Implementation of an Ultralight Autopilot Drone for Service Robotics

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Summary

In this thesis, after a brief introduction on the regulation and classification of UAVs, the main sizing criteria of each component of a multirotor will be shown. Starting from the design constraints and a state of the art of the main flight controllers, the hardware and firmware components chosen for the implementation of an autopilot quadcopter under 250 grams will be described. The sizing of the components will be strongly influenced by the weight of each of them and will be flanked by a test on the motor / propeller coupling to evaluate the performance and then to choose the most suitable devices for the purpose. Once the Pixracer has been identified as the best flight controller for the project, the PX4 firmware and related software for remote control (Mission Planner and QgraounControl) will be described. Finally, after the assembly phase, the evaluation tests of the performance of the aircraft, the problems encountered and the possible solutions and improvements will be described.

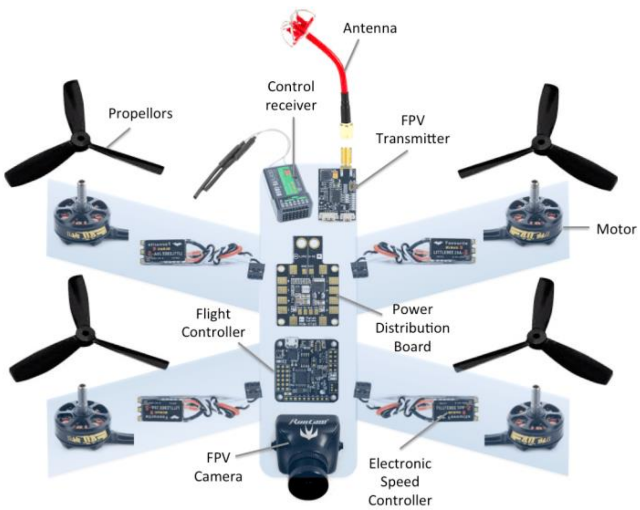
Introduction

The term “service robot” does not have a strict technical definition but the International Federation of Robotics (IFR) has proposed a tentative definition: “A service robot is a robot which operates semi- or fully autonomously to perform services useful to the well-being of humans and equipment, excluding manufacturing operations”. UAVs are used in different fields and applications thanks to their adaptability and versatility and in recent years their use has increased considerably.

Drone Anatomy

A UAV is an aircraft without a pilot aboard able to move by remote control of an operator using a remote controller or an integrated autopilot system. A system composed by control station, UAV and communications system is called UAS (Unmanned Aerial System). Taking a quadcopter as reference, a drone consists of the following components:

- Frame
- Flight Controller
- GPS
- Motors
- Propellers
- ESC
- Telemetry module
- Receiver
- Battery
- Additional components



Design

The aim of this thesis is to design and build a quadcopter with a mass of less than 250 grams intended for service robotics applications. The drone must comply with the following specifications:

- **Autopilot Drone:** the term autopilot refers to a system able to manage part of the movement of an aircraft (trajectory management, speed control, height maintenance, etc.) without the constant intervention of an operator.
- **Open Platform:** The whole system must be based on open standards (such as published and fully documented external API).
- **MAVLink communication protocol:** The MAVlink communication protocol (Micro Air Vehicle Link) is a system created specifically for vehicles with remote piloting systems that allows communication between aircraft and ground control station but also between devices inside the vehicle.
- **ROS compatible:** ROS (Robot Operating System) is the operating system that provides developers with the tools necessary to create robot control applications.
- **Ultralight:** The MTOW must be under 250 g in order to be classified as a A1C0 category aircraft.

The starting point of the project was initially to identify the available firmware able to satisfy the design constraints. Most of the constraints can be complied by simply choosing a suitable firmware. The two most used flight management firmware of a multirotor are arducopter and PX4. Both can be used on the most common flight controllers. Thanks to the state of the art of the flight controllers that are compatible with arducopter and PX4 firmware, the Pixracer has been chosen as the best flight controller for the purpose because it represents the best product in terms of technical specifications with the lowest weight. All the others components have been size in order to maximize the performance of the multirotor in terms of TOF.

First test; motor and propeller coupling

The most important subsystem of a quadcopter is surely the system composed by motors, propellers, ESC and battery. For this reason a test has been carried out to evaluate the performance of the Tiger Motor MT1306 3100 KV and the Tiger Motor CF 6020 propellers coupling. The test has been implemented in two different fashions:

- Constant VN = 7.4 V; varying PWM
- Varying VN; Constant PWM = 100 %

In both cases the thrust measurement was carried out by push upwards (weight difference of a known initial mass) and downwards of the motor/propellers by means of a sling bar. For this test an oversized ESC has been chosen in order to supply the current required by the motor. The speed controller, powered through a power supply, has been connected to the three phases of the motor according to the correct direction of ration and to a PWM signal generator to control the throttle of the motor also connected to a power supply (5 V). By Collecting and processing the test data, it was possible to derive the characteristic curves of the propeller motor coupling obtaining the following conclusions:

- The evaluation of the thrust by using the “pulling” (push up) configuration of motor and propellers is affected by an error due to the low distance between the propellers and the ground;
- The experimental data are comparable to those obtained from the analysis carried out by the Ecal tool.
- The current absorbed by the motors in the hovering condition is equal to 4.8 A; by using a 1300 mAh battery the flight time is about 16.25 min.

Firmware and Software

PX4 consists of two main layers: the flight stack and the middleware. The first is an estimation and flight control system while the second is a general level of robotics (it supports any type of autonomous robot) that provide internal and external communications and hardware integration. An Unmanned Aircraft System is equipped with a ground control station. It is a software that runs on a computer, tablet or smartphone that communicates with the aircraft via wireless telemetry. There are several software of ground control stations but the most important are Mission Planner and QGroundControl.

Throubleshooting

Once all the hardware components have been recovered it was possible to start the assembly and testing phase of the aircraft. During these operations, a series of problems have been identified:

Problem	Description	Solution
One motor in protection mode	one of the four motor did not work properly and immediately enter in protection mode	ESC replacement
No signal from GPS	absence of signals from the GPS that could not hook to any satellite	“cold start” procedure using Ublox U-center software
No binding between receiver and transmitter	the FrSky x4r receiver do not enter in binding mode	Firmware upgrade

Conclusion

The prototype must surely still be submitted to the evaluation tests, but it is possible to state that the main target of the project has therefore been achieved. The first flight tests confirmed the TOF expected in fact with a 2S 800 mAh battery the TOF is equal to 10 minutes and 15 minutes with a 2S 1300 mAh. The final weight analysis and the final prototype are shown below:

Component	**Weight [g]**
FC: mRo pixracer	10.54
PM: ACSP5	5
GPS: mRo GPS u-Blox Neo-M8N	20
Wifi medule: Pixracer Wifi module	1
Motors: T- Motor MT-1306-10	44.8
Propellers: T-motor 6020 CF	8.8
ESC: Lumenier Mini 12A 4 in 1	20
Battery: TP870-2SE55J	49
Receiver: FrSky X4R-SB	5.8
Frame: Three Layer Frame Light Version	40.25
3D printed support layer	6
Payload	21
Cables, screws, rubbers and cable ties	17.11
MTOF	**249**