DIGITAL PHOTOGRAMMETRIC WORKSTATION FOR TOPOGRAPHIC MAP UPDATION USING IRS-1C STEREO IMAGERY

B Gopala Krishna, B Kartikeyan, KV Iyer, Rebanta Mitra, PK Srivastava
Image Processing and Data Products Group
Remote Sensing Area
Space Applications Centre
Ahmedabad 380 053, INDIA

ISPRS Commision IV, Working Group IV/3

KEY WORDS : IRS-1C, Photogrammetric Workstation, Texture Mapping, DEM, Orthoimage, Topographic Map Updation

ABSTRACT

Panchromatic (PAN) camera onboard Indian Remote Sensing Satellite 1C (IRS-1C) acquires data in stereo mode with 5.8m ground resolution. It is expected that, this resolution can be comfortably used to update the topomaps with required accuracy for 1:50000 scale. Digital Elevation Models (DEM) can be generated from IRS-1C PAN stereo data with sufficient planimetric and height accuracies required for topographic mapping at that scale, whereas the thematic information can be derived from the merged products generated by combining IRS-1C PAN data with other medium resolution multispectral data sets either from IRS-1C LISS-3 (23m resolution) or from SPOT PLA (20m resolution). Keeping all the above points in mind, a digital photogrammetric workstation is being developed at Space Applications Centre (ISRO), INDIA, for topographic map updation using IRS-1C data. This paper describes in detail, the design concepts, various components of the system and their functionalities. Some early results from IRS-1C stereo data are given to show the capability of this data for topographic map updation. The map updation system specifications and the status of its development are given at the end.

1. INTRODUCTION

With the advent of IRS-1C launch during December 1995, and its subsequent operationalisation, remote sensing user now has panchromatic data in high resolution (5.8m) in stereo mode. This is in addtion to the already available SPOT 10m PLA data. Earlier resolutions from IRS-1A, IRS-1B, LANDSAT TM, and SPOT, topomap updation between 1:250000 to 1:50000 scales were possible, whereas IRS-1C panchromatic data resolution promises capability for updation of maps with scales 1:50000 and better. With the stereo capability of the panchromatic data DEMs can be generated with sufficient planimetric and height accuracies for topomap updation of the above scales. Thematic information required for updation can then be derived from the coarse resolution multispectral data either from IRS-1C LISS-3 or from SPOL MLA, by merging these data sets with the high resolution PAN. Though various systems are available at various centers in INDIA for Geographic Information System (GIS), Image Processing (IP) and stereo data processing , an end-to-end topomap updation was not possible with any of these individual systems. Also the data input/output formats are different at different systems. Hence a digital photogrammetric workstation is conceptualised and being developed at this center for exclusively updating the topographic maps using IRS-1C stereo data. However plans are being made to use/extend this system to utilise the data from other sources i.e. data from different satellites having stereo imaging capabilities like SPOT or the future missions of IRS and SPOT. The system includes GIS, IP and stereo processing functions/subsystems in an integrated mode. The system uses the texture mapping as the basic tool for integrating all the three subsystems. In section 2 the map updation methodology is explained briefly and in sections 3 and 4 fuctionalities and system requirements respectively are described. Section 5 gives some early results from IRS-1C stereo data. Status of system development and some conclusions are also given in this section at the end.

2. MAP UPDATION METHODOLOGY

A server client configuration is assumed (Fig. 1), where server does most of the database work and client performs the required photogrammetric functions and data processing. A database containing digital map layers are maintained at the server. This is used as a base information at server node, as an input for map updation. Additional information is derived from various sources of data from satellite/aerial images and previous maps, if any. Hence as and when a request comes for map updation, all the existing layers for that map sheet will be extracted and sent to the photogrammetric client. Additionally other inputs like stereo pairs/triplets, Ground Control Points (GCP) from a library or from a map digitizer/scanner or from an external DEM, are also sent to client. When no map layer is available for a given map sheet, it has to be first created by scanning the map with the relevant information and updating the database with this. This procedure is to be carried out at server level as an input data base creation task.

Updation of each map layer (one for each feature, viz, road network, elevation, annotations, and other cultural features) is done at the photogrammetric client, once all the required information is available. DEM generation is the first step to be performed, in case it is not available or the available DEM is not a recent one. DEM is generated, using the IRS-1C PAN stereo pair and a few GCPs, with the help of an orbit/attitude model, automatic conjugate point finding algorithms and space intersection [IRS-1C Stereo Data Products Team, 1993.]. Then the DEM editing is done in real time using stereo display, image draping and image processing concepts. Hence a powerful CPU at the client end is a minimum requirement. The DEM also can be obtained by the external sources like by digitising map, or previously derived from stereo pairs etc. After having DEM an orthoimage is generated using the image data and the corresponding ground to image transformation model. The generated orthoimage will form as the base information for the map sheet to be updated. Now using the DEM, model (in back ground), orthoimage, the desired map layers can be freshly obtained using 3D feature coding and online editing. This involves stereo display, image processing concepts like automatic topographic feature identification, edge detection, image classification and several other functions like vector to raster conversion, vector raster overlay, contouring etc. All the map layers created at client will be stored in a local database.

Verification (automatic and manual, some times ground verification of obtained features), validation, editing and labeling is performed for all the derived layers before updating the database. A number of tools are required here finally. These include annotation generation, symbolisation, data conversion routines etc. Standard data formats like DVD1 and DVD2 are to be used throughout, so that the inputs and outputs are compatible with those of Survey Of India (SOI) standards. Finally all the map verified layers can be transferred to the server and then the main database will be updated with these layers. A separate map compilation, map drawing software is used to make the paper prints of final updated maps.

As an integrated version, this system has a multi-user environment, where at a given time 2 to 3 users simultaniously can work on different map sheets or on different layers of the same map sheet. Each client has its own database. There is no client to client communication planned, which may hamper the system performance. All the final layers of the map are compiled at server for map making/ updation.

3. FUNCTIONALITIES OF THE SYSTEM

For the above described procedure the various important functionalities/ software elements required are as follows:

3.1. Data Ingest

This is done through cartridges, CD-ROMs or from DAT devices. Different input data sets can be (a) stereo pairs/triplets , (b) DEM derived from external source or digitized from a scanned map (c) GCPs (d) map/image database (e) required layers of map information and (f) other ancillary information for image rectification/orientation. Data conversion routines, digitiser/scanner software, database extraction/ updation are the main software elements.

3.2. Models

Models for DEM generation and image correction with or without GCPS are required in the system. Two different models are available currently. The first one uses the space resection for updating the satellite orientation and space intersection technique to generate 3D ground co-ordinate of a given conjugate point [IRS-1C Stereo Data Products Team, 1993. ,Rebanta Mitra etal, 1994.]. Modified collinearity conditions are the basic equations in this model. As a second model (for refining both satellite orientation and the derived DEM) a bundle adjustment software developed jointly by Space Applications Centre and German Aerospace Research Establishment (DLR), Germany is used [Gopala Krishna, B., 1994.]. In this approach DEM is computed in a combined solution for GCP coordinates, conjugate point coordinates and orientation parameters of the stereo pair imageries. In addition to these two models image-to-ground and ground-to-image transformations and image resampling are part of this software for generating the final corrected images. Several height interpolation algorithms are inbuilt in the system for generating regular grid of DEM from a set of irregular DEM points.

3.3 Stereo Display Related Functions

Stereo display related functions are required at several places like (a) GCP identification (b) conjugate point verification, (c) DEM editing and (d) 3D feature coding. The related software elements are (i) stereo display, (ii) epipolar image creation, (iii) floating cursor and its positioning, (iv) DEM editing and feature coding, (v) height interpolation, (vi) point height measurements etc. These functions are implemented on R-4000 based workstation and are tested with several data sets of SPOT PLA and IRS-1C PAN data.

3.4. Conjugate Point Finding

This is an important task in automatic/semi-automatic way of DEM generation on a digital photogrammetry workstation. This has several components like interest operator, digital correlation, local mapping and blunder detection. In this system a hierarchical automatic point matching technique based on an interest operator followed by an area based correlation is implemented. Hierarchical approach helps in reducing the search area size for correlation, in turn reducing the overall computation time. Interest operator selects candidate points for matching at each pyramid of the hierarchy. There are total three pyramids in the approach, starting from resolution/4, resolution/2 and the full resolution image. At each pyramid interest operator is applied on one of the images and the approximate coordinates of these points in the other image is obtained through a local mapping on the previous level's conjugate points. However system needs some seed points, which are identified manually at the first stage (or at the highiest level of the pyramids). The procedure continues till the last level i.e up to the full resolution. The number of points matched in the last level are the final list of conjugate points for DEM generation. A number of inbuilt checks on the reliability of the match points are implemented.

3.5. Image Processing Functions

Apart from the simple image processing functions like image display, roam, zoom, pixel dump, enhancement and filtering, specific functions like (a) automatic cartographic feature identification techniques using pattern recognition methods (b) cartogrphic feature dependent enhancements (c) image classification using contexual and texture features and (d) data merging are envisaged. In this list many are already available, development is being carried out towards the cartographic feature dependent enhancements.

3.6. Perspective DEM and Image Draping

For DEM editing online and for other terrain analysis, draping of image on to the DEM is required. The tools required here are (a) online DEM editing, (b) perspective DEM plots (c) 2D feature coding or data capture (d) image draping on DEM (e) image rectification using warping methods, (f) flight simulation/flight path generation, (g) z-tracing and (h) image and DEM mosaicking.

3.7. Analysis Tools

In addition to the above functions, the terrain analysis tools like (a) slope, aspect, volume and surface area computations, (b) Line of sight computation, (c) contouring and (d) delineation of linear features like drainage lines from DEM etc. are also required [ISROGIS Design Team, 1993.].

3.8. Final Map Layer Preparation and Updation

This mainly deals with creation and verification of different map layers and interactive editing and final compilation for printing. Different format conversions, compilation and comparision with existing layers, line linking and thinning are the elements required here.

4. SYSTEM REQUIREMENTS

The implementation of the proposed methodology imposes four basic requirements on the system

4.1 Stereo Display

This comprises of hardware on the display monitor and viewing glases and related software for switching the monitor to stereo mode as a minimal element. This facility is required at all the basic stages of processing, viz, registration, DEM evaluation, DEM editing, and spatial/cartographic feature extraction. Further facilities/ functionalities like floating cursor, z-tracing etc., for stereo measurements have to be implemented using a stereo display software library.

4.2 Texture Mapping

Texture mapping (TM) is the process of projecting/visualizing a 3-dimensional phenomenon on a 2D surface under different viewing geometry and illumination conditions [Paul S. Heckbert, 1986.]. TM also comprises of a hardware component and associated software libraries.The basic concept of DEM generation involves relating the stereo pair/triplet to the object space (terrain). Therefore , the implementation of any modeling algorithm becomes very efficient, simple and elegant, when built around the TM concept.The editing of DEM again involves the projection on 2D display of a 3D process. In this sense the overlay of any topographic/cartographic theme on a stereo pair or DEM has to be performed through TM. The updation of any layer of map involves visual display of that layer draped on the DEM or overlaid to be viewed in stereo mode for interactive feature extraction, editing and updation.

4.3 Integrated IP-GIS

The map updation involves an intermixing of image processing and GIS functionalities as we have to consider both the GIS map layer and the remote sensing (RS) imagery on a common platform for the efficient extraction of topographic features. This leads to the requirement of a software which can handle both vector based typical GIS operations like proximity, union, intersection and raster based typical IP operations like edge/line detection, and area and size measurements, with equal ease, viz, an integrated IP-GIS in terms of functionality.

4.4 Database Driven and OODBMS

Topomaps are moving from paper to digital form handled by a GIS. The current and future trend is to exploit the state-of-art in information technology and enhance maps to provide various levels of information at the click of a button - namely the Multi-media extension. To handle such maps the traditional Relational Databases have to be replaced by Object Oriented Databases .

5. RESULTS AND CONCLUSIONS

At Space Applications Centre (ISRO) the above facilities are being developed in following phases:

1. Development of models and software for DEM, orthoimage etc,
2. Development of GIS and IP functionalities
3. Integration with a standard mapping package for integrated testing
4. Development of texture mapping based integrated software system for topographic map updation.

The first phase has been completed and is available on Silicon Graphics Indigo-2 R-4000 workstation with stereo viewing capability. The model is checked on three data sets of 23x23 km area of IRS-1C stereo data having tarrain undulations of about 2 km. Overall DEM accuracies of 10-35m (rms value) in planimetry and 13-30m in height are obtained using four control points per scene. Accuracies quoted above are obtained on check points. It is to be noted the control and check points are collected from the existing 1:25000 and 1:50000 scale maps, hence the point accuracy itself may vary between 10-20m in planimetry and 10-20m in height (depending on the contour interval). In addition to this one has to count for identification error of the point in the image (order of one pixel). Hence the accuracy of DEM can be further improved by using a better control.

Three orthoimages are generated one from each set, corresponding to an area of 1:25000 scale map. The rms accuracies on check points obtained are 15-35m depending on the control accuracy (derived either from 1:25000 scale map or from 1:50000 scale map). As a qualitative evaluation the map features are traced and overlaid on to the orthoimage generated to the same scale. The features are matching within a mm. The above results show, that the accuracies obtained from IRS-1C stereo data are in conjunction with the required onces, for updating maps of 1:50000 scale [Srivastava, PK etal, 1996a. ,Srivastava PK etal, 1996b.].

The second and third phases are currently in progress Once these are ready, a digital overlay of map features with the orthoimage is possible for direct verification. The third phase is in design stage and it is expected to be completed by the end of 1996, for testing and usage of very high resolution imagery from spaceborne line scanner sensors likely to be available by then. The proposed system specifications are shown in figure 1.

Acknowledgements

Authors wish to acknowledge with gratitude, the guidance and encouragement provided by Dr. George Joseph, Director, Space Applications Centre (SAC), Shri. AKS Gopalan, Deputy Director, Remote Sensing Area, SAC, Shri. AR Dasgupta, Group Director, Image Processing and Data Products Group, SAC and Dr. KL Majumder, Head, Image Processing and Products Division, SAC.

References

1. Gopala Krishna, B., Manfred Lehner, 1994. Mathematical Formulation and Design for Photogrammetric Bundle Adjustment Software for Optical Stereos, IB Nr. 552-5/94, DLR-OP, June 1994.

2. IRS-1C Stereo Data Products Team, 1993. IRS-1C Data Products, Detailed Design of Derived Stereo Products Software, Report IRS-1C/SAC/DP/TN-01/June 1993, Image Processing and Data Products Group, Space Applications Centre (ISRO), Ahmedabad, India.

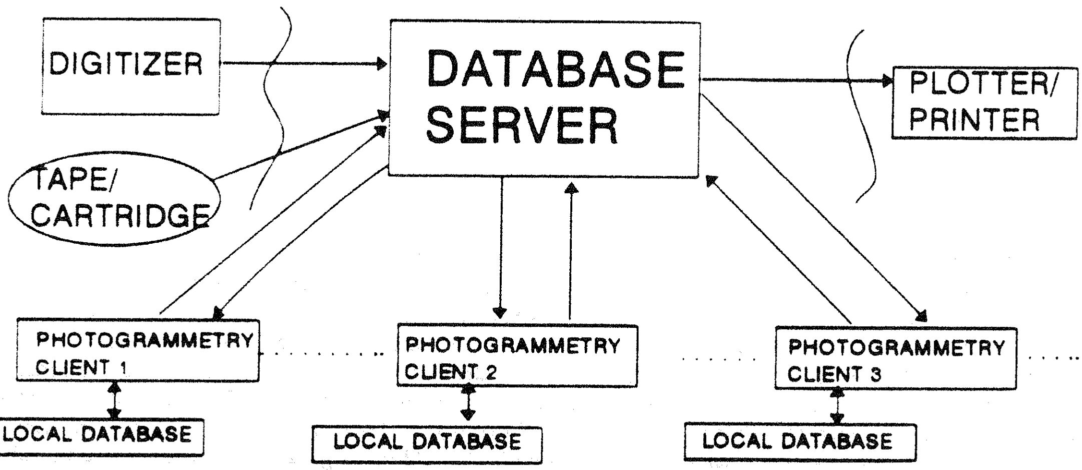
3. ISRO-GIS design team, 1993. ISROGIS PHASE-II: Baseline Design (3D Module, Network Module, Symbol manager and Customisation Toolkit), Report SAC/IPDPG/IPPD/TN-06/April 1993, Space Applications Centre (ISRO), Ahmedabad, India.

4. Paul S. Heckbert, 1986. Survey of Texture Mapping, IEEE CG&A, Dec 1986, pp. 56-67.

5. Rebanta Mitra, Gopala Krishna, B., Medha S. Alurkar, Trivedi, SP., Rana, YP., Srivastava, PK., 1994. Methodology for Generation and Evaluation of Orthoimage for IRS-1C Stereo Data, Presented at 14th INCA Congress, Nov. 1994, Bangalore, INDIA.

6. Srivastava, PK., Gopala Krishna, B., Majumder, KL., 1996a. Cartography and Terrain Mapping using IRS-1C data, Current Science, Special issue on IRS-1C, Under Publication.

7. Srivastava, PK., Ramakrishnan, R., Nandkumar, R., Padmanabhan, N., Gopala Krishna, B., Majumder, KL., 1996b. Cartographic Potential of IRS-1C Data Products, to be presented in this same ISPRS working group.



SERVER			CLIENT		
SOFTWARE	HARDWARE	FUNCTIONS	SOFTWARE	HARDWARE	FUNCTIONS
. DATABASE: OODBMS . NETWORK CAPABILITY .DRIVERS FOR I/O DEVICES . GIS FUNCTIONALITIES FOR I/O UPDATE ONLY	.DISK: ORDER OF TERRA BYTES .HIGH SPEED I/O PROCESSOR	.DATA INGEST/ UPDATION OF MAP DATABASE .SUPPLY DATA TO CLIENT .SERVICE OF I/O REQUESTS .SYSTEM ADMINIS-TRATION	.GIS ANALYSIS TOOLS .PHOTOGRAMMETRY FUNCTIONS .IP LIBRARIES .GRAPHICS LIB WITH STEREO CAPABILITIES .NETWORK SUPPORT .DRIVERS FOR I/O DEVICES	.STEREO DISPLAY .GRAPHICS ACCELERATOR .TEXTURE MAPPING .HIGH SPEED CPU(~100 MFLPS) .DISK:ORDER OF GIGABYTES .PERIPHERALS FOR BACKUP	.GIS QUERY/ ANALYSIS .DEM GEN. .DEM EDITING .FEATURE EX-TRACTION AND CODING .IP .MONO AND STEREO DISPLAY MANIPULATION AND MENSURA-TION

Figure 1. System Configuration and Specifications