Polarimetry Shareware in Support of the RADARSAT-2 Mission: Implementation Challenges

Mo Farhat and Robert Fiset
RADARSAT-2 Program Office,
Canadian Space Agency,
6767 route de l'Aéroport
Saint-Hubert, Québec, J3Y 8Y9, Canada

Abstract

This paper describes work being undertaken by both authors to develop a set of polarimetry tools in support of the RADARSAT-2 mission. The focus of the paper is on the challenges faced in the implementation and evolution of the tool. The application can ingest various fully polarimetric data formats, perform image synthesis routines, generate polarimetric signatures and it includes a prototype coherent decomposition method. This tool is still being tested and will be released shortly as a shareware available on the Canadian Space Agency (CSA) Website.

Introduction

Except for airborne SAR images, polarimetric data are not widely available. No satellite is yet providing a recurrent and regular covering of the earth with a fully polarimetric sensor. Consequently, research interests in this area have not reached critical mass yet and very few polarimetric processing software tools are available. Most of the software that can ingest fully polarimetric data can only perform superficial processing since the full processing potential of such data to extract information is still not reached.

The RADARSAT-2 satellite, a fully polarimetric C-band SAR, will make this type of data available on a regular basis. This paper describes work being undertaken by both authors to develop a set of polarimetry tools in support of the RADARSAT-2 mission. The focus of the paper is on the challenges faced in the implementation and evolution of the tool. The tool is still being tested and will be released shortly as a shareware available on the Canadian Space Agency (CSA) Website.

Several drivers determined the current requirements of the tool. These include low development cost and delivery in a common programming language within reach and budget to a wide range of users. Specifically the tool is targeting researchers with low budgets and who can benefit from a SAR polarimetry research environment to test new algorithms. The final driver is to establish basic capabilities within the environment to enable a common programming language to perform base-line image processing functions.

Implementation Challenges

The programming environment

A very important aspect of this whole exercise is defining a programming language to use. Since the idea is to reach as many researchers as possible, the environment must combine flexibility and availability. We have been considering several concepts ranging from popular office tools to common programming languages, including total research environments.

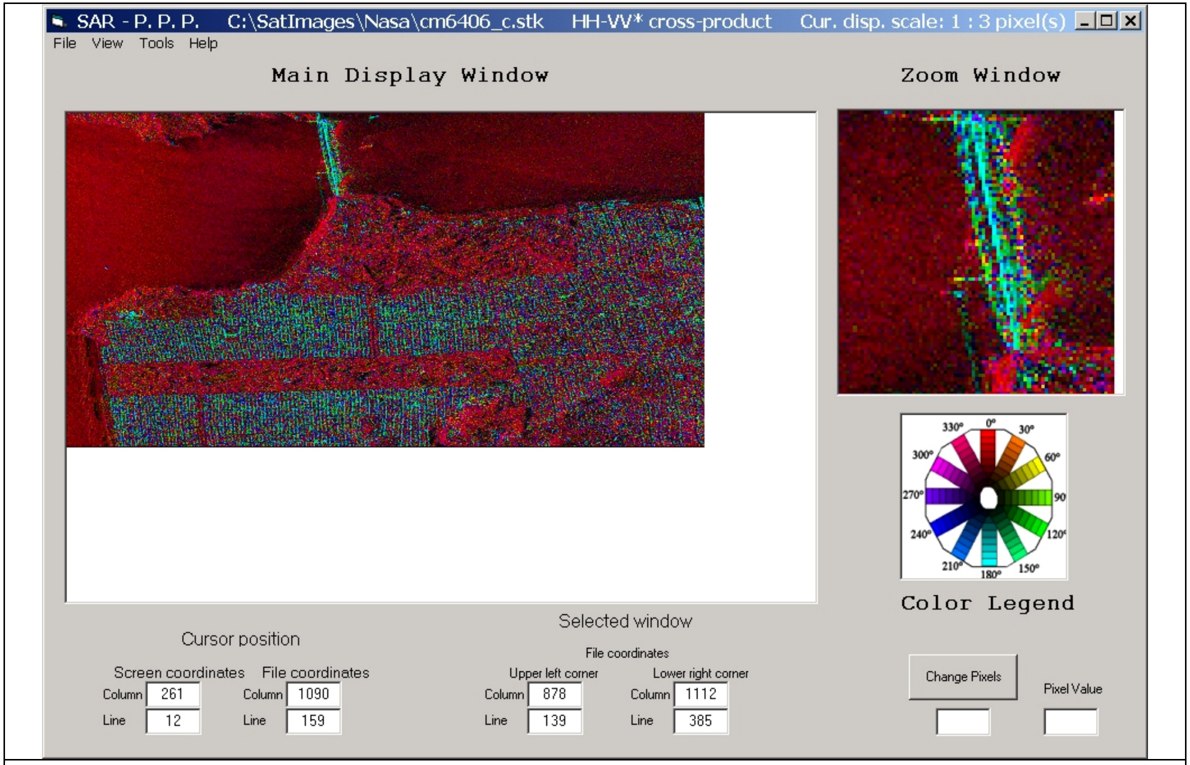
Popular low-cost office tools such as spreadsheets are simple to develop, modify and maintain, although their use for image processing is very limited. This is especially true when considering the size of remote sensing images and the very limited display routines provided. However, spreadsheets include powerful capabilities in terms of arithmetic and output for small subsets of data, so this approach was very appealing as a first cut and yielded an interesting tool to compute and display polarimetric signatures [1] [2].

Total research environments such as IDL or MATLAB are another choice that was considered. These have architectures and functions that are remote sensing/image processing user-friendly. Most of the basic required functions are available including input, processing, output and display. The programming languages they employ are higher-level and easier to learn than common programming languages. Also, the available processing modules are stable and easy to reconfigure. However, these environments require run time or developer licenses, the cost of which makes it difficult to consider them for shareware use, unless the users or developers are able to absorb the license cost. Realistically, there are many universities that could contribute to research but are operating on very stringent budgets that do not allow them to equip their labs with such software licenses.

Visual basic (VB) was identified as an ideal programming language to meet our requirements. The language is very rich in its basic set, where procedural or object oriented programming paradigms are available. It has excellent graphical user interfaces (GUI) building capabilities, many extensions and interfaces to databases and other Microsoft applications. With the ever-increasing speed of the PC and with some attention to the way image-processing algorithms are implemented it becomes possible to develop serious applications. The greatest advantage of this language is the fact that there are many shareware programs available on the net, which the user can benefit from.

Displaying images

One of the first programming issues that we had to deal with was to display the image data stored in an image array on the VB image forms. This was eventually accomplished by using the SAFEARRAY technique to generate and display a bitmap. The next challenge was to develop a 2-D image editor. At the beginning we adopted an existing shareware "imaging editor" originally owned by Wang and later Eastman Software. Although the original version was free, the new Active-X controls (oleImgEdit1 & ImgAdmin1) require a license and could affect the evolution of the tool. Running away from this complication we ended up developing an in house dual-windows editor with basic zoom and image segment selection capabilities (figure 1).



Cursor position

Screen coordinates: Column 261, Line 12

File coordinates: Column 1090, Line 159

Selected window

File coordinates

Upper left corner: Column 878, Line 139

Lower right corner: Column 1112, Line 385

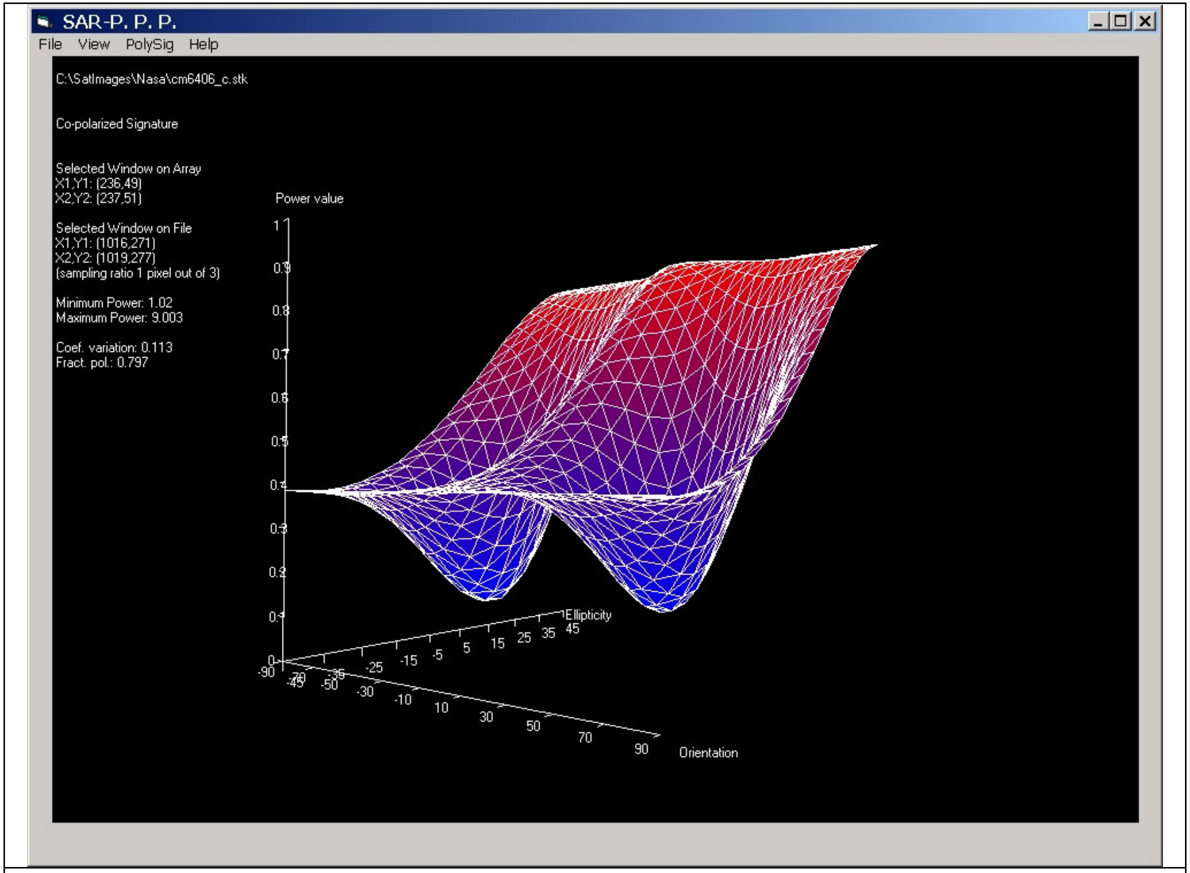
Pixel Value

Figure 1. Main application window: the 2-D image editor

Another challenge in the development work was to meet a requirement for a 3-D editor/viewer to display and interact with polarimetric signature. With permission from the author (Jerry J. Chen) we ended up using the Dex3D, a 3-D graphic engine shareware written in Visual Basic. The engine capabilities, which we adopted as the 3-D surface plot module, are impressive (figure 2). These capabilities include 3-D zoom, 3 axis rotation and three vertices facet surface manipulation. The use of this engine proved to be a time saver.

Dealing with large files on desktop computers

Fully polarimetric data files may sometimes be very huge, this especially being the case for AIRSAR single look complex data files. A non-negligible aspect of designing this software was to have the ability to deal with very large files in a reasonable time. For example, a scene may easily be over 1.5 gigabytes, which makes it impractical to open and load entirely in memory in the same way most paint applications are designed to do. To be able to open and navigate rapidly in very large files a sampling method is used. The sampling rate is determined by the size of the display window and the size of the processed file. Upon opening the file a decimated version of the file is loaded so the entire image may fit the display window, thus yielding an overview of the whole scene. Areas of particular interest may then be selected and reloaded for closer examination (figure 3). All further computations (image synthesis, signature generation, etc.) are performed on the arrays containing the loaded portion of the file.



C:\SatImages\Nasa\cm6406_c.stk

Co-polarized Signature

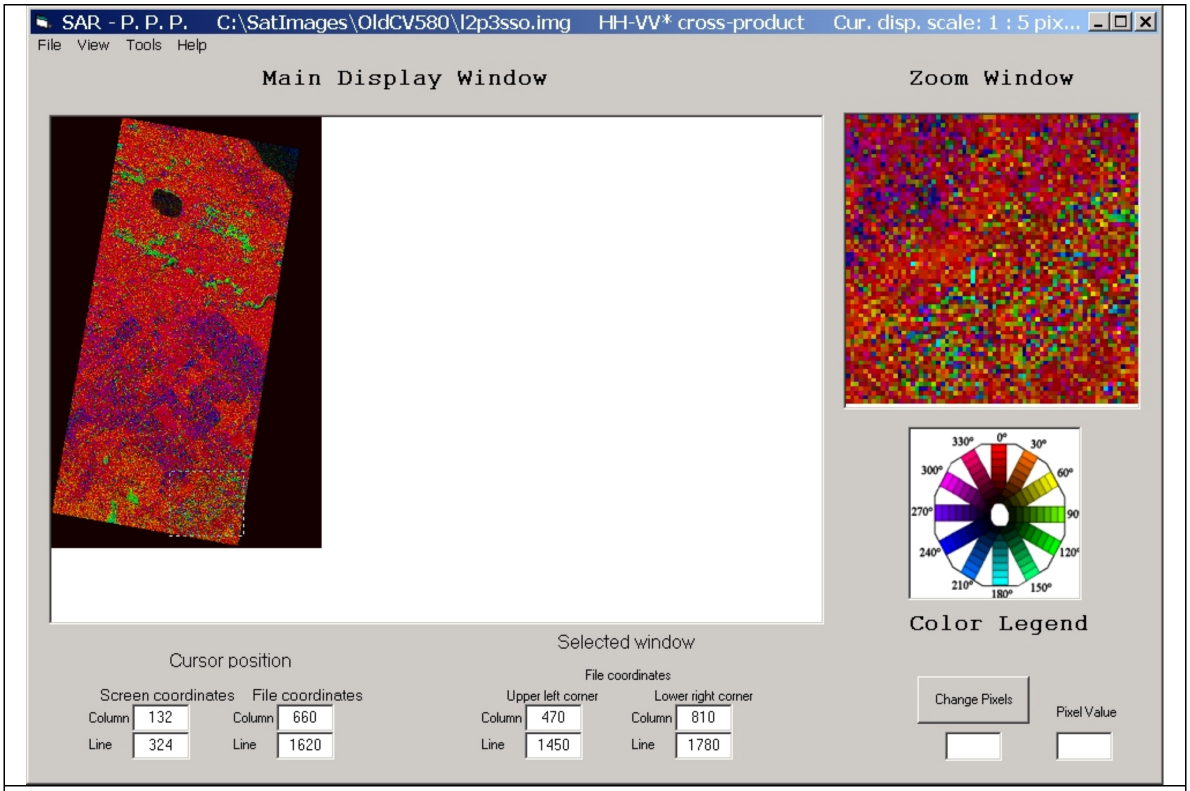
Selected Window on Array
X1,Y1: (236,49)
X2,Y2: (237,51)

Selected Window on File
X1,Y1: (1016,271)
X2,Y2: (1019,277)
(sampling ratio 1 pixel out of 3)

Minimum Power: 1.02
Maximum Power: 9.003

Coef. variation: 0.113
Fract. pol.: 0.797

Figure 2. Polarimetric signature display window: the 3-D image editor



SAR - P. P. P. C:\SatImages\OldCV580\l2p3sso.img HH-VV* cross-product Cur. disp. scale: 1 : 5 pix...

Cursor position

Screen coordinates		File coordinates	
Column	132	Column	660
Line	324	Line	1620

Selected window

File coordinates

Upper left corner		Lower right corner	
Column	470	Column	810
Line	1450	Line	1780

Figure 3. Selection of a region of interest for reloading, zooming in or polarimetric signature generation

Architecture Evolution

In order to meet the evolving tool requirements we started modifying the structure to work in a multi-image planes paradigm. In this paradigm, each new image plane is formed by applying a specific function to a previous image plane. The functions are either user specified or selected from a list of compatible functions.

Functional Evolution

An evolutionary development approach was chosen to develop the tool, where we started by implementing common polarimetric synthesis algorithms such as the ones implemented in the Sigma0 software [3]. After that we developed a polarimetric signature synthesis function using the Stokes matrix [4]. Currently we are implementing polarimetric signature decomposition using the Krogager method and polarimetric filtering [5]. We have plans to include also other decomposition methods. The final goal is to include classification methods, which are based on polarimetric signature and polarimetric filtering, and implement applications using these techniques.

Current Capabilities

File formats

The tool can ingest various image data formats including SIRC compressed Stokes matrix, single look complex scattering matrix and Convair Mueller matrix. Internally the tool functions work on Stokes matrices, so scattering matrix data are first converted to Stokes matrix before image synthesis routines.

Image synthesis

The software is able to synthesize the following images from the Stokes matrix.
1- Total power (all channels at once)
2- H-H, 3- V-V, 4- H-V (linear polarization combination of sent/received signal; H for horizontal and V for vertical)
5- R-L, 6- R-R (circular polarization combination of sent/received signal; R for rotating right and L for rotating left)
7- HH-VV*, 8- HH-HV*, 9- HV-VV* (these combinations are cross-products taken from the Stokes matrix and are combining phase and intensity information)
10- HH-VV phase only (this is the same as # 7 with phase information only)

Image types 1 to 6 are displayed as grey level images and image type 7 to 10 are displayed using various 8-bits color schemes to represent amplitude and phase of synthesized images.
The image selection functionality allows the user to choose a rectangular region on the synthesized image in order to zoom in from the array or to reload the selection from file (figure 3). The selection is also used to compute the polarimetric signature. Selection may be performed on the main display screen or on the zoom window, which allows selecting a single pixel if needed.

Polarimetric signatures

The image selection discussed in the previous section may be used to generate polarimetric signatures. If more than one pixel are used, an average Stokes matrix is computed and used to obtain the signature.

The signatures are computed with the following equation.

$$P = \vec{S}_R^T [K] \vec{S}_T = \begin{pmatrix} a \\ b \\ c \\ d \end{pmatrix}^T * \begin{pmatrix} k_{(1,1)} & k_{(1,2)} & k_{(1,3)} & k_{(1,4)} \\ k_{(2,1)} & k_{(2,2)} & k_{(2,3)} & k_{(2,4)} \\ k_{(3,1)} & k_{(3,2)} & k_{(3,3)} & k_{(3,4)} \\ k_{(4,1)} & k_{(4,2)} & k_{(4,3)} & k_{(4,4)} \end{pmatrix} * \begin{pmatrix} e \\ f \\ g \\ h \end{pmatrix} \qquad (1)$$

where:

P is the computed power value,

$\begin{pmatrix} k_{(1,1)} & k_{(1,2)} & k_{(1,3)} & k_{(1,4)} \\ k_{(2,1)} & k_{(2,2)} & k_{(2,3)} & k_{(2,4)} \\ k_{(3,1)} & k_{(3,2)} & k_{(3,3)} & k_{(3,4)} \\ k_{(4,1)} & k_{(4,2)} & k_{(4,3)} & k_{(4,4)} \end{pmatrix}$ is the Stokes matrix of a single or averaged set of pixels,

$\begin{pmatrix} a \\ b \\ c \\ d \end{pmatrix}^T$ and $\begin{pmatrix} e \\ f \\ g \\ h \end{pmatrix}$ are the Stokes vectors corresponding to the receive and transmit antennas

respectively and are equal to $\vec{S} = \begin{bmatrix} 1 \\ \cos 2\chi \cos 2\psi \\ \cos 2\chi \sin 2\psi \\ \sin 2\chi \end{bmatrix}$

In order to compute the signatures, equation 1 is used with values of χ (ellipticity) and ψ (orientation) varying with increments of 5° (0° to 180° or -90° to 90° for ψ and -45° to 45° for χ). The increment of 5° is used to save computation time and does not alter significantly the overall shape of the signature. Both co-polarized and cross-polarized signatures may be computed. For the co-polarized case both Stokes vectors are set with identical values, whereas in the cross-polarized case the Stokes vector representing the receiving antenna is set orthogonal to the transmitting antenna by subtracting 90° to the ellipticity value. The user is able to toggle between co- and cross-polarized signatures using the menu.

The software also comes with prototype theoretical signatures computed for simple geometrical shapes. These shapes are: the sphere, the dihedral, the cylinder (selective orientation) and the helix.

Signature decomposition

Since one of the main concerns of polarimetry is to be able to relate the data to geophysical objects or quantities, the first step toward that goal is the mathematical description of a complex polarimetric signature in terms of more simple basic signatures. The current version of the software includes a prototype of the Krogager coherent decomposition method. This method is applicable to complex scattering matrix data and yields an image representing the relative proportion of three basic shapes: the sphere (odd number of reflection), the dihedral (even number of reflection) and the helix.

Conclusion

A shareware infrastructure was developed in support of the RADARSAT-2 mission and the SAR remote sensing community in general. The shareware started with modest capabilities and is continuing to evolve in the direction of including tools to support applications.

References

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