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# REMOTE SENSING IMAGE DATA ANALYSIS SYSTEM "TSUKUSYS" AND IT'S APPLICATION

## — Especially Classifing Coastal Area around a Bay Using TM —


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Abstract

A system called as "Tsukusys" has been developed to distinguish and analyze land use and land cover patterns by using remote sensing image data, especially Landsat Multispectral Scanner (MSS) image data. As, in Japan, Landsat Thematic Mapper (TM) image data can be acquired since last year, the application of TM data by the Tsukusys was attempted. As a result, the advantage of the TM data is completely vertified. This investigation is to interprete water quality condition around the Kojima Bay, where water pollution becomes a social issue.

Contents

# 1. Introduction

An investigation on regional scale is indispensable for the research of earch science, for the inventories of natural resource and for the monition of environment. It is also important to investigate the temporal variation on the region. Earth-observational sensor systems loaded in satellites have met these requirements since 1970's . Now Landsat MSS data are commercially obtainable and extensively used in Japan. To store the multitemporal MSS data may be one of necessary conditions to develop the application of remote sensing technique. Therefore, a databank consisting of a large amount of the image data should be established, based on database concepts. With the realization of the databank in mind, remote sensing image data analysis system called as "Tsukusys" was developed in 1983.

This paper gives an outline of the Tsukusys. Section 2 describes the hardware organization and software organization of the system. Section 3 discusses the application of the system, especially the usefulness of Landsat TM data to classify coastal area around the Kojima Bay that includes a desalted reservoir where water quality has been degraded.

# 2. Configuration of Tsukusys

## 2-1 Configuration of hardware

### a. Host Computer System

A host computer of 48 M bytes memory capacity, which runs at Science Information Processing Center, University of Tsukuba (Fig-1), is used as remote sensing image analysis system. Here the most important design was how can transfer data from large capacity disk memory to image memory at high speed. This problem was resolved by developing an interface between them and by connecting them online

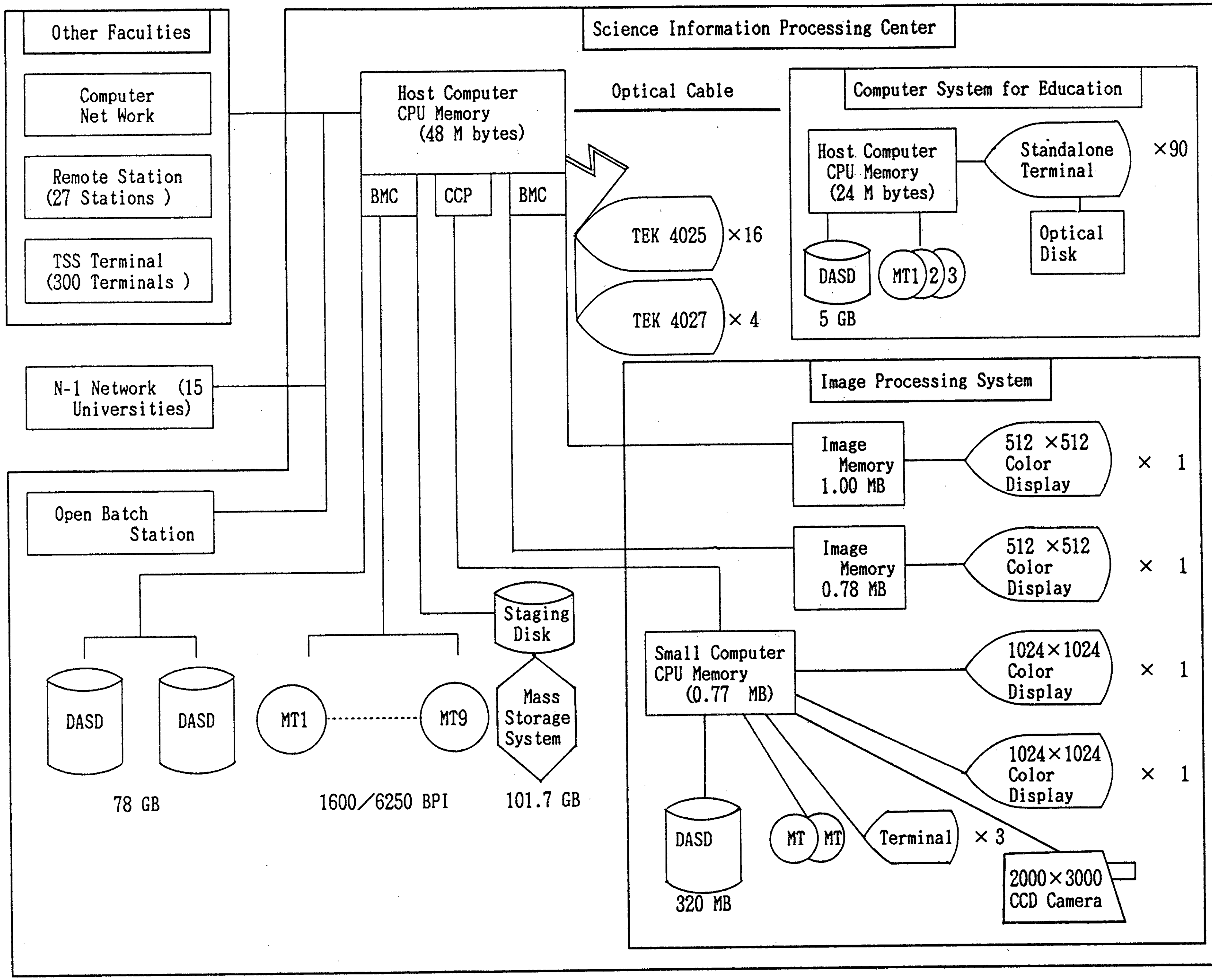


Fig-1 Configuration of Host Computer System through central processing units (CPU). The auxiliary storage of the host computer consists of 9 magnetic tape (MT) units, a disk system (DASD) (78 G bytes) and a mass storage system (101.7 G bytes).

Interdata 8/23 system is also available at the center as a sub-computer system for analyzing remote sensing image data. The sub-system includes a high-density drum-scanner, which the Tsukusys uses for digitizing color aerial photographies.

b. Mass Storage System

Image databank of Landsat MSS data was constructed and has been arranged so far as to store 106 Landsat images taken within and outside Japan < Hoshi et al (1983) >. Two important features of the databank are to bring Landsat image data into unity data format, that is, BIL format and to be able to process them online. The later feature is performed by the mass storage system. Two cartridges as shown in Photo-1 (size of cartridge is 4.7 cm in diameter and 8.8 cm in height) can efficiently and systematically store a whole image taken by Landsat.

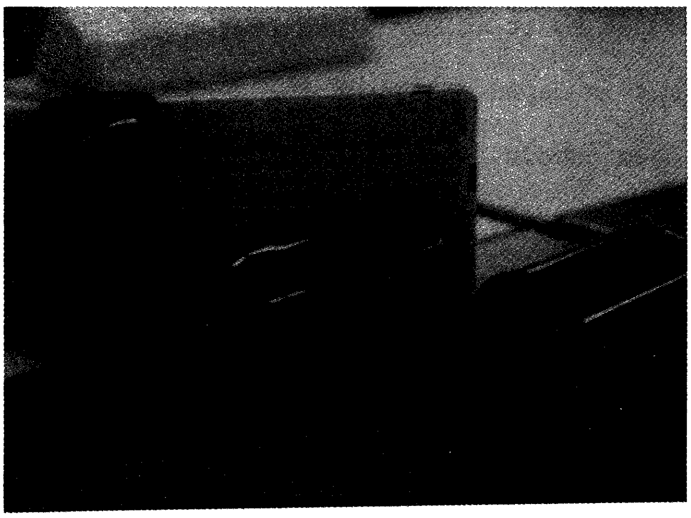

Photo-1 Cartridge of Mass Storage System

Using the databank composed of mass storage system, it is possible to select an interested image through image retrieval system < Ishii et al (1983) >, to take out the data stored in mass storage system to staging disk, and then to convert the data stored in staging disk to disk system. This process reduces operation in respect to labour and time, by comparing with the operation that a data stored in magnetic tape is directly copied to data file of DASD. In addition, this mass storage system has the merit of smaller cost than the disk system in performing.

c. Color graphic display

Two color graphic displays are included in the image I/O processing units connected to the host computer. The display units have 1.78 M bytes (512 x 512 bytes x 4 frames and 3 frames) image memory. The reason why two displays are adopted is to be able to operate them independently and to compare the image before and after processing. This is convenient for image processing.

d. Color ink-jet printer/plotter

It is desirable to preserve some images or maps represented on color graphic displays. Of color printer/plotter on sale, a color ink-jet printer/plotter made by Applicon Comp. in U.S.A. was thought having enough capability for use. The maximum picture size produced by it is more than four times than quarto paper. It is larger than an ordinary map in Japan. Although the design of hardware is planed to process online as mentioned above, the printer/plotter is not connected online. Because printing and other processing can proceed at the same time, total processing time will be reduced, owing to offline processing. As a soluble ink in water jets, the printer/plotter has a demerit that color of pictures fades out as moistening. It had better laminate pictures in order to prevent color from fading out.

2-2 Configuration of software

a. Usable input image data sets

If only Landsat MSS data are concerned,the mass storage system is enough for practical use. But there are other remote sensing image data sets, so I/O software is installed for analyzing these image data sets. Usable input image data sets are

Landsat MSS data stored in floppy diskette, digitalized aerial color photographic data and airborne MSS data.

(1) Landsat MSS data

In Japan, for micro-computer user, 8 inch floppy diskette (1 M bytes) in which image data belonged to a portion of a image taken by Landsat MSS is stored can be acquired.

(2) Digitalized aerial color pnotographic data

An aerial color photography is digitalized as 8 bits data with Red-Green-Blue color coding system, using above-mentioned drum-scanner < Hoshi et al (1981) >.

(3) Airborne MSS data

The airborne MSS data like MSS data produced by Jirco Comp. in Japan or Daedalus Comp. in U.S.A. are also available.

b. Pre-processing

Pre-processing includes 4 different components, that is, specification of test site, elimination of striping noise, geometrical registration and correction to normal distribution.

(1) Specification of test site

In order to specify a test site at will by using truck-ball, a whole Landsat MSS data or other image data are extracted at interval of 7 pixels, so all of the selected pixels can be displyed on a color graphic display simultaneously. At this operation, a mesh at 512 pixels interval is displayed together with remote sensing image data, so the specification of a test site is easily performed.

(2) Elimination of striping noise

MSS embarked on Landsat has 6 detectors per channel. Due to the difference of response , the lag of offset and A/D conversion with these detectors, stripes turn up systematically. The Tsukusys has capability to correct them.

(3) Geometrical registration

As remote sensing image data do not correspond geometrically with ordinary map, it is difficult to combine other data with some resulting images or maps produced from the image data. In order to resolve this problem, the Tsukusys prepares a software especially for geometrical registration through universal transverse mercator (UTM) projection < Nagamine et al (1982) >. UTM projection was adopted by the reason that ordinary maps on the scales of 1/25,000 and 1/50,000 in Japan have been produced using this projection.

(4) Correction to normal distribution

The memory of host computer and image memory are capable of assigning a dat into a byte. Therefore, previous acquired Landsat MSS data which are formed as bits data are converted to 8 bits ones and corrected to normal distribution wit taking the effect of enhancement into account.

c. Unsupervised classfication

The unsupervised classfication analysis applied in this system is th hierarchical clustering method which includes the 6 different components as follows

(1) Ward method

(2) Group average method

(3) Centroid method

(4) Median method

(5) Furthest neighbour method

(6) Nearest neighbour method

Although it is desirable that all pixels within a test site are submitted to clustering algorithm for producing a resulting map, it is not efficient in terms o calculation time. Hence, in this system, an approach to improve classification spee is adopted according to below-mentioned procedures < Hoshi et al (in press) >.

The 256 pixels that are randomly located are extracted from interested sub-tes site. They are regarded as representative of test site. One method chosen from thos mentioned above is performed within the 256 pixels. The 256 pixels are finall combined into 20 clusters. Every pixel of test site is then assigned to the cluste whose mean vector is closest to the pixel vector. For display, each pixel assigne to same cluster is labeled with one corresponding color, a color scheme is manuall altered so as to match well.

d. Supervised classification

The well-known maximum likelihood method is implemented to assign the pixels to one of pre-determined classification items according to the analysis objectives. 2 criterions are adopted to assess the degree of success of the classification results.

(1) Average performance

The average performance is obtained on the basis of correct recognition for each item and is expressed as

$$S = \sum_{i=1}^{n} r_i / n \qquad \text{------------------} \qquad (2\text{-}1)$$

Where r and n refer to the percentage of correct recognition for each item and the number of items respectively.

(2) Equivocation quantification

The equivocation qunatification is based on the concept of entropy by information theory and considers the infuluence of rejection items. The function is denoted by T(G,G) as expressed in equation (2-2).

$$\begin{aligned} T(G, \bar{G}) &= I(G; \bar{G}) / H(G) \\ &= 1 - \{ H(G, \bar{G}) - H(\bar{G}) \} / H(G) \quad \text{-----} \quad (2\text{-}2) \end{aligned}$$

Where I(G,G), H(G,G), H(G) and H(G) refer to mutual information, joint entropy, entropy of a prior item and entropy of the posterior item respectively.

T(G,G) varies from 0 to 1. If the value is obtained to be higher than 0.65, the classification result is generally considered as good.

e. Evaluation of distance and area

The estimation in distance and area can be carried out on the basis of counting the number of line and colume in interested image data. A distance can be evaluated by specifying two points on CRT with truck-ball. Also, an area can be sized up from sum total of pixels belonged to same classification item not only in a rectangular region but also in an irregular region. A distance or an area evaluated in this way will be compared with bygone data acquired by ground survey or image data.

f. Image description

Output devices for describing image data include color graphic display, color ink-jet printer/plotter and X-Y plotter.

(1) Display on color graphic display

The subroutines for providing a function to display on CRT were developed. These subroutines include the data conversion from one CRT to other CRT and the representation of image data depending on some formats.

(2) Display on color printer/plotter

Although the color ink-jet printer/plotter installed at the center adopts Magenta, Yellow, and Cyan (M.Y.C) color coordinate, Red, Green, and Blue (R.G.B) color coding system can be transformed to M.Y.C according to an expression below,

$$\begin{bmatrix} M \\ Y \\ C \end{bmatrix} = \begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \text{------------------ (2-3)}$$

Where the matrix elements are experimentally determined.

Histograms for each of M, Y and C are constructed for each image. The M-Y-C levels are transformed to color plotter patch which is composed of 16 dots either in equal distance basis or in equal probability basis. 16 dots patch can represent 17 cube color levels.

(3) Display on X-Y plotter

It is important to observe features of training data utilized by supervised classification analysis. The Tsukusys has capability to represent these data on X-Y plotter, using "constellation method" by which multivariate data can be displayed on plane or "4-axis method" by which 4 efficient channel data can be displayed on orthogonal coordinate system, so distribution of these data becomes clear.

2-3 Some features of the Tsukusys

Landsat MSS data cover all over the world and are represantive of remote sensing imade data. It is important as a system for education and training to analyze the popular image data by using the authorized unsupervised and supervised classification analysis. In designing digital image data analysis system, most of designers only have an inclination to construct hardware system and to develop software system, not including image databank. The reason is that the databank is too expensive to be worthy of study objective. However, in future, it may be indispensable for remote sensing image data analysis system to contain an image databank and the retrieval system.

A Color graphic display plays an important role for observing image data. So, the Tsukusys efficiently employes the 2 displays. It is also important to shorten the time for displaying image data. Here, high-speed processing is realized by developing the interface between host computer and image memory.

Citing other features, the way how to extract the data applied in cluster algorithm with unsupervised classification, new criterion with accuracy of supervised classification (equivocation quantification) and so on are included.

## 3. An example of Tsukusys's application

Here, the attempt to classify coastal area around a bay using TM is introduced as one of applications < Ishida et al (1985) >.

3-1 Objective to classify coastal area

The objective of this study is to investigate the usefulness of TM data for interpreting water quality. Especially, the study was focused on classifying water zones and extracting flow patterns.

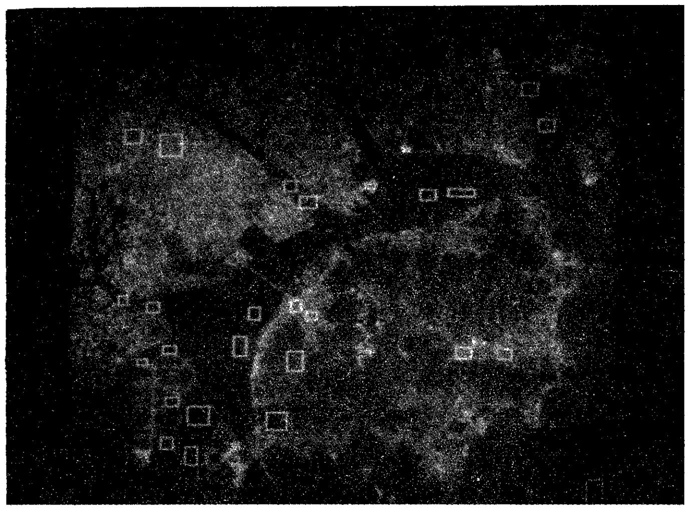

Photo-2 Natural Color Image of Test Site and Training Classes

3-2 Description of test site

The area studied includes the Kojima Bay in Japan. It is encompassed by the Kojima Peninsula which is located in the central part of Seto Inland Sea and several Kilometers away from Okayama City in the southern direction. A reclamation project around the bay by drainage has been begun more than one hundred years before. However, because there is no sufficient water for the reclaimed agricultural land, crops frequently sustained drought damage. In order to solve this problem, a levee across the middle of the bay was constructed in 1962. It prevents sea water from flowing into the bay, and a desalted reservoir with an area of 1,088 ha was formed. As a result, sufficient irrigation water supply got guarantee and reclaimed land became available.

Lately, Kurashiki and Sasagase River catchments proceeded to be urbanized, with the increase of population on the outskirts of Okayama City. Accordingly, urbanization caused water pollution in the reservoir. Because both industry waste water and domestic sewage of cities are poured into rivers and water from the Yoshii, Asahi, Sasagase and Kurashiki River flows into the bay (Fig-2). So various chemical materials move into the reservoir and deposit there. Water quality of the reservoir comes to be degraded. It is thought that it is important to construct a regional sewerage net to draw clear water from the upper reach and to drain water flowing in lower stratum by desalination underdrain, as to improve the water

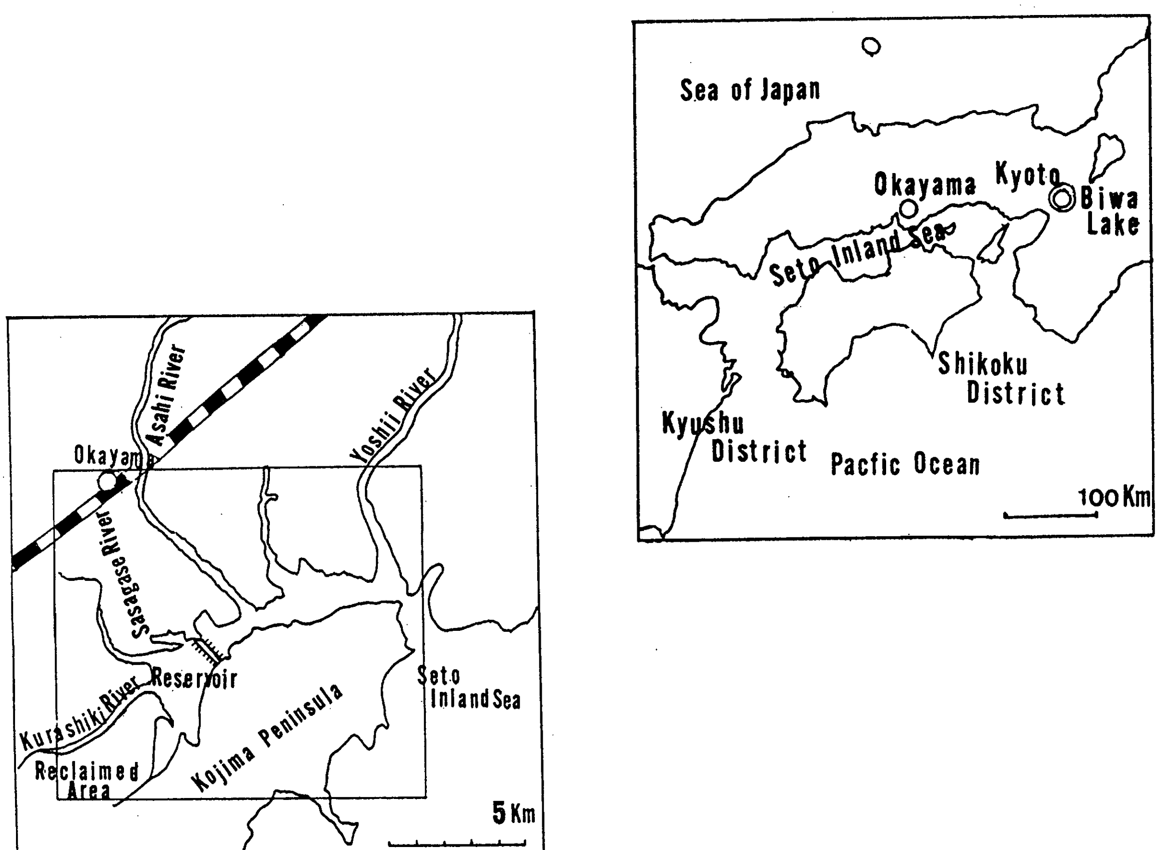


Fig-2 Geographical Location of Test Site quality. The present study was attempted to extract the information about flow patterns around the bay from TM data < Torii et al (1985) >, in order to provide scientific evidence for the project of water purification.

3-3 Hydraulic structure in test site

The level of sluice gate for drainage in Kojima desalted reservoir is usually adjusted according to the rise and fall of tide. The sill of the gate is founded at the elevation of 3 meters below the sea-level and some spots are deeper than 3 meters. Fig-3 shows the isobath of desalted reservoir at present. Most area of the reservoir are shallow, about 2.5 m in depth. There are only two deeper spots along the levee and two deeper spots near left and right shore respectively.

Fig-4 shows the distribution of velocity of plan flow obtained by solving two dimensional shallow water equation < Kawachi et al (1983) >, using depth distribution data as boundary condition. The result is acquried on the calculation condition that much water water flows into the reservoir, on the other hand, much water emits from the gate, and so the stream patterns can be completely understood.

3-4 Analytical procedure

Of softwares mentioned in configuration of software, pre-processing, unsupervised classification, supervised classification and image description are adopted and the image processing proceeds in turn. To begin with, the TM digital data that were acquired on 8th May 1984, are converted for handling as MSS data and pre-precessing is performed on the converted data sets.

In this case, pre-processing does not include geometrical registration and correction of striping noise, because the registration is not necessary judging from the objective of the present study and striping noise can not be found. 4 bands TM data corresponding to wave range of MSS, that is, Band 2,3, 4 and 5 were selected for analysis. The test site is displayed by composing bands data in Photo-2. And then, unsupervised classification is performed using centroid method. The result is utilized as reference data for supervised classification. Supervised classification is performed using maximum likelihood method.

3-5 Results and discussion

Photo-3 is the classification map on the case that training sites amount to 14 sites shown in Table-1 and Table-2. Water bodies and land area were classified into 8 and 6 types respectively. Judging from the contingency table (Table-2), average accuracy is high at 83.9 percentage of correct classification and at 0.86 equivocation quantification . It is considered as high as the results acquired from airborne MSS data <Hoshi (1979) and Torii et al (1979) >. However, the accuracy of classification item 4, 5, 12 and 13 are extremly low. Limiting notice to the types concerning water body, although 8 types are correctly classified, the types do not lead the resultant map representing some features of flow. 4 combined types in respect of land and 3 combined types of water body are displayed in Photo-4 so as to distinguish definitely the status of flow.

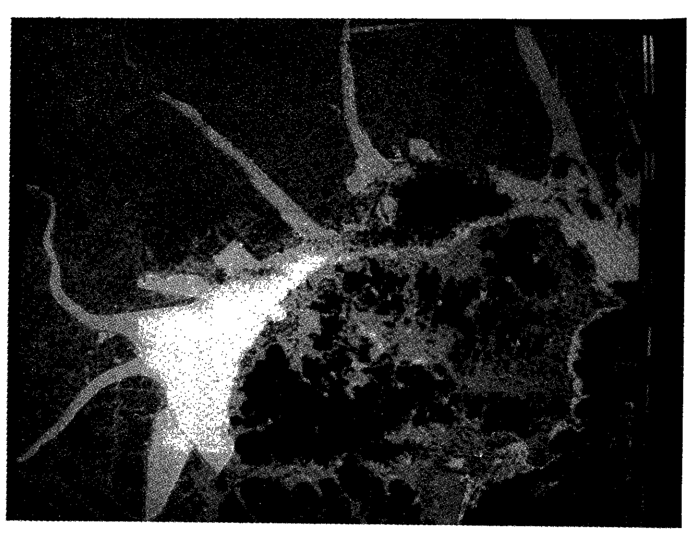

Photo-3 Supervised Classification Map (No. of Training Classes is 14)

Table-1 Characteristic of Training Classes

| Classification item | No.of pixels | Band 2 | Band 3 | Band 4 | Band 5 |
|---|---|---|---|---|---|
| 1. Waters in the reservoir | 216 | 105.6± 1.2 | 42.2± 0.7 | 41.4± 0.8 | 28.8± 0.5 |
| 2. Waters in the Kojima Bay | 200 | 115.2± 1.5 | 49.1± 0.7 | 45.7± 0.9 | 27.3± 0.8 |
| 3. Waters in the Inland Sea | 416 | 109.5± 1.3 | 40.9± 0.7 | 36.8± 1.0 | 21.3± 0.8 |
| 4. Waters in Sasagase River | 120 | 117.3± 3.2 | 49.3± 2.4 | 51.0± 4.7 | 44.6±14.8 |
| 5. Waters in Kurashiki River | 104 | 112.7± 1.4 | 47.3± 1.4 | 48.2± 1.9 | 49.1±20.9 |
| 6. Waters in reclaimed area | 204 | 110.8± 1.5 | 45.8± 0.8 | 44.1± 1.2 | 33.2± 4.8 |
| 7. Waters in Yoshino River | 192 | 119.3± 1.5 | 49.6± 1.1 | 50.4± 1.9 | 32.0± 3.3 |
| 8. Waters in Asahi River | 208 | 119.1± 1.6 | 49.5± 1.2 | 48.6± 3.1 | 33.3± 7.6 |
| 9. Paddyfields in planting season | 132 | 111.6± 2.5 | 47.9± 1.6 | 47.3± 3.3 | 122.4± 7.4 |
| 10. Urban areas | 483 | 137.6± 4.1 | 60.5± 2.1 | 71.8± 4.3 | 65.8± 4.8 |
| 11. Trees | 304 | 103.0± 2.0 | 46.7± 1.9 | 43.6± 1.8 | 107.3±15.0 |
| 12. Bare fields | 45 | 140.9± 6.9 | 68.0± 4.1 | 87.9± 7.6 | 76.9± 6.5 |
| 13. Concrete structures around coast | 80 | 126.3± 4.7 | 56.7± 2.9 | 65.5± 5.5 | 69.3± 8.5 |
| 14. Shadows | 140 | 122.6± 4.6 | 55.7± 2.6 | 63.4± 4.6 | 84.5± 9.6 |

Table-2 Contingency Table of Supervised Classification

| Classification item | No.of pixels | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Waters in the reservoir | 216 | 98.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 |
| 2. Waters in the Kojima Bay | 200 | 0.0 | 84.5 | 0.0 | 2.5 | 0.0 | 7.5 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3. Waters in the Inland Sea | 416 | 0.0 | 0.0 | 99.5 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4. Waters in Sasagase River | 120 | 0.0 | 0.0 | 0.0 | 35.0 | 45.8 | 11.7 | 0.0 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5. Waters in Kurashiki River | 104 | 0.0 | 0.0 | 0.0 | 1.9 | 25.0 | 66.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6. Waters in reclaimed area | 204 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7. Waters in Yoshino River | 192 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 87.5 | 5.7 | 0.0 | 2.1 | 0.0 | 0.0 | 2.7 | 0.0 |
| 8. Waters in Asahi River | 208 | 0.0 | 1.0 | 0.0 | 0.5 | 0.0 | 0.0 | 22.5 | 76.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9. Paddyfields in planting season | 132 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 93.9 | 0.0 | 0.8 | 0.0 | 0.0 | 0.8 |
| 10. Urban areas | 483 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 85.5 | 0.0 | 8.1 | 4.8 | 0.0 |
| 11. Trees | 304 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.0 | 98.0 | 0.0 | 0.0 | 0.3 |
| 12. Bare fields | 45 | 0.0 | 0.0 | 0.0 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.7 | 0.0 | 22.2 | 66.7 | 0.0 |
| 13. Concrete structures around coast | 80 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 62.5 | 35.0 |
| 14. Shadows | 140 | 0.0 | 0.0 | 0.0 | 0.0 | 2.9 | 0.0 | 0.0 | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 | 22.9 | 69.3 |

Average performance=83.9% Equivocation quantification=0.86

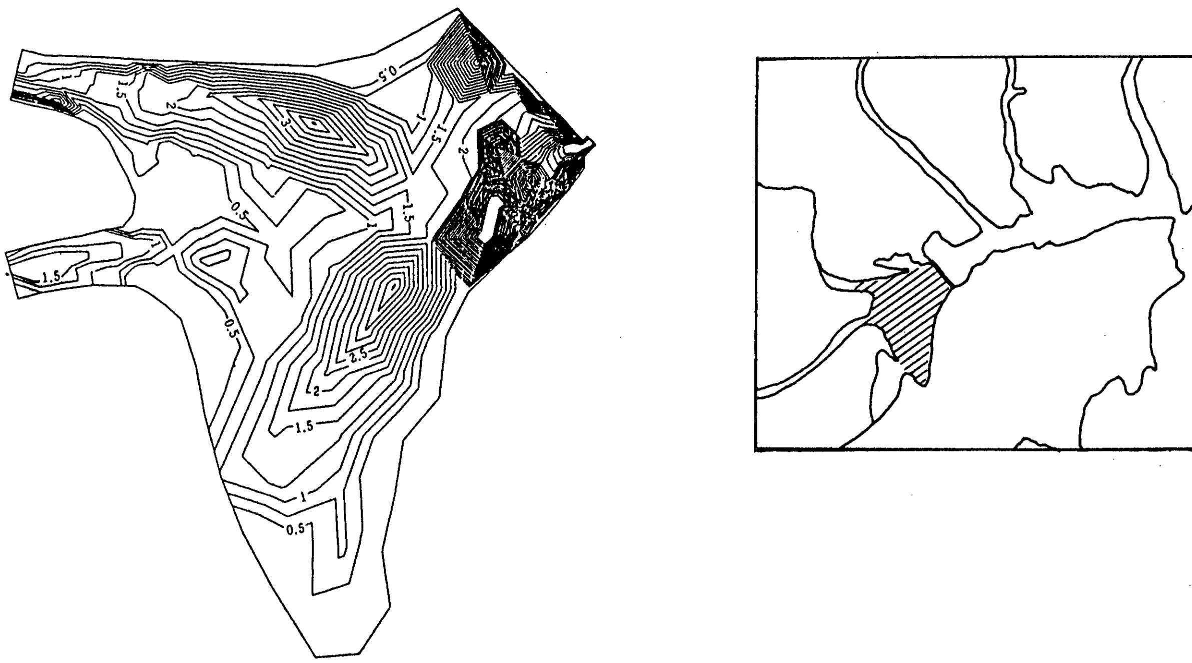


Fig-3 Isobath (m) in the Reservoir

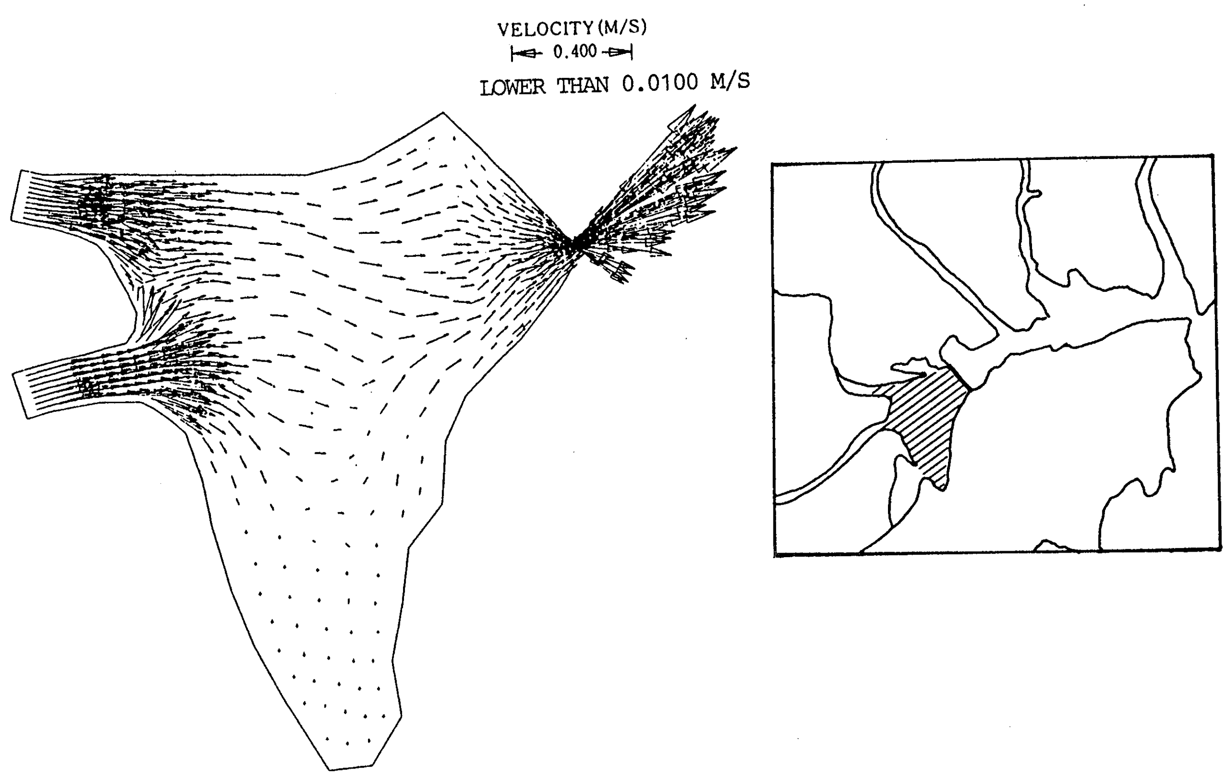


Fig-4 Caluculated Velocities in the Reservoir

It is very interesting to compare the map with the distribution of calculated velocity (Fig-4). Because the map represents water flowing outside through water gate, so it is supposed that water from Sasagase and Kurashiki River flows into the reservoir.

3-6 Conclusion of application

From this test example, following conclusions can be made;

(1) The accuracy of the TM data is as well as airborne MSS data.

(2) If successive TM digital data of a test site are stored, it may be possible to detect exactly future transition on the environment around the test site.

(3) In addition, the remote sensing techniques may bring their capabilities into full play, taking together with simulation model in respect of water and chemical material flow.

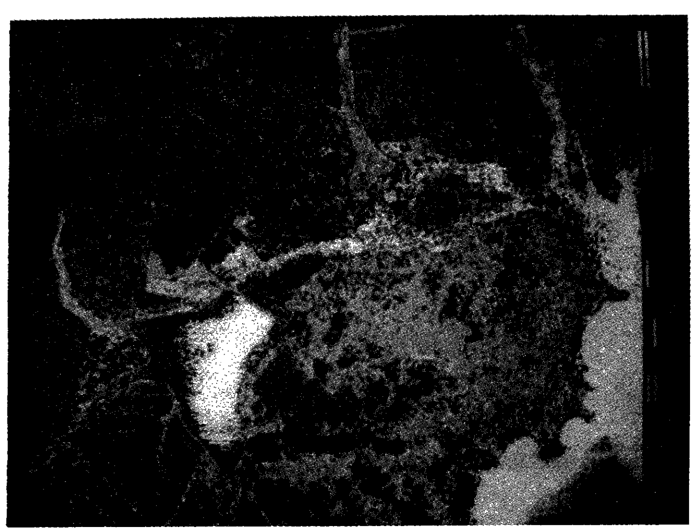

Photo-4 Supervised Classification Map (No. of Training Classes is 7)

## 4. Conclusion

It has been shown that the Tsukusys was developed mainly for the analysis of Landsat MSS data, could cope with the Landsat TM data. However, in order to expand the utilization of Landsat TM data, it is necessary that the Tsukusys can select spectral bands with analysis or more than 4 bands data can be processed, while the Tsukusys presently only deals with 4 bands data.

The second system is being designed, taking notice of the selection and enlargement of the bands. The system is scheduled to process Landsat TM data, MOS-1 MESSR data and SPOT XS data. When the new system is accomplished, the system will also be open for education and training as well as the Tsukusys.

## Acknowledgments

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TITLE

Remote Sensing Image Data Analysis System "Tsukusys" and It's Application

- Especially Classifing Coastal Area around a Bay Using MT -

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ABSTRACT

A system called as "Tsukusys" has been developed to distinguish and analyze land use and land cover patterns by using remote sensing image data, especially Landsat Multispectral Scanner (MSS) image data. As, in Japan, Landsat Thematic Mapper (TM) image data can be acquired since last year, the application of TM data by the Tsukusys was attempted. As a result, the advantage of the TM data is completely vertified. This investigation is to interprete water quality condition around the Kojima Bay, where water pollution becomes a social issue.

SUPPLEMENTARY NOTES