Image segmentation based on hexagonal sampling grids

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Abstract: Image processing based on hexagonal lattices is certainly less widespread than that based on squared grid cells. Nevertheless, it is possible the same manner and shows for diverse applications several advantages. In the GIS domain hexagon based spatial analysis is common especially for analysing and simulating dynamic processes. This is because a hexagon grid tiles the plane consistently into primitives of equal area and it allows for each equally distributed punctual measurement to describe geometric neighbourhood relationships on edges. In our research we compare segmentation results based on hexagons and squared grids of equal size together with basic analysis operations, such as filter operations or skeleton analysis. Our research is based on 2m WorldView‐2 satellite images aggregated to squares and hexagons of 30m height.
Keywords: Hexagonal image processing, hexagonal image analysis, image segmentation.

1. Introduction

Image processing based on hexagonal lattices is certainly less widespread than that based on squared grid cells. Nevertheless, it is possible the same manner and shows for diverse applications several advantages (Middleton and Sivasamy, 2005). In the GIS domain, hexagon ‐based spatial analysis has been used already in 1992 (Carr et al., 1992; White et al., 1992) and is meanwhile an accepted alternative to square‐based designs especially for analysing and simulating dynamic processes (Ritsema van Eck and de Jong, 1999; Kardos et al., 2007; Jurasinski and Beierkuhnlein, 2006). From a conceptual point of view, hexagons are even more eligible to represent equally distributed, punctual measurements of the earth surface (such as remote sensing data), than squared pixels are (Mersereau and Speake, 1983; Goodchild and Shiren, 1992; Ferhatosmanoglu et al. 2001; Sahr et al., 2013). This is, because the hexagons shape is simply a better approximation of the circle than triangle or square are. Besides square and triangle, the hexagon is the only geometric primitive capable to tile the plane consistently into primitives of equal area. However, only hexagons allow describing consistent geometric neighbourhood relationships on edges. In a squared lattice either four‐neighbours edge relationships or eight ‐neighbours edge ‐corner relationships are describable both lacking a describable border length with the neighbours in the corners. Triangles face the same problems with neighbours sharing only one common point. Last but not least in a hexagon grid the centre points of neighbouring hexagons are all of equal distance. From a biological point of view, several hexagon‐like arrayed sensors exist, e.g. compound eyes of diverse insects or the human retina (Hess et al., 2006; Hubel, 1995) (Fig. 1). However, there are still no technical hexagon‐shaped optical sensor arrays available. Thus, in order to work with a hexagon based grid it needs to be generated based on squared pixels. In GIS this is usually

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done by creating respective hexagon polygons in a mesh of points using Thiessen polygons (Voronoi diagram). In traditional image processing environments, hexagons can only be approximated within the given squared grid of pixels.

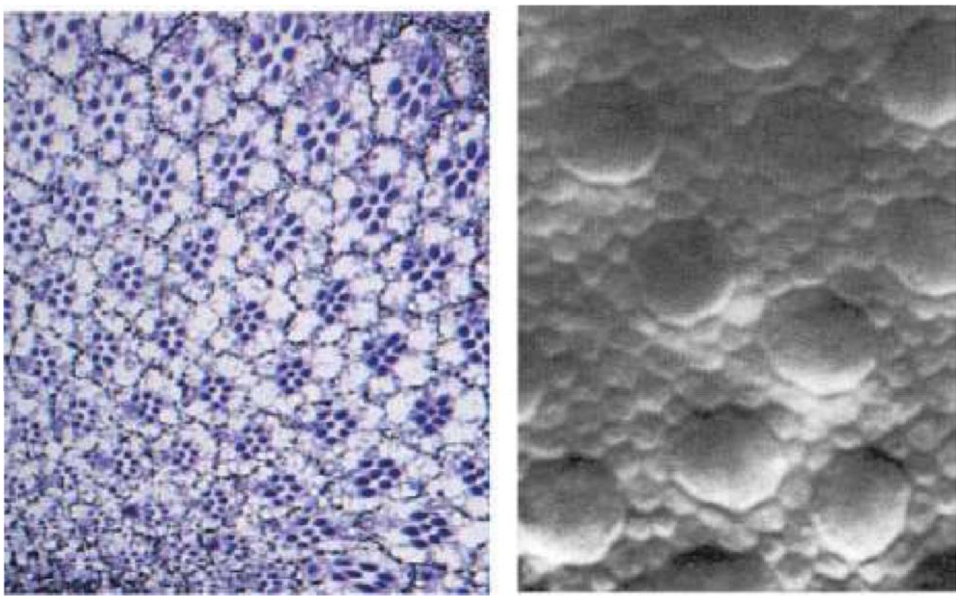

Figure 1. Left, thin section of a facet eye from Drosophila fly (Hess et al., 2006). Right, micro image of the human retina with cones (bigger cells) and rods (small cells) (Hoffman, 1998).

OBIA allows aggregating image pixels to regularly shaped objects such as squared cells or hexagons. In a hierarchically organized network of image objects the creation of aggregated objects (such as hexagons) based on initially created regular grids is feasible, mimicking e.g. a hexagon-shaped optical sensor. Based on these regularly shaped objects further image segmentation algorithms can be applied, such as the Multi-Resolution Segmentation (Baatz and Schäpe, 2000). In our research, we compared segmentation results based on hexagons and squared grids of equal size together with basic analysis operations, such as filter operations or skeleton analysis.

2. Material and Methods

For our research we have used a subset of a multi-spectral WorldView-2 satellite image scene with 2m spatial resolution. The scene depicts the northern parts of Munich (Germany). It has been captured 12th July 2010 at 10:30h local time. For illustration purposes, we selected an area around the soccer stadium (Fig. 2). For implementing our analysis, we have used the Cognition Network Language (CNL) in conjunction with eCognition 8.9.

2.1. Grid tesselation

While the tesselation of squared objects from a pixel image is relatively simple, aggregating squared image pixels to hexagon grid cells reflects an approximation of the desired hexagon shape. For our analysis, we have aggregated 2m pixels to hexagon-and pixel-objects with a height of 30m for the comparison process (Fig. 2). The hexagon tessellation algorithm is an encapsulated rule-set written in CNL and can be loaded as an additional segmentation (tessellation) process in eCognition (URL 1). The rule-set starts from a mesh of mid points of a hexagon grid based on a user defined hexagon size. Starting from these mid points the tool is applying an adapted region-growing algorithm for regular symmetric growth of objects. The result is a complete hexagon tessellation of the area of interest; border objects without a hexagonal shape are automatically deleted.

Figure 2. Grid segmentation (tessellation) with squared cells (middle) and hexagon cells (right). Each has a height per cell of 30m. Cell outlines in black, cell colors equal the mean gray values of the underlying image pixels.

2.2. Moving-window algorithms

Moving window algorithms or filter operations in position space based on equally shaped image object can be realized in eCognition by object lists or object arrays containing the centre object and all its neighbours. While lists can be used for filters which are independent from the objects' relative positions, arrays must be used if the position is relevant. We have implemented a mean-, a median and a stdev-filter, as well as a Sobel- and Laplace-Filter for a 3x3 respectively 6-hexagon neighbourhood (Fig. 3).

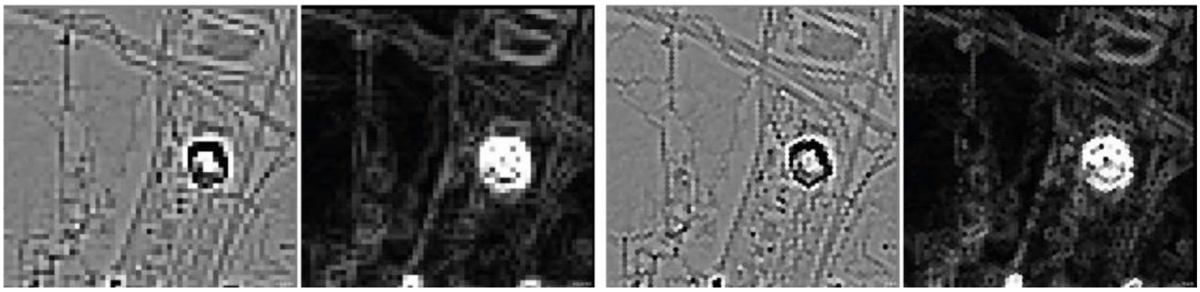

Figure 3. 3x3 resp. 6-hexagon neighborhood Sobel- and Laplace-Filter applied on 30m square grid (left) and hexagon grid (right).

2.3. Image segmentation

In order to investigate the impact of the elementary objects' form on segmentation algorithms we first applied a Multi Resolution Segmentation (MRS) starting from the object layer (hexagon/grid tessellations) and merged neighboring objects by their spectral difference in a second step. For comparison reasons we applied the same segmentation sequence on the original image data (Fig. 4).

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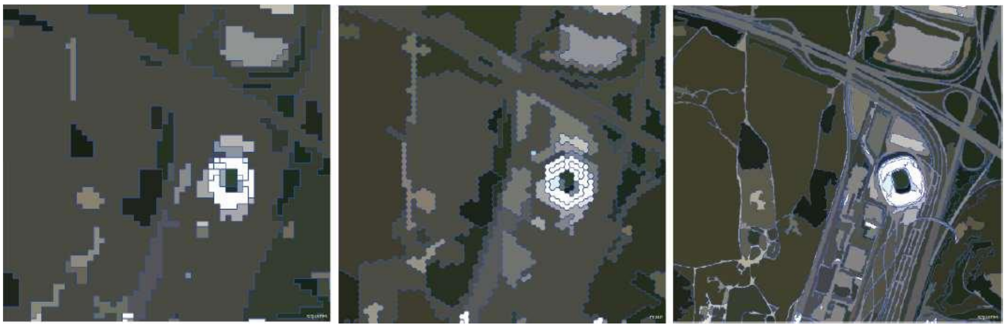

Figure 4. Segmentation results based on 30m squared grid cells (left), 30m hexagon cells (middle) and original 2m image data (right).

3. Conclusions

Hexagons can be used alternatively to standard squared pixels in order to image a given scene. They have several geometric advantages beginning from data handling and ending up with a better shape representation of image objects. In our ongoing research we investigate their behavior in the context of OBIA mainly for image segmentation, but also for spatial modeling. Our preliminary results show that hexagon based segments are capable to represent the image objects' shape better than pixel‐based segments of similar size. Especially linear features and round shaped objects are represented more precise by hexagon based segments.

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Useful links (accessed April 2014):

URL 1:
http://community.ecognition.com/home/hexagon_segmentation_enc.zip/view

