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Automatic greenhouse delineation from QuickBird and Ikonos satellite images

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ABSTRACT

The area of production under greenhouses has been in rapid growth in recent years, and at present there are over 500,000 ha scattered all over the world. Due to the vast amount of inputs (water, fertilizers, fuel, etc.) required, and outputs of various agricultural residues (vegetable waste, plastic sheeting, phytosanitary product containers, etc.), the impact of this type of production system to the environment is considerable in particular if pursued without a sound and sustainable territorial planning. Thus, very high-resolution images provided by satellites such as QuickBird and Ikonos can be useful to plan the expansion of the greenhouse crop-production system in a sustainable way, as well as to reduce the environmental impact of the actual greenhouses improving the inputs use efficiency (water, fertilizers, phytosanitary products, etc.).

This work is focused on automated detection of the boundaries of greenhouses using for this purpose the classification results from very high-resolution multi-spectral images of Red, Green, Blue and Near Infrared (RGBNIR) from QuickBird and Ikonos satellites. First, a supervised Maximum Likelihood Classification (MLC) and an Extraction and Classification of Homogeneous Objects (ECHO) both using all the four bands were carried out with focus on plastic greenhouses detection. In the second step, the detected greenhouses according to the classification results were vectorized automatically to generate polygons with irregular borders. In the third step, the irregular contours of polygons were converted into straight lines using an algorithm based on the Hough transformation. The input parameters of this algorithm were obtained by two different procedures: calibration and pseudo-calibration. In the calibration process, the parameter set is obtained from a sample of greenhouses minimizing the area and perimeter errors. In the pseudo-calibration process, a parameter set is obtained for each greenhouse but it is a high time-consumer task. The calibration yielded 66.7% for QuickBird and 49% for Ikonos image of correct delineation of greenhouses. Pseudo-calibration improved success rate and reduced performance difference between the two types of images. The proposed algorithm is able to delineate any greenhouse contour if the proper parameters set is correctly derived.

1. Introduction

On a global scope, the area of plastic greenhouses spreads over 500,000 ha with the largest concentrations in the south-east Asia, followed by the Mediterranean basin, where the coverage is over 130,000 ha. The influence of the greenhouse agriculture to the local economy is significant representing, in some areas, the only source of income. This is the case of the Almería coast, in the south-east of Spain, with an annual production of approximately 3 billion kg, and an approximate value of 1900 billion Euros. As a consequence of the rapid expansion of greenhouses without planning in some parts of this area, a number of environmental problems have risen such as the generation and accumulation of vegetable and plastic residue, over-exploitation of the water resources in the area and the invasion of protected natural areas. These factors make the production system unsustainable and endanger the economy of the area (Parra, 2004). In order to alleviate these problems and to find solutions for the future, the development of methods and technology to map as accurately as possible the land cover of greenhouses is of great interest to several government, commercial and research organisations.

Spatial data extraction from remotely sensed images has been carried out manually for decades, but manual spatial data acquisition using conventional photogrammetric techniques is slow, requires well-trained operators and therefore is an expensive task. Furthermore, for dynamic areas where land use or land cover changes quickly, this technique may not be sufficient for updating the spatial information (Ruther et al., 2002). It is therefore necessary

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to develop a methodology which automates, as much as possible, the spatial information extraction from remotely sensed images. However, most methods are so far operating at a rudimental level (Gruen, 2000) due to image variation in terms of type, scale, and the required level of detail (Wang and Tseng, 2003) on one hand, and difficulty of recognition of semantic information from the object using computers (Mayunga et al., 2007) on the other hand. Sohn and Dowman (2007) indicated that the scene complexity due to its very rich information content, the incomplete cue extraction due to occlusion, poor contrast and shadows, and disadvantageous image perspective are among the most hindering factors.

The very high-resolution satellite images (e.g. Ikonos, EROS, QuickBird) offer the possibility of fast and accurate mapping of man-made features. Considerable research work has been reported on localization of building boundaries and reconstruction of 2D and 3D shapes of buildings from Ikonos images (Kim et al., 2006), QuickBird images (Mayunga et al., 2007), as well as the combination of spectral images with other information such as Ikonos images and LIDAR (Sohn and Dowman, 2007; Guo and Yasuoka, 2002), Ikonos images and classification results (Lee et al., 2003), and QuickBird and classification results (Agüera et al., 2006). The work of Mayer (1999) presents a comprehensive survey on the techniques used for image-based building extraction.

With the aim to automate the delineation of building boundary or other man-made feature from digital images, several algorithms have been developed or adapted from other science fields. Vozikis (2003) and Lee et al. (2003), proposed a method based on the Hough transform, while Kim et al. (2006) used a similar voting process as the one used in the transform for achieving the objective. All these algorithms can be regarded as a multidimensional voting process, where the dimension is determined by the number of parameters. In these works some restrictions were imposed to the extracted lines (parallelism, perpendicular, etc.), making the extraction of lines from objects with complex geometry infeasible. In the work of Ruther et al. (2002), contours were generated automatically by locating elevation blobs in digital surface models, and the identification of lines was achieved by active contour models as is described in the work of Kaas et al. (1987), and dynamic program. In this approach, no restrictions to the contours lines were imposed. In all the mentioned techniques, it is necessary to input a set of parameters to ensure the success of the automatic delineation. This implies a calibration process or other appropriate technique to obtain the optimum values for the parameters.

This work is focused on automated detection of the boundaries of greenhouses using for this purpose the classification results from very high-resolution (VHR) multi-spectral images of Red, Green, Blue and Near Infrared (RGBNIR) from QuickBird (QB) and Ikonos (IK) satellites. First, a supervised classification of images with focus on plastic greenhouses detection was carried out. Then, the detected greenhouses in the classification results were vectorized resulting in polygons with irregular borders. Finally, the irregular contours were converted into polygons composed of straight lines, using an algorithm based on the Hough transformation. Input parameters of this algorithm were obtained by a calibration process. No restrictions on contour shape were imposed. Results accuracy was measured by taking the manually delineated greenhouses as ground truth.

2. Study area, imagery data and methodology

2.1. Study site

The area selected is located in the east of the Almería province, in the south-east of Spain (Fig. 1). This is at present the most dynamic zone in Spain in terms of increasing greenhouse coverage, of approximately 6000 ha within an area of 180,00 ha. Additionally,

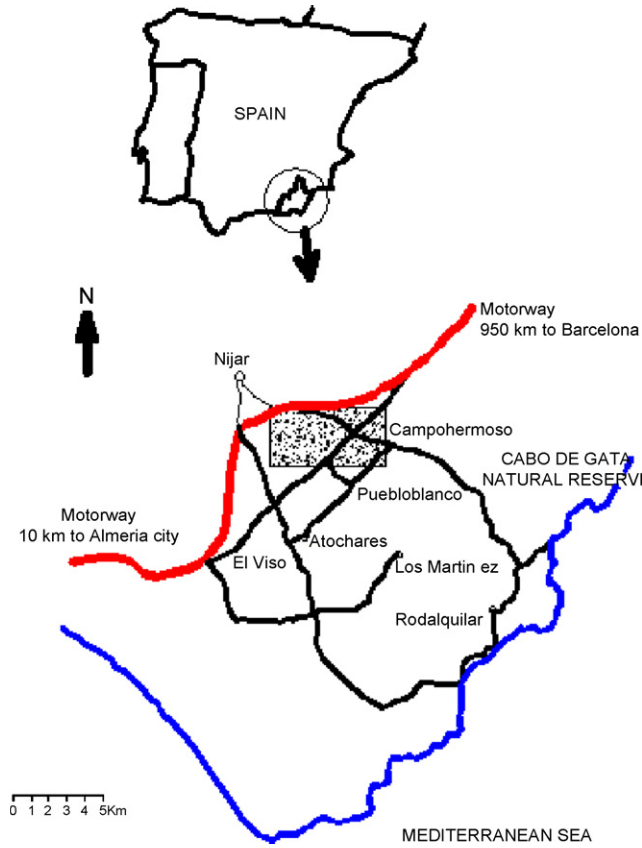

Fig. 1. Location of the study area (shadow rectangle), where main villages and roads have been located. Coordinates are UTM (zone 30, ED50).

the area is characterised by low quality water resources. It is adjacent to the Cabo de Gata Natural Reserve where the great ecological wealth is threatened by over-exploitation of resources and polutions from the vast greenhouse overcrowding nearby (residues, sewage, etc.).

2.2. Data preparation

A QB image and an IK image were used in this study. The QB image was taken on 19 December 2004 and scene centre coordinates are WGS-84 36.93045°N and 2.12685°W. The QB imagery consists of one panchromatic band and four multi-spectral bands of B, G, R, and NIR wavelengths in 11-bit quantification. Basic imagery products are radiometrically and sensor corrected, but not geometrically corrected or mapped to a cartographic projection and ellipsoid. They are accompanied by information relating to satellite attitude, ephemeris and camera model information. The imagery was orthorectified to 2.5 m for multi-spectral bands and 0.61 m for panchromatic band (Aguilar et al., 2005). The IK image was taken on 2 June 2005. The IK imagery consists of a panchromatic band and four multi-spectral bands (B, R, G, NIR), recorded in 11 bits The imagery was orthorectified to 4 m for multi-spectral bands and 1 m for panchromatic band (Aguilar et al., 2006).

For our study, we chose a rectangular area. Because of different spatial resolutions, the chosen study area is not measured as exactly the same size in the QB and IK images and the corner coordinates are also slightly different. For the QB image, the SW and NE rectangle vertexes are at the UTM coordinates (zone 30, ED-50) 572740, 4086640 and 579165, 4089885, giving an area of 2084.27 ha (6425 m $\times$ 3245 m). However, for the IK image, the equivalent vertexes are at the UTM coordinates (zone 30, ED-50) 572740, 4086640 and 579164, 4089884, giving an area of 2083.95 ha