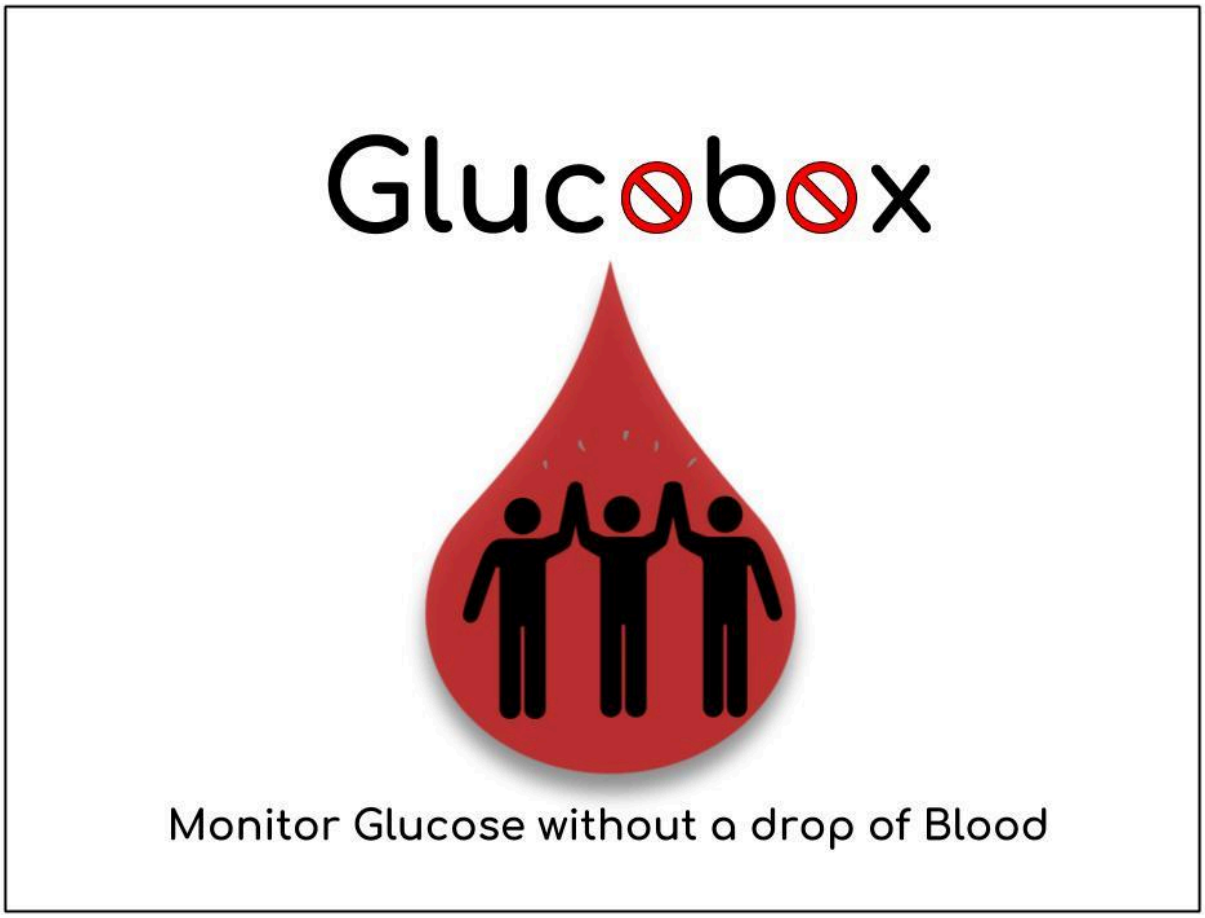
eCYBERMISSION

“A Cost-Effective non-invasive blood glucose monitor using Near InfraRed spectroscopic sensors”

Stumptown Glucobats, 2018-19 Season



According to www.diabetes.org, nearly ten percent of Americans who are diabetic invasively collect blood samples multiple times daily. We have built a non-invasive artificial intelligence based solution using near-infrared spectroscopic sensors to predict blood glucose levels without a drop of blood.

We are affiliated with

http://www.stem4girls.org/roborink/

Special thanks to our team advisor and to our parents
for their support throughout the season

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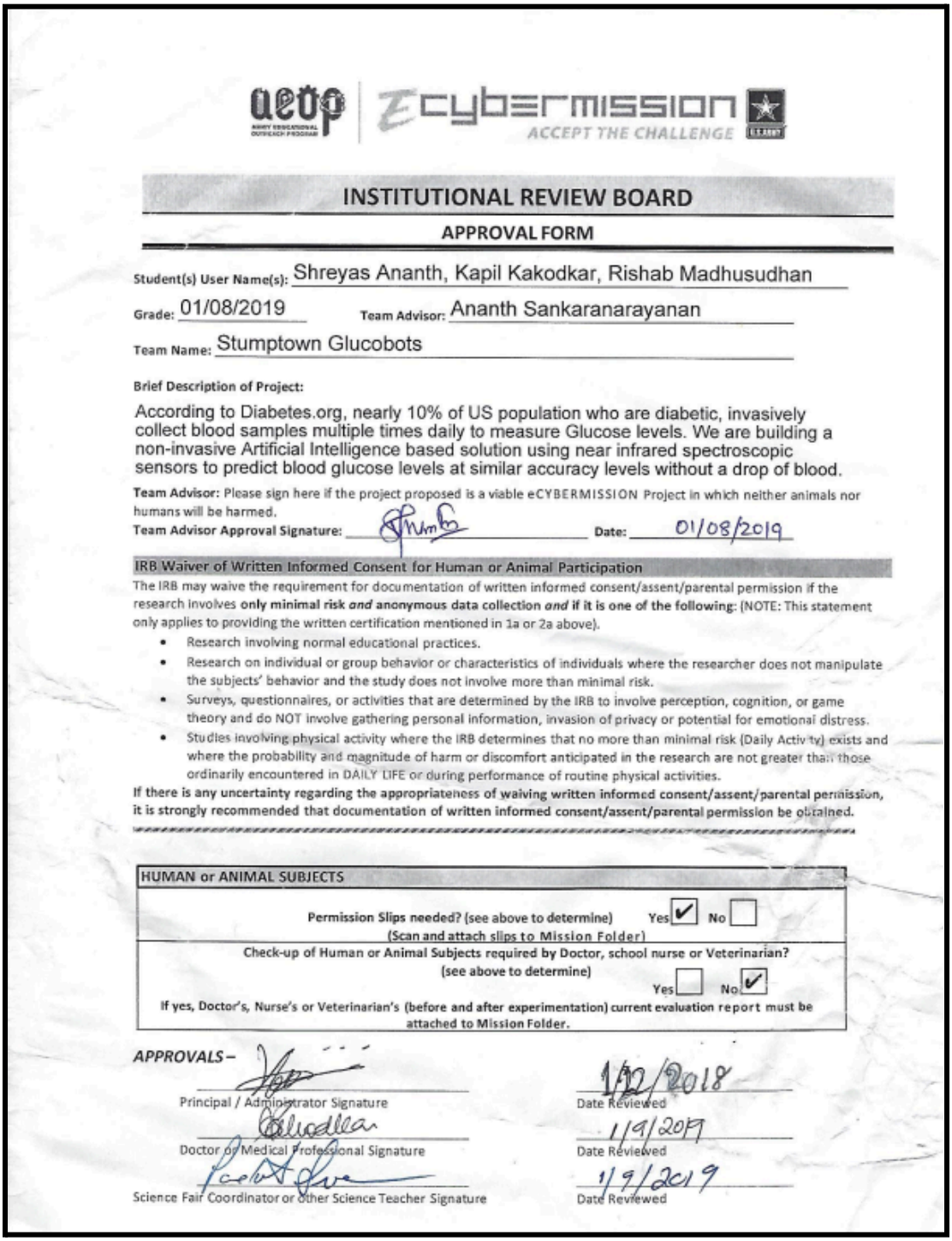
Abstract

According to *diabetes.org*, 193,000 American children under 20 have some form of diabetes. We noticed many patients who had experienced distress caused by this issue, whether by experiencing it as a trained medical professional or personally knowing a diabetic. According to the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), diabetes is defined as any instance in which the hormone insulin, generally secreted from the pancreas, is not produced in sufficient quantities. Since insulin is the main factor in the movement of glucose to the cells, a lack of it results in blood sugar levels in cells being abnormally low. This further results in weak cells, and high amounts of glucose in your blood, a catastrophic issue that can result in fatigue, fainting, vomiting or even hospitalization.

Most commercially-sold solutions to the issue of diabetes are invasive, meaning they draw blood to specifically interact with an enzyme-coded strip, allowing machines to calculate the amount of blood glucose in the blood samples. Drawing blood from minors with frequent samplings often result in pain, soreness, and irritation, which is amplified by a child's lower pain tolerance. The few present solutions out there that are non-invasive, meaning they do not require blood drawings and instead utilize sensors, are mostly not commercially sold nor FDA-approved. Those that do pass the previous requisites usually cost upwards of a hundred, sometimes even two hundred dollars. These absurd prices aren't feasible for most parents who would question the ability of these devices compared to the invasive ones. That is the main reason why we set out to create a device that was cost-effective, yet yielded very similar results to invasive solutions.

Resources

IRB Form



aeop | eCYBERMISSION
ACCEPT THE CHALLENGE

INSTITUTIONAL REVIEW BOARD

APPROVAL FORM

Student(s) User Name(s): Shreyas Ananth, Kapil Kakodkar, Rishab Madhusudhan

Grade: 01/08/2019 **Team Advisor:** Ananth Sankaranarayanan

Team Name: Stumptown Glucobots

Brief Description of Project:

According to Diabetes.org, nearly 10% of US population who are diabetic, invasively collect blood samples multiple times daily to measure Glucose levels. We are building a non-invasive Artificial Intelligence based solution using near infrared spectroscopic sensors to predict blood glucose levels at similar accuracy levels without a drop of blood.

Team Advisor: Please sign here if the project proposed is a viable eCYBERMISSION Project in which neither animals nor humans will be harmed.

Team Advisor Approval Signature: _____ **Date:** 01/08/2019

IRB Waiver of Written Informed Consent for Human or Animal Participation

The IRB may waive the requirement for documentation of written informed consent/assent/parental permission if the research involves **only minimal risk *and* anonymous data collection *and* if it is one of the following:** (NOTE: This statement only applies to providing the written certification mentioned in 1a or 2a above).

- Research involving normal educational practices.
- Research on individual or group behavior or characteristics of individuals where the researcher does not manipulate the subjects' behavior and the study does not involve more than minimal risk.
- Surveys, questionnaires, or activities that are determined by the IRB to involve perception, cognition, or game theory and do NOT involve gathering personal information, invasion of privacy or potential for emotional distress.
- Studies involving physical activity where the IRB determines that no more than minimal risk (Daily Activity) exists and where the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in DAILY LIFE or during performance of routine physical activities.

If there is any uncertainty regarding the appropriateness of waiving written informed consent/assent/parental permission, it is strongly recommended that documentation of written informed consent/assent/parental permission be obtained.

HUMAN or ANIMAL SUBJECTS

Permission Slips needed? (see above to determine) Yes ☑ No ☐
(Scan and attach slips to Mission Folder)

Check-up of Human or Animal Subjects required by Doctor, school nurse or Veterinarian? (see above to determine) Yes ☐ No ☑

If yes, Doctor's, Nurse's or Veterinarian's (before and after experimentation) current evaluation report must be attached to Mission Folder.

APPROVALS –

Principal / Administrator Signature — Date Reviewed 1/12/2018

Doctor or Medical Professional Signature — Date Reviewed 1/9/2019

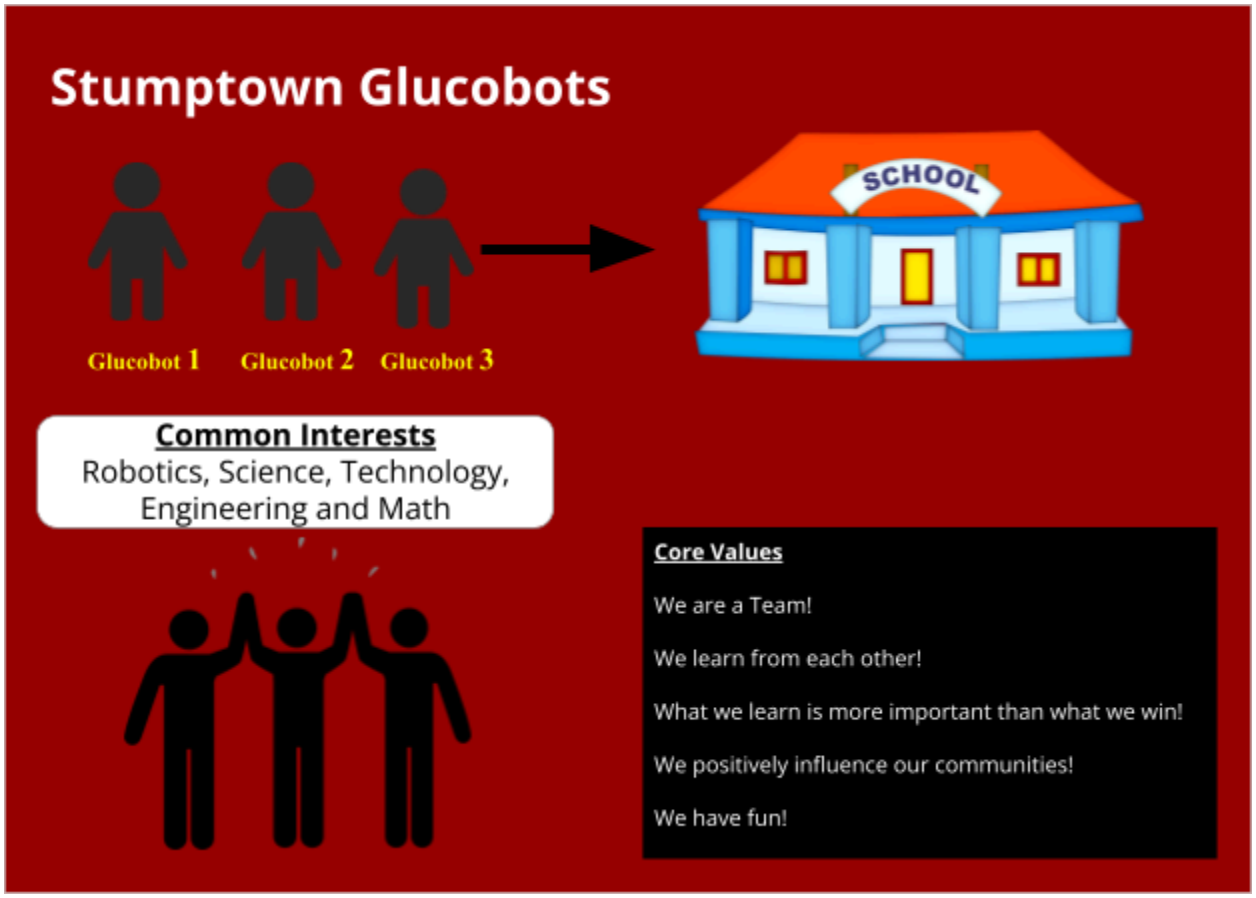
Science Fair Coordinator or other Science Teacher Signature — Date Reviewed 1/9/2019

Team Collaboration

How was your team formed? Was your team assigned or did you choose to work with each other?:

Team Formation

We are the Stumptown Glucobots. One of our team members' sister participated in eCYBERMISSION last year. Our team advisor introduced eCYBERMISSION as part of RoboRink, a non-profit based in Portland, Oregon that one of us is part of. We are a three-member team and we all go to the same middle school in Portland. We also have several common interests such as science, technology, robotics, and programming. Two of us have been together since kindergarten and have participated in FLL robotics programs for the past 5 years. We added the third glucobot to our team to form the "Stumptown Glucobots" to participate in the eCYBERMISSION challenge this season. As the three of us have known each other and fortunate to be attending the same middle school, we really work well with each other while at school as well as outside of school on weekends an. We adopted and practiced several core values, some of them derived from FLL. We weren't assigned to be a team, we just chose to be one because of our common interests.



Provide a detailed description of each team member's responsibilities and jobs during your work on the Mission Folder:

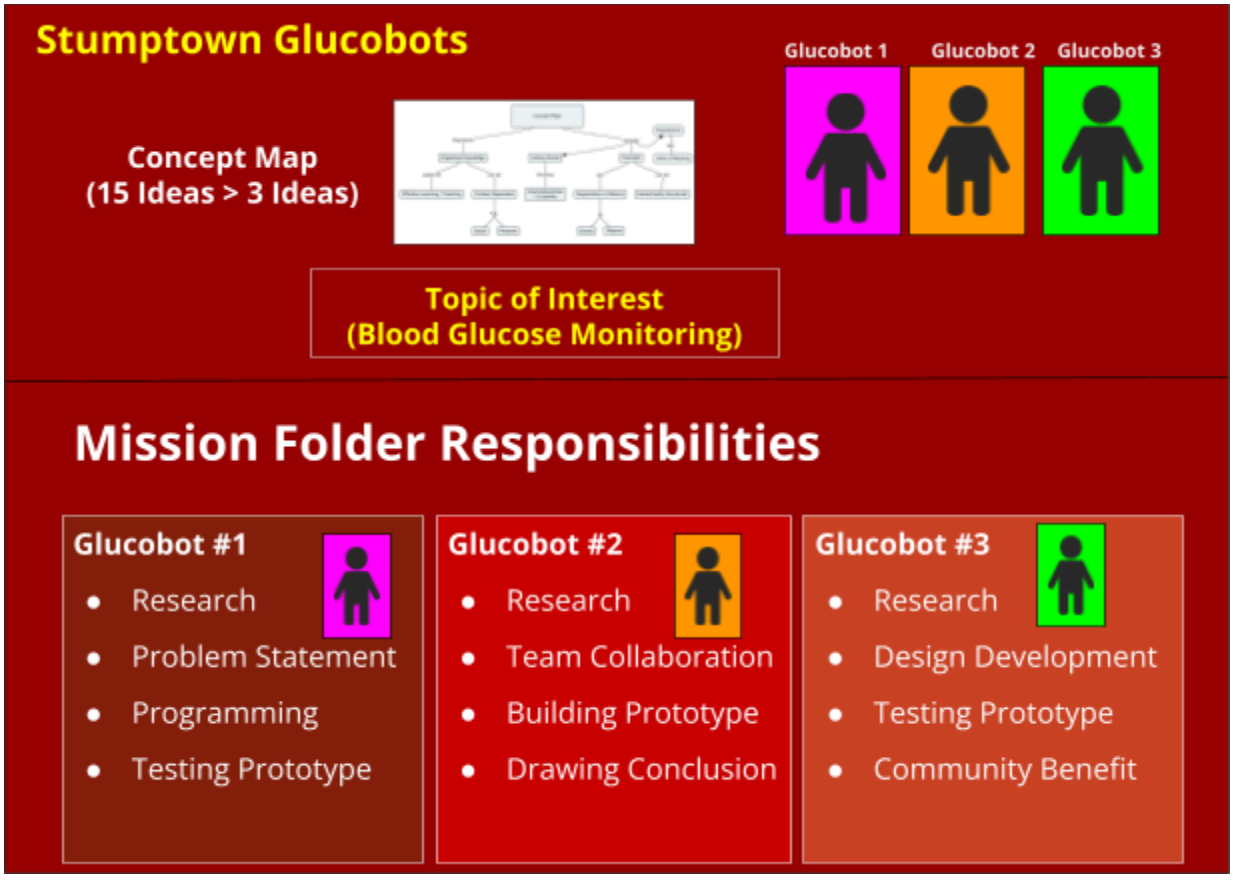
Roles & Responsibilities

When we began this season, all three of us researched in fifteen different areas and identified the top three areas that have the maximum benefits to our communities worldwide. Every meeting, each of us presented two research areas to the rest of the team. Once the idea was presented, we all provided one positive and critique feedback. Based on various factors, such as the magnitude of the problem, impact on the community, cost, and accuracy of existing solutions, we narrowed down to top three ideas to further research and identify one problem statement. We held each other accountable for completing our respective sections in the mission folder, while at the same time we reviewed each other's work and provided feedback. We also helped each other when any one of us were stuck. At the end of each meeting, we followed the Rose, Bud, Thorn analogy to discuss what we accomplished, homework for the next meeting, and areas for improvement. We split up the mission folder responsibilities among the three of us as follows:

Glucobot #1: Research, Problem Statement, Programming, Testing Prototype

Glucobot #2: Research, Team Collaboration, Building Prototype, Drawing Conclusion

Glucobot #3: Research, Design Development, Testing Prototype, Community Benefit

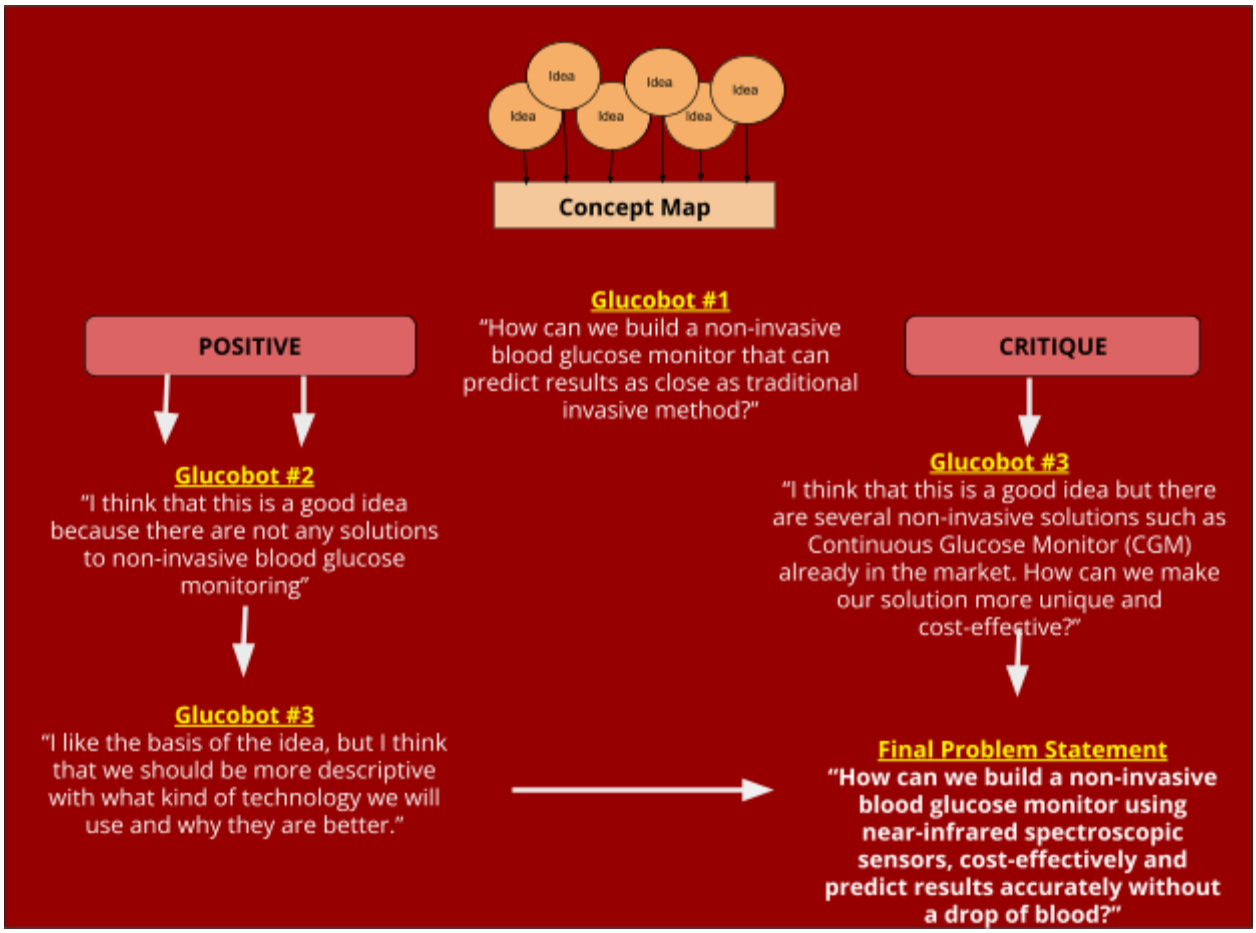


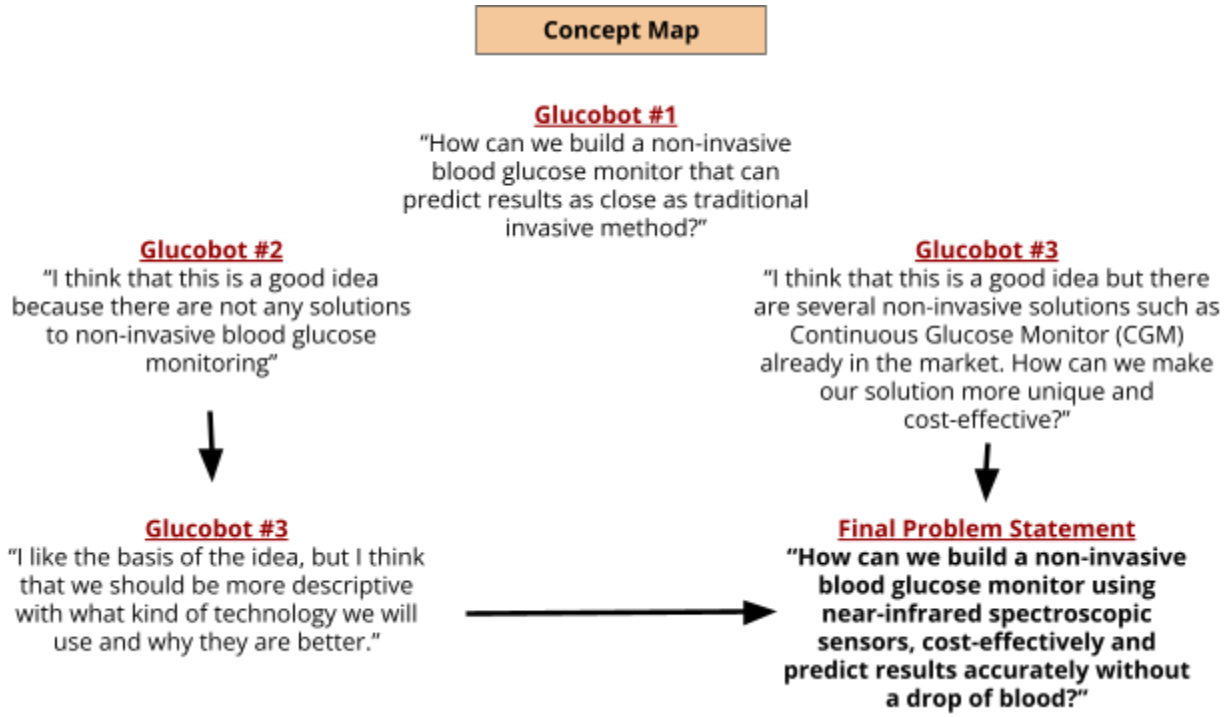
Did your team face any problems working together? If so, how did you solve them? If not, why do you think you were able to work together so well?:

Operating Model

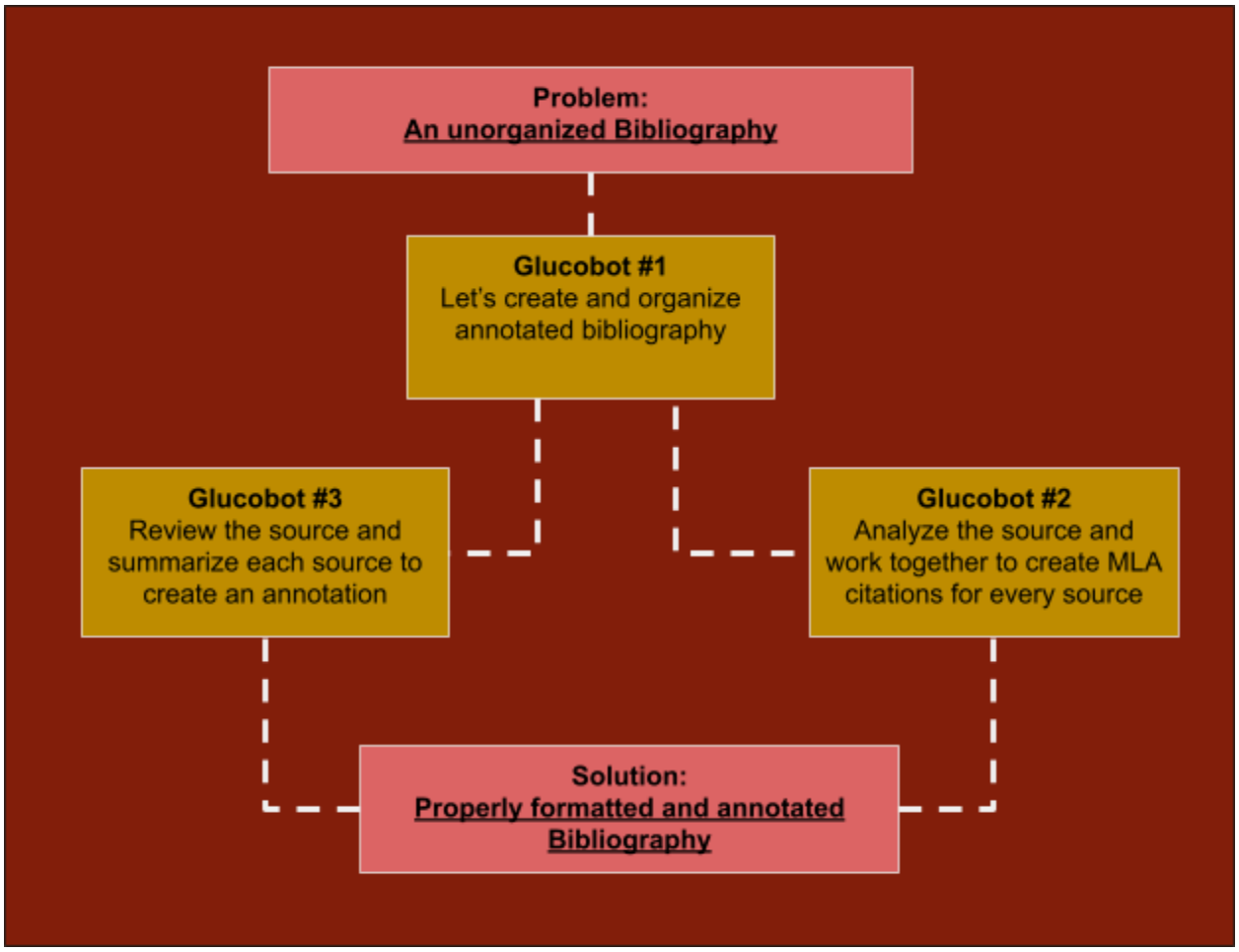
When we formed the team, we originally faced some challenges in keeping track of our progress and updating each other with our research. We adopted a Google team shared drive to keep track of each other's work and stay organized throughout the season. By constructively critiquing each other's ideas, we were able to work together well as one team to achieve our goals.

We shared our research work with each other between our meetings and its benefits to the community. We would collect as many resources as possible and we would decide if that source was usable. Most of the time we would scrap it for two main reasons. One, because the source was unreliable and two was because it was not something that helped the community.





While each of us had specific focus areas for the mission folder mapped to our areas of interest, we learned from each other based on our research work and challenged each other to perform at our very best. For example, for every source that we used in our research, we had to follow the MLA format for the reference section in the mission folder. Glucobot #1 took the responsibility of holding all of us accountable for following the MLA standard, so overall as a team we met all our objectives.



What were some possible advantages to working together as a team on this project? How would working as individuals have made this project more difficult?:

Importance of Teamwork

Our coach taught us, “Teamwork is the ability to work together toward a common vision”. We observed several advantages of working together as a team. As a team, we were able to learn a lot more new topics than as individuals. We shared what we learned with each other in team meetings, and while each of us had specific roles and responsibilities, we also helped each other when we were not able to make progress. Working as individuals, each of us would have had to do at least three times more work in conducting research, building and testing our prototype, meeting with experts to gather feedback and in completing mission folder requirements.

Our teamwork was very effective in many ways. We gave each other a lot of feedback, learned from each other, finished all the work by the due dates we set for ourselves and had fun. For example, our brainstorming process involved the use of a whiteboard to produce concept maps and write ideas that we thought affected our community. We all split the fifteen total relevant ideas and did a page long research segment on each topic. At our next meeting, we went over what we learned from the topic and any feedback or related queries we had with the topic. We used the provided resources to develop team-building skills which we used to conduct research, solve arguments and make important decisions. We also worked together to edit and review the others' work which provided a more polished final product.

After working out the details of our problem statement and coming up with a rough idea for our solution, we decided to split up the work. Although our research and designing were handled individually, we worked as a team to assist each other throughout the way, for example, taking on someone's work with them if they were stuck in an area which was not their core expertise.

Plan

Timeline

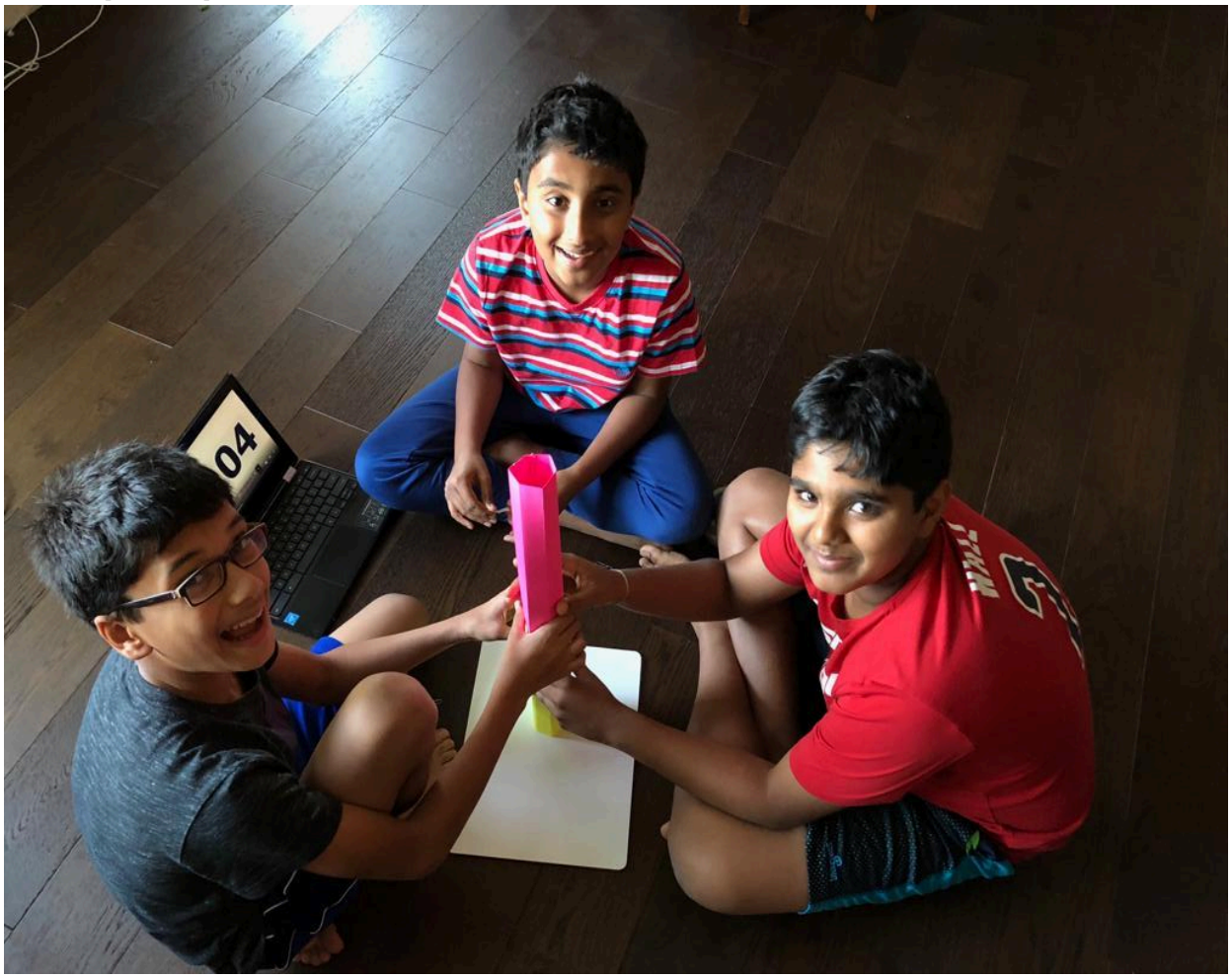
- Week 1: Team Kick-Off
- Week 2: Create a Concept Map, watch the Three videos at Ecybermission.com
- Week 3: Select A Topic, Choose A Community, and found a problem
- Week 4: Research and Expert Meeting and Interviews
- Week 5: Criteria and Constraints
- Week 6: Research The Prototype
- Week 7: Plan Prototype
- Week 8-End: Prototype/Mission Folder and Data Collection and Conclusion

Meeting Logs

w	Goal:	Accomplishment:
9/8	Team Kick off	Generated more than 15 Ideas!
9/16	Create a ConceptMap, Watch 3 videos and do the worksheets for the videos	Went down to 9 ideas
9/22	Select a Topic	We narrowed down to top 3: Blood glucose meter privacy filter and weapon surveillance
9/30	Find a Problem	Still Researching
10/6	Select Our Community	Still Researching
10/13	Research	Selected Topic: Blood Glucose Meter
10/20	Expert Meeting + Interviews	Went in-depth on aspects of BGM
10/27	Criteria + Constraints	Went in-depth on experts, generated mail template, began Udemy courses on AI
11/3	Plan Prototypes	Started UDEMY Course
11/10	Every Week Until End: Prototypes	Criteria + Constraints
11/17	Prototypes	NO MEETING
11/21	EARLY REGISTRATION ENDS. LAST CHANCE TO RECEIVE FREE STEM KIT	NO MEETING
11/24	Prototypes + Mission Folder	Did Udemy
12/1	Prototypes + Mission Folder	Sent emails
12/9	Prototypes + Mission Folder	Got Course For PANDAS And Started It
12/15	Prototypes + Mission Folder	Setup Raspberry PI
/	Prototypes + Mission Folder	
12/29	LAST CHANCE TO FINALIZE TEAM	
1/5	Prototypes + Mission Folder	
1/12	Prototypes + Mission Folder	
1/19	Prototypes + Mission Folder	Prototype:Deadline
1/26	Prototypes + Mission Folder	
2/2	Prototypes + Mission Folder	
2/9	Prototypes + Mission Folder	
2/16	Prototypes + Mission Folder	
2/23	Prototypes + Mission Folder	
2/27	MISSION FOLDER SUBMISSION DEADLINE	
3/2	Prototypes + Mission Folder	

3/9	Prototypes + Mission Folder	
3/13	VIRTUAL JUDGING STARTS	
3/16	Prototypes + Mission Folder	
3/23	Prototypes + Mission Folder	
3/27	VIRTUAL JUDGING ENDS	
4/22	REGIONAL JUDGING STARTS	
4/25	REGIONAL JUDGING ENDS	
4/27		
Early May	STATE WINNERS, REGIONAL FINALISTS, AND NATIONAL FINALISTS ANNOUNCED	

Concept Map Creation



Expert Meeting (Mr. Jaspreet Jhoja)

http://ece.ubc.ca/~jaspreetj/

It is nice to meet you.

The project sounds very exciting. Unfortunately, I'll be on vacation until the second week of January 2019, and will be busy with masters' thesis work early next year.

However, I would be happy to meet the team and provide some comments and suggestions on the project. The publication was the result of my bachelor's thesis project that I no longer work on. So feel free to publish any findings that your team discovers.

A few comments on the project:
- I would advise to work with longer wavelengths in the near/mid-infrared region as they have better absorption ratio(refer to the attached image).
- The sensor (https://www.sparkfun.com/products/14351 [1]) may not work with longer wavelengths.
- In my opinion, it might be difficult for 6th graders to work with bodyfluids. Instead they can look into other applications of transmission spectroscopy such as studying water, soil and sedimentary contaminations.

Heres a link to a presentation that you and your team may find interesting:
https://www.slideshare.net/TechRentals/quality-measurements-using-nirmir-spectroscopy-a-rotten-apple-could-turn-your-product-into-a-lemon

I wish you and the team all the best, and kudos to your team for taking on a challenge.

Best Regards,
Jaspreet

Jaspreet Jhoja
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Jaspreet Jhoja
Graduate Student

MiNa Microsystems and Nanotechnology Group

jaspreetj@ece(dot)ubc(dot)ca

MiNa Profile

Summary

I am a graduate student working with Prof. Lukas Chrostowski in MiNa lab. My research interests include **"Stochastic prediction of manufacturing variations in PICs"** and developing **"Compact Tunable Delay Lines"** for applications such as Photonics based **LIDAR**.

Research Projects

Expert Meeting (Mr. Shashi Jain - 3D Printing Expert)

Engineering Design

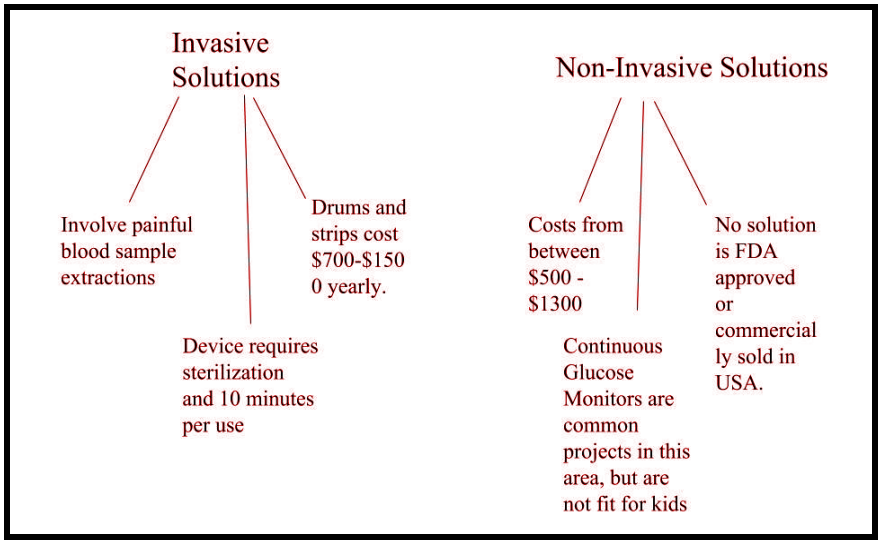
Problem Statement

What problem in your community will your team attempt to solve using the engineering design process?:

Problem

As the population of minors is growing in the United States, the amount of children with juvenile diabetes (type one) has also grown to a staggering 200,000 kids, which is a dramatic increase compared to past years. Diabetes is an illness that occurs when insulin, an essential hormone for providing glucose (the life energy to cells) is not produced in sufficient amounts by the pancreas. This usually results in fainting, vomiting, fatigue, and even death. Currently, the only FDA approved a way to measure blood glucose is to invasively prick your finger. This solution involves a syringe extracting blood from an area of designated skin, usually the fingertip, and coating this blood sample on a thin enzyme-coated strip and then inserting the strip into a glucose monitor. However, the large population of children finds themselves irritated and sore, and according to medical professionals, this results in very big tantrums and disruption in the clinic or hospital. The method also costs over $700 yearly, with strips and drums used by these devices is extremely and unnecessarily expensive. Convenience is also lacking in this solution with repeated washes and multiple uses being necessary for the safety of diabetics. Some proposed solutions such as LifeLeaf and Freedom Meditech are not FDA approved nor commercially distributed, and cannot make a difference. Our team noticed this issue through our relatives and friends in the medical field and set out to create a cost-effective, non-invasive, and accurate displayer of this data.

Problem Statement: What can be done to cost-effectively and reliably prevent diabetic children from having to prick their finger daily?



Research

Explain what you learned from your research. What did you find out about your problem that you didn't know before? What kinds of possible solutions already exist? Be sure to put this in your OWN words, do not just copy and paste information. Also, be sure to cite your sources:

However, the large population of children finds themselves irritated and sore, and according to medical professionals, this results in very big tantrums and disruption in the clinic or hospital. The method also costs upwards of $700 a year, with strips and drums used by these devices is extremely and unnecessarily expensive. Convenience is also lacking in this solution with repeated washes and multiple uses being necessary for the safety of people with this disease. Although there are attempts to address this problem of children with diabetes, the majority of non-invasive solutions either are pending an FDA approval, or not commercially sold.

Whilst massive tech companies such as Apple are taking a shot at incorporating a blood glucose detection feature into their devices, users are forced to buy unnecessary features to get a single function of the devices. This inflates the price to around four to five hundred dollars, a price not many are willing to pay simply for their children's comfort. Other proposed solutions such as LifeLeaf and Freedom Meditech are not FDA approved nor commercially distributed, and cannot make a difference. Our team noticed this issue through our relatives and friends in the medical field and set out to create a cost-effective, non-invasive, and accurate displayer of this data.

Key Learnings

We explored all different forms of diabetes mellitus to achieve a better understanding of the illness. Diabetes mellitus is defined as the lack of insulin procreated by the pancreas, a vital organ located near the stomach of the body. Not only does the pancreas provide insulin, a hormone vital to move glucose from the bloodstream to blood cells, but also glucagon, a hormone vital to the expedition of the aforementioned process. When pancreatic cells are dying usually either due to pancreatitis, another illness altogether, or just being overextended and not oxygenated enough, the pancreas as an organ produces significantly less insulin and glucagon. This leaves the blood glucose in the bloodstream or doesn't produce it altogether depending on the form of diabetes. Such forms of diabetes include prediabetes, type 1 diabetes, and type 2 diabetes.

Existing Solutions

After briefly exploring the world of diabetes, we looked into blood glucose itself, a compound essential to all life on this planet. Blood glucose is created in the human body by either being consumed through its presence in all foods or by saccharification, the breakdown of carbohydrates such as sucrose into the two compounds of fructose and glucose. Insulin in the normal human body expedites this process, but in those who are immunocompromised with type 1 diabetes, insulin isn't produced for this. We decided that this was a very significant problem, so we began courses in Python and Machine Learning to attempt to solve this non-invasively. We read up on different solutions, but all were either not FDA-Approved, or not cost-effective. We originally wanted to use other devices to generate an algorithm to capture this info, but we settled on creating a device ourselves after observing multiple documents detailing the use of NIR Sensors by the Sparkfun company. We read further on this, and as different components came into the picture, our project became clearer and clearer.

Our Solution

We brought these all together in our first GlucoBox design, that featured a box with the Raspberry Pi as the processor of the information produced by the NIR Sensor. The NIR spectroscopic sensor is capable of emitting six light rays and reflecting these back to producing a nanometer wavelength value. In order to interpret this into a value used commonly in the diabetic community (milligrams per deciliter) we had to collect real data and corroborate it. After collecting data from diabetics and non-diabetics alike, we produced an algorithm to help measure the accuracy of our device utilizing the knowledge which we had gathered from the Python tutorials. The information we have learned has been applied in every aspect of our project, from attempting to get a basic understanding of the research components in play to the programming and designing of our solution.

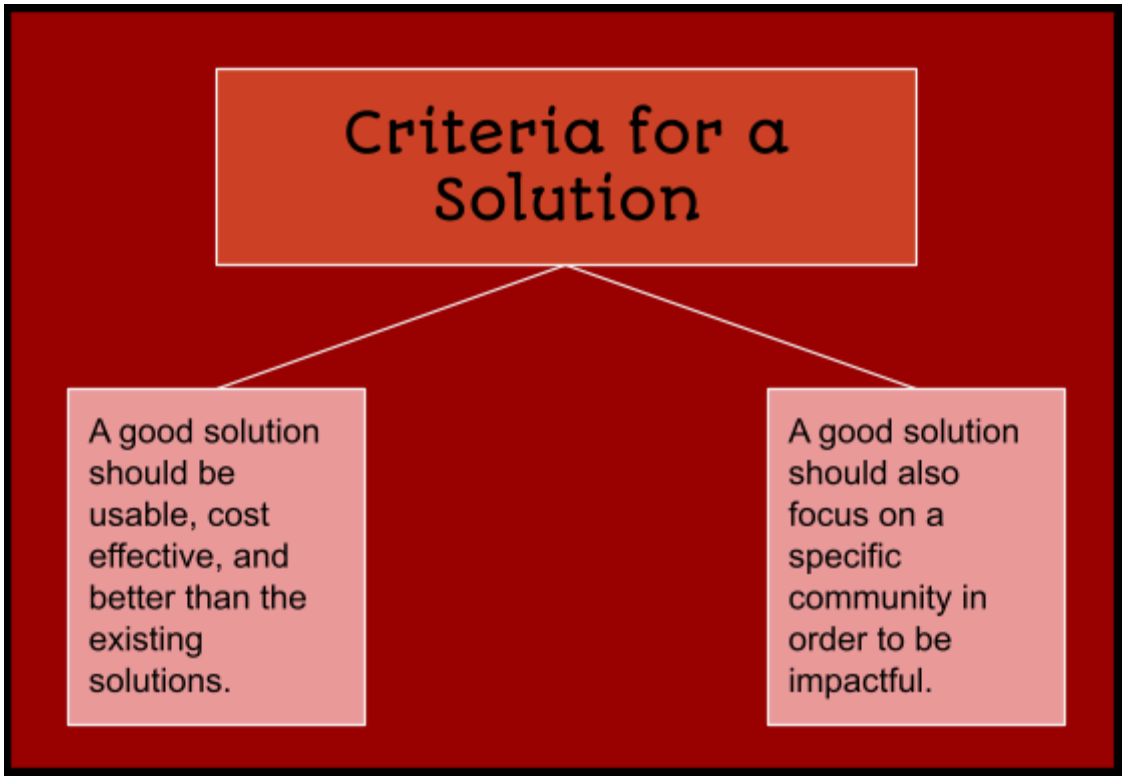
Experimental Design

What MUST be a part of your solution? This is called the criteria. What does your solution need to have in order to solve the problem? (NOTE: Don't discuss a specific solution here, just the characteristics of a good solution):

Statement

The terms for success include a few things:

- It should solve a problem effectively and efficiently. That should be completed because even if the solution solves a problem, it should not create any extra problems which reduce the effectiveness of the solution. It should also use as little parts as possible because if it is too big, it might be hard to use. If it is too expensive, nobody will bother to buy it.
- The solution should focus on solving a problem in a specific community. This is necessary because a solution must impact a demographic or community in order to be powerful and to make a difference.



Constraints

What limits are there on your solution? These are called constraints. Does it need to be a certain size? A certain weight? Is the cost a factor? Write down all of the limits on your solution:

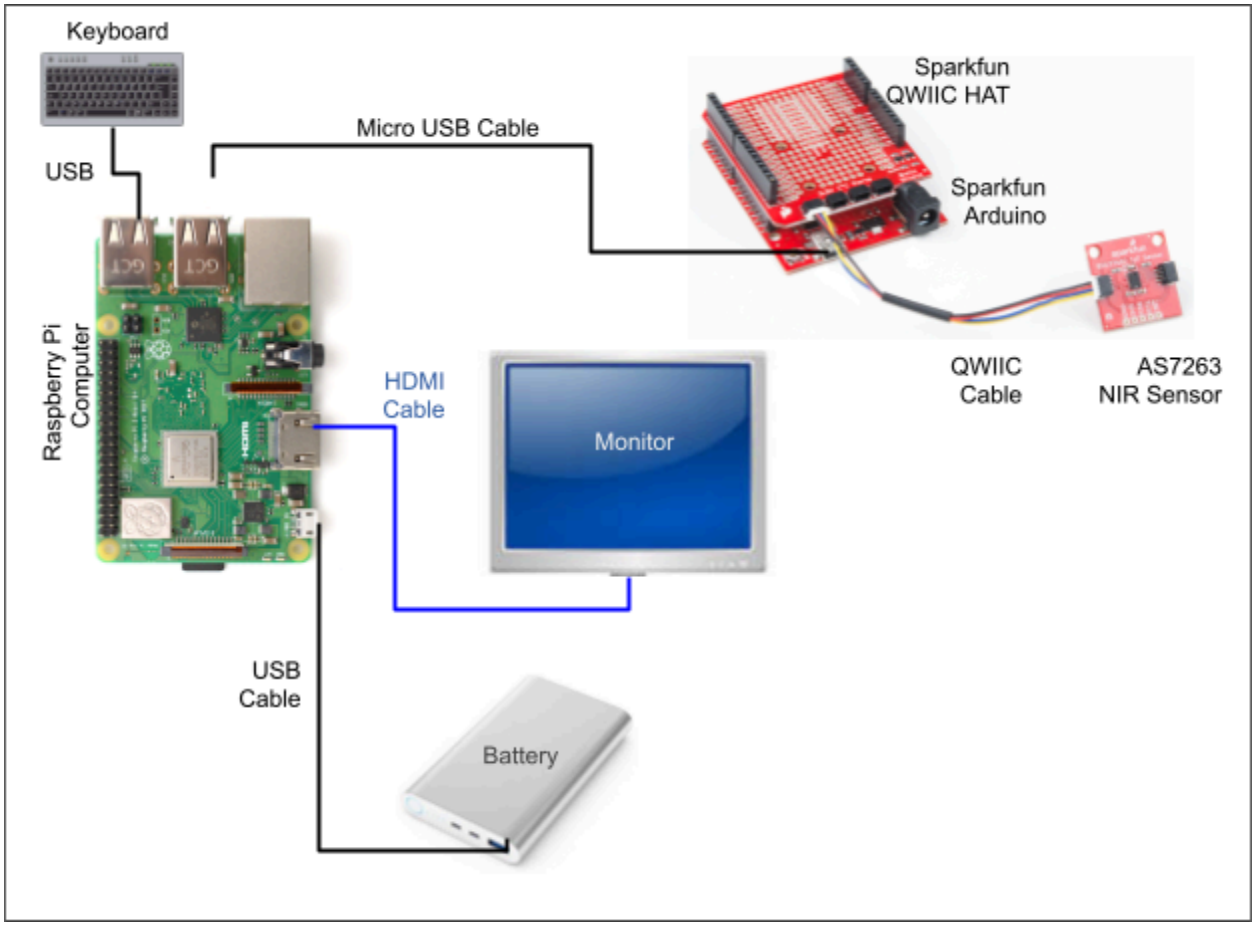
There were a few constraints on our solution that restricted us:

- We had to keep our solution under $250. This restricted us because we had to make our solution as simple as possible while sufficiently solving the problem. We managed to do this by not adding any extra features that we thought we would add early on.
- We also only had 8 months to complete our solution. This restricted us because we could not spend too much time on one part of the solution such as hardware or programming. We completed this by trying to do as much as we could per meeting. For example, we would equally split up the work so that we could get as much done as possible.
- Our solution also had to be compact. We had to do this because the device should not have taken up too much space while performing the necessary functions. We managed to do this by putting our solution in a box and putting all the circuitry inside of it.

Based on your criteria and constraints, what is your proposed solution to the problem you chose? Explain what it will look like and how it will work. If you can, include a detailed, labeled drawing:

Prototype

As our primary objective is to build a cost-effective solution to monitor blood glucose level without a drop of blood, we researched on spectroscopy. We learned about how the spectroscopic sensors work, and measure the interaction between matter and electromagnetic radiation. We specifically chose the Near Infrared (NIR) sensors based on our expert interviews, as they can report the NIR response by an emission spectrum, a plot of the response of interest as a function of wavelength. This value can then be correlated with the actual measured glucose level (via invasive traditional methods), using linear regression modeling to be used as an effective alternative to traditional invasive methods,

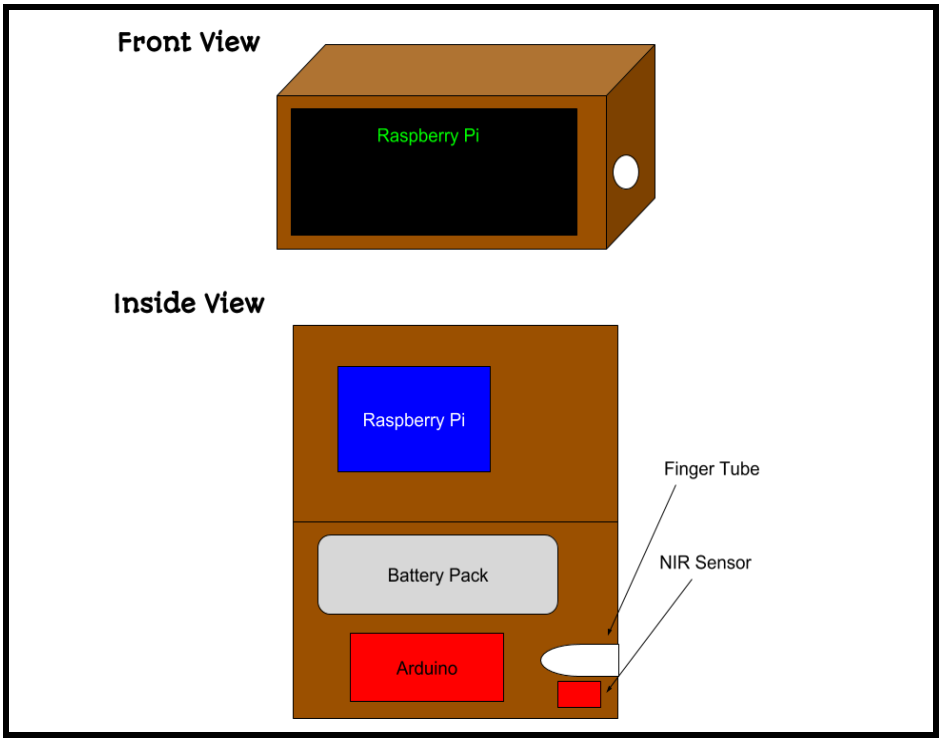


We used a Near Infrared (NIR) sensor to measure the glucose value. It is a sensor that emits and receives wavelengths from 610 to 860nm. It utilizes 6 light rays of different value; R (610nm), S (680nm), T (730nm), U (760 nm), V (810nm) and W (860nm). We used the W value because it is the most powerful. The NIR sensor is connected to the Raspberry Pi through an Arduino Uno. A Raspberry Pi is a microcomputer and the Arduino Uno is the device that we connected the NIR

sensor to because it was not able to be connected directly to the Raspberry Pi. We have a tube next to the NIR sensor where you put your finger in. The tube has a hole so that the NIR sensor can get a reading. All of this technology is located in a box with a 5-inch screen on top of it. To get the readings, we have a Python 2.7 file that runs our program. This code is the program that gets the sample data so that our device can convert the NIR reading to mg/dL. Our code basically does this:

1. Opens up a screen that says “Stumptown Glucobots” in big letters
2. Goes to a screen that asks for the user to insert their initials, their age and what their measured glucose value currently is. This screen also has flashing text saying “Insert finger into flashing hole and press start.”
3. Once the user clicks start, the device waits for 5 seconds and then starts to get 15 NIR readings.
4. Our program writes the date, the time, initials, age, and the NIR W value
5. The program show flashing letters saying “Data recorded. Thank You!”
6. Once the user clicks cancel, the program will terminate.

When we collected 20 samples of data, we used that sample data to make our program automatically convert the NIR readings to mg/dL. We made a python script to transfer the data from the files to the Google Sheets to run the linear regression model. A linear regression model is where we plot data points with the input being the x value and the output being the y value. Google Sheets will automatically try to create an accurate rule for correlation. The rule will be in $y = mx + b$ format, such as $y = 0.17x + 2.3$. We can refine the rule by getting more data points. Our x value is the NIR reading and the y value is the mg/dL value. This means that the more samples that we had, the more accurate our device was.



Materials

1. Near Infrared Sensor from Sparkfun
    - A Near Infrared (NIR) sensor is a sensor that emits and receives wavelengths from 610 to 860nm. It utilizes 6 light rays of different value; R (610nm), S (680nm), T (730nm), U (760 nm), V (810nm) and W (860nm). We used the W value because it suits our needs because it is the most powerful.

2. Arduino Uno + Supplementary Devices
    - We used the microprocessor Arduino Uno because our NIR sensor from Sparkfun could not connect directly to the Raspberry Pi.
    - We connected the Arduino Uno to the Raspberry Pi using 600mm of Qwicc cable

3. Raspberry Pi + Supplementary Devices
    - The Raspberry Pi is a microcomputer that we used to process and record the data that we collected from the NIR Sensor. We coded our programs for the user interface and text file recordings on this device as well.
    - We connected the Arduino to the Raspberry Pi using a Pi Tin which gave us five USB ports instead of three.

4. Elecrow 5-Inch Touch Screen 800p x 400p
    - This was the screen that we used to display our user interface + data collected.

5. SanDisk 32gb Micro SD Card
    - We used this SD Card to provide storage to our device.

6. Battery Pack
    - The battery pack was used to power the Raspberry Pi so that we didn't have to plug it into a wall outlet.

Software used

1. Python 2.7
    - We used Python to write the code for our program.

2. Arduino IDE
    - We used the Arduino IDE to show our NIR readings.

3. Raspbian Linux OS
    - This was the operating system that our Raspberry Pi ran on

Procedure

1. We first placed the 5-inch screen onto the box

2. We put the Raspberry Pi inside the box

3. We put the Arduino device in and connected it to the Raspberry Pi

4. We attached and NIR sensor to the inside of the box and connected it to the Arduino

5. We connected the battery pack to the Raspberry Pi and put it on styrofoam

6. We put a tube for the finger to be inserted

Program: Start.py Steps (Algorithm)

1. Opens up a screen that says “Stumptown Glucobots” in highlighted letters
2. Goes to a screen that asks for the user to insert their initials, their age and what their measured glucose value currently is. This screen also has flashing text saying “Insert finger into flashing hole and press start.”
3. Once the user clicks start, the device waits for 5 seconds and then starts to get 15 NIR readings.
4. Our program writes the date, the time, initials, age, and the NIR W value
5. The program show flashing letters saying “Data recorded. Thank You!”
6. Once the user clicks cancel, the program will terminate.

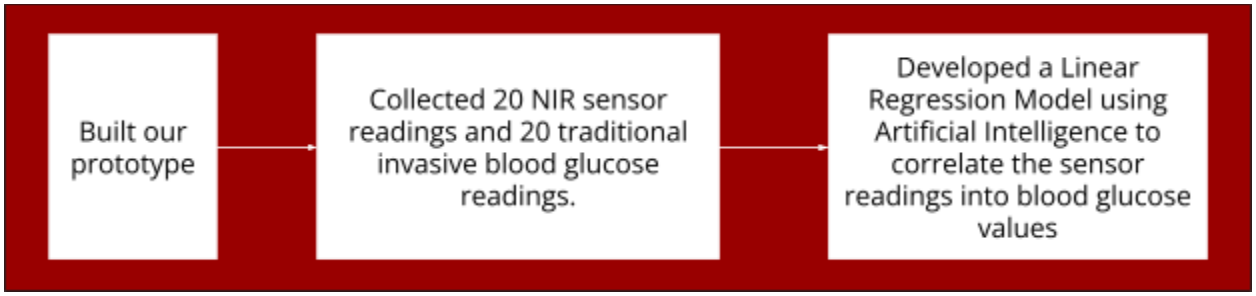
Program: Predict.py Steps (Algorithm)

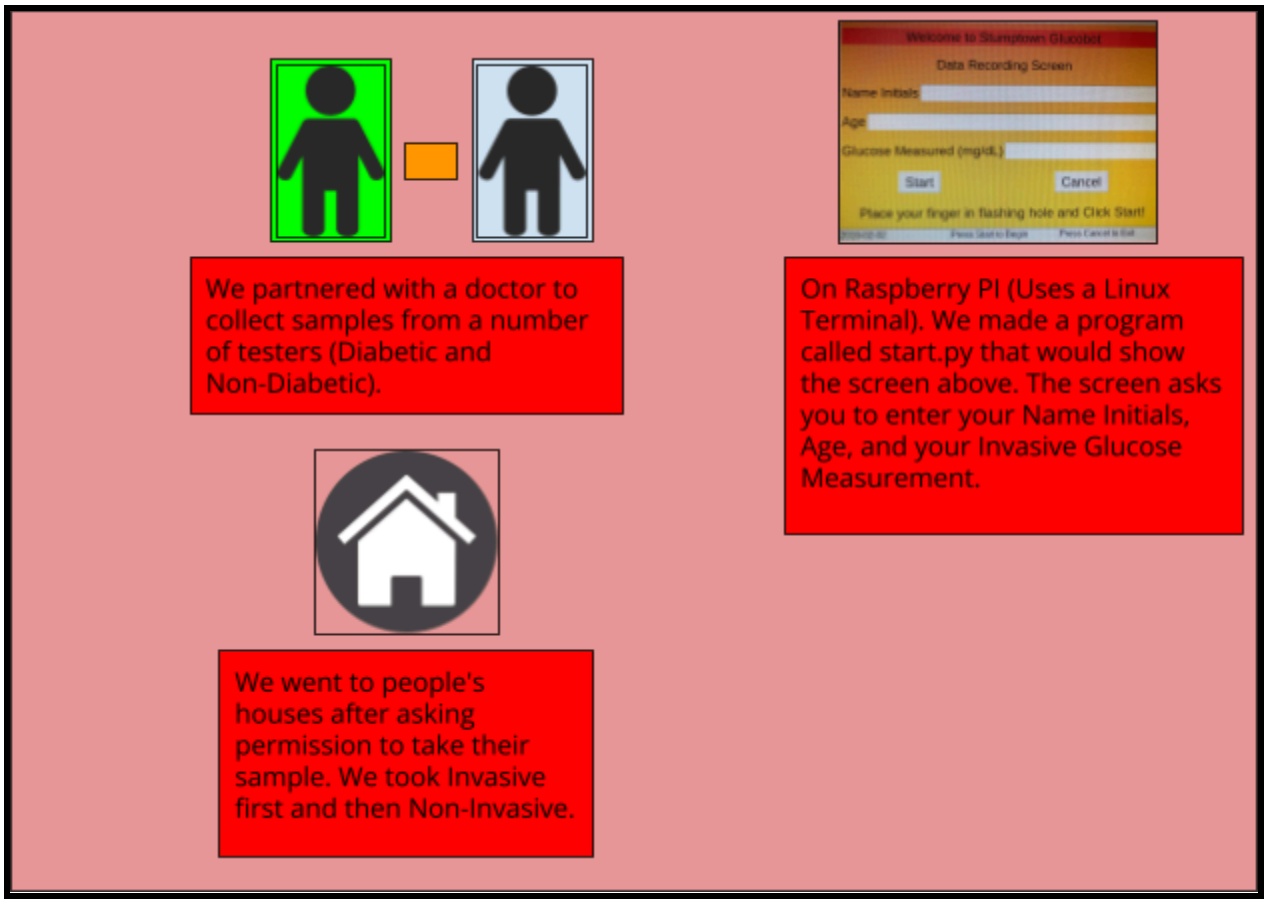
1. Displays Stumptown Glucobots in highlighted letters
2. Goes to a screen that asks for the user to insert their initials, their age and what their measured glucose value currently is. This screen also has flashing text saying “Insert finger into flashing hole and press start.”
3. Will take samples based on your invasive recording.
4. Our program writes the date, the time, initials, age, and the NIR W value
5. Based on the measured NIR value, it takes the average of 20 sensor readings
6. The NIR value is then correlated to derive predicted blood glucose level using linear regression
7. The program show flashing letters saying “Data recorded. Thank You!”
8. Once the user clicks cancel, the program will terminate.

Testing Solution

How will you test your solution? The BEST way to test your solution is to build a working model or a prototype that you can actually use. Or you can guess how your solution will work BASED ON your research. Which method will you use and why?:

We built a working prototype to measure blood sugar and used traditional methods to verify accuracy. We chose to make a prototype because if it worked, we would know that it was built correctly rather than to predict based on research. To test it, we first had to get 20 or more samples to be able to convert the NIR readings to mg/dL. After we got our rule, we used our 20 NIR readings and compared what the rule predicted to the actual value to see how accurate our device was.





Data Collection Program (Start.py)

```
# import the library
import serial
import time
import sys
import os, datetime
import datetime
from appJar import gui

now = datetime.datetime.now()
displaynow = now.strftime("%Y-%m-%d")
serial_port = '/dev/ttyUSB0';
baud_rate = 115200; #In arduino, Serial.begin(baud_rate)
ser = serial.Serial(serial_port, baud_rate,timeout=1)
maxval = 68
flag = "true"


# handle button events
def press(button):
    flag = "true"
    if button == "Cancel":
        app.stop()
    else:
        flag = "false"
        time.sleep(5)
        app.clearLabel("title4")
        fname = app.getEntry("Name Initials")
        age = app.getEntry("Age")
        glucose = app.getEntry("Glucose Measured (mg/dL)")
        now = datetime.datetime.now()
        displaynow = now.strftime("%Y-%m-%d")
        index = 0
        flname = fname+"-"+str(displaynow)+"-"+str(glucose)+"-output.txt"
        print flname
        flhandle = open(flname, "w+");

        while (index < maxval):
            now = datetime.datetime.now()
            displaynow = now.strftime("%Y-%m-%d %H:%M:%S")
            index = index + 1
            line = ser.readline().strip();

            if index > 43:
                reading,R,S,T,U,V,W,tempF = line.split(' ')
                w = W.replace("W[","")
                w = w.replace("]","")
                print(index, displaynow, fname, age, glucose, w, tempF)
                line = str(displaynow)+","+fname+","+str(age)+","+str(glucose)+","+str(w)+"\n"
                time.sleep(0.5)
                flhandle.write(line)

                if (index > maxval-1):
                    app.setLabel("title4", "Data Recorded.. Thank You!")
```

```
# create a GUI variable called app
text = "Stumptown Glucobots"
app = gui("Stumptown Glucobot Main Menu", "600x400")
app.setBg("orange")
app.setFont(18)
app.showSplash(text, fill='red', stripe='black', fg='white', font=44)

# add & configure widgets - widgets get a name, to help referencing them later
app.addLabel("title1", "Stumptown Glucobot - Data Collection")
app.setLabelBg("title1", "red")
app.setLabelFg("title1", "black")
app.addLabel("title2", "Data Recording Screen")

app.addLabelEntry("Name Initials")
app.addLabelNumericEntry("Age")
#app.integerBox("Age", "Enter Numeric Value", parent=None)
app.addLabelNumericEntry("Glucose Measured (mg/dL)")

# link the buttons to the function called press
app.addButtons(["Start", "Cancel"], press)

app.addFlashLabel("title4", "Place your finger in flashing hole and Click Start!")
app.addStatusbar(fields=3)
app.setStatusbar(displaynow, 0)
app.setStatusbar("Press Start to Begin", 1)
app.setStatusbar("Press Cancel to Exit", 2)

app.setFocus("Name Initials")
# start the GUI
app.go()
#------------------------------------------------------
```

Data Prediction Program (Predict.py)

```
# PROGRAM: Predict.py
# PURPORSE:
# Predict measured blood glucose based on NIR sensor value
# Use Linear Regression model to predict value
# Store confirmation data in predict output file

# Owner: Stumptown Glucobots
# Jan 2019

# import the library
import serial
import time
import sys
import os, datetime
import datetime
from appJar import gui
```

```
now = datetime.datetime.now()
displaynow = now.strftime("%Y-%m-%d")
serial_port = '/dev/ttyUSB0';
baud_rate = 115200; #In arduino, Serial.begin(baud_rate)
ser = serial.Serial(serial_port, baud_rate,timeout=1)
maxval = 68
flag = "true"

#-------------------------------------------------------------------------------
# Function to apply Linear Regression model to predict Glucose Level from NIR value
#-------------------------------------------------------------------------------
def predictGlucose(NIRvalue):
    GVal = 0.229 * NIRValue + 64.9 return GVal
#-------------------------------------------------------------------------------

# handle button events
def press(button):
    flag = "true"
    avgcounter = 0
    wTotal = 0.0
    glucose = 0.00
    if button == "Cancel":
        app.stop()
    else:
        flag = "false"
        time.sleep(5)
        app.clearLabel("title4")
        fname = app.getEntry("Name Initials")
        age = app.getEntry("Age")
        glucose = app.getEntry("Glucose Measured (mg/dL)")
        now = datetime.datetime.now()
        displaynow = now.strftime("%Y-%m-%d")
        index = 0
        flname = fname+"-"+str(displaynow)+"-"+str(glucose)+"-PREDICT.txt"
        print flname
        flhandle = open(flname, "w+");

        while (index < maxval):
            now = datetime.datetime.now()
            displaynow = now.strftime("%Y-%m-%d %H:%M:%S")
            index = index + 1
            line = ser.readline().strip();

            if index > 43:
                reading,R,S,T,U,V,W,tempF = line.split(' ')
                w = W.replace("W[","")
                w = w.replace("]","")
                print(avgcounter, displaynow, fname, age, glucose, w, tempF)
                time.sleep(0.5)
                avgcounter = avgcounter+1
                wTotal = wTotal + float(w)

                if (index > maxval-1):
                    app.setLabel("title4", "Data Predicted.. Thank You!")
                    wAverage = wTotal/avgcounter
                    print "Average W =", wAverage
```

```
                    GlucoseValue = predictGlucose(wAverage)
                    print "Predicted Glucose Value = ",  "%+2.2f" % (GlucoseValue)
                    glucose1 = "%3.2f" % (GlucoseValue)
                    app.setLabel("title4", glucose1)
                    line =
str(displaynow)+","+fname+","+str(age)+","+str(glucose)+","+str(w)+","+str(glucose1)+"\n"
                    flhandle.write(line)
#-------------------------------------------------------------------------------
# create a GUI variable called app
text = "Stumptown Glucobots Prediction"
app = gui("Stumptown Glucobot Main Menu", "600x400")
app.setBg("green")
app.setFont(18)
#-------------------------------------------------------------------------------
# Start-up Screen
app.showSplash(text, fill='black', stripe='red', fg='white', font=44)
#-------------------------------------------------------------------------------

# add & configure widgets - widgets get a name, to help referencing them later
app.addLabel("title1", "Stumptown Glucobot - Prediction")
app.setLabelBg("title1", "blue")
app.setLabelFg("title1", "yellow")
app.addLabel("title2", "Data Prediction Screen")

app.addLabelEntry("Name Initials")
app.addLabelNumericEntry("Age")
#app.integerBox("Age", "Enter Numeric Value", parent=None)
app.addLabelNumericEntry("Glucose Measured (mg/dL)")

# link the buttons to the function called press
app.addButtons(["Start", "Cancel"], press)

app.addFlashLabel("title4", "Place your finger in flashing hole and Click Start!")

app.addStatusbar(fields=3)
app.setStatusbar(displaynow, 0)
app.setStatusbar("Press Start to Begin", 1)
app.setStatusbar("Press Cancel to Exit", 2)

app.setFocus("Name Initials")
# start the GUI
app.go()
#-------------------------------------------------------
```

Bill of Materials

ITEM	COST
AS7263 NIR	$25.95
100mm Qwiic Cable	$3.00
500mm Qwiic Cable	$3.90
Raspberry Pi 3 B+	$39.95
SanDisk 32GB UHS Memory Card	$7.98
Shipping Fees	$12.86
Elecrow 5 Inch Touch Screen 800x400	$36.99
Sparkfun Redboard	$19.95
Arduino Uno Enclosure	$7.95
Pi Tin for Raspberry Pi	$5.95
Sparkfun Qwiic Shield for Arduino	$6.95
Total	$169.43

Testing

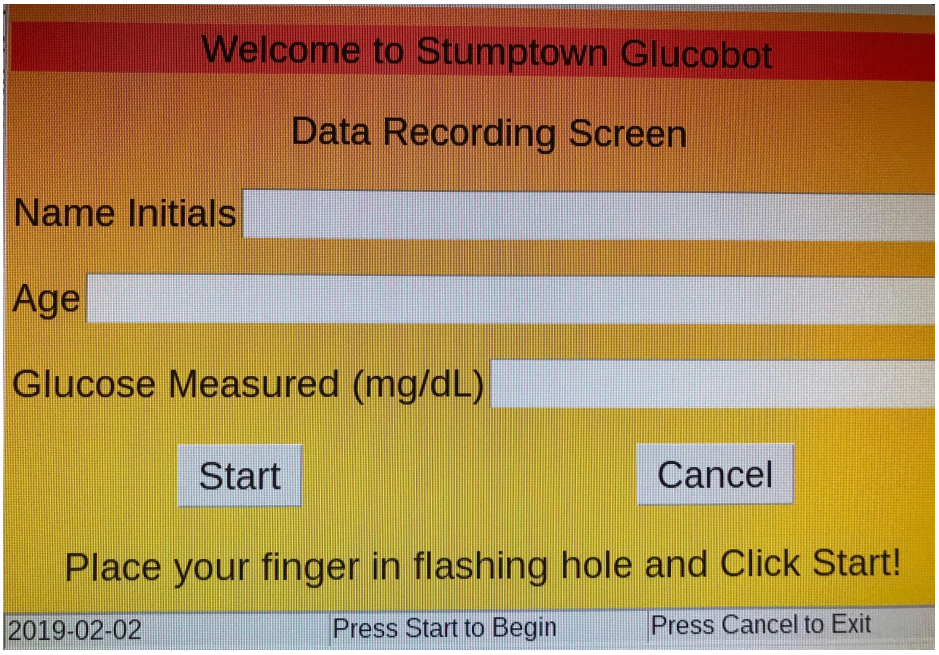
Explain how you tested your prototype or model. Be sure to include every step of your testing including all safety precautions that were taken. If not stated it will be assumed no safety precautions were taken. If you are using research to guess how your solution will work, explain step-by-step how it will work and why:

Data Collection

Procedure

Step-by-Step Instructions

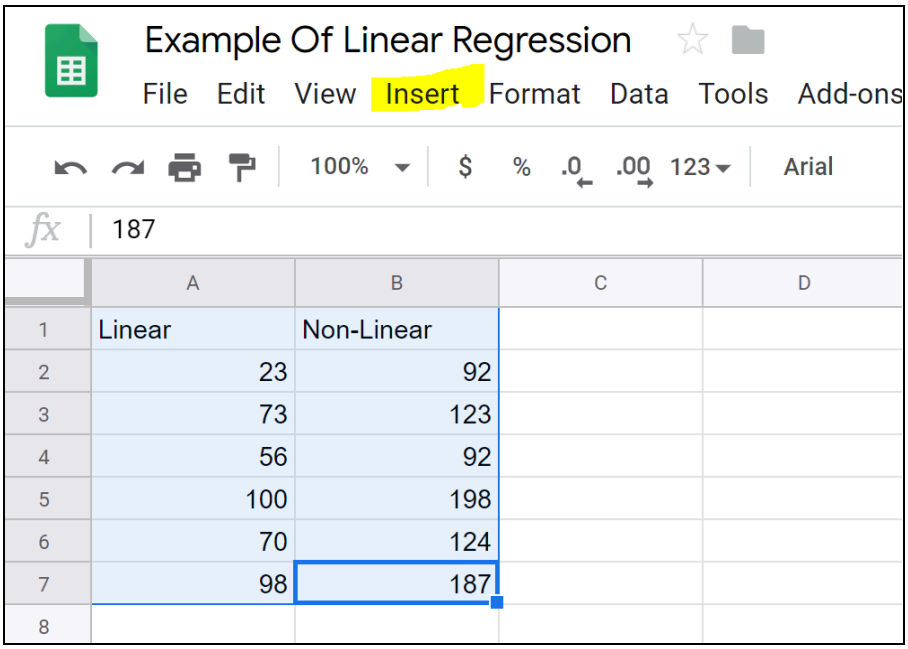
a) Start Raspberry Pi
b) At the terminal window, type following commands
   - cd Documents
   - cd srk
   - mkdir 09Feb19
   - cp 03Feb19/* ./09Feb19
   - cd 09Feb19
   - python start.py



Linear Regression on Google Sheet

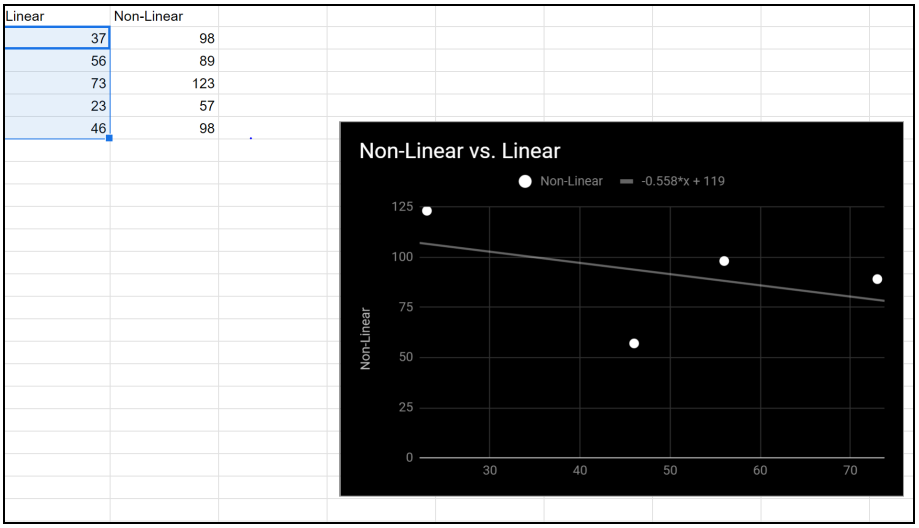
Once the data samples are collected in step #1 above, copy the output.txt files to Google Sheet

A. Upload Sample Data
B. Format Your Data Into Google Sheets
C. Highlight the data and press the graph button on the overhead bar



	A	B	C	D
1	Linear	Non-Linear		
2	23	92		
3	73	123		
4	56	92		
5	100	198		
6	70	124		
7	98	187		
8				

D. Make a Scatter Plot with the data you have in google sheets

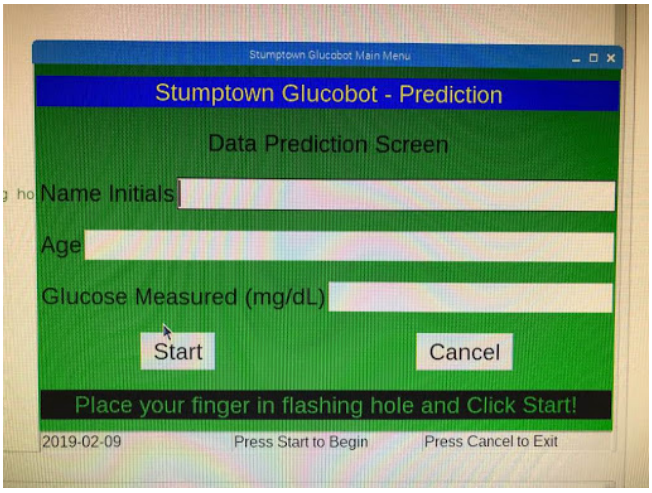


E. Got to the customize button in the right-hand corner
F. Do any customization you may want
G. Go to the series button and press the trendline button
H. After pressing trendline, go down and when you see the type button, press linear.
I. Press Label and then press (use equation).
J. Under the Label checkbox R^2

Data Prediction

Step-by-Step Instructions

a) Start Raspberry Pi
b) At the terminal window, type following commands
   - cd Documents
   - cd srk
   - mkdir 09Feb19
   - cp 03Feb19/* ./09Feb19
   - cd 09Feb19
   - python predict.py



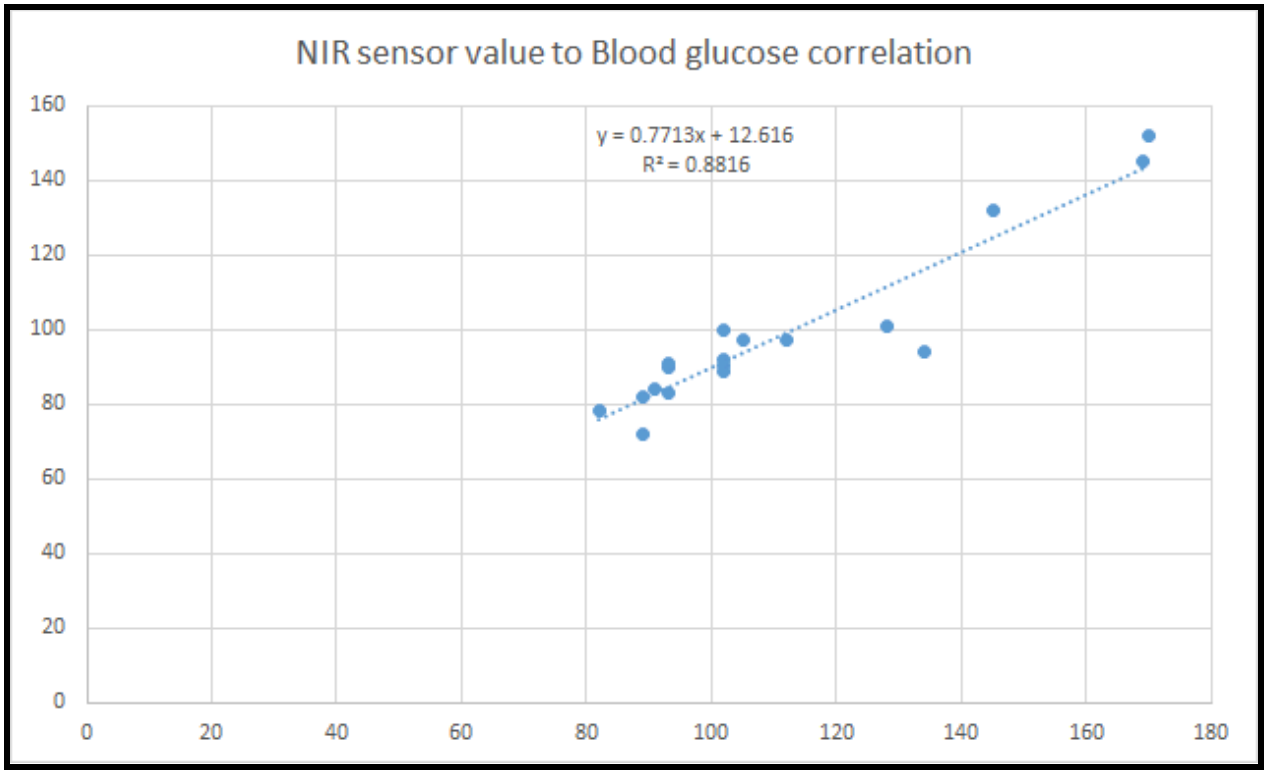
Data Analysis

Present the data you collected from your tests or from your research. If you tested a prototype or model then include all of the numbers you gathered during your testing and all observations you made. Use of graphs and charts is HIGHLY encouraged. If you used research to prove how your solution would work, be sure to include all of the numbers, charts, and graphs you used to make your case:

We collected more than 20 samples from various patients in different age groups. Same patients also collected their blood glucose samples using traditional invasive methods, and within a minute, we sanitized their finger and placed it in our glucobox to collect the NIR sensor value. These values are captured in the table below.

Initials	**Age**	**Glucose measured mg/DL**	**NIR sensor (860nm)**	**Predicted Glucose Value Glucose = 0.7713 * NIR + 12.616**	**Error Rate**
AP	12	93	90.06	84.3469	9%
GB2	46	134	93.87	115.9702	13%
rj	45	169	145.2	142.9657	15%
SJ	42	128	101.2	111.3424	13%
AS	44	102	99.7	91.2886	11%
SK	46	105	97.2	93.6025	11%
SG	40	93	83.1	84.3469	9%
MR	40	112	97.2	99.0016	12%
Sa	43	93	91.2	84.3469	9%
bg	38	82	78.2	75.8626	7%
vs	57	102	90.2	91.2886	11%
sm	23	89	72.2	81.2617	9%
sk	39	91	84.3	82.8043	9%
sk2	41	102	88.9	91.2886	11%
ng	44	145	132	124.4545	14%
uv	42	89	82	81.2617	9%
uv2	45	102	92	91.2886	11%

de	82	170	152	143.737	15%



Glucose Value = 0.7713 * NIR Sensor Value + 12.616

Errors

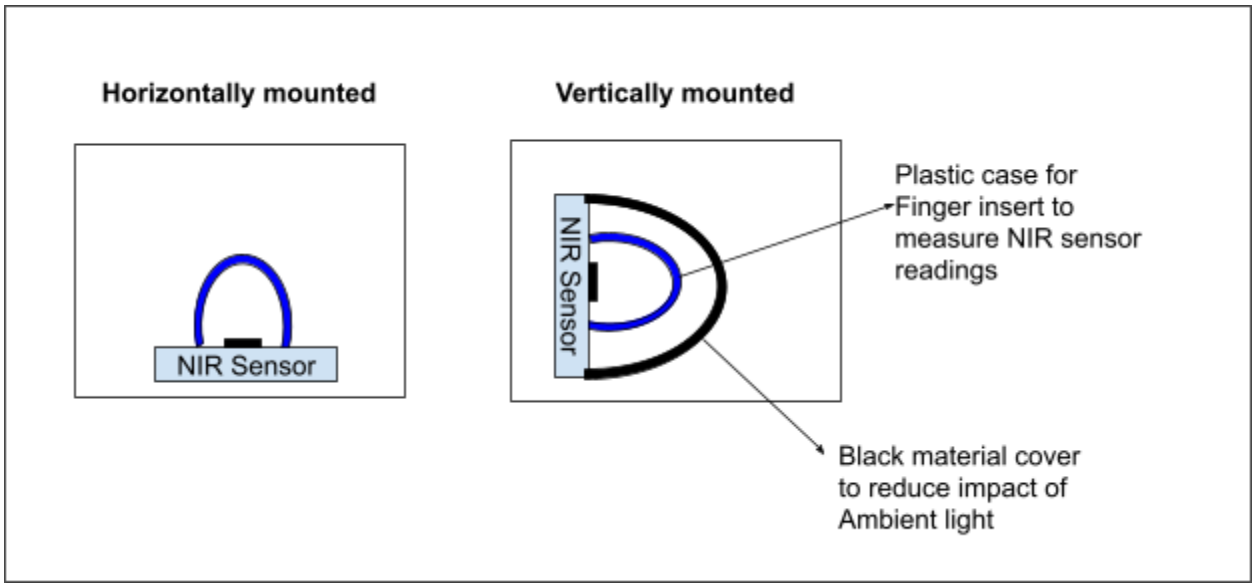
What problems did you find with your solution? Be specific since you will need to redesign based on these problems:

Our team experienced quite a few errors in our prototype due to our budgeted use of complex parts. For example, in our original design, the positioning of the parts wasn't completed correctly as we didn't know what to anticipate to produce the best results. We also realized that there was no interval between the start button being clicked and the NIR beginning reading, which caused us to lose out on samples. We realized that the process to open the user interface was too long as well.

NIR Sensor placement: We first tried to mount the NIR sensor facing up, however, this design expose maximum exposure to external lighting condition and resulted in huge variation in sensor values. Therefore, we chose to mount the NIR sensor vertically to control the ambient light and designed a concealed box to hold the parts.

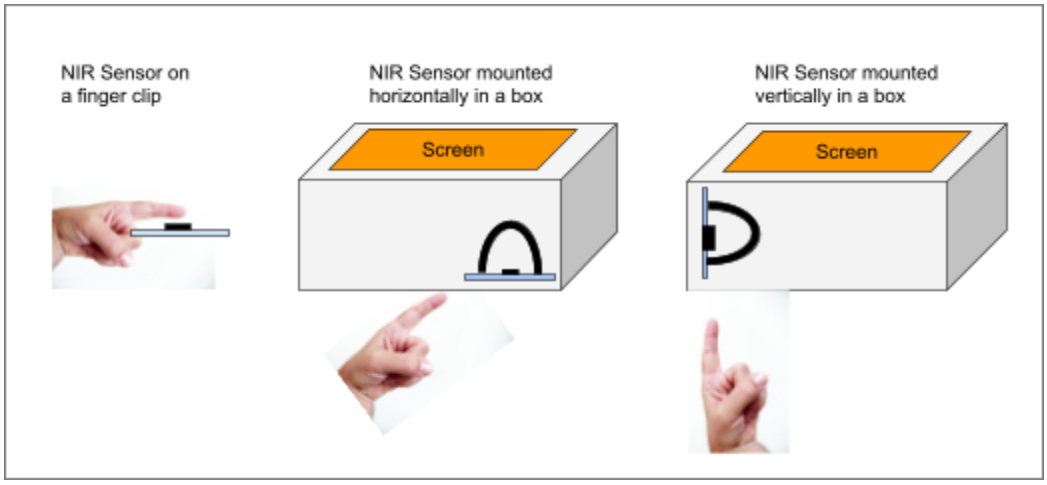
Effect of external ambiance in NIR sensor readings: We first came up with a design to clip the NIR sensor to testers finger, however, that design resulted in several incorrect sensor values due to external ambient conditions (ie: light turned on or off). Therefore, we built our solution to minimize the external ambient influence on sensor readings and chose to cover the NIR sensor with a black sheet of paper.

Skin thickness and finger width: When we first designed our solution, we came up with a clipping model. Since that didn't result in consistent sensor readings, we moved to use a finger like a plastic model with a hole to cover the NIR sensor. However, our chosen design is not big enough for some adult fingers but was too big for some children. We then chose a moderately sized fingertip to address the gaps. We plan to come up with a 3D printed design and also research squishy component to best-fit fingers.

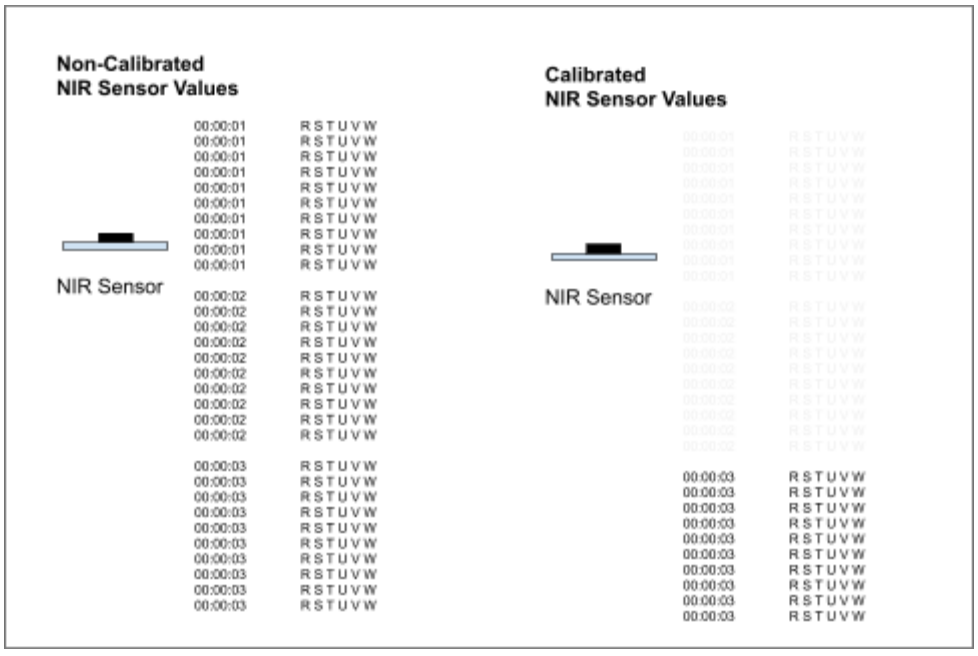


Describe all of the changes you made to your prototype or model (or proposed prototype) after your first test. Why will these changes improve your solution?:

Problem-1 Device Mounting: After a few live test runs and repeated use, part of the structure in which the finger is inserted collapsed, which we solved by adding additional structure to stabilize the tube.
Solution: We used hot glue to permanently place the plastic finger cap into the box.

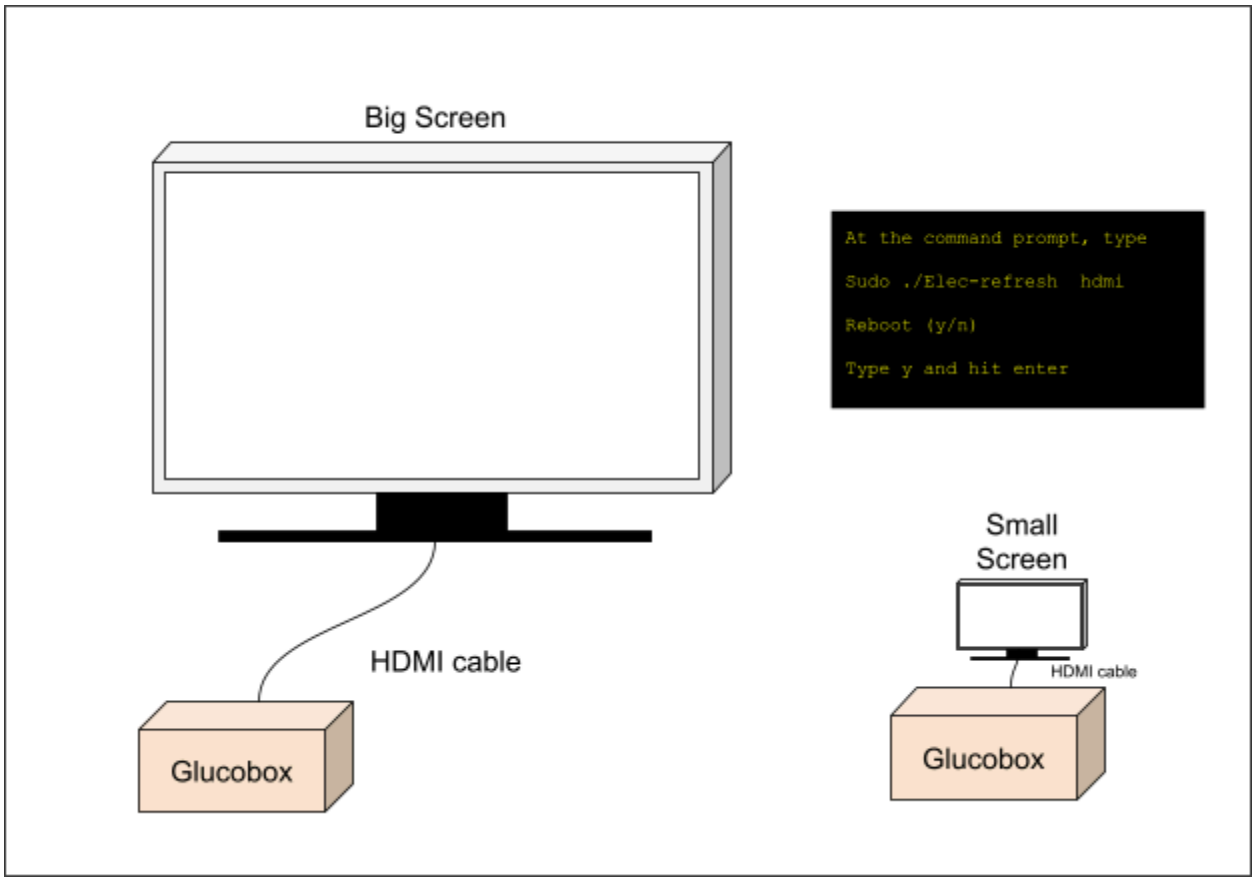


Problem-2 NIR Sensor calibration: NIR A7263 sensor from Sparkfun takes multiple samples per second and the readings were inconsistent.
Solution: We learned from Sparkfun that the NIR sensor A7263 had to be calibrated for lighting conditions. We updated our program to skip first 20 samples (for a total of around 2 seconds) and then record the NIR 860 nm wavelength values into a text file for linear regression modeling offline.



Problem-3: Screen resolution: As the LCD screen that was attached to the device resolution was different from the bigger computer monitor, the display of Python script output was incorrectly displayed.

Solution: We read the product manual from the LCD screen and executed the driver program that they had developed to adjust the display resolution each time we switched from smaller to a bigger screen and vice versa. Each time we switched monitors, the Raspberry Pi had to be restarted. We also documented these procedures in our design document.



Potential Sources of Error

What are your potential sources of error? Remember, this doesn't mean "Did everything work?", all tests have potential sources of error, so make sure you understand what that means. Explain how these sources of error could have affected your results:

As we measure a value that is inside the human body, our device has many sources of error as the human body is unpredictable in nature and some factors are beyond our control. However, there are also factors that we could control, the mechanics of the device, the software, etc. We assorted these into Random, or uncontrollable factors to do with precision, and Systematic, or controllable factors to do with accuracy.

Random:
Our potential sources of error were mainly involved with the sensor readings; if those were off, our model would be inaccurate. Some factors that made it difficult to measure through the skin and measure the blood glucose concentration would be skin thickness, skin texture, finger size, and skin color. Skin thickness is important because light penetrating the skin is largely dependent on this variable.

Skin texture could change the readings based on the level of moisture and oil on the skin sample. Not only could this factor make it hard to read the blood value, but could also damage the light and sensor on our device.

Finger size was probably the biggest source of error we had to work around in our tests. If we hadn't cut a big enough hole in our box to fit the finger, our solution would be ineffective to many people.

Ambient lighting was important because we couldn't afford to let light into our device, as it was very dependent on its own light source, and disturbing that could have had severe repercussions.

Finger Color: Probably the least challenging was finger color because although different variations of skin color had different reactions to light (i.e. some darker skin tones absorbed more light than others), our light was powerful enough to penetrate the skin and take measurements from the blood.

Systematic
Ambient lighting was important because we couldn't afford to let light into our device, as it was very dependent on its own light source, and disturbing that could have had severe repercussions.

Conclusion

What conclusions can you draw based on the data you gathered during your tests?:

Based on various tests we conducted we successfully proved that the non-invasive method using Near Infrared spectroscopic sensors can measure blood glucose levels within fifteen percent of accuracy for most patients. The outliers detected during the verification process could be based on the lighting conditions and its impact on NIR sensor readings or due to the placement of the finger incorrectly, that's not on top of NIR sensor.

By appropriate training and user guide, we believe we can improve the overall prediction accuracy. In addition, by collecting more samples, we can improve the overall accuracy of our device to predict blood glucose level within 5% of actual value without a drop of blood.

This furthermore proves that noninvasive solutions under $200 can be almost as accurate as invasive solutions despite having only a fraction of the pain, irritation, and inconvenience. We have successfully demonstrated that non-invasive methods can be as effective as traditional invasive methods for blood glucose monitoring.

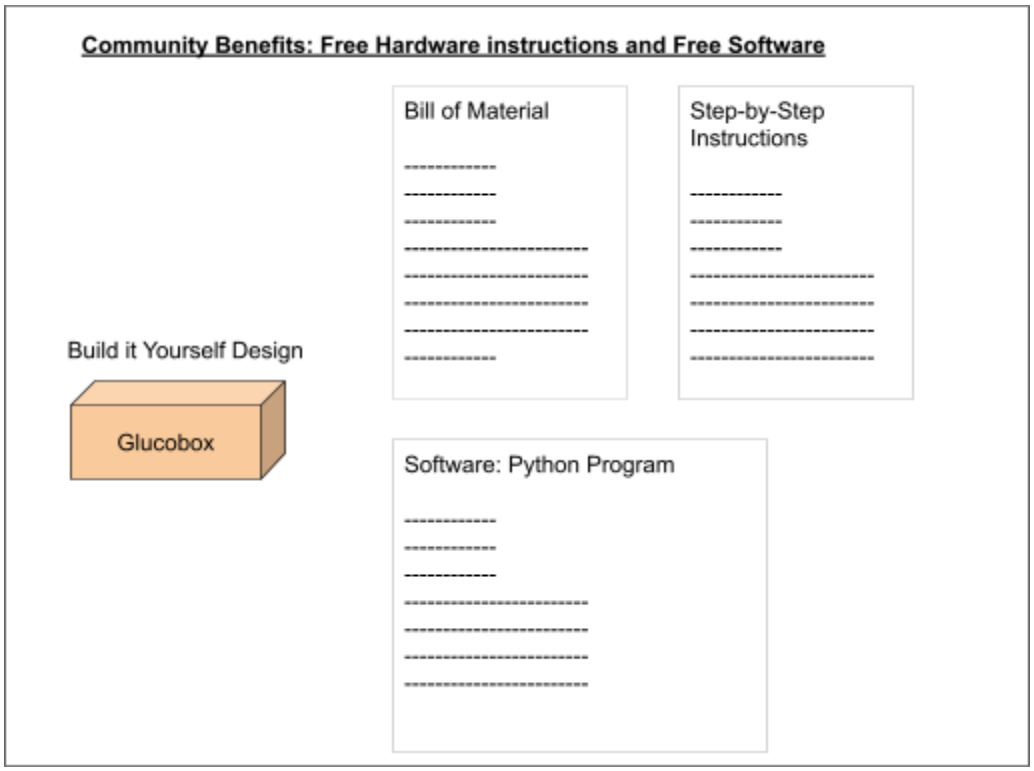
Community Benefits

Explain how investigating the problem your team chose will help the community. Be sure to include the impacts your research will have on individuals, businesses, organizations, and the environment in your community (if any). Make it very clear why solving this problem would help your community:

Our solution benefits the community by allowing millions of diabetic population to create and use a painless solution that can quickly be used. This is a vast improvement from the painful and time-consuming invasive monitors that are used throughout the world. We are planning on posting the programming and parts required onto the internet so anyone who wants to buy, assemble and program the parts can if they so choose. Our solution is under $200 which makes it more affordable. We will work to refine our model to find the most efficient parts after the first round is completed so we can have additional time to test different components of our device.

In addition, since our solution is non-invasive and does not require a blood sample, we can prevent any spreading of contagious diseases in our communities.

To further benefit our communities, we plan to share all our design documentation so anyone can build their own glucobox within one hour. We also plan to upload all our software programs to Github for further advancement of our solution.



We have also conducted presentations in our school and community showing our friends and classmates how they can help this issue. Our team has become actively involved in the issue and

we hope to make a change in at least our community for the children and adults alike who have had to struggle with this tiring, scary, and irritating disease that has taken over the lives of hundreds.

References

Research your problem. You must learn more about the problem you are trying to solve and also what possible solutions already exist. Find AT LEAST 10 different resources and list them here. They should include books, periodicals (magazines, journals, etc.), websites, experts, and any other resources you can think of. Be specific when listing them, and do not list your search engine (Google, etc.) as a resource:

1. *What Is The Pancreas?*, pathology.jhu.edu/pc/basicoverview1.php?area=ba.

- This source explained what the pancreas is and how it is important for regulating blood sugar levels. It states that the pancreas is a gland located in the abdomen with two primary functions; the endocrine function and the exocrine function. The endocrine function of the pancreas is to release hormones such as glucagon and insulin that are used in tandem to manage blood glucose. The exocrine function of the pancreas is to produce enzymes to help with food digestion.

2. "SparkFun Spectral Sensor Breakout - AS7263 NIR (Qwiic)." *Sparkfun*, www.sparkfun.com/products/14351.

- This is the website that explained to us what the Near Infrared (NIR) sensor is. It is a sensor that detects wavelengths of 610, 680, 730, 760, 810 and 860nm. Once we learned about this device, we also ordered the NIR sensor from this website to be a part of our solution.

3. Jhoja, Jaspreet, and Haxha. "Optical Based Noninvasive Glucose Monitoring Sensor ." *IEEE Photonics Journal*, IEEE, 2018, ieeexplore.ieee.org/document/7782291.

- This was a research paper that provided us with an inexpensive and efficient plan to track blood sugar levels noninvasively. It also gave us a lot of insight on how invasive solutions can cause many problems. The patient is in pain, and the finger pricking can damage skin tissue. The needle can also induce an infection in the bloodstream. Some current solutions to this problem are Continuous Glucose Monitoring, but they have a limited battery life. We also managed to get contact information with one of the authors and they were willing to contact us to give us the necessary guidance and answers to questions we had.

4.Y, Kanazawa, et al. "Do Blood Glucose Levels in the Elderly Have Different Metabolic Significance than in Non-Elderly Subjects?" PubMed, 30 Apr. 1993, www.ncbi.nlm.nih.gov/pubmed/8315849.

- According to this abstract, there is no age effect on blood glucose levels.

5. Ko, G. T., Wai, H. P., & Tang, J. S. (2006, October). Effects of Age on Plasma Glucose Levels in Non-diabetic Hong Kong Chinese. Retrieved from

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2080461/

- In this scientific research paper, a study was conducted where 15,603 nondiabetic citizens of Hong Kong had their plasma glucose concentration measured. The ages ranged from 12.7 years to 96 years. According to their research, plasma glucose levels increase with age in Hong Kong.

6. Lin, T., Mayzel, Y., & Bahartan, K. (2018). The accuracy of a non-invasive glucose monitoring device does not depend on clinical characteristics of people with type 2 diabetes mellitus. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5769775/

- This research paper is of a study conducted to prove that GlucoTrack is suitable for people with type 2 diabetes. This was conducted on 114 people of various ages who had type 2 diabetes

7. Saccharification. (n.d.). Retrieved from https://www.merriam-webster.com/dictionary/saccharification

- This website defines saccharification. It states that saccharification is the hydrolysis of carbohydrates such as the hydrolysis of sucrose into glucose and fructose or the hydrolysis of cellulose.

8. Statistics About Diabetes. (n.d.). Retrieved from http://www.diabetes.org/diabetes-basics/statistics/

- This website gave us many statistics about diabetes. According to it, 1.5 million people are diagnosed with diabetes every year. Over 23 million adults in the US are diagnosed with diabetes and an estimated 7 million are not diagnosed. 193,000 people under the age of 20 are diagnosed with diabetes. In the US, 1.5 million people are diagnosed with type 1 diabetes, which is the most deadly type of diabetes. An estimated 18,000 kids have been diagnosed with type 1 diabetes and 5,300 kids have type 2. Over 252,000 people have died from diabetes.

9. Bura, John. “Build and Train a Data Model to Recognize Objects in Images!” *Udemy*, www.udemy.com/pythondatascience/.

- This was a course that we took to learn the basics of Python and how to recognize objects in images. We used what we learned to create a program for our prototype’s data collection and data prediction.

10. The Pancreas and Its Functions. (n.d.). Retrieved from http://columbiasurgery.org/pancreas/pancreas-and-its-functions

- This article gave us information on the pancreas. It stated that it can be 6 to 10 inches long. It is located in the upper left abdomen.

11. What is Diabetes? (2016, November 01). Retrieved from https://www.niddk.nih.gov/health-information/diabetes/overview/what-is-diabetes

- This article gave us an overview of what diabetes was. It stated that diabetes is glucose is too high in your blood. Type 1 diabetes is when your body produces no insulin. This occurs mostly in children. Type 2 diabetes is when your body doesn't make a sufficient amount of insulin. It occurs more in people over the age of 45. One less common diabetes type is monogenic diabetes which is inherited. About 9.4% of the U.S. population has some form of diabetes, whether they know it or not. High blood glucose levels can lead to heart disease, stroke, kidney disease, and many other health problems.