

DEVELOPMENT OF EDUCATIONAL SAR PROCESSOR USING AJAX TECHNOLOGY

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ABSTRACT:

Processing techniques used for analyzing synthetic aperture radar (SAR) data have recently become more complicated, as new SAR sensors have included a variety of sensing functions. Understanding the SAR processing technique is necessary to develop a new approach employing SAR data. This paper presents a concept, a system structure, and an implementation method for an educational SAR processor (EduSAR). The processor uses Ajax technology in consideration of the typical computer systems found in schools. EduSAR has three software components, an EduSAR server, an HTTP server and a web browser, in each client computer. The EduSAR server is the main component for managing the SAR database and processing all SAR data sets. Operation of EduSAR, sample processed images and performance capabilities are shown to exhibit actual examples of processing ALOS PALSAR data. An experiment involving the reflection of radar waves, conducted to study the principles of the SAR technique practically, is introduced. This experiment was conducted in the field, and employed several corner reflectors (CRs) which learners constructed themselves, for a spaceborne SAR. EduSAR focused the signals reflecting from the CRs as cross points in the raw SAR data. Students were able to determine the amount of backscattering and the location of the CRs by identifying the corresponding cross points. As a result of the radar reflection experiment, EduSAR was demonstrated to be useful for learning SAR technology through both practical activities and raw SAR data processing.

1. INTRODUCTION

Since the release of images captured by spaceborne SARs such as ALOS PALSAR, ENVISAT ASAR and TerraSAR-X, the active remote sensing technique using synthetic aperture radar (SAR) has become popular with the public. These SAR sensors have a variety of sensing functions, including polarimetric, interferometric, and wide scan modes. They are also capable of recording high resolution imagery. Since this data has become available, more sophisticated methods have been applied to analyze it.

A number of lectures and seminars have focused on educating others of the advantages of SAR images. At these lectures and seminars, only focused SAR images were provided and investigated to avoid the complex SAR focusing technique required in most practices. Understanding the SAR technique is, however, necessary to develop new approaches employing SAR data with various sensing modes. Relevant parameters and algorithms for focusing raw SAR data should be carefully chosen to assure high quality. Recently, SAR training processors for a personal computer (PC) or Linux-based system have been introduced by several universities and communities over the Internet (AFS, 2006; Nicoll, 2003; Rosen, 2007). However, the computing power, memory and disk space necessary to process the SAR data often exceed the limitations of standard PCs in an educational environment.

In this paper, an educational SAR processor using Ajax (Asynchronous JavaScript and XML) technology, able to overcome the limitations of these PCs, is proposed. Ajax, a web

development technique used for creating interactive web applications such as Google Maps, drastically improves a web page's interactivity, speed, and usability. Ajax makes web pages more responsive by exchanging small amounts of data with the server behind the scenes, so that the entire page does not need to be reloaded each time a user requests a change.

This paper presents a concept, a system structure, and a method of implementing an educational SAR processor. Operations using the processor's GUI, sample processed images and the performance of the developed SAR processor are shown using practical examples. An educational approach, including an experiment involving radar wave reflection and an activity involving the focusing of raw SAR data, is described.

2. EDUCATIONAL SAR PROCESSOR

2.1 Concept and Specification

In general, advanced expertise in information processing is necessary to generate raw SAR data as a well-focused image. For this reason, it is difficult for a beginner of remote sensing to study the SAR technology. In this study, learners are assumed to have little expertise in advanced mathematics and signal processing. To enable these users to work with the data on a standard educational PC, it is necessary to develop special treated software which can process the SAR data. The software must take into consideration the following requirements:

1. Intermediate complex data generated by focusing the raw SAR data must be displayed as a set of grayscale images.

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2. User-friendly GUI and intuitive operation methods are key functions.
3. A simple operation that allows the user to understand the procedure at a glance is necessary.
4. Complex file management is implicitly processed in a server computer.
5. Appropriate parameters are automatically provided each time data is processed.

An efficient display methodology is also necessary from an educational viewpoint. The system must be able to show that the basic SAR technique is similar to a hologram by including many overlapping zone plates in the raw SAR data. In the case of focusing SAR data using the range-Doppler algorithm, the difference between a range and an azimuth compressed image can be easily identified. The processing history can be checked by retrieving intermediate data from the server individually. The display area of the image can quickly be shifted and zoomed in/out by using a PC mouse with a wheel. An arrangement of the icons on the tool panel follows a processing procedure of the SAR data.

The learner does not need to learn commands for the SAR processing in advance. Processing is started simply by clicking the corresponding icon. Since all generated intermediate data with the reference file name are automatically stored in the server, operation of a complicated file management system is not necessary. In this way, it is possible to concentrate on just the processing results without having to learn about the file management system. There are many kinds of parameters in the SAR data processing, and it is necessary for these parameters to be set appropriately. In this system, following each procedure, the best default values are included in the dialog for the setting of the parameters. The default parameters can be easily fine-tuned.

The educational SAR processing system has to be newly developed in consideration of the specification of the learners' computer, as we have described. The server processes the SAR data and stores all of the intermediate data. Special software, other than a standard web browser, is not employed by the client PC. Thus, this system, adopting Ajax technology, is composed of a rich internet application that requires minimal communication between the web server and clients.

2.2 System Structure

Figure 1 shows a simple system structure of the educational SAR processor (EduSAR). EduSAR has three software components: the EduSAR server, the HTTP server, and the web browser in each client computer. The EduSAR server is a main component for managing the SAR database and for processing all of the SAR data sets (Ito, 2007). The EduSAR server has a data manager, a SAR processor, and a database. The SAR database contains all of the raw data, intermediate data, and processing parameters. EduSAR has complex data layers to deal with multi-temporal, frequency, interferometric and polarimetric SAR data sets, which facilitate interpretation by a user. Thus, the intermediate and final data can be displayed using more intuitive and interactive methods by layer and screen managers.

Standard free software is used as the HTTP server and the web browser. The HTTP adapter and user interface component are executed in the HTTP server and the web browser, respectively. The software used by the client is a standard web browser with

a JavaScript interpreter. Clients do not need to have a SAR processor or SAR data set. The user interface component is provided by web contents sent from the server.

2.3 Implementation

SAR focusing methods such as the range-Doppler, chirp scaling and omega-K have been proposed in past studies (Comming, 2005; Hein, 2004). The range-Doppler algorithm is particularly useful for educational purposes because of its ability to apply pulse compression on one dimension by separating two-dimensional raw SAR data into range and azimuth directions, respectively. The SAR processor in the EduSAR server focuses raw SAR data using the range-Doppler algorithm. The processor keeps precise phase accuracy to apply the secondary range compression (SRC). The processor also stores all of the intermediate processing results, as well as the effects of the processing options and parameters, into the SAR database.

Figure 2 depicts a flowchart of data and parameter files generated by the range-Doppler algorithm. First, a system maintainer of EduSAR prepares the following parameter and data files. The maintainer makes a parameter file (A) by extracting the SAR sensor, state vector, etc., from the SAR leader file with the Committee on Earth Observation Satellites (CEOS) format provided from SAR distributors. Indispensable parameters for focusing the SAR raw data are also computed. An estimated Doppler centroid is included in the parameter file (A). The format of the parameter files is plain text with hierarchical structure. The raw SAR data file is converted from the CEOS format to the EduSAR format by employing an original format converter. A quick-look image file is generated from the whole raw data file using the range-Doppler algorithm.

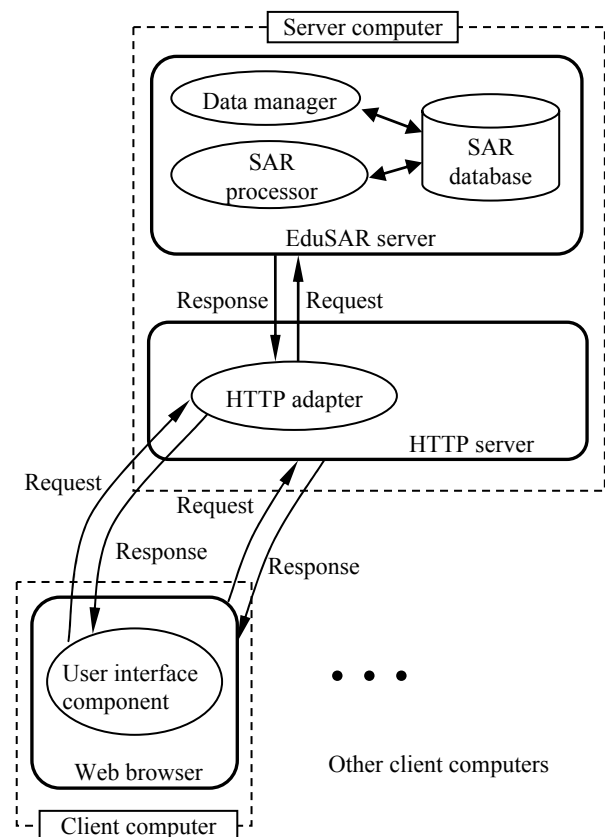


Figure 1. System structure of the educational SAR processor using Ajax technology

The user's first operation is to crop the raw data file according to a region of interest specified on the quick look image. The parameter file (C) is generated by adding cropping parameters to the parameter file (A). The cropped raw data file is also generated by cropping the whole raw data file. Consequently, the range and azimuth compression is executed, and the corresponding parameter and data files are newly generated, respectively. Finally, the map projection is executed, and the parameter and map projected image files are also generated.

The HTTP adapter is the web application software working in the HTTP server that connects the web browser to the EduSAR server. The adapter was developed by a web application framework called "Ruby on Rails" written in the Ruby programming language (Matsumoto, 2007; Hansson, 2007). The user interface component enables users to specify various parameters and algorithms using menus and dialogs in the web browser. This component records events resulting from user operation, such as menu and range selections. The contents displayed in the window are updated by transmitting the request to the HTTP adapter and receiving a response. The processed SAR images are then sent to the client through the network again and displayed in the web browser. HTML, CSS (Cascading Style Sheets) and JavaScript are integrated to provide these functions. JavaScript libraries such as prototype.js and script.aculo.us are employed (Stephenson, 2008; Fuchs, 2008).

Current applicable SAR data types are ERS-1/2 AMI Level 0 (raw data) with C band, JERS-1 SAR Level 0 (raw data) and ALOS PALSAR (FBS, FBD and PLR modes, raw data) with L band, as shown in Table 3.

3. PROCESSING EXAMPLE

3.1 Operation of EduSAR

An example of the educational use of EduSAR is described. Processing results using SAR raw data observed by ALOS PALSAR FBS mode is shown in Figure 4. First, the user specifies the URL of the EduSAR server in the web browser and gives the EduSAR server an individual user name and password. After authentication, a list of the SAR data is shown as a catalog list that consists of a thumbnail icon, the name of SAR file, a scene ID, an observation mode, an identification name, an area, and a date/time (Figure 4 (a)). The quick-look image is displayed by clicking the thumbnail icon in the catalog list (Figure 4 (b)).

The user can interactively change the display area by sliding the first right and lower scroll bars in the window, or by dragging the PC mouse and pushing the left button while the "Image shift" icon in the tool panel is active. Similarly, the user can zoom in/out of the image by either sliding the second right scroll bar in the image window or by rotating the mouse wheel.

After activating the "Rectangular region" icon in the tool panel in Figure 2 (c) and clicking the "Crop" icon, the dialog of the processing region is displayed. The processing region is indicated as a rectangular frame specified by either the mouse operation or the rectangular location. The latter is useful when the user wants to specify a region accurately or repeatedly. This location is set by the start azimuth line number, the number of azimuth lines, the start range bin number, and the number of range bins in this dialog. If the specified region is beyond the

bounds of the entire scene or is not sufficiently large for range and azimuth compression, an error dialog is displayed after the "Go" button in the processing region dialog is clicked. Otherwise, the cropped raw SAR data is shown as a grayscale image converted from the integer complex data, as seen in Figure 4 (d).

In Figure 4 (d), the user can visually recognize what the SAR sensor obtains from the ground by confirming the location and intensity of the overlapped zone plates. The observation status, such as change of sensor gain, saturation, interference from the ground, missing lines, etc., can be discovered simultaneously.

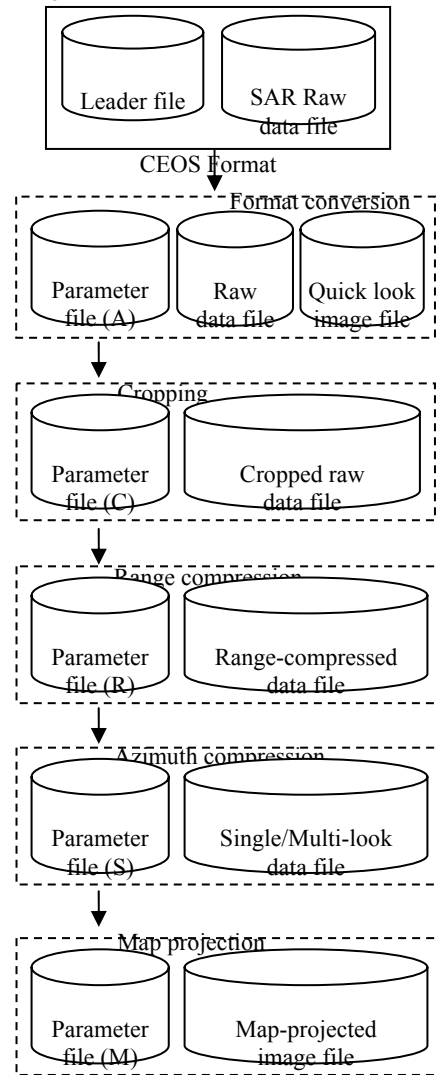


Figure 2. Flowchart of SAR data processed by the range-Doppler algorithm

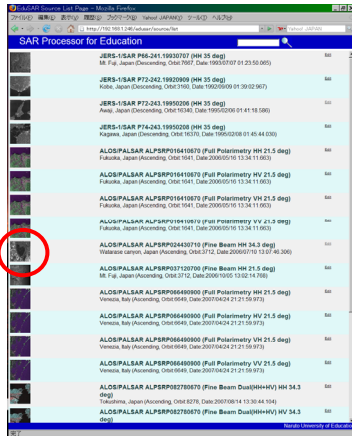
Satellite	Sensor	Observation Mode	Distributor
ERS-1/2	AMI	Single Pol., VV	JAXA
JERS-1	SAR	Single Pol., HH	JAXA
ALOS	PALSAR	Fine Beam Single Pol. (FBS), HH or VV	JAXA
		Fine Beam Dual Pol. (FBD), HH+HV or VV+VH	JAXA
		Quad Pol. (PLR), HH+H V+VH+VV	ERSDAC

Table 3. Applicable SAR data types of EduSAR

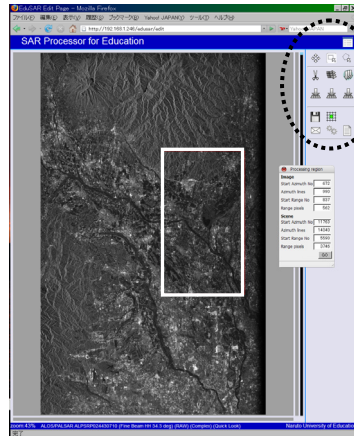
While the "Pixel information" icon is activated, an information dialog with the real and imaginary part of the complex data is shown in the window. The pixel information can be displayed by a similar operation thereafter.

Next, the user clicks the "Range compression" icon. The dialog containing parameters, such as window function, handling of the throwaway region, length of FFT, cutting ratio of

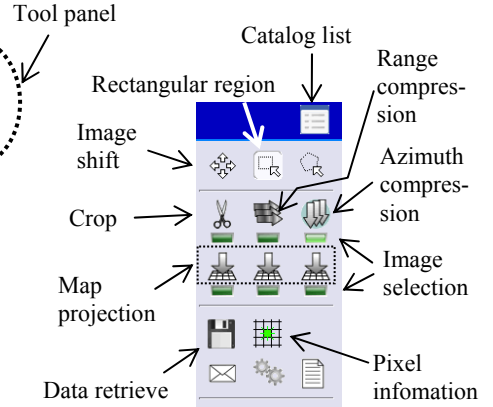
interference noise, SRC, etc., for the range compression is shown, and the options can be set at the user's request. After the processing of the range compression is completed, the range-compressed image is shown as a grayscale image, converted from floating point complex data (Figure 4 (e)). The user can confirm the numerous vertical lines, so-called range-walk, and the invalid region with the range compression in this image.



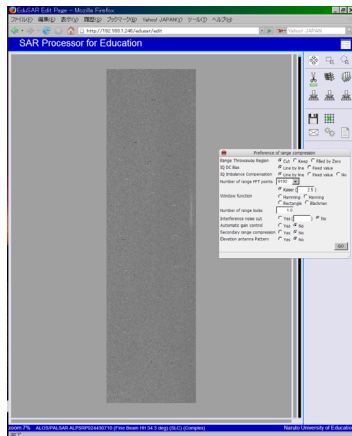
(a) Catalog list



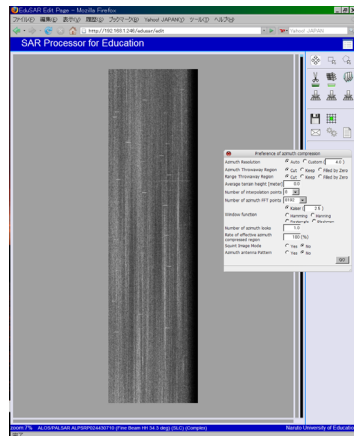
(b) Quick look image, region of interest as a rectangle and dialog of processing region



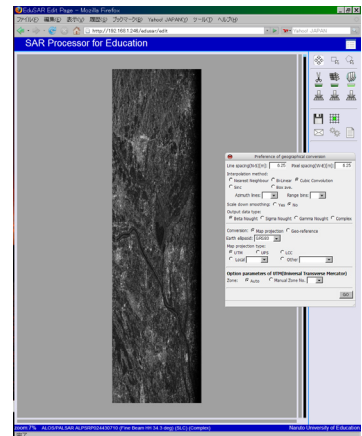
(c) Operation and icons in the tool panel



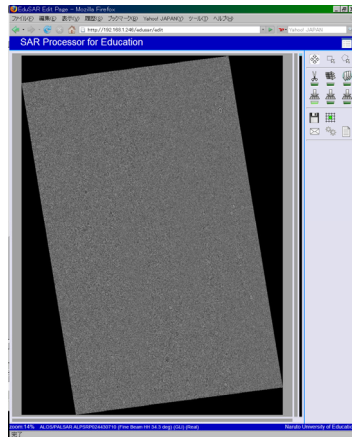
(d) Raw image with slant range coordinate and dialog of range compression



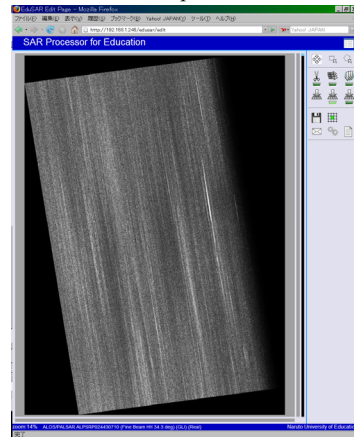
(e) Range-compressed image with slant range coordinate and dialog of azimuth compression



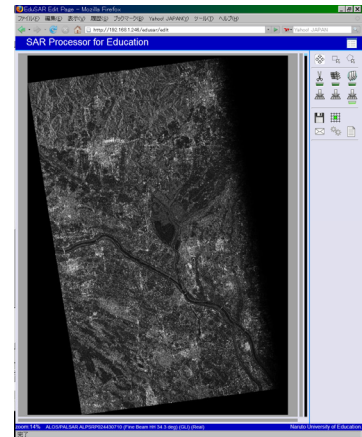
(f) Single-look image with slant range coordinate and dialog of map projection



(g) Raw image after UTM projection



(h) Range-compressed image after UTM projection



(i) Single-look image after UTM projection

Figure 4. Processing examples of SAR data observed by PALSAR FBS-HH (Scene ID: ALPSRP024430710, Off-nadir: 34.3deg., Date: 10 Jul. 2006, Location: 36d 11' 11"N, 139d 40' 4"E, Watarase, Japan). © METI and JAXA 2006

Consequently, another dialog is displayed after clicking the "Azimuth compression" icon in the tool panel. The detail options of the azimuth compression are set using this dialog. The indicator with the progress of the azimuth compression and the processing patch number is displayed in the center of the window since the processing time for the azimuth compression is longer than that for the range compression. After the azimuth compression is completed, a single-look image with slant range coordinates is shown as a gray scale image converted from the floating point complex data (Figure 4 (f)). The azimuth compressed image with no blurring indicates that the SAR data is correctly focused. The user can confirm the status of the SAR focusing and the invalid region with the azimuth compression.

The user can visually recognize the effect and location of the invalid region in accordance with the compression process by applying one of three following options, "Cut", "Keep" and "Filled by zero", for treating the invalid region alternately. "Cut" is the default option, and means that the invalid region is cut out from the final image. The "Keep" option means that the invalid region will not receive any treatment. The "Filled by zero" option fills all invalid region by complex zero data to clarify the location.

The parameters of the map projection are set by clicking the "Map projection" icon, and the SAR image with the slant range coordinate is re-sampled according to the specified map projection in order to display the image more efficiently. The map-projected image is shown in Figure 4 (i). One of the map projections, UTM, is only available in current version. The map projection can also be applied to both the raw and range-compressed images in the same way. Figures 4 (g) and (h) show the map-projected raw and range-compressed images, respectively. The user can consider how ground objects were observed by comparing the three map-projected images with each other.

Moreover, the displaying image instantaneously switches to one of the images that has already been generated by clicking the corresponding "Image selection" button. The image produced from the source image to which the parameter is changed automatically becomes invalid. It is easy to generate and observe the image with various parameters experimentally using the "Image selection" buttons. The principles of SAR processing can be understood by following the processing procedure and showing the consecutive images in a stepwise manner.

EduSAR has a function to convert the image data of the specified region into a data file of Comma Separated Values (CSV), which can be transferred to the client by clicking the "Data retrieve" icon. For instance, the image data can be graphed using a spreadsheet if necessary. The ERS-1/2 AMI and JERS-1 SAR data can be similarly processed following the procedures described in this section.

3.2 Processing Performance

The EduSAR server can undertake transactions requested by multiple clients simultaneously. The maximum number of processes that can be executed in parallel depends on the amount of memory in the server. One process typically requires more than 64 megabytes of memory. Figure 5 indicates the computing time for multiple PALSAR processing requests, in which the number of azimuth lines and range bins are 10000 and 8000, respectively. The PALSAR data is the same as that

shown in Figure 4. Single processing time of the whole scene in Figure 4 is 15.5 minutes on average.

Comparing the results of the number of processes 1 and 2, the ratio of the processing time is 1.1 using the 2.4 GHz CPU with two computing cores employed in the server. The total processing time is approximately 3 minutes when the number of processes is two. Therefore, EduSAR enables interactive SAR processing for the users. When two or more processes are run simultaneously, the processing time increases linearly. For instance, a practical processing speed can be expected to be offered to the requests from eight clients when double CPUs with 4 computing cores in the server are used.

4. EXPERIMENT OF REFLECTING RADAR WAVE

One purpose of the experiment involving the reflection of radar waves is to study the principles of the SAR technique practically. The experiment is conducted in the field and employs several corner reflectors (CRs) which the learners construct themselves for a spaceborne SAR. Synchronizing with the observation time of SAR, the CRs are deployed on a flat area with little vegetation and low backscattering. The incidence angles of both azimuth and range directions are adjusted so as to maximize the power of reflection.

EduSAR focuses the signals reflected from the CRs as cross points in the raw SAR data. The learner is able to understand the amount of backscattering and the location of CRs by identifying the corresponding cross points. The structure of the CR is a trihedral corner reflector composed of three electroconductive square panels, 80 cm each side, connected perpendicularly each other. The maximum radar cross section (RCS) of this CR is approximately 24.4 dBm² in the case of L band SAR, whose wave length is 23.6 cm. Even though the RCS of this CR is generally too small to calibrate the SAR signal, the CR is suitable for educational applications because of its simple structure, small size, and mobility.

The experiments involving the reflection of radar waves transmitted from the ALOS PALSAR on both ascending and descending orbits were conducted in November 2007. A total of eight CRs were deployed. Three CRs were intended to have the same range length, and the two pairs of two CRs were intended to be on the same azimuth lines on the dry riverbed in Yoshino

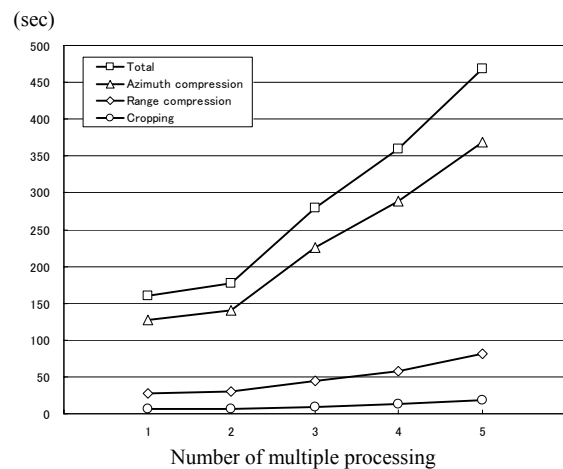


Figure 5. Computing time for multiple SAR processing of PALSAR FBS-HH (Scene ID: ALPSRP024430710)

River in Tokushima, Japan. This was done to ensure that the geometrical positions of CRs were clear for both the ascending and descending observation (Figure 6 (a)). As a result of focusing the raw SAR data with the reflections from the eight CRs using the ascending orbit, eight cross points corresponding to each CR were clearly identified in the single-look image with the slant range coordinates in Figure 6 (b).

After the coordinates of the pixel with the strongest reflection from each CR was read using EduSAR, the distances between those pixels in the image were measured. As planned, three CRs (Nos. 2, 6, and 8) had the same range length, and two pairs of CRs (Nos. 1 and 2) and (Nos. 5 and 8) were on the same azimuth lines, respectively. When the descending orbit was used, a similar result was obtained. Finally, the effect of re-sampling the image is shown by comparing the map-projected image and the location map of CRs.

5. CONCLUSIONS

We described a novel educational SAR processor using Ajax technology, EduSAR. As shown in the concept, the GUI of EduSAR makes the processing SAR data simple and visual. The computer systems adopting EduSAR will be more effective than current systems for furthering the instruction of SAR technology. As a result of the experiments involving radar reflection, it was demonstrated that EduSAR was useful for learning about the SAR technology through practical activities and raw SAR data processing. Improvements of the core software and GUI are planned to also allow the processing of interferometric and polarimetric SAR data.

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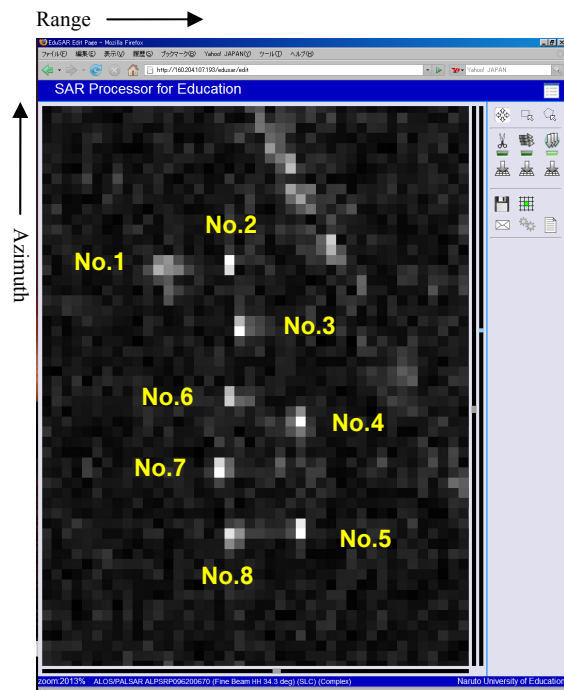
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(a) Eight CRs deployed on dry riverbed in Yoshino River



(b) Reflections from eight CRs using ascending orbit

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Figure 6. Single-look image of PALSAR FBS-HH (Scene ID: ALPSRP096200670 Off-nadir: 34.3deg., Date: 14 Nov. 2007, Location: 34d 5' 18"N, 134d 33' 42"E, Tokushima, Japan).