# Investigation on Turbidity and Flow Patterns in Half-closed Sea Area

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The sea features on half-closed bays and coastal areas were investigated by satellite remote sensing. The turbidity on the Kanmon area and Hiroshima Bay was estimated by using a new classification technique with the aid of the sea truth data. The performance of this method on a personal computer was examined for comparison with the most likelihood method(MLM) in the course of the investigation. It has been found that this method is more stable against noise and fluctuation of system parameters in addition to the improved computing time than the MLM, and that the classified results are almost same as those of the MLM. This technique was extended and applied to the environmental researches on the coastal areas of the southernmost Korea which face the Sea of Japan and the industrialization has been emphasized there. The data used in the present study are LANDSAT MSS and TM, NOAA AVHRR and MOS-1 MESSR.

## Introduction

The Seto Inland Sea, along which many factories are located, is known as a very active industrial district as well as the largest half-closed sea in Japan. The industirial activity on the Seto Inland district is so high that its environmental conditions have been long doubted. The Seto has, therefore,certain possibility to send one of the most important signals to the world since it has been productive maintaining the environmental conditions moderately well.

The inflow from the Kanmon Channel into the Seto Inland Sea is much less than that from the Bungo Channel. Therefore, the water in the Suo Sea tends to be stagnant.Once the water was polluted, it requires long time to get refreshed due to the slow recovery rate. In this paper, we will focus our attention to the sea area closer Kyushu side at first.

The Japan Sea would be also regarded as an inland sea enclosed by Northen-East Asian countries. Its water exchanging rate is supposedly low. In addition to this, many large factories are located on the coastal areas of continental side of the sea , though there are not many factories on the Japan

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side.

The industries in the South Korea has been intensively developed. In fact, the bottom of the peninsula has been thoroughly industrialized from east to west in recent years. The production has been the primary requirement for the South Korea as same as other neibouring socialist countries and none of them can invest much for the prevention of the pollutions. It is therefore too optimistic to suppose that the quality of the water there is still sound. If we ignore this fact, we may repeat the same failure as done in the Seto Inland Sea.

In this paper, the industrial activities on the coastal areas of the South Korea are discussed in connection with the bitter experience regarding the water pollution in the Seto Inland Sea.

**Extraction of sea features**

Various classification techniques are used to extract the features from satellite image data. The existing classification methods are almost all based on the pixel by pixel processing technique no matter how sophisticated they may be. Accordingly, its data processing time is very long exclusively, regardless of supervised or unsupervised. It is therefore difficult for us to carry out the classification of satellite data consisting of multi-bands on a personal computer in tolerable time.

The application fields of satellite remote sensing technique have much expanded recently. There is a strong demand to develop new techniques which enables nonprofesional users to analyze image data using personal computers. The more the number of users increases, the easier analyzing techniques, classification ones in particular, are required.

The authors propose here a new techniue which we call HOM(Histogram Overlay Method). The time required for classification is surprisingly shortened since the computation simply uses Fuzzy likelihood on the basis of the cell unit which comprises several pixels to some hundreds. The idea is based on the fact that the variation of CCT counts on water areas is relatively small and pixel to pixel processing is not necessarily required except extreme cases.

In the present study, the authors carried out the investigation on the turbidity profiles of the Kanmon channel, the Seto Inland Sea and the coastal areas around the bottom of the Korean Peninsula.

**Supervised classification by HOM**

The sattelite data used here are shown in Table 1. The individual original image consists of 512x400 pixels for ordinary personal computers. At the first stage of the data processing, the images were reduced to 32x25 cells by putting 16x16 pixels together.

First, histograms of CCT counts in each cell are all calculated. Then the overlapped area of a pair of histograms is in turn calculated and listed for classification. In this case, the overlap of two histograms indicates the degree of the likelihood. As shown in Fig.1, the higher the degree of the overlap is ,the closer their features are. We define the likelihood Li,j between ith and jth cells by the overlap of the histograms. This idea is the same as the Fuzzy likelihood.

**Turbidity on Kanmon area**

The quality of the water on the area have been observed every month by gorvenments Shimonoseki and Kitakyushu. The data which we used here as supervisors are officially announced in the white paper on the water pollution(1,2). In this study, 8 stations out of many obsevation stations were chosen as training areas. The turbidity on these 8 points ranges from low to high. The location of the trainig area is shown in Fig.2.

Fig.3 shows the results classified for a single band by the HOM using the data listed in Table 1. The same procedure was done for all the bands so as to classify the most likelihood trainig area to a cell. The final result using three bands was obtained without multiplying any weight on them for comparison with that of the most likelihood method(MLM). The results will be shown at the oral presentation. The results by MLM for the same scene are as well shown at the presentation. Fig.4 shows the comparison of HOM with MLM.

As can be seen from these results, the turbidity levels around the mouth of the Yoshida River and the Yasuoka area in Shimonoseki side are very high. In Kitakyushu side, the Sone area shows the highest level.

According to the white paper published by the goverment Kitakyushu, it is mentioned that the water quality on Sone area has not been improved yet although other areas are all improved. This fact is in good agreement with our results.

This classification technique enables us to estimate the turbiditiy at spots where no sea truth data are obtained as we mention below.

**Unsupervised classification by extended HOM**

The cluster method is frequently used when there is no sea truth data. This method is also based on pixel by pixel processing concept which leads to long computing time. The processing by cell unit is tried here again.

The following two steps of procedures are carried out to obtain better efficiency.

(1) Cluster formation by sampled cells;

The likelihood of a pair of randomly sampled cells is calculated. If the likelihood between them is high enough, these two cells are unified to make a cluster. The same procedure is repeated till the number of clusters reaches the number specified beforehand by analysts.

The image data used here includes Hiroshima Bay and the Kure harbor. The histograms of specified 8 clusters for three bands and the likelihoods among these clusters are also shown at the presentation.

(2) supervised classification;

The clusters obtained by the step 1 are used tentatively as training areas. The procedure mentioned above is applied for the classification with pseudo-supervisor. The results classified by the HOM for a single band are very similar to Fig.3. The final result using three bands is shown at the presentation. No weight was also multiplied to each band for comparisom with the results of the clustering method here again. The comparison of the HOM with the clustering method shows close correlation. It has been found that the turbidity levels around Hatsukaichi, Miyajima, Hirosima, Ondo-ohashi and Nomisima are very high and that the level around Kure is low in agreement with the sea truth data(3,4)

**The turbidity on the Sea of Japan**

The Tsushima current goes up approaching the West Japan through the Korean and the Tsushima Straits. It is commonly believed that the width of the current is comparatively narrow and that the branches of the current direct the West Japan. By-products discharged from the industrial areas on the bottom of the Korean Peninsula would be transported to Kyushu and West Japan by the branched flows.

**Environmental conditions on the bottom of the peninsula**

The monitoring by stellite on this area was carried out using the unsupervised HOM as done in the case of the Seto Inland Sea. The bay water of P'ohang was expexted to be severely polluted since the large steel manufacturing works and related works are located facing the bay.

As expexted, the classified results revealed that the innermost of the bay is the most polluted. The results are shown at the presentation along with those of Masan and Yosu which are attracting attention as newly developed industrial areas.

**Literature**


1) Kitakyushu city, "Pollution in Kitakyushu", 1988.
2) Shinomoseki city, "Pollution in Shimonoseki", 1988.
3) Hiroshima city, data in 1987.
4) Kure city, data in 1987.


Table 1 Satellte data used here

| | Satellite | Type(path/row) | Date | Area |
|---|---|---|---|---|
| 1 | MOS-1 | MESSR(26/72E) | Jun.16, '88 | Kanmon |
| 2 | MOS-1 | MESSR(25/72E) | Jun. 4, '87 | Hiroshima |
| 3 | LANDSAT | MSS (115/36) | Oct.8 , '89 | Mokp'o |
| 4 | LANDSAT | MSS (114/35) | Oct.18, '89 | P'ohang |
| 5 | LANDSAT | MSS (114/36) | Aug.31, '89 | Pusan |

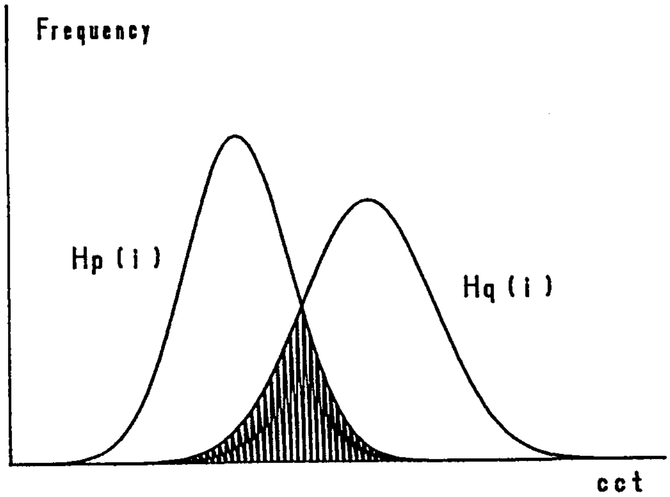



Fig.1 Concept of histogram overlay method

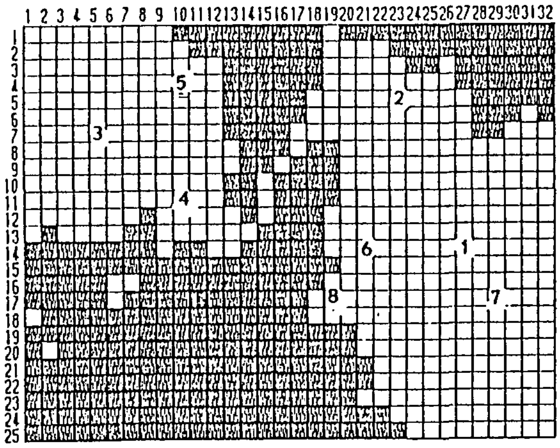


Fig.2 Locations of training areas

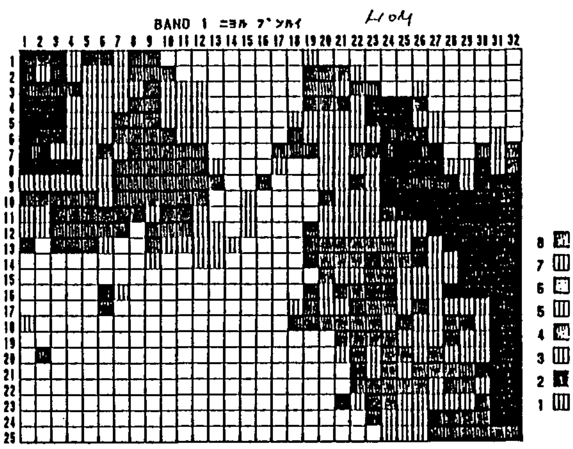
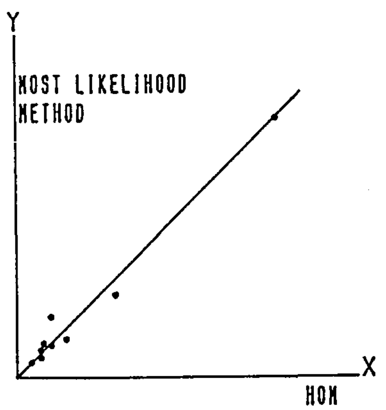


Fig.3 Classification for a single band




| | X(%) | Y(%) |
|---|---|---|
| LAND | 45.75 | 45.46 |
| TA.1 | 6.13 | 5.67 |
| TA.2 | 8.75 | 6.78 |
| TA.3 | 4.75 | 6.02 |
| TA.4 | 4.25 | 4.86 |
| TA.5 | 17.38 | 14.58 |
| TA.6 | 6.00 | 10.60 |
| TA.7 | 4.38 | 3.42 |
| TA.8 | 2.63 | 2.61 |

CORRELATION= 0.988

Fig.4 Comparison of HOM and MLM