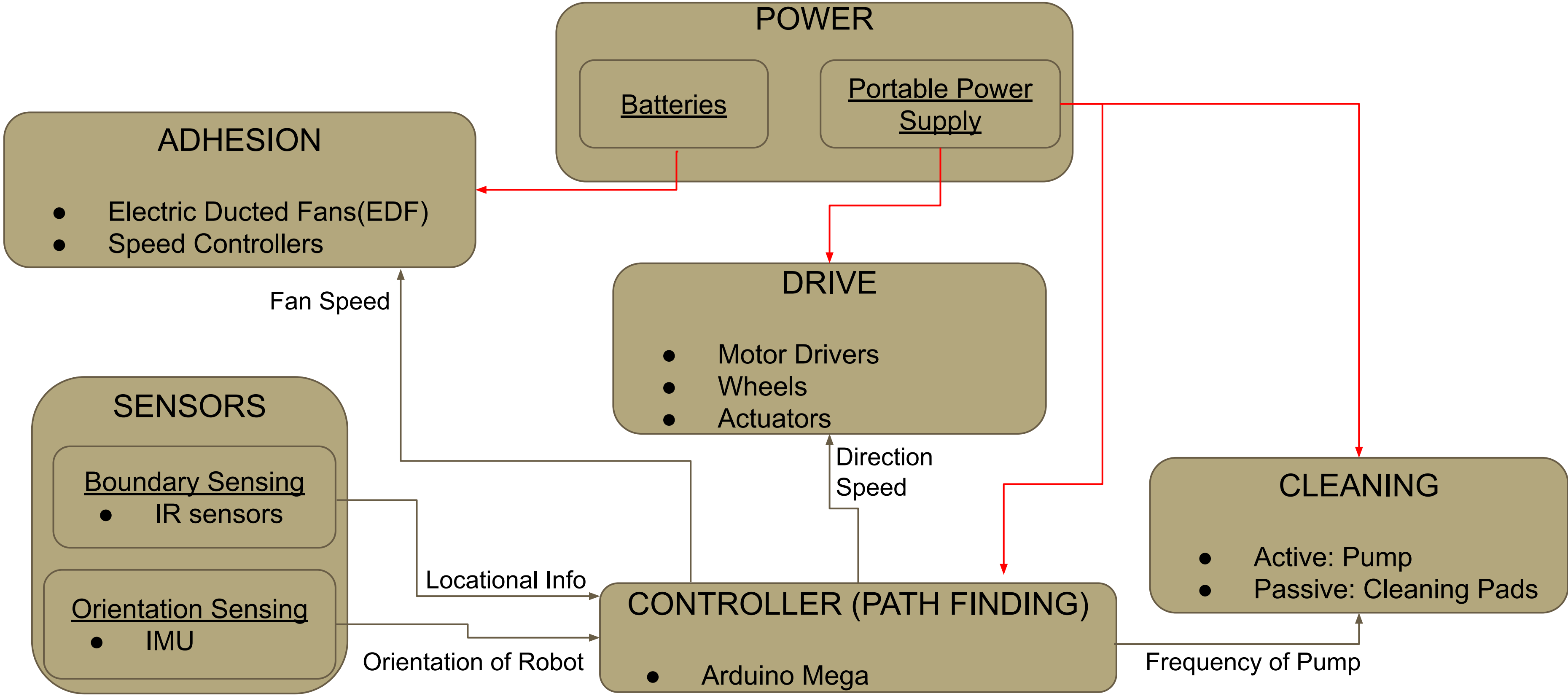
While cleaning the windows of a building, workers suspend themselves mid-air, and this poses a risk of falling. We, in our project, aim to eliminate the workers and automate this process. Our robot can sense the dimension of the window van can automatically do the cleaning without any human input.

The aim is to make the process of cleaning fast and completely automatic.

System Requirements

1. Able to clean window ranging from 3’x4’ to 5’x6’ at a speed of at least $10f^2$.
2. The bot structure should fit within a $2ft^2$ footprint.
3. Cleaning supplies should also be contained within the bot.
4. The cleaning devices should not cross the vertical plane of the window; a major concern is the protrusions around the window border.
5. The bot should clean both glass and acrylic plastics without scratching or damaging the window surface.

Functional Architecture

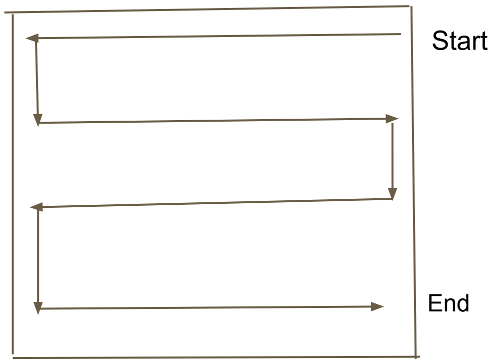


Controller

The controller acts as the **interface** between all other subsystems and pathfinding. This receives information and from that controls adhesion, cleaning, and driving as needed.

We can use the **Arduino Mega** as our controller. It has 256 KB of storage, 8 KB of RAM, and several other features that make it fit for our choice.

The path of travel we should choose should be like this to make gravity work in our favor and not work against it.



Adhesion

This subsystem is responsible for **adhering the robot to the window surface**. It should also **not reduce the robot's ability to maneuver.**

Our bot will use an **EDF** to create a vacuum that will hold the robot in the window plane. The adhesive force acting on the window will primarily be controlled by a PID controller.

Possible options for adhesion system and their advantages and disadvantages have been discussed below:

<u>EDF</u>: Ability to **manipulate the fan speed** via speed controller, thus changing the adhesive force whenever required. Provides high adhesive strength, ease of actuation, faster than suction cups. But the robot needs to be light as the suction force created is not as strong as in sealed suction cup.

<u>Gecko adhesives</u>: Directionally controllable. Disadvantageous to use as max shear, normal and moment loads are very small than that of suction cups.

<u>Suction cups</u>: Fairly easy to actuate, offer significantly more adhesive strength. However, this force can be too large to be desirable for climbing robot, which can also destabilize it during motion. Requires large pull off force to disengage.

<u>Magnets</u>: This constrains the surface to be cleaned to strictly ferromagnetic materials, which glass or acrylic is not. We can use magnets to both sides of the window but this will increase the complexity and is not practically possible.

Drive

This subsystem is to ensure the robot moves, turns and changes its speed of movement according to the inputs from controller.

This consists of a motor driver and two independent sets of **actuators** and **wheels**. Four **DC Motors** are used to drive the wheels and differential steering will be used for navigation based on the inputs from the controller system.

There are two main options to enable the robot to move about the window – a wheeled chassis or by suction cups.

Our chassis consists of 4 wheels. A small brushed DC gear motor is driving a wheel. The four independent motors are enabling torque and enabling movement in robot. Treads can also be used to increase the contact area between window and robot. This will lead to better steering control but will lead in weight increase.

While using Suction Cups, two cups will always need to be engaged to the window surface. 4 cups in total can be used and pairs of cups will be alternated amongst them, which will lead to movement of bot.

With the use of EDF, we can use the simple wheeled chassis mechanism for locomotion. EDF with wheeled chassis will enable the robot to have good mobility. Thus wheeled chassis is chosen.

Sensors

To interpret information from the environment, two main components are being used: Boundary Detection Sensor and Orientation Sensor.

<u>BOUNDARY SENSOR</u>

This sensor will provide the location of robot to the controller. **IR sensors** will give the feedback on the distance, say, to the nearest obstacle.
The sensor will transmit the data to the microcontroller which will in turn calculate the distance to the nearest obstacle. The IR sensor is placed in front of the robot in between the two nozzles.

To detect the window edge, proximity and tactile sensors are being used. When moving at the boundary, tactile sensor has greater accuracy and thus leads to precise movement. For fine tuning movements near boundaries, proximity sensor is used owing to its larger range.

<u>ORIENTATION SENSOR</u>

This sensor will give information regarding the orientation of our robot. This sensor assists in robot's turning. This consists of **IMU**. IMU and **Force sensitive resistor (FSR)** will send feedback to controller. This input will be used to detect 3D orientation of bot on window and to see if the EDF is providing sufficient adhesive force or not.

Cleaning

This subsystem consists of **cleaning pads** (passive mechanism placed below the bot) and **solution dispenser** (active cleaning) mechanism. The pump receives signal from controller periodically to release this solution every few seconds. This is sprayed in the window surface by spray nozzles and the pads will scrub the window when the bot moves. A **spiral multi brush** is also installed at the head as the main cleaning method.

The pumps have been timed to reduce the usage of solution in comparison to continuous spraying of solution. This also reduces the weight of solution that needs to be carried and thus reducing overall weight of our robot. A microcontroller will be used to send these periodic signals.

The cleaning mechanism is also present at the back to clean in the window in case the front one misses.

The solution dispenser can be powered using a battery.

The solution can be made up of **Windex**, which helps in quick cleaning and mixed with **isopropyl alcohol** which enables quick evaporation of solution from windows surface.

Power

Our system's power supply consists of 3 **3S batteries** connected in parallel and a **9V power supply**. This provides power to Arduino, pump and motors. The power is supplied through an **emergency switch** to switch of the supply to arduino if needed in emergency. Connection is made in parallel to provide longer runtime.

The controller and motor drivers are supplied power using an external power supply. All the other components are provided power using the 5V power output from the arduino.

Components used

Boundary Detection : Sharp GP2Y0A21YK0F Analog Distance Sensor with a range of 10 to 80 cm
Orientation sensor: Popolu MinIMU-9 v3
Power: 3S LiPo Battery30C 2200mAh
VeriFone 9V 4A 36W Power Supply AC Adapter
Controller: Arduino Mega
Grip: FACILLA® Mystery Fire Dragon 60A Brushless Motor ESC
EDF 5" 7 blade
3D-Printed EDF Skirt
Chassis: Acrylic Sheet
Cleaning: Pump Mounts, Adapter, Nozzles and Fluid Chamber

Shortcomings

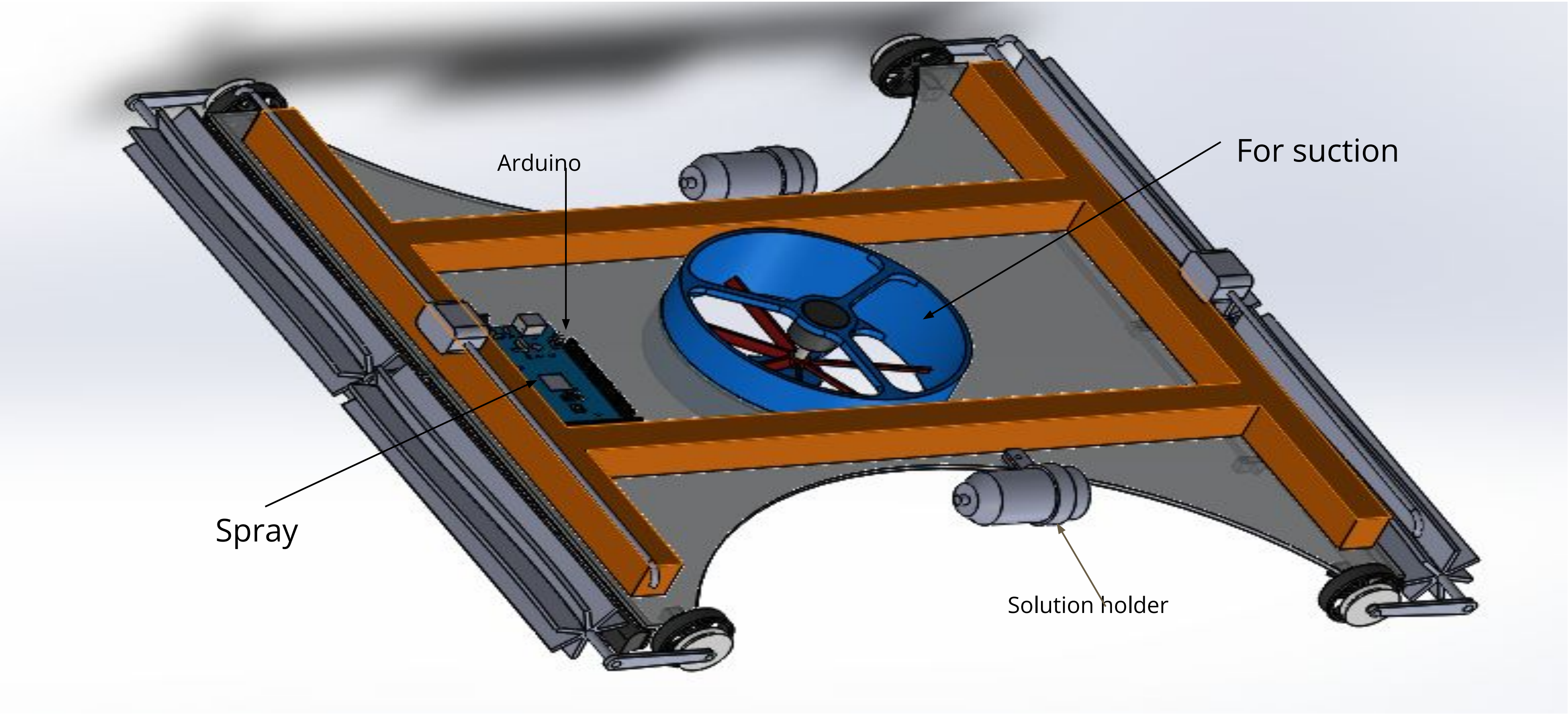
Main problem will arise if the weight of robot is high. This can result in fast drainage of battery, or in worst case the suction not able to handle the weight and keep the robot on window.

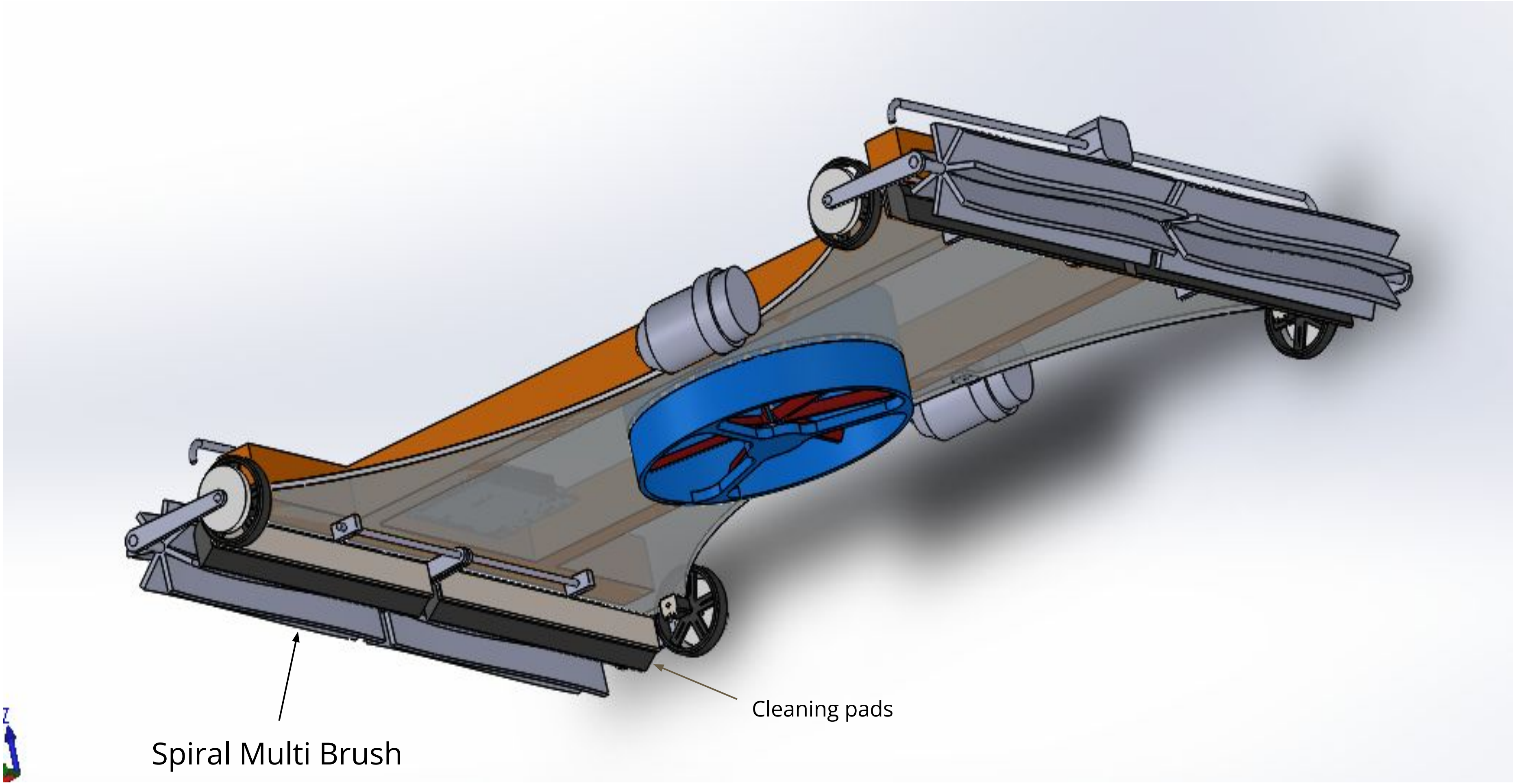
This can be avoided by

1. Reducing weight of wheels by reducing the number of wheels from 4 to 2
2. Material of body to be as light as possible
3. Reducing the solution weight by finding and maximising (by trial and error) the periodic time of solution spray to reduce usage of solution
4. Using high powered battery to provide high power to EDF and thus increasing its suction power

Every gram reduction in weight will be required and useful.

Final CAD Model





Cleaning pads
Spiral Multi Brush