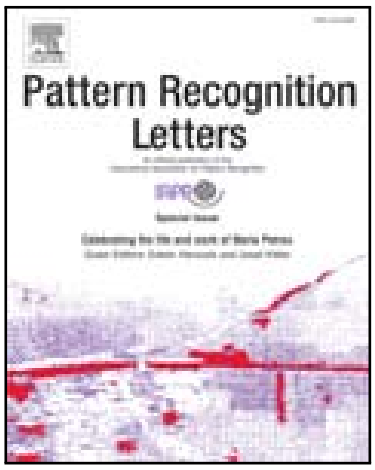

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Morphological Path Filtering at the Region Scale for Efficient and Robust Road Network Extraction from Satellite Imagery

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ABSTRACT

Roads are important elements in geographic information systems and remote sensing applications. Their automatic extraction is challenging when only aerial or satellite images are used. Recently, some promising attempts have been made with (incomplete) path opening/closing, morphological filters able to deal with curvilinear structures. We propose here to apply morphological path filters not on pixels directly but rather on regions representing road segments, in order to improve both efficiency and robustness. The overall process is organized in two steps: first we map road segments by rectangular areas made of similar content, before we connect such segments into paths of segments or polylines using region-based path filtering. Robustness to occlusion is ensured through the adaptation of the incomplete path filtering strategy to the region scale, while better discrimination between road segments and other objects is achieved through an hit-or-miss transform that exploits background knowledge. Experiments conducted on several satellite images illustrate the interest of the proposed approach, and shows it outperforms pixelwise detection.

1. Introduction

Road networks are important elements for urban planning or environmental monitoring. Despite being often modeled as geographic information systems (or GIS), their extraction from remote sensing data eases GIS updating (on a regular basis or after a disaster). It is even mandatory when no GIS is available. Manual extraction of the road network can be achieved on small areas with photo interpretation, but it is not possible anymore when satellite or aerial images of larger extent are considered. Automatic extraction of road networks from aerial or satellite images has thus been addressed since 40 years (Bajcsy and Tavakoli, 1976) and led to numerous works, see (Mena, 2003) for a review. Various frameworks have been used in this intent, e.g., Markov random fields (Wegner et al., 2015; Besbes and Benazza-Benyahia, 2014), neural networks (Mnih and Hinton, 2010) and deep learning (Wang et al., 2015), mathematical morphology (Géraud and Mouret, 2004; Zhu et al., 2005; Gaetano et al., 2011; Sujatha and Selvathi, 2015), graph modelling (Unsalan and Sirmacek, 2012; Bae et al., 2015), spatially-adaptive classification (Shi et al., 2014), multiscale analysis (Ouled Sghaier and Lepage, 2015), etc.

Among them, mathematical morphology has recently led to promising results in providing fast but accurate solutions, with the work from Valero et al. (2010) that was relying on path opening and closing. These morphological filters aim to extract (or highlight) curvilinear structures (Talbot and Appleton, 2007). However, as most of the automatic techniques, such an approach is relying on pixelwise analysis and filtering, thus presenting two drawbacks. On the one side, the volume of information to be processed (pixels) prevents from efficient (fast) extraction and does not allow processing large remotely-sensed images. On the other side, it is not adapted to images with a very high (spatial) resolution where roads are described by a large set of pixels (e.g., a road of 7m width is mapped by image segments of 10 to 100 pixels wide for spatial resolutions of 0.7m to 0.07m per pixel, corresponding respectively to VHR satellite and aerial images).

Inspired from the promises of path filtering operators, we propose here a novel morphological technique for road network extraction from remote sensing. Conversely to Valero et al. (2010), we consider the region level instead of the (standard) pixel one when applying morphological filters. We thus propose a 2-step approach which first extracts rectangular regions corresponding to possible road segments, before connecting these regions through region-based morphological operators. Our contributions also consist in: adapting the (incom-

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