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

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**Abstract** This paper shows performance of a float type water level measuring tool by image processing technique. Instead of using a water-level sensor, a water level image at a staff gauge was used to estimate the depth of water. A digital camera is set on the float perpendicular to the staff gauge. A series of water level images were taken while camera moves along the water level. Newly developed image processing software called KUGaugeCam is used to determine the water levels. A process of image analyses consists of number reading and water surface level estimation processes from the acquired images.
An experiment study was carried out in a hydraulic laboratory for performance testing and data validation. The environment controls such as low light situation, water wave, and water level adjustment were applied to test ability of the optical water level tool. A pattern matching and cross- correlation techniques were used to obtain the number of the water level. The water surface line was obtained by two different methods, constant line and shape line. The constant line method applies a constant value of water surface. The shape line method applies the contrast differences between the water surface and staff gauge.
The result of the constant line and shape line methods compare to the actual reading in locations shows average error percentage of -0.464 and 0.005 percent consequently. Comparisons of two methods in the data analysis show a small accuracy improvement of the shape line method over the constant line method. This water level equipment helps reduce needs of water level calibration and improve accuracy of water level measurement.

**Keywords** Float, Water Level Measurement, Image Processing, Digital Camera,

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## Introduction

Automatic water level measuring tools have been developing for a long time. It provides a number of advantages such as reliability, reduced man labor, continuously update data, weather resistance. Most recent models offer features such as wireless data communication, long-period back up power and solar cell. Water level data can be sent from many locations to a server via wireless network communications for data collection and analysis. A new system, multi-sensor equipment, used in order to improve performance and reduce time consumption.
There are various types of water level measuring tools in the market. Some of them are very expensive and packed with multiple sensors such as temperature, depth, and velocity sensors. Many high-tech sensors apply non-contact solutions such as ultrasonic wave and laser depth probes, to achieve better durability in field measurement.
An optical solution is a good method for water level measurement. It delivers high accuracy and less complexity of hardware. The float type optical water level tool was first developed in 2009.
The water level is obtained by analyzing an image of the staff gauge and a water surface line as shown in figure 1. The water surface estimation methods, constant line and shape line methods, were used in the experiment. The comparison result of two estimation methods shows advantages and disadvantages in different situations.


**Figure 1. An image of the water level and the staff**

## 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.

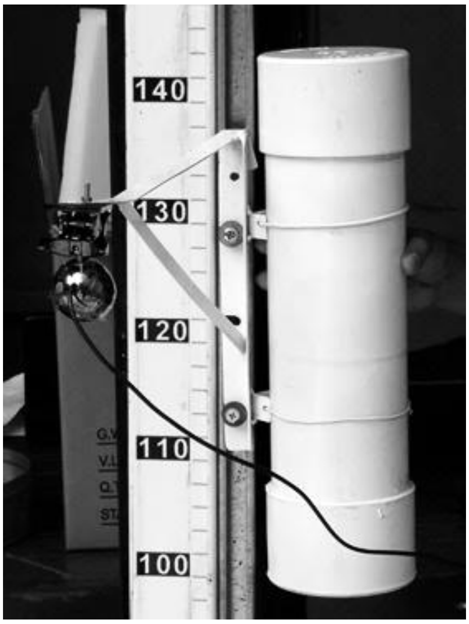


**Figure 2. A float type optical water level tool**

## 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 in 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.

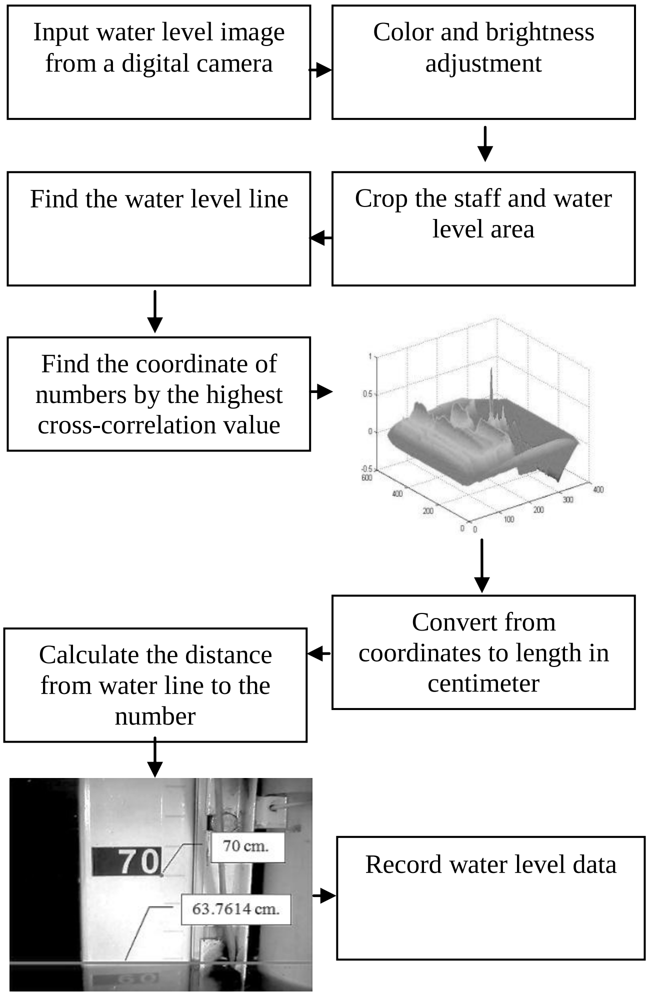


**Figure 3. An optical water level image analysis processes**

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.

$$g(x,y) = \frac{1(x,y) > T}{0(x,y) \le T} \qquad (1)$$

where:

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**

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.

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

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.

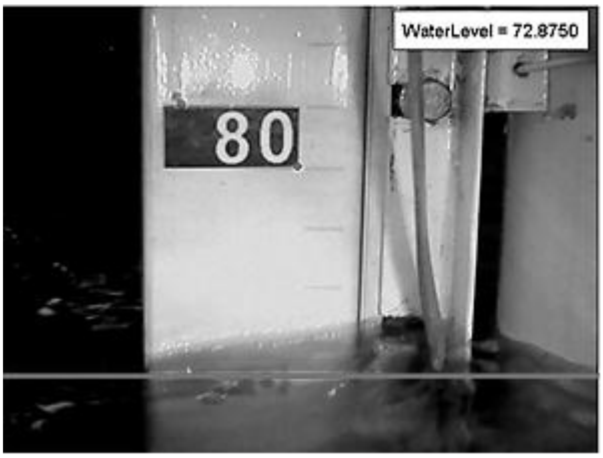


**Figure 5. Image of water level with water wave**

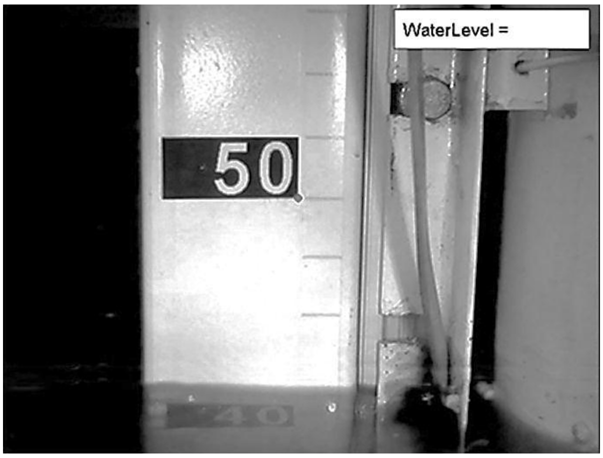


**Figure 6. Image of water level with marked number**


**Figure 7. Water surface estimation methods, constant line and shape line**

An example of methods comparison between constant line and shape line methods is shown in figure 8.

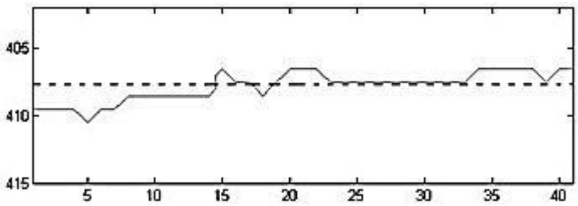

**Figure 8. Comparisons of water surface estimation methods**

### 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.

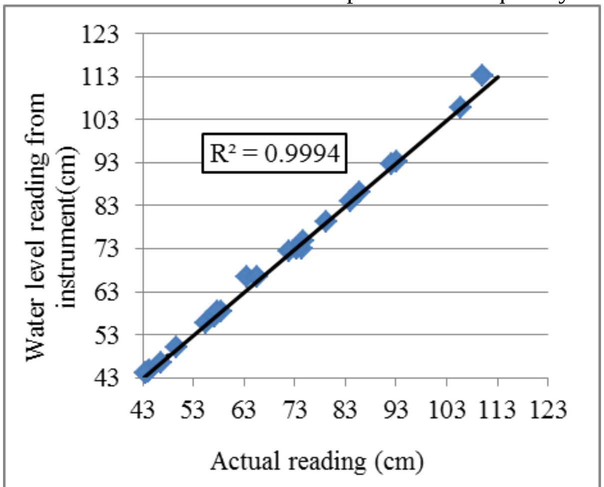


**Figure 9. Water level reading (constant line method)**

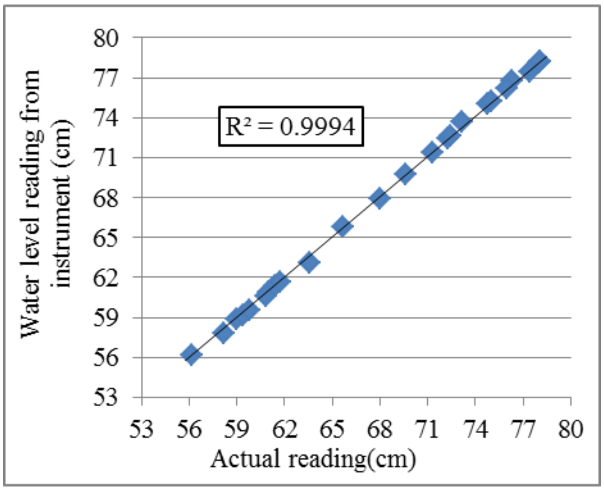


**Figure 10. Water level reading (shape line method)**

The results of the optical water level experiment show a good precision of water measurements. They are compared to the actual reading by visual inspection. The result analyses of water level data sets are shown in figure 11, 12 and table 1. The water waves greatly affect the error percent of the constant line method data set. The $R^2$ values of both methods are almost the same. Since the constant line method uses the constant coordinate of water level, it doesn't reacts to water wave at all. The RMSE values of both methods show higher percentage of error in the constant line method than the shape line method. The cause of high variation in the constant line method data set is movement of the float. Therefore an average percentage of error is higher than a shape line method. The adjustment of both methods can be done by calculating the adjustment from the average error of water level reading.

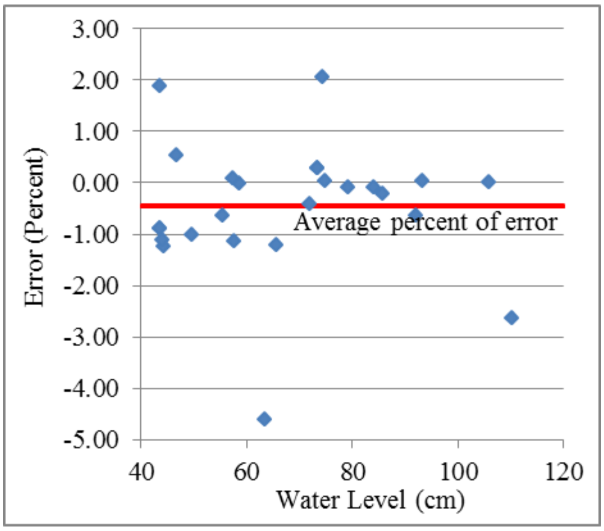


**Figure 11. Percent error of water level reading (constant line method)**

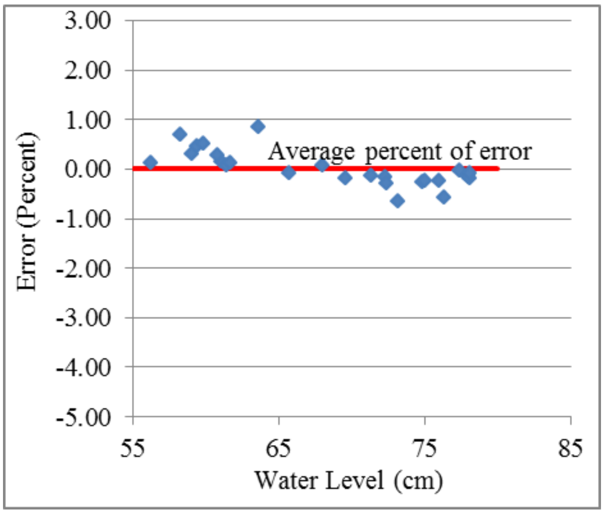


**Figure 12. Percent error of water level reading (shape line method)**

**Table 1 Statistic Comparison of line estimation methods**

| Water surface line detection method | $R^2$ | RMSE | Average percent of error |
|---|---|---|---|
| Constant line method | 0.9994 | 0.955 | -0.464 |
| Shape line method | 0.9994 | 0.219 | 0.005 |

## 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.

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