Accuracy and crop line misalignment over HIGH RESOLUTION ORTHO-MOSAICS from UNMANNED AERIAL VEHICLES

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Introduction

Recently, unmanned aerial vehicles (UAVs) have been presented as a promising tool for many agronomic applications (Schmale et al., 2008). The advantages of using a UAV over a piloted aircraft include lower image acquisition costs, the ability to deploy the aircraft relatively quickly and repeatedly and the capability to fly at a very low altitude (Rango et al, 2006). One of the most recently approaches for the acquisition of crop and weed spatial information is through remote images, which can be classified and divided in a series of sub-plots for further personalized applications according to the specific weed emergence (Gómez-Candón et al, 2012; López-Granados et al, 2011).The UAV ortho-mosaics are turning into an important tool for the development of precision agriculture prescription strategies, in particular for site specific weed management (SSWM). The UAV platforms are able to take remote images at a very high spatial resolution. This high spatial resolution is necessary for SSWM at early grow stages which requires to discriminate small plants (crops and weeds) that can not be detected using other kind of platforms with coarse spatial resolution, like the satellite or aerial ones. Little changes in flight altitude may cause important differences in the final spatial resolution. Furthermore, a decrease of the flying altitude reduces the area covered by each single image; which implies an increment of both the sequence of images and the complexity of the image mosaicking to obtain a cover of the whole study area. On the other hand, prescription control maps need geo-referenciation accuracy in agreement to the details of the objectives that we want to discriminate. Consequently, it is necessary to find a balance between spatial resolution (which depends on flying height and sensor) and geo-referenciation accuracy.

Thus, the aim of this study was to assess the geometric accuracy of image mosaics taken in wheat crops at early stages using UAV images. We focused our studies in two parameters flying altitude and crop line misalignment.

Materials and methods

The studies were conducted in wheat crops located in the province of Seville in Andalusia (Southern Spain). Two plots of about 1.00 ha were sampled at the Monclova farm, named Monclova and Infantado (Fig. 1). The ground is flat (average slope <1%). At study plots, the images were taken from a Microdrones MD4-1000 quadrotor UAV (Fig. 2) equipped with an Olympus EP-1 camera (Red, Green and Blue bands) on January 2012.

Wheat crops were sown on November 2011 and were naturally infested by broadleaved and grassy weeds, every plant was at seedling growth stage (2-3 true leaves). Over the whole field, a total of 53 artificial GCPs (Ground Control Points, formed by 0.40 m² squared targets) were placed on a grid of about 12.5 x 12.5m, and every GCP was geo-referenced using a Trimble Geo-XH differential GPS.

Accuracy assessment

The geometric accuracy of the orthorectified mosaic was assessed by determining the coordinates of 7 independent check points of visible features with a Trimble Geo-XH differential GPS unit. We then calculated the root mean square error (RMSE) between the 7 checkpoints and image points for two mosaic outputs: Monclova and Infantado.

Effect of flying height

A series of 30, 45 and 100 images corresponding to 100, 60 and 30 m flying altitudes, respectively, were taken and processed in order to orthorectify and mosaic them using Leica Photogrammetry Suite (LPS) software to create a unique orthoimage of every wheat field. Once the orthoimages were generated, the RMSE was calculated using the validation GCPs in order to assess the accuracy of the orthoimage as described above.

Crop line misalignment

The study of crop misalignment in the border of two consecutive single images from each mosaic was made by following. In every of the mosaics 14 crop lines were taken between borders of the single image of the series. The Euclidean distance between axis of the same crop line at both sides was measured.

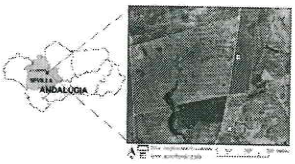


Figure 1. Study area location.

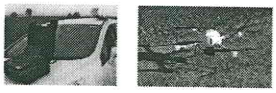


Figure 2. Illustration of important piece of equipment, or perhaps a flow chart summarizing experimental design. Scanned, hand-drawn illustrations are often preferable to computer-generated ones.

Results

The RMSE associated with aerial triangulation is shown in tables 1 and 2. With conventional aerial photography, an RMSE of 1 pixel is desirable. This is difficult to achieve with this type of UAV imagery due to larger distortion of the imagery, greater difference between UAV image resolution and digital ortho-photo quadrangle resolution, and greater differences in roll, pitch and heading during flight. Therefore, we consider errors of 1.5 to 2 pixels from the aerial triangulation acceptable for UAV imagery acquired with low-cost cameras at this resolution as Laliberte et al. (2010). An example of the resulting ortho-mosaics of the 100 m height series at both locations is shown in figure 3.

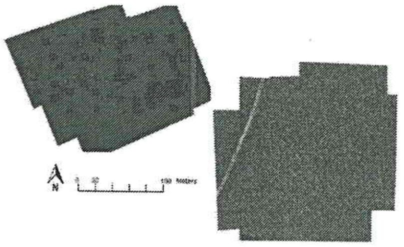


Figure 3. Example of the resulting ortho-mosaics of the 100 m altitude flight at Monclova (left) and Infantado (right).

Effect of flight altitude

Three UAV remote image series at two different locations were taken, orthorectified and mosaicked. RMSE was lesser than 0.30 m in every case (Table 1). Furthermore, errors were very similar between ortho-mosaics regardless of the flight altitude. Furthermore, overall errors were very similar between ortho-mosaics regardless of the flight altitude and ranged from 0.21 to 0.28 m and 0.08 to 0.28 m for Monclova and Infantado, respectively.

Results did not show remarkable accuracy differences on the interval of altitude studied (30-100 m). Therefore, one of the relevant results of our study is that flying altitude did not affect the geo-referenciation accuracy of the mosaicked image.

Discarding the altitude as a cause of error, there are other factors that could have been involved in the geo-referenciation accuracy, like number of GCPs, use of Digital Elevation Models (DEM), DGPS accuracy and sensor and aerial platform characteristics. Regarding to the number of GCPs used in the orthorectification process, in this study the same number of GCPs than single images has been used. It is expected that an increment in the number of GCPs will improve the geo-referenciation accuracy (Gómez-Candón et al, 2011).

Crop line misalignment

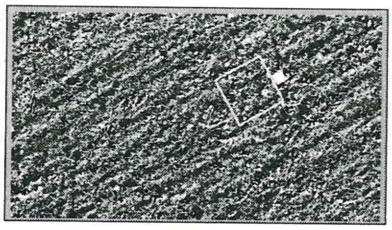
Crop line misalignment in any case it was higher than 2 pixels (Table 1), which do not break the crop line continuity. Flying height affects crop alignment but not the number of GCPs.

At every flight altitude, results where the same regarding of the number of GCPs used. These data were not shown to avoid redundancy.

Table 1. RMSE of Monclova and Infantado plots at different flying altitudes.

		Flying height (spatial resolution)		
		100 m (2.47 cm)	60 m (1.48 cm)	30 m (0.74 cm)
Monclova	RMSE±s.d. (m)	0,285±0.161	0,244±0.137	0,211±0.167
	Misalignment±s.d. (m)	0.045±0.055	0.012±0.015	0.015±0.017
Infantado	RMSE±s.d. (m)	0.214±0.067	0.280±0.101	0.080±0.027
	Misalignment±s.d. (m)	0.047±0.053	0.011±0.026	0.014±0.026

Figure 4. Mosaic overlapping area. Division line between single images is marked in red.



CONCLUSIONS

- Flight altitude did not affect the geo-referenciation accuracy of the ortho-mosaiced image for 100 and 30 m altitude.
- When choosing flight altitude, two decisive parameters are the optimum spatial resolution required, and the number of single images to handle in order to study the entire field area

References

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