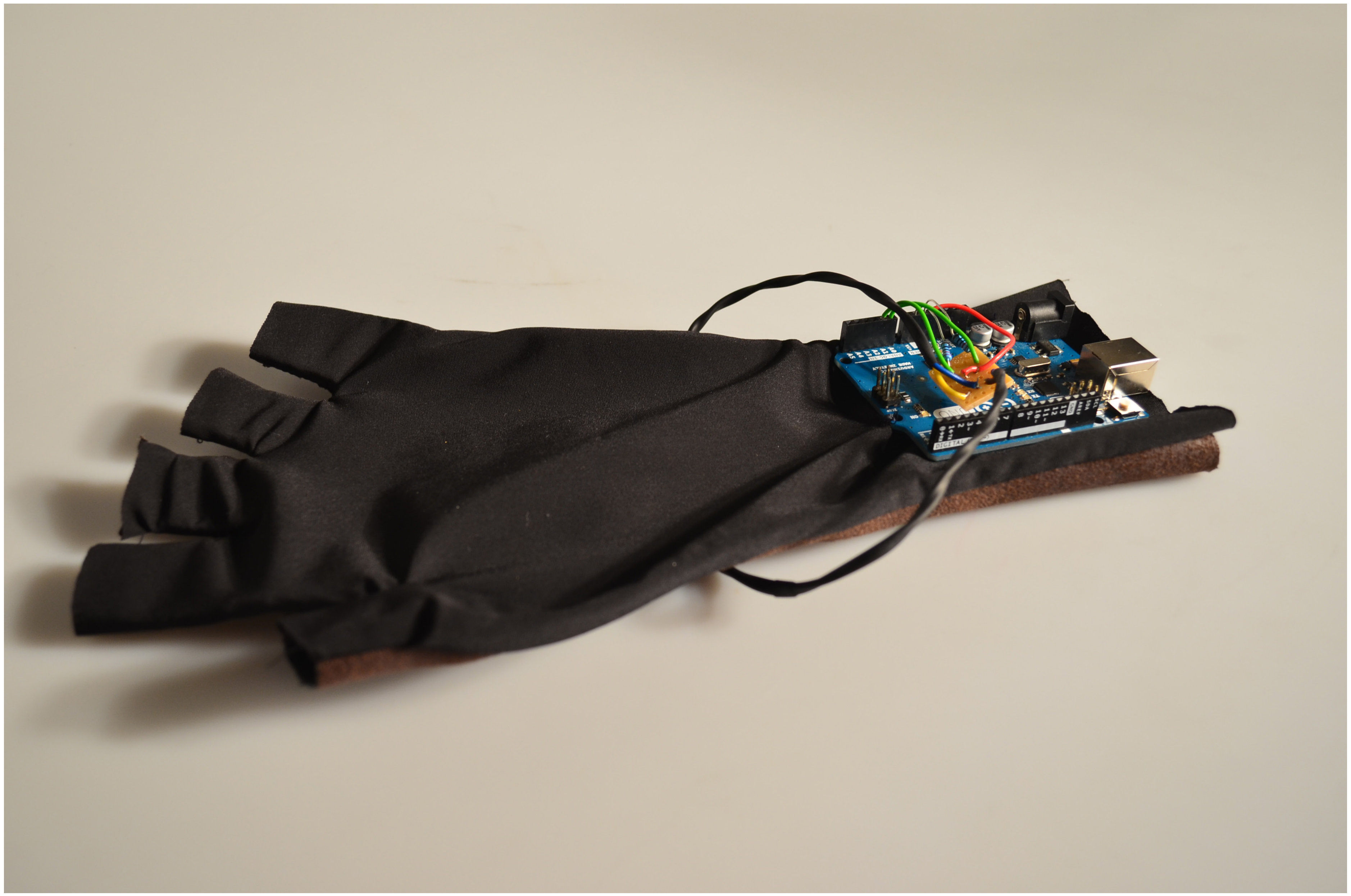
DGB111

Making Sense of Sensors



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INTRODUCTION

This elective has been one that required us to devise a sensor system for the human body to help people exercise, sport or keep a healthy state of living. We each started this elective with similar but somewhat different learning goals in mind. When the project goal was revealed to us, we started the ideation process by each generating different concepts involving different sensors we can use. After analysing the concepts, a decisive choice had to be taken in consideration of what sensor(s) we want to work with, how feasible and how difficult the concept can be.

TABLE OF CONTENT

| INTRODUCTION 2

| CONCEPTS 3
FIRST CONCEPT
SECOND CONCEPT
THIRD CONCEPT

| SELECTION 7

| REALIZATION 8
THE SENSOR SYSTEM
IMPLEMENTATION

| DATA AQUISITION 10

| INFORMATION ANALYSIS 11
FORCE SENSITIVE RESISTORS
STRAIN GAUGE

| CONCLUSIONS & IMPROVEMENTS 14

| PERSONAL REFLECTIONS 15
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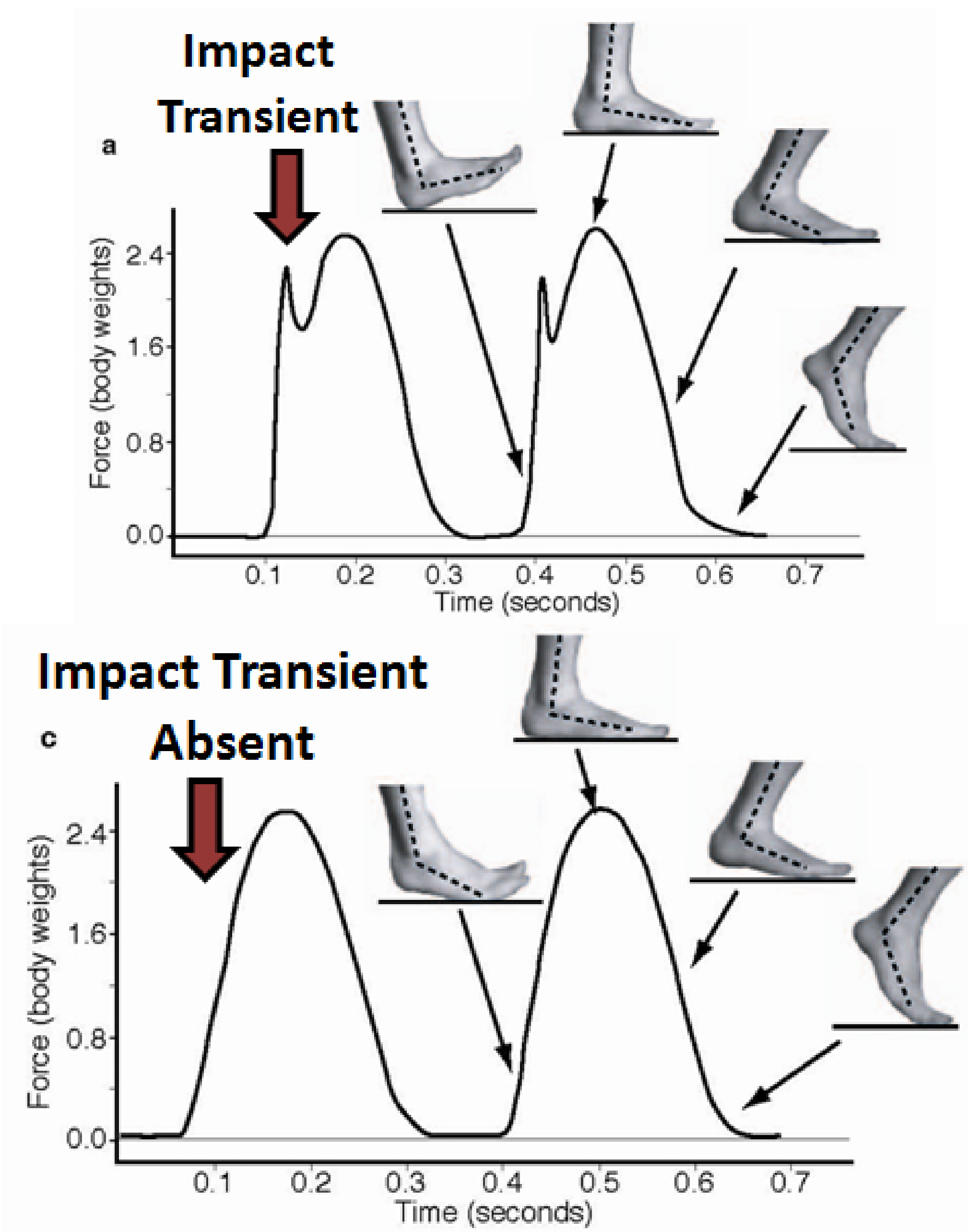
CONCEPTS



Lieberman DE, Venkadesan M, Werbel WA, Daoud AI, D'Andrea S, Davis IS, Mang'eni RO, Pitsiladis Y. (2010) Foot strike patterns and collision forces in habitually barefoot versus shod runners. Nature 463: 531-5.
http://www.barefootrunning.fas.harvard.edu/4BiomechanicsofFootStrike.html

FIRST CONCEPT

The goal of this first concept is about using the right technique while running and make runners aware of it to prevent injuries. By measuring the position angle of the foot strike on the ground and measuring the impact force while running, the position of the foot during the strike can be read. There are two different ways of striking your foot. Heel striking and forefoot striking. If running barefoot it is better to land on your forefoot than on your heel. The graphs at the left shows why. The impact with heel striking is less fluent than with forefoot striking
Nowadays running shoes absorb most of the impact force on the heel but it is still better to land on your forefoot.

The sensors that can be used are the following:

Force Sensitive Resistors | The two force sensors will be implemented in the insole, one under the heel and one under the forefoot. In this way the highest impact force can be measured and in which order.

Strain Gauge | The strain gauge will be implemented in a sock to measure the position angle of the ankle when landing.

Angular sensor & Tilt sensor | The angular sensor and the tilt sensor can measure the position angle of the foot strike but as it is quite big, the way of implementation is a difficult issue.

SECOND CONCEPT

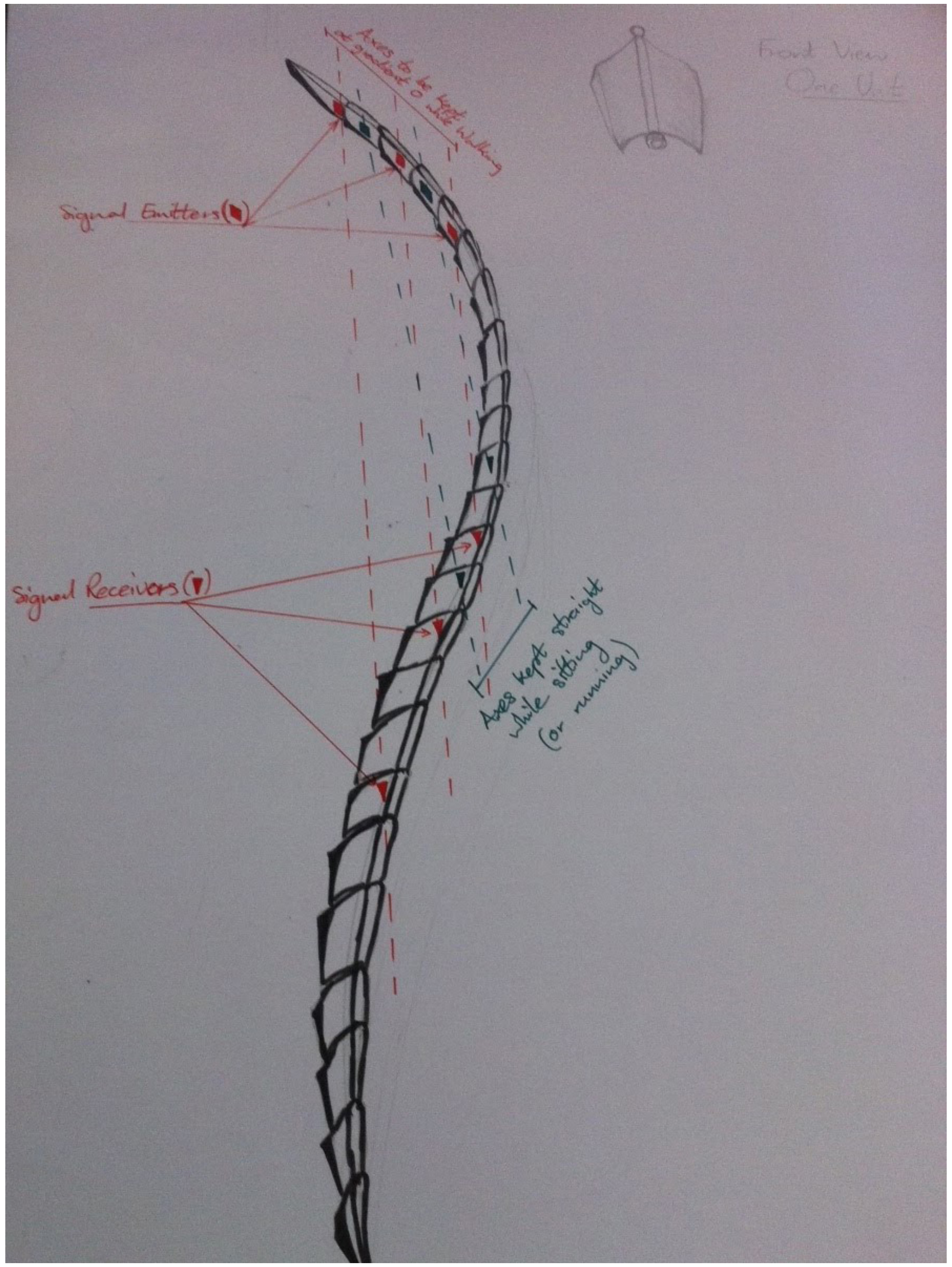
When you go for a bike ride on a Sunday morning you see several kind groups of cyclists. You got for instance groups of older guys who think they still can become a pro cyclist, they have really expensive bikes and gear, but if you see the position on their bike it is really awful. Their arms are overstretched or their wrists are too much
bended, they arch their back to much. This was the starting point on doing some research on cycling injuries and how they are related to bad posture on your bike.

Research[1] showed that the position of the hand on the handlebars could cause several injuries. These injuries go from a painful wrist to complains in the lower back. The goal of this concept is to prevent at least one of these injuries. The concept is been concentrated on the wrist area.

Wrist injuries can have several sources; it could be over bending your wrist and when your hands don't have the right position on the handlebars. If you do not have the right position it could lead to carpel tunnel syndrome.

In this concept we want to measure how much you bend your wrist and where your hand is positioned on the handlebars. We are going to this by measuring the angle of the wrist with a strain gauge, and for where your hands are positioned on the handlebars we are going to use force resistive sensors these can measure where and how much
force is being given on the handlebars.

[1] Bennet. S (2009) cycling injuries. retrieved from https://www.sportsmed.org/uploadedFiles/Content/Patient/Sport_Tips/ST%20Cycling%202-18-11.pdf



THIRD CONCEPT

People exercising or even doing usual daily activities everyday need to have a correct posture while doing so, else it will bring more strain to the body rather than helping the person getting more healthy. Sitting, standing or walking continuously in one particular position might become more problematic if the posture in question is a bad one. It might bring damage to the backbone joints, neck and shoulders and even the spinal cord, which can cause different types of back pains and the even adding to stress levels of individuals.

Things the Backbone support can provide:

Helps good posture | The backbone support prevents the user from going into a bad posture frequently, and reminds he/she to get back into a good posture when not doing so. The ways to provide this feedback can be in various ways, such as sound or light emission, or even feedback on screen or phone.

Not visibly a very active exercise | This concept does not require you to become active with it and do movement. It is something that reminds you about your posture when the latter is not right, and prevent u from getting into those bad postures. Most of the times the user might forget it is there, thus not disrupting the focus they need in any type of work or exercise they are doing, making it more appropriate in such cases. Therefore, the user does not have to actively participate in what the product is doing or needs to do.

Work the abs and lower back muscles (among others) | Doing movement or exercises implicate a lot of work within the body muscles. But how can one manage to keep up to this amount of body work while being continuously in a stagnant position or for instance, work abs and back muscles while standing, sitting, walking or running. Keeping the back and neck into the right position, especially for those people who usually have bad posture, requires a lot of muscle work and energy even while being still. Thus keeping a nice rate of blood flow and body reaction, keeping the body internally active.

Back pack support | Some people often have back pack they need to carry even while exercising(running long distances for example) which, even if not that heavy, does contribute to potential back pains. This product can be designed to help with supporting the back pack as well, in such a way that its mechanism shifts the pressure force points due to the weight of the back pack from the shoulders or back to the product itself.

Can be worn | The product is a wearable one, which bring both certain advantages and challenges. It might be annoying to constantly have something in your back preventing you from going into a bad posture. If this concept is brought forward, a lot of work would be required in making the experience to the user as unnoticeable and not disturbing as possible, especially while exercising. It should also not temper with the general usual movements of daily life. And being on the back, it might be in the way between the back and back seat for someone sitting. However, being a wearable design, if designed correctly, thin enough and mostly unnoticeable for both user (with daily movements) and people around, it might be helpful in blending into the daily life atmosphere. It does not require users to imply a major change in their daily life. One just wears it and go to work and exercise afterwards as he/she normally does. It only provides feedback when required (when in bad posture). It thus does not disrupts the usual daily exercise and routine.

Can be used while sitting, standing, walking or running | As state in the previous point, the product is a wearable one. Therefore, it is always on you during daily life without you really needing consciousness of it. Thus, one can use it anytime, while sitting, standing, walking or even running. And it helps the people keeping a good posture in all case, and for most, if not all, activities they engage in daily. There can be different positions available, using different or the same sensor.

Sensors that might be used:

Gyroscope
Use 2-3 for the different positions (sitting, standing, running).

Tilt sensor
Triggered by the angle of tilting by a curved back posture.
Measures for vertical axis (Normal axis).
Need 2-3 for each turning (tilting) point.

Strain Gauge
Measures the increase in strain forces between the backbone parts.
Need many as the stress and strain can be almost anywhere along the backbone.

SELECTION

During our presentation, it was mentioned that is was quite hard to realise the concept about the right running technique. It is hard to get good measurements as the movement of the foot while running happens fast and you even need to measure it at least ten times faster to get a good measurement.

The other two concept were easier to realise as there were no quick movements. We chose to work on the concept about the position of the wrist while cycling.

We thought that the concept about the backbone was harder to realise as we needed more sensors and thus a bigger system. We also weren't really sure if the measurements were going to be useful as there are many positions of the backbone.

We also knew already how we wanted to measure the position of the wrist and how to implement it into a design. That made it clear to us, that we wanted to continue with the wrist concept.

THE SENSOR SYSTEM

The sensors we chose are two force sensitive resistors and a strain gauge. We call them sensors but they are actually variable resistors. By measuring the difference in voltage we can collect data from them.
The two force sensitive resistors are to measure the force on the hand palm. With an increase in the force applied to the sensors the resistance decrease. To get data we measure the difference in voltage and with the data of both of the sensors we can conclude on which side of the hand palm most of the force is applied.
The circuit we made can be seen in figure 1.

The strain gauge has a more complicated circuit. We want to measure the angle of the wrist to see if it overstretched or not. A wheatstone bridge is implemented in the system to convert the resistance change to a voltage output. As the range of the voltage is too small to get good measurements, an instrumentation amplifier is needed to make this range bigger.
This circuit is showed in figure 2.

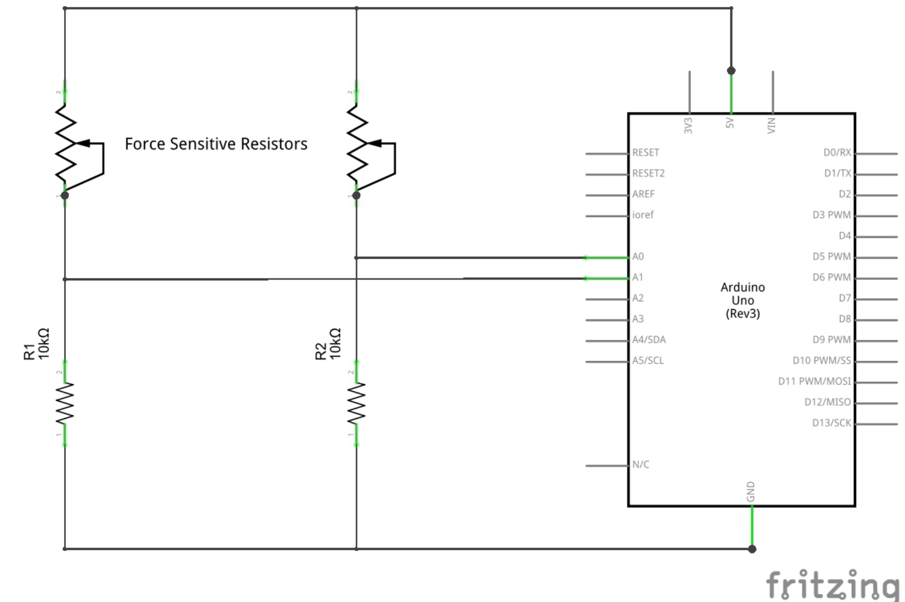


figure 1: Force Sensitive Resistors circuit

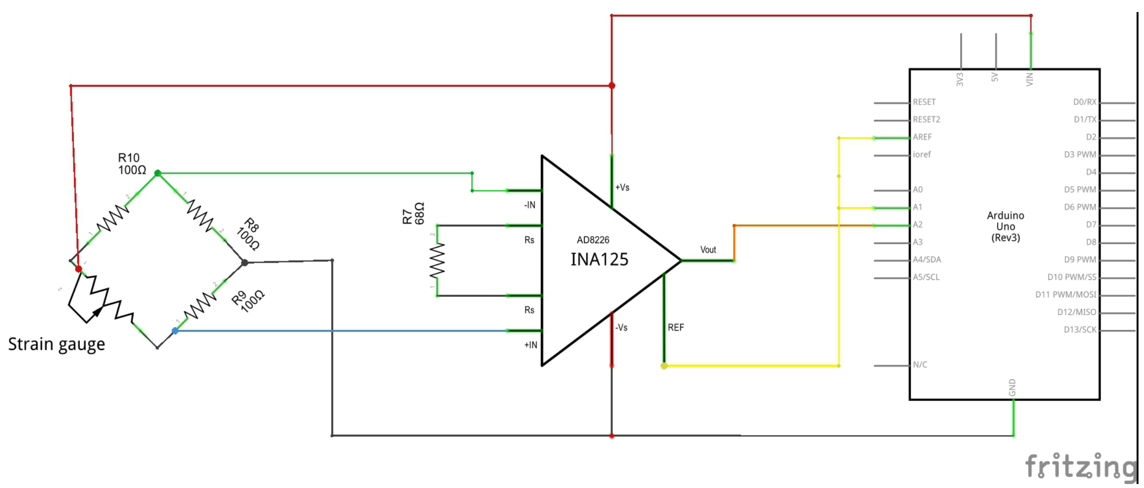


figure 2: strain gauge circuit

IMPLEMENTATION

We want to integrate this circuit, where the arduino uno will be replaced by a microcontroller, into a cycling glove. The two force sensitive resistors will be placed in the palm of the hand and the strain gauge will be placed on the inside of the wrist (see figure 3).

Faced difficulties |

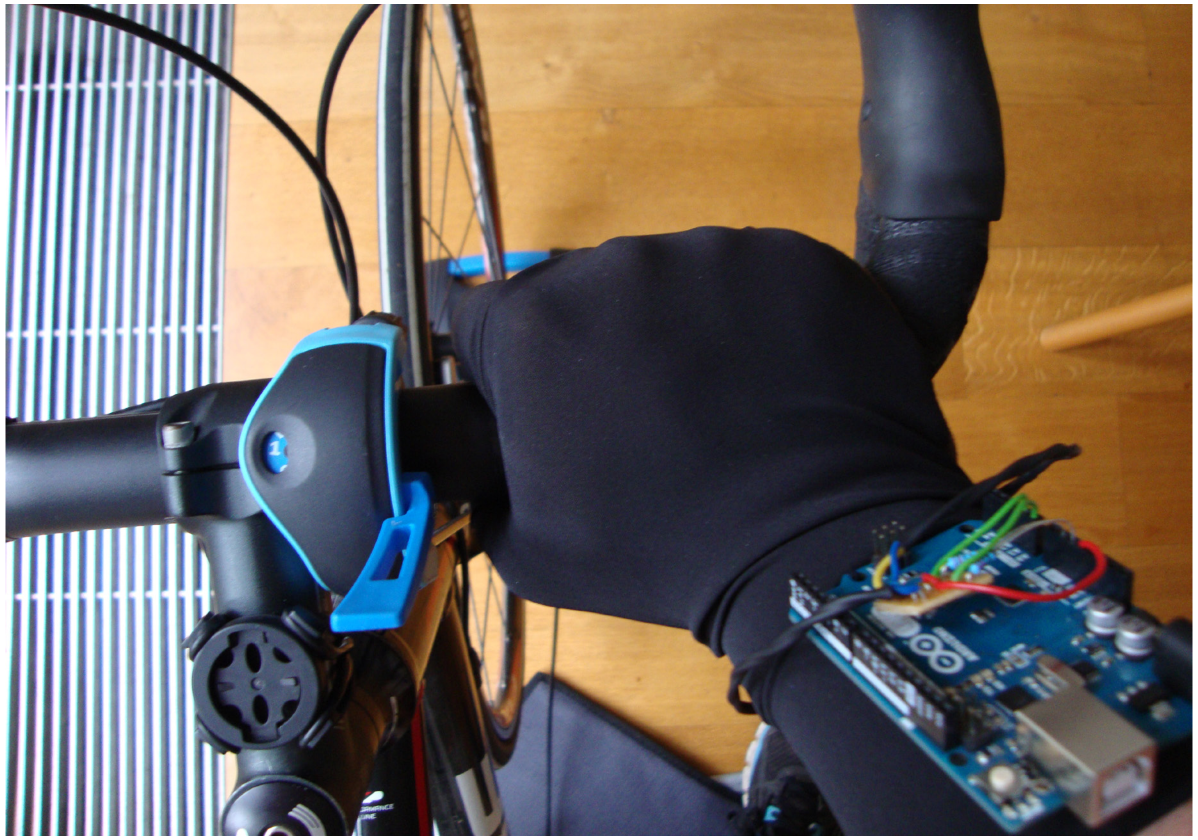
The Force Sensitive Resistor worked as expected, and was not hard to implement in the glove, as the materials used for the glove is not too force absorbent and the sensors are on the palm of the hand, which would be between the hands and the handle in such a case. Therefore causing the force sensing to run smoothly. Only the exact placement of the sensors caused some trouble. The first prototype had too much space between the two FSRs that in some positions the handlebar would be exactly between the sensors. We adjusted this in the following prototypes.

The strain gauge however was a more difficult one to implement. Firstly because due to the type of sensor itself, a stretch is required to be generated within the gauge in such as way that it correlates to the hand movement; meaning, the strain gauge has to stretch proportionally to the hand wrist movement to give the correct data sets and provide feedback. The material used in the glove however did not have enough grip to hold such a sensor, and the latter would just slip away in between the layers of the glove, causing no changes in voltage at all.

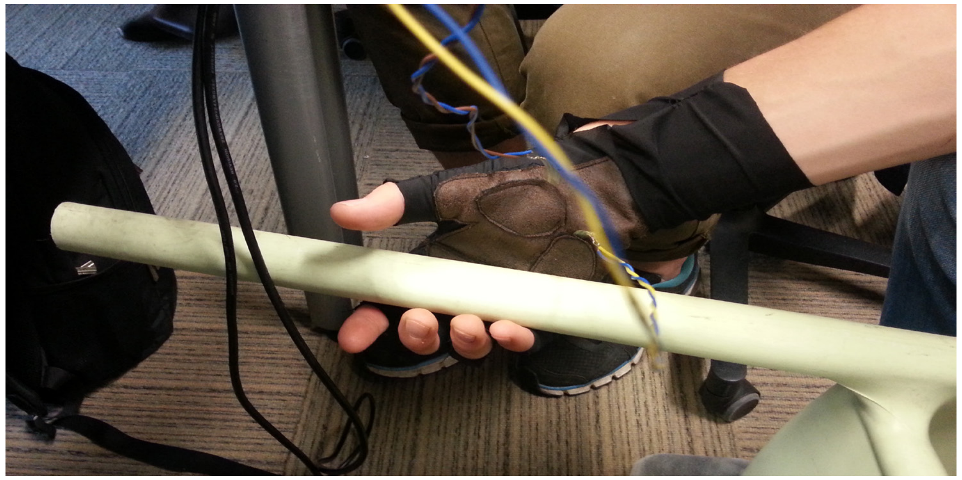
Secondly, the strain gauge which ordered, was not large enough for our purpose in the glove. Having a strain gauge smaller than required brought more difficulties in implementing it into a glove and

still have a correct stretch rate for valuable data. Although the stretching did provide values, and the circuit working, the voltage differences were not high enough for our desired purpose. One thing that could be done in this case scenario is to “amplify” the stretch of the small strain gauge using a high frictional surfaced material, or fixing it somehow on another material that would still stretch similarly but involving a larger surface of stretch. But the correction methods might be risky, which is not advisable for a short period of time left.

DATA AQUISITON



Next to all the components in the circuit, a memory card or such was needed to save all the acquired data. This part was really complicated, because several options were possible. After a few trade-offs a SD-module had been bought for data storage. Regrettably the SD-module was very rare and not a common use within the faculty, even E-lucid was not able to help. So another option has to be thought of. Fortunately another group within the course advised us to try EEPROM, an internal storage of data on arduino itself. The programming part was not able to work and save all the values which needed for an useful visualization. Finally, E-lucid could help, but now with useful outcome. They adviced to use the program 'Coolterm'. This is a program which is able to store all the data from the 'Serial Monitor' to a text document. It was a solution for the first data acquisition, but eventually use of wirelessly data storage, which is not possible with this solution, was necessary. This should be possible with microSD cards for a next step.



INFORMATION ANALYSIS

FORCE SENSITIVE RESISTORS

Force sensitive resistors
After obtaining data, from our first sensor set working, it became a necessary following step to determine how the data was corresponding with all the different attributes. The selection of sensors and the rest of the circuit had to be corrected if needed through visualizing data. During the first check of the data cliff was immediately visible in the histogram(figure 4), which had to be prevented. This was a sign that the sensor probably measured values abroad its reach. This understandings leaded to some resistor changes in the circuit. By changing the resistors with a factor 10 the right histogram(figure 4) was obtained, so the circuit was installed correctly.

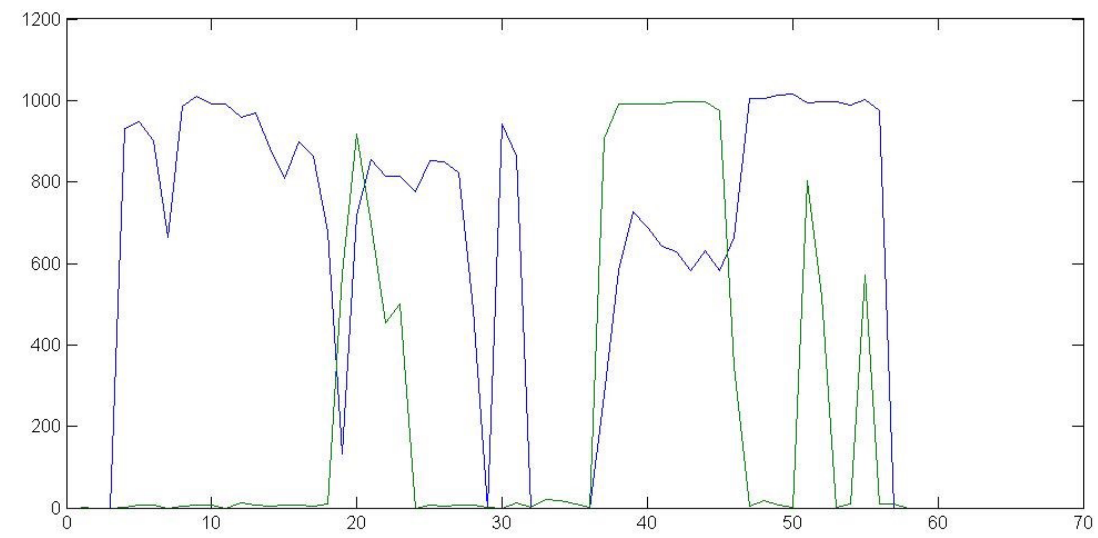


figure 3: Graph of first test

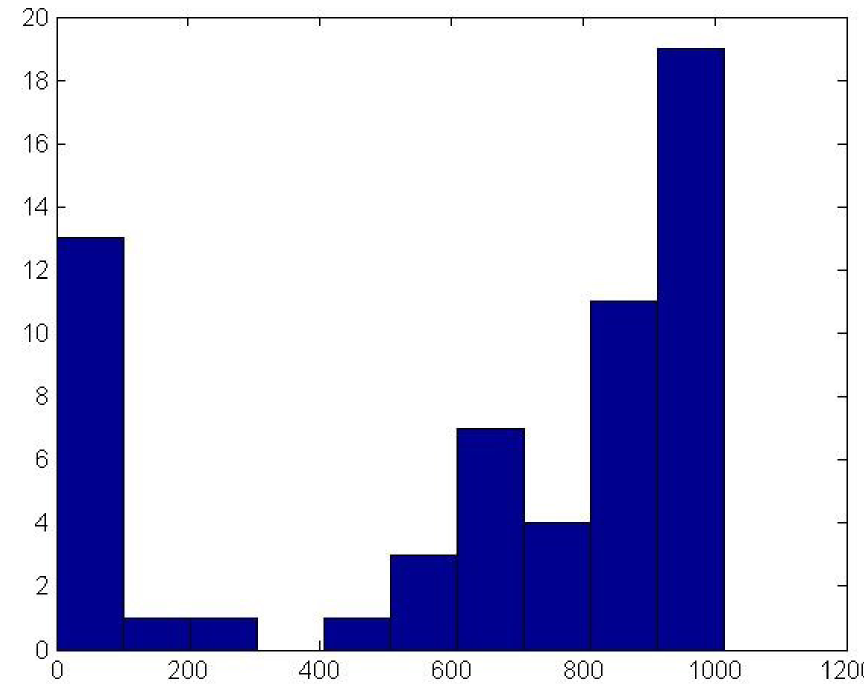


figure 4: Histogram of first test

INFORMATION ANALYSIS

FORCE SENSITIVE RESISTORS (2)

The attributes which had been measured are the different positions on the bike to steer. In the first set of the second test measurements of both sensors' values increase. That first set is explainable because of the hand position which is exerting force on both sides of the hand palm(where the sensors are placed). The test person is biking with his hands on the front bar of the steer. Right after that the test person is accelerating with his hands on the ring of the steer, where he exerts more force on his hands when biking with a higher speed. Right after this acceleration the test person brakes a few times in a row, which is easy to recognize in the extremely fluctuating part nearly at the end of the test. Then he stops cycling. Overall can be concluded that the graph is fluctuating a lot, but this is reasonable because of the shaky effect when cycling. Furthermore after each transition a small gap is visible. This is because the user changes his position.

figure 5: Graph of second test

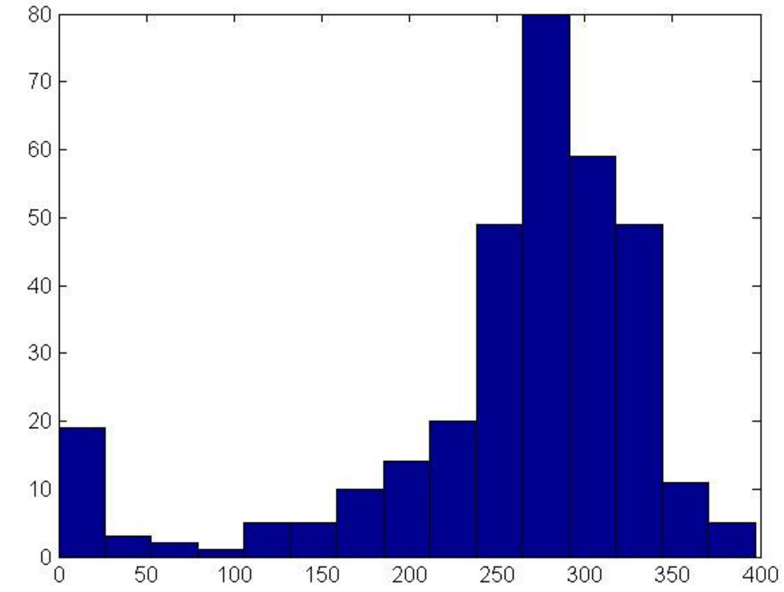
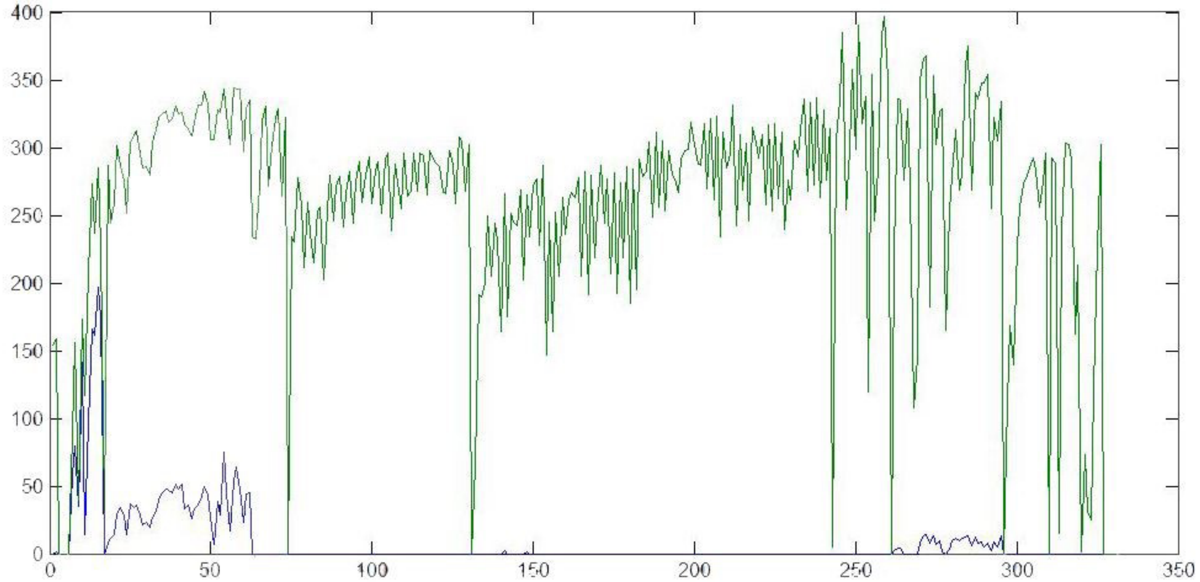


figure ?6 Histogram of second test



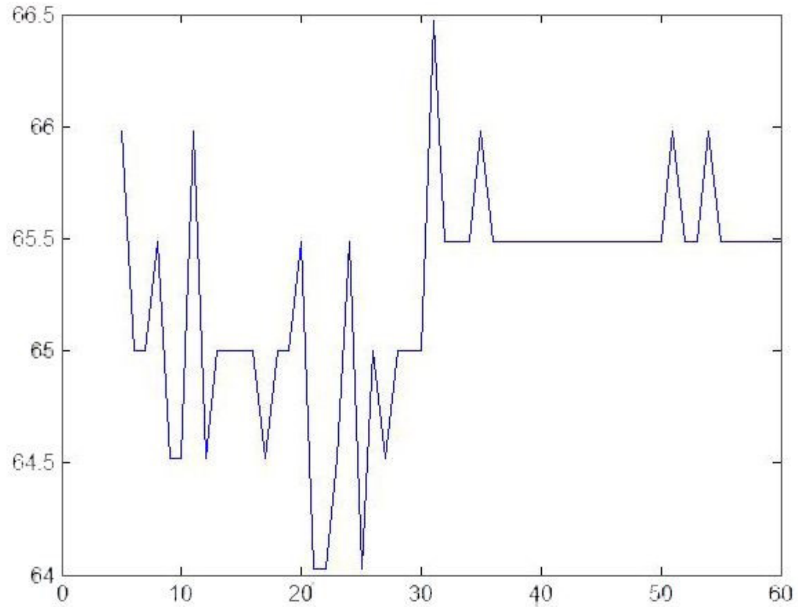


figure 7: Graph of strain gauge test

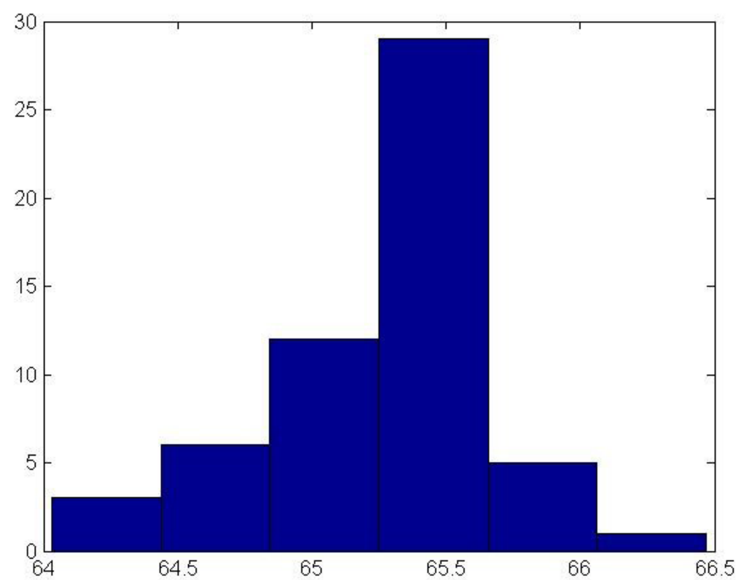
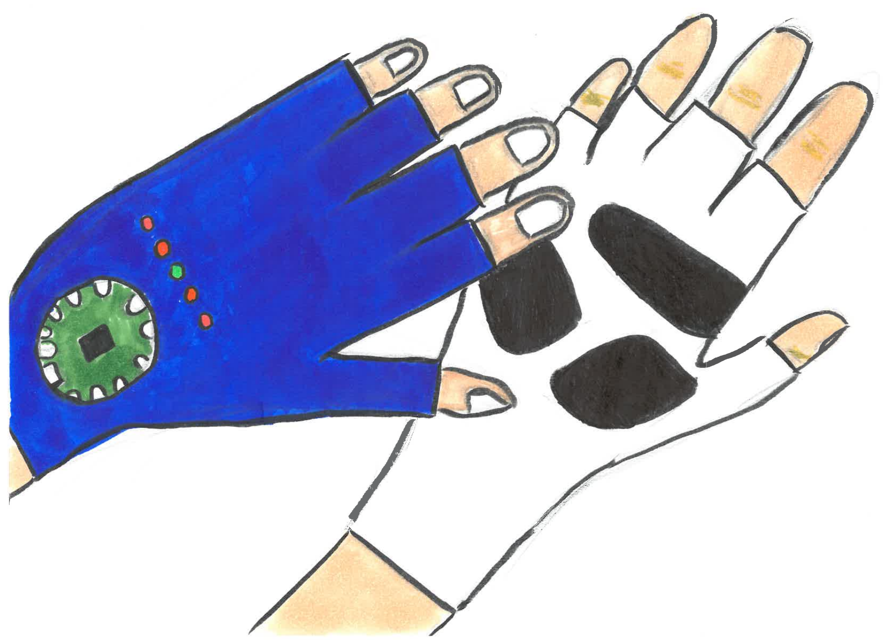


figure 8: Histogram of strain gauge test

STRAIN GAUGE

Strain gauge
After the installation of the second part of our system, trying to obtain data as well was the next step. The graph as seen in both figures at the left was what was acquired. Then a very fast conclusion could be drawn. The range of our sensor was simply to narrow. The values measured were only between '64' and '67'. That range made our sensor not useful enough. Due to all the technical problems occurred in the first few weeks, another sensor could not be selected any more. So still the sensor values could be read and checked if it is understandable. Within this strain gauge test also its attributes had been tested and afterwards tried to recognize in the visualizations got. In the first set of values(first 15 seconds) the sensor was not touched, this was supposed to be its rest position. Yet, the figure shows peaks during this set. So the sensor might show a lot of noise. The fluctuating part in the middle is equal to stretching the sensor. The small surface of the sensor caused a slip of fingers , this might be the relation between the big gap around 20 seconds. The stabilized set of values at the end stood for bending the sensor both sides, both 15 seconds. Since bending was tested very constantly this might be the cause of the almost not-steep line. Although the histogram shows a similar one as shown above. Besides the low amount of measurements a kind of nice distribution is visible.

CONCLUSIONS & IMPROVEMENTS



Conclusions |

A few conclusions can be drawn after the data analysis.

The data related to the force sensitive resistors is useful. After changing the amount of resistence, the result is clear data. The histogram shows a normal distribution which confirms this. The high amount of null values can be signed to not having the hands on the handlebar.

The data of the strain gauge is not useful. The range of the sensor is too narrow. It does not give a clear indication in which position the wrist is positioned.

Improvements and future |

In the future we want to make the sensor system into a actual product. This product is a glove, which gives the user feedback on his/her riding position. How do we want to achieve this?
First we need to get another strain gauge that measures the bending of the wrist. Besides the position of the hand this data is very important to know if you got a good riding position. We than need to implement this the same way as we did with the force resistive sensors.
To get a better understanding of the data we collected we need to have more data sets of different users to see if the attributes we got are right. This makes that the feedback system could be more accurate on the different positions.
For this prototype we used a arduino uno and this is very big. This needs to be much more smaller to be used in or on a glove. And this gives more space for the feedback system that need to be designed.
We were thinking about a system with LED's that indicates if your position is the right one.

We believe if we implement all these changes we would have the product that we imagined in the beginning of this course.

PERSONAL REFLECTIONS

OLIVIER VAN DUUREN

Beforehand I expected that this course was helping me to get a better view how mathematical modeling could became useful in my designs. How to analyze data and improve visualizations of that obtained data. I hoped to get more knowledge about the design process beyond prototyping. What sensors can actually mean for the outcome of my design and especially how to get a valuable interaction between the user and my product.

The eventual result was not totally what I hoped it to become. This in particular for my own group work. The course itself had a useful set up and supposed to teach me everything I wanted to learn in this course. With our own made design we had to analyze data and visualize it to sensitive value. This was new to me so a valuable development in means of this part. Furthermore during the first theoretical lectures showed me how sensors actually make sense in our world. How every specific sensor should be seen as a source of new interaction. Every design with its sensor(s) could interact with the user if it is used correctly. In this course I realized how sensors can make sense in every product. This should lead to big improvements in my design process. Unfortunately, I thought to learn more and to deliver a better final product at the end of this course. I found it really hard to cooperate with the group I worked in, this for the first time. Individual work delayed a lot and I in particular had the idea that I had to wait on others in the project. Also the selection of sensors made it hard to accelerate in our hardware building part(which was not the main objective to learn in this course). We had a big delay caused by these two factors and this was the main reason of my shortcoming development. I think I could have learned more if these two did not affect our process that much. In my opinion we missed a lot of depth where other groups did not. At the final presentations I noticed that those other projects also helped me to get insights of further stages. These other groups supported me to be able to develop my abilities in this aspect of designing later on. So as goal for my next individual work, I want to apply the obtained knowledge to get a better picture of what users need in words of data visualization. How they are supposed to interpret my design in a better way. Let the user interact with my product as good as possible.

VASHIST RAMCHURN

I chose this elective since I believe it might be useful in combination with the USE learning line I chose: Overall Robots. This semester, I chose to focus my learning goals in the Integrating Technology competence, since last year has proven to me that this is one field I lack experience on. This elective helps me keep the balance between the use of sensors and output function electronics as well as intelligent systems. For I believe technological system mostly work at optimum when the tasks are divided in two parts; just like the nervous system of the human body, with sensory neurones and motor neurones (of course with a relay neurone in between).

During my first year, even though I came across sensors a lot, I still wanted to learn how to work with them properly and knowing which sensors are best to be used in each cases. The elective also provides me with a more in depth knowledge of using sensors, compared to my Overall Robots course.

This Elective has proven to be a very useful one, in terms of working with different types of sensors, investigating in how each sensor works and choosing the right one for the purpose required. It also help point out the different things that can go wrong while working with such sensors. After the decision upon the concept is chosen though, we work on the particular sensor(s) we chose, but do not take time to learn and experience all the different types of sensors practically (although if we did so theoretically).

However, at the data acquisition and analysis part, there is a lot that this elective has exposed me to and make me learn how to deal with certain situations or problems that might happen while working with sensors in any type of project. Working with the strain gauge for instance, I manage to learn about the different types of amplifiers I have come across, connect the circuit using the right components and alter different parts of the code to improve the data collected. One important part that I have learnt is that, even if theoretically a sensor is supposed to work in a way and while testing the circuits it does work, the materials around the sensor and even the size of the sensor requires great consideration according the impact it might have on the data sets collected.

The strain gauge for instance, needed to have a material with good grip and high frictional forces around it, to activate the sensor with any type or stretch; else the strain gauge will just slip in between the materials, and not giving any change in voltages supplied.
The size of the strain gauge also did matter a lot, as we bought quite a tiny one, which was not really useful for our particular concept, and less easy to implement. I actually feel better about this happening and us not being able to implement it in our concept, rather than having an actual good size for it and everything working; as if the latter was the case, I probably wouldn't have learn how important the size and structure of such a sensor could impact on the data acquisition.

My overall view on this elective was really good. Even if not all thing worked out as expected, I really enjoyed the work, and the fact that the elective keeps you really active on working on sensors every week; something that you don't usually experience in other project. The explanations and presentations in each lecture were also really clear, to the point and useful; and keeping in touch with what the other group are doing through presentations and just minor conversations really helped to keep a good overview of what type of sensors others are using, what can be done with them, and what problems one can usually face using such sensors. And all that done while still keeping the focus on the sensors themselves, and not the product or what the sensor should do (which often happen in conversations on other projects).

CHIEL VAN DER VLIST

In my previous projects I already worked with sensors. Those sensors were used in combination with actuators. If the sensors gave strange data, I just tried to change a few things without really analyzing the data itself. To improve my work with sensors I chose to do this elective as I expected that it would help to improve my understanding of sensors by analyzing the obtained data. I hope that a better understanding of sensors and their data can help me create better interaction between users and my design.

This elective learned me multiple things. It started already with the first concept I worked on. I worked together with Olivier on the running technique concept. This seemed a difficult subject to work on with sensors as the movements are really fast. Thinking about the measurements you want to made and taking all the details into account is the first, and an important part of obtaining the right data. I also experienced that further on the process. We didn't order the right components the first time and had difficulties with connecting them. This costed us a lot of time in which we couldn't progress. Starting too quickly without really thinking through what you want to measure is something I will try to avoid as much as possible in the future as it costs time and money.
For the project I set up the circuits. The circuit of the force sensitive resistors was rather simple but the circuit of the strain gauge costed some time to figure out, especially the wheatstone bridge as it was a thing I didn't work with before. New aspects of building a circuit was something I learned during the course as well.
The most important part I learned was how to optimize the obtained data of the sensors. Last year I experienced during a project some difficulties with the data a sensor gave. If I had done this course before I would have known that visualizing the data would have given a better view of possible problems. By analyzing the data with help of a program like Matlab noise can be found so you can try to solve it and finally filter it out.
Working in the group didn't go as well as expected. There were days that people didn't show up or that things were forgotten to do. This was annoying and gave a stressed feeling as we saw that we weren't progressing as well as the other groups. This delay was also a result of ordering the wrong sensors. I learned from it that, as a group, clear communication is needed and everyone needs to be involved with decisions being made.
Overall I developed my skills, knowledge and attitude. I could have developed even more if we ott further into the process. We missed a real life measurement of riding a bike outside and the corresponding data. I can say that I manage the basics of obtaining and analyzing data of sensors to get better and clearer results out of them.

DIMI WIERTZ

I chose this elective because I need to focus on my technology and realization and math data, computing competency areas. These are underdeveloped and during this elective I wanted to figure out the importance of sensors in my designs. Sensors are needed to create a valuable interaction between my product and the user.
In earlier projects I tried to use sensors, because of the lack of knowledge I was not able to use the obtained data on the right way. During this elective I hope to learn more about sensors, I also want to learn how I could use these sensors in a way they make my future designs better and more valuable for the user.

During this elective we had to design a sensor system, in which we had to make the obtained data visual and analyze this data. In the end I believe we did manage to get a good data set, preferably we had more data sets that we could have analyzed. It is partially I to blame we did not get more data. This came that we had some struggles to get the sensors in our hands. This was also the reason we had to do a little catch up at the half point of the course.

For the sensor system we decided to work with force resistive sensors (FSR) and a strain gauge. The FRS seemed to be easier to work with than the strain gauge. We wanted to make the 'product' we designed, to give feedback to the user. That was a pitfall we ran into this caused we were more focussing on making a product and not getting the data sets we needed to analyze. We lost some time in doing this and that was another reason of our delay.
For the strain gauge we did not use the right one and therefore we got no good data we could work with, that's the reason we did not use it in the glove we made. This gave me the insight that you have to choose your sensors carefully otherwise you end up analyzing bad data.
Another insight I gained during this course is besides using the right sensors the placing of the sensor needs to be right. I made several prototypes of the glove and in one of them the positions of the sensors were not right and I did not have any data at all. I also saw this in another group that the position of the sensor made a big difference in the obtained data.

The overall expectations of this course are met. And in the near future I am not so afraid to use sensors anymore because now I know what to do with them, how to use the obtained data and analyze the data to get a better product at the end.