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Use of Image Processing Technique to Estimate Sediment Concentration

Mahmood Shafai Bejestan and Shabnam Nouroozpour
Department of Hydraulic Structures, Faculty of Water Science Engineering,
Shahid Chamran University, Ahwaz, Iran

Abstract: In this study, image processing technique is used as a method to estimate the amount of sediment concentration and facilitate and increase the speed of measurement. In comparison to the conventional methods this technique can be applied as an efficient tool. The major purpose of present study was to define the sediment concentration as a function of digital image data. To accomplishing this, a numerical algorithm was developed which can process any image into three bands. Then samples were prepared with different concentration and thickness and digital images were taken from these samples. The correlation between image data and concentration were determined. The analysis of results derived from the processing of captured images suggested that there is a strong correlation between the sediment concentration and the image data.

Key words: Digital image, concentration, sediment, RGB, Karoon River

INTRODUCTION

Estimation of Total Sediment Load (TSL) is a primary tool for designing storage dams, river navigation, water intakes and de-silting basin structures. The traditional method is to measure suspended load by direct measuring of sediment at river hydrometry stations. This method is more costly and time consuming. Usually the measurements take place one or two times a month. During the peak flow discharge, usually no measurement is done because of high flow velocity which is difficult to keep the boat stationary or to keep the sampler perpendicular to the flow, although it is very important to conduct accurate measurement when the flood occurs. This is because most of annual sediments is transported during floods. Analysis of Ahwas hydrometry station data in Karoon river of Iran, have shown that about 85% of annual sediment are transported during a few floods. This implies that new tools for measuring of total sediments have to be conducted. The new technique must be accurate, simple, eliminate manual sampling and can be applied at any desired time.

Remote sensing is a new technique which has been widely used successfully in the past decades. Such technique has been used for determination of water quality elements. Lopez Garcia (1990), Tassan (1993), Dekker *et al*. (2002) and Lim *et al*. (2003) have developed analytical or numerical algorithm for water quality mapping. In this technique satellite data are used to monitor water quality. Suspended sediment concentration and turbidity also have been the subjects of many remote sensing studies. Jorgensen and Edelvang (2000), Doxaran *et al*. (2002) and Mobasheri (2003) are among these pioneer researchers.

As it was mentioned earlier, satellite data used in all of the above studies. The major disadvantage of satellite data is that data will not be available during the clouds. Also data are available during a specific time which depends on the satellite and the subject location. Therefore, although remote sensing eliminates manual sampling, data is not available at any time which might be desired.

Digital camera is another new technique which can bring many advantages. Since it can be easily captured data at any time. Pictures are taken very close to the subject and can eliminate any side effect. Digital camera may be connected to the computer for on line processing.

The application of digital camera image for estimation of TSS, has been reported by Lim *et al*. (2003). The purpose of their study was to verify the application of new algorithm for estimation of TSS, at Prai river estuary. The digital images were taken by Kodak DC 290 camera from an aircraft. At the same time the true samples were taken. From the comparison of digital image processing with the measured TSS, they concluded that estimated TSS concentrations correlated fairly well to the in situ data. Figure 1 shows good agreement between predicted and measured sediment concentration.

The most important and difficult part of digital camera technique, is the processing of the captured images. For reliable results, the process must be accurate enough and very fast. Processing is possible only by an algorithm to

Corresponding Author: Mahmood Shafai Bejestan, Department of Hydraulic Structures, Faculty of Water Science Engineering, Shahid Chamran University, Ahwaz, Iran

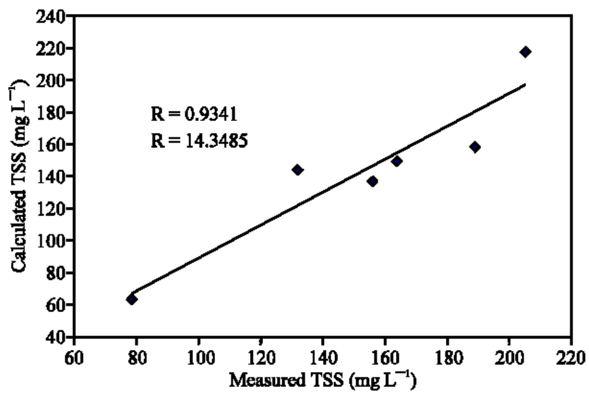

Fig. 1: Relationship between measured and calculated TSS (Lim *et al*., 2004)

convert the image into numerical data. In the present study, first an algorithm for processing of digital images has been developed then the experimental tests conducted to determine the correlation between the imaginary data with the sediment suspended concentration.

DEVELOPING NEW ALGORITHM

To reach the main purpose of this study first an algorithm was developed to process the digital images. In fact the algorithm must be able to read the pictures, which is a qualities' parameter and transferred to numerical data. These data then can be applied for further analysis. In this study the captured images is transferred into three visible bands, of red, green and blue or RGB.

In the RGB system any digital image is composed of pixels. A typical size of an image is 512-by-512 pixels. This means that the data for any image must contain information about 262144 pixels, which requires a lot of memory. Hence, compressing images is essential for efficient image processing. Digital images are saved in many different formats; one of these format is RGB. It represents an image with three matrices of sizes matching the image format. Each matrix corresponds to one of the colors Red, Green and Blue and gives an instruction of how much of each color a certain pixel should use. The maximum number of each color is 255. Black images have no pixel of Red, Green and Blue and are shown as (0, 0 and 0). On the other hand for white images, the values of Red, Green and Blue are 255 and are shown as (255, 255 and 255) (Fig. 2).

To reach the purpose of this study an algorithm was developed in Matlab software (version 7.0). The algorithm is able to process any digital image into three visible bands of Red, Green and Blue. This algorithm is capable

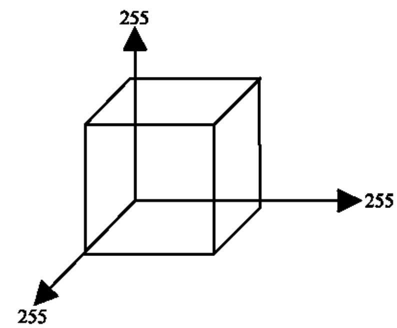

Fig. 2: Schematic of RGB format

Table 1: Developed algorithm for processing digital images

Program of calculation of RGB and gray level

```
********************************************p=input('Image = ');
n=input('Number of picture (>1000) = ');
[m s]=size(p);
a=[];
for i=1:n;
    if i<10
        a=[a,sprintf('%s (%g).jpg ',p,i)];
    else if i<100
            a=[a,sprintf('%s (%g).jpg ',p,i)];
        else
            a=[a,sprintf('%s (%g).jpg',p,i)];
        end
    end
end
matrix_name=sscanf(a,'%c',[10+s,inf])'
rgb=[];
for j=1:n
    img1=imread(matrix_name(j,:));
    k=size(img1);
rgb=[rgb;sum(sum(img1(:,:,1)))/k(1,1)/k(1,2),sum(sum(img1(:,:,2)))/k(1,
1)/k(1,2),sum(sum(img1(:,:,3)))/k(1,1)/k(1,2)];
end
```

to process any digital black and white picture into a Gray band. This new algorithm is shown in Table 1.

EXPERIMENTAL TESTS

Using the above algorithm any digital image can be processed and the values of R, G and B or Gray band are determined. To apply this algorithm for determination of Total Suspended Sediment (TSS), a relation is required to correlate the value of TSS to the RGB or Gray values. To find out this equation experimental data has to be conducted. The experimental procedures were as follow:

- Prepare a sample with a desired concentration; in the first series of tests the samples were prepared with 1.5 centimeters thickness. In the next series of tests the thickness was taken as 3 and 5 centimeters to see the effects of thickness sample.
- Captured digital images from the sample.

- Determine the image data or values of R, G and B by the developed algorithm.

Samples were prepared by sediment which was taken from Karoon banks. Figure 3, shows the size distribution of the sediment used in this study. Samples were prepared under different concentration ranged from zero ppm to 10,000 ppm. Each sample was put in a ceramic dish. Sediment was mixed with clean water carefully and then images were captured from the sample.

A Sony digital camera, model, SONY DSC-H1, were used in this study. During capturing the image, it was tried to minimize any side effects and the image were taken at the same conditions of light, weather etc.

The sediment concentration of the samples ranged from zero to 10 g L^{-1}. Within this range twenty samples were prepared. This range was selected because, most of sediment concentration measurement in Karoon river is within this range (Nouroozpour, 2007). Analysis of measured data from Ahwaz station in Karoon river for 12 years is shown in Fig. 4. The concentration of 99.7% of data is less than 10 g L^{-1} and only 0.3% of data have more than 10 g L^{-1} suspended sediment (Fig. 4).

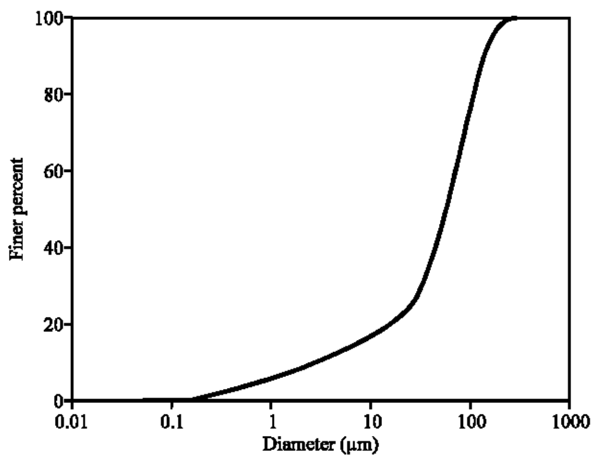

Fig. 3: Size distribution of the sediment

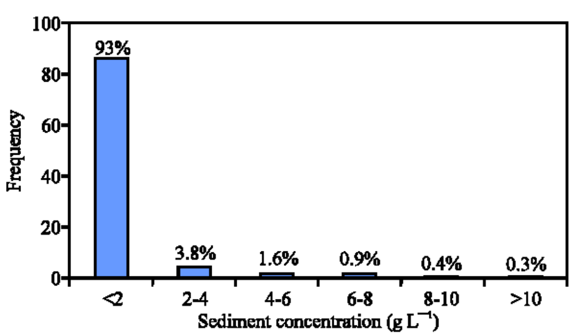

Fig. 4: Analysis of TSS data for Ahwaz station in Karoon river (Nowroozpour, 2007)

RESULTS

By applying the developed algorithm which was discussed earlier, the ten images of each sample were processed and the value of three bands of Red, Green, Blue for each image were determined. Although the conditions for capturing of these images were kept constant, the image data obtained from image processing were not the same and can vary a little from a picture to another picture. Therefore, the average values of R, G and B of the ten images were used in the final analysis. Figure 5-8 are presenting the variation of sediment concentration versus Red, Green and Blue values, respectively. As it can be seen from these figures, there is a good correlation between sediment concentration and the values of image data. Table 2 shows the equations which have been developed by analyzing data by Excel. Any of this equation can be included in the developed

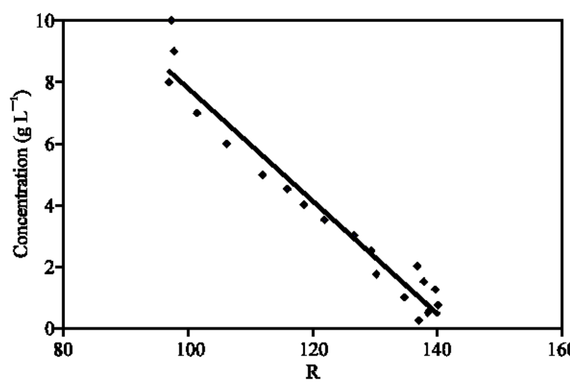

Fig. 5: Concentration versus value of Red for samples of 1.5 cm thick

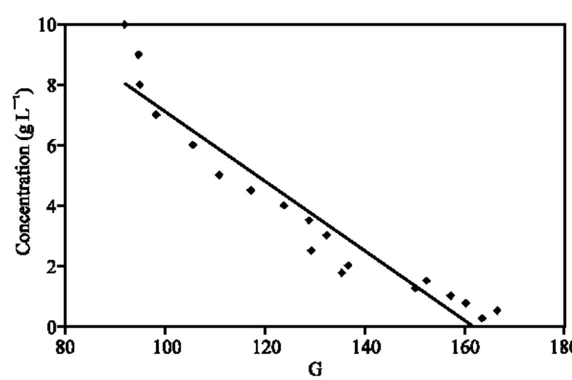

Fig. 6: Concentration versus value of Green for samples of 1.5 cm thick

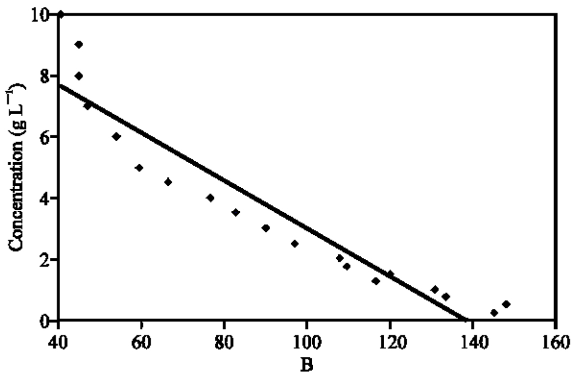

Fig. 7: Concentration versus value of Blue for samples of 1.5 cm thick

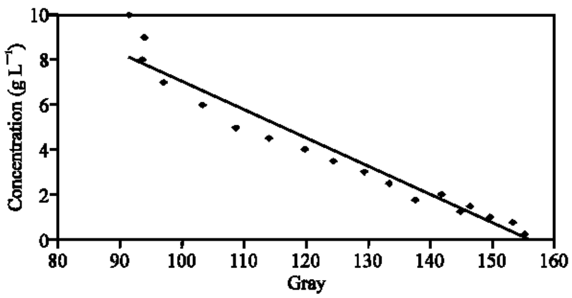

Fig. 8: Concentration versus Gray level for samples of 1.5 cm thick

Table 2: Equations developed in this study(for sample with 1.5 cm thick)

Eq. No.	Equation	R^2	RMS	Fig. No.
1	$C = -0.184\,R + 26.219$	0.9502	0.9850	5
2	$C = -0.115\,G + 18.641$	0.9180	1.2916	6
3	$C = -0.078\,B + 10.830$	0.8923	1.4679	7
4	$C = -0.126(\text{Gray}) + 9.645$	0.9407	2.7868	8
5	$C = 666.57\,e^{-0.0431\,\text{Gray}}$	0.9351	2.8617	9
6	$C = 2178.2\,e^{-0.0528\,\text{Gray}}$	0.9590	2.7735	10
7	$C = -0.0575(\text{Gray}) + 9.75$	0.8985	0.1379	11

algorithm to get the sediment concentration directly. The procedure then will be that the algorithm will read the captured image and the output will be the amount of sediment concentration.

The developed algorithm is also capable of reading the black and white image. In such case the out put of the algorithm will be the average values of R, G and B which is shown as Gray level of image. Converting the captured color image to a black and white is possible through an operating option which is provided by most of the digital camera. To investigate the use of Gray image data on the sediment concentration level instead of G, R and B data, the Gray level for each image also were determine. Then sediment concentration was related to the gray level as shown on Fig. 8.

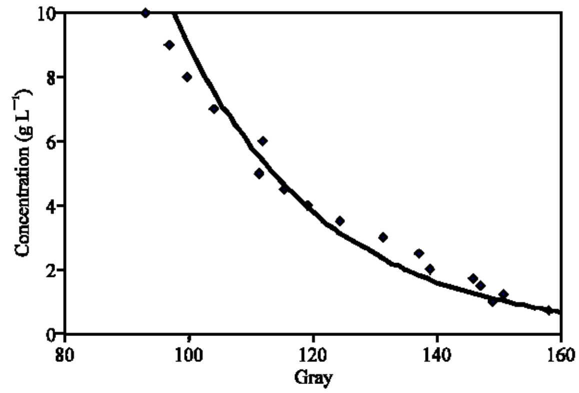

Fig. 9: Concentration versus Gray level for samples of 3.0 cm thick

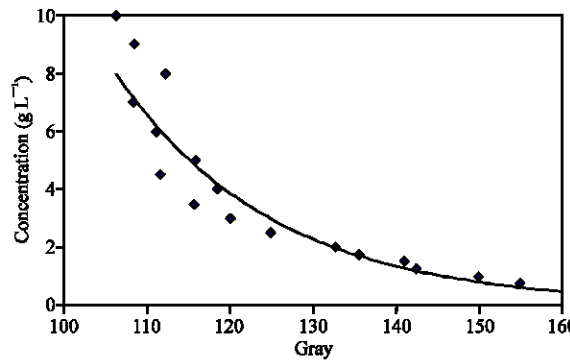

Fig. 10: Concentration versus Gray level for samples of 5 cm thick

The best fitted equation on Fig. 8 was obtained by Excel and is shown in Table 2. The R^2 value shows a good correlation between sediment concentration and Gray level of image. Therefore in the forgoing analysis, the gray level will be used.

To study the effect of sample thickness on image data, samples were also prepared for two thickness of 3 and 5 cm. Figure 9 and 10 show the relation between sediment concentration versus the value of image Gray for 3 and 5 cm thickness, respectively. The best fitted equations for data on Fig. 9 and 10 are presented in Table 2.

Figure 11 also was plotted for all data of three different thicknesses, as it can be seen from this figure, sample thickness has not shown any significant effect on the final Gray level of image. The best fitted relation between sediment concentration and Gray level for all experimental data was developed by Excel and is as follow:

$$C = -0.0575(\text{Gray}) + 9.75 \tag{7}$$

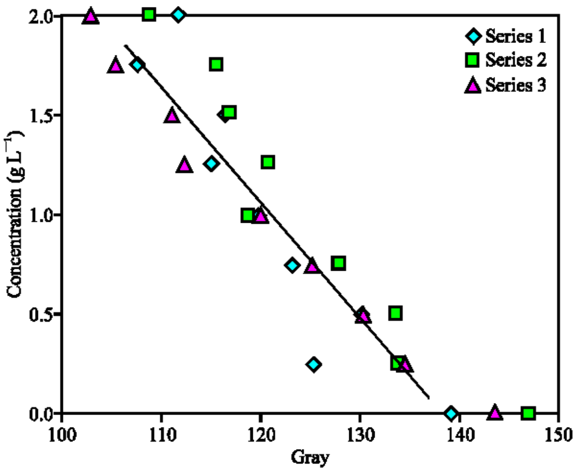

Fig. 11: Concentration versus value of Gray for samples of 1.5, 3 and 5 cm thick

$$R^2 = 0.8985 \quad RMS = 0.1379$$

In which C is the sediment concentration in g L^{-1} and Gray data was obtained from processing of the image using the algorithm developed in this study.

Equation 7 can be added to the algorithm developed in this study to determine sediment concentration through processing of a digital picture which has been captured from water-sediment mixture. This relation may vary if the type of sediment changes. Therefore it is recommended to modify this equation for any hydrometric station by conducting the same procedure which was discussed in this study.

CONCLUSIONS

In this study the application of digital image process technique for estimating suspended sediment concentration was introduced. An algorithm was developed which is able to process any digital images and determine the image data. To show the relation between image data and sediment concentration, samples were prepared under different sediment concentrations. The images were taken from these samples and were processed by the algorithm. From analysis of data it was found that there is a good correlation between image data and sediment concentration. The new technique can be applied in any hydrometric station for online monitoring of sediment concentration. However the new technique which was introduced here is in initial steps and it is recommended to collect further in situ data to calibrate concentration-image data relation (Eq. 7).

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