POSITION ERROR OF INPUT PRESCRIPTION MAP DELINEATED FROM REMOTE IMAGES

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ABSTRACT

The spatial variability of biotic factors (e.g., weeds and pathogens) and abiotic factors (e.g., nutrients and water content) are likely to be mapped through remote sensing and therefore high spatial resolution satellite and airborne remotely sensed images can be used to delineate input prescription map for precision agriculture. First, the whole image need to be accurately geo-referenced and/or co-registered, ideally with a position error <0.3 to 0.5 m, or 1 pixel. Generally, once isolated the selected parcel image where site-specific operations are to be implemented, the following processes are required: a) assessing/ discriminating the agro-environment indicator in which to implement the variable rate input application; and b) splitting the parcel image into tiny rectangular plots (i.e. 25 to 200 m^2); and c) designing the variable-rate input prescription map according with the selected decision taking criteria.

Precision agriculture requires high spatial resolution images, pixel size <1.0-1.5 m. As spatial resolution increase the relative position error estimated in pixels increase. Normally, satellite and airborne images are commercially provided with position errors not acceptable for precision agriculture (e.g. >5 to 10 m). Therefore a geo-referenciation process to improve/ decrease the position error is needed. The aim of this paper is to discuss the position and the geo-referenciation and co-registration errors of high spatial resolution images for precision agriculture. Specific objectives are as following: 1) to indicate common position errors of commercially provided satellites; 2) to discuss the disadvantages of conventional image geo-registration using ground “hard-edge” points; 3) to resume the use of the semi-automatic geo-referenciation AUGEO® system for geo-registration; and 4) to indicate the prescription input map error as affected by the positioning error.

Keywords: Precision agriculture, geo-referenciation, co-registration, AUGEO-2.0®, image splitting, variable-rate prescription maps.

INTRODUCTION

Input prescription maps (IPMs) are a key tool for the implementation of site-specific management (SSM) strategies. IPMs are generally composed of tiny rectangular plots ("micro-plots") with an indication of the variable input rate to be applied into each micro-plot (Gómez-Candón et al., 2011b and c). The size of the micro-plot varies widely, for example from approximately 1 x 2 m to 10 x 30 m, with the micro-plot width (W) equal to, or a multiple of, the width covered by a nozzle of the application machinery, and the micro-plot length (L) normally a multiple of W (Fig. 1). Mapping the biotic/ abiotic patch area to be treated and delineating the subsequent IPMs are critical for site-specific strategies (SSM) implementation using remote-sensed images and, for practical reasons, both need to be matched (Ruiz et al., 2006).

IPMs can be obtained from remotely sensed images through the following processes: a) estimating the image position accuracy and geo-referencing it based on ground control points, which will be described in this paper; b) image processing for mapping the targeted agro-environmental information, such as achieved for weed infestations by Brown and Nobel (2005) and Lopez-Granados et al., (2006, 2011); c) sectioning and assessing the image into micro-images through specific software, such as SARI® (Gómez-Candón et al., 2012a, b).

The aim of this paper is to discuss the positioning and geo--registration/ co-registration error of high spatial resolution images for precision agriculture. Specific objectives are as following: 1) to indicate common positioning errors of commercially provided satellite images; 2) to briefly discuss the disadvantages of conventional image geo-referenciation using ground "hard-edge" points; 3) to resume the use of the semi-automatic geo-referenciation AUGEO-2,0® system for geo-registration; and 4) to indicate the IPMs errors as affected by the position/ geo-registration error.

1) POSITION ERROR OF SATELLITE IMAGES

The geo-referenced commercial panchromatic satellite images with 0.6 m spatial resolution such as those from QuickBird are normally provided with coregistration errors of 15 to 20 m (Toutin and Chenier, 2004). Similarly Gomez-Candón et al. (2011) found in panchromatic and multispectral QuickBird (QB) and GeoEye-1 images positioning errors of 7 to 9 m and around 6 m, respectively (Table 1 and 2). Generally, a coregistration error higher than 1 or 2 m is inadequate to establish a site-specific prescription map for variable-rates application.

2) PRO AND CONS OF TYPES OF GEO-REGISTRATION

Conventional

Commonly authors have developed procedures to obtain more accurate image geo-referencing using ground control points (GCP) for verification and validation (Toutin and Chenier, 2004; Weber et al., 2008). The GCP, also known as "fixed points" or "hard-edge points", are usually assigned at the corners of structures such as buildings or road intersections, and their geographic coordinates are usually available from geographic information systems that can be accessed through public websites (e.g., SIG-PAC, www.marm.es). However in some areas the identification of GCP is not feasible, or can be achieve accurately. Moreover, typical field operations to support geo-referencing is time-consuming and therefore expensive

Table 1. Position / geo-referenciation error between QuickBird images and the National Geographic Information System as affected by years and zone of the image (*Posadas, Southern Spain)*

Quick Bird (Year)	Image Zone				Overall
	Centre	Centre-Interm.	Interm.	Periphery	
			(Meters)		
2002	14±2	17±3	16±2	18±4	16
2004	20±1	21±1	19±2	20±3	20
2006	55±16	50±25	35±11	26±12	41
Overall	30	29	23	21	

Table 2. Average positioning errors of QuickBird images taken at Campina (Cordoba, Spain) at 2009 as affected by the image type and the geo-referencing method (ORI, original image; AUGEO system; NGIS, Spanish National GIS).

	Panchrom		Multispect.		*NGIS*
	ORI	*AUGEO*	*ORI*	*AUGEO*	
			(Meters)		
Overall s.d.	7.6 ± 2.3	1.3 ± 0.5	9.4 ± 2.7	2.56 ± 0.97	6.5 ± 3.6

AUGEO-2.0 system

To facilitate the remote imagery geo-referencing processes for precision agriculture we have developed a system based on artificial terrestrial targets (ATT) and software called Automatic Georeferentiation® (AUGEO-2.0®)

(Figure 1; García-Torres et al., 2009b; Gómez-Candón et al., 2011a, b). The ATT consist of colored tarps of about 1.0 to 2.0 m in diameter, placed on the ground and geo-referenced. The AUGEO software works as an add-on of ENVI® and has been designed to semi-automatically locate the ATT in remote images based on its spectral band specificity, which differentiates the ATT from the surrounding land uses. AUGEO-2.0 provides a visualization of the location of the ATT in the image, interact with the map registration menu and register/ co-register the image providing the resulting accuracy/ geographical error (root mean square error, RMSE).

Table 3. Averaged location accuracy of GeoEye-1 images originally acquired (IOA), geo-referenced through ground-control-points (CGP), or co-registered through the image to image procedure (ITI).

		(Meters)			
IOA-PAN	Overall	5.93	IOA-MUL	Overall	6.46
	± s. d.	2.7		± s. d.	2.22
	Range	3.3-8.5		Range	4.2-9.0
CGP PAN	Overall	1.78	CGP –MUL	Overall	3.36
	± s. d.	0.86		± s. d.	0.61
	Range	0.8- 2.4		Range	2.6-4.4
ITI-PAN	Overall	3.16	ITI-MUL	Overall	4.74
	± s .d.	0.93		± s .d.	0.79
	Range	1.5-3.9		Range	3.9-54

The root mean square errors (RMSE) from the panchromatic and multi-spectral QB images were around 8 m and 9 m, respectively and, once co-registered by AUGEO, they were about 1.5 m and 2.5 m, for the same images. Overlapping the QB-AUGEO-geo-referenced image and the National Geographic Information System (NGIS) produced a RMSE of 6.5 m, which is hardly acceptable for precision agriculture. The AUGEO system efficiently geo-referenced farm airborne images with a mean accuracy of about 0.5 to 1.5 m, and the UAV images showed a mean accuracy of 1.0 m to 4.0 m (Gomez-Candón et al., 2011)

3) INPUT PRESCRIPTION MAP ERROR FROM REMOTE IMAGES

The IPM delineated from remote-sensed images takes up the image geo-referencing error and, consequently, each micro-plot does not coincide with its corresponding ground-truth micro-plot (Figure 1). In this report the percentage of non-overlapping area (%NOA) has been developed as a function of the position error (PE/ RMSE), αº (the angle between Φge and the operating direction, Φop), and the micro-plot size (Gómez-Candón et al., 2012, submitted).

$$\%NOA = \frac{\left[\left(RMSE \cdot \cos\alpha \cdot W\right) + \left(RMSE \cdot \sin\alpha \cdot L\right) - \left(RMSE^{2} \cdot \sin\alpha \cdot \cos\alpha\right)\right]}{W \cdot L} \cdot 100$$

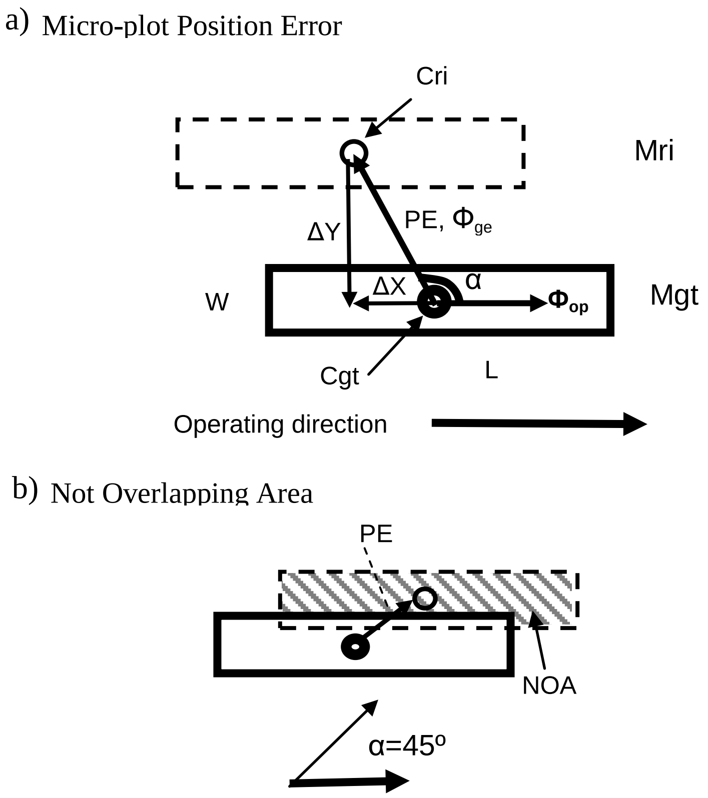

Fig. 1. a) Position error: the micro-plot ground-truth (Mgt) and micro-plot remote image (Mri), with an indication of its centers (Cgt and Cri), Length (L), Width (W) and position error (PE); the overlap of the Mgt and Mri, as affected by the geo-referencing error direction angle (, Φge) as related to the field operating direction (, Φop): b) Acute direction error, α ≥ 0º and ≤ 90º, e.g., = 45º. The center "movement" and the "non-overlapping area" (NOA) area indicated.

The %NOA consistently increased as the RMSE and αº increased, and it decreased as the micro-plot width (W) or length (L) increased. The decision about micro-plot size should be based on the RMSE, αº, and the maximum admissible %NOA (Gómez-Candón et al., 2012), submitted. In the case of the GeoEye-1 images studied with an average RMSE of 6 m, a micro-plot size of 6 m x 30 m would have yielded an IPM inaccuracy (%NOA) of approximately 5%, assuming an α° = 0° .

4) FINAL COMMENTS

The IPM inaccuracy resulting from the geo-referencing error was consistently affected by the position error (PE or RMSE), α° (directional error) and the micro-plot size. The %NOA consistently increased as the RMSE and α° increased and, conversely, decreased as the micro-plot increased (Fig. 1 and 2). Assuming a micro-plot width W equal to 6 m and an error direction coinciding with the machinery operational direction (α° = 0°), if the RMSE

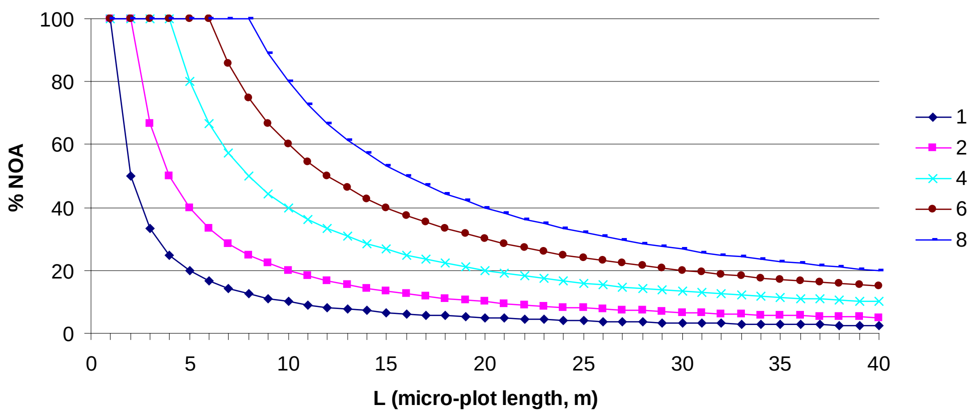

Fig.. 2. The % of micro-plot non-overlapping area (%NOA), as affected by the RMSE and the micro-plot length (L from 1 to 40 m), assuming that the micro-plot width W is 6 m and the α, the geo-referencing error direction angle, as related to the field operating direction, is 0°.

was 2 m and 5m, the L should be approximately 15 m and 30 m (or higher), respectively, to obtain a %NOA value of < 10% (Fig. 2). The angle, α°, considerably affected the %NOA, increasing it as the absolute sin α° values increased from 0 to 1. If the error direction was perpendicular to the operational direction (|sin α° |= 1), for a PE = 1, the minimum %NOA would be approximately 20%, regardless of the micro-plot size, and would, therefore, be unacceptable. For a α° of approximately 30° and a W = 30 m, the L should be ≥ 15 m to obtain a %NOA of approximately 10% to 15%. The %NOA increased as the α° increased. For example, if the PE was 3 m and the W = 6 m and L = 40 m, the %NOA would be approximately ≤10% and 50% for α° values of 0° and 90°, respectively (Fig. 2). In the case of the GeoEye-1 images studied with an average PE of 6 m, a micro-plot size of 30 m x 6 m would have yielded an IPM inaccuracy (%NOA) of approximately 5%, assuming the α° = 0°.

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