SmartWear: A Wearable Heat Stress Monitoring and Alert System for Elderly Health Management

Preparation, Construction and presentation of the design/development project

Abstract

Elderly individuals are particularly vulnerable to heat-related health risks due to factors such as impaired thermoregulation and pre-existing medical conditions. This proposal outlines the design and development of a wearable Smart Heat Stress Monitoring Device aimed at safeguarding elderly individuals from excessive heat exposure. The device will continuously monitor environmental heat levels using the Wet Bulb Globe Temperature (WBGT) index and provide alerts when conditions become unsafe. Additionally, notifications will be sent to family members or caregivers, enabling timely intervention. This proposed solution seeks to enhance the safety and well-being of elderly individuals in hot environments, offering both the elderly and their caregivers greater assurance in managing heat-related risks.

I. INTRODUCTION

Heat stress is a series of conditions where the body is under stress from overheating. Studies have shown that older adults face a higher risk of experiencing serious health problems during extreme heat events. This increased vulnerability is due to several factors. Firstly, many older individuals have a high prevalence of pre-existing medical conditions, such as cardiovascular and respiratory diseases, which can worsen under heat stress. Secondly, the use of certain medications commonly prescribed in older age, such as diuretics and beta-blockers, can interfere with the body's natural ability to regulate temperature. Lastly, impairments in the autonomic nervous system, which plays a critical role in thermoregulation, further limit their ability to adapt to high temperatures. These impairments can affect the perception of extreme heat, delaying appropriate behavioral responses like seeking cooler environments or staying hydrated. Combined, these factors make older adults particularly susceptible to adverse outcomes during periods of extreme heat [1].

To reduce the risks elderly individuals face from excessive heat, we propose a wearable heat stress monitoring device designed specifically for their needs. This device will monitor environmental heat levels using the Wet Bulb Globe Temperature (WBGT) and provide alerts when conditions become unsafe. The alerts will notify both the elderly person wearing the device and their family or caregiver, ensuring timely action to prevent heat-related health issues. This solution seeks to improve safety and offer reassurance to both the elderly and their families.

Objectives

This project focuses on creating a wearable device that monitors heat stress in the elderly using the WBGT index, sending real-time alerts to users and caregivers for timely intervention.

- Develop a wearable device that continuously monitors environmental heat levels using the Wet Bulb Globe Temperature (WBGT) index to assess heat stress for elderly individuals.
- Design an alert system that notifies both the elderly user and their caregivers or family members when heat conditions become unsafe, enabling timely intervention.
- Enhance the safety and well-being of elderly individuals by providing real-time monitoring and improving their ability to manage heat-related risks in hot environments

Threshold Values for Heat Index Indicators Used in Device Alert System for Elderly Health Monitoring

Thermal Stress	WBGT (°C)	PMV
No Heat	< 18	0
Low Heat		+1
Moderate Heat	18–23	+2
High Heat	23–28	+3
Severe Heat	28–30	
Critical Heat Risk	≥30	

Scale and Temperature threshold of particular thermal sensations (stress) in some thermal indices (Binarti et al., 2020)

Thermal Stress	WBGT (°C)	PMV
No Thermal	< 18	0
Slight Heat		+1
Moderate Heat	18–23	+2
High Heat	23–28	+3
Extreme Heat	28–30	
Extreme Danger	≥30	

The thermal comfort standard is an index of the thermal sensation known as the Predicted Mean Vote (PMV) index. According to Dyvia and Arif (2021), the determination of thermal comfort by a person can be determined by the predicted mean vote (PMV) index. [2]

Wet Bulb Globe Temperature (WBGT) Calculations

Outdoor WBGT is calculated as the weighted sum of natural wet bulb temperature (T_{nwb}), globe temperature (T_g), and dry bulb/ambient temperature (T_a) (Carter et al., 2020).

$$WBGT = 0.7T_{nwb} + 0.2T_g + 0.1T_a$$

For Natural Wet Bulb Temperature (T_{nwb}) Calculations :

$$T_{nwb} = Ta \times arctan[0.151977 \times (RH\% + 8.313659)^{\wedge}(1/2)] + arctan(Ta + RH\%) - arctan(RH\% - 1.676331) + 0.00391838 \times (RH\%)^{\wedge}(3/2) \times arctan(0.023101 \times RH\%) - 4.686035.$$

The value for T_a, and the calculation for specific humidity of T_{nwb} is expendable, as the corresponding values can be directly obtained and measured using the SHT3X sensor.

For globe temperature (T_g) Calculations:

T_g is a measure of radiant temperature and direct measurement requires use of a copper globe painted black, with a thermometer in the center (Dimiceli et al., 2013). [4]

Given the unavailability and difficulty of obtaining the required materials in Davao City, manual calculations were employed to determine the value.

Carter et al. (2020) generated a single, cross-site equation for Tg based on Kestrel monitor data from all three sites. A 30% holdout was used to generate the Tg equation since it was based on data from the same device in which Tg was measured.

$$T_g = \mathbf{0.009624(SR) + 1.102(Ta) - 0.00404(RH) - 2.2776}$$

SR refers to Solar Radiation which can be measured and obtained through the using a Pyranometer.

II. SYSTEM ARCHITECTURE

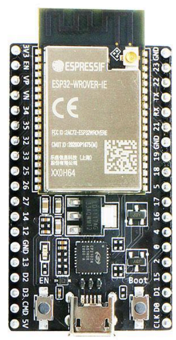
Components Used

The following are the components used in creating the smartwear device:

SHT3X

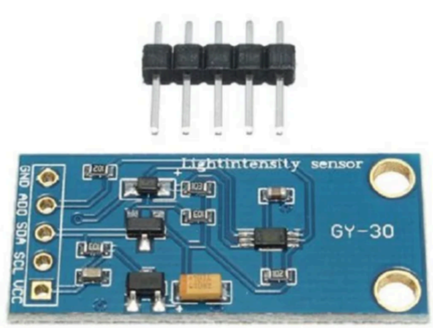
*The **SHT3X** is a high-precision temperature and humidity sensor used to monitor environmental conditions in real-time. In the **SmartWear** device, It helps assess heat stress by providing continuous monitoring of temperature and humidity, enabling timely alerts for the elderly wearer and caregivers when unsafe conditions are detected.*

ESP32-WROOM-32



*The **ESP32-WROOM-32** is a powerful and versatile microcontroller module with built-in Wi-Fi and Bluetooth capabilities, making it ideal for IoT applications. In your SmartWear device, it serves as the central processing unit, collecting data from the SHT3x sensor (temperature and humidity), photoresistor module (solar radiation monitoring), RTC module (real-time clock), and LoRa module (long-range wireless communication). The ESP32 processes this data to evaluate heat stress levels and triggers alerts for elderly health management, ensuring real-time monitoring and efficient connectivity for wearable applications.*

Digital Light Intensity Sensor



*The **Digital Light Intensity Sensor** is a precise light-sensitive sensor designed to measure ambient light intensity and solar radiation levels. In the SmartWear device, it is used to detect variations in solar radiation by converting light intensity into a calibrated digital output. This sensor provides more accurate and reliable measurements of solar radiation compared to analog-based sensors, enabling the ESP32 to process the data for assessing heat stress risks. Its high precision, low power consumption, and digital interface make it an ideal choice for wearable devices focused on monitoring environmental conditions like sunlight exposure.*

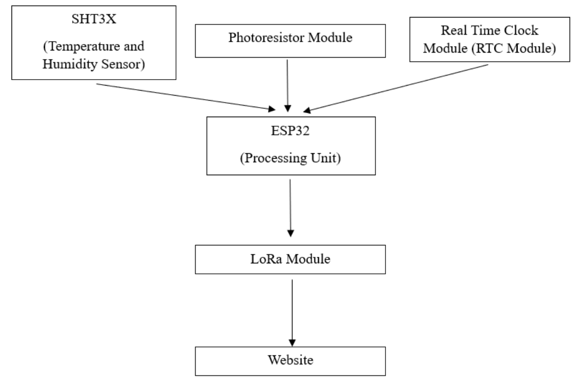
Real Time Clock Module (RTC Module)

*The **RTC (Real-Time Clock) module** is a timekeeping component designed to maintain accurate date and time, even when the main system is powered off. In your SmartWear device, it ensures precise time-stamping of environmental data, such as temperature, humidity, and solar radiation, which is crucial for tracking heat stress trends over time. The RTC module communicates with the ESP32 to provide reliable timekeeping, allowing the system to* *operate efficiently and maintain synchronization for real-time monitoring and alerts.*

LoRa Module

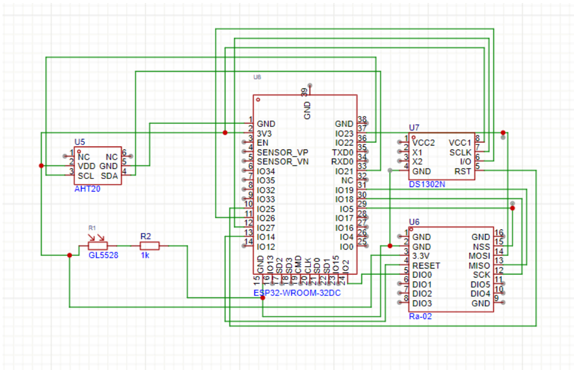
*The **LoRa (Long Range) module** is a wireless communication device that enables low-power, long-range data transmission, making it ideal for IoT applications. In the SmartWear device, the LoRa module is used to transmit measured environmental data, such as temperature, humidity, and solar radiation, to a LoRa gateway. The gateway forwards this data to an internet-connected server, which processes and stores it for access through a mobile app or website. This setup allows for real-time monitoring and tracking of heat stress levels, enabling caregivers and healthcare professionals to make informed decisions.*

Block Diagram



The system is designed to monitor environmental conditions and transmit data for analysis using various sensors and communication modules. The SHT3X sensor measures temperature and humidity, while the Photoresistor module (LDR) detects light intensity, providing essential environmental data. A Real-Time Clock (RTC) module ensures accurate time-stamped data collection. These inputs are processed by the ESP32 microcontroller, which acts as the system's central processing unit, performing necessary computations and preparing the data for transmission. The processed data is then sent via a LoRa module, enabling long-range, low-power wireless communication. This data is displayed on a website, offering users a clear interface for real-time monitoring and historical analysis, making the system ideal for applications in agriculture, industrial safety, and smart city infrastructure.

111. SCHEMATIC DIAGRAM



The figure above presents the schematic diagram of the proposed project. However, the pyranometer sensor, which is typically used to measure solar radiation for WBGT computation, has not been utilized in this project. Instead, a photoresistor module was employed for monitoring solar radiation. Since the selected sensor and other components are not available in any simulation software, the proponents were unable to verify the circuit through simulation. Consequently, the circuit will be directly constructed and tested in reality.

For this project, the proponents opted for the ESP32 microcontroller due to its lightweight design, making it an ideal choice for wearable applications aimed at the elderly. The ESP32 is programmed to compute the WBGT using the formula provided earlier and is configured to trigger alerts based on the heat stress threshold defined by Dyvia and Arif (2021).

IV. CALIBRATION OF THE DEVICE

The calibration process is crucial to ensure the accuracy and reliability of the SmartWear device. Each component will be carefully calibrated to achieve optimal performance and precise measurements.

The **SHT3X sensor**, responsible for monitoring temperature and humidity, will be calibrated in a controlled environment, such as a closed area with predetermined temperature and humidity settings. This ensures that the sensor's readings align closely with standard reference values.

The **BH1750 sensor**, used for measuring light intensity, will be calibrated by comparing its digital output to standardized light intensity values under controlled lighting conditions. This process involves placing the sensor in environments with known illumination levels and fine-tuning its data interpretation to ensure precise and reliable measurements.

The **Real-Time Clock (RTC) module** will be calibrated by synchronizing it with a reliable time source, such as an internet-based time server or a GPS module. This ensures that all data collected from the sensors is accurately time-stamped for precise logging and analysis.

The **ESP32 microcontroller**, which serves as the system's processing unit, will be tested to ensure that it accurately processes data from the sensors and transmits it without delay. The calibration process includes validating its ADC (Analog-to-Digital Converter) performance and ensuring consistent communication with other components via I2C and SPI protocols.

Finally, the **LoRa module** will be calibrated to optimize its transmission range and power consumption. This involves testing the module's performance in various environments and adjusting its signal strength and frequency parameters to ensure reliable data transmission over long distances. Together, these calibration steps ensure that the SmartWear device operates with high precision and reliability in real-world conditions.

III. REFERENCES

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