REAL TIME MONITORING OF TURBID WATER BY USING VIDEO CAMERA, PERSONAL COMPUTER AND IMAGE PROCESSING

Nobuyuki Mizutani,Kazuya Saito,Yoichi Numata
ASIA AIR SURVEY CO.,LTD.
13-16 Tamura-cho,Atsugi-shi,Kanagawa-ken,243,Japan.

Shigeru Kurosaki,Shigeru Sakama, Osamu Nakamura
TOKYO ELECTRIC POWER COMPANY CO.,LTD.
1-6 Uchisaiwai-cho,1-Chome,Chiyoda-ku,Tokyo,100,Japan.

ABSTRACT

Turbid water caused by engineering work-ing, harbors works and so forth sometimes damages to the fishery and inhabitant in the water. To monitor and to prevent water environmental deterioration, it is needed not only to construct the real time monitoring system but also to deter-mine the standard value of turbidity for assessment of water environment.

In this study, the real time monitoring system which consists of video camera, personal computer, image processing unit and software has been developed and exam-ined to confirm the adaptability for monitoring the turbid water distribution.

The results of examination show the potentiality of monitoring the turbid water distribution and estimating the value of turbidity.

Key word: Video Camera, Remote Sensing, Image analysis, Environment,

1. INTRODUCTION

In recent years attention has been focused on the global environmental problems such as the green house effect, acid rain, desertification, deforestra-tion, and marine pollution. On the other hand, local environmental problems such as noises, air pollution, red tides, and turbid water have also become to obstruct the comfortable human lives.

In this study, we have treated the turbid water which caused by the engineering or construction works for marine institu-tions, since the turbid water sometimes damages to the fishery and inhabitant in the water.

In the conventional method to monitor the environmental deterioration of water, we used to measure the water quality in the fields from the ship and/or analyze the turbidity of water in the laboratory. The another method is the remote sensing technique which gather the information about the water surface from the space. This method is practically used for surveying the water quality such as the red tide, oil pollution, etc. and is realized its usefulness. However these methods have some problems. In the former case, the observations are done at points or along the route, so areal information that shows the extent and pattern of turbid water can not be got from this method. In the later case, the chances of observation are restricted with weather conditions such as cloud, fog, and strong wind and interval of satellite observa-tion.

We have developed a new water quality monitoring system which consists of color video camera, personal computer and image processing software, and tested this system's utility for monitoring of turbid water distribution caused by harbor works at power plant.

The result shows the potentiality of this system for monitoring the distribution of turbid water and for estimating the value of turbidity in real time with succes-sively. The accuracy of estimated turbid-ity value is within +/- 5ppm in the range between 10 ppm and 40 ppm. The 40ppm is the upper limit value for self control.

2. BASIC FUNCTIONS REQUIRED TO THE SYSTEM

Two basic functions are needed in this system. Those are as follows.

2.1 Analog/Digital conversion of video images

Image processing to extract the distribu-tion of turbid water should be done digitally in real time. So, the function of A/D conversion of video data (input to image processing system) in real time is required.

2.2 Conversion of digital image data to value of turbidity

The degree of influence by turbid water should be assessed according to the value of turbidity. So, the function of conver-sion of image data to value of turbidity is required.

Further, the results of image processing should be displayed on CRT with pseudo color image having interval of 10ppm from 0 to 80ppm range of turbidity.

3. THE CONFIGURATION OF SYSTEM

3.1 Hardware

The configuration of developed system is shown in Figure-1. It consists of color CCD video camera (SONY XC-711), image processing unit (IMC-518V8, include A/D converter), personal computer (NEC PC-9801) and color temperature meter etc. All of these instruments are off-the-shelf.
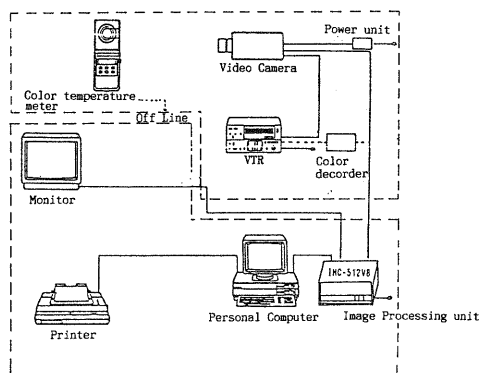
Figure-1 The configuration of system.

3.2 Software

The softwares for this system mainly consists of two parts as follows, and are written by C language and macro assembler.

3.2.1 Initialize   The values needed for correction processing should be entered for initializing the system. Based on these values, preliminary correction factor is determined by multiplying shading correction factor by surface reflection correction factor. Regard to shading correction factor and surface reflection correction factor refer the following section.

3.2.2 Image processing   In the image processing step, we make final correction factor at first from multiplying preliminary correction factor by RGB's balance correction factors that calculated from color temperature meter. Then using bi-band image calculated from video image data which after correction and the quantitative model which represents the relation between value of image and turbidity, we convert the image data to turbidity's value, and finally display the result on the CRT. The details of this step are mentioned next section. The flow of image processing is shown in Figure-2.
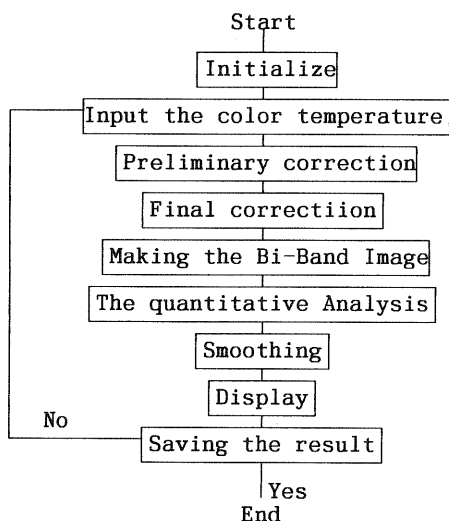

Figure-2 The flow of image processing

4.CORRECTION OF VIDEO IMAGE DATA

The video images taken in the field include many kind of noises which prevent the precise analysis.
In the following, we show the correction algorithm which developed for system to remove these noises and to extract the turbid water distribution exactly from video images.

4.1 Correction of shading

Shading is the phenomenon that the brightness decrease according to the separation from the center of image and is often observed in the optical instruments which use the lens. In the video images, this shading effect occurred and bring about wrong data to the analysis of turbidity. This shading is inherent to the system including the lens to be used and signal processing unit. Then the correction to eliminate shading effect is needed for each system.

In our system, the correction factor of shading for whole image area is calculated by taking ratio of each pixels value to the value of pixel positioned center of image.

4.2 Correction of surface reflection

The developed system is designed to monitor the object area from the land. This means that the object area is viewed obliquely by video camera. In this case, the reflected ray from the surface add to the ray reflected from the materials under the surface which relate to the turbidity. This surface reflection becomes to the noise and its volume depends on the relation between incident angle of ray and viewing angle of video camera. As the surface reflection is influenced by many factors such as wave and billow caused by wind, distribution of sunlight and skylight and etc., we adopt the empirical method as follows.

The video image data at many depression angle are collected synchronously with the vertical video image data for homogeneous water surface. Using these data, the ratio of image to vertical image at each depression angle are calculated. Figure-3 shows the procedure of taking oblique image and vertical image for same target.
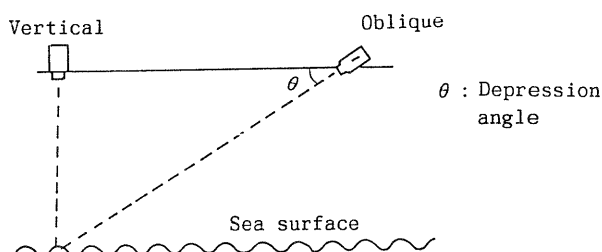

θ : Depression angle

Figure-3 The procedure of taking oblique image and vertical image for same target.

And Figure-4 is the graphs which show the ratio between each depression angle data and vertical data of blue, green and red band. In the graphs the regression lines are plotted. To correct the surface reflection noises in video image, we have used these formula and correct on each pixel of whole image.

Actually these correction factor may be changed according to the weather condition, sea state, altitude and azimuth of sun, viewing angle of video camera and so on, we must make the correction factor for each case. But, it is not practical to make the correction factor for each case. Therefore, we make the regression line which possible to be used for all of data.The formula of each regression line are as follows.

R : $Crr=1.01-exp(-0.046*D-0.60)$
G : $Crg=1.01-exp(-0.045*D-0.50)$
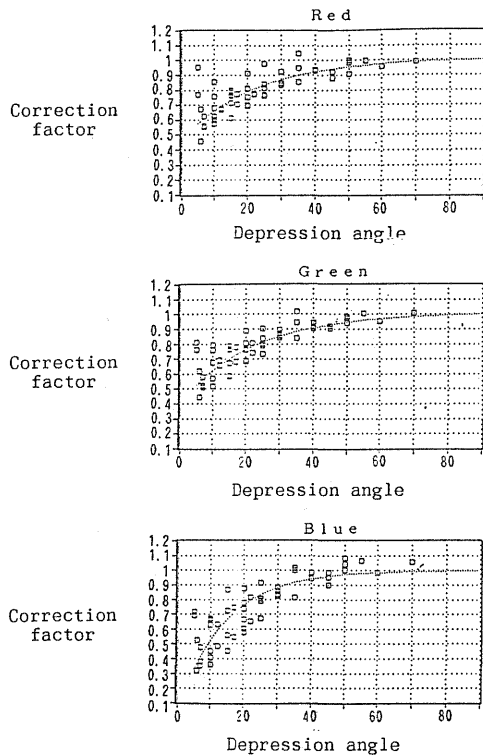B : $Crb=1.00-exp(-0.070*D-0.05)$
(D: depression angle;degree)

Figure-4 The graphs which show the ratio between each depression angle data and vertical data of blue, green and red band.

4.3 Correction of RGB balance

The video camera collects the information with three band, namely, blue, green and red. To express the color of object exactly as color temperature by video camera, it is necessary to adjusting the balance between red, green and blue. This is called as "white balance" and is essential factor for extract physical characteristics of object from video images, such as quantilization of turbidity of water(expressed by reflectance) from the data obtained by video camera.

The output values of red, green and blue from video camera are written as follows.

ER' = Kr * ER
EG' = Kg * EG
EB' = Kb * EB

ER, EG and EB are reflected energies from the turbid water at wavelength red, green and blue respectively, and ER', EG' and EB' are values of output signals from video camera respectively. Kr, Kg and Kb are white balance coefficients of video camera determined by system's intensity. The ideal values of white balance coefficients for the "white" is Kr=Kg=Kb=1.

Though we can adjust white balance at every color temperature with the method mentioned above, we must take the data of white object at each time when the color temperature changes to correct white balance. It is not practical to do this process during the field observation because of incessant fluctuation of color temperature of the object.

On the other hand, the video cameras made recently have a mechanism of adjusting white balance. It uses the balancing of output from video camera about reflected energy from object, namely, equalizing the value between ER-EG and EB-EG. This method is not in need of taking a information of target of white color, and the correction process can be done automatically. However, this method is liable to be affected by changes of color temperature, because the value of output signals from video camera is not related to color temperature linearly.

Therefore, we adopted a new method to the system. We determined at first experimentally the ratios of output signals of red and blue bands to output signal of green band respectively for many color temperatures. Then these relations are entered in the system. Through these process, once the color temperature at observation time is entered to the system before the start of data gathering, we can extract color information(physical characteristics such as reflectance from turbid water) based on the given standard value. The relation that entered into the system is shown in Figure-5.
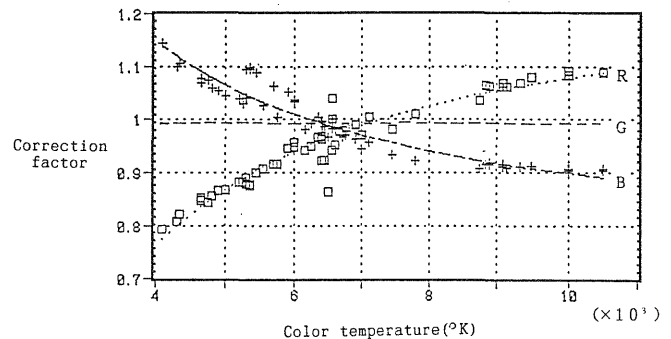

Figure-5 The relation between color temperature and correction factor that enterd into system.

522

4.4 Bi-band calculation and quantitative analysis

It is necessary to estimate the turbidity of water for assessing the influence of turbid water to environment. We have developed the quantilization model which uses the correlation analysis between video image data and turbidity of water. To get a absolute value of turbidity, the field observation using turbidmeter was done synchronously with the collection of video image data.
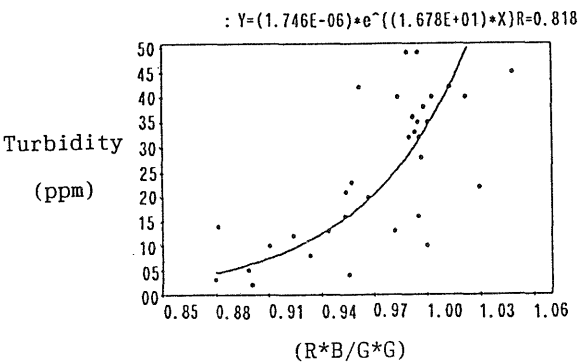
For correlation analysis, we use the bi-band video data which can represent more accurate turbidity of turbid water.
The formula of quantilization model changes according to the component of soil included in water, namely color of soil. Therefore it is necessary to examine the relation between video image and turbidity and to make a quatilization model for each construction site before starting the monitoring.

5.RESULTS AND DISCUSSION

5.1 The quantitative analysis model

We have made two kinds of quantitative analysis models in this study. One is the model for dark blown water which occurred by the soil of sea bottom at the harbor of power plant as a turbid materials, and other is the model for yellow brown water which occurred by the soil at construction site.

Bi-band video image which normalize the change of radiance are used as input data for the model. Through the model which correlate the video image and turbidity of water, we have derived the exponential functions as a regression line for quantitative analysis. The regression line for dark blown water at the harbor, of course, differed from the yellow brown water at construction site as mentioned before. Those are shown in Figure-6, and the 99% significance level of the regression lines are shown in Figure-7. It is realized that the accuracy of model is 40ppm's turbidity. This value satisfies the accuracy requested for the system.
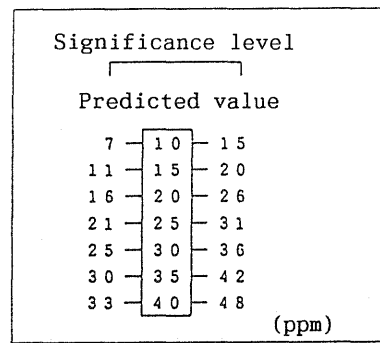
: Y=(1.746E-06)*e^((1.678E+01)*X)R=0.818

(1)Model for dark brown water.

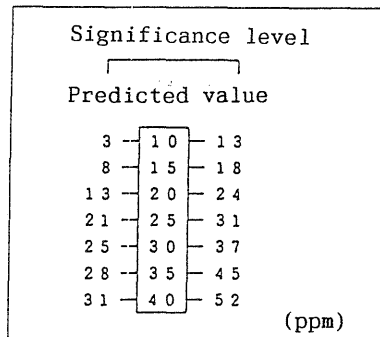: Y=(2.312E-01)*e^((3.891E-02)*X)R=0.936
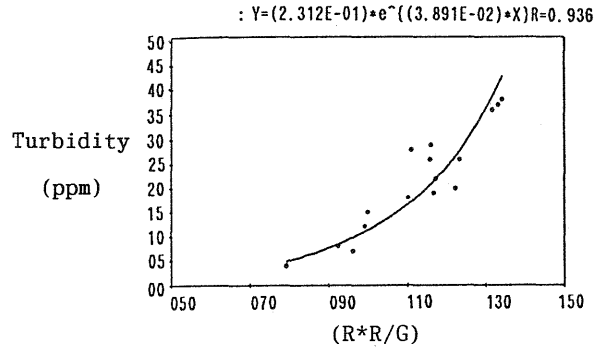
(2)Model for yellow brown water.

Figure-6 The exponential function of the regression line for quantitative analysis.

(1)Model for dark brown water.

(2)Model for yellow brown water.

Figure-7 The 99% significance level of the regression lines shown in Figure-6

5.2 Evaluation of image data

The video camera of the system was set up at the smokestack of the power plant, and the images which show the distribution of turbid water caused by the tanker in the harbor were taken. These video images were analyzed using the method mentioned before. Photo-1 is a video image printed through the video-printer, and Photo-2 is the result of analysis which shows the distribution pattern of turbid water.

This data was taken with 18 degrees depression angle, so the specular reflection of the sun was included in the image. Though the specular reflection

can't be corrected in this system, the result obtained from our system shows the relatively good agreement with the field observation. For example, turbidity of 4-5ppm derived from the system correspond to 3ppm of field observation.
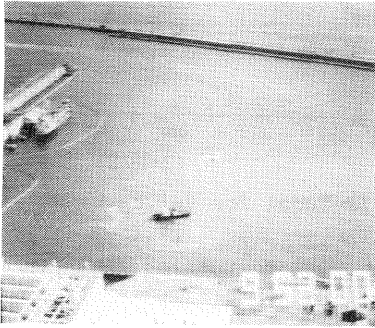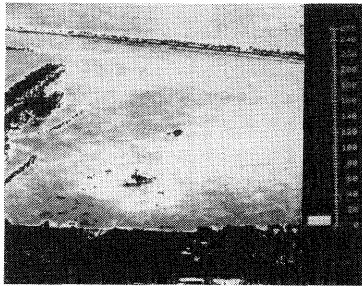

Photo-1 The color video image.

Photo-2 The Image is result of analysis.

On the other case which uses the color of sea bottom soil(dark brown), we can't get a good result because of the similarity with the color of sea surface and turbid water. That is, we can't apply the same model to different case because of the difference of red, green and blue reflectance value at each turbid water.

6.RESTRICTION OF THE SYSTEM AND IM-PROVEMENTS OF THE SYSTEM

The turbid water whose color is similar to the surrounding water can't be extracted using the developed system. But, for the other case, we can get the turbidity within the required accuracy, for example, to control the turbid water of construction field within environmental standard value(e.g. 25ppm).

The effect of sun glitter and the reflection of breakwaters, ground, construction machines and etc. can't be removed by the surface reflection correction, and the parts of image where ships, foams, waves and so on exist are tend to estimated relatively high or low value. Then, we have to develop the method to discriminate the materials which mislead the results from the turbid water.

For practical use of this system, we must solve the problems mentioned above and must to construct advanced system which automatically judge the level of turbidity and warn to manager about the condition of turbid water distribution.

7.CONCLUSION

We have developed the simple system for monitoring the turbid water. It consists of inexpensive color video camera, personal computer and etc. Though the utilization of this system is restricted with weather condition, environmental condition and etc., The images which show the distribution of turbid water can be got about three minutes after the collection of video image data. Further, once the model which converts the video image data to turbidity is constructed, we can get the distribution of turbid water with required accuracy.

The result obtained through the experiment shows the possibility of this system for application to monitoring the environment of construction site and so on.

8.REFERENCE

Audiovisual Consultant Center, 1988, Video Communication Magazine, AVCC, p19-p50

Group V, 1988, Technical Hand Book For Video, Audio Video Magazine

Japan Remote Sensing Research institution, Image Processing and Image Analysis, p24-p47

Syouji Hashimoto, 1980, CCTV System Design Guide, Corona

Yasuhiro Sugimoto etc, 1985, Optics of Ocean Environment, Tokai Unv, p80-p106