Diabetic Foot Ulcer Treatment Device Using Peltier and Embedded Electronics

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Abstract. People’s degrading lifestyle reflects their health graphs and occurrence of different disease in their bodies. With different food habits and exercise patterns the endurance capacity of the body changes. Foot ulcer is a disease quite common today among Indians around. The foot ulcer creates a threat to the movement for human beings. It is a deep infected sore or damage in the foot sole commonly caused by nerve/skin damage. Several infections in the foot may also result in leg amputations. Foot ulcer is very common among diabetic patients. India is the country with the highest number of diabetics worldwide. Over 3 million people are infected with diabetes which is a big number to worry about. The CPR (Crude Prevalence Rate) for cities is around 9% of the population whereas in village areas the occurrence is around 3 percent [1]. Though the foot ulcer prevalence of diabetic patients in India is 3% which looks small but it is a big number. Our proposal is an embedded system innovation to develop a foot ulcer treatment system. It deals with the combined approach to embedded electronics and biomedical engineering to overcome the situation. We create a footrest equipped with Peltier, vibrator, and UV rays to overcome the issue. It is the first of its kind foot ulcer treatment equipment that can solve the issue. We also used the android technology to provide the vocal user interface to help the user. Clear instructions are displayed and spoken upon usage to the patients. The result obtained on the patients are highly acceptable and recommended for both urban and rural populations. The Atmega 328 P PU microcontroller is interfaced with the HC-05 Bluetooth and Vibrators through Relays to perform the task. The microcontroller acts as the overall think-tank to control and coordinate the overall system.

Index Terms. Crude Prevalence Rate (CPR), Peltier, HC-05 Vibrator and Ultraviolet (UV)

1. Introduction
As per the recent survey of Sree Chitra Tirunal Institute for Medical Sciences and Technology, Kerala and Indian Council of Medical Research. Kerala tops the total number of diabetic patients in India with 19.4% of their total population. The second and third among the list is Chandigarh and Tamil Nadu with 13.6% and 10% respectively. In the age group of 46-68, almost two-thirds of the population got affected by diabetes. The result was published in a leading daily newspaper. [2] Diabetes is the mother for many other diseases like heart disease, kidney disorder, nerve damage, foot ulcer, etc. Foot ulcer is the disease that creates immense difficulty for the people to walk and in some cases even to stand on the foot.

Our proposal is for a remedial system for foot ulcers where we use embedded technology to project UV rays which acts as the antibacterial projection device. We also use vibrators to oscillate the foot skin to revive it. The Peltier device is used to heat and cool the wound to further rejuvenate the foot skin to sustain the faster recovery. The HC-05 Bluetooth device transmits the instructions which are decoded by the android application installed on the phone. These instructions are decoded in the form of audiovisuals and provided to the users for better understanding and usability. Each session is created for multiple heating, cooling using Peltiers. The vibration of the skin part is done using vibrators and antibacterial part by UV rays. The overall operation is synchronized using the Atmega 328 P PU microcontroller. The programming is done by using Embedded C code which makes it way efficient and flexible for further changes and scalability.

**DIABETIC FOOT ULCER**

![Figure 1. Reasons of Foot Ulcer](image)

It is planned to be designed as a plug and play device which should be easy to use and handle. The additional visual instruction makes it very easy to use because of its easy design and audio announcements.

In our next section, we look forward to analyse the previous works done as the literature surveys to help our proposed concept.

2. Literature Survey
Manohara Pai M. M. and their team explained briefly in their article about “foot ulcer stating, foot ulcer is the most common complication and disorder in diabetic patients. The foot ulcer patients are most prone to hospitalization compared to other patients suffering from diabetes. It is very essential to early diagnose the foot ulcer as this is the most prone cause to lower amputation. This paper is mainly focused to develop a smart sole so that the pressure detected on different spots by foot can be analyzed and produced to the medical examination database.

This can cause to bring the decision based on clinical data available due to smart sole. The design methodology deals with embedding multiple pressure sensors on the sole which continuously monitors the pressure exerted on both the feet. It is linked wirelessly to the mobile app. The mobile app continuously receives the data and stores in the clinical database. The clinical data of pressure exerted on the sole through the mobile app is interfaced with the visualization of prediction analysis and imported on the web app. There is a prediction algorithm to further analyze this data and provide evaluation results. The result is categorized into mind, moderate, and severe. The prediction algorithm is very realistic and real-time pressure data makes it much accurate” [3].

Samsunnisha Patel and the team explained briefly in this paper about medical image processing to “help the physician diagnosis to the foot ulcer wound. The image processing technique like a neural network, KNN classification, fuzzy logic, etc. are used to analyze the foot ulcer wound region. The system performs the foot ulcer detection system by efficiently using the image processing process. The MATLAB tool is used to detect the wound and its condition and the stage. MATLAB is the most efficient tool for efficient and reliable image processing techniques.

The overall process deals with multiple stages like image preprocessing, segmentation, feature/texture extraction, and image classification. The preprocessing is used to enhance the quality of the input image by removing the noise. This can be done by several filtration processing using MATLAB code. The image segmentation separates the Region of Interest (ROI) part of the image from the rest of the image. It makes the system much accurate by focusing the analysis on the desired locations only. The image classification deals with a thorough analysis of the wounded texture from the foot ulcer image. Different disfigured, yellow and dead tissues are analyzed in detail in this stage. The combined result of the different image processing stage provides a very accurate wound analysis report” [4].

Sarah Ostadabba and team discussed briefly in this paper which deals with the “severity of foot ulcer stating that 1/4th of diabetic patients get the chance to develop the foot ulcer during their lifetime. Unattended or severely infected leg results lower amputation. This show based monitoring system deals with the indicators of the peak pressure on the shoe. The design of the insole system results in the required pieces, its place and extent of the pressure feelers to be engraved. They mainly pointed out the design and embed complexity for foot sensors for evaluation of foot ulcer pressure data. The overall process is also challenging to develop as it should also provide the normal walking experience to the user. There should not be any difficulty or change in the walk patterns of the patients” [5].

3. Development and Implementation

The block diagram below represents the overall functionality of our proposed concept. The building block has different modules assembled as fashioned in the diagram. The system is centered on the microcontroller to control all the peripheral components. The overall devices are controlled as instructed by the microcontroller.
Figure 2. Block Diagram

The circuit diagram below provides the connectivity schematic of whole circuitry and components interfacing. The diagrammatic representation of the circuit implementation makes it much easier to visualize the overall scheme. The circuit diagram provided below also represents the pin connectivity of the overall modules.

Figure 3. Circuit Diagram
4. Implementation Components

The implementation components represent the overall components usage and information. The detailed description of the overall used components is provided below.

4.1. Power Supply

The power supply module is used to provide sufficient power to run the overall system. The step-down transformer, rectifier circuitry, and voltage regulator are the building block of the module.

![Figure 4. Power Supply Unit](image_url)

4.2. Arduino Nano

Arduino Nano is one of the smallest form factor microcontroller unit to make portable electronics much easier to program and fabricate. It is very powerful and also very feasible to use with simple C programming.

![Figure 5. Arduino Nano](image_url)

4.3. Peltier

Peltier is a thermoelectric semiconductor device that uses the heat flux on the junction of two materials which are the building block of the Peltier. When the proper power is provided through the
power input terminal of the Peltier then the opposite sides get heated and cooled simultaneously. This module is used to heat and cool the wound to improve its recovery rate.

![Power Supply Unit](image1.png)

**Figure 6.** Power Supply Unit

4.4. *Vibration Motor*

Vibration motor is used to vibrate the foot. This makes the dead and inactive cells to rejuvenate and reduces the damage chance for healthy foot cells.

![Vibration Motor](image2.png)

**Figure 7.** Power Supply Unit

5. *Conclusion and Future Enhancements*

Thus we developed an automatic foot ulcer remedy system. Which can solve the foot ulcer problem to much extent? It has the all possible systems to overcome the foot ulcer issue. The system is connected with the vibrator, UV rays LED, Peltier to heat/cool the wound and power supply to run the overall modules. We used Arduino Nano to control the overall system due to its compact size, programming ability, and easy to configure. The audiovisual unit helps the patients to see the overall process and get instructed in realtime. As the future enhancement, we plan to add IoT systems so that the overall process gets updated online automatically for patients to maintain their treatment record.

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