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

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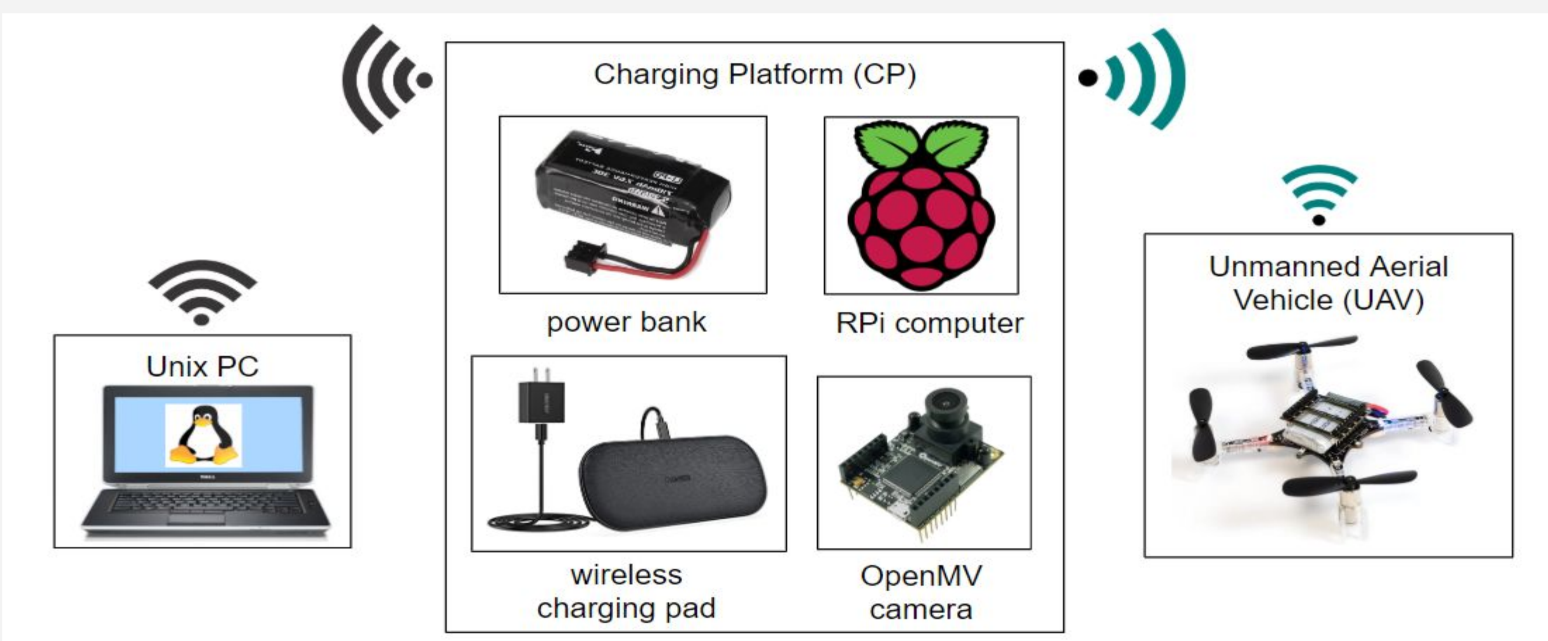
Background

Commercial UAV operations are becoming increasingly common. Particularly in the realms of parcel delivery, remote data collection, and visual infrastructure inspection. Currently, system designers must rely on proprietary solutions that are expensive and not open to customization on a user-level. Our research sought to provide a low-cost solution for use in development and research while offering a potential solution to battery life limitations for remote operations.

System Block Diagram



Operating Model of the System

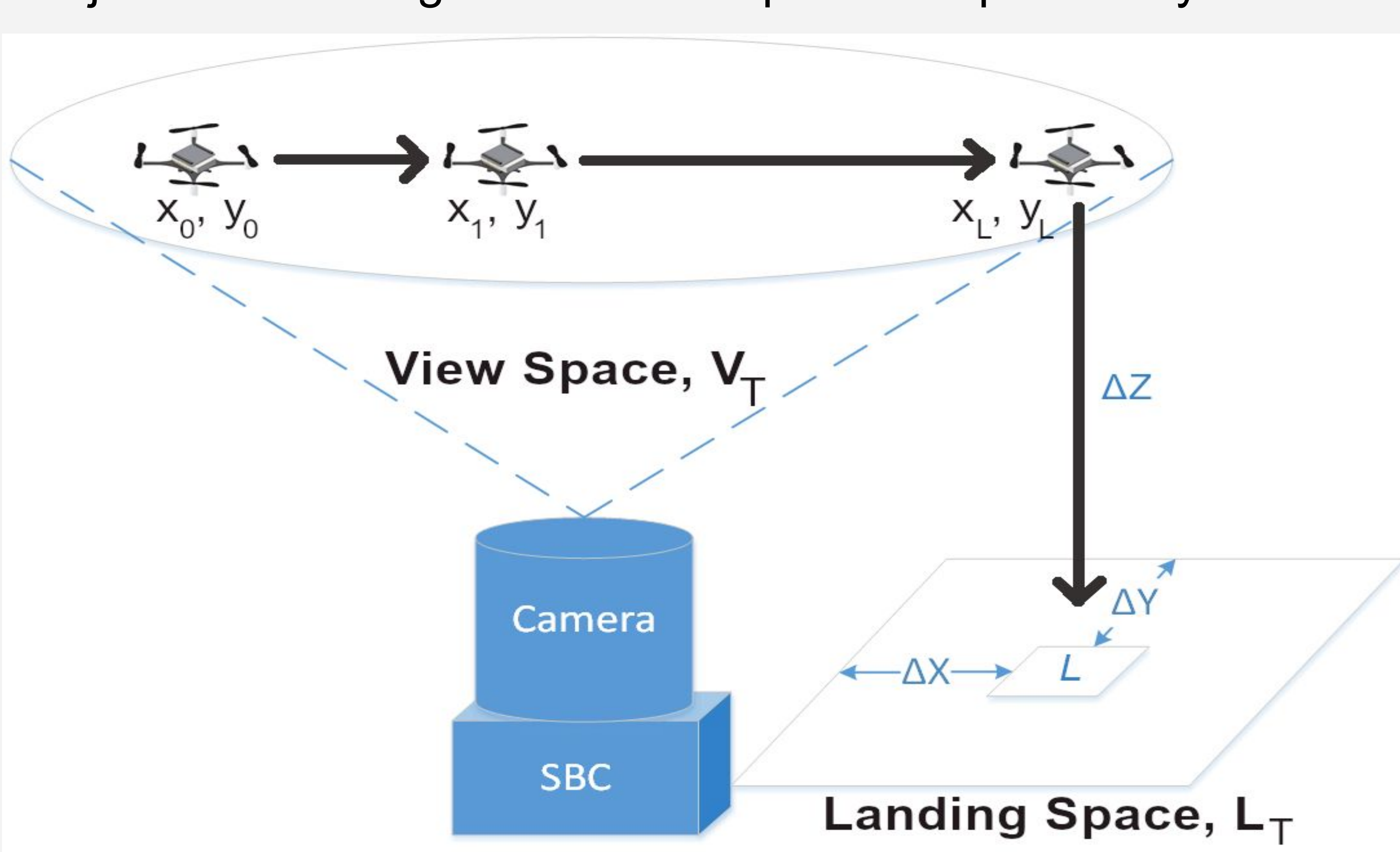
The UAV is detected via OpenMV Camera Module which then sends pixel values to the Raspberry Pi. These pixel values are then transformed to world coordinates using:

$$\langle x, y\rangle = \langle (h/f)S_z\Delta P_x, (h/f)S_y\Delta P_y\rangle$$

These world coordinates are then concatenated with the UAV ToF sensor to achieve 3D coordinates in space. 3D coordinates are then projected onto the X-Y plane to determine the UAV distance from chosen landing target via:

$$\langle \Delta X, \Delta Y, \Delta Z\rangle = \langle Lx - Xn, Ly - Yn, Lz - Zn\rangle$$

Distances are then assessed for an offset threshold and, if above threshold, sent to the UAV to make positional adjustments to align with desired point and potentially land.

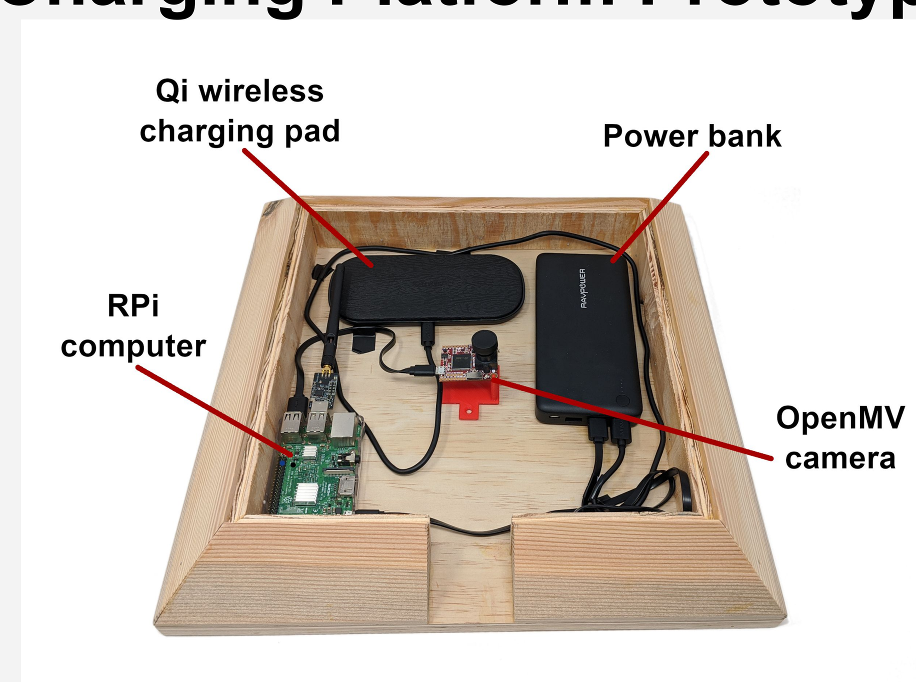


Tracking Methods

In the frame difference tracking method, Canny edge detection is used to yield an image with binary color depth which then allows the reporting of UAV centroid within the largest area of contiguous white pixels.

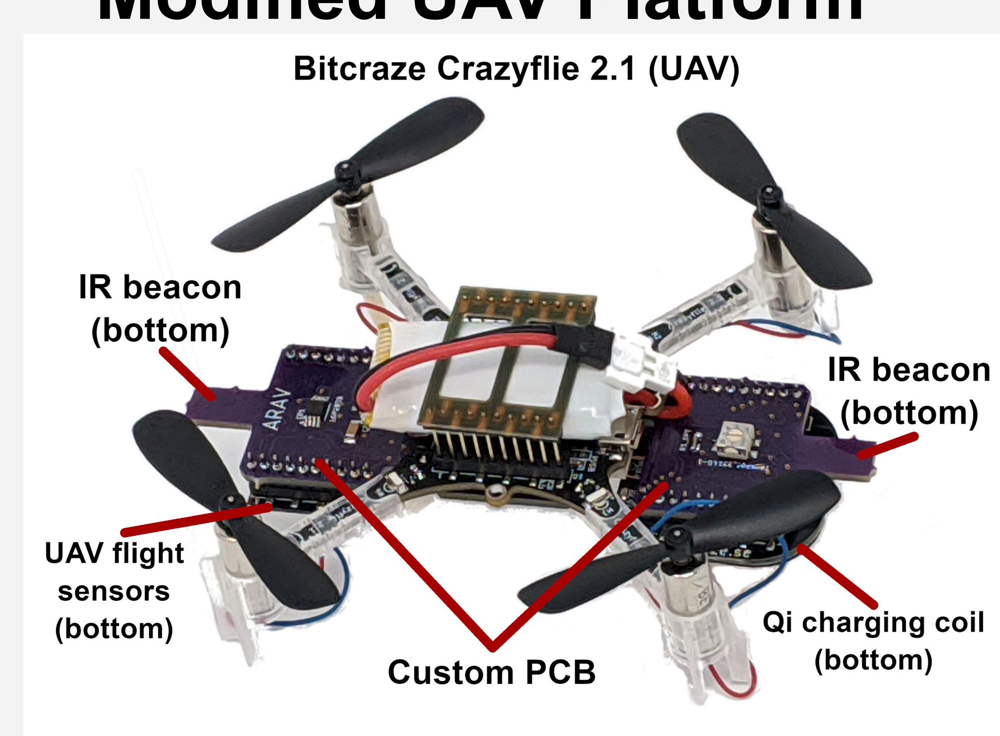
The IR tracking method uses a 940nm bandpass filter on the camera to determine the midpoint of two infrared beacons on the quadcopter which is then reported.

Charging Platform Prototype



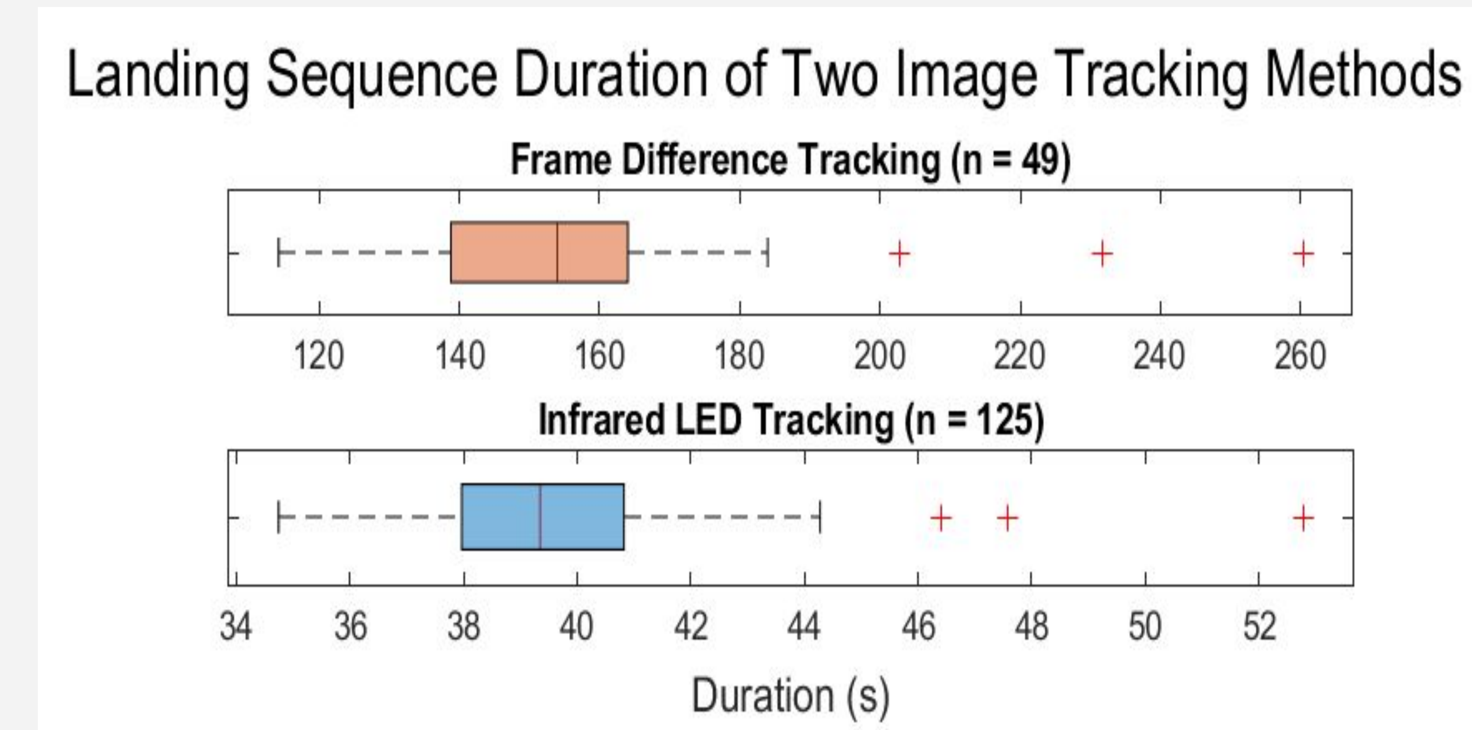
The modular nature of the charging platform allows for reconfiguration to fit the specified requirements of any particular deployment. 3D printed mounts with screw tabs have been created to allow for all components to be firmly stationary while still allowing changes. Software on the platform is also built to object-oriented standards to allow substitution of the UAV. As we intended this platform to be low-cost, all software and schematics are freely available under open-source licenses.

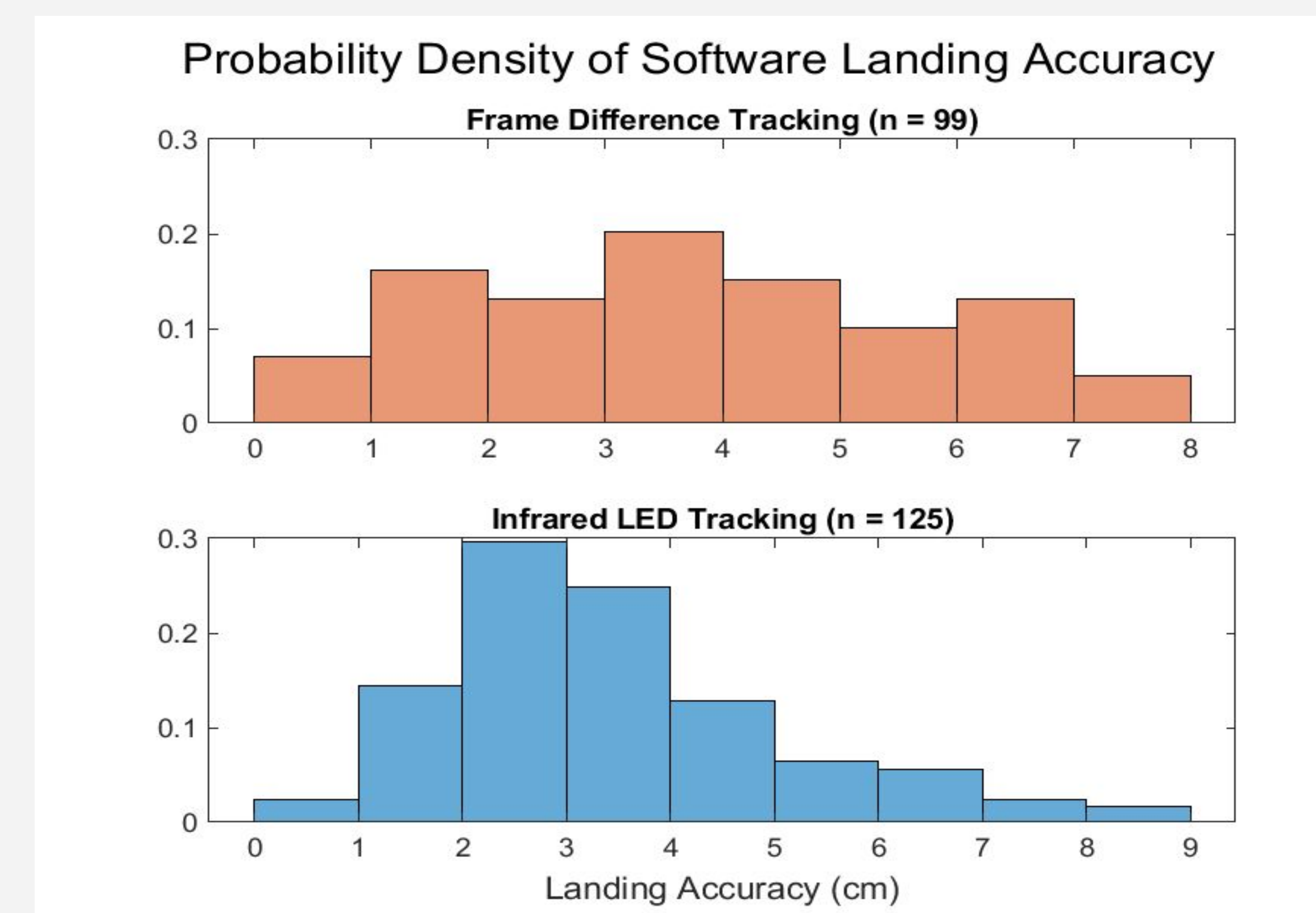
Modified UAV Platform



UAV modifications allowed for better tracking via IR beacons as well as an increase in the functionality of the UAV platform. Due to the increased weight of the custom PCB, new motors were added which, combined with the IR beacon circuit, increased power consumption and reduced potential flight time. The custom PCB is also necessary to support simultaneous mounting of the flight sensors and Qi charging coil on the UAV.

System Performance





Conclusion

With an overall landing time under 3 minutes, the system performed within our target goal for both tracking methods. As UAV will want to maintain longer flights or heavier loads, IR LED tracking is the optimal choice. The average landing accuracy of 3.7 cm fell within our goal of 5 cm, but smaller targets are currently infeasible. IR tracking proved superior in this regard as frame difference was subject to high frequency noise that was increasingly difficult to account for in tracking the UAV. IR tracking removed this limitation with the ability to lower the exposure time to remove overhead IR sources. The system exceeds our specified goals, but could still be improved.

Future Works

Work will continue on the landing control algorithm as it needs a way to reliably detect UAV angle. Further weight reductions through minimization of hardware will enable longer flights as the custom PCB is a significant portion of the overall payload. Other, tracking methods could be considered.