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Development of Mobile-based Robotic Control for Real-Time Radiation Residue Monitoring System

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Abstract: Radiation has many different forms and comes from many other sources in good term nor can be harmful to humans. Radiation congested environments importance to monitor regularly for minimize from risk. Although there is, exist many advance radiation-monitoring systems, but some human interaction during monitoring can direct exposure to radiation related disaster. Therefore, to avoid radiation related disaster due to direct exposure, a robot can replace human interaction during monitoring radiation. In this project, a mobile-based robotic control develops for real-time radiation residue monitoring system using Geiger-Muller Counter sensor. This sensor consists Geiger-Muller tube j305, which read radiation value in units of Counter Per Minutes (CPM) and micro Sievert per hour (uSv/h). A separate algorithm is implemented into this robot, which the robot control using android application and enable the user to monitor the radiation value on OLED display and Wi-Fi through display on graphical user interface. Therefore, a dashboard created using an Adafruit IO platform for analyzed the radiation value in real-time. The data can observe in unit term of Counter Per Minutes (CPM) and radiation dose in micro-Sievert per hour (uSv/h). The experiment conducted using tested with a harmless radiation contain material for analyzed the result. The threshold (CPM) value exceed makes an alert warning notification on dashboard in real-time.

Keywords: Mobile-Based Robot, Radiation Residue Monitoring System, Robotic Control

1. Introduction

Malaysia moves towards era of modern technology it is helping various organizations in different industries progress at a much faster rate. Sometimes the way we implement various technologies ends up harming human life [1]. Moreover, the impact of technology on the environment has included misuse and damage of our natural earth. It may come from pollutants such as air, soil, water and even electromagnetic wave [2].

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There are two types of electromagnetic waves in term of radiation, which are ionizing, and non-ionizing radiation. Ionizing more energetic then non-ionizing radiation When presenting ionizing radiation in environment can affect human by damaged the body tissue which then leads to organ failure and result in death [3]. The environment of radiation hazards should monitor using radiation monitoring system to ensure acceptably safe and satisfactory radiological. To monitor radiation contamination area, must keep at least certain distance from the source, the farer as much the less intensity will be.

In this project, design a radiation-monitoring sensor with Geiger Muller counter consists of j305 tube. The Geiger counter tube j305 support to monitor radiation value. The Geiger sensing element, which detect the radiation wave and processing electronics, and produce measurement reading. The tube is filled with an inert gas such helium, neon or ardon at low pressure. In addition, when a single gamma or beta ray entering the tube a small amount of ionization is produce. Then the center electrode, which is at high positive potential, attracts the electrons and gives them energy to produce further ionization until the whole volume contains ion pairs. This Geiger counter count CPM value and produce uSv/h. This monitoring system are durable an portable [4]. This radiation monitoring system can take reading in real- time. There was a mobile control robot system build for monitor radiation residue in kept distance. The monitoring system intermediated with Global Positioning System (GPS), which can locate exact location with reading value.

2. Methodology

2.1 Project Overview

The system developed with mobile robot and radiation monitoring system in different algorithm flow. Figure 1 shows the system overview of this project. The structure was made into one robot and support the scope of the project to produce the real- time result. The robot controlled using Bluetooth module Hc-06 and Arduino Mega2560 microcontroller with android application. The application develops with robot direction and live stream video for change direction. The controlling device of the whole robot system are an Arduino Mega2560.

The robot is developed for monitor radiation. The radiation sensor board was design on robot to monitor radiation in real-time. The monitoring system of an Esp32, Geiger Muller counter sensor, OLED display and GPS module. The robot can move one place to another place of residue location and read the data through radiation sensor board. The sensor board send the data to Esp32 acting as the base station. The data from Esp32 can display in both OLED display and Adafruit IO dashboard for live monitoring. The robot is controlled from mobile and its main task to monitor radiation value in real-time. This overall system is mounted on a chassis consisting with four DC motor and Mecanum Wheel.

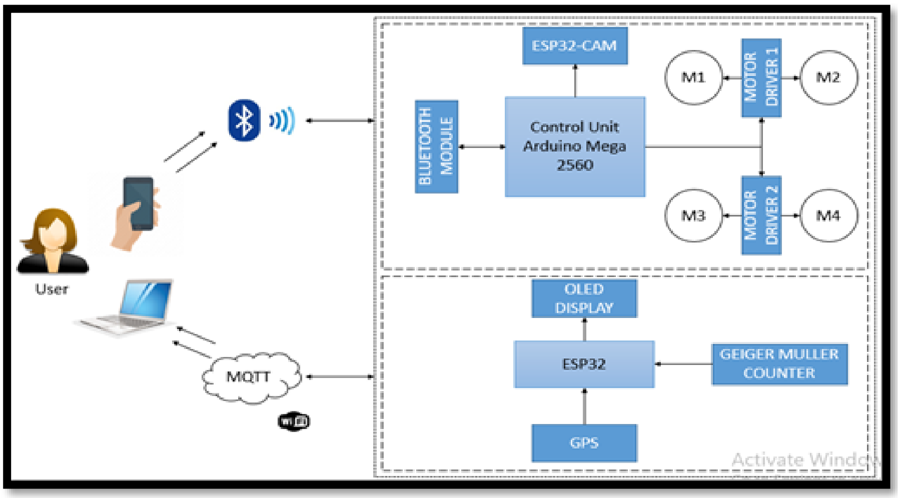


Figure 1: System overview

2.2 Hardware Design

The circuit diagram of this robot was explained in this stage. The robot in the project is made to move in Omni-directions using the Android mobile phone. The circuit is built around Arduino Mega 2560 controller board, Blue-tooth module HC-06, Esp32-CAM, motor driver 2x L293N, DC motors motor 1, motor 2, motor 3 and motor 4. The circuit uses two power source batteries. First battery 9volt is used to power the Arduino Mega 2560 controller board and the other is 12volt used to power the motors. Figure 2 shows the mobile based robot control.

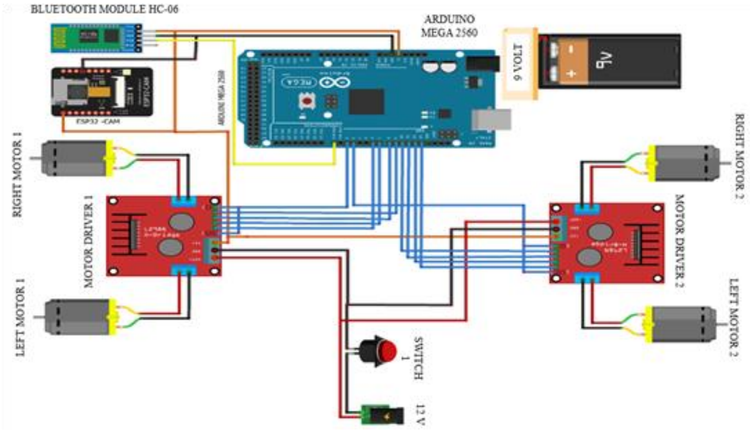


Figure 2: Circuit connection of Mobile Control Robot

On other hand, another algorithm electronic circuit implemented for real-time radiation monitoring system. Figure 3 shows the circuit diagram of radiation sensor board. The sensor platform was integrated with ESP32, Geiger Muller Counter, NEO-6M GPS, 0.96"OLED display and 5v power supply. Geiger Muller counter will read radiation values on its surrounding through the robot control movement. The Geiger counter tube j305 for support to monitor radiation value. The Geiger sensing element, which detect the radiation wave and processing electronics, and produce measurement reading. This Geiger counter count CPM value and produce uSv/h. The reading value from Geiger Muller Counter and GPS location from NEO-6M GPS store on ESP32.

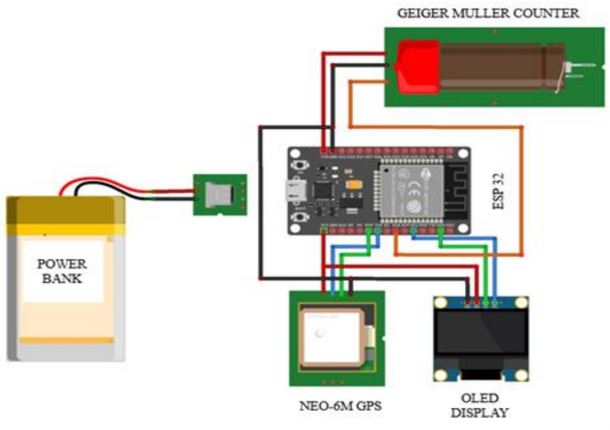


Figure 3: Circuit diagram of radiation sensor board

2.2.1 Mechanical Design

This section is essential in constructing the robot. Since the robot is loaded with two main boards, the size of robot must be in medium size with less weight. The weight of the robot around 3 kg and the motor can torque high to 12V, 120rpm in per minutes. This could easily move around the surrounding. The material that has been used to build the prototype of this robot is acrylic sheet with 3 mm thickness and an aluminum border 30L x 20W cm. Acrylic sheet is a transparent thermoplastic material, which regular used for to build robots chassis with mounted with wheel. The following Figure 4 shows the side view of the proposed robot using SolidWork and the structure view of two main board of radiation sensor board and motor controller.

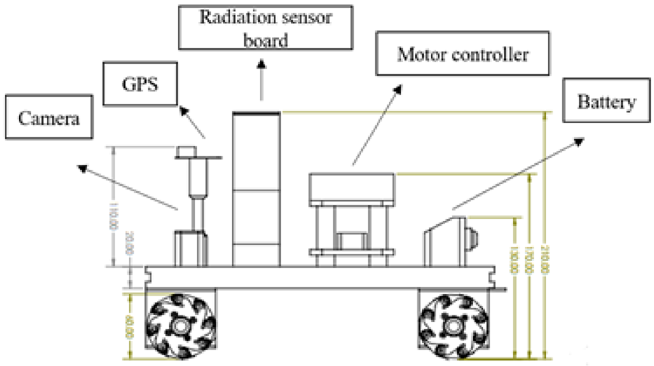


Figure 4: Side view of the robot

Besides, the basement of robot design with Mecanum wheel. The principle of a central wheel with a number of rollers placed at an angle around the periphery of the wheel [5]. Figure 5 shows the schematic diagram below shows consists of four Mecanum wheels. Each individual wheel direction and speed, resulting force vector in any desired direction thus allowing the platform to move freely and without changing the direction of the wheel [1]. The wheel is driven by a 12V DC motor and contains set of passive rubber cylinders that are oriented at an angle of 45° to the axis of rotation of the wheel. The 45° orientation of the rollers is what gives the robot the ability to move in directions other than command forward and backwards..

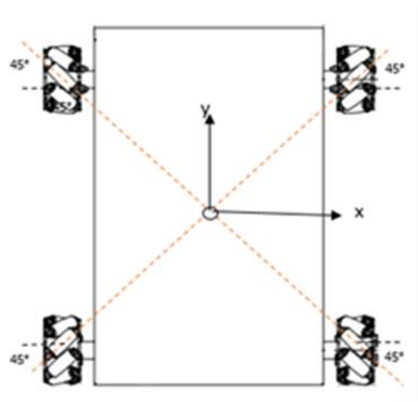


Figure 5: Schematic diagram of Mecanum wheel with chassis basement [5]

2.2.2 Prototype Set-Up

The robot is built around Arduino Mega 2560 controller board, Blue-tooth module HC-06, Esp32-CAM, motor driver 2x L293N, DC motors M1,M2, M3 and M4. Moreover, robot in the project is made to move in Omni-directions using the Android mobile phone. The received instruction from mobile application controls four DC motor through L293D motor driver. A wireless camera is mounted on the robot for streaming real visual video, which can navigate the robot in same mobile app. The mobile is interfaced to the device by using Bluetooth. The Bluetooth device HC-06 module is too added to Arduino mega to receive command from mobile. The prototype of the robot shows in Figure 6.

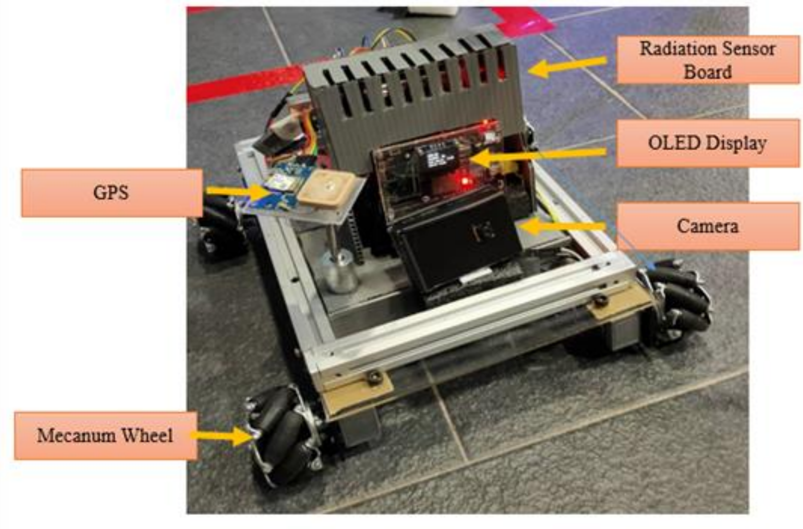


Figure 6: Prototype of Mobile based Robotic control in real-time Radiation Residue Monitor system

2.3 Software Design

In this project, Arduino IDE used to program software coding. This project developed on two main microcontrollers, which is Arduino Mega 2560 (Mobile Control Robot) and ESP32 (Radiation Monitoring System). The microcontroller Arduino Mega 2560 coding for interfaced to the Bluetooth module through UART protocol and it is embedded in C language. Furthermore, the coding for robot direction tested on serial monitor before tried on android application. After the testing, the readString on coding successfully change the robot direction and testing made too speed mode. Furthermore, the ESP32 is the microcontroller of radiation sensor board. ESP32 and ESP32-CAM is a different developer board. The Arduino IDE is compatible board so for testing the coding, there need to install different library for ESP32 and ESP32-CAM. To support program on Arduino IDE, needed to add an additional source file (JSON) to the Arduino IDE preferences. The coding software developed on radiation sensor board to interface between ESP32 to read data from Geiger Muller Counter.

2.3.1 Android Application Design

The name of the application is ‘Mecanum Wheels Robotic Vehicle’ shows in Figure 7. The application configures with Bluetooth connecting with HC-06 and Wi-Fi connection with ESP3- CAM from Robot. Moreover, the camera was streaming after the button CAM-CONNECT click. There was ten different direction control for Mecanum wheel. The robot can control to Forward, forward Left, Forward Right, Left, Right, Backward, Backward Left, Backward Right, Rotating Left and Rotating Right. The direction also can control depend on speed of the motor. The normal dc motor can run motor speed maximum to PWM 255. In the project the speed motor set to three, various option which; Speed A is PWM 150, Speed B PWM 200 and Speed C is PWM 255.

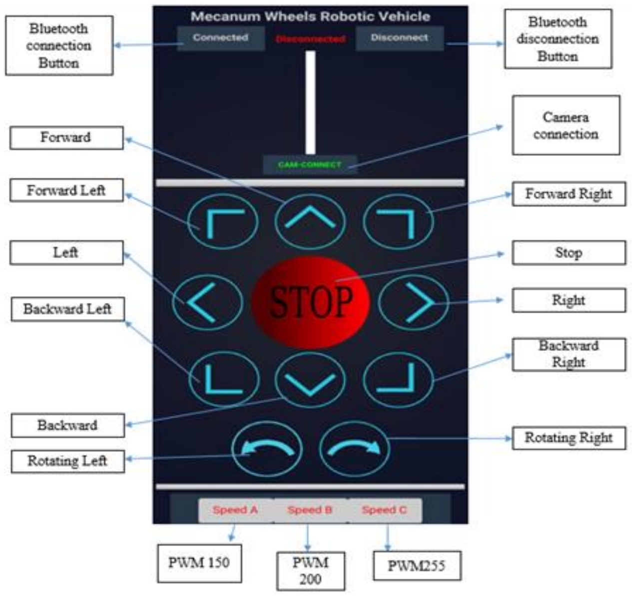
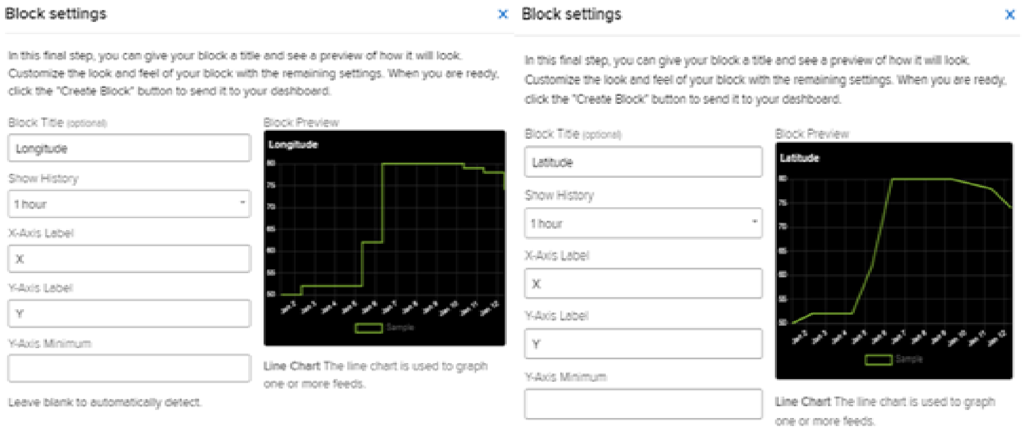


Figure 7: Android Application

2.3.1 Adafruit IO Dashboard

Adafruit IO is a simple web server that can access in real-time. In this project the dashboard support to monitor the radiation value in real-time and notify the warning message if the radiation readings exceed the threshold value. This platform will achieve third objective of the project by collecting data in cloud service. This server board can access any time via internet. There is several progresses have to setting up for this project. Figure 8 and Figure 9 show the setting of each blocks on dashboard.

Figure 8: Dashboard block settings for CPM, uSv/h and Alert system



Block Longitude   Block Latitude

Figure 9: Dashboard block settings for longitude and latitude

3. Results and Discussion

The robot was tested on the On-way Track with different length of measurement. The On-way track is monitor start at one place to exit another place .Totally the robot was tested with 3 different length starting from 1.2-meter, 2.4-meter and 3.0-meter. The image of test for this experiment is shown in Figure 10 and Figure 11.The reading of the testing were recorded in a table measuring the time taken to reach the location of Ionization chamber, to monitor the radiation value. The time reached to every distance was used to record on timer. Then compare the 'time taken to reach' and 'the time taken to read' in seconds. The experiment was repeated with different distance and was tabulated in Table 1.

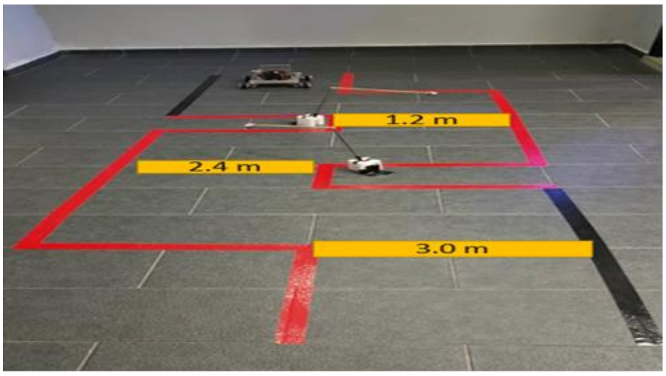


Figure 10: On-way Track testing of robot

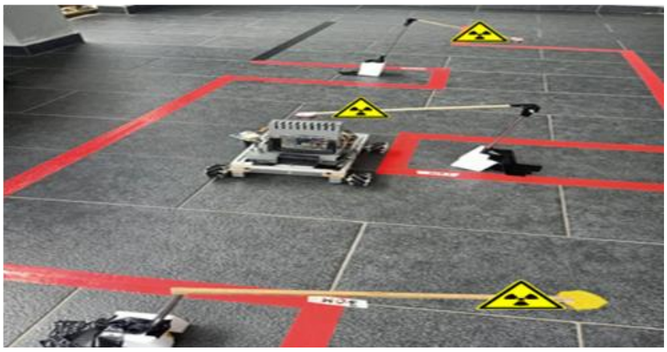


Figure 11: The robot monitoring radiation

Table 1: Result of On-way track testing

Distance (m)	Time taken to reach	Time taken to read	Time taken to read (s)	CPM value more then 80	Time taken to send warning
1.2	2:39:39PM	2:41:10PM	1.31	92	2:41PM
2.4	2:41:55PM	2:44:26PM	2.31	80	2:44PM
3	2:45:12PM	2:46:27PM	1.15	80	2:46PM

The tabulated data shows the peak value of every distance, which produce threshold value for CPM. Every distance consists ionization chamber and it is not failed to detach the hazard of radiation. The time taken to send warning notification as the same time read threshold value for CPM. Although all the three processes take extra time as the distance, but it proves that this robot can monitor and warning the user within the real-time. Table 2 shows the reading takes from real-time radiation monitoring system. The threshold value of CPM exceeds to more than 80 should consider to the place exiting radiation.

Table 2: On-Way Track Monitoring Result from Dashboard

Date	Time	CPM value more then 80	uSv/h	Latitude	Longitude
15/06/2021	2.41PM	92	0.61	3.133089	101.3797
15/06/2021	2.44PM	80	0.53	3.133305	101.37993
15/06/2021	2.46PM	80	0.53	3.133286	101.37995

Figure 12 and Figure 13 shows the distance 1.2 meter, the CPM value 92 and uSv/h value 0.61 obtain at 2.41PM the same time warning notification received shows in Figure 14. The GPS location was at latitude 3.133089 and longitude 101.3797.

The converting factor (CF) for GM tube for this robot (J305β). The calculation of μSv/h under Amerium^{241}.

(J305β): CPM/ 151 for dose level Amerium^{241} [6]

Thus;

1 CPM = 0.006622516 μSv/h

92 CPM = 92/151

→ = 0.609271523 μSv/h

80 CPM = 80/151

→ = 0.529801324 μSv/h

80 CPM = 80/151

→ = 0.529801324 μSv/h

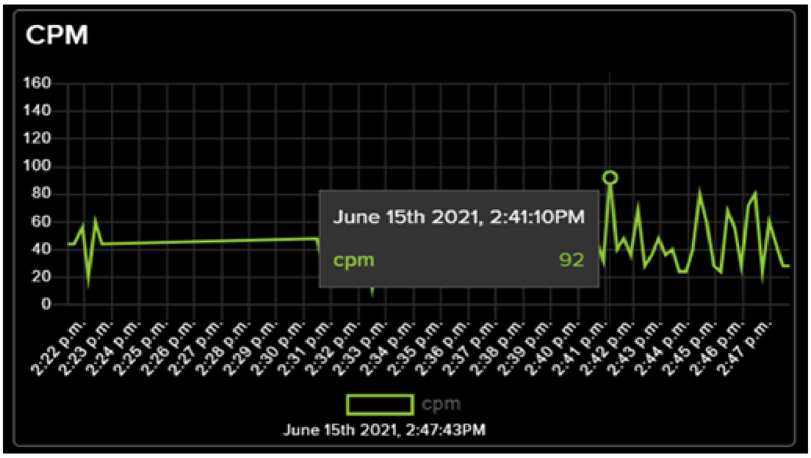


Figure 12: CPM value at 1.2-meter distance

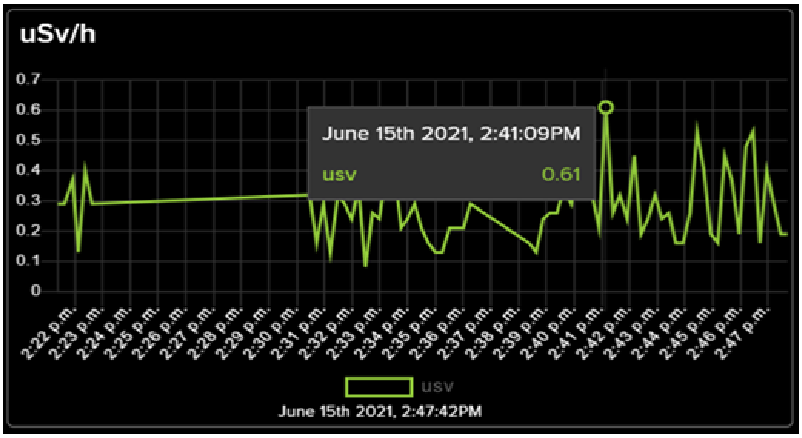


Figure 13: uSv/h value at 1.2-meter distance

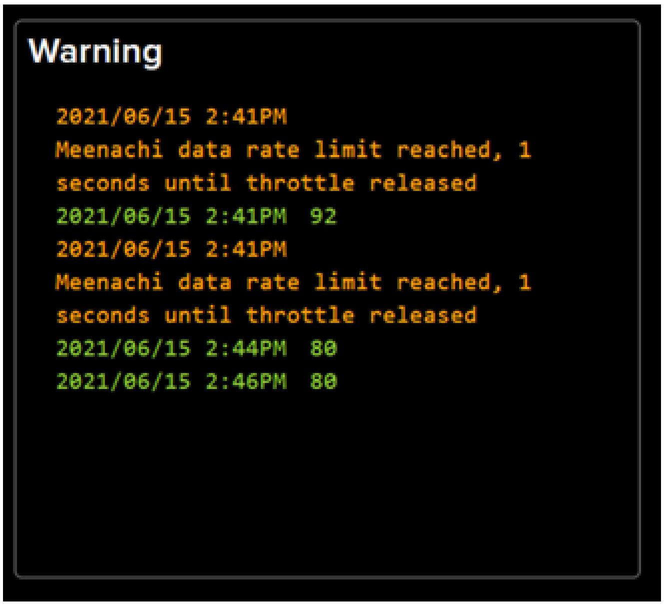


Figure 14: Warning notification

4. Conclusion

In conclusion, the target to test radiation contamination material measure in term of CPM and uSv/h achieved successfully using tested Ionization chamber. Finally the project is to alert the user in case the hazards area exceed threshold value in real-time by using Adafruit IO. It has been achieved with develop on a cloud server to produce the radiation monitoring value in Real-Time and able to follow up the alert configuration if the threshold value exceed, the functionality tested in Real-Time.

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