SWIMMING POOLS LOCALIZATION IN COLOUR HIGH-RESOLUTION SATELLITE IMAGES

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1. INTRODUCTION

The exploitation of satellite images is becoming relevant for ecological reasons, due to the climatic change, and it has being used for monitoring coastlines, river courses, forests, etc. In this line, one of the main problems that causes for concern nowadays is the control and management of limited and indispensable resources, as for instance potable water. Regions that undergo long periods of drought have to become aware about the responsible use of this valuable resource, strictly controlling and punishing its waste. This problem is especially significant in tourist areas where a high demand of water is required to maintain, for example, golf courses, swimming pools, etc. This is the case of the south of Spain, where tourism is the major element of its economy, but it is having a great negative effect on the water reservoirs. An example of this situation can be observed in figure 1a) where almost every plot of land entails a swimming pool. Bearing in mind this problem, our work strives for developing techniques for the automatic detection of open-air swimming pools which are filled up during drought periods. This would permit a city council to keep an inventory of the swimming pools located in its area, as well as, to impose fines to those who waste water.

Detecting and localizing land features from space is a challenging task with multiple applications in remote sensing: it can be used to detect a variety of objects, both man-made such as roads or buildings, and natural such as lakes, or rivers. Although high resolution satellite images, as for example Quickbird or Orbview, achieve enough resolution to recognize these kind of elements, they may lack precision when measuring and localizing them.

Some previous works, such as [1, 2], have proposed the classification of basic terrain classes, like water or green areas in satellite images, but to the best of our knowledge, the relevant issue of the accurately detection of filled swimming pools using high resolution satellite images has not been tackled in the literature. This paper approaches this issue and proposes an algorithm that automatically detects open-air swimming pools in Quickbird satellite images of urban areas. More precisely, it considers colour analysis for detecting areas in the image with a high probability of containing water. These areas are then refined through the use of active contours. The proposed method has been tested in both satellite and aerial images with satisfactory results.

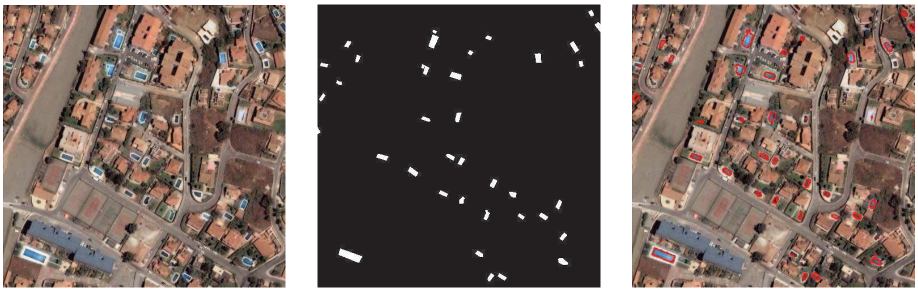
2. DESCRIPTION OF THE PROPOSED METHOD

Our approach works in a two-steps scheme. The first stage consists of a colour analysis of the image that searches for homogeneous regions that according to their colours, could correspond to filled swimming pools. The second stage considers the extracted regions and image gradient information to refine the swimming pool borders using the Snakes active contours algorithm [3].

2.1. Detecting swimming pool areas in colour images

Our method for the detection of swimming pools uses the $C_1C_2C_3$ colour space [4], and in particular C_1 which has demonstrated its suitability for detecting watered areas. For each RGB pixel, its normalized component C_1 is defined as:

$$C_1 = \frac{2}{\pi} \cdot \arctan \frac{R}{\max(G, B)} \quad (1)$$



a) b) c)

Fig. 1. Typical image of tourist areas in Spain. a) Quickbird image from a region in the South of Spain where almost each apartment entails a swimming pool. b) Localization of regions containing water. c) Detected swimming pools.

This conversion transforms the three band image into a grayscale-like image (the C_1 band), which is then binarized applying Otsu's optimal thresholding technique [5]. The result of this process is a binary image composed of a black background with small white regions which very likely correspond to swimming pools (see figure 1b). Additionally, those regions smaller than the typical size of swimming pools are discarded since are highly probable to be false positives.

2.2. Precise shaping of swimming pools

This phase refines the actual contour of each candidate regions. To do that we extract the centroid of each region and execute a modification of a Snake algorithm [3]. Snake algorithms adjust objects' contour by minimizing the energy function:

$$E_{snake}\left(v\left(s\right)\right) = \int \left(\alpha \left| \frac{dv}{ds} \right|^2 + \beta \left| \frac{d^2 v}{ds^2} \right|^2 - \gamma \left| \nabla I\left(v\right) \right| \right) ds \tag{2}$$

where $|\nabla I\left(v\right)|$ represents the gradient image. This function has three weighted parameters that account for the continuity of the contour, its smoothness, and the image gradient value, respectively. Experimentally those weights have been set to $\alpha = 2.5, \beta = 2.0, \gamma = 0.5$. Moreover, in our approach the considered Snake algorithm has been modified to consider not only internal pixels of each region but also close external ones for a better adjustment of the swimming pool shapes.

3. EXPERIMENTAL RESULTS AND CONCLUSIONS

Our approach has been tested with Quickbird colour images of *Costa del Sol*, in the south of Spain. The suitability of the algorithm has been contrasted with a visual localization of the swimming pools entailed in a given area, achieving excellent results: more than the 93% of the filled pools were correctly detected, failing mostly in those that exhibited occlusions and shadows.

4. REFERENCES

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