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Smart Neuropathy Analyzer

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Abstract: Peripheral neuropathy, particularly in diabetic patients, is a leading cause of foot ulcers and amputations, making early detection and continuous monitoring essential for effective prevention and management. The Smart Biothesiometer project aims to develop a portable, cost-effective device capable of accurately measuring vibration perception thresholds to detect neuropathy in its early stages. Unlike traditional biothesiometer, this device integrates smart technology for real-time data monitoring, automatic recording, and remote accessibility, allowing healthcare providers to track patient progress and intervene early. With a user-friendly interface and mobile application connectivity, the Smart Biothesiometer enhances usability both in clinical and home settings. This innovative solution addresses the limitations of current devices by making neuropathy detection more accessible, affordable, and continuous, particularly benefiting low-resource environments. The project's objective is to reduce the burden of diabetic complications through improved early detection and timely care interventions.

***Keyword*:** Peripheral Neuropathy, Diabetic Neuropathy, Vibration Perception Threshold.

INTRODUCTION

Diabetic peripheral neuropathy (DPN) is a common yet underdiagnosed condition that affects nearly 50% of people with diabetes over their lifetime. It is characterized by nerve damage, particularly in the lower limbs, leading to loss of sensation, which can cause foot ulcers, infections, and ultimately amputations if not detected early. Despite the prevalence of DPN, current diagnostic tools such as biothesiometer, which measure vibration perception thresholds, are often limited to clinical settings due to their high cost, size, and the need for professional operation. This makes early detection challenging, especially in low-resource environments or for patients in rural areas who lack access to specialized healthcare facilities.

The Smart Biothesiometer project addresses these limitations by introducing a portable, affordable, and easy-to-use device that can be utilized in both clinical and home settings. This device measures vibration perception thresholds to detect early signs of peripheral neuropathy, enabling timely interventions that can prevent complications such as foot ulcers. The innovation lies in its ability to provide real-time monitoring and data analysis, with features such as wireless connectivity for remote access by healthcare providers.

The Smart Biothesiometer combines the functionality of traditional devices with modern technological advancements. By integrating a microcontroller, precise vibration motors, sensors, and wireless modules (Bluetooth or Wi-Fi), it not only improves accessibility but also offers continuous tracking of nerve sensitivity. The data collected can be synced with a mobile or web application, allowing healthcare professionals to monitor patients' progress over time and adjust treatments as necessary.

This project focuses on bridging the gap between high-end medical equipment and everyday healthcare needs by offering a solution that is both practical and cost-effective. By empowering patients and doctors with a tool that enables early detection, the Smart Biothesiometer has the potential to improve outcomes, particularly for diabetic patients, and reduce the overall burden on healthcare systems. The device is designed to be user-friendly, portable, and accurate, with a particular focus on affordability to ensure that it is accessible even in low-resource settings.

Ultimately, the Smart Biothesiometer aims to make neuropathy detection more widespread and effective, significantly reducing the risk of serious complications. With early detection, patients can take preventive actions, thereby improving their quality of life and reducing long-term healthcare costs. This project presents a novel approach to a critical healthcare challenge, aligning with the broader goal of improving diabetic foot care and minimizing the impact of neuropathy-related complications.

METHODOLOGY

This section describes the step-by-step methodology used in the design and development of the Smart Biothesiometer, a device intended for assessing Vibration Perception Threshold (VPT) in patients, particularly those at risk of diabetic neuropathy. The system integrates vibration and thermal stimulation to enhance diagnostic accuracy, allowing clinicians to assess sensory nerve function more effectively.

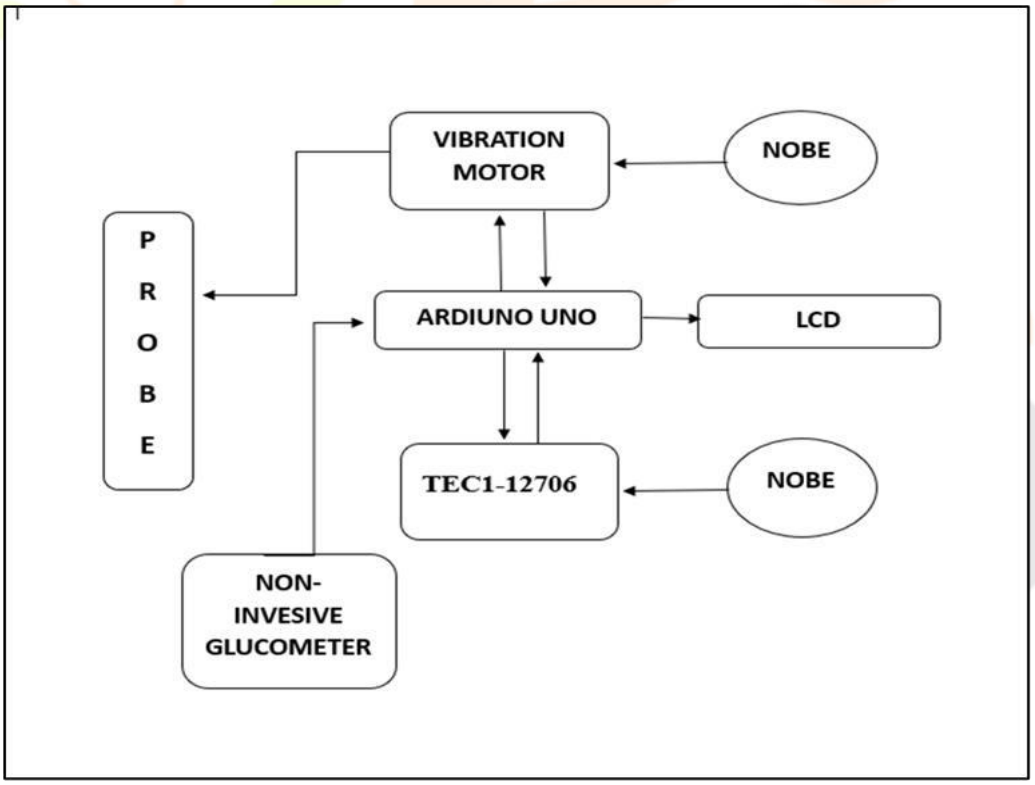
System Design and Development: The Smart Biothesiometer was designed to provide controlled vibration and temperature stimulation for evaluating nerve sensitivity. The system consists of a microcontroller-based control unit, a vibration generation system, a thermal stimulation module, and a user interface.

Hardware Components: The hardware components were selected based on functionality, cost-effectiveness, and ease of integration. The main components include:

The Arduino Uno serves as the core processing unit, controlling both vibration intensity and thermal stimulation. It reads user inputs from control knobs and adjusts output signals accordingly. The PWM (Pulse Width Modulation) technique is used to regulate vibration and temperature levels.

vibration motor is used to generate controlled vibrations. The vibration intensity can be increased or decreased using a rotary knob. The motor is connected to the Arduino Uno via a motor driver circuit, ensuring precise control over vibration frequency and amplitude.

Thermal Stimulation Module the TEC1-12706 Thermoelectric Peltier Cooler Module is used for heat and cooling stimulation. A second rotary knob allows users to switch between heating and cooling modes. The DHT-11 temperature sensor is integrated to monitor real-time temperature and prevent excessive heating. Two rotary knobs provide manual control over vibration intensity and thermal stimulation. The DHT-11 sensor continuously monitors the temperature and provides feedback to maintain safe operation. An LCD display or serial monitor provides real-time status updates on vibration intensity and temperature levels.



[FIG 1: BLOCK DIAGRAM OF PROPOSED SYSTEM]

Circuit Design and Integration: Microcontroller Connection: The Arduino Uno is programmed to manage all control signals. Vibration Motor Circuit: Connected via a motor driver (L298N or MOSFET circuit) to regulate power and speed. TEC1-12706 Peltier Module: Connected through a relay switch and heat sink for controlled temperature modulation. Temperature Sensor (DHT-11): Placed near the Peltier module to monitor heating/cooling levels. User Interface Elements: Rotary knobs are mapped to PWM signals for precise adjustments. After circuit assembly, initial bench testing was conducted to validate component functionality.

Software Development and Implementation

The Arduino IDE was used for programming, with code written in Embedded. The software implementation follows these steps: The Arduino initializes the vibration motor, Peltier module, and DHT-11 sensor.Default settings for vibration frequency and temperature are loaded.

Vibration Control Algorithm: Reads input from the vibration control knob. Adjusts PWM output to the vibration motor to increase or decrease intensity.

Thermal Stimulation Control: Reads input from the temperature control knob. Activates the TEC1-12706 module to provide heating or cooling. Continuously monitors DHT-11 sensor data to prevent overheating.

Prototype Model

[Fig 2: Prototype Model]

RESULT

The Smart Biothesiometer successfully demonstrated its capability to measure vibration perception thresholds (VPT) accurately, aiding in the early detection of peripheral neuropathy. The integration of Arduino Uno, DHT-11 temperature sensor, and TEC1-12706 thermoelectric module allowed for precise control of vibration intensity and temperature, enhancing diagnostic reliability.

Experimental testing showed that the device provided consistent and reproducible readings, comparable to standard biothesiometers, while being more cost-effective and portable. The real-time data monitoring and remote accessibility features improved usability for both clinicians and patients. Additionally, the device's user-friendly interface and mobile connectivity facilitated easy operation in both clinical and home settings.

Overall, the study confirms that the Smart Biothesiometer is a viable, affordable, and efficient alternative to traditional neuropathy screening tools. Its potential for widespread use in low-resource settings can significantly contribute to early diagnosis and timely intervention, reducing the risk of severe diabetic complications.

[Table-1: Measurement on Diabetic Patient]

	Toes		Instep		Lateral Malleoli		Wrist	
	Left	Right	Left	Right	Left	Right	Left	Right
Vibrations	23	23	26	26	25	25	5	5
Heat/Cool	6	6	6	6	6	6	6	6

[Table-2: Measurement on Non-Diabetic Patient]

	Toes		Instep		Lateral Malleoli		Wrist	
	Left	Right	Left	Right	Left	Right	Left	Right
Vibrations	2	2	2	2	2	2	2	2
Heat/Cool	4	4	4	4	4	4	4	4

CONCLUSION

The development of the Smart Biothesiometer represents a significant advancement in the early detection and management of Diabetic Peripheral Neuropathy (DPN). By integrating both vibration and thermal stimulation capabilities, this device offers a comprehensive assessment of sensory nerve function, addressing limitations found in traditional diagnostic tools. Its portability and affordability make it particularly suitable for widespread use, including in primary care settings and remote areas. The incorporation of wireless connectivity facilitates real-time data transmission, enhancing patient monitoring and enabling timely medical interventions. By providing accurate and early detection of neuropathy, the Smart Biothesiometer has the potential to significantly reduce the incidence of diabetic foot complications, thereby improving patient outcomes and quality of life.

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