Image-based Water Level Measurement Method under Stained Ruler

Jae-do KIM, Young-joon HAN, Hern-soo HAHN
(*Dept. of Electronic Engineering, Soongsil University, Seoul* 156-743, *Korea*)

Abstract – This paper proposes the water level measuring method based on the image, while the ruler used to indicate water level is stained. The contamination of the ruler weakens or eliminates many features which are required for the image processing. However, the feature of the color difference between the ruler and the water surface are firmer on the environmental change compare to the other features. As the color differences are embossed, only the region of the ruler is limited to eliminate the noise, and the average image is produced by using several continuous frames. A histogram is then produced based on the height axis of the produced intensity average image. Local peaks and local valleys are detected, and the section between the peak and valley which have the greatest change is looked for. The valley point at this very moment is used to detect the water level. The detected water level is then converted to the actual water level by using the mapping table. The proposed method is compared to the ultrasonic based method to evaluate its accuracy and efficiency on the various contaminated environments.

Key words* – *water level measurement; image processing; surveillance system; histogram analysis

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1 Introduction

The rivers overflow due to the typhoon and regional torrential rains, and this caused sudden flood to damage properties and lives in worldwide. To prevent these serious disasters, humans are interested in controlling the water level of river to prepare for the overflow of river. Currently, researches for controlling water resources are going on, and the research for measuring change in water level is the most basic matter required for these ongoing researches.

There are three main groups of these methods according to its form and type of sensors for measuring water levels on rivers and lakes. The first system is in a form which measures the site of buoy, and this system is used universally[1]. However, this system requires pipes to fix the buoys, and most of them are depend on the water pressure. Also, the sensor has to be changed rapidly if the system is used for long time. The second system uses the ultrasonic wave sensor; the ultrasonic wave is released to the surface of water, and the time it requires to return back to the system after it is reflected off the water surface is measured[2-3]. This system is appraised as an accurate system. However, since the ultrasonic wave depends on the incidence angle, temperature, vibration and moisture, measuring apparatuses are required to measure these. Besides, the system is hard to be designed due to its install location. Moreover, the system has to design and build up some pipe-like structure to isolate the exterior environmental factors from the measuring conditions. For the above two systems, an error cannot be detected easily if a specific error occurred. Therefore, the maintenance and repair takes long time. On the contrary, the water level measuring system which uses the image information, can confirm the image by observing the indicator Furthermore, the image also contains also the broad information about the surrounding. For these reasons, the system using image is more accurate and reliable. Takagi[4-5] have proposed Image recognition algorithms for water level detection. They are based on detecting bending points of diagonal lines on a measuring board. However, their performance is sensitive to stains on the lines and it is strictly controlled by an administrator to install any obstacle to water flow such as the board in the water. Tsunashima[6] proposed a simple method based on edge detection. It detects a horizontal line as surface of the running water with a "vertical" edge detector. It also employs "subtraction" of frames to make it robust against horizontal line like disturbances on the wall of a channel. However, it is sensitive to moving disturbances such as rain or snow drops due to the subtraction. Iwahashi[7] proposed a method based on horizontal edge detection and frame addition. In this paper, the water level is recognized as a boundary line between the land region and the water region. Two region is distinguish by FIR Filtering. However, if the texture of

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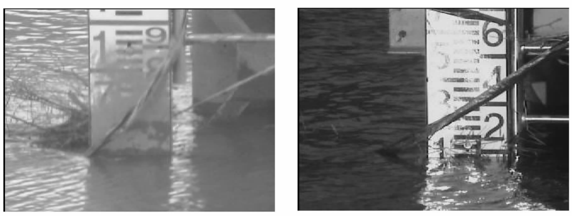
Corresponding author: Jae-do KIM(duckjd@ssu.ac.kr)

land and water is similar, the boundary between the two regions is indistinct. S. B. Park[8] used the feature, that the change of the waver surface occurring due to the wave is greater on the image than change on the ruler, to measure the water level.

However, if the environment of the water surface and its comparing target change as shown in Fig. 1, the performance decreases greatly if the above methods are used. In this paper, the comparing target is the ruler. The strong reflection of the illumination causes error in a short period of time, and the dirty ruler causes error in a long period of time. If the condition of the ruler is poor as this, the image processing methods, such as the character recognition or the horizontal ingredient detection, cannot be used to detect the water level directly.



(a) (b)

Fig. 1 Example of bad condition: (a) shows the stained ruler, (b) shows the strong reflection

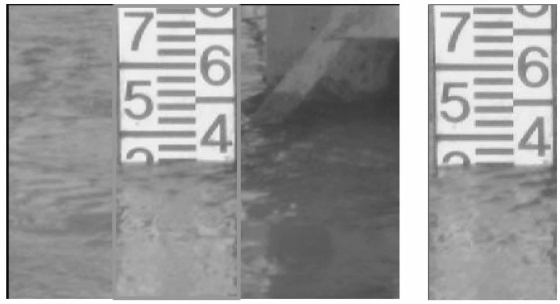
This paper proposes the water level measuring method, in the case where the ruler is stained, or is damaged due to the strong illumination reflection. Firstly, only the ruler is set as the Region of Interest (ROI) to reduce the noise caused by the other regions except for the ruler region. Here, the feature that the brightness contrast of the ruler and the water surface is not affected by the environmental change, such as the strong reflection or the contamination on the ruler, is used. Moreover, to reduce the noise caused by the wave, the average image is produced by using continuous images of certain time. A histogram is produced by using the intensity of the produced average image as the height axis of the image. The reasonable water level is detected by analyzing the change of the produced histogram. Furthermore, by carrying out the experiment with the images of various conditions, the accuracy and efficiency of the proposed method is confirmed.

2 Initial setting

After the initial location and pose for the camera shooting is decided, ROI is set manually, and the mapping table is produced. This simplifies the calculation during after-water level-measuring-operation by achieving one-step set initialization.

2.1 ROI setting

ROI refers only the region of the ruler inside the image. It is set to eliminate the noise appearing on external region and to shorten the after-image-processing time. Fig. 2(a) represents the ROI inside whole image, and Fig. 2(b) represents the separated ROI. After the pose of the camera is set, and is designated.



(a) (b)

Fig. 2 ROI setting: (a) is input image, (b) is selected ROI

2.2 Generation of mapping table

To convert the measured distance of the pixel inside the image to the actual numerical value, the correcting method of the camera is used. The major methods of the camera correction are the methods proposed by Tsai[9] and Zhang[10]. However, the method of Tsai requires an accurate data on the location and movement of the camera and the targeting object, and the method of Zhang, which does not requires the accurate data, requires more complex and larger operational amount, compare to the method of Tsai. To simplify this, K. J. Kim[11] made a table about the actual distance per pixel, and detected the reference pattern from the image. Then, the researcher used the produced table to convert it to the actual water level. However, because the shooting region is large, the actual distance per pixel in the image gets far, and therefore, more errors occur.

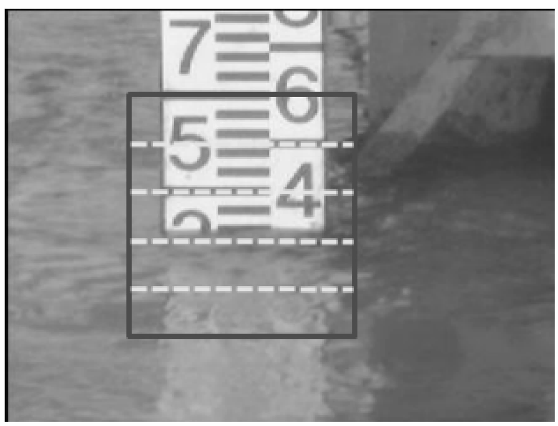


Fig. 3 Generation of the mapping table

In this paper, the mapping table, which can simply convert the water level on the image to the actual water level without using complicated correcting method of the camera, is produced by setting the camera's pose in advance. Also, the actual distance, which appears on the image, is fixed to 80 cm, to reduce errors. Fig. 3 represents the setting of the imaginary ruler to produce the mapping table. The black rectangle shows the 50 cm region based on the ruler shown on the image, and the dotted-line inside the black rectangle represents 10 cm. The actual height of the starting point of the black rectangle can be figured out by the location of set camera. Based on this, the actual location of each dotted-line can be figured out. Thus, if the water level of the image is detected, the actual water level can be calculated according to this. Furthermore, if the water level is measured outside from the black rectangle, the location of the camera is moved.

3 Water level measurement

The strength of the features, such as the change of the water surface and the interior features of the ruler, are weakened or eliminated according to the environmental change. On the other hands, the intensity difference between the ruler and the surface of the water is the feature is not eliminated by the environmental change, thought less change occurs on the strength of the feature.

3.1 Average image and histogram generation

The average image is used to eliminate the noises, which occur due to the rolling of the current or the sudden change of the illumination. The average image calculated with the continuous image for certain period of time.

The intensity of the average image is cumulated based on height axis of the image, then its size is normalized. Many parts change its color rapidly due to the mark on the ruler. The weighted moving average method is used to keep the overall shape of the whole histogram, while eliminating the noises occurring on the ruler. Fig. 4 shows the produced average image and the histograms.

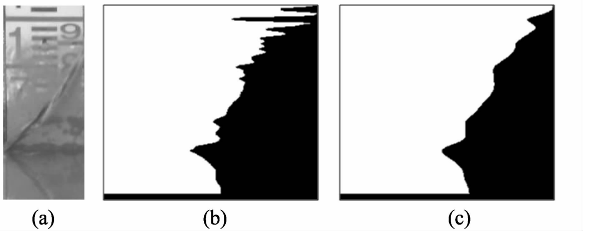


Fig. 4 Setting the ROI: (a) is a average image, (b) is original histogram, (c) is smoothed histogram

3.2 Water level detection

Since the colors of the ruler and the water surface have a huge gap, a point with a sudden color change appears. This point represents the approximate water level. To find the point where the sudden color change occurs, the local peaks and local valleys are found on the histogram. The greatest value among the values of the surrounding is regarded as the peak, and the smallest value is regarded as the valley. The section with the greatest difference between the peak and the valley existing on its bottom is then found. The water level exists in this section. Fig. 5 shows the peak, valley and the section, which is predicted to have the selected water level.

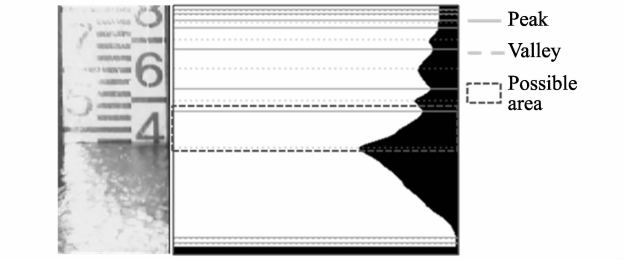


Fig. 5 Expected water level detecting section

To analyze out the accurate water level, the original histogram is analyzed minutely at the expected water level detecting section. As same as detecting the expected water level section, the local peaks and the local valleys are detected on the original histogram. The point which has the greatest difference between the peak and the valley is detected, and the local valley at this point is judged as the accurate water level. Fig. 6 shows the peaks and the valleys inside the expected water level detecting section, and shows the final water level detected. The detected water level of the image is converted into the actual water level by using the mapping table.

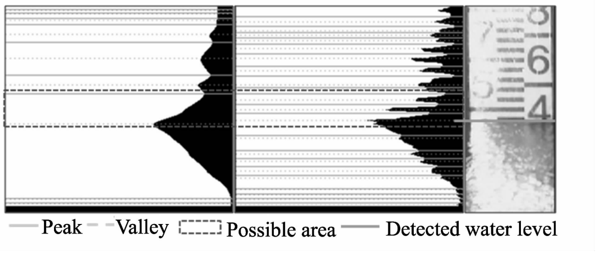


Fig. 6 Detected water level

4 Experiments and results

The size of the image used in this experiment is 320×240, and the experiment is carried out at about 20 different conditions. Each video clip is composed with 120 continuous frames per second, and it is 1 frame per second.

The first 20 frames are used for producing the average image, and it shows the result of the measured water level during 100 seconds. Fig. 7 shows the examples of the various experimental conditions and its corresponding results.

Fig. 8 shows the experimental result of the continuous frames, Fig. 8(a) shows the result obtained when the ruler is stained, and Fig. 8(b) shows the result obtained when the strong reflection occurred. The "Real Level" refers to the manually measured water level, and the "Measured Level" refers to the detected water level by using the proposed method.

Total number of 100 water levels of the image is detected from a single image, and only the cases which are in error by less than 12 pixel and 4 cm are assumed as the accurate water level detection. Its accuracy is then calculated.

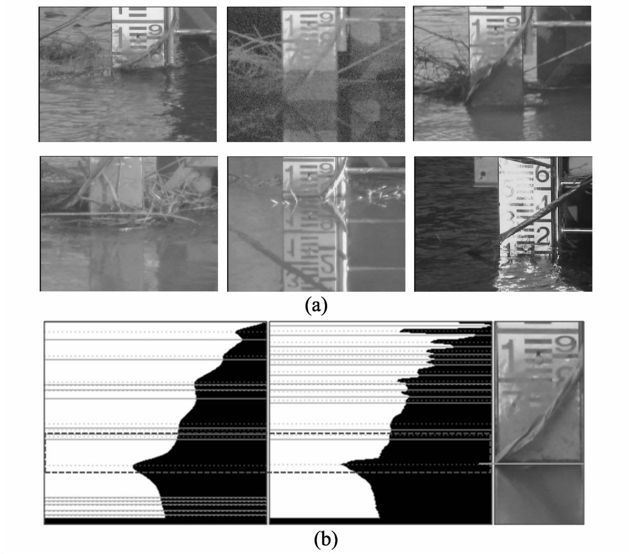


Fig.7 Results of water level detection: (a) is the example of various condition, (b) is the process steps

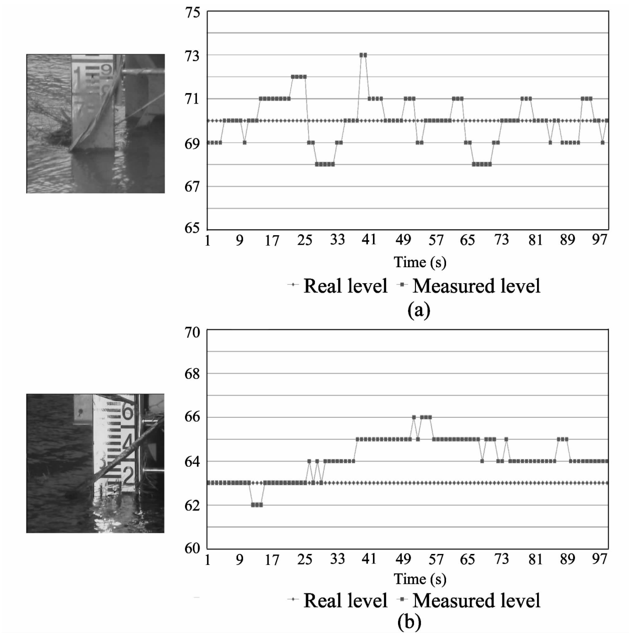


Fig.8 Graphs of continuous water level detection: (a) is the case where the ruler is stained, (b) is the case where the strong reflection exists

Tab.1 Detection accuracy

Condition	Detection accuracy		
	Average Success	Average Failure	Accuracy (%)
Stain	93	7	93
Reflection	90	10	90

The average error of whole images was 5 pixel, and the maximum error was 15 pixel.

5 Conclusions

In this paper, a reliable method of measuring the water level, with the condition where the ruler cannot measure the water level, is proposed. Even thought the most of the features inside the ruler are eliminated due to the reflection of the strong illumination and the stained ruler, the intensity difference between the surface of water and the ruler still exists. By using this feature, an accurate water level can be measured. The safety and the excellent performance of the proposed method are confirmed by referring to the experimental results, which used the image obtained from the camera set on the actual pier.

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