Effective Drone Powering Methods for Synthetic Aperture Radar Applications

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For radar imaging of disaster sites, autonomous drones reduce the risk of human volunteers being in danger on the field. By utilizing effective powering methods, this autonomy can be enhanced and can improve the imaging capability of the drones. The Blue Team's project to build an autonomous synthetic aperture radar drone can be expanded to incorporate these methods in order to remove the necessity of a human pilot.

Introduction

Imaging dangerous locations such as military hotspots or natural disaster sites can be difficult because of the safety risks associated with accessing these areas. Highly accurate images of these places are imperative for military and humanitarian purposes, but obtaining these kinds of images can be expensive and time-consuming. Additionally, large sized aircraft, while often able to accomplish this task, can be costly and have safety risks. Visible light is often used as the basis for creating the images, but in environments with low visibility, this method is ineffective. Given these concerns, an ideal imaging method would have to be relatively low cost, reduce potential safety hazards for the operator, and provide accurate results in areas with diminished visibility. One solution that addresses these three aspects is Synthetic Aperture Radar (SAR) which uses radar imaging to overcome this kind of obstacle.

SAR imaging works by continuously sending out pulses of radio waves and collecting them as they are reflected back by the environment (Figure 1). The aircraft moves along a specific aperture while receiving the data, and by processing the radar pulses, the images can be created. However, SAR imaging is precise in cross-range, but not depth. This means that a one-

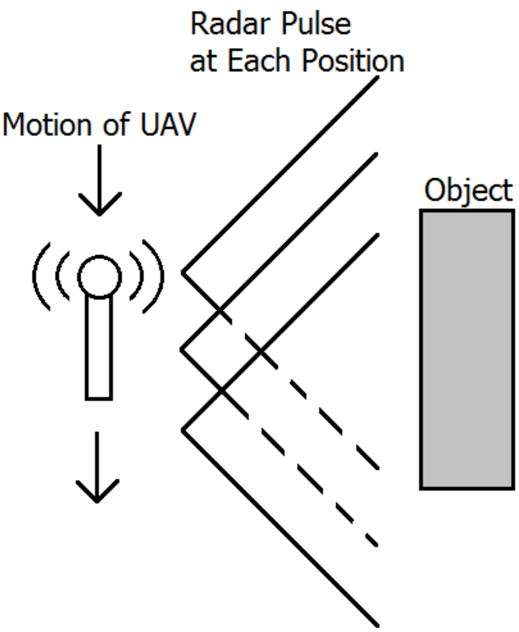

Figure 1. Demonstration of SAR on a UAV

dimensional aperture is only able to enhance the horizontal cross-range of the image, and another dimension for the aperture is needed for the vertical cross-range. So, by following a 1-D aperture, a 2-D image can be formed, and by following a 2-D aperture, a 3-D image can be formed. These radar pulses can provide data even in reduced visibility environments, so for natural disasters such as forest fires where smoke covers most of the area, SAR is significantly helpful for obtaining a clearer image of the state of the location.

One distinct advantage of SAR is that it can be equipped to small Unmanned Aerial Vehicle (UAV) drones. Drones are inexpensive and prevent a potential pilot from being at risk because of their autonomy. They can easily navigate through dangerous sites and still provide accurate imaging through SAR. So, utilizing drones with SAR is a low cost, safe, and effective solution for imaging.

Figure 2. Blue Team's SAR UAV Drone

Based off of these concepts, the Blue Team is working on a UAV SAR project. The overall goal is to create a high resolution 3-D SAR image of a baseball field scoreboard using a SAR drone (Figure 2). To take the image data, the drone will be manually controlled to fly in a 2-D aperture. For this project, the drone only needs to fly for about 15 minutes, long enough to complete this aperture. Despite these being the requirements for the project, the actual intended applications for SAR will extend upon these concepts.

For the purpose of imaging dangerous areas, SAR drones will need to be autonomous and fly for an extended amount of time. Ideally, each of the drones will image separate parts of the location and collectively form the complete SAR image. However, depending on the size of the area and the number of drones, this may be impossible to accomplish without replenishing the drones' power supply. This would require manual management of the drones, which may require workers to be present at the unsafe location. To avoid this safety hazard, it may be necessary to use an enhanced powering method to increase the overall autonomy of the drones.

Powering Methods

Although numerous ways for powering UAVs have been researched, only a few are suitable for the smaller scale of drones. The Blue Team's SAR drone currently utilizes a Pulse Lipo 16000mAh 6S1P 22.2V 15C battery, so the methods presented were chosen with consideration to the size of the drone and the application of SAR imaging.

PEM Fuel Cell

A project by Herwerth experimented with using a Proton Exchange Membrane (PEM) fuel cell to power a drone. In this application, "fuel cells are an energy conversion device that converts the chemical energy of the fuel into electrical energy" (2007). The cells contain hydrogen that can react with oxygen from the air to provide energy for the drone. The fuel cell lasts as long as there is fuel, so if the aircraft is able to hold a sufficient amount, then this cell should be able to power all of its functionalities.

Herwerth tested the fuel cell on a UAV designed specifically for the purpose of long range and long duration flight. The testing results showed that the fuel cell was able to power the UAV for about 13 hours. Since the SAR UAV drone's primary functionality is imaging, this type of power source would not last that long though it is unclear how much the difference would be. Assuming that the fuel cell would be able to power the drone for approximately that amount of time, it seems reasonable that several drones using this as a power supply would be able to complete the SAR imaging of a large area without needing replacement.

Automated Battery Replacement

Another method for handling the powering problems of drones is called the Endless Flyer. The Endless Flyer utilizes a battery exchange platform to automatically swap the battery of a UAV drone when it lands at the station (Fujii, 2013). It has a position measurement system to detect the drone, and it uses arms to adjust the drone's position and orientation for battery replacement.

For this system, a battery carriage had to be designed to easily attach and detach the battery from the drone. Once the battery's charge depleted to below 15%, the drone would fly to and land on the landing platform to replace its battery. This process is entirely autonomous, so it would eliminate the need for there to be workers present at the area for the replacement. Furthermore, the drones could replace the card with their imaging data, so this Endless Flyer system could also solve the problem of limited space for data on the drone. This method could be easily realized with few modifications to the drone to accommodate the battery carriage. In particular, the Blue Team's drone has the battery positioned on its underside for easy replacement. A battery carriage could be easily integrated to work with the drone, so this automatic battery replacement system would likely work fluidly with this drone. The Endless Flyer system is a viable solution that would enhance the SAR drones' overall autonomy.

Summary

By utilizing SAR imaging, accurate images of dangerous locations can be obtained for low cost and with few safety risks. Using this method on drones enhances these advantages and provides an effective system for autonomous imaging. Effective powering methods also augment the autonomy of the drones, so SAR UAV is a useful solution for imaging. Although the Blue Team's SAR drone does not need to use any of these methods to satisfy the requirements of the project, these concepts would improve the overall imaging capability of the drone. For the intended application of large scale imaging, these powering methods would greatly aid the drones' ability to accomplish that goal.

References

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