Global Health: Prevention of diabetic foot ulceration and amputation

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Abstract

Some diabetic patients suffer from ulceration in their feet which, in an extreme, can result in amputation of the foot. In order to detect ulceration, others have employed a thermal imaging system paired with image processing software in order to detect statistically significant changes in temperature due to ulcer development. The team has been tasked with designing an imaging device along with image processing software and an algorithm for early-stage detection of ulceration. The device proposed is an insulated box that is foldable in order to increase portability. Image processing software will comprise of grayscaling and pixel extraction; the client has already performed calculations that have been implemented into an algorithm to place individuals in a class based on risk level. Integration into a mobile software for ease of use has been developed and will continue to be improved upon more data collection and testing.

Problem Statement

Motivation:

- Over 60 million in the population suffer from the disease [1]
- Diabetic patients often suffer from peripheral neuropathy as a result of diabetes, meaning that they lose feeling in their peripheries
- The repeated shear forces acting on tissue over time can cause inflammation and tissue damage, regardless of the magnitude of the forces being minimal [2]
- Many patients develop foot ulcers which, if not properly taken care of, may become infected and ultimately end in the amputation of the foot

Background:

- Thermal imaging has proven to be an effective technique in early-stage ulcer detection in diabetic patients. Specifically, research has shown not that an increase of 2.2 ℃ is associated with the beginning of ulceration [3].
- Existing devices that utilize this temperature difference, such as temperature monitoring socks, which alert users when a given temperature threshold has been reached [4].
- A gap exists in the design of thermal imaging systems for low-resource settings. The team has been tasked with creating a thermal image acquisition device, as well as an algorithm that will be able to analyze thermal images and separate them into categories based on levels of risk for ulceration
- Goal is to create a low-cost system that will minimize the time spent by patients in clinic.

Acknowledgements

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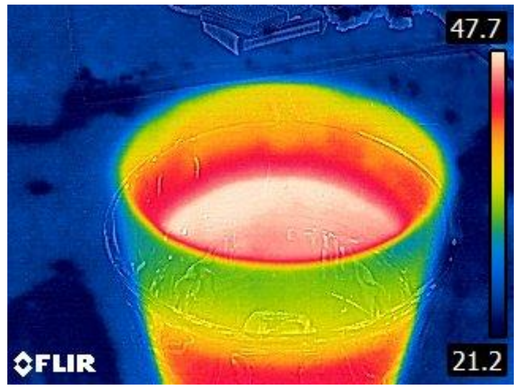
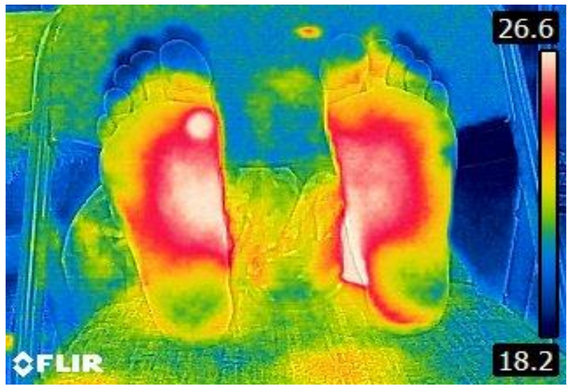
Testing



Testing Methodology. Water was heated up to 48.89 degrees Celsius; images were captured every 15 seconds for the first five minutes and every 60 seconds for the second five minutes. This test was performed with the FLIR camera and the MLX camera to compare resolution capabilities.



Ulcer detection: To test the ability to pick up hotspots on the foot, a coin was heated and placed on various spots of the foot. The average temperature was taken from the hotspot and the subsequent spot on the opposite foot. The difference in temperature was calculated; if successful, the camera should be able to detect at least a 2.2 degree Celsius difference

Final Design

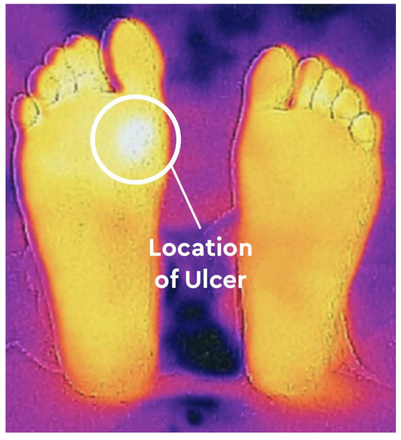
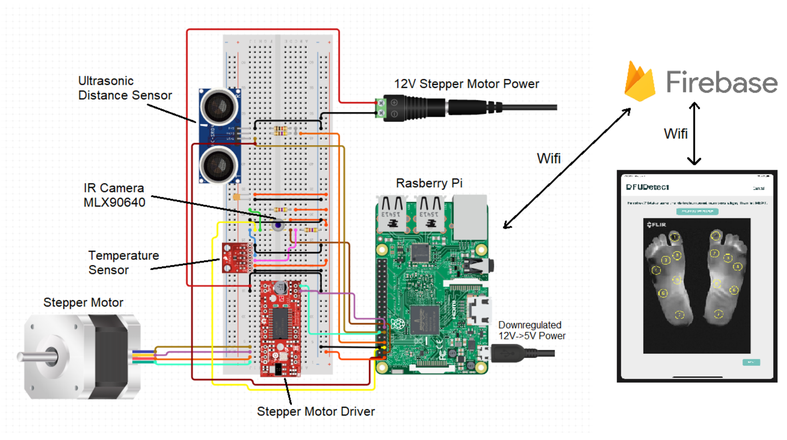


Figure IR pic of ulcer foot. A thermal image reveals a “hot spot” on the ball of the foot. This high temperature area correlates to the location of an ulcer, validating our assumption regarding the viability of thermal imaging to detect ulceration in diabetic feet.



Circuit Schematic of Intended Imaging System. A master (Raspberry Pi**)** is connected to the temperature sensor, IR camera, ultrasonic distance sensor, stepper motor, and stepper motor driver. Data is transmitted to the database via WiFi connection.

References

[1] S. Kaveeshwar, “The current state of diabetes mellitus in India,” *Australasian Medical Journal*, vol. 7, no. 1, pp. 45–48, 2014.
[2] BRAND PW (1989). Repetitive stress in the development of diabetic foot ulcers. The diabetic foot./4th edition./edited by ME Levin, LW O'Neal p83-90.
[3] Reyzelman AM, Koelewyn K, Murphy M, Shen X, Yu E, Pillai R, Fu J, Scholten HJ, Ma R “Continuous Temperature-Monitoring Socks for Home Use in Patients With Diabetes: Observational Study”, 2018.
[4] L. Fraiwan, M. Alkhodari, J. Ninan, B. Mustafa, A. Saleh, and M. Ghazal, “Diabetic foot ulcer mobile detection system using smart phone thermal camera: a feasibility study,” *BioMedical Engineering OnLine*, vol. 16, no. 1, Mar. 2017.

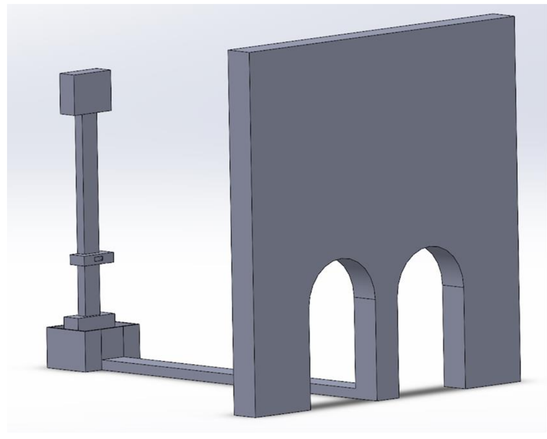
Design Criteria

- The device must be cost effective as it is targeted for low-resource settings; the target cost is under $200
- System must be capable of detecting hot spots on the foot of ~1-2 inches diameter
- System must be capable of detecting 2.2 degrees Celsius hot spots
- Device should be portable and weigh less than 35 lbs to consistently transport around a hospital

Future Directions

As we were unable to achieve all of the goals that we had set for this semester, there are plenty of improvements we look to implement going forward, including:

- Stitching together multiple images
  - We hope that by taking multiple images of one patient and stitching them together will allow us to maximize the abilities of a lower cost camera. By utilizing multiple images we will be able to capture more data points for analysis
- Improving structural integrity of imaging box
  - Developing a more sound imaging studio with stronger materials will aid in maintaining
- Developing image processing software compatible with the collected images
- Using MLX to image diabetic feet
  - While we were able to perform some preliminary tests with the MLX camera, we will best be able to tell whether its capabilities are adequate for the scope of this project if we are able to collect images of an actual diabetic patient’s feet



CAD rendering of planned design.
Shown is the planned design for construction of the imaging studio. It includes a box to reduce background noise, drawer sliders to adjust the distance of the camera from the box, and a motor to operate the movement of the camera up and down.