

Determination Of Varicose Veins Problems Using Concurrent Sensor Network With Heat Treatment Module

Karthikeyan D¹, Dhanush D², Harikrishnan S³, Jagadesh J⁴, Jagan K⁵

¹Associate professor, Department of Biomedical Engineering, Dhanalakshmi Srinivasan Engineering College (Autonomous) Perambalur-621212.

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Abstract- Varicose veins are a prevalent vascular disorder caused by weakened vein walls and malfunctioning valves, resulting in improper blood circulation and vein enlargement in the lower extremities. Early identification and timely intervention are essential to prevent complications such as venous ulcers and chronic discomfort. This paper presents a wearable healthcare system designed to detect and manage varicose vein conditions using a concurrent sensor network integrated with a heat treatment module. The proposed system employs multiple sensors, including photoplethysmography (PPG), temperature, infrared, and pressure sensors, to acquire physiological data related to blood circulation and skin temperature variations. The collected signals are processed using a microcontroller-based system that performs real-time analysis and identifies abnormal vascular patterns. Upon detecting irregularities, the system activates a controlled heat therapy module to improve blood flow and reduce discomfort. The integration of sensing and therapeutic functionality enables continuous monitoring and immediate intervention, enhancing patient convenience and reducing dependency on hospital visits. The proposed framework demonstrates the effectiveness of IoT-based wearable systems in improving vascular health monitoring and providing automated therapeutic response for varicose vein management.

Keywords- Varicose veins, wearable healthcare system, concurrent sensor network, heat therapy, IoT-based monitoring, biomedical sensors, ESP32 microcontroller.

I. INTRODUCTION

Varicose veins are a common vascular disorder that occurs due to the weakening of vein walls and malfunctioning venous valves, leading to improper blood flow and vein enlargement. This condition is frequently observed in the lower limbs and is associated with symptoms such as pain, swelling, heaviness, and visible vein distortion. These symptoms significantly affect daily activities and reduce the overall quality of life of affected individuals. Conventional diagnostic techniques such as clinical examination and Doppler ultrasound imaging are commonly used for identifying varicose veins. However, these methods are generally limited to periodic clinical assessments and do not provide continuous monitoring of vascular conditions.

Recent advancements in embedded systems and biomedical technologies have enabled the development of wearable healthcare devices capable of real-time physiological monitoring. The integration of multiple sensors in wearable systems allows continuous data acquisition and analysis, enabling early detection of abnormalities. Such

technologies play a vital role in improving healthcare accessibility and reducing the need for frequent hospital visits.

In this work, a wearable monitoring system is proposed to detect varicose vein conditions using a concurrent sensor network. The system integrates photoplethysmography sensors to measure blood volume variations, temperature and infrared sensors to detect thermal changes in skin tissue, and pressure sensors to assess venous load conditions. These sensors operate simultaneously to capture multidimensional physiological data. The collected data are processed using a microcontroller-based system that performs signal conditioning and analysis.

An intelligent decision-making mechanism evaluates the physiological signals and identifies abnormal vascular patterns such as reduced blood circulation or localized inflammation. Upon detection of abnormal conditions, the system activates a heat treatment module that delivers controlled thermal energy to the affected region. This heat therapy enhances blood circulation and reduces discomfort associated with varicose vein conditions. The combination of continuous monitoring and automated therapeutic



response forms a closed-loop healthcare system that improves patient outcomes and supports preventive healthcare strategies.

II. LITERATURE REVIEW

Several studies have explored the use of advanced sensing technologies and imaging methods for detecting and monitoring varicose vein conditions. Traditional diagnostic approaches primarily rely on Doppler ultrasound imaging, which provides accurate visualization of venous structures but requires clinical infrastructure and trained personnel.

Recent research has focused on the development of non-invasive diagnostic techniques using thermal imaging and wearable sensors. Infrared thermography has been widely used to identify temperature variations associated with venous insufficiency and inflammation. Studies have demonstrated that abnormal temperature distribution patterns can be used as indicators of vascular disorders. Additionally, photoplethysmography (PPG) has been applied in vascular monitoring systems to measure blood flow characteristics and detect circulatory abnormalities.

Wearable healthcare systems incorporating multiple biosensors have gained attention due to their ability to provide continuous monitoring. Researchers have developed sensor-based platforms capable of capturing physiological signals such as temperature, pressure, and blood flow. These systems enable early detection of vascular abnormalities and provide valuable insights into disease progression.

Furthermore, the integration of therapeutic modules within wearable systems has been explored to improve treatment effectiveness. Heat therapy has been recognized as an effective method for enhancing blood circulation and reducing pain associated with vascular disorders. Controlled heat application improves tissue oxygenation and supports recovery in affected regions.

Although several existing systems focus on either detection or treatment, limited research has addressed the integration of both functionalities into a single wearable platform. Therefore, the proposed system aims to bridge this gap by combining concurrent sensor-based monitoring with an automated heat treatment module to provide a comprehensive solution for varicose vein detection and management.

III. PROPOSED SYSTEM

The proposed system is designed to detect varicose vein problems using a concurrent sensor network integrated with a controlled heat treatment module. The system operates as a wearable device that continuously monitors physiological parameters associated with blood circulation and venous health. The primary objective of the system is to identify abnormal vascular conditions and provide immediate therapeutic support through localized heat application.

The system consists of multiple sensing units, including a photoplethysmography (PPG) sensor, temperature sensor, infrared sensor, and pressure sensor. These sensors operate simultaneously to collect real-time physiological signals from the affected region of the lower limb. The PPG sensor measures blood volume changes within the veins, while the temperature and infrared sensors detect variations in skin temperature that indicate inflammation or poor circulation. The pressure sensor measures external pressure applied to the veins, which may influence blood flow.

All sensor outputs are connected to a microcontroller unit that performs signal acquisition and processing. The microcontroller continuously monitors incoming sensor data and compares it with predefined threshold values. If abnormal conditions such as reduced blood circulation or abnormal temperature variations are detected, the system activates the heat treatment module. The heat therapy module applies controlled thermal energy to the affected region to improve blood circulation and reduce discomfort.

Additionally, the system supports data visualization through an IoT-based interface. The physiological parameters collected by the sensors are transmitted to an external device for monitoring and analysis. This enables continuous observation of patient health status and supports preventive healthcare management.

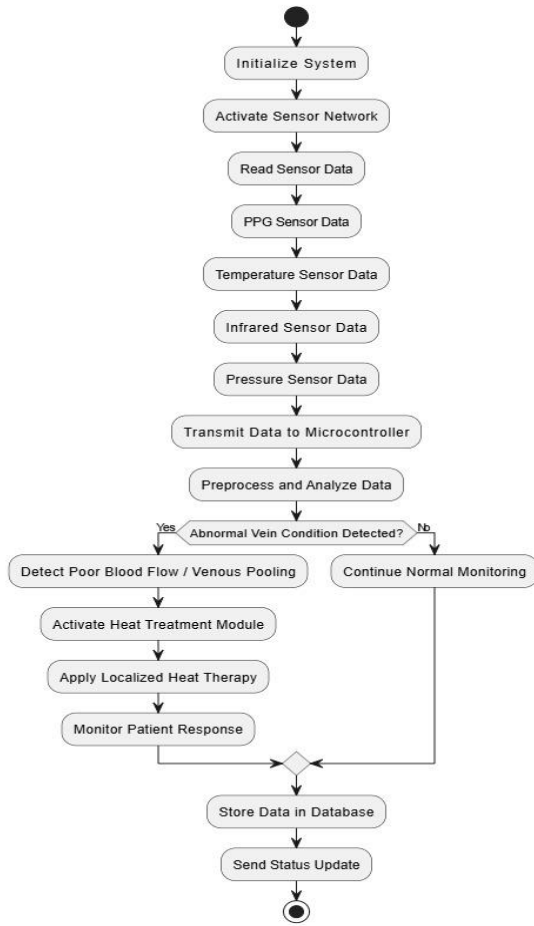
The integration of concurrent sensing and therapeutic functionality makes the proposed system efficient for early detection and treatment of varicose vein conditions in a non-invasive manner.

IV. SYSTEM METHODOLOGY

The methodology of the proposed system involves multiple stages, including sensing, signal processing, decision-making, and therapeutic response. Each stage plays a vital



role in ensuring accurate detection and effective treatment of varicose vein conditions.



Data Acquisition

In the data acquisition stage, multiple sensors are used to collect physiological data simultaneously from the targeted area. The PPG sensor measures variations in blood flow by detecting changes in light absorption through biological tissue. This information provides insight into vascular health and circulation patterns.

The temperature sensor measures surface temperature variations that may indicate inflammation or abnormal blood flow. The infrared sensor detects localized heat differences, which are commonly associated with vascular disorders. The pressure sensor measures the applied force on the affected region, helping to evaluate venous pressure conditions.

All sensors are connected to the microcontroller through analog and digital input channels. The microcontroller continuously reads the sensor values at predefined intervals to ensure real-time monitoring.

Signal Processing

The raw signals obtained from the sensors are processed within the microcontroller to remove noise and improve measurement accuracy. Signal conditioning techniques such as filtering and normalization are applied to enhance signal quality. The processed signals are then converted into digital values for further analysis.

Threshold values are defined based on physiological standards and experimental observations. The processed sensor readings are continuously compared against these threshold values to determine whether the readings fall within the normal or abnormal range.

Decision-Making Mechanism

The decision-making mechanism plays a crucial role in identifying abnormal conditions related to varicose veins. The microcontroller evaluates sensor data patterns to detect irregularities such as decreased blood flow, abnormal temperature rise, or excessive pressure conditions.

If the system identifies abnormal readings from multiple sensors simultaneously, it interprets the condition as a potential varicose vein problem. This multi-sensor verification approach improves detection accuracy and reduces false alerts.

Upon confirmation of abnormal conditions, the microcontroller triggers an alert signal and activates the heat treatment module.

Heat Treatment Module Activation

The heat treatment module consists of a PTC heating element designed to deliver controlled thermal energy to the affected region. Once activated, the module generates heat at a safe temperature range to improve blood circulation and relieve discomfort.

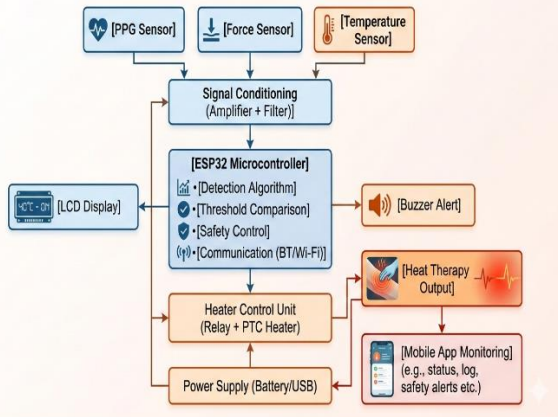
The heating duration is controlled by the microcontroller to prevent overheating and ensure patient safety. Temperature feedback from the sensor is used to regulate the heating process and maintain stable operation.

IoT-Based Monitoring

The system supports remote monitoring through IoT connectivity. Sensor readings are transmitted to an external monitoring platform where healthcare providers or users can view physiological parameters in real time.

The IoT-based system enables continuous observation of patient conditions and supports early intervention when abnormal patterns are detected. Data logging functionality also allows historical analysis of physiological changes.

Smart Wearable Heat Therapy System - System Block Diagram



V. HARDWARE IMPLEMENTATION

The hardware implementation of the proposed system consists of multiple sensing units, a microcontroller, a heat treatment module, and communication interfaces. The system is designed as a wearable device that enables continuous monitoring of physiological parameters related to varicose vein conditions.

Microcontroller Unit

The core component of the proposed system is the ESP32 microcontroller, which is responsible for data acquisition, processing, and decision-making. The ESP32 is selected due to its high processing capability, built-in Wi-Fi module, and support for multiple input/output interfaces. It receives signals from various sensors, processes the data, and controls the operation of the heat treatment module.

The microcontroller continuously reads sensor outputs and compares them with predefined threshold values. If abnormal conditions are detected, the microcontroller activates the heating element and transmits data to the IoT platform for monitoring.

Photoplethysmography (PPG) Sensor

The PPG sensor is used to measure blood volume variations in the veins. It operates based on optical principles, where

light emitted from the sensor penetrates the skin and is reflected based on blood flow conditions. The variation in reflected light intensity corresponds to changes in blood circulation.

This sensor plays an important role in identifying abnormal blood flow patterns associated with varicose vein conditions.

Temperature Sensor

The temperature sensor measures the surface temperature of the skin near the affected region. Increased temperature in localized areas may indicate inflammation or reduced blood circulation. The temperature sensor provides real-time thermal data that is used to detect abnormal conditions.

Infrared Sensor

The infrared (IR) sensor detects variations in thermal radiation emitted from the skin surface. It helps identify localized temperature differences, which are often associated with vascular abnormalities. The infrared sensor improves detection accuracy by providing additional thermal information.

Pressure Sensor

The pressure sensor measures external pressure applied to the veins. Excess pressure can influence blood circulation and contribute to vein swelling. This sensor helps monitor pressure-related conditions and supports accurate decision-making.

Heat Treatment Module

The heat treatment module consists of a PTC heating element designed to provide controlled thermal energy to the affected region. When abnormal vascular conditions are detected, the microcontroller activates the heating module. The PTC heater generates safe and stable heat levels, which improve blood circulation and reduce pain associated with varicose vein conditions. The heating duration and temperature are controlled to prevent overheating.

Display Unit

A 16x2 LCD display is used to show real-time sensor values and system status. The display provides user-friendly information such as temperature readings, blood flow status, and heating module activation.

Power Supply Unit

The power supply unit provides regulated voltage to all system components. A stable power source ensures reliable operation of sensors, microcontroller, and heating modules.



VI. SOFTWARE IMPLEMENTATION

The software implementation of the proposed system is developed using embedded programming techniques. The microcontroller is programmed to read sensor values, process data, and control system operations.

The software begins by initializing all connected sensors and communication modules. The microcontroller continuously reads sensor inputs and converts analog signals into digital values. The collected data are processed using filtering techniques to remove noise and improve measurement accuracy.

Decision-making logic is implemented using conditional statements. If sensor values exceed predefined threshold limits, the system identifies abnormal vascular conditions and activates the heating module. Simultaneously, the system sends sensor data to the IoT platform for monitoring.

The IoT interface enables remote monitoring of physiological parameters. Users can view real-time data and receive alerts when abnormal conditions are detected. Data logging functionality supports long-term analysis of patient conditions.

VII. RESULTS AND DISCUSSION

The proposed system was tested to evaluate its performance in detecting abnormal vascular conditions. The sensors successfully collected physiological data such as temperature, pressure, and blood flow variations.

During testing, the system demonstrated the ability to detect abnormal temperature rise and reduced blood flow conditions. When these abnormal conditions were identified, the heat treatment module was automatically activated.

The PTC heater generated controlled thermal energy that improved localized circulation. The temperature sensor provided feedback to maintain safe heating levels. The LCD display showed real-time sensor readings, allowing users to monitor system operation.

The IoT platform enabled remote visualization of sensor data, improving accessibility and convenience. The

concurrent operation of multiple sensors improved detection reliability and reduced false readings.

Overall, the proposed system demonstrated effective performance in detecting varicose vein-related conditions and providing controlled therapeutic support.

VIII. ADVANTAGES OF PROPOSED SYSTEM

- Non-invasive monitoring method
- Real-time detection of vascular abnormalities
- Portable wearable design
- Automated heat therapy support
- Reduced dependency on hospital visits
- Improved patient comfort

IX. APPLICATIONS

- Varicose vein monitoring
- Vascular health assessment
- Home-based healthcare monitoring
- Physiotherapy support systems
- Rehabilitation monitoring

X. CONCLUSION

In this paper, a wearable system for the determination of varicose vein problems using a concurrent sensor network with a heat treatment module has been successfully designed and implemented. The system integrates multiple sensors to monitor physiological parameters associated with vascular health.

The use of concurrent sensing improves detection accuracy by analyzing multiple physiological indicators simultaneously. The integration of a heat treatment module enables immediate therapeutic response when abnormal conditions are detected. This combined detection and treatment capability enhances the overall effectiveness of the system.

The IoT-based monitoring feature allows real-time visualization of physiological data and supports remote healthcare applications. The proposed system provides a reliable, non-invasive, and cost-effective solution for early detection and management of varicose vein conditions.

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