145

GENERATION, VISUALIZATION AND ANALYSIS OF IMAGE CUBES

M.Millot, K.Maurice, M. Karspeck, W.Kober and F.Leberl

VEXCEL Corporation
Boulder, Colorado, USA

ABSTRACT

The continuous increase in volume and diversity of remote sensing and collateral data implies that new methods of visualization and analysis must be devised to meet the challenge of efficiently processing these data. We discuss our solutions in the context of the future EOS era, applied to the two main classes of image cubes:

- Homogeneous image cube acquired by one instrument with multispectral capabilities, for example:
  - . Thematic Mapper,
  - . AVIRIS,
  - . Multispectral/Multipolarization SAR.
- Heterogeneous image cube composed of coregistered images coming from different sources, for example:
  - . Satellite image,
  - . Aerial photography,
  - . Digital Elevation Models and maps.

INTRODUCTION

The continuous increase in volume and diversity of remote sensing and collateral data implies that new methods of visualization and analysis must be devised to meet the challenge of efficiently processing the data. To generate image cubes containing different images acquired using different sensors with different geometric characteristics, an excellent coregistration is required. Once the image cube is generated, it can be visualized using several techniques. We investigated stereo visualization, animation and manipulation of the image cube as a 3D object, and insertion of a small window containing one layer into a different layer of the image cube. In addition to this visualization, the image cube may be analyzed. Among the numerous possible analysis to perform on an image cube, we implemented spectral analysis allowing the user to compare a pixel signature to a database of laboratory spectral prototype signatures.

IMAGE CUBE GENERATION

It is possible to categorize the various methods for producing coregistered images by the model used for the image deformation:

. Empirical model: A general estimation of the mapping, between two images or between one image and the ground, is built without considerations regarding the sensor or the platform; this is sometimes referred as "warping" or "rubber sheeting" [1]-[2],

.Physical model: Some data representing the geometric effects of the sensor and of the platform are available, so that a model of the physical phenomena can be found [3]-[6].

Independently of the model chosen, the coregistration of two images may be performed following two different processing paths.The first path begins with the acquisition, by manual or automatic (correlation or matching) means, of common points between the images, and assumes that one image is the reference, while the other image is the image to resample. The other path assumes that there exists a third reference system (i.e the ground) and each image is registered to this third reference system. The images' coregistration then becomes an indirect result of this processing. The second processing path is the preferred way when image distortion due to relief is significant.

We experimented with the physical modeling on two types of images, SPOT (acquired from Spot Image Corporation) and NHAP (acquired from USGS) over Boulder, Colorado. The two multispectral SPOT images used had a viewing angle difference of 29 degrees, their mapping with the ground was estimated, using 1:24000 USGS maps, by the Kratky method [6]. Also, the two infrared NHAP images were scanned at a pixel resolution of 2.5 meters and a photogrammetric modeling was performed. Each image was resampled using the previously estimated mapping from the ground to the image and USGS 7.5 minute DEMs. The coregistration of the four images that resulted from this processing may be qualitatively checked using the visualization tools described later. Over Boulder, we also acquired a geocoded SEASAT image from JPL (Jet Propulsion Laboratory) and a geocoded THEMATIC MAPPER image from EOSAT.

An image cube may also be contain GIS information . As an example, we included in our Boulder image cube rasterized hydrography 1:100,000 USGS DLG (Digital Line Graph), and contour lines computed from USGS 7.5 minute DEM's.

VISUALIZATION

We investigated three types of image cube visualizations, each one showing a different facet of a given image cube.

Stereo visualization

A software package called the Light Table has been developed by Vexcel. Currently, it provides basic functions for displaying stereo image pairs and measuring the parallax between features on those images. Two types of features can be created: singe point and polyline. Features can be selected, deleted and selectively displayed or blanked. The Light Table was used to acquire the ground control points needed for the modeling of the SPOT and NHAP stereo pairs, and also to visualize what we call a "virtual image cube" (A virtual image cube is an image cube where the mapping between layers is known but applied only partially). As an example, after estimation of the mapping between the ground and the SPOT images, the DLG data and the contour lines were projected into the geometrically raw images, therefore allowing their visualization in stereo and adding the third dimension to data classically represented in two dimensions.

3D representation

A program provided with the Stardent 3000 computer for C/T and NMR volumetric visualization was the perfect prototype, possessing the basic functions we were envisioning. The display functions include panning, zooming (in predefined increments), brightness/contrast adjustment, overall image cube display, layer selection, arbitrary slicing through the image cube, animation with adjustable speed and graphical display of the line and column intensities defined by the cursor position. It allows the user to qualitatively detect spectral changes (for example using an AVIRIS image), to display the spectral response of a given line or column, and using the animation to check and use the layers coregistration.

Region Of Interest (ROI)

Using the X Window System and low level Stardent routines, we were able to implement two instances of the ROI:

. Zooming: using a virtual image cube containing two images coregistered but at two different resolutions (called image low and image high in this paragraph), display image low as the background and inside a smaller window whose center is defined by the cursor position, display:

. image high at the resolution of image low,
. image high at an intermediary resolution,
. image high at full resolution,
. continuously interpolated image low from its original resolution to the image high resolution,
. continuously interpolated image high from the image low resolution to its original resolution,
. continuously a weighted average of the two interpolated images at different resolutions. It can be represented mathematically as :

$$(1-\beta)*IL+\beta*IH$$

β is a function of the zooming factor, IL and IH are the grey levels of the low and high resolution images respectively.

. Multiple layer display: Selecting one layer as the background image, display inside it a smaller window containing other layers or any arithmetic combination of several layers. The position of the small window inside the background image is controlled dynamically by a mouse.

ANALYSIS

Using PV WAVE (from Precision Visuals Inc), we built the spectral analysis program [7]. Five windows are available to the user:

. A window (called window 1 here) containing one fixed layer of the homogeneous image cube. Using the cursor, the user indicates a pixel in the image or defines an area by drawing a closed polygon.
. A window (called window 2 here) containing the spectral response of the entire line indicated by the cursor in window 1. Using the cursor inside this window, the user indicates the layer she/he wishes to be displayed.
. A window containing the spectral band indicated by the cursor in window 2.
. A window (called window 4 here) containing a graphical representation of the spectral response of the area or pixel defined in window 1. Inside this window, the user can sequentially display the response of laboratory prototypes and visually compare the image response with laboratory prototype responses.
. A window containing a scale used to define the spectral interval used as the X axis in window 4. The user can adjust this in order to focus on a particular area of the spectral dimension.

This program was tested using a calibrated AVIRIS image of Death Valley and some normalized mineral spectral responses.

CONCLUSION

We investigated the three important parts of the image cube processing: generation, visualization, and analysis. Although a lot remains to be done to finalize and integrate this work, we strongly believe that the image cube concept associated with powerful computers and window systems, will be a good way to present and analyze data during the EOS era.

ACKNOWLEDGMENTS

This paper presents one portion of the research completed under SBIR phase II contract number NAS7-1070, sponsored by the National Aeronautics and Space Administration.

REFERENCES

[1] G.E Ford and C.I.Zanelli "Analysis and quantification of errors in the geometric correction of satellite images" *Photogram. Eng. Remote Sensing,* vol. 51, No. 11, pp. 1725-1734, 1985.

[2] A. Goshtasby " Registration of images with geometric distortions" *IEEE Trans. Geosci. Remote Sensing,* vol. 26, no. 1, pp.60-64, 1988.

[3] M. Naraghi, W. Stromberg, M.Daily " Geometric rectification of radar imagery using digital elevation models" *Photogram. Eng. Remote Sensing*, vol. 49, no. 2, pp. 195-199, 1983.

[4] R. Kwok, J.C. Curlander, S.S Pang " Rectification of terrain Induced distortions in radar imagery" *Photogram. Eng. Remote Sensing,* vol. 53, no. 5, pp. 507-513, 1987.

[5] T. Westin " Precision Rectification of SPOT imagery" *Photogram. Eng. Remote Sensing,* vol. 56, no 2, pp. 247-253, 1990.

[6] V. Kratky " Rigorous photogrammetric processing of SPOT images at CCM Canada" *ISPRS J. of Photogram. and Remote Sensing,* vol. 44, pp. 53-71, 1989.

[7] A.S. Mazer, M. Martin, M. Lee and J.E. Solomon " Image processing software for imaging spectrometry data analysis" *Remote Sensing Environ.*, vol. 24, pp. 201-210, 1988.