

DETECTION OF ALIGNED OBJECTS FOR HIGH RESOLUTION IMAGE UNDERSTANDING

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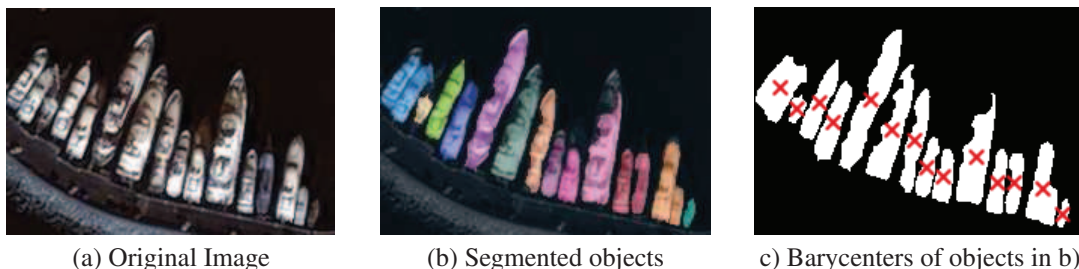
1. INTRODUCTION

Satellite images provide a huge amount of geographical information and extracting structural information may help interpreting such images. Aligned groups of objects can be seen as a way to reduce this information in a meaningful way. For example in cartography, it is necessary to find groups of aligned buildings for map generalization [1]. This provides information about the structure of buildings arrangement, and whether they belong to a urban, rural or residential area [2]. As another example, in object detection, complex semantic classes such as parking areas (car parkings, ports, truck parkings or airports) comprise aligned groups of transport vehicles. Therefore, the identification of aligned groups of transport vehicles can be useful for detecting instantiations of these complex classes.

In computer vision, alignments are considered as a salient feature for image interpretation. According to the gestalt theory, the human perceptual vision system groups objects together using certain rules. Among these rules there is one called continuity of direction which groups together objects in the same direction, and one particular case would be constancy of direction that refers to alignments [3].

The detection of aligned groups of objects has been studied for the case of objects with aligned barycenters [4, 5]. In [4] an *a contrario* approach is used to detect the points (the barycenters) that fall into a thin enough strip. In [5] an algorithm to detect aligned groups of buildings is presented. The barycenters of the buildings are projected into several planes with different orientations. Then for each plane, clusters of projections are searched. A candidate for an aligned group is formed by the buildings which have projections that belong to the same cluster.

However, when the groups are composed of objects of different sizes, it is not possible to detect the alignment by observing just their barycenters (see Fig. 1). In this work we propose a novel method to detect alignments of objects of different sizes.



(a) Original Image

(b) Segmented objects

(c) Barycenters of objects in b)

Fig. 1. Example of an aligned group of objects with non-aligned barycenters

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2. ALIGNMENT DETECTION

To determine whether a group of points is aligned, there are two possible strategies. The first one, used in [4], is to search a thin strip where all the points fall into. The second one deals with searching an angle θ such that every point of the group is approximately located at a direction θ or $\theta + \pi$ from the other points of the group. If we try to extend the first strategy to groups of objects, we face the problem of defining the width of strip when objects have different sizes. The difficulty of extending the second strategy is measuring the angle between the objects. One alternative, which is the one proposed in this work, is to use measures of relative direction used in spatial reasoning to determine the orientation (or angle) of the group formed by two objects with respect to the horizontal axis. In order to determine if an object is “approximately” located at an angle θ from another object, it is necessary to take into account the imprecision related to “approximately”. Therefore we propose to model the orientation as a fuzzy number.

2.1. Measuring the orientation between two objects

Let A and B be two regions of the image which represent two objects. We define an orientation histogram between them as a fuzzy number $O(A, B) : [0, \pi) \rightarrow [0, 1]$ with membership function:

$$O(A, B)(\theta) = \frac{|\{(a, b) : a \in A, b \in B, \text{ mod } (\angle(a, b), \pi) = \theta\}|}{\max_{\phi \in [0, \pi)} |\{(a, b) : a \in A, b \in B, \text{ mod } (\angle(a, b), \pi) = \phi\}|}, \quad (1)$$

where $\angle(a, b)$ denotes the angle between the segment joining a and b and the horizontal axis. An orientation histogram is simply an angle histogram [6] where the angles are computed modulus π and its support has a length equal to π . It represents the relative orientation of the two objects.

We define the similarity value between two orientation histograms $O(A, B)$ and $O(C, D)$ as the maximum of the intersection of $D_{\mu_0}(O(A, B))$ and $D_{\mu_0}(O(C, D))$, where $D_{\mu_0}(O(X, Y))$ is the fuzzy morphological dilation of $O(X, Y)$ by a structuring element μ_0 [7]. μ_0 represents the imprecision attached to the comparison of almost similar angles, and can be modeled by a trapezoid function.

2.2. Finding alignments

Our primary goal is to identify the possible subsets of aligned groups of objects. Given a group of objects $\mathcal{A} = \{a_1, \dots, a_n\}$ we construct a neighborhood graph $G_N = \{V, E\}$, where the vertices represent the objects of the group, and there is an edge between two vertices if and only if the corresponding objects are neighbors according to a maximum acceptable distance. Each edge of the graph is attributed with a fuzzy number given by the orientation histogram between the two objects that are represented by its vertices. Using the neighborhood graph we construct its dual graph. The dual graph is denoted by $\tilde{G}_N = \{\tilde{V}, \tilde{E}\}$ where each vertex \tilde{V}_i represents an edge in the graph G_N . An edge exists between two vertices \tilde{V}_i and \tilde{V}_j of \tilde{G}_N if the two corresponding edges of the graph G_N have a common vertex. Each edge \tilde{e}_{ij} is attributed with the similarity value between the orientation histograms of \tilde{V}_i and \tilde{V}_j . The dual graph allows us to compare directly the orientation between the couples of objects which have one object in common. Figure 2 shows an example of neighborhood graph and its dual graph. Notice that the edges of \tilde{G}_N with a high value represent two couples of objects with a similar orientation histogram, which share a common object. For instance, in the dual graph the edge between the nodes (1 - 2) and (2 - 3) has a similarity value of 1, this edge corresponds to the objects labeled 1, 2 and 3 of Fig. 2(a). In a similar way, edges with a low value represent objects which are not aligned, for example in the dual graph the edge between the nodes (1 - 2) and (6 - 2) has a similarity value of 0.11 and corresponds to the objects labeled 1, 2 and 6, which do not form an alignment.

Following the approach proposed here, a subset $\tilde{A} \subseteq \tilde{V}$ for which all the edges connecting its vertices have a value superior to α , where α is a user defined tolerance, corresponds to the edges joining a locally aligned group in G .

The locally aligned groups are the possible candidates for aligned groups. To determine if they form an aligned group they have to be observed as a whole. Let $\mathcal{A} = \{a_0, \dots, a_n\}$ be a locally aligned group, then the similarity value between all the orientation histograms $O(a_i, \mathcal{A} \setminus a_i)$, for $i = 0, \dots, n$, gives the degree of alignment of the group, where $O(a_i, \mathcal{A} \setminus a_i)$ is the orientation histogram obtained between a_i

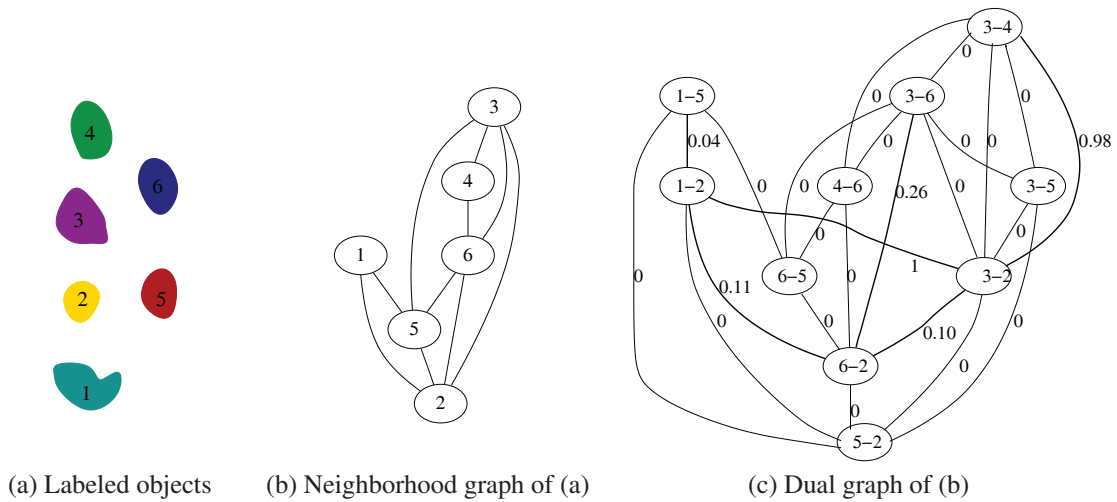


Fig. 2. Neighborhood graph and dual graph of a group of objects

and the rest of the group. Only the groups which have a high degree of alignment (greater than 0.7 in our experiments) are considered as aligned.

3. RESULTS

The algorithm was applied on objects of Figs. 1(b), 2(a) and 3(b). For Fig. 1(b) the whole group is successfully obtained with a degree of alignment of 0.88. For the case of Fig. 2 the group containing the objects 1, 2, 3 and 4 is found and has a degree of alignment of 1.0. Fig. 3(c) shows some of the aligned subsets of houses obtained from the set of segmented houses of Fig. 3(b). It is not possible to show all the aligned groups found by the algorithm since there are objects which belong to more than one group. In this experiment, houses were obtained by thresholding the derivative morphological profile [8], and retaining the connected components that are closer in average to the spectrum of a reference pixel with respect to the spectral angular distance. In Fig.3(c) we can observe that the algorithm obtains the most distinctive groups of the image (pink, orange, white, red and blue sets), which can be used for the description of the scene. However, not all the obtained groups are meaningful for the description of the scene (purple and light green sets), since these are subsets which are aligned but they do not give any information about the arrangement of the houses. Hence it would be necessary to use additional information, for instance the orientation of the roads, to put the aligned groups into context. Finally, note that all the obtained groups satisfy the notion of alignment discussed in Sec. 2.

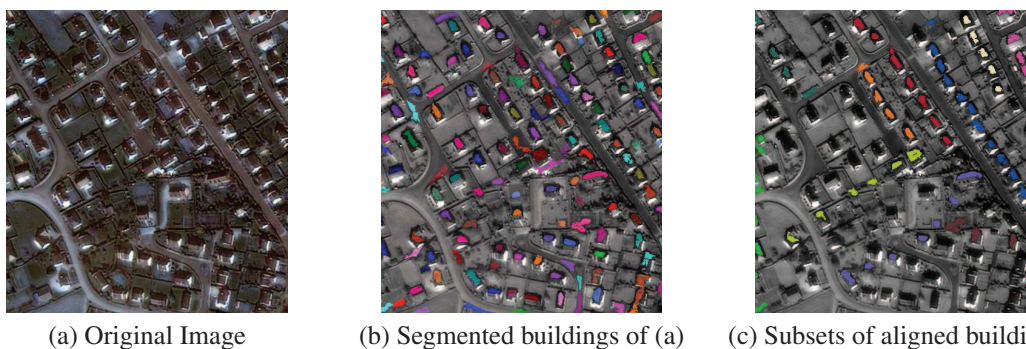


Fig. 3. Some of the aligned subsets found by the algorithm with a degree of alignment greater than 0.9

4. APPLICATION: IMAGE DISAMBIGUATION AND URBAN IMAGE INTERPRETATION

To interpret the image it is necessary to consider only the meaningful groups of aligned objects (those which give us some information about the objects arrangements). In the case of Fig. 3 the meaningful groups of aligned objects correspond to the groups that are parallel and close to the streets. We extracted the roads using the method of [9] and we kept:

- (i) the aligned groups which were parallel and close to at least one road, and
- (ii) the roads which were parallel and close to at least one group, and not adjacent to a group.

The number of groups was reduced from 62 to 21. Fig. 4 shows the groups satisfying (i) and the roads satisfying (ii). By using the spatial relations of alignment and parallelism it was possible to eliminate most of the false detections of the road extraction algorithm. The obtained groups of buildings and roads can be used to describe the scene in a graph representation.



(a) Extracted roads of Fig. 3(a)



(b) Meaningful roads and groups of aligned houses

Fig. 4. Extracted roads used for determining the meaningful groups of aligned houses

In this work, we proposed an original method to determine aligned groups of objects in a satellite image, and we illustrated its interest for high level image interpretation. The full paper will include additional application cases. Future work, aims at further investigation this interpretation tasks, by combining alignments with other types of structural information.

5. REFERENCES

- [1] S. Steiniger and R. Weibel, "Relations among map objects in cartographic generalization," *Cartography and Geographic Information Science*, vol. 34, no. 3, pp. 175–197, 2007.
- [2] E. Dogrusoz and S. Aksoy, "Modeling urban structures using graph-based spatial patterns," in *IEEE International Geoscience and Remote Sensing Symposium, 2007. IGARSS 2007, 2007*, pp. 4826–4829.
- [3] A. Desolneux, L. Moisan, and J. M. Morel, *From Gestalt Theory to Image Analysis: A Probabilistic Approach*, vol. 34 of *Interdisciplinary Applied Mathematics*, Springer-Verlag, 2008.
- [4] A. Desolneux, L. Moisan, and J.M. Morel, "A grouping principle and four applications," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 25, no. 4, pp. 508–513, 2003.
- [5] S. Christophe and A. Ruas, "Detecting building alignments for generalisation purposes," in *Advances in Spatial Data Handling (Proceedings of 10th International Symposium on Spatial Data Handling)*, D. Richardson and P. van Oosterom (Eds), 2002, pp. 419–432.
- [6] K. Miyajima and A. Ralescu, "Spatial organization in 2D segmented images: Representation and recognition of primitive spatial relations," *Fuzzy Sets and Systems*, vol. 65, pp. 225–236, 1994.
- [7] I. Bloch and H. Maître, "Fuzzy Mathematical Morphologies: A Comparative Study," *Pattern Recognition*, vol. 28, no. 9, pp. 1341–1387, 1995.
- [8] M. Pesaresi and J. Benediktsson, "A new approach for the morphological segmentation of high resolution satellite imagery," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 39, no. 2, pp. 309–320, Feb. 2001.
- [9] E. Christophe and J. Inglada, "Robust road extraction for high resolution satellite images," in *IEEE International Conference on Image Processing, 2007, 2007*, vol. 5, pp. 437–440.