UAS photogrammetry with on-board RTK positioning; ground control, mission planning, and Accuracy.

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Photogrammetric extraction of elevation models and image mosaics from photo grids collected using Unmanned Aerial Systems (UAS) is cool, but positional accuracies fit to the very high image resolution are difficult to reach.

Where extensive ground control is unpractical, on-board Real Time Kinematic positioning (RTK) is a promising solution. In this study we compare RTK and ordinary GNSS positioning on multiple flights and different ground control densities of two test scenes and ask:

How accurate is on-board only RTK positioning?

Do oblique images or multiple flights decrease errors?

What added value does ground control have to on-board RTK?

Methods:

We use two study areas in The Netherlands for testing: A dune blowout trough near Bloemendaal, and the reconstructed roman fortres 'Fectio' near Bunnik. These cases represent an area with relatively poor contrast and strong elevation differences, and a more level site with more artificial structures.

The area of interest at each of the study sites was ~10ha. The image grids are flown with 70% overlap side to side and within path using a 'DJI Phantom 4 pro RTK'. For each site we collected three set of images: 1: 100m Nadir looking, 2: 100m 15° Oblique, 3: 120m Nadir to evaluate the effects of adding additional flight configurations to position accuracy. Positions of the images were recorded using on-board network RTK, and on-board ordinary GNSS in Bloemendaal, on Vechten we used one set of images only but truncated to 4 degree-decimals to simulate less accurate locations.

On the ground, control targets were laid out irregularly spread in the AOI and locations were recorded using a survey grade network RTK system. We use either 0, 1, 5, or 20 control points to align the images, and 23 separate targets to validate the accuracy. Validation GCPs are localized on the generated orthomosaics and elevation models outside of the photogrammetry application to get fully independent locations.

All images were processed in Agisoft MetaShape 1.5. using default settings. After primary alignment the sparse cloud was filtered to remove any suspect matches: images ≤ 2, reconstruction uncertainty ≤ 20, projection accuracy ≤ 8, and reprojection error ≤ 0.5. Final camera optimization was run with all parameters checked, and for the RTK positioning optimization of GPS offsets was also enabled. Orthophotos and Elevation models were generated in MetaShape based on the dense cloud using default settings and exported in in raster format. Ground resolution of all missions was around 3 cm.

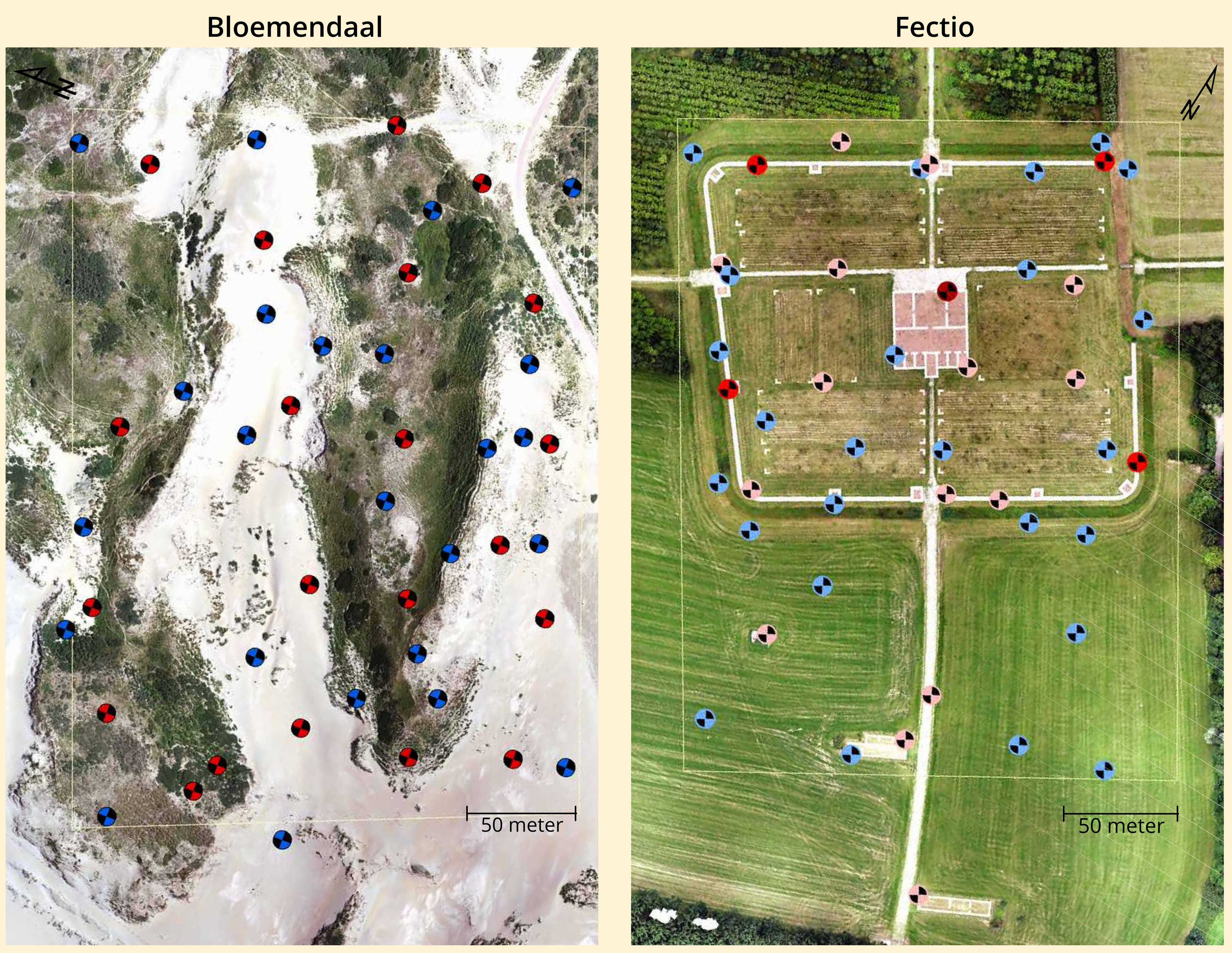

Figure 1:
Quick look orthomosaics of our two test sites, right: Bloemendaal dunes, left: Castellum Fectio. The yellow line indicates the flight plan AOI. Markers indicate ground control points, red: training, blue: valitaion

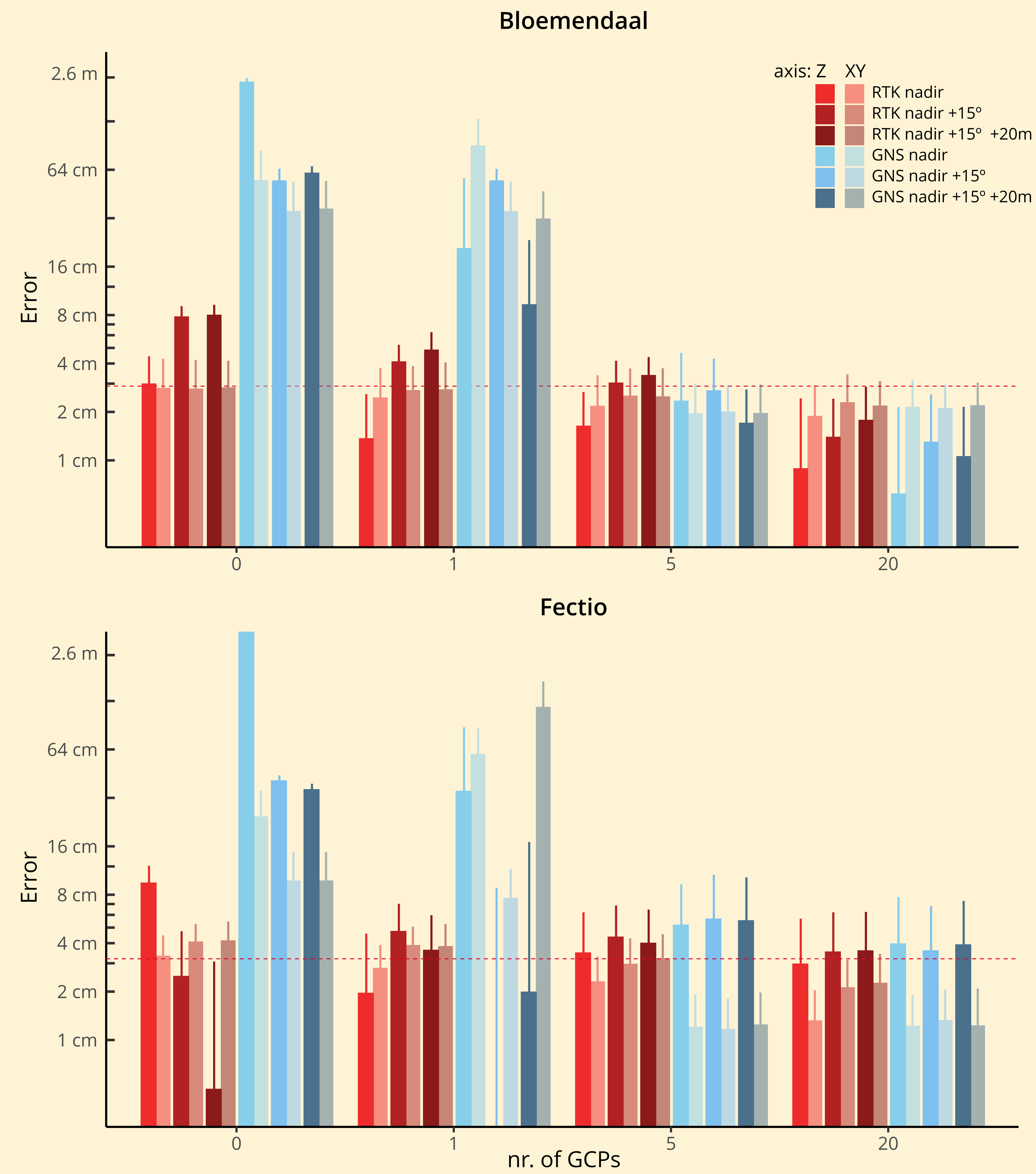

Figure 2:
Bias (bars = absolute mean distance) and varibility (wiskers = distance standarddeviation) between image and field measurements of independent check locations (n = 23). Upper: Bloemendaal dunes, lower: Castellum Fectio

With on-board RTK positioning we reach mean errors around 5 cm in XY and Z. Ordinary GNSS positioning is able to produce similar accuracies with five or more well placed GCPs for our 10ha areas.

Additional (oblique) images decrease errors when positioning is poor, but the advantage quickly diminishes when sufficient ground control or RTK positioning are present. A bias in de order of 2-4 cm was found between on-board and on-ground positioning. When more images are included with precise positioning that bias is retained stronger in the results unless accounted for by reducing the accuracy estimates before image alignment.

Dense ground control does improve geometric calibration stability and position accuracy over on-board RTK, but the magnitude of improvements is rather small. When position accuracies beyond 5 cm are required, target stability on vegetation, ground resolution limits, and on-ground positioning uncertainty become increasingly important error sources compared to photo geometry and aircraft positioning.

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