Journal of Namibian Studies, 35 S1 (2023): 4225-4245 ISSN: 2197-5523 (online)

# Wearable Heat Stroke Detection With Stages Using Tinyml And Iot

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Abstract

Heat stroke, a potentially fatal medical emergency, is defined as a fast rise in body temperature caused by prolonged exposure to high temperatures or excessive physical exertion in hot surroundings. To avoid serious repercussions or deaths, early diagnosis and action are important. Using Tiny Machine Learning (TinyML) algorithms and Internet of Things (IoT) technologies, this study proposes a unique approach for real-time wearable heat stroke diagnosis. The suggested wearable device has many sensors for monitoring vital signs and environmental conditions. A heart rate monitor, skin temperature sensor, and ambient temperature and humidity sensors are among the sensors. The gadget is lightweight, low-power, and non-invasive, making it suited for continuous use during outdoor activities or work in hot environments. TinyML, which uses the power of machine learning models built for resource-constrained contexts, processes the data gathered by the wearable device locally. TinyML algorithms analyze sensor data quickly to identify early indicators of heat stroke, allowing the device to categorize the disease into stage 1, stage 2 and stage 3 depending on the severity of the heat stress. The wearable gadget is incorporated into an IoT ecosystem to improve the system's capabilities. The processed data is wirelessly transferred to a central server or cloud platform for additional analysis and storage. This allows healthcare experts, emergency responders, and concerned people to follow the wearer's health state in real time and remotely. The suggested system's performance is tested by thorough real-world testing in a variety of heat-intensive circumstances.

Keywords: Heat Stroke Detection, Internet of Things, Machine Learning, Sensors, TinyML.

## I. INTRODUCTION

Heat stroke is a potentially fatal medical illness induced by extended exposure to high temperatures or excessive physical exertion in hot conditions, which causes a hazardous rise in body temperature [1]. It is a severe kind of heat-related sickness that offers serious health concerns, especially in hot and humid conditions. Heat stroke affects millions of people globally each year, with many instances ending in major health consequences or even death [2]. The harmful consequences of heat stroke highlight the critical necessity for adequate and prompt detection systems [3]. Early detection of heat stroke symptoms is critical for initiating appropriate medical measures and averting potentially fatal effects [4]. Traditional techniques of detecting heat stroke either depend on subjective observations or need the use of specialist medical equipment, limiting their usefulness in real-world circumstances [5]. Wearable technological advancements, together with the developing subject of Tiny Machine Learning (TinyML), provide a viable path to solve this essential problem [6]. Wearable systems with different sensors may continually monitor vital signs and environmental data, offering significant insights into a person's health state under heat stress [7]. TinyML, a type of machine learning targeted for resource-constrained devices, allows for fast sensor data processing and analysis directly on the wearable device [8]. In this regard, the goal of this study is to provide a unique approach for wearable heat stroke detection using TinyML technology [9]. The wearable gadget may correctly recognize early indications of heat stroke by combining a variety of sensors capable of monitoring crucial physiological and environmental markers [10]. Furthermore, the gadget may categorize the situation into multiple phases, representing the degree of the wearer's heat stress [11-12].

The gadget is incorporated into an Internet of Things (IoT) ecosystem to increase the capabilities of the wearable system and provide seamless connection [13]. The gadget may broadcast real-time health status updates to a central server or cloud platform through wireless data transfer, providing remote monitoring and easy access to crucial information by healthcare professionals or carers [14-15]. The study will concentrate not only on the technological elements of designing the wearable heat stroke detection device, but also on real-world validation [16]. Extensive testing in a variety of heat-intensive situations will be carried out to evaluate the system's accuracy, sensitivity, and responsiveness [17]. The objective is to guarantee that the suggested technology can identify heat stroke cases consistently and effectively, reducing the risk of major health effects and possibly saving lives [18-20].

## II. BACKGROUND STUDY

A.Takada et al. [1] this was the first study to examine the body temperatures of older citizens in Nagoya, Japan, who have been diagnosed with heat-related diseases. There were 1,302 patients over the age of 65, and information on those who need transportation was gleaned from records of those who were picked up at their homes. The author used one of four sweating models to estimate each patient's core temperature under the assumption that they were at home. In 31.4% of the patients, the measured core temperature was greater than the daily expected core temperature, even when sweating was little. Although there was significant water loss, the lack of dehydration was consistent with good sweating. This may give support to an earlier study's idea that dehydration over a period of days may have a role in the development of heat-related diseases.

K. Matsumoto et al. [7] Epidermal or interstitial sodium ion (Na+) concentration, perspiration rate, and core body temperature were the three biomarkers of heat stroke. A prototype earbud-style wearable (hearable) equipped with an eardrum temperature sensor and a perspiration rate sensor might aid in the early diagnosis and prevention of the condition.

M. Z. Ismail and M. Inoue [9] This study gathered quantitative data from pedestrians' smartphones using a participatory sensing technique to detect incidences of heat stroke in a specific location, utilizing just air temperature and humidity sensors. Models differ in how effectively they depict the internal sensor. More accurate Smartphone data will be utilized to build the map ahead of time. In reality, however, variables like as radiant heat, surface temperature, and the condition of telephones must be considered. When a Smartphone was not in direct contact with its surroundings, such as when it was in a user's pocket or purse, its inbuilt environmental sensors become less accurate.

Mao, G.-J. et al. [11] In a nutshell, the author created a near-infrared fluorescence probe (Lyso-NIRpH) for liposomal pH that was light stable. The probe has excellent lysosome-targeting properties in cells, an in vitro pKa of 4.63, and outstanding pH detection selectivity and sensitivity.

Mitchell, K. M. et al. [13] an inaccurate RTA assessment during exertional heat illness may have a number of emotional, professional, and legal ramifications. The RTA choice was complicated by a lack of recognizable signs (physiological and/or blood) and established criteria. The RTA test idea was valid for evaluating the body's physiology and thermoregulatory response to exercise-induced heat stress. However, as the author has shown, the HTT as it now exists has serious flaws. Despite the fact that it tells the tester whether or not the subject can execute the unique HTT at the time of the test, it seems that the HTT's information has only moderate sensitivity and low (or nonexistent) specificity for true RTA state / readiness.

R. Bhaskaran Venugopal and R. Dudhe [15] much study has been conducted on the different systems and their intended use. The bulk of the papers analyzed used complex systems in their research. If a person's core temperature exceeds 40 degrees Celsius, this effort offers a simple option to help them care for themselves, lowering their risk of dehydration and heat stroke. Knowing your core temperature before getting behind the wheel may also help you stay alert and aware, minimizing the chance of an accident.

W. Yimyam and M. Ketcham [17] the use of image processing algorithms in the development of a system to detect heat stroke. The solution, which was accessible on PC and smartphone platforms, may help identify those who were at risk of heat stroke. The system was tested using data from 100 thermal imaging cameras and found to be 82.5% accurate.

## III. MATERIALS AND METHODS

This section describes the methods, equipment, and materials used to carry out the experiment. It lays the groundwork for future researchers to replicate the study and validate the results.

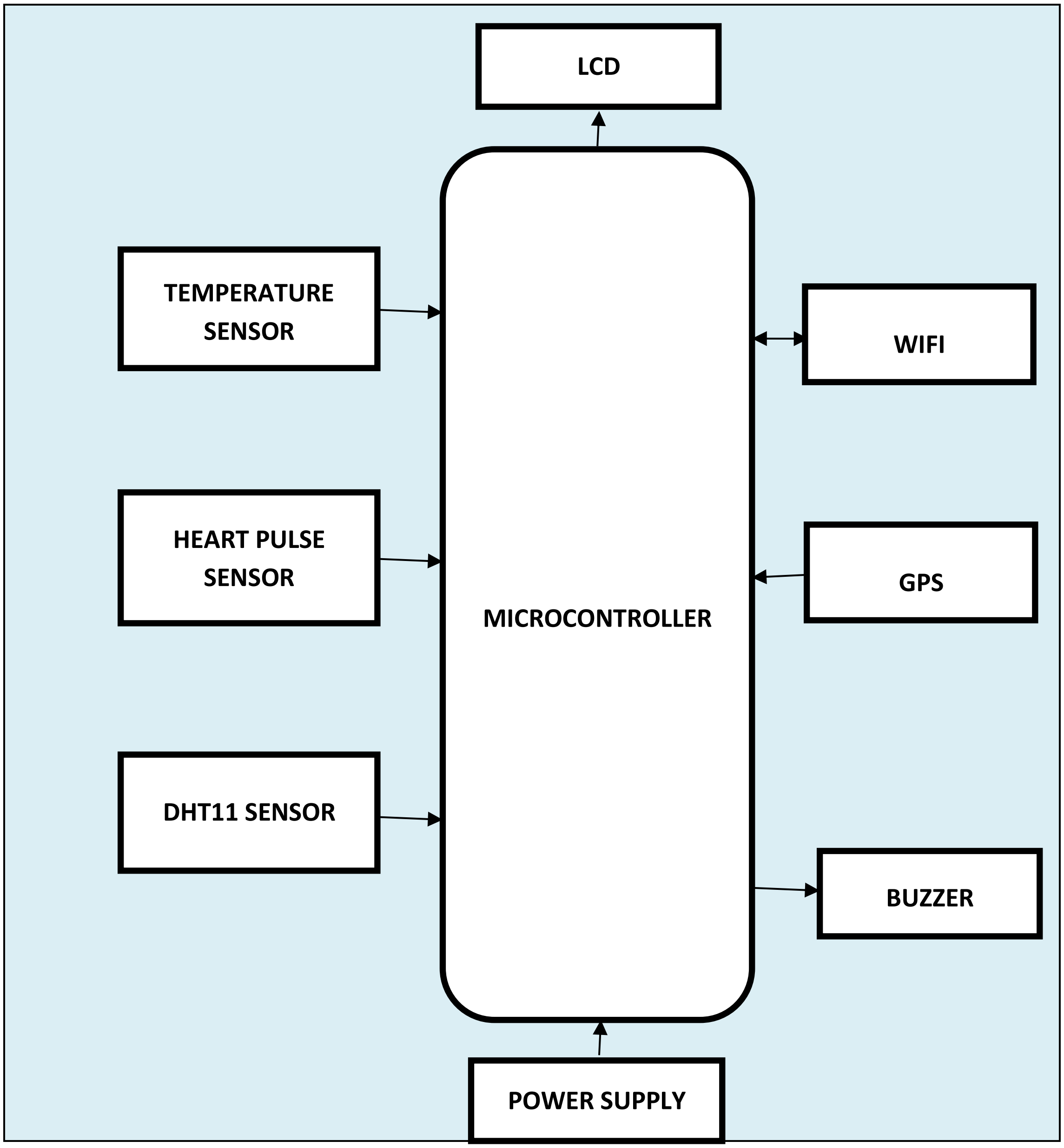


**Figure 1: block diagram**

### 3.1 Arduino

The Arduino Uno is a microcontroller board based on the ATmega328. There are 16 MHz crystal oscillator, reset button, and ICSP header in addition to the 14 digital I/O pins and 6 analog inputs. The microcontroller is ready to go as soon as you plug it into a computer's USB port or provide power using an AC-to-DC converter or battery. The FTDI USB-to-serial driver chip is not present in the Uno, as it has not been on any prior boards. Instead, a programmed Atmega8U2 is used as a serial-to-USB converter. The upcoming 1.0 version of Arduino was given the codename "uno" (Italian for "one") to reflect its simplicity. The Uno and the original Arduino will thereafter be held in the highest regard. The Uno is the newest member of the USB Arduino board family and the most fundamental version of the Arduino platform; for more on the evolution of the platform, go here.

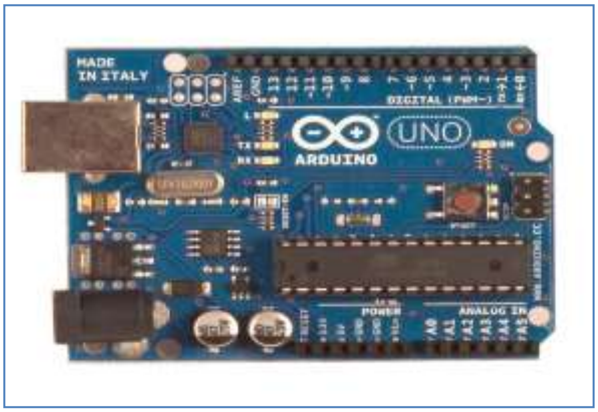


Figure 2: Arduino Uno

**3.2 Temperature Sensor**

A temperature sensor for heat stroke detection is used to monitor and recognize elevated body temperatures in humans, particularly those at risk of heat stroke. Heat stroke is a potentially fatal medical emergency that occurs when the body's natural cooling systems are overworked as a result of exposure to excessive heat or strenuous exertion in hot weather. It may be lethal if not detected and treated promptly. Non-contact infrared thermometers (also known as pyrometers or IR thermometers) are often used to detect heat stroke. It can take a person's temperature without touching them by detecting and converting their infrared radiation. In an emergency, the ability to gauge temperatures without touching the thing is quite important. Here's how the temperature sensor for heat stroke detection typically works:

1. Infrared Radiation Detection: A lens in the sensor focuses infrared radiation produced by the person's body onto a detecting element. The detector receives radiation in accordance to the person's body temperature.
2. Signal Conversion: Based on the intensity of the incoming infrared radiation, the detector element

creates an electrical signal. Using built-in electronics and algorithms, this signal is subsequently transformed into a temperature readout.

3. Temperature Display: The temperature reading is presented on the sensor's screen or an integrated display, enabling the user to rapidly determine the body temperature of the individual.
4. Alert System: Many heat stroke detection temperature sensors have an alert system. If the detected temperature reaches a harmful threshold (e.g., signaling a risk of heat stroke), the sensor may emit an audio alert or show a warning message to promote rapid action.
5. Data Logging: Some modern heat stroke detection sensors may also include data logging capabilities, enabling temperature measurements to be recorded over time. Medical practitioners and academics may use this to examine temperature patterns and trends.

Figure 3: Temperature Sensor

### 3.3 Heart Pulse Sensor

A plug-and-play gadget dubbed a "Pulse Sensor" that interacts with an Arduino may be used to compute the patient's pulse rate. On one side, the sensor includes an LED and an ambient light sensor, and on the other, noise reduction and amplification circuitry. There are three pins on it. The prongs are designated "ground," "VCC," and "signal." When we place the sensor on our fingertip, it detects the vein there, and when there is a change in blood flow, we know it's time for a heartbeat. This sensor, which is now available on the market, is inexpensive and easy to use.

1. Two Surfaces:

a. Surface LED and Ambient Light Sensor: An LED (Light Emitting Diode) and an ambient light sensor are located on one side of the sensor. The LED shines light into the fingertip, and the ambient light sensor determines how much light goes through or reflects back. This procedure aids in collecting fluctuations in blood volume beneath the skin caused by heartbeat.

b. Circuit Board Surface: A circuit board comprising noise cancellation and amplification components is located on the sensor's opposite surface. The circuit board analyses the input from the ambient light sensor and filters out extraneous noise, which improves the accuracy of heart rate estimations.

2. Three Pins: a. Ground (GND): This pin is linked to the Arduino's ground or the system in which the Pulse Sensor is incorporated, and it provides the reference voltage for the sensor's functioning.

b. VCC (Power Supply): This pin is linked to a power supply (e.g., 3.3V or 5V) in order to power the sensor and its internal circuitry.

c. Signal: The processed analog signal from the ambient light sensor is sent to the Arduino through the Signal pin. This signal comprises heart rate information, which the Arduino receives and analyzes to determine the patient's heart rate.

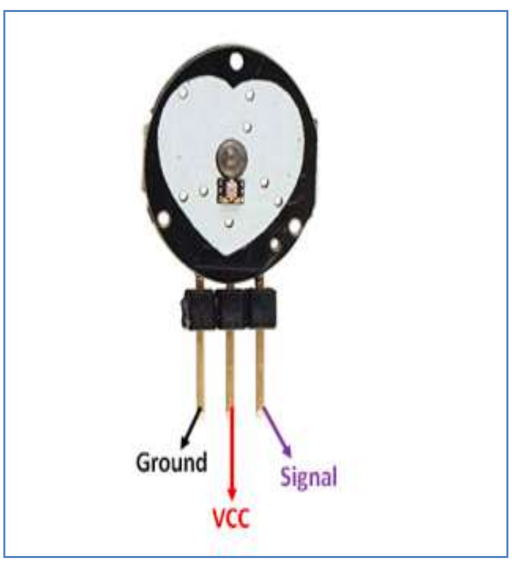

Figure 4: Pulse Sensor

**3.4 DHT 11 Sensors**

The DHT11 temperature sensor is used. The DHT11 is a temperature and humidity sensor with a high return that is synchronized. The DHT11 is a low-effort temperature and humidity sensor that can be linked to microcontrollers such as the Arduino, Raspberry Pi, and others. It gives consistent quality over a long period of time. Stepper motors are DC motors that convert electrical impulses into mechanical motion. Brushless direct current motors spin and react to input pulses. The shaft is propelled at a steady angle by these waves. The electromagnetic moments begin to rotate. Although there are customized servos that can rotate a full 360 degrees, a servo motor can only rotate 180 or 270 degrees. This motor assists in tilting the window to a specific degree. The opening and shutting of the window is controlled by a stepping motor connected to a window, and the Arduino board is attached to a DHT11 temperature sensor. The sensor sends a temperature measurement to the Arduino board. The arduino instructs the stepping motor's turning mechanism using the arduino programming language and the specified standard temperature. The force is converted into a mechanical moment that causes the window to revolve.

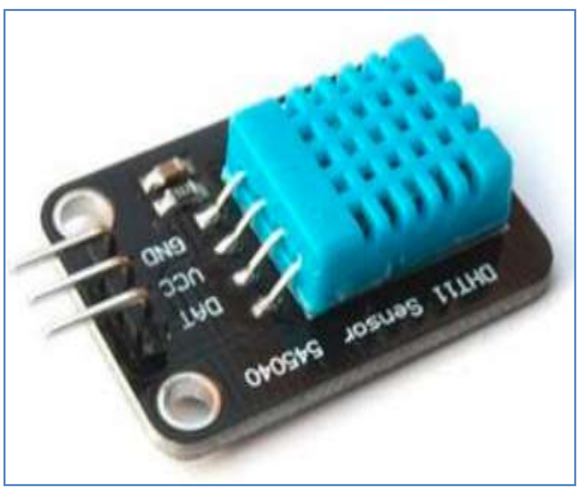


Figure 5: DHT 11 Sensors

**3.5 GPS Sensor**

A Global Positioning System (GPS) sensor is used in defensive robotics to locate an unmanned device's exact position, speed, and time synchronization. GPS receivers depend on a constellation of satellites orbiting the Earth for precise location data. GPS sensors receive messages from a constellation of satellites in Earth orbit in order to work. Satellites provide signals that contain location information as well as the current time. The GPS receiver uses the time difference between when a signal is broadcast and when it is received to calculate the distance between each satellite. The unmanned system's GPS sensor can detect its accurate position by triangulating distances to a minimum of four GPS satellites. This information is often shown as coordinates (latitude, longitude, and elevation).

In addition to location, GPS sensors provide velocity and time synchronization data. The speed and direction of movement of the robotic system are computed by tracking the change in position over time. Time synchronization is crucial for coordinating operations, data capture, and communication across a networked defense architecture's various unmanned systems or components. GPS sensors provide many advantages in defensive robots. They provide exceptionally accurate and globally available positioning data to autonomous systems, enabling them to navigate, carry out mission objectives, and retain situational awareness. GPS sensors are trustworthy and can operate in a wide range of situations, including open regions, urban landscapes, and, with the assistance of other technologies such as differential GPS, even certain inside environments. In military applications, GPS sensors are utilized for operations such as autonomous navigation, mission planning, target tracking, localization, and unmanned system coordination. They are crucial for preserving exact real-time position, especially in dynamic and rapidly changing environments. While GPS sensors are quite reliable, they may be altered by a number of factors that might impair their accuracy. GPS reading errors may be caused by causes such as signal obstruction, meteorological conditions, and intentional jamming or spoofing. As a consequence, sensor fusion, sensor integration, and advanced algorithms are often utilized to increase the accuracy and durability of GPS-based positioning in defensive robots.

Figure 6: GPS Sensor

**3.6 LCD Display**

LEDs are utilized in circumstances where liquid crystal cell displays (LCDs) are used. Dot matrix and segmented displays are used for such purposes, and they may be used to show both numbers and letters.

The liquid crystal substance is only one of several possible ingredients that retain their liquid state while displaying crystal-like optical characteristics. Glass sheets with transparent electrodes on the inside are used to encase the liquid crystal. When a voltage is applied across a cell, charge carriers in the liquid disturb the alignment of the molecules and cause turbulence. The liquid is invisible until it is triggered. Light is scattered in all directions when the liquid is triggered, giving the cell a vivid look. The term "dynamic scattering" describes this phenomenon. Similar to how a dynamic scattering display is built, a field effect liquid crystal display consists of two glass sheets with tiny polarizing optical filters embedded in them. The liquid crystal material used in the field effect cell is distinct from that used in the dynamic scattering cell.

Small and flat, an LCD uses liquid crystals to create a variety of colors or black and white pixels that are then placed in front of a light source (backlight) or reflector. Due to its very low energy consumption, it is often used in battery-powered electrical goods. Liquid crystal displays (LCDs) use a material that blends liquid and crystal states. They don't melt, but instead have a transition temperature where the molecules are pliable like a liquid yet still ordered like a crystal.

Figure 7: LCD Display

### 3.7 BUZZER

A signaling instrument, sometimes known as a buzzer or beeper the buzzing sound produced by early buzzers, which were electromechanical devices powered by stepped-down alternating current (AC) line voltage at 50 or 60 hertz, is where the word "buzzer" comes from. A ring or a beep are two other popular noises used to signify that a button has been pushed.

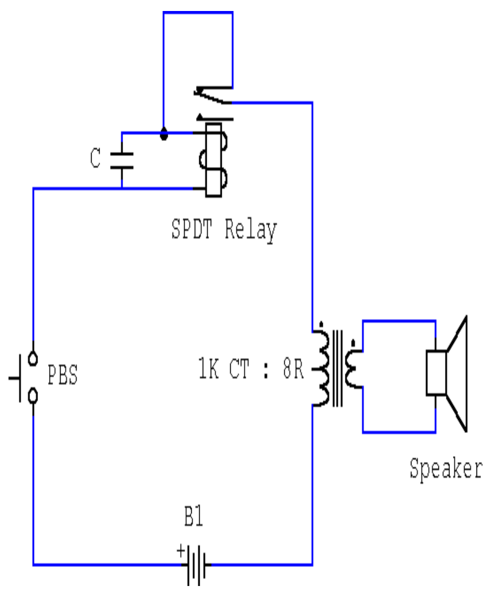


Figure 8: Buzzer Circuit

This novel buzzer circuit has a relay wired in series with a miniature audio transformer and a speaker. When the button is depressed, power is sent between the transformer's primary and the relay's closed contact. As soon as the relay activates, the typically closed contact opens, withdrawing power from the relay; the contacts shut, and the procedure repeats...all extremely quickly...so fast that the pulse of current creates oscillations in the transformer's main, and hence secondary, voltage.

The frequency at which the relay is running directly correlates to the pitch at which the speaker emits sound. The capacitor C is used to "tune" the sound. The buzzer tone is diminished when the capacitance is increased above its nominal value of 0.001uF.

**3.8 WIFI UART**

Wi-Fi UART (Universal Asynchronous Receiver/Transmitter) is a prominent wireless communication protocol in the Internet of Things commercial environment. It enables a microcontroller and a Wi-Fi network, for example, to interact without the need of physical cables. In embedded systems, the Universal Asynchronous Receiver Transmitter (UART) is a prominent serial communication standard. Data may be delivered and received between microcontrollers, sensors, and other devices with a single cable. The Wi-Fi universal asynchronous receiver/transmitter (UART) provides a safe and simple solution to connect several devices to a network in an industrial Internet of Things environment, allowing them to communicate and exchange data wirelessly. This is a big help in large-scale manufacturing facilities or outdoor monitoring systems where actual cables would be difficult or impossible to install. Because of its scalability and versatility, Wi-Fi UART may be used in a variety of industrial IoT applications. Wireless data transmission and reception enables devices to be connected and relocated without the need for wiring or configuration adjustments.

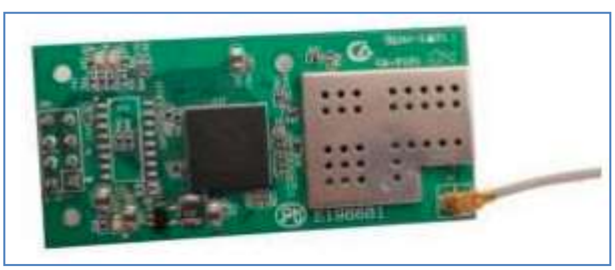

Figure 9: WIFI UART

The figure 9 shows WIFI UART WIFI UART (Universal Asynchronous Receiver-Transmitter) refers to a communication module that combines WiFi (Wireless

Fidelity) capabilities with UART serial communication. It allows devices with UART interfaces, such as microcontrollers or embedded systems, to establish wireless connectivity and exchange data over WiFi networks.

### 3.9 TINYML

Outside of open-source contributions from IT behemoths, there aren't many licensed items available. The AIfES library provides a C-based, platform-independent tool for creating NNs that can run on a variety of open-source MCU boards. To ensure optimal functionality, AIfES develops DLLs that run smoothly on both Windows and embedded Linux systems. In contrast to the previously mentioned frameworks, AIfES allows the ML model training process to be implemented on embedded devices, much as ML-MCU, Edge2Train, Train++, and TinyOL. Developers may implement ML static libraries into Cortex-M MCUs with the help of Cartesiam NanoEdge AI Studio. As a consequence, the training process may be integrated into the restricted apparatus. It can also train MCUs using unsupervised techniques.

Machine learning needs a large amount of memory and computing power. Thanks to recent advancements in the field, new machine learning algorithms may now be adapted to a range of microcontrollers. Models that can work on low-powered devices may be built. Tensor flow has an experimental l version that may be utilized on microcontrollers. Adels produced using TensorFlow may be transformed with Tensor Flow lite. TFLite file conversion. TinyML, which stands for "Tiny Machine Learning," is a computer science branch concerned with the use of machine learning models on low-power, low-memory devices. The idea is to save resources while yet allowing accurate algorithms to be performed locally at the network's edge. TinyML uses approaches like quantization, pruning, and transfer learning to optimize models to fit within limited computing power and memory, enabling for sophisticated and intelligent applications at the edge without relying heavily on cloud-based processing. This machine learning discovery opens the path for low-latency, privacy-preserving solutions in a variety of industries, including health, industry, and smart devices.

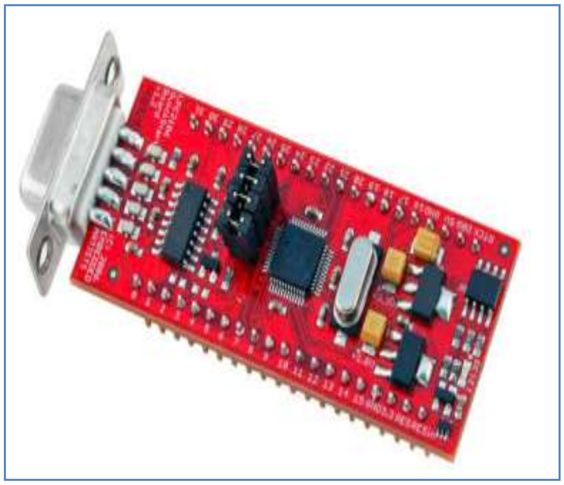

Figure 10: Tinyml board

**3.10 POWER SUPPLY**

Any device that can generate energy is considered a power source. A PSU, or power supply unit, is any device or system that supplies electricity to an output load. The phrase is most often used to describe electrical energy sources, sometimes used to describe mechanical ones, and rarely used to describe others.

A linear or toggling power supply is often used in electronic devices. The linear supply may be inefficient since it adjusts voltage, and it is inconvenient and heavy when utilized with high-current devices. A switched-mode power supply is more compact, efficient, and complex to construct than a linear power supply of the same wattage.

**3.11 LINEAR POWER SUPPLY**

A transformer is often used in a linear AC power supply to reduce the high voltage that comes from the wall outlet (mains). If DC is to be created using this approach, a rectifier is required. A capacitor is employed to smooth out the rectifier's irregular current. Ripple is defined as small, periodic deviations from completely uniform direct current. These tremors occur at intervals that are multiples of the alternating current power frequency (for example, 50 or 60 Hz). Voltage in unregulated power sources fluctuates in response to variations in load and input AC voltage. A linear regulator is used to steady and control voltage for critical electrical applications. This regulator will also significantly minimize the ripple and noise of the DC output. In most circumstances, linear regulators are employed to protect the power source and associated circuit from harm caused by high current demand.

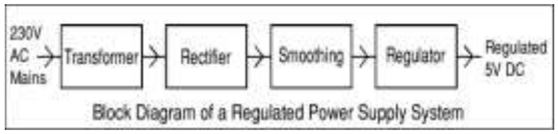


Figure 11: Power supply

## IV. RESULTS AND DISCUSSION

The "Results and Discussion" portion of any scientific or research report is critical. In this part, we give the findings of our research, including data from experiments or studies, and then evaluate and interpret these findings in light of the research question or hypothesis. The goal is to provide readers a thorough knowledge of the results and their consequences.

Figure 12: Hardware tool Kit

Figure 12 depicts the hardware. The phrase "hardware" refers to the many physical components required for the functioning of computer systems, devices, and networks in the area of information technology.

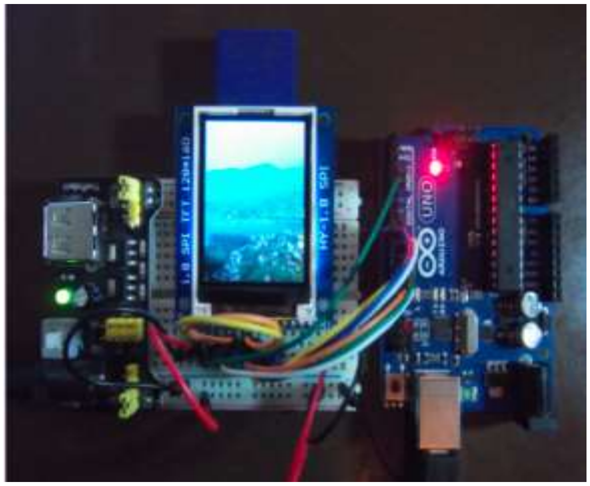

Figure 13: The hardware function

Figure 13 depicts the device's operation. The many components of hardware that comprise a computer system each perform a specialized function while also cooperating to ensure the system's overall performance.


Figure 14: Output Message

The hardware implementation is shown in Figure 14. Hardware implementation refers to the process of physically designing, constructing, and assembling the various hardware components that compose a computer system or electrical device. It requires translating specifications, requirements, and designs into tangible, functional hardware components.

## V. CONCLUSION

Finally, combining wearable technology, Tiny Machine Learning (TinyML), and the Internet of Things (IoT) for heat stroke diagnosis constitutes a huge development in healthcare technology. The design of the wearable device, together with TinyML algorithms, enables efficient and precise monitoring and categorization of heat stroke phases, while IoT integration enables real-time remote monitoring and quick treatments. The system's dependability and potential to save lives by detecting heat stroke cases early has been shown via extensive testing, the tinyML has classified into stage 1 as normal stage is $97.5^{o}$, stage 2 as severe stage is above $103^{0}$ and stage 3 as complication stage is above $108^{0}$. This unique technology has the potential to greatly enhance public health outcomes with further refining and broader implementation, especially for persons at risk of heat-related disorders in high-temperature conditions. For further, to introduce a data security and data management in big data servers.

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