ECS520U Creative Group Project

2020/2021 Semester B

Project Report

Group 6

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I. Introduction

This project intends to create a health device that monitors user data. Our stakeholder, Omar is a professional runner, but often suffers from overtraining. Overworking during his part time job also affects his health. He suffers from hypertension and high cholesterol caused by the high level of stress and unhealthy diet. Our goal was to design a device that helps him improve his health, and we decided to focus on preventing overtraining while helping him to improve his running performance. Optimizers' design focuses on Omar's running habit. Optimizers are the trainers that notify the user when the running goal is reached to prevent overtraining. It can monitor multiple running aspects, as symmetry, cadence and ground contact time. The main feature plans on notifying the user whenever pace must be changed to reach running goal, therefore improving his energy distribution throughout the run.

II. The Concept

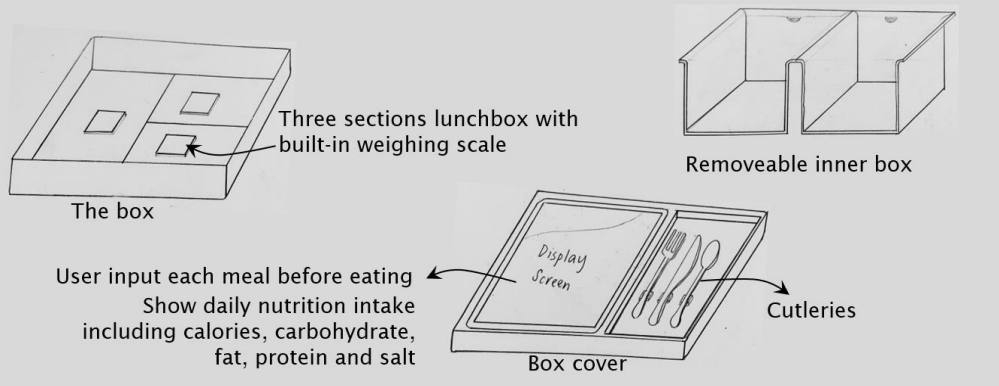
a. Market research

During the early stage of this project, market research has been done to determine the current supply in the market that matches with the target user needs. A few products have been reviewed, including Bragi The Dash Pro, Diet sensor SCiO and Digital Scale, and TytoHome remote exam kit. Bragi The Dash Pro is a pair of multifunctional wireless earphones that have standalone music player, in-ear fitness tracker, heart rate monitor and headset. (Bragi, 2019) This matches Omar's career as a professional runner. Diet sensor SCiO and Digital Scale can be used to get information of the amount of carbs, proteins, fat, alcohol and calories of the food. (DietSensor, 2021) It is ideal for Omar as he needs to monitor and improve his diet to maintain his health and running performance. Besides, the TytoHome remote exam kit is portable and can be used to examine many aspects including heart, skin, heart rate, and body temperature. (TytoCare, 2020) This is useful for Omar to monitor his health condition as he has hypertension and high cholesterol.

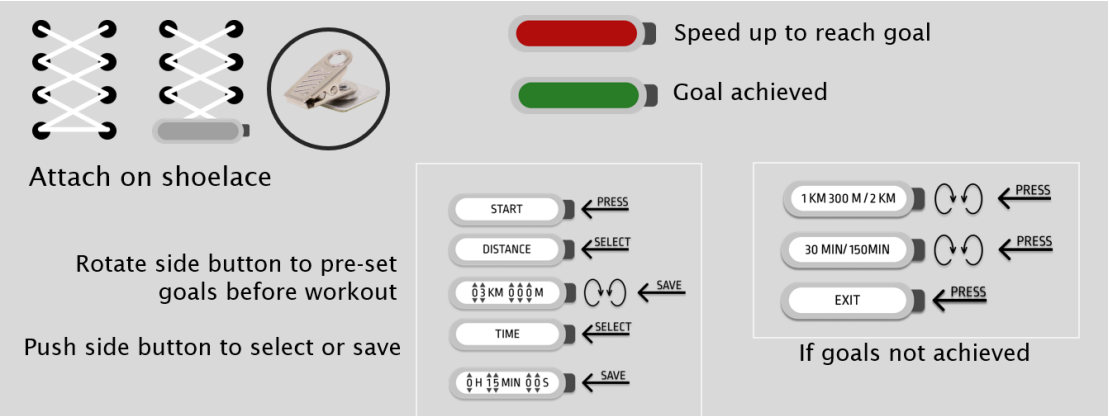
After taking different aspects into consideration, Bragi The Dash Pro and Diet sensor SCiO and Digital Scale have been chosen as references to design the personal health system for the target user. Bragi The Dash Pro has the fitness functionality that helps Omar in his running career. It can track his running performance and monitor his body condition. Besides, Diet sensor SCiO and Digital Scale helps Omar in monitoring his diet. Using this product allows Omar to understand his diet intentionally and change his habit of eating unhealthy snacks. A healthy diet can also improve his health problem such as high cholesterol.

b. Design approach to the brief

A lunchbox and shoe attach device have been designed based on the concept of improving the target user's diet and running performance. The lunchbox has three sections with a built in weighing scale. An input screen and cutleries are attached to the lunchbox cover. Using a lunchbox can encourage the user to pay attention to his diet. The user can input his food before eating it, and the display screen will show the nutrition value and recommendation level of the food. By understanding the benefits and bad sides of eating the food, the user can be self-cautious and think of the consequences before he eats.



On the other hand, the shoe attach device aims to track Omar's running and prevent him from overtraining. It can be attached to the shoelace. Before a training, Omar can input his running goal. Light feedback will be given during the run when he achieves his goal, or when he needs to speed up for reaching his goal.



c. User centered design

Considering the usability and practicality of the products, the idea of shoe attach device has been chosen to develop in the project. However, less information can be obtained by only having a separated attached device. Therefore, a personalised pair of shoes that can be worn during training has been designed. This decision has been made because the using a lunchbox will introduce a new habit to Omar but wearing a running shoe for training is a usual routine as a professional runner. Other than that, running is the main activity in Omar's daily life, therefore it's essential to track and monitor his running.

Further market research has been done based on this idea. NURVV run is a smart insole with sensors that can measure the user's performance from the feet. It can measure aspects such as distance, time, pace, foot strike, pronation and many more. The visual and audio feedback can be given real time via the smartphone or smart watch. However, this requires the user to bring a second device during the run, which is not recommended as this increases the burden of the runner. By taking it as reference, the design aims to provide haptic feedback during the run without the need of having a second device.

III. Practicalities

a. Key tasks

The tasks have been broken down and assigned to each group member for each week.

Market analysis

At this stage, we will identify the existing market of health devices and find the gap we can step in. The market has many health devices that come with an application on the phone. Creating a design that does not rely on an app is one of the goals in this project in order to avoid building a similar product that already exists in the market.

Target user analysis

There are two target users in the early stage, filtered into one for the final design. To prevent unnecessary features, the target user's background and his problems have been identified. The product design is influenced by the user background - a professional niche product that satisfies specific goals.

Product design

The product design was done based on the analysis done in the previous stages. Several possible designs were generated, and each of them fulfills the user's needs in different measures. It is important to keep the diversity of ideas in the discussion.

There are some details required to be discussed during the design:

- the concept (how to satisfy the needs)
- the components required (how the functional aspects work)
- the view of the product (how it looks and how it fits all components)

Prototype development

In this stage, multiple prototypes were created. First, a low-fidelity prototype that involves story boarding and a rough model of the product have been created . This was used to inspect whether the idea is doable. After this, the feedback received has been considered to improve the quality of the prototype. .This iterative process continues until a prototype that fulfils most of the user requirements is created. This was the stage that took the longest time, therefore it is prioritised in the working schedule.

Presentation

This is the stage we make a presentation to the general market to announce our product. The finalized product will be demonstrated through a video. The video will demonstrate the followings: concept, view of the product, how it tackles health issues.

We will put our priority in the part that demonstrates how it solves health issues as that is what the stakeholders will pay attention to.

b. Division of tasks

While all of us contributed to each task, some are assigned more to the member that has more experience with it.

Nora Kennech

Nora's tasks were mainly focused on the design and appeal of the product. This includes producing a CAD model in the prototyping stage and in charge of making the presentation video for the shoe.

Zi Yen Chang

Zi Yen is in charge of all presentation slides that were used for presentation. She contributed multiple design graphs and did resource gathering throughout the development. The components wiring layout of the product was done by Zi Yen too.

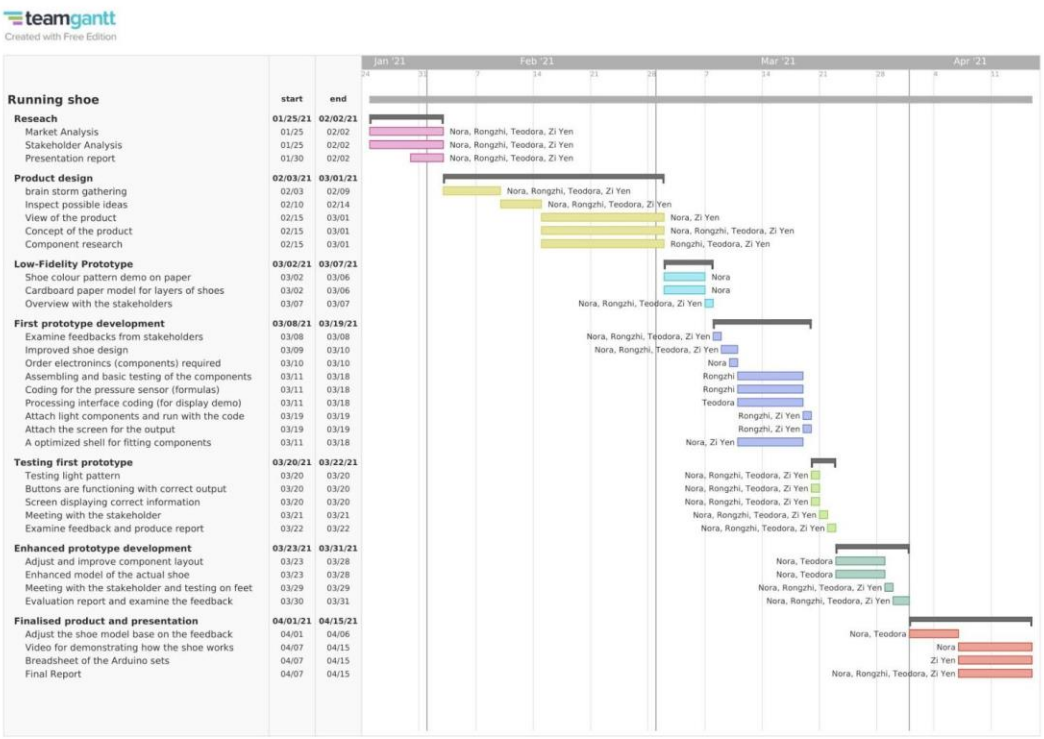
Teodora-Elena Toma

Teodora in charge of the programming for processing, which is the demonstration program for visualising the shoe. The demo includes the interface of the shoe and how the vibration pattern works.

Rongzhi Zhong

Rongzhi wrote Arduino code for technical aspects during the prototyping stage. The task required communication with Zi Yen as the wiring is crucial in Arduino.

c. Gantt chart



IV. The Design

a. Concept justifications and prototyping

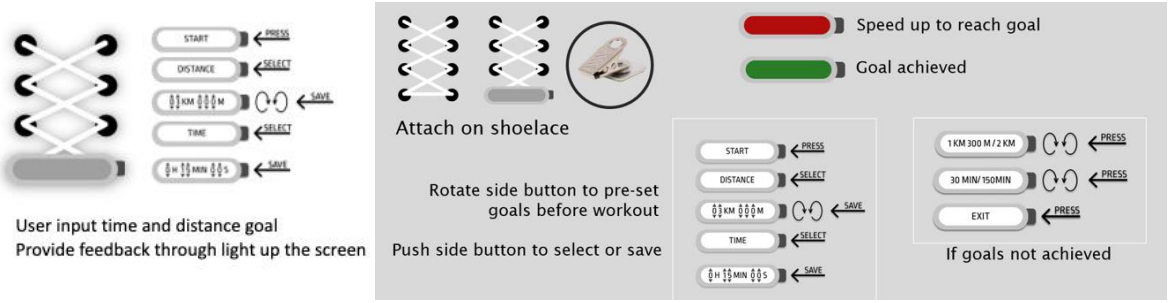
After coming to the conclusion that the best design approach to the brief and to the user profile would be a wearable device that targets to improve running performance, research has been done regarding running techniques and what are the best factors to track for performance improvement. The research led us to a list which included distance, time, pace, heart rate, blood pressure, oxygen

consumption, pronation, foot strike pattern, running symmetry, cadence, ground contact time and stride length.

Having a list of the most relevant ones, focus has been put on which ones would be more important to fulfil the user's needs and how these could be measured within the designated placement for the device: the feet.

In the first design iteration, distance, time and pace were considered to be the main factors to be tracked as it allows tackling overtraining and controlling improvement regarding timings.

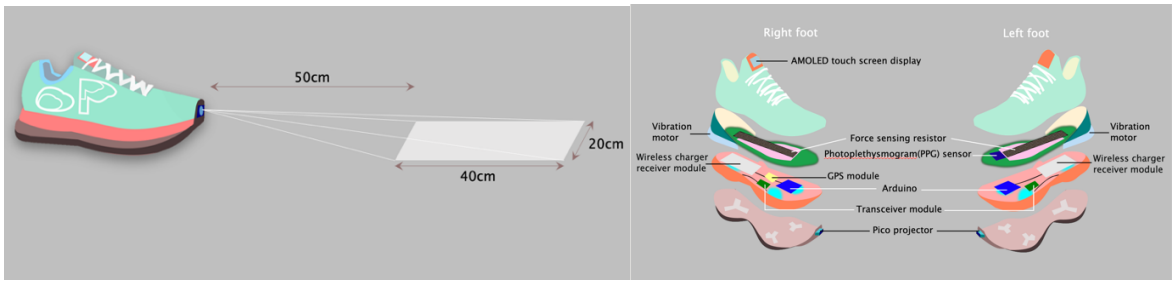
This design approach consisted of a small shoe attachable device that was used for tracking timings and distances by manually setting goals, using a side button similar to the ones digital watches have. It provides feedback through a light up screen that indicates the user when running goal is achieved or a change of the pace is needed, by changing light modes and colours. Post-training, the user could retrieve feedback regarding the training as which will be displayed on the device's screen.



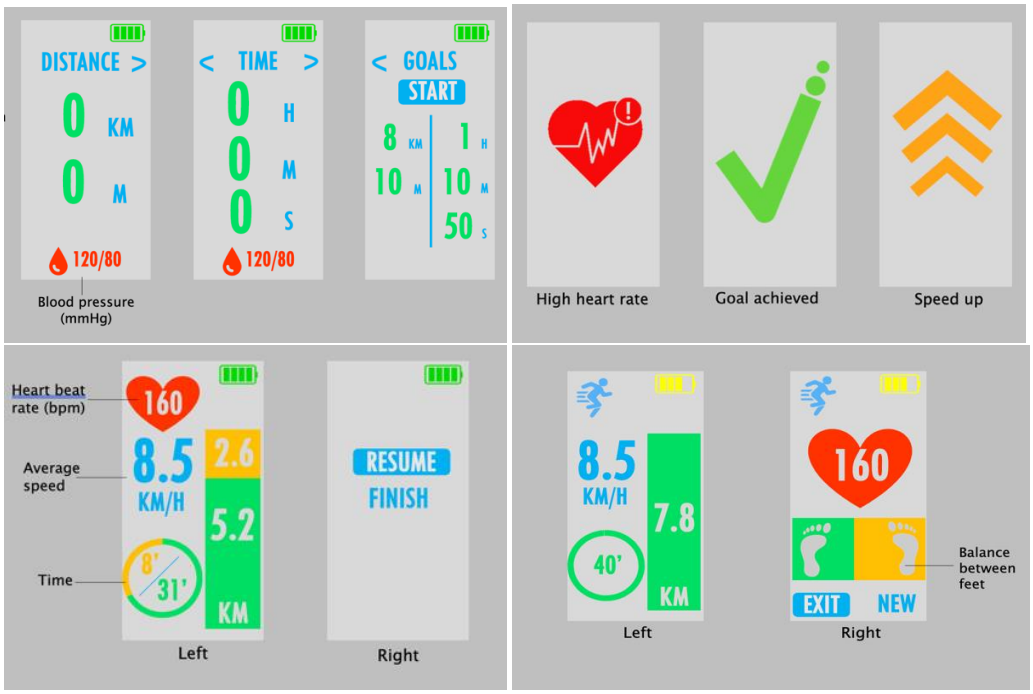
However, this display was small which would make it difficult to get real time feedback, and the factors that were being tracked were common as many devices have already included these, and running health and technique could not be monitored.

Therefore, in the second design iteration, heart rate, blood pressure and running symmetry were included as factors to be tracked, as these provide detailed data about the runners running technique and health. Running symmetry is a key factor to take into account as running asymmetry is one of the main causes of injuries in runners, since one side of the body is suffering from muscular and effort imbalance. For every 1% increase in imbalance, the running economy decreased by nearly 4%.(raining4endurance, 2020). Therefore, including this measure can help tackle more in-depth injury prevention. This also indicates to the user the needs of doing unilateral exercises.

Having more factors to track thus more components to include into the device we decided that the best approach would be making the concept into a pair of running shoes. This allows more space for component placement, a larger surface to display feedback, and a more attractive product for the user. The shoes included a pico projector as a way of displaying visual feedback via projection. The user can input their time and distance goals controlling a touch screen located on top of the shoe that controls the projection.



During the run different icons would be displayed to indicate increase of pace, high heart rate and achievement of goal. Post-run final distance, time, symmetry, and heart rate would be displayed as training feedback. To advise the runner to look out for feedback we incorporated a vibration component that would also indicate the end of the training.



Incorporating a Photoplethysmography(PPG) sensor under the toes would allow us to track blood pressure and heart rate. However, checking these health factors in real time would not help tackle issues like energy management or wouldn't allow analysis of running patterns more in depth. As these factors cannot be rectified during the run and would be useful only to know about the person's health condition rather than performance, we decided to not trach blood pressure and heart rate in our next design iteration.

Another aspect of the design that was impractical was the use of the projector display as it could be distracting and might not be as visible when running as the interface is shaking. Therefore, in the next iteration the visual feedback needed was replaced by another component.

All these changes were applied into the next stage of the design, in which health factors were not tracked, and would be substituted by aspects such as cadence and ground contact time, which help tracking the efficiency of the runner's technique, and allow to give guidance towards less variability in pacing, as it is proved that, pacing strategy during training is one of the main factors of performance success at competitions. Component placement was also questionable as them being inside the shoe sole would expose them to high impact levels and possible connectivity issues. In this stage they are placed in a waterproof compartment located in the outer part of the ankle.

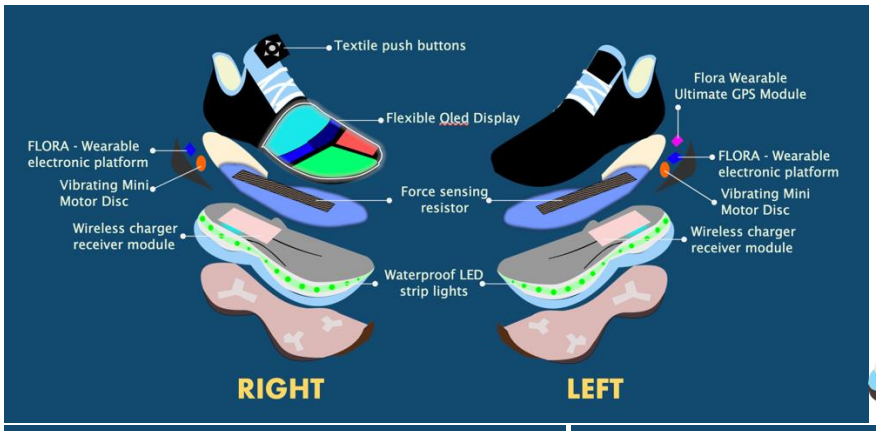
Looking into soft electronics and which ones were most appropriate for our wearable device was also needed to tackle our components and risks issues.

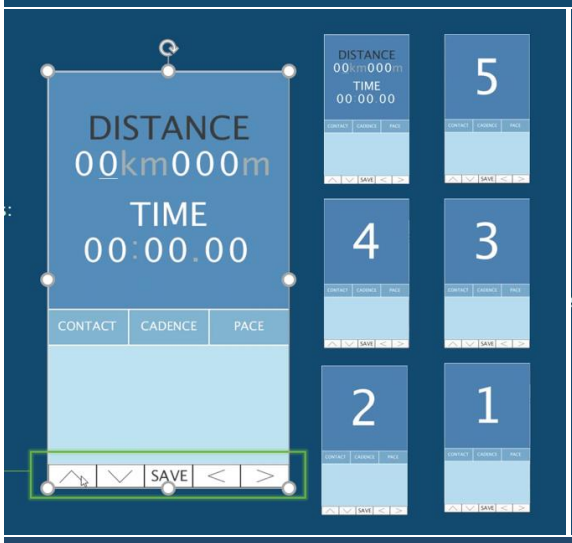
Thus, on the next iteration instead of the projector, a big OLED display would be placed on top of the shoes to display information before and after running. The user can input their time and distance goals by controlling the buttons placed on the shoe's tongue, and the visualisation on the symmetry difference would be delivered through an LED light strip which surround both shoes. Haptic feedback would be included as well in the form of vibration to provide with real time guidance to increase or reduce pace, and to indicate the end of training.

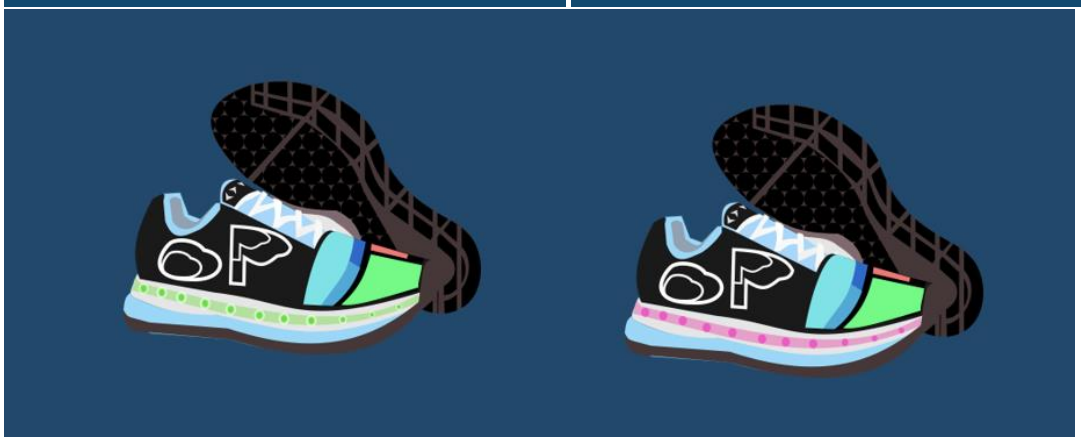
After inputting the desired distance and time goals the user will perceive a countdown of 5 seconds to indicate beginning of training. Once the user is running, the system identifies the need of changing pace, based on current measures of time distance cadence, and contact time. Then the vibration will start, allowing the current pace. The frequency pattern of the vibration would increase or decrease gradually until recommended cadence is achieved for the chosen goals.

For the distance and time, we assigned one side of the screen and one colour to each. The distance and time bars progress during the run until the distance bar is completed.

Post-run, the running symmetry feedback would be delivered by the led strips surrounding the shoe, having two different colours depending on the level of it indicating the more dominant foot.

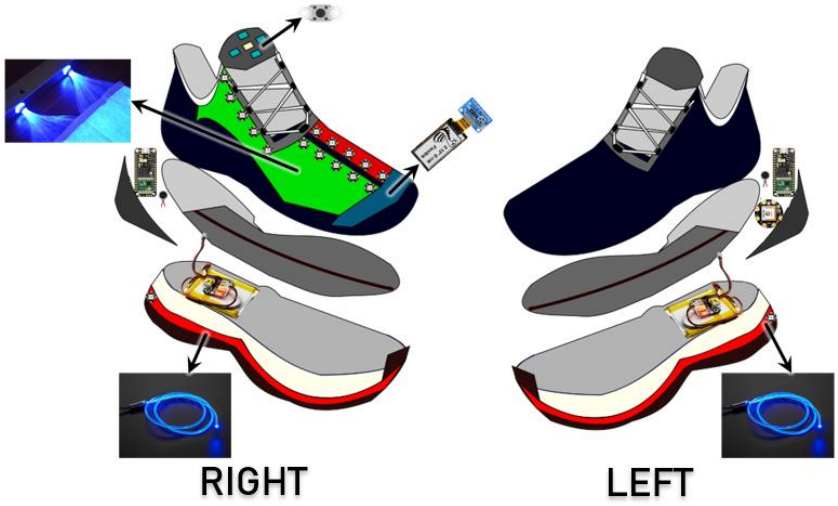




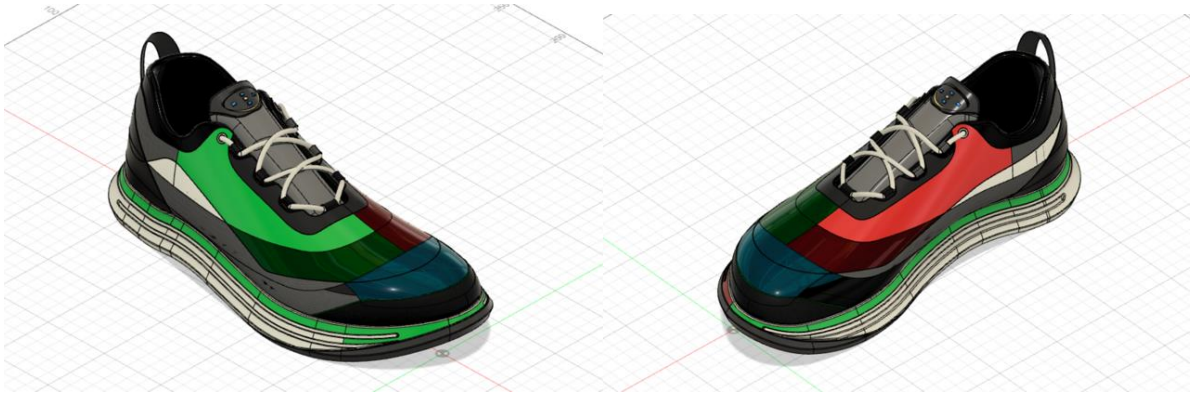


However, having such a big display was not practical neither for the user nor for the implementation, as it would be hard to adjust and sew into the shoe and would not be comfortable when running. Vibration patterns were also not defined very accurately which would cause confusion in the user when receiving feedback.

These considerations lead to our final design, which allows the user to set distance and timing goals via the textile buttons that this time control a small display (replacing the OLED screen), placed on top of the shoe. Real time haptic feedback is also given in the form of vibration to give guidance and help with energy management throughout the run as well as indicate goals achievement.



To display time and distance progress fibre optic LEDs placed on top of the shoe inside a protective waterproof case would light up progressively. The balance would still be reflected on the sides of the shoes but replacing LED strips with again fibre optic LEDs.



A vibration pattern was also created, guiding the user with vibration pulses into the recommended pace range for their distance and objectives.

The recommended range is the pace at which the user should have at different times during the run. It is calculated using the saved distance and time. The vibration starts whenever the user is out of this recommended range, whether he is running too fast to be able to store energy or too slow to even meet the saved time. The vibration starts with the user's pace firstly, and advances to the recommended pace range gradually, always checking for the user's response.

Therefore, there are three scenarios. The user may follow the vibration feedback. Therefore, the vibration pace and the user's pace gradually progress to the recommended range. In the second scenario, the user might also get even slower or accelerate further after the vibration starts. In this case, the vibration will constantly adapt and adjust from the user's current pace. Finally, the user might steeply accelerate or slow down, entering the recommended range much faster. In this case, the vibration will stop shortly.

That same vibration would indicate the end of the training with a continuous pulse.

Post-training the user can get information about average pace, cadence and contact time via the small screen, controlled by the bottoms placed on top of the shoe.

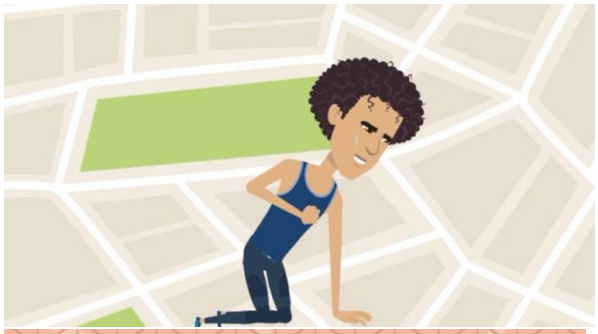
b. Design concept and scenarios of use

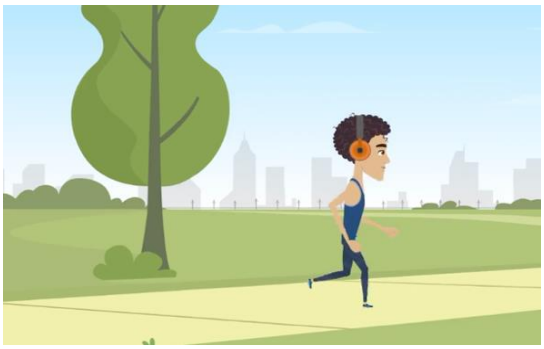
This product is targeted to experienced runners that have already settled running habits and methods; however, he still struggles to improve their performance. Normally training sessions are based on strictly measured distances, for which best timings are recorded to track improvement. Demanding and high intensity training sessions frequently cause injuries, as these lack supervision and pacing, which one of the biggest challenges runners face as energy distribution is proved to be one of the key factors of competition success , as many fail to increase or reduce their pace at convenient times during the race,

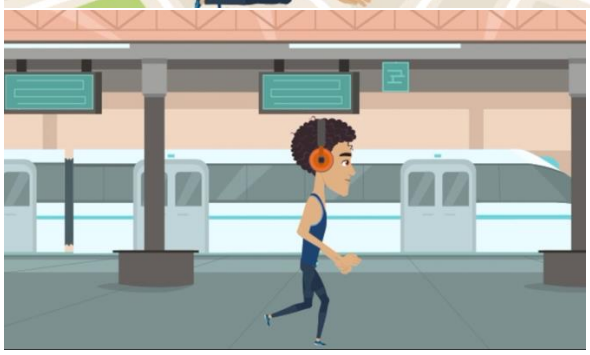
which leads to feeling exhausted early on.

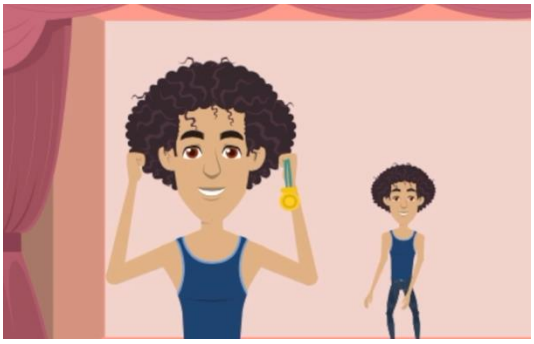
Our design aims to be a tool to help users with concerns like these improve their training and performance, based on the tracking of the mentioned factors. This includes setting a personalised distance and time goal for the training and providing guidance during and after the training, having total focus on the run without the need of having to look away for guidance, and receiving information-post run to motivate and track training sessions and prevent overtraining and possible injuries.

By tracking the best timings achieved for each distance the user performs we also enhance self discipline and motivation, and encourage overcoming personal goals. All of this, keeping track of the running technique, and avoiding overtraining, which are both a main source of injuries.

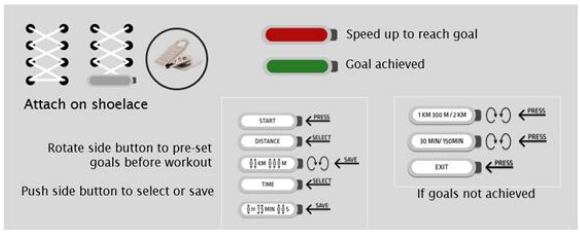


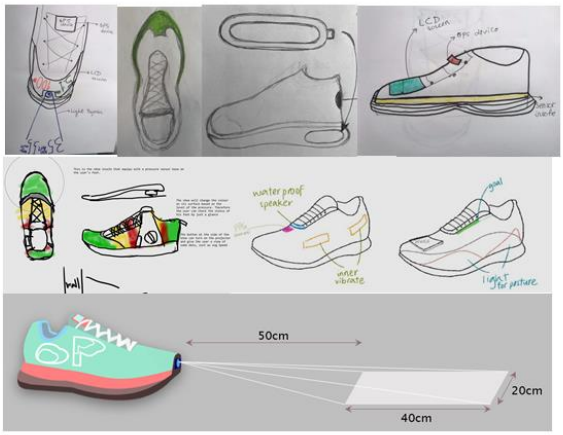


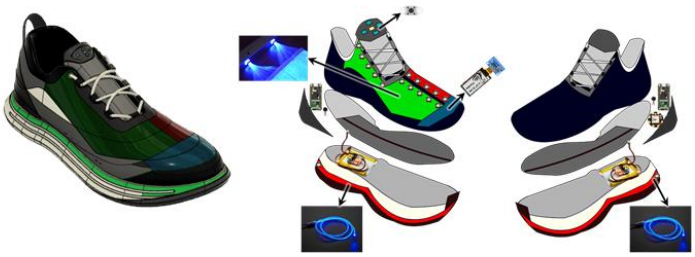




c. Sequence of prototypes







V. Evaluation Plan

The evaluation plan for the Optimizers prototype proposes a series of targeted tests in order to ensure durability, comfort, usability and efficiency for the user.

As a wearable electronic, Optimizers relies on sensors to respond to changes in the environment with the appropriate electric output. However, as trainers, Optimizers' components will usually be subject to shocks and damage, especially those placed insoles (e.g., the pressure sensitive conductive sheet). As each step during a run can trigger a shock equivalent to 3x the weight of the user body, the first concern to overcome when testing is the components protection. Therefore, a first evaluation should be conducted by the development team, consisting of identifying the material with the best capacity of absorbing impact. This includes testing components' functionality and efficiency over several days of use.

Optimizers relies on different computing portions to display the output. Firstly, the shoe sole uses the fiber optic fabric surface to display the running symmetry. Associated with improved running efficiency and speed, as for every 1% of asymmetry the energy requirements of running increase by nearly 4%, symmetry feedback clarity is a second important concern proposed to be handled by the development team. The aim is to evaluate the viable colour options to show the running symmetry: intensity of colour or a red to green gradient colour scheme.

Fiber optic fabric surface is also used to display the real-time distance-time feedback during the run. For long running distances, it is important for the user to visualize remaining running distance and record time during a break. The number of proposed Flora RGB Smart NeoPixel to shine up the fiber optic fabric surface should be alternated during the evaluation by the development team to ensure visualization efficiency for the user.

The second level of evaluation requires testing the product interface by new users. After presenting the Optimizers' capabilities, but without providing usage instructions, we propose to ask the users to perform a series of tasks and record the time taken by each of them to complete each task.

Timed actions:

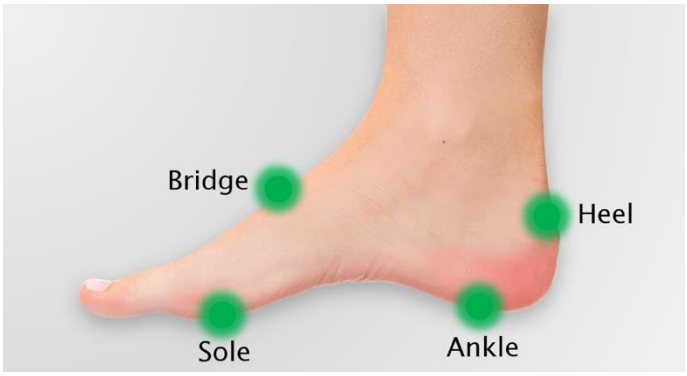
- Turn on/off the product (center button click turn on, long center button presses to turn off)
- Input distance/time (control buttons)
- Save inputted distance/time (center button click)
- Visualize screen feedback (horizontal control buttons)

Moreover, it would be worth pointing at each type of visualization: time-distance and assuring that common users understand what each of those represents.

The most important feedback of the Optimizers, however, the haptic during-the-run feedback, is proposed to be evaluated throughout different stages.

Firstly, it is crucial for the user comfort to determine not only the appropriate placement of the vibration motor, but also its vibration intensity. This would affect not only the product comfort, but also its efficiency, as it can disrupt the user's running at an over-amplified power and frequency, but it could also be unnoticeable for the user during the run, becoming impractical.

In order to identify the ideal vibrating motor position and intensity for the individual, experienced runners would be asked to run for 100m with different placements of vibration and intensities, and rank from the most comfortable and noticeable experience to the least effective one. For this, a series of placement locations shown in the figure below have been chosen for testing.



Moving on to the product efficiency, once a final placement and intensity of the vibration motor has been concluded from the previous evaluation, we plan on observing the runners' behaviours and performance on longer runs, wearing their usual running shoes first, and the Optimizers, for the second trial on a different day. The aim of this evaluation is to compare the difference between a user's performance when using the two pairs of trainers. However, during this phase numerous trials have to be made to adjust and understand how effectively users can respond to the changes in the vibration speed to maximize the efficiency of the pace guidance.

For this, during Optimizers running trials we intend to record how frequently the motor functions throughout the run, what is the variation of the pace throughout the run, and most importantly, how long does the user take to adjust to the recommended pace range when out of range. All of this data can be generated by altering the product code and printing the results.

Once a user experiences the full Optimizers capabilities, the final stage of the proposed evaluation considers using interviews to receive final reviews on the prototype. The following questions would be asked to decide on possible changes needed in the next product development stage.

Questions:

- Is the text on the screen large enough to be seen comfortably?
- Do you need more time between saving the goals and starting the timer?
- Can the running symmetry be easily interpretable?
- Are the shoes heavy?

Furthermore, users would be asked to rank the interaction with the following Optimizers functionalities:

- Input buttons (Control display)
- Fibre optics fabric distance-time feedback
- Running symmetry feedback
- Pace guidance (Motor vibration)

VI. Discussions and Conclusions

a. Strengths and weaknesses

Smart sport equipment sector is adding new possibilities to conventional sport devices by enabling rapid analysis of data to allow virtual coaching. Therefore, the Optimizers has established a defined set of possible product goals: provide real-time guidance to user during the run to enhance training efficiency, prevent overtraining and provide valuable feedback.

Hence, as a device created for performance runners who compete for certain running distances and often record their timings, the first product prototype was based on a small attachable device,

requiring distance and time input from the user to calculate recommended pace. This prototype relied on light colour for feedback, flashing the screen whenever the user's speed would need adjustments.
Further research convinced us that runners are never advised to look at their feet while running, as it affects their running posture, and their running efficiency further. Our first solution to this challenge was the Pico projector. Its visualisation capabilities convinced us that more running aspects could be displayed, leading to a component's heavy product. Moreover, even if the feedback is projected further away from the user, it could still cause the use distress provoked by the risk of overlooking it.
The final Optimizers prototype proposes to overcome these weaknesses by using haptic feedback, which, adjusted to the right intensity, cannot be unnoticed by the user; and by taking full advantages of the indispensable components to provide valuable post-running feedback.
This could allow:

- Improved running economy by following symmetry feedback for unilateral exercises.
- Effective energy usage through following the haptic feedback to maintain recommended pace.
- User's best timings storage for training distances.

However, the proposed prototype could reveal the following weaknesses:

- Because of the different number of components of each shoe, the weight difference could be strongly noticeable.
- Product might run out of battery at unexpected times, as current design does not provide any insight into the battery level and when it needs charging.
- Time and distance feedback might cause unwanted user behaviour: the user might start to look at their feet more often to check progress.

b. Future work

If there is a chance, OptimiZer can be built physically and testing can be done to modify some design decisions. In terms of shoe maintenance, an easier method of assembling the shoe can be considered so that disassembling and reassembling the shoe can be done easily. In the design, a lot of aspects are included, therefore, more components are used to fulfill each aspect. Focus can be put on the aspects that indicate improvement, for example, the running symmetry. Besides, making the shoe that does not need to input information before running can be tried and considered as it takes time to get used to a new habit. Currently, the design provides all feedback using the shoe and the user needs to look at his shoe to get visual feedback. Having another interface or application to show the feedback can be considered, for example, using his smartphone or connecting with a watch to see the analysed data. Other than that, rather than having haptic feedback in the shoe which might not be noticed when the person is running, sound feedback can be used by connecting to a pair of earphones. In short, many possibilities can be explored while new issues will also arise at the same time. It is important to keep testing and get feedback from the user so that the design can improve and suit the user's needs.

VII. Appendix 1

Evaluation Criteria	*Nora Kennech*	*Rongzhi Zhong*	*Teodora-Elena Toma*	*Zi Yen Chang*
Attends remote group meetings regularly and arrives on time.	4	4	4	4
Contributes meaningfully to the project design and development.	4	4	4	4
Completes their assigned tasks in a quality manner and on time.	4	4	4	4
Demonstrates a cooperative and supportive attitude.	4	4	4	4
Maintains a constant communication with the rest of the group outside of lecture and lab sessions.	4	4	4	4
Contributes significantly to the success of the project.	4	4	4	4
TOTAL	24	24	24	24

Group work main Successes:

- Group members are all active and contribute to this project.
- Meetings have been organized to finish the last part of the project, which is the final report and the animation video.
- It took some time to learn how to do an animation video, but the video that introduces OptimiZers has been done by Nora while other group members help her by providing ideas.
- The final report has been divided into different sections where each person in charge of a few sections

Group work main Challenges:

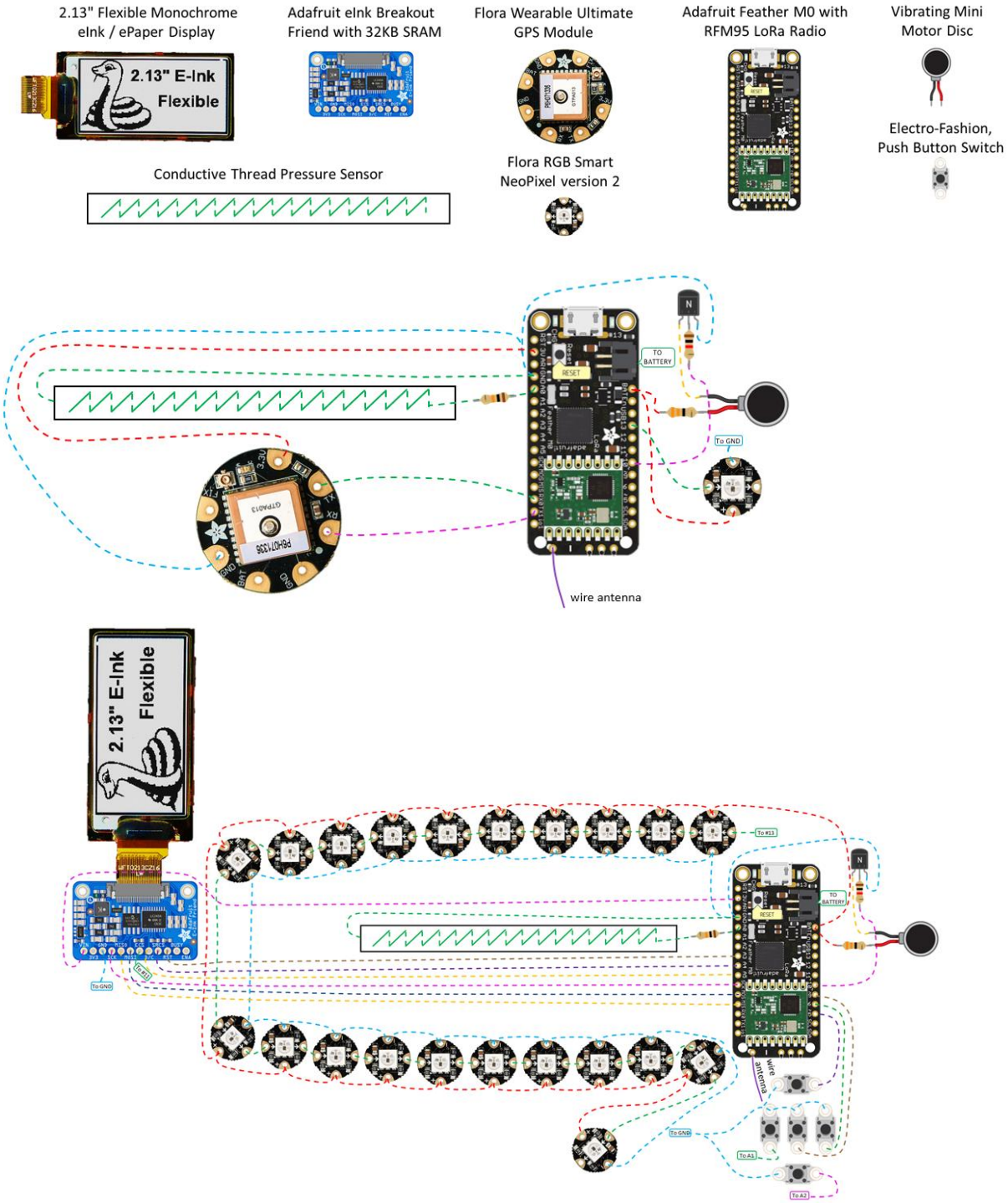
- The final report has been done separately, which causes some repetition of context in different sections. Therefore, checking needs to be done constantly to avoid that.
- We didn’t have the chance to build out the prototype physically, which makes some part of the report difficult to evaluate.
- As the report needs to be submitted during the last week of the semester, which is the same as all of the other modules, fewer meetings can be held. Therefore, asynchronous communication is important to update each other's progress.

VIII. Appendix 2

a. GitHub repository

https://github.com/Teodora2508/Creative_TT

b. Breadboard layout



c. Prototyping evidence

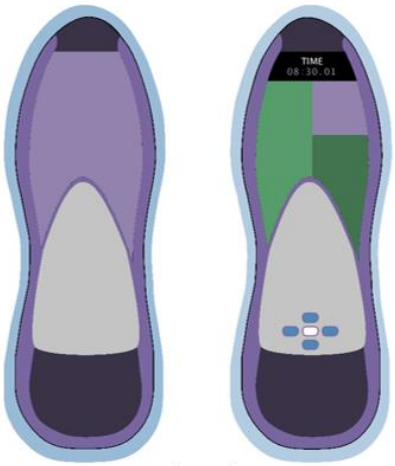
To demonstrate how OptimiZer works, Processing is used to visualise the look of Optimizer before and after running.

Before running

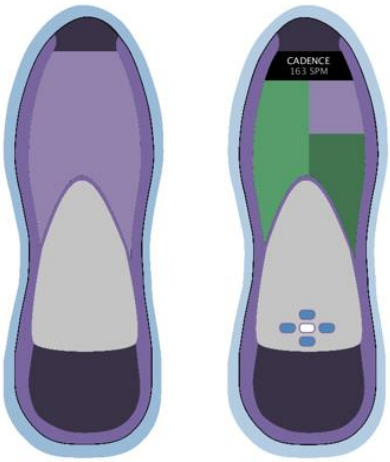
Distance Input

Time Input

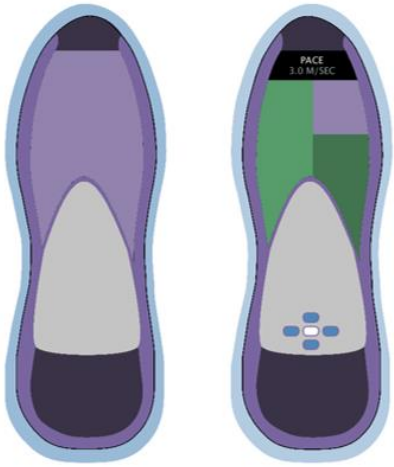
After running



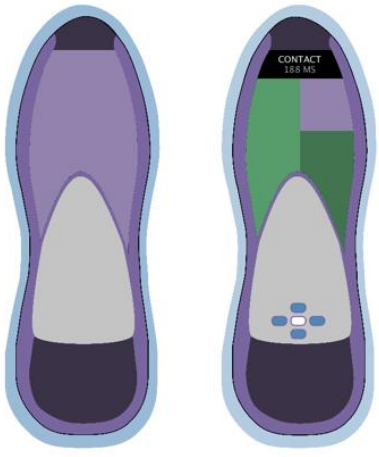
Time Taken



Cadence



Pace



Ground Contact Time

d. Video Link

https://www.youtube.com/watch?v=CWS82SdhJrU

IX. References

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