OBJECT BASED CHANGE DETECTION USING TEMPORAL LINKAGES

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ABSTRACT:
Change detection plays an important role in GIScience. Using appropriate methods of change detection allows us to observe, detect and analyse spatial processes which took place in the past. Furthermore, it enables us to understand processes in more detail, develop models and predict potential future situations. Remote sensing data as data source for change detection has the advantage of imaging the earth’s surface as is just using electromagnetic radiation. However, using remote sensing data as the basis for change detection has always been difficult since a lot of knowledge from image processing and remote sensing is necessary in order to detect and outline relevant changes. Space-temporal knowledge about the object categories to observe is necessary in order to determine which changes are the result of the natural space temporal behaviour and which are a relevant change. By linking image objects of images taken at different dates via the time axis it is possible in principle to observe and assess their space-temporal behaviour and to decide whether this behaviour is natural or relevant in terms of a change or not.

1. INTRODUCTION

1.1 Change detection
Change detection based on geo-data is certainly one of the most important and challenging tasks in the GIScience domain. Focusing on multi-temporal remote sensing data, change detection methods are used in order to point out and document changes relevant for diverse application domains. Typical examples of such applications are: mapping processes like urban sprawl, desertification or dry-out of lakes (Jat et al., 2008; TRIPATHY et al., 1996; Collado et al. 2002; Diouf et al., 2001). That is, when doing change detection with multi-temporal remote sensing data at least two images of a given region taken at different dates (t0 and t1) are compared and differences relevant for the application domain are mapped. For detecting changes over longer periods and with data measured at more than two dates (t0 … tn) the term monitoring is commonly used. In this context, a critical point for change detection using remote sensing data is to detect only the relevant changes.

1.2 Object based change detection
A rather simpler approach is to independently segment all images taken at t0, t1 or tn, virtually overlay them and identify corresponding image objects. However, this method presumes a spatial overlap of the temporal corresponding objects in order to establish a respective connection between them. Nevertheless, this way it is possible to observe and document the objects’ courses and to decide whether the observed behaviour is normal or a change.

2. METHODOLOGY

2.1 Image segmentation and object linkage
In order to perform an object based image analysis using linked objects it is necessary to generate image objects which are timely independent. That is, each image of t0, t1 and tn needs to be segmented independently. For this purpose we have been using the software eCognition 8.7 by Trimble Germany, which allows to segment images on several scale levels and additionally to link spatially coherent objects using so-called maps. Each map in this particular case represents a single date and image, respectively. The software even allows loading image sequences. It automatically generates for each time frame a respective map. The map concept can also be used to independently segment images of different sensors and link corresponding objects (fig. 1).
When linking objects of two different time frames the following principle relationships have to be considered:

1. Each object of time frame $t_0$ can be linked to one or more objects of time frame $t_1$ ($1:n$ relationship).
2. Several objects of time frame $t_0$ can be linked to one object of time frame $t_1$ ($n:1$ relationship).
3. Objects of time frame $t_0$ and $t_1$ can be linked pairwise ($1:1$ relationship).
4. Objects of time frame $t_0$ and $t_1$ can have no object linked in either $t_1$ or $t_0$ respectively ($1:0$ and $0:1$ relationship).

2.2 Multi-temporal image data

For our research we decided to investigate two different scenarios:

a) Detect changes in a pair of cohesive images of date $t_0$ and $t_1$.

b) Monitor the behaviour of objects in a series of images $t_0$ ... $t_n$.

For case a) we selected two small subsets of two LANDSAT scenes in the north-western part of Kyrgyzstan both depicting the Orto-Tokoy reservoir southwest of the lake Yssykol (Fig. 2) from 5$^{th}$ of July in 1993 and 20$^{th}$ of August 2001. For case b) we resort to a sequence of microscope images showing golgi organelles with a temporal resolution of 4s per frame (see fig. 3).
Figure 3: Sequence of microscope images from golgi organelles from. Top-left to bottom-right: t0, t4, t8, t12, t18 and t24 of 24 frames.

2.3 Linking objects in an image pair

To investigate object based change detection with image pairs (case a), we were loading the images as an image stack into the software and create respective maps representing the images of t0 and t1. We then segmented both maps independently using the multi resolution segmentation as described by Baatz & Schäpe, 2000). Each image then has undergone an object classification, whereas the classes waterbodies, vegetation and other non-waterbodies were created. We have then defined different linkage classes indicating the change on a class-level. Each linkage-class connects overlapping objects of the selected classes in the t0- and t1-image via the time axis. The degree of spatial overlap can be adjusted. This way, all dried out areas and all vegetated areas that have been waterbodies formerly can be identified (fig. 5).

This way, it is possible to identify corresponding image objects in t0 and t1 and to assess the amount of changing area per object by analysing the underlying pixels. Additionally, by linking corresponding image objects it is possible to analyse their changing shape. For example an object that has been classified as vegetation in t1 has been by one part waterbody and by another part vegetation in t0. Analysing the underlying pixels, we can determine the respective area ratios (Table 1).

<table>
<thead>
<tr>
<th>id</th>
<th>Class</th>
<th>Area at t0 [ha]</th>
<th>Area of unclassified at t1 [ha]</th>
<th>Area of waterbodies at t1 [ha]</th>
<th>Area of vegetation at t1 [ha]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>waterbodies</td>
<td>2046.14</td>
<td>1088.17</td>
<td>666.29</td>
<td>291.68</td>
</tr>
<tr>
<td>1</td>
<td>waterbodies</td>
<td>0.73</td>
<td>0.73</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 1: Example for change of area amounts per t0-object calculated on per-pixel basis.

By analysing the t1-objects we can determine the change of shape and position, although the outer border of the t1-objects are not coherent with the linked t0-object(s) (see Fig.5).

Figure 4: Linked objects in LANDSAT scenes. Left t0, red waterbodies. Right t1, green (top) waterbodies, green (bottom) non-waterbodies.

2.4 Linking objects in an image sequence

In order to process the microscope image sequence we were loading the sequence as a time series. This allows performing each image processing step equally on each frame. We firstly eliminated background and separated noisy areas from those which might be of interest (organelle candidates). In order to document the space-temporal behaviour of the organelles, they were sequentially linked. This means, only successional organelles classified in each frame were linked (Fig. 6).
3. RESULTS AND DISCUSSION

We were linking corresponding image objects in an image pair of different dates t0 and t1 in order to detect changes of properties (size and shape) and simultaneously spatially document the observed changes. Further, we took an example from biology for practical reasons to demonstrate the potential for calculating space-temporal features. For this example, we were calculating the mean speed (in pixels per second) for each organelle and the distance travelled in the sequence (Tab. 2).

Table 2: Results of analysing temporally inked image objects (microscope images). Each object with FID (unique ID for the whole sequence) belongs to a starting object in the first frame (t0_Obj_ID). The velocity is indicated by “v” and calculated in pixels per second.

4. CONCLUSION

Our results demonstrate the potential of multi-temporal object based image analysis using object links. We have demonstrated that it is necessary to consider four principal potential situations for temporally linked objects. Referring to the LANDSAT example in order to identify changes in many cases it might be necessary to have a clear space-temporal model of the desired object classes. In the case present it is not clear, whether the observed change is due to some natural behaviour or a true change in terms of a to-be-mapped change. The second example has demonstrated, that it is even possible to analyse complex dynamic processes using methods of object based image analysis. In order to separate different types of changes more accurately the temporal resolution of the image data used must be adequate. Especially for space-time modelling of object classes typical for Land Use and Land Cover (LULC) classifications and a reliable identification of changes temporal high resolution image data will be necessary.

REFERENCES


