IMAGE ANALYSIS TOOLBOX AND ENHANCED SATELLITE IMAGERY INTEGRATED INTO THE MAPPLACE

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INTRODUCTION

The Image Analysis Toolbox and Enhanced Satellite Imagery, integrated into the MapPlace project of the BC and Yukon Chamber of Mines' Rocks to Riches program, is a merging of two initial proposals. The two projects, though different in purpose shared common data and their results could be distributed through a common method, the MapPlace.

The "Image Analysis Toolbox" project developed and implemented an image analysis capability for the MapPlace and was delivered by Cal Data Ltd. The Toolbox is a framework in which a variety of multi and hyperspectral imagery can be added and processed online by end users. The results of the analysis are georeferenced and can be completely integrated with the information already contained in the MapPlace.

The "Enhanced Satellite Imagery" project produced a series of enhanced Landsat images which facilitate structural interpretations and was delivered by McElhanney Consulting Services Ltd. These images are integrated into the MapPlace so all existing information contained in the system may be referenced to this new set of imagery.

The same Landsat imagery used in the "Enhanced Satellite Imagery" project has been incorporated into the "Image Analysis Toolbox".

IMAGE ANALYSIS TOOLBOX

Purpose

The Image Analysis Toolbox (IAT) was developed to be a system that could hold multispectral and hyperspectral imagery, analyze the imagery and display it through the MapPlace. A suite of initial analysis tools have been provided but the system is designed to be able to incorporate unlimited additional analysis tools. The IAT was added to the Exploration Assistant page of the MapPlace. The appearance and operation of the IAT was designed to maintain the general look and feel of the Exploration Assistant. The purpose of the Toolbox is to provide the ability for MapPlace users to experiment with a variety of imagery and analysis procedures in their search for exploration targets.

Imagery

Twenty Landsat 7 and five ASTER multispectral images and one AVIRIS hyperspectral image have been included in the IAT. All three sets of imagery were available at no cost. The Landsat and ASTER imagery were available orthorectified in UTM NAD83 projections. The AVIRIS image was simply geopositioned in approximately the correct geographic position. The Landsat and AVIRIS images were obtained from the Geogratis website (http://geogratis.ca) and were from their "Landsat 7 Orthorectified Imagery Over Canada" series and a single hyperspectral image example of the Canal Flats area. The ASTER images were obtained from a NASA website (http://asterweb.jpl.nasa.gov) and were obtained from their "DataPool @ LP DAAC" offering of free imagery over the United States. Both these sites provide extensive descriptions of the imagery and its uses. The images used in this project and many more are available as free downloads from these two sites.

The IAT utilizes 6 of the Landsat bands and 14 of the ASTER bands and 223 of the AVIRIS bands. Table 1 lists the bands, their wavelength range and ground sample spacing for Landsat and ASTER. The AVIRIS band centre wavelengths are available from the selection boxes in the Image Analysis Toolbox. All sets of imagery contain radiance measurements. In the future the imagery could be atmospherically corrected to provide reflectance measures that could be compared more successfully to laboratory spectrum for individual ground features. All ground features reflect or absorb solar electromagnetic radiation at different levels across the spectrum. The reflected electromagnetic energy is what is measured by these three sensors. Some of the energy is in the visible light range and provides the colours we see. A large part of the reflected energy is invisible to the human eye but can be measured with these sensors. These three instruments measure energy in the near infrared (NIR),

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shortwave infrared (SWIR) and thermal infrared (TIR) region of the spectrum. A library of reflectance spectrum for common minerals, rocks, soils and man made materials can be viewed online at the ASTER homepage at the address given above.

BAND	WAVELENGTH	GROUND SAMPLE DISTANCE
L1	.450 - .515	30
L2	.525 - .605	30
L3	.630 - .690	30
L4	.775 - .900	30
L5	1.55 - 1.75	30
L7	2.090 - 2.35	30
L8	.52 - .90	15
A1	.52 - .60	15
A2	.63 - .69	15
A3	.76 - .86	15
A4	1.6 - 1.7	30
A5	2.145 - 2.185	30
A6	2.185 - 2.225	30
A7	2.235 - 2.285	30
A8	2.295 - 2.365	30
A9	2.360 - 2.430	30
A10	8.125 - 8.475	90
A11	8.475 - 8.825	90
A12	8.925 - 9.275	90
A13	10.25 - 10.95	90
A14	10.95 - 11.65	90

TABLE 1. AVAILABLE LANDSAT (L) AND ASTER (A) BANDS, WAVELENGTHS RANGE AND GROUND SAMPLE SIZE.

Knowing the range of the spectrum that each sensor band samples allows one to develop various combinations of the bands that can differentiate between materials on the ground. There is a vast resource of information on remote sensing and image analysis in the literature and on the WWW. A simple search with one of the common search engines will yield a large number of articles describing past experiences using these three sensors to identify features on the ground. Texts such as those by Vincent, (1997) and Lillesand and Kiefer, (2000) provide excellent geology and mineral exploration examples plus a thorough description of the technology.

System

The IAT system was developed using a variety of Commercial Off The Shelf (COTS) software and standard web-based languages such as HTML and JavaScript. The Autodesk MapGuide® Server by Autodesk® is the software that serves many types of spatial data out over the Internet to form map views on the client's computer screen. The MapGuide® Viewer resides on the client's computer and in association with an Internet browser accepts the data sent from various MapGuide® Servers and fabricates the map image as well as providing an Application Program Interface (API) which can be accessed by client-side JavaScript to perform local functions. ColdFusion® by Macromedia was used to generate dynamic web pages, write specialize files for backend processing and access databases. ION™ (IDL ON NET) from Research Systems, Inc. was used to provide the image analysis capability and provide the resultant imagery to the MapGuide® server. IDL® is a specialized image and signal processing language which is used extensively in secondary products related to all types of image processing.

Operation

This section describes the operation of the system from the client's perspective. The image index page is described followed by brief descriptions of the 5 analysis tools. Many of the IAT's functions are common to the individual tool pages and the index page. They will be described as they are first encountered.

INDEX PAGE

Upon selecting the Image Analysis Toolbox by clicking on the appropriate button in the right-side panel of Exploration Assistant a new panel labeled "Image Analysis Toolbox" will appear and several new layers will be added to the map. Depending on the viewing scale of the map either Landsat, ASTER and AVIRIS images or their outlines will be visible. At a scale larger than 1:6 000 000 the images will become visible. The images are presented as a stack of images, often overlapping each other. The ASTER, Landsat and AVIRIS related layers may be toggled on and off with the buttons in the right-side panel. The ASTER group of images will always overlay the Landsat image group and the AVIRIS image overlays all the other image types. To view an image that is partially covered simply, select the image by a single click on the image with the arrow cursor. Then click the "Bring to Top" button and the desired image will be brought to the top of the stack of images. Only one image can be brought to the top at a time. Use the "Clear Selection" button to deselect an image. One can return to the original image stack order by clicking the "Original Order" button. If a particular image cannot be selected with the cursor because it is completely overlain by other images it can be selected by using the MapGuide Pop-Up menu selection option. Simply right mouse click on the map to bring up the Pop-Up menu, then proceed to Select >

Select Map Objects… > then highlight ASTER Analysis Areas or Landsat Analysis Areas and select the desired image number. As there is only one AVIRIS image at this time there is no reason to use this procedure for AVIRIS. The image will then be highlighted on the map and one can proceed as if it were selected with the cursor. The images focus automatically as one zooms in and out but they can be sharpened at anytime by clicking on the "Focus Image" button.

At any time any of the map layers in the left-side legend may be turned off or on or the user may return to one of the other Exploration Assistant tools.

To proceed to the analysis of an image the image must be selected as described above and then the "Analyze Image" button clicked.

IMAGE ANALYSIS TOOLS PAGE

The Image Analysis Tools Page provides a selection of analysis tools in the right-side panel or the opportunity to return to the Exploration Assistant. The map window is centered on the selected image. The map projection is now UTM where the projection of the Image Index map was BC Albers. All analyses are performed using the UTM projected data. Follow the instructions in the lower window, *WAIT* until the image has fully loaded. As instructions and data are flowing over the Internet it is possible for some of either to be lost if the user does not wait for each task to complete. When the image has loaded and the system is ready to proceed the lower window will contain some image information such as the system's tracking number for the image, the image's acquisition date and time and a link to the source of the image. The source link for all sets of imagery provides download access to many more images and a thorough description of the imagery and potential uses. The user may zoom into any portion of the image and turn on any of the available map layers contained in the left-side legend. To proceed to an analysis tool simply click on the appropriate button and that tool panel will appear in the right-side panel.

ONE-BAND ANALYSIS

The One-Band Analysis tool provides the ability to examine the readings of a single image band (electromagnetic spectrum range) contained in the image. The "Band" selection box allows the user to select any one of the available bands. The band number and the band's wavelength are displayed in the selection box. Once the desired band has been selected a point of interest may be selected on the main image. To digitize a point of interest first click on the "Digitize Centre of Interest" button and then click on the desired position in the main image. An overlay image will be prepared and sent to the map centered on the digitized point. A histogram equalization stretch is applied to the analysis overlay to provide good contrast of the range of values contained within the analysis area. Initially the overlay image is set to 128 X 128 pixels in size. The user may adjust the size of the analysis overlay from 1 to 1000 pixels by changing the value in the "Analysis Area Pixel Width" input box. The analysis overlay image may be toggled off and on with the "TOGGLE Overlay" button to compare with features between the two images. There are 41 colour schemes that may be applied to the analysis overlay. Simply select the desired colour map from the selection box and re-digitize the area of interest. The various colour maps may be used to highlight features not readily apparent in a grayscale or rainbow coloured image. Different bands have different ground sampling dimensions (pixel widths) therefore a single "Analysis Area Pixel Width" may cover different sized areas with different resolution depending on the band selected. The "Print Image" button opens the print setup dialog box so a hardcopy printout can be configured. Use the "Back to Image Analysis Tools" button to return to the Image Analysis Tools page (Figure 1).

THREE-BAND ANALYSIS

The Three-Band Analysis tool allows the user to create an image by assigning specific bands to the three primary colours: red, green and blue (RGB). The presence of any of the three primary colours in the image represent 100% of that band for that pixel. All pixels containing components of the three bands will appear as secondary colours. This tool provides a visual display of the relative portions of the three selected bands at any pixel location. To assign bands to each colour simply select the desired band in one of the three primary colour selection boxes. Proceed to digitize the area of interest as described earlier. The image values for each of the three selected bands within the analysis area are stretched using the histogram equalization process to enhance the band's image contrast. Some common band combinations for Landsat images are:

$L_{3,2,1}$ will generate a natural colour image

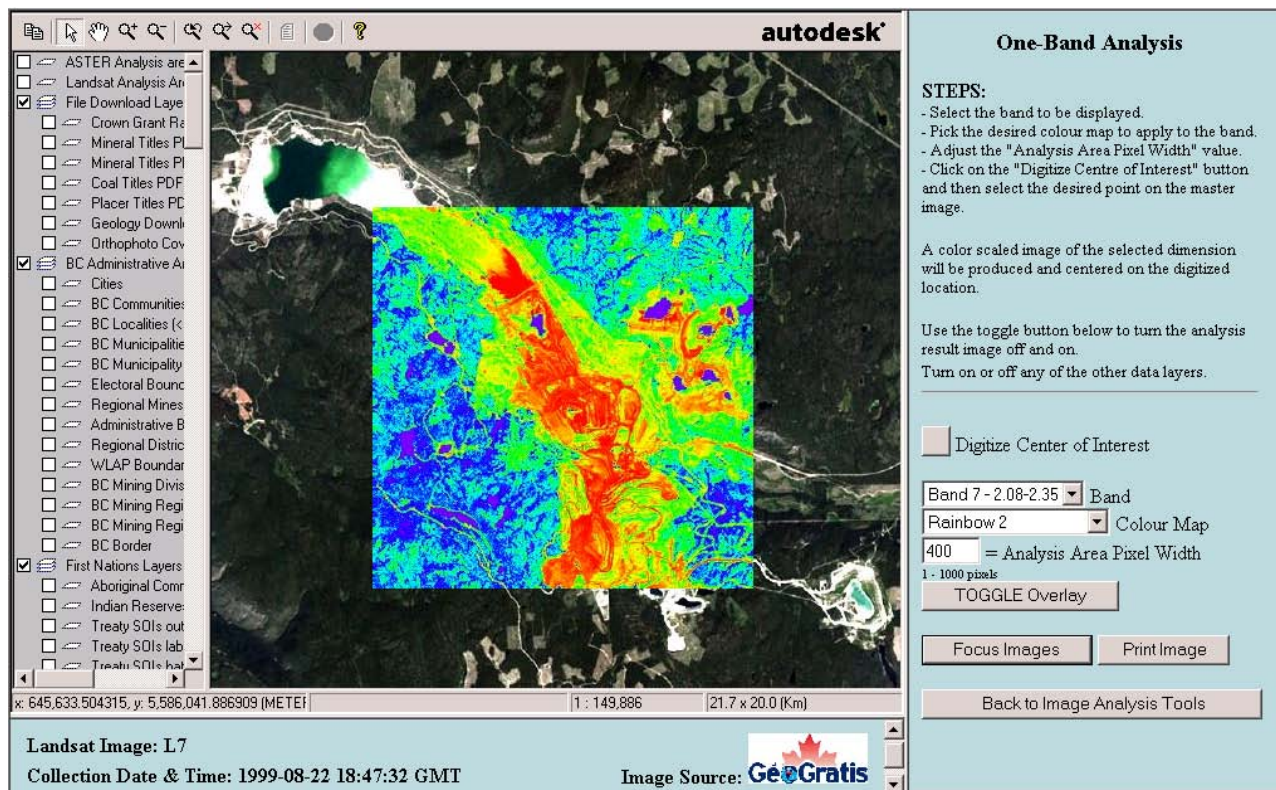$L_{2,3,5}$ common colour IR composite image highlighting vegetation

Figure1. Screen view of the One-Band Analysis window illustrating all the major user input components. The overlay analysis image covers a portion of the Highland Valley mining operation. Landsat Band 7 has been selected, the analysis image is 400 pixels square and the Rainbow 2 colour map has been used to colour the image. Most MapPlace data layers are available from the left-side legend.

TWO-BAND RATIO ANALYSIS

The Two-Band Ratio Analysis allows the user to generate band ratio analysis images. The ratio between two bands is used to display the variability between two regions of the electromagnetic spectrum across the analysis area. This type of analysis has been used to discriminate between many features such as minerals, water clarity, water depth and vegetation vigor. The ratio process also reduces the effect of shadows on the analysis. But the result should be used with caution as the ratio for two materials may be the same even though the actual reflectance spectrum values for the materials are completely different. A good example of this is the $L_{3/1}$ ratio. This ratio identifies oxide minerals very well but equally as well identifies ice.

The resultant ratio image is stretched using the histogram equalization process to enhance its contrast. If the same band is selected for both the numerator and the denominator then a ratio image is not generated but a simple one-band image is presented. Assigning various colour maps to the ratio image may enhance features of interest. Some common ratios are:

$L_{3/1}$ oxides

$L_{5/7}$ clays

$L_{5/4}$ ferrous

FALSE COLOUR COMPOSITE ANALYSIS

The False Colour Composite Analysis tool allows the user to assign ratio images to each of the three primary colours and create a RGB image. By selecting band ratios that identify specific characteristics and then combining them into a single image a large amount of information can be conveyed in that image. Each of the three ratio images is stretched using the histogram equalization procedure prior to construction of the final RGB image. A commonly employed combinations is:

$L_{3/1,5/4,5/7}$

NDVI VEGETATION INDEX

The Normative Difference Vegetation Index is a measure of chlorophyll content or plant growth. This measure has long been used with Landsat imagery and uses the Red and near infrared (NIR) bands in ratio (Landsat bands 3 and 4, ASTER bands 2 and 3, AVIRIS 25 and 48). The AVIRIS image (V1) currently loaded is an early image which had poor signal to noise characteristics. The NDVI produced from it is mainly noise. The index is a ratio of NIR+RED / NIR-RED. The resultant NDVI image is again stretched using the histogram equalization procedure to enhance its contrast. This tool can be very useful in assessing

212

vegetation stress differences that could be due to the underlying rock formations or water availability. Age and type of vegetation in logged areas can be inferred with some minor ground verification.

ENHANCED SATELLITE IMAGERY

Purpose

A set of eighteen enhanced satellite images over parts of BC were produced for the purpose of facilitating the interpretation geological structures. This part of the project involved the use of free Landsat 7 ETM data, which is available for download from www.geogratis.ca, and BC TRIM digital elevation models (DEM) provided by the BC government.

The total geographic coverage of the eighteen images comprises approximately 40% of British Columbia (Figure 2). For information about the Landsat 7 ETM satellite, refer to
 http://landsat7.usgs.gov/index.php.

Figure 2. Area covered by enhanced Landsat imagery.

Figure 3. Natural Colour Landsat image based on bands 3, 2, 1 as red, green and blue, respectively.

Figure 4. Greyscale "hillshaded" image based on TRIM digital elevation model.

Figure 5. Enhanced Landsat image formed from the fusion of hillshaded image and natural colour image.

Image Enhancement

Image enhancement involved the combination of two types of images:

1. Conventional "natural colour" imagery produced with 30m/pixel Landsat bands 3, 2, 1 as red, green, blue respectively (Figure 3.).

2. Greyscale, "hillshaded" imagery produced by the application of artificial lighting to the 25m/pixel TRIM DEM (Figure 4).

Many geological structures have some topographic expression, often in the form of creeks, ravines, escarpments and on the larger scale, valleys and coastal inlets. By nature, DEMs record topographic features and can therefore be used to aid in the interpretation of geological structures. The fusion of the two image types results in a final product where the visually detectable features of conventional colour imagery (vegetation, water, rocks, ice, snow, etc) are preserved and topographic features (faults, fractures, glacial landforms etc.) are greatly enhanced (Figure 5).

ER Mapper software was used for all aspects of image processing. All images have been provided with 25m/pixel size, in geotiff and ecw formats, in both UTM NAD83 and BC Albers projections.

Uses of Enhanced Imagery

These enhanced images are intended for interpretation at scales between 1:80,000 to 1:100,000. The limitation of scale of use is determined in part by the 30m pixel size of the original Landsat imagery but more importantly by the ground resolution of the BC TRIM DEM.

Geological structures are detectable in all eighteen of the final enhanced images. Furthermore, many glacial features such as drumlins and eskers are also detectable. Each enhanced image was visually compared with the corresponding conventional image. Of particular note here is that many structures detectable in the enhanced images were not detected in the conventional image. It must be noted that there are some problems in the TRIM DEMs where there is a visually noticeable linear smear of data values across the width of a few pixels. These linear artifacts are known by the BC government.

SUMMARY

The project has achieved all of its objectives. Eighteen Landsat 7 ETM images were enhanced to highlight structures with topographic expression. These image products are available for download in several formats and map projections from the MapPlace. An image analysis framework has been added to the Exploration Assistant page of the MapPlace web site to allow basic image analysis processes to be performed on multispectral and hyperspectral images. Twenty Landsat 7 ETM images, five ASTER images and one AVIRIS image have been loaded into the system and are available for analysis. Five general analysis tools are included in this initial version of the site.

This project was designed to test the value and acceptance of providing image products and image analysis tools for use by the exploration community over the Internet. If warranted, additional enhanced Landsat imagery could be produced and added to the system. Addition types of multispectral and hyperspectral imagery can be added to the analysis system as well as additional analysis tools and more complete coverage of existing image types.

ACKNOWLEDGMENTS

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