How to broaden the bases for digital remote sensing data analysis for everybody -From the experiences of promoting "MultiSpec 'hands on workshops-

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Abstract:

Digital Image Analysis techniques are essential for extracting useful and practical information from remotely sensed images. The recent advancement of information technology has made it possible for every body to use computers and to access various remote sensing data. However, it is difficult to use computers for digital analysis of remotely sensed images without appropriate application software. A lot of software is available as commercial packages, but only professional organization or people in remote sensing communities can afford to use them. However, most of end-users of remote sensing such as schoolteachers, students and local governments as well as small business interested in applying remote sensing are not able to afford to use commercial packages.
This paper will describe the author's experiences in Japan to educate and train the peoples interested in remote sensing and digital image analysis techniques through a series of hands-on workshops on 'MultiSpec". During past five years, more than 650 peoples attended the workshops from wide variety of user communities

1. Introduction

1.1 Global Environments and Remote Sensing

Global environment and resource problems are one of major concerns of these days in the world. More than 3 decades have passed since the first satellite for earth resource and environment observation was launched. Since then, many countries have launched many similar satellites for remote sensing, and planned to launch more satellites. Currently every satellite is dumping a lot of scenes to the earth every second.

However, it would be difficult to say that every scene observed has been analyzed and utilized t o contribute to solve the practical problems of resources and environment.
Potential application areas are not limited to the existing scientific areas but there must be more practical applications or potential applications not yet identified. This means they need to involve more people of other disciplines as well as increasing the population in existing remote sensing communities.

1.2. Brief History of Digital Image Analysis for remote Sensing in Japan

Availability of digital tapes for ERTS program (Landsat 1) stimulated interest in digital image analysis for remote sensing in Japan. However, there were few demands on digital image analysis in Japan in the earlier period of 1970s, because of lack of competence with the digital image processing in remote sensing community in Japan. At that time, some organizations and institutes like large universities or computer companies like IBM Japan, Fujitsu, Toshiba and Hitachi Co. Ltd. had general computers for computing services, but software environment for image analysis for remote sensing was so poor, and mostly every body had to write programs by themselves. RESTEEC imported later a special purpose computer for image analysis, such as IMAGE -100, but only limited persons could access it.

As Japanese government, the Ministry of Education did not fund any software purchasing at that time, and every users, professors and students, at universities needed to write application programs with less advanced programming language.
On the other hand, there was already a lot of good software in US. Among them, LARSYS developed by LARS, Purdue University, was well documented and looked easy to use and to transplant to Japan.

LARSYS is one of the first remote sensing multispectral data processing systems, originally created during the 1960's. Originally, LARSYS was developed for the time-sharing system of IBM System 360-67. As that time, no time-sharing system was available in Japan, but there were nation- wide commercial based network computing services by IBM Japan and Fujitsu Co. Ltd.

Fortunately, a private foundation founded a project to promote remote sensing in Japan. A part of this fund was used to transplant the LARSYS to support all scientists participating this project having permission from LARS, Purdue University. The original version of LARSYS was modified for IBM and Fujitsu to fit their remote computing environment, i.e. Remote Job Entry systems.
Many workshops were held in the major big cities in Japan to educate how to use LARSYS for remote sensing data analysis. This is the first large scale promotional activity for digital image analysis for remote sensing.

Figure 1. The manual of LARSYS

2. Current Situation with promotion of Digital Remote Sensing in Japan

During the past three decades, Japan launched many earth observation satellites and developed many sensors for earth observation. However, fewer operational use of remote sensing has been implemented in Japan compared with the other countries in the world.

2.1 Resource environment for Remote Sensing Education and Promotion

Fortunately, during past three decades, there emerged a lot of technologies to support remote sensing, and the environment for operational remote sensing has been very much improved.

Data accessibility and cost: the environment for data availability of remote sensing has been dramatically improved, and now it is possible to download image data sets through internet and the cost of data sets became an affordable range. Recent data storage technologies such as CD /DVD facilitated to distribute, exchange and copy the remote sensing data of large volume. Now, many people have their own PC with CD/DVD drives.

Image Analysis Hard ware System: Now almost everybody can afford to have their own PC, which is capable to process large images at home. They have faster processing speed and more capacities than what they used to have in 1970s.

Availability of Digital Image Analysis Software: Many professional institutes of remote sensing are using many commercial products, but most of potential users of remote sensing cannot afford to purchase such expensive products.

2.2 Remote Sensing Education:

Above situation is an aspect of positive side. Unfortunately, there is another side with little progress. The number of universities or colleges, which provide courses related to remote sensing, is definitely increasing, but there are few departments, which dedicate to remote sensing in Japan. Even with department of geography, very few courses are offered. Education on geography itself at high schools is getting less appreciated now, because of the guide lines of government and most of education at high schools is addressed to pass the entrance examination of universities or colleges. Therefore few teachers has interest in depicting the earth and remote sensing. So the numbers of university graduates who have been educated remote sensing is very small compared with that of North America and Europe.
This situation might be influenced by the feeling of the people of Japan: they are wondering about job opportunity after graduation with remote sensing, much less interest in remote sensing at governmental organization, less industries appreciate importance of remote sensing. Past major concerns of government was to develop manufacturing industries, they have not paid enough concern about spatial design, landscape management, sustainability of the nature and balance between land development and ecological impacts.
They need to have more educators who understand remote sensing technology and its importance. It is also required to make them understand that remote sensing is not only scientific tools for the earth science, but also useful technology related to everyday lives.

Major tasks remained for promoting remote sensing to every sectors of Japan is to provide image analysis software of reasonable cost and increase the number of educators or professionals who are able to transfer their expertise to the potential people who wish to know about remote sensing and to apply it to solve their own tasks for environment and resource related problems.

3. What is “MultiSpec”?

3.1 MultiSpec:

The ‘MultiSpec’ (©Purdue Research Foundation) is a processing system for interactively analyzing multispectral image data including hyper spectral image data from current and future airborne and space borne systems. The primary objective of MultiSpec is as an aid to export the research results on multispectral image analysis of Purdue University.

MultiSpec has the following design objectives, and it is available in public through Internet. The implementation should be on a readily available computer platform, which has adequate processing power, but is financially within the reach of any Earth science researcher (i.e., computer platforms < $2000).

(1) The system should be easy to learn and easy to use, even for the infrequent user, using the most modern of software environments.
(2) The system should provide for easy import of data in a variety of formats, and easy export of results, both in thematic map and in tabular form.

The work of building the current capability began by implementing an upgraded version of the LARSYS multispectral image data analysis system. The current system, called MultiSpec, has been implemented for the Apple Macintosh and PC-Windows personal workstations. A reasonably current generation, middle range machine and color display, would have a street price of less than $2000 at the present time.

(1) Import data
(2) Display multispectral images
(3) Histogram data
(4) Reformat
(5) Create new channels
(6) Cluster
(7) Define classes (via designating rectangular or polygonal training fields or mask image files, compute field and class statistics, and define test fields for use in evaluating classification results quantitatively.
(8) Determine the best spectral features
(9) Classify: Six different classification algorithms are available: use of minimum distance to means, correlation classifier (SAM), matched filter (CEM), Fisher linear discriminant, the Gaussian maximum likelihood pixel scheme, or the ECHO spectral/spatial classifier.
(10) List classification results
(11) Utility functions including listing out a subset of the data e.g., for use externally, conducting principal component analysis, etc.
(12) Transfer intermediate or final results.

Not only conventional functions for image analysis for remote sensing, but also they are continuing to add new functions including many functions required for hyperspectral image analysis.

4. Approach:

The most important task is to increase the numbers of educators who have experiences with digital image analysis of remote sensing.
Thus, the author established the following strategies.
Advertise the availability of digital image analysis software in public domain.

(1) Provide the user; s guide in Japanese, translating from the English version, and open it on a web site. This is motivated by the fact many Japanese such as school teacher, public servants in local governments, young university students and so on, are still reluctant to read and use the thick manuals in English
(2) Conduct hands-on workshops to educate the people in every level at every geographical place as much as possible.
(3) Provide learning materials on remote sensing and digital image analysis.
(4) Establish a group of advisors who are able to make consultation on remote sensing.

5. Workshop on "MultiSpec"

5.1 Hosts of the workshops:

The workshops were hosted by the following organizations, and they advertised the workshops, and conducted every logistic activities necessary. A series of the workshop was conducted first by the computing center for Agriculture, Forestry and Fisher Research, Ministry of Agriculture, Forestry and Fishery, and JSPRS (the Japanese Society of Photogrammetry and Remote Sensing) took over the major parts of this later.

Central Government	Ministry of Agriculture, Forestry and Fishery
Local Government	Environment Research Center, Hokkaido
Academic Society	Japanese Society of Photogrammetry and Remote Sensing
University	Faculty of Fishery Science, Hokkaido University Kanazawa Institute of Technology Kobe University Tokyo University of Information Science
Teachers Association	Science Teacher's Association of Hakodate

Table 1: Workshop Hosting Organizations

5.2 Target participants:

Almost every people is welcome to the workshop.

5.3 Prerequisite:

Potential participants are assumed to have PC experiences and be familiar with popular PC operating systems such as MS-windows. Although MultiSpec is originally developed for MAC PCs and it have more functions that the Windows version, main participants are windows users since the window users in Japan is more popular and the author does not have Mac OS experiences. The Mac users were also welcome as well. However, no previous knowledge about remote sensing was assumed, but interest in remote sensing and global environment is essential.

5.4 Course Contents:

Two courses were offered based on the experiences of participants, their interest and previous knowledge with digital image processing.
1) Beginners' level and intermediate level.
2) Some workshops were combined these two.
In Japan, it is difficult to have workshops of longer duration more than two days; most of them should be one day or two days at most. So every workshop were designed as one day workshop and two day workshop combining the two courses Duration of each workshop is 6 hours, 3hour in the morning and 3 hours in the afternoon.
The major subjects for each course are summarized in Table 2. These contents are always modified and improved

Introduction of Remote Sensing	Definition, Principles of remote sensing. Outlines of remote sensing programs How obtain a data set.	1 hour.
Brief history of Digital Image Analysis for remote sensing	Digital Image Analysis Basic Outlines of digital image format for remote sensing data .	1 Hour
MultiSpec basic	What is 'MultiSpec" How to download and install it Basic operation and workspace and windows	1 Hour
Fundamentals of ground cover analysis with hands-on	Fundamental of ground cover classification Basic Procedure for ground cover classification Ground cover definition Retrieving of Ground information through internet	1 Hour
Example of Image processing	Image Arithmetic: NDVI and Others	30 min.
Ground Cover Classification	Principles and methods of Classification Exercise	1 1/2 Hour

Table 2-1 Workshop contents for the Beginners

Advanced Techniques for	Training Class Improvement	3 Hours

Ground Cover Analysis	Methods, Classification Feature Extraction Feature Selection Accuracy Assessment (confusion Matrix and Kappa coefficient)	
Introduction of Hyperspectral image analysis	Sensor Principle Hyperspectral Remote Sensing vs. Low Spectral Resolution Sensor data Application of Hyperspectral Remote Sensing	1 Hour
	Problems of Hyperspectral Data Analysis	1 Hour.
Hands-on of Hyperspectral Data Analysis	Ground Cover classification Using Hyperion data	1 Hour.

Table 2-2 Workshop contents for the intermediate level

5.3 Course materials

Program: If the Internet connection is available at the classroom, each participant was requested to download, uncompress and install "MultiSpec" at the beginning to the workshop.
Data set: Data sets for hands-on exercise were provided by the following organizations: TM images are EROC (Earth Observation Center) of JAXA (Japan Aerospace Exploration Agency) and RESTEC (Remote Sensing Technology Center), ASTER images were provided by ERSDAC (Earth Resources Data Analysis Center). Aircraft Hyperspectral Images were offered by PASCO.
The scenes were selected as much as possible to cover the geographical location of each workshop.
A CD is created for each course to store all materials including program, image data and hands-out, and distributed to each participant. And these materials were
As the last two materials are opened on Web Site, every potential people interested in "MultiSpec" can be downloaded.

Figure 2. Hands－On Training Course of MultiSpec : Every attendee is requested to bring their own PC or note-book PC.

Presentation Materials: All of the materials presented during each course is included in a CD-ROM, and uploaded to a Web site.

5.4 Physical Planning：

Power Supply: Every workshop participants are requested to bring their own PCs, the workshop room should be able to supply enough electric power to accommodate required power even with PC are being used. . Required capacity is proportioned to the number of attendees. It is also desirable to provide much power cable extension code. These requirements should be well examined before workshops in advance. Some workshops were held in rooms for computer lab, where sufficient computer environments are provided.

Air Conditioning: The workshop rooms are ordinary well air- conditioned,
But they might not have enough cooling capacity to cover many PCs. Especially, in summer time in Japan; the cooling capacity will not be enough

Projector: Two Projectors: One projector would be fine, but it is more desirable to use two projectors: the one will be used for general explanation, and the second one will be used to present the current tasks, procedures or operation.

Internet connection: It is also desirable that each PC of participants is able to have Internet connection. Through which every participants is able to access and download the software, data and other reference data. In Japan, various digital maps are available through Web, and many high-resolution images area accessible.

5.5 Size of Works Shops

As the workshop has hands-on training using PCs, the number of participants is limited to it manageable size to supervise the progresses of each participants. In some cases with large number of participants, say, over 30, we provided some assistants to help computer operation or computer oriented questions as each participants have different levels of PC operations and competences.

5.6 Image Analysis Hands On -Ground Cover Classification-:

Land-cover classification using a TM image or ASTER image is selected as a hands-on subject.

Class Definition:

First of all, they have to define all of ground cover classes of user's interest. It is very common to use existing categories such as land use map categories, but they might have their own categories of interests based of their objectives of analysis. However, most of participants had difficulty to define their own class categories, and in many cases, they expect some classes, which might not be observable by existing remote sensors. For simplicity, existing categories were used.
Simple image arithmetic was exercised first to generate NDVI maps, and this helps them understand to significance of digital image processing and band combinations.

As for a set of ground reference, it was suggested to use the following information:

(1) Conventional map information: 1:50,000 scale maps can be retrieved through Internet.
(2) Digital landuse map: digital urban landuse data (10mx10m resolution) is available on CD
(3) Air-photographs/high spatial resolution satellite images: most of these data is also available through internet (i.e. Google Earth)

These ground information helps to define classes to be classified and to identify the location of objects and to define classes.

Training Field Selection:

In order to locate the objects on ground, it is helpful if a conventional digital map can be overlaid to the displayed image of the study area. If the image is projected to same mapping projection systems with GIS systems and formatted as a shape-file, "MultiSpec" has this function to overlay the GIS date on an image displayed on screen. The Figure 3 is a sub-image of ASTER data overlaid with the road net work in a shape file.
Some software is available in public or as commercial basis that can convert existing digital numeric maps into a shape file.

Major tasks of this hands-on were to select s set of training fields and test fields for accuracy assessment. Ordinary, they are selected by means of spatially defined and spectrally homogeneous areas spectral band.

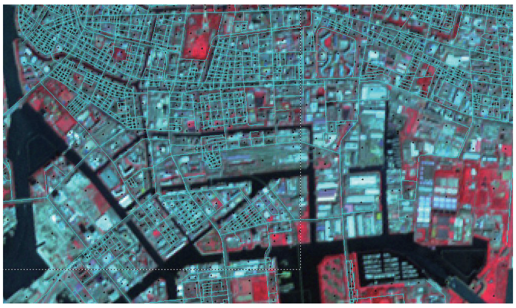

Figure 3. ASTER sub-image of Tokyo, overlaid with GIS data(road network) :

Interactive training/test field selection method is widely used, and "MultiSpec" has this function, too. However, in Japan, the sizes of ground cover parcel or objects are very small compared with the resolution sizes of satellite based remote sensors. Therefore, ground features observed in remote sensing images are complicated. Thus, even with image magnification functions, it is so difficult to find spatially and spectrally homogeneous areas, and interactive selection of training/test fields are less useful.

Therefore, alternative approach was emphasized at the workshops.
Step 1: Identify spectrally similar pixels using conventional unsupervised methods (See Figure 4.) The cluster map can be separated into masks of each class.

The result stored as an integer-file coded with class codes (cluster No.) is used to estimate the class statistics, instead of drawing rectangles or polygons interactively. Associating this mask with the image of study area, operators can define other fields interactively from the inside of masked areas.

Labeling of each cluster class is conducted by common procedure. A NDVI image also assists to label the cluster. Spatial patterns and shapes of objects assist to label the clustered class. At least, use of his procedure can guarantee the spectral similarity of the pixels selected for training field much more consistently compared with interactive visual selection method.

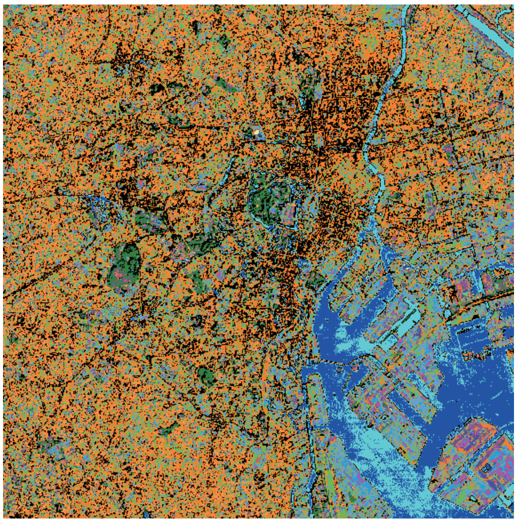

Figure 4. Clustered Result as a Mask

Step 2: Some features are still difficult to select them interactively. For an example, road/ or railroad features are a line-like object, and difficult to extract them with a polygon. This kind of masks can be generated using external image processing programs and integrated into "MultiSpec'.

Figure 5 illustrates an image of a mask to select fields of line-like patterns generated from TM visible bands applying local fractal information of dimension 1 between 1 and less than 2.0. (Joji Iisaka. 1998;Joji Iisaka 1994)

Figure 5 Line-like Object Mask

Step 3: Use of Classification Probability Map: With the conventional classification methods such as maximum likely hood classifier, the images are classified based on the defined classes or assigned to an extra class, unclassified class if a threshold is set to the classifier. and the classifier assign the label of that pixel to a class which shows the maximum probability among the probabilities of all classes.
If this maximum probability is not being large enough to convince for that pixel belong to

than, the number of classes defined for that classification For this purpose, "MultiSpec" had an option to generate a probability map during a classification process, which pixel values correspond to the probability with which the class label is assigned. . If this pixel does not belong to the one of these classes, they need to add some new classes and have a complete list of classes in a scene.

Associating these masks with the images of study areas, training fields can be selected consistently.

6. Discussions and Finding

6.1 General Observation:

As explained before, only one-day workshops were affordable for most of participant to attend .It is difficult to cover every required topic in depth in six hours. It might need at least one week to explain every topic sufficiently, or one-term courses at universities or college to educate students at expert levels.

6.2 Computer Skill:

some participants were not so good at the common computer operation such as mouse dragging and window switching, cut –past operation, file navigation and selection, and so on. So there was some complaining that the author was demonstrating the operation too fast. With these circumstances, the assistants standing in the classroom did great help.

6.3 Remote sensing General:

some terminologies were not so familiar especially with the beginners of remote sensing. On-line help with remote sensing, or at least on-line glossary of remote sensing might help them. To understand remote sensing basics, some background of scientific knowledge such as physics and chemistry is required. Especially, it is essential to explain the significance of Hyperspectral images, principles for classification principle for multispectral images, knowledge of probability concept and statistics are required. Fortunately, they had most of required knowledge, as they graduated colleges or universities. However, advanced knowledge such as multivariate date analysis, hyper-space geometry and communication signal processing are required to understand the functions of "MultiSpec" for Hyperspectral data classification; it was difficult to explain the details of them.

6.4 Mathematical knowledge:

In order to explain basic algorithms for classification and feature selection and extraction, university level knowledge about statistics and algebra will be essential.

6.5 Image Analysis Methods:

Many graphic or picture processing software for digital cameras is getting more popular, so they could understand visual effects of processing, but not for multispectral images and quantitative analysis.

6.5 Defining Classes:

This was most important part as hands-on. Most of existing categories are not well define quantitatively. It was also essential to make them understand the concept of spectral classed and conventional ground cover types. They might need to establish a standard ground cover types based on sensor resolutions and objectives of classification

7. Conclusions and Future Plan:

Through these activities, "MultiSpec" has been proved to be a useful image analysis program not only for remote sensing experts but also for the people of non-professionals of remote sensing ._ At the end of 2005, more than 650 peoples attended this series of workshop.

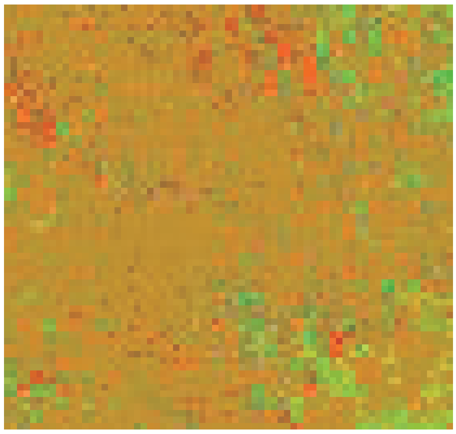

Figure 6. Color-coded Probability Map:
Red and orange area indicate higher probability
Green and Blur areas are of lower probabilities Additional classes can be defined from these areas.

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Already some participants from academic educational institutes started courses of remote sensing with MultiSpec for domestic and international students. The author's aspiration is to extend this activities to cover other countries.

8. References:

MultiSpec related References: With the following URL, Every material related to "MultiSpec" including program, documents, sample data sets and links to other references.

http://dynamo.ecn.purdue.edu/~biehl/MultiSpec/

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