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An edge-region cooperative multi-agent approach for buildings extraction

The Second International Conference on Digital Information and Communication Technology and its Applications

University of the Thai Chamber of Commerce(UTCC), Thailand
May 16-18, 2012

Dear Aymen SELLAOUTI

We are happy to inform you that your paper (Paper ID: 382 , Title: An edge-region cooperative multi-agent approach for buildings extraction) submitted to The Second International Conference on Digital Information and Communication Technology and its Applications has been accepted for an oral presentation. We cordially invite you to attend the DICTAP2012 conference.
Please prepare the camera ready paper as per the instructions listed on http://www.sdiwc.net/thi/. Your paper will not be published unless the following are done:

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The conference will take place at University of the Thai Chamber of Commerce(UTCC), Thailand in cooperation with The Society of Digital Information and Wireless Communications, from May 16-18, 2012, with optional activities after the conference. As soon as the schedule is completed, it will be posted on the conference website. Details concerning a hotel reservation will be posted on the conference website in due course.

All related conference materials can be found at http://www.sdiwc.net/thi/. Please let us know if you have any questions regarding registration.

We sincerely look forward to welcoming you to Thailand in May 16-18, 2012.

Sincerely yours,

Waralak V. Siricharoen

Waralak V. Siricharoen

An edge-region cooperative multi-agent approach for buildings extraction

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***Abstract*—This paper presents a new approach for automatic building detection in very high resolution satellite images. The proposed method is a cooperative multi-agent approach between both an edge and region approach. In the pretreatment step, a supervisor agent finds a building's corner using Harris detector. Starting from these points, a cooperation process is used to extract buildings. Experiments are done on images of Strasbourg city taken by Quickbird.**

I. Introduction

Building information is extremely important for many applications such as urban planning, telecommunication, cartography, environment monitoring etc. However, the traditional manually building extraction from raw imagery is highly labor-intensive, time-consuming and very expensive. During the past two decades, building extraction from digital images was and still one of the most complex and challenging tasks faced by computer vision and photogrammetric communities. In an effort to make building extraction processes efficient, various researches that have been reported attempt to automate extraction processes. However, existing automated building extraction techniques are still operating at a very rudimentary level, time-consuming and very expensive. Most of them are related to the building structure that varies from one region to another and from one country to another. Also, they are made of diverse materials, very close to each other and have no proper orientation which makes the extraction process very difficult. Most of those methods use generic models by assuming that all buildings follow a certain pattern. However, the generic models do not provide practical results when dealing with unstructured buildings like informal settlements [1].

Moreover, many different types of source images ranging from single intensity images, color images and laser range images to stereo and multiple images were used [2]. Recently some researches use the collaboration of two or more different datasets to improve the detection of building [3].

In this paper, we concentrate in other type of collaboration; we introduce a new multi agent solution for buildings extraction from high-resolution images based on cooperation between two techniques known in image processing as: Edge detection and region growing.

In the next section, we remind of some works related to building extraction. Following that, our new method based on multi agent system is presented and justified in section 3. In the fourth section, the efficiency of our approach is demonstrated by experiments on several images.

II. Related Work

There have been several attempts to detect buildings in the literature, based on its characteristics: shape, color, building's height and neighborhood. According to the image taken with a vertical view or remote from the nadir, the extraction step of buildings' edges refers to the removal of footprint, edges of roofs and may include the management of the facades. We propose to decompose buildings extraction approaches into five classes: (i) edge based approaches; (ii) texture based approaches; (iii) morphological operator based approaches; (iv) classification approach and (v) mixed approaches.

In several researches the buildings are extracted based on edge detection. In [4], Haverkamp uses the Nevatia-Babu filter with non-maximum suppression to extract edge information. He retrieves all chains form edges and rights angles included in database then he adds hypotheses to find the missing edges. This approach is only valid for buildings with linear edges. Theng and Chiong [5] find that choosing buildings' corners as a starting point can solve the problem of snakes' initialization used in buildings extraction. Lhomme et al.[6] use texture to find buildings, they propose to classify building into two parts: corps and peripheral. Then they build a vote matrix and consider maximums as centers of buildings. Lari and Ebadi [7] use the building characteristics to identify the footprint: from a region growing segmentation of the image, they apply the morphological operator of opening and closing to smooth impure edge and close small holes. After that, they match that region goes with the geometric, structural and photometric characteristics of a building.

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Other researchers have used morphological operators to detect buildings; Lefvre et al. [8] use the opening operation to filter small structures, then they propose to use the Hit Or Miss Transform (HMT) that consists in a double erosion of the image and its complement to extract building. In [9], classification has been integrated as a preliminary step in the process of buildings' extraction. Authors filter regions that have enough height and detect their edges with a vectorization. Results were reassuring but their quality is too related to combined sources.

The combination of these different approaches can give better results. Vinson and Cohen [10] adopt a classification using 'Canu' algorithm to distinguish two classes: "ground" and "on-ground". They estimate each region classified on "on-ground" with a rectangle and check similarity with the "Hausdorff" measure.

Jin and Davis [11] apply the opening operation followed by the closing operation, and then use the region growing algorithm with the constraint of watershed segmentation and shadows as a stop criteria.

III. Proposed approach

The major problem of region-based approaches is that the boundaries of the regions obtained are usually inaccurate and does not coincide exactly with the limits for buildings in the image. Edge-based approaches can present false detections and not closed. There has been growing interest in the use of the cooperative approach in Building detection. We propose a region-edge cooperation which aims to improve the results by taking into account the complementary nature of both edge and region information. Contour detection allows finding the most evident frontiers of buildings. The region growing procedure will serves to finer contours and to obtain more precise buildings. Based on a structure that promotes cooperation, the multi agent system are frequently used in image processing [12], [13]. We introduce our multi-agent system for building extraction from high resolution satellite images. This system is based on cooperation between edge detection and region growing algorithm. It contains two principal steps managed by a supervisor agent:

1) A first pretreatment step, which is a filtering and a data preparation for the next step. This allows the elimination of vegetation pixels and the detection of building corners candidates.
2) The second step is the building extraction starting from the potential building corners' points, two agents will cooperate to validate the point's membership to a building and to extract this latter.

The workflow of the system is illustrate in figure 1.

A. Structure

The proposed multi-agent system consists of a supervisor agent, NDVI agent, edge agent and region agent. The functionality of these agents is briefly summarized:

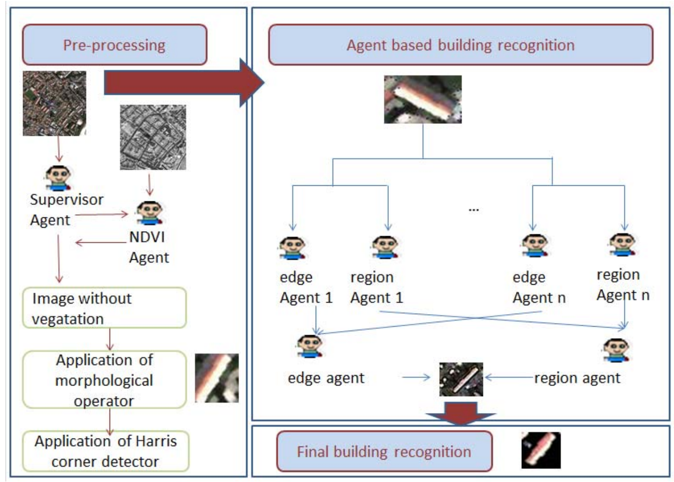


Fig. 1. Workflow of the proposed approach.

- **Supervisor agent**: applies different techniques to the image in order to detect the corners of building, manages the life cycle of systems' agent and their communications.
- **NDVI agent**: eliminates the vegetation pixels from the image.
- **Edge agent**: this agent has two roles:
  1) *Edge detection:* detects the pixels belonging to buildings' edges using its own knowledge. After it finish the edge detection phase, it sends its results to the region agent to start its own treatment.
  2) *Edge correction:* it receive the results of the region agent, to correct the edge using those results and its own results provide by its first role.
- **Region agent**: uses the region growing algorithm and the edge detection results to detect the building region. This results help the edge agent to detect the missing contour pixels.

In order to exchange information between different entities of our system, a communication module is integrated to manage this service as Figure 2 illustrates, there are four types of message defined by our system: launch, kill, request, and response.

B. Pretreatment

Considering the variety of the satellite images content, it is very useful in the pretreatment step to eliminate the pixels judged as not buildings. For these reasons, the supervisor agent deploys an NDVI agent. It computes for each pixel the NDVI vegetation index [14] given by this formula :

$$NDVI = \frac{(NIR\ -\ VIS)}{(NIR\ +\ VIS)} \tag{1}$$

where VIS and NIR stand for the radiometry measurements acquired in the visible (red) and near-infrared regions and returns to the supervisor agent the pixels judged as non-vegetation.

After that the supervisor agent applies the morphological operator of dilation on the resulting image, to improve the

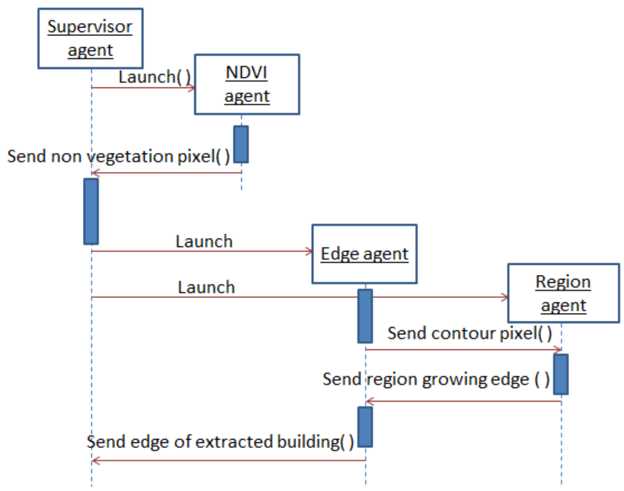


Fig. 2. Sequence diagram of our system.

objects' contrasts, especially buildings' roofs and to correct irregular and discontinuous edges. Once the image is dilated, the same agent uses the Harris detector [15] to extract the corners in the image; the Harris corner detector is a popular interest point detector due to its strong invariance to rotation, scale, illumination variation and image noise. It is based on the local auto-correlation function of a signal; where the local auto-correlation function measures the local changes of the signal with patches shifted by a small amount in different directions.

C. Buildings extraction

There are several approaches in literature seeking to delineate the objects in the image, which include region based approaches and edge based approaches. Both of them have advantages and disadvantages; the choice of approach depends on types and characteristics of images. However, the use of these algorithms separately can give inaccurate results. As it's illustrated in figure 3, the independent use of both canny edge detector and region growing algorithm present many problems. Indeed, the canny edge detection provides a mislocate buildings. Also, many extracted buildings were incomplete. Moreover, for the region growing algorithm, there are over-extraction *(i.e. road and vegetation pixels are extracted with buildings)*.

Hence the idea to combine these two approaches. This cooperation takes the benefits of both approaches. Moreover, we notice that most buildings contrast with their neighborhood, they also have the property of being homogeneous in terms of radiometry this is a cultural heritage of the city of Strasbourg, which imposes specific properties for the construction of buildings which are the angle roofs, building materials and colors. This knowledge is a part of our agents conception.

1) Edge agent: The edge agent is based on the canny edge detector. From each candidate corner, the agent follows the building edge by applying two steps:

(a) Canny edge extraction result (site1)

(b) Region growing extraction result (site1).

(c) Canny edge extraction result (site2).

(d) Region growing extraction result (site2).

Fig. 3. Illustration of region growing and edge detection inconvenient.

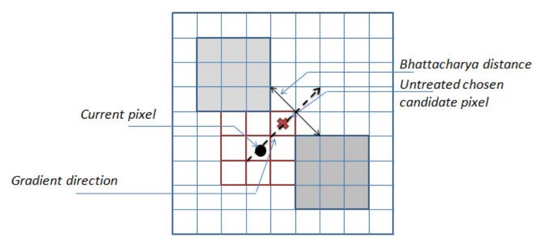


Fig. 4. Calculation method of the distance of Bhattacharya between two regions.

- From the current pixel, the agent seeks for candidate pixels not already treated in a 3×3 window.
- Uses the region information to filter non-buildings edge pixels, we based on the building radiometry homogeneity criteria. The agent creates two windows as shown in figure 4, then it uses the Bhattacharya distance [16] to compute the distance between the two windows. The Bhattacharya distance,D_{bhat} , is a separability measure between two Gaussian distributions and is defined as follows:

$$D_{bhat} = \frac{1}{4(m_1 - m_2)^t(\Gamma_1 + \Gamma_2)^{-1}(m_1 - m_2)} + \frac{1}{2} ln \frac{\frac{1}{2}|\Gamma_1 + \Gamma_2|}{\sqrt{|\Gamma_1||\Gamma_2|}} \quad (2)$$

where m_i design the mean of radiometry and Γ_i the covariance matrix. The first term gives the class separability due to the difference between class means, while the second term gives the class separability due to the difference between class covariance matrices.

The figure 4 illustrates how we choose the two windows that will be include in the calculation of the Bhattacharya distance.

Once an edge agent crosses with another edge agent, the two agents merge together to yield a new edge agent, this agent contains the union of the pixels treated by the former agents.

After the edge agent compleat the detection phase described above, it gives the hand to the region agent to begin its treatment phase using the results given by the edge agent as constraints for the region growing. The edge agent is put in standby phase until the region agent finish its role. After that, with the help of the region growing results, the edge agent will be capable of correct and compleat the missing buildings edge.

2) Region agent: The ultimate aim of region agent is to help the edge region to determine missing edges. for that purpose, it grows from the building corner as long as the two following conditions are satisfied:

- The added pixels shouldn't contain pixels' contours.
- A pixel can be added to the area only if it keeps the average homogeneity.

The major problem of the region growing technique is to find the best homogeneity threshold for the region growing; to solve this problem the region agent uses the following iterative procedure:

In the first iteration, the threshold is initialized to zero. The growth process is than launched. At the end this process, we evaluate the percentage of edge point detected by the edge agent and that are reached by the growth agent. If it's less than 90 percent, the agent repeat the region growing process after the increment of the homogeneity threshold. When the threshold is deduced, the agent region determines the edge of the region and sends the list of determined pixels to complete the buildings' missing pixels.

If the region agent crosses another region agent,they merge together and give a new agent, the treated pixels of which the ones already treated by the two agents that give birth to it.

IV. Experiments

We try our approach on a Quickbird image covering urban areas of Strasbourg, token in 2008, having four bands, each band with 2.44-2.88m/px. This type of image contains a variety of object: building, tree and road ....

To evaluate the aptitude of our approach, we test it on a set of test area. Figure 5 presents two examples of test areas. The first one is sparse (figure 5(a)) rather the second is dense (figure 5(b)).

Figure 5 presents two extracts of the image to be interpreted. To evaluate the aptitude of our approach, we test it on two type of test area. The first one is sparse (figure 5(a)) rather the second is dense (figure 5(b)).

(a) Site 1 (sparse) (b) Site 2 (dense)

Fig. 5. The initiale Quickbird image of Strasbourg City.

Figure 6 presents the different steps of the pretreatment result. As it is depicted in this figure, the complicated relationship between buildings and other objects especially trees and vegetation and the density of the buildings can lead to problems for building extraction.

Figures 6(a),6(d) show how the application of NDVI filter can prune the vegetation pixels and help the buildings extraction. Figures 6(b),6(e) illustrate how the morphological dilation applied to the extracts emphasizes shapes of objects especially buildings' roofs. The final step in pretreatment process which is corner localization by Harris detector is given in figure 6(c),6(f).

(a) Vegetation extraction from site 1 (b) Site 1's image dilated (c) Harris corner detector for site 1

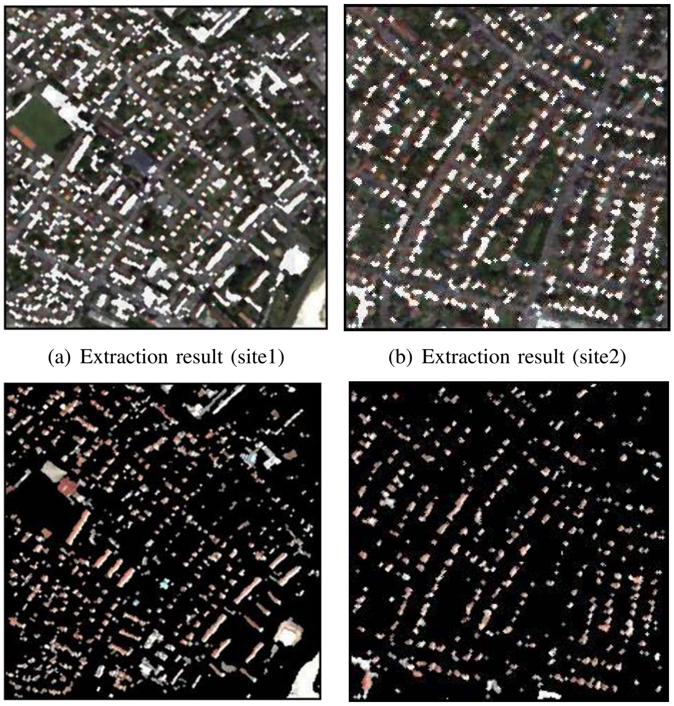
(d) Vegetation extraction from site 2 (e) Site 2's image dilated (f) Harris corner detector for site 2

Fig. 6. Pretreatment results.

The figure 7 present the result of the buildings extraction. we remarque that the result of the sparse site in the figure 7(a), 7(c) are better than those of the dense site in the figure 7(b), 7(d).

In the quantitative analysis the objective was to determine the practicability of the proposed approach whereby a building extracted percentage rate is calculated. We find four categories of the extracted objects:

- BCE : the number of building correctly extracted.



(a) Extraction result (site1) (b) Extraction result (site2)

(c) Buildings map (site1) (d) Buildings map (site2)

Fig. 7. Building extraction results.

- BPE : the number of buildings partially extracted.
- BNE : the number of buildings not extracted.
- FA : false alarm, is when a segment that is not really a building, identifies as an one in the resulting image.

The following metrics are computed [17] :

$$BER = \frac{BCE}{(BCE + BPE + BNE)} * 100. \tag{3}$$

$$Exactness = \frac{BCE}{BCE + FA} * 100 \tag{4}$$

$$Quality = \frac{BCE}{BCE + BPE + BNE + FA} * 100 \tag{5}$$

The building extraction rate (BRE) is the simplest metric, measuring the fraction of objects which were correctly denoted as buildings by our system. The exactness is a measure of number of objects truly buildings from the number of objects extracted as buildings. Finally, the quality percentage measures the absolute quality of our approach. The building extraction rate can be treated as a measure of object detection performance which is a quantitative metric. The exactness is a measure of delineation performance. The quality percentage combines aspects of both measures to summarize system performance. The last two can be seen as a qualitative metric. All three measures taken together give a clear picture of system performance with simple and unambiguous interpretations and without any subjective elements.

Table I presents the extraction rate for a set of test areas. Site We note that our approach is more effective and efficient for sparse image, but it remains quite satisfactory results for the dense area. Often, the extraction rate reach a 90%, also each building is clearly delimited. Moreover, the results of the cooperation is higher than the sum of the separate results of each of the edge and region detection, this show the importance and reliability of our cooperation approach.

TABLE I
BUILDING EXTRACTION RESULTS OF OUR APPROACH.

	BCE	BPE	BNE	FA	BER%
site 1	170	15	3	18	90.42
site 2	179	16	10	25	87.31
site 3	61	16	8	5	71.76
site 4	46	7	8	2	75.40
site 5	71	5	10	8	82.55
site 6	35	4	10	1	71.42
site 7	67	10	4	3	82.71

For comparison, we have selected a Change Detection of Buildings (CDB) method proposed by Bouziani *et al.* [18]. We have taken care of choosing reference which use similar image features to our framework, but they exploit them in different manners. More precisely, in CDB [18], the authors based there work on prior knowledge existing in geodatabase, this methodology is composed of several stages. The existing knowledge on the buildings and the other urban objects are first modeled and saved in a knowledge base. Some change detection rules are defined at this stage. Then, the image is segmented. The parameters of segmentation are computed thanks to the integration between the image and the geo-database. Thereafter, the segmented image is analyzed using the knowledge base to localize the segments where the change of building is likely to occur. The change detection rules are then applied on these segments to identify the segments that represent the changes of buildings. These changes represent the updates of buildings to be added to the geodatabase.

In table II, we put a comparison between the average of the results given by our approach and the CDB approach.

The results shown in table II proves that, despite the other method is a semi-automatic method and is depends on many expert knowledge, our method also generate a good results. In term of extraction rate the average is about 91% which is better than the CDB approach. In the other hand, our approach depends only in the knowledge about the site. In the same, for the exactness and excellence terms the results are satisfier but the CDB results are better and that is logical, because the CDB approach is depends on a very large knowledge base, which includes the knowledge given by Google.

V. CONCLUSION

Considering the difficulty of the task of extraction of the buildings starting from the images with very high-resolution, several approaches were implemented to solve this problem. In this paper, a method based on artificial intelligence was presented, in which a cooperation edge-region was used to solve the problem. The results of the system are very encouraging. Our approach is dependent on the choice of threshold. To remedy this we propose a choice based on that automate

TABLE II
NUMERICAL COMPARISON BETWEEN THE CDB [18] AND OUR PROPOSED METHOD.

Different approaches	Extraction results %	Exactness	Excellence
Our approach	80	91	77
CDB [18]	92	90	85

the integration of expert knowledge such as the shape and the area.

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