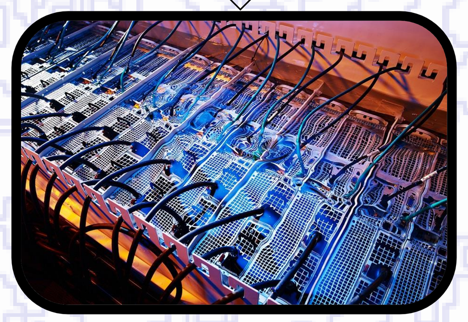
Multiresolution image segmentation algorithm development for Sentinel-2 satellite imagery

Iván Barton[1,2], Kornél Czimber[1]
[1]University of Sopron, Hungary - Faculty of Forestry, Institute of Geomatics and Civil Engineering
[2]University of Washington - School of Environmental and Forest Sciences
Email: ivan.barton@gastudent.nyme.hu

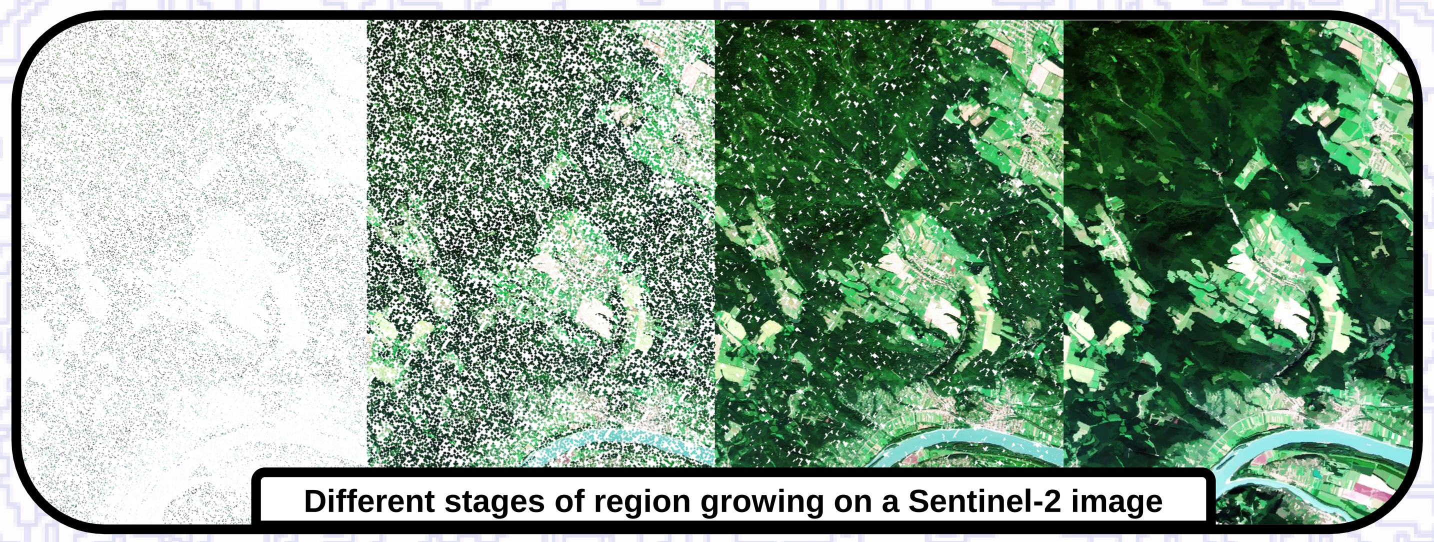
Introduction

The first Sentinel-2 satellite was sent to orbit in 2015 as part of the European Copernicus program. It provides free, high resolution Earth observation data on global scale, collecting an incredible amount of data (1.6 TB/orbit). In the past, image interpretation was done by human operators, but in the last few decades computer vision has played a significant role in mapping due to the increasing data volume. With object based image analysis (OBIA) the mapping quality could approach or even overtake the man-made maps with high resolution images. The first and most important step in OBIA is the image segmentation, wherein the image is taken apart into homogenous regions. The state of art image segmentation methods are not frequently used in satellite remote sensing. Most modern methods are data driven, which perform well in artificial environment, but fail in natural environment due to the lack of training data. Therefore the older, unsupervised image segmentation algorithms are preferred by users. There are several commercial and open source OBIA solutions for processing long time series in order to extract thematic information. However, all of them have strengths and weaknesses which limits their research and operational applications. To overcome this problem, we implemented a modified multiresolution image segmentation algorithm which could be utilized for Sentinel-2 data processed in High Performance Computing (HPC) environments.

source: https://nationalmap.gov



source: http://primeurmagazine.com



Different stages of region growing on a Sentinel-2 image

Date: 13.09.2016.; Composite: R:B4 G:B3 B:B2; Data source: https://scihub.copernicus.eu

Algorithm description

The presented multiresolution segmentation algorithm is based the previous work of Baatz & Scäpe (2000) and Czimber (2009). The basic concept for creating an image object is to merge adjacent pixels where the heterogeneity is minimized, while it is meaningful and acceptable by human vision. The initial seeds for the region growing were generated with a 16-bit Xorshift algorithm. To avoid unbalanced growing of adjacent segments, a pseudo random sequence was used. During the region growing, only one segmentation cycle was applied on the image object. The segments were merged by the local mutual best fitting rule. The growth of a segment is constrained by the adjustable scale threshold, shape compactness, and weight parameters. It handles single and multi-band images which makes it feasible for Sentinel-2 imagery. The weights for the individual input bands are adjustable. Reference polygon vector layer could be added to force the border of the segments. The algorithm was implemented in a self-developed, cross platform image processing framework (Barton et al. 2017), which can run be used on a HPC system to process Earth observation big data.

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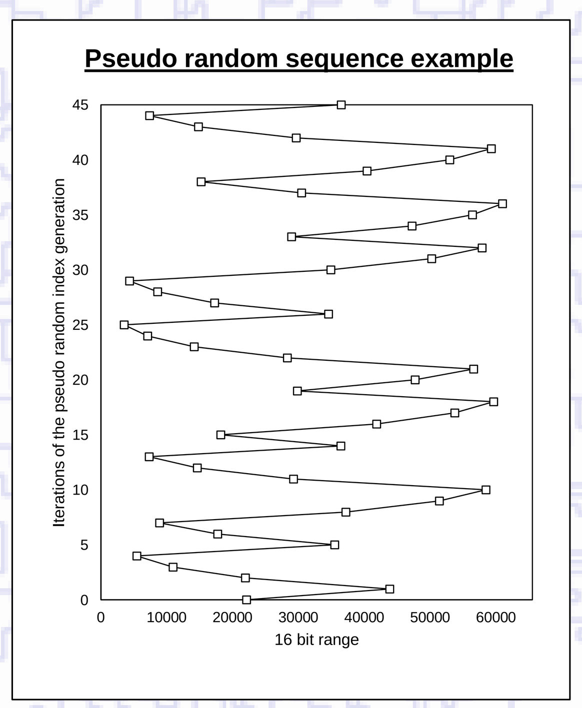
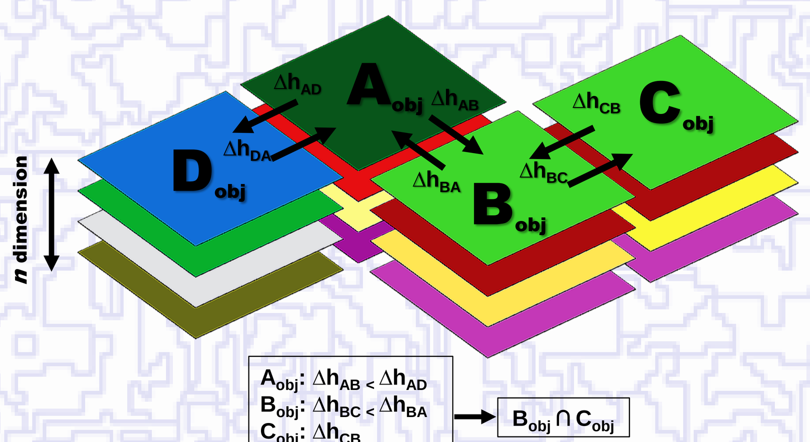
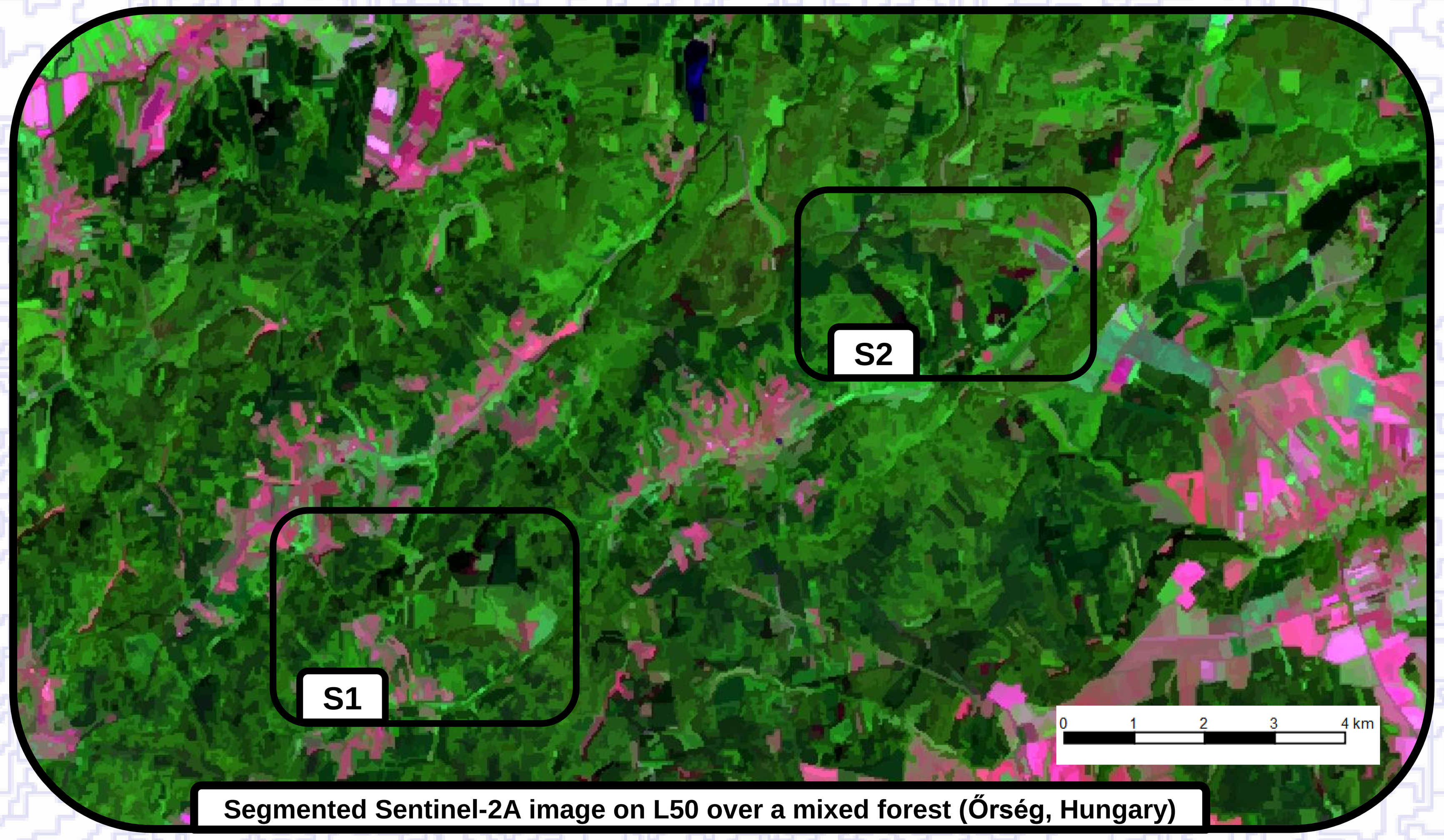




Local Mutual Best Fitting rule: The virtual merge of A and B object would result the less heterogeneity change with A object. However, A object will not be merged with B object while B has a better fitting neighbor (C object). C object has the less virtual heterogeneity change with B. Therefore, B object will be merged with C object.

Imagery for testing

Several types of remotely sensed image data hold more or less textural content about the surveyed objects. The multiresolution segmentation method can handle the texture and preserve shapes during meaningful image object creation, without regard to the spatial resolution. Therefore, multiple image sources were used during the development, including very high resolution aerial orthophotos, optical satellite imagery, and digital surface models to test the algorithm. The MSI sensor on the Sentinel-2 satellites provides 12 band multispectral imagery at 10,20,60m spatial resolution and 12-bit radiometric depth. An urban scene in Seattle, Washington and a forested rural scene in Hungary was selected to demonstrate the algorithm on Sentinel-2 imagery. The capacity of the algorithm with a single band image was demonstrated on an image matching based canopy height model (CHM). The model has 0.4m spatial resolution and covers several poplar tree (*Populus sp.*) plantations.



Segmented Sentinel-2A image on L50 over a mixed forest (Őrség, Hungary)

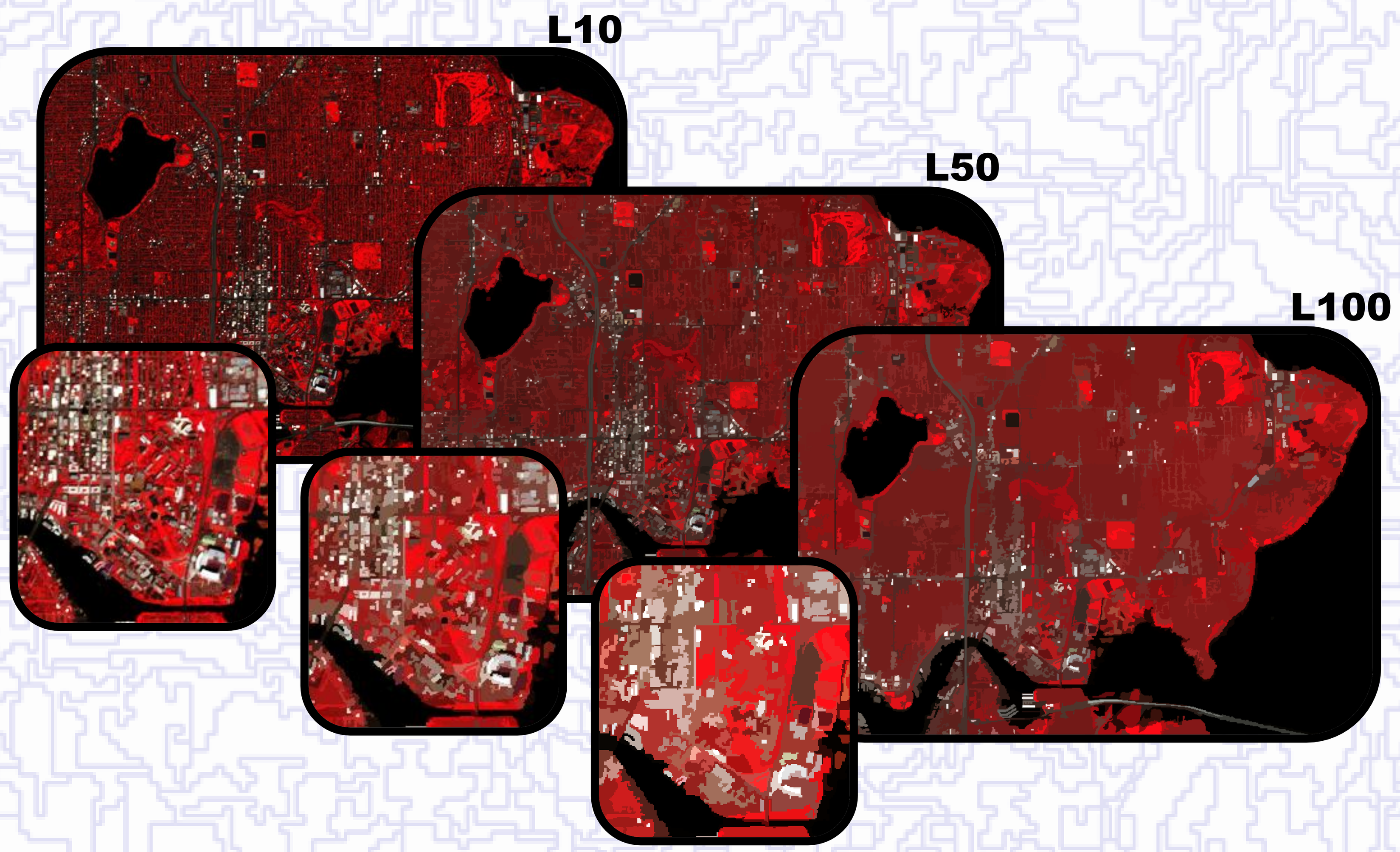
Date: 20.07.2017.; Composite: R:B12 G:B8 B:B3; Original resolution: 20m; Data source: https://scihub.copernicus.eu

Results

The segmentation was performed on the selected test images with success. The processing time was comparable with the commercial software. In the Seattle dataset the effect of the different scale threshold parameters could be observed. The highly homogenous objects like the water bodies, highways, and the husky stadium preserved their shape on each level. The heterogeneous, highly textured suburban regions and parks showing progressive merge ratio along with the changing parameter. On the Őrség dataset borders of forest compartments are preserved. The bark beetle attacked spots and different forest types are aggregated into image objects. The CHM segmentation resulted image objects, where trees have similar heights. Thus, information is available for more precise annual growth calculation on sub-compartment level.

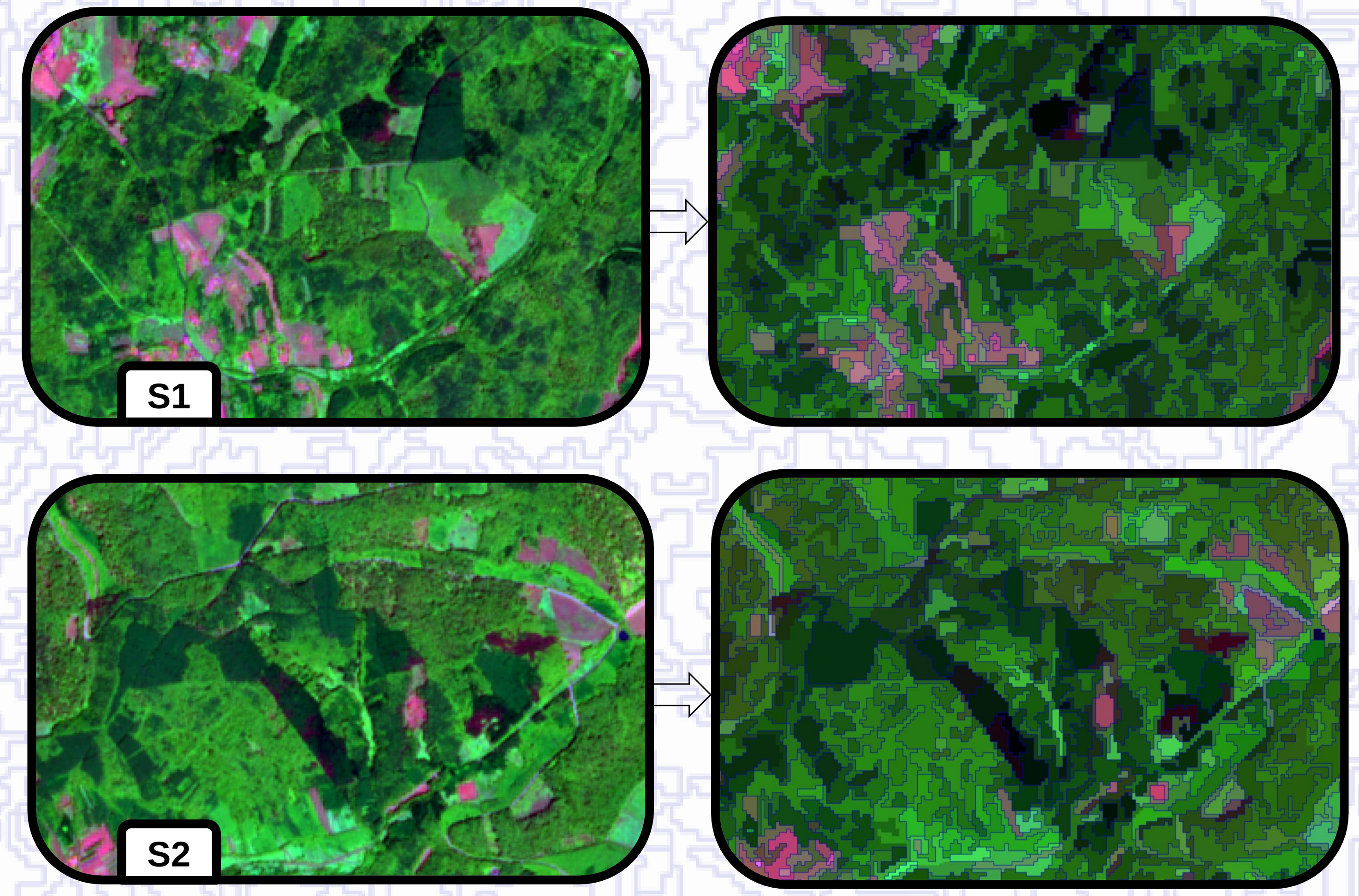
Data Source: http://www.ftf.bfkh.gov.hu

CHM (L) over a poplar (*Populus sp.*) plantations and the L50 segmentation over the area (R)



Sentinel-2B image segmented with multiple scale threshold over the University District, Seattle

Date: 23.04.2018.; Composite: R:B8 G:B4 B:B3; Original resolution: 10m; Data source: https://scihub.copernicus.eu



Mixed forest types and pure Spruce (*Picea abies*) stands with bark beetle attacked spots on the original 20m resolution Sentinel-2 image (L) and it's L50 segmentation (R).

Conclusion

The implemented algorithm is suitable for Sentinel-2 and any other imagery to create meaningful image objects. The method focuses the image information into segments for easier interpretation. The extracted image objects can be used in further in OBIA workflows. Segments are preserving the original shape of the surveyed object. The position and amount of seed segments highly influence the results. On image parts, where homogenous texture is present the pixels are aggregated into a segment. This way their type could be specified with advanced classification methods. With pixel based approaches this is not possible. The software framework used allows can be used in HPC environment for analysis of big data. The implemented sequential algorithm can be optimized for parallel processing in the future.

References

Baatz, M., Schäpe, A. (2000): Multiresolution Segmentation – an optimization approach for high quality multi-scale image segmentation. In: Strobl/Blaschke/Griesebner (eds.): Angewandte Geographische Informationsverarbeitung XII, Wichmann-Verlag, Heidelberg, 12-23

Barton I, Király G, Czimber K (2017): Képfeldolgozó program fejlesztése nagy mennyiségű földmegfigyelési adat feldolgozásához és kiértékeléséhez; VI. Kari Tudományos Konferencia kiadvány, 266 p.(2017) Soproni Egyetem Kiadó (ISBN 978 963 359 089 8) pp. 164-167.

Czimber, K. (2009): Új, általános célú képosztályozó kifejlesztése nagyfelbontású, textúrával rendelkező digitális képek feldolgozására. Geomatikai Közlemények XII., 249–. 258.

Acknowledgement: