Analysis of Internet-Based Smart Safety Helmet Systems in Occupational Health and Safety Implementation

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KEYWORDS

Work accident, Smart Helmet, Nodemcu, IoT, Occupational Safety and Health

ABSTRACT

The Smart Safety Helmet, utilizing Industrial Revolution 4.0, addresses the high rate of construction accidents with efficient data management. Equipped with Nodemcu technology, it constantly transmits location data to related parties through a smartphone link. Upon a strong impact, the GPS Shield retrieves accident coordinates, sending an instant location link to users. Crash sensor testing reveals a baseline value of 0, triggering notifications only upon a significant impact. The tilt sensor, yielding X: 325.5, Y: 348.65, Z: 253.73, measures helmet inclination. Android smartphone testing confirms accurate data presentation. The GPS module records latitude: 0.542073, longitude: 123.089958. Discrepancies in displayed location on Google Maps result from GPS signal variations, device factors, and module placement. This integrated system ensures swift accident alerts, enhancing safety measures in the construction industry.

1. Introduction

In work, construction workers have a risk of at work, construction workers have a higher risk of work accidents because workers have direct contact with heavy, sharp, and electrical objects. Construction projects are activities that are prone to work accidents. If a work accident occurs, the impact will vary from mild to serious. This fact results in the need for work safety management which plays an important role in preventing work accidents in construction projects. Developments and new thoughts are expected to universally bring down the quantity of work accidents in the development business, given the high rate of work accidents in Indonesia and even. Ensuring likely workers in the development business are qualified is one move that might be made (Edriani and Supriani, 2020). Worker safety has expanded because of the advancement of occupational health and safety achieved by information and communication technology (ICT) (Gómez-Fernández and Mediavilla, 2021). Since ICT-based personal protective equipment (PPE) can make decisions based on natural boundaries, utilizing it brings down the probability of accidents at work. Project Helmet: The main thing to a firm and a representative is work safety (Priyanka et al., 2023). The Work Regulation additionally contains guidelines about K3, or occupational health and safety (Kodric et al., 2021). Bosses and representatives should know about fitting standards for workplace safety, one of which is the utilization of personal protective equipment (PPE). PPE models can be created all things considered and gadgets with further developed highlights like observing, ecological detecting, and take a chance with recognizable proof can be made thanks to standards like the Modern Internet of Things (IoT) and Artificial Intelligence (man-made intelligence) (Lomotey, R.K., & Deters, R. 2013). These models watch out for the workplace and ready staff individuals and directors to any inconsistencies or dangers. Eldemerdash, Jayapal, Nataraj, Abdulla, and Abbas (2020). The turn of events and plan of an Internet of Things-based smart safety helmet framework for the use of occupational safety and health (K3) in the development business was the point of this review (Bobir et al., 2024).

2. Methodology

Dataset

The IoT-23 dataset is a comprehensive resourcespecifically created for conducting research and experimentation in the field of Internet of Things (IoT) security. The dataset consists of 23 varied

IoT devices, encompassing a broad spectrum of commonly found devices in smartenvironments, such as thermostats, cameras,and smart TVs. The main characteristics of IoT-23 encompass a wide range of device types, authentic network traffic patterns, and a multitude of security challenges, rendering it avaluable asset for assessing and improving the security of IoT systems. IoT-23 offers a valuable framework within healthcare systemsto comprehend and address potential security vulnerabilities that arise from the incorporationof IoT devices. The utilization of this technology enables to examine weaknesses, evaluate the effectiveness of security measures,and create plans to protect sensitive healthcare information in the rapidly growing network of interconnected medical devices.

Preprocessing

Materials

Internet of Things (IoT)

The thought behind the Internet of Things, or IoT for short, is to build the upsides of consistently connected internet connectivity. Genuine items are remembered for the elements, for example, information trade, remote control, and so on. For instance, food items, gadgets, collections, and any equipment including living things that is connected to neighborhood and international networks through embedded, constantly-dynamic sensors.

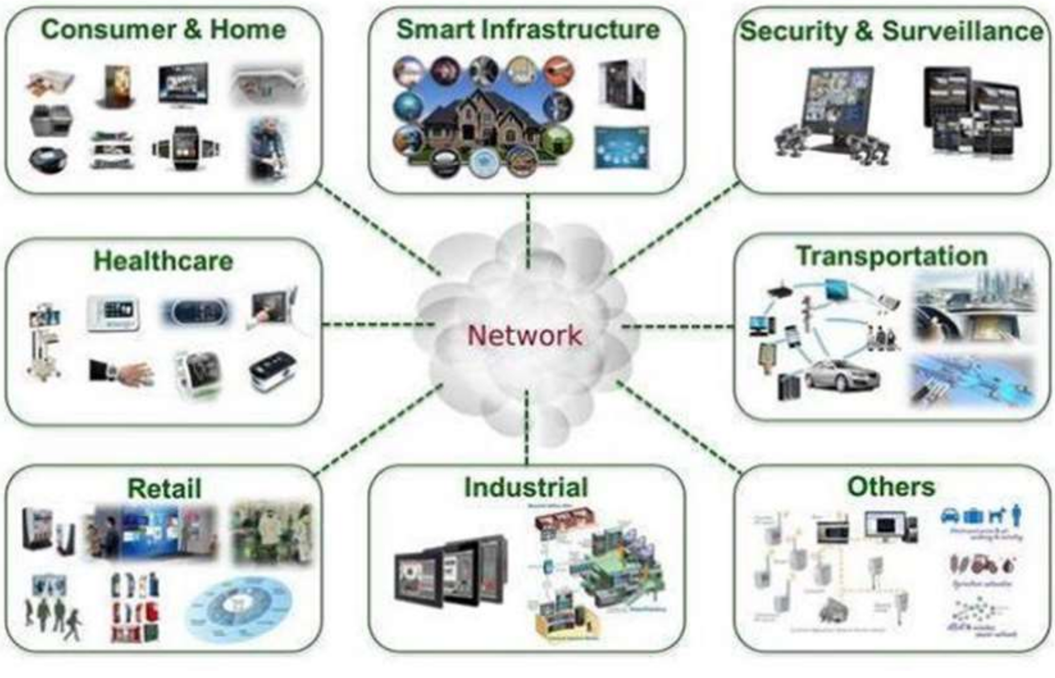

Figure 1. Human Activity Connected to the Internet

The Internet of Things (IoT) is a concept/situation that gives information move over a network between objects without expecting human-to-human or human-to-PC interaction (Sholihah, Hardiningtyas, Hulukati, and Kuncoro, 2024). This definition is like the past one. A subject, for example, a person wearing a heart embed monitor, an animal on a homestead with a biochip transponder, or an auto outfitted with sensors to caution the driver when tire pressure is low, is alluded to as "a Things" in the context of the Internet of Things. Machine-to-machine (M2M) communications in assembling, power, oil, and gas are by a wide margin the most firmly associated with IoT. Systems that are constructed with M2M communication abilities are often called "smart" systems. (For instance, a smart network sensor, smart meter, or smart name). The Internet of Things, or IoT, acquired reputation in 1999 when cofounder and chief overseer of MIT's Auto-ID Center Kevin Ashton involved the term in a presentation. We are pushing toward the following period of internet improvement, where gadgets other than PCs and smartphones can connect to the internet. Be that as it may, different genuine articles will be connected to the internet. Production equipment, vehicles, wearable technology, electronic gadgets, and any other genuine item that is connected to neighborhood and international networks through inserted sensors and/or actuators are a couple of models. (Singh, et al., 2022).

Artificial Intelligence

There are several definitions of Artificial Intelligence (AI), including:

1. A simple way to make computers "think" intelligently.
2. Part of computer science studies the design of intelligent computer systems, namely a system that exhibits characteristics that exist in human behavior, such as understanding a language, studying, considering, and solving a problem.
3. Research on how to program computers to perform tasks that people can currently perform more effectively (Rich and Knight, 1991).
4. Fields of computer science enable him to understand, reason, and act.

Artificial intelligence (man-made intelligence) is characterized by H. A. Simon (1987) as a field of study, applications, and rules relating to PC programming to achieve undertakings that are considered shrewd by people. As indicated by the Reference book Britannica, artificial intelligence (man-made intelligence) is a subfield of software engineering that processes information utilizing heuristic methods or various standards, and utilizes a bigger number of images than numbers to communicate information (Singh, et al., 2022). Based on the few definitions given above, we can say that artificial intelligence (artificial intelligence) is the most common way of planning a PC framework with savvy includes that empower the framework to understand, reason, and act like a human. The objective of simulated intelligence improvement is to make systems and techniques to solve issues like picture handling, arranging, forecasting, and different issues — that are commonly resolved by human mind. It also expects to upgrade the functionality of PC based information systems and develop our understanding of how the cerebrum functions. Individuals work. Winston and Prendergast [1984] revealed that there are three goals of artificial intelligence :

1. Making machines smarter (main goal)
2. Understand what intelligence is (scientific goal)
3. Making machines more useful (entrepreneurial goal)

Smart Helm

A Smart Helmet or Smart Safety Helmet is a helmet that is implanted with Artificial Intelligence (AI) which can do work as can be done by humans and work that cannot be done by humans. The major objective of the Smart Helmet solution is to lower the incidence of workplace accidents in Indonesia's construction industry. In this research proposal, artificial intelligence is implanted into a project helmet, which can subsequently notify hospitals, the employment office, and the relatives of the injured parties about the occurrence of an accident and the coordinates of the accident area.

IDE Arduino

The expression "Integrated Development Environment," or "IDE" for short, alludes to an integrated environment used in the development cycle. The reason it's named an environment is that Arduino might be configured to execute installed undertakings utilizing programming sentence structure utilizing this software. Arduino uses a programming language that is like C. To make programming from the original Arduino programming language (Sketch) simpler for learners, changes have been made. Prior to being offered for deal, the Arduino.

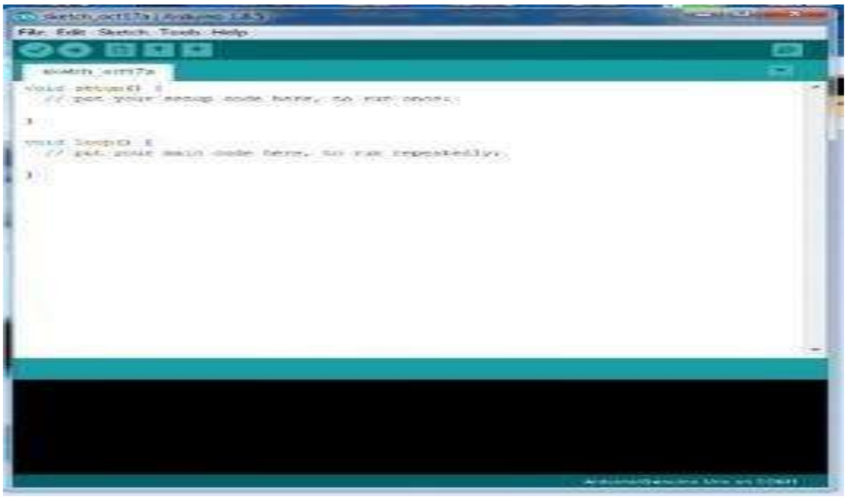

Figure 2. Arduino Uno IDE.

A program named Bootlader has been put inside the microcontroller IC to go about as a scaffold between the microcontroller and the Arduino compiler. In Figure 2, the Arduino Uno IDE is shown.

NodeMCU ESP8266

You can use portrays with the Arduino IDE or NodeMCU, which are open source IoT platforms and development packs that assistance with IoT gadget prototyping utilizing the Lua programming language. The ESP8266 module, upon which this development unit is fabricated, joins GPIO, ADC (Simple to Computerized Converter), IIC, 1-Wire, and PWM (Heartbeat Width Modulation) on a solitary board. ESP8266 GPIO NodeMCU as portrayed in Figure 3. NodeMCU is 4.83 centimeters long,
, 2.54 cm expansive, and 7 grams in weight. This board has open-source firmware and WiFi capacities.

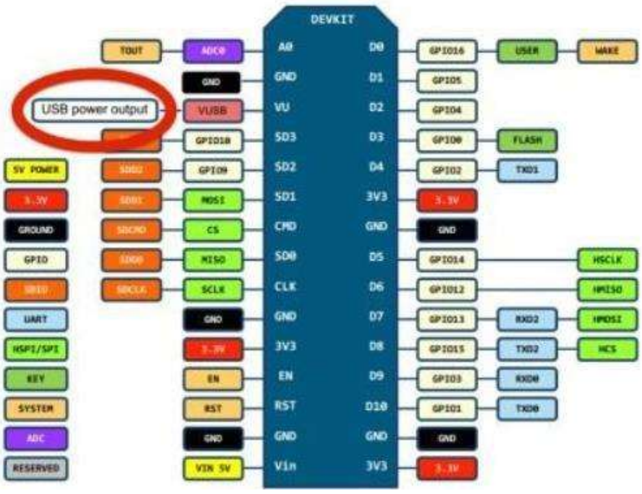

Figure 3. GPIO NodeMCU ESP8266 v3

2.5 Sensor SW-420

SW-420 is a vibration sensor module that has been widely used in various applications involving vibration detection. By using the SW-420 and LM325 vibration sensors as comparators for the output current. It works by detecting vibrations on the surface, if vibration is detected, the indicator light on the vibration sensor module will turn off and give a high output value on the data pin. And if there is no vibration, the indicator light will turn on and give a low output on the data pin. The sensitivity level for detecting vibrations on the SW-420 vibration sensor module can be adjusted using the available potentiometer (Berglund & Lindwall, 1995). The SW-420 Vibration Sensor can be seen in Figure 4.

Figure 4. SW-420 Vibration Sensor

Modul GPS

GPS utilizes the arrangement of satellite signs to decide a client's location on Earth's surface. GPS Deciphered Using Location-Based Service Books. Perceiving A navigation framework called GPS utilizes satellites that are designed to convey constant position, speed, and time information in basically every location on The planet, whenever of day, and under any sort of climate. While GPS Tracker or GPS Following is the wide term for the gadget that permits clients to get satellite signs, also a device permits clients to follow the location of individual cars, armadas, or vehicles progressively. (Rahajeng, Muhardi, Wahyuni, & Irawan, 2020).
GPS Ublox Neo-6M One of the GPS modules included in the GPS Ublox Neo-6 series is the NEO-6M. The advantages of the Neo-6M are that it has high performance, a flexible receiver, and also offers a variety of connectivity options with a relatively small size of 16 x 12.2 x 2.4 mm3 (Smith, Drew, Ziebland, & Nicholson, 2020). Other advantages possessed by the Neo- 6M are:

1. Small power usage.
2. It has 2 million correlators which makes it possible to find satellites quickly.
3. Time-To-First Fix (TTFF) under 1 second.
4. A more compact and innovative design.

The Ublox Neo-6M GPS module can be seen in the following Figure 5.

Figure 5. Ublox Neo-6M GPS Module

Sensor MPU6050

The MEMS Motion Following sensor MPU6050 is delivered by the Invensense corporation. The MPU6050 is an integrated circuit that consists of a computerized accelerometer and gyrator, every one of which has three development hatchet orientations: X, Y, and Z. According to Fadillah, Putrada, and Abdurohman (2022) development along the X hub is named Roll, development along the Y pivot is called Pitch, and development along the Z hub is called Yaw. The accompanying Figure 2.8 shows the development of pitch, roll, and yaw. The MPU6050 sensor provides 2 I2C addresses that we can choose from, namely 0x68 and 0x69. If you want to use address 0x68, then the ADO pin on the MPU6050 must be low, whereas if you want to use address 0x69, then the ADO pin must be high, which is technically connected to a voltage of 3.3 V (Hsieh & Lin, 2020). The MPU6050 sensor can be seen in Figure 6 below.

Figure 6. Sensor MPU6050

1) Accelerometer is a sensor that can detect acceleration, both the acceleration of an object and the acceleration of gravity. Acceleration can be measured in SI units, such as meters per second squared (m/s2), or, for the acceleration due to gravity, it is measured in g- force (g) where 1g = 9.8 m/s2. Accelerometer can also be used to measure the slope of an object.
2) Gyroscope is a tool in the form of a disc whose axis rotates between two supports and can maintain its position based on the angular momentum. The sensor measures the angular velocity of a rotation which has units of radians per second (rad/s). In this study, an electric gyroscope was used on the MPU6050 sensor. The output from this gyroscope is angular velocity data (Ooi, et al., 2021).

Methods

Strategies for trial research were utilized in this review. Specifically, by testing the smart safety helmet device in the construction business from both comfort and safety based on workplace safety standards in the business, which incorporates conformance with needs, the examination means to make sense of the issues concentrated by laying out a causal relationship between subordinate factors and free factors that influence the event of issues (Sholihah Q., 2020). The execution of this study was finished by:

1) Literature studies are carried out by searching literature through national journals, previous research, the internet, and books regarding theories related to the problems studied.
2) Pre-experimental design it is used for testing to make prototype designs of smart safety helmets and research instrument equipment with parameters of suitability for comfort and work safety of tools in the world of construction. This is important to ensure that the installation of examination instruments and apparatuses will work correctly when the investigation is conducted.
3) Experimental: Testing the smart safety helmet prototype design by assessing the results based on the suitability of the world of construction in the industrial engineering laboratory of Brawijaya University with the following steps: Plan the creation of astute safety helmets for construction workers that will have functions like temperature, slant, and vibration monitoring based on the Internet of Things.
4) Data collection: Two sorts of information are utilized in this review: essential information about the results of the item, which is the creation of smart helmets for the construction business.
5) Tool Design: Steps in designing a smart helmet for the world of construction by adding specifications using a solar-based energy changer, early protection program, data transfer process, and airflow control on a smart safety helmet.

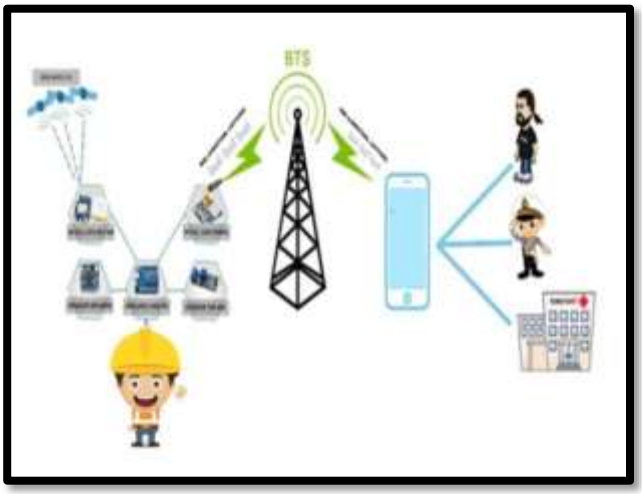

Figure 7. The working principle of the Smart Safety Helmet

System build begins after all components are available. The system consists of sending information in the form of changes in angles that occur, shocks, and temperatures received by the system, as well as receiving information that will be displayed on the cellphone in the form of location coordinates. The first step is to manufacture a sensor device to read the angle changes provided by the MPU6050 sensor and the SW-420 vibration sensor to read shocks. Additionally, Nodemcu will decipher the information that the sensor peruses and send it to the wifi module that is straightforwardly connected to Arduino. The second step is programming. This step also determines the cellphone number that will get a warning from the wifi module. Then from the wifi module, it will send information in the form of data containing coordinates, vibration, and temperature to the predetermined blynk application. So that when the drop angle and shock parameters are met, the wifi module will send a message to a predetermined cell phone.
The work design of the smart helmet system is in outline, namely reading data by the sensor module, sending data by the transmitter module, and monitoring display on the cellphone. The design stages are as follows:

a. The MPU6050 Gyrator sensor and the SW-420 sensor will be utilized by the sensor module to identify changes in the point of the client's helmet regarding the world's surface. The Ublox Neo 6M GPS will be utilized to determine the location coordinates, and the DHT 11 temperature sensor will send temperature data in real-time. Then processed by Nodemcu.
b. The wifi module available on Nodemcu will send data obtained from nodemcu processing to the supervisor's cell phone.

6) 6) Exploration tests from the Internet of Things-based Smart Safety Helmet Framework preliminaries in the Construction Occupational Safety and Health (K3) were conducted at the Workforce of Engineering, Brawijaya College, Malang's Industrial Engineering Laboratory.
7) Data Collection of methods: The Internet of Things-Based Smart Safety Helmet Framework was tried in the Application of Occupational Safety and Health (K3) in Construction, and the apparatus used to accumulate this data is the result of it. Data processing is the most common way of analyzing field data considering the objectives, system, and nature of the review. The review's methods for processing data are:
   a. Data reduction is reducing or sorting out data according to the topic where the data is generated from research.
   b. Coding data is the adjustment of data obtained in conducting library research and field research with the subject matter by giving certain codes to each of these data.
8) Data source
   a. Essential data collection is done at the Industrial Engineering Laboratory, Workforce of Engineering, Brawijaya College, using information straightforwardly from the respondent's assertion through the device's testing findings.

Secondary data is data obtained from the Manpower Office on the main factors of work accidents in the world of construction.

3. Results and discussion

Modeling the Smart Safety Helmet Tool

Modeling the Smart Safety Helmet Tool will be carried out in the overall system design stage. Modeling the Smart Safety Helmet system for detecting accident locations based on Nodemcu, based on Figure 8 below:

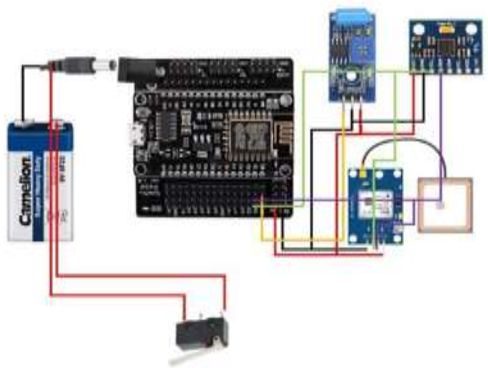

Figure 8. Schematic of the Smart Safety Helmet series.

Working Principles of the Smart Safety Helmet Tool.

After modeling the Smart Safety Helmet tool, then proceed with making the system starting after all tools and materials are available. How the framework is planned, information is sent through the Internet of Things, for example, changes in the helmet's inclination point, the force of the effect, and the size of the collision, and information is gotten that will be displayed on the smartphone as location coordinates with a guide of the area. The first step is to manufacture a sensor device as a reader for changes in angle provided by the MPU6050 sensor and the SW-420 vibration sensor to read crashes on helmets. Moreover, Nodemcu will process the data that the sensor reads, and the processed data will then be transmitted over the internet to the Blynk application. (Ardhian Nugroho & Angel Tandiawan, 2022). The second step is making a program for the Blynk program. This section will use the Blynk platform by designing a separate application system consisting of monitoring the tilt of the helmet, the amount of impact received, and the location of the helmet. In the blynk application there is already a token for sending data and using a modem for connection between the Smart safety helmet device and the Smart Phone.

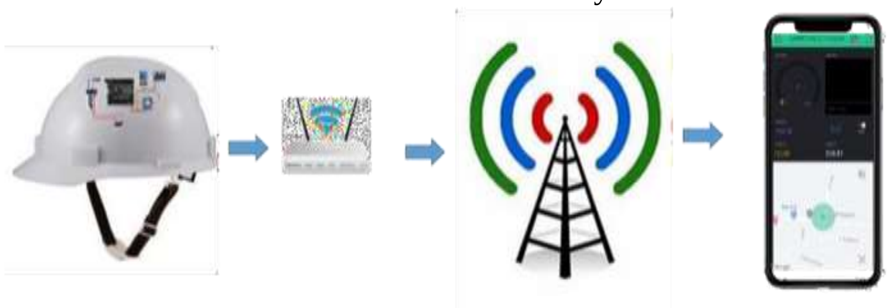

Figure 9. Smart Safety Helmet circuit flow

Figure 10 is an image of the system flow of the Smart Safety Helmet system to detect the location, tilt, and impact of hard objects in the event of a work accident which is made to facilitate the realization of tools made in all Internet of Things-based systems.

Figure 10. Workers wearing Smart Safety Helmets.

Smart Safety Helmet System Analyst

Analysis of the safety helmet system is a series of Nodemcu esp 8266 to process sensor data and then carry out internet-based interactions of things. The overall system design is carried out by wiring the nodemcu circuit with the MPU6050 Gyroscope sensor and the SW- 420 vibration sensor. A Nodemcu configuration based on the Internet of Things, an MPU6050 gyroscope sensor, a SW-420 vibration sensor, an U-Blox Neo 6M-V2 GPS, a limit switch, a battery for power, and jumper cables make up the SSH Toolkit, according to the schematic analysis (Baihaqi, Djatmiko, & Yusro, 2019). after which we may put the tool together as seen in Figure 11 below:

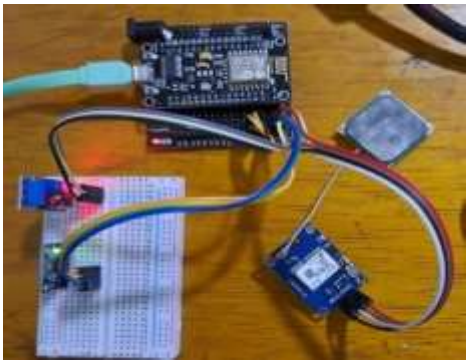

Figure 11. Workers wearing Smart Safety Helmets.

Then the tool is programmed according to the purpose of the Smart safety helmet. Then analyze each sensor that has been programmed. After the tool functions properly, the next step is to install the tool on a safety helmet that will be used by construction workers. Figure 11 is a picture of the placement of the components on the helmet used.

Testing the Smart Safety Helmet System

System testing is testing based on software specifications/requirements. This test is usually carried out based on specifications that are analyzed informally and manually. This test does not have formal methods and criteria so the test results can be inconsistent and ambiguous. Tool support for this test is rare.

Black Box is the testing system that is utilized. According to Azodi, Tang, and Shiu (2020), black box testing is the most common way of evaluating a gadget based on its functional specifications without examining its plan or code. The reason for testing is to determine whether the results and functions are operating true to form. The slant sensor, shock sensor, and GPS module are only a couple of the flow sensors and inputs that should be tried in order to begin the test. The other systems involve testing the input gadgets. Then, test the whole system.

Impact sensor

Impact sensor testing is carried out when the safety helmet is hit by a hard object or a worker falls. Next, the impact sensor will analyze the results via blynk, whether the sensor is capable of sending IoT-based crash notifications. Testing is done by looking at the impact value on the blynk application terminal. It can be seen in Figure 11 below the value obtained when the helmet does not get a shock, and Figure 12 is the value when the sensor receives a shock. From Figure 12 it can be seen that the physical form resulting from the design of the impact sensor or commonly called the vibration sensor. Researchers used 1 Nodemcu esp 8266, node MCU board, jumper cables, breadboards, and power using a cellphone charger during system testing.

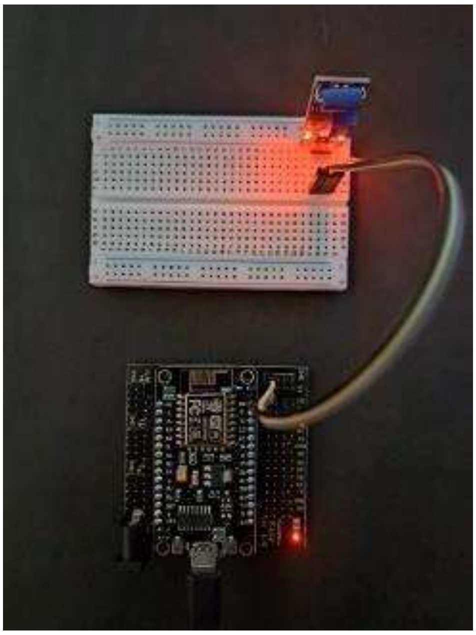

Figure 12. System Testing Steps

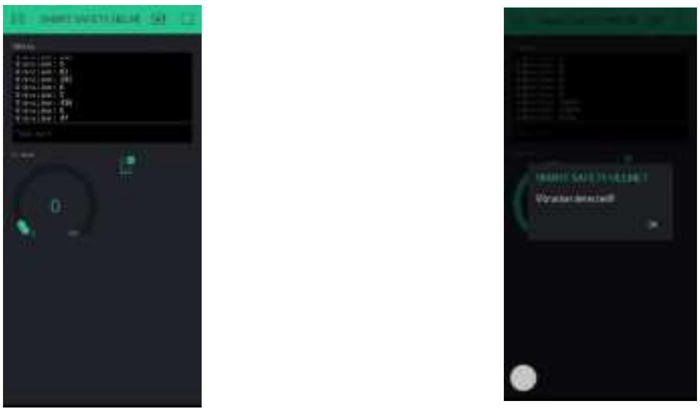

Figure 13. Impact sensor test results.

In Figure 13 above it can be seen that the displayed value is 10874 when the sensor does not receive shocks which is 0. This test is carried out by giving a crash to the safety helmet so that the minimum impact value is obtained which will be determined to send accident notifications to the supervisor.

Tilt Sensor Testing

Tilt sensor testing is carried out by testing the device as a whole whether the device is capable of sending SMS or not. Testing is done by using a helmet.

Figure 14. The results of the tilt sensor test.

In Figure 14 above the tilt sensor test was carried out with the help of the blynk application on an Android smartphone to find out how many degrees of inclination there is when a work accident occurs on a construction project. This test is carried out by tilting the tool to be installed with a safety helmet and then seeing the results via the blynk application.

Figure 15. Tilt sensor Blynk notification.

From Figure 15 above it can be seen that the tilt sensor from the tool series can read the slope of the helmet concerning the ground plane. About testing the tool with the help of an Android smartphone, it can be seen that the degree of inclination of the helmet can be seen in the results, namely the X axis: 325.5 then the Y axis: 348.65, and the Z axis: 253.73.

Modul GSMTesting

Tests on the GSM Module are carried out to send worker locations to the blynk application, sent via smartphone. The test was carried out 2 times. The display of SMS sent to three Android smartphones can be seen in Figure 16 below.

Figure 16. Result Gps.

To check the correctness of the coordinates obtained from the GPS Module, testing is done on the module. To test the GPS Module, slant and shake the helmet until the GPS Module sends the coordinates to the smartphone, as found in Figure 16.

Figure 17. Blynk Gps Notification.

From Figure 17 it can be seen that the GPS Module can read the location where the device is at latitude: 0.542073 and longitude: 123.089958. The difference in distance between the actual location and the location shown by Google Maps is influenced by several factors such as the GPS signal, the GPS module device itself, and the place where the GPS module is placed.

Smart Safety Helmet Testing

Testing the Smart Safety Helmet to detect work accident locations based on the Internet of Things based on Nodemcu is carried out by looking at the process and overall analysis of the system starting from sensor readings to sending notifications to the blynk application.

Figure 18. Installing the Smart Safety Helmet.

The test is carried out by using the Smart Safety Helmet on humans or construction workers, then tilting it up to find out the slope of the plot of land and the Smart Safety Helmet receives a collision, it is stated that the construction worker is in a state of the work accident, so the tool will send an accident notification to the K3 supervisor, then K3 supervisors provide first aid in the event of a work accident. The sensor will re-check the sensor several times to determine whether the worker is in an accident or not.

Figure 19. Display of the Blynk Smart Safety Helmet application.

From Figure 19 it can be seen that workers who use the Smart Safety Helmet are in good condition where the impact is 0. Notification is sent to blynk if the collision is > 3000, so the limit switch distributes voltage to the tool due to pressure from the construction worker's head. Furthermore, a blynk notification about the location of a work accident will be sent to

the K3 supervisor's smartphone due to a trigger in the form of a tilt sensor and a collision sensor.

Figure 20. Graph of collision of Smart Safety Helmet. Figure 20 is a graph of the collision on the smart safety helmet which is sent to the blynk application on a smartphone, where the biggest collision is 150 to 161 and the lowest is 0 – 80 for the collision value.

4. Conclusion and future scope

Here are the conclusions of the innovative smart safety helmet to pave the way to a safer and more responsive construction future: Smart Safety Helmet to detect the location of internet-based construction work accidents when using the blynk application. The value of the 10874 crash sensor when the sensor does not receive a shock is 0. This test is carried out by giving a crash to a safety helmet so that a minimum impact value is obtained which will be determined to send accident notifications to the K3 supervisor. The tilt sensor from the tool kit can read the slope of the helmet about the ground plane. About testing the tool with the help of an Android smartphone, it can be seen that the degree of inclination of the helmet can be seen in the results, namely the X axis: 325.5 then the Y axis: 348.65, and the Z axis: 253.73. 4. The GPS module can read the location where the device is at latitude: 0.542073 and longitude: 123.089958. The difference in distance between the actual location and the location shown by Google Maps is influenced by several factors such as the GPS signal, the GPS module device itself, and the place where the GPS module is placed.

Acknowledgment

We express our sincere thanks to Brawijaya University for its dedication and support in developing this innovative idea. Not to forget, we also convey our highest appreciation to all related parties and stakeholders who took part, because without their support, the success of this project would not have been realized. Hopefully this collaboration will continue to bring benefits and positive breakthroughs in the future.

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