Implementation of an Autonomous Charging Platform for the Purposes of Enabling Long-Haul and Off-Grid Operations by Electric Quadcopters

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I. Background

Commercial use of battery-powered unmanned aerial vehicles (UAV) for various operations has become popular with instruments such as heat sensors, LIDAR, and cameras [1]. While the viability of UAV use has vastly increased, such battery-reliant systems typically suffer from limited flight durations [2]. Increasing the overall flight time is being investigated and improved upon in the realm of battery technologies that increase the overall energy density of any particular cell. However, such technologies are not readily available and the desire to use UAV systems is increasing daily. This trend highlights a key constraint in utilizing UAV systems for remote tasks that would otherwise require the use of conventional, fossil-fuel-powered vehicles. Likewise, as an appropriately-equipped UAV must first be deployed by a larger host vehicle to its area of operations, it cannot currently function as a standalone system.

Completely autonomous UAV systems have enormous potential to address unique challenges in remote data collection, ranged surveillance, parcel delivery, and more. Delivery vehicles can be taken off the road by substituting cargo drones, saving lives, reducing CO_2 emissions, and decongesting roads. Digital systems have eliminated the need for hand-delivered postal messages, and soon they could eliminate the need for hand-delivered packages all together. Furthermore, UAV systems that support autonomous landings on distributed recharging stations would allow for long-haul and off-grid operations to be performed without the need for regular return trips to a centralized base station for battery recharging. Eliminating these return trips would reduce, perhaps drastically, the total energy budget for UAV missions.

II. Objective

A. Proposed Solution

Our solution to this problem is the creation of an autonomous system involving a lightweight UAV paired with an intelligent Charging Platform. The Charging Platform will be equipped with an on-board camera and single board computer (SBC) capable of accomplishing image recognition of the UAV. Combined with an onboard wireless charging pad, these key elements of the Charging Platform will support the autonomous landing and recharging of the UAV. The Charging Platform will further be designed as a portable subsystem capable of being deployed on a variety of surfaces, thus allowing for further developments in autonomous vehicle applications.

B. Operating Model

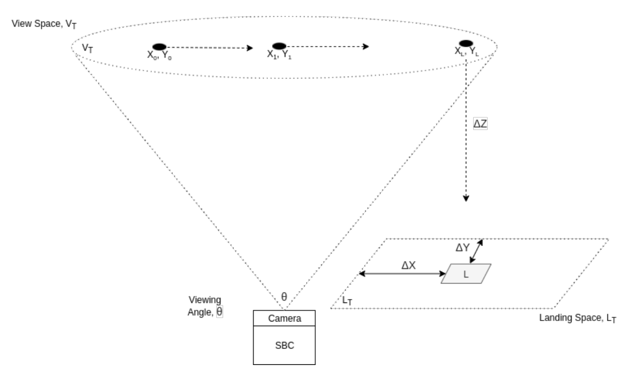

Fig. 1. Operating Model of System

As shown in Figure 1, the operational model of the entire system will be such that UAV coordinates (x_n, y_n, z_n) are interpreted by single board computer (SBC) and then compared against target position L in the landing space. Positional errors

$$\Delta x = x_n - x_L \tag{1}$$

$$\Delta y = y_n - y_L \tag{2}$$

$$\Delta z = z_n - z_L \tag{3}$$

as shown in Eq. 1, Eq.2, Eq. 3 are determined by the SBC from reading the camera output. These positional errors are then used to generate flight commands. As $(\Delta x, \Delta y) \to 0$, the SBC will instruct the UAV to descend ($z_n \to z_L$). This model will correctly land the UAV to within desired precision regardless of differences in height between the target landing point and the position of the camera so long as the target landing point is able to be projected into a plane that overlaps with the view space, V_T.

C. Software Implementation

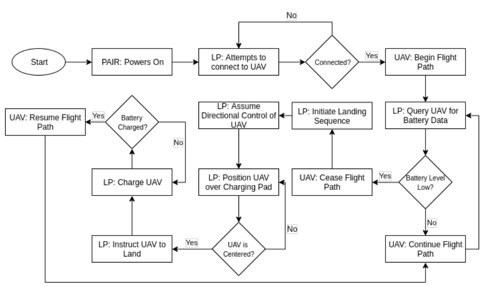

Fig. 2. Software Flowchart of Standalone Charging Platform

Shown in Figure 2 is the software model to allow for an autonomous landing that would guide the UAV through its flight routine until the battery was below a certain threshold. At that moment, the Charging Platform would assume directional control of the UAV, calculate the positional offsets necessary, and instruct the UAV to move. To reduce the positional error to zero, the position would be redetermined after every movement and the errors recalculated. Once the UAV is within the desired area determined by the camera, it is instructed to reduce its height by a factor. Once at a new height, the position is determined and the errors calculated to prevent any errors within the UAV systems causing position changes. If done successfully, the UAV is instructed to move to a lower height once again. Otherwise, further positional adjustments must be made. In this limited use case, the UAV would be well within the operating cone of the system camera. However, future cases could see a Charging Platform being located via GPS sensors on the UAV. The operations would proceed similarly as described, except for the inclusion of a resumption of flight after the landing and charging operations were successful.

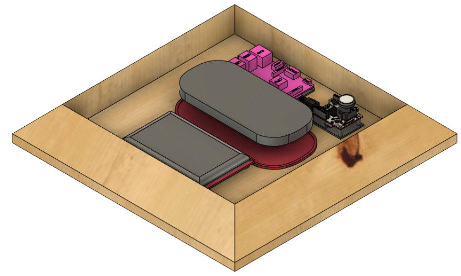

Fig. 3. CAD Render of Proposed Charging Platform

D. Charging Platform Construction

Shown in Figure 3, the charging platform prototype will be designed to accomodate all of the subsystem components necessary to perform the autonomous landing and recharging of the UAV. The base, walls, and lid of the platform will consist of relatively simple geometrical features such that the majority of the platform enclosure may be made from reusable lumber scraps. 3D-printed, PLA mounts will cradle the individual components within the wooden enclosure, ensuring precise placement of both the camera and the wireless charging pad as required for successful navigation of the UAV within the cameras field of view.

The charging pad is specified to the common Qi wireless charging technology standard, which will allow for our system used with a wide variety of Qi compatible vehicles. By mitigating the need for a human operator to make physical connections between the UAV and its charging system in remote locations, our system will support greater levels of UAV flight routine autonomy This will reduce the monetary and ecological costs of requiring UAV mission personnel to routinely transport and accompany their battery-powered systems in the field. We have also adopted a strategy for implementing a power subsystem circuit board to provide pass-through charging of the platform's power bank from an external source. This feature enables the deployment of our UAV system in remote areas supported by small-scale solar or wind-powered microgrids.

III. References

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