Design of Automated Drone for Agricultural Soil Sample Collection

(Technical Topic)

Analysis of Environmental Impacts of Drones

(STS Topic)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

As profit margins continue to get increasingly tighter in the agricultural industry, farmers are looking for ways to increase crop yield at a lower cost. Since crop production is a skill of resource management, many farmers are also looking to find new ways to predict their yield given the amount of resource use (e.g., fertilizer, water). Given this, the agricultural industry is trending towards more increasingly complex equipment to streamline many of the costly and time dependent processes and develop more complex models that can be used to maximize a plot of land's potential. Much of the newer equipment used to aid farmers is "smart" tech, meaning its functionality is automated to decrease labor cost. The Soil Testing Drone is proposed as a method of automating the process of collecting soil nutrient data as a means of helping farmers understand the viability of their land and allow them to more precisely plan their use of fertilizer and other resources.

Technical Project Discussion

The Soil Testing Drone is a product that will be useful to farmers looking to have a better understanding of their land's potential for crop yield. The drone will be equipped with an electronic sensor that can read nitrogen, phosphorus, and potassium concentrations in a given location. Measurements for each of these factors are important for a farmer's decision making on which crops to plant and how much fertilizer to use (Noble Research Institute, n.d). Since soil nutrient concentrations vary, fertilizer use is not homogenous across a given field; certain sections may require different amounts. Therefore, soil tests are currently conducted at a rate of anywhere from 1 sample per 20 acres of land to 1 sample per 2 acres of land (Warncke 2013). The size of farms can range in magnitude from several hundreds of acres up to thousands of acres, so the soil sampling process can be very time consuming (Koerth 2016). Samples are conventionally taken by hand, where a laborer will travel across a field and dig up samples, bag and label them, and send them off to a lab to be tested. There are a number of inefficiencies involved with this process which can be improved with the Soil Testing Drone. Automating the process saves time, but also enables more soil tests to be conducted per area of land. It is also more cost effective to collect the data with an electronic sensor than to send the samples to a laboratory. Lastly, the drone simplifies the book-keeping process. An on-board GPS module is used to label the time and coordinates of every sample; this information is wirelessly sent to a database so farmers have a consolidated record of their soil history.

The Soil Testing Drone will consist of the following 3 major systems: the flight and probe deployment mechanism, the flight computer, and the ground station. The flight and soil mechanism are part of the physical drone – it will be custom built with landing gear that moves independently of the chassis. The sensor is mounted to the chassis and is deployed by inverting the direction of the motors to create thrust to push the sensor into the dirt while the landing gear stays fixed to the ground. The chassis and landing gear will be custom designed using CAD software (Inventor Pro) and implemented with a 3D printer. The electronic speed controllers and flight controller are commercial microprocessors that were chosen to be compatible with firmware that measures drone speed, altitude, direction, etc. The next system, the flight computer, is the brain on-board the drone. It will be a custom PCB (printed circuit board) containing a microprocessor that communicates with separate WiFi and GPS modules. The main microprocessor is responsible for automated flight duties. It will be loaded with a C program (written and debugged with Code Composer Studio) that has algorithms for automated take-off, landing, travel, soil sensor deployment, and data transmission. It works in aid of the WiFi module that forwards manual directional input sent from the ground station. The GPS module tells the microprocessor the coordinate location of the drone so it can be sent on missions to specified locations, can return to base, and can fly without an operator. The last system is the ground station, which can send directions for the drone to be operated manually, and can receive all the sensor data collected in real time. The ground station is an application built using C++ with a graphical user interface that displays all info in a neat display.

This project is currently being developed by team Up in Frames and is planned to be completed at the end of the Fall 2021 semester on December 16th, 2021. Guidance for this project is provided by Professors Harry Powell and Todd DeLong in UVA's department of Electrical and Computer Engineering.

STS Discussion

Drone products are becoming a wide-spread technology and have been available on the commercial market for a number of years now. As such, many companies and recreational pilots have begun flying their drones over public and private property. Since drone flight is still a newly emerging industry, many jurisdictions have not implemented policy regarding drone flight. Drones pose a number of safety risks to the operator, to pedestrians, and to the surrounding land. Many have especially raised concern with physical safety of those in the surrounding area. The risk presented by drones is in extreme interest to developers that deploy automated flight, such as the Soil Testing Drone. This paper will research the risks and effects that automated drone flight can pose on the surrounding area of flight. This will directly aid the developers of the Soil Testing Drone to implement safety measures to decrease risk to people and wildlife, and diminish the impact of carbon emissions.

Drones can have significant negative consequences on their environment when flown or crashed near delicate wildlife populations. For instance, in June of 2021 a drone was flown over the Bolsa Chica Ecological Reserve in Huntington Beach, California. The reserve was made home by over 3000 elegant terns, a species of seabird that used the beaches of the reserve as a nesting ground. However, when a drone crash-landed on the beaches where the birds were nesting, the entire population of elegant terns was scared off by the drone's perceived threat The birds left behind between 1,500 to 2,000 eggs never to return (Wigglesworth 2021). This ecological devastation could have been avoided had the pilot adhered to the laws preventing drones from being flown over state wildlife reserves. However, lessons can be learned for preventative design. Since we are building the interface for the Soil Testing Drone's flight control, it is possible to display wildlife reserves on the flight map. A display can be developed to warn the flyer if they are nearing a no-fly zone. Potentially, a flight controlling algorithm can be implemented to even stop the drone if it gets close enough to a forbidden area and automatically navigate it out. This preventative design would help protect environmental sanctuaries and could have uses in other no-fly areas, thereby keeping the pilot out of legal trouble while also preventing ecological and physical damage.

One advantage coming to light from drone use is the potential for a smaller footprint for commercial applications compared to modern methods. For instance, many companies such as Amazon are looking into using drone flight to deliver packages to homes around the country (Palmer 2020). Many organizations commend drone delivery as being a greener alternative to traditional delivery methods. Rather than using gasoline/diesel vehicles for delivery, small packages could be brought to homes using drones. The European Environment Agency even claims that delivery drones are much more CO2-efficient than other modes of transport, and the amount of CO2 emitted could be significantly reduced (European Environment Agency, n.d.). If drone usage can reduce carbon emissions and pollution for delivery applications, it’s likely that these positive implications also apply for an agricultural setting. The Soil Testing Drone has the potential to impact agricultural emissions in two ways. Firstly, the drone could reduce CO2 emissions by replacing the techniques currently used to test soil, which include driving through farmland and shipping samples to a lab. However, the more significant change would be through helping farmers increase their yield. Increasing crop yield could reduce the number of resources used by farmers, including reduced use of heavy machinery and fertilizer.

Conclusion

This technical report will propose a new technique for collecting soil samples using semi-automated drone flight. This technique allows for quicker and more repeatable sample collection, as well as provide farmers a better record of their soil’s nutritional history. These statistics can help farmers keep track of their resource usage, which can reduce costs and increase crop yield. The STS research paper will provide further insight into the ecological implications of the Soil Collection Drone, including negative impacts on wildlife as well as the positive impacts that this product can have on reducing CO2 emissions.

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