“NEUROCARE”: A PILOT STUDY ON CUSTOMIZED SOLE THERAPEUTIC DEVICE FOR PERIPHERAL NEUROPATHY WITH VIBRATION ACUPRESSURE, PHOTOBIOMODULATION AND OXYGEN ENRICHMENT

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Keywords:

Diabetic Neuropathy, Photobiomodulation, Vibration Acupressure, Oxygen Enrichment, Smart Therapeutic Insole

Introduction:

Diabetes mellitus is a chronic metabolic disorder affecting millions worldwide and leading to several complications. One of the most serious is diabetic peripheral neuropathy, which causes loss of sensation in the feet due to nerve damage. As a result, patients are unable to feel pain or injuries, making the foot vulnerable to unnoticed wounds that can develop into diabetic foot ulcers (DFU).

Diabetic foot ulcers are open sores commonly found on the bottom of the foot and are a major cause of hospitalization and amputations. Early stages such as Wagner Grade 0–1 often go unnoticed, making timely detection and prevention extremely important.

Current treatment methods mainly focus on post-ulcer care and require frequent hospital visits, making them costly and less accessible. Existing devices are often bulky and limited to single-mode therapy, reducing their effectiveness for continuous use.

Key parameters such as temperature, blood circulation, and oxygen levels help in identifying early abnormalities. Monitoring these parameters can significantly reduce the risk of ulcer formation.

Hence, NeuroCare is proposed as a multi-modal, non-invasive therapeutic system that integrates vibration acupressure, photobiomodulation, and oxygen enrichment to provide early intervention and improve diabetic foot care.

*Note: Interacted with a Podiatrist, Diabetologist, and Vascular Surgeon at Jain Institute of Vascular Sciences, Bangalore.

Visited CDSIMR (Orthopaedics) and Aarogya Clinic to gain insights from an acupressure specialist

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Fig 1:Types of Diabetic Foot Ulcer

Fig 2: Classification Of Ulcer Grades

OBJECTIVES:

1. To design a therapeutic insole combining the Vibrational Acupressure, Photobiomodulation and Oxygen Enrichment for early-stage diabetic peripheral neuropathy (Wagner 0)
2. To develop a mobile software for monitoring patient data.
3. To integrate patient data logging (age, ID, ABI index, SpO_2, thermal/pressure data) for monitoring and analysis.
4. To establish validation methods using pulse oximeter, thermal imaging, and plantar pressure analysis.
5. To evaluate the combined hardware-software system for usability and clinical relevance in early detection and therapy.

METHODOLOGY:

Materials:The NeuroCare system consists of vibration motors, photobiomodulation LEDs (660 nm Red and 940 nm Infrared), and oxygen enrichment modules integrated into a single therapeutic platform. Sensors such as DHT11 (temperature and humidity) and pulse oximeter (SpO_2) are used for monitoring.An ESP32 microcontroller controls all modules and ensures synchronized operation. The setup is built in a therapeutic box model for proper foot placement. A software interface is used to display sensor values and analyze thermal patterns of the foot for identifying abnormal regions.

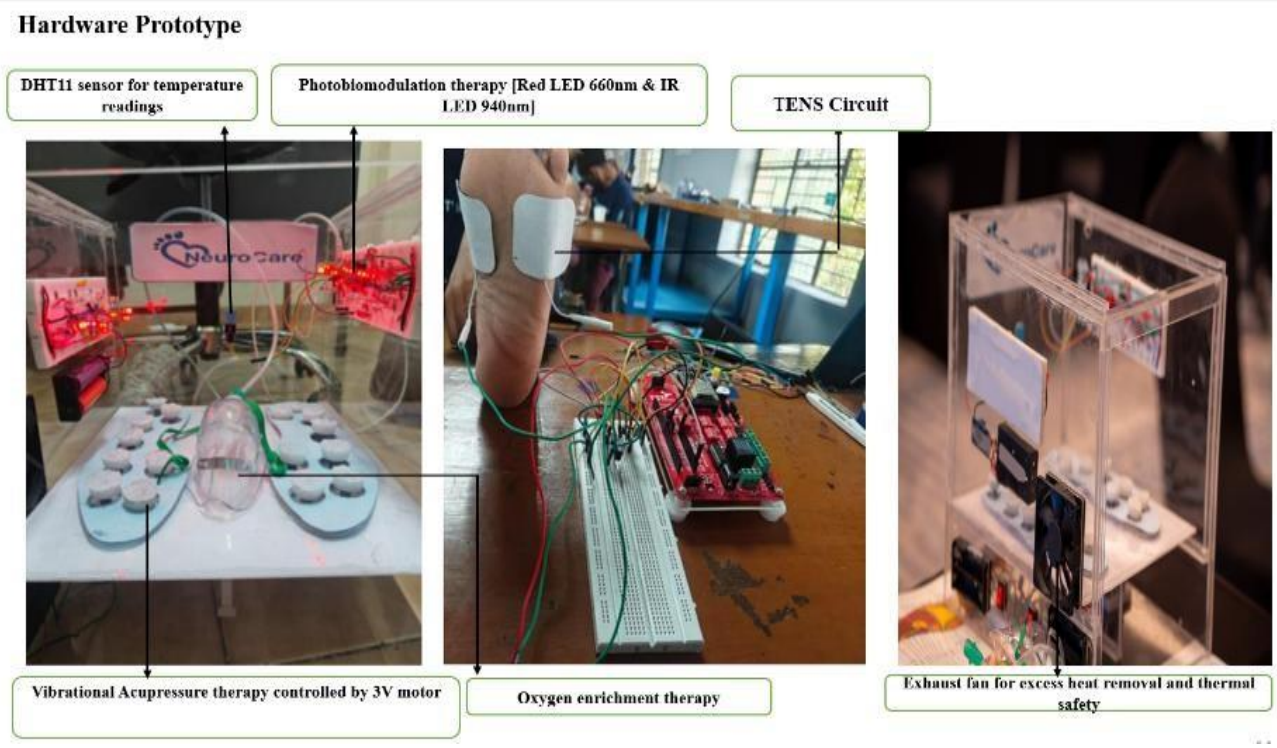

Fig 3: Integration Of Vibration Acupressure, Photobiomodulation, And Oxygen Enrichment Within A Single Therapeutic Platform

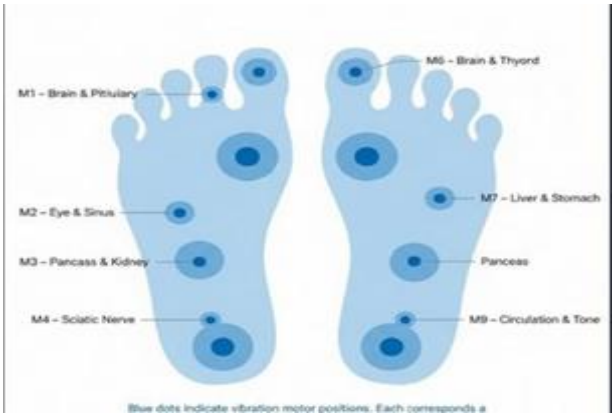

Fig 4: Vibration Nodes Mapping

Methods:

1. The system begins with patient data collection and thermal analysis to identify hotspots and safe regions. Based on this, therapy is planned.
2. During the session, vibration acupressure stimulates nerve endings, while photobiomodulation improves blood circulation and tissue healing. Oxygen enrichment is activated when required based on SpO_2 levels.
3. All parameters are continuously monitored to ensure safety. After therapy, thermal patterns are analyzed to evaluate improvement.
4. Thus, NeuroCare provides a non-invasive, multi-modal, and personalized therapy for early- stage diabetic neuropathy management.

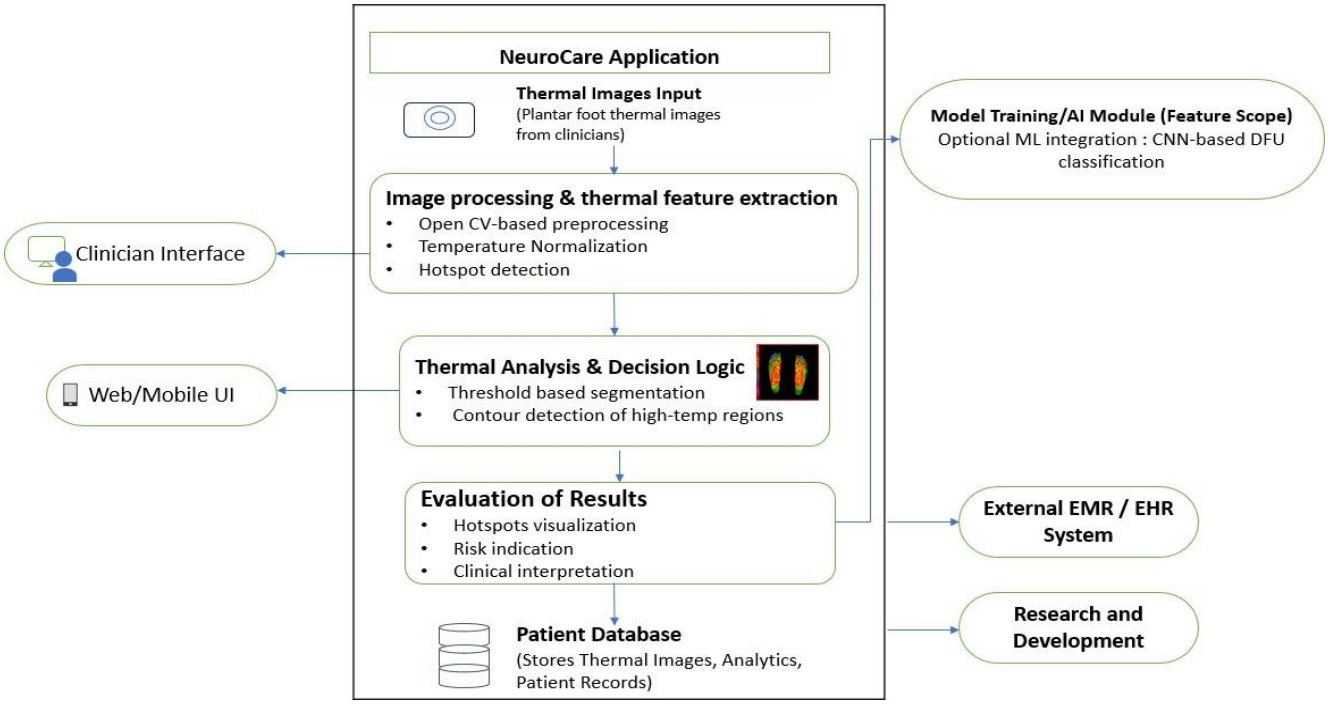

Fig 5: Software Architecture

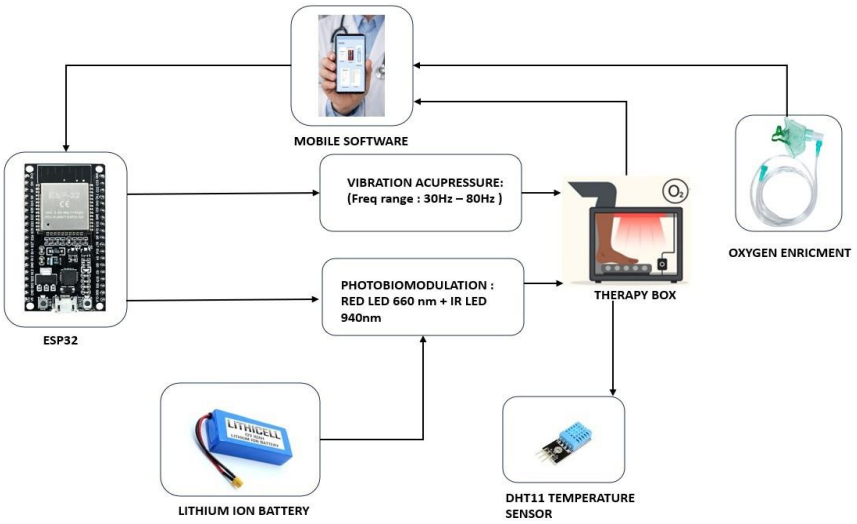

Fig 6: Block Diagram

Result And Conclusion:

The project outcome demonstrates the effectiveness of the NeuroCare system in providing early-stage therapeutic support for diabetic neuropathy. When the user places the foot inside the system, multiple therapy modules such as vibration acupressure, photobiomodulation, and oxygen enrichment are activated in a synchronized manner.During the therapy session, sensor parameters including temperature, humidity, and SpO_2 are continuously monitored. All readings remained within safe physiological limits, indicating that the system operates safely without causing discomfort or adverse effects.The thermal analysis before and after therapy shows improved temperature distribution across the foot, indicating better blood circulation and activation of microvasculature. Regions with abnormal temperature patterns are identified and treated selectively, ensuring targeted and safe therapy.The LED outputs (Red and Infrared) remained stable without overheating, while vibration motors provided

uniform stimulation across plantar regions. The ESP32-based control system ensured reliable execution and uninterrupted operation throughout the session.These results confirm that the integration of multiple therapeutic modalities provides better effectiveness compared to single-mode systems.

In conclusion, NeuroCare proves to be a safe, non-invasive, and efficient therapeutic platform for early intervention in diabetic neuropathy. With further refinement and clinical validation, the system has strong potential to evolve into a clinically deployable solution for diabetic foot care and prevention of ulcer formation

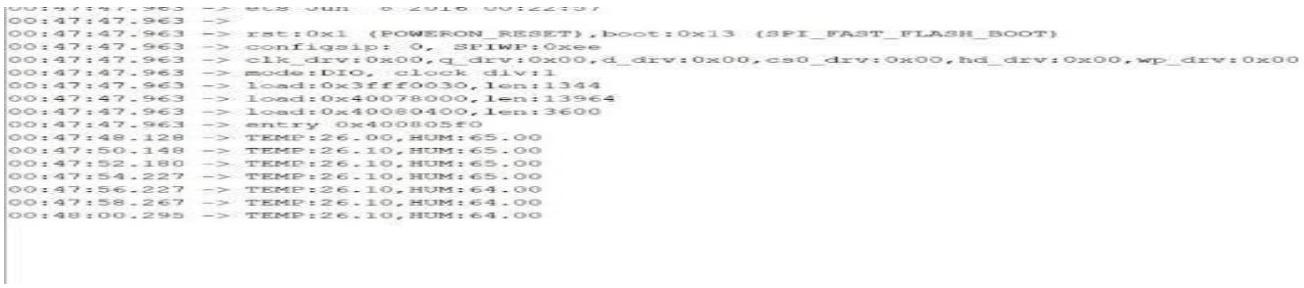

Fig 7: DHT 11 Sensor Readings

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Future Scope:

The future scope of this project includes:

1. Miniaturization and medical-grade certification with clinical trials to develop NeuroCare into a scalable solution for diabetic foot care in both rural and urban settings
2. Integration of AI-driven analysis for early ulcer prediction and improved clinical decision-making
3. Implementation of personalized therapy and remote doctor monitoring through cloud connectivity