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Water Level Detection for River Surveillance utilizing JP2K Wavelet Transform

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***Abstract*—This report discusses how to detect water level of a river from video signal for the purpose of environmental surveillance. Video signal is assumed to be taken 24 hours a day with a web camera installed to the river side. A DSP inside the video sensor is supposed to send the water level data regularly and video signal irregularly on demand. It is our purpose to utilize JPEG 2000 (JP2K) core technology for not only "compression" of video data but also "recognition" of river's water level so that redundancy of signal processing of the video sensor can be reduced.**

I. INTRODUCTIONOBSERVED WITH THE "TELEMETER" INSTALLED BY THE GOVERNMENT.

So far, in Japan for example, water level of a river is The facility employs a water level detector with a probe in the water. However the number of the telemeter is limited to only a few at principal rivers administered by the government since it costs high and its installation is strictly controlled [1,2]. On the other hand a large number of web cameras connected via internet have been installed to various size of rivers for surveillance. They can transmit video data of the river with high communication bit rate, however, can not detect water level of the river which is needed to be monitored regularly at low bit rate.

A water level detection algorithm from video signal has been proposed by Takagi [3-5]. It employs a measuring board with inclined lines. However, it is strictly controlled and difficult to be permitted to install an object such as the board in the water. It is our purpose to detect the water level from video signal without setting anything in the water. We have already proposed a generation method of panorama image of a river focusing on observation of water region [6]. The method is based on Gabor filter bank and maximum likelihood (ML) estimation developed for texture classifications [7,8].

In this paper, we utilize the 9/7 wavelet transform in the JPEG 2000 (JP2K) "compression" algorithm [9], instead of the Gabor filter bank, for "recognition" of water region to detect water level. We also introduce frame addition technique to separate water region and land region in the feature vector space. As a result, it becomes possible to reduce total signal processing complexity sharing the wavelet transform between "compression" and "recognition". It contributes to developing a low power video sensor which sends the water level data regularly and video signal irregularly on demand.

II. WATER LEVEL DETECTION ALGORITHM

A. Detection of Water Level

Video signal is assumed to contain "land" region in upper part and "water" region in lower part as illustrated in figure 1 (a). Teacher region of the "land" and the "water" are extracted from a previous frame and they are used to determine which class a pixel in a current frame belongs to. Figure 1 (d) indicates a result where "water" pixel is black and "land" pixel is white. Based on this result, the water level is detected as a boundary of these two regions.

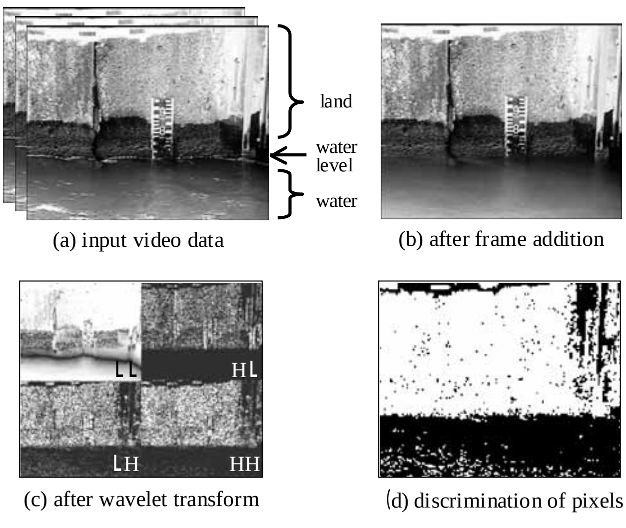


Figure 1 Each pixel is classified into water or land with wavelet transform in JP2K and ML estimation. Boundary of the two regions is detected as the water level.

B. Recognition of Water Region

The proposed method classifies each pixel into one of the two classes, "land" ($k=0$) or "water" ($k=1$), using four band signals obtained with the JP2K wavelet transform [9]. These band signals, HL (horizontally High passed and vertically Low passed signal), LH, LL, HH illustrated in figure 1 (c), are intermediate outputs of "compression" process. We utilize them as the feature vectors for "recognition" of the water region so that "compression" and "recognition" can share same processing to reduce total hardware complexity and electric power supplied to the video sensor.

Assuming that the feature vector $\mathbf{G}(m,n)$ of a pixel at location (m,n) has a Gaussian probability density function

$$P\left(\mathbf{G}(m,n)\middle|T_k\right)=\frac{1}{2\pi\sqrt{|\mathbf{C}_k|}}\cdot exp\left(\frac{-d_k^2(m,n)}{2}\right), \quad (1)$$

the class T_k , ($k=0$ or 1) of each pixel is determined according to the Mahalanobis distance

$$d_k^2(m,n)=\left[\mathbf{G}(m,n)-\mu_k\right]^T \mathbf{C}_k^{-1}\left[\mathbf{G}(m,n)-\mu_k\right] \quad (2)$$

where μ_k and $\mathbf{C}_k$ denote average vector and covariance matrix respectively [6].

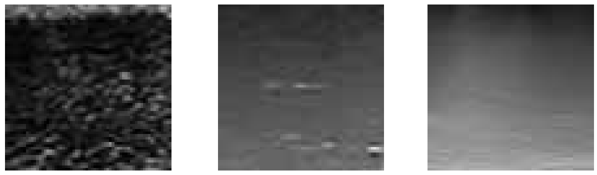
C. Applying Frame Addition for Discrimination

We propose adding some frames before the classification (discrimination) described above to increase recognition precision. It is equivalent to introducing a temporal low pass filtering on video signal. Figure 1 (b) indicates an example of adding 60 frames. Under the assumption that texture in the land region does not move and texture in the water region moves as water is running, this frame addition makes distance between the two regions farther in the feature vector space. This can be confirmed with figure 2. If the water is clear and is not running, it is difficult to discriminate water and land. On the other hand, when the water is running after heavy rain for example, in this case monitoring the water level is critical to preventing disaster, this temporal low pass filtering makes distance farther resulting in robust discrimination.

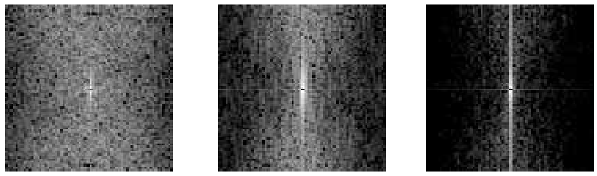
III. EXPERIMENTAL RESULTS

A. Video Signals to be Tested

Video signals under various conditions were tested in our experiment. All of them has 320 x 240 pixels and 30 frames per second and taken with SONY *handycam* on a tripod in Nagaoka, Niigata, Japan. Each of the first frame of the video are listed in figure 3.

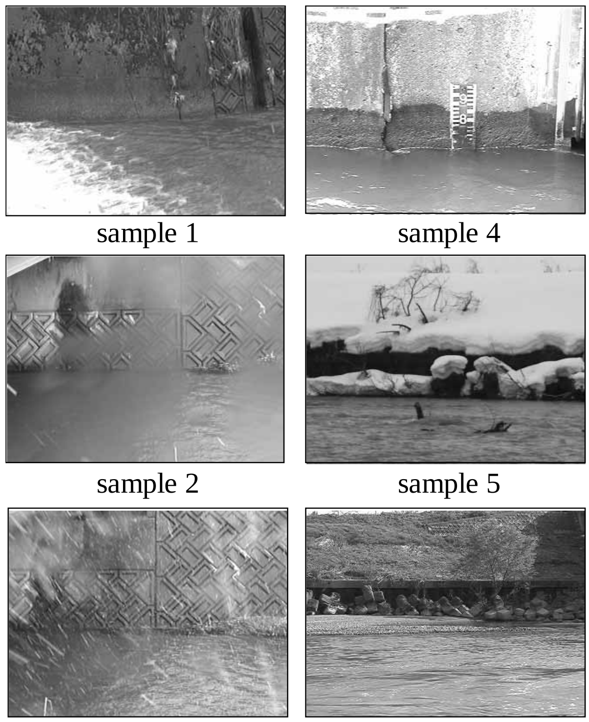


(a) Teacher image for "land". (b) Teacher image for "water" **without** frame addition. (c) Teacher image for "water" **with** frame addition.



(d) spectrum of (a). (e) spectrum of (b). (f) spectrum of (c).

Figure 2 Teacher images and their spectrums. The frame addition procedure reduces signal components in high frequency in the running "water" region.



sample 1 sample 4

sample 2 sample 5

sample 3 sample 6

Figure 3 Video signals tested in the experiment.

B. Optimum Band Signal as Feature Vector

In this report, performance of the detection is evaluated by "detection error" of water level in pixel and "recognition rate" in percent. If all the pixel is truly classified into one of water or land, the rate is calculated to be 100 %. The "true" recognition result to be used for this evaluation is given by hand and therefore it contains a little turbulence.

Figure 4 indicates the "recognition rate" for the case when only one of four band signals is used as a feature vector. It indicates that the HL (horizontally High passed and vertically Low passed) band signal is the best for the discrimination. HH is nearly same. LH is a bit worse. LL is the worst and it is not suitable for the discrimination. This is because there is no significant difference in LL band between water and land. If the land region contains vertical (or horizontal) stripe, HL (or LH) band tells the difference well under the assumption that spectrum of the running water region is concentrated in LL band.

Figure 5 indicates the best combination of the band signals, namely the best dimension of the feature vector. In case of one dimension, HL is the best as in figure 4. For two dimensional case, adding the HH second in figure 4, the recognition rate is increased. Further addition of the third HH makes the dimension three and the recognition rate higher. However, it indicates that including the LL is not a wise choice. It is possible to increase the dimension more than four by means of multi-stage decomposition of the wavelet transform. However, the increase is not always better and also it costs decrease of spatial resolution.

Figure 6 shows the water level detection error versus the recognition error rate. It indicates that the recognition error rate should be maintained under 30 % to keep the detection error within plus or minus 5 pixels. In other words, it indicates that tolerable recognition rate is 70 % at minimum.

C. Effectiveness of The Frame Addition

Effectiveness of the frame addition or temporal low pass filtering on video signal introduced in the proposed method in combination of the wavelet transform and ML estimation is evaluated in figure 7 and 8.

Figure 7 indicates the number of frames for the addition versus the recognition rate. It is confirmed that the addition increases the recognition rate. It saturates at 20 to 30 frames.

Figure 8 illustrates the number of frames for the addition versus the water level detection error. It saturates at 15 frames since the detection is more robust than the recognition.

The frame addition suppresses a moving signal in video resulting in reduction of high frequency component of the region which contains moving signals. It is not a suitable case when grasses are swaying in the wind, and therefore the video should be taken so that the land region contains solid objects with fine texture full of high frequency components.

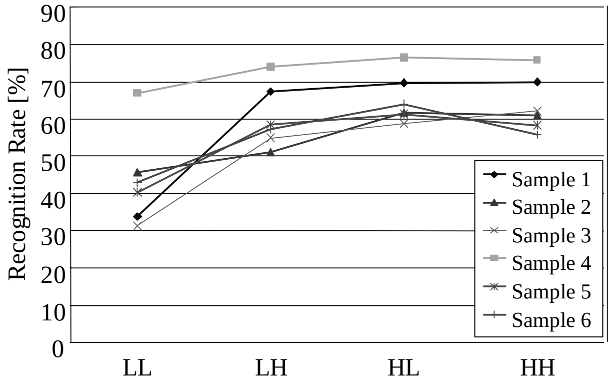


Figure 4 An optimum band signal for recognition.

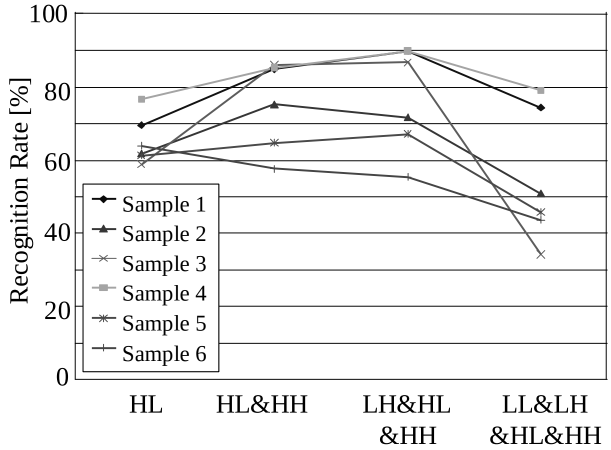


Figure 5 The best combination of the band signals.

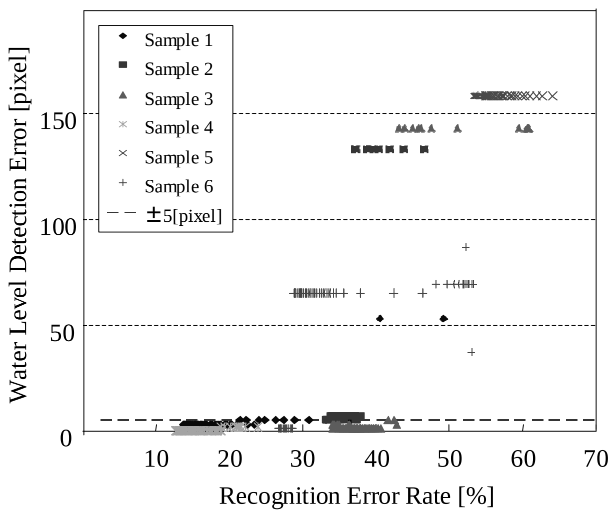


Figure 6 Detection error versus recognition error rate.

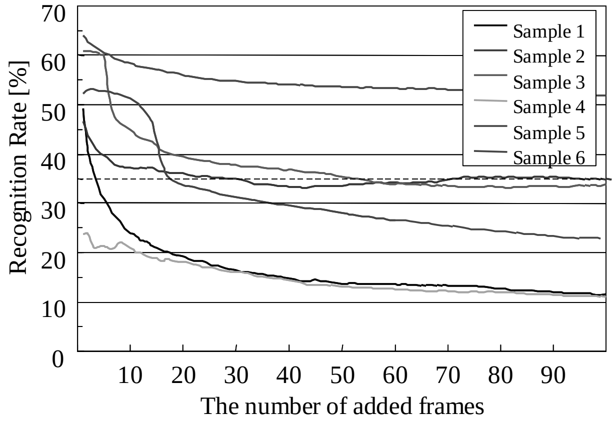


Figure 7 The number of frames for the addition versus recognition rate [%].

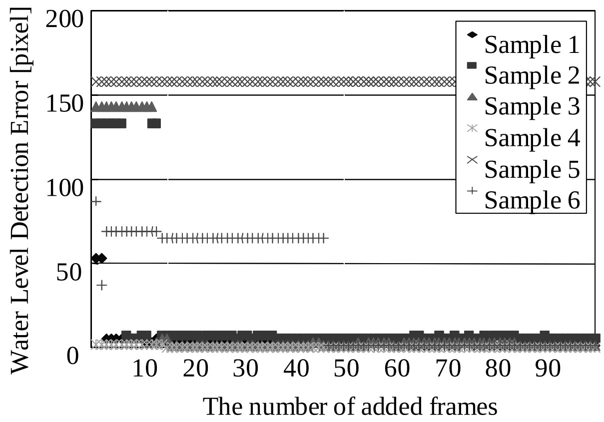


Figure 8 The number of frames for the addition versus water level detection error [pixel].

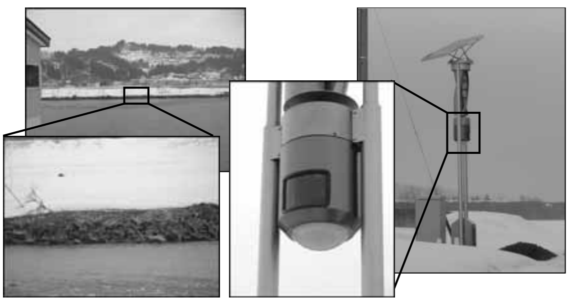


Figure 9 A video sensor installed in Niigata for 24 hours-a-day monitoring of the river and its video signal output.

IV. CONCLUSIONS

Water level detection algorithm for river surveillance was proposed in this paper. The algorithm is based on the 9/7 wavelet transform (WT) in the JPEG 2000 (JP2K) and maximum likelihood (ML) estimation. A frame addition technique (or temporal low pass filtering on video signal) is also introduced to separate running "water" region and "land" region in the feature vector space. It was found that the best combination as the feature vector is {LH, HL, HH} and tolerable recognition error rate is 30 [%] to keep water level detection error at low level.

It can be expected to reduce total signal processing complexity sharing the wavelet transform between "compression" and "recognition". It contributes to developing a low power video sensor which sends the water level data regularly and video signal irregularly on demand.

It is our next work to monitor a river 24 hours-a-day with the video sensor illustrated in figure 9 and compare our method and a water level detector with a probe in the water.

ACKNOWLEDGMENT

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