Precision Processing System for High Resolution Satellite Data

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Abstract

Precision products of high-resolution satellite data is a general requirement for resource monitoring as well as topographic map updating at larger scales. As the accuracies of the standard product of the available high resolution satellite data (including IRS-1C/1D PAN) usually varies between 400 m to 2 km, there is a need to develop more accurate products which are useful in precision applications. Towards this, Precision Processing System (PPS) for high resolution data is being developed at Data Products Group, Space Applications Centre, to generate precision products for the required user area for High Resolution Satellite Imagery (HRSI) using Ground Control Points (GCP) identified from topo sheets or acquired through GPS. The radiometrically corrected scene product of the HRSI in super structure format is taken as input and the precision geometrically corrected product is delivered as output. The GCPs are used to correct the satellite orientation parameters. The output is planned to be in superstructure, Geotiff, fast format or photoproduct. The software is being developed using the Object Oriented Analysis and Design (OOAD) technology and will have the Graphical User Interface (GUI) developed in Java, while the back-end processing will be in C++. This paper describes various components of this system and highlights of the design.

Overview

1. Introduction

Precision products of high-resolution satellite data is a general requirement for resource monitoring as well as topographic map updating at larger scales. As the accuracies of the standard product of the available high resolution satellite data (including IRS-1C/1D PAN) usually varies between 400 m to 2 km, there is a need to develop more accurate products which are useful in precision applications. Towards this, PPS for high-resolution data is being developed at Data Products Group, Space Applications Centre, to generate precision products for the required user area for HRSI using GCPs identified from toposheets or acquired through GPS. The radiometrically corrected product of the HRSI in IRS super structure format is taken as input and the precision geometrically corrected product is delivered as output. The output is planned to be in superstructure, Geotiff, fast format or photoproduct. The software has Java front-end for Graphical User Interface (GUI) while back-end processing is in C++. This paper describes various components of this system and highlights of the design.

The PPS contains eight major components viz., Pre-processing, GCP collection and Identification, Modeling, Grid, Resampling, Product formatting, Mosaicing and Utilities.

The process sequence for the precision processing system is shown in Figure 1.

2. Preprocessing

The initial preparations for the processing of the data is done under pre-processing. This involves reading the user requirements and the input data and storing these information & data for further processing in the appropriate format under a project area. The input data is assumed to be radiometrically corrected (with no geometric correction applied) and is available in Superstructure format. The input media is assumed to be DAT / CDROM / DISK.

The sub-tasks under preprocessing are GetInput, Data Downloading and Area Selection.

2.1 Get Input: The user is provided with a GUI form for giving inputs like project name, single scene or mosaic case, map projection, datum, input media, output product format and media type. A sub-directory with the user given project name will be created after user confirmation; and this will be the project area for further processing. The user given inputs will be stored in appropriate format under the project area.

2.2 Data Downloading: The user will be prompted for loading the input media in the appropriate drive. On user confirmation, the input media will be scanned and the relevant satellite & image data will be copied onto the disk under the project area, in the specified format. The scene information such as orbit number, scene number

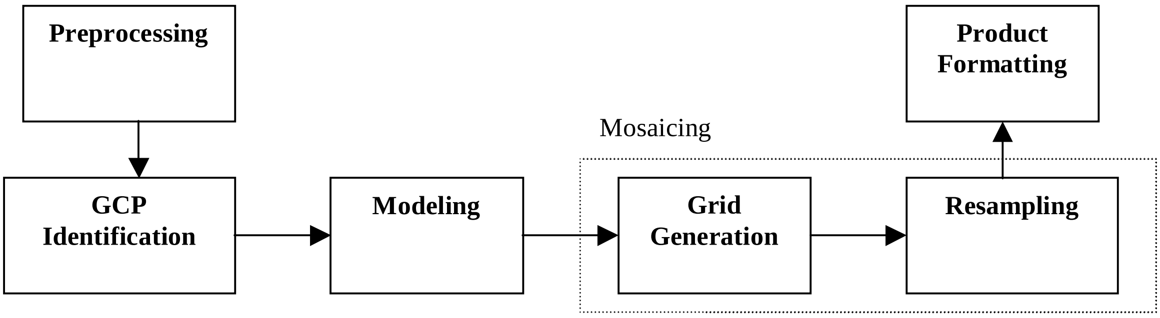

Figure 1: Process sequence diagram

and date of pass are updated in the project information file.

2.3 Area Selection: The downloaded image scene corner coordinates will be plotted on the screen with Survey of India (SOI) toposheets as background in the GUI. The user will have the option to decide the toposheet number for the area of interest from the displayed plot or mark any rectangular sub-area or the full scene. The full scene / user corner coordinates are updated accordingly in the project information file.

Preprocessing may be done to create a fresh project. In case of subsequent processing for already existing project, only the corresponding project area needs to be selected.

3. GCP Collection and Identification

GCPs are required for geometric modeling and they need to be identified on the image. GCPs can be selected within the system either from scanned toposheet or can be entered manually, when they are available through some external sources like, GPS measurements.

3.1 Map digitzation: In Map digitization the scanned toposheet relevant to the area of interest, in RAW / TIFF format will be read and the user is required to mark all the available grid points on the toposheet. In either case the user is required to specify the SOI map index number for the toposheet and also the size in pixels in case of RAW format. The user has to precisely identify all the grid points on the toposheet, refer them to the corresponding grid number and then digitize the point. Provisions for checking the accuracy of the digitized points after all the points have been digitized also exists. This digitized toposheet will be used for GCP identification.

3.2 GCP Identification from toposheet: This procedure is adopted only if the GCPs are needed to be collected freshly from the toposheet. The digitized scanned toposheet and the imagery are displayed simultaneously on the same screen and the user is required to identify the GCPs on the toposheet and the imagery. The user can mark any of the probable GCP on the toposheet; this will display the GCP latitude and longitude at the bottom of the toposheet window. The latitude & longitude are computed by fitting a two dimensional projective transformation between the latitude & longitude and the digitized scan line & pixel of the four nearest grid points. The mathematical formulation is as follows:

$$Latitude = \frac{a_1 p + b_1 s + c_1}{a_3 p + b_3 s + 1}$$

$$Longitude = \frac{a_2 p + b_2 s + c_2}{a_3 p + b_3 s + 1}$$

where p and s are pixel and scan line values of the grid point.

The identified GCP can be estimated on the imagery using the option. Here also the approximate scan line / pixel of the probable GCP is computed by fitting the two dimensional projective transformation between the corner latitude & longitude and their corresponding scan line and pixel values of the imagery, which is available from the scene information file. Provision will be made for navigating between toposheet to imagery and vice-versa for ease of GCP identification. The user is required to manually enter the height information for each GCP.

3.3 GCP identification through manual entry: In case the GCPs are already collected through some external source like GPS, then this procedure is to be adopted. This does not call for any Map digitization activity and hence it can be skipped. Here the imagery is displayed on the screen and the user is required to manually enter the GCP coordinates and identify the same on the imagery. Provision for estimating the approximate position of the GCP on the imagery will be made to ease GCP identification.

In either case GCPs are to be identified and precisely positioned on the satellite imagery. A well-developed GUI provides the required facilities to the user for precisely positioning the GCPs on the imagery. A minimum of six such points need to be identified, of these four will be used for modeling and the rest can be used as checkpoints.

4. Mathematical Modeling

Geometric models developed for HRSI products (including IRS-1C/1D PAN) generation is planned to be integrated in this system, which provide options to the user for selecting various models. Photogrammetric collinearity equations (Anon., 1998 & Alurkar, et al, 2002) are the basis for relating ground and image. Space resection is one of the models available, which uses GCPs to update the satellite orientation parameters.The collinearity condition equations are used in the satellite model.

$$(x, y, -f)^T = s M (X_A - X_S)$$

where $(x,y,-f)$ is the image coordinates. X_A are the GCP coordinates and X_S are the position of perspective centre in space, s is the scale factor and M is the rotation matrix which is function of satellite orbit, attitude and rates.

GUI plot of the distribution of the GCPs on the scene is displayed, which provides option for users to choose the configuration of the model points and checkpoints with respect to their distribution and accuracy. Thereby the residual model errors are to be made minimal. Facility to toggle the status of points between Model, Check and Delete will give the user, option to try out various configurations, to give optimum result. The points with high errors can be marked for deletion, so that they are not considered for residual error computation. Models are already tested and validated with the available high resolution data sets including IRS-1C/1D PAN & GCPs and it is observed that, less than 10 m accuracy can be obtained, when the control points are obtained from GPS measurements.

5. Grid

The updated orientation parameters along with the map projection parameters, and the user corner coordinates and the image data are used to do the geometric correction of the input image. The minimum and maximum ground extents in terms of eastings / northings are computed based on the option of map projection and user corner coordinates. The ground extents are modified such that it can be divided into exact multiples of specified grid intervals. A geometric correction grid is generated using the ground to image model for each of the ground grid points. Thus, there exists a one-to-one mapping between the ground coordinates and the image. The grid interval is a user fixed one and can be easily varied by the user externally through GUI. Moreover, the tickmark locations at a pre-defined interval of latitude and longitude are also calculated and stored.

6. Resampling

Resampling uses the grid file generated from the previous step along with the radiometrically corrected input image file to generate the geometrically corrected grey level image. Various resampling options like cubic convolution, sinc with various kernel sizes are available to compute the final gray count using the input image for each output point. Bilinear interpolation method is used for computing intermediate image point (between grids) co-ordinates.

7. Mosaicing

The mosaicing option will be exercised only for multi-strip HRSI data to generate precision products for user interested areas larger than single strip image data. The updated satellite orientation parameters as one of the strips are taken as reference. The reference control points are identified using digital correlation technique in the overlap area of adjacent strip image data. Different strip data are subsequently mosaiced after generating a mosaiced grid for the user area and then carrying out resampling of the corresponding strip image data. This will enable generation of mosaiced precision products of the HRSI spread over multiple strips. The details of the mosaicing procedure is given in (Naidu, et al, 2002)

8. Product formatting

The Product formatting consists of generating the output product as per the user requirement. The supported output product formats are superstructure, fast format, GeoTiff and photo-product. These products can be generated on one of the media DAT, CDROM or DISK based on user request.

8.1 Super-structure: In super structure format the digital product contains scene identification, location information, sensor, platform and processing related information over and above the video data.

8.2 Fast format: In fast format the digital product contains a header file with scene information in ASCII format in addition to the video data.

8.3 GeoTiff: This format complies with the standard GeoTiff format standards, which uses some sets of reserved TIFF tags to store georeferencing information.

8.4 Photo-product: This format is meant for generating photographic/paper prints. The video data consists of scene information as the part of the annotations and also the annotated tick-marks with ground coordinates at specified intervals.

9. Utilities

The utilities for evaluating the planimetric accuracy of the generated geometrically corrected precision product and modifying some of the tunable software parameters are provided as part of this PPS package.

9.1 Evaluation: The GCPs identified during the GCP identification process are used for evaluation. The GCP chip is extracted from the input image and the same is displayed for the user to identify the same in the corrected image output. The estimated GCP position is calculated by fitting a bilinear transformation between the latitude & longitude of the tickmarks and their corresponding scan line & pixel positions on the corrected image. The RMS error is calculated using the differences between the estimated and the actual as identified by user and the same is displayed on the screen.

9.2 ModiParam: This utility displays the current values of the tunable software parameters and provides option to modify them one-by-one, based on user requirements. The software then uses the updated values for further processing.

10. Design Highlights

The software is being developed on IRIX platform, using object-oriented analysis and design technology with the scope for porting onto other platforms. All expected error conditions will be handled with proper messaging. The proposed front-end GUI based on Java provides, easy to use user interfaces. Majority of the options involves mouse button clicks and minimal keyboard entries, so as to avoid the manual entries by users. The back-end processing will be in C++. This has been with a view to improve upon the throughput timing for highly computation oriented processing.

The generalised design of the PPS system leaves the scope open for porting the system to various platforms including Windows/Linux as they are widely available and used by most users.

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12. References

[1] Alurkar Medha, Arvind Kumar Singh, Gopala Krishna, B., Amit Gupta., 2002, Precision Processing of High-Resolution Satellite Data, *XXII INCA International Congress* , Oct. 30- Nov. 1, 2002, Ahmedabad, India

[2] Anon., 1998, IRS-1C/1D Stereo Data Processing System, *SAC-SIIPA-SIPG-IRS1D-DP-TN02-1998*, July 1998

[3] Naidu Devakanth, Gopala Krishna, B., Amit Gupta, Srinivasan, T. P., Srivastava, P. K., 2002, Strip Mosaicing of Satellite Data Acquired by Step and Stare Imaging, *XXII INCA International Congress*, Oct. 30- Nov. 1, 2002, Ahmedabad, India.