Efficient Representation for Large-Scale Satellite Images

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Context: This project takes place in the general context of ***information extraction from massive satellite data using advanced machine learning tools***. The continuous proliferation and improvement of satellite data sensors yields a huge volume of Earth's images with high spatial, spectral and temporal resolution (up to 50cm/pixel, 50 bands, twice per day, covering the full planet!). These data open the door to a large range of important applications, such as the monitoring of natural disasters, the planning of urban environments and precision agriculture. However, petabytes of these massive images are stored in binary files as the raw data, unstructured and for a big part never used.

Subject: The goal of this PhD thesis is to devise a novel ***effective summary representation*** for satellite images, which would help to structure large-scale data. Such a representation must be highly ***generic*** to be applicable for images from all over the world and suitable for a wide range of applications. At the same time, it it has to best represent the ***meaningful*** objects in the image scenes, with the possibility to be enriched by semantic or other kinds of information.

Our primary goal is to design a representation which can accurately convey information from the image with as few primitives as possible, i.e. we seek for a compact yet faithful representation with good ***complexity/fidelity*** tradeoffs. The vector-based representation is well-known to provide several important advantages over raster images, the three most salient ones being compactness, scalability and easiness of updating [1]. We thus plan to devise a multi-resolution **vector-based representation**, together with the required algorithms for the efficient generation and manipulation.

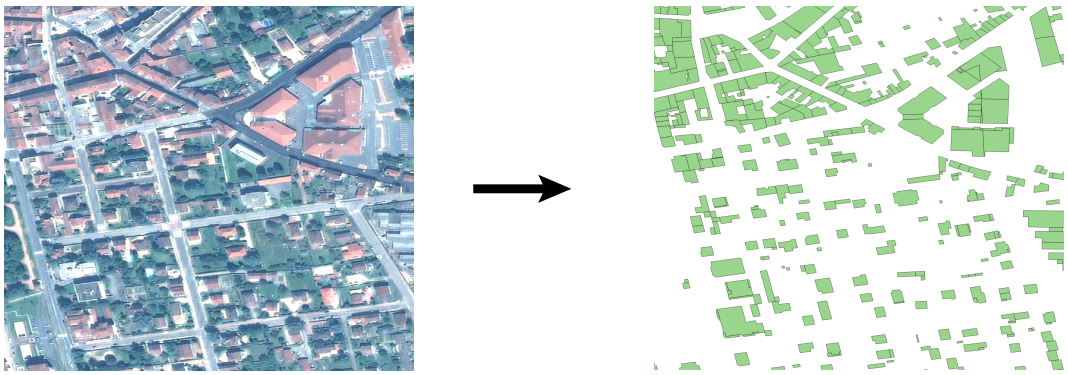

Fig. 1: Example of a satellite high-resolution image (©CNES) and OpenStreetMap building map.

To preserve geometric structures and their accurate scale alignment, we will investigate the use of a large source of free-access maps, such as OpenStreetMap [2], and the advanced deep learning architectures [3, 4] to learn about the **geometric structures** and their relations in the image scene. The OpenStreetMap collaborative database provides large amounts of maps over the Earth, delineating (a contour) or pointing out (one spatial point) at objects of numerous semantic categories, such as *roads, buildings, residential areas, parking lots, trees*, *etc* (see example on Fig. 1). These data will serve as a training dataset for a convolutional neural network-based semantic segmentation to detect the changes in the existing maps, such as new or disappeared roads or buildings. The updated maps will then be used to infer both structure and semantics of the objects in the image (naturally the ones present in the maps).

Validation and impact: A detailed experimentation validation will be conducted on large-scale satellite images acquired by the latest sensors, with a special focus on Pléiades imagery. If successful, the proposed novel representation has the potential to impact the remote sensing community via a new information layer for the satellite image data, which would represent the essential image content, with the capability to support new modes of navigation, indexation and exploitation.

References:

• [1] Z. Liao, H. Hoppe, D. Forsyth, and Y. Yu, "A subdivision-based representation for vector image editing," *IEEE Trans. on Visualization and Computer Graphics*, vol. 18, no. 11, pp. 1858–1867, 2012.

• [2] M. Haklay and P. Weber, "Openstreetmap: User-generated street maps," *Pervasive Computing, IEEE*, vol. 7, no. 4, pp. 12–18, 2008. [Online]. Available: `openstreetmap.org`.

• [3] E. Maggiori, Y. Tarabalka, G. Charpiat and P. Alliez, "Convolutional Neural Networks for Large-Scale Remote Sensing Image Classification," *IEEE TGRS*, 2016. • [4] E. Maggiori, Y. Tarabalka, G. Charpiat and P. Alliez, "High-Resolution Semantic Labeling with Convolutional Neural Networks," ArXiv, 2016.

Requirements for the student:

• Master degree in Mathematics, Signal Processing or Computer Science

• Knowledge of Mathematics (functional analysis, derivatives, probabilities, statistics)

• Interest in or knowledge of image processing, optimization (gradient descent), machine learning

• Good C++ / python coding skills • Fluency in English