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A Noval Approach of Tile Based Design for Region Merging Segmentation

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Abstract:

Processing large very high-resolution remote sensing images on resource-constrained devices is a challenging task because of the large size of these data sets. For applications such as environmental monitoring or natural resources management, complex algorithms have to be used to extract information from the images. The memory required to store the images and the data structures of such algorithms may be very high (hundreds of gigabytes) and therefore leads to unfeasibility on commonly available computers. Segmentation algorithms constitute an essential step for the extraction of objects of interest in a scene and will be the topic of the investigation in this paper. The objective of the present work is to adapt image segmentation algorithms for large amounts of data. To overcome the memory issue, large images are usually divided into smaller image tiles, which are processed independently. Region-merging algorithms do not cope well with image tiling since artifacts are present on the tile edges in the final result due to the incoherencies of the regions across the tiles. In this paper, we propose a scalable tile-based framework for region-merging algorithms to segment large images, while ensuring identical results, with respect to processing the whole image at once. We introduce the original concept of the stability margin for a tile. It allows ensuring identical results to those obtained if the whole image had been segmented without tiling. Finally, we discuss the benefits of this framework and demonstrate the scalability of this approach by applying it to real large images.

INTRODUCTION:

Recent Earth observation satellites, such as Quick Bird, Worldview, Geo Eye, and Pleiades, provide very high resolution (VHR) images, which are useful in applications such as environmental monitoring or natural resources management. The Pleiades satellites provide images with a ground sampling distance of 0.5 m and a spatial coverage of 400 km2 (40 000 × 40 000 pixels) allowing for detailed observation of the Earth surface. As a result, a scene contains billions of pixels, which represents a large amount of data to process. Dealing with such quantity of data has become a challenging issue for the remote sensing community because of the limitation of memory available on computers. The classical way to solve this problem is to divide these large images into smaller tiles (rectangular image subsets of the image) and process each one of these tiles independently. This operation is called image tiling. For traditional pixel wise or with fixed-size regular neighborhood image processing algorithms, image tiling is straightforward to apply without introducing artifacts in the results. However, those algorithms consider only spectral information from the pixels since a pixel does not have morphological information. That is why new trends known as object-based image analysis (OBIA) [1], object-based image classification, spatial reasoning

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[2], [3], and geospatial analysis have recently emerged using segmentation techniques to extract objects of interest in the scene and derive spatial relations between them. Some textural and morphological attributes are then computed from these objects for a subsequent classification. Segmentation quality is therefore essential for a correct characterization of these objects. Finally, we present some experiments, which demonstrate the following.

• The expression of the stability margin for our generic region-merging algorithm avoids artifacts on the tile edges, while ensuring identical results.
• The feasibility of the new framework to segment full VHR scenes.

PROBLEM STATEMENT:

In order to illustrate the problem of applying a tiling procedure for image segmentation, we propose the following experiment. A 500 × 500 image is considered. The region-merging algorithm uses the Baatz&Schäpe criterion [5] to form the partition of the image into disjoint segments. This criterion needs three user-defined parameters: two parameters for the relative importance of the spectral and shape weights and avalue for the scale threshold.The first result is obtained from the segmentation of thewhole image at once. This result represents the reference segmentation and is denoted GT. For the second segmentation, the image is first divided into four tiles of 250 × 250 pixels. Each tile is segmented independently, and the result is obtained from the mosaicking of the results of each tile.

Previous Work:

Several approaches have been investigated to remove theartifacts on the tile edges. In [7] and later in [8], the authors introduced the idea of “contagious” segments. At the beginning of the segmentation procedure, the contagious segments are the pixels along the tile edges. During the merging process, when a segment merges with a contagious segment, the resulting segment becomes contagious.

A solution proposed by the authors was to prevent two contagious segments from merging, in order to limit the propagation of the contagious property. However, as mentioned in [9], this approach is unreliable because, oftentimes, there are so many segments, which became contagious, that the region-growing process would stall prematurely. Another idea was to divide the image into adaptive tiles [10]. The borders of the tiles are built along the line of the maximum image gradient. This way, it is expected that the lines follow the border of the segments. However, the authors warn that, in certain cases, this approach creates inconsistent objects. In [9], the authors propose an alternative solution for the contagious segments.

They propose the RHSeg algorithm, which is an approximation of the original algorithm HSeg [11]. A split-and remerge process is performed after each iteration to remerge the contagious segments. This method successfully removes the artifacts on the tile edges but remains an approximation of HSeg. Therefore, the equivalence of the results, with respect to the segmentation without tiling, is not ensured. A different idea was to process the artifacts after stitching the segmented tiles together. In [12], the authors propose using a topological criterion to remove the artifacts on the tile edges.

Background Elements of Region-Merging Segmentation:

Region-merging algorithms appear to be very well suited for the interpretation of high-resolution images [13] because of their high-quality results compared to other approaches [14]. To obtain a partition of the image, region-based segmentation algorithms [15], [16] do not handle pixels but segments, which are sets of connected pixels. The pixels that belong to the same segment exhibit common properties according to a homogeneity criterion. These algorithms have received a lot of attention from the OBIA community. Region-merging algorithms start by assigning a different segment to each pixel of the image. The algorithm consists of merging adjacent segments until a termination criterion is fulfilled.

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At each iteration, merging costs are computed between adjacent segments. These merging costs are based on a homogeneity criterion and can represent not only how two similar segments are but also how homogeneous the resulting larger segment would be. The adjacent segment, for which the merging cost is the smallest compared to the other adjacent segments, is called the best adjacent segment of the given segment. A segment and its best adjacent segment are merged, if their merging cost is smaller than a threshold. This threshold avoids under segmentation. The merging process stops when there are no more possible fusions of segments. The homogeneity criterion can be based on statistical measures [17], spectral attributes [18], or topological attributes [5]. A specific criterion for partitioning the image can be defined for a particular need.

PROPOSED SOLUTION:

A. Stability Margin for Segmentation Algorithms and Its Expression for Region-Merging Algorithms

1) **Overview of the Definition of Stability:** The goal of thiswork is to ensure the equivalence of the result when applying segmentation with and without tiling. As described inSection II, one experimental way to prove this equivalence is to use the Hoover metrics and check that RC = 1. The reference segmentation is the segmentation of the whole image at once, and the test segmentation is the tiled segmentation. There is equivalence of the results, when each segment obtained from the reference segmentation matches a segment from the test segmentation. In [4], the procedure to ensure that this property is fulfilled consists of stabilizing segmentation algorithms. The authors define two stability properties called the "inner" and "cover" properties. The inner stability property implies that each segment inside a tile matches a segment from the reference segmentation. The cover stability property implies that segments located on the tile edges are fully included in a segment from the reference segmentation.

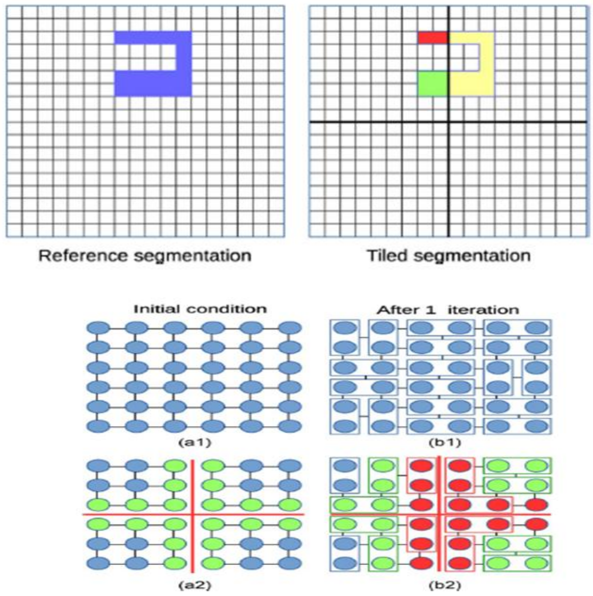

Fig. 3. Impact of image tiling on a region-merging segmentation result. (a2) Green nodes represent the nodes for which the set of edges is different due to the tile division. (b1) Region-merging iteration has been performed on the entire graph. (b2) Region-merging iteration has been performed on each subgraph. Segments different from the ones in (b1) are red. The green segments in (b2) are the segments for which the neighborhood is different.

Data-Driven Nature of Region-Merging Segmentation Algorithms and Impact of Image Tiling:

Image tiling has an impact on the resulting segments. The region-merging procedure can be seen as a succession of operations on a graph. At the beginning of the segmentation procedure, each node represents a segment of one pixel and has four or eight edges depending on the choice of the neighbor connectivity. During the different stages of the algorithm, the graph is modified, as some pairs of segments are merged at each iteration. Operations on a node at a certain iteration require transforming and getting information from other nodes and edges. A decision to merge two segments leads to the fusion of two nodes in the graph. All the nodes have to be explored at each iteration to determine whether they have to be merged or not. This implies that a new iteration can be performed on the graph if all the nodes were processed at the previous iteration.

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Based on these characteristics, region-merging algorithms belong to the irregular data-driven algorithms category [28]. Applying image tiling on an initial graph modifies the initial set of edges for the nodes located on the borders of the tiles. After having performed one iteration of the region-merging procedure, these nodes might merge with different nodes from the ones expected and lead to different resulting segments. As a consequence, the neighborhood of other additional segments will be different.

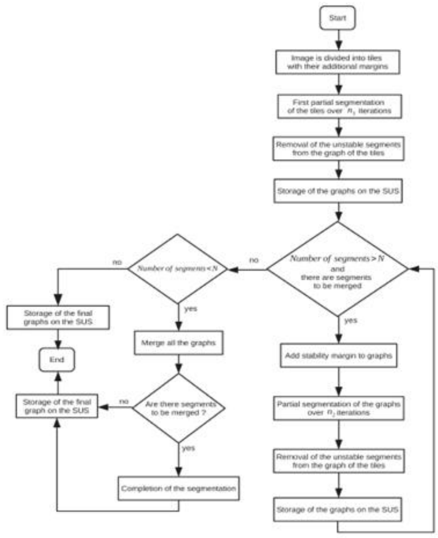
This impact might be propagated to other segments over the segmentation procedure. Above Fig. illustrates the impact of image tiling on a region-merging segmentation result. The study of this impact of image tiling was first introduced in [7], where the green segments in Fig. 3 were qualified as contagious. Also, in [9], the authors explain that image tiling leads to non-optimal fusions of segments due to the absence of knowledge of some segments, which belong to other tiles.

Tile-Based Framework for Region-Merging Segmentation of Large Images

1) High-Level Overview:

To simplify our discussion, we initially walk through the main steps of the entire approach. In the remainder of this paper, we consider a standard computer with two types of memory: the Quick Limited Storage denoted as QLS, which is typically the random access memory (RAM),and the Slow Unlimited Storage denoted as SUS, which can represent the hard disk drive.

The objective of this section is to exhibit how the framework works when the QLS limits the region-merging algorithm to operate on a graph of maximum N segments. The flow diagram is described below.



The new algorithm breaks up the process of region merging into successive partial segmentations of the graphs of segments of the tiles. The first step consists of determining the size of the margin for each tile, knowing the capacity of the QLS. Different strategies are possible for choosing the size of the margin. Increasing the margin implies a higher reduction of the number of segments since more iterations of the region-merging procedure can be performed.

However, this strategy implies a higher number of tiles since their sizes are smaller. More I/O operations are therefore necessary to load and store the tiles on the SUS. Increasing the size of the tiles implies a smaller size of the margin and, hence, a lower reduction of the number of segments. This strategy implies more iterative partial segmentations of the graphs of the tile.

RESULT AND CONCLUSION:

RESULTS:

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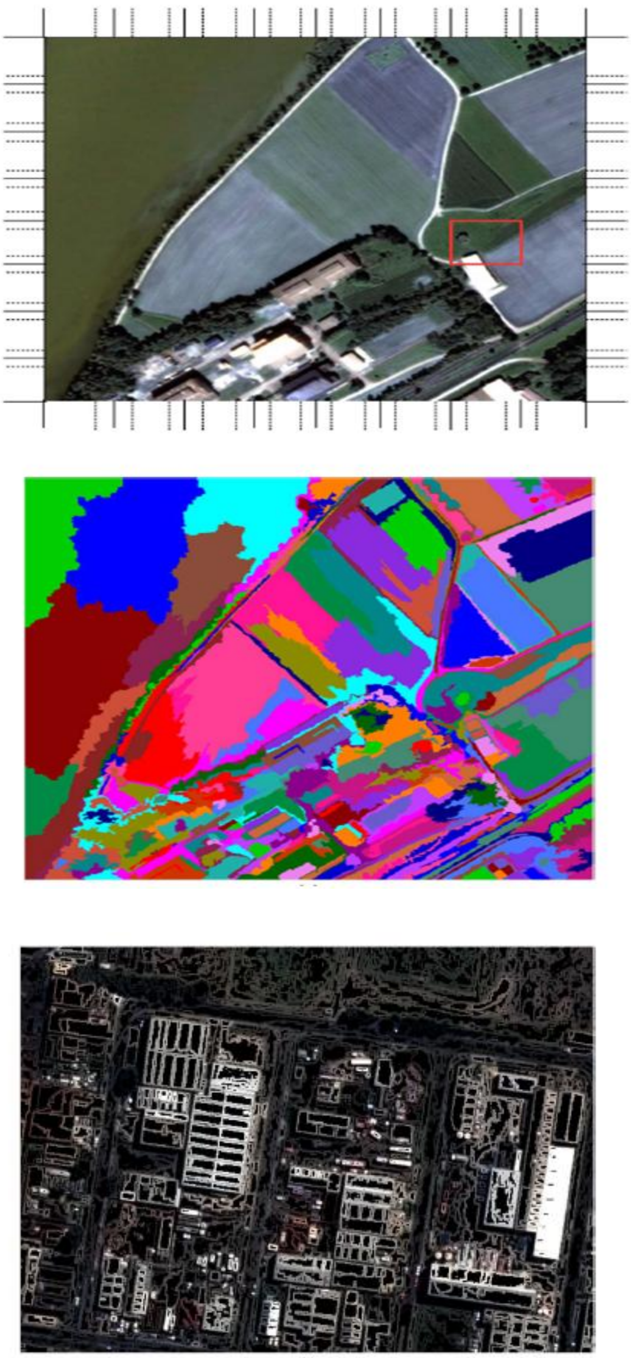

FIGS: TILE BASED SEGMENTATON

This paper has presented a solution to ensure equivalent results for the segmentation of satellite images of arbitrary size with tiling. It was experimentally shown that the region merging algorithms do not cope well when using image tiling.

The impact of image tiling has been studied for region-merging algorithms, and the critical steps have been identified. The concept of stability margin has been defined and expressed quantitatively as a function of the number of iterations ofthe region-merging procedure. Using the stability margin in atiling approach has allowed ensuring the equivalence of the results between the segmentation with and without tiling. The practicality of the tile-based framework for region-merging algorithms has been illustrated by the segmentation of a full entire Pleiades scene of billions of pixels in a computer with limited storage memory.

However, additional work to improve the efficiency of this framework, by minimizing the number of partial iterations and the number of I/O operations, should be carried on. The first improvement would consist of finding an optimal solution to determine the size of the tiles and the stability margin. Thesecond improvement would consist of allowing more iterationsfor each partial segmentation of the graphs. Additional study may also include the portage of this framework to a parallel and distributed environment to reduce the processing time. Finally, it would be interesting to unify this solution, by extending it to other families of segmentation algorithms.

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