Development of a Float Type Optical Water Level Measurement by Image Processing Technique: Comparison of Water Surface Estimation Methods

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Experimental Setup
The float type optical water level tool consists of a digital camera, a float, a staff gauge and an image processing software. A digital camera is attached to a float and set perpendicular to the staff gauge as shown in figure 2. The float moves up and down freely by water tidal in vertical directions along the staff gauge. The staff gauge is set in a water tank. Water pumps are used to simulate the tidal wave by circulating water in and out of the tank.

Image Processing Technique
Image processing is a technique to acquire information from the image. The technique is done by changing properties of the image such as color, brightness and contrast in order to obtain the desired properties, then convert the right image into data. The image processing of digital image is a popular system. This project chose the image processing because of its advantages such as reliability, highly adjustable and easy to use. It also has been proved by many useful real-life applications. Techniques used in a digital image processing can be grouped into five major categories

1. image enhancement
2. image restoration
3. image analysis
4. image compression
5. image synthesis

Image information improvement
The entire processing diagram of the optical water level measurement is shown in figure 3. The first process of water level image adjustment is image enhancement. A water level image is converted into gray-scale to improve the detail information in the image. The image at this step should include the necessary information and do not need further processing. Otherwise, others image processing techniques are needed. Noise and unwanted objects are eliminated by transform the gray-scale image into black and white (binary image). The information details of binary image are adjusted by threshold adjustment.

\[
g(x, y) = \begin{cases} 1 & f(x, y) > T \\ 0 & f(x, y) \leq T \end{cases}
\]  

(1)

where:

Input water level image from a digital camera

Color and brightness adjustment

Find the water level line

Crop the staff and water level area

Find the coordinate of numbers by the highest cross-correlation value

Calculate the distance from water line to the number

Convert from coordinates to length in centimeter

Record water level data

Figure 3. An optical water level image analysis processes

The popular method to convert image from a gray scale image into a black and white image (binary image) is intensity threshold adjustment. This method delivers good information of binary image and also adjustable content features. This adjustment based on the relationship of the degree of histogram from 0 to 255 levels of gray scale as shown in equation 1.
g(x,y) = bi-color image convert from gray scale image
f(x,y) = brightness of the image (x,y)
T = threshold

Pattern Matching by Cross-Correlation
The next process is reading the number on the water level image. A series of number image were taken as a sample images or templates as shown in figure 4. They are kept as database templates to identify values on a water level image.

![Figure 4. A template image of number 90](image)

The numbers on the staff gauge are read by comparing the templates to the water level image by cross-correlation calculation. The Cross-Correlation equation is shown in equation 2.

\[
r = \frac{N \sum XY - (\sum X)(\sum Y)}{\sqrt{N \sum X^2 - (\sum X)^2} \sqrt{N \sum Y^2 - (\sum Y)^2}}
\]

where:
- \( r \) = cross-correlation
- \( X \) = horizontal coordinate
- \( Y \) = vertical coordinate
- \( N \) = number of data

The Cross-Correlation calculation is used in process of comparing between templates to water level image. In this process, series of number images in a database are compared to an input water level image one at a time. The matched template shows an outstanding result of cross-correlation value. The other areas of the staff image show very low cross-correlation value. After the template is matched to the staff image, a value and coordinate of matched number are recorded for further steps.

The vertical scale in the picture is in a linear scale only when the camera face positioned perpendicular to the staff gauge plane. A perspective correction equation may be applied to correct the image scale.

**Methodology**

Water surface line estimation methods
There are two methods used to estimate the water surface line in the picture. The first method, constant line, assumes a constant vertical coordinate of the water surface. This method will not process the water surface line. The water level value in this method is calculated from the distance between a fixed vertical coordinate of water surface line to the coordinate of number. The values of water level by this method seem unresponsive to water wave or turbulent on the water surface as shown in figure 5.

The second method, shape line, used the difference in contrast value between staff gauge and water surface acquire the water surface line at the staff. A series of image analysis techniques were used to detect and draw the water surface line on the staff image. Normally, turbulent on the water surface line happens in a fraction of second. Most water level sensors don’t respond quickly enough to flash water waves. On the other hand, the digital camera captures image in split second. The image of flash water wave is shown in figure 5. This flash water wave image contains irregular water surface line. This results in incorrect water level value.

In this method, an average value of water surface coordinate is calculated. The water level value is determined from the distant between the coordinate of average water surface line and coordinate of marked number. An image comparison of constant line and shape line methods is shown in figure 6 and 7.
Results and Discussions

The water level readings from the laboratory experiments were compared to the actual reading by visual inspection as shown in figure 9 and 10. Both laboratory data sets show a little fluctuate in the water level reading. This is caused by tidal wave in the water tank. The shape line method shows most result agrees to the actual reading. Statistical analysis shows the error percentage of constant line and shape line methods were -0.464 and 0.005 percent consequently.
Figure 12. Percent error of water level reading (shape line method)

Table 1 Statistic Comparison of line estimation methods

<table>
<thead>
<tr>
<th>Water surface line detection method</th>
<th>R²</th>
<th>RMSE</th>
<th>Average percent of error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant line method</td>
<td>0.9994</td>
<td>0.955</td>
<td>-0.464</td>
</tr>
<tr>
<td>Shape line method</td>
<td>0.9994</td>
<td>0.219</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Conclusion
Finally, this technique uses a digital camera to read the water level from the staff gauge. The water level value can be checked again by the water level photos. Unlike most water level measuring tools in the market, this tool doesn’t need calibration of the actual water level. However, this experiment of the water level reading is a prototype in the laboratory. This tool still needs a lot of improvement before proceed in the field experiment. The tool is designed on the basis of a float moving up and down on the water surface by a roller in the track. The roller movement can be jammed by many unexpected reasons. The float may not move smoothly after a period of time in water. A digital camera needs to have better quality materials to withstand outdoor environments.

References


