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Evaluation of unmanned aerial vehicles (UAV) high spatial resolution data to produce digital terrain model and visible spectral imagery

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Abstract: This article presents the results obtained with Unmanned Aerial Vehicle (UAV) high spatial resolution data to produce a digital terrain model and visible spectral imagery. The UAV developed in the Civil and Environmental Engineering Department at the University of Brasilia (UnB) was used to obtain remote sensing visible spectral imagery with 6 cm spatial resolution. The area of study, located in the city of Brasilia near Lake Paranoá, was imaged with 500 images of 60% common area overlapping in the 1/1000 flight scale. Two Dense Surface Models (DSM) and one orthomosaic of the study area were produced with Pix4D software using a point cloud algorithm, the UAV`s GPS and altitude parameters and geographic coordinates from ground control points (GPC) obtained using a topographic GPS survey. The orthomosaic imagery obtained from the UAV was registered using GPC measured in the area studied with topographic GPS using an ArcGis Georeferencing Module and the following transformations were tested: 1st to 3rd order polynomial, adjust, projective transformation and spline transformation. A total RMS deviation inferior to 10 cm was obtained with spline transformation, which allows the UAV's imagery to be used to update the cartographic base with scales above 1/2000. In the ArcGis 10.2.1 system, spatial analyst module algorithms (TIN generator, Raster Calculator, mathematical operators, etc.) were used to transform the DSM into a digital terrain model (DTM) and compare it with Terracap's digital terrain model (DTM) cartographic base , showing that the UAV's DTM presented high geometric quality with an RMS error lower than one meter. The results obtained from the UAV`s high spatial resolution imagery developed by the Civil and Environmental Engineering Department at the University of Brasilia confirmed the high geometric and cartographic quality of its data to be used in study areas of up to 10Km^2, thus making it a quality option in regards to the elevated cost of high spatial resolution satellite images.

Keywords: Unmanned Aerial Vehicle, Digital Orthomosaic, Dense Surface Models, Digital Terrain Models, Geoprocessing.

1. Introduction

The high spatial resolution imagery obtained by Unmanned Aerial Vehicles (UAVs) has become a recognized alternative for producing digital terrain models and thus visible spectral imagery. The applications of the UAV's data could be the same as the high spatial resolution imagery from satellites such as Ikonos, Quick-Bird etc. This is due to the fact that there are mechanisms in the UAV to control attitude (path, yaw, roll) of its imagery system

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and high geodesic precision network of ground control points to produce an imagery set with cartographic precision quality. There are several applications of UAV imagery, principally owing to its capacity to produce digital surface models (DSMs) and digital terrain models (DTMs) in civil and environmental engineering for studies of hydrographic watershed, analysis of the erosion process, among others.

The UAV (Fig.1) developed in the Civil and Environmental Engineering Department at the University of Brasilia (UnB) has a Sony camera model RX-100, equipped with a calibrated CMOS sensor, which produced images with 5472 x 3648 pixels (20 megapixels) and three main modules: navigation by GPS control, altitude control and imagery system. The other UAV features are: 200 meters of typical flying height; cruise speed of 30 km/h; flight operation remote control range of 2 km, flight range of 30 minutes, total weight of 1.5 kg and was used to obtain remote sensing visible spectral imagery with 6 cm spatial resolution. The UAV was classified in the category of Micro-UAV according to Remotely Piloted Systems (UVL-International, 2012).

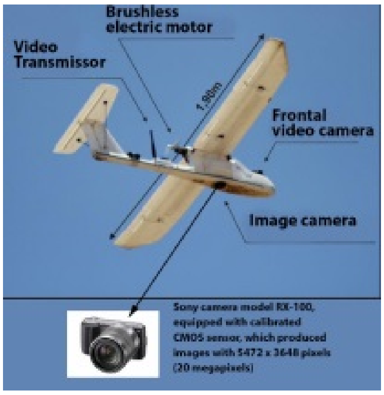

Figure 1. The UAV developed by the Civil and Environmental Engineering Department at the University of Brasilia (UnB).

2. Objective

The objective of this article is to compare the geometric quality of the DTM produced from the UAV/UnB's DSM with the DTM produced with classical aerial photogrammetric methods like DTM produced by Terracap Co. in the cartographic survey carried out to produce the cartographic base of the city of Brasília.

2.1. Study Area

The study area is a region called "Morada da Serra" located in the city of Brasília near Lake Paranoá, between the geographic coordinates of south latitude: 15° 50'28" and 15° 51' 19" and west longitude: 47° 45'50" and 45° 45'09", an area of approximately 1,12 Km^2.

3. Materials and Methods

3.1. Materials

The following materials were used in this research: a) UAV/UnB imagery: The imagery used corresponds to 500 images of the study area, visible spectral bands, with 60% of overlapping common area, 5472 x 3648 pixels (20 megapixels) each image, approximately six (06) centimeters of spatial resolution; b) Global positioning system (GPS) topographic survey, model Ashtech ProMark2, with 2 cm of accuracy; c) Software: - Google Earth: to produce the flight routes to be followed by UAV/UnB during study area imaging; - Pix4D: this is a photogrammetric package to produce orthomosaics and digital surface models; - ArcGiS 10.1: to register the orthomosaic and to carry out the geoprocessing algorithms.

3.2. Methods

The methodology can be summarized according to the following steps:
a) UAV/UnB flight route/imagery: in Amorim et al. (2012) are the principles of software developed for the UAV/UnB to follow the flight route planned in Google Earth, to obtain the 500 images of 60% common area overlapping in the 1/1000 flight scale and UAV/UnB's altitude control.
- Pix4D software: in Vorster and Strechia (2013) are Pix 4D's operation principles. After the flight, the UAV/UnB imagery was processed using interior and exterior parameters determined by bundle-blocked adjustment. Next, Pix4D generated the DSM and orthomosaic of the study area.
b) Measurement ground control points (GPC) using a topographic GPS survey identified in the orthomosaic in the study area. The GPC geographic coordinates in WGS-84 Datum were used in Pix4d software to produce new DSM and an orthomosaic of the study area.
- ArcGis 10.2.1 System: In Almeida et al. (2012) is the Geoprocessing methodology steps used in the research. In the ArcMap module georeferencing algorithms were used to register the UAV/UnB orthomosaic with Terracap orthophotos. The following transformations were tested: 1st to 3rd order polynomial, projective transformation and spline transformation to obtain the smallest root mean square (RMS) deviation. Next, the features editor was used to digitalize the trees and constructions (houses, small buildings etc.) present in UAV/UnB orthomosaic and to produce features which were used in the next step of the methodology.
- ArcGis 10.2.1 System: a spatial analyst module in the ArcMap was used to produce a mask with those features. This mask was used by "Extract by Mask tool" to subtract the trees and constructions of the UAV/UNB's DSM. Next, "Extract by Mask tool" was used in Terracap's DTM to subtract the same area of UAV/UnB's DSM, in order to allow the comparison between these models. Next, the "Raster Calculator tool" was used to subtract the UAV/UnB's DSM and Terracap's DTM and to produce an image of the difference between those models.

4. Results Achieved

4.1. Production of the orthomosaic and DSM

The UAV/UnB's imagery was processed with Pix4D's algorithms and two dataset data were generated: b) orthomosaic and DSM obtained with GPS parameters on board in the UAV; b) orthomosaic and DSM obtained with GCP in which geographic coordinates were measured with Ashtech GPS survey.

4.2. Orthomosaic Georeferencing

The UAV/UnB's orthomosaic was georeferenced with GCP and the following transformations were tested: 1st, 2nd and 3rd order polynomial (affine), projective transformation and spline transformation. The spline transformation had the lowest root mean square (RMS) deviation with 0,134 meter. This RMS allows producing cartographic maps with scale below to 1/10000.

4.3. Evaluation of Digital Terrain Data

With the UAV/UnB's georeferenced orthomosaic and according to the methodology steps mentioned above, in the ArcMap's computational environment features digitized from the trees, houses and buildings present in the study area were produced. Next, those features, as a mask, were subtracted from Terracap's DTM and the UAV/UnB's DSM and both models were subtracted from each other. With DSM generated only with GPS parameters on board, the difference of Terracap's DTM produced a variation in elevation of -32 meters (near the drainage network) to 31 meters. With a DSM generated with GCP obtained from a topographic GPS survey this difference needed to be verified until the Geobia data some results are still being processed with Pix4D. Figure 4 presents the results obtained with methodological steps carried out in ArcMap.

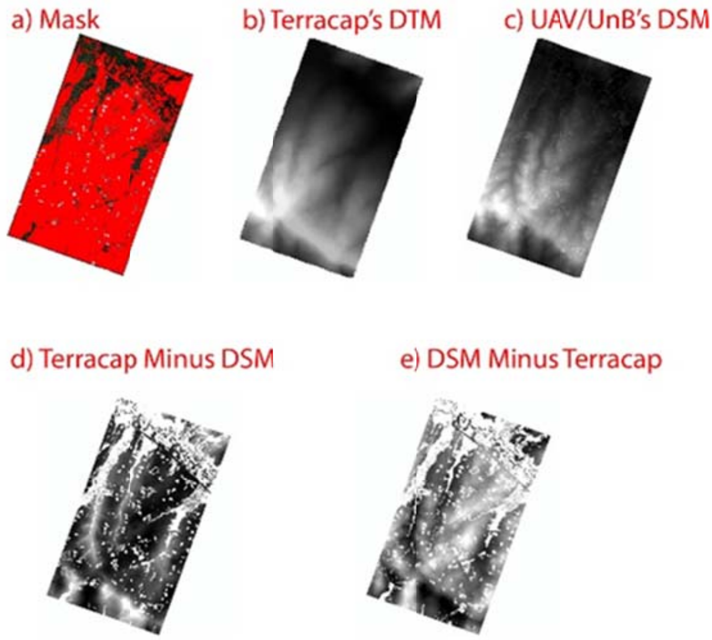

Figure 4. Results obtained with ArcMap methodology, a. mask with features subtracted (trees, constructions, etc.), b. Terracap's DTM, c. UAV/UnB's DSM, d. DTM difference between Terracap – UAV/UnB, e. DTM difference between UAV/UnB – Terracap.

5. Conclusions

The results obtained with the UAV/UNB's orthomosaics confirmed the cartographic quality to update maps up to 1/10.000 scales, since there is field control using GPC geographic coordinates obtained with a GPS topographic tracking survey to be used in the georeferencing process. The results obtained with UAV/DSM are still in the evaluation phase, but surely using GPC geographic coordinates obtained with GPS topographic tracking survey will be able to improve the geometric quality of the terrain model.

The results obtained from UAV`s high spatial resolution imagery developed by the Civil and Environmental Engineering Department at the University of Brasilia confirmed the high geometric and cartographic quality of its data for use in study areas of up to 10Km^2, therefore making it a quality option in relation to the elevated cost of high spatial resolution satellite images.

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