Real Time Image Display and Exploitation Software for Synthetic Aperture Radar

Surya OV, S.Manikandan, Chhabi Nigam, Vardhani JP and Ramakrishnan S
Electronics & Radar Development Establishment, DRDO
suryasreejith@gmail.com

Abstract: Synthetic Aperture Radar (SAR) on UAVs will form the image on board and send the image data to the Ground Exploitation Station (GES). The received image data at the GES has to be displayed for visualization and interpretation purpose. Image Display and Exploitation Software (IDES) is developed and tested in airborne SAR system for visualizing and analysing the SAR images in real time. IDES is generic in nature for image processing techniques and functionalities essential for any airborne radar. In this software, SAR image gets displayed in real time, Geocoded and saved. SAR mission planing module is also provided in this software.

Key Words: Display, Image, SAR, Mission Planning, Geocoding.

I. INTRODUCTION

In recent years, the usage of Synthetic Aperture Radar (SAR) data became more and more popular and is used in many scientific fields. SAR data are ideal for land surface mapping owing to their high spatial resolution and ability to penetrate clouds and darkness. Several new and promising software products are available in the market for the image exploitation. However, such products are capable of some basic and very well-established SAR functionalities. Based on the SAR design constraints and users' requirements, customised algorithms have to be implemented by designer. Real Time Image Display and Exploitation Software (IDES) is such a SAR image handling platform.

II. DESIGN & FEATURES OF IDES

The IDES was developed to have GUI based software to provide a generic SAR image handling platform and user control for SAR system. This software provides an option to verify the SAR images acquired during the mission by analysing and interpreting the images in offline. Mission planning is another requirement for the SAR system to calculate the mission information and radar configuration for the user defined inputs. This module was expected to visualise the real scenario from the radar point of view. The image

processing algorithms and techniques required for any generic airborne radar is given in this software. IDES operates in real time mode to display mission parameters and radar data as multiple views. On the other hand, for the mission planning and image exploitation modules, it operates in offline mode. It can display the captured images online. Displayed images can be geocoded and saved. Thus the application can be utilised as an analysis tool online as well as offline to analyse the SAR images. The geocoded SAR images can be cross-verified with satellite maps for accuracy.

IDES has the capability of indicating the own aircraft platform graphically on a geocoded reference map. This leaves the track of aircraft over the map as shown in Figure 1.

In a separate small window, the relation between aircraft heading, true north, antenna bore sight and current antenna position will be indicated graphically and updated in real time missions.
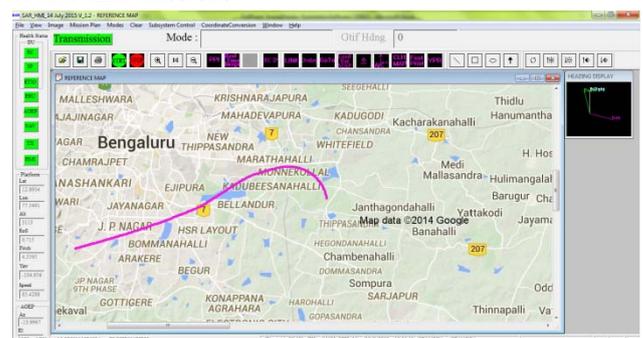

Figure 1 IDES in operating state

IDES is a Multi Document Interface (MDI) based multithreaded application made in Visual C++ with CxImage library as the base in windows platform. OpenGL also is used in this software for to display some of the graphical features.

IDES was tested with simulator running on same platform. Main challenges faced were in terms of time and memory when integrated with Radar, which is running on RTOS. In IDES, real time image display entirely depends upon the usage of queues internally.

IDES is capable of handling a data rate of 1.25MBps. Static memory allocations reduced exceptions that were occurring due to improper memory allocations. Image size that can be displayed in a screen is limited to solve the issue on memory constraint. The images will be saved in memory before getting cleared to display the next batch of image. This makes the exploitation of each image easier.

III.   MISSION PLANNING

The mission planning helps in planning the sortie and verifying the captured image online. On the geocoded reference map, the operator can plan the missions. The objective is to find the positions of the aircraft trajectory by defining the swath area to be imaged and to find the swath area by defining the aircraft trajectory.

In Figure 2, given the positions of points S1 and S2 in geodetic co-ordinates [1] (latitude, longitude and altitude), the positions of points A1 and A2 on the aircraft trajectory has to be computed and vice versa.
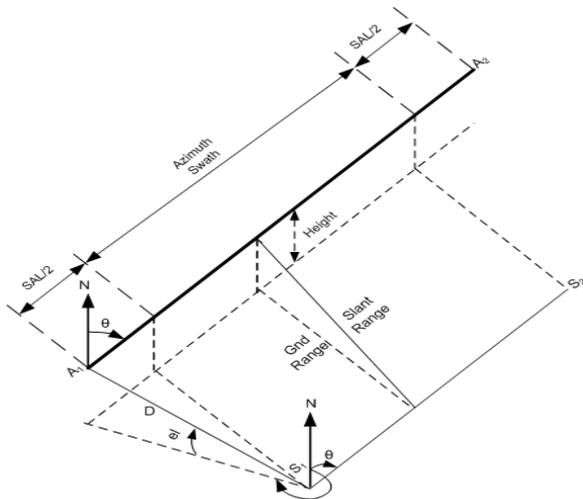

Figure 2 Stripmap SAR Imaging Geometry

In IDES, mission planning can be done over a geocoded map alone. At first, radar parameters like platform height, slant range, squint angle and range swath can be entered in the dialog box provided, as the input parameters to the mission planning module in IDES. Look down angle is calculated as follows:

$$\text{Look down Angle} = \sin^{-1}\left(\frac{\text{Platform Height}}{\text{Slant Range}}\right) ----- (1)$$

Squint angle can be either Left or Right of the radar. It determines the position of the antenna on the radar. If squint angle is selected as Left, the mission planning module considers that the antenna is positioned to the left side of the radar platform. 'Range Swath' is the user requirement of the swath area.

The mission planning can be done by both manual and automatic methods. In the case of automatic mission planning, along with the radar parameters, the operator

can feed the input values for the mission plan also. These fields include general information about mission, such as mission number, date and description. Also, the user can either specify the geodetic locations for the target area or the aircraft path. IDES computes the swath area and flight route and draws it over the map in case the target location is provided. If the aircraft path is provided then the swath area will be calculated and drawn over the map.

In manual mission planning, the operator can draw the target area using mouse, around the required swath points S1 and S2 indicated as rectangles in purple colour in the figure below. IDES calculates the whole swath area to be imaged. It computes the aircraft route. IDES draws the same over the map as shown in Figure 3.
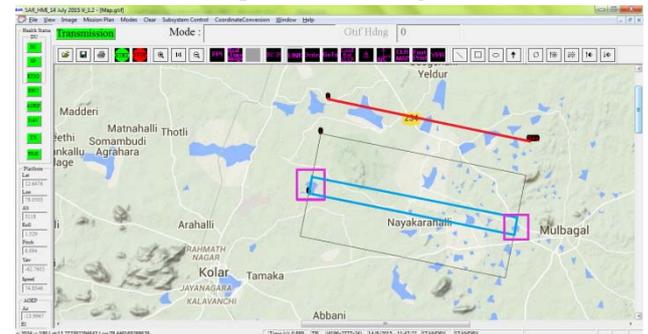

Figure 3 Mission Planning over the geocoded map

In Manual mission planning, the operator, using mouse, can draw the aircraft route - a straight line in red colour as shown in the above figure. IDES calculates the swath area to be imaged and draws the same over the map.

IV.   REAL TIME IMAGE DISPLAY AND IMAGE RECTIFICATION

IDES can operate in STRIP map mode. A dedicated real time image window displays the images in selected mode of operation.

IDES uses vertical tiling in STRIP map mode [2] and thus giving an impression of displaying images, strips after strips as shown below:

Figure 4 Image display in STRIP map mode

For a selected strip map mode, during the operation, range swath and azimuth swath will be constant. As far as IDES is concerned, range swath and azimuth swath are the height and width of one strip of image. As the radar moves, the image grows in the direction of azimuth but the number of strips that can be displayed in a screen is limited to solve the memory constraint issues.

In a packet, 200bytes of greyscale data is received. It is converted to an image called grid. This grid is placed on the screen as per the strip and grid numbers associated in the header. Ideally, grid data will come sequentially one by one. So in a strip of image, every grid will be stitched below the previous one. On completion of display of one strip, the first grid will be received for the next strip which will be stitched adjacent to the first grid of the first strip. In Figure 4 the display of second strip progresses on reception and stitching of grids. This continues until the screen is full of specified number of strips.

In the background, the image on the screen will be saved in bmp format and gtif format. To save in gtif format, image will be geo rectified and then geocoded. By then the screen will be cleared to display the next set of strips.

Parallely, on the reference map, aircraft position and radar returns (dots in green colour) are plotted as shown in Figure 5:
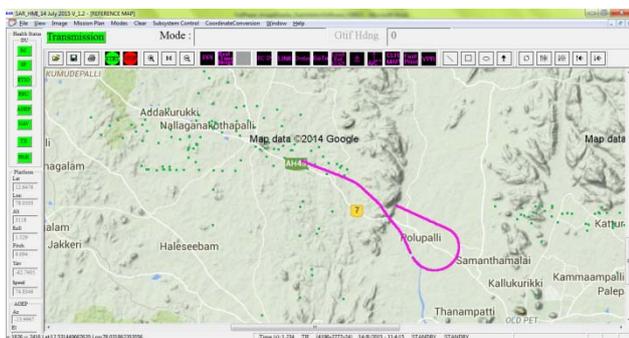

Figure 5 Reference Map with Aircraft position and Radar Returns

Georectification& Geocoding

In real time, every image will be saved in bmp format as well as gtif format. Gtif file holds the georectified and geocoded image. Figure 6 shows the image in bmp format as well as corresponding gtif format. In the gtif format, the image is rectified which is a result of georectification and the status bar shows the latitude and longitude of the current cursor position.

Figure 6 Normal Image and corresponding Georectified & Geocoded Image

Normally, each strip in real time is associated with a header for geocoding. It contains the geodetic locations of the center of the strip image, slant range from the aircraft, aircraft heading, azimuth resolution and range resolution. The image will be georectified based on the aircraft heading.

From the given geodetic location, IDES calculates the geodetic locations corresponding to the top left corner of the rotated image. Rectangular coordinate points (N,E,D) corresponding to given slant range, aircraft heading and look angle are calculated. These NED coordinates are converted to ECEF coordinates with respect to the given latitude and longitude of the center of the first strip. These coordinates are converted to geodetic points which will form the latitude and longitude of the starting point of the image. While geocoding, these corner points, aircraft heading, Azimuth Resolution (X Resolution) and Range Resolution (Y Resolution) are saved in the file header.

When gtif files are opened in IDES, on mouse movement over the image, IDES computes the latitude and longitude of each pixel, based on the latitude and longitude of the top left corner of the image, azimuth resolution (x resolution) and range resolution (y resolution).

V. OFFLINE IMAGE EXPLOITATION FEATURES

The IDES supports all types of standard image files. When an image is opened in IDES, the size and format of the opened file will be displayed on the status bar at the bottom framework of IDES. On mouse movement over the image, x and y coordinates corresponding to the pointed pixel, along with the RGB values at that point will be displayed on the status bar .

IDES can zoom in and zoom out the image as shown in Figure 7:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \qquad \text{----------- (2)}$$

Equation 2 is used for scaling operation and Sx and Sy is the scaling operators.

Figure 7 Zoom-In and Zoom-out operation

IDES can adjust the brightness [4] and contrast features of an image as shown in Figure 8 Figure 9 Figure 10 and Figure 11.

Figure 8 Image Enhancement – More Brightness

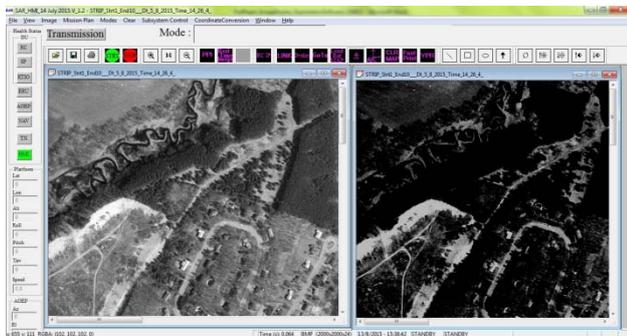**Figure 9 Image Enhancement – Less Brightness**

Figure 10 Image Enhancement – More Contrast

Figure 11 Image Enhancement – Less Contrast

Geometric transformation [4] like rotation of the image also is implemented in IDES as shown in Figure 12. In Figure 12, image is rotated 12.345^o using bilinear interpolation method. Equation 3 is used for rotation and Θ is the angle to be rotated.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\Theta & -\sin\Theta \\ \sin\Theta & \cos\Theta \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} \quad \text{----- (3)}$$
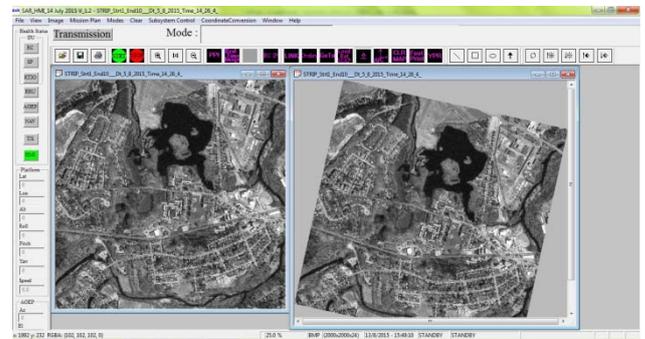

Figure 12 Geometric Transformation – Image Rotation

In IDES, the operator can find the length and area of the image by selecting the appropriate line or rectangle option. The length of the object in the image is given in pixels.
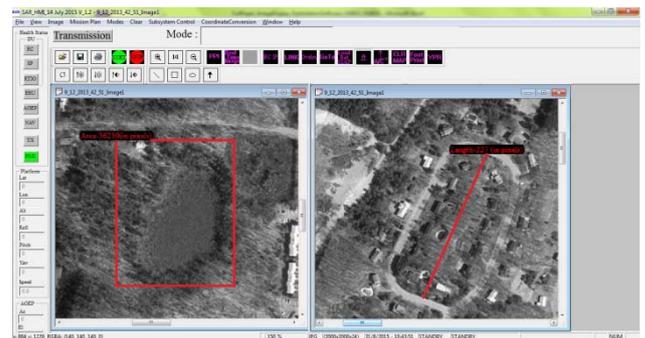

Figure 13 Line and rectangle drawn over the image

IDES can open geotiff image files also. This software provides the option to save an image as geotiff by allowing the operator to feed the latitude and longitude of the top left corner of the image. The operator is supposed to provide the x resolution, y resolution and heading with which the image to be rotated.

After opening the geotiff images, on mouse movement over the image, latitude and longitude values corresponding to each pixel will be displayed on the status bar.

Linking of two windows is another option provided in IDES tool. If reference map window and the imaging window are opened, these two can be linked. One operation performed on one of the linked image will have the same effect on the other too. Figure 14 shows two linked images – one SAR image and a reference map. On SAR image, a rotation of 12° is performed. IDES applied the same operation on the linked reference map also.
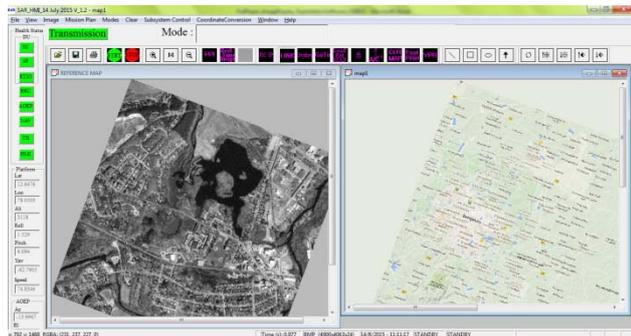

Figure 14 LINKING of images

CONCLUSION

Image Display and Exploitation Software (IDES) is developed and tested in airborne SAR system for visualizing and analysing the SAR images in real time. The image processing techniques such as brightness, contrast, image rotation, drawing of shapes on the image, finding the area and length of the target in SAR images, linking of two windows, converting the raster images (jpeg,bmp,tiff) to Geocoded images (geotiff) are implemented and tested in this software. Speckle filtering techniques, georectification with reference images, object detection and many image post processing techniques can be implemented in further versions. Mission planning module can be improved by providing for multiple targets with optimized routes.

REFERENCES

1. G. Cai et al., Unmanned Rotorcraft Systems, Advances in Industrial Control, DOI 10.1007/978-0-85729-635-1_2, © Springer-Verlag London Limited 2011

2. Li Yong, Zhu Daiyin, Zhu Zhaoda, "Study on high resolution sub aperture imaging algorithm for airborne synthetic aperture radar processing", Journal of Electronics and Information Technology, vol.26 suppl. Sept. 2004, pp91-96.

3. Gonzalez, Woods, 'Digital Image processing using Matlab", IInd edition, McGrawhill publication.

4. 1. Yong Li, Daiyin Zhu, Zhaoda Zhu, "Geometric distortion correction in the sub aperture processing for high squint airborne SAR imaging", IGARSS '04. Proceedings, vol.6, Sept. 2004, pp 3919-3922.

BIODATA OF AUTHORS

Surya O V is Technical Officer A working for software development, integration and testing of Ground exploitation software for airborne Synthetic aperture Radar.

Dr.S.Manikandan is Scientist D, working for software development, integration and testing of Ground exploitation software for airborne Synthetic aperture Radar.

Chhabi Nigam is Scientist E in LRDE, DRDO Bangalore. Currently working for software modules development, integration and testing of airborne Synthetic aperture Radar.

Vardhani J P is Scientist F in LRDE, DRDO Bangalore. Currently she is group officer of airborne software group.

Ramakrishnan S is Scientist F in LRDE, DRDO Bangalore. Currently he is project director for Synthetic Aperture Radar.