A Robust Concurrent Approach for Road Extraction and Urbanization Monitoring Based on Superpixels Acquired from Spectral Remote Sensing Images

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ABSTRACT

The segmentation of Remote Sensing images of the visible spectral range into meaningful regions has a long tradition in the field of image processing, analysis and interpretation. It is the necessary first step to assign sets of pixels to certain imaged objects and is widely used in Earth observation tasks. Thus, image segmentation forms the base for many classification and change detection tasks.

In this paper, we propose a novel and generic approach, which abstracts from the pixel ordering of an image but starts at the level of superpixels. Following Ren and Malik, a superpixel is said to be a local, and coherent set of (sub) pixels, "which preserve most of the structure necessary for segmentation at the scale of interest." [1]. Superpixels may be derived from an image using the Watershed Transform (WT) as well as the SLIC approach [2, 3]. We propose to store the superpixels in novel structure, which we refer to as a region shell graph (RS-graph). This graph does not only hold the geometry and adjacency of the superpixels, but of the boundaries (topological: shells) in between. We implement various morphological operations on the RS-graph, e.g. the merging of superpixels according to cost measures, based on statistical and geometrical properties of the superpixels or their shells. The successive application of these operations results in a fully navigable irregular image pyramid of RS-graphs. The top layer of this pyramid may represent the final segmentation. Unlike other approaches, the RS-graph can be constructed in a concurrently, which fits modern machines' architectures and speeds up the process. Many of the operations on the RS-graph may also be performed in parallel. Moreover, the explicit inspection of partial results is supported by means of a free navigation though the irregular pyramid.

To demonstrate the use of the RS-graph and the irregular pyramid for monitoring of urban areas, we have selected the field of road segmentation and road tracking on publicly available Remote Sensing images. This also allows an indirect urbanization monitoring, since the expansion or development of a road network is a promising indicator. Compared to other pixel-based road detection approaches (like e.g. [4]), our approach combines statistical information about the superpixels and the boundaries following the Gestalt law of good continuation. Experiments show that our combined approach results in a higher overall accuracy and is invariant to the paving and the width of the roads. It also provides a partial invariance to occlusions of the road, e.g. by trees in rural areas. These properties strongly suggest the use of our approach for semi-automatic monitoring or change detection of urban areas. Three demos of our approach are shown in the PDF attached to this abstract submission.

This research study has been performed in cooperation with the Centre for Science and Peace Research (ZNF) in Hamburg/Germany to detect and monitor infrastructural changes in rural areas.

REFERENCES

[1] Xiaofeng Ren; Malik, J., "Learning a classification model for segmentation," in Computer Vision, 2003. Proceedings. Ninth IEEE International Conference on , vol., no., pp.10-17 vol.1, 13-16 Oct. 2003

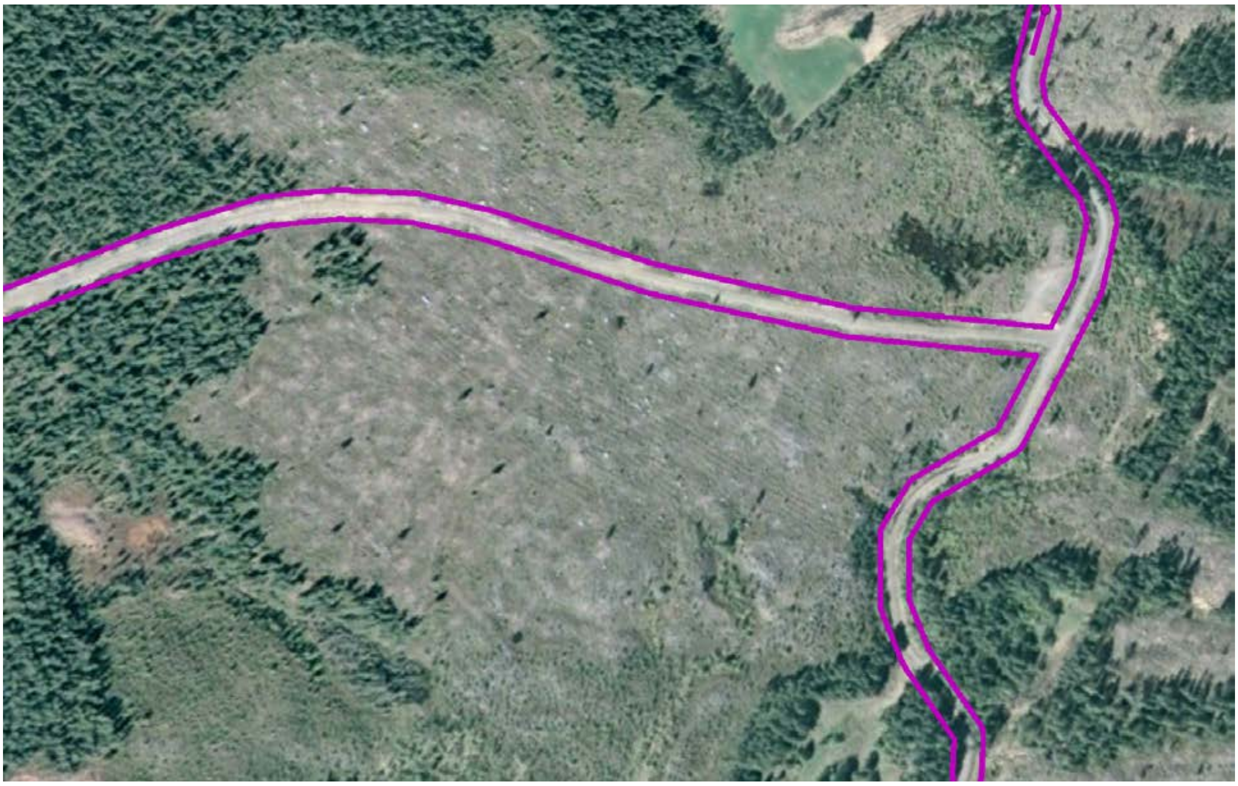
[2] Jos B.T.M. Roerdink; Arnold Meijster. 2000. The Watershed Transform: Definitions, Algorithms and Parallelization Strategies. Fundam. Inf. 41, 1,2 (April 2000), 187-228.

[3] Achanta, R., Shaji, A., Smith, K., Lucchi, A., Fua, P., & Susstrunk, S. (2012). SLIC superpixels compared to state-of-the-art superpixel methods. Pattern Analysis and Machine Intelligence, IEEE Transactions on, 34(11), 2274-2282.

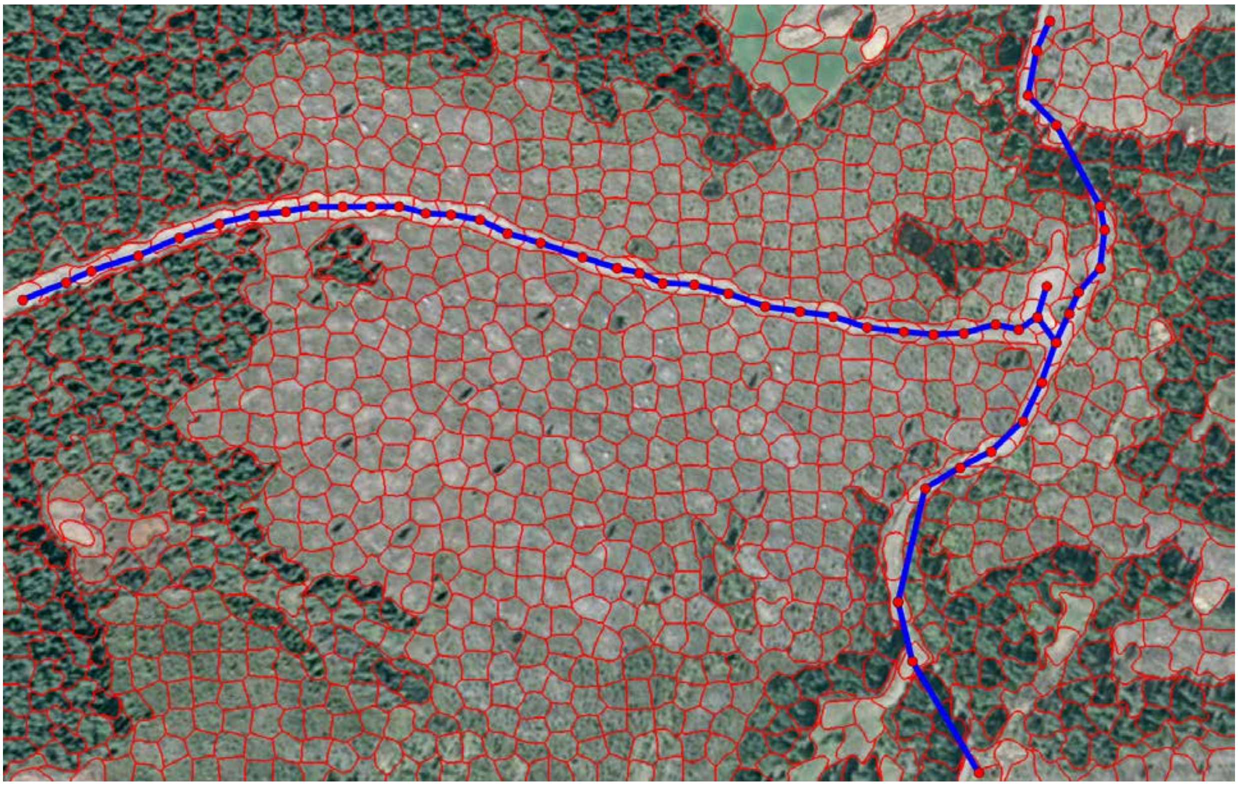
[4] Shukla, Vandana ; R.Chandrakanth ; R.Ramachandran: Semi-Automatic Road Extraction Algorithm for High Resolution Images Using Path following Approach. In: Proceedings of the Third Indian Conference on Computer Vision, Graphics and Image Processing, 2002

Results of the Road detection (1)

Area: Bäckmark (Sweden) – 65°17'59.94" N 16°43'38.00" E
Image source: Google Earth, Copyright by Google Inc.



(1.a) Gold standard for area 1 (Bäckmark) with manually set seed and direction (upper right)



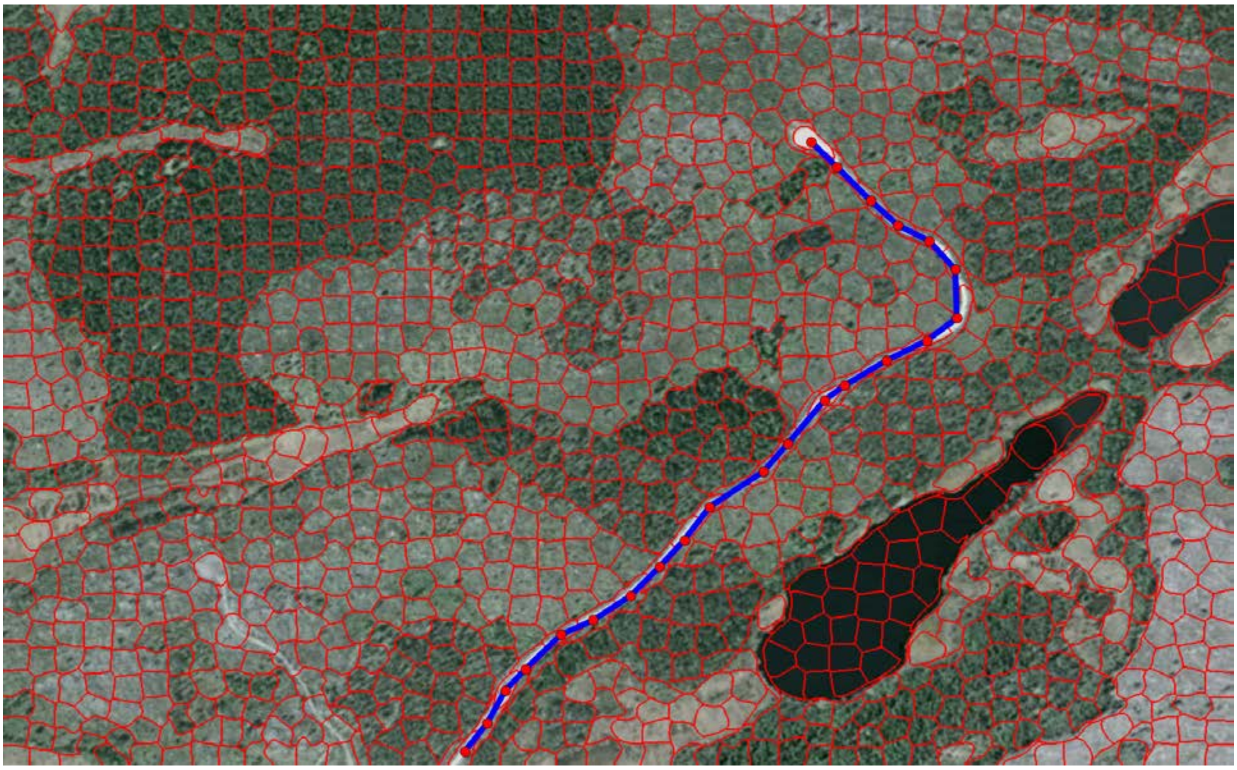
(1.b) Result of the road tracking approach for area 1 (Bäckmark)
The blue line denotes the extracted road graph,
the red dots represent the centers of gravity of each involved superpixel,
the SLIC superpixels are highlighted by means of their boundaries (red).

Note that our approach was able to handle the partial occulusion at the image (lower right corner) and correctly tracks the T-junction (right).

Results of the Road detection (2)

Area: Skålbygge (Sweden) – 61°24'54.51" N, 15°04'42.80" E
Image source: Google Earth, Copyright by Google Inc.

(2.a) Gold standard for area 2 (Skålbygge) with manually set seed and direction (lower border)



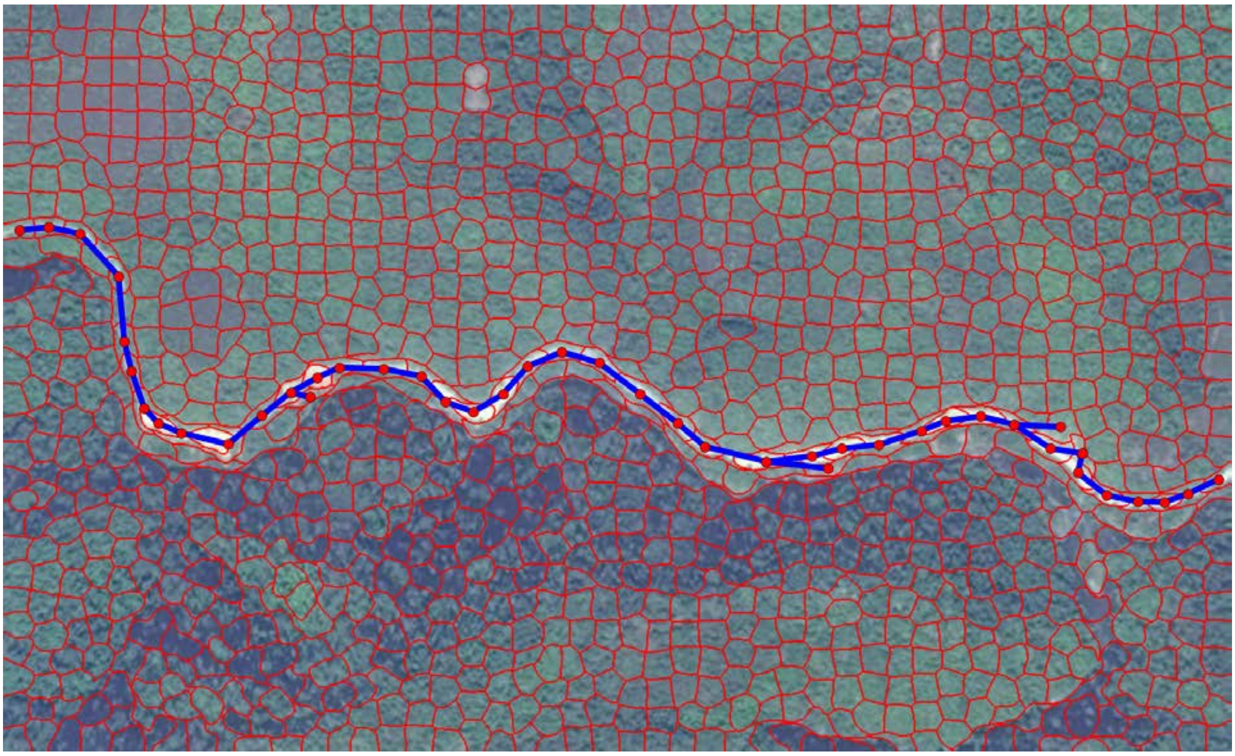
(2.b) Result of the road tracking approach for area 2 (Skålbygge)
The blue line denotes the extracted road graph,
the red dots represent the centers of gravity of each involved superpixel,
the SLIC superpixels are highlighted by means of their boundaries (red).

Note that our approach was able to detect the end of the road correctly, since it did not find a salient continuation.

Results of the Road detection (3)

Area: Mongping (Myanmar) – 21°20'15.90" N, 99°03'53.10" E
Image source: Google Earth, Copyright by Google Inc.

(3.a) Gold standard for area 3 (Mongping) with manually set seed and direction (left)



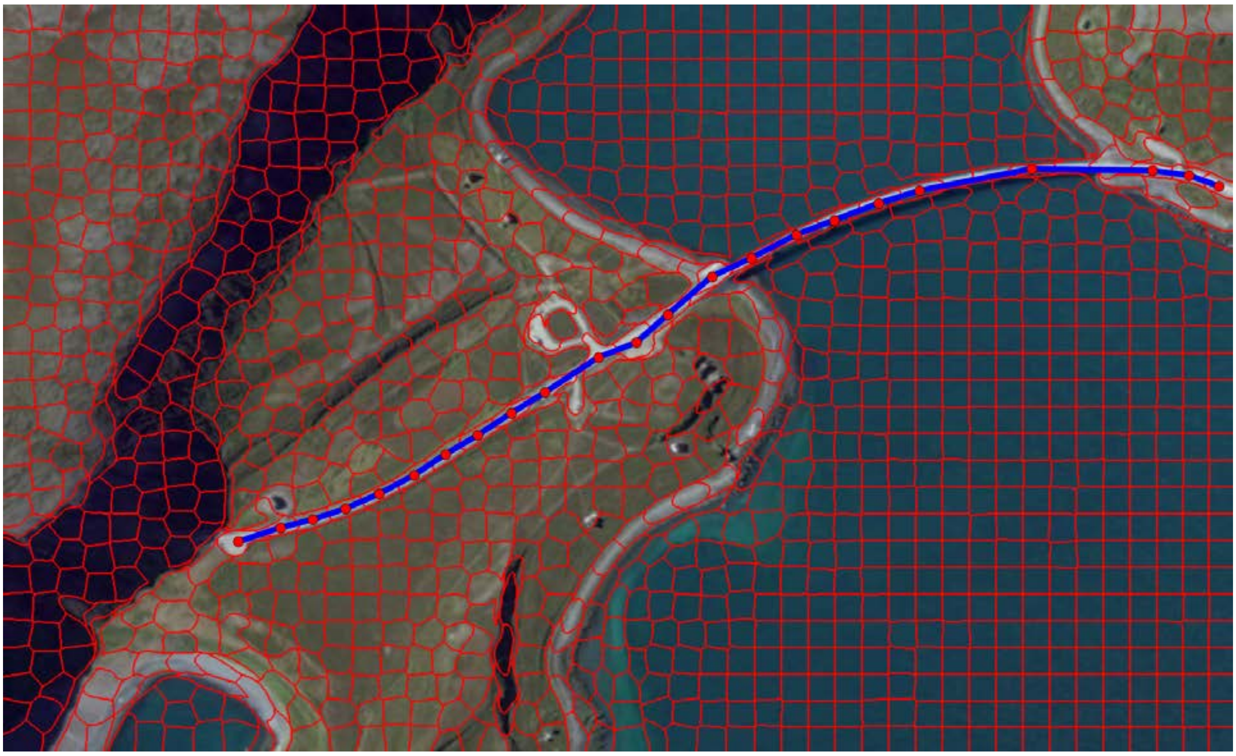
(3.b) Result of the road tracking approach for area 3 (Mongping)
The blue line denotes the extracted road graph,
the red dots represent the centers of gravity of each involved superpixel,
the SLIC superpixels are highlighted by means of their boundaries (red).

Note that our approach was able to handle the partial occulusion of the road at the image but introdruced some small artificial branches.

Results of the Road detection (4)

Area: North Cape (Norway) – 70°57'27.77" N, 25°41'56.54" E
Image source: Google Earth, Copyright by Google Inc.

(4.a) Gold standard for area 4 (North Cape) with manually set seed and direction (right)



(4.b) Result of the road tracking approach for area 4 (North Cape)
The blue line denotes the extracted road graph,
the red dots represent the centers of gravity of each involved superpixel,
the SLIC superpixels are highlighted by means of their boundaries (red).

Note that our approach was able to follow the street across different surroundings and over the bridge in the upper right region, too.