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Lighting Level Measuring Device Based On Web Using Kalman Filter Method

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ABSTRACT

The need for lighting in each room depends on the activities carried out. According to the Indonesian National Standards (SNI) 03-6575-2001, the minimum recommended lighting strength for lecture hails is 200 lux to 250 lux and for laboratories is 300 lux to 500 lux. In measuring the level of lighting in a room, a tool called a lux meter is needed. But as is known light sensor is a sensor that quite sensitive. In this research the writer uses the Kalman Filter method to increase the accuracy and precision of the BH1750 lighting level sensor. In addition, this tool is also integrated with a website to make it easier for users to monitor measurement results both stored and in real-time. Tool testing is done by measuring 28 different locations. The test scheme is adjusted to the standard operating procedure for measuring light intensity which refers to SNI 16-7062-2019. From the test results for measurements using the Kalman Filter method, the stability level is 78.57%, the precision level is 1.46% and the accuracy error value is 0.92%. While the test results for measurements without the Kalman Filter method obtained a stability level of 53.57%, a precision level of 2.80% and an accuracy error value of 2.77%.

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INTRODUCTION

Light is energy in the form of electromagnetic waves. In a vacuum room, the speed of light is the same as the electromagnetic waves, reaching 3x108 m/s (Rokhaniyah, 2019). A light that radiates can be seen by humans when the wavelength reaches out the range of the human eye. But if the wavelength of light does not reach the reach of the human eye, then humans cannot see it. It is known that the wavelength of light that can be seen by humans is from 380 nm to 750 nm (Rizal, 2018).

The need for lighting in each room is different it depends on the activities carried out. It is necessary to measure the lighting of the environment in order to identify the fulfillment of K3 requirements based on Permenaker No. 5 of 2018. A good level of lighting is one of the factors in providing a good vision because this factor can affect humans in seeing objects around them. Several studies on the relationship between productivity and lighting state that adequate lighting for the type of work can increase maximum results and work effectiveness. In addition, poor lighting can cause eye fatigue because it reduces the efficiency of eye performance, causing soreness and headaches around the eyes (Becker, 2018).

The use of a lux meter to measure the level of lighting in a room is easy. Users only need to point the sensor on the device to the light source. But as is known light sensor is a sensor that is quite sensitive. So that in accordance with the Indonesian National

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Standard (SNI) 16-7062-2019 regarding the measurement of lighting levels for the general lighting category, the measurement of each point is repeated three times, and then the average value is taken. Of course, this will take a long time and the data obtained is very large, even less if these measurements are manually.

From the problems mentioned above, this research will focus on the stability of the sensor reading the lighting level. So, the Kalman Filter method is used to improve the accuracy and precision of the BH1750 light sensor. The way this filter works is to find the mean squared error in the calculation and then calculate the current estimate. After that, the sensor will read the data that has been filtered. In addition, a website has been created to display the results of sensor readings where the website is also a storage place to read these values. This website will be part of the K3 management system (SMK3) belonging to the PPNS. The creation of this tool is expected to facilitate the PPNS K3 team in measuring the level of lighting in the student study area more effectively and efficiently. This web is also helps them to reduce paper usage (paperless) and the data can be more securely and practically.

EXPERIMENTAL METHOD

1. Light

Light is energy in the form of electromagnetic waves. In a vacuum room, the speed of light is the same as the electromagnetic waves, reaching 3x108 m/s (Rokhaniyah, 2019). A light that radiates can be seen by humans when the wavelength reaches out the range of the human eye. But if the wavelength of light does not reach the reach of the human eye, then humans cannot see it. It is known that the wavelength of light that can be seen by humans is

from 380 nm to 750 nm (Rizal, 2018). The visible light is between ultraviolet (UV) light and infrared (heat) energy. These light waves stimulate the retina to produce a visual sensation called vision.

2. Kalman Filter

Kalman Filter is a method that can estimate the result based on the latest data. This data is a significant part of the Kalman Filter because the latest data will correct the predicted data of the measurement so that the estimation results are always close to the conditions of the last data. This algorithm is usually used to estimate or filter data that has noise or interference (Amalia, 2020). There are two processes in Kalman Filter. The first is the prediction process the second is the updating process.

Prediction Process

$$\hat{x}_{t|t-1} = F_t\hat{x}_{t-1|t-1} + B_t u_t \quad (1)$$

$$P_{t|t-1} = F_t P_{t-1|t-1} . F_t^T + Q_t \quad (2)$$

Update Process

$$\hat{x}_{t|t} = \hat{x}_{t|t-1} + K_t (y_t - H_t x_{t|t-1}) \quad (3)$$

$$K_t = P_{t|t-1} H^T (H_t P_{t|t-1} H^T + R_t)^{-1} \quad (4)$$

$$P_{t|t} = (1 - K_t H_t) P_{t|t-1} \quad (5)$$

Description:
x = estimated state
F = state transition matrix
u = control variables
B = control matrix
P = state variance matrix
Q = process variance matrix
y = measurement variables
H = measurement matrix
K = Kalman Gain
R = measurement matrix
t|t = current time period
t-1|t-1 = previous time period

3. Hardware System Design

The design of the hardware system in this research is shown in the following figure.

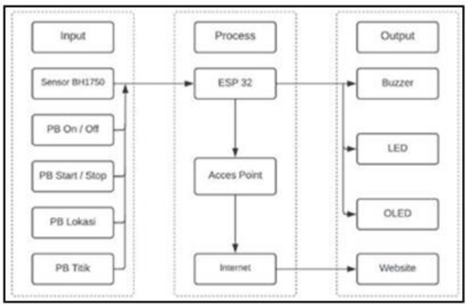

Figure 1. Hardware system design

Figure 1 describes the hardware that will be used in the design of the lighting level measurement. There are three parts to the picture above. The first is input. The input used in the project of this tool is four buttons and 1 BH1750 light sensor. The second is a microcontroller. In this project the microcontroller used is ESP32. Lastly the output section consists of a buzzer, LED, and OLED.

4. Software System Design

The design of the software in this study is a website that is used to monitor the measurement results both that have been stored and in real-time. The website created is integrated with the server that has been available so that it can be accessed by online.

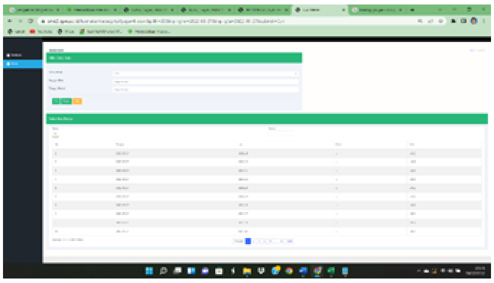

Figure 2. Dashboard page

Figure 2 is the start page on this website. Users use the dashboard page to monitor the results of the lighting measurement. On this start page there are charts and analog gauges to display the measurement results in real-time. Another facility from this page is that there is also a display of values for each building. This value will appear when the device connects to the server and available internet network.

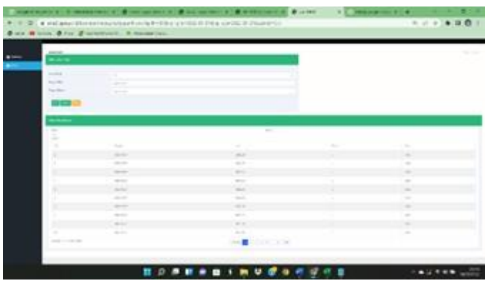

Figure 3. History page

Figure 3 is a history page. This page function is to check the results of measurements that have been made on a specific date and place. The results are stored in the database and then displayed on the website. This page also has other facilities, namely printing the results of measurements that have been carried out on a specific date and place in the form (.pdf).

5. System Workflow

At this stage, there is system workflow that shows about how the device works. These steps divided into eighteens parts. Starting from how to activate the device until how the data will be displayed on web. Besides that, this will make the troubleshooting process easier if an error occurs to the device. The system workflow from this design can be seen in the figure 4.

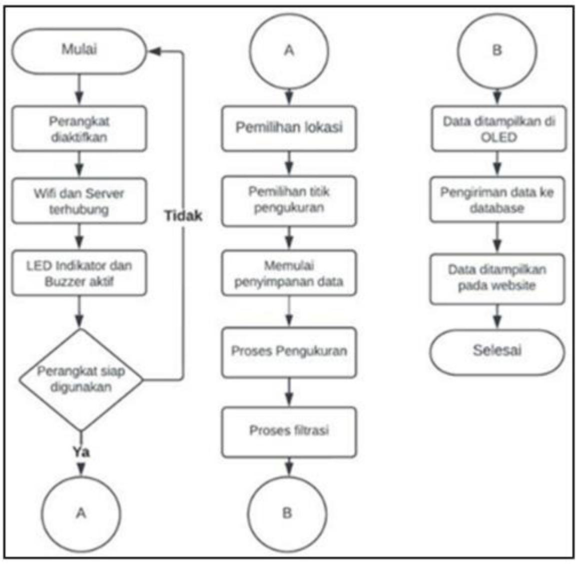

Figure 4. System workflow

The system workflow carried out in this study is described in Figure 4. The first stage is to activate the device. This process begins by pressing the ON pushbutton on the tool. Then the device will automatically connect to available Wi-Fi and servers. When the device is ready for use, there will be an indication from the Buzzer and LED. The fourth stage of this process is selecting the measurement site. After that, choose the point selection for each measurement point. Then the Start button is pressed to start data storage (recording). The seventh stage is the process of measuring the level of lighting using this tool. After that, the filtration process is running to stabilize the sensor readings. Then the measurement results will be displayed on the OLED. In addition, the measurement result data is also stored in the database. Finally, the data on the database is then sent to the website for monitoring

RESULTS AND DISCUSSION

1. Sensor Testing and Calibration Results

In this research, the BH1750 sensor functions to detect the value of the light intensity of a room. This process will test the sensor readings and show the error percentage value. The error value has obtained by comparing an artificial lux meter with a calibrated lux meter (Dekko-HS6612). Testing is done by placing the sensor and measuring parameters in the same place. To get a representative sensor reading the test is carried out by taking 60 data sampling with details of 20 locations, each point is taken 3 data. This table is the sampling results obtained.

Table 1. Sensor test result

No	BH1750 Sensor	Dekko-HSS6612	Location
1.	14,17	0	0
2.	14,17	0	
3.	15	0	
4.	115,83	51,2	1
5.	115,83	51,3	
6.	121,67	51,5	
7.	121,67	54,5	2
8.	121,67	54,6	
9.	126,67	54,6	
10.	132,5	62,1	3
11.	135,83	64,5	
12.	135,83	64,5	
13.	138,33	62,2	4
14.	138,33	62,3	
15.	138,33	64,5	
16.	140,83	67,8	5
17.	140,83	67,8	
18.	140,83	67,9	
19.	142,5	68,7	6
20.	142,5	68,8	
21.	146,67	72	
22.	146,67	72,2	7
23.	146,67	72,7	
24.	147,5	68,8	
25.	176,67	90,8	8
26.	176,67	90,9	
27.	176,67	90,9	
28.	185	96,3	9
29.	185	96,4	
30.	185	96,7	
31.	196,67	103,9	10
32.	196,67	104	
33.	196,67	104	
34.	208,33	111,3	11
35.	208,33	111,4	
36.	215,83	111,5	
37.	224,17	121,2	12
38.	224,17	121,3	
39.	224,17	121,4	
40.	253,29	127	13
41.	256,87	127	
42.	256,87	127	
43.	261,23	134,9	14
44.	266,55	134,6	
45.	267,67	134,8	
46.	271,67	139,1	15
47.	273,33	139,8	
48.	273,33	140	
49.	294,17	150	16
50.	295	150,3	
51.	295,83	150,7	
52.	315	159,5	17
53.	315,83	159,8	
54.	316,67	160,2	
55.	326,67	158,6	18
56.	330,83	165,6	
57.	330,83	165,7	
58.	331,67	166	19
59.	343,33	169,9	
60.	343,33	170	

Table 1 shows the sampling results that have been obtained. There are 20 locations measurements and from each point was taken 3 data. This table is comparing a measurement between BH1750 sensors with Dekko-HSS6612.

After taking data and comparing it with a digital luxmeter, the results are much different. This difference is gotten because the sensor has not been calibrated yet. The sensor calibration process is carried out using the Linear Progression method. The equation used in this method is

$$y = ax + b \qquad (6)$$

Description:
y = luxmeter value
a = constant
b = constant
x = sensor value

To find out how much error value is left from the results of the calibration process. So, the table below will compare the results of the actual sensor readings with the sensor calibration results. The error percentage value is obtained by calculating the average value for each point first and then comparing it.

Table 2. Error comparison result

No	BH1750 Sensor	Dekko-HSS6612	Location	Error (%)
1	1	1	0	0
2	2,03	2,03	1	2,03
3	1,33	1,33	2	1,33
4	0,61	0,61	3	0,61
5	0,96	0,96	4	0,96
6	0,69	0,69	5	0,69
7	2,02	2,02	6	2,02
8	0,57	0,57	7	0,57
9	1,83	1,83	8	1,83
10	3,13	3,13	9	3,13
11	2,76	2,76	10	2,76
12	1,73	1,73	11	1,73
13	0,78	0,78	12	0,78
14	2,51	2,51	13	2,51
15	0,50	0,50	14	0,50
16	0,94	0,94	15	0,94
17	2,03	2,03	16	2,03
18	1,13	1,13	17	1,13
19	0,73	0,73	18	0,73
20	0,45	0,45	19	0,45
Average Error				1,34

Table 2 show the error comparison results that has been calculated. The error percentage value is obtained by calculating the average value for each point first and then comparing it. The average error percentage is 1,34% that means the error is low enough. So, the calibration using Linear Progression method is success.

2. Controller Testing Result

Controller testing is carried out by applying the method used to the microcontroller. In this research, the method used is the Kalman filter. While the microcontroller is ESP32. This test function to find out how effective the Kalman filter method is if it is integrated with ESP 32.

Previously, it is necessary to know in advance that there are two parameters whose values have been determined. The parameters are the process variance matrix (Q) and the measurement matrix (R). The determination of this value is obtained through a trial-and-error process to get a constant with the best filter reliability.

In the filtration process, the values of the variables R and Q applied are 100 and 1. Once determined, the next step is to test the filter applied to the BH1750 light sensor. There are several variants of the values used in this test. Starting from the smallest to the largest. The test scheme is carried out by comparing the graph of the filtered sensor readings with those that do not use the filter on the Serial Plotter in the Arduino IDE. To make it easier to understand, the following is a picture of the results of the tests that have been carried out.

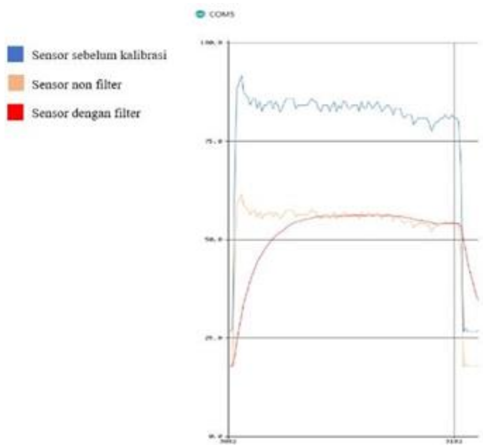

Figure 6. Comparison results for controller testing

Figure 6 is a chart that show the comparison between uncalibrated sensor, calibrated sensor, and calibrated sensor with Kalman filter. The blue one is for uncalibrated sensor, the cream one is for calibrated sensor, and the red is for calibrated sensor with Kalman filter. From the picture above the best reading result is the red one. A sensor that has been calibrated will have appropriate reading result with the calibrated lux meter and then the Kalman filter will help to make the reading result more stable.

3. Stability Test Result

At this stage, the test is carried out through a process of calculating the distribution of data with a 95% confidence level. The measurement data is said to be stable if it is between the lower and upper limits of the calculation results. The following is the formula used for testing the stability of the data.

$$X' \pm 2S \quad (7)$$

Description:
X' = mean of sample
s = standard deviation of sample

Based on the calculations. The use of the Kalman Filter method is quite effective in helping to stabilize the data from the BH1750 light sensor readings. The results are proved by the increase in the percentage level of stability. Which was initially 53,57% when not using the Kalman Filter, then increased to 78,57% when already using the Kalman Filter. The calculation of these percentages can be seen in the table 3.

Table 3. Calculation of the percentage level of stability

stability test result for measurement without Kalman	
amount of test data	28
amount of stable data	15
amount of unstable data	13
percentage level of stability	53,57%
stability test result for measurement using Kalman	
amount of test data	28
amount of stable data	22
amount of unstable data	6
percentage level of stability	78,57%

4. Precision Test Result

In this subsection, the level precision of the measurement result will be tested for each of the data obtained. The test is to compare the level precision of the measurement results without the Kalman filter with those using Kalman Filter. In this test, the confidence level used is the same as the previous process, which is 95%. so, the formula used is as follows.

$$\%precision = 2*s*100 / X' \quad (8)$$

Description:
X' = mean of sample
s = standard deviation of sample

It should be known that the higher the percentage value of the precision level, the wider the distribution of the data from the average value. The more the data spreads away from the average value make an indication of a decrease in the quality of accuracy in a work process in generating data. The table below will show the calculation results of the two measurements.

Table 4. Calculation of the percentage level of precision

precision test result for measurement without Kalman	
percentage level of precision	2,80%
stability test result for measurement using Kalman	
percentage level of precision	1,46%

Based on the table 4, the measurement without the Kalman Filter has the average value of the precision level test at 2,80%, while the average value of the precision level test using the Kalman Filter at 1,46%. It means that the use of the Kalman Filter method can help the BH1750 light sensor reading process become more precision.

5. Accuracy Test Result

At this stage, the test is to see the accuracy of the artificial luxmeter in this research. The comparison process is carried out for both measurements. That is that use Kalman Filter and that do not use Kalman Filter. The following is a comparison result for the two measurements.

Table 4. Calculation of the percentage level of accuracy

accuracy test result for measurement without Kalman	
Error Percentage	2,77%
accuracy test result for measurement using Kalman	
Error Percentage	0,92%

Based on the table above, the measurement without the Kalman Filter has the average value of the accuracy level test at 2,77%, while the average value of the accuracy level test using the Kalman Filter at 0,92%. It means that the use of the Kalman Filter method can help the BH1750 light sensor become more accurate.

CONCLUSION

Based on the analysis that has been mentioned. The comparison process between sensors that use the Kalman Filter and those that do not use it through 3 stages of testing. At the stage of testing the stability level, the percentage value for sensors that use Kalman Filter is 78.57%, while for sensors that do not use Kalman Filter is 53.57%. At the stage of the testing percentage of precision of average percentage value for sensors that use Kalman Filter is 1.46%, while for sensors that do not use Kalman Filter is 2.80%. Finally, at the testing stage, the percentage of accuracy of the average error value for sensors that use Kalman Filter is 0.92%, while for sensors that do not use Kalman Filter is 2.77%.

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