GEOPORTAL: TÜBİTAK UZAY Satellite Data Processing and Sharing System

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***Abstract*—Over the years, rapidly developing satellite technologies have greatly increased the amount and size of data; e.g. high resolution imagery of 30 cm (e.g. World View 3) and even video. As satellites become increasingly more complex and remote sensing capabilities improve, the demands on faster and more accurate data processing to enable the full potential of data exploitation likewise increases. In this light, TÜBİTAK UZAY has developed a satellite image processing and sharing platform, dubbed GEOPORTAL, to provide the software and informatics infrastructure required to facilitate sharing and processing. GEOPORTAL also includes modules enabling critical functions, such as radiometric and geometric correction, as well as other core satellite image processing routines, to serve images in formats ready for research and remote sensing applications.**

***Keywords*— informatics infrastructure; remote sensing software; radiometric and geometric calibration; image processing**

I. INTRODUCTION

RASAT satellite is the first nationally built satellite of Turkey [1]. The aim was to independently design and build a remote sensing satellite and develop new modules in space. RASAT has a 7.5 m resolution pan and 15 m resolution RGB bands. Since its launch on 17th August 2011, over 7 million km^2 imagery has been acquired by RASAT. It is currently operated by TÜBİTAK Space Technologies Research Institute.

TÜBİTAK UZAY develop GEZGİN image sharing platform which is supported by Ministry of Development under Satellite Image Processing Center and Geoportal Development Project (GeoPortal). The project aims to increase research capability of TÜBİTAK UZAY in satellite image processing and develop a satellite image sharing system with public institutions and universities. RASAT images benefits mapping, disaster monitoring [2], agriculture, ecology and city planning areas. RASAT images have been shared with government agencies and universities including Prime Ministry, the Disaster and Emergency Management Authority of Turkey (AFAD), Turkish Petroleum Corporation, Mineral Research & Exploration General Directorate (MTA) and Municipalities.

II. SATELLITE IMAGE PROCESSING

TÜBİTAK UZAY develops its own satellite image processing suite. RASAT and Göktürk-2 images are processed in their own workflows with minimal user interaction. Automation also decrease the amount of processing errors and processing time.

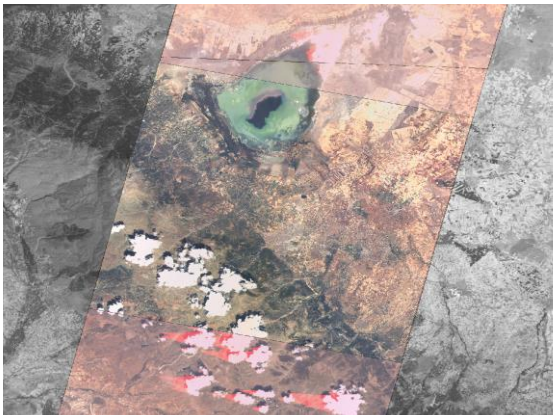

Figure 1 An example of a frame automatically processed with our software

A. Radiometric Correction

Radiometric correction of RASAT is performed in Level 1 operation. First operation in radiometric correction is pixel response non-uniformity normalization (PRNU). Response values of pixels are first measured in laboratory, then response values are computed regularly.

Excess light from clouds sometimes saturate red band, this effect cause flares around clouds. This effect is corrected using the relationship between pan, blue and green bands.

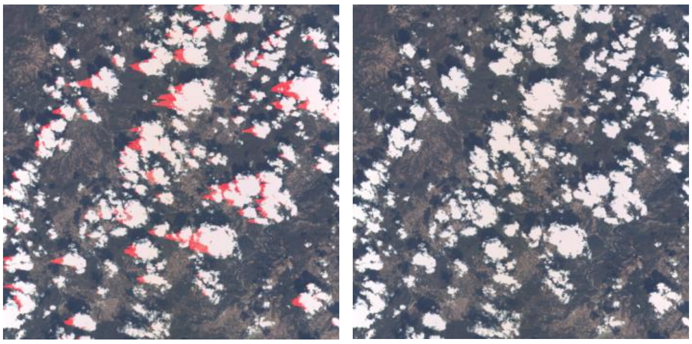

Figure 2 Removal of statured regions around clouds.

Red band may saturate entirely while imaging dry regions in summer. Saturated areas are corrected similarly.

B. Geometric Correction

Geometric correction activities includes band registration, georeferencing, RPC computation and orthorectification.

RASAT camera has a push broom sensor, where each band is acquired by a line sensor in an order. In band registration step, multispectral bands are registered to pan band. RASAT is capable of acquiring 960 km long image strips. However for better registration image strips are divided into 32x32 km^2 frames.

Georeferencing is another crucial step in satellite image processing. Star tracker of RASAT is not operating properly, as a result RASAT images have up to 5 km positional errors. A system for georeferencing is developed using Landsat 8 images as a referenced image. Landsat 8 images have 12 meter CE90 accuracy [3]. The main challenge in registration is that Landsat mosaic and RASAT images have different imaging conditions as land surface changes continuously.

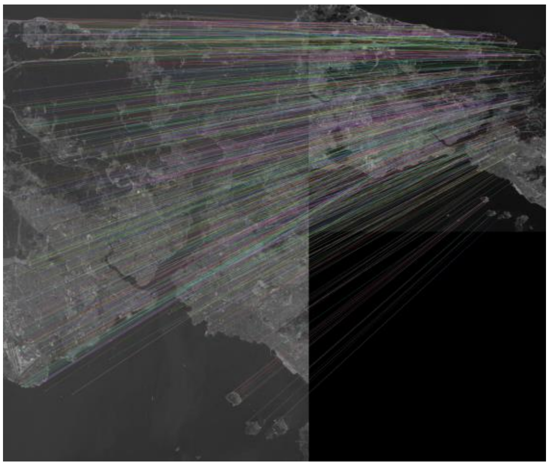

Figure 3 RASAT (left) and Landsat 8 (right) Gereferencing

Rational polynomial coefficients (RPCs) describe the geometric transformation between the image and Earth coordinates. Image matching should be robust and key points should be distributed equally for optimal RPC computation. In the frame of GEOPORTAL projects we have adopted the technique described in [5] in order to solve for these coefficients.

Due to the fact that there are much more observations available then unknown parameters, i.e. hundreds of ground control points and eighty coefficients to estimate, an over determined system is to be solved. As a remedy to this issue, Tikhonov regularization technique is implemented.

Final step in geometric correction is orthorectification. Our orthorectification process is based on computed RPCs. Orthorectification process requires high quality Digital Elevation Model (DEM). Our solution use 90m SRTM DEM. 30 meter SRTM-2 data will be globally available in 2015 [6]. Orthorectified RASAT images have 20-30 meter positional errors [7, 8].

C. *Pansharpening*

Pansharpening algorithms one of the active research areas in satellite image processing in which companies and research institutions try to develop better algorithms. Pansharpening is image fusion of high resolution pan image and spectral low resolution images. Pansharpening methods for RASAT are evaluated in [9]. RASAT use Unsharp-HCS method pansharpening which is a modified version of HCS method [11]. Unsharpening operation applied to pan band increase sharpness of the image while preserving color information. GPU implementation of pansharpening algorithms with RASAT images are compared in [12].

D. *Data Processing*

A final set of optional operations may be applied to satellite images before sharing in multimedia or for presentation purposes. Color of RASAT images are enhanced with contrast limited adaptive histogram equalization (CLAHE) [13]. An additional sharpness layer maybe added with unsharpening filter. After these operation RASAT images have an appealing and natural look.

Cloud cover images are automatically computed from normalized images with simple thresholding operation over all multispectral bands.

E. *Data Processing Application*

RASAT functionalities which are served by Vİ (Veri İşleme/Data Processing) software. RASAT image information is acquired from task planning database. Then image processing workflow is run by the operator. Different combination of data processing can be implemented by the application. Since the development platform is based on plug-ins, integration between processes are made by a manager plug-in. The application designed with object oriented software development principles so that the problem domain and solution domain are close to each other. Each process desired as a job and these jobs are managed by the manager plug-in. Flexibility in the software derives from this idea. The application also stores historical processing parameters for future automations. Eclipse RCP platform has been used for development and SWT graphical user interface libraries has been used. For image processing GDAL, and Java Image IO libraries has been integrated to the software. Also the processes can call an external application for image processing. This capability used for integrate .NET applications with the Java application. With default parameters the application can prepare an image from raw data to product for GEZGİN Portal. VI software fetches imaging data from mission planning database, with this information software prepares metadata in DIMAP 1.1 format.

The architecture of the software has been redesigned through GEZGİN Portal development process. For simple image processing development is straightforward but while implementing complex processes and combination of processes the initial architecture model was insufficient. Many different ideas have been argued for a new architecture so that software system will behave as required. At the end of designing process, we decided to move on object oriented development model. In order to create flexible and an up-to-date software all 32-bit libraries switched with 64-bit libraries. In initial architecture software was relying on JAI (Java Advanced Imaging) libraries which is only 32-bit for Microsoft Windows application, it replaced by combination of 64-bit Javax ImageIO and 64-bit GDAL libraries.

III. Tuz Gölü Radiometric Calibration Campaign

A. Radiometric Calibration

Radiometric calibration is essential to ensuring the quality of data obtained from space assets as well as the inter-operability of data obtained from different satellites, especially for earth observation applications. The pixel values of an image are related to the radiance of a scene on the earth's surface only after going through a number of transformations. The top-of-atmosphere (ToA) radiance measured by a space-borne sensor is the sum of a number of radiance sources, including direct solar radiation reflected from the ground to the sensor, scattered, direct and indirect reflections, as well as upwelled radiance scattered from the atmosphere to the sensor. Meaningful interpretation of satellite data requires relating the surface radiance to the ToA radiance, as well as characterization of the sensor to account for any distortion due to the satellite optics, detector and electronics that may occur during the process of forming the satellite image. It is only through radiometric calibration – a calibration of the measurements relating to electromagnetic radiation at all wavelengths – that pixel values of an image can be related to physically meaningful quantities, consistent with measurements of other satellites.

B. Tuz Gölü and CONTROLS project

Absolute radiometric calibration refers to the use of spectrally and spatially homogenous white surface on the earth that may be use to radiometrically define a reference pixel value. Through the European Space Agency funded CONTROLS (Comparisons to Maintain Traceability for Optical Sensors) project, field campaigns were conducted in 2008-2010 to assess the spatial and spectral characteristics of the Tuz Gölü (Salt Lake) in Turkey and its suitability as a natural reference for absolute radiometric calibration. As a result of this study, Tuz Gölü was found to have exceptional qualities and it was thus selected by the Committee of Earth Observation Satellites (CEOS) as a LANDNET site [14]. Since 2008, Tuz Gölü has been annually used for the radiometric calibration of Turkish satellites, including RASAT and Göktürk-2.

C. Tuz Gölü 2014 Absolute Radiometric Campaign

An absolute radiometric calibration campaign is carried out Radiometric Calibration Campaign is planned to include RASAT, Göktürk-2, Landsat 8 and Hyperion. Landsat 8 has 15 days revisit time; as a result based on Landsat 8 orbit, the same day RASAT, Göktürk-2 and Landsat 8 is determined.

Satellite	Date	Time	Roll Angle	Sun Zenith	Sun Azimuth
Landsat 8	29/08/2014	10:27	0	34.65	142.61
Göktürk-2	29/08/2014	10:58	-3.71	38.38	132.87
RASAT	30/08/2014	12:30	5.97	30.01	173.40
EO-1 Hyperion	02/10/2014	10:30	9.17	43.46	126.18

EO-1 Hyperion image acquisition is coordinated with NASA [15]. EO-1 image was acquired after several attempts.

Tuz Gölü is the second largest lake of Turkey. It's 905 m above sea level. Tuz Gölü is also a national park. There are salt production facilities around the lake. Our entry point is inside Mutlucan salt processing facility. We surveyed the lake during the dry season to determine driest and most homogenous area.

Tarpaulins are used to mark our locations so that it will be possible to locate measurement area correctly. Four 3x50 meter tarpaulins are placed in the flight direction of Göktürk-2 (-9.95°) to serve as an MTF target.

Figure 4 Tarpaulins as seen in Göktürk-2 images

Measurement locations are determined with hand computers which supports DGPS. Measurements are acquired

In this radiometric calibration campaign, sun-photometer, weather station and spectrometer were used to make measurements. Sun-photometer and weather station were installed near Salt Lake 3 days before the satellite pass (Figure 5). Data collection was conducted during these days.

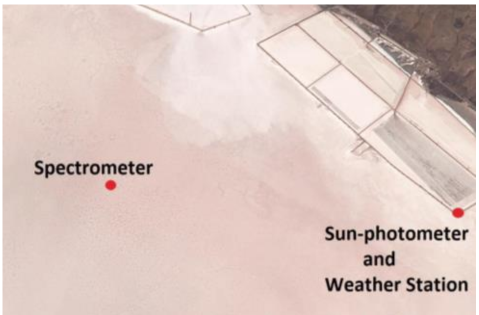

Figure 5 The coordinates of instruments

The make and model of the sun photometer is CIMEL CE 318 (Figure 6). The main purpose of the instrument is to measure sun and sky radiance in order to derive total column water vapor, ozone and aerosols properties using a combination of spectral filters and azimuth/zenith viewing controlled by a microprocessor [16]. Different scenarios were used in order to make various kinds of measurement automatically. The device is programmed to run a scenario with respect to 15 minutes intervals.

The data from the memory of the sun-photometer can be transferred to a PC or via the Data Collection Systems (DCS), to one of the three geostationary satellites, GOES, METEOSAT or GMS and then retransmitted to the appropriate ground receiving station [16].

The results obtained from the sun-photometer are uploaded to on the webpage of NASA Aerosol Robotic Network (AERONET) which is a ground-based network based on Cimel sun-photometers. Our measurements are stored and made online under the name "Tuz_Golu_3" on Aeronet webpage. One can access to our measurements via the address given in [17]. The data products are provided as raw (level 1.0) and cloud screened (level 1.5)

Figure 6 Meteorological Station Vantage Pro 2Plus (left) and Cimel CE318-2 Sun-photometer (right) at Salt Lake

Davis Vantage Pro2 Plus is used as weather station which provides information about temperature, humidity, barometric pressure, wind speed and direction, precipitation amounts. The instrument includes a digital console that provides readouts of the data being collected (Figure 6).

The weather station was adjusted for 5 minutes intervals data collection and storage. Data logs were then transferred to the PC using *weatherlink* software.

The average value of temperature (28.8539 °C) and humidity (43.6154%) at the time interval 12:00 to 13:00 is calculated which is half an hour before and after the satellite passing over Salt Lake.

ASD Field Spec 3 spectrometer is used for the measurements of DN, reflectance and transmittance at Salt Lake. Spectral range of ASD Field Spec3 is between 350-2500 nm and it collects data with speed of 1/10 second/spectrum (Figure 7). This instrument has 3 detectors, VNIR, SWIR1 and SWIR2. Measurements from 32 different points are illustrated in Figure 8 Spectral measurements from 32 points in Tuz Gölü (Figure 8).

Figure 7 ASD Field Spec 3 Measurements at Salt Lake

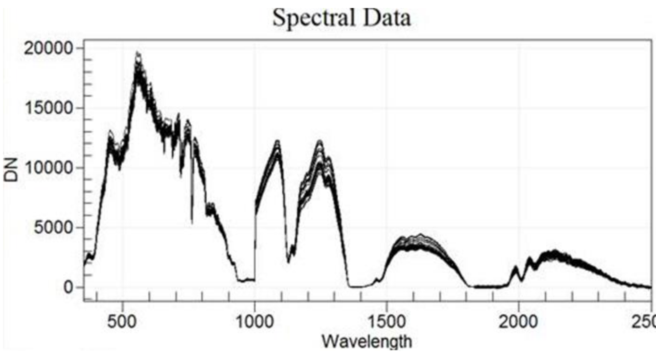

Figure 8 Spectral measurements from 32 points in Tuz Gölü

Radiometric Calibration aims to find sensor's gain and offset parameters to convert pixel values from digital numbers (DN) to radiance values.

Spectral measurements along with viewing conditions and other data are input to a radiative transfer code, 6S, which simulates the top of atmosphere radiance (ToA). Once the ToA is obtained, gain and offset parameters can be estimated. Since the relative calibration of the linear CCD array is already done, only one gain and one offset value are sufficient to calculate radiance from DN for any given pixel.

IV. GEZGİN SATELLITE DATA SHARING

A. *RASAT Task Planning*

RASAT data acquisition planning software [18] enables visualization of satellite orbit with roll limits over the globe. Software has an engine that calculates satellite orbit and orbital parameters. For a selected point over the globe, engine extracts the passes of the satellite with roll angle and illumination values. Software helps data acquisition planners selecting the gain parameters of the satellite optical instrument. Clouds have a significant impact on data acquisition planning for optical instrumentation. Software features a cloud cover layer from open weather map

Processed RASAT images' overlays are exported to ESRI shape format and merged into single file. A heatmap is generated using ArcMap's Count Overlapping Polygons addin [19]. Resulting vector file contains location and number of occurrences.

The results are classified into 5 classes according to the count value and exported as kml file with transparency of 20%. In Figure 9, dark red color shows the places where there are five or more images and the light yellow color shows the places where there is only one image.

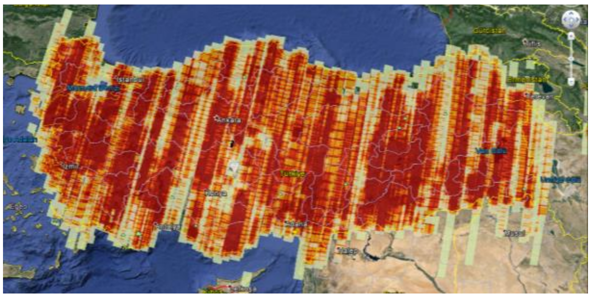

Figure 9 Heat Map

B. *Data Sharing Infrastructure*

GEZGİN GeoPortal is based on serving RASAT satellite images to authorized stakeholders and taking new requests. The network services and technologies available within the GeoPortal are: search, preview, download, request etc.

- Users are able to search RASAT images by selecting political boundaries, uploading files (.shp, .kml and .kmz), drawing on map or entering coordinates. Search activities can be filtered by entering date interval and cloud ratio.
- GeoPortal gives the result set according to the search criteria. Up to this result set users may preview the images and get information about data such as acquisition date, cloud coverage, other related explanations, etc.
- Authorized users may also download the images if they think archive data is adequate for them.
- If end-users wish to provide new RASAT imagery, they may request a new image by filling the new request form.

Items that may be considered as components of GeoPortal are; GeoPortal Architecture, Map Tools, Sustainability, Security, Usability, and Performance. Our project team try to perfect all these items to maximize efficiency of RASAT satellite usage. With its user-friendly tools and fast-loading map layers all remote sensors will benefit from this web portal without paying any cost.

Infrastructure used for Geo-Portal development are;

- Geoserver: Open source WMS ,
- Java: J2EE, JSF, Spring Framework, PrimeFaces, Mysql Database
- OpenLayers: An open source javascript library to load, display and render maps from multiple sources on web pages

C. *GEZGİN Data Products*

GEZGİN provides variety of RASAT image products. Processed RASAT products are available to public institutions and universities. RASAT images are shared in several raster and vector levels.

Level	**Description**
L1	Radiometric Corrected Image
L1R	Band Registered Image
L1RB	Cloud Flares Removed Image
L2	Georeferenced Image
L3	Orthorectified Image
Pansharp	Pansharpened and enhanced image

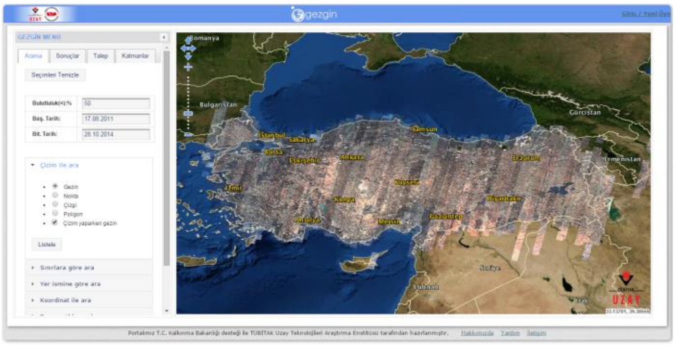

Figure 10 TÜBİTAK UZAY Data Sharing Portal, GEZGİN

More than 3000 frames of the years 2012, 2013 and 2014 is used to generate a mosaic. First, ENVI 5.2 is used to generate 30 small mosaic files, each consists about 100 frames. Low cloud ratio and similar colored images is chosen for these mosaics. Afterwards, by using Global Mapper these 30 small mosaics are combined to get a whole mosaic of Turkey (Figure 11) with RASAT images. The final mosaic GeoTiff file has 36 GB size with LZW compression.

Figure 11 RASAT Mosaic Image

V. CONCLUSIONS

Satellite image processing tasks should be considered a central part of any earth observation satellite development program. Satellite image processing and serving activities are vital for end users as these activities directly affect quality of images.

TÜBİTAK UZAY has developed its in-house software for processing satellite images. RASAT images are shared with GEZGİN portal has set an example to public and universities. We look forward to further improve our image processing chain with algorithms to improve image quality.

TÜBİTAK UZAY also plans to make Tuz Gölü LANDNET site more active in international community especially with APSCO member states and EU countries.

Acknowledgements

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