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PÔSTER

Analysis of the Accuracy of Orthophotos Generated by UAS with RTK Sensors for Application in Urban Land Regularization (REURB)

Autores:

Renato Zetehaku Araujo | IFSC/UDESC | renato.araujo@ifsc.edu.br

Allan Gomes | IFSC | allan.gomes@ifsc.edu.br

Francisco Henrique de Oliveira | UDESC | francisco.oliveira@udesc.br

Adolfo Lino de Araujo | IFSC | adolfo.lino@ifsc.edu.br

Introduction

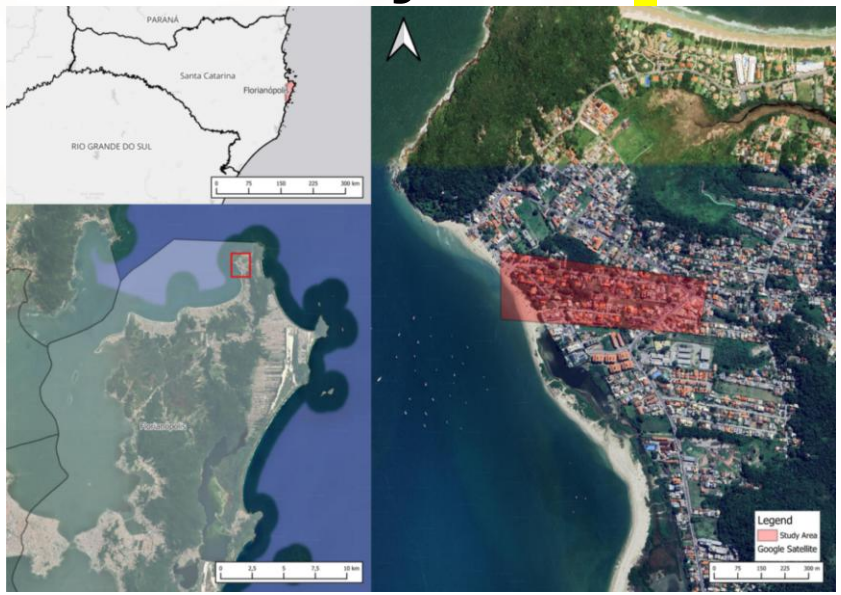
- The unplanned occupation of urban areas challenges municipal territorial management in Brazil, creating land conflicts and compromising urban planning and quality of life.

- Law No. 13,465/2017 (REURB) establishes legal and technical mechanisms for urban land regularization, requiring accurate cartographic bases to define parcel boundaries.

- Traditional GNSS and total station surveys ensure precision but are costly and time-consuming, while Unmanned Aircraft Systems (UAS) offer a faster and more economical alternative for high-resolution mapping.

- This study evaluates the geometric quality of UAS-derived photogrammetric products and proposes technical guidelines to ensure their reliable use in urban land regularization (REURB).

Study Area



The selected study area is located in Ponta das Canas, in the municipality of Florianópolis, State of Santa Catarina, Brazil. It covers approximately 15 hectares and 80 parcels, including two complete blocks, three full streets, and two segments of streets/avenues.

Methodology

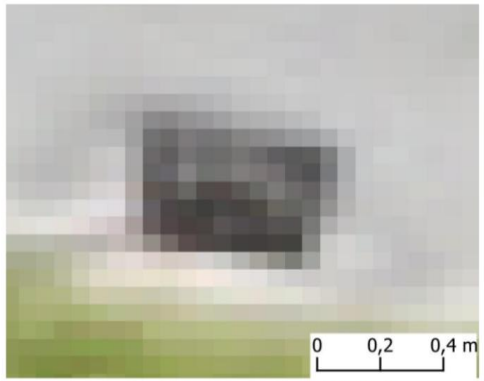
- The methodology combined aerial and ground surveys, with UAS (DJI Matrice 3 Enterprise with RTK) flights conducted at different altitudes, producing orthophotos with GSDs of 5 cm, 2 cm (linear and oblique), and 1 cm, supported by RTK/PPK technology for high positional accuracy.

- A ground survey was carried out using a Total Station and a GNSS receiver, surveying property vertices accessible without entering parcels and establishing control points for the flights.

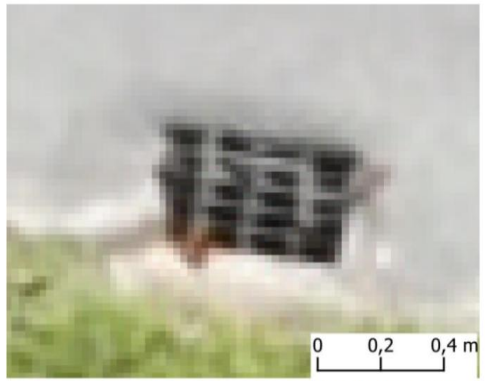
- The images were processed in Agisoft Metashape 2.1, and terrestrial data were adjusted in GeoOffice and Magnet Tools, followed by vectorization in QGIS.

- Accuracy assessment was performed in GeoPEC, applying the Student’s t-test and Chi-square test to compare vertex coordinates obtained from the four UAS surveys with ground-truth data.

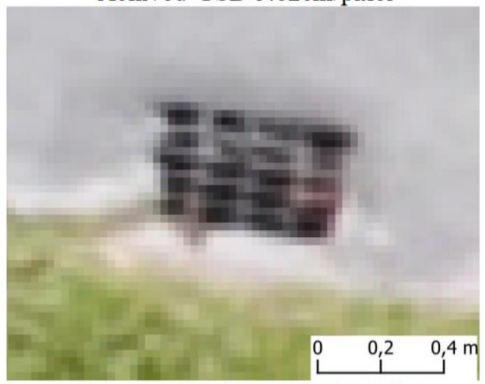
UAS Surveying and Ground Survey



Achived GSD 5.62cm/pixel



Achived GSD 2.23cm/pixel (linear)



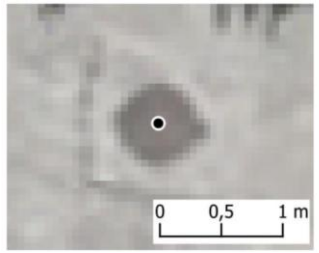
Achived GSD 2.41cm/pixel (Oblique)

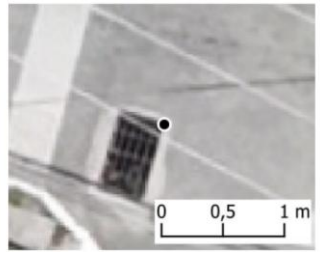
Achived GSD 1.16cm/pixel

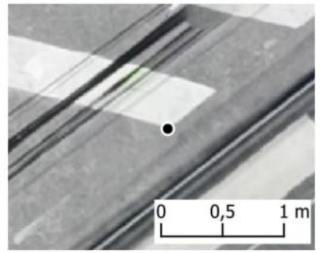
Flight	Expected GSD	Achieved GSD	Type	Flight Altitude	Number of Photos	Flight Time	Processing Time
1	5 cm/pixel	5.62 cm/pixel	Linear	200 m	60	2min 31s	20min
2	2 cm/pixel	2.23 cm/pixel	Linear	83.1 m	288	4min 59s	1h 43min
3	2 cm/pixel	2.41 cm/pixel	Oblique	85 m	1,112	20min 55s	16h 53min
4	1 cm/pixel	1.16 cm/pixel	Linear	44.5 m	1,06	12min 18s	13h 11min

Flight Parameters (source: the authors)

A total of 27 points were measured using this method, which were employed as check points to evaluate the positional accuracy of the orthophotos in relation to the traditional method and the requirements established by cadastral survey standards. Notable features such as manhole covers, storm drain corners, and street marking intersections were surveyed







Vetorization

- Four orthophotos were vectorized in QGIS, beginning with parcel boundary lines to identify vertices and assess visibility or obstacles.

- Lines were prioritized to extend alignments (e.g., walls), defining vertices by intersections for later accuracy comparison.

- 202 vertex points and 27 check points were created and classified by acquisition method.

- Coordinates were extracted with the Field Calculator ($X, $Y) in UTM Zone 22S / SIRGAS 2000, enabling planimetric accuracy analysis.

Vectorization of parcel vertices.

GCP and vertex points in the study area.

Discrepancy calculations, trend and accuracy analysis.

	5cm/pixel			2cm/pixel (Linear)			2cm/pixel (oblique)			1cm/pixel		
	x (m)	y (m)	hz (m)	x (m)	y (m)	hz (m)	x (m)	y (m)	hz (m)	x (m)	y (m)	hz (m)
Mean	-0.065	-0.033	0.097	0.004	-0.038	0.058	0.051	0.022	0.032	0.060	0.022	0.031
Standard Deviation	0.046	0.066	0.47	0.041	0.040	0.035	0.020	0.026	0.023	0.018	0.021	0.017

Differences in the x, y, and Hz components between check points.

		5cm/pixel		2cm/pixel (Linear)		2cm/pixel (oblique)		1cm/pixel	
	t tab	t calc	Trend	t calc	Trend	t calc	Trend	t calc	Trend
di(N)	1,7056	-2,0849	Presents	0,5576	free	1,3317	free	1,6307	free
di(Y)	1,7056	-2,6988	Presents	-4,9331	Presents	-4,3967	Presents	-5,317	Presents

Trend analysis of the 4 orthophotos and GCP.

	s	% ΔhZ< SE	Outlier	Result
5cm/pixel	0,047	84,615	1	Reproved
2cm/pixel Linear	0,035	100	0	Aproved
2cm/pixel Oblique	0,023	100	0	Aproved
1cm/pixel	0,017	100	0	Aproved

Accuracy Comparation - GCP and Ortophotos

		5cm/pixel		2cm/pixel (Linear)		2cm/pixel (oblique)	
	t tab	t calc	Trend	t calc	Trend	t calc	Trend
di(N)	1,6532	-11,2062	Presents	1,7826	Presents	1,7826	Presents
di(Y)	1,6532	2,9137	Presents	0,7604	free	0,7604	free

Trend analysis comparison between 1cm ortophoto and others.

	s	% ΔhZ< SE	Outlier	Result
5cm/pixel	0,091	43,243	12	Reproved
2cm/pixel Linear	0,081	72,105	11	Reproved
2cm/pixel Oblique	0,074	75,63	10	Reproved

Accuracy comparison between 1cm ortophoto and others.

Analysis of the Results Obtained

- Higher positional accuracy was achieved as GSD decreased, especially at 2 cm/pixel, improving feature identification and orthophoto adjustment.

- All orthophotos showed a trend along the Y-axis, likely caused by GNSS-RTK or NTRIP base displacement, accentuated by the 20 km distance to the reference base.

- Most outliers (90%) were linked to vertices defined by line extensions, resulting from the lack of vertex visibility in the orthophoto, indicating the need for complementary ground surveys for validation.

- Orthophotos with 1 cm and 2 cm GSD met accuracy standards under a 24 cm tolerance (3×8 cm) per NBR 14047; oblique flights and 1 cm GSD provided no significant advantages.

- DJI M3M RTK/NTRIP mapping with 2 cm GSD complies with NBR 14047 accuracy standards, achieving an optimal balance between precision, flight time, and processing efficiency.

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