Automatic Determination of GIS Boundaries from Satellite Imagery

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Automatic interpretation of images by computers is one of the oldest and most eagerly sought objectives in the history of computing. The true power of the human mind is clearly revealed by its ability to easily perform visual interpretation tasks that are exceedingly difficult for computers. Yet the desire to use computers for these tasks persist because of computers' ability to handle vast quantities of data quickly and without becoming bored.

The prospect of using computers to automatically update GIS data from satellite images is attractive for obvious reasons. Information updates would no longer have to wait until the need was compelling enough to devote human resources to the tedious process. Changes in the geographic information could be monitored over very short time scales, potentially down to the order of hours. This drastic change in the currency of the GIS could lead to many new and exciting applications.

The image processing team of Manaaki Whenua – Landcare Research at Gracefield have begun a long-term project aimed at solving some of the many problems that computer interpretation of satellite imagery presents. In particular, we have been investigating algorithms to automatically identify visible edges in satellite images of New Zealand. Eventually we expect to be able to detect a variety of land usage boundaries in different kinds of satellite imagery, but in the early stages of the project we have focused on a simple boundary problem, that of finding coastlines, and concentrated on a single type of satellite imagery, synthetic aperture radar (SAR). The algorithm we have developed for this application performs quite well, and we are optimistic that it will meet with similar success when modified for finding different types of boundaries in other kinds of satellite imagery.

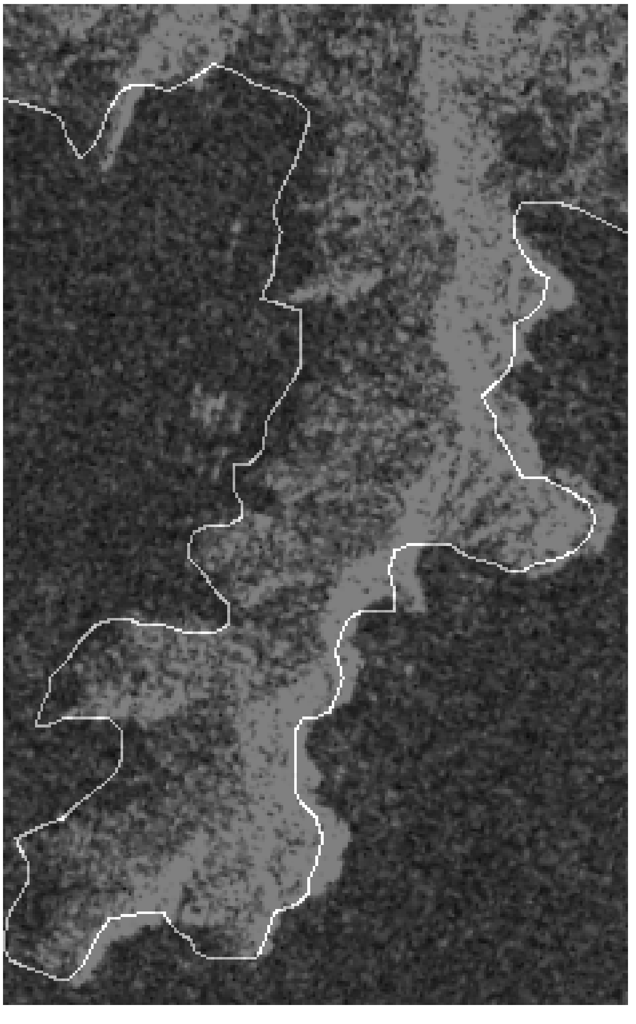
The algorithm we have developed rests on a sound understanding of the nature of SAR imagery. We have developed a filtering algorithm that takes into account the speckle noise process and reduces the noise and sharpens edges in the image simultaneously. The enhancement provided by this filter greatly simplifies the task of finding significant edges in an image using conventional computer edge detection algorithms. This new filter design is also capable of operating at multiple scales; that is, the size of the filter can be varied depending upon whether we wish to find fine details in an image or limit our search to the longer, most clearly defined edges. This is important because we have found that information from multiple scales may be integrated to greatly improve the accuracy and precision of the edge recognition algorithm.

The first step in this process consists of filtering the original SAR image with the custom filter with a progression of different sizes. Each of the resulting images is then subjected to a standard edge detection process (Canny edge detection). The resulting "edge maps" consist of grey levels at each pixel indicating the likelihood of an edge being located at that point. These edge maps can be considered to be an "ensemble" that progresses from coarse, well-defined edges at the largest scale to detailed but noisy edges at the finest scale. The next step in the edge finding process is to successively "adapt" the well-defined edges at the coarsest scale to the more detailed edges of the next finest edge map in the ensemble. This process is carried out by computing the "gravitational forces" exerted by the finer edge map on the points in the coarser edge map. By repeating this procedure for all the images in the edge map ensemble, a detailed map with few spurious edges is produced.

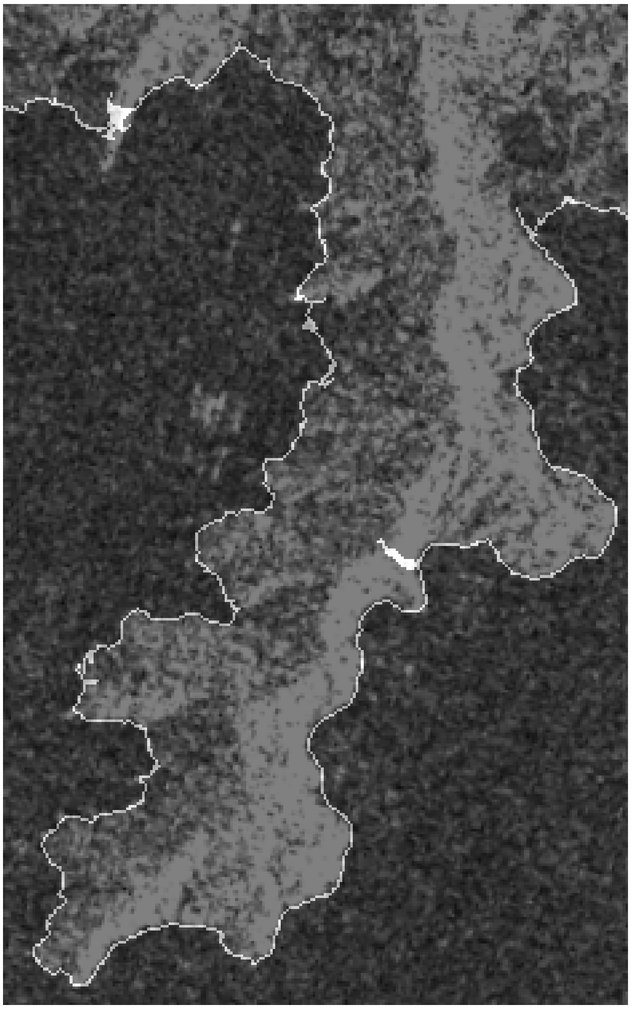
The gravitational attraction algorithm can also be used to update existing boundary maps by allowing the old boundaries to be attracted to the boundaries found by the edge detection algorithms. The advantage of this technique is that much of the uncertainty over the existence of an edge in a vicinity is eliminated. The major disadvantage is this technique is not capable or introducing new edges that appear in the image but not in the old map, and edges that do not appear in the image may or may not be appropriately removed. These issues will be the subject of future research on this project.

An example of the results of our algorithm is illustrated below. The image on the left shows a SAR image taken with the Japanese JERS-1 satellite of a portion of Port Underwood in the Marlborough Sounds, with the existing coastline data overlaid. There is a slightly displacement to the left of the coastline in this image. On the right, the results of our algorithm starting with the coastline shown on the left. In areas where the boundary is distinct in the image, the algorithm has performed very well. Two particular situations cause problems, however. One is where the boundary is indistinct; it is not surprising that if a human finds the exact coastline difficult to delineate that the computer is likely to have trouble as well. The second problem area is where the original coastline lies close to a ridge line or other distinct edge in the SAR image that does not correspond to the coast. In this situation it is obviously very difficult for the computer to determine that it has found the "wrong" edge in the image.

Our results indicate that automatic updating of GIS boundaries using computer image analysis is no longer a distant goal, but may be achieved with appropriate levels of accuracy in the near future.



SAR image with old coastline overlaid.



SAR image with updated coastline overlaid.

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