Proceedings (GISRUK) Geographical Information Science Research Conference, Norwich, UK, pp 15-18, April, 28-30 2004.

Using Context to Repair Partial Occlusions in Topographic Data

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1. Introduction

This paper addresses the segmentation problem that frequently occurs in topographic information. This is where one topographic object (such as a *road* or *rail* bridge) obscures a segment of an underlying object (such as a *river*). A serious consequence of occlusions is that the obscured object is frequently divided into two apparently separate objects, eliminating the identity and integrity of the composite object. This is a particular problem for computational processing of topographic data, as the disunited segments can hinder any processing that is based on the composite object.

We describe a solution to this segmentation problem that does not require stereoscopic information, and instead it uses the local topographic context in which these problems arise. We describe how the CSM algorithm (O'Donoghue and Winstanley, 2001) is extended to identify "missing" objects, which are then re-instated to re-connect the partitioned object. Finally, we present some statistics that describe the performance of our algorithm on one topological data-sets provided by the UK Ordnance Survey.

2. Occlusions

Topographic maps are two-dimensional (2D) representations of three-dimensional (3D) information. Some of the information-loss inherent in this translation is acceptable, however crucial 3D information is frequently eliminated when creating the 2D description. Occlusions are one of the more obvious and serious problems caused by this translation, where one object obscures another and causes part of the obscured object to be omitted from the 2D map. This frequently results in the partitioned object being slit into two apparently independent objects.

A relatively minor class of occlusion involves one object obscuring a small portion of an underlying object, such as a building obscuring part of a land-parcel. This is not a serious problem as the presence of the obscured object is still recorded, though its extent may be reduced by the occlusion. A much more serious category involves completely obscured objects, whose presence is not detected because of the extent of the occlusion. A common source of occlusions in topographic maps involves bridges that conceal the presence of some underlying object (*roads*, *railways*, *rivers*, *canals* or *footpaths*). These occlusions can have a serious impact on the usefulness of a map, causing large objects to become split into apparently independent smaller objects. Automated processing of topological data is complicated by the lack on contiguity amongst the individual polygons of the larger object. Thus, an apparently trivial problem like giving a name to all segments of a river, becomes an exhaustive task of (manually) identifying the individual segments of the river and assigning the name to each turn.

These occlusions are a serious and ubiquitous problem, particularly for maps derived from aerial or satellite imagery. One solution to detecting and repairing these occlusions is to use stereoscopic images. However this can be a complex task requiring the retrieval of the appropriate image pair, feature identification and registration to perform height calculations and using the height disparity as a basis for identifying occlusions (Hartley and Zisserman, 2000). However, this still leaves us with the problem of identifying the boundaries and categorisation of the partially occluded object.

Alternate approaches to completing partially occluded objects have investigated the use of symmetry within the occluded object (Zabrodsky *et al*, 1990). Another approach has been adopted to deal with partly occluded buildings (Englert and Gülch, 1996), but this is based on a complex geometric matching. As far as the authors are aware, there has not been any work on repairing occlusions in topographic data.

3. Finding Problematic Structures

We present an alternate solution to this problem, one that does not require stereoscopic images. We utilise the local topographic context within which segmentation problems arise. This solution builds on our previous work with the Cartographic Structure Matching algorithm - CSM (O'Donoghue and Winstanley, 2001) which has been used for topographic tasks like classification and error detection (O'Donoghue *et al*, 2003). The CSM algorithm adopts a Case-Based Reasoning (CBR) approach (Kolodner, 1993), which has been successfully applied to a broad range of industrial and other problems. The basic philosophy behind CBR is to see if the presented problem is similar to a recorded problem, and if so a previously stored solution is re-applied. CBR applications consist of two core components. One is a Case Retrieval algorithm for identifying past solutions, and the other is an easily modifiable collection of previously recorded solution (the Case Base). Extending the Case-Base allows novel problems to be solved without modifying the core retrieval algorithm.

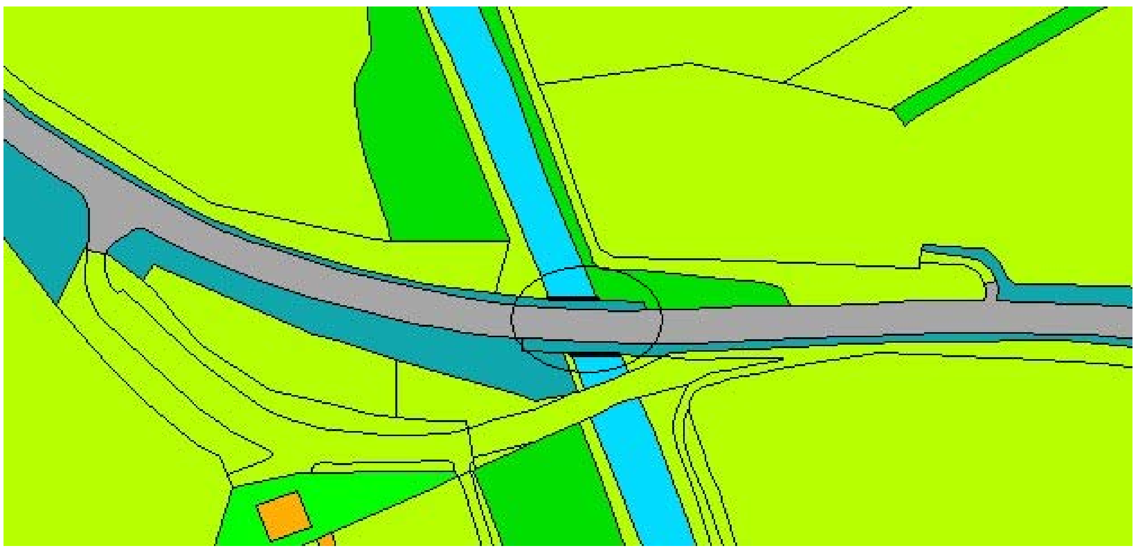

Figure 1. A river (running top to bottom) is segmented by a road (running left to right). The edges of the occlusion are highlighted.

CSM first generates descriptions of the topological context of every targeted polygon. In this paper we focus on polygons that segment other polygons – namely objects from the themes: *road*, *footpath*, *rail*, *inland waterway*, and *structure*. This is because each instance of these polygons can potentially obscure another object. The topological context of these polygons is recorded, which describes this objects relationship to each neighbouring polygon, as well as the relationships between each pair of neighbouring polygons. Two distinct relationships describe this local topology, one signifying that the two polygons share a boundary, and the other signifies that the polygons meet at a vertex (as occurs when two polygons are diagonally opposite each other). Collections of these relationships, together with the theme of each object, represent the structure of the local region.

Having described the context of all targeted polygons, we now wish to identify which of these correspond to occlusions. The Case Base was populated with the following seven descriptions of structures that cause partial occlusions (these cases were derived by manually examining the topographic data). CSM tests for isomorphism between the map data and any of the following Cases, and it is only when such isomorphism's are identified that occlusions are identified and the repair mechanism is invoked.

i) Road over River
ii) Structure over River
iii) Rail over River
iv) Road over River

v) Rail over Road
vi) Path+road+path over River (ie a road plus adjoining footpaths crossing a river)
vii) Path+road+path over Rail

Interestingly, these topological descriptions ignore the size, orientation and description of the individual polygons involved. The only influence that an individual objects size has on the test results that are discussed below, is via a single filter that was added to the otherwise purely topologically driven process. This filter restricts the length of the occlusions that were considered.

When the appropriate structures were identified, the process of asserting an "occluded object" is in fact, quite straightforward. The two line-segments representing intersection between the occluded and occluding polygons are calculated (see Figure 1). These line segments are connected to form a polygon, whose theme (road, rail *etc*) is determined from the occluded object. This new polygon is added to the topographic database, rejoining the previously segmented object.

4. Results

Tests were performed on the Moffat topographic database containing over 11,000 polygons covering an upland region. This data contained a river that repeatedly crossed under a major road than ran beside a rail line, including several tributaries that interacted with more minor roads. There were also a number of *structures* that transected the river. Each of these occlusions partitioned the underlying object.

A total of 55 occlusions were identified across the seven categories listed in section three above. The details of the tests are listed in Table 1. Manual inspection of the map allowed us to determine the accuracy of our technique.

Scenario	***Number of Occlusions***	***Accuracy***
Road over River	20	85%
Structure over River	16	100%
Rail over River	0	100%
Road over River	3	66%
Rail over Road	4	50%
Path+road+path over River	12	58%
Path+road+path over Rail	0	100%

Table 1. - Results obtained from the Moffat dataset

These results indicate that the technique is very promising overall. The results for "Path+raod+Path over river" of 58% would have been far higher but for a single structure that caused significant difficulty. This generated a number of "false positives" – bridges that should not have been generated. In fact, this revolved around a single misclassified polygon in the original data.

5. Conclusion

We adapted the CSM algorithm to identify partially occluded objects from a topographic dataset, without the use of stereoscopic information. This uses a Case-Base describing local structures of topographic objects, which represent situations of occlusion. These specific structures were identified on a topographic dataset and then passed to the repair phase to re-insert the missing polygon segment, rejoining the segmented object. Results obtained from initial tests are presented and discussed. We briefly investigate some additional filters that examine features of the individual polygons, to refine the structure matching process.

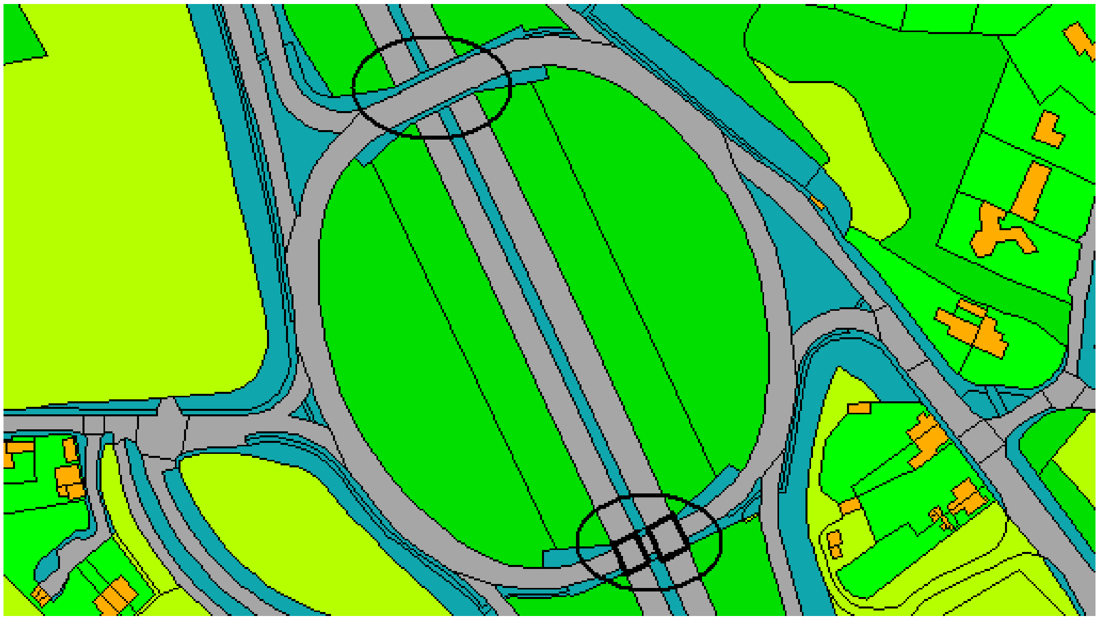

Figure 2. The road running from top to bottom was originally segmented by the roundabout (depicted on top of this figure). Adding additional “occluded” road segments (highlighted at the bottom of this figure) reconnects the original road segments.

6. Acknowledgements

Glen Hart and The Ordnance Survey Research Centre, Southampton, UK. Leo Mulhare, Department of Computer Science, NUI Maynooth.

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Biography

Diarmuid O’Donoghue is a lecturer in the Department of Computer Science, whose primary interest are in machine learning, analogical reasoning, case-based reasoning and GIS. A particular focus lies in applying cognitive modelling and case-based reasoning techniques to geographical data.