Autonomous Window-Cleaning Drone

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Executive Summary

The purpose of this proposal is to offer a more efficient, cost-effective and safe solution to clean the windows of buildings compared to current methods. Currently, window cleaners climb up and down the sides of buildings while attached to a harness. Window-cleaning systems have remained stagnant while other technologies have advanced. Our solution to modernizing cleaning windows uses a drone to clean windows, while a rover on the ground acts as its supply line. The drone will not make contact with the building at any time during the process since a solution will be sprayed to clean debris.

We are applying for the Abbot Academy Fund for one year to initiate the project and evaluate additional costs and improvements for the upcoming years. This year we will create a semi-autonomous drone connected to a pump that will continuously supply the drone with water and a cleaning solution. A thin nylon tube will carry the cleaning solution from the pump up to the drone. According to our calculations, this design will allow the drone to clean windows over 30 floors from the ground. A pilot will fly the drone to a window, and the sprayer will automatically adjust itself to aim at the window. The pilot will then engage the spraying with a click of a button while having access to cameras on the front of the drone as well as data such as speed, angle, and distance from objects nearby. The drone will automatically adjust itself against wind pressure to prevent collisions with the building.

In future years, we plan for the drone to be fully autonomous, utilizing smart sensors to detect windows. The drone will not require a pilot, instead it will use AI to create flight routes for each task. The operation altitude of the drone would also increase by utilizing the top of skyscrapers and buildings to place the portable pump. Using this method, the drone will be able to clean 60-story buildings effortlessly. This project aims to solve the problem of how painstaking cleaning windows is by utilizing modern technology. Although we are only applying for one year of the grant, we plan for this project to be a multi-year project.

Project Description

Need Statement

Today, the price of cleaning a window can reach as high as $14 a window[1]. With the requirement to follow safety standards, cleaning windows can total to an unreasonable amount of thousands of dollars, even with flourishing technologies.

This problem can largely be attributed to the outdated process of window cleaning in use today. Harnesses and scaffolding are required to prevent human workers from risking their lives.

[1] "KompareIt - Compare Product Choices and Make a Good ...." https://www.kompareit.com/. Accessed 20 Oct. 2019.

This conventional and outdated method is inconvenient and inefficient. The owners of buildings currently pay an extreme price to hire window cleaners, and equipment is exorbitant and takes time to set up. There are many safety regulations put in place that increase the prices for this simple task which unfortunately still costs the lives of many.

In addition to the difficulties incurred for the building owners, this is also dangerous and difficult for the window cleaners. While the window cleaners hanging hundreds of stories high may not be frightened by height, simple mistakes such as dropping tools can induce catastrophic consequences.

Furthermore, there are still problems for the inhabitants of the buildings. The old method infringes on the privacy of inhabitants and creates an unpleasant noise.

Finally, while there are already some concepts and models of a window cleaning drone, they are inefficient compared to our solution. The Aerones drone is the only current solution that functions properly, yet it weighs around 55 kg by itself[2]. The price of the Aerones drone makes the system unaffordable by nearly all households and businesses. This system is expected to cost hundreds of thousands of dollars, while our design will cost around a thousand dollars. Because of our drone's ability to use high-pressure water to spray windows from afar, it will avoid the effect of wind shear that creates unbalanced air pressure and thus removes the risk of collision.

In conclusion, our proposal aims to completely reform the window cleaning process, thus lowering its overall cost, improving efficiency, safety, and privacy.

Goals

In this project, we aim to create a system capable of cleaning windows more efficiently while being safer, cheaper and more flexible. To do this, we plan to build a drone using existing drone kits and then add the functionality of spraying the solution. In short, the drone will be a hexacopter with a small tank, battery, and sprayer. As stated briefly above, a pump tethered to the ground will pressurize the cleaning solution and supply it to the drone at an adjustable pressure. This enables the drone to clean the window with the lowest waste of water and solution possible. The drone will automatically adjust the pressure of the spraying water according to the toughness of the debris measured with a machine learning algorithm that uses data from previous cleanings. Additionally, by using pressurized liquid to clean off a debris instead of the traditional squeegee, the efficiency of the system can be boosted significantly. Two cameras will be attached to the drone, one of which will be a pilot camera that transmits a first person view to the remote controller. The other camera will be wired with the flight controller as a sensor that automatically detects windows. Specifically, we plan to exploit the special photoelectric property of glass for a smart method for detecting and locating the window. Since glass as a diamagnetic material polarizes the light reflected off of it, the spinning polarizer in front of the camera will be used to detect windows, by recognizing the changing intensity of the light reflected off the

[2] "Window washing drone takes flight - BBC News." 22 Nov. 2018, https://www.bbc.com/news/av/business-46292361/window-washing-drone-takes-flight. Accessed 20 Oct. 2019.

window. Then, a machine learning model will be trained to detect the window based on spots where light intensity varies. On the other hand, the pump will have a power supply and tank, to push water through a tube to the drone.

Throughout this process, the seven of us hope to improve our problem solving skills. Due to the complexity of this project, we will inevitably encounter problems in terms of programming, designing, mechanical engineering, and etcetera. In addition, this project will increase our skills for collaborating as a team, an important quality in today's work environment. After this project, we will be able to apply the skills we learned through the experience in other projects we partake in the future.

This project and its goals align with the mission of the Abbot Academy Fund as it is beneficial to the whole community. In addition to lowering cost for the school, cleaner windows also positively impact students' and faculty members' mental well-being. Beyond the Andover community, our solution revolutionizes the entire business of window cleaning, which will motivate students in the world to innovate and establish Phillips Academy as a leading catalyst of innovation.

Impact

Within Andover, this system will help clean the windows on campus. Many of the windows on campus are hard to clean from the ground, which provides us with good testing grounds that will benefit both the campus and our project. It will be easier to keep the windows of taller buildings such as Pearson Hall, Morse Hall, and Paresky Commons clean with our method. Instead of manually wiping the windows, employees would only need to set up the drone, pump, and pilot it during the semi-autonomous operation.

A drone offers more possibilities for cleaning windows, because of its capability to reach spaces unreachable by humans. The US government has regulations that limit where and how humans can clean windows for safety reasons. In contrast to humans, drones are not restricted nearly as much as humans by safety regulations. Unlike other drones that attempted at this concept in the past, our drone will only spray instead of physically wiping windows with squeegees, meaning virtually any window can be cleaned.

Beyond Andover, this system will help clean the windows of buildings in towns and cities around the world. Instead of using expensive equipment and risking lives, humans will only need to set up a drone. There will no longer be over-priced window cleaning, and the time taken to clean windows will be significantly lowered. By adopting our system, the owners, employees, and residents of buildings will be satisfied with how windows are cleaned.

To visualize the impact of our drone, we will acquire a quote for the current cost to clean the windows of a building on campus and ask them to approximate the time it takes. We will then be able to compare the cost and time they approximate to our method and calculate the percentage of improvement. There will also be interviews with the maintenance staff to see which system they prefer and why. By doing this, we will be able to measure our success and compare how much more efficient each modification can make the drone.

Project Implementation Plan

This is a project implementation plan for the first year of our project. We are applying for one year of the grant, and we will re-evaluate next year and create more target dates when we apply again.

Activity	**Target Date**
All Parts Arrive	Early December
Pump/Tank Built	Mid-December
Flight System Assembled	Late December
Sprayer + Water Infrastructure Built	Mid-January
CPU Placed, Electrical Infrastructure Built	Late January
Rudimentary Flight Program in Place	Late March
Drone Structure Built and can Fly	End of School Year

Budget

This is a budget plan for the first year of our project. After the first year, we plan to apply for the grant again with another budget plan. The prices listed are accurate as of October 20, 2019. Here is the link to our budget's google sheet: https://docs.google.com/spreadsheets/d/1UTHYUZQFavgKiyc7XnXBQ2j0tmPr_2-y7v25lgG9AH4/edit#gid=0

Execution

Our group's diversity in experience will allow us to solve each problem we face efficiently. On our team, there are young chemists, programmers, physicists, mathematicians, and designers ready to resolve issues that come up. With our specific backgrounds, we can split up tasks to according to our strengths. All seven of us share the same goal of solving a prevalent problem in communities today. In addition, Mr Peters, our sponsor, will help us find optimal solutions for the topics beyond our knowledge. Throughout the process, if we need any help understanding a concept needed for this project, we will reach out for help from the faculty without hesitation. With the seemingly endless amount of resources on campus, the seven of us are confident that we can complete the work outlined in this proposal.

Long Term Success

Our window cleaning drone is targeted towards both corporations and homeowners, so we are interested in tailoring drones towards these respective fields in the future. A fleet of drones, normally docked in self-preserving hubs at the roof of buildings, could be used to target specific

dirty patches to efficiently clean buildings. Coordinating these drones using graph or machine learning algorithms could be used to thoroughly and systematically clean tall buildings. Further development of computing power and overall design would enable the drones to communicate from longer distances and reach higher windows. We are also interested in storing water in the drones themselves, as mass quantities of rovers in any location is dangerous and inefficient.

Similarly, our project could also branch out to cater towards individual homeowners' needs. Unlike the fleets of drones required to efficiently clean a skyscraper, only a single drone would be required to clean mid-sized homes. Reflecting this change in scale, the drone wouldn't need to carry its own cleaning solution. A single rover, similar to the current rover-drone setup we are working on, would suffice for this task. This drone also won't need to be as powerful in horsepower and complex in terms of the communication network, so it would be much less expensive.

As we continue to develop these cost-effective drones for their respective uses, we may also set up mass production facilities. Our goal is to provide a cheap alternative to the dangerous jobs of window cleaners, and we will continue to strive towards this goal.