Autonomous Landing with a DJI Spark and April Tags

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Problem Description

Goal

- Autonomously land a drone on a landing pad marked with a fiducial marker.
- Identify the landing pad via a gimbal-mounted, monocular camera that tracks the fiducial marker (to increase detection range).
- Distinguish between multiple landing pads and actively choose one for landing.
- Search for landing pads safely if one is not yet found.

Key Background Points

- Landing is a hard part of autonomous drone flight because it is risky and requires high precision.
- GPS alone does not provide a sufficiently accurate position estimate for landing.
- Fiducial markers can allow a drone to recognize a landing pad cheaply and accurately, unlike GPS.
- Previous methods have used a fixed, downward facing camera to identify fiducial markers on a landing pad, with the disadvantage that they can easily lose track of it.

Contribution

In this project, the gimbal-mounted camera tracks the landing pad, giving the advantage that the drone doesn't lose sight of the landing pad easily, but with the disadvantage that the drone must accurately detect not only the position, but also the orientation of the landing pad. The orientation is particularly hard to accurately detect because of the camera's limited pixel resolution and distortions.

Methods

- **Drone System:** DJI Spark with DJI Mobile SDK.
  This is a cheap and stable drone platform that can be flown indoors. The DJI Mobile SDK can accept programmatic, high-level commands to ``go left,'' ``rotate right,'' ``decrease altitude'' etc.
- **Fiducial System:** April Tag.
  This is a well-tested and popular fiducial system which (since April Tag 3) has a flexible layout, so that many aspects of the markers can be adjusted.
- **Tracking:** PID Controller.
  A PID controller adjusts the pitch rate of the gimbal in order to keep the marker in the vertical center of the camera frame.
- **Approach:** Velocity Targets
  The x, y, z components of the position of the camera relative to the landing pad are used as velocity targets, which are passed to the Mobile SDK to make the drone approach the landing pad.

Marker System: April Tag Custom 24h10

Overview

- April Tag allows embedding smaller markers inside larger markers, which allows a drone to keep the marker in view even when it is extremely close.
- The default embeddable marker family, April Tag 48h12, is too computationally expensive for embedded hardware, e.g. Raspberry Pi.
- April Tag 24h10 is a smaller version of April Tag 48h12 that can run at a sufficiently high framerate on embedded hardware.

Additional Parameters

We have added the following parameters to the default April Tag ROS code for autonomous landing:

- `position_target_enu`: the distance from the drone to the landing pad in 3 dimensions. This is calculated by transforming the *position* of the landing pad by the inverse of the pitch and roll components of its *orientation* (ignoring yaw). It is subject to occasional incorrect readings, since it is dependent on the orientation of the marker which cannot always be determined unambiguously.
- Normalized pixel centers u, v of the marker, where $u, v \in [-1, 1]$ correspond to the x, y positions respectively. Values of -1 and 1 indicate the negative and positive extremes of the screen respectively, and 0 indicates the center. These are used as inputs to the PID controllers that aim the camera at the marker.

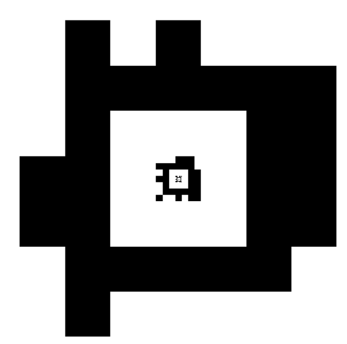

Figure 1:The landing pad with 3 embedded April Tags of the 24h10 family.

System Design & Equipment

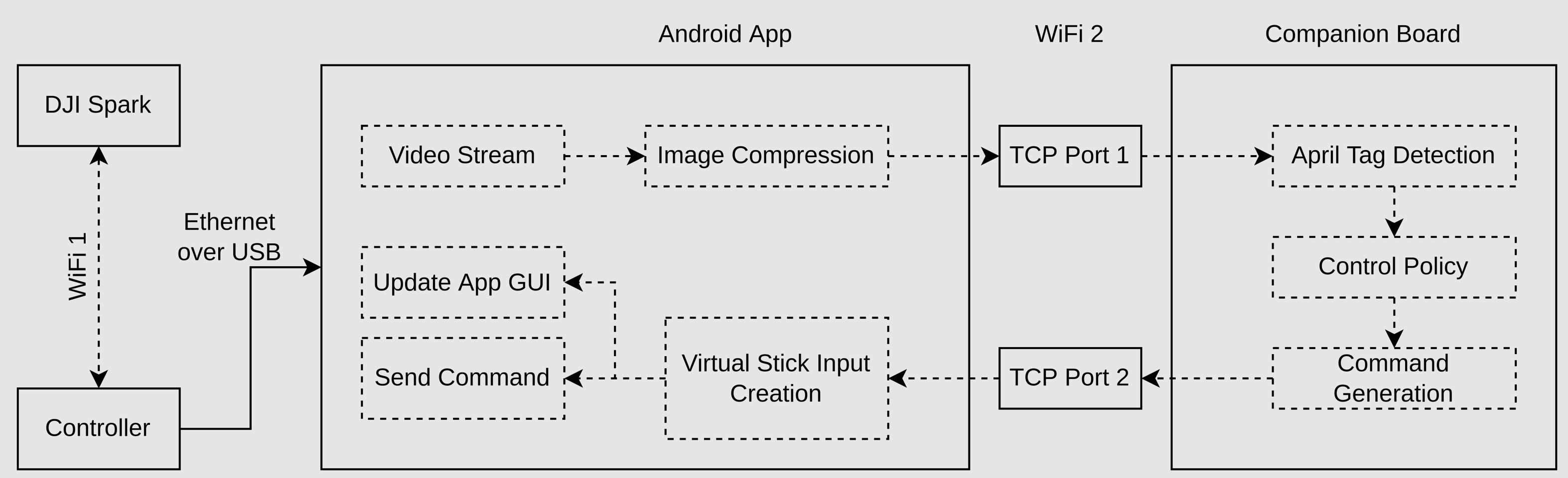

Figure 2:System data flow.

Results

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References

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