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The Water Level Detection Algorithm using the Accumulated Histogram with Band Pass Filter

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Abstract**—** In this paper, we propose the robust water level detection method based on the accumulated histogram under small changed image which is acquired from water level surveillance camera. In general surveillance system, this is detecting and recognizing invasion from searching area which is in big change on the sequential images. However, in case of a water level detection system, these general surveillance techniques are not suitable due to small change on the water surface. Therefore the algorithm introduces the accumulated histogram which is emphasizing change of water surface in sequential images. Accumulated histogram is based on the current image frame. The histogram is cumulating differences between previous images and current image. But, these differences are also appeared in the land region. The band pass filter is able to remove noises in the accumulated histogram. Finally, this algorithm clearly separates water and land regions. After these works, the algorithm converts from the water level value on the image space to the real water level on the real space using calibration table. The detected water level is sent to the host computer with current image. To evaluate the proposed algorithm, we use test images from various situations.

Keywords**—** accumulated histogram, water level detection, band pass filter.

I. Introduction

THE water resource is very important for our lives. There is no doubt how important water is in the human history. That is why many researchers concern how to control water resource. The damage caused by drought is slow in progress unlike damage from storm or flood and is hard to observe so that the social, ecological, and economical damage cannot be assessed systematically. Droughts have been a part of our environment since the beginning of recorded history. Along with droughts, floods have brought untold wealth and prosperity to civilizations, and yet at the same time, they have caused tremendous losses and resulted in untold suffering for millions of people. Today, about 700 million people live in countries experiencing water stress or scarcity. By 2035, it is projected that 3 billion people will be living in conditions of severe water stress. Many countries with limited water availability depend on shared water resources, increasing the risk of conflict over these scarce resources. Water resources management is the integrating concept for a number of water sub-sectors. Use of an integrated water resources perspective ensures that social, economic, environmental, and technical dimensions are taken into account in the management and development of surface waters such as rivers, lakes, and wetlands and groundwater [1~3].

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Many researchers concerned how to measure water level accurately, because measuring water level is basic requirement to manage water resources. The general methods to detect water level can be divided with three ways[3]. The first method is measuring a position of buoy in the pipe. These kinds of method are using displacement, transformation of water, and they are currently adopted in the industrial field, but they are depending on water pressure and these systems are short-lasting because many sensors in the system are changed regularly. The second method is based on an ultrasonic sensor. This method is to measure a reflectance time between the sensor and water surface[4]. However, this method is needed an expensive device and it is difficult to decide accurate value. Nevertheless, above two methods are widely used in the industry, because they are simple and stable to detect water level. They are even good methods, but these systems only serve water level date except image data. In this time, most system also requires image data for monitoring. For monitoring whole situation around the water region, they have to another system including camera, communication modules. In economical aspect, we have to build measurement station with high cost. Thus many researchers have focused on this problem using sequential image in the past decade. Therefore, the third method is using image information. In this method, the person who in the host station can see the water level directly, and this image are able to include whole information for an environment around the water surface[5,6]. When this system is used detecting water level, the system needs a huge storage space because image information is larger than the number of water level data. And, to transfer big image file through long distance, this system ensure reliable connection between a control center and a remote client.

The purpose of this paper is to provide a method to measure water level in the image space. To detect water level, the accumulated histogram is included. Water level in the image space is on the y-axis, so each difference between current image and previous images are projected on the y-axis. Changes of water surface are very small, but another difference in the land region is smaller than on the water surface. It means noises could be detected in the land region, so we adopt a filter to remove that noises. To detect the water region easily, the proposed algorithm uses the band pass filter. The algorithm can easily separate water and land regions using the filter. The result of this histogram is expressed as pulse histogram using a proper threshold. The proposed method in this paper is composed of two steps: 1) construction of accumulated histogram using difference between current and previous images; 2) water level detection by pulse histogram which is created using accumulated histogram. In this paper, we evaluate the proposed algorithm with various environments such as sunny, rainy, snowy days.

II. Water Level Detection

A. Algorithm Flow

The proposed algorithm is shown in Fig. 1. Sequential images are taken with a CCD camera are with 320×240[pixels], 30[frames/sec].

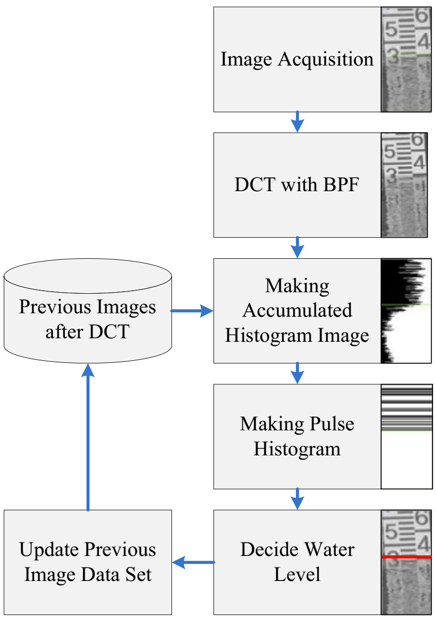


Fig. 1 Flow chart of the proposed algorithm

Acquired image is transferred by DCT(Discrete Cosine Transform) for adopting BPF(Band Pass Filter). In this step, specific region in the frequency domain is filtered by the band pass filter. High frequency components in the water and low frequency components in the land regions are reduced. Impulsive noises are often detected in the land region, and there are not useful low surface features in the water region. The accumulated histogram image is cumulating difference between the last image and previous images. In the next step, the algorithm separates land and water regions using pulse histogram. The pulse histogram is made by suitable threshold. The threshold is determined concerning maximum and minimum values in the histogram. The pulse histogram helps to decide accurate water level in the image space. To measure water level, shape features about each two regions is used. Finally, the algorithm translate water level in the image space to the real world space. The final value is sent to the host computer with current image frame.

B. Accumulated Histogram

It is difficult to notice the difference between the surface of water and the land region in a single still image. They often have same values in the color space. It is also difficult to find different features to distinguish each region in an image. There are not proper properties in an image, therefore the algorithm uses sequential images. To reduce noisy effect, this algorithm uses the band pass filter. The filter is adopted in the frequency domain. So, every images are translated from the time domain to the frequency domain using DCT in the (1).

$$I_{Freq}(u,v) = AuAv\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} I(i,j)\cos\frac{(2i+1)u\pi}{2N}\cos\frac{(2j+1)v\pi}{2N} \quad (1)$$

In this case, N is typically 8 and the DCT formula is applied to each row and column of the block. The DCT matrix becomes orthogonal if one further multiplies by an overall scale factor of $\sqrt{2/N}$. After DCT, this algorithm take BPF using (2).

$$I_{BPF}(u,v) = BPF\left(I_{Freq}(i,j)\right)_{Lower}^{Upper} \quad (2)$$

The upper and lower cut-off frequency points for the BPF can be found from normal data set. These point values are not fixed, because they are depending on situation. In this paper, they are determined using the variance of image after DCT. The lower frequency is under the 8% and the upper frequency is over the 140% of the variance. After this work, the result frequency image is translated to the real image using IDCT(Inverse DCT) in the (3).

$$I(i,j) = \sum_{u=0}^{N-1}\sum_{v=0}^{N-1} AuAvI_{Freq}(i,j)\cos\frac{(2i+1)u\pi}{2N}\cos\frac{(2j+1)v\pi}{2N} \quad (3)$$

The 2D basis functions can be generated by multiplying the horizontally oriented 1D basis functions with vertically oriented set of the same functions. This filtered image is compared with previous images. This result serves a distinguishable feature, the result images of this filter are shown in the Fig. 2.

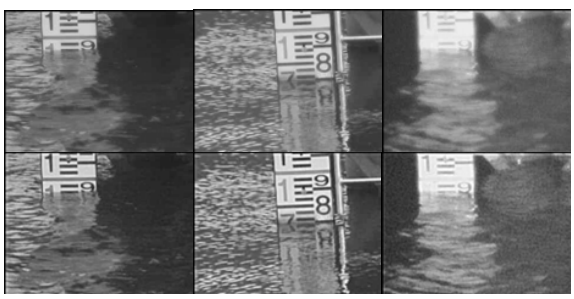


Fig. 2 Accumulated histogram images in the various environments

As we can see in the Fig 2, upper 3 images are original images and lower images are filtered images. An Each previous image is already processed using DCT and BPF. As we know, DCT is widely used in the compression field. This method can reduce storage space by the DCT. An accumulated histogram image is stored differences between the last image and previous images.

C. *Water Level Detection*

In the accumulated histogram, water and land regions are intuitively distinguished each other.

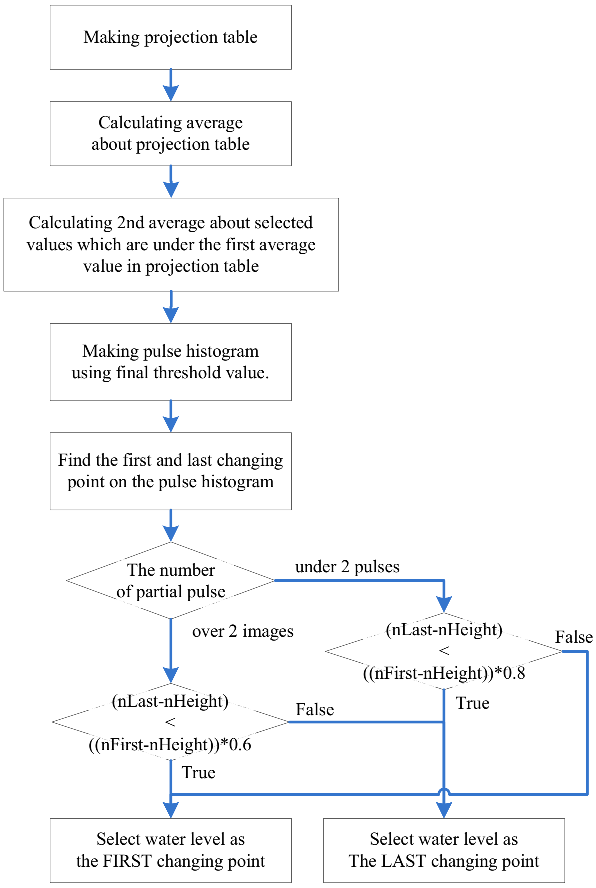
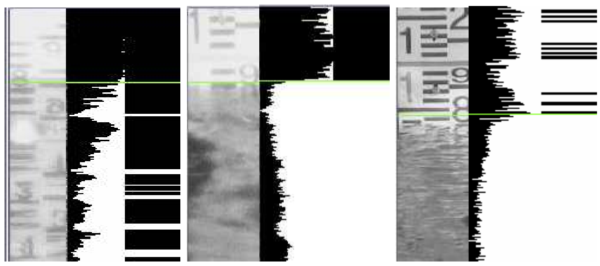


Fig. 3 Flow chart of the water level detection algorithm

In the Fig. 3, the algorithm to detect a water level is illustrated. As we mentioned above, every parameters are depending on situations. There are different threshold values in each weather environment such as rainy, snowy or sunny day. Therefore, the flow chart in the Fig.3 is dealt features what are different in the each weather environment. This method requires 2 assumptions. The first one is running water region with no-standing waves in lower part, the second one is land region with standing textures in upper part. According to these reasons, this algorithm can decides single feature to separate each region. In the first step, projection table is made from the accumulated histogram. The water level is on the y-axis, so the projection is also on the y-axis. The number of projection table is decided by the height of interest region. The average value for the projection table is calculated in the next step. This method that is decided threshold value as average value is widely used in the binary threshold method. So, this average value is useful to separate each region roughly. After this work, the algorithm makes 2nd average value using 1st average value from the previous step. As we assumed, there is a little variance in the land region, so 2nd average value is suitable to extract the land region from whole image space. The pulse histogram is made using the final threshold as the 2nd average value. In the pulse histogram, the shape of pulse is totally depending on situation. Some of the results are as shown in Fig. 4.



(a) calm (b) night (c) day

Fig. 4 Accumulated histograms and corresponding pulse histograms

In the Fig. 4.(a), there are few differences in the water region. This image is can acquired at early morning without wind. There are only detected few water flow. Fig. 4.(b) is captured at the mid-night. Many reflections in the water surface are detected, on the other side there are few disturbance in the land region. Fig. 4.(c) is the image about sunny day. In this case, many noisy pulses are detected in the land region. Through these results, we can separate pulse histogram into the 2 kinds of them. The feature to distinguish them is there are pulses in the land region or not, and there are pulses at intervals in the water region. In the next step in the flowchart in Fig 3, the algorithm counts pulses in the pulse histogram. The number of pulses is the feature to separate night case or not. In the night case, in Fig 4.(b), only single pulse is detected, so the algorithm can decide the end of the first pulse as the final water level. The method to distinguish case (a) and (c) in the Fig. 4 is that measuring the end of the first pulse from the bottom, and check the rest ports in the pulse histogram. If there are pulses, then the water level is the end of the first pulse in Fig 4.(c), otherwise the last detected pulse position is the water level in Fig 4.(a). The rest parts of the proposed flow chart in the Fig. 3 are about it. *nLast* in the Fig. 3 is the position of the last pulse, *nFirst* is the position of the first pulse, and *nHeight* is the height value about interest region. The height value is the base to determine water level. To briefly explain the flow, the pulse histogram is made from the accumulated histogram using suitable threshold value. And, the water level is decided from the pulse histogram. The pulse is always appeared in the water region, and the number of the pulse is the feature to separate between single pulse and multiple pulses, then the case of broken pulses in the water region and the other case are able to distinguish each other.

III. Experimental Results

In order to evaluate the proposed algorithm, we apply the algorithm to images about various environments. The system is divided as master and slave. The master computer is in the office, and the slave board is in the booth near the river. The master program as client is on the windows machine and the slave program as server is on the Linux system with TCP connection. The whole system is shown as Fig. 5.

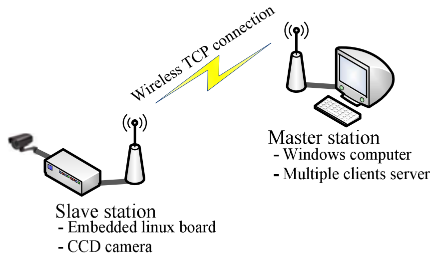
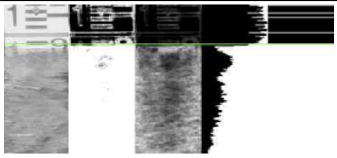
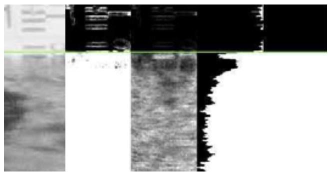
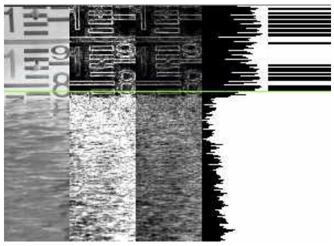
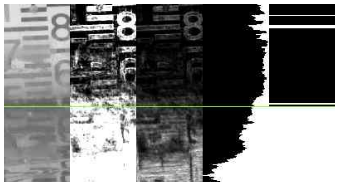


Fig. 5 The system block diagram

The test results are shown in the Table I. There are 5 images in each environment. The first one is the original image, and 2nd, 3rd images are accumulated images. The 2nd image is accumulated image using absolute difference, 3rd image is the normalized image from 2nd image. The absolute difference in the pixel domain is shown as white color, otherwise black color is used. The normalized image is expressed in the pixel intensity, so the range of them is from 0 to 255. The 4th image is projected image into the y-axis using the accumulated image. This projection is also normalized using local maximum value in the projected values. The final image is the pulse histogram image. The pulse histogram image is made by the proposed algorithm. As we can see, the pulse histogram is depending on situation. In the sunny case, the pulse histogram is intuitively made from the accumulated histogram. There are even appeared some noises in the land region, they are not affect to decide the accurate water level. In the night case, there are few projected values in the land region. As we can see the pulse histogram, there is existing single pulse. In the 3rd row, the reflected image is extracted. As we know, the water surface is acting like a mirror, so sun light is reflected in the water surface. They made a lot of noises in the land region. The reflectance even affect to the land region, they also affect to the water region, so there are more differences in the water region than in the land region. This problem is appeared in the 4th snowy environment. However, the snowy noises are reduced by DCT with BPF, so the pulse histogram is simpler than reflected case. The most serious problem is appeared in the calm case. In this case, the water surface looks like a real mirror, so difference between last image and previous images is very small. To solve this problem, the system changes the number of accumulated images, and emphasizes difference between them using weight value. Finally, the proposed algorithm is evaluated in every environment, and it acts well.

TABLE I
Units for Magnetic Properties

Environment	Result images	Water level
Sunny		880
Night		880
Reflected		780
Snowy		520
Calm		680

The accumulated histogram is acting as noise removal filter. Because, the current water level is decided using previous image set. The number of accumulated images is more big, then output value is slowly changed. It doesn't even work well in the real-time system, but the changing rate of the water level is very low. This is why the water level from the proposed method is stable. Finally, we can get stable and robust water level measurement from the proposed algorithm.

IV. Conclusion

This paper is dealt with robust water level detection algorithm using the band pass filter with visual information. When measuring water level using arbitrary sensor system, the system is even acting well, but it needs another system for monitoring. Using this method, this problem is solved. Moreover, this method is serving stable result based on the accumulated histogram. It should be useful tool to measure flood environment. The system with the proposed algorithm is acting well over the six months with 24 hours.

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