Automatic water level monitoring system based on computer vision technology for supporting the irrigation modernization

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Abstract. Measurement of water level in the irrigation channel is required to calculate the irrigation discharge so that crops can be irrigated precisely. Large irrigation areas require a real-time and accurate monitoring system that cuts operational costs. In a previous study, ultrasonic technology has already been developed and implemented. However, during the actual operation, visual verification is needed. To address the problem, an automatic water level monitoring system based on visual appearance using computer vision technology is developed. The image-based system works by automatically capturing canal gauge, identifying canal gauge in an image using colour detection method, measuring the length of the pixel of canal gauge, and convert it to an actual water level. As a result of the performance test, five photos were taken in 24 hours. One image was accurately measured by the microcomputer. This is because the intensity of sunlight affects the colour of the canal gauge so that the microcomputer incorrectly or inaccurately identifies the canal gauge length. A pre-calibration is needed to find a specific colour range for specific light intensity. Also a robust, less colour sensitive such as night vision imagery needs to be developed to overcome luminescence problems.

1. Introduction
Irrigation is crucial to fulfilling the crop water requirement to increase crop productivity. Therefore, water should be supplied precisely, in terms of volume, frequency, duration, and space. The water level is a critical component for controlling water supply in the management of water resources. Water supply volumes, flood discharge, sediment, and nutrient transport rates are all commonly calculated based on water level measurements [1, 2]. Staff gauge (canal gauge) is the most used tool for water level observation. River discharge monitoring is reasonably well-instrumented, but not happened on the channel or channel level, while water surveillance affects a farmer’s productivity directly [3]. Generally, discharge in an irrigation canal is measured using measuring structures, such as flume, sharp crest, and broad crest. Measuring structures used water level showed in canal gauge with formulas derived from critical flow concept to show discharge. Mostly, laborers are needed to observe and control the water level in a hydraulic structure. With the rapid use of Information and Communication Technologies (ICT) and the development of affordable devices such as low-price...
microcomputers, sensors, and open-source software, to build continuous monitor the water level is possible. Therefore, reduce operational cost, increase work efficiency, and data accuracy [4]. Some previous works of automatic water level gauge include the float-type, the pressure-type, the ultrasonic-type, and the radar-type, but there are usually limited, expensive and high cost of installation and maintenance [5].

Nowadays the function of human eyes can be replaced by a camera to capture an image. Some image processing algorithm such as morphological operation, image thresholding, and image filtering is applied to correct noise and further enhance desired object region [6]. The other operation that can divide an image into several specific sections and extract the interests section is called colour image segmentation. In the process of colour image segmentation, colour space needs to be determined then select the appropriate segmentation method. But the image is sensitive to the effects of light and noise, image colour appearance would change when the light would change. To obtain good segmentation, it needs the brightness information and colour information concurrently [7, 8]. An online data collection based on cloud system architecture needs to be built to support a real-time monitoring system, e.g. a web-based monitoring system, and remote environmental monitoring [8, 9, 10]. In some previous work, an ultrasonic sensor for water measurement has an advantage of cost-efficiency and simplicity but additional field information for ‘visual’ interpretation and validation of measuring results are required.

The objective of this study is to develop an automatic water level monitoring system based on visual appearance using computer vision technology. The image-based system works by automatically capturing canal gauge, identifying canal gauge in the image by colour variation, measuring pixel length, and converting to an actual water level.

2. Measurement site and system

2.1. Time and Location
The research was conducted on 20-21st July 2020 at the Grembyangan irrigation system, Berbah, Sleman, Yogyakarta, Indonesia which is used to supply water for paddy and sugarcane cultivation. Grembyangan irrigation canal was built using concrete material and has a rectangular cross-section. The water is abstracted from the Opak River. Several hydraulic structures such as Parshall flume and watergate were built in this canal to control water flow across the plantation. Usually, a gauge is fixed in the side of the canal, integrated with the Parshall flume to determine the volumetric flow in a given location of the canal. The water depth varies from 0 m to 1 m depends on the season and water allocation.

2.2. Hardware
The measurement system is installed at the edge of the canal on the opposite side of the canal gauge, as shown in Fig. 2. The hardware consists of parts as below:

1) Canal gauge is a metering device used to measure water depth. It is made from a metal plate and fixed on the side of the canal near hydraulic structures (in this case Parshall flume) with a concrete foundation. Patterns on the canal gauge are a line-shaped indicator for every 5 cm length and numbers 0-50 in centimeter units, thus make the reading precision of water level up to 1 cm. Canal gauge is painted in blue colour for the background and white for the indicator. It has about 20 cm in width and 50 cm in length.

2) Microcomputer: A microcomputer (Raspberry pi 3) is used as the main operator of the system. It connects and enabling the camera operation, store and processes the image from the camera, and act as a node to connect to an internet network. It handles the camera to capture an image periodically, run a computer vision program on the image, and send the output to a web server. Equipped with 16 GB micro SD card to store the OS, program script, captured photos, and data log.
3) Camera: The Raspberry Pi Camera Board (version 3.0) plugs directly into the CSI connector on the Raspberry Pi. It can deliver a 5MP resolution image or 1080p HD video recording at 30fps.

4) Network communication equipment: The microcomputer has a built-in Wi-Fi module that enables it to connect to a router. The router supports a 4G Internet connection using TELKOMSEL as the internet provider. It provides up to 5 Mbps Internet network speed and good internet signal, which satisfies sending data to a web server.

5) A solar panel as power supply equipment. Considering the inconvenient power access in the field, a solar power supply is designed to keep the measurement system continues running for at least 24 hours. It consists of a photovoltaic module (200 W, a solar charge controller, and no-maintenance colloidal batteries (12 V 300 Ah).

2.3. Software
To support the hardware system above, a computer vision program is developed using an open-source computer vision library (Open CV) written in Python language. The program-controlled by a build-in scheduler application in the Raspberry Pi (Cron). Cron is a tool for configuring scheduled tasks on Unix systems. It is used to schedule commands or scripts to run periodically and at fixed intervals. The computer vision program works as a script to extract useful information in an image (in this case, the length of the canal gauge). The output of the program is a value that represents the water level based on the length of the canal gauge. This value is then sent to a web server as a GET request and saved in a web server database. This system design provides real-time water level monitoring. A web server and a database build using a web hosting provider designed to accept and save the value.

3. Measurement method

3.1. System Workflow

Figure 1. Schematic design of the system.
Figure 2. Panel box and camera installation (a) top-view, (b) side-view and (c) in-site canal gauge.

Figure 3. Algorithm flowchart.

A build-in scheduler application inside the raspberry pi operating system (Cron) works to run program. The program runs to enable the raspberry camera to capture the canal gauge image periodically. The image is then processed with computer vision program to extracts the length of the canal gauge from the image, save the value then send it to a web server as a GET request. The webserver is built to accept and save the value in a database. The image then saved in raspberry pi file storage with the time the image was captured as the image file name.

3.2. Algorithm
The algorithm is designed to segment canal gauge colour, calculate its pixel length and convert it to actual water level.

1. Colour detection: The water line detected using the length of the canal gauge as base information. Canal gauge length is detected based on colour detection method. The canal gauge that used in this experiment has the overall colour of blue, so some range of blue
coloured pixel is selected, and other pixels are changed to black. In this experiment an RGB based colour between R: 149, G: 69, B: 81 and R: 202, G: 172, B: 154 are selected to segment the canal gauge.

2. Binary threshold: The image is then converted to grayscale and a binary threshold algorithm is applied. Binary threshold algorithm converts pixel value in an image above the specified threshold to maximum intensity (white) and below the threshold to minimum intensity (black).

3. Image filtering: Image filtering is a process to remove noises from images. In this case, a median filter is applied to remove noises. Usually, some "salt and pepper" noises are detected in the image because of some other region of pixels has colour in the range of the specified colour.

4. Morphological operation: is an image processing algorithm to change the shape of an object in a binary image. Morphological operation algorithm works by “dilating” or “eroding” the edge of the object in the binary image. In this case, a morphological operation is applied to remove additional noises and further enhance the desired image region.

5. Calculate contour height: The largest region in the binary image is selected then assigns the minimum y pixel coordinate as the top of the canal gauge and maximum y pixel coordinate as the bottom of the canal gauge.

6. Convert to a water level scale: maximum y pixel – minimum y pixels represent canal gauge length in pixel. This value is then converted to centimetres.

7. Send data to a web server. The water level value is sent to a web server as a GET request with python request library.

4. Result and Discussion

4.1. Dataset

The dataset that was used in this experiment was taken manually using a 12 Megapixels (resolution: 1960 x 4032 pixels) Samsung S9+ camera because of the electrical system malfunction when the experiment was conducted. The images were taken at 13.00, 15.00, 18.00, 22.00, and 22.00 with flash at Western Indonesian Time.

4.2. Captured and processed images

![Figure 4. Original images (a) taken at 13.00, (b) taken at 15.00, (c) taken at 18.00, (d) taken at 22.00 (e) taken at 22.00 with flash.](image-url)
According to the algorithm, canal gauge length is determined based on the RGB colour range. From the result images (Figure 7.) water level can be determined based on some of the images and some others are not. The gauge segmentation based on the colour selection method is proven to be not so robust. The water level in Figure 7. (b) is measured correctly by the computer because of a clear
distinction between the gauge and background colour and the canal gauge colour is within the pre-determined RGB colour range. While on the other images (Figure 7. (a), (c), (d), (e)) are measured either incorrect or inaccurately, it's caused by the blue colour of the gauge is changed as the light intensity changes thus effecting the segmented region in the image.

Inconsistent image capture angle, distance, and elevation also affected the canal gauge measurement. A different canal gauge position in an image affecting pixels to centimeter value conversion. In Figure 7. (d) and (e) no water level value is displayed because of no contour detected in an image. In Figure 7. (a), the computer failed to determine a correct gauge contour in the image because of too many noises and undetected canal gauge colour. In Figure 7. (c) Computer successfully detects gauge colour and determined the correct gauge contour. But because of the colour uniformity of the canal gauge, only a part of the gauge is detected. Material, paint, and maintenance used for canal gauge is a key factor of the image-based method to gives the best result.

5. Conclusion

The computer vision algorithm has successfully determined water level in a specific condition but failed under different light intensity. The development of a water level monitoring system based on computer vision, need to be improved. A pre-calibration needs to be performed to find a specific colour range for specific light intensity. A static camera installation to capture image periodically need to be built to gives a consistent canal gauge image position. Also, a robust, less colour sensitive such as night vision imagery need to be developed to overcome luminescence problem [10].

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