Name: Edward Stevens
Name of Project Advisor: Jennifer Hasler
Group Name: Auto Quads

Hardware available for Quadcopters

Introduction

Unmanned Arial Vehicles or UAVs have made numerous advances in the past decade, especially in the multirotor subcategory of UAVs. These advancements have brought to light generational defining applications available to almost anyone. Some of these applications are well defined, such as photography, while others are just being researched. For instance, research is being conducted on specific mapping applications, search and rescue, fighting fires, and many more. This technical review will explore the current affordable options in both commercially available and custom built multirotors, with an emphasis in quadcopters (quads).

Commercially Available Quads

There are many quads available commercially, however, only a few are developed from reputable brands; the best quad brands being arguably Parrot and DJI within the consumer market. These quads range from $500 for the DJI spark up to $14,000 for the DJI inspire [1]. While most of these store bought quads will include a variation of features, most include obstacle avoidance, GPS, various other sensors, and occasionally some levels of autonomous flight. It is important to note none of the commercially available quads will offer full autonomy or any type of 3D mapping/guidance features. The benefits of store bought quads would be availability and, in most cases, the simplicity of use since no compatibility issues or flight controller tuning is required to achieve a flyable quad. Although the entry level quads seem affordable, it is important to note they may not contain all the necessary sensors and control options required for this project. In the long run, the cost could be significantly higher to buy a commercially available quad to get all the necessary sensors. Most store bought quads are designed around their current center of gravity and would not perform well, if at all, with added sensors and weight. Since these quads are not really designed to be modified or customized, the locked down software may inhibit making modifications allowing the quad to fly.

Custom Quads

Using a Custom built quad has become a feasible task within the last few years due to part availability as well as the influx of research and development put into embedded systems designed to provide autonomous flight at an affordable price. One such module, called the Holybros Pixhawk 4, runs PX4 flight software and sells for about $180 [2]. The Pixhawk 4 allows for a fully autonomous open source quad to be built for about $350-$600 [2]. Due to the open source nature of a custom built quad, all parameters and flight characteristics would be controllable by user. As the quad is being modified during development and flight characteristics change, proportional integral derivative (PID) controller gains may be adjusted to regain desirable behavior. Although full ability to customize the hardware and software of the quad could be beneficial for the project, it also means more time and energy would have to be put towards achieving a flight ready quad.

Additional Potential Hardware

There are numerous options of hardware which can be added to aid in computer vision for a quad including the two most prominent options being Light Detection and Ranging (LIDAR) and depth of field (RGB-D) cameras. When using LIDAR, weight and power consumption becomes an issue for the quad, therefore, the Velodyne VLP-16 and Quanergy M8-1 tend to be the preferred choice for LIDAR modules [3]. The Quanergy M8-1 is a lightweight weather resistant module with a detection range of 1M to 150M and runs on 24V [4]. Some options for depth of field cameras are the Microsoft Kinect and Intel RealSense D435. The RealSense D435 weighs 72g and has a detection range of 0.105M to 10M and runs on USB 5V [5]. The pros and cons of both LIDAR and RGB-D cameras will have to be considered closely as the application of the drone would determine which option will be optimal for the project. Although some LIDAR options are affordable compared to other LIDAR modules, they still cost roughly 17 times as much as RGB-D options. The RealSense D435 weighs 12 times less than the Quanergy M8-1, however, also has a much shorter range of 10M instead of 150M.

Underlying Technology

Most quads contain eight core components; the frame, motors, propellers, electronic speed controller (ESC), flight controller (FC), receiver, battery, and a power distribution board (PDB) [6]. Lift is created by the propellers and stable flight is maintained as long as the same numbers of props spin clockwise as counter clockwise to cancel any rotational forces. Predictable and smooth flight is possible due to the PID controller on the FC. The PID gains can be adjusted to create a feedback signal and generate a more desirable output signal [7]. The ESCs consists of various components, however, rely on six transistors or gates to control the amount of current and direction to the motors generating lift [7]. It will be important to choose ESCs which will provide the necessary max current. The FC frequently utilizes a commonly used algorithm known as the Kalman filter algorithm, or linear quadratic estimation (LQE), which derives the position, velocity and altitude of the quad by taking measurements from the GPS, gyroscopes, LIDAR, and accelerometers [8]. The Pixhawk 4 flight stack architecture demonstrates how all required sensors will feed signals into the controller to help facilitate information for the Kalman filter [9].

Building Blocks to Implementing the Technology

Both hardware and software are an integral part of quads. With use of a store bought quad, the software will vary depending on manufacture. If a custom quad is built, some open source software will be available to adjust the necessary parameters. Software has already been developed for various functionalities in quads including Px4, QGround Control, and Ardupilot [10]. There are hundreds of quads and modules on the market, however, a few of the most optimal options include the Pixhawk 4 mini (microcontroller designed for autonomous flight), Parrot quads, DJI quads, sensors, LIDAR, and RGB-D.

References

[1] DJI, Pricing Information. 2019. [Online]. Available: https://store.dji.com/?site=brandsite&from=nav [Accessed Sept. 29, 2019]

[2] GetFPV, Pixhawk Pricing Information. 2019. [Online]. Available: https://www.getfpv.com/pixhawk-4-autopilot.html [Accessed Sept. 29, 2019].

[3] T. Peckover, “3D LIDAR: True 3D sensing and spinning 2D alternatives,” Clearpath Robotics, Jan. 10, 2017. [Online]. Available: https://clearpathrobotics.com/blog/2017/01/3d-lidar-true-3d-sensing-spinning-2d-alternatives/ [Accessed Sept. 29, 2019].

[4] Quanergy, “M8 Sensor Specifications,” M8 LIDAR Sensor datasheet, Jul. 18, 2019. [Online]. Available: https://www.egps.net/datasheets/quanergy-m8-datasheet.pdf [Accessed Sept. 29, 2019].

[5] Intel, “IMU Specifications” RealSense Camera 400 Series datasheet, Jan. 20019. [Online]. Available: https://www.intel.com/content/dam/support/us/en/documents/emerging-technologies/intel-realsense-technology/Intel-RealSense-D400-Series-Datasheet.pdf [Accessed Sept. 29, 2019].

[6] D. Still, *How to build a quadcopter drone*. Worcester, England, UK: Duncan Still Publishing, 2015.

[7] D. Citrin. ECE 3084. Class Lecture, Topic: “Closed-loop feedback.” School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA, Mar. 28, 2019.

[8] K. Dennehy, “Hovering in High Performance UAS-based LiDAR Space,” *inside unmanned* systems, Apr./May, pp. 32-34, 2017. [Online]. Available: https://lsc-pagepro.mydigitalpublication.com/publication/?i=611882#{%22issue_id%22:%22608813%22,%22page%22:32} [Accessed Sept. 29, 2019]

[9] F. Ricciardi, “Automatic search of missing people in avalanches,” M.S. thesis, University of Bologna, Bologna, Italy, 2017. [Online]. Available: https://tinyurl.com/y4qk2gbm [Accessed Sept. 28, 2019]

[10] PX4 Development Team, *PX4 Autopilot User Guide (v1.9.0)*, GitBook, 2019. [Online]. Available: https://docs.px4.io/v1.9.0/en/ [Accessed Sept. 29, 2019].