Journal of Engineering and Applied Sciences 13 (Special Issue 12): 9480-9484, 2018
ISSN: 1816-949X

Implementation of Stable Water Level Management System Using Digital Weighting Algorithm

[1]Ki-Deok Kweon, [2]Koo Rack Park, [1]Jae Woong Kim and [3]Han-Jin Cho
[1]Department of Computer Engineering, University of Kongju National, Chungnam, Cheonan Subuk, 1223-24 Cheonan-Dearo (275 Budeadong) 32588, South Korea
[2]Department of Computer Science and Engineering,
[3]Department of Smart Mobile, University of Far East, 76-32 Daehak-gil, Gamgok-myeon, Eumseonggun, 27601 Chungcheongbuk-do, South Korea

Abstract: A measuring instrument for measuring water level is one of the measuring equipment widely used everywhere in the industry as well as places where people live. In particular, the ultrasonic level meteris usedin the field of environmental water treatment to measure real time numerical data to manage operation and prevent disasters from sudden changes in water level. However, it is necessary to study to secure reliable measurement values without errors. This study proposed and implemented digital weighting algorithm for fine ultrasonic signals to stably measure 2nd reflective wave of measuring errors which are irregular and abnormal depending on the structure or environment of the site. The result of applying the proposed algorithm showed that the measured values are implemented stably. This makes us expect stable operation of the integrated operation system linked with the monitoring system and the processing system as well as data management for water level measurement. In the future, we will continue to study to complement the integrated prediction system that remotely controls the pump by interlocking stabilizing the stable measurement level signal which overcame the limitation of the measurement error of the conventional level meter with the real-time water level monitoring system.

Key words: Ultrasonic, level meter, water measurement, 2nd reflective wave, digital weighting algorithm, monitoring system

INTRODUCTION

Recently, global interest and investment have been actively done for the prediction system of environmental change to prevent various natural disasters caused by rapid climate changes. Among them, the environmental fields are largely divided into the air and water quality fields. Especially, the importance of precision measuring instruments in the field of water quality environmental facilities is more important than other facilities. These precision measuring instruments are used as essential equipment for inventory management and pump operation management in the process of oil tanks, drug reservoir of petrochemical-related fields including dams or rivers, waterworks and sewage treatment plants and are also, essential for operation and management such as monitoring and control etc. Of these precision measuring instruments that play such a major role, the level meter can be divided into contact type measuring in direct contact with the object and non-contact type and is used in conjunction with the real time monitoring system. The contact type includes an input type, a differential pressure type, a capacitive type, an electrode type and a float type while the noncontact type includes an ultrasonic type, a radar type and a laser type (Sung-Taek and Gang-Wook, 2016; Kweon, 2017; Taek *et al*., 2017; Kim *et al*., 2010) Government agencies that monitor and operate measured water level data in real time include water and sewage operation division of local governments, Korea Water Resources Corporation, Environmental Management Corporation, the Meteorological Administration, Ministry of Land infrastructure and Transport (Hwang *et al*., 2013; Kim *et al*., 2016) and conventional water level rise detection systems include the use of a level meter, a method of reading the water level table displayed on the bridge and a method of monitoring. The core of the water level rise detection system using a level meter is to detect the water level rise in real time. However, the level meter of the conventional system often does not generate signals due to various problems when a problem should

Corresponding Author: Koo-Rack Park, Department of Computer Science and Engineering, Kongju National University, Chungnam, Cheonan Subuk, Cheonan-Daero 1223-24 (Budeadong 275) 32588, South Korea

be reported immediately. There are reliability problems with the quality of the level meter itself as shown in the examples that when this happens, the level meter's problems cannot be found out directly and the image system should be installed separately from the level meter etc. (Sung-Taek and Gang-Wook, 2016), (Anonymous, 2001, 2007).

In order to solve this problem and address the problem that the 2nd reflected wave generated from the influence of the structure and the environment in the water level measurement proposed in the previous studies is the error and hunting of abnormal measured values, this study is to apply digital weighting algorithm 2 and improve the problem of conventional system by implementing this. Based on these results, more stable operation of the monitoring system through level measurement signals is expected.

MATERIALS AND METHODS

Ultrasonic level meter: Ultrasonic level meter is a non-contact method applying piezoelectric materials and the principle of measurement is to measure the time from when the ultrasonic pulse emitted from the ultrasonic sensor is reflected from the surface of the object to be measured and returns to the ultrasonic sensor to obtain information depending on the object to be measured. As shown in Fig. 1, we use the method to calculate the distance by measuring the delay time until returning after transmitting the ultrasonic wave and compensating the sound velocity according to the temperature of ultrasonic wave in air (Kim *et al.*, 2010; Cho, 2003; Um, 2000; Hwang, 1999; Jeong, 2005). The distance measurement using the ultrasonic sensor is shown in the following Eq. 1:

$$\text{Level} = \text{Empty-Distance} \tag{1}$$

Distance, Empty and Level represent the distance (m) from the ultrasonic sensor to the object to be measured, the total distance (m) from the ultrasonic sensor to the floor and the distance (m) to the object to be measured and the floor, respectively. The distance measurement from the ultrasonic sensor to the object to be measured is as shown in the following Eq.2:

$$\text{Distance} = V\times Dt/2 \tag{2}$$

Where:

V = Sound speed of liquid (= 331.5+0.6T)

Dt = Echo flight time (sec)

Generally, the sound velocity in the air is calculated by V (m/sec) = 331.5+0.6 t, where t represents the temperature °C. The threshold method (threshold detection method) and the envelope method (envelope detection method) are applied when measuring the distance from the ultrasonic sensor to the object to be measured. Since, a sound wave is reflected, absorbed or scattered in the surrounding environment or a structure, a method of making a judgement from the transmitted signal is used only when a signal exceeding a threshold value is detected (Lee *et al.*, 2007; Marioli, *et al.*, 1992; Han and Hahn, 2000).

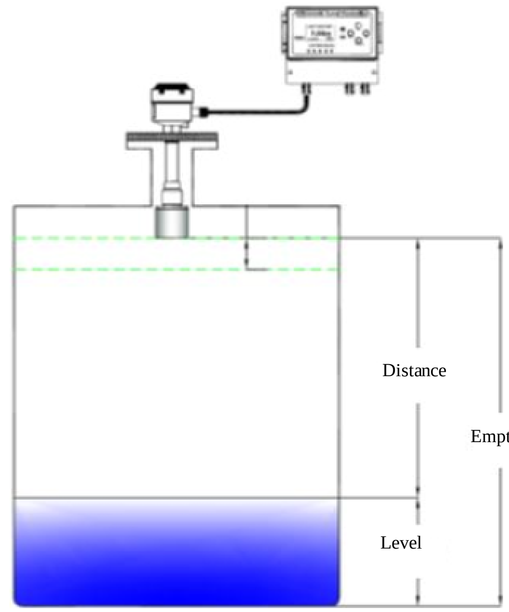

Fig. 1: Water level system structure

Conventional block diagram vs. proposal block diagram: Using a fixed threshold, the currently used ultrasonic level meter recognizes a signal exceeding the threshold as a sleep signal which causes frequent measurement errors that recognize the 2nd reflective wave as a sleep signal. Therefore, in order to minimize the effect of the algorithm of the currently applied level meter and the 2nd reflective wave, the comparison of the algorithms proposed in the previous research is as shown in Fig. 2.

We obtain the time taken when the signal transmitted from the sensor radiating surface is propagated after amplification and integration through high pass filter after receiving the ultrasonic signal reflected on the target object and the speed of the sound wave varies with temperature, so, we measure the temperature-compensated sound wave velocity after measuring the current temperature and measure distance and level based on it. The algorithm proposed in this

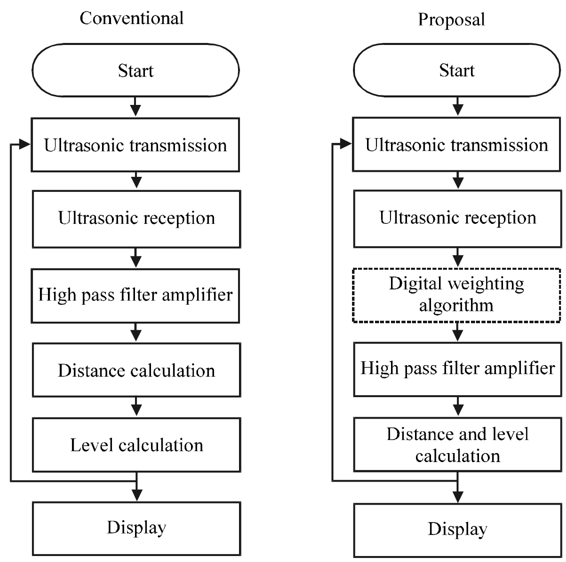

Fig. 2: Conventional diagram

study applies the digital weighting algorithm to the received ultrasound signals to convert the abnormal signals into normal signals using the weights. Equation 3 of the digital weight to improve the measurement error due to the abnormal signal is shown in the following Eq. 3:

$$SPVc = SP\times\left[1-\frac{1}{M-N}\times(c-N)\right] \quad (3)$$

Where:

SPVc = Sampling Position Value
SP = Sampling Position
M = Total M samples
N = Position where EP1 is located
c = Position constant increasing from N+1 to M

MATERIALS AND METHODS

The ultrasonic level meter uses the TVG (Time Variable Gain) to vary the ultrasonic reception signal reflected by the distance and amplify it. When the ultrasonic signal is received at the position of the curve (EP1) where this TVG curve increases, it is received smaller than the original signal size. The digital weighting calculation formula first sets the EP1 to the weight 1, sets the position where the empty is located to the weight 0 and then represents the order of multiplying the sampled values (sampling position value) by weights sequentially. Figure 3 is an example of application of the digital weighting algorithm with empty as weight zero.

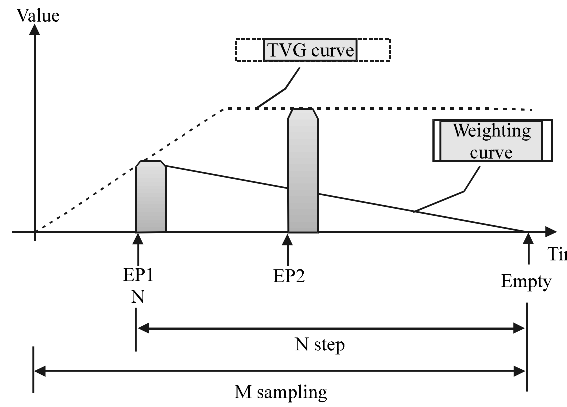

Fig. 3: Example of theapplication of the digital weighting algorithm (with empty as weight 0)

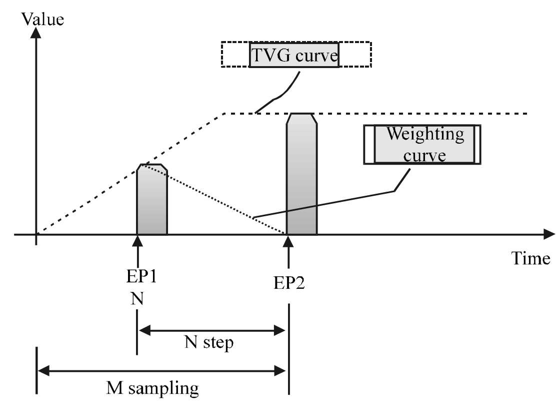

Fig. 4: Example of the application of the digital weighting algorithm (with EP1×2 as weight 0)

A digital weight is given to the signal existing on the right side of EP1 (Echo Position1: Real Echo) on the time axis. This digital weighting algorithm is set to operate only under the condition of EP1<(Empty/2). The following Fig. 4 is an example of application of the digital weighting algorithm when EP2 which is twice the EP1 is applied as weight 0.

Analysis of the level meter waveform screen of the current algorithm: Figure 5 is the wave form screen in which the conventional ultrasonic level gauge displays minor current from the sensor by signal processing, showing that the abnormal signal is constantly appearing due to the influence of structure or environment. The horizontal axis represents the time and the vertical axis represents the water level. Intermittent hunting phenomena are repeated over time. Due to these abnormal level measured values, precise control linked to other facilities is difficult.

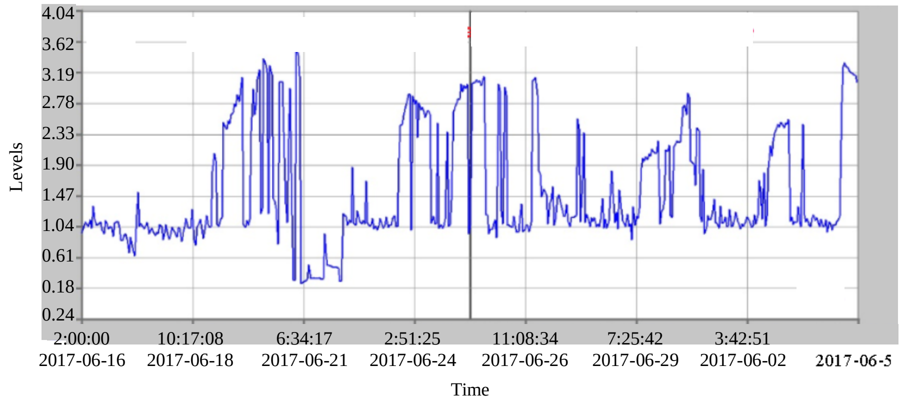

Fig. 5: Conventional level chart; Lots of abnormal signal due to 2nd reflective wave

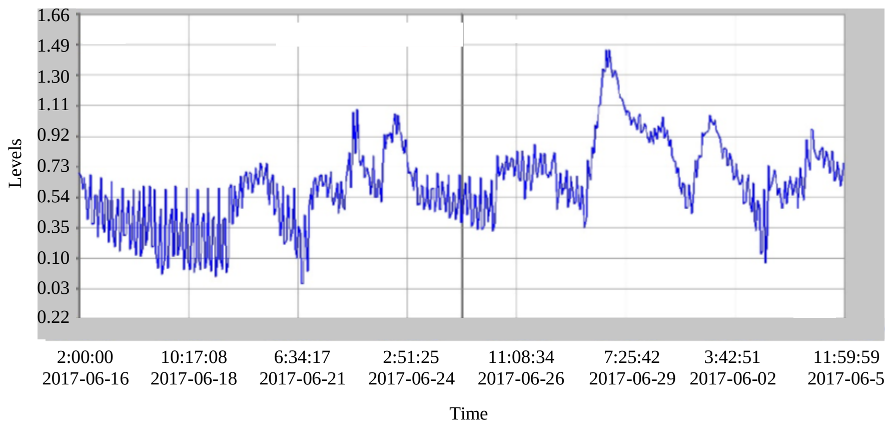

Fig. 6: Application chart of the digital weighting algorithm (With EP1×2 as weight 0); Stable signal along trend wave

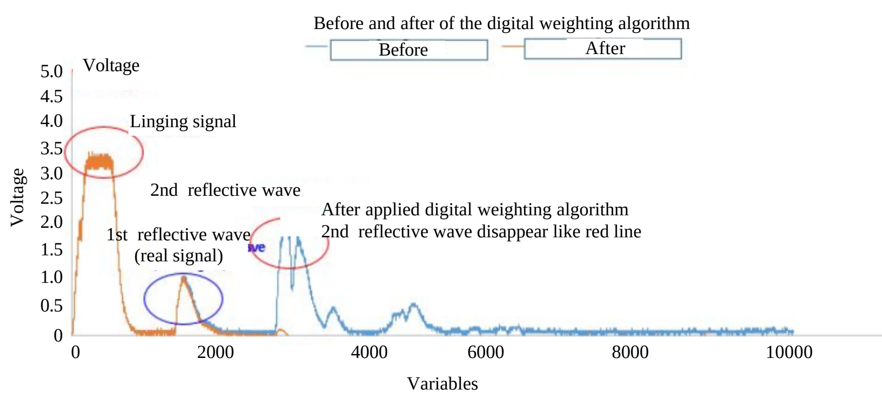

Fig. 7: Before and after of the digital weighting algorithm

Analysis of level meter waveform screenafter the application of digital weighting algorithm: Figure 6 shows the measured values of the water level in the product applying the digital weighting algorithm and it shows that the water level is stable over time compared to Fig. 5.

Analysis of time and voltage waveform screen before and after digital weighting algorithm: Figure 7 shows the voltage waveforms with time before and after applying the digital weighting algorithm and it was foundthat the 2nd wave reflective generated after 1st reflective wave which is reflected to the actual object before the algorithm application and is measured as a valid value, disappeared after the algorithm is applied.

It shows that the data waveform of the digital weighting algorithm proposed and implemented in this study and the conventional method in the same location and environment is more stable in the conventional method than in the conventional method. Therefore, using the level meter applying the proposed algorithmis expected to have a significant effect on reliable operation of water treatment system such as rainwater pumping stations and reservoirsoperating the pump by working with real-time monitoring system based on more reliable and efficient maintenance and reliable data.

CONCLUSION

This study observed measurement errors of the ultrasonic level meter applying existing algorithm and implemented a digital weighting algorithm to solve the abnormal signals such as reflective waves due to the influence of structure and environment. Based on the results of comparison and analysis of ultrasonic level meter with conventional and new algorithm at water treatment site, it was found that the data waveform applying digital weighting algorithm was measured stably without any abnormal signal depending on the flow of water level. Level measured values obtained by using the results from this study are expected to contribute to the real-time monitoring of water level and flow rate linked to rainwater pumpingstations and other facilities such as reservoirs and stable operation of remote control systems.

RECOMMENDATIONS

In the future, it is necessary to continue to study algorithms that can secure and analyze the water level data applied at various sitesand can interwork with real time water level monitoring system.

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