DEVELOPING A LOW COST VERTICAL TAKE OFF AND LANDING UNMANNED AERIAL SYSTEM FOR CENTIMETRIC MONITORING OF BIODIVERSITY - THE FONTAINEBLEAU FOREST CASE

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1. INTRODUCTION

Monitoring biodiversity is a very important task for numerous environmental studies, particularly in the Global Warming context. Remote sensing (aerial or spatial) has played a key role in this monitoring for years. With space imagery, the main limitation is actually due to the resolution (metric) which is not well adapted for estimating biodiversity in areas where species present only small areas are shrinking, like in the Fontainebleau Forest case. For aerial imagery, the main problem is the cost of a specific mission or the availability of the plane or the pilot. We propose in this article another solution : the use of a home-made Unmanned Vertical Take Off and Landing Aerial System, which is a good compromise between the spatial and aerial solutions, and test the validity and the robustness of the tools developed for biodiversity on a specific area of the Fontainebleau Forest.

The first part of this article deals with to the home-made Unmanned Aerial System (UAS) and specific payload in charge of the image acquisition. The second part details the software solutions developed for efficiently managing the huge amounts of data acquired and the last one presents different classification algorithms and the results obtained.

2. THE UNMANNED VERTICAL TAKE OFF AND LANDING AERIAL SYSTEM

2.1. The quad-rotor

To be compatible with a wide range of operating areas, we have decided to develop a Vertical Take Off and Landing (VTOL) solution, and more precisely, a small scale quad-rotor (Less than 70 cm, 1.6 kilogram) with constant pitch propellers (figure 1). The degrees of freedom of the UAV come from the differential speed of the pairs of rotors [1, 2]. Simple from a mechanical point of view, a quad-rotor is intrinsically unstable (compared to planes or helicopters) and thus needs efficient control algorithms and accurate sensors (like Inertial Measurement Unit for example) to perform any flight. In practice, the poor absolute measurement

Thanks to DGA/ONERA for helping us to fund our Unmanned Aerial System

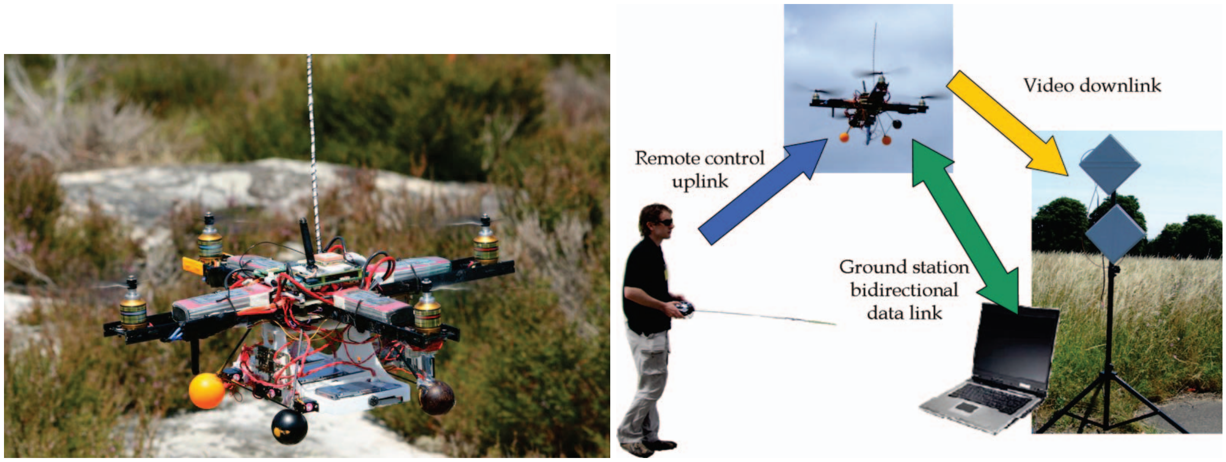

Fig. 1. The quadrirotor with the cartographic payload developed (left) and an overview of the communication system(right).

of light IMU does not allow any semi-automatic flight and it is a necessity to merge this information with other sensors like Global Positioning System (GPS) and ultrasonic, barometric and accelerometer systems. Efficient fusion algorithms of all data is a crucial point for VTOL systems because data needs tobe processed in near real time. More on the actual performances of our quad-rotor and some inboard videos can be found in [3]. The development of this UAS started in the context of an international contest of UAS organized by the DGA/ONERA french agencies, where we won the 3rd place [4].

2.2. The dedicated payload

The quality of the final products (mosaics, cartography, 3D, species classification...) drastically depends on the quality of the data acquired. For cartographic purposes, best results are obtained with synchronous photographs of the same area seen from different points of view. Then the main problems are : how to control the on-board digital camera enough precisely to take a picture and how to synchronize each photograph with other external data like GPS position, IMU or other sensors data? To do this, we have designed a payload controling three digital cameras (Figure 1) and detailed the method in [5]. In this way, we geo-reference the images on-board and in near real time the images. This upgrade of the raw data is very important for managing huge image databases.

2.3. The ground station

The ground station is a vital part of the UAS. The main tasks performed by our ground station are facilitating the security checklists, providing real-time checks of the internal status of the on-board system, of the data communication signal power and of the remaining flight time. It is also used to locate the UAV's orientation and position, to set any control parameters and to give high level orders (camera control). For cartographic missions, an extend module permits to see in real time the really overflown areas, so it limits the risk of incomplete dataset, which occurs often in systems with small paths. The ground station is also dedicated to on-board video reception, HUD immersion flight and data exploitation (storing the images and trajectory data between two flights).

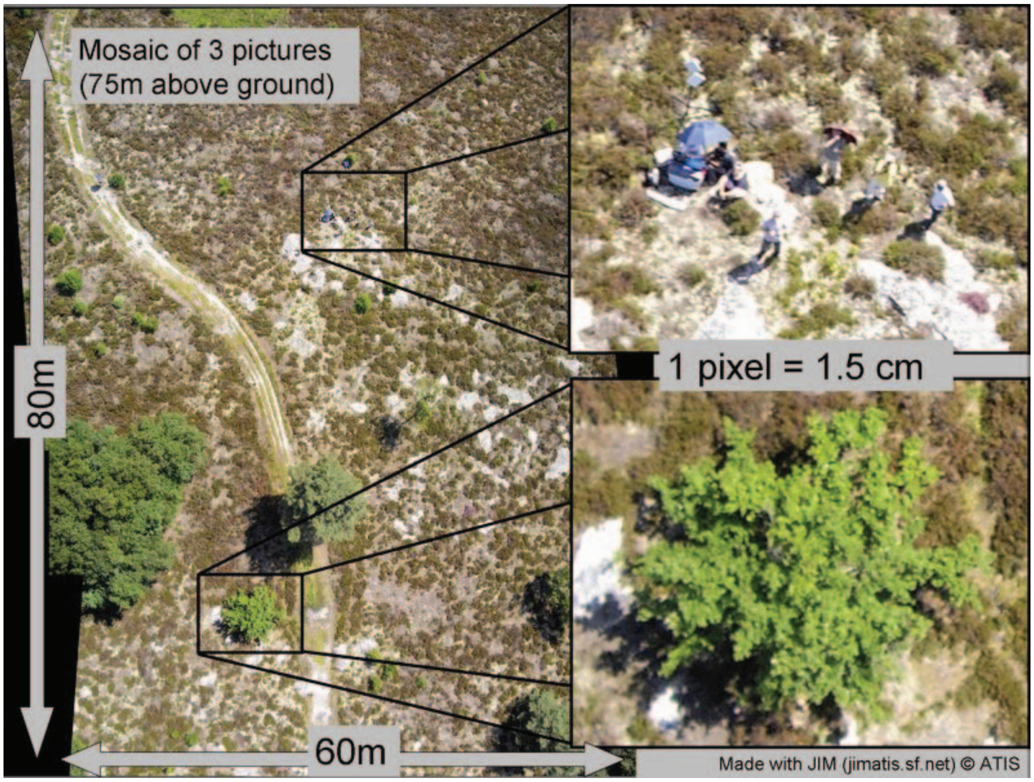

Fig. 2. A mosaic realized by JIM on a part of the Fontainebleau Forest.

3. NEW SOFTWARE SOLUTIONS AS A KEY OF AN EFFICIENT OPERATIONAL DATA PROCESSING

3.1. Visualization and Navigation in a huge image database - Drone Eye

A practical problem of centimetric photographic campaigns is the huge amount of data very quickly obtained. To give an idea of this, a 20 minute flight produces about 1500 high resolution images. So, efficient management of the data is very important. To permit to non computer specialists to deal with data, we have developed a solution to navigate in the database and visualize each interesting image by a specific add-on to the well known GoogleEarth software.

3.2. An Open-source automatic mosaicker - JIM

To extend the centimetric information on areas bigger than just one image, we have developed an open-source tool [6] to realize mosaics. The main steps of the algorithm [7] are find interest points detection by Harris corner detector on each picture, match interest points by Zero-mean Normalized Sum of Square Difference (ZNSSD), filter match possibities by RANdom SAmple Consensus algorithm (RANSAC) [8] and use of Enblend software for radiometric rearrangement [9]. A mosaic realized by JIM on a part of the Fontainebleau Forest is shown in figure 2.

4. THE FONTAINEBLEAU FOREST CASE

4.1. The study area

The study area is on the edge of the Fontainebleau Forest (located to the south of the city of Paris) and moor and marsh areas. On this edge, the competition between different vegetable species can be shown on decade observations. The Museum National d'Histoire Naturelle has worked on this area for years. The goal of the mission was to help them to cartography the area with the images taken from the UAS and compare the results with their own cartography.

4.2. Different classification strategies

In this section, we detail the different strategies of classification algorithms. The main approaches use :

- the spatial information (i.e. the textural information),
- the 3D information to help in separating different species and for same species, gives an idea of the age of the plant,
- temporal information by exploiting the fact that it is easy to organize ground missions at different moments of the year.

This section concludes by the performance obtained by each algorithm and by the fusion of them in comparison with ground truth.

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