Study on the Near-IR Light Detection and Ranging (LiDAR) Potential Use as Water Level Sensor

M S Jannata, R A Salam and A Suhendi

1 Engineering Physics Department, Telkom University, Bandung, Indonesia
2 Research Center of Internet of Things, Telkom University, Bandung, Indonesia

Email: safikka@student.telkomuniversity.ac.id*

Abstract. Measuring water level is an important component in various applications, especially in hydrological applications. There are various methods of measuring surface water levels, from contact methods to non-contact methods, each has various techniques depending on the measuring instrument used. Among the available techniques, the use of the Near-IR LiDAR for distance measurement has potential uses because it can be used without direct contact with water. In this study, Near-IR LiDAR (850nm) was tested to determine its suitability as a water level sensor. Measurements were tested for variations in water patterns and turbidity. Although water has a low reflectivity for infrared radiation, it was found that in this study there was still the possibility to be able to detect surface water under certain conditions. In the dynamic water test, the measurement error is <10%. In the turbidity test, minimal information on turbidity that can be used by Near-IR LiDAR to detect the water level is 700 NTU with a measurement error of 5.2%.

1. Introduction
Measuring water level is an important component in various applications, especially in hydrological applications. For example, in terms of water resources management, measuring the water level is the first step in collecting river flow data as a hydrological baseline data [1]. Another example is flood disaster management, where water level data can be used as a prediction of a disaster. Information about the water level is very important to support various applications. By understanding this, it is necessary to develop innovations in measuring the water level in order to obtain accurate and efficient data. According to literature [2] there is a classification of water level measuring instruments based on the method of application, namely the contact method where the measuring instrument is in direct contact with water and the non-contact method where the water level is measured from the height between the sensor and the water surface. In its development, the measurement of the water level can use pressure sensors [3] and buoy [4] which are included in the contact method. However, its implementation is very prone to contamination of measuring instruments and increases the potential for damage in case of extreme weather or natural disasters.

The use of sensors with the non-contact method is considered to be able to minimize this because of its flexibility and convenience in installation and maintenance. For example, the use of radar and ultrasonic sensors [5] which uses the time-of-flight principle to measure the distance between the sensor and the water surface. Another concept offered is the use of near-infrared LiDAR for distance measurement. Notice that the use of LiDAR in distance measurement uses the same principle as ultrasonic sensors [6] and can be used to measure distances without direct contact with water or non-contact. So, this research will study the potential of LiDAR in measuring water level.
2. Basic Theory and System Design

LiDAR uses the time-of-flight principle to measure distances. Where \( D \) is the distance, \( c \) is the speed of light, \( f \) is the modulation frequency, and \( \Delta \phi \) is the phase shift between the measurement signal and the reference signal.

\[
D = \frac{c}{2f} \cdot \frac{\Delta \phi}{2\pi}
\]  

(1)

From this equation [7], the distance can be obtained by measuring the phase shift between the reference signal and the measurement signal.

2.1. System Configuration

The system uses the TFMini Plus LiDAR with a wavelength of 850 nm. LiDAR is integrated with the data logger using an Arduino Pro Mini microcontroller which is connected to a microSD module to store LiDAR measurement results, and there is an additional RTC module as a time recorder for taking measurements by LiDAR. The schematic of the LiDAR system is attached in Figure 1.

![Figure 1. Schematic of the Hardware System](image)

2.2. Measuring in Field Configuration

Figure 2 shows the LiDAR test arrangement scheme in dynamic water patterns or in the field. LiDAR is placed facing the water surface with a 0° sensor placement angle and is integrated with the measurement system. In the field test, static measurements were made at a distance of 200 cm and 150 cm from the water surface.

![Figure 2. Field Experiment Configuration](image)
2.3. Sensor Calibration

Figure 3 shows the LiDAR test arrangement scheme for a static water pattern, where the water medium used has a depth of 10 cm and is in a container with a size of 50 x 35 x 30 cm. Water media with a specified water depth of 10 cm was used and the volume of water media in the box was about 17.5 liters. Information on the volume of water media is used to calculate the concentration of the material in order to achieve a certain turbidity value. Referring to research [8] regarding the relationship between Total Solid Dissolve (TSS) and the Nephelometric Turbidity Unit (NTU) or the turbidity unit in kaolin clay, an approach was used to measure the composition of suspended solids in order to obtain the desired turbidity value as a medium for variation against distance. The following is the composition of the required kaolin clay, which is shown in Table 1.

| Turbidity (NTU) | Kaolin Composition (mg/l) |
|----------------|---------------------------|
| 100            | 200                       |
| 200            | 365                       |
| 300            | 530                       |
| 400            | 700                       |
| 500            | 900                       |
| 600            | 1050                      |
| 700            | 1227                      |
| 800            | 1404                      |
| 900            | 1580                      |
| 1000           | 1757                      |

3. Testing Scheme

3.1. Effect of water patterns on distance measurement
In this test, distance variations are given by moving the sensor vertically to variations in water patterns, namely static and dynamic water patterns under certain conditions. In the dynamic water pattern test carried out on the irrigation flow of Sentir Reservoir, Kec. Kedungpring, Kab. Lamongan, East Java, while the static water pattern test was carried out using container media in Laboratory.
3.2. Effect of water turbidity on distance measurement
In this test, the turbidity variation is given at a predetermined distance and calculates the bias from the measured results to the actual measurements. The turbidity medium used kaolin clay and the material composition approach was used to obtain various turbidity values.

4. Result and Discussions

4.1. Laboratory Experiment
- Static measurement of turbidity variation
  Testing of variations in water turbidity was carried out by repeated measurement experiments at a distance of 200 cm with a measurement sample of 20 times for each turbidity variation. Information is obtained from measurement results as in Table 2, where the turbidity range from 700 NTU, the measurement error reaches <10%, referring to the literature [9], the error limit accepted in the engineering world.

| NTU | Mean  | STD   | Precision | Accuracy | Bias  | Error (%) |
|-----|-------|-------|-----------|----------|-------|-----------|
| 300 | 197.1 | 13.467| 40.041    | 43.301   | 2.9   | 21.65     |
| 500 | 206.45| 6.03  | 18.091    | 24.541   | 6.45  | 12.2      |
| 700 | 197.4 | 2.591 | 7.774     | 10.374   | 2.6   | 5.18      |
| 800 | 202.35| 1.531 | 4.593     | 6.943    | 2.35  | 3.4       |
| 900 | 201.2 | 1.361 | 4.083     | 5.289    | 1.2   | 2.6       |
| 1000| 203.45| 1.605 | 4.815     | 8.265    | 3.45  | 4.1       |

- Dynamic measurement of turbidity variation
  Testing was carried out at 10 up to 200 cm with a resolution of 10 cm. Measurement samples were taken 1 minute per distance for each turbidity variation. Information on the measurement results is obtained as in Figure 4, where the relationship is obtained that the higher the turbidity value of the water, the more the measurement error is minimized or the closer to the linear graph of the measurement results.

![Dynamic Measurement 10-200 cm](image)

Figure 4. Dynamic distance measurement result
4.2. Field Experiment

In testing the distance measurement to dynamic water, static measurement experiments were carried out at predetermined distances of 200 cm and 150 cm to the dynamic water surface. Attached information on the measurement results of 200 cm and 150 cm in Table 3. Each measurement found a measurement error of about 9.8% and 4.3%.

Table 3. Static distance measurement result.

| Distance (cm) | Mean  | STD   | Precision | Accuracy | Bias  | Error (%) |
|---------------|-------|-------|-----------|----------|-------|-----------|
| 150           | 149.6 | 2.013 | 6.039     | 6.407    | 0.368 | 4.2       |
| 200           | 200.6 | 6.357 | 19.073    | 19.673   | 0.6   | 9.8       |

5. Conclusions

A system for measuring the water level using LiDAR has been designed, which from this study shows that LiDAR has the potential to measure the water level by taking into account several parameters, namely water patterns and turbidity. Although infrared rays have a low reflectivity to clear water, it was found that if the water is cloudy with a turbidity value of at least 700 NTU, LiDAR can measure the water level with a measurement error of about 5.18%. In a dynamic water pattern, LiDAR can measure the water level with a measurement error of 9.8% at 200 cm and 4.3% at 150 cm.

6. References

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Acknowledgments

The author would like to acknowledge a research grant of PDUPT from Ministry of Research and Technology Republic of Indonesia/National Research and Innovation Agency.