An Object-based Methodology for Mapping Mires Using High Resolution Imagery

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Abstract:
Mire monitoring can be facilitated through a combined use of high resolution imagery and object-based mapping. We demonstrate a mapping methodology in which multiple scales of image-objects within a single aerial photograph are delineated through segmentation and, in a second step, heuristics are encoded to hierarchically link the image-objects. Through this linking, knowledge specific to the local mire ecology and its state of integrity is integrated into a hierarchical ‘rule base’. The recursive and hierarchical modelling of image-objects to ‘real’ objects, we hypothesize, allows us to capture ecological processes of interest better than pixel-based image analysis. We call the methodology multiscale segmentation / object-relationship modelling (MSS/ORM). We suggest that this expert-based methodology should transfer neatly to other international wetland monitoring programmes.

1. Introduction
Mires (bogs, swamps and fens) cover only 4.2 mill sq km globally (Mitsch, Mitsch & Turner, 1994). These unique examples of natural ecosystems are important as resources of pure water, peat and energy and only wise use of them can avoid their negative influence to global climate change and biological diversity. There has been an on-going dramatic decline in bog areal extent and condition in northern Europe. Restoration of bog sites is difficult and thus timely monitoring is needed to regularly assess conservation status. Mire mapping methods vary through-out Europe and are often site specific. The goal of our research is to develop a methodological guideline which could be modified to accommodate a variety of mire mapping needs, and scales. We seek a methodology wherein the mapping caveats are embedded transparently so that mapping can be contrasted between geographic location, earth observation data differences and through time.
2. Mapping Methodology

In ecosystems representations (e.g. aerial photographs), the patterns of homogeneity can be thought of as derivatives of the energy, matter and information gradients (Müller 1998) that churn in Nature. By Nature we refer to a self-organizing thermodynamically open (SOHO) system (Kay 1991) which is structured hierarchically, or holarchically, after Koestler (1967). This conceptualization of Nature is a useful guide to mapping methodology. Our mapping method is one of selectively partitioning images where strong local gradients (indicators of flux) occur, and then linking the resulting segmented image-objects via rules (Figure 1). These theoretical underpinnings open the door for the introduction of a multiscale approach (Hay et al. 2001). The methodology advocated here is an iterative 2-step cycle of image-object partitioning and image-object linking. Burnett & Blaschke (in press) call this multiscale segmentation/object-relationship modeling (MSS/ORM).

3. Study area: Männikjärve Bog, Estonia

Männikjärve bog, part of the large Endla mire system in Central Estonia, is situated on the southern slope of the Pandivere Upland. This bean-shaped, convex, raised bog (208ha, maximum peat depth 7.3m) is of limnogenic origin. The convex shape, the distribution of bog pines, and the presence of *Chamaedaphne calyculata* prove that it belongs to the East-Estonian type of bogs (Masing, 1982). The tree layer consists mainly of sparse pine (*Pinus sylvestris*) and only at the bog edges can true pine forest be found. In the bog interior, pines grow on ridges and are important components of the characteristic treed ridge-hummock-hollow-pool complexes. Dwarf shrubs and grass layers are made up of *Calluna vulgaris*, *Eriophorum vaginatum*, *Andromeda polifolia*, *Chamaedaphne calyculata*, *Rhynchospora alba*, *Oxyccoccus microcarpus* and *O. palustris*. Moss layer species include *Sphagnum fuscum*, *S. balticum*, *S. magellanicum* and *S. rubellum*. Some *Cladonia* species are quite common in places.

Männikjärve bog is relatively undisturbed. This is due to its conservation status: in 1981 the Endla Mire Reserve was created which in turn was promoted to a Nature Reserve in 1985 and in 1997 added to the list of Ramsar Sites. Human influence has, however, dates back to the beginning of 19th century (Vegesack, 1913) when the Männikjärve Lake water table was lowered approximately 50 cm. Between 1930 and the 1960s, small area in the north-eastern part of the bog was used by Tooma Mire Experimental Station for research purposes. A drainage network was created around the bog in 1930s. In the eastern neighbourhood of the bog, where area of minerotrophic fens occurred, drainage in 1938 changed wet lands into grasslands. Recently, tree cover inside Männikjärve bog seems to have become denser.
4. MSS/ORM Mapping

In the following section we describe the steps followed to segment and classify a 1:20,000 CIR aerial photograph covering the central part of Männikjärve bog (Table 1). In this paper we will discuss only a subset of the more important steps. For much of the analysis we used an object-oriented image analysis software called eCognition (http://www.definiens-imaging.com).

Table 1. MSS/ORM steps (using eCognition)

<table>
<thead>
<tr>
<th>Step</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Define sub-object and mapping level classes relative to adopted general mire classification (Masing 1982), our mapping goal, and data available (aerial photo)</td>
</tr>
<tr>
<td>2</td>
<td>Create new project in eCognition and load imagery</td>
</tr>
<tr>
<td>3</td>
<td>Create segments at lowest (holarchy level -2) and at sub-objects (holarchy level -1) (see table 3)</td>
</tr>
<tr>
<td>4</td>
<td>Classify the holarchy level -1 objects</td>
</tr>
<tr>
<td>5</td>
<td>Load mask of area ‘not-lake’,incl. ‘not-bog’</td>
</tr>
<tr>
<td>6</td>
<td>Refining classification with feature heuristics</td>
</tr>
<tr>
<td></td>
<td>- make super-level</td>
</tr>
<tr>
<td>7</td>
<td>Create segments at level 150</td>
</tr>
<tr>
<td>8</td>
<td>Semantic classification</td>
</tr>
</tbody>
</table>

Step 1. Defining the classification

We set up our classification based on Masing’s (1982) guidelines and our mapping goal: delineate and quantify pool complex expansion and forest encroachment. Since we can make full use of a hierarchical classification system (one of the benefits of doing multiscale analysis), we end up with a three tiered classification structure as show in Figure 2. The Sphagnum moss surface of Männikjärve bog is covered with plant species which can be differentiated by life form. For tree cover, discontinuous (sparse pine) and continuous (bog pine forest) assemblages can be separated. These objects differ from stands on mineral ground: they are lighter in tone because of the spectral contribution of sphagnum mosses. Birches are not common in bogs, however there are stands in vicinity of raised bog. In the north-eastern experimental area at the edge of the bog (drained and fertilized for scientific purposes 50-70 yrs ago), we find healthy birch stand mixed by some coniferous species. Dwarf shrubs are very common for Männikjärve bog. They occupy higher sphagnum hummocks (which often form continuous sets as ridges) everywhere, even under trees. Smaller cotton grass hummocks occur also on dryer places when compared with hollow sites, where lawn communities growing on wet sphagnum moss. Lawn communities situated between ridges are mainly represented by *Rhynchospora alba*. Sometimes they are covered with mud. Open
water is found around in sphagnum hummocks and in the large Männikjärve Lake. Where water is not deep, aquatic plants can grow and it is possible to see these features visibly in the picture. Some very narrow stripes of overgrowing areas on lake shore consist of floating mats which we call quaking mire.

**Step 3. Multiscale segmentation**

Once the data is loaded into the eCognition program, we do a first segmentation at an over-fine level, with a scale parameter of 10. It is important to understand that this scale parameter does not define a rigid constraint on the size of the resulting segments. Rather, it is a relative guide, and the conditions of local homogeneity/heterogeneity will determine the size and shape of the segments. We start with an over-fine segmentation because subsequent multiscale segmentations will refer to this layer (i.e. larger segments will be merged versions of these ones), and thus we save processing time. Then begins the really interesting part: we iteratively explore the boundary placement of segments at various higher image-object scales. We search for the parameter that provides us with image-objects which coincide with our understanding of real world ecological objects (as set out in our hierarchical classification system). In the end we chose the parameters listed in Table 2. The Level +1 is the final map polygons used to quantify change. Please see Figure 2 for a pictorial description.

**Table 2. Values within eCognition to segment the aerial photo**

<table>
<thead>
<tr>
<th>Holarchy level</th>
<th>eCognition level</th>
<th>Scale parameter</th>
<th>Homogen criteria Color</th>
<th>Shape</th>
<th>Smooth</th>
<th>Compactness</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>Level 1</td>
<td>10</td>
<td>0.8</td>
<td>0.2</td>
<td>0.9</td>
<td>0.1</td>
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<tr>
<td>-1</td>
<td>Level 2</td>
<td>30</td>
<td>0.7</td>
<td>0.3</td>
<td>0.5</td>
<td>0.5</td>
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<tr>
<td>0</td>
<td>Level 3</td>
<td>150</td>
<td>0.7</td>
<td>0.3</td>
<td>0.5</td>
<td>0.5</td>
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<tr>
<td>temp</td>
<td>Level 4</td>
<td>Class-based</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>+1</td>
<td>Delivered map</td>
<td>level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step 8 Semantic classification**

After spectrally classifying the image sub-objects (Step 4) and using spatial heuristics to further constrain how these sub-objects are classified (Steps 5-7), we undertake the crucial step in the multiscale analysis. With sub-objects appropriately identified, we can proceed to develop the rules that define the composition of the super object classes. For example, the “pool mire (PM) complex class” is defined by the percentage of deep water sub-objects. Thus if the amount of deep water sub-objects covers between 0 and 30 percent of the relative area of the super-object, the super-object will be classified as PM. Note that with eCognition, we can use fuzzy or crisp membership rules to assist with this rule-
setting. We used fuzzy membership and thus the rule-sets may overlap each other but the firing of the final classification decision will be decided in a fuzzy manner.

5. Discussion of methodology
The goal of this study was to introduce and test a mapping (and monitoring) methodology that utilizes standard aerial photography. Using the Männikjärve study area, our goal was to accurately map the pool mire complex extent and forest encroachment, as set out in a hierarchical classification system based on the work of Masing. We are satisfied with the visual result of this methodology and it is clearly more robust in mapping mire community assemblages than traditional pixel-based approaches. We are unsatisfied with some of the features of eCognition relating to the delineation of highly structured (patterned) super-objects. More research and development is needed to constrain the growth of some image-objects through scale. Our future plans are to conduct field surveys in July 2003 to further test the accuracy of the methodology and to devise new spatial rules. We are also actively experimenting with imagery from a mire in Austria (Wenger Moor), where we have a long times series of images and can thus examine the utility of the methodology for monitoring (our poster in Tallinn will show some of these monitoring results).

6. References
Appendix 1. Images

Figure 1. Iterative and intuitive two step methodology: segment then relate segments (multiscale segmentation / object relationship modelling or MSS/ORM). Super-objects are (a) hummock-dominated, and (b) ridge-pool complexes.

Figure 2. Object-based mapping of Männikjärve Mire (clockwise from top left): CIR aerial photograph; photo showing pool-ridge complexes; final classification; hierarchical classification structure; level -1 objects (segments) classified spectrally.