

DEVELOPMENT OF TECHNOLOGY EDUCATION FOR SECONDARY SCHOOL WITH EARTH OBSERVATION TECHNIQUE

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ABSTRACT

In this research, we propose to introduce earth observation technique using synthetic aperture radar (SAR) to secondary education. Our purpose is that learners are interesting and raise awareness for the earth observation technique through practical activities. Teaching program is planned based on a result of questionnaire surveys to school teachers. The program is composed of 16 units. Teaching materials with the earth observation technique are researched and developed. We design a visual SAR processor and a small corner reflector (CR) from educational points of view as a new type of teaching materials. In teaching practices at secondary school, the developed teaching materials and software were utilized effectively. In the observation experiments, the learners set up the CRs produced by themselves and ALOS PALSAR was able to observe all the CRs correctly. It was clarified that the learners understood the usefulness of the earth observation technique in the proposed technology education.

1. INTRODUCTION

Recently, global environmental problems such as global warming and deforestation have been caused. In school education, a variety of classes to learn the global environmental problems are developed and practiced widely. However, earth observation technique was not positively dealt with in those classes. It is necessary to develop more practical education program including observation experiments by a sensor equipped in an artificial satellite.

In this research, we propose to introduce the earth observation technique using synthetic aperture radar (SAR) to secondary education since SAR is not influenced easily by observation time and weather conditions. Our purpose is that learners are interesting and raise awareness for the earth observation technique through practical activities. Teaching program and materials with the earth observation technique are researched and developed. We design a visual SAR processor and a small corner reflector (CR) from educational points of view as new teaching materials. The developed technology education are evaluated by teaching practices.

2. TEACHING PROGRAM

2.1 Planning of teaching program

The technology education with the earth observation technique using SAR was investigated by questionnaire surveys to secondary school teachers. The learning contents were chosen based on a result of the surveys. The main contents are as follows:

- (1) Introduction of earth observation technique.
- (2) Basic observation method by SAR.
- (3) Design and production of CR as a ground target.
- (4) Observation experiment using SAR and CRs.
- (5) Browsing earth observation images.
- (6) Processing SAR data and analyzing images.

The planned teaching program with the practical activities is composed of 16 units. One unit is implemented in 50 minutes. Table 1 indicates the learning contents and activities in this program.

2.2 Teaching materials

There are a high speed digital communication line connected to the Internet and more than 40 personal computers (PCs) for students at a secondary school in Japan. The following software is adopted in the planned teaching program in consideration of a present school information system.

(1) Digital globe
Google Earth (<http://earth.google.co.jp/>) as a digital globe is useful to know an outcome of the earth observation technique. Google Earth provides huge amount of earth observation images observed by optical sensors without charge.

(2) Web contents
Web contents (<http://www.eorc.jaxa.jp/hatoyama/experience/kids/>) provided by JAXA are employed to study an outline of the earth observation technique. Original web contents by us are also adopted to introduce the basic observation method by SAR.

(3) Software
A visual SAR processor specialized for educational use is newly developed. Detail of the visual SAR processor

is described in section 3. A spreadsheet with a helper program is employed to confirm pixel values in earth observation images and to make profiles in a region of interest.

(4) Corner reflector

A small size CR with relatively large backscatter is designed in consideration of learners' making skill, time, and how to set up ground targets. A trihedral CR is adopted to get wide tolerance of installation angles for reflecting radar signals strongly. A square panel as the reflector is chosen to make larger radar cross section (RCS) than a triangle one. Fig. 1 illustrates structure of the adopted CR. The panel is a wooden board attached an thin aluminum sheet instead of a metal plate. Three square reflectors are connected perpendicularly to each other by L-type metal joints and diagonal braces. The

Table 1 Teaching program with earth observation technique.

Unit	Learning contents and activities
1	- How to know global environment. - Outline of earth observation technique.
2	- Browsing earth observation images by a digital globe and getting ground information.
3	- Role of a corner reflector (CR) as a ground target. - Design of a trihedral square CR.
4	- Cutting down reflectors and diagonal braces from a plane wooden board.
5	- Assembling the reflectors and L-type metal joints temporarily.
6	- Marking hole in the reflectors to connect each other.
7	- Planning arrangement of CRs on the ground.
8	- Disassembling CR. - Cutting aluminum sheets.
9	- Pasting the aluminum sheets on the reflectors. - Assembling CR completely. - Reinforcing CR by the diagonal braces such that the three reflectors are perpendicularly connected each other.
10	- Deploying CRs on the ground following the planned arrangement. - Observation experiment by an artificial satellite with SAR.
11	- Using web contents to understand the basic observation method by SAR.
12	- Confirming pixel values in earth observation images and making profiles in a region of interest.
13	- How to operate visual SAR processing software.
14	- Identifying observation status of CRs in focused SAR images.
15	- Confirming that CRs are clearly observed by drawing graphs from a part of the SAR image. - Measuring locations of CRs in the SAR image.
16	- Getting geometric accuracy by computing distance between CRs. - Usefulness and future of the earth observation technique.

square panels and the diagonal braces are cut down from a plane wooden board such as plywood. Worksheets for instructing design and production of the CR are also compiled in consideration of learners' knowledge and skills.

Each side of the square reflector as the teaching material is 0.8m. In general, maximum RCS of the trihedral square CR can be computed by $12\pi a^4/\lambda^2$, where a and λ denote the side of the square panel and the radar wavelength, respectively. Since the CR is too small to compute the maximum RCS for L-band SAR such as PALSAR, a model of the CR is designed on a simulation grid and the Finite-Difference Time-Domain method is applied to the model [1]. As a simulation result, the maximum RCS of the CR is $\sigma_{max}=21.6dBm^2$, where $\lambda=0.236m$. In preliminary experiments employing PALSAR (FBS and FBD modes), the deployed CRs in a flat area with low-density vegetation were able to be identified in these SAR images clearly [2].

3. VISUAL SAR PROCESSOR

3.1 Concept

The learners are assumed to have little expertise in advanced mathematics and signal processing. To enable these users to work with the earth observation data on standard PCs, it is necessary to develop special treated software which can process 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.
- (2) User-friendly GUI and intuitive operation methods are key functions.
- (3) A simple operation that allows the learner 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

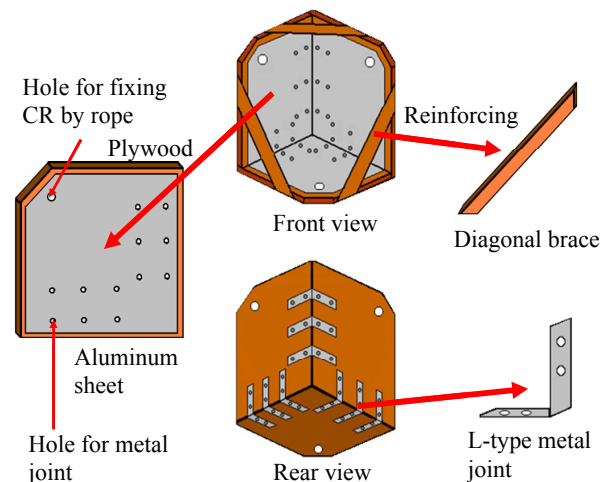


Fig. 1 Structure of a trihedral square CR.

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 know 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 visual SAR processing system has to be newly developed in consideration of the specification of the learners' computer. 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 [3, 4].

3.2 System structure

Fig. 2 illustrates the system structure of the developed visual SAR processor. The system has three software components: the SAR server, the HTTP server, and a web browser for client computers. The HTTP server and the web browser work together under the Ajax technology. The SAR server is the primary component for managing users and SAR data sets by relational database management system and for processing all SAR data sets. The SAR server has managers for the user, data, processor, and image display. The data manager accesses both the SAR and the user databases indirectly through Open DataBase Connectivity (ODBC).

An antenna-pattern data file is shared in all SAR data with the same sensing mode. The processor manager invokes the SAR processor to focus the raw SAR data by the range-Doppler method. The SAR database can manage the processing parameters, the calibration data,

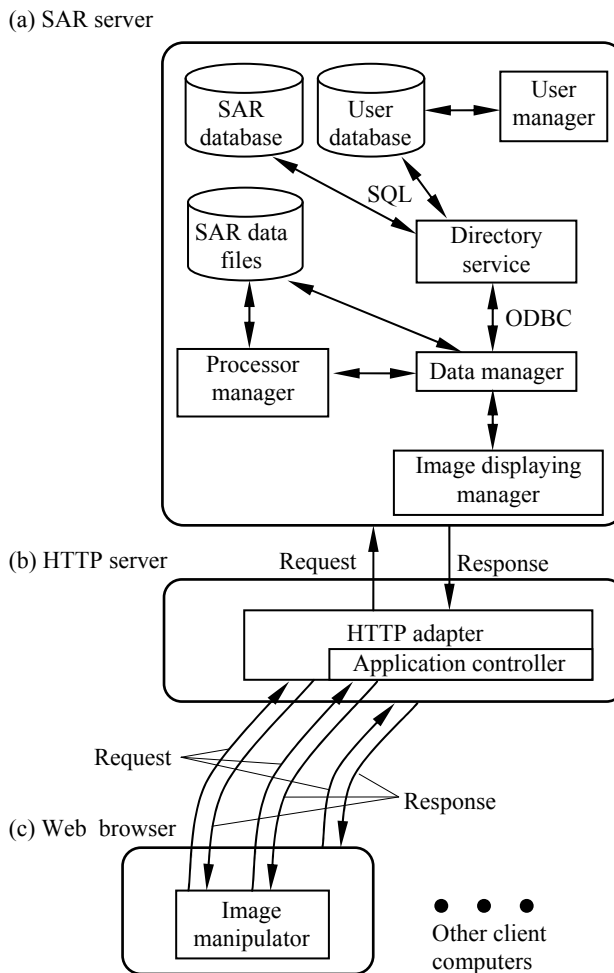


Fig. 2 System structure of the visual SAR processor.

Table 2 Applicable SAR and DEM data.

Satellite	Sensor	Observation mode	Provider
ERS-1/2	AMI	Single Pol., VV	JAXA
JERS-1	SAR	Single Pol., HH	JAXA
ALOS	PALSAR	Fine Beam, Single Pol. (FBS), HH / VV	JAXA
		Fine Beam, Dual Pol. (FBD), HH+HV / VV+VH	
		Polarimetric, Quad Pol. (PLR), HH+HV+VH+VV	ERSDAC
		Scan SAR, Single Pol. (WB1, WB2), HH / VV	
DEM	Resolution	Accuracy in height	Provider
SRTM-3	3" mesh	10m	NASA USGS
ASTER GDEM	1" mesh	7-14m	NASA ERSDAC
GSI-DEM	50m	5m	GSI

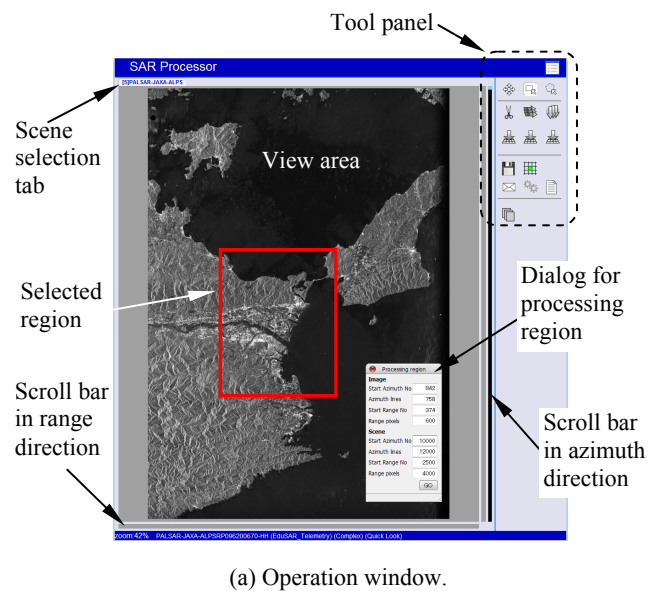
and all of the raw, range-compressed, single/multi-look complex, map-projected images. The image displaying manager provides complex data layers to overlap and display multi-temporal, frequency, interferometric and polarimetric SAR data images. The processed images can be shown using more intuitive and interactive methods by the image displaying manager and the image manipulator.

3.3 System specification

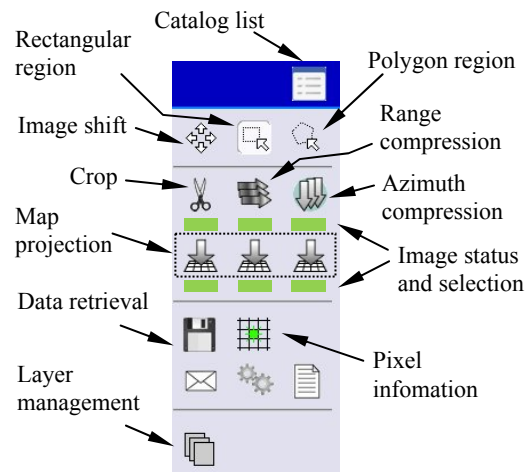
The range-Doppler method focuses on the two-dimensional raw SAR data by carrying out one-dimensional pulse compression sequentially in the range and azimuth directions. In the compression procedure, the user can set various options for the image quality and the processing time. Range compression has options for the range throwaway region, DC bias and imbalance between the in-phase and the quadrature-phase signals, number of FFT points, window function, interference noise reduction, automatic gain control, secondary range compression, and antenna-pattern correction. Similarly, azimuth compression has options for resolution in the azimuth direction, azimuth and range throwaway regions, average terrain height, number of interpolation points for correcting range cell migration, number of FFT points, window function, number of azimuth looks, and rate of adoption of the effective azimuth compressed region. The SAR image is processed by applying official time offsets for both the range gate and the state vector.

The map-projected image is generated from an image with slant range spacing according to the specified projection, the Digital Elevation Model (DEM), and the geoid model. The SAR processor compensates for radiometric distortion by the antenna-pattern, the duration in synthetic aperture time, and by applying a window function in FFT and eliminating interference noise. The radar brightness coefficients (β^0) of a specified region in the SAR image are transferred to the client computer for investigating scattering process and radiometric calibration. The RCS of the target is estimated by integrating a set of β^0 with a calibration tool. The geometric calibration is carried out by using the ground control points and the corresponding locations in the SAR image. The result of the geometric calibration indicates the location errors in both the range and azimuth directions.

In the user interface of the visual SAR processor in the client computer, the web browser displays an operation window consisting of the view area, scene selection tab, tool panel, and scroll bars in the range and the azimuth directions, as shown in Fig. 3 (a). The user can process the SAR data by using the tool panel with various icons and indicators, shown in Fig. 3 (b). As shown in Table 2, the applicable SAR data are ERS-1/2 AMI Level 0, JERS-1 SAR Level 0, and ALOS PALSAR Level 1.0. For the map projection and the geometric calibration, one of the DEM data in Table 2 and a geoid height



(a) Operation window.



(b) Tool panel.

Fig. 3 User interface of the visual SAR processor.

Full-text search Advanced search

Image	Scene ID Name Description	Path No. Row No.	Date Time	Last Used	Actions
	ALPSRP089562930 PALSAR-JAXA-ALPSRP089562930-HH Tokushima Pref., Japan	67 2930-2930	2007/09/30 01:32:20.701909	2009/11/19 11:55:26	Edit Show properties Show application info
	ALPSRP089562940 PALSAR-JAXA-ALPSRP089562940-HH Kochi Pref., Japan	67 2940-2940	2007/09/30 01:32:28.918555	2009/11/19 12:00:08	Edit Show properties Show application info
	ALPSRP096200660 PALSAR-JAXA-ALPSRP096200660-HH Tokushima Pref., Japan	416 660-660	2007/11/14 13:29:55.740412	2009/12/18 11:20:10	Edit Show properties Show application info
	ALPSRP096200670 PALSAR-JAXA-ALPSRP096200670-HH Tokushima Pref., Japan	416 670-670	2007/11/14 13:30:03.955988	2010/08/23 10:09:13	Edit Show properties Show application info
	ALPSRP096200680 PALSAR-JAXA-ALPSRP096200680-HH Hyogo Pref., Japan	416 680-680	2007/11/14 13:30:12.172029	2010/01/06 13:16:16	Edit Show properties Show application info
	ALPSRP096200690 PALSAR-JAXA-ALPSRP096200690-HH Okayama Pref., Japan	416 690-690	2007/11/14 13:30:20.387140	2009/11/19 11:54:54	Edit Show properties Show application info
	ALPSRP096200700 PALSAR-JAXA-ALPSRP096200700-HH Tottori Pref., Japan	416 700-700	2007/11/14 13:30:28.602715	2009/11/19 11:55:09	Edit Show properties Show application info

Fig. 4 An example of a catalog list.

model (EGM-96 or GSIGEO 2000) can be employed [5, 6].

3.4 Operation and processing examples

First, the user specifies the URL of the SAR server in the web browser and enters a user name and a password. After authentication is performed, an initial catalog of the SAR data is listed as shown in Fig. 4. Each row in the catalog displays a thumbnail icon, scene ID, identification name, area description, path and row numbers, observation date/time, and last used date/time. The list can be individually sorted by each item except for the thumbnail icon. A full-text search by arbitrary keywords and an advanced search are implemented. The advanced search is executed by specifying options such as the sensor name, instrument name and type, scene ID and name, path and row numbers, flight path direction, polarizations, data provider, processing level,

and observation location in latitude and longitude. The detailed information for the acquisition and the calibration is also shown using the “Actions” column. When the target SAR data is decided, the user clicks either the thumbnail icon or “Edit” in the catalog. A quick-look image is displayed as shown in Fig. 3 (a). After activating the “Rectangular region” icon in the tool panel and clicking the “Crop” icon, the dialog for the processing region pops up. The processing region is specified as a rectangular area.

Fig. 5 shows processing examples of the PALSAR data. The cropped raw SAR data are shown as a grayscale image with the slant range spacing converted from the complex data in Fig. 5 (a). The brightness and contrast of the grayscale image in the view area is automatically adjusted by the average and standard deviation computed from the source SAR data. Many zone plates are confirmed in the raw SAR image and abnormal

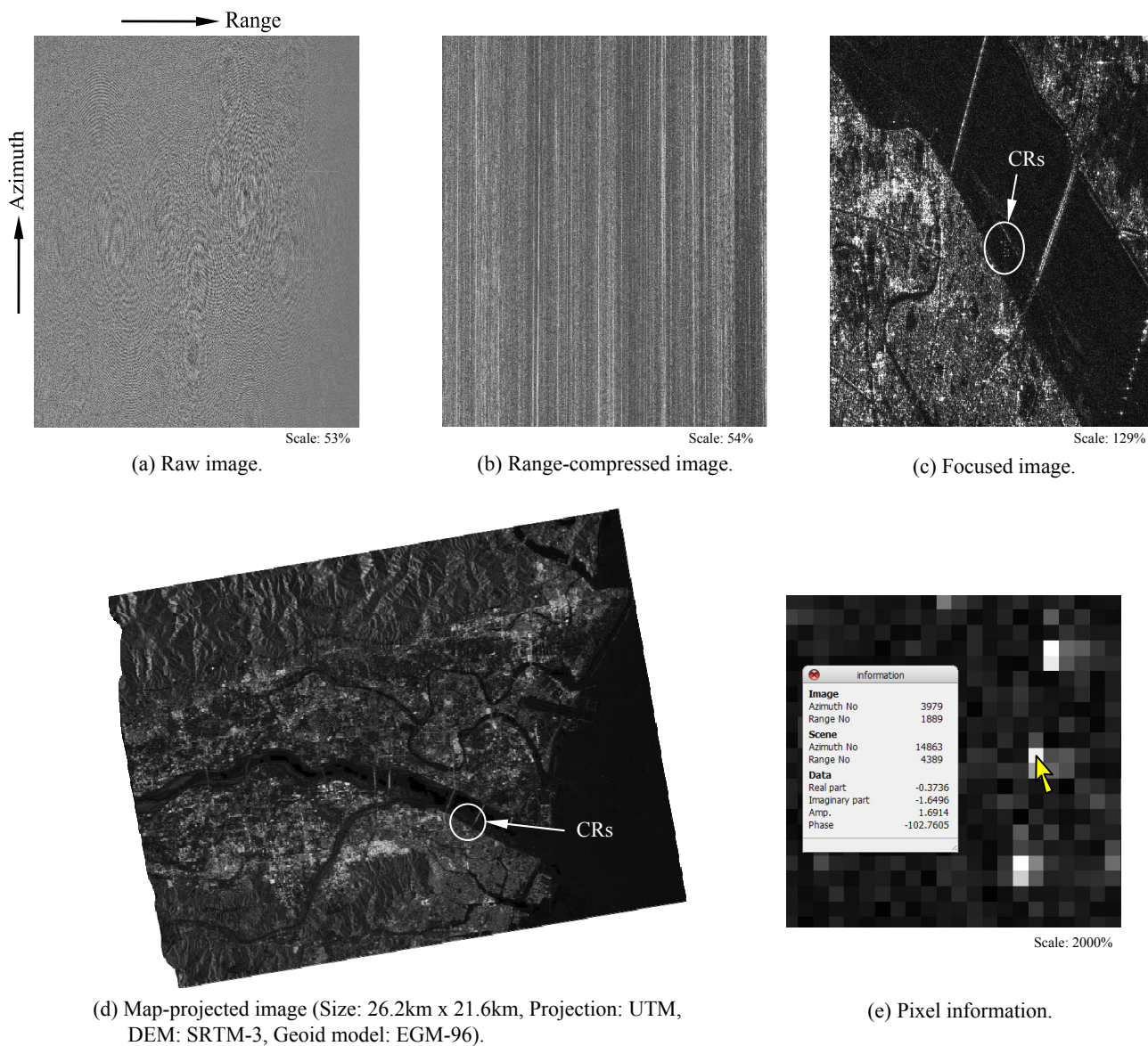


Fig. 5 Processing examples of PALSAR FBS-HH (Scene ID: ALPS096200670, Ascending orbit, Off-nadir: 34.3°, Date: 14 Nov. 2007, Scene center: 34° 10' 34" N, 134° 36' 31" E, Tokushima, Japan).

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signals in the wide range can be easily identified, if necessary. When the “Range compression” icon is clicked, the dialog for options of the range compression appears. After setting the options appropriately, the range compression is started and a progress bar indicates the processing status. In Fig. 5 (b), the range-compressed image with the slant range spacing is shown as the grayscale image converted from the floating-point complex data. Many lines along the range cell migration appear in the range-compressed image. The azimuth compression is applied to the range-compressed image in the same manner. The focused image with the slant range spacing is shown in Fig. 5 (c). The well-focused image clearly represents backscatter from objects on the ground surface.

In the post processing, the image with the slant range spacing is re-sampled according to the specified ground resolution, map projection, DEM data, and the geoid model in the dialog, which pops up after clicking the “Map projection” icon. Fig. 5 (d) shows the map-projected image generated from the image in Fig. 5 (c). The foreshortening caused by the ellipsoidal height is corrected in this image. The calibration procedure requires the location and the value of each pixel in the SAR image. Once the “Pixel information” icon in the tool panel is clicked, the sub-window appears and the mouse cursor can be pointed at the pixel to show the information in real time, indicated in Fig. 5 (e). After selecting the investigation area, the data file including the partial SAR image is transferred from the SAR server to the client computer by using the “Data retrieval” icon. The data file is used to make profiles and to integrate the amount of backscatter around the target.

4. TEACHING PRACTICES

4.1 Outline

The planned teaching program was practiced twice in accordance with the research schedule. The first teaching practice was carried out at the secondary school attached to Naruto university of education in 2007. This practice followed the teaching program excluding use of spreadsheet in Table 1. Group study was adopted to promote mutual cooperation. Each group produced and set up one CR. The second teaching practice was also carried out at the same school in 2008. This practice followed the teaching program excluding units 3-10 in Table 1. Total 16 students in the third grade were participated.

The questionnaire surveys on the earth observation technique were carried out before and after the teaching practice to evaluate effectiveness of the proposed technology education. The students were self-evaluated by themselves on the learning contents after each class as well.

4.2 Results of teaching practices

First of all, the students discussed how to deal with the global environmental problem. Most of their opinions were to know present status on the ground widely. The earth observation images in various regions were easily shown by using the digital globe software, Google Earth. The students recognized importance of the earth observation technique as one of the methods getting the global environment. They learned the outline of the earth observation technique by an artificial satellite through the web contents provided by JAXA as well. They knew characteristics on both passive and active sensors. They were very interested in a mechanism of the active sensor such as the SAR because the ground information with high resolution was obtained without sunlight.

Next, the teacher proposed to set up an object reflecting an electromagnetic wave strongly on the ground to



(a) Marking-off.



(b) Cutting out parts.



(c) Making holes.



(d) Pasting aluminum sheets.



(e) Assembling of CR.

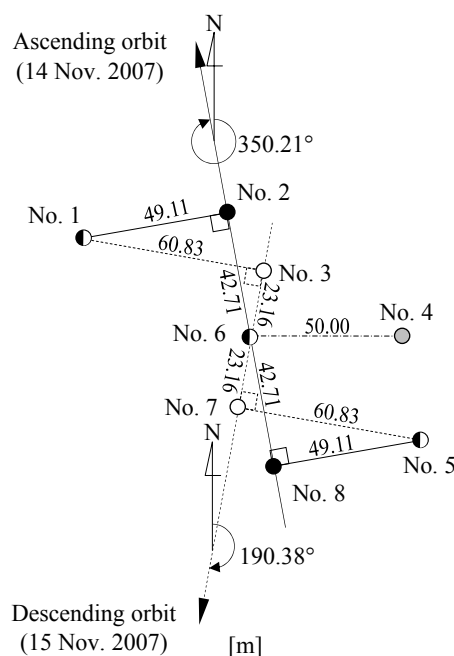
Fig. 6 Student activities in producing CR.

understand the observation technique by the SAR. He presented an example of the target. The CR was produced in each group according to the observation schedule by PALSAR equipped in ALOS. The students had skills for cutting wooden boards in the previous study. Activities of making-off and cutting out wooden parts from a plane board following the work-sheets for instructing design and production were well-done as shown in Figs. 6 (a) and (b), respectively. A double-edged saw and an electric driver / drilling machine were used in the production. Fig. 6 (c) shows the student activities for making holes in the reflectors. When the holes were made, the students devised to put an additional board at another side to reduce burrs as much as possible. They were able to paste thin aluminum sheets on each reflector as smooth as possible (Fig. 6 (d)). The CR was assembled by using three square reflector, nine L-type metal joints, and three diagonal braces as shown in Fig. 6 (e).



(a) Setting up the produced CR.

In the first teaching practice, the observation experiments were carried out in 14 and 15 November 2007. The CRs were observed by PALSAR with the FBS-HH mode on both ascending and descending orbits. The CRs were set up at a riverbed in the Yoshino river, Tokushima, Japan. The area was almost flat with little vegetation and its location was within 5 minute walk from the secondary school. All the students cooperated and set up the CRs. Fig. 7 (a) shows the setting work of the students. The radar incidence angles of both azimuth and range directions were adjusted to maximize the power of reflection. After the observation experiment in 14 November, all the CRs were horizontally rotated by about 160 degrees. Total eight CRs (Nos. 1-8) including three CRs (Nos. 6-8) produced by the students were deployed at the riverbed according to the arrangement illustrated in Fig. 7 (b). Fig. 7 (c) shows the deployed CRs and state on the ground in 15 November 2007. The three CRs (Nos. 2, 6, and 8) have the same range length and the two pairs of CRs (Nos. 1 and 2) and (Nos. 5 and 8) are on the same azimuth lines in the ascending orbit. Similarly, the three CRs (Nos. 3, 6, and 7) have the same range length and the two pairs of CRs (Nos. 1 and 3) and (Nos. 5 and 7) are on the same azimuth lines in the descending orbit.



(b) Arrangement of CRs.

Total four servers implemented the visual SAR processor with the same SAR data were operated to shorten the processing time. Up to three students were able to use the single server simultaneously. The laptop computers were connected to the processing server through the wireless LAN. The SAR data was smoothly processed and displayed in the browser (Fig. 8). The students acquired operation skills of the visual SAR processor referring the user's manual without difficulty. The SAR images were generated according to the procedure as shown in Figs. 3-5. To investigate the characteristics of the SAR images, the teacher introduced that the longest suspension bridge, the Akashi Kaikyo bridge whose length is about 4km, was observed like diamond shape. A student immediately noticed that the main factor was the multi-pass effect caused by the single reflection from the wire-rope only



(c) Deployed CRs and state on the ground.

Fig. 7 Observation experiment at riverbed in Yoshino river, Tokushima, Japan.

and the double reflection from the wire-rope and the sea surface.

The SAR data with reflection signals from the CRs was focused as shown in Fig. 8 (b). The students found out the pixels corresponding the CRs in both the focused and the map-projected images (Figs. 5 (c) and (d)). Eight cross points corresponding to each CR were clearly shown in the focused image with a single look and the slant range spacing in Fig. 9. The amount of backscatter and the location of the CRs were obtained from the information of the corresponding cross points. As expected, 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 shown in Fig. 9 (a). When the descending orbit was used, a similar result was obtained, as shown in Fig. 9 (b). The numerical data set of the small rectangular region including the eight CRs in the SAR image were retrieved to the client computer by the student's operation. The students were able to make profiles in both range and azimuth directions around the CR by using the spreadsheet and the transmitted numerical data set (Fig. 10). Each location of CR was identified by the cross point in the SAR image. The distance between the CRs was measured by the locations and the ground pixel size. The difference between the measured distance and the actual distance indicated in Fig. 7 (b) was small. Finally, the students discussed the usefulness and the future of the earth observation technique.



(a) Processing SAR data and confirming reflection from a suspension bridge.

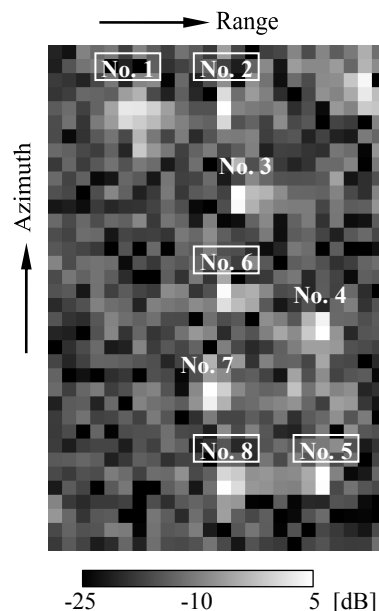


(b) Finding the CRs in SAR images.

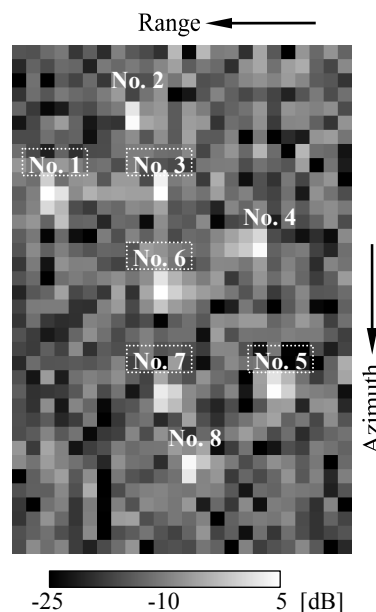
Fig. 8 Scenes of using the visual SAR processor.

4.3 Evaluation

Each student answered all questions for the learning contents by one of scores from 1 to 5. Table 3 shows average scores before and after the teaching practices. Upper and lower columns of the average score denote results of the first and the second teaching practices, respectively. Evaluation results on the common learning contents indicated a similar tendency. The average



(a) Scene ID: ALPSRP096200670, Ascending orbit, Date: 14 Nov. 2007.



(b) Scene ID: ALPSRP096272930, Descending orbit, Date: 15 Nov. 2007.

Fig. 9 Focused SAR images with a single look, β^0 , and slant range spacing by the visual SAR processor.

scores of “after teaching” became higher than those of “before teaching” for all the learning contents excluding the global environmental problem and the notation of location on the earth. The score on the earth observation technique rose remarkably. On the other hand, the score on the global environmental problem declined in the first teaching practice. The reason was considered that the earth observation technique as a main topic was dealt with in all the units.

To investigate learning process in the first teaching practice, the questionnaire after the class included two evaluation points; having a vision of an assembled CR and understanding the earth observation technique. Each student answered the questions by one of scores from 1 to 4. Fig. 11 indicates the learning process. The students were able to have the clear vision of the produced CR through making-off, cutting out the parts, pasting the aluminum sheets, and so on. In addition, it was clarified that the students had the interest and concern on the earth observation technique before teaching and understood it very much. It was also shown that the understanding of the earth observation technique had deepened more by processing the SAR data with the reflection signals from the CRs produced by the students.

5. CONCLUSIONS

The technology education was developed to enlighten the earth observation technique employing the SAR equipped in the artificial satellite. In the teaching practices at the secondary school, the newly developed teaching materials and software were utilized effectively. In the observation experiments, the learners set up the ground targets produced by themselves and ALOS PALSAR was able to observe all the targets. It was clarified that the learners understood the usefulness of the earth observation technique in the proposed technology education. We would like to introduce more sophisticated earth observation technique such as interferometric, polarimetric, and scan SAR to the technology education. Functions of the visual SAR processor have to be enhanced according to them.

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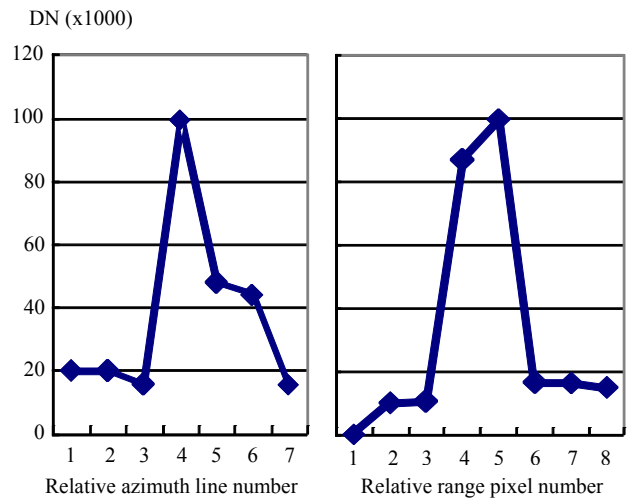


Fig. 10 Profiles around the CR.

Table 3 Evaluation results.

Learning contents	Average score	
	Before teaching	After teaching
Global environmental problem	4.11	3.78
	4.00	4.00
Resource mapping	3.33	3.44
	2.71	4.52
Earth observation technique	3.11	4.44
	3.17	4.60
Map service	3.78	4.78
	3.83	4.83
Digital globe	3.78	4.67
	3.52	4.86
Processing digital images	2.11	4.44
	2.79	4.79
Notation of location on the earth	4.78	4.33
	NA	NA
Use of spreadsheet	NA	NA
	4.07	4.50
Use of visual SAR processor	NA	4.13
	NA	4.29

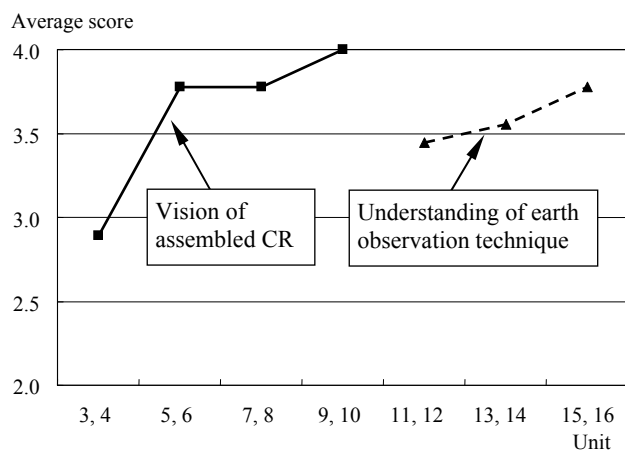


Fig. 11 Learning process.

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