BME Design-Fall 2019 - THOR LARSON
Complete Notebook

PDF Version generated by

JARETT JONES

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▪ THOR LARSON ▪ Sep 10, 2019 @05:54 PM CDT

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Project description

▪ THOR LARSON ▪ Sep 10, 2019 @05:48 PM CDT

Course Number:

BME 200/300

Project Name:

Global Health: Prevention of diabetic foot ulceration and amputation

Short Name:

ulcer_detector

Project description/problem statement:

Diabetes is becoming an international epidemic with India being tagged the “Diabetic capital of the world” in recent years. It is estimated that anywhere from 50-90% of Indian diabetics are undiagnosed in rural areas of the country which allows these patients’ blood sugars to go unregulated for years. This leads to costly complications of diabetes, of which the most common is the development of a diabetic foot ulcers leading to lower limb amputation. These amputations from diabetic foot ulcers account for 85% of all non-traumatic amputations world-wide. In addition, a diabetic in India is 10 times more likely to need an amputation in comparison to a diabetic living in the US because of the lack of treatment and accessibility to healthcare services.

We currently have no way of identifying which patients are at greatest risk or on the brink of ulceration. In addition, patients often do not come in to the clinic until the ulcer is already developed. Thus, healthcare professionals and their resources are primarily dedicated to treating the formed ulcers rather than preventing them. Thus, healthcare costs and the incidence of amputation could greatly be reduced if we could identify and perhaps predict which patients are at greatest risk for developing an ulcer in order to initiate treatment to prevent amputation. During the client’s time in India, she asked the question thermal imaging could be used to reveal which diabetic patients had patches of inflammation perhaps indicating an impending ulcer.

The client spent 9 months in India on a Fulbright Grant interacting with healthcare professionals and Indian diabetic patients, and conducted a thermal imaging study of over 250 patient’s feet. Primitive data analysis of the images shows that this could be a novel method of determining which patients are on the brink of ulceration, and we’d like to implement AI algorithms to further strengthen the interpretation and predictive power of these images.

There are two parallel aspects to this design project. Please indicate your teams’ strengths with respect to both aspects:
Thermal Device (Instrumentation-based):
We would like to develop a streamlined way of measuring temperature from the feet of diabetic patients to serve as a diagnostic tool in Indian hospitals. Currently, the clients uses an IR camera and simple tripod. We’d like to explore other ways of collecting temperature that would fit in the context of an Indian hospital (cost, portability, ease of use etc). This would require students interested in fabrication, CAD, instrumentation and electronics, and image processing.

AI Algorithm and Phone App (Medical Imaging, Computer Science):
We would like to develop an app-based software to further interpret the images collected by the client while in India as well as the thermal maps that the team will collect with their instrumentation. Specifically, we’d like to develop an artificially intelligent algorithm to be able to categorize which patients are at greatest risk of ulceration based on the thermal scans of their feet. This would require students interested in medical imaging, image processing techniques (MATLAB etc), computer science and app development, and AI algorithms.

About the client:

Kayla Huemer graduated from UW in BME in 2018 and currently works at Exact Sciences with their Robotics and Automation team in System development. During the 2018-2019 academic year, she spent 9 months in India on a Fulbright Fellowship developing an approach for the prevention of diabetic foot ulcers. Kayla is not only looking forward to return to BME Design as a client, but she hopes to be a resource for team members looking for opportunities and mentorship to get involved with Global Health Innovation.

9/14/19 – Brainstorming Client Questions

▪ THOR LARSON ▪ Sep 14, 2019 @11:41 AM CDT

Title: Brainstorming Client Questions

Date: 9/14/19

Content by: Team

Present: Team

Goals:

- Compile a list of questions to give to our client prior to our first meeting
- Make a plan for background research process

Content:

The team compiled the below questions with regards to the project. We discussed the possible difficulties of the project and the areas that were not made clear within the project description.

- What role is AI playing?
- What are we looking to achieve with the new thermal device/what changes should be made from the existing one?
- Should this be a completely new device or something to add on to the existing device?
- Are there any controls to work with (images from non-diabetic feet)?
- What are the design constraints specific to India that we are working with (inexpensive)?
- Do we have access to the IR camera?
- Will the tool be used in the field or in hospitals, how mobile should it be?
- Would an AI camera be of interest?
- Do we have someone who would be able to improve our implementation once more samples are acquired in India?
- What would the phone application need to be able to do?
- Should the phone app be Android or iPhone based?

The questions were sent to the client prior to our first client meeting. We then discussed the areas of background research that we needed to perform listed below.

- Physiology of foot ulcer development and diagnosis
- Competing designs for ulcer detection
- Methods of measuring thermal data and/or other useful measurements
- Artificial Intelligence techniques, where to learn, plausibility in time frame, etc.
- Costs of IR cameras or other methods
- Design constraints of Indian hospitals

Conclusions/action items:

- The team will prepare for the upcoming meeting by doing background research from above

9/23/19 - Meeting with Dr. Nimunkar

▪ JAN WODNICKI ▪ Oct 09, 2019 @10:35 AM CDT

Title: Meeting with Dr. Nimunkar

Date: 9/23/2019

Content by: Jan

Present: Carson, Thor, Jan

Goals: To discuss an approach for processing data, and get advice on how to proceed with the software component of our project.

Content:

Dr. Richard Barker

- Dr. Nimunkar recommended we check out Dr. Barker's thermal imaging lab
- Dr. Barker is thermal imaging plants, and has devised some methods to standardize his measurements
- We can find out about his Raspberry Pi setup (low cost) and see what we can adopt or improve from his setup

Emmanuel Guzman

- Dr. Nimunkar also recommend we approach Emmanuel with questions related to using machine learning algorithms
- He has experience with AI, and can help us out as we start to learn TensorFlow
- Emmanuel suggested we use CAE / CS computer resources to run our algorithms
- He also suggested using Keras, which runs on top of TensorFlow and may be easier to use
- Finally, Emmanuel advised we use Python instead of Matlab to analyze our thermal data, as there are powerful image analysis packages for python, and it would be helpful for integrating it into our detection script

General Advice

- Before the meeting, we were focused on producing an app which would take up a majority of our time and distract us from developing an algorithm to detect diabetic patients at risk of ulceration
- Instead, we should focus on taking bits and pieces of other people's work in order to develop a functioning identification system
- This is more important than developing an app, which relates less to the engineering design process

Conclusions/action items:

- We feel a lot more confident about the software aspect of our project
- Dr. Nimunkar helped us change our mindset and shift it towards the design process, where we combine research and work already out there to produce something novel
- We schedule a meeting with Dr. Barker to check out his thermal imaging lab

9/30/19 - A Visit to Dr. Barker's IR Imaging Setup

▪ JARETT JONES ▪ Oct 09, 2019 @10:31 AM CDT

Title: A visit to Dr. Barker's IR Imaging Setup

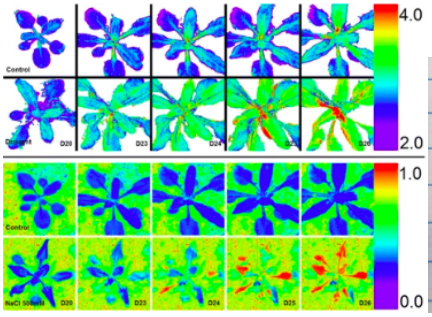
Date: 9/30/19

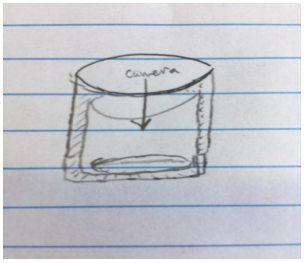
Content by: Jarett Jones

Present: Carson Gehl

Goals: Today we visited the lab space of Dr. Richard Barker, an astro-botanist on campus, in order to see how he takes consistent and accurate IR images of plants and their root systems. Additionally, we wanted to hear any advice he had to offer when it comes to obtaining IR images for further analysis.

Content:





Although the overall field of study and application of IR imaging techniques varied between us and Dr. Barker, he provided a lot of useful advice and design ideas. Dr. Barker uses a setup similar to the one sketched above. The IR camera was mounted on top of a foam/air insulated cylinder. The rationale behind this design is that creating walls of foam that have an air pocket between them would provide as a good temperature insulator to aid in the quality of images. The camera took images downward onto the plants below as seen above. We were also particularly interested in this setup because Dr. Barker implemented a simple Raspbarry Pi image acquisition mechanism which would be a feasible, cost effective, design idea for our purposes. Dr. Barker also preached the importance of image consistency when conducting this type of analysis and data set training.

The insight Dr. Barker provided has motivated us to investigate further the idea of foam insulation of our imaging studio rather than using a cold, wet towel. The wet towel idea is intriguing as the contrast in foot temperature to that of the towel should be vast; however, the integrity of our data could be compromised if the patient's foot bumped into the wet towel (as this would cool their foot).

Overall, the team was happy with the advice and design thoughts that the meeting with Dr. Barker provoked.

Conclusions/action items:

Investigate design ideas to implement the foam walls and air insulated imaging studio as well as utilizing a raspberry pi image acquisition setup.

9/17/19 - Client Meeting #1

▪ THOR LARSON ▪ Sep 21, 2019 @04:59 PM CDT

Title: Client Meeting #1

Date: 9/17/19

Content by: Thor Larson

Present: Team

Goals:

- Compile notes from the initial client meeting

Content:

Our client typed up answers to our questions (below) that we previously sent her which directed our conversation during the meeting. We discussed the direction of the project and additionally specific aspects of the PDS.

1. What are we looking to achieve with the new thermal device/what changes should be made from the existing one?

2. Should this be a completely new device or something to add on to the existing device?

The bottom line is that we need an ergonomic way of collecting the thermal scans from the patients. I believe that the FLIR camera that I currently have is sufficient, and we just need a repeatable way of taking the photos. If you guys want to dive into the low-cost side of things, we could look into experimenting with the use of thermochromic materials (that change color with temperature) and see the feasibility of then taking a picture of the material after the patient has stood on it (and it's durability for repeated use etc)/ This is a discussion we could have.I heard that one of you is into biomaterials - so although a stretch, it could be a cool thing that you could have ownership of.

3. Are there any controls to work with (images from non-diabetic feet)?

Currently we have about 225 pictures from the feet of patients in India. About 50 from each of these categories:

- Control Patients without diabetes
- Diabetic patients without neuropathy
- Diabetic patients with neuropathy
- Ulcerated patients

The remaining 25 pictures are almost all exclusively diabetics without foot ulcers.

4. Do we have access to the IR camera?

Yes, I'll bring it to the meeting!

5. What role is AI playing?

Right now, I've manually built an algorithm that uses the thermal image data to give a score to each patient as to whether they have an ulcer, are at risk, or they are fine. We want to instead train an AI algorithm on this dataset - say the control patients' and ulcerated patients' thermal images. We'd then feed it images of diabetic patients that don't yet have an ulcer (but have neuropathy) to give a confidence rating of how likely they will develop a foot ulcer.

6. Would an AI camera be of interest?

From my understanding, the AI loaded into these "AI cameras" hasn't yet been paired with thermal imaging. That's essentially what we're trying to build. An AI thermal camera.

7. What would the phone application need to be able to do?

Take photos, pull data out of the pictures, run the algorithm on the pictures, report a score.

8. Should the phone app be Android or iPhone based?

100% it should be android based at this stage in the game. No one in India has iPhones - it's a very stereotypical American thing to have an iPhone.

9. Will the tool be used in the field or in hospitals, how mobile should it be?

The real hurdle is that patients in India aren't coming in often enough for check-ups or they come in after their ulcer has developed and already infected. (this is because many people only earn enough money to pay for the next day's food and can't afford to miss work). And even if the patients do come in, unless they already have an ulcer, the nurses don't know which patients are at highest risk for developing a problem. Long-term, I want it to be a simple device that patients can stand on at home, and have their smartphones run the algorithm on the temperature readings to notify them when they should be going in for a checkup. I think that could be achievable with the use of a low-cost thermochromatic material which could be turned into a door mat which patients would step on. But I don't know if those materials are durable, or how quickly the thermal image fades off of them once someone steps on it.

10. What are the design constraints specific to India?

So the main thing is cost. If it's anything over about $150 it's going to be hard to get it in many rural hospitals. If we're going for a take-home device, it can't be much over $5. Right now, I don't want us too constrained by cost because we can always streamline that later. We should design with that price range in mind, but it doesn't need to define us right now. We just want to do it well and show that it works.

11. Do we have someone who would be able to improve our implementation once more samples are acquired in India?

Not sure what you mean by "improve our implementation" but there are doctors at CMC Vellore who could take more pictures for us once they get their own thermal camera. In addition, the goal is that we've got funding to send a few students to go to India next summer (May - August) as US Bose Scholars (I think Pucc sent out a link to the scholarship). I'm planning to accompany those students to India for the first few weeks to get things set up next summer, and then the students would continue to implement the design, collect images, check the system in multiple Indian hospitals and settings. We've already got all the IRB approval, so things would be seamless from that standpoint. I'm hoping that some of you would be interested to fill those spots perhaps in fulfillment of Global Health Certificate field-work or as international research experience.

The client also provided us with a large set of relevant literature on this topic so that the team can split up and read up on a lot of background information.

Notes from the team:

-Thermochromatic materials (could aid in design question for different ideas to consider)

- This would be a good thing for the patient to potentially take home in the future to monitor their own feet

-$70 camera vs. FLIR camera

Conclusions/action items:

- Use this information to create a Product Design Specifications
- Split up the provided literature and share with the team during the next team meeting

9/24/19 - Brief Client Meeting

▪ CARSON GEHL ▪ Oct 09, 2019 @11:11 AM CDT

Title: Brief Client Meeting

Date: 9/24/19

Content by: Carson Gehl

Present: Carson Gehl

Goals: Pick up camera from client and have client demonstrate how to use camera.

Content:

I was able to meet with Kayla to pick up the camera and phone containing the images she took in India. She showed me how to use it and edit images; she also shared with me that she has calculations associated with the images in order to assign a score to each image based on how at risk the patient was. This will be very helpful when it comes to developing an algorithm for detection.

Conclusions/action items:

Begin to edit images and upload them onto a computer to begin working with them ASAP.

9/13/19 - Advisor Meeting #1

▪ CARSON GEHL ▪ Sep 14, 2019 @11:35 AM CDT

Title: Advisor Meeting #1

Date: 9/13/19

Content by: Team

Present: Team

Goals: Go over the general project and begin discussing ideas for it.

Content:

Discussed possible ideas for the project. Dr. Tompkins mentioned looking into an AI camera on sparkfun electronics. We also discussed questions about the project that we will ask the client in the meeting with her on Tuesday. A major question we had was about the size of the data set; it may be difficult to develop an AI algorithm with only 250 images of the diabetic feet. We also discussed how an app would be developed such as what language would be used.

Conclusions/action items:

The first thing to do is to meet with the client so we have a better idea of what is desired for this project. We also need to do research into existing technologies. After the client meeting we will know more and can begin to start brainstorming ideas.

9/20/19 - Advisor Meeting

▪ CARSON GEHL ▪ Oct 09, 2019 @11:14 AM CDT

Title: Advisor Meeting

Date: 9/20/19

Content by: Carson Gehl

Present: All

Goals: Discuss client meeting

Content:

Established goals of the project after meeting with client the past week. Professor Tompkins proposes AI deep learning camera for analysis of pictures.

Conclusions/action items:

Research will be done into the AI camera suggested as well as in to other ideas for the device being developed.

9/27/19 - Advisor Meeting

▪ CARSON GEHL ▪ Oct 09, 2019 @11:20 AM CDT

Title: Advisor Meeting w/ Client

Date: 9/27/19

Content by: Carson Gehl

Present: All

Goals: Meet with advisor as well as client to further establish goals of project as well as current ideas.

Content:

Kayla discussed need for AI algorithm as others that have worked on similar projects have not incorporated this. We also discussed options for AI, specifically supervised vs. unsupervised learning. We are looking to develop a supervised learning algorithm as unsupervised does not give you a say in what information the algorithm is extracting. We need to be able to target specific data we want to look at and make predictions based on that; Kayla's calculations and scoring system will help with this.

Conclusions/action items:

Prepare for preliminary presentations the next week.

9/15/19 - Client Recommend Video Notes

▪ THOR LARSON ▪ Sep 15, 2019 @10:47 PM CDT

Title: Client Recommended Video Notes

Date: 9/15/19

Content by: Thor

Present: Individual

Goals:

- Compile notes on Prof. Paul Brand lecture: Leprosy, Diabetes, Wounds, and Life of Service (https://youtu.be/30piDE5iIVw)
- Compile notes on Client Kayla Huemer Fulbright talk: 'Smart Shoe': tackling India's diabetic problem one STEP at a time (https://youtu.be/C-EA2DJcuhc)

Content:

Prof. Paul Brand Video:

- Brand described his time in India dealing with Leprosy patients, specifically with regards to the wounds they experience due to neuropathy in their limbs
- Patients could not feel pain and in addition to not being able to heal from small wounds resulted in extensive tissue damage from mundane tasks where they weren't able to feel pain
- Brand performed many studies giving evidence to neuropathy being the main issue for the wounds patients were experiencing
- Gave a background on the differentiation between High Threshold Mechano-Receptors (HTMs) and Poly-Modal-Nociceptors (PMNs)
    - HTMs actives with high stress, traumatic to cuts
    - PMNs only active with very little stress and only after a period of initial stress, usually after small swelling or tissue damage occurs
    - PMNs are responsible for the shifting of your stance when standing for long periods of time to evenly distribute stress on the foot
- Brand noticed that temperature was a good measure of the amount of stress delivered to the foot when running or walking
- Performed experiments repeatedly providing stress to a rat in the same location on the foot, found that temperature increased as the rat approached an ulcer in the location
- When reducing the number of repetitions of stress provided per day, there was a significant decrease in the tissue damage and ultimately no ulcer developed
    - Brand determined that it was not entirely the amount of pressure that needed to be reduced but much more the number of applications of that pressure that needed to be lessened (like less steps)

Kayla Huemer Video:

- Kayla initially studied the pressure in the feet of patients to identify where the significant pressure points were in the foot in order to try and distribute the weight
- She realized that measuring the pressure was not a viable option for treating the disease because people would not show up in the hospital until after they noticed an ulcer
- Kayla summarized a study done showing that measuring the temperature of the feet every night and changing how many steps the patient was taking based upon this data proved helpful in reducing ulceration
- Kayla proposes a low cost solution specific to India to measure the temperature and prevent ulceration

Conclusions/action items:

- Do more research on the background physiology of foot ulceration and neuropathy
- Start thinking of ideas of low cost temperature measurement

10/9/19 – (1) Mobile DFUDetect Application

▪ THOR LARSON ▪ Oct 09, 2019 @03:35 AM CDT

Title: (1) Mobile DFUDetect Application

Date: 10/9/19

Content by: Thor Larson

Present: Thor Larson

Goals:

- Highlight the initial progress on the mobile application that connected with the FLIR camera
- Give evidence to the software platform decisions

Content:

- Began development of mobile application (I've preliminarily named it DFUDetect) in Android Studio
- Using the FLIR Mobile SDK (https://developer.flir.com) and the getting started guide (https://developer.flir.com/getting-started/android-platform-guide-flir-one-cat-s60/) and the documentation (https://developer.flir.com/sdk-documentation/)
- App below simply demonstrates the ability to connect with the FLIR camera and display frames on the mobile display, VERY PRELIMINARY
- Background set up was performed outside of the code below, only showing the MainActivity.java file that instructs the main screen of the mobile application which contains a text view (for print statements) and an image view

---

```
package com.example.dfudetect;

import androidx.appcompat.app.AppCompatActivity;

import android.graphics.Bitmap;
import android.os.Bundle;
import android.widget.ImageView;
import android.widget.TextView;

import com.flir.flironesdk.*;

import java.nio.ByteBuffer;
import java.util.EnumSet;

public class MainActivity extends AppCompatActivity implements Device.Delegate, FrameProcessor.Delegate {


    private FrameProcessor frameProcessor;

    @Override
    protected void onCreate(Bundle savedInstanceState) {

        super.onCreate(savedInstanceState);


        setContentView(R.layout.activity_main);
        frameProcessor = new FrameProcessor(this, this, EnumSet.of(RenderedImage.ImageType.BlendedMSXRGBA8888Image));


    }

    Device flirDevice;

    @Override
    protected void onResume() {
        super.onResume();
        Device.startDiscovery(this, this);
    }

    @Override
    protected void onPause() {
        super.onPause();
        Device.stopDiscovery();
    }

    @Override
    public void onTuningStateChanged(Device.TuningState tuningState) {
```

```
    }

    @Override
    public void onAutomaticTuningChanged(boolean b) {

    }

    @Override
    public void onDeviceConnected(Device device) {
        TextView textView = findViewById(R.id.textView2);
        textView.setText("Connected");


        flirDevice = device;
        device.startFrameStream(new Device.StreamDelegate() {
            @Override
            public void onFrameReceived(Frame frame) {
                frameProcessor.processFrame(frame);
                System.out.println("processing");
            }
        });
    }

    @Override
    public void onDeviceDisconnected(Device device) {

    }

    @Override
    public void onFrameProcessed(RenderedImage renderedImage) {
        final Bitmap imageBitmap = Bitmap.createBitmap(renderedImage.width(), renderedImage.height(), Bitmap.Config.ARGB_8888);
        imageBitmap.copyPixelsFromBuffer(ByteBuffer.wrap(renderedImage.pixelData()));
        final ImageView imageView = findViewById(R.id.imageView2);
        runOnUiThread(new Runnable() {
            @Override
            public void run() {
                imageView.setImageBitmap(imageBitmap);
            }
        });
    }
}
```

Conclusions/action items:

- Currently struggling with testing the application quickly because the Samsung phone needs to be plugged into the computer to upload the code but the FLIR camera needs to be connected to the phone at the same time, therefore I have been uploading the code, then unplugging, then plugging in the camera each time which can get very time consuming and also doesn't allow print statements to be displayed on the computer
- Look into possible getting a splitter so the phone can be connected to the computer and the camera at the same time
- Explore if it is possible to simulate the FLIR camera on the computer
- Explore the plausibility of developing a desktop application instead of mobile, provided isolation from the thermal camera, check with client if this is feasible in the context of the Indian hospital
- Continue to develop this application, specifically find a way to upload pictures already taken into the app
- Integrate OpenCV into the application for validation of the platform
- Explore possible machine learning algorithms that are feasible to be pursued first on the OpenCV platform

9/27/19 - Positioning Systems Used in Research

▪ THOR LARSON ▪ Sep 27, 2019 @11:40 AM CDT

Title: Positioning Systems Used in Research

Date: 9/27/19

Content by: Thor Larson

Present:

Goals:

- Compile foot positioning systems that have shown up in the research on other areas of the project
- Get ideas of potential designs or methodology's of keeping the foot stable for thermal image acquisition

Content:

Design 1: Automatic detection of diabetic foot complications with infrared thermography by asymmetric analysis

Link: https://www.ncbi.nlm.nih.gov/pubmed/25671671

- Overview
    - Figure 1 depicts the experimental setup for foot scanning used in the research article
    - Included 2 cameras installed, an upper thermal camera and a lower RGB camera
    - Also had a hyper spectral imaging and photometric stereo imaging system (reason for it being so large)
    - Article notes that the system is quite large for repeated medical use but was repeatable at the large scale and was useful for research purposes

Design 2: Infrared Dermal Thermography on Diabetic Feet Soles to Predict Ulcerations: a Case Study

Link: https://ris.utwente.nl/ws/files/5391469/Liu13infrared.pdf

- Overview
    - Positioning system similar to Design 1 in which the foot is placed on foot rests in order to keep stationary measurements
    - Thermal camera placed in 860mm long housing
    - Included a set of 6 thermal reference elements mounted in the field of view of the thermal camera, heated to constant and specific temperatures that serve as long term reference absolute temperatures for calibration
    - Temperatures of the reference elements are read by PT1000 resisters and stored in the image data

Conclusions/action items:

- Research additional designs for potential positioning solutions
- Evaluate the above designs for design aspects we would like to include in the final design

▪ THOR LARSON ▪ Sep 27, 2019 @11:27 AM CDT

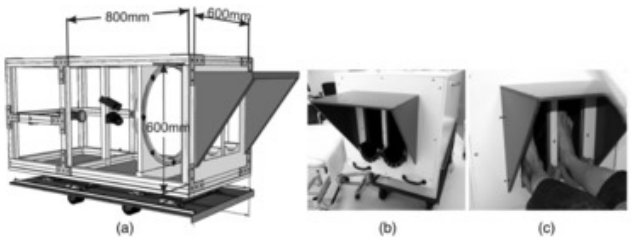


Fig. 2 The experimental setup for foot scanning: (a) the schematic of the experimental setup with two cameras installed, which are the thermal camera (upper) and the RGB camera (lower). (b) The appearance of the experimental set and (c) positioning of patients' feet during measurement.

figure_1_design_1.png(580.1 KB) - download Figure 1: Experimental setup for foot scanning, Design 1 article

▪ THOR LARSON ▪ Sep 27, 2019 @11:33 AM CDT

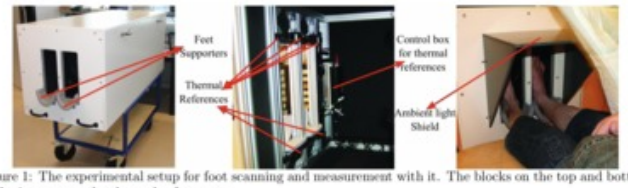


Figure 1: The experimental setup for foot scanning and measurement with it. The blocks on the top and bottom of the images are the thermal references.

figure_2_design_2.png(1.1 MB) - download Figure 2: Experimental foot positioning setup for Design 2

9/26/19 - OpenCV DFU Mobile Application

▪ THOR LARSON ▪ Sep 27, 2019 @11:11 AM CDT

Title: OpenCV DFU Mobile Application

Date: 9/26/19

Content by: Thor Larson

Present:

Goals:

- Compile notes on a paper describing a competing system
- Gather more background research on the scope of the project

Content:

Mobile Application for Ulcer Detection (Fraiwan et al)

Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6048827/

Overview:

- This article outlines a mobile application for the detection of possible Diabetic Foot Ulcers (DFU) using a smart phone along with a thermal camera (FLIR ONE)
- Mobile applications takes thermal images of the bottom of the foot and analyzes them through the Android Studio application with OpenCV
- Ulcer detection was based upon a thermal distribution on the two feet, comparing the difference between the temperature distributions and evaluating if there is a mean temperature difference grater than 2.2 degrees Celsius
- The researchers tested their system by simulating temperature differences on the feet by heating different locations
- Did not test the system on actual DFU in a medical application but determined that their system could accurately determine and locate the position of DFU's with a temperature difference of 2.2 degrees Celsius

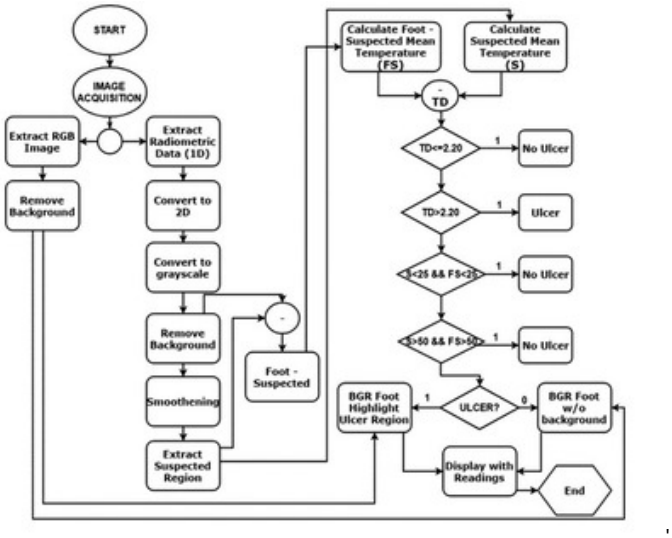
Image Processing Techniques (flow diagram system attached below)

- Image processing was performed through the OpenCV library that integrated with the android studio application
- Images collected consisted of a color image and a thermal image (MSX image and thermal radiometric data)
- Using the FLIR SDK, the data was converted into 2D, data scaled to range between 0 and 255 which represented the lowest and higher temperatures in the data
- A binary threshold was introduced to differentiate between the background (cold) part of the image and the foot (hot) part of the image
- The researchers decided on temperature thresholds to evaluate positions of possible ulcers and then calculated average temperature in these regions
- Decisions were made based on the mean temperatures calculated in these regions

Conclusions/action items:

- This paper highlights an easy way to process images from the FLIR camera which is what we are using for our project
- It highlights that this type of image segmentation is possible and can be built upon in the context of our project
- Action Items
    - Perform more research to see if we want to use OpenCV as a platform for image analysis
    - Research more competing systems to evaluate other methods of image analysis

▪ THOR LARSON ▪ Sep 26, 2019 @05:30 PM CDT



TOBEJ-12-16_F1.jpg(109.5 KB) - download Figure 1: Image processing system flow diagram

9/26/19 - MATLAB DFU Mobile Application

▪ THOR LARSON ▪ Sep 27, 2019 @11:12 AM CDT

Title: MATLAB DFU Mobile Application

Date: 9/26/19

Content by: Thor Larson

Present:

Goals:

- Compile notes on another competing system for DFU thermal analysis
- Research another method for processing thermal images in the context of diabetic foot ulcers

Content:

Diabetic foot ulcer mobile detection system using smart phone thermal camera: a feasibility study

Link: ncbi.nlm.nih.gov/pubmed/28974212

Overview:

- System consists of a thermal camera (FLIR ONE) connected to a Samsung smart phone, in conjunction used to take thermal images
- Images are processed and segmented using image processing techniques: Otsu thresholding and Point-to-Point mean difference
- System was implemented under the MATLAB Mobile platform in which thermal images were analyzed and interpreted
- System was tested in simulated conditions but has feasibility to be tested in a clinical environment

Image Processing Techniques

- Segmentation was applied twice to extract the object of interest from the thermal image (the feet) and the second to extract and identify possible ulcers
- First segmentation used histogram shape thresholding which find the optimum threshold to separate the background (dark or cold region) from the foreground (warm object) which was calculated using the Otsu method
    - Won't go into detail later but will note this method for possible more research in conclusion
- Image smoothing was performed to take care of anything that the thresholding was not able to highlight or remove
- Similar Otsu thresholding performed to separate the normal feet and the ulcerated regions
- After thresholding an independent t test was done to check if the difference between the foreground (suspected ulcer) mean temperature and the background (diabetic feet) mean temperature was greater than 2.2 degrees Celsius '
- *Figure 2* describes the second segmentation process (actual algorithm in the paper)
- Point-to-point mean temperature difference method was used to determine the 2.2 degree difference if it existed
    - Algorithm described in paper, should reference later when discussing image processing pathways

Conclusions/action items:

- Useful paper in evaluating another method for image acquisition and analysis
- Provided an alternative to the OpenCV method, in this case using MATLAB Mobile platform instead
- Action Items:
    - Refer back to this article when evaluating possible image segmentation and processing pathways
    - Research more competing designs, possibly other camera systems?
    - Start testing own methods of image segmentation and evaluating what system will be best for integration into eventual phone application and pattern recognition/AI algorithms

▪ THOR LARSON ▪ Sep 26, 2019 @05:49 PM CDT

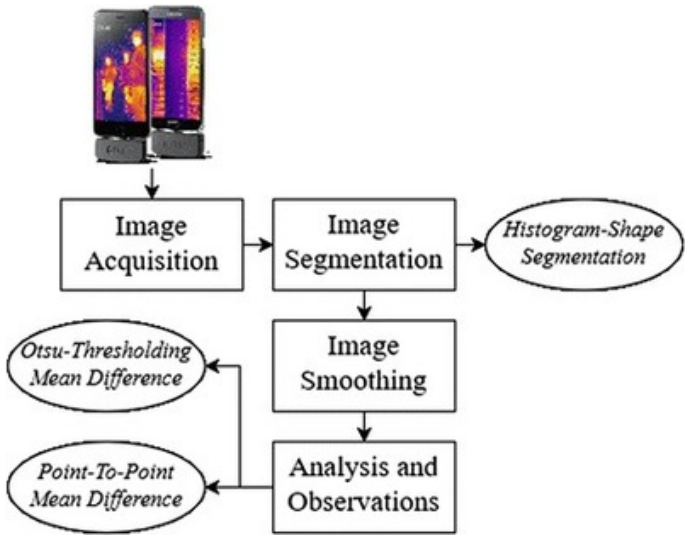


fig_1_image_processing.jpg(31.5 KB) - download Figure 1: image processing flow diagram

▪ THOR LARSON ▪ Sep 26, 2019 @06:01 PM CDT

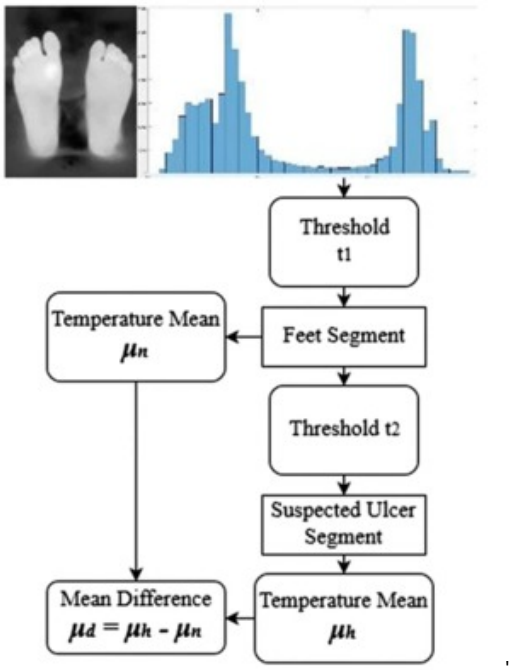


fig_2_segmentation_Otsu.PNG(97.1 KB) - download Figure 2: Second segmentation process diagram

10/8/19 - Design 1 Thermochromic Mat

▪ THOR LARSON ▪ Oct 08, 2019 @11:41 PM CDT

Title: Design 1: Thermochromic Mat

Date: 10/8/19

Content by: Thor Larson

Present: Team

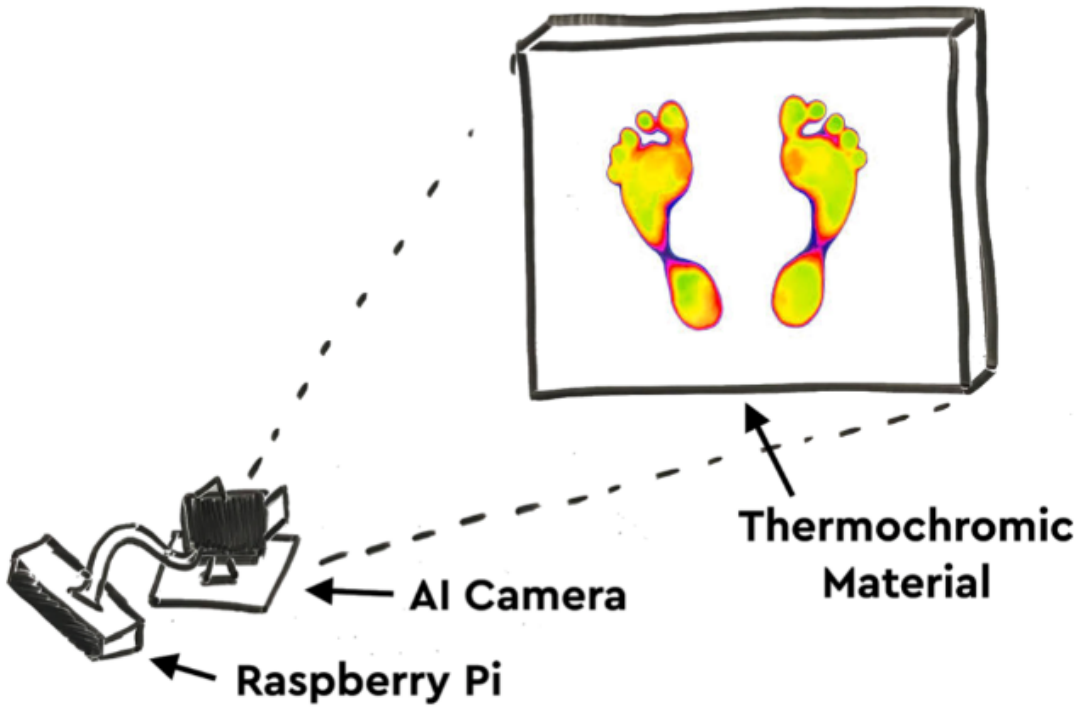
Goals:

- Compile design idea proposed by our client

Content:

Overview:

- Design involves two main systems:
    1. Thermochromic Mat:
        - Composed of a thermochromic–liquid crystal layer that changes color in response to changes in temperture
        - Patient would step on the mat for a period of time, leaving behind a color map that corresponds to the thermal distribution of their foot
        - Could explore the use of thermochromic pigments to replace the thermochromic crystals (could be less expensive)
        - Would have to do testing to calibrate what colors correspond to what temperatures
    2. Data Analysis/Acquisition System:
        - Composed of an AI camera connected to some sort of processing system (Arduino, raspberry pi)
        - AI camera would interpret the color map and translate it to a thermal map of each foot
        - Also would perform all of the predictive algorithms



Pros:

- Mat would be very inexpensive

- Very compact system, lightweight, ergonomic, easy to use
- Would allow for at home DFU detection, other designs would not generally have this capability in the context of India

Cons:

- Consistent measurements/accuracy could be a drawback depending on the algorithm used to analyze the images
- Different angles/light might affect the data
- Longevity of the thermochromic material, whether crystal or pigment, is unknown and may wear down quickly which could also affect measurements
- If not used under the supervision of the doctor, could have a lot of confounding effects on the data

Conclusions/action items:

- **Conclusion**:
    - This design would require a lot of iterative testing and also a novel algorithm to translate the color map into a thermal/temperature map on top of the predictive algorithms that would use that data
    - Could be a good design for later in the process as a supplemental system for at–home use
- **Action Items:**
    - Evaluate this design against the others
    - Explore possible thermochromic materials and accuracy in relating to temperature
    - Any competing designs that use a thermochromic material? Explore possible validation in the literature

10/8/19 - Design 2: Heat Strip Box

▪ THOR LARSON ▪ Oct 09, 2019 @12:05 AM CDT

Title: Design 2: Heat Strip Box

Date: 10/8/19

Content by: Thor Larson

Present: Team

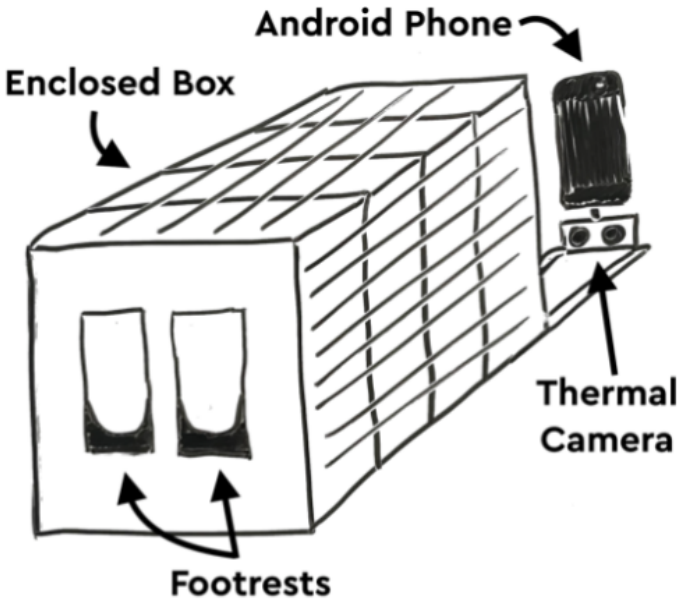
Goals:

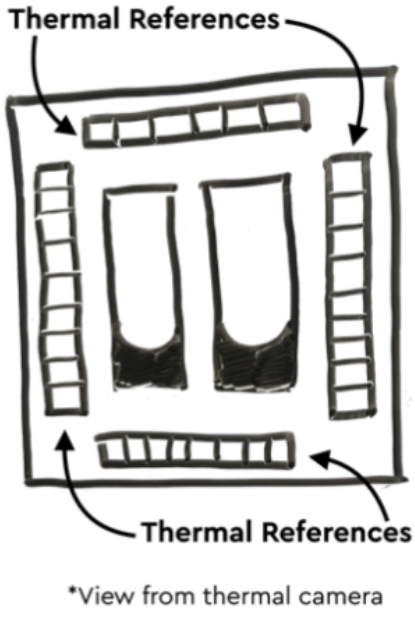
- Compile notes on another design that involves thermal references as a thermal camera calibration

Content:

Overview:

- Design involves 3 main part:
    1. Foot Positioning System:
        - Involves 2 foot rests enclosed in a long box which functions to minimize light entry
        - Patient meant to place both feet on the rests with the openings able to fit a multitude of patient feet sizes
    2. Thermal Calibration Mechanism:
        - Shown in the images below from the viewpoint of the camera uses heated strips in addition to direct temperature measuring sensors that record the real temperature at the moment a thermal image is taken in order to calibrate the color of the thermal image to the real temperature in the box
        - The thermal strips would be visible in the thermal picture and a color to temperature translation would be performed in the image processing algorithms
    3. Thermal Camera/Output Display:
        - Would consist of a thermal camera attached to a mobile device that would be able to capture thermal images and display them to the user
        - System would be placed on a sliding track connected to the foot positioning enclosed box that allows for a modular distance to be set between the feet and the camera
        - All image processing and predictive algorithms would be run on the mobile device processor
        - Display would include a mobile application that allows the physician to save, edit, and observe patient data and also upload any data into any electronic medical record or other system





Pros:

- Would provide a comfortable system for the patient to take pictures in, more plausible for someone who is already ulcerated and shouldn't be standing on their feet
- Output display that is a mobile device would be beneficial in a high paced hospital, able to store information data and analyze it, reduces cost of multiple devices
- Thermal camera would be more accurate with the thermal references, accurate temperature data important for consistent analysis

Cons:

- Thermal references would require some type of power source, could have replaceable batteries but this would add to costs/ease of use
- Enclosed box is bulky for the context of an Indian hospital, hard to store/transport in a high paced environment
- Setup may be a little taxing depending on the training of the doctor and the patient

Conclusions/action items:

- **Conclusion**:
  - Cost is still unknown as the fabrication material still needs to be explored
  - Thermal reference is a great way to calibrate the thermal data that the camera receives, however the power source could be a major drawback considering it adds an extra, non-reusable component that the other designs don't have
- **Action Items:**
  - Compare this design to there others
  - Possibly design a way to use the phone battery to power the heat strips, thus removing the extra component
  - Explore different materials to use
  - Explore similar designs in the literature for improvement ideas

10/9/19 - Design 3: Folding Studio

▪ THOR LARSON ▪ Oct 09, 2019 @01:43 AM CDT

Title: Design 3: Folding Studio

Date: 10/9/19

Content by: Thor Larson

Present: Team

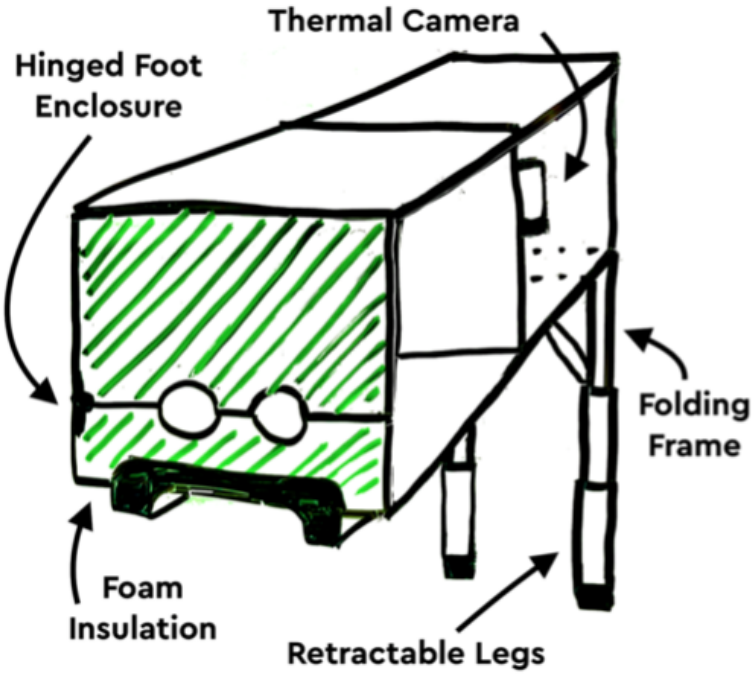
Goals:

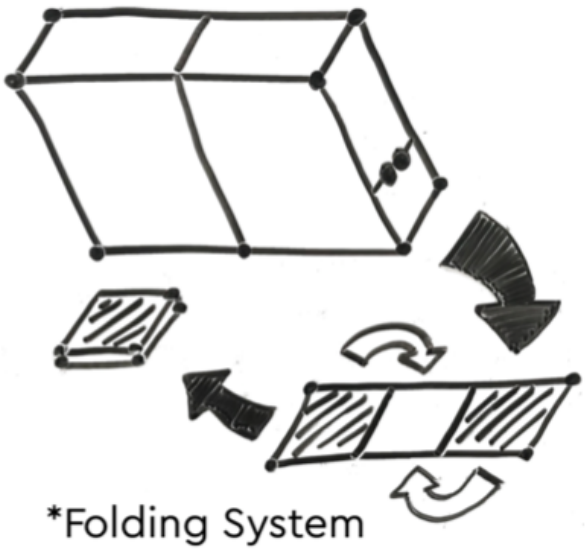
- Compile notes on another design that allows for folding of the positioning system

Content:

Overview:

- Design involves 3 main parts:
    1. Foot Positioning System:
        - Supported by multiple structural rods that have hinges at connecting points that allow the box to fold as seen in the image design below
        - Faces of the box are open and would be covered with some sort of cloth to minimize light entry
        - Foot rests are positioned similar to Design 2 however a hinge in the foam allows for easy placement of feet and then subsequent closure that isolate the foot in the box and minimizes readings from the ankle or body behind the foot
        - Consists of retractable legs that can be adjusted to the height of the bed for stabilization
    2. Thermal Calibration Mechanism:
        - Foot rest face consists of a 2 foam layers with an air gap in the middle, this provides a consistent background temperature for thermal readings
        - While not a calibration mechanism per se, the consistent background temperature would be used for easy segmentation of the foot which would speed up and simplify the algorithm used
    3. Thermal Camera/Output Display:
        - Exactly the same function and composition to Design 2: Heat Strip Box, repeated below
        - Would consist of a thermal camera attached to a mobile device that would be able to capture thermal images and display them to the user
        - System would be placed on a sliding track connected to the foot positioning enclosed box that allows for a modular distance to be set between the feet and the camera
        - All image processing and predictive algorithms would be run on the mobile device processor
        - Display would include a mobile application that allows the physician to save, edit, and observe patient data and also upload any data into any electronic medical record or other system





Pros:

- Similar pros to Design 2, repeated below:
    - Would provide a comfortable system for the patient to take pictures in, more plausible for someone who is already ulcerated and shouldn't be standing on their feet
    - Output display that is a mobile device would be beneficial in a high paced hospital, able to store information data and analyze it, reduces cost of multiple devices
    - Thermal camera would be more accurate with the thermal references, accurate temperature data important for consistent analysis
- Additional pros over Design 2:
    - Folding system allows for easy transport which could prove beneficial for use in an Indian hospital
    - Foam calibration system would be better than using a cold towel/fabric, minimize error by not having any water touch the patient which could contaminate readings
    - Non-enclosed box would reduced weight of the positioning system

Cons:

- Could be hard to set up from the completely folded state
- Foam might need to be replaced, durability is a question we need to explore more
- Use of the cloth to minimize the light could be used incorrectly, room for error

Conclusions/action items:

- **Conclusion**:
    - Leading design at this point as it has the most pros and least cons, still need to evaluate it formally against the other designs however
    - Folding mechanism would need to be explored more for feasibility in the mechanism and the fabrication of it
- **Action Items:**
    - Evaluate all designs in a design matrix
    - Search for similar designs in the literature
    - Keep designing for improvements on top of this design

10/9/19 – Design 4: Retractable–Compaction Box

▪ THOR LARSON ▪ Oct 09, 2019 @02:12 AM CDT

Title: Design 4: Retractable–Compaction Box

Date: 10/9/19

Content by: Thor Larson

Present: Self

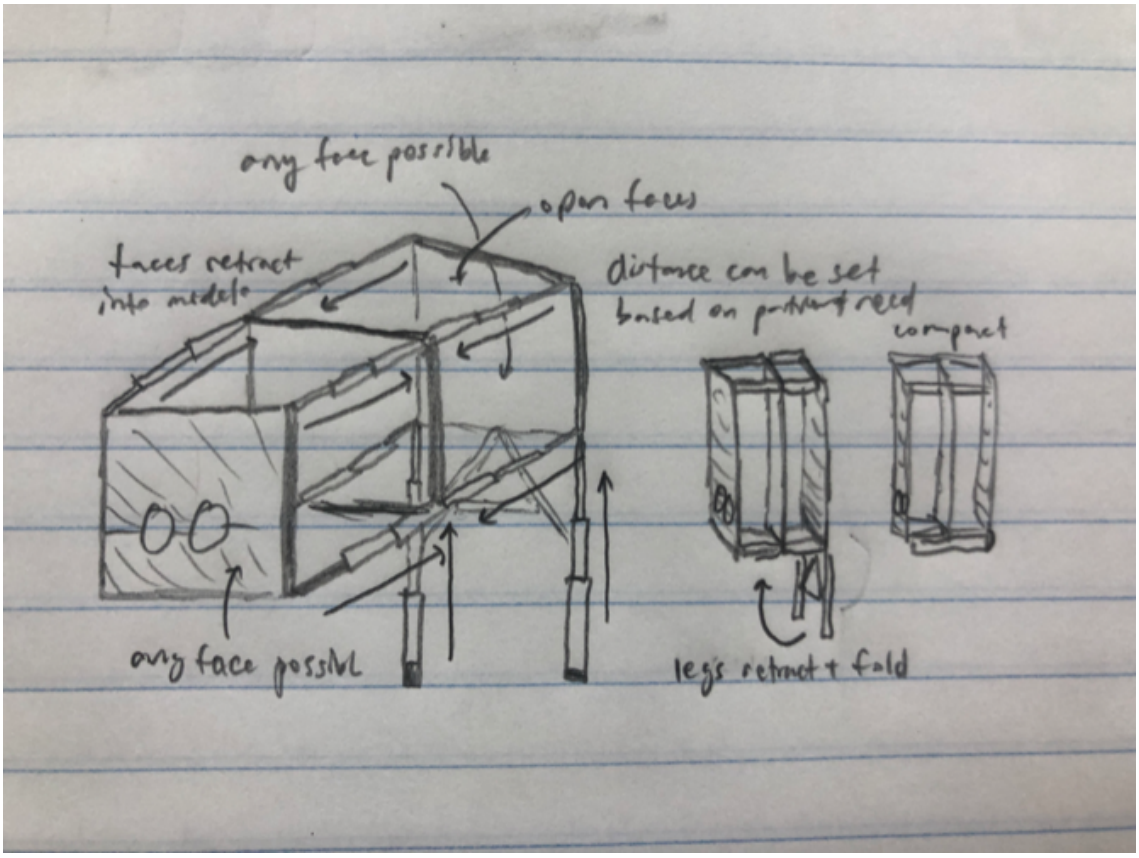
Goals:

- Compile notes on another design that builds upon Design 3 with a different compaction mechanism

Content:

Overview:

- This design is the same as Design 3 with regards and the design with the exception of the mechanism used to reduce the size of the positioning system for easy transport
- In Design 3 the size reduction mechanism consists of folding each of the faces onto each other giving a 3 face result with the size of the rods in between
- This design consists of retractable rods (similar to the retractable rod on a tripod) that connect to each of the faces of the positioning system
- The faces would then extend from the middle face and the distance can be adjusted based upon patient requirements



Benefits in comparison to Design 3:

- Folding mechanism could be difficult to fabricate, different mechanisms for different hinges in the design, this design would have the same consistent design for all lateral rods making fabrication a more repetitive process
- Setup would be a lot easier in comparison to the folding mechanisms as it would just involve extension and locking the retracting rods, in the folding mechanism multiple different points would need to be secured

Conclusions/action items:

10/8/19 – Specific Impact to India

▪ THOR LARSON ▪ Oct 09, 2019 @02:36 AM CDT

Title: Specific Impact to India

Date: 10/9/19

Content by: Thor Larson

Present: Thor Larson

Goals:

- Compile research and thoughts on the impact of diabetes and specifically diabetic foot ulcers in India

Content:

Article: Burden of Diabetic Foot Ulcers in India: Evidence Landscape from Published Literature

Link: https://www.sciencedirect.com/science/article/pii/S1098301517308239?via%3Dihub

- This article describes many statistics related to diabetes and specifically to the impact of foot ulcers in India
- Notable quotes:
    - "*Out of 62 million diabetics in India, 25% develop DFUs, of which 50% become infected, requiring hospitalization while 20% need amputation."*
    - *"Patients with a history of DFU have 40% higher 10-year death-rate, than those without*"
    - "*India is the most expensive country for DFU care, as 5.7 years (68.8 months) of an average patient's income is required to pay for complete DFU therapy*"

Reactions:

- It is obvious that diabetes as a whole is a major problem in India, with diabetic foot ulcers being a major consequence fo this fact and being one of the main repercussions of the diabetes epidemic
- The viscous cycle of treatment being very expensive and the prevalence of diabetes to begin with makes the diabetic epidemic require a different solution then it would in a place like the United States
- In this case it is not just the medical and physiological aspect that needs to be cured, but the health system and process of treatment that needs to be tailored to the context of India

Conclusions/action items:

- **Conclusion:**
    - The impact of this project goes beyond the specific way of detecting the diabetic foot ulcer, but all the way to finding a way to get the patient to get to the hospital, reducing the cost of treatment, and finding a way to give more people access to the treatment they need
    - It will be important to keep in mind the context of which we will be applying our solution as this will dramatically affect what routes we pursue with regards to design, materials, and our overall solution

9/16/2019 - PNM Mechanoreceptors

▪ JARETT JONES ▪ Sep 16, 2019 @11:28 PM CDT

Title: Neuropathy Research

Date: September 16, 2019

Content by: Jarett Jones

Present: N/A

Goals: Neuropathy of the foot research.

Content:

The following research was obtained from a recorded presentation given by Professor Paul Brand. It should also be noted that these videos were recommended for our viewing by our client.

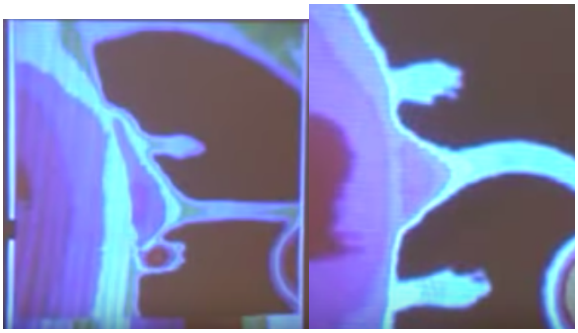
Here is the link to said presentation : https://www.youtube.com/watch?v=30piDE5iIVw.

Neuropathy is defined as a result of damage to the nerves outside of the brain and spinal cord (peripheral nerves), often causes weaknesses, numbness and pain usually in the hands and feet. Professor Brand described the basis of his personal attachment to researching and helping individuals experiencing neuropathy due to Leprosy in India. Many of the stories were rather startling to put some perspective on the effects neuropathy as a result of Leprosy or Diabetes; Brand described individuals losing chunks of flesh to rats while they slept because they could not feel the attack they were under. In a less extreme manner Brand found that individuals experiencing neuropathy were at risk for severe wounds, ulcerations, and amputations resulting from everyday tasks at high repetition breaking down weak tissue.

Professor Brand also analyzed the differences in mechanoreceptors responsible for signaling forces on the body. Well documented High Threshold Mechano-Receptors also known as HTM's are responsible for signaling to the brain in the presence of high stress trauma such as forceful impact or cuts. However, in regards to the severe negative effects of neuropathy the more relevant receptors are Poly-Modal-Nociceptors. Professor Brand conducted many case studies on such receptors. PMN activate when previously enflamed or irritated tissue is subjected to stress (such as bumping a previously bruised area). Additionally, this mechano-receptor is responsible for establishing a limp in a stride or overcompensation to reduce stress on an inflamed area during repeated activity.

In order to quantify the shortcomings in detecting and neurologically interpreting these PNM signals Brand used temperature mapping of areas of stress to determine effected areas. In healthy individuals after heat was produced in a stressed region the body began to compensate by altering motion to shift stress. However, patients with neuropathy were incapable of detecting these PNM signals and noticing the stress imposed upon already weak, inflamed tissue.

In an experiment conducted on mice to study the relationship between tissue breakdown and types of stress, Brand determined that indeed repetition frequency played a larger role than repetition force. As applied to diabetic patients it is clear that making them aware of their step count for the day is far more important than quantifying step pressure in regards to preserving foot health and functioning.



On the left is the low force high repetition and on the right is low repetition high force. It can be noted that the image on the left has a higher temperature reading than those on the right.

Conclusions/action items:

Continue research beyond client recommended videos to learn more about the development of neuropathy and the physiological rationale behind diabetes causing it. Learn more about physiology of the foot and the effect/physiological timeframes of ulceration/infection/amputation to determine a timeline for pinpointing areas of concern prior to negative effects on foot health and functioning.

9/17/2019 - Diabetic Ulcer Research

▪ JARETT JONES ▪ Sep 17, 2019 @12:26 PM CDT

Title: Diabetic Ulcer Research

Date: 9/17/2019

Content by: Jarett Jones

Present: N/A.

Goals: Research relative timelines of ulcer formation and infection in neuropathic feet of diabetics.

Content:

https://www.ncbi.nlm.nih.gov/pubmed/26072202

The Diabetic Foot.

Peripheral Neuropathy

Around 60% of diabetes patients are impacted by peripheral neuropathy. This disease becomes more prevalent as age increases. For diabetic patients, peripheral neuropathy encompasses large and small fibers; disrupting temperature discrimination and automatic functions. As a result of failing to accurately discriminate between temperatures or pain often early signs of foot deformity or lesions go unnoticed and subsequently uncorrected. Callus is commonly present in neuropathic ulcers and they reduce the potential for a healthy ulcer leading to infection. In addition to ulcers, neuropathy of the foot also diminishes the function of intrinsic muscles of the foot leading to a subsequent imbalance between flexor and exterior mechanisms (clawing to the toes, increased prominence of metatarsal heads, loss of sweat gland function, increase of distal arterial flow leading to edema and osteopenia).

Infections

Neuropathy of the foot in diabetic patients can often lead to severe damage resulting from infection. Infection can be bacterial (often the case for irritated and poorly managed ulcers) or can result from fungal growth between toes or under toe nails. Foot ulcers have either an active or passive infections. Active infections of ulcers includes ascending erythema, edema, purulence, increased drainage and malodour. These symptoms usually are associated with temperature increase but are these changes are not felt by diabetes patients. However, infection is already onset when symptoms such as loss of blood glucose control or flu like symptoms are present. Biofilms of ulcers consist of bacterial colonies that form on the surface of wounds.

Common foot deformity locations

Most diabetic neuropathy damage occurs at the forefoot with equal distribution on the plantar and dorsal surfaces (these should be areas of interest when imaging with the IR camera).

https://www.ncbi.nlm.nih.gov/books/NBK537328/

Diabetic Foot Ulcer

Pathophysiology of Ulcers

Diabetic foot ulcers usually form in a three stage process. The first stage results in callus formation due to neuropathy inhibiting the recognition of repeated stress on a given area. Continually this area will undergo drying and cracking of the skin as a result of autonomic neuropathy which inhibits the proper functioning of glands in the foot. Eventually, the combination of the traumatized callus and the drying of the skin in that region, a hemorrhage of the skin will occur and erosion leads to ulcerification.

Following the diagnosis of an ulcer, the wound is categorized into different grade stages. Grading occurs 1-5 (5 being most severe): Superficial ulcer; deep ulcer involving tendon, bone, or joint; deep ulcer with abscess or osteomyelitis; Gangrene involving the forefoot; Gangrene involving the entire foot.

Conclusions/action items:

Continue research on the pathophysiology of ulcers and callusification prior to being visible on the skins surface. Find research on the stages of a callus prior to making its way to the skins surface (how is the tissue affected on a subepidermal scale?).

Conduct research on competing designs for monitoring the staging of ulcers both on the surface of the skin as well as other products that image the feet of at risk diabetic patients. Additional product specifications will be made at tonights client meeting number 1.

9/17/2019 - Temperature Changes in Diabetic Foot

▪ JARETT JONES ▪ Sep 17, 2019 @06:32 PM CDT

Title: Temperature in Diabetic Foot

Date: 9/17/2019

Content by: Jarett Jones

Present: N/A

Goals: Compile research about temperature thresholds indicative of ulcers in diabetic foot.

Content:

https://www.ncbi.nlm.nih.gov/pubmed/18060924

Skin temperature monitoring reduces the risk for diabetic foot ulceration in high-risk patients.

A physician-blinded study with 225 diabetic patients at high risk for ulceration were analyzed. Dermal Thermometry Group was assigned an infrared skin thermometer to measure foot temperatures on 6 different spots on the foot, twice daily. The group was instructed to see their medical professional for temperature differences greater than 4 degrees F between left and right foot corresponding sites. In addition to contacting a medical professional, the patients with large temperature differences were instructed to drastically reduce activity time until temperatures normalized. Subjects in the study group without the thermal monitoring were 66% more likely to ulcerate within this study population. The patients that did experience ulceration experienced temperature differences that were 4.8 times greater at the site of ulceration in the week before ulceration than patients who did not ulcerate.

https://www.ncbi.nlm.nih.gov/pubmed/17192326

Preventing diabetic foot ulcer recurrence in high-risk patients: Use of temperature monitoring as a self-assessment tool

A physician-blinded study with 173 diabetic patients with a history of diabetic foot ulcerations were analyzed. Subjects in the enhanced therapy group used an infrared skin thermometer to measure temperatures on six different foot locations each day. Temperature differences greater than 4 degrees F between left and right corresponding foot locations were determined to be of importance. Patients in this study who were not able to use the infrared monitoring system were almost 5 times more likely to develop full blown ulceration than those patients who had access to home monitoring.

Inflammation is one of the earliest signs of tissue injury and ulceration; clinical signs of inflammation are too subtle for the naked eye of even a medical professional. However, inflammation can be seen by infrared temperature readings taken of the tissue in question to visualize subepidermal changes.

Conclusions/action items:

Infrared temperature analysis seems to be a common method for early detection of diabetic foot ulceration. I would like to place more emphasis on specific designs of competing products and their available design budgets to see where we can optimize what already exists for our client base in India.

9/20/2019 - Client Recommended Publication Review

▪ JARETT JONES ▪ Oct 09, 2019 @09:41 AM CDT

Title: Client Recommended Publication Review

Date: 9/20/2019

Content by: Jarett Jones

Present: N/A

Goals: Literature review of the list of relevant publications provided by our client.

Content:

Assessment of Signs of Foot Infection in Diabetes Patients Using Photographic Foot Imaging and Infrared Thermography

https://www.researchgate.net/publication/261290230_Assessment_of_Signs_of_Foot_Infection_in_Diabetes_Patients_Using_Photographic_Foot_Imaging_and_Infrared_Thermography

PFID, Photographic foot imaging device. The PFID contains a camera module (charge-couple device image sensor with a resolution of 4 pixels/mm^2). The PFID produces three images under different lighting conditions (diffusive and medially and laterally oriented to improve quality of produced three-dimensional foot contours. Foot skin temperatures were measured with an infrared thermometer which is designed to measure subsurface temperatures on the plantar foot surface. Foot temperatures measured with the probe are measured to .1 degrees celsius accuracy.

Researchers obtained sub-skin foot temperatures in six plantar regions. Additionally, a flow chart was established to determine the relationship between a hotspot, presence of erythema, and presence of ulceration. It is essential to note the thermal probe analysis is not being directly coupled but rather used together to cross validate findings. The study recognizes some shortcomings as temperature readings are limited to the planar surface of the foot; however, only 50% of ulceration occurs directly on the planar surface. The other 50% occur on the dorsal or lateral foot surface and even sometimes between the toes. Additionally, the study plans to in the future further look into methods of comparing and defining hot spot regions by referencing other temperatures on the same foot to better accommodate amputee patients.

Conclusions/action items:

There exist a lot of competing designs that are used for early detection of diabetic ulceration; however, the cost of fabrication/implementation of many of these products is not feasible for our target patient population. Continue researching ways to maximize the quality of our diagnostic output while cutting cost. At what cost threshold do we lose the precision and accuracy necessary for clinic?

09/24/19 - Portable IR Camera Setup

▪ JARETT JONES ▪ Sep 27, 2019 @08:06 AM CDT

Title: Development of a Portable Near Infrared Camera for Early Detection of Diabetic Ulcers

Date: 09/24/19

Content by: Jarett Jones

Present: N/A

Goals: Continue researching ideas of other similar early ulcer detection methods.

Content:

Development of a Portable Near Infrared Camera for Early Detection of Diabetic Ulcers

file:///Users/jarettjones/Downloads/10%20Development%20of%20a%20Portable%20Near%20Infrared%20Camera%20for.pdf

This product wanted to view the venous blood within a diabetic foot. Viewing of venous blood is a rather simple task when using vascular ultrasound or narrow-band imaging however the group wanted to create a cheaper portable method for monitoring the venous blood in diabetic feet. Perhaps a certain infrared wavelength could be used to discern the quality of blood in certain venous blood as the oxygenation of the blood would alter its color. Shortcomings of the challenge were creating a product that worked for all skin tones, thickness and depth of veins.

The study states "optimized illumination is the key to obtaining the best images" and for that reason a light fixtures was created composed of 9 LED lights ranging from 650nm - 900nm wavelength. And as one would expect fair skin generally provided the best venous image quality.

Raspberry Pi used for image acquisition and then was further analyzed by matlab. The illumination device coupled with near IR NIR optical filters were used to minimize outside conditions. The pictures were obtained from the Raspberry Pi from an ethernet WI-FI connection. The goal of the study was by exposing areas of poor blood flow through poor oxygenation of veins one could target the regions of the foot being deprived of oxygen and make steps toward early identification and prevention of diabetic ulceration.

Conclusions/action items:

This item is a competing design as it offers a way of categorizing areas of interest for potential ulceration by the monitoring of quality of oxygenation in the veins of the feet. It is interesting the implementation of a Raspberry Pi to cost effectively aid in obtaining the images and this is something we should look into. Plan to reference this setup when we meet with Dr. Richard Barker to see his Infrared Camera/Raspberry Pi setup in a few days.

10/4/19 - Competing Design (smartphone & application)

▪ JARETT JONES ▪ Oct 09, 2019 @10:03 AM CDT

Title:

Date: 10/4/19

Content by: Jarett Jones

Present: N/A

Goals: Research existing patents/designs that already exist.

Content:

Diabetic foot ulcer mobile detection system using smart phone thermal camera: a feasibility study

ncbi.nlm.nih.gov/pmc/articles/PMC5627424/

This study is overall very similar to what we had in mind based on our own design brainstorming as well as the specifications given to us by our client. Basically the thermal imaging process using this setup occurs using a FLIR camera that is adaptable to a standard Samsung smartphone (important to note that the use of Samsung over Apple is crucial when considering the patient populations ability to access this brand). This particular study implemented a crucial temperature threshold of +2.2 degrees celsius as indicative of early stage ulceration. The physical image capturing process of this study does not seem to be very standardized and this is something we hope to exploit as a benefit in our imaging system. Temperature thresholding was done using Otsu and Point-to-Point mean difference technique in MATLAB. This process was indeed successful in quantifying the regions of interest for ulceration. Additionally, it is necessary to note that this design/project was solely developed and tested upon simulated conditions which may in fact be more profound than the ulcerated regions of a diabetic patient's foot.

This study is lacking actual clinical testing on a patient population. We hope to use similar techniques as this team; however, our training set data for the AI algorithm will be taken from actual patient photos obtained in clinic. Additionally, methods to standardize the image collection process could make our project more novel and successful.

Conclusions/action items:

Continue brainstorming effective ways to standardize the image capturing process in the hospital to make image capturing efficient and consistent.

10/2/19 - Competing Design (Socks)

▪ JARETT JONES ▪ Oct 09, 2019 @10:05 AM CDT

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

10/8/19 - Project Impact

▪ JARETT JONES ▪ Oct 09, 2019 @12:51 PM CDT

Title: Project Impact

Date: 10/8/19

Content by: Jarett Jones

Present: N/A

Goals: Compile research regarding the need for a cost effective ulcer detection method for diabetic patients in India.

Content:

https://pdfs.semanticscholar.org/46ae/5c6caeb57df0001fd844d530f3cbffe51004.pdf

Prevalence of Diabetic Foot Ulcer and Associated Risk Factors in Diabetic Patients From North India.

This article highlights the prevalence and severity of the diabetic outbreak in India. India is currently known as the diabetic capital of the world as nearly 60 million people suffer from the disease and lack the treatment/guidance to make informed decisions to negate the complications that arise from this disease. A large percentage of the population that is subjected to this disease experience neuropathy in their feet. In developing regions, shoes are not commonly worn; therefore, the neuropathic feet experience many severe complications such as ulceration, infection of ulcer, and ultimately the need for amputation as a whole which results in life altering consequences. For all of these reasons it is our duty to not only develop a device for early-stage ulcer detection but to develop one at a low enough cost that it can become common place in India and hopefully stop these horrific complications of diabetes before they begin.

Conclusions/action items:

Continue discussion as a team about the broader impact our work could have on the lives of diabetic patients in developing regions of the world. As we progress into IRB approval and data acquisition at the Veterans Administration Hospital of Madison, we should look to review research ethics as well as fully understand the scope of our work and our procedures to give our subjects the best possible experience.

10/5/19 - The Image Wand

▪ JARETT JONES ▪ Oct 09, 2019 @12:33 PM CDT

Title: Design Idea - The Image Wand

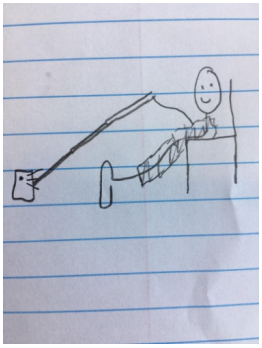
Date: 10/5/19

Content by: Jarett jones

Present: N/A

Goals: Convey the image wand design idea through sketch as well as discussion of benefits/pitfalls.

Content:



The motivation for this design was to implement a better way for the patient to be able to "self-check" the state of their feet rather than needing someone to image them through a box. The idea is similar in construction to a "selfie stick" (linked) in that the "rod" is made of all retractable pieces to offer variability in length and ease of storage/transportation. Additionally, the free background behind the patients feet for this design is different than all others in the sense that there is no standardized background. For this reason we would need to use a normal (not IR) image of the foot and some software to trace that outline and detect that same shape in the IR image (as the foot may blend in with the background temperatures).

Pros:

-Patient is able to self check the state of their feet

-retractable down to a single rod, most compact design

-Can vary in length giving it adjustability depending on the leg length of the patient

Cons:

-No standard background (would need to utilize normal picture of the foot to design software to extract the foot shape in the IR Image)

-In terms of standardizing imaging process this leaves a lot of variability in distance from foot/blurriness of picture (could lead to a loss in consistency)

Conclusions/action items:

Team should begin comparing group brainstormed design ideas as well as individual ideas to determine the design that most closely meets the requirements of the PDS and has the best chance at succeeding with accurate data acquisition.

10/7/19 - The Thermo-Dome

▪ JARETT JONES ▪ Oct 09, 2019 @11:49 AM CDT

Title: Design Idea - ThermoDome

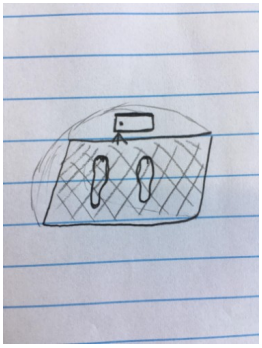
Date: 10/7/19

Content by: Jarett Jones

Present: N/A

Goals: Convey a thermal image standardizing design via sketch and figure caption/rationale.

Content:



The sketch is a poor representation of the complexity of this design. My idea was to fabricate some sort of plastic shell/dome over a mat of base Thermochromic materials. The dome would have foot cut-outs that the patient would simply step into (ensuring the feet are in the same location on the mat every time). Between each of the foot cut-outs the AI camera imaging device would be fixed (again ensuring that the feet are always in the frame at the same distance from the camera. The patient would simply step out of the cut outs, and bend over and press to take an image of the colored heat map. The rationale behind the dome is to limit outside temperature influencing the colors on the thermochromic materials as well as slowing the dissipation of the colors after the patient removes their feet.

Pros:

- Standardize camera location to feet distance (*per Dr. Barker emphasis)

- Limit the heat loss/color change of thermochromic materials by partial insulation

- Limit outside temperature influence on thermochromic materials

- Patient can self operate

Cons:

-Very difficult to fabricate

-Lacks portability in terms of shipping it to India for testing

-Expensive to fabricate

Conclusions/action items:

Fabrication of plastic dome with adjustable foot cutouts may be impractical. Brainstorm/literature review methods for preserving the colored heat map on the thermochromic materials to slow loss of heat to surrounding environment (gives more time for AI picture to be taken of heat map).

Cause of ulcers in diabetic feet

▪ CARSON GEHL ▪ Sep 15, 2019 @07:48 PM CDT

Title: Cause of ulcers in diabetic feet

Date: 9/15/19

Content by: Carson Gehl

Present: N/A

Goals: Summarize the process of ulcer formation in the feet of diabetic patients.

Content:

Video that Kayla sent to us:

https://www.youtube.com/watch?v=30piDE5iIVw

In this video, Dr. Brand discusses how he discovered the cause of ulcer formation in patients suffering from leprosy. This is related to diabetic patients as the root cause of ulcer formation is neuropathy, in this case the degradation of nerve endings, which is also experienced by diabetic patients. Dr. Brand found that regular humans possess mechano-receptors that are more sensitive to repeated low-force mechanical pressures, as opposed to the more obvious mechano-receptors that only respond to forces over a certain threshold. When a typical person has been walking around quite a bit and a specific area of their foot has been repeatedly exposed to the pressures of walking, the body sub-consciously adjusts its stride to redirect the pressures to other areas of the foot. However, in patients suffering from this neuropathy, these receptors are inactive. When an area of the foot has been repeatedly exposed to these pressures, the body does not adjust. This causes inflammation in that area, which can be detected by an increase in temperature relative to the rest of the foot. After inflammation has occurred, the person continues to walk the same as they cannot feel the pain that most would. This is the beginning of ulceration, which can then lead to infection and amputation of the foot.

Conclusions/action items:

Research neuropathy.

Pathophysiology

▪ CARSON GEHL ▪ Sep 16, 2019 @09:56 PM CDT

Title: Pathophysiology

Date: 9/16/19

Content by: Carson Gehl

Present: N/A

Goals: Research into the processes behind diabetic foot ulcer formation

Content:

https://en.wikipedia.org/wiki/Diabetic_foot_ulcer#Pathophysiology

-Damaged extracellular matrix triggers response from immune system which recruits fibroblasts to build collagen. This influx of fibroblasts is the cause of inflammation.

-Perclean, which is found in the epidermal and endothelial basement membrane, is an important part of wound healing that is responsible for binding growth factors. It is known that high levels of glucose can decrease the expression of perclean in some cells through transcriptional and post-transcriptional modification. For this reason, poor wound healing abilities in diabetic patients could possibly be attributed to low perclean expression.

-Skin suffers from reduced hydration making the tissue less elastic and more vulnerable to mechanical stress. Compression and shear stresses experienced are greater in the average diabetic foot compared to that of a regular foot.

Conclusions/action items:

Continue research, meet with client.

1 Diabetic foot ulcer mobile detection (paper #1)

▪ CARSON GEHL ▪ Sep 18, 2019 @08:15 PM CDT

Title: Diabetic foot ulcer mobile detection system using smart phone thermal camera: a feasibility study

Date: 9/18/19

Content by: Carson Gehl

Present: N/A

Goals: Beginning to review papers that Kayla sent in order to gain a better understanding of the project, current projects working on the same thing, and to view ideas as to how others have went about this.

Content:

There were a lot of good takeaways from this publication that I will explain below. More in depth information on them can be found in the publication itself

- a temperature difference of 2.2 degrees C can indicate a possible development of ulcers (this is before the ulcer has formed however, so that it is not too late to act). Kayla had mentioned that we may want to be more on the safe-side (i.e. identifying false positives would be better than under-diagnosing). We could consider this value or possibly a smaller value depending on the accuracy.
- They performed two image segmentations in their program - the first to remove the feet from the background and the second to detect ulcers
    - They used a technique called Histogram shape thresholding which results in a bi-modal histogram with two peaks. This requires finding the optimal temperature to act as the threshold to separate the feet from the background. Quite a bit of statistics included in this that I will not list in here.
    - Image smoothing was performed to further clean up the images before final analysis. Most of the smoothing needed to be done around the edges of the feet.
    - To analyze for ulcers, the same method was used as before, except that now the feet act as the background, and any region in which the mean pixel value was 2.2 degrees Celsius above the mean pixel value of the feet themselves, it was considered the start of a possible ulcer.
- It seemed that they had issues with background noise which could be relatively easily improved by prototyping something in which the patient can place their feet and the background will be significantly cooler to assure for a cleaner image. Kayla utilized a wet towel behind the feet to achieve this.
- No actual clinical trials were done to test the prototype. It was tested by heating up various areas of an individuals foot and testing if the program was able to detect the change in temperature. This is a good idea that we talked about using to help train the program since we do not have an adequate amount of images to create an efficient AI algorithm yet.

A shareable link to the paper being discussed: https://drive.google.com/open?id=1ZFcxfG0QB2VoTKxC-JnVwfruBgy1uvA5

Conclusions/action items:

Continue parsing through the paper's Kayla sent us and begin to assemble a knowledge of how we may want to go about this.

1_3 Automatic detection of diabetic foot

▪ CARSON GEHL ▪ Sep 20, 2019 @12:25 AM CDT

Title: Automatic detection of diabetic foot complications with infrared thermography by asymmetric analysis

Date: 9/19/19

Content by: Carson Gehl

Present: N/A

Goals: Research into competing designs to increase knowledge of topic

Content:

Takeaways:

- Improved foot segmentation from background by utilizing color images to guide segmentation
    - Method for segmentation described in citation [20]
- Improved comparison between left and right foot regardless of foot shape, size, position, etc. using nonrigid landmark-based registration B-splines
- Machine learning split into two main groups
    - Supervised - parameters learned during design stage based on data provided by the programmer
    - Unsupervised - program adapts itself to statistics of the data being presented and learns on the go. This is what we are looking for so that we can get a start here and then take more images in India to further train the program.
        - They used K-means clustering and expectation-maximization clustering. Could look further into these methods
        - There is a lot of statistical analysis for each general step of their program in the publication which could be of use (but I do not understand as of now)
        - Used MATLAB with additional toolbox PRtools V5
- IR camera was 80-90 cm from object
- Final thoughts on article: very very good information in this article, although I simply do not have the statistical background to understand large portions of it. This seems to be a very accurate but expensive model, and the imaging device itself was very large (which they noted). They also noted the inability to detect ulcers if a foot has already been amputated as well as the ability to detect ulcers if they are forming in the same area on both feet

Conclusions/action items:

Continue research - especially existing applications to use for machine learning techniques. May want to look in to citation 20 to see segmentation method.

3 Infrared Dermal Thermography on Diabetic Feet Soles to Predict Ulcerations: a Case Study

▪ CARSON GEHL ▪ Sep 22, 2019 @07:26 PM CDT

Title: Infrared Dermal Thermography on Diabetic Feet Soles to Predict Ulcerations: a Case Study

Date: 9/22/19

Content by: Carson Gehl

Present: N/A

Goals: Continue reading papers given to us by Kayla

Content:

This paper was very similar to the first couple papers in the scope and the methodology used:

1. Foot segmentation
    - Extract left and right foot from the background in the acquired thermal images
2. Feet Registration
    - Register the left and right foot based on the contours of the feet so that corresponding points on left and right foot can be compared
3. Abnormality Detection
    - Compare the pixel values of the left and right feet to determine whether there is risk of abnormality

They note the three different categories used to foot ulcerations

1. Dermal infrared (IR) thermometer (local measurement)
2. Liquid crystal thermography (LCT)
3. Traditional IR camera systems

Conclusions/action items:

I would like to find more about the methodology used for segmentation, registration, and detection. They go into some detail, but I think it would be more useful sitting and talking to someone who is more informed on the topic. I am curious to what add-ons are available for MATLAB or Python for machine learning features, and what others have used in the past.

2 Association Between Plantar Temperatures and Triaxial Stresses in Individuals With Diabetes

▪ CARSON GEHL ▪ Sep 22, 2019 @07:01 PM CDT

Title: Association Between Plantar Temperatures and Triaxial Stresses in Individuals With Diabetes

Date: 9/22/19

Content by: Carson Gehl

Present: N/A

Goals: Reading Kayla's papers

Content:

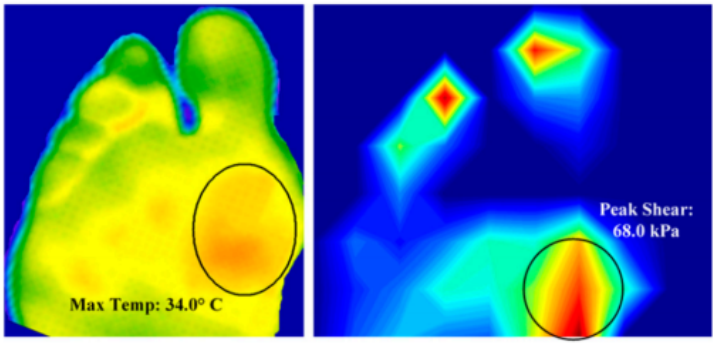


Figure 1—Resting plantar temperature (left panel) and plantar PS (right panel) profiles of a representative DN subject. Note the match between the sites of peak temperature and PS at the first metatarsal head.

This article more or less justified the means for detecting ulceration using temperature monitoring.

Conclusions/action items:

Continue reading papers

K Means Clustering

▪ CARSON GEHL ▪ Sep 22, 2019 @08:48 PM CDT

Title: K Means Clustering

Date: 9/22/19

Content by: Carson Gehl

Present: N/A

Goals: Look into K means clustering as a way of foot segmentation in AI program

Content:

https://www.datascience.com/blog/k-means-clustering

From some of the reading I have done, others have demonstrated using a method known as K means clustering to segment the feet as the first step of dealing with the images taken from the diabetic feet. It seems that there is a package available for Python that is made to perform K means clustering. Once we receive the camera/phone and can work with the images, I would like to try this out. I would also like to ask someone who is more familiar in the subject about this method, but it seems promising.

Conclusions/action items:

Receive images from Kayla and try K means clustering

9/16/2019 - Diabetic foot ulcer mobile detection system using smart phone thermal camera: a feasibility study

▪ JAN WODNICKI ▪ Sep 17, 2019 @04:06 PM CDT

Title: Research Notes: Diabetic foot ulcer mobile detection system using smart phone thermal camera: a feasibility study

Date: 9/16/2019

Content by: Jan

Present: Individual

Goals: Discover and analyze existing methods for detecting foot ulcers using a smart phone and thermal camera. Because this study is so similar to what the client has requested from us, I will try to focus on potential improvements in accuracy, efficiency, and cost that could be made.

Content:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5627424/

General Information

- The system uses a 2.2 degree Celsius temperature gradient to detect possible ulcers, they note that this threshold is supported in literature
- System implemented using Matlab (Desktop) / Matlab mobile (Android)
- Used Java to build an app with user-interface
- Used FLIR ONE mobile thermal camera which can detect up to 0.1 degrees Celsius changes and has a -20 to 120 degree Celsius detecting range
- Resolution of FLIR ONE Infrared Thermal Camera is 160x120

Data Collection

- Wet towel placed behind vertical plane of feet in order to separate the background from the foreground
- Patients sat and relaxed for 3 minutes to "maintain stable blood flow within their plantar feet"
- Simulated ulcers by placing heated coins near the surface of the foot

Image Segmentation

- Extracts objects from images
- First, feet were extracted from the image
- Second, possible ulcers were extracted from the foot temperature data
- Technique used to separate feet from background was Histogram shape thresholding, and was used to identify temperature ranges to separate data points into warm (feet) and cold (wet towel)
- "Otsu method picks a threshold by maximizing the between-region variance or minimizing the within-region variance. The total variance, which is the sum of the within-region variance and the between-region variance, is constant for different partitions."

Image Smoothing

- Borders clearing technique used to eliminate objects "attached" to the perimeter of the foot
- Segments' smoothing eroded the edge of the image with a diamond-structuring element
- The binary aspect of the image segmentation left "holes" in the feet which were filled

Image Analysis

- Again, the Otsu thresholding technique was used to detect possible ulcers within the defined foot region
- Additionally, they used the point-to-point difference technique which measures the change in temperature from one pixel to the next

Additional / Important Notes

- When using thresholding, it's important to separate mean values of the left foot and right foot
- Hot objects in the backgrounding can also create inaccurate results

Possible Improvements / Notable Shortcomings

- Only four images of feet were used to test the system, while this may be able to test the accuracy of identifying temperature differences, it is also necessary to test how applicable and accurate this system is in identifying possible foot ulcers on patients in the field
- We could also include variables such as intensity of temperature difference, size, and location in order to more accurately predict ulcer development

Conclusions/action items:

- Determine whether a more multidimensional analysis of temperature data is feasible and likely to improve accuracy
- Investigate mentioned methods of image analysis as well as others that may provide more insight
- Brainstorm how to leverage more data (250 samples) in order to produce more accurate and applicable results

10/9/2019 - Automatic detection of diabetic foot complications...

▪ JAN WODNICKI ▪ Oct 09, 2019 @10:59 AM CDT

Title: Research Notes: Automatic detection of diabetic foot complications with infrared thermography by asymmetric analysis

Date: 10/9/2019

Content by: Jan

Present: Individual

Goals: Explore existing thermal imaging methods for detecting foot ulcers, in order to improve our own design.

Content:

Imaging Setup

- IR camera
- FLIR SC305
- Commercial digital RGB camera, Canon EOS 40D
- IR camera 860 away mm from object
- IR resolution 320 × 240 pixels
- Accuracy is +-2C, but **using thermal references reduced this to just +-0.25C**

Methodology

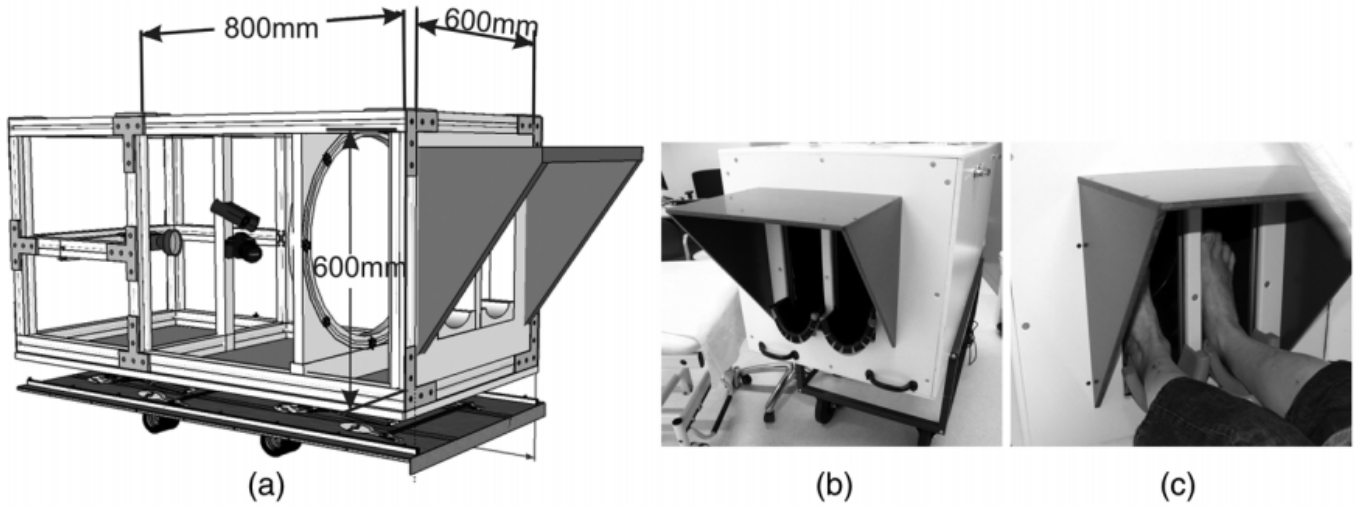


Fig. 2 The experimental setup for foot scanning: (a) the schematic of the experimental setup with two cameras installed, which are the thermal camera (upper) and the RGB camera (lower). (b) The appearance of the experimental set and (c) positioning of patients' feet during measurement.

- They use a box to create an isolated environment to measure feet for thermal information
- The camera is placed at a fixed distance from the feet
- First, they segment images to separate the feet
- Next, they aligned the RGB image to the thermal image
- Then, they analyzed the image by comparing the feet

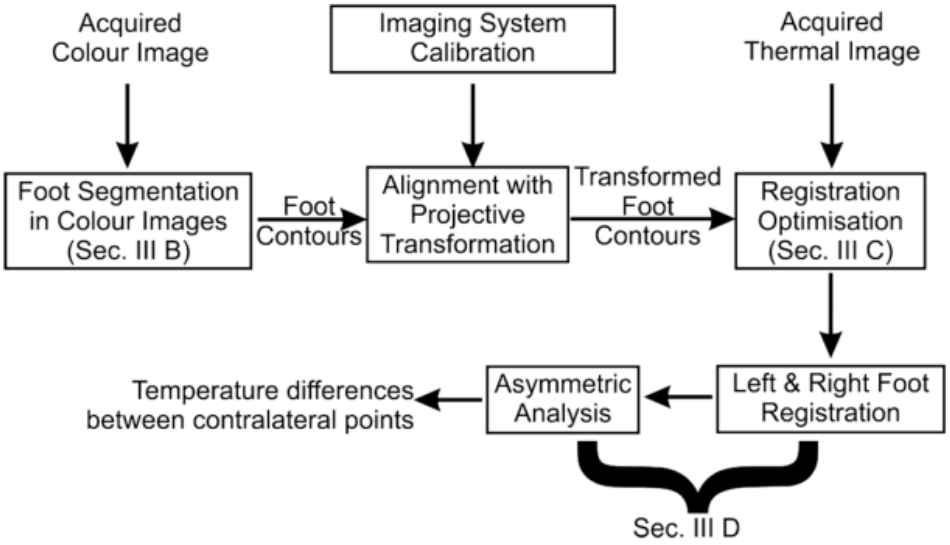


Fig. 3 Schematic flowchart of the proposed methodology for automatic detection of diabetic foot complications.

Conclusions/action items:

- Continue brainstorming and researching specific data segmentation and analysis methods
- Finalize plan for software development
- **Temperature accuracy can be significantly improved with thermal references**

9/17/2019 - Prof. Paul W. Brand On Leprosy, Diabetes, Wounds, and a Life of Service

▪ JAN WODNICKI ▪ Sep 17, 2019 @04:05 PM CDT

Title: Video Notes: Prof. Paul W. Brand On Leprosy, Diabetes, Wounds, and a Life of Service

Date: 9/17/2019

Content by: Jan

Present: Individual

Goals: Gain background knowledge on the subject of foot ulcers from diabetes, specifically in India.

Content:

https://www.youtube.com/watch?v=30piDE5iIVw

Background

- Prof. Paul Brand recalls his experience as a medical student in India where people with leprosy would beg in front of the hospital
- He was particularly disturbed by the attitude of medical providers, who considered the disease to be an untreatable curse
- It was the lack of pain that lead to the wounds and not the disease (introduction to neuropathy)
- The Indian doctors claimed patients would wake up to discover horrible wounds, when in fact it was rats the were nibbling and chewing away at people
- Patients acquired more wounds to their insensitive feet, because they limped in an opposite manner on the way to the Hospital, sparing the healthy foot

Physiology

- High Threshold Mechanoreceptor (HTM): nerve endings which produce pain in high stress / impact (normally 200 pounds per square inch)
- Poly-Modal Nociceptors (PMN): respond to mechanical stresses by severe pain, but at much lower forces
- PMN's respond once they've been activated by chemical products from inflammation or tissue damage

Thermal observations

- After running or walking for long distances, we all develop a "limp", meaning we redistribute the weight on our foot to minimize forces on already inflamed or hot areas of the foot
- Pain is required to regulate this limp, and without it can cause severe damage

Frequency and Intensity of Stress

- Reducing the number of steps a rat took from 10,000/day to 8,000/day eliminated ulceration by day 7 and created stronger foot pads in 6 weeks
- More important than the amount of stress, is the frequency of stress on the feet
- Comfy foot insoles are not as important as reducing walking time and distance (steps per day is more important)
- "Temperature is our best remaining index that a foot is about to break down
- Compare hot spot to side of heel (typical cold spot), if temperature differential between hot spot and cool spot is getting higher, they are walking too many steps

Conclusions/action items:

- It seems as if though the challenge in India is patient education and developing a convenient way to track areas of possible ulceration
- Brainstorm cost effective and convenient solutions to measuring foot temperatures
- Frequency is significantly more important than intensity of stress in the development of foot ulcers

9/17/2019 - Fulbright in India E17: My talk at Fulbright Midway Conference

▪ JAN WODNICKI ▪ Sep 17, 2019 @04:38 PM CDT

Title: Video notes: Fulbright in India E17: My talk at Fulbright Midway Conference: 'Smart Shoe'

Date: 9/17/2019

Content by: Jan

Present: Individual

Goals: Watch and take notes on client's talk for Fulbright in India. Gain additional background understanding of the problem.

Content:

https://www.youtube.com/watch?v=C-EA2DJcuhc&list=PLD95pGtO4j5zz7ERyHLHamfiq-2eQcNJ_&index=17

Background Information:

- 50-90% of rural Indian diabetics are undiagnosed
- Neuropathy (death of nerves) occurs after 10-15 years in up to 90% of patients
- 80% of lower limb amputations in India are the result of diabetic foot ulcers

Current Treatment:

- Inspection and tracking of neuropathy
- Inspection or prescription of proper footwear
- Education to check daily, avoid infection, offload areas of stress

Importance of Pain

- HTMs respond to high level of stress in healthy tissue
- PMNs responds to much lower thresholds of stress in unhealthy or inflamed tissue

Texas Hospital Experiment

- One group (n=58) received only standard education while the second group (n=69) received same education, skin temperature advice and was told to contact the nurse if a +4 degree Fahrenheit temperature difference developed (between L and R feet)
- 29.3% vs 8.5% ulceration rate (140 days) in the first and second group, respectively (significant)
- Of the 5 in the second group, 4 stopped measuring and one didn't respond: no one used temperature correctly

Proposed Solution

- Monitor temperature at home and then reduce daily activity / visit clinic if temperature goes beyond a certain threshold

Conclusions/action items:

- Meet with Kayla to discuss whether an both an at-home and clinic solution needs to be developed, varying in cost
- Can we use location of temperature differences to produce more accurate patient recommendations?
- Figure out how our team can develop something that's different than apps which have already been produced for this application

9/17/2019 - Pedometer/Activity Monitor Ideation

▪ JAN WODNICKI ▪ Sep 17, 2019 @05:00 PM CDT

Title: Pedometer/Activity Monitor Ideation

Date: 9/17/2019

Content by: Jan

Present: Individual

Goals: How can we send patients home with an inexpensive way of tracking activity?

Content:

Ideas

- Relatively inexpensive fitness trackers are on the market ($9 Amazon) ($5 Alibaba)
- Other temperature tracking apps do not include support for pedometer

Challenges

- Additional application development would be required
- Not sure if constant bluetooth connection is required to track activity
- Not sure how accurate these

Conclusions/action items: Find our whether an app supported pedometer accessory would be useful / feasible at a price point of around $5.

9/17/2019 - Low Cost Mobile Thermal Cameras

▪ JAN WODNICKI ▪ Sep 17, 2019 @05:54 PM CDT

Title: Low Cost Mobile Thermal Cameras

Date: 9/17/2019

Content by: Jan

Present: Individual

Goals: Shop around for phone-based thermal cameras with price points less than FLIR.

Content:

Mini Thermal Imager (USB-C) Alibaba

- $1-75 / unit based on order quantity
- 32 x 32 resolution compared to 80 x 60 FLIR ONE PRO LT and 160 x 120 FLIR ONE PRO
- Probably around $50-60 for a small order (guess)

Dali Thermal Imaging FPA Detector 160*120 25um Core sensor

Conclusions/action items: Start chatting with manufacturers to get a sample, and find out what price for small to large order would be.

9/17/2019 - Ideas after Client Meeting #1

▪ JAN WODNICKI ▪ Sep 17, 2019 @09:02 PM CDT

Title: Ideas after Client Meeting #1

Date: 9/17/2019

Content by: Jan

Present: Individual

Goals: Summarize / wrap up ideas that were shared during our first client meeting as well as record some of my own initial ideas / thoughts.

Content:

Important concepts to keep in mind

- Collecting data is significantly easier than in the US and will be continued next summer
- The Veterans Hospital could be a good learning opportunity as there are long lines and ordering by need based on a quick analysis could be very useful
- <$5 for a take home device is a pretty big constraint, but we shouldn't focus on it too much for now
- Pressure is not as important because it doesn't tell us when to treat, heat tells us when there is a problem
- Only Android is necessary
- There can be one design analysis for the physical product and another for the application / data analysis
- Implementation seems to be the focus: how can we get this in the hands of Indian patients and how can we make it useful?
- Siren socks might be an interesting partner if they get back to Kayla at some point...
- We should reach out to the colleague Kayla mentioned to see if we can get on the ISB so we have permission to work with patients at the Veteran's hospital
- We can also look into reaching out to the lab on campus that just bought some awesome thermal camera

What could be worked on

- Extracting data from the FLIR camera, this can be done with the SDK
- Improving data analysis with more variables
- Methodology for collecting data samples, Kayla mentioned a tripod rig that could slide forward and was used to standardize images of feet
- Though not as important for now, analyzing images from thermochromic materials may be a low-cost solution

Individual thoughts

- Because we don't have a ton of data, enhancing the accuracy of a detection system with physiological and historical-based emphases on variables like location and size could be a viable and meaningful improvement to manual analysis
- Could we build our own low-cost thermal phone sensor?
- What do I need to start learning how to make an Android app?
- It looks like FLIR has an APK so more advanced data analysis should be achieveable

Conclusions/action items:

- Start learning Android Studio, see if extracting data from FLIR is viable
- Talk to someone with app architecture experience to see what the best way to connect FLIR and do analysis
- Prioritize focus on a particular aspect of the project / create project development order

9/22/2019 - Initial Design Sketches

▪ JAN WODNICKI ▪ Sep 22, 2019 @09:41 PM CDT

Title: Initial Design Sketches

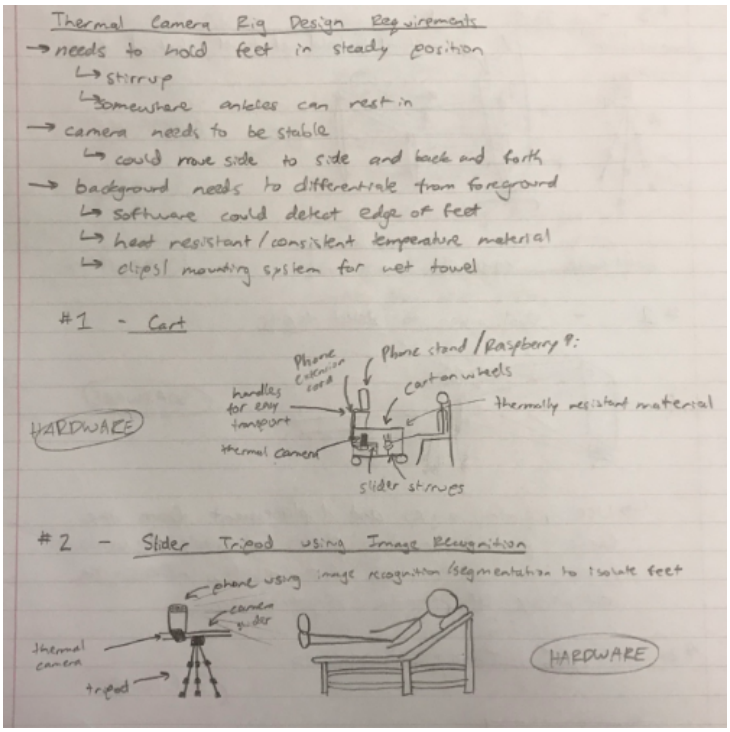
Date: 9/22/2019

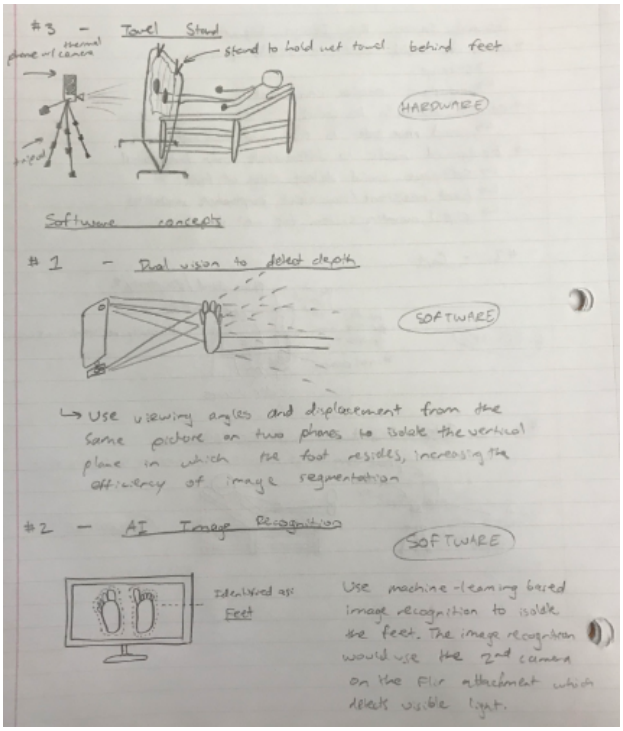
Content by: Jan

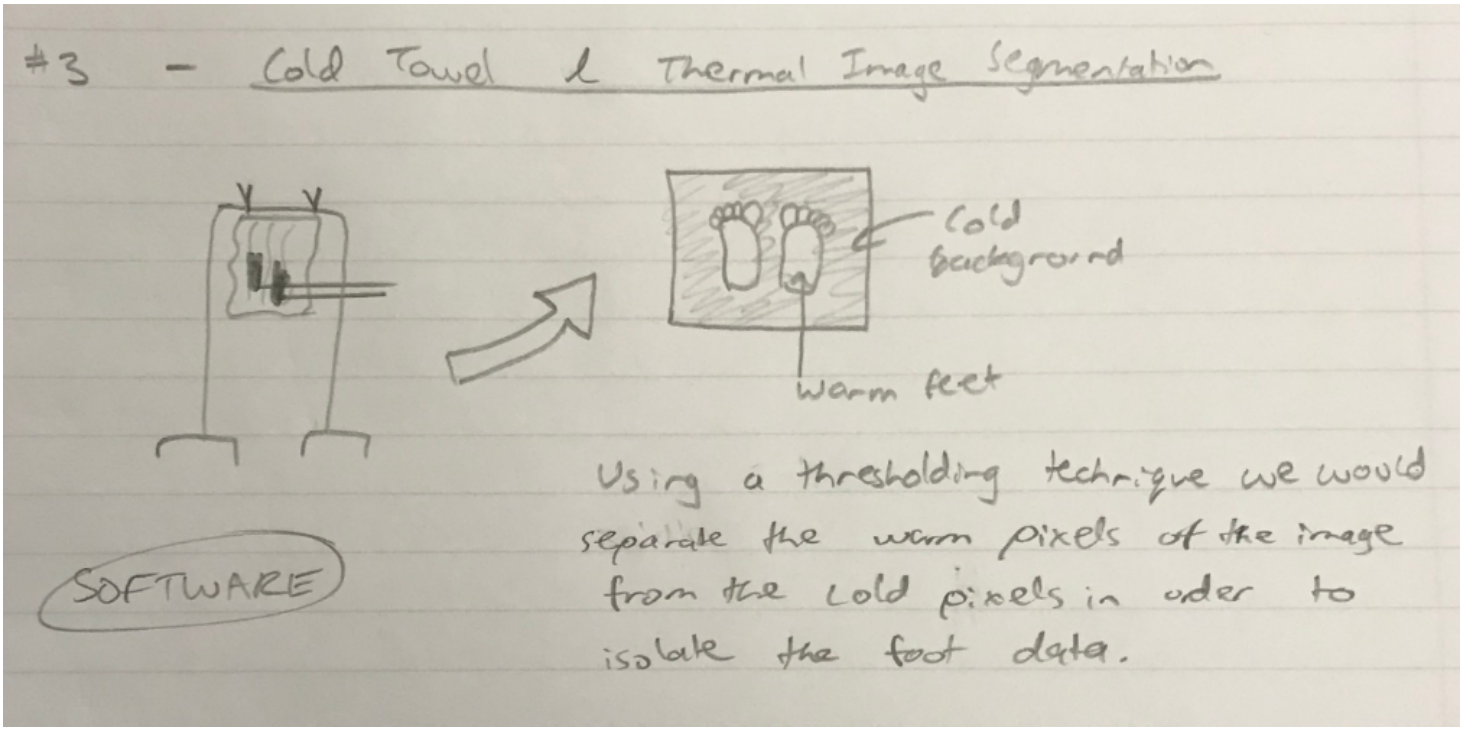
Present: Carson, Kelson, Jarett, Jan

Goals: Sketch initial design concepts for Friday's design matrix deadline.

Content:







Conclusions/action items: We need to continue ideating and revising our ideas and model the best ideas in CAD.

10/2/2019 - Design Sketches for Prelim Presentation

▪ JAN WODNICKI ▪ Oct 09, 2019 @11:07 AM CDT

Title: Refining Design Sketches for Preliminary Presentation

Date: 10/2/2019

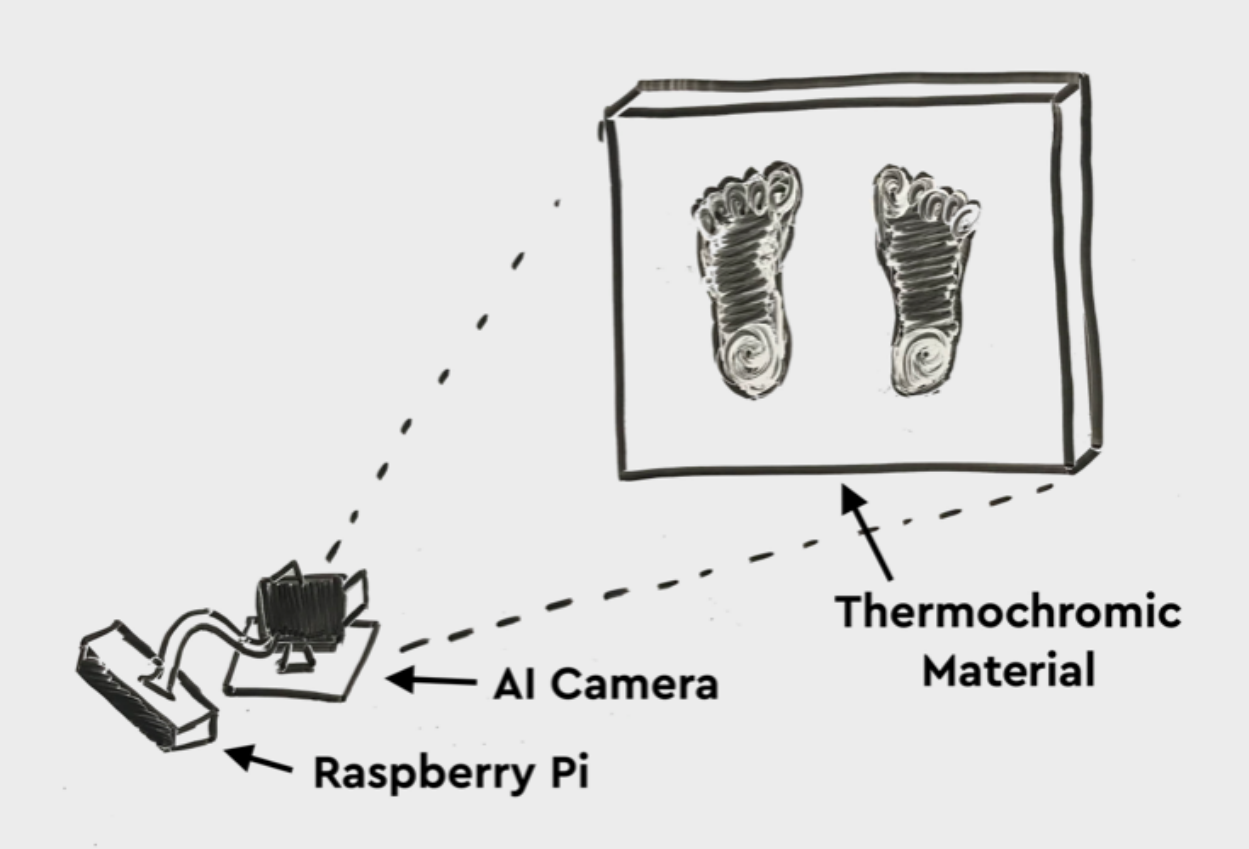
Content by: Jan

Present: Jan

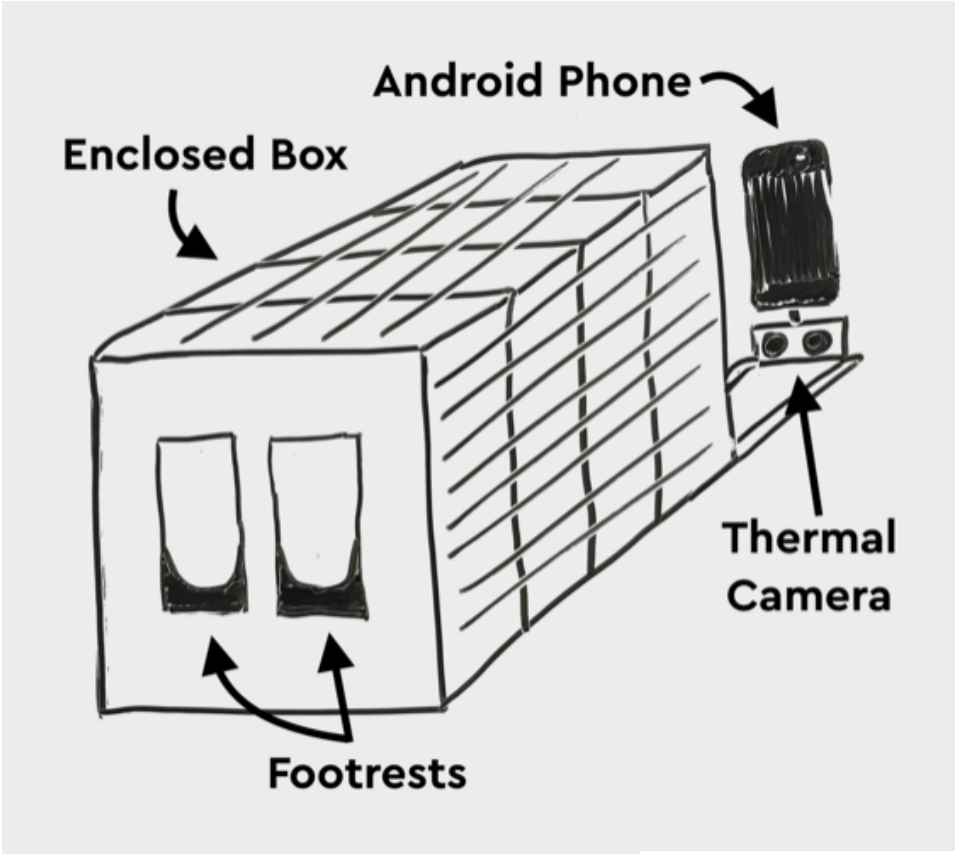
Goals: Refine the sketches of our design concepts that will appear on preliminary presentation and design matrix

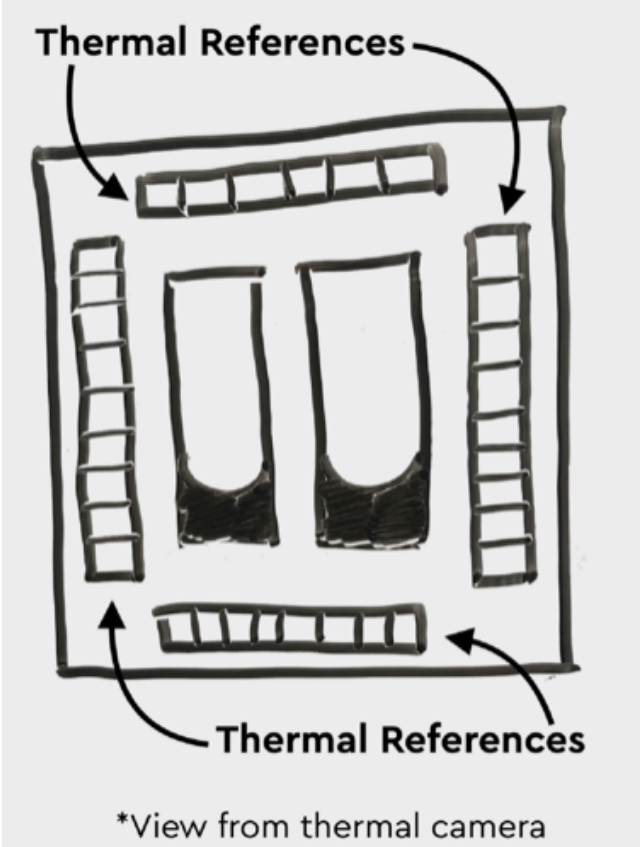
Content:

Design 1: Thermochromic Material

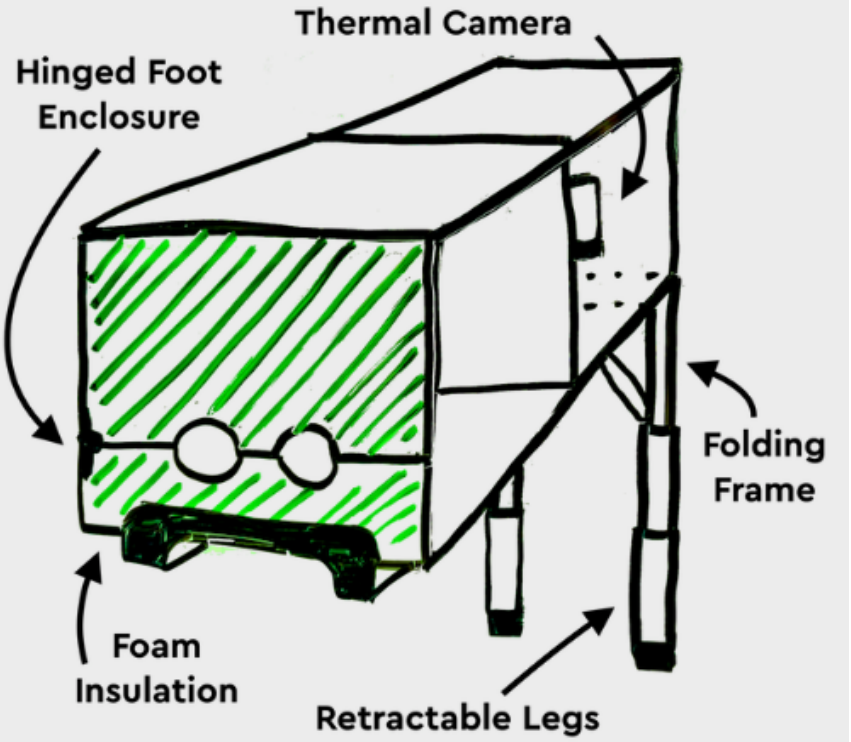


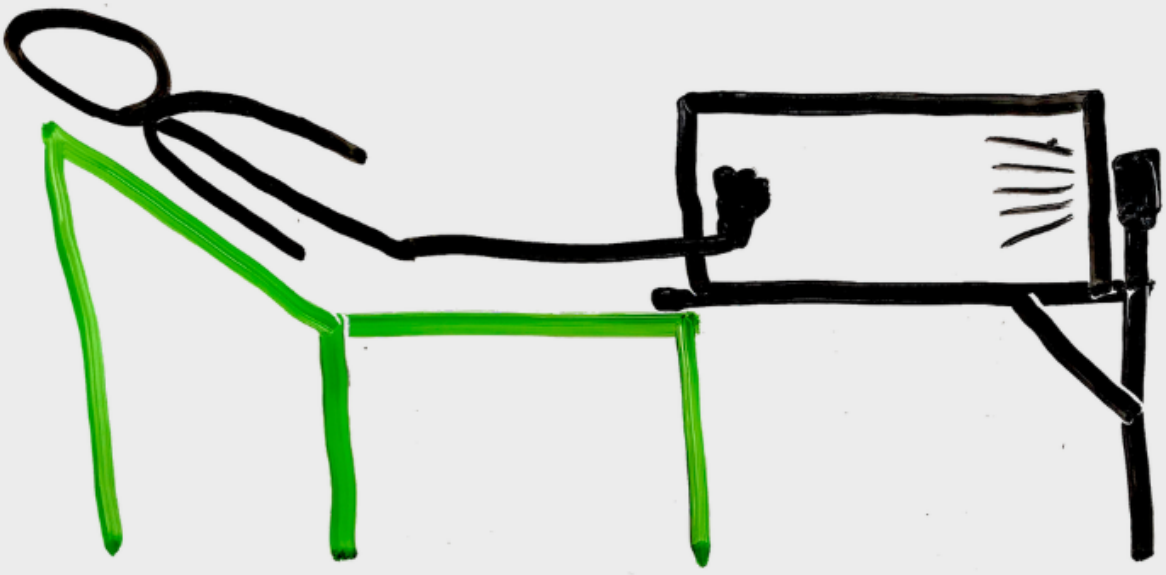
Design 2: Heat Strip Box



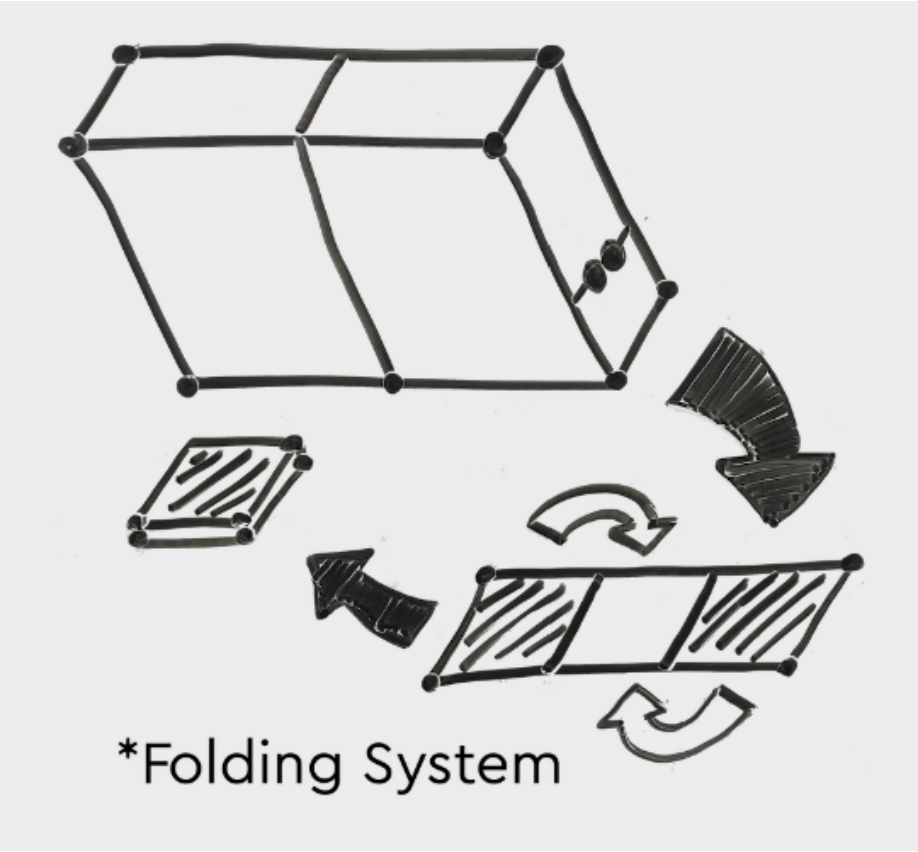


Design 3: Insulated Folding Studio


Thermal Camera
Hinged Foot Enclosure
Folding Frame
Foam Insulation
Retractable Legs



*Side view



Conclusions/action items: Finalize preliminary presentation and design matrix.

Thermal Imaging Foot Ulcer

▪ KELSON RAUSER ▪ Oct 09, 2019 @09:29 AM CDT

Title: Use of Thermal Imaging in Ulcer Detection

Date: 9/20

Content by: Kelson

Content:

Behzad Aliahmad et al. Is Thermal Imaging a Useful Predictor of the Healing Status of Diabetes-Related Foot Ulcers? A Pilot Study, Journal of Diabetes Science and Technology (2018).

Diabetic Related Foot Ulcer present in 4-10% of diabetic patients worldwide.

Costs exceed 13 billion per year.

2.2 degree C difference between two areas of the feet has been determined as a sign of skin circulation issues.

Study demonstrated that thermal imaging is viable for early stage ulcer detection.

Conclusions/action items:

Provides basis for our project. Our objective is to make a system allowing for easy capture of images.

Biometric Sensor Socks

▪ KELSON RAUSER ▪ Oct 09, 2019 @09:37 AM CDT

Title: Siren Socks

Date: 9/18

Content by: Kelson

Content:

https://siren.care/

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.

Siren Socks

- Socks equipped with biometric sensors measuring pressure and temperature on various areas of each foot

- Tracks steps and will give warning when sensors detect an area of the foot that may be prone to ulceration

Problems:

Project targets Indian population that may not have adequate footwear

Not viable for our target audience

Conclusions/action items:

Not a viable product for use in Indian population. Does not solve the need established in our PDS.

Suitcase Box

▪ KELSON RAUSER ▪ Oct 09, 2019 @09:32 AM CDT

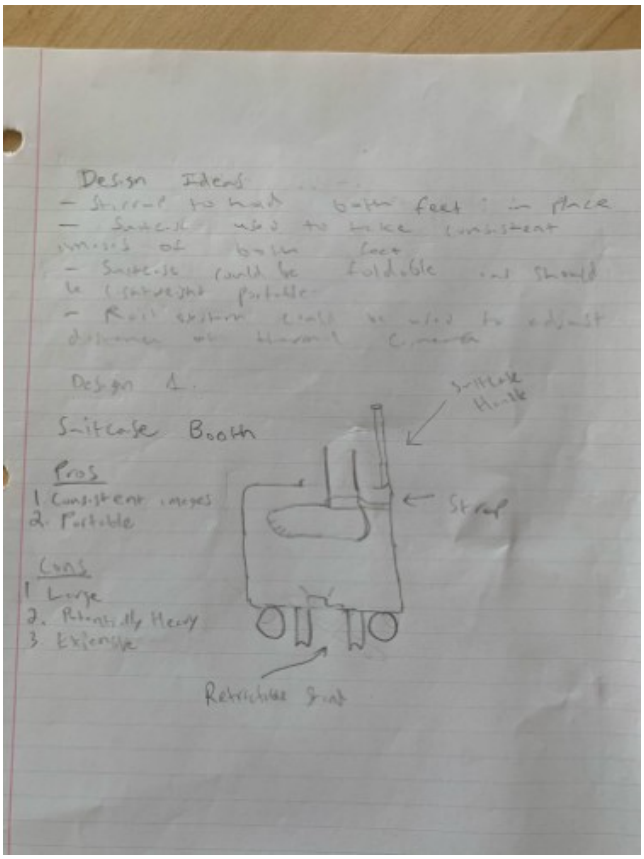
▪ KELSON RAUSER ▪ Oct 09, 2019 @09:34 AM CDT

Title: Suitcase Box

Date: 9/24

Content by: Kelson

Content:



Conclusions/action items:

Idea is likely not viable to its large size. It is not foldable. The camera distance cannot be adjusted. Other designs should be explored.

2014/11/03-Entry guidelines

▪ John Puccinelli ▪ Sep 05, 2016 @01:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

▪ John Puccinelli ▪ Nov 03, 2014 @03:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: