Development of a Low Cost DIY UAV Mapping Platform

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Abstract

In the past few years UAV (Unmanned Aerial Vehicle) mapping has exploded into the survey industry. There are now countless companies offering the "Total UAV Mapping Solution". UAV mapping has allowed the smaller operator to gain entrance into the aerial mapping industry, at a reduced financial investment, thus allowing surveyors to utilize this method for topographical surveys.

This paper discusses experiences gained through the development of a low cost DIY fixed wing UAV system. Topics such as types of UAV's systems and their advantages and disadvantages, hardware and software utilized and comparisons of DIY solutions to off-the-shelf commercially available products will be covered.

1. Introduction

Unmanned Aerial Vehicles (UAV) and their employment within the military and defence industry is not new, but their use within the survey industry for mapping applications, is still in its infancy, and growing rapidly. The growth of UAV mapping systems has mainly been due to the miniaturisation and mass production of key components used. This has allowed the prices to fall, bringing the technology to the general public and not just the military and large research organisations. There are a number of commercially available mapping UAV systems but they still come with a hefty price tag. In this paper the author shares experiences gained and lesson learned through the development of a DIY UAV mapping platform.

2. Objectives

The objective of developing a DIY UAV was to create a method of cheaply and easily capturing high resolution, low altitude photography for aerial mapping. The use of an UAV allows the mapping of a larger area in higher detail quicker than conventional topographic survey methods would.

3. Components of a UAV Mapping Platform

A UAV mapping platform comprises of 4 major components, namely:

- Aircraft (fixed wing or multi rotor)
- Autopilot
- Sensor payload
- Ground Control Station (GCS)

3.1. Aircraft Platform

The choice of an aircraft platform has a great impact on the capabilities of the UAV. There are a number of advantages and disadvantages to both fixed-wing and rotary-winged aircrafts. The main differences are that fixed-wing aircrafts generally have greater endurance and so are better suited for mapping larger areas. They do, however, require a larger area to take off and land. Rotary-winged aircrafts, usually multirotors, can hover and ascend vertically allowing them to operate in much more restricted environments. Lastly, learning to fly a fixed wing aircraft is considered to be easier and cheaper than multirotors.

Based on the above, a fixed wing platform was chosen. Initially a 1.4m wingspan foam trainer aircraft was used as a proof of concept before further investment was made in the larger 1.6m wingspan plane. In order to keep the costs down, both planes were RC model aircrafts that were modified for UAV use. This was a time consuming and challenging task as the modifications needed to get the planes into suitable UAV mapping platforms, were substantial.

Figure 1. 1.6m fixed wing mapping platform

3.2. Autopilot

The autopilot is the system used to fly the UAV on its own, without any intervention from the pilot. For it to be considered a full autopilot, it should be capable of autonomous flight, including waypoint navigation. To achieve this, a modern UAV autopilot system is comprised of a hardware chip, sensors and the software loaded onto the chip. The system also typically has the following components to determine each of the important factors in allowing autonomous flight, namely:

- GPS for positioning
- Three axis gyros, accelerometers and magnetometer for orientation and positioning
- Barometre for height

There are also a number of optional sensors which can be included in the above to allow for better control and flight analysis. These include, amongst others, airspeed sensors, battery current and voltage sensors, and sonar sensors for accurate height determination. The code or firmware running on-board the autopilot is just as important as the sensors, with it having to analyse all the sensor data and make decisions based on the sensor inputs.

There are numerous UAV autopilot systems available, ranging in price from $160 to tens of thousands of dollars. The bottom end of the price range it dominated mainly by open source projects that have collaborated efforts to develop low cost autopilot systems (mainly for the hobbyist), such as ArduPilot Mega (APM), OpenPilot and Paparazzi.

The decision to go with ArduPilot Mega (APM), as the hardware chip, was based on it being multi-platform (i.e. can be used on multirotors and fixed-wing) and has the largest and most well supported open source development project at the time. The APM then allows three branches of firmware code, ArduPlane, ArduCopter and ArduRover, to be run on the same hardware platform. ArduPlane is the fixed wind branch of the code. The APM and Arduplane is supported by a large community on DiyDrones.com. Members are very active with constant improvements being made to the code and online support. At the time of purchase, the AMP2.5 was the latest release, but has subsequently been superseded by the APM 2.6, which has minor changes. Pixhawk is the latest release, which is a completely new chip design with improved processors, memory and sensors.

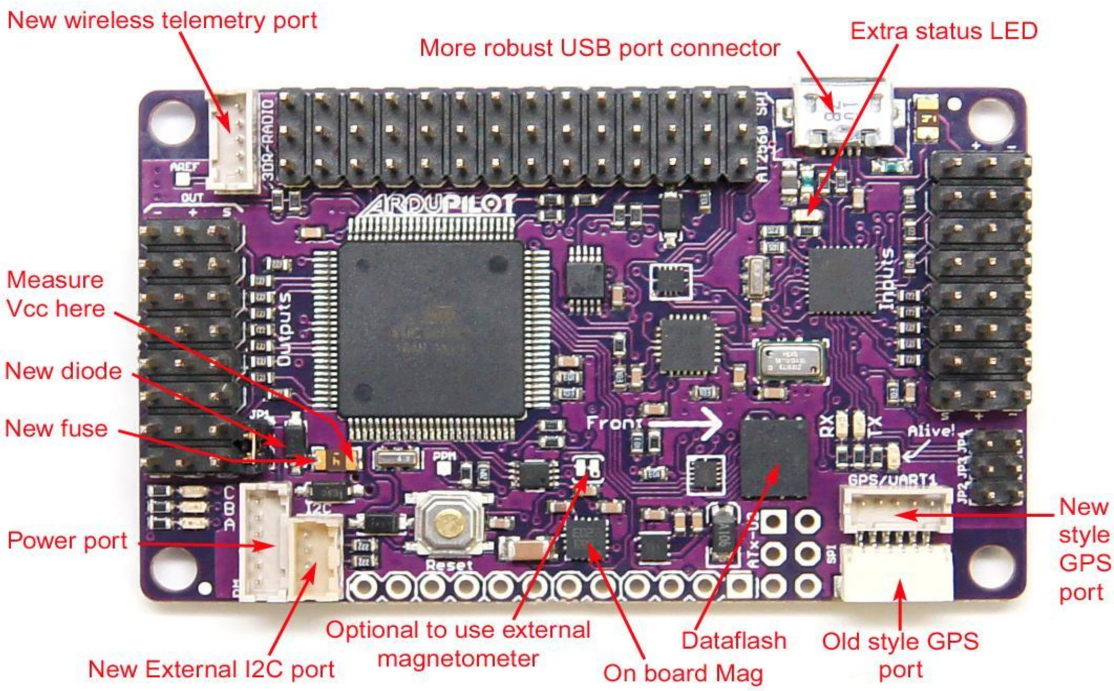

Figure 1. APM 2.5 Autopilot (http://plane.ardupilot.com/wiki/common-apm25-and-26-overview)

3.3. Sensor

Small UAV's are restricted both by the size and weight of the payload that they can carry. Any additional weight added to the aircraft is done so at the expense of endurance and flight range so every effort is made to minimise the mass of all components, including the sensor. A compact point and shoot camera is therefore considered the best option, due to its small size and low cost.

The Canon A2200 camera, a small compact point and shoot, was chosen as the mapping sensor. The open source Canon Hack Development Kit (CHDK - http://chdk.wikia.com) was then added onto the camera's firmware. This allows full manual control of the camera to be gained as well customised script files to be run on the camera. The camera has been setup to shoot continuously with a high-shutter speed, re-exposing and focusing of each shot. Besides the camera type, the camera mounting also needs to be considered, namely, payload protection, vibration isolation, mounting and gimbal stabilization.

3.4. Ground Control Station

Although the UAV can be operated without the GCS by pre-programming missions and controlling it with the radio transmitter, it should be considered an essential component of any UAV system. It is a critical link in the safety system, providing some redundancy for controlling the UAV. The GCS software runs on a laptop or tablet and communicates with the UAV via a telemetry link on a frequency different to that of the radio controller.

There are a number of freely available Ground Control Systems which run with the APM. The biggest and most advanced system is Mission Planner, available freely and developed by a DIYdrones.com community member, Michael Oborne. Mission Planner runs on a laptop and connects with the plane via the telemetry radios. Mission Planner is well established with excellent planning functions, mission observing, and detailed post-flight logs analysis.

Figure 2. GCS Software Mission Planner showing an aircraft flying an auto mission

4. Building and Testing

In order for a UAV to function properly, all of the above systems must work flawlessly together. It takes practice and experience to fly a remote controlled plane and thus the same must be said about a UAV. The simplest components must be mastered before adding additional parts and complexity. My previous experience in Remote Control glider flying was an advantage, but I honed my RC flying skills before adding the autopilot and camera components. The Autopilot was also extensively ground tested before being installed in the plane.

The current ArduPlane firmware (2.78b) has 311 parameters, many of which require setting up and tuning in order for ArduPlane to fly the UAV correctly. The default parameters are purposely set low to ensure that the first flight of the UAV is docile or even unresponsive. It is then the user's responsibility to tune the autopilot system to their aircraft by following a tuning procedure. Tuning is still a bit of an art, as it is aircraft specific, but is important as it sets the aircraft up to achieve efficient mapping flight paths through accurate waypoint navigation. With a basic understanding of the control algorithms, and a methodical approach to the tuning, great results can be achieved. An example of a successful efficient flight path can be seen in the picture below where the same double grid pattern with 50m line spacing was flown three times in windy conditions. The path actually flown, follows the intended path very closely, which indicates an efficient flight.

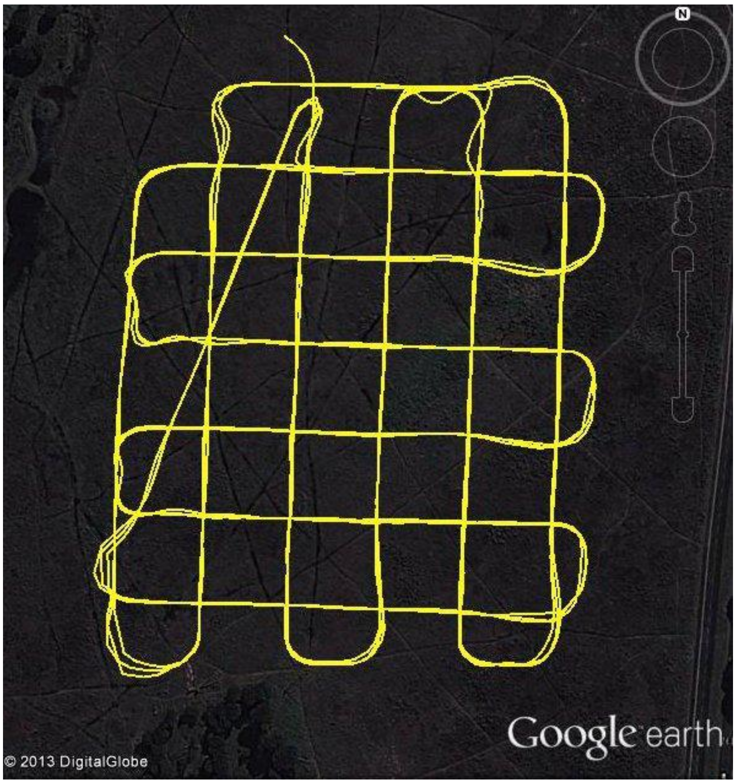

Figure 3. Plot of flight path flown in double grid pattern

Tabled 1. A summary of the current UAV system and its capabilities:

Aircraft	Fixed wing RC Model plane (1.6m wingspan)
Autopilot	ArduPlane running on APM2.5
Sensor	Canon A2200 Camera with CHDK
Ground control station	Mission Planner
Total flying weight	1.5kg
Distance covered per flight	13km
Area mapped flying double grid with 3.6cm GSD	15ha

5. DIY UAV versus Commercial UAV

There are a number of distinct differences, besides the costs, between the system developed here and the commercially available mapping UAVs. Currently, most commercially available fixed wing platforms are completely autonomous, requiring no flying input from the operator. The system I have developed requires the operator to be a competent RC pilot. This can be seen as both an advantage and disadvantage. An advantage being that the pilot can intervene in an autoflight path, if necessitated by a possible safety issue i.e. collision. A possible disadvantage is that an operator might crash the UAV through pilot error.

My system is based on an open source autopilot, and thus is reliant on the open source community to provide support and updates. There is also the risk that there could be a bug in the firmware resulting in a system crash. However, the converse means that there is rapid development and advancements at no cost, not necessarily seen in a commercial product.

Repairs on my system can also be done quicker and cheaper due to the direct knowledge of the aircraft and its systems. Commercial products are not necessarily able to be repaired by the user and must usually be sent in for repairs.

6. Conclusion and Comments

There is no one solution that fits all problems and projects in the UAV mapping industry. Communities like DIYDrones.com and the development of open source autopilot systems have opened UAVs to the hobbyist and independent UAV mapping developer.

To date my system has logged over 70 flights, with 26 hours and 1100 km covered. All without any major incident. The costs of this system, excluding the substantial number of man hours researching, building and tuning, is approximately R15,000. This amount obviously differs according the type of aircraft and camera used.

Going forward I will upgrade the autopilot to the latest hardware, and hope to install a roll stabilised gimbal for the camera as well as have the camera controlled via the autopilot.

The development of this low cost UAV mapping platform has shown that these systems can be developed by the individual, and are not just for the domain of large corporations. This mapping platform has allowed for a flexible alternative solution to traditional topographical surveying.