INSIGHT (Intelligent Smart Garments for IoT Tracking & Health)

Research Plan

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ABSTRACT

The evolution of wearable technology has transformed the way individuals interact with clothing, extending its purpose beyond mere aesthetics and protection. The Smart Uniform based on the Internet of Things (IoT) integrates embedded sensors, microcontrollers, and smart fabrics to create an intelligent clothing system that ensures health monitoring, safety, and security of the wearer. This project focuses on designing a uniform embedded with biosensors and environmental sensors connected to an ESP32 microcontroller, enabling continuous monitoring of health parameters such as heart rate, body temperature, blood pressure, blood oxygen level (SpO_2), and dehydration status.

Additionally, the uniform incorporates fall detection using accelerometer sensors and provides emergency alerts through SMS and mobile applications. Safety features include GPS-based tracking, geofencing, automatic attendance logging, and panic button functionality. Environmental adaptability is achieved through the use of fire- and chemical-resistant materials, UV exposure detection, and temperature-regulating smart fabric.

The data collected by the uniform is transmitted to a cloud platform through Wi-Fi or GSM connectivity, where it is processed, stored, and visualized on a mobile app dashboard. Alerts are triggered in abnormal situations, ensuring immediate communication with guardians, teachers, employers, or security personnel. The proposed system aims to provide practical solutions in educational institutions, industries, healthcare, and defense, where monitoring and safety are critical. The Smart Uniform project highlights the convergence of IoT, wearable sensors, and smart textiles into a unified platform that enhances well-being, safety, and operational efficiency.

INTRODUCTION

In the digital era, the integration of smart systems into daily life has gained remarkable momentum. The Internet of Things (IoT) has emerged as a transformative technology that connects physical devices, sensors, and systems to the internet, enabling real-time data collection, monitoring, and decision-making. Among its diverse applications, wearable IoT systems stand out as one of the most impactful innovations, particularly in the field of healthcare, safety, and workplace efficiency.

Uniforms are traditionally used for identity, discipline, and protection, but their function has been limited to clothing alone. The Smart Uniform concept redefines the role of uniforms by embedding IoT-enabled sensors into textile materials. This innovation provides a dual advantage: it ensures comfort and protection while also delivering intelligent features that enhance security, safety, and performance monitoring.

Smart Uniforms can play a vital role in multiple sectors. In **educational institutions**, the uniform can automatically record attendance, monitor student health, and provide safety through GPS tracking. In **industrial workplaces**, it can monitor worker health, detect harmful gases, and send alerts in case of accidents. For **military personnel**, Smart Uniforms offer tactical advantages such as live location tracking, fatigue detection, and emergency alerts during field operations. Similarly, in **healthcare**, doctors and nurses can benefit from uniforms that continuously monitor their vital signs and reduce risks associated with stress or fatigue.

The Smart Uniform IoT project uses the ESP32 microcontroller as the core component for data acquisition and wireless communication. Biosensors such as MAX30102 for SpO_2 and heart rate, DS18B20 for body temperature, and accelerometers for fall detection are embedded into the uniform. Additional modules like GPS and panic buttons ensure real-time tracking and safety. Data is transmitted to cloud-based platforms such as Blynk or Firebase, where it can be accessed through mobile or web applications.

This project addresses critical issues such as health emergencies, delayed response to accidents, poor attendance management, and lack of real-time monitoring. By integrating IoT with wearable uniforms, the project creates a comprehensive solution that is both innovative and socially relevant.

STATEMENT OF THE PROBLEM

Statement of the Problem

Traditional uniforms lack intelligent features, leaving students, workers, or soldiers vulnerable to health risks, accidents, and safety threats. Manual attendance tracking is time-consuming and error-prone. Parents, teachers, and employers often lack real-time updates about the safety and well-being of individuals wearing uniforms. Emergencies such as fainting, accidents, or unauthorized absence often go undetected until it is too late. There is a need for an intelligent uniform that integrates health monitoring, safety, and communication features into a single system.

Background Information

The rapid advancement of IoT, smart fabrics, and low-power sensors has paved the way for intelligent wearables. IoT wearables like smartwatches and fitness bands have already proven the feasibility of continuous health monitoring. However, these devices are limited in scope and are not seamlessly integrated into clothing. Smart Uniforms build upon this technology by embedding sensors directly into the fabric or pockets of uniforms, making them less intrusive and more natural for daily use.

Global trends in **smart textiles** demonstrate successful applications in military uniforms, firefighter suits, and medical clothing. These developments have shown the potential of smart fabrics to detect environmental hazards, regulate temperature, and improve performance. IoT further extends these capabilities by allowing real-time communication of collected data to cloud systems and mobile applications.

Thus, the Smart Uniform project is positioned at the intersection of wearable technology, IoT, and smart textiles. By embedding multiple sensors into a uniform and enabling IoT connectivity, the system provides a holistic solution for real-time monitoring, safety, and communication.

OBJECTIVES

1. To design and develop a Smart Uniform embedded with IoT-enabled sensors.
2. To monitor vital health parameters such as heart rate, body temperature, blood pressure, SpO_2, and dehydration.
3. To integrate safety features including GPS tracking, geofencing, panic button, and SOS alerts.
4. To automate attendance logging through smart identification and geofencing.
5. To ensure environmental adaptability through fire/chemical resistance, UV detection, and temperature regulation.
6. To transmit data to a cloud platform for real-time monitoring and analysis.
7. To provide guardians, employers, and security personnel with live updates and emergency alerts.

HYPOTHESIS

A uniform is embedded with **IoT-enabled health and safety sensors**, then it can provide **real-time monitoring, emergency alerts, and automated tracking,** thereby **improving safety, security, and efficiency** for students, workers, and defense personnel.

EXPERIMENTAL PROCEDURE

1. Core Controller

- **ESP32 Dev Board** (with Wi-Fi + Bluetooth, 30-pin or 38-pin version)

2. Sensors

- **MAX30102 / MAX30105** → Heart Rate + SpO_2
- **DS18B20 (Digital Temperature Sensor)** → Body temperature
- **MPU6050** → Accelerometer + Gyroscope (Fall detection + motion sensing)
- **NEO-6M GPS Module** → Location tracking
- **Optional**:
  - Sweat sensor → Dehydration
  - UV sensor (ML8511) → UV exposure monitoring
  - MQ-135 → Air quality

3. Supporting Components

- **Panic Button (Tactile push button)** → Emergency SOS trigger
- **Li-ion Battery Pack (3.7V, 2000mAh+)** with charging module (TP4056)
- **Voltage regulator (if needed)**
- **Connecting wires (Male-to-female jumper wires)**
- **Small breadboard / PCB** for prototyping
- **Heat-shrink tubing or fabric pockets** to embed in uniform

✅ ESP32 Pin Mapping

Component	**Pin on ESP32**	**Notes**
MAX30102 (HR+SpO_2)	SDA → GPIO 21 SCL → GPIO 22	I2C interface
DS18B20 Temp	Data → GPIO 4	Needs 4.7kΩ pull-up resistor
MPU6050 (Fall)	SDA → GPIO 21 SCL → GPIO 22	Shares I2C with MAX30102
NEO-6M GPS	TX → GPIO 16 (RX2) RX → GPIO 17 (TX2)	UART interface
Panic Button	One side → GPIO 25 Other side → GND	Use INPUT_PULLUP
Power	3.3V / 5V (depends on sensor)	Common ground required

Hardware Integration

- Embed sensors into the uniform fabric or pockets.
- Connect sensors to the ESP32 using I2C/SPI/UART interfaces.
- Power system with rechargeable Li-ion battery, with optional solar/kinetic charging.

Software Development

- Program ESP32 in Arduino IDE.
- Read sensor data and preprocess values.
- Establish Wi-Fi/GSM communication for cloud upload.
- Configure Blynk/Firebase for real-time monitoring.

Cloud and Mobile App Setup

- Create a dashboard with parameters: heart rate, SpO_2, temperature, GPS.
- Configure geofencing and fall alert notifications.
- Enable SMS/WhatsApp emergency alerts via APIs.

Testing & Validation

- Test health sensors under controlled conditions.
- Simulate fall detection with accelerometer.
- Validate GPS accuracy for geofencing.
- Test emergency button and SMS alert system.

Code:

```
/*********************************************************
  SMART UNIFORM IoT Project - ESP32
  Features:
  ✅ Heart Rate, SpO2 (MAX30102)
  ✅ Temperature (DS18B20)
  ✅ Fall Detection (MPU6050)
  ✅ GPS Tracking (NEO-6M)
  ✅ WiFi + Blynk Cloud
  ✅ Emergency Alert (SMS/WhatsApp)
*********************************************************/

#include <WiFi.h>
#include <HTTPClient.h>
#include <Wire.h>
#include "MAX30105.h"
#include "heartRate.h"
#include <OneWire.h>
#include <DallasTemperature.h>
#include <Adafruit_MPU6050.h>
#include <Adafruit_Sensor.h>
#include <TinyGPSPlus.h>
#include <HardwareSerial.h>
#include <BlynkSimpleEsp32.h>

/************* WiFi + Blynk *************/
char auth[] = "Your_BLYNK_AUTH_TOKEN";
char ssid[] = "Your_WIFI_SSID";
char pass[] = "Your_WIFI_PASSWORD";

/************* Heart Rate & SpO2 *************/
MAX30105 particleSensor;
long lastBeat = 0;
float beatsPerMinute;
int beatAvg;

/************* Temperature Sensor (DS18B20) *************/
#define ONE_WIRE_BUS 4   // GPIO4 for DS18B20
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

/************* Accelerometer (Fall Detection) *************/
Adafruit_MPU6050 mpu;
bool fallDetected = false;
```

```
/************* GPS *************/
HardwareSerial SerialGPS(1);
TinyGPSPlus gps;
double latitude, longitude;

/************* Setup *************/
void setup() {
  Serial.begin(115200);

  // WiFi + Blynk
  WiFi.begin(ssid, pass);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500); Serial.print(".");
  }
  Serial.println("\n✅ WiFi Connected!");
  Blynk.begin(auth, ssid, pass);

  // MAX30102 (Heart Rate + SpO2)
  if (!particleSensor.begin(Wire, I2C_SPEED_STANDARD)) {
    Serial.println("❌ MAX30102 not found!");
    while (1);
  }
  particleSensor.setup();

  // DS18B20
  sensors.begin();

  // MPU6050
  if (!mpu.begin()) {
    Serial.println("❌ MPU6050 not found!");
    while (1);
  }

  // GPS (RX=16, TX=17 on ESP32)
  SerialGPS.begin(9600, SERIAL_8N1, 16, 17);

  Serial.println("✅ System Ready");
}

/************* Loop *************/
void loop() {
  Blynk.run();

  // ✅ Heart Rate & SpO2
  long irValue = particleSensor.getIR();
```

```
 if (checkForBeat(irValue)) {
   long delta = millis() - lastBeat;
   lastBeat = millis();
   beatsPerMinute = 60 / (delta / 1000.0);
   if (beatsPerMinute < 255 && beatsPerMinute > 20) {
     beatAvg = (beatAvg * 0.9) + (beatsPerMinute * 0.1);
   }
   Serial.print("BPM: "); Serial.println(beatAvg);
   Blynk.virtualWrite(V1, beatAvg);
 }
 Blynk.virtualWrite(V2, irValue / 1000.0); // simplified SpO2 demo

 // ✅ Temperature
 sensors.requestTemperatures();
 float tempC = sensors.getTempCByIndex(0);
 Serial.print("Temp: "); Serial.println(tempC);
 Blynk.virtualWrite(V3, tempC);

 // ✅ Fall Detection
 sensors_event_t a, g, t;
 mpu.getEvent(&a, &g, &t);
 if (abs(a.acceleration.x) > 15 || abs(a.acceleration.y) > 15 || abs(a.acceleration.z) > 15) {
   fallDetected = true;
   Serial.println("⚠ Fall Detected!");
   Blynk.logEvent("fall_alert", "Fall Detected!");
 }

 // ✅ GPS
 while (SerialGPS.available() > 0) {
   gps.encode(SerialGPS.read());
   if (gps.location.isUpdated()) {
     latitude = gps.location.lat();
     longitude = gps.location.lng();
     Serial.printf("GPS: %.6f , %.6f\n", latitude, longitude);
     Blynk.virtualWrite(V4, latitude);
     Blynk.virtualWrite(V5, longitude);
   }
 }
 // ✅ Emergency Alerts
 if (beatAvg < 50 || beatAvg > 120 || tempC > 38 || fallDetected) {
   sendEmergencyAlert(latitude, longitude);
 }

 delay(1000);
}
```

```
/************* Emergency SMS/WhatsApp *************/
void sendEmergencyAlert(double lat, double lon) {
  if (WiFi.status() == WL_CONNECTED) {
    HTTPClient http;
    String url = "https://api.callmebot.com/whatsapp.php?phone=+YOURNUMBER"
                 "&text=🚨+Smart+Uniform+Emergency!+Location:+"
                 + String(lat, 6) + "," + String(lon, 6) +
                 "&apikey=YOUR_API_KEY";
    http.begin(url.c_str());
    int httpResponseCode = http.GET();
    if (httpResponseCode > 0) {
      Serial.println("✅ Emergency Alert Sent!");
    } else {
      Serial.println("❌ Failed to send alert.");
    }
    http.end();
  }
}
```

RISK AND SAFETY

- Electrical Safety: Proper insulation of circuits to avoid shocks.
- Data Privacy Risks: Sensitive health/location data must be encrypted.
- Battery Safety: Use certified Li-ion batteries to prevent overheating.
- Fabric Comfort: Sensors should be embedded without causing discomfort to the wearer.
- Environmental Risks: Components must be washable or detachable for uniform cleaning.

DATA ANALYSIS

TABULATION

Parameter	Normal Range	Recorded Value	Status
Heart Rate (BPM)			
SpO_2 (%)			
Temperature (°C)			
Fall Detection			
GPS Location			

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