



**Universidade Estadual Paulista**  
Presidente Prudente - Brazil

## ACCURACY ASSESSMENT OF BUNDLE ADJUSTMENT WITH UAV-BASED IMAGES OF TROPICAL FOREST USING SPARSE CONTROL

**ADILSON BERVEGLIERI**

**RAQUEL A. OLIVEIRA**

**ANTONIO M. G. TOMMASELLI**

**ALEXANDRE MAINARDI**

**RICARDO AFFONSO**

Sofia– Bulgaria 2015

## INTRODUCTION

- The conservation and recovery of native forests are global needs widely recognized:
  - These tasks require updated maps;
  - environmental monitoring with temporal frequency.
- This work proposes to perform a study on the image orientation and DSM generation in a small tropical forest using images acquired with a UAV;
- The objective is to assess the effects resulting in two flying strips when GCPs are only available outside the forest.

## BUNDLE ADJUSTMENT USING SPARSE CONTROL FOR DSM GENERATION

- Methodology to produce a DSM in tropical forest:
  1. Camera calibration;
  2. Data acquisition;
  3. Image orientation;
  4. DSM generation.

## EXPERIMENTS

### • CAMERA CALIBRATION



Camera model	Sony Nex-7
Image dimensions	6000 × 4000 pixels
Pixel size	0.0039 mm
Nominal focal length	21.0 mm (Voigtländer)

## EXPERIMENTS

### • DATA ACQUISITION SYSTEM

**Sony camera**

**gimbal**

**Dual frequency GNSS receiver**



- Positions were acquired with GNSS receiver as well as the time stamps of camera events;

- Attitude angles were not available, but the camera was stabilized with a gimballed platform.

## EXPERIMENTS

### • DATA ACQUISITION - Pre-marked target positioning and flying survey

**Sample area**



**Control  
points**

**Two flying  
strips**

- Two pre-marked targets were installed out of the forest;

- The flying survey was performed with the UAV at a flying height = 150 m, acquiring two strips composed of 67 images with a GSD of 3 cm;

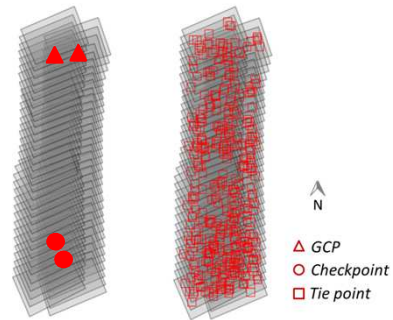
Two clearings existing in the test area were used to collect two checkpoints with GNSS receiver, but only the altimetry was considered;

## EXPERIMENTS

### • Image orientation

- A photogrammetric project was configured in the ERDAS-LPS:
  - EOPs were based on the raw data collect by the GNSS receiver;
  - IOPs were calibrated;
  - GCPs were considered with  $\sigma = 5$  cm;
  - Image coordinates with  $\sigma = 1/2$  pixel;
  - Tie points were automatically generated;

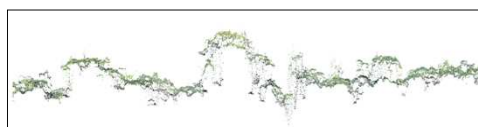
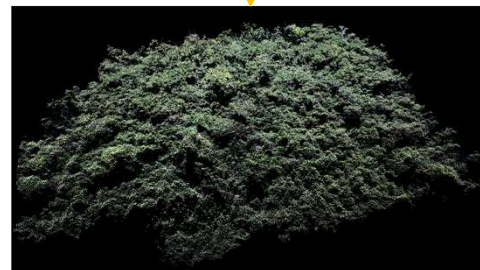
- **Five experiments** were performed varying the weighted constraints in the PC coordinates
  - $\sigma = 10$  to 50 cm;
  - Attitude angles = unknowns.



## EXPERIMENTS

### • DSM generation

- Inpho software was used to generate a DSM of the test area (with 6 images);
- A cross section was extracted from the DSM to show the forest canopy



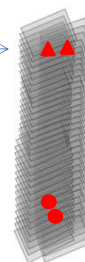
*profile*

## EXPERIMENTS

• Validation and analysis of results

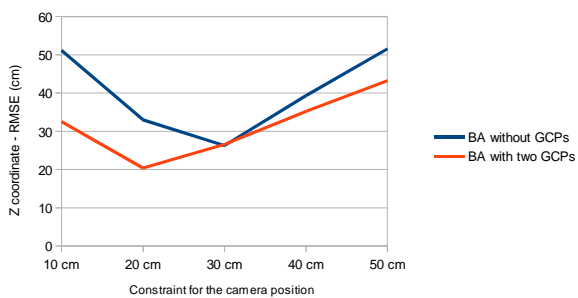
GCP Coordinate	$\sigma_{\text{position}} = 10 \text{ cm}$	$\sigma_{\text{position}} = 20 \text{ cm}$	$\sigma_{\text{position}} = 30 \text{ cm}$	$\sigma_{\text{position}} = 40 \text{ cm}$	$\sigma_{\text{position}} = 50 \text{ cm}$
	RMSE (m)	RMSE (m)	RMSE (m)	RMSE (m)	RMSE (m)
Ground X	0.004	0.003	0.002	0.001	0.001
Ground Y	0.121	0.065	0.041	0.031	0.028
Ground Z	0.033	0.023	0.015	0.010	0.009
	(pixel)	(pixel)	(pixel)	(pixel)	(pixel)
Image x	0.47	0.35	0.28	0.24	0.22
Image y	0.31	0.21	0.17	0.16	0.16

Results in the 2 GCPs

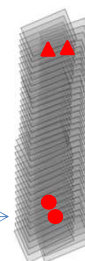


## EXPERIMENTS

• Validation and analysis of results



Results in the 2 checkpoints



## CONCLUSIONS

- The experiments showed that better results obtained with GCPs, even with a weak configuration;
- The assessment based on RMSE in Z from 2 checkpoints indicated better results with a constraint of 2 cm in the PC position, which generated a  $RMSE_z = 20$  cm;
- Although the tie point generation in vegetation area is time-consuming due to the manual editing, the technique showed:
  - the sparse control can guarantee outcomes with acceptable accuracy;
  - Pre-marked targets can be used because few points are required and they can be installed outside the forest;
  - With this technique, it is not required to go into the forest
- In future works, more experiments will be developed using other configurations and number of points.

## ACKNOWLEDGEMENT



Thank you for your attention!