

Free-Flight Mapping: Pix4Dcapture & dji Spark

Jerry Davis, SFSU Institute for Geographic Information Science

The best way to do mapping is using a GPS-guided grid pattern programmed by an app like Tower or Pix4Dcapture to ensure reliable coverage with suitable overlap, and with little user input needed during the flight. But what do you do if GPS is not reliable, such as under forest canopy, in deep canyons, or maybe in urban canyons with tall buildings degrading GPS signal? Free-flight mapping may be the only choice under these conditions.



This guide provides a method that will work for the dji Spark, which is a light-weight drone easily flown without GPS with a perfectly capable camera on a gimbal, but it doesn't accept a flight plan. Its obstacle avoidance, visual positioning and propeller guards make it safe flying in difficult locations with limited GPS signal. The same method could be applied to other drones that can be flown manually. *Note: not described here, but you'll also need to survey in ground control points; the photos don't have accurate GPS tags.*

One challenging mapping task is along stream corridors where riparian canopy can be very dense. These sites can be very difficult and in the coastal selva environments we commonly encounter (e.g. in streams in San Mateo County) the vegetation can often be so dense that it's difficult to envision doing any drone-based mapping. However many of these creeks with mature riparian canopies can be open enough below canopy to allow drone flights if we can accurately control the aircraft. While this does take practice, recent technological developments of drones with 3D sensing and vision systems provide two key capabilities that make mapping under these conditions possible (though admittedly still challenging):

- Precision Hovering: Using the downward looking vision system which includes a 3D infrared module and a camera, the dji Spark (and other recent units) can measure distance and use pattern visual patterns to maintain position when GPS is not available. This can also work indoors, which is featured in all of their promotional materials.
- Obstacle Avoidance: Drones such as the dji Spark and Phantom 4 actively avoid obstacles using their 3D sensing systems. If the aircraft is in P (Positioning) mode, not S (Sport) mode, the forward-looking 3D Sensing system causes the unit to brake when an obstacle is detected ahead of the aircraft. *Note that this only looks forward!*



Figure 1. Vision System of dji Spark, with (left) downward-looking 3D infrared module and camera, and (right) the forward-looking 3D sensing system.

Basic Controls on the Remote Controller

See the user manual at <http://geog.sfsu.edu/field-equipment/dji-spark> , but here is a brief tour of the remote control. Its basic components include:

- Return to Home (RTH) button. Press and hold to initiate RTH. Press again to cancel RTH. RTH only works with GPS, and you need to make sure there's nothing it's going to run into. See the user manual for a lot more on this.
- Pause button. Press once for emergency braking – works only with GPS or visioning system works.
- Sport (Flight Mode Switch). Normally leave it to the left (P) mode. In sport mode:
 - The drone can move very fast, so only use this if you have enough space.
 - Obstacle sensing is disabled, though GPS is still used for positioning.
- On/Off power button. Press twice to turn on RC. Wait to see the red light (above the pause button) turn green when it has connected with the aircraft.
- Shutter button at your right fingertip. *Note that it's easy to press the wrong button. The shutter is the one to the top.* Alternative to using shutter button in dji Go or triggering by pix4Dcapture. On the corresponding left rear of the RC is a video record button.
- Fn: Programmable function button.
- Joy sticks:
 - Left sends the aircraft up and down, or rotates left or right. Note that the red lights are in the front.
 - Right goes forward, backward, left and right, or angles in between.
- Antennae. Should be perpendicular to the direction of the aircraft.
- Mobile device holder. Fits a phone or a mini tablet. Must be connected to the RC via Wi-Fi, and can be a bit challenging on Android, often requiring restarting or turning on airplane mode and then connecting Wi-Fi, but works well in iOS.



Free-Flight Mapping Method in Pix4Dcapture

If you can still get enough GPS, Pix4Dcapture can be used with the dji Spark in Free-Flight mode. In this case, GPS isn't used for grid mapping or navigating, but just for spacing out photos longitudinally and laterally along a grid you fly manually. A double grid might be the best choice however.



1. Estimate Grid Spacing

To take the pictures we'll need for mapping, we'll need to create the same gridded flight pattern used in autonomous flights and have the camera take pictures at the correct interval. Pix4Dcapture has a pretty functional Free-Flight mode that can help with this. You'll need to determine the spacing to ensure 75% overlap by moving 25% of the scene width or height. The scene width is determined the height (h) of the camera and the angular field of view (FOV), which in turn is determined by the 35-mm equivalent focal length (f) of the camera:

$$FOV = 2 \cdot \tan^{-1} \frac{35}{2f}$$

$$W = 2 \cdot \tan \frac{FOV}{2} h$$

The scene length (L) for a 4:3 aspect ratio camera would then be 0.75 times the W. Note that the following table also converts radians to degrees with the DEGREES function, then reverts back to radians with the RADIANS function. The spreadsheet is provided as a separate document.

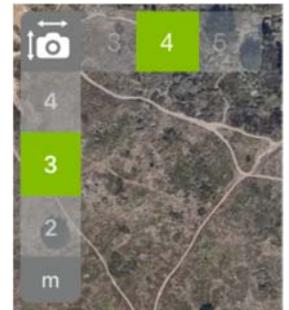


Figure 2. Free-Flight lateral and longitudinal spacing settings.

Then we can use this to make the appropriate setting in Pix4Dcapture, such as 4 m wide and 3 m long at a height of 10 m. The camera will be triggered as these detected spacings, so you will mainly need to control the spacing of each flight line, by estimating the size of the site and approximating the number of flight lines. You will need to be pretty close to the aircraft to do this reasonably accurately. It's probably best to make them a bit closer together and make the lateral spacing lower than indicated to make sure to get sufficient overlap.

All dimensions in meters	focal length	35mm equiv	FOV°	At heights (m)								
				10	20	30	40	50	60	80	120	
Canon S90/S95 default (min)	6	28										
scene width W			64	12.5	25.0	37.5	50.0	62.5	75.0	100.0	150.0	
scene length L			50	9.4	18.8	28.1	37.5	46.9	56.3	75.0	112.5	
longitudinal spacing 75%				2.3	4.7	7.0	9.4	11.7	14.1	18.8	28.1	
lateral spacing 75%				3.1	6.3	9.4	12.5	15.6	18.8	25.0	37.5	
dji Spark		25										
scene width W			82	17.4	34.8	52.2	69.5	86.9	104.3	139.1	208.6	
scene length L			62	11.9	23.8	35.7	47.6	59.5	71.4	95.2	142.8	
longitudinal spacing 75%				3.0	5.9	8.9	11.9	14.9	17.8	23.8	35.7	
lateral spacing 75%				4.3	8.7	13.0	17.4	21.7	26.1	34.8	52.2	

2. Flight Procedure

Even though Pix4Dcapture's Free-Flight mode can't program the flight and upload it to the aircraft, it can use a similar process for executing the flight. Once the aircraft system has initially been activated using dji Go 4.0 once, you do not need to run this app to fly the aircraft; the aircraft is simply flown manually and Pix4Dcapture triggers the camera to take pictures at the correct spacing, using the following procedure:

- (a) Power on the aircraft and RC.
- (b) In the WiFi settings, select the Spark. It will indicate 'No Internet Connection'.
- (a) In Pix4Dcapture, look for the drone readings to show up with green icons, turn on the camera and rotate it downward, rotating out to the left the control in the left back of the RC, then START (Figure 3).
- (c) If Drone connection is shown, Next to Drone take off checklist. Wait for all items to be checked.
- (d) The main display will show PAUSE and ABORT. These are used simply for controlling the photography, and do not control the drone – that is controlled manually.
- (e) Start the propellers by moving both joysticks *downward* and both inward at 45° (both outward at 45° also works).
- (f) Then proceed through your flight plan, watching the aircraft at all times (a team member can monitor the screen if desired):
 - a. Fly to the desired height.
 - b. With the left joystick, orient the aircraft with the red lights in front facing in the direction of longitudinal travel.
 - c. Using the right joystick, move the aircraft along the first flight line, move sideways to the next line, move backward down the next flight line, etc.
- (g) When finished, land manually and ABORT to stop the photography. It will download the pictures for uploading to Pix4D's cloud service, but you can also pull them from the micro SD

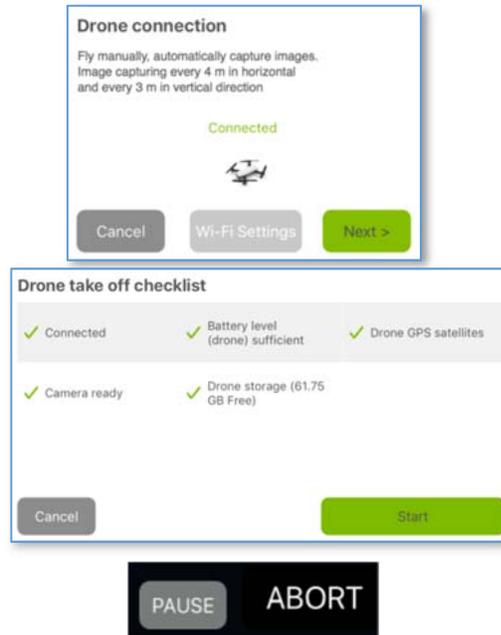


Figure 4. Sequence of dialogs when starting the mission. The checklist must all be green checked to Start. Once started, PAUSE and ABORT are the only controls, and these only pause and abort the photography. All drone operations are controlled manually.

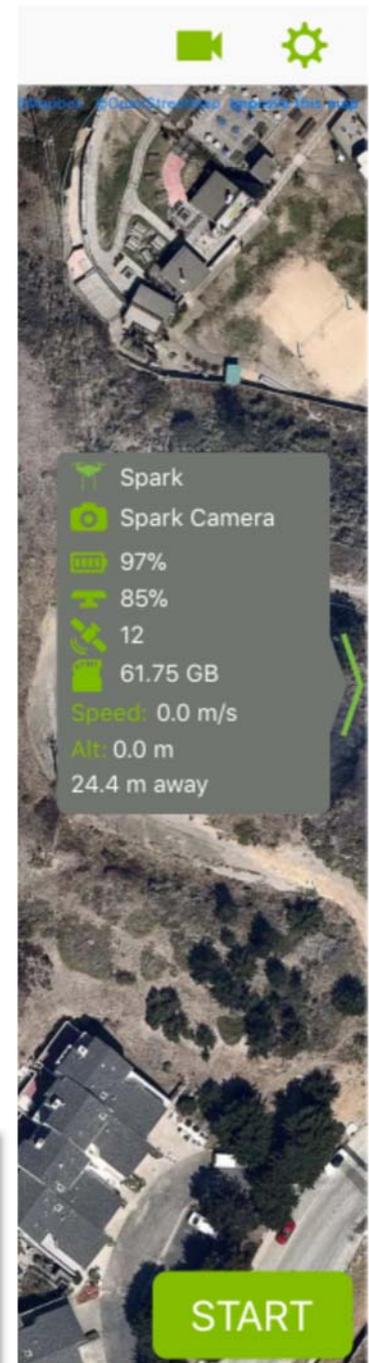


Figure 3. Right side of Pix4Dcapture showing active Spark connection. Camera is turned on with camera icon at top, and mission is started with START button.

card.

Free-Flight Method with no GPS using dji Go and Timed or Individual Photographs

The above method requires GPS in order to use Pix4Dcapture to space the photographs out with the proper overlap, but as described at the top of this document we're often faced with situations where GPS is unreliable or completely unavailable. So instead we'll use dji Go 4 to control the camera. There are at least two options: (1) using the Timed Shot setting to take pictures every 2 s or so; or (2) taking pictures individually.

For the timed shot, just set this up and touch the shutter button and it will start.

For individual shots, you could just use the shutter button on the back of the RC, just at your right index finger, and not even use dji Go. However, it would probably be best to have one person watching the screen and taking the individual pictures from dji Go, directing the RC operator to move through the grid and probably hover for each shot, ensuring sufficient overlap. You'll still need to estimate grid spacing (see above), requiring a bit of guesswork, though the app does display a height estimate. Otherwise the procedure is similar to the previous method:

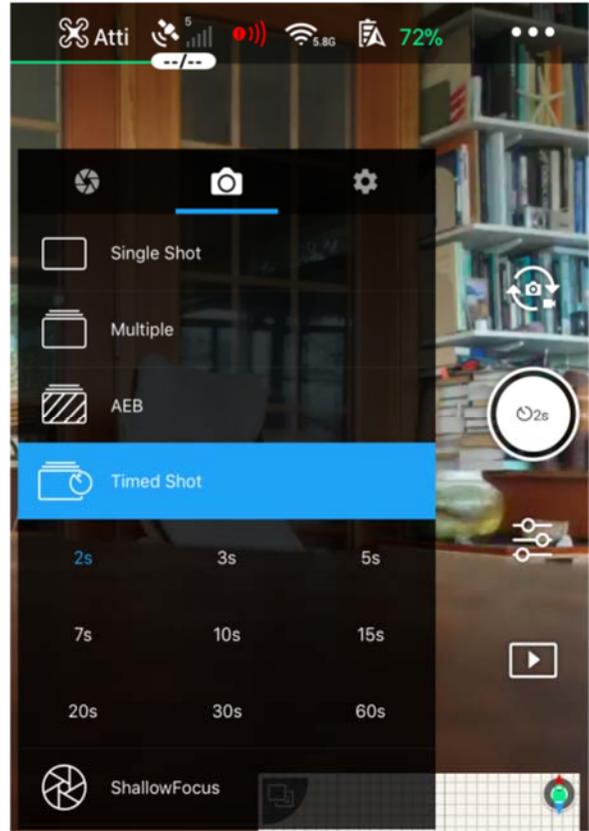


Figure 5. dji Go Timed Shot in Atti mode.

- (a) Power on the aircraft and RC.
- (b) In the WiFi settings, select the Spark. It will indicate 'No Internet Connection'.
- (c) In dji Go, note that without GPS you'll be in **Atti** (attitude only) mode.
- (d) Make any desired camera settings and set up Timed Shots if desired.
- (e) Rotate the camera downward, rotating out to the left the control in the left back of the RC.
- (f) Start the propellers by moving both joysticks *downward* and both inward at 45° (both outward at 45° also works).
- (g) Then proceed through your flight plan, watching the aircraft at all times (a team member can monitor the screen if desired, especially if individual shots are used):
 - a. Fly to the desired height.
 - b. With the left joystick, orient the aircraft with the red lights in front facing in the direction of longitudinal travel.
 - c. Using the right joystick, move the aircraft along the first flight line, move sideways to the next line, move backward down the next flight line, etc. Pause to get individual shots.
- (h) When finished, land manually and stop the photography.
- (i) Shut down the RC and aircraft.
- (j) Pull the photos from the micro SD card.