IMPLEMENTATION OF IMAGE-BASED WATER LEVEL MEASUREMENT SYSTEM

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Abstract – In recent years, it is important to measure the level of water due to frequent floods and localized heavy rains. However, the recent observations of water level depend on manpower.Therefore, we developed a system that automatically observes the river level to prevent disasters and reduce costs. In this paper, we describe a method of measuring the water level by recognizing the ruler that appears at different size and at arbitrary positions in the image. That is, only the region with ruler is extracted through the image processing step and scalenumberson the ruler are recognized by ANN(Artificial Neural Network) classifier. The resultsshowed the superiority of the proposed method by comparing the integral channel feature with other one.

Index Terms - Water level measurement, Integral channel features, Adaboost

I. INTRODUCTION

It is becoming important to measure the water level due to frequent floods and localized heavy rains in recent years. However, the water level observation of the river has depends on the monitoring by manpower. By automating a series of processes to measure the water level, it is easy to prevent disasters such as river flooding, and the cost due to manpower can be also reduced if the water level change is automatically recorded. In addition, it is necessary to develop a system that automatically observes the river level in accordance with the recent trend of increasing importance of data collection.

In this paper[1], we find the ruler at arbitrary position in the water level image using Haar-like feature, and then find the boundary of the water surface using the integral channel feature [3].Finally, thewater level is measured by separating the ruler and recognizing the number.

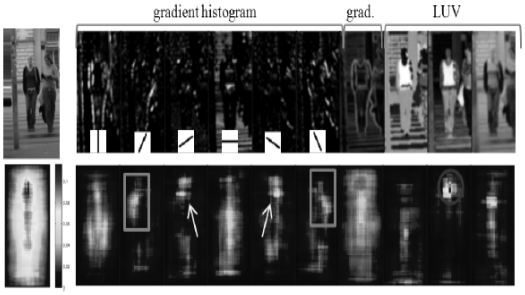


Figure 1. Visualization of integral channel features

In Section 2, we describe the features and classifiers used in water level measurement system and explain how to roughly specify the position of the ruler using it. In the last Section 3, we will show the result of comparison with the proposed method and other methods.

II. PROPOSED METHOD

A. Integral channel feature extraction

Integral channel features are used to specify the boundary of the water surface.In the case of HOG [1] or Haar-like features, a single channel is used, whereas the integral channel feature uses a variety of channels such as R, G, B, Gray, Edge, Gradient magnitude and gradient histogram.

In this paper, we use 10 channels of L, U, V, Gradient magnitude and a gradient histogram with 6 bin. The sum of arbitrary pixel values is obtained from ten channels andused as a feature value. Finally, the feature vectors are learned by the Adaboost.

B. Adaboost classifier

In this paper, the feature is learned by Adaboost [2] and to determine the water level and the position of the ruler. The Adaboost algorithm generates a strong classifier that combines several weak classifiers with higher performance.The weak classifierreduces the weights of correctly classified samples, and increases the weights of misclassified samples. The strong classifier consists of a combination of several weak classifier as follows.

The weak classifier used to generate classifier is represented by the following (1).

$$h_j(x) = \begin{cases} 1 & p_j f_j(x) < p_j \theta_j \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

In(1), $f_j(x)$is a function representingjth feature value of the training sample$x$. $\theta_j$is a jth threshold and $p_j$is a parity that determines the sign.The weak classifier in (1) represents the classification result as 1 or 0.

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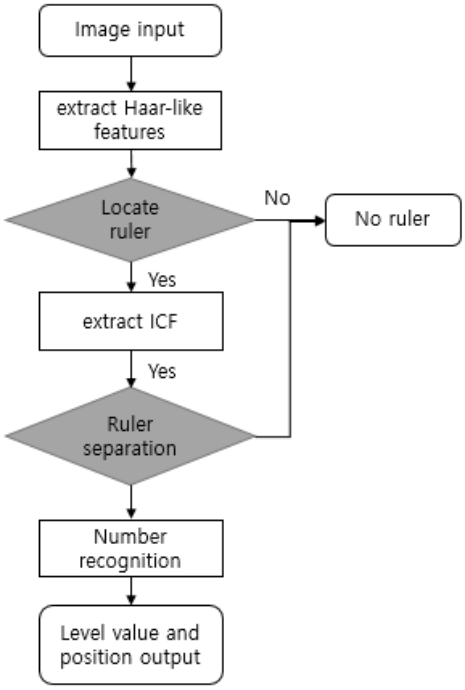


Figure 2. Flowchart of the proposed method



Figure 3. Approximate location of the ruler

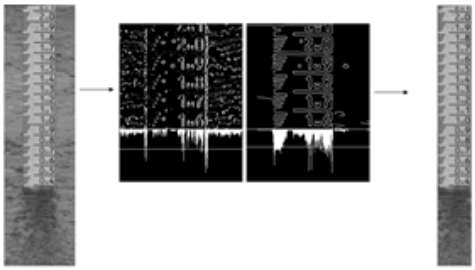


Fig.4. Detecting the ruler region using x-coordinate projection histograms

C. Level measurement system using optimal multi-classifier

The flowchart of the proposed method in the paper is shown in Fig 2. When the input image arrives, the approximate position of the ruler in the image is determined by using anAdaboost classifier that has learned the Haar-like feature of the ruler. This area is set as the region of interest. The x-coordinate projection histogram in the region of interestis used to leave only the part of the ruler that removed the background. The boundary between the water surface and the ruler is found by the classifier that has previously learned boundaries between the water surface and the ruler. In the separated ruler, only numerical regions are extracted through the segmentation algorithmand transferred to the ANN (Artificial Neural Network)'sinputin order to recognize the numerical value in the ruler [4].

C-1) Haar-like feature based ruler region detection

Step 1. To extract the Haar-like feature, a certain area of the image is scanned using the sliding window method, and the extracted feature is transferred totheAdaboost classifier to distinguish whether or not the corresponding window is a ruler area.

Step 2. The approximate position of the ruler is set as the region of interest. This region of interest is used to rotate the image, which is needed for cases where the ruler is not standing perpendicular to the water surface. First, Canny edge detector is applied to the region of interest[5]. Then, a straight line is detected by applying Hough transform to the image that edge lines are extracted [8]. The most voting straight line is selected to find the angle to be rotated, and the image can be rotated as follows:

$$\tan\theta = \frac{dy}{dx}$$
$$\theta = \tan^{-1}\frac{dy}{dx} x \frac{180}{\pi} \quad (2)$$
$$\theta' = \frac{\pi}{2} - \theta$$

where the angleθcan be calculated by selecting two pixel positions on the selected straight line. Here, dy is the difference between the y coordinates of the two pixels, dx is the difference between the xcoordinates of the two pixels, and θ' is the angle at which to be rotated.

Step 3.After generating x-coordinate projection histograms of the binary image and Canny edge image in the region of interest,the ruler region is found in detail by sequentially applying the threshold values as showed in Fig. 4.

The first binary image is generated by applying an adaptive threshold[6]. And then, the image is applied to the erosion operation using a horizontal mask[9]. Thesecond binary image with only the vertical edge component is obtained by subtracting the first binary image from eroded image. A y-coordinate projection histogram of the imageis generated. Finally, the region that exceeds the threshold value in the y-coordinate projection histogram is defined as the ruler region.

C-2) Adaboost classifier based water level detection

When the area of a specific ruler is given through c-1 process, a boundary between the ruler and the water surface is searched using anAdaboost classifier that has been learned beforehand. At this time, the ICF(Integral Channel Feature)extracted through the sliding window method is transferred to the classifier input. The boundaries between the ruler and the water surface are used as the learning data, unlike the case of the previous rough position of the ruler. And the learning data should include ones from the contaminated ruler. Then, the number area for digit recognition is extracted.

Then, only the ruler part is set as the region of interest

from the boundary position founded through the classifier. And like Fig 5 (a), the binary image of the ruler image is obtained using an adaptive threshold algorithm. To extract the scale from the binary image as shown in Fig 5 (b), the erosion operation with the horizontal direction mask is applied.

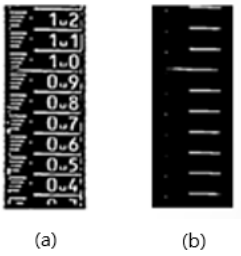


Figure 5. (a) Binary image applied daptive threshold (b) Scale extraction image by erosion

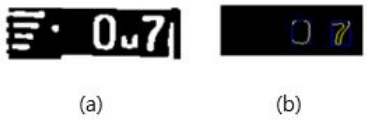


Fig. 6. Numerical Candidate region and segmentation

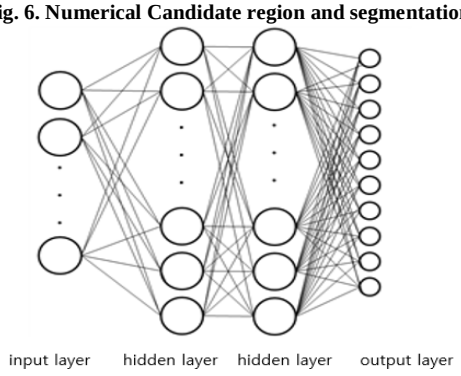


Fig. 7. Structure of artificial neural network

As shown in Fig. 6, the numerical candidate region can be selected near the position of the extracted scale, and only the numerical region is extracted by a segmentation algorithm.The extracted numerical area is recognized through the ANN(Artificial Neural Network) [4].When the number is recognized by the ANN classifier, the final water level value can be measured.Our artificial neural network for numerical recognition consists of an input layer, a hidden layer, and an output layeras shown in Fig 7.First, 1064 one-dimensional array of numeric images normalized to 28x38 sizesis transferred to the input layer.The hidden layer consists of two layers, each layer consisting of 100 neurons.Finally, the output layer is composed of 10 neurons, and the result between 0 and 9 calculated through two hidden layers in each neuron is shown as a probability.

III. EXPERIMENTAL RESULTS AND ANALYSIS

A. Experiments

The experimental environment is as follows. The images are given sequentially, and the ruler in the image appears at a different size in any position. At this time, the size of the ruler does not change greatly. Also, the experiment is conducted in an environment where only one ruler perimage is displayed.

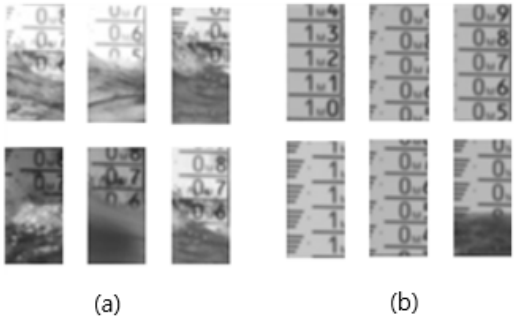


Fig.8. Example of database for water level detection

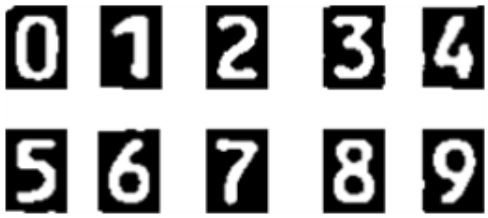


Fig. 9. Example of database for numeric recognition

The training data was then generated from the accumulated data over two years. To find the approximate position of the ruler, we trained the classifier using 1452 ruler images and 4072 background images. And the Adaboost classifier used to find the boundary between the ruler and the water surface used 1560 boundary images and 4563 background images. Also, learning of the artificial neural network for numerical recognition was done by using 300 number images as shown in Fig 9.

The parameter values used in the experiments were found experimentally different from the previous experiments. First, the number of dimensions of the integral channel feature is 1000, and the number of weak classifiers used in Adaboost learning is about 800. Although the number of weak classifiers exceeds 800, performance has not improved much.

Performance evaluation of the proposed method was performed in the environment of Intel i7-2600 CPU @ 3.40GHz, 16GB DDR3 RAM, and HOG and Harr-like features were used as parameters commonly used. The experiment was performed on a 1920x1080 image.

We performed the processing time and performance experiment to compare the integral channel feature and the conventional one.The recognition criterion was based on the comparison of the water level with the ground truth. The processing speed was calculated by calculating the processing speed of all the verification images and averaging.

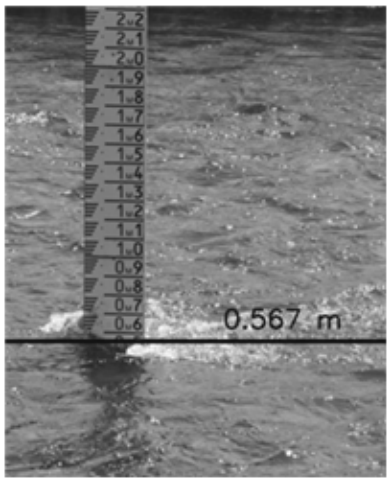


Fig.10. Result image of Measurement

Table 1. Performance comparison

	Haar-like	HOG	Proposed method
Test image	1772		
True Positive	1647	1719	1751
False Positive	125	53	21
Accuracy	92.9%	97.0%	98.8%

Table 2. Processing time comparison

	Haar-like	HOG	Proposed method
Test image	1772		
Average detection time	0.041ms	0.072ms	0.108ms

Table 3. Ruler split success rate

	Sobel	Canny	Adaptive threshold	Proposed method
Test image	1772			
Failure	121	56	85	2
Success	1651	1716	1687	1770

B. Analysis

In Table 1 and Table 2, the result of the Haar-like feature shows the fastest processing speed but the low recognition rate, and the integral channel feature showed the slowest but the best recognition rate. The HOG feature showed a medium performance between recognition rate and processing speed. Based on the results, it is found that the best method is to use the integral channel features with high recognition rate although there is no significant difference in speed.

Table 3 shows the success rate for each image when creating the histogram image and extracting the ruler by applying the threshold value. Sobel [7] has the worst performance in extracting the most of rulers. Canny and binary images show slightly better performance, but each performance is still insufficient to apply. The proposed method shows that the success rate of the ruler is the highest.

CONCLUSION

In this paper, we have studied the development of a system that can automatically detect the water level of a river without manpower monitoring, prevent the disasters such as abnormal weather and flood which are frequently occurring recently, and automatically detect the water level with low cost and high efficiency. The system used Integral Channel Feature that outperforms traditional HOG and Harr-like features.

Experimental results showed that the position of the ruler and the water level of the river can be detected with high recognition rate through the integration channel feature and the Adaboost classifier, and the river level can be measured through the ANN classifier automatically.

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