The Genesis of AUSLIG's Canberra 1:100 000 scale Satellite Image Map

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Despite the advances in remote sensing technology and the recognition that medium and large scale mapping and updating requires an enormous technical and financial effort which is generally unable to be met by most countries, the incorporation of remotely sensed data into cartographic map products has progressed very slowly.

This paper draws on the recent satellite image mapping experience of the Australian Surveying and Land Information Group (AUSLIG), in Australia and its Antarctic Territory, to show that with the high spatial resolution satellite remotely sensed data now available, topographic maps, approaching and often meeting cartographic specifications, with image backgrounds can now be produced. As an example AUSLIG produced the Canberra 1:100 000 scale satellite image map using modern image analysis and computer aided cartographic and lithographic techniques.

Introduction

It is over 20 years since LANDSAT 1, then ERTS 1, became operational acquiring and sending its digital data back to Earth. Since then remote sensing technology has progressed. Not only has the spectral and spatial resolution of the sensors been increased but advances in computer handling, manipulation and output now allows improved enhancement, analysis and hardcopy reproduction of the remotely sensed data acquired.

Yet despite these advances and the recognised fact that medium and large scale mapping and updating requires an enormous technical and financial effort, which is generally unable to be maintained at a realistic level by most countries, the incorporation of remotely sensed data into topographic map products has progressed very slowly.

This paper draws on the recent satellite image mapping experience of the Australian Surveying and Land Information Group (AUSLIG), in Australia and its Antarctic Territory, to show that with the high spatial resolution satellite remotely sensed data now available, topographic maps, approaching and often meeting cartographic specifications, with image backgrounds can now be produced. As an example AUSLIG produced the Canberra 1:100 000 scale satellite image map using modern image analysis and computer aided cartographic and lithographic techniques.

Topographic Mapping from Spaceborne Imagery

Topographic maps are a large scale portrayal of the spatial associations of a selection of diverse natural and man-made features such as roads, boundaries between areal features, waterbodies, elevations, coastlines and settlements. Topographic maps are accurately made to a standard set of specifications (National Mapping Council of Australia, 1975).

For the compilation of topographic maps at a scale of 1: 250 000 or larger, the imagery from which the position and type of detail is extracted must have a high spatial resolution. Welch (1982) suggests a resolution of between 5-10m, whereas Konecny et al. (1982) suggest the lower resolution of 14m. Data with such spatial resolution are now able to be acquired.

Conventional line maps, of which topographic maps are one type, include information on names, road classification and feature identification, that cannot be obtained from any airborne/space imagery (Colvocoresses, 1984). However, the fact that any image data from space will generally always need to be augmented by data from other sources need not be a significant deterrent to its application.

The major advantage of image based mapping from space, supported by AUSLIG's own recent map production experience in the Antarctic, is that it readily lends itself to automation and rapid map production, whereas preparation of line maps may take up to several years.

Overview of Antarctic Satellite Image Mapping in AUSLIG

Mapping in Antarctica presents a technical challenge to the cartographer (Manning and Rogers, 1990). There is very little aerial photography available, and only a limited amount of ground control. Satellite imagery and positioning from satellite systems such as Transit (Doppler) and Navstar (GPS) offer a means of economically producing selected mapping products for areas of special interest to scientists in the Australian Antarctic Territory.

The initial satellite image based maps were a black and white dyeline series which utilised LANDSAT MSS prints and traditional photographic mosaicing techniques.

The mosaicing, geocoding and enhancement of the digital data on an image analysis system allowed a superior mapping product to be generated, provided image data at a suitable spatial and spectral resolution and ground control were available. However, because of reproduction costs, only a few copies of the final map were produced.

Through more efficient project planning and technological development the problems of appropriate data and ground control availability and mass map reproduction were overcome.

Image Data

While raster digital data may be considered "scaleless" the acquisition process actually imparts scale limitations. These limitations become apparent when presenting the data on a display screen or on hardcopy media and determine the range of scales at which the data can sensibly be reproduced. Presentation of the data at very large scales results in the information appearing coarse or blocky. Conversely at very small scales the information becomes compressed and difficult to interpret.

Currently available, high resolution, satellite remotely sensed data can be presented at scales between 1:250 000 and 1:25 000. Thus for most mapping scales an appropriate resolution satellite data set either exists or can be generated from the existing data for example merged data sets. (A merged data, where both high spatial and spectral resolution is achieved, is generated through a mathematical transformation which incorporates, for example, the SPOT HRV PAN (10m) band with a triplet of either SPOT HRV or LANDSAT TM multispectral bands to produce a new data set that has 10m spatial resolution and retains the multispectral "colour").

It should be noted that while the ground resolution, indicated by the pixel size, of satellite data can be altered by mathematical processes information not obtained during data acquisition cannot be created just by manufacturing smaller pixels. It is possible, however, to generalise the information content by creating larger pixels.

Ground Control

All satellite data contain systematic errors that cause geometric distortions in the imagery. Most systematic errors are introduced by the characteristics of the satellite sensor system and the shape of the earth. Typical systematic distortions are those introduced by earth rotation and curvature, non-linear sensor scanning, and variable optical pixel size. Thus, any remotely sensed data products must be corrected for such distortions and rectified to the map coordinate system through the process of grid registration or geocoding. The source of most systematic errors can be modelled and removed from the data. The satellite models included with most image analysis systems will undertake this task.

The distortion remaining in an image after the removal of systematic errors can be removed by registering the image to the geographic coordinate system chosen for any particular map. The registration procedure initially involves selecting image features that have matching ground coordinates in the desired coordinate system. The ground coordinates may be scaled from a map or derived by field survey methods.

The probable error in the coordinates of the ground control points should ideally be minor relative to the spatial resolution of the satellite data. A good guide to follow is that the error in the coordinates should be an order of magnitude less than the spatial resolution of the original data.

The next stage of the registration process is the development of a mapping function using the set of coordinates from the uncorrected data and the coordinates of the output or corrected data. The mapping function or polynomial model chosen should be appropriate for the errors in the original data and more importantly the distribution of the control points throughout the uncorrected data set.

The order, generally first, of the polynomial is selected to account for the remaining distortions in the satellite data. Second or higher order polynomial mapping functions should only be implemented when the distortions in the data can only be modelled by such higher order functions and the behaviour of the mapping function can be well controlled by a good distribution of control points. This approach ensures that unwanted local distortions are not introduced during the geocoding process.

The polynomial is then used to map each pixel coordinate in the satellite projection into the geographic coordinate system. This mapping usually yields non-integer positions in the new projection, so the desired pixel intensity for each position is usually calculated using an algorithm selected to maintain radiometric resolution. During the transformation process the data are also resampled to a specified output pixel size.

Fit to ground control is generally within 1.5 pixels (RMS) which for TM data with 30m pixels is nearly twice the planimetric error allowed for 1:100 000 scale maps.

With modern satellite positioning equipment and the ability to enter sub-pixel coordinates it is believed possible to fit control within 1 pixel (RMS). Imagery controlled this way would then meet the planimetric topographic mapping specification.

It is worth noting that imagery controlled using both map and surveyed control points when overlaid with previously existing cartography showed no evidence of misfitting indicating that with care satellite imagery can provide positionally accurate image bases that will meet existing map specifications.

While fitting imagery to ground control can appear to be highly accurate inaccuracies, due to relief, do remain but are generally not significant. Nevertheless, in areas of extreme relief the imagery will need to be corrected and an orthoimage generated to mitigate the significant errors extreme relief differences can introduce.

Lithographic Map Reproduction

While the digital satellite data could be geometrically and spectrally enhanced a problem arose when there was a requirement to produce multiple quality copies of the final image based map.

The traditional cartographic approach was to print multiple copies by photo-lithography which usually involved scanning composite colour transparencies or prints produced on a film writer. The information portrayed on maps produced this way was quite good and provided an adequate solution for urgently needed cartography in the remote areas of Antarctica. However, the image resolution had been significantly degraded during the scanning / colour separation and printing processes. This degradation and clarity could be seen when compared with the original image / data when displayed on the computer screen. The problem of degradation was solved by developing, in conjunction with a private sector firm, the Satellite Image MAPping process or SIMAP.

Essentially this technique takes the enhanced digital data and reformats it for subsequent transfer to a graphics art scanner / plotter computer system. The colour balance is customised in this raster system, before the plate-making film is produced by a laser plotter. As the SIMAP process is computer controlled, an accurate output scale is always achieved. Accurate scale is crucial in image mapping where the image and grids and graticules must overlay precisely. After combining manually produced surround details and vector information, careful printing is undertaken to match an approved colour proof using dot screens between 175-200 dots per inch. Choice of dot size is governed by the type and quality of paper.

The improvement in detail and resolution quality achieved by this process is quite significant, not only is the resolution better on the SIMAP products but the colours have been carefully controlled to highlight important features.

With a carefully planned data and GPS ground control acquisition program maps of various areas of the Antarctic have been produced at 1:25 000, 1:50 000, 1:100 000 and 1:1M scale. The process has also allowed data acquired during one summer season to be used to generate a map for the forthcoming summer operations, a production time of less than nine months.

The Canberra 1:100 000 Scale Satellite Image Map

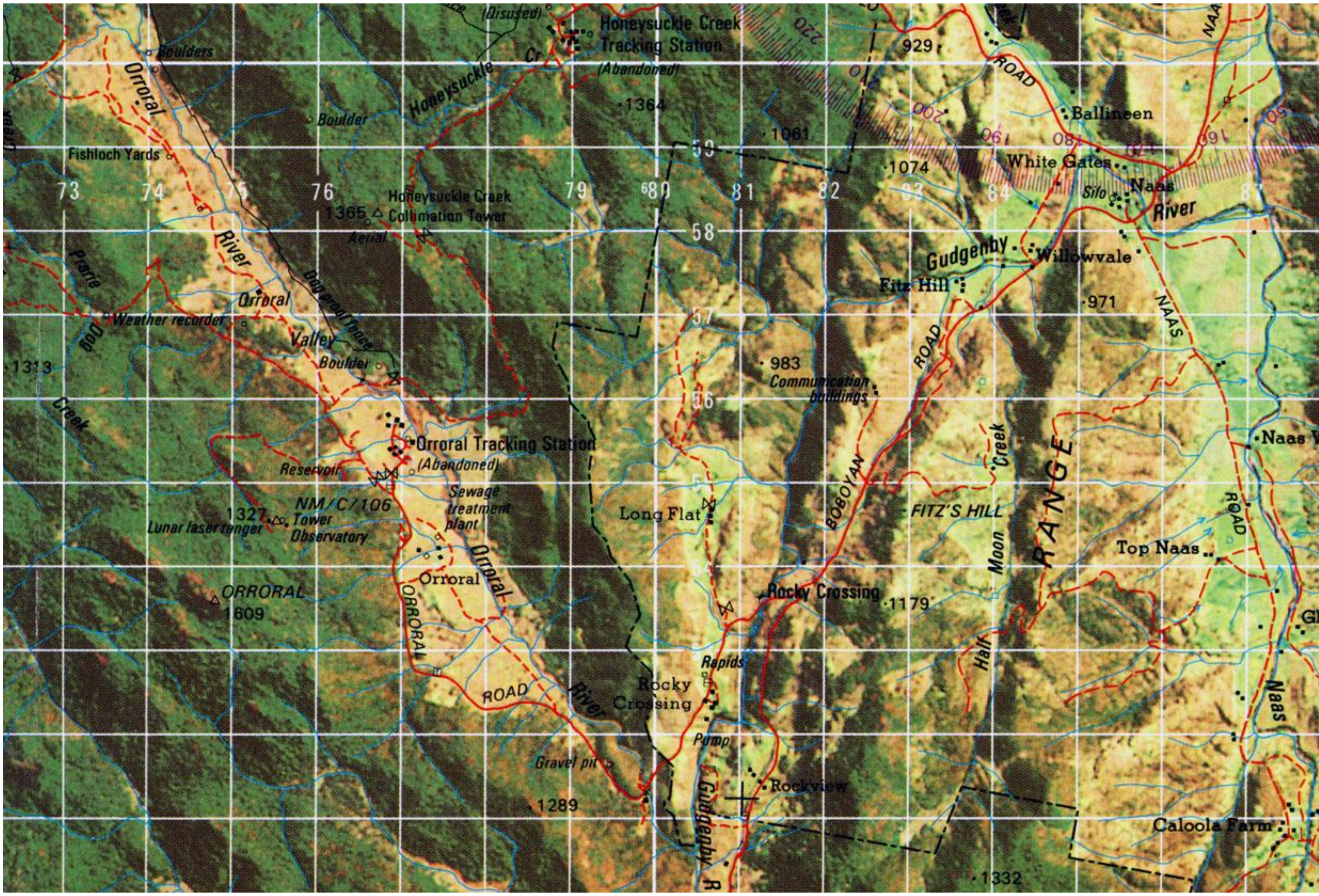
The specifications for the Canberra 1:100 000 scale satellite image map were for a 4 colour map with an image base overprinted with selected existing vector data, mainly roads, railways, major rivers and streams, names and a 1cm grid. Contours and vegetation were not required.

LANDSAT TM was selected as the data set and three bands were geocoded and enhanced to provide pseudo-natural colour. When the image base was overlaid with the existing vectors the major "misfitting" was identified as recent road realignments or original cartographic infidelity in tracing complex patterns. These minor irregularities were manually corrected prior to printing.

As the colouring in the image base was deemed to be "too strong" it was screened back in the final printing. The major water features which had different tones were all printed in the same blue. All other vector information was printed in traditional colours over the top.

The final map, part of which is shown below, appears to achieve an excellent mix of colour and information and the combined vector and raster data does not overwhelm the user with a complex visual pattern.

The map with all its teething problems was produced in under three months. However, the hurdle that still needs to be overcome is the representation of height.



Future Developments

The major development will focus on portraying height information without significantly obscuring the image background. There are a number of options available, ranging from using spot heights to selective contouring and automated hill shading using information derived from a Digital Elevation Model (DEM) or a mix of each and even printing this information in opaque inks. Each will need to be tested in differing terrain. However, this is a difficult task and one where the cartographer needs to undertake the compilation of the "height" layer interactively.

This would mean that with the image background displayed on the screen the various digital contours / spot height / hill shading combinations could be interactively manipulated and displayed by the cartographer so that the effect could be seen and output as an intermediate plot to gauge overall impact.

Taking this one stage further. If the height layer is to be interactively compiled then why not the other vectors. Misfitting, where the position of the vector data did not coincide with that of the raster data, as occurred with the Canberra data, could be simply rectified, and the "revised digital data" saved.

Once compiled the vector layers would output on a cartographic plotter and combined with the image base through SIMAP and printed.

The interactive compilation of image based maps has the ability to maintain the vector data layers in the digital data base as well as generating an up to date map thus providing a practical link between remote sensing and GIS technologies.

Summary

This paper has provided an insight into the development of image mapping in AUSLIG. While initially image mapping was seen as a solution to mapping the Australian Antarctic Territory these developments suggest an approach AUSLIG might take to the generation of its topographic maps of Australia and maintenance of its digital vector data base.

Overall AUSLIG's image mapping experience has shown the advantages of continuing to develop the most effective combination of remote sensing, image analysis, cartographic and lithographic technologies to generate satellite image based topographic maps and thereby reduce production time through scale retention, accuracy of scale, and quality of reproduction.

Acknowledgements

The author acknowledges the contribution made by AUSLIG's remote sensing and cartographic personnel during the production of the Canberra 1:100 000 scale satellite image map.

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