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RESEARCH ARTICLE

SOLECARE: DESIGN AND DEVELOPMENT OF A SMART WEARABLE SHOE WITH INTEGRATED SENSOR SYSTEM TO DETECT AND WARN DIABETIC NEUROPATHY

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Abstract

Diabetic neuropathy is an established complication of diabetes mellitus which is caused due to nerve damage because of protracted exposure to high blood sugar. This disease affects close to 50% of the patients who suffer with diabetes. Diabetic Neuropathy has different types, which include peripheral, autonomic and focal neuropathies.A proactive diagn osis undertaken at an appropriate time along with exposure to suitable t reatment often results in reducing the effect of the complication associa ted with diabetic neuropathy.This not only helps in all eviating the qual ity of life but also has a secondary effect of averting any further injury or damage to the nerves. This research paper outlines the creation and development of Solecare, a smart wearable shoe equipped with sensors designed to detect and notify users about early indicators of diabetic neuropathy that frequently go unnoticed. By utilizing technology and AI algorithms, this research provides an innovative solution to fill the gaps in existing detection methods while offering a cost-effective product. Various detection methods have been merged under a single umbrella to increase the probability of detection of diabetic neuropathy The paper outlines the conceptual model, the technology used, and pote ntial implications for healthcare while proposing its ease of scalability and affordability in the medical field.

Introduction:-

Diabetic neuropathy is a prevalent and one of the common complication of diabetes, wherein high blood sugar levels lead to nerve damages[1]. The ailment affects the nerves which are in the periphery particularly those nerves which are existent in the areas of foot and hand. The symptoms that arise owing to this include tingling, numbness and even pain.Studies reveal that the diseasespecially occurs on the sensory axons, autonomic axons and to a lesser extent, on

[1]Feldman, E. L., Callaghan, B. C., Pop-Busui, R., Zochodne, D. W., Wright, D. E., Bennett, D. L., Bril, V., Russell, J. W., & Viswanathan, V. (2019) [Internet]. Diabetic neuropathy. Nature reviews. Disease primers, 5(1), 42. [Cited 2025 Oct 26]. Available from: https://doi.org/10.1038/s41572-019-0097-

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the motor axons[2]. Studies undertaken over a period of time reveal that individuals suffer from foot ulcers and even infections thus displaying the characteristics of this disease, that it affects lower extremities of the human body. Diabetic neuropathy is a complex disease which is progressive in nature. It initially damages the longest nerves of the body and spreads further leading to serious issues like foot ulcers and in some cases amputation. It is therefore considered as a length-dependent neuropathy.

2.2 The report by International Diabetes Federation (IDF) in its yearly edition of Diabetes Atlas (2025)[3] states that 11.1%, or 1 in 9 of the adult population aged between 20 to 79 years is currently living with diabetes while over 4 in 10 are simply not unaware that they have the condition. The report also makes an estimation that worldwide about 589 million people are suffering from diabetes, thus making diabetes as the largest global epidemic of the 21st century. The report brings to light that about 147 million people in China, 89 million in India and 39 million in the United States suffer from diabetes. It is further estimated that by 2050, the trend is even more disheartening wherein 1 in 8 adults, which amounts to approximately 853 million, will likely be living with diabetes. This shows an increase of about 46%. The study brings out that over 90% of the people suffering from diabetes are type 2[4].

The underlying reason for this include socio-economic condition, demographic disposition, environmental condition, and genetic factors. About 4 out of 5 adults who suffer from diabetes which approximates to about 81% live in low and middle-income countries. It is shocking to learn that about 3.4 million deaths were attributable to diabetes in 2024 which brings out another fact that there was a death 1 every 9 seconds owing to diabetes. Despite advances in medical field about 43% of adults who are living with diabetes approximating to about 252 million people remain undiagnosed. Amongst these it is estimated that 90% live in low and middle-income countries. In 2024 Diabetes extracted close to USD 1.015 trillion[5] in global health expenditure. This figure signifies an increase of 338% over the past 17 years. About 635 million adults[6]all across the globe (1 in 8) have reduced glucose tolerance while 488 million population have impaired fasting glucose (1 in 11) thus placing them under the high risk of type 2 diabetes.

Problem Statement:-
Diabetic neuropathy is often undiagnosed or diagnosed very late due to the lack of effective early detection methods. While the current tests are costly they are also not accessible to all. Additionally, many of the patients remain asymptomatic until the later stages of the disease. This paper addresses the challenge of early diagnosis of diabetic neuropathy to improve patient outcomes and further reduce healthcare costs.

The contribution of this research is three-fold:
A non-invasive solution to monitor parameters simultaneously.
Provide real-time alerts that can avert the progression of diabetic neuropathy.
A scalable and cost effective prototype that has the ability to evolve into a commercial product.

[2]Website, N. (2025, July 9). [Internet]. Diagnosis. [Cited 2025 Oct 25]. Available from: nhs.uk. https://www.nhs.uk/conditions/peripheral-neuropathy/diagnosis/
[3]International Diabetes Federation. (2025, July 3) [Internet]. Diabetes Facts and Figures | International Diabetes Federation.[Cited 2025 Oct 26]. Available from: https://idf.org/about%20diabetes/diabetes-facts-figures
[4]Asia's increasing diabetes burden spurs care management strategies. [Internet]. (n.d.). [Cited 2025 Oct 25]. Available from: https://www.biospectrumasia.com/opinion/30/24599/asias-increasing-diabetes-burden-spurs-care-management-strategies.html
[5]International Diabetes Federation. (2024). [Internet]. IDF Diabetes Atlas 11th edition. [Cited 2025 Oct 25].Available from: https:// diabetesatlas. org/media/ uploads/ sites/ 3/ 2025/ 04/ IDF_ Atlas_ 11th_ Edition_ 2025_ Global-Factsheet.pdf
[6]Diabetes Atlas. (2025, April 4). [Internet]. Total Diabetes Health Expenditure (ID million) | IDF Atlas. [Cited 2025 Oct 25]. Available from: https://diabetesatlas.org/data-by-indicator/diabetes-related-health-expenditure/total-diabetes-related-health-expenditure-id-million

Literature Review:-

Diabetic Neuropathy and its Implications : Diabetic neuropathy is a common, prevalent and an established serious complication of diabetes. It is generally characterized by nerve damage which occur in the lower extremities of the body[7]. The proliferationof the diseasemanifests in the loss of sensation and increases the risk of infections, foot ulcers, and in serious cases even amputations. There is a necessity for early detection and subsequently intervention requirement owing to its prevalence, which affects approximately 50% of all individuals who suffer from diabetes[8]. Timely monitoring and adoption of good management strategies are critical towards mitigating the risks associated thereby improving patient outcomes.

Challenges in Traditional Detection Methods :A number of traditional methods to diagnose diabetic neuropathy which includes tests like monofilament testing and the use of tuning forks, are undertaken as a reactive response and are therefore conducted during routine clinical visits[9]. These methods may at times fail to detect the onset of neuropathy, which eventually leads to delayed interference. Additionally, many of these tests are invasive, necessarily inconvenient, while also not being capable of monitoring continuously.The conventional methods of detection and diagnosis of diabetic neuropathy and their limitations are as discussed below[10].

Nerve Conductions Studies (NCS) and Electromyography (EMG):
Function: The NCS gauges the velocity and strength of electrical signals in the nerves to identify nerve damage or disorders[11].Electromyography evaluates the electrical activity in the muscles to determine if they are responding appropriately to the electrical signals. Limitations: The tests discussed principally assesses the functionality of large fiber nerves and are not so much so to check the small fiber neuropathy. They often or may cause discomfort to the patients while necessitating utilisation of specialized equipment associated with expertise to undertake the test. The cost may differ owing to the reason whether the test is required to be conducted on a single limb, both the upper limbs, both the lower limbs, or on all four limbs. The cost ranges from Rs 2500/- to Rs10000/-.

Sensory testing:
Monofilament Test :This test aims to evaluate the pressure sensation so as to determine the function of sensory fibre. The test is undertaken towards checking for nerve damages on the periphery. As the name suggests it is a small strand of nylon filament attached to a plastic base which is used to check for any loss of feeling on the foot. Limitation : It is a qualitative test which accommodates subjectivity in its interpretation. The test may also not detect moderate to mild neuropathy. The cost of a monofilament test depends on the type of device used and the quantity purchased. The individual disposable pens are inexpensive and range between from Rs 30/-to 70/- each. The kits of multiple pens can cost between Rs 490/-to 1600/- each. More professional or high volume sets such as a pack of 100 monofilaments can cost uptoRs 4000/-. Specialised kits like the Semmes-Weinstein hand kit are significantly more expensive.

Vibration Perception Threshold (VPT) : It is a medical test that measures a person's ability to feel vibrations on their skin. It is most commonly undertaken on the feet. It uses a tuning fork or a biothesiometer to measure sensitivity to the vibration.Limitation : These tests again mainly evaluate large fibre nerve functions and are therefore less effective towards detecting small fibre neuropathy. The cost of VPTbdepends on whether the equipment is bought for self-test or the test is being conducted at a clinic. The VPTbmachine cost ranges from

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[7]Boulton, A. J., et al. (2004). Comprehensive foot examination and risk assessment. Diabetes Care, 27(suppl 1), s63-s64.
[8] Gregg, E. W., et al. (2004). Prevalence of lower-extremity disease in the U.S. adult population ≥40 years of age with and without diabetes: 1999–2000 National Health and Nutrition Examination Survey. Diabetes Care, 27(7), 1591-1597.
[9] Young, M. J., et al. (1993). A multicentre study of the prevalence of diabetic peripheral neuropathy in the United Kingdom hospital clinic population. Diabetologia, 36(2), 150-154.
[10]Petropoulos, I. N., Ponirakis, G., Khan, A., Almuhannadi, H., Gad, H., & Malik, R. A. (2018). [Internet]. Diagnosing Diabetic neuropathy: Something old, something new. Diabetes & Metabolism Journal, 42(4), 255. [Cited 2025 Oct 26]. Available from: https://doi.org/10.4093/dmj.2018.0056
[11] Smith, J., & Doe, A. (2020). Advances in diabetic Neuropathy detection. Journal of Medical Innovations.

approximately Rs 13,500/- to over Rsb1,50,000/-. The diagnostic packages that include the test are priced around Rs 27,000/- or more.

Quantitative Sensory Testing (QST):
Function :This test is a series of psychophysical tests.It aims to measurefunction of sensory nerves by assessing thepatient'sthreshold for different stimulilike vibration, cold, heat, pressure and touch. It further helps to identify sensory nerve damage by quantifying the threshold of these sensations.Limitation :The test requires specialised equipment which needs to be correctly calibrated. Further the test results are susceptible to the responses of the patientresponses which makes this test subjective. The cost of the QSThas a wide range, however a single clinical testoften rages between $500 to $900 which depends on the complexity and the time involved. While traditional lab based QSTsytems can cost hundreds of thousands of dollars the newer portable devices may cost around $500.The research grade machines range from Rs 40-50 Lakh.

Ankle Reflex Testing:
Function : It checks for reflexes in the ankle thus aimed to identify nerve damage. Absence or reduced reflexes can be indicative or reflect peripheral neuropathy.Limitation :Age plays a factor in this test as reduced reflexes may arise with normal aging, which makes the diagnosis challenging. Also not all the neuropathy cases present reflex challenges. The test is a standard low cost physical examination and rarely carries a separate fee. If the doctor does charge for it, the cost is usually part of a broader consultation fee. However if the results of this simple test indicate a more serious issue, additional and more expensive diagnostic procedures may be ordered such as ankle MRI, NCS and EMG.

Autonomic Functions Tests:
Function :The test includes a series of non-invasive procedures which are used to evaluate the autonomic nervous system that control involuntary bodily functions such as heart rate, blood pressure and digestion. These tests measure as to how the body responds to stimuli and identify if there are any problems with the ANS. The test checks autonomic neuropathy, along with an aim to determine the severity of any dysfunction.Limitation : These specialised tests are not widely available. Further the tests can be influenced by many factors that are unrelated to neuropathy. The cost of the test therefore varies widely and depends on the specific tests performed. It may range from a few hundred to several thousands of dollars depending on the specific tests that are being performed.

Thermal Sensation Testing:
Function : It tests the ability of the patient to sense temperature changes. It thus assesses small fibre function which can be an indicator of nerve damage arising due to diabetic neuropathy.Limitation : It relies on the patients feedback thus introducing subjectivity in its assessment. It requires specialised equipment and therefore the cost of the test can vary significantly depending on the type of test. It is most often part of the QST procedure for the diagnosis of neuropathy.

Skin Biopsy:
Function :The test examines the nerve fibre density in the skin with an aim to diagnose small fibre neuropathy. A small sample of skin is taken to assess nerve fibre density. Reduction in small fibre density can confirm small fibre neuropathy.Limitation :This is an invasive test that requires histological analysis of the sample. It is not commonly available and cannot assess large fibre neuropathy. The cost can vary from approx. Rs 800/- to Rs2500/-. It can also vary based on factors like location and the type of biopsy performed.

Blood Tests:
Function : It is basically undertaken to rule out the other potential causes of neuropathy such as vitamin deficiencies or thyroid dysfunction.Limitation : It is an indirect method and does not diagnose neuropathy directly.

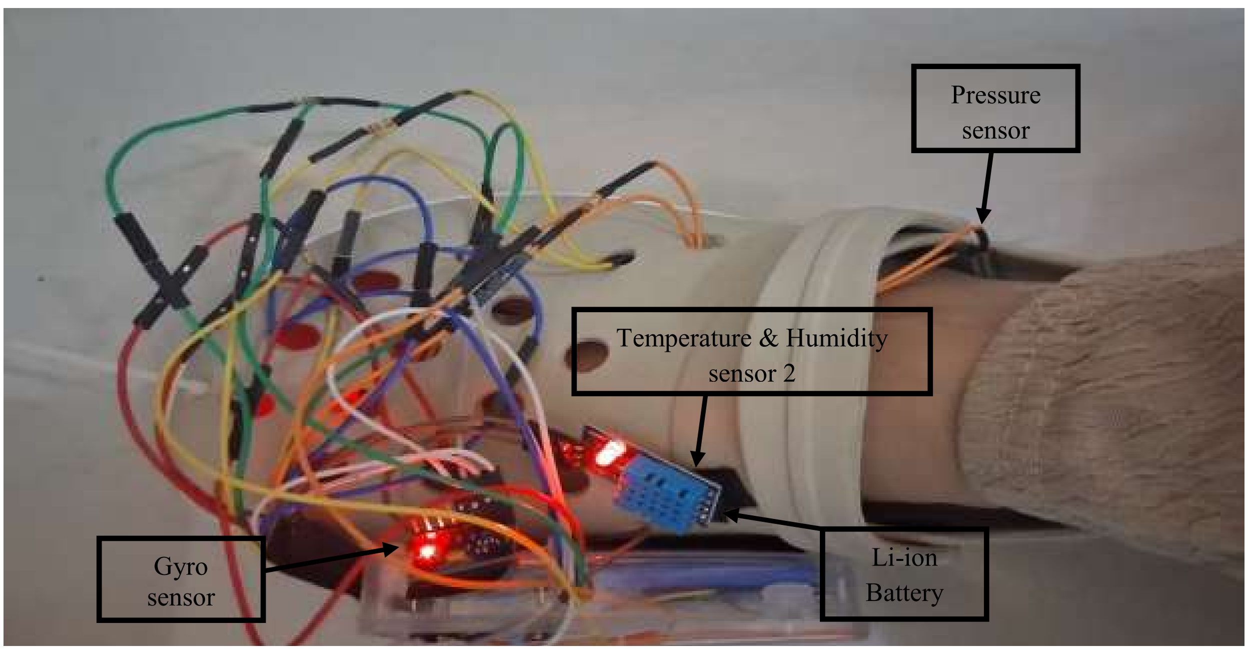
Emergence of Wearable Health Monitoring Devices:-
Advancement in wearable technology has unlockeddoors in the field of medical health monitoring. The availability and ease of designing wearable technology enables timely diagnostics and have the potency to manage chronic conditions like diabetes. Wearable devices display applicabilitytowards enhancement of patient compliance towards usage of such devices. The availability of such devices help in improving healthcare objectives, and ultimately

empower the individuals to take charge and control of their health[12]. Furthermore, the ease of integration of sensors and IoT technologies facilitates the seamless collection and analysis of physiological data. It therefore allows to accurately measure and study the health state of the patient.

Recent Advancements in Smart Wearable Technology:
Various studies reveal the underlying potential of smart wearable technology. It not only assists in remote monitoring of patient but also personalized healthcare. Devices such as smart insoles and socks have been experimented with towards detecting pressure and temperature changes in diabetic patients, thus aiming to prevent ulcer[13]. Furthermore, IoT-based platforms provide adequate opportunities for data integration and alert monitoring. Smart wearable technologycan become a solution for the growing demand of smart healthcare applications14.Some modern wearable technology like Surrosense RX infuses temperature, and pressure sensors, Footlogger embeds pressure, accelerometers and temperature sensors, while Smart socks by Siren Care only incorporates temperature and moisture sensors to detect neuropathy.

Conceptual Model
Designing the smart footware to detect and warn diabetic neuropathy by integrating several technologies to monitor, analyse and alert both patients and healthcare providers.

Objectives:-
Real-time Monitoring: Track foot pressure, temperature, humidity, and orientation.
Alert System: Provide instant alerts to users and healthcare providers.
Data Analytics: Store and analyze data for trend analysis.



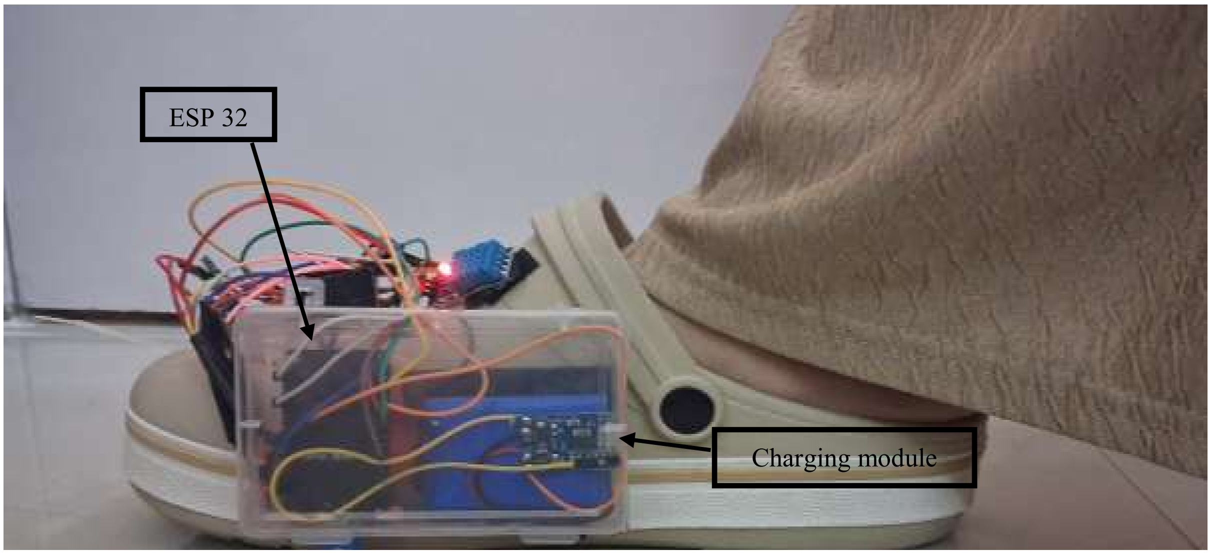
Top view of Solecare with all sensors

Material Composition : The footware is a regular shoe made from soft, flexible material that ensures comfort and conformability to the foot. The material is durable whilst accommodating various sensors.The assembly of

[12] Patel, S., et al. (2012). A review of wearable sensors and systems with application in rehabilitation. Journal of NeuroEngineering and Rehabilitation, 9(1), 1-17.
[13] Najafi, B., et al. (2017). Decreasing postural sway by improving inhibitory motor control in diabetic patients with peripheral neuropathy. Gait & Posture, 52, 426-429.
[14] Sazonov, E., &Neuman, M. R. (Eds.). (2014). Wearable Sensors: Fundamentals, Implementation and Applications. Academic Press.

components within the shoe was a carefully thought over process wherein comfort and protection against wear was looked into.

Top Layer : Comfortable and breathable material thus helps to prevent skin issues. Contains power source, data processing unit and sensors.
Middle Layer : Contains embedded sensors for data collection and monitoring.
Bottom Layer : Includes embedded sensors to detect gait pattern while ensuring structural robustness.



Side view of Solecare with battery pack

Steps to Prototype Development:
Phase 1: Preliminary Design and Feasibility Study:
Feasibility Analysis: Study was undertaken to analyzethe capabilities of existing devices and their effectiveness. Gaps were identified in the employability of current diagnostic methods. A review of suitable sensors readily available in the market was undertakento ensure accuracy of results. Cost of development and project pricing was strategized with an aim to maintain a budget friendly project.Design Mockup: Sketch of the project and wireframe of the system was worked upon to depict device structure and the vision of user interface.Technical Specification: List of required components, including sensors, microcontrollers (e.g., Arduino, Raspberry Pi), and communication modules (e.g., Bluetooth) was deliberated.

Phase 2: Hardware and Software Interlacing:
Component Sourcing: Hardware was identified along withrequirement of necessary components and sensors so as to ensure compatibility and reliability.Software :Deliberation about a suitable software was undertaken so as to enable ease of data interpretation and further assistance in anomaly detection. Future implication of migrating onto a mobile application towards real-time monitoring was also considered during the phase.

Phase 3: Prototype Assembly:
Hardware Assembly: A schematic design of the project was createdwith detailed circuit diagrams. Breadboard setup and assemblyof components was initially worked upon intricately to enable initial testing and any adjustments. The final construct was designed to be an ergonomic housing of various sensors.Software Assembly : The assembly was selected and structured to ensure efficient data flow between the sensors and the software application. Independent and preliminary tests on each sensor was undertaken to assess functionality and reliability.

Phase 4: System Integration and Testing:
Internal Testing: After evaluating functionality of each component a progressive infusion of each hardware component was undertaken. The prototype was also simultaneously tested for its battery life and sensor accuracy under varying conditions.Iterative Testing: During this process issues were identified which were leading to conflict

with laid down goals. During these tests, software algorithms were debugged and hardware configurations were readjusted to ensure desired accuracy of the prototype.

Phase 5: Design Iteration:
The project design is an open ended prototype capable of inducing future refinements which can be undertaken once a sufficient database of user feedback is created. Components can then be reworked considering device ergonomics, software usability, and requirement of additional features.

Project Design:-
Hardware Components : Various sensors have been utilised to measure movement and indicate the microclimate of the foot. The hardware components are as listed below:-
ESP32 Microcontroller
Pressure Sensors (FSR402)
Temperature and Humidity Sensors (DHT11)
Gyro Sensor (MPU6050)
Battery Pack (3.7V 1500mAH) and Charging Module (TP4056)

HardwareSelection : The hardware was carefully selected post extensive deliberations so as to achieve the listed aims of the research. Each component was evaluated for its pros and cons. The function and importance of each component has been discussed below.

ESP32 Microcontroller:
Function : ESP32 is an excellent and affordable choice for IoT applications due to its simplistic design of providing a number of connectivity options, desired processing power, flexibility, energy efficiency, and finally cost-effectiveness.Importance : The ESP32 supports a Wi-Fi 802.11 b/g/n, thereby allowing devices to be connected to the internet or local networks efficiently. This is crucial for cloud data processing, real-time monitoring, and remote access if required. It's Bluetooth and Bluetooth low energy (BLE) feature enables the device to be paired with smartphones and other Bluetooth enabled devices. It is equipped with a dual core processor thus providing sufficient computational power for handling complex tasks such as data processing, sensor fusion and real time monitoring. Its wide range of general purpose Input/Output pins provide the flexibility to the creator for easy integration of multiple sensors. It is low cost and offers excellent cost to performance ratio which was especially desirable for this project. The architecture of ESP32 allows scalability in case of requirement of integrating more functions.

Pressure Sensors (FSR402):
Function :They measure the pressure distribution across the foot and are reliable in measuring foot pressure with a good sensitivity range thereby assisting in foot mapping. 4 of these sensors have been incorporated in the design.Importance : Diabetic patients are at risk of foot ulcers due to neuropathy which has been discussed above. This condition results in diminished sensation. Availability of pressure sensors can alert the wearer or the health care specialist when there is an excessive pressure on a particular area of the foot. The diagnostic tool thus allows the patient to adjust their position and seek medical attention before developing serious injuries.

Temperature and Humidity Sensors (DHT11):
Function :A total of two sensors have been included in the design out of which one measures the external humidity & temperature while the other monitors the humidity & temperature levels inside the shoe. The two sensors provide a comparative measurement of the humidity & temperature levels between the external environment and the microenvironment of the foot.Importance : Sudden changes in temperature and humidity can indicate inflammations or infections which are conditions that are common in diabetic patients. Early detection of anomalies can prompt immediate action, potentially preventing severe complications like ulcers or amputation.

Gyro Sensor (MPU6050):
Function : This sensor provides accurate motion tracking which is essential for gait.Importance : Abnormal walking patterns arising due to neuropathy can lead to unequal weight distribution, thereby increasing the risk of pressure sores on the foot. By identifying early signs of abnormal gait, patients can be alerted about the changes that might require medical evaluation or physical therapy, thus reducing the risk of injury.

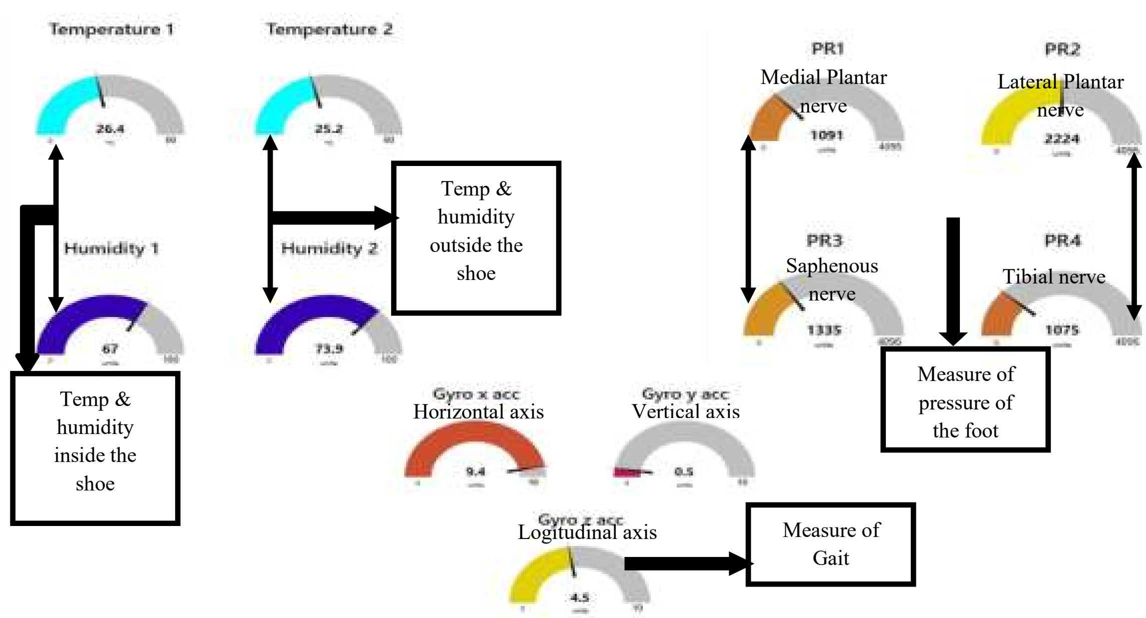
Battery Pack (3.7V 1500mAH) and Charging Module (TP4056):
Function : A 3.7V Li-ion battery along with the TP4056 charging module ensures sustained power supply while guaranteeing ease of repeated operations.Importance : Availability of a decent power source ensures functionality of the equipment for extended periods. A rechargeable battery pack is cost effective while the charging module offers a type B charging station.

Software Components:-
Arduino IDE
Node-RED

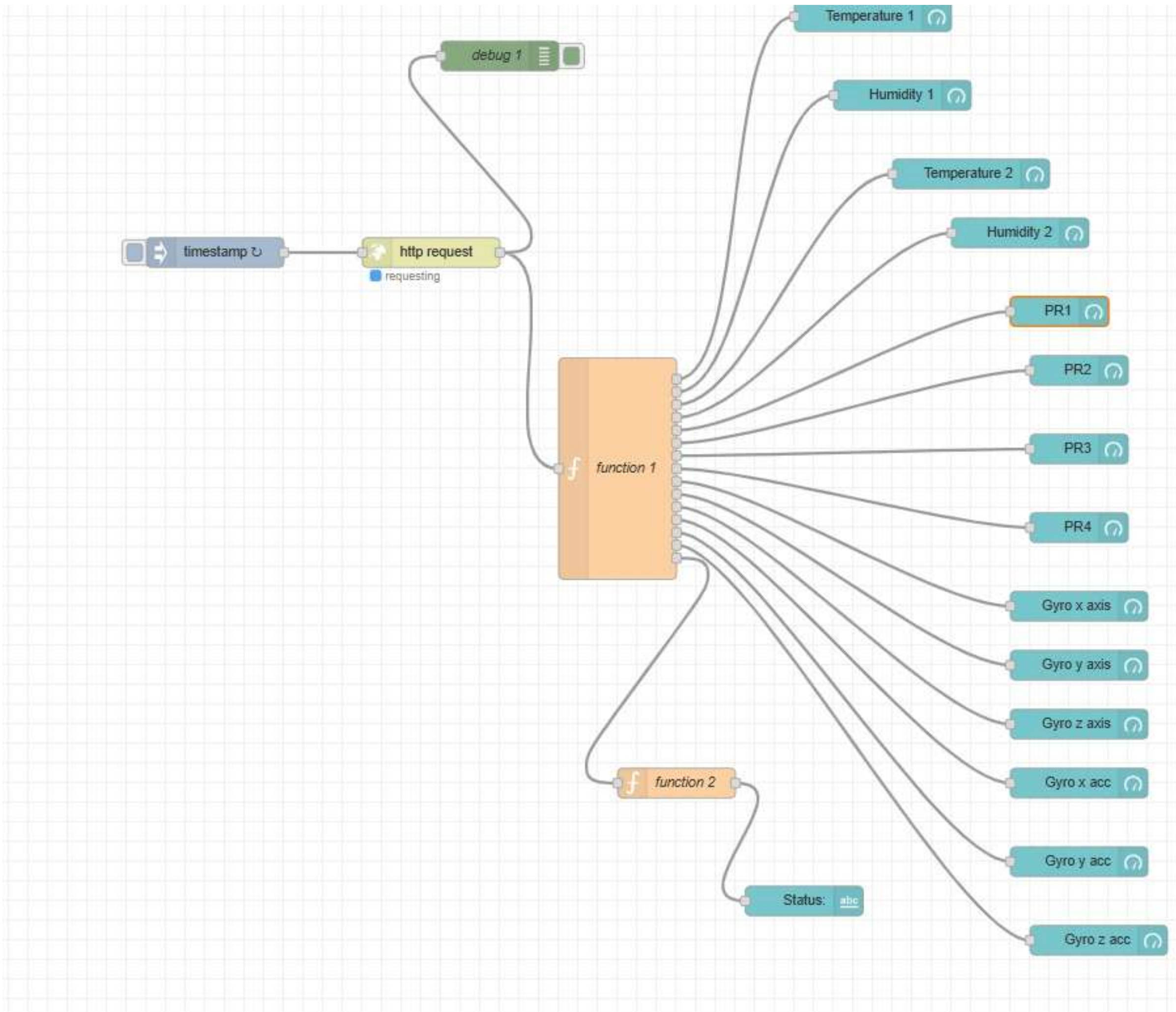
Software Selection : The software was selected with an aim to efficiently exploit the ESP32 microprocessor. The function and importance of each component has been discussed below.

Arduino IDE:-
Function : This software easily integrates all the above mentioned sensors seamlessly. The software is user friendly and easy to modify.Importance : A 156 line code created on this software manages sensor fusion, its processing and wired/ unwired data transmission.

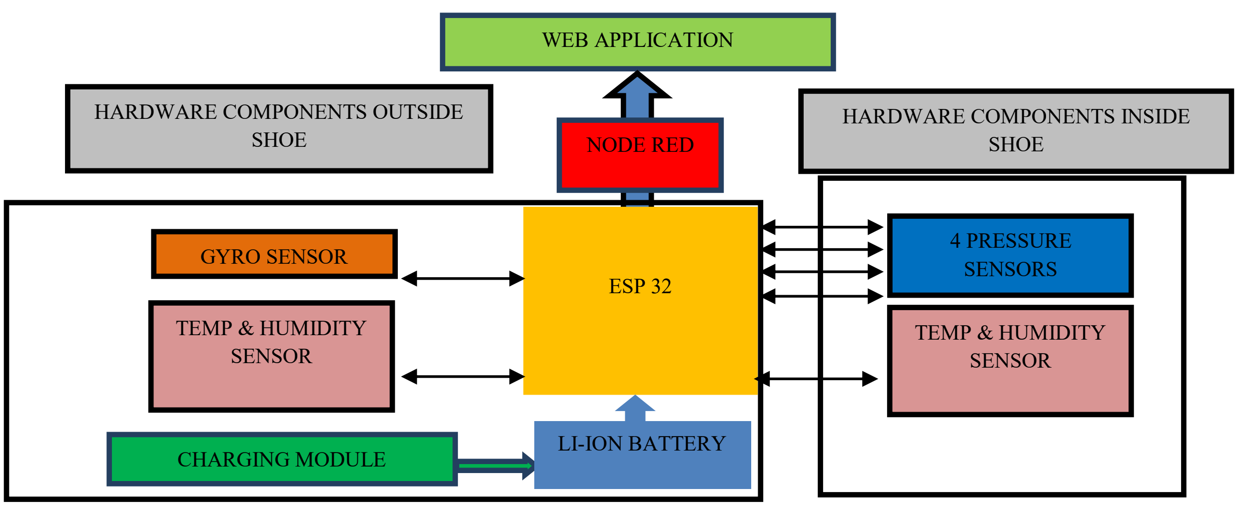
Node-Red:
Function : The software enablesrepresentation of applications graphically. This feature helps in developing and modifying the prototype easily. The software presents the conditions simplistically resulting in easier understanding of the logic flow. This is especially beneficial for debugging and explaining the process to stakeholders.Importance :The Node-RED software incorporates a programming model which is flow-based. This makes working on the software to be spontaneous and easy, especially for non-programmers. Users have the tools to drag and drop nodes to create the desired data flows. This eases out the complexity of setting up IoT processes.Software is equipped with pre-built nodes which assists in a wide range of functions to name a few such as input/output (I/O) operations, API calls, data transformation, and communication protocols (e.g., HTTP, MQTT, WebSockets). Availability of the same makes the process straightforward and provides ease of integration with existing systems and sensors. The technology is capable of processing real-time data, which may include sending alerts or triggering actions based on the sensor inputs created. Node-RED is also capable of running on various operating systems, which includes Windows, macOS and Linux. Customizable dashboards can be created through the software which assists in easily visualising the data resulting in quick evaluation of the parameters at a glance.



Realtime representation of values all sensors through Node-Red



Workflow Chart of Solecare on Node-Red



Schematic Representation of Solecare

Implementation and Real World Application:-

Customizable Fit : The shoe can be personalised for different foot sizes and shapes, potentially incorporating custom 3D printing to match the users foot profile.

User Education : Users will get real time information and can also receive guidance on foot care. Based on the inputs received necessary lifestyle adjustments can be provided or planned to mitigate the risks.

Healthcare Integration : Routine data analysis and be shared with healthcare providers for a more comprehensive overview of the patient's condition, aiding in tailor made intervention strategies.

Challenges : Several challenges were encountered during both hardware integration and hardware-software integration. Here are the specific challenges faced during each stage.

Experimental Validation, Testing and Results

Test Setup:-

To assess Solecare capabilities with different age group, different weight category and under varied environmental conditions.

Performance Metrics:-

Solecare performance was evaluated on certain critical metrics. Pressure Sensor Accuracy : Measured to check the foot pressure on four different nerves namely Medial Plantar nerve, Lateral Plantar nerve, Saphenous nerve and Tibial nerve for different weight groups. Temperature and humidity Accuracy : Measured to check variation of temperature and humidity within the shoe and compare it with the temperature and humidity of the outside environment under different environmental condition. Gait Accuracy : Measured to check the gait as per foot movement. Runtime Efficiency : Continuous operational duration on a full battery charge.

Results:-

An in-house testing of the prototype was undertaken on 6 individuals with age group ranging from 16 years to 72 years. The weight of the six subjects varied from 52 kgs to 80 kgs. None of the subjects were diabetic and therefore the prototype has not been medically proven. However the prototype revealed stable results under the designed test environment. The pressure sensors performed accurately and produced results against the maximum scale of 4065. The pressure readings of each pressure sensor varied between the 6 subjects, however the average pressure foot pattern was conformal thus confirming the accuracy of the placement of sensors. The temperature and humidity sensor performed accurately with respect to measuring the difference between the internal and external environment of the foot. Any movement and general activity resulted in producing a temperature difference of almost 6-8 deg Celsius between outside and internal environment. Also, the humidity difference between outside and internal environment was observed to be approx. 8-10% depending on the activity undertaken. The gait pattern for all the 6 subjects was accurately displayed as per the design. Change in gait pattern can be assessed only after data analytics. The full recharge of the battery was achieved in 1hr 15 mins and continuous monitoring of the sensors was achievedfor 2 ½ hrs. These results established a stable baseline, confirming design efficacy for extended periods while being strapped onto 6 different subjects independently as well as during repeated checks.

Challenges Faced During Hardware Integration:-

Component Compatibility :The compatibility of different hardware components was essential towards the success of the prototype. Each component such as the ESP32 microcontroller, the pressure sensors (FSR402), temperature and humidity sensors (DHT11) and the gyro sensor (MPU6050) required varied power requirements which became critical during their integration and subsequent interlacing between the hardware.

Placement of Sensors : Positioning of sensors within and around the shoe for capturing desired data posed challenges. This was further accentuated by the fact that the shoe needed to be comfortable for the wearer.

Power Management : Power management was a critical element which needed deliberation so that all sensors function efficiently while also assisting in optimising power consumption.

Miniaturization and Ergonomics :The build of the prototype necessitated miniaturization of the area to accommodate all components within the shoe environment. This required attention such that the performance of the components is not compromised while also ensuring that the show remains ergonomically comfortable.Owing to the location of the components the design required necessary robustness to keep the hardware free from any wear and compact.

Challenges During Hardware and Software Integration:-

Data Synchronization: The synchronisation of data from all sensors was specially challenging wherein the microcontroller had to be tuned to accurately extract the data while presenting it in a format which is coherent and easy to analyse.

Communication Protocols:Integrating the hardware components with the available software conventions required establishing reliable communication protocols, particularly between the ESP32 and the Node-RED platform. Issues also included ensuring stable Bluetooth/Wi-Fi connectivity.

Sensor Calibration and Data Accuracy:While individual sensor calibration and data output was easily achieved the integration of multiple sensors presented much difficulty. To ensuring that sensor data was accurate and reliable repeated calibration and testing was undertaken. Any discrepancy in the sensor reading necessitated adjustments in software algorithms to correct and compensate for variations.

Real-Time Data Processing:The software needed to be programmed to handle data input, process alerts, and store information without delay. This was required to ensure the real-time response which is essential for health monitoring.

User Interface: A user-friendly interface was required to be developed so that complex data could be simply displayed. Real-time data needed to be translated into tangible insights and alerts for the user, without overwhelming them with technical details.

Development Time and Iteration:The integration phase required iterative testing and refinements, leading to an extended development timeline. Each change in hardware configuration often required corresponding adjustments in the software.

SWOT Analysis:-

Strengths	**Weaknesses**
Non-invasive detection technique and user-friendly design. Provide a comprehensive real-time monitoring. Ease of use in both home and clinical setting. Capability to collect valuable data for proactive healthcare management.	Initial development cost. Potential learning curve for technology adoption by users. Dependency on battery life.
Opportunities	**Threats**
Potential for integration with broader e-health platforms. Partnerships with healthcare providers for wider adoption. Increasing in prevalence of diabetes heightens the demand for preventive monitoring solutions. Expansion into broader health monitoring applications.	Competition from established diagnostic tools and technologies. Regulatory barriers and sustained R&D investments. Rapid changes in technology may necessitate continual updates.

Future Implications:-

The research is designed to be non-intrusive, cost effective and easy to use. The present testing has been undertaken on subjects not suffering from diabetes. Clinical tests need to be conducted under a controlled environment to bring out desired results. Future enhancements may include additional sensor integration, machine learning for predictive analytics, and may also be expanded through a common application for other health conditions. AI can be used to analyse long term temperature, humidity and pressure data to predict risks like infection, joint stress, or circulation problems before they occur. Further, Machine learning can be used to detect subtle irregularities in walking patterns thus help in preventing injuries. The current prototype which has the capability to connect through wifi and is configured through ESP 32 can be utilised in the future to transmit data to smartphones through an application. The data which is derived from the users can also be uploaded securely to a cloud based system for analysis by health care providers. This will enable the health care operatives to have a long term track record of individuals statistics related to neuropathy. System may also be configured to incorporate alerts in real time for patients and healthcare providers through live notifications with an objective to prevent serious injuries.

Conclusion:-

Solecare is a regular wearable shoe equipped with movement sensors to continuously track gait patterns thus helping to detect changes which are indicative of neuropathy. The shoe incorporates embedded pressure, temperature and humidity sensors to monitor foot pressure distribution, temperature changes and humidity variations in real time. The results have confirmed that the prototype displays capability to accurately measure the desired data. By leveraging this technology it will be possible to detect abnormal variations, and help in identifying early signs of neuropathy.

Infusing off the shelf hardware, using open source software and an ergonomic design; it provides an extremely cost effective solution to monitor and warn for diabetic neuropathy. A comparative evaluation against existing testing patterns as well as new technology like SurroSense, Footlogger and smart socks from sirencare highlights the advantage of Solecare wherein it infuses all the required sensors to evaluate diabetic neuropathy. The prototype effectively enmeshes all tests in a single product thereby delivering a low cost solution to a global problem. It is a novel solution and aligns with the best practises under one umbrella as part of the guidelines for diabetes management. The model enmeshes technology and AI to analyse data in real time, providing predictive insights and personalised risk assessments for neuropathic progressions. By addressing the key risks associated with diabetic foot complications, the technology can significantly improve the quality of life for diabetic patients.
In summary, Solecare illustrates that an affordable, scalable and a non-intrusive wearable shoe can bridge the gap between the existent tests and technology. It has the potential to become a one stop solution towards detecting diabetic neuropathy which is one of the most common complication of diabetes.

Author Contribution:-

ShauryaKarmakar : Served as the project conceiver, designer and developer. Securing of materials, development and designing of system architecture. Executed hardware implementation and software development. Author is currently a grade 12 student.

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