Semi-automated delineation of thematic maps with SCRM  
(Size-Constrained Region Merging)  

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ABSTRACT  
For decades, photointerpretation has been, and to a good extent is still, the method of choice for producing fine-scale forest and landcover thematic maps. Recent computer techniques have eased the task of the interpreter, who is now able to delineate polygons through on-screen digitization in a Geographic Information System (GIS) environment. Notwithstanding these advances, a good deal of craftsmanship is still required in the delineation. In an effort to contribute to the automation of this process, we introduce Size-Constrained Region Merging (SCRM), a recently implemented software tool that provides the interpreter with an initial template of the to-be-mapped area that has the potential to significantly reduce the manual digitization portion of the interpretation. In essence, SCRM transforms an ortho-rectified aerial or remote sensing (RS) image (single or multi-channel), into a polygon vector layer (in ESRI .shp format) that resembles the work of a human interpreter, whom without a priori knowledge of the scene, was given the task of partitioning the image into a number of homogeneous polygons all exceeding a minimum size. This layer may then be used as an initial template in the task of the interpreter, who now needs to aggregate (and sometimes correct) pre-delineated regions by simple drag-and-click operations. We provide background information on how SCRM works and illustrate its application in forest map updating.

INTRODUCTION  
Image interpretation is a complex cognitive process that is customarily used for producing fine-scale forest and landcover maps. Since significant research remains until fully automated RS image interpretation is achieved, the general approach should be a pragmatic one. As such, the short term goal, rather than trying to replace human interpreters, would be to support them in generating more timely, consistent and accurate products (Leckie et al., 1998). Therefore, new and or better tools are required that produce incremental improvements in these areas. They need not provide final solutions or 100% correct results, they simply need to be tools that are useful and that can be easily corrected when things, go awry. Specifically, they must be simple to apply, not require expensive equipment, not substantially alter the mapping workflow, nor involve inordinate fine-tuning by the interpreter (Leckie et al., 1998). In order to facilitate these requirements, we introduce our Size-Constrained Region Merging (SCRM) tool.

Essentially, SCRM transforms an ortho-rectified aerial or satellite image (single or multi-channel), into a polygon vector layer. This layer resembles the work of a human interpreter, whom without a priori knowledge of the scene, was given the task of partitioning the image into a specific number of relatively homogeneous polygons all exceeding a minimum size. This layer may then be used as an initial template in the task of the interpreter, who simply needs to aggregate (and sometimes correct) pre-delineated regions by simple drag-and-click operations. We note that SCRM results are only meant to be an intermediate aid for the work of the interpreter, since i) SCRM only considers radiometric features for the segmentation, and ii) the correspondence between radiometric similarity and semantic similarity is not straightforward. We also note that although the SCRM sequence includes procedures other than region merging, we named the algorithm after this condition because it is the most influential step.

The objective of this paper is to provide an overview of SCRM as a tool for assisted photointerpretation. We (1) briefly describe the SCRM workflow; and (2) illustrate with an example how it may be used as an automated delineation aid for computer-assisted photointerpretation.
SCRM WORKFLOW

SCRM source code was conceived and written by Dr Castilla in IDL® (ITTVIS, 2007a), and can be run either within the commercial remote sensing software ENVI® (ITTVIS, 2007b) as a user extension, or stand-alone in conjunction with the IDL Virtual Machine. In order to use SCRM, four parameters must be specified: i) the desired mean size of output polygons (DMS - in hectares); ii) the minimum size required for polygons, or minimum mapping unit (MMU - in hectares); iii) the maximum allowed size (MAS - in hectares); and iv) the minimum distance between vertices in the vector layer, or minimum vertex interval (MVI - in metres). MVI is an indication of the positional accuracy of boundaries and is internally used to define the working pixel size (i.e., spatial resolution). The default values of these parameters are shown in Table 1. We note that there are also some optional parameters, including the possibility to take into account both the internal texture of regions and the saliency of edges separating...
regions. With the latter option, merging of similar regions separated by a strong edge (like a narrow road separating two fields with the same crop) is precluded.

**Table 1.** Default values of SCRM input parameters for three common multispectral image-types, and suggested output scale for the final map product.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Minimum Mapping Unit (ha)</th>
<th>Desired Mean Size (ha)</th>
<th>Maximum Allowed Size (ha)</th>
<th>Minimum Vertex Interval (m)</th>
<th>Potential map scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quickbird MSS</td>
<td>0.01</td>
<td>0.06</td>
<td>0.30</td>
<td>5.0</td>
<td>1:10,000</td>
</tr>
<tr>
<td>SPOT MSS</td>
<td>2.50</td>
<td>10.00</td>
<td>50.00</td>
<td>20.0</td>
<td>1:50,000</td>
</tr>
<tr>
<td>ETM+ MSS</td>
<td>22.50</td>
<td>90.00</td>
<td>450.00</td>
<td>60.0</td>
<td>1:100,000</td>
</tr>
</tbody>
</table>

SCRM workflow is as follows (Fig. 1). The input image (previously ortho-rectified to some cartographic projection) is (if necessary) resampled to a suitable pixel size, and then filtered with Gradient Inverse Weighed Edge Preserving Smoothing (GIWEPS, Castilla, 2003). The output of this step is an almost piecewise constant image, from which the gradient magnitude is computed. This gradient magnitude image is then searched for local minima, and the area of influence of each minimum is contoured and labeled with the watershed algorithm. The resulting regions are then aggregated iteratively by increasing dissimilarity until they all exceed the size of the minimum mapping unit (MMU). Next, the labeled image containing the final partition is converted into a vector layer (Fig. 2). Further details can be found in Castilla et al., (2007).

**Figure 2.** Vectorization sequence in a sample partition. Left: raw vector. Centre: vector after spline interpolation. Right: final vector after Douglas-Peucker simplification. The vertices of arc AB are highlighted.

**EXAMPLE**

In this section we illustrate how a SCRM output vector layer may be used as an initial template for computer assisted photointerpretation. Before proceeding, the user should have a ‘feel’ for how ‘broken up’ the scene needs to be. For example, if we are interested in delineating forest stands with a 10 ha average size, a suitable Desired Mean Size (DMS) would be some 2.5 ha. In this way we would generate sufficient units to avoid excessive manual digitization in a latter stage. The Maximum Allowed Size (MAS) could be set to 10 ha, so that units larger than 20 ha would be rare, or left blank, if this is not a concern. The Minimum Mapping Unit (MMU) of the final map must be known in advance, or the user must recognize that any region below the default size will not be retained in the output partition, no matter how distinct the region is. The last SCRM input parameter, the Minimum Vertex Interval (MVI), can also be intuitively set. If there is no formal requirement, a good rule-of-thumb is the recommended digitizing visualization scale. For example, for a visualization scale of 1:10,000, a reasonable MVI would be 5 m, and 50 m for 1:100,000.
Fig. 3 shows a 1.4x0.92 km² sub-scene from a semi-natural landscape centred on Muskilda hill, a 50 ha forest near Estella (Navarra, Spain), covered by *Quercus faginea* trees and shrubs, and surrounded by vineyards, pastures and ploughland. The color composite (RGB bands 4, 3, 2) is a 2.8 m pixel Quickbird-2 multispectral image acquired in September 2004. This is the base image we will use in figures 4-6 to illustrate how SCRM may be used for photointerpretation.

Fig. 4 shows SCRM results for DMS= 1.5 ha, MMU= 0.5 ha, and MVI= 10 m (no MAS restriction). Imagine we want to compile a forest map with a minimum mapping unit of 2 ha. The partition produced from Fig. 4 SCRM-inputs would be too profuse for this purpose. In addition, it has units, like the 1.4 ha rectangular patch of scrub to the left of the forest (marked with an ‘A’), that even if they were densely populated by trees, would not qualify as forest in this map. Fig. 5 illustrates SCRM results for DMS= 6 ha, MMU= 2 ha, and MVI= 10 m (no MAS restriction). Here, the aforementioned scrub no longer constitutes a separate unit, as it is smaller than the MMU. Also, some regions now form part of a different aggregate than in the previous partition, like the small area marked with an ‘X’ in the right side of the forest in Figs. 4 and 5. In Fig. 4, this region had as its most similar neighbor, the scrub located below it. However, in Fig. 5, the bright barren area surrounding it has merged with some slightly darker agricultural fields, lowering the average brightness of the aggregate, while at the same time the scrub has merged with the (also darker) forest, so that now the most similar neighbor is the barren area instead of the scrub.

**Figure 3.** A 1.4x0.92 km² Quickbird-2 RGB 432 sub-scene showing Muskilda hill, a 50 ha oak forest that requires delineation.

**Figure 4.** SCRM result using the following parameters: DMS= 1.5 ha, MMU= 0.5 ha, and MVI= 10 m.
The partition of Fig. 5 is better suited than that of Fig. 4 as an initial template to delineate our forest map, since it has no unit smaller than the specified 2 ha MMU. Therefore, the basic operation is to manually merge connected regions that in our opinion are forests. In this example, this would be done in a few seconds (in any GIS with editing capabilities) by hold-clicking and dragging with the left mouse button over the polygons we want to merge as to select them, and then right clicking to confirm the merge. The rectangle shown in Fig. 5 represents an instance of such movement that would produce the merging of the eight polygons within Muskilda hill. Next, we would need to correct several small areas along the perimeter of the newly formed polygon that look similar to the forest but that are actually scrub with less trees than would qualify as forest (Fig. 6). This is the case of the two patches lying at both extremes of the lower half of Muskilda, and also of its NE corner (marked respectively ‘B’, ‘C’ and ‘D’). In addition, there is a gravel pit surrounded by a thin corridor of trees in the upper right half of Muskilda that we have decided not to retain within the forest because of the narrowness of the corridor. All these operations can be done with a stream digitizing tool that manually splits the undesired parts into separate polygons, where the latter would be subsequently merged to the surroundings using the above standard procedure. Finally, Fig. 6 illustrates how Muskilda forest would look in the final map. In this example, less than ten percent of the polygon (those arc segments that appear labeled) has been delineated manually.
FINAL REMARKS

In this paper we have introduced Size Constrained Region Merging (SCRM), a novel segmentation method that may be used for computer assisted photointerpretation. SCRM transforms a single or multichannel ortho-image into a polygon vector layer (.shp) that may be used by the interpreter as an initial template. SCRM may be applied to any kind of RS imagery (in geotiff, jpeg, or ENVI format), of any size (images larger than 2 Mpixel at working resolution are subject to tiled processing) and any number of channels. Typical processing time in a standard PC is less than two minutes per Mpixel. After having applied SCRM to many images, none of the output partitions produce a visual impression of a ‘bad segmented’ image. Furthermore, compared to other segmentation algorithms embedded in already available commercial software, SCRM is less demanding computationally; requires only intuitive input parameters that enable the user to explicitly control the level of cartographic generalization applied to the image (both the size distribution of polygons and the edge complexity); and tackles the fractal nature of landscapes and its hierarchical structure in a conceptually coherent manner. Moreover, SCRM is grounded on a solid conceptual basis (Castilla 2003), an asset that many segmentation algorithms lack. We advocate that SCRM can be of benefit to the natural resources mapping industry by increasing efficiency, consistency, and repeatability. Based on the success of current versions, we aim to commercialize SCRM by 2008, and welcome all interest.

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REFERENCES


BIOSUMMARY

Guillermo Castilla is a Spanish Forest Engineer (MSc from the Polytechnic University of Madrid, 1990) who specialised in Remote Sensing (PhD from UPM, 2003) with a fellowship from the European Space Agency (ESA, 1999-2000). He works in the development of theories and methods to automate the production of geographic information from remote sensing imagery. The approach he follows involves the design of new image segmentation and classification methods that operate at several scales, based respectively on image morphology and multicriteria decision-making theory. He moved to Canada in May 2006 as a Postdoctoral Fellow, where he joined the Foothills Facility for Remote Sensing and GIScience in the Department of Geography at the University of Calgary.