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Development of Infrared Therapy Device Based on Android Application Using Bluetooth Communication to Minimize the Patient Contact

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ABSTRACT Infrared therapy is a therapeutic tool that has the function of dilating blood vessels so that blood flow becomes smoother and the healing process of wounds or inflammation in the body is faster. The heat from infrared therapy lamps can also reduce joint or muscle pain. With the current covid-19 pandemic situation, which requires minimizing physical contact from humans to the equipment used, we have developed infrared therapy technology, which was originally only controlled manually, can now be controlled automatically via an Android smartphone. This research aims to design an infrared therapy device equipped with light intensity settings and a timer controlled by an android. The contribution of this research is the infrared lamp irradiation media system. It has also been equipped with a safe distance of 30-70cm using the HC-SR04 sensor, then equipped with a choice of a maximum therapy time of 10-30 minutes which is used to select the length of the therapy process. In addition, it can adjust the light intensity as needed via Android, which is connected via the HC-05 Bluetooth module, which is enabled to regulate how much the lamp emits light intensity. After carrying out the measurement process, the error value on the timer measurement is obtained from the selection of Low, Medium, and High switches, 10 minutes (1%), 15 minutes (0.6%), 30 minutes (0.3%). The distance measurements are, 10cm (10%), 20cm (2.5%), 30cm (1.6%), 40cm (0%), 50cm (4%), 60cm (1.6%), 70cm (0%). This new development of infrared therapy has three kinds of timer selection with seven kinds of distance measurements. We can conclude that the longer the therapeutic irradiation distance, the lower the error value. The implication of this research is we can easily monitor and adjust the light intensity and time of the therapeutic using our android smartphone without touching the infrared therapy so that it will minimize physical touch from humans to infrared therapy.

INDEX TERMS Infrared Therapy, Distance, Timer, Bluetooth

I. INTRODUCTION

Infrared therapy is a type of therapy using infrared rays as the therapy. This therapy tool can serve to help patients who have complaints of pain such as low back in patients [1]. Infrared therapy has shown improved wound healing [2][3] and relief of arthritic knee pain [4]. Infrared radiation is an electromagnetic wave [5]. According to the difference in wavelength, infrared radiation is divided into Near-infrared radiation (0.8 to 1.5 μm), middle-infrared radiation (1.5 to 5.6 μm), and far-infrared radiation (5.6 to 1000 μm) [6]. Infrared radiation transfers energy as heat by thermoreceptors in the surrounding skin [7]. Some research indicated that far-infrared radiation therapy might improve endothelial function and reduce the frequency of some cardiovascular diseases [8][9][10]. Infrared light can penetrate the top layer of skin and provide healing to muscles, bones, or joints, so it is very

suitable for use as a therapeutic tool. Some therapeutic methods, optical radiation of wavelength approximately equal to 630 nm, can induce selective destruction of tumors [11]. Some sensors have been developed to study the distribution of optical radiation inside the tissues [12][13]. The longer the wavelength, the deeper the light's penetration [14]. Penetration depends on the absorption properties of the skin microstructure [15]. For correct dosimetry, the penetration depth of the light into the tissue is one of the important parameters [16]. A change in blood flows in tissues despite screening from irradiation [17]. The infrared rays' warmth will provide a sense of comfort to the affected organ. According to Michlovits [18], the length of irradiation [19] takes 10 minutes - 30 minutes; according to Tharimsyam states, infrared lamps are good to use with an irradiation distance of 45cm - 60cm because everyone's skin sensitivity is different and can harm the patient and affect the therapeutic effect received. The dose of infrared therapy is for acute cases of irradiation with infrared rays can be given for 10-15 minutes a day as much as one to three times as needed. It is given for up to 30 minutes once or twice a day for chronic cases. Infrared irradiation [20] can be applied at a distance of 50-70 cm. During irradiation, cover the face, eyes, and hair. The eyes must be protected by wet cotton compresses to prevent the clouding of the lens. The temperature of between 34°C and 43°C could cause heat sensitization and corresponding hyperalgesia [21].

Estimates based on national survey data indicate that more than 26% of U.S. adults experience low back pain [22] lasting at least one day during the past three months, and the lifetime prevalence rate of low back pain in Western societies is over 70% used to manage chronic low back pain. Infrared radiation is an invisible electromagnetic wave [23] adjacent to the visible light region of the wave spectrum in nature. Infrared radiation transfers energy, in the form of heat, to surrounding tissues and can be perceived as heat by thermoreceptors [24] in the surrounding skin. Infrared radiation is divided into three categories: near-infrared radiation (0.8-1.5 mm), intermediate-level infrared radiation (1.5-5.6 mm) and far-infrared radiation (5.6-1000 mm). Side effects of infrared therapy [25] are minor burns, increased inflammation, increased pain, and skin allergies in patients with a history of heat allergies. According to the author's observations, therapeutic tools that have been made by users are less effective because patients still have to adjust their position to be treated. The development of science and technology cannot be separated from gadgets (smartphones) which are software used on mobile devices, including operating systems a d core applications. The presence of smartphones with the Android operating system provides a new alternative for gadget users. The use of Android smartphones as a communication tool and smartphones has undergone many developments today [26] to control medical devices. In the development of increasingly modern and increasingly sophisticated medical technology, almost all medical devices are made automatically so that operators can easily operate these devices without disturbing the patient's comfort. The design of infrared therapy [27] has been carried out by several researchers both in terms of process and technology. However, the development does not yet have On/Off automatically. However, this tool uses a standing stand that endangers the user, and the tool's performance is less than optimal. The infrared therapy tool was developed again with the development of three selection modes, namely proximity [28] [29] sensor without a timer, selection of switches (low, medium, high) with timer, and dimmer [30]. This development tool still has a lot of error values for the comparison and does not correctly position the HC-SR04 sensor with the patient.

Based on the description of the literature study that has been described, several things need to be resolved through a study, including reducing the error value against the comparison value, using Android as a light intensity setting, and a timer on infrared therapy devices. Therefore, this study aims to develop an infrared therapy device based on previous research [28][29][30], that is equipped with a proximity sensor, light intensity linkage, and a timer that is set via Android to make it easier for users to use infrared therapy and not reduce comfort for the patient. The use of this design is more effective because it has the advantage of being able to be set remotely.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

The experiment was conducted by patient respondents who experienced muscle and joint complaints. Done for 10-30 minutes by receiving infrared light beam therapy. This study uses the Beurer IL 21 as infrared therapy that emits infrared rays, the HC-SR04 sensor as the distance sensor between the lamp and the patient placed under the Beurer IL21 lamp. Minimum system ATMega 328 is used to process the value of the output display distance through a 2x16 LCD. Bluetooth HC-05 as a liaison between Android and infrared therapy devices. In this study, after the design was completed. Tested the HC-SR 04 and Bluetooth HC-05 sensors according to these specifications. For the output value of Distance that is known through the HC-SR 04 sensor, it will be compared with a ruler. Each measurement range is different, the test results will be different at 7 points of measurement distance, namely 10cm, 20cm, 30cm, 40cm, 50cm, 60cm, 70cm. Timer measurements are carried out to get the results of data carried out 6 times by comparing the length of time set with a time of 10, 15, 30 minutes.

B. THE DIAGRAM BLOCK

In FIGURE. 1, the 220V PLN voltage will be lowered by using an infrared lamp driver to supply the circuit, make a connection with Android using Bluetooth. If it is connected, the Android will control the intensity of the light and the timer required for irradiation. Then the proximity sensor will work to measure the distance that is reflected/hit by the sensor and is displayed on the LCD as a notification of the safe distance

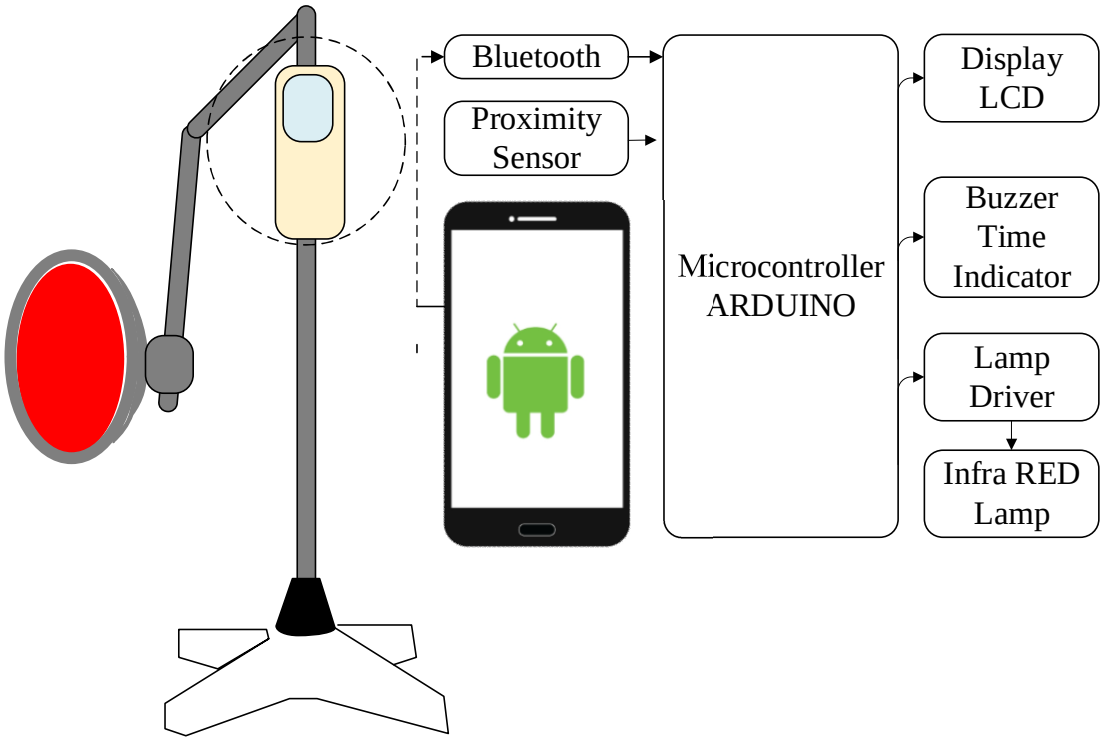


FIGURE 1. Diagram block of the proposed design

of irradiation with the tool range on when the distance measures from 30-70 cm, the sensor is still in scope, the tool is on automatically and when the sensor is not entered in the scope of the tool off automatically. If the timer and light intensity have been set via Android, press the start button to start the therapy process, the microcontroller will send data to activate the driver then the timer will match the specified time when the time is up, the light driver will be turned off by the microcontroller and then the buzzer will sound as a sign of time out.

C. THE FLOWCHART

FIGURE 2 describes the operation of the infrared therapy device. When the tool is turned on by pressing the switch button, the display will light up and the proximity sensor will start working. When the proximity sensor will censor the object to be treated if it is within the range of 30-70 cm, the sensor is still within the range, the device will automatically turn on and when the sensor is not within the scope, the device will automatically turn off. Then connect the Android with a Bluetooth device to set the timer and light intensity. After that press the start button on Android to do therapy. The timer will start working to calculate the counting down according to the timing. The process of calculating this time to perform infrared irradiation. When the time is up the buzzer will sound.

D. CIRCUIT

FIGURE 3(a) is a series of HC-SR04 which is an ultrasonic sensor that can read a distance of approximately 2 cm to 4 meters. This sensor is very easy to use on the microcontroller because it uses four pins contained in the sensor, namely two power supply pins for ultrasonic sensors and two trigger and echo pins as input and output data from the sensor to Arduino. FIGURE 3(b) uses a dimmer circuit that functions to regulate the current of the lamp, heater, and motor speed. This driver circuit uses a resistance of 5 watts because to withstand very high AC voltages it can cause the resistor to burn easily if with a small wattage.

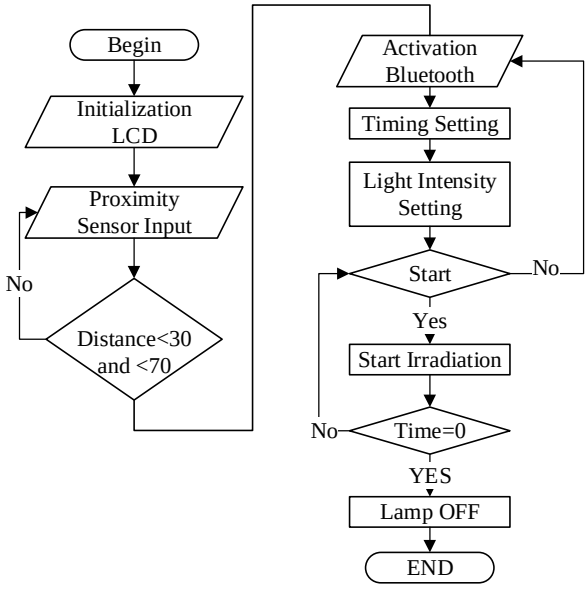
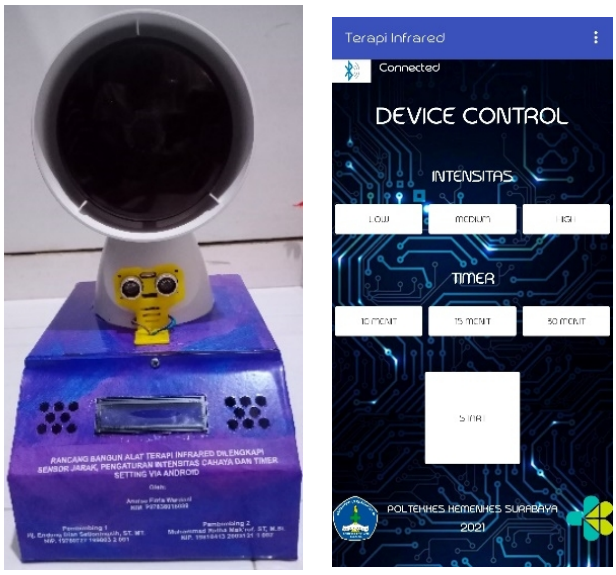


FIGURE 2. **The flowchart of the IR theraphy**



(a) (b)

FIGURE 3. **Results of Design Tool Designs and Results of Android Applications, (a) the design, and (b) the Android Application.**

III. RESULT

TABLE 2
The effect of distance on Light Intensity Measurement (mean± standard deviation) for low, medium and high. Each distance setting, the measurement was conducted in ten times. Mean indicates the average value of the ten measurement and SD indicates standard deviation.

Distance	Low (lux)	Medium (lux)	High (lux)

TABLE 1
Timer setting selection measurement (error value and standard deviation) for low, medium and high selection. Error values calculate based on standard and proposed design and SD indicates the standard deviation value.

Timer Setting	Low (minute)		Medium (minute)		High (minute)	
(minute)	Error (%)	SD	Error (%)	SD	Error (%)	SD
10	1	0.22	1	0.15	1	0.15
15	0.6	0.15	0.6	0.22	0.6	0.22
30	0.3	0.15	0.3	0.15	0.3	0.31

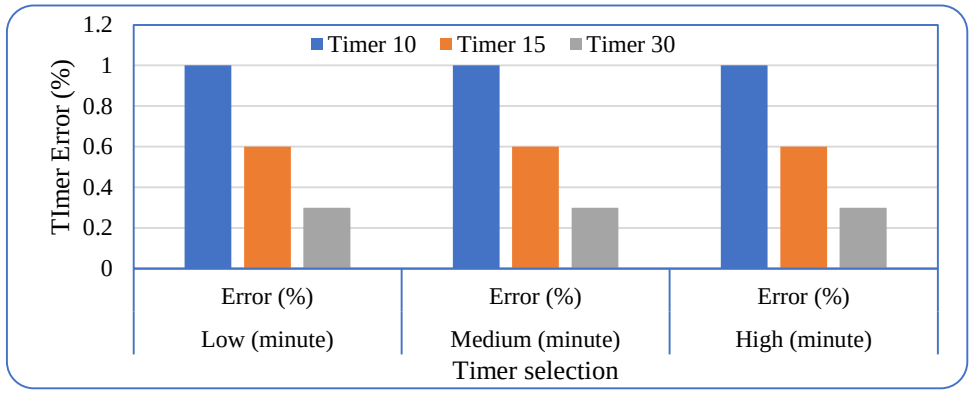


FIGURE 4. The timer error among timer setting selection measurement (error value and standard deviation) for low, medium and high selection. Error values calculate based on standard and proposed design and SD indicates the standard deviation value.

FIGURE 3 shows that the HC-SR04 is placed under an infrared lamp. LCD is at the front. In the android application, there is a selection of light intensity, namely low, medium, and high, and a timer selection of 10, 15, 30 minutes. After making the module, it is necessary to carry out testing and measurement. To find out how precisely the manufacture of this module. For this reason, the authors collect data through measurement and testing. The goal is to determine whether each component can run according to its planned function and the location is carried out to collect research data at the Surabaya Electrical Engineering Campus Workshop. In TABLE 1 measurements have been measured against the output of the lights drivers with 3 conditions, namely low, medium, and high. TABLE 1 shows timer setting selection measurement (error value and standard deviation) for low, medium and high selection. Error values calculate based on standard and proposed design and SD indicates the standard deviation value. The difference in the timer setting in high mode shows an increase in the standard deviation value. A decrease in the standard deviation value in low mode and there is an increase and decrease in the standard deviation value in medium mode. FIGURE 4 shows the timer error among timer setting selection measurement (error value and standard deviation) for low, medium and high selection. Error values calculate based on standard and proposed design and SD indicates the standard deviation value. There is no change in the value of the timer error in the three preset modes (low, medium and high). TABLE 2.shows the effect of distance on Light Intensity Measurement (mean± standard deviation) for low, medium and high. Each distance setting, the measurement was conducted in ten times. Mean indicates the average value of the ten measurement and SD indicates standard deviation. There is a decrease in the value of the standard deviation for every 20 cm increase in the given distance.

TABLE 3
Distance Results

Distance (cm)	Error (cm)	SD (cm)
10	10%	0
20	2,5%	0
30	1,6 %	0

40	0%	0
50	4%	0
60	1,6%	0
70	0%	0

FIGURE 5 shows the effect of distance on Light Intensity Measurement (mean± standard deviation) for low, medium and high. Each distance setting, the measurement was conducted in ten times. Mean indicates the average value of the ten measurement and SD indicates standard deviation. There is a decrease in the intensity value for every increase in a given distance that is in each mode. TABLE 3 shows the measurement that have been carried out to determine the average, deviation, and error on the proximity sensor. The data was taken using a comparison, namely the meter with units of cm. FIGURE 6 shows the value of light intensity at a fixed distance, namely a distance of 30, 50, 70 cm at low conditions. Data collection was repeated 10 times to get the average value. The percentage of error light switch selection which is divided into three-timer selections (low is for 10 minutes, the medium is for 15 minutes, and high for 30 minutes), the result shows that there is no differentiation of the error light switch selection it is about 0% -1 % of error. The average of error light intensity measurement which is divided into three kinds of distance (30 cm, 50 cm, and 70 cm), the result shown that in high conditions, the average of light intensity measurement has the highest average result, that is 9318.3 in 30 cm distance, 4758.3 in 50 cm distance, and 2123.3 in 70 cm distance

using a comparator with low, medium, and high conditions show the highest error value of 10% at a distance of 10cm. Measurements of light intensity have been carried out in low, medium, and high conditions (TABLE 1, 2, and 3) using a Lux Meter with different distances, and there are differences in light intensity.

The limitation of this research is using three kinds of timer selection (low, medium, high) with 7 kinds of distance measurements (10cm, 20cm, 30cm, 40cm, 50cm, 60cm, 70cm). The implication of this research is we can easily monitor and adjust the light intensity and time of the therapeutic using our android smartphone without touching the infrared therapy, so it will minimize physical touch from humans to infrared therapy.

The benefit of this research is that it can set the light intensity and timer remotely within Bluetooth range. The weakness of this study is that there are still many error values in this study.

V. CONCLUSION

The purpose of this study is to make it easier to use and this module can be set the light intensity and timer remotely using an android connected via Bluetooth. When testing the module, the module works well according to what is set by Android. The experimental results show that there are differences in the error value and intensity in infrared therapy made with low, medium, and high conditions, also at seven different distances that have been set. The highest error value in distance measurement is 10% at 10 m distance, this shows the shorter the measurement distance, the greater the error The average of error light intensity measurement which is divided into three kinds of distance (30 cm, 50 cm, and 70 cm), the result

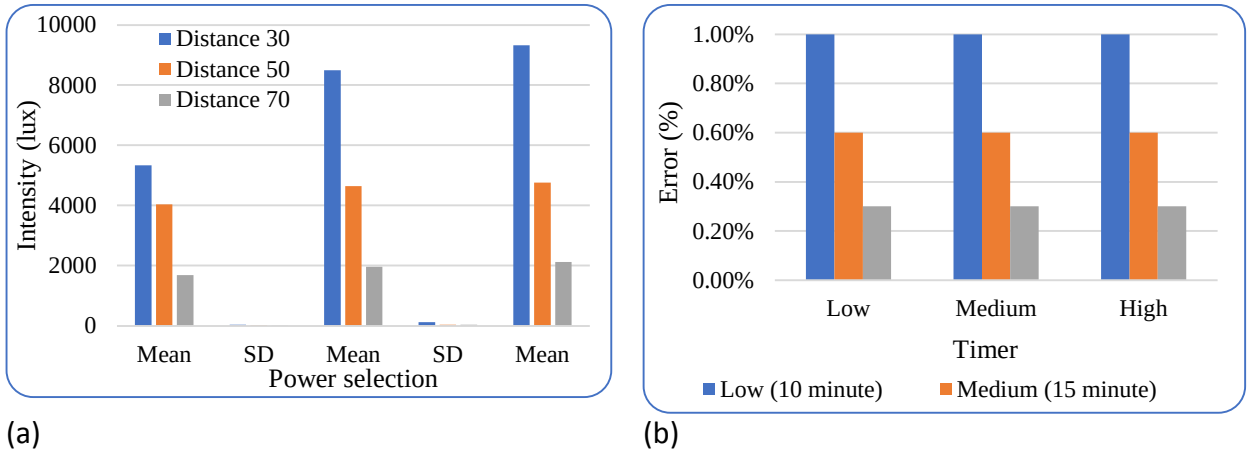


FIGURE 6. Effect of distance to Intensity (in lux), a) intensity variation based on distance, b) error value for each timer selection.

IV. DISCUSSION

Based on the measurement used a timer (TABLE 2, and 3) for low, medium, and high (TABLE 1) setting, the error value is not more than 1%. Measurements on the proximity sensor shown that in high conditions, the average of light intensity measurement has the highest average result, that is 9318.3 in 30 cm distance. It can be concluded that the best therapeutic irradiation is obtained at a distance of 30 cm in 30 minutes

irradiation. For the future work, It is hoped that this module can be developed by reducing the error value and the sensor can be replaced with a better one with the times.

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BLUETOOTH CONNECT PROGRAM

Figure. 6 is a listing of the Bluetooth connection program in the MIT App Inventor application. Android will display a "Select Device" notification if Bluetooth has not been activated and "Connected" will appear if Bluetooth is connected.

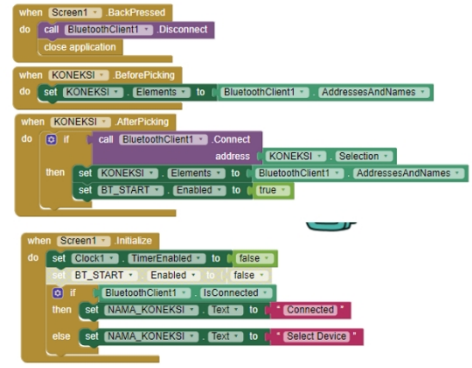

FIGURE 6. **Bluetooth Connect Program**

SELECTION OF LIGHT INTENSITY

Figure. 7 is a low-intensity selection program. The button pressed corresponds to the selection of the desired light intensity. There are 3 light intensity selection buttons

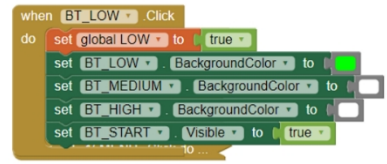

FIGURE 7. Selection of Light Intensity

TIMER PROGRAM

Figure. 11 is a listing of the timer program. The timer will work if you have selected the intensity of the light and the desired timer.

FIGURE 11. Stop Button

APPENDIX

THE LISTING PROGRAM FOR ARDUINO

Pseudocode: 1. Describes a proximity sensor pulse signal with a duration of at least 5 S (5 microseconds) applied to the trigger pin. After that, the sensor transmits eight pulses of ultrasonic waves at a frequency of 40 kHz. Meanwhile, the echo pin goes high to start forming the initial echo signal. If there is an ultrasonic signal that is reflected or received by the receiver, then the Echo signal immediately changes to Low (low). The width of the time of the Echo signal is used to measure the distance between the sensor and the object or objects.

```
#define echoPin 7
#define trigPin 6
{
 Serial.begin (9600);
 pinMode(trigPin, OUTPUT);
 pinMode(echoPin, INPUT);
 }
void Device()
{
 digitalWrite(trigPin, LOW);
 delayMicroseconds(5);
 digitalWrite(trigPin, HIGH);
 delayMicroseconds(5);
 digitalWrite(trigPin, LOW);
 delayMicroseconds(5);
 duration = pulseIn(echoPin, HIGH);
 distance = (duration/2)/29.1;
 //lcd.setCursor(0,0); lcd.print("       ");
 //lcd.setCursor(0,1); lcd.print("       ");
 lcd.clear();
 lcd.setCursor(0,1); lcd.print(distance);
 lcd.setCursor(4,1); lcd.print("cm");
 }
```

Pseudocode: 2. Listing program.2 is a distance activation program that enters through the HC-SR04 sensor by giving HIGH and LOW logic to the echo and trigger pins. In addition, there is also a distance reading command from the sensor. The NPN is used to cut off the voltage to turn off the lights when the distance is not following the regulation.

```
IF (distance > 0 && distance < 30 )
 {
  digitalWrite(NPN, LOW);
  lcd.setCursor(0,0); lcd.print("jarak dekat");
 }
 IF (distance > 29 && distance < 71)
 {
  digitalWrite(NPN, HIGH);
  lcd.setCursor(0,0); lcd.print("jarak menengah");
 }
 IF (distance > 70)
 {
  digitalWrite(NPN, LOW);
  lcd.setCursor(0,0); lcd.print("jarak jauh");
 }
 delay(500);
 }
 analogWrite(3, 0);
 lcd.setCursor(0,0);lcd.print("jarak jauh");
 }
 delay(500);
 }
```

Pseudocode: 4. In the program, there is a command to call void as a command to control the light intensity and timer from Android

```
String android;
void MitApp()
{
while (Serial.available()>0)
{ android = Serial.readString();
Serial.println(android);
IF(android== "1")
{ analogWrite(SSR,51);
delay(2);
//analogWrite(SSR,0);
//delay(8);
Serial.println("LOW");}
IF(android== "2")
{ analogWrite(SSR,51);
Serial.println("LOW");}
IF(android== "3")
{ analogWrite(SSR,51);
Serial.println("LOW");}
IF(android== "4")
{ analogWrite(SSR,140);
Serial.println("MEDIUM");}
IF(android== "5")
{ analogWrite(SSR,140);
Serial.println("MEDIUM");}
IF(android== "6")
{ analogWrite(SSR,140);
Serial.println("MEDIUM");}
IF(android== "7")
{ analogWrite(SSR,255);
Serial.println("HIGH");}
IF(android== "8")
{ analogWrite(SSR,255);
Serial.println("HIGH");}
IF(android== "9")//kondisi HIGH & 30 MENIT
{ analogWrite(SSR,255);
Serial.println("HIGH");}
IF(android== "0")//kondisi MATI
}
```