Graph-theoretic issues in remote sensing and landscape ecology

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Abstract

Graph theory came into existence early in the 18.th century as Leonhard Euler solved the Köngisberger-Bridge-problem. It is a mathematical branch that deals with relationships between objects (topology). A graph G(V,E) as defined in graph theory consists of a set of nodes V={v_i} and a set of edges E={e_i}. An edge connects two nodes and is thus defined by these two, e_i={v_k,v_l}.
Graph theory distinguishes between different types of graphs with specific properties, e. g. a *tree* which is a graph that contains no circles, i.e. between each pair of vertices exists exactly one series of edges that connects the two of them. *Planar graphs* are of special importance in remote sensing and landscape ecology. This set of graphs can be drawn on a plane without any edge crossing.

The topology of objects gained importance in the fields of remote sensing as well as landscape ecology. In remote sensing image analysis, graphs and graph algorithms are mainly used to solve segmentation problems, whereas in landscape ecology the graph was used primarily as a means of representing objects and their topology.

In landscape analysis graphs have several functions:

1. The representation and documentation of objects, e. g. the well-known node-edge-structure of GIS or CAD systems.
2. The automatic determination and delineation of landscapes from satellite images based upon land use, topography, and topology of landscape elements.

3. The evaluation of landscapes based upon spatial and topological indicators, which are important for environmental protection and landscape ecology.

The vectorised representation of objects according to item 1 is a typical planar graph with all its mathematical properties. However, in this case geometry plays an important role. The graph dual to a vectorised representation of object borders represents the topology of the objects. It is important to note that these graphs are parameterised graphs, i.e. the nodes and edges are attributed with parameters such as spectral parameters (spectral information from satellite images), spatial parameters (area, perimeter, fractality, etc.) and nominal parameters (land cover, land use, etc.).

A digital satellite image can be viewed as a graph, where the pixels represent nodes and edges exist between neighboured pixels. The process of image segmentation can be executed using this graph structure and graph theoretical methods similar to minimum spanning tree methods (Felzenszwalb, 98; Kropatsch, 95). Graph-based segmentation of satellite images leads to a partition of the image into landscape elements, such as patches and corridors, where the topology is implicitly stored in the resulting graph structure. However, in landscape ecology one is interested in groups of landscape elements defining a landscape unit. The automatic determination of landscape units from an already segmented image is termed metasegmentation and is applied to the landscape element graph. This metasegmentation may be performed using the same segmentation methods as for detecting landscape elements but this time on an irregular graph structure rather than on the raster structure of digital images.

Concluding, it can be stated that graphs represent a universal data structure that can be used for the extraction, representation and evaluation of landscape elements and landscape units.