Effect of Scale on the Information Content in Remote Sensing Imagery.

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I. Introduction

Over the next few years a large number of satellites designed to image the earth's surface will be launched. These satellites, quite commonly, will have a large range in spatial as well as spectral resolutions. The potential for users to become overwhelmed, not only by the quantity of data, but also by the problem of multiple pixel sizes is very real. Second, individual platforms and sensors will have the ability to image at multiple resolution simultaneously. It may therefore be useful and necessary to integrate, or fuse, the images from a number of sources into a single data set.

The approach taken in this study is that high resolution data should be degraded when fused with coarser data, rather than the more common approach of "sharpening" coarser imagery. This approach is at odds with the more common attitude but conforms with the generally accepted notion that one cannot introduce detail into a generalized data set.

II. Research Questions

A number of research questions can be developed as a result of the anticipated increase in the number of sensors. These include:

- Do we need to collect data at a variety of scales or can we collect imagery at a single resolution and degrade the data set to the desired resolution?
- Can we incorporate more relevant information into a pixel which has been upscaled (degraded) than one which has been collected at coarser scales?
- Can we combine the data collected by multiresolution sensor packages, such as MODIS, into a single image?
- Is it reasonable to collect data at a certain scale/resolution for process models generated at an entirely different resolution?

III. Project Description

A project was developed to address the research questions outlined above. This project has a number of objectives. These include:

- the assessment of resampling strategies for upscaling;
- the assessment of changing information content of varying resolution remote sensing imagery;
- automated cartographic generalization coincidental with image upscaling;
- the development of expert systems to help resolve scale/resolution/application questions.

Multiresolution, multi sensor data been collected over three separate forested sites on Vancouver Island, British Columbia. These sites represent a range of oldgrowth and regeneration conditions. Two of these sites are located on the west coast near Tofino. The first site, located on Flores Island, is covered by an unmodified oldgrowth west coast temperate rain forest. The species composition is dominated by both Western Red-cedar (*Thuga plicata* Donn *ex.* D. Don in Lambert) and Yellow-cedar (*Chamaecyparis nootkatatensis* [D. Don in Lambert] Spac). The second site, centered on Tofino Creek Watershed, is substantially drier, and has a greater elevation range, extending above tree line (approximately 1000m). The species composition is dominated by cedar (both Yellow- and Western Red-cedar) with lesser quantities of Sitka Spruce (*Picea sitchensis* [Bongrad] Carriere). There is substantially less precipitation at this site so that the similarly aged trees are significantly smaller than at the Flores Island site. Also there has been a substantial amount of clearcutting and regeneration yielding a range in forest stand age classes. Both the Flores Island and the Tofino sites start at sealevel The third site is located on southeastern Vancouver Island in the Sooke Watershed. This is a substantially drier site that the previous two. As a result the predominant species is Coastal Douglas Fir (*Pseudotsuga mensiesii* [Mirbel] Franco) with

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minor inclusions of Western Hemlock (*Tsuga heterophylla* [Rafinesque] Sargent [T. Mertensiana (Gordon) Carriere]) and Western Red-cedar. Logging activities, as well as an active fire history over the past 50 years has resulted in a range of age classes from less than 10 years to oldgrowth greater than 160 years. The topography in this site is less rugged than the coastal sites with a relief of less than 500 metres.

The remote sensing data collected for each of these sites is itemized in Table 1. The data collected over the three sites represents three seasons of imaging. The first was 1993 when AVIRIS and MEIS data were acquired for the Sooke and Tofino sites. Landsat Thematic Mapper data from those years were also acquired. During the second season, 1994, AVIRIS data were acquired over the Flores Island site. The third season was summer 1996 when CASI data were flown over the Flores Island site.

Table 1

Flores Island
1 m. Orthophoto (pan)
2 m CASI (15 bands)
4 m KFA1000 (pan)
10 m SPOT (pan)
20 m SPOT (4 bands)
20 m AVIRIS (224 bands
30 m Landsat TM (7 bands)
50 m Landsat MSS (4 bands)
1000 m AVHRR (5 bands)
Tofino Creek
1 m. Orthophoto (pan)
4 m MEIS (8 bands)
4 m KFA1000 (pan)
10 m SPOT (pan)
20 m SPOT (4 bands)
20 m AVIRIS (224 bands
30 m Landsat TM (7 bands)
50 m Landsat MSS (4 bands)
50 m MAS (11 bands)
50 m AOCI (11 bands)
1000 m AVHRR (5 bands)
Sooke
1 m. Orthophoto (pan)
1 m MEIS (8 bands)
20 m AVIRIS (224 band)
30 m Landsat TM (7 bands)
50 m Landsat MSS (4 bands)
1000 m AVHRR (5 bands

IV. Project Components

To achieve the stated objectives, a number of different facets are being undertaken. These include:

1. Evaluation of a number of approaches to upscaling (resampling);
2. Assessment of the information transfer between images;
3. Generalization of cartographic products to reflect the varying scales.

1) Upscaling:

A number of different approaches to degrading the resolution of remotely sensed data are being assessed. These include the more traditional approaches commonly incorporated into the image processing packages: nearest neighbour, bilinear interpolation, cubic convolution and nonoverlapping averaging. In addition we are investigating the potential of using a variance based approach (4) which works on the premise that there are scene objects which are not all the same size. This is in contrast with the approach outlined by Woodcock and Strahler (6) whose assumption was that an optimal pixel size could be identified to represent for objects. This project recognizes that forest objects (including trees as well as areas with shrub and herbaceous cover and no cover at all) are represented by varying sizes, so that a representative pixel size may not be realistic.

2) Assessment

The upscaled images created by applying the various resampling methods will be assessed through the application of a number of strategies. These include global methods such as the Wald-Wolfowitz test (1, 5), a nonparametric test used to assess the degree of randomness, or the existence of spatial trends, in a sequence of numbers or pixels. This test does not address the image qualities, or give an impression of local variations within the image. Histogram moments were used to achieve this local evaluation (3) The moments are defined as:

$$\mu_n(z) = \sum_{i=1}^{L}(z_i - m)^n p(z_i),$$

where $p(z_i)$, i=1,2,3,...,L for the corresponding histogram, where L is the number of distinct histogram values, and n is the moment. The mean pixel value (m) is defined as:

$$m = \sum_{i=1}^{L} z_i p(z_i)$$

The second moment, variance, is especially important in that it relates to the contrast within the kernel. The third moment is a measure of skewness, while the fourth is the relative flatness, or kurtosis.

To investigate the degree of similarity between images of varying resolutions, the use of a Principal Component Analyses is being investigated. In the cases where the degraded images do not change substantially a high correlation between the images is encountered. Where the images have experienced a substantial degree of change there will be less redundancy.

An alternative assessment strategy will be to segment the images into individual forest objects at the highest resolution, and track the statistical characteristics of the objects with decreasing spatial resolution. This will also allow for the effective application of spectral unmixing in the image and the investigation of the statistical behaviour of the objects with changing resolutions.

The images that will be evaluated will include the resampled images as well as the images collected at similar resolutions but by different sensors. The correspondence of the images is being assessed.

A final assessment as to correspondence will be in the classification accuracy of the various images generated. The class resolution as well as classification accuracy will be investigated. The classifications will be based on and compared to the Forest Inventory and ecological land evaluation maps for the study areas.

3) Cartographic Generalization

In an effort to develop maps which are representative of the various resolutions being produced, or processes being modeled, a cartographic generalization strategy has also been implemented in ARCINFO. The intent is that thematic maps originally produced at scales of 1:20,000 will be generalized to representative scales of 1:50,000, 1:100,000, or 1:250,000. Three cartographic issues have being addressed: polygon size, class definition, and line generalization.

- Polygon size: a minimum polygon size that will be cartographically reproduced can be specified. This is operator specific but should follow standard cartographic protocol.
- Class definition: as the scale of the map changes, so does the label that can represent the cover class. Smaller scales will have a less detailed class definition.
- Line generalization: as the cartographic scale becomes smaller the number of points used to define boundaries and features become fewer as the level of detail decreases. The generalization approach adopted for this study allows for the reduction of points according to the Douglas and Poiker (2) method.

V. Conclusions

The project that has been described addresses some of the issues relevant to the successful fusion of multiscale and multi resolution data sets. The results of the study will enable the user of multiresolution data to merge these data using the most appropriate procedures possible.

VI. References

[1] Chen, R., D.L. Jupp, C.E. Woodcock, and A.N. Strahler (1993) Nonlinear estimation of scene parameters from digital images using zero-hit run-length statistics. IEEE Trans. Geosci. Remote Sens. GE-31:735-746

[2] Douglas, D. and T. Poiker (1973) Algorithms for the reduction for the number of points required to represent a digitized line or its caricature. *The Canadian Cartoigrapher*, 10:112-122.

[3] Gonzalez, R.C. and P. Wintz (1987) Digital Image Processing. Addison-Wesley publishing Company. 503pp.

[4] Hay, G.J., K.O. Niemann, and D.G. Goodenough Spatial Thresholds, Image-Objects and Upscaling: A Multi-Scale Evaluation. (Accepted and in press) Remote Sensing Environ.

[5] Marceau, D.J., P.J. Howarth, and D.J. Gratton (1994) Remote sensing and the measurement of geographical entities in a forested Environment. 1. The scale and spatial aggregation problem. Remote Sensing Environ. 49:93-104

[6] Woodcock. C.E. and A.N. Strahler (1987) The factor of scale in remote sensing. Remote Sensing Environ.21:311-332

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