Experiences with the eBee Drone

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Under SASSCAL Task 159, Biodiversity monitoring network in Namibia, we are faced with the dilemma that there are more observatories than our manpower is capable of surveying each year. To crown it all - we are able to determine the diversity of species, but are to date unable to track the life history of individual trees and shrubs.

In order to get to grasp with this dilemma, we motivated for, and purchased a survey drone to at least obtain every year a high-resolution aerial image of each observatory. Here is a summary of our experiences to help other tasks interested in drone photography make wise decisions. Choices, Choices...

1. Choice of Drone

There are two basic purposes for drones, and two basic types of drones:

We make a distinction between surveying and surveillance drones. Surveying drones are meant for survey work - the individual photos are geo-tagged (i.e. a location is saved for each image taken), and the resulting images after stitching are geo-referenced. Depending on the model of drone, flying conditions, ground control points available as well as ground resolution, these images are georeferenced to between 3 cm and 1 m accuracy. The important thing to remember, though, is that the imagery is not real-time, meaning there is a time-lag of between one hour and several days until the imagery can be analysed. The main purpose is surveying: towns and settlements, disaster areas, mining, infrastructure development, crop production, biodiversity (as in our case), etc.

Surveillance drones, in contrast, deliver real-time imagery and videos. These are typical the small hobby-drone you would use to spy on your neighbour (tsk, tsk!), or used in sport reporting on TV, or more serious applications like monitoring of poachers in game parks or even military drones. Yes, the photos can be geo-tagged and the imagery georeferenced, but the main emphasis is the real-time transmission of data.

We opted to buy the former type, a survey drone.

The second choice is between the two physical types: a fixed-wing drone (like a small aeroplane) and the multi-rotor type (your typical quadro-copter or hexacopter). Both have their advantages and disadvantages. The multi-rotor type can start and land in very confined spaces, but has a limited endurance and range. The fact that these are able to operate in confined spaces makes them ideal for building- and structure inspection, but also suitable to work in built-up areas or densely wooded areas. Fixed-wing drones, on the other hand, have a considerable longer range (and endurance), and are thus able to cover a far larger area. However, they need space to take off and land. The eBee typically needs at least 30 m for this, preferably as much as 100 m.

We opted for a fixed-wing drone - we have the space, but we also need the range (with an observatory being 1 x 1 km, or 100 ha, in size).

Even with these basic choices sorted out, there are a plethora of choices: drones for agricultural applications, high-precision survey drones (using differential GPS), multi-purpose drones, drones suitable for experimental cameras, etc. Your choice will have to consider cost, ease of use, support, and availability of supplies. We considered an out-of-the-box solution, completed with all accessories and spare parts, including a set of tested and working software for controlling the drone and processing the data.

2. Choice of cameras

With the eBee / eBee Ag, a variety of cameras are available. In the table on the next page, a summary of these models with possible applications is given.

The regular cameras (Canon, Sony) have been specifically adapted to be controlled by the Autopilot of the drone. This also includes the power supply of the camera - for the S110, the battery needs to be removed before flight, and for the G9x, the battery compartment has been closed. The Canon S110 cameras are the only range which has been modified with filters for specific wavelengths in the red-edge / near infrared range. Unfortunately, this camera is an end-of-range model. SenseFly is at this stage not considering the development of either the Canon G9x nor the

The eBee ready for take-off

Camera	Resolution (MegaPixel)	Ground resolution at 100 m flight height	Bands (wavelength in nm)	Purpose, comments
Sony WX	18.2	2.8 cm	R 660 G 520 B 450	Supplied as standard with eBee. Not capable of saving RAW images. Regular RGB orthophotos, digital surface model
Canon S110	12	3.5 cm	R 660 G 520 B 450	Regular RGB orthophotos, digital surface model
Canon S110 NIR	12	3.5 cm	NIR 850 R 625 G 550	Supplied as standard with eBee Ag. NIR orthophotos, digital surface model, index maps
Canon S110 RE	12	3.5 cm	RE 715 G 500 B 450	Red Edge orthophotos, digital surface model, index maps
Canon G9X	20	2.4 cm	R 660 G 520 B 450	Regular RGB orthophotos, digital surface model
Parrot Sequoia	RGB: 16 NIR, RE, Red and Green: 1.2	3 cm 18.8 cm	R 660 G 520 B 450 NIR 790 RE 735 R 660 G 550	Regular RGB orthophotos, digital surface model, NIR orthophotos, index maps. Has a high-resolution RGB camera as well as 4 additional cameras recording at NIR, Red Edge, Red and Green. Has a sunlight sensor with which exposure and images quality is adjusted.
SenseFly S.O.D.A.	20	2.3 cm	R 660 G 520 B 450	Regular RGB orthophotos, digital surface model
thermoMAP	0.328	37.8 cm	7 - 15 µm	Sensitive to between -40° and 160° C. Produces videos and photos for soil temperature related applications

Possible Camera Models

S.O.D.A. with such special filter adaptations; instead they are actively promoting the Sequoia as suitable alternative.

I have my drone - now what?

Obvious - unpack it, and get to know it! The provided manual will give you information on how to assemble and handle your drone. Take the time to work through this manual!

3. Control Software

You will likely be given a code allowing you to download software from the internet - in the case of SenseFly, the eMotion software to control the drone (multi-seat software, i.e. can be installed on several computers) and Pix4D to process the imagery (single-seat software - you may install it only on one computer).

eMotion allows you to simulate flights with different camera configurations in your eBee drone. This feature is an important tool to get to know your drone. Play with locations, landing sites, landing approaches, areas to be covered, using altitudinal data (especially important in mountainous areas), wind speeds and wind directions, and battery endurance. Remember - you will need to put in a safety margin for battery power - I found that, depending on altitude of the flight and wind speed, batteries last between 20 and 30 minutes. So rather plan two or three shorter flights than a single flight taking the drone to its limit. I still use the simulator feature extensively to plan flights in terrains I have not surveyed before.

Once confident with the controlling software, it is time to graduate to the real drone. SenseFly agents offer a short (2-3 day) training course in the use of the drone, or you can ask somebody with experience to show you how. It does help to get some practical training before the first solo flight! You will use the same software as when simulating the flight, and you will refine your flight planning skills. The starting is a totally new experience, with the prop blowing against you (frightening for many!), and if you don't launch it correctly, the drone will crash-land ten meters on. Once successfully launched, the other big difference is that the drone actually flies off and looks rather flimsy up there in the wind. And it might just disappear out of sight as well! This is there the constant radio link with the drone, and monitoring of the screen becomes important.

4. Planning your Flight

Before going into the field, you will want to look at the site you want to cover on both Google Earth and on eMotion. eMotion uses Google Earth and/or Microsoft Satellite imagery from the internet, as well as a set of SRTM data readied for use by SenseFly. Remember to download the imagery and SRTM data onto your computer - in the field you will NOT have internet access to see these images (Microsoft Satellite imagery can be readily downloaded, Google Earth imagery not. You can also upload your own data once you have flown the area previously). It is rather awkward to stand in the field, after a couple of hundred kilometres of driving, to find that you forgot to download the imagery, and that you have to adjust your landing approach by good luck.

One of the first things to decide is your ground resolution. Here we have to consider serious trade-off's: the higher our ground resolution is to be, the lower the drone needs to fly, and the less area can be covered. For safety reasons, eMotion will not allow you to fly lower than 50 m above take-off (ATO). With the G9x camera you will roughly cover four to six ha in at a ground resolution of 1.7 cm flying at just over 50 m ATO in a single flight. If you need to cover a bigger area, you will likely have to consider flying at a higher altitude. For an observatory (100 ha, or 1 x 1 km), I usually fly at a planned ground resolution of 5 cm. With the G9x camera, this results in a flight altitude of 244 m ATO and a flight duration of between 24 and 30 minutes. With a Canon S110 camera (for NIR images), this will be done at 144 m ATO, and under fairly quite conditions, in a just over 30-minute flight. In most cases I split the flight into

The eBee comes in a neat, sturdy travel box, holding all necessary parts and accessories together

two because of battery endurance / safety reasons.

Optimally, you will fly for a ground resolution of between 5 and 10 cm. Flying higher means that more energy is spend climbing - and in this way, you actually reduce the area you can cover in a single flight. For a 10-cm ground resolution, you can theoretically cover a 230 ha area in a single flight with the Canon G9x camera, flying at 423 m ATO (and default overlap settings). Remember also that the drone has to cover a considerable distance for such an endeavour - easily between two and three km from your start point before the mission commences at the furthest point away. Will the drone be near enough to reach your landing spot in case of a sudden battery failure due to an old battery? (From experience we know that this usually happens after 15 to 18 minutes in the air - if one of the three cells has a problem. See also the section on battery care later.)

One way to save energy is to allow the drone to climb during transit to the first waypoint, or to descend from the last waypoint to the home waypoint before landing. This avoids long times circling overhead to gain (or loose) altitude. Climbing during transit is NOT recommended in mountainous terrain - you will want to gain altitude before crossing over to the mission area.

5. Overlap and Image Quality

The next consideration is the degree of overlap between photos. The degree of overlap is important for successful stitching of the images later in Pix4D. Pix4D also calculates a digital surface model (DSM), using stereoscopic effects created by a high degree overlap. This DSM can be used for calculating tree heights and -volumes (amongst others), which is an important output from the drone imagery. Pix4D also uses the DSM to create an orthophoto from the stitched image. The higher the overlap, the better the resulting imagery and the calculated DSM.

Overlap can be set as lateral and longitudinal overlap. Lateral overlap refers to the degree the photos overlap between flight lines. Increasing this number will increase the number of flight lines, and thus will decrease the total area which can be covered in a single flight. Longitudinal overlap refers to the degree of photo-overlap between consecutive photos on a single flight line. As a default, I use a 60 % lateral, 75 % longitudinal overlap, with good results. You will find that with low-altitude flights you cannot use such a high degree of longitudinal overlap (as the camera cannot be activated fast enough by the autopilot between consecutive photos), and will have to compensate this either with an increase of lateral overlap, or by using perpendicular flights. If perpendicular flying is selected, eMotion will add a second set of flight lines perpendicular to the first, i.e. truly criss-crossing the area. Perpendicular flights basically double the number of photos, but also double the flying time. If highly accurate DSMs are required (e.g. for volume calculations), or for small areas photographed at ultra-high ground resolution, perpendicular flying is recommended.

6. Starting and Landing

Next to consider are potential start- and landing sites. Whilst it is good to pre-select such sites before your trip, in practise you will find that things look different on-site. In selecting your start- and landing site, you need to consider the following:

- wind direction and speed
- an open, even site
- any obstructions

It helps at this stage to look at the default behaviour of the eBee at starting and landing:

The eBee starts best against the wind. After successful start-up, the eBee climbs as rapidly as possible to 20 m ATO and turns to the start waypoint. This is typically 30 m west of the take-off site. Here the eBee will circle to 75 m, and either climb further to working altitude (circling), or fly off to the first waypoint climbing en route to working altitude.

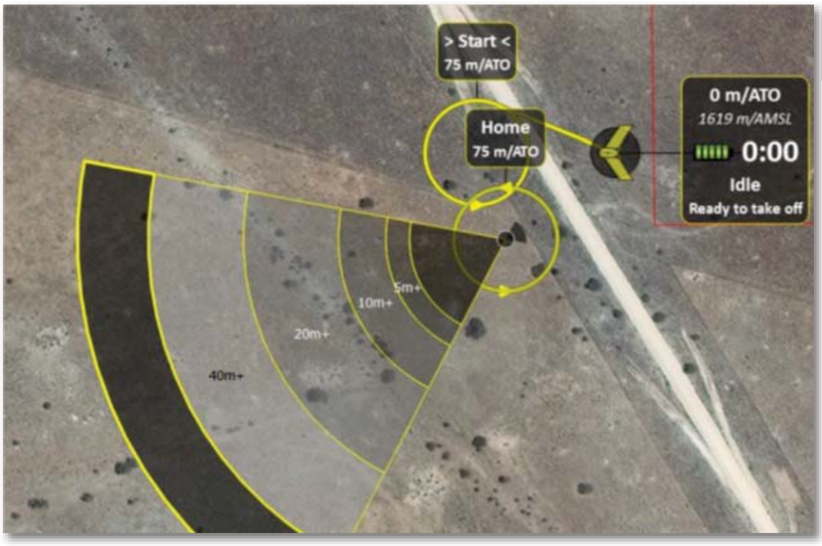
Once the mission is done, the eBee returns to the home waypoint. The home waypoint is by default the point where the eBee was started (i.e. the battery put in, and the first position fix taken by the autopilot). This is important to remember, especially if you assemble and start up the drone at your vehicle, as I do. Once over the home waypoint, the eBee descends to 75 m ATO. When it flies about 250 m out, turns, and starts its landing descend along the pre-set approach sector towards the home waypoint. Landing is generally within 5 m accurate on this point. The eBee lands on its belly, and will fall the last meter after switching off its engine just before landing.

If you need to start in confined spaces (e.g. in a dry river lined with tall trees), it makes sense to shift the starting waypoint in line with the launching direction. By also increasing the distance between launch point and start waypoint, you can increase the transit altitude to the start waypoint (e.g. from default 20 m to 50 m) to clear all obstructions before the drone starts circling to gain altitude. The start waypoint obviously needs to be adjusted before launching the drone.

The same holds true for the home waypoint. A grassy plain, sand or gravel are ideal (even a gravel road or farm path). Problematic however are big stones, rocks, shrubs and trees, etc on the landing spot. The home waypoint should be placed in such a way that the approach sector towards it is free of obstructions, especially no fences, large shrubs and trees within the last 10 to 20 m of the landing approach. The direction of the landing approach needs to be adjusted accordingly, also keeping in mind that the eBee lands best (most accurately) against the wind. As a matter of fact, it will choose the final approach path according to the prevailing wind direction (as determined whilst circling above the home waypoint) within the landing sector.

End of Part 1

This article will be continued in the next SASSCAL Newsletter Issue of September 2017.



Screenshot of the landing planning tool in eMotion. The drone symbol represents the position of the drone prior to launching, the 'start' waypoint is a position by default 30 m west of the launch point. The home waypoint is the point there the drone will land. In this case it has been shifted away from the launch position so that it can land on a grassy plain. The approach sector is situated to the west of the home waypoint, and can be quite broad as there are no obstructions in the approach higher than 5 m.

Starting and landing in confined spaces (e.g. at Claratal): Here (a) directional take-off is selected, (b) the start waypoint has been moved ahead of the directional take-off line, and further out, and (c) the landing approach sector adjusted in such a way that trees near the dam wall are missed.

Bottom: View of the actual starting site at Claratal, 19 April 2017. Note the tall trees and steep mountains lining the river.