ME 410 - Mechanical product design and development

Helmet with automatic visor

SUPERVISOR

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Fall semester 2020

EPFL

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Introduction

Personal mobility is actually one of the most expanding modern domain. Bikes, and scooters have been transformed electric to cover larger distance and foldable for easy storage. These modes of transport are becoming more and more common in areas of high traffic and crowded spaces. Their portability makes them nice travel companions on longer trips with trains or metro.

Typically these device can deliver larger torque and speed, making them more dangerous than their none electric counterparts. For this reason ensuring security should be a top priority. These modes of transport specially recommend the use of a helmet. Equally important is making yourself easily visible (with lights and reflective materials). If we focus only on the helmet, we observe that it can offer a more complete protection. In addition to playing a role of safety during a fall or a shock, some helmets include a visor which also protects the eyes. The visor can be tinted, transparent and manually retractable.

However, these visors can be source of danger as they are still manual. Let us take the example of a user riding a bike during traffic jam. He has to be fully focused on the road and surrounding traffic. Intense headlights, rain, or wind can distract the user for seconds which could have serious consequences. Another example is that of riders going down a hill on a sunny day. Naturally, they wear a helmet with a tinted visor. But once they enter a forest, the light is not shining as bright as before and the tinted visor blinds them rather than protecting them. The tricky rooted terrain and steep decline can not allow the user to leave one hand from the handlebar to operate his helmet. These sudden extreme changes can also occur in non extreme environments. Everyday weather can also be relatively unpredictible cylcing form sun, rain, and snow in a couple of minutes.

These few lines that describe our problematic led us to think about a completely new product: a product that is smart and easy to use. We came up with a smart helmet that we call Supervisor. Our helmet has a visor with modulation capabilities so that it adapts to any environment. This report will show the different steps that we took in order to come up with a functional prototype.

1 State of the art

In this section, we analyze the existing types of helmet on the market. We already know that the majority of bikers are used to wear a helmet and sunglasses at the same time. So, to spare some space, we will only show here below existing products with visors.

Images 1 and 2 : https://bbbcycling.com/ch_de/bhe-56f-indra-faceshield
Image 3 : https://www.bikester.co.uk/uvex-finale-visor-helmet-black-741121.html
Image 4 : https://www.velomotion.de/magazin/2018/11/test-casco-speedairo-rs-mehr-speed-und-klarer-durchblick/
Image 5 : https://www.probikeshop.ch/fr/ch/casque-casco-speedairo-2-rs-blanc-vautron-2020

Figure 1: Examples of different helmets with a visor

The principle of the first helmet (1 and 2) consists of a visor with two positions (open and closed). The positioning though has to be done manually. The visor is already tinted (2) in order to protect the user from the bright sunlight. Even if this is not a main criteria for our project, the futuristic and minimalist design of the helmet can be inspiring.
The second product (picture 3) also shows manually-adjustable visor but this time, it is transparent with any tint. This would be perfect for a cyclist riding in dark places and who wants to protect his eyes from the rain or the cold wind. However, this protection is only earned at the expense of the sunlight protection.
The last helmet (4 and 5) shows a fixed visor. The main particularity of this visor is its coating which becomes more tinted when the light becomes brighter. It is a chemical process that is not controllable once the coating has been applied. Another disadvantage of this type of helmet is that the process takes a long time period to become transparent.

2 Motivation

The question to answer is the following: Why is an automatic helmet necessary ?

1. **To provide a system that does not yet exist:** With respect to the state of the art previously established, there is no helmet with a transparent and tinted visor that already exists. Cyclists must then choose whether to wear sunglasses or protective glasses on every ride.

2. **To prevent danger of riding without one hand:** While riding a bike, it can be tricky to control the handlebar. Indeed, on a downhill ride for example, one must rigidly tighten the arms in order to avoid falling from the bicycle. In the other case, climbing demands a huge amount of effort. To be stable when going uphill, naturally, we need to hold on tight onto the handlebar.

3. **To provide comfort:** By protecting from eye discomfort during an activity caused by the variation of luminosity, wind, rain etc. The visor offers a comfortable and non-intrusive means of protection.

4. **To prevent environmental hazards:** Having an automatic helmet allows you to concentrate on riding rather than on environmental disturbances, most accidents are caused by external factors.

3 Engineering specifications (CdC)

The "Cahier des Charges" is a reference document for the project. It allows during the achievement of the project to refer to it and to control that the features of the system must satisfy are well respected. The table 1 gives an overview of the technical requirements and constraints of the product.

Functionalities and features			**Value**
F1	**Protection (head)**	The helmet has to protect the user against the falls, impacts etc.	NF EN 1078+A1 [1]
F2	**Luminosity**	The device has to protect the eyes when there is a lot of light	Maximum set by user
F3	**Rain**	Eyes must not be disturbed by the droplets	$>$ 2 droplets
F4	**Wind velocity**	Under high speed, the user has to be able to see the road without irritated eyes	High speed $\approx$ 20 km/h
F5	**Adaptability**	The device sensitivity to light and speed limit should be changeable	Adjustable input parameter
F6	**Manual mode**	Possibility to switch from manual to automatic mode	-
Performance specifications			**Value**
P1	**Protection (Eyes)**	The device must also allow the user to ride the bike under any conditions without performing operations	Number of operations = 0
P2	**Reactivity**	Has to be reactive	$<$ 2 seconds
P3	**Autonomy**	At least for one big trip	6 hours
P4	**Total weight**	Meet the requirement of wearable technology	600g [2]

Other specifications			Value
O1	**Durability**	Durable under daily use operation, Warranty	2 years of warranty [3]
O2	**Manufacturing**	Eco-friendly, Maintenance	Robust components and clear indications for defects
O3	**Cost & energy**	Must be cost and energy efficient	Rechargeable battery $300<P<400$ CHF
O4	**Marketability**	Conforms with required regulations (EU, CH) for safety and operation	« certified helmet CE EN 1078, ANSI et SNELL » [4]

Table 1: Cahier des Charges of the Supervisor

From this analysis, a clear definition of "major functions" and "sub-functions" can be established:

Major functions

1. Protect the head of the user;
2. Protect the user from environmental hazards (sun, rain and wind) without his intervention;

Sub-functions

1. Measure and evaluate environmental parameters;
2. Transform energy into movement of the visor;
3. Take in input user sensitivity;

We can also decompose our system in several subsystems as shown in Figure 2.

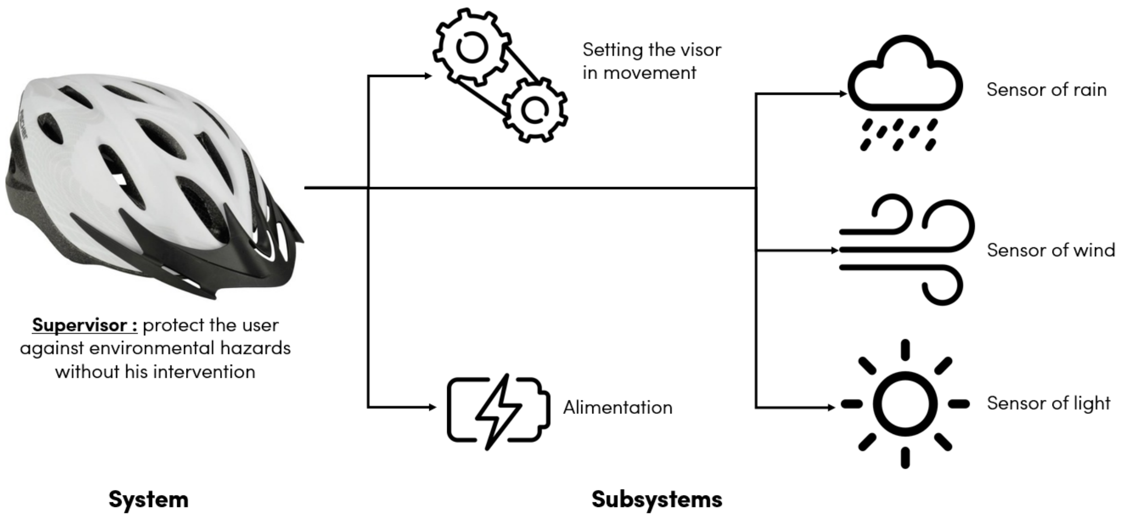


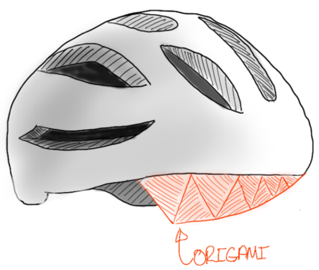
Figure 2: The Supervisor divided in subsystems

4 Potential solutions

In order to solve the stated problem, while respecting the specifications defined previously, we have studied three potential solutions, which are the following.

4.1 Deployable visor with fixed transparent visor

The first solution consists in deploying the visor thanks to an origami structure, as shown figure 3a. The origami structure will only protect the user from the sun. That's why we need a fixed transparent visor to protect him from the rain and the wind. Concerning the motorization of the system, we would choose Brushless DC motors, which seem to be the most adapted for origami structure. The choice of each sensor is detailed in the table 3b. Finally, the system would be powered by a rechargeable battery.



(a)

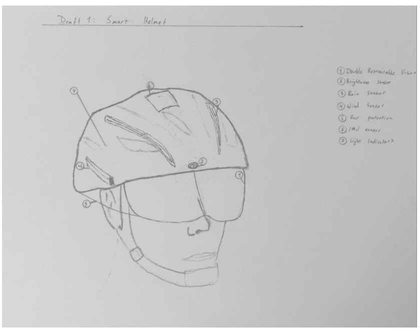
Sensor detection	**Sensor type**	**Location**
Measure Brightness /Detect sun orientation	Light Dependent Resistor (LDR)	*Sensors located at the front above the helmet*
Rain Detection		*Rain sensor located above the helmet*
Relative Wind Speed	Wind Sensor Rev. C	*On top of the helmet*
	Microphone	*On the side of the helmet*
	Pressure sensor	*A tube on the side of the helmet with the sensor at the bottom*

(b)

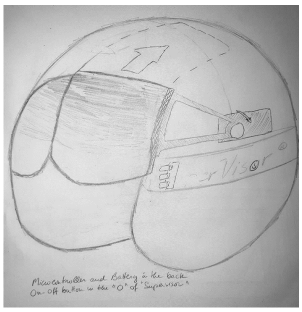
Figure 3: Solution 1

4.2 Helmet with tint gradient visor

For the second solution, the visor deploys depending on the light level (Figure 4). In other words, when there is no luminosity the visor is slightly extended: so transparent. On the other side, when there is luminosity the visor is fully extended: hence tinted. This gradient brings modularity to the system. This time the motorization is provided by servomotors, allowing the position of the visor to be controlled at all times. Again, we will use the same sensors presented in table 3b as well as the rechargeable battery to meet our energy specification.



(a)



(b)

Figure 4: Solution 2

4.3 Helmet with a rotating visor with fixed transparent visor

For the last solution, instead of having an on/off system, we thought of a helmet that can follow the direction of the sun. As pointed in Figure 5, the helmet automatically unfolds the visor and rotates according to the direction of the maximum luminosity. Hence, the eyes of the user are protected. Even if we plan to use the same sensors as in the table 3b, we are aware that the code will not be the same. In this case, a servomotor will be implemented for the horizontal movement, and a stepper motor for the vertical one.

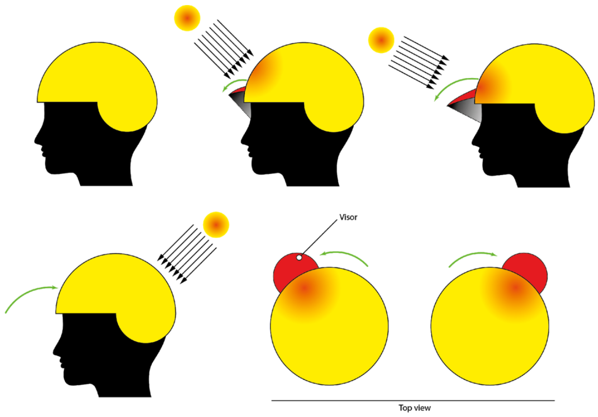


Figure 5: Solution 3

5 Design of the final product

5.1 Choice of the solution

In front of these three solutions we had to make a choice. The second solution **"Helmet with tint gradient visor"** was chosen unanimously for many reasons, which are the following:

- First, this solution offers a **wider range of functionalities**, all obtained with **a single visor** (unlike the other two solutions, which use two visors: one transparent and the other tinted).
- In addition, **the simplicity and efficiency** of the motorization represents a strong point compared to other systems. Indeed, the origami structure seems not to add a particular value to the deployment of a transparent visor while it adds a lot of mechanical complexity. And the rotating visor can be simplified by a moving gradient.

5.2 General description of the system

The visor of the Supervisor helmet will therefore be activated according to external conditions: rain, wind and sun. The question raised now is "How does it work?".

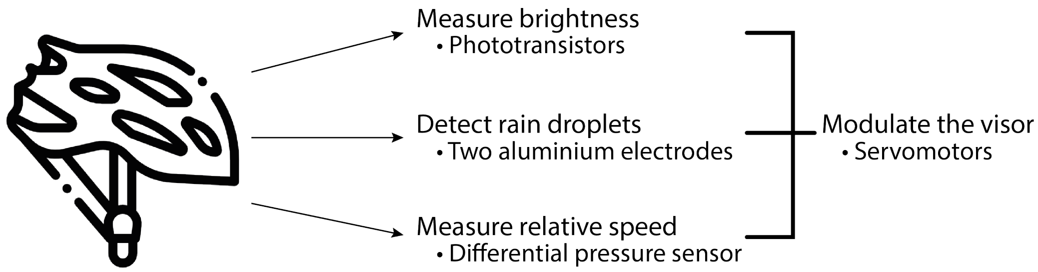


Figure 6: General description of the linkage between the components

Without going too much into details, we are first going to talk about the components that are included in our helmet and how they are linked together. If we look at the figure 6, we observe that our product can be decomposed into three principal components: The light detection is made by phototransistors which measure the ambiant light. We use them to determine when the visor should come down and to compute the modulation angle for the visor to deploy in order to protect the eyes. For the rain detection, we use aluminum electrodes that are sticked onto the top of the helmet. These arrays of aluminum measure a difference of potential when a drop, which plays the role of a resistance, falls on it. Regarding the speed, we thought that it would be important to measure the relative wind velocity, because it is the "speed" felt by the user that matters. In order to do that, we used a differential pressure sensor. All these different components determine how to actuate our motors and regulate the modulation and the angle of our visor.

Wind	**Rain**	**Light**	**Open visor**	**Transparent**	**Opaque visor**
0	0	0	1	0	0
0	0	1	0	0	1
0	1	0	0	1	0
0	1	1	0	0	1
1	0	0	0	1	0
1	0	1	0	0	1
1	1	0	0	1	0
1	1	1	0	0	1

Table 2: Helmet logical operating table

The motion of the visor will be set according to a finite state machine. The table 2 details the functioning of the helmet, namely the states (open, transparent and opaque visor) as a function of the inputs (wind, rain and sun). These ones are represented in binary form in order to understand all the possible combinations. For example, a 1 for the wind input means that the wind speed is higher than the threshold set by the user, and a 1 for the rain input means that the rain sensor has detected water droplets. For a given combination of the three inputs, only one state of the visor is possible. Note that the state "Opaque" means that the visor is in the tint gradient part, and that the modulation according to the luminosity will be done here.

5.3 Details of subsystems

Electronic aspect

Figure 7: Localization of the sensors

As shown in Figure 7, in order to better detect rain, we have chosen to create a **self made water sensor** with aluminum tape instead of a commercially available rigid one, it allows a better flexibility and thus a better integration on the helmet.

Regarding the luminosity, the helmet has four **phototransistors** which have all been positioned at 90° (in blue in Figure 7), one on each side of the helmet, one at the rear and another one in front of the shark fin for the light coming from the front. These different positions are given in order to measure the global, surrounding luminosity.

Finally, a huge amount of work has been done on the **pressure sensor**. Several experiments were carried out in order to calibrate this sensor to measure the relative wind speed, which is likely to hinder the cyclist while bringing tears in the eyes.

In order to implement each of these sensors on the helmet, it was necessary to add additional elements such as an analog amplifier, I2C multiplexer, small capacitors etc. The connections of these different elements and the fluxes between them are shown in the following diagram:

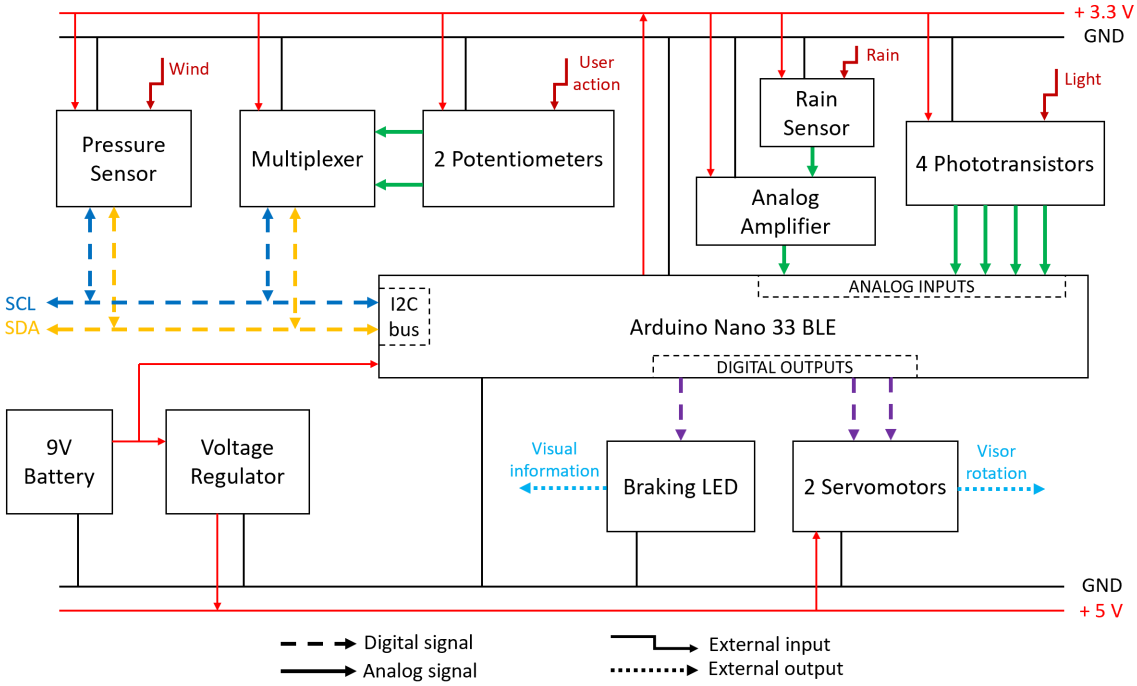


Figure 8: Simplified electrical diagram showing the fluxes between the components

A more complete diagram showing all the wiring between the components is shown in Appendix 10. Note that the rain sensor is represented by a commercial one for representation purposes. A sophisticated microcontroller is used on Supervisor helmet: **the Arduino Nano 33 BLE**. It was chosen for its integrated motion sensor, its small compact design and also for its I2C compatibility and its ability to run on a wide array of prebuilt libraries including low energy bluetooth for example.

Mechanical aspect

As shown in the following picture 9, there is a **transparent visor** on which a **tint gradient film** has been partly applied. On this prototype, the visor is a simple rigid plastic sheet but for the final product it will be made from thicker Plexiglas.

Figure 9: Illustration of mechanical aspect

A rigid structure makes it possible to maintain the visor and to connect it to the servomotors that control its movement. These servomotors (**Servomotor-RC-5V-high torque/Adafruit**) have been dimensioned to be used in the final product. We have achieved a **static dimensioning** in addition to a **dynamic dimensioning**. For this 35 grams visor, they are largely oversized, meaning that they can lift a visor of up to 136 grams. Finally, it can be seen that there has been a significant amount of work to **integrate the components** into the helmet. As shown in Figure 9, a box was 3D printed to contain all the electronic elements, as well as a shark fin to properly position the front phototransistor in order for it to be above the opened visor as well as the pressure sensor in order for it to have a good wind take.

6 Demonstration of the proof of concept

6.1 Satisfaction of CdC

Once our prototype was completed, the CdC requirements were verified. The Supervisor helmet has been stimulated several times indoors and outdoors, the metrics that have been measured are presented in the following table.

Ref	Function	Expected value	Measured value	Validation
P1	Protection (Eyes)	0 operation	0 operation	
P2	Reactivity	< 2 seconds	less than 1s	
P3	Autonomy	6 hours	Unknown	
P4	Total Weight	600g	580g	

Table 3: Assessment of metrics

The results shown above in table 3 prove that the values expected by the specifications are mostly satisfied. The system created is **fully automatic** (ref P1). As the metric of **reactivity** is respected (ref P2) and as it is a function of the luminosity (ref F2), the humidity (ref F3) and the wind (ref F4) consequently it can be concluded that these performances are also satisfied. Concerning **the autonomy** (ref P3), it is impossible to conclude given the use of batteries for our prototype.

6.2 Performance assessments and future developments

The prototype seems to work perfectly under any weather conditions. However, we still must bring some **improvements to the visor**. The design can be improved by putting the visor in a housing or nearer from the face of the user as well as reducing the gap between the visor and the eyes. We can also think about an automatic sensitivity sensor. For this, we can for instance sense the squinting with a technology as Face ID which will change the threshold at which the visor will deploy. **The algorithm** can also be improved to obtain better precision. Finally, Supervisor could be more **Eco-friendly** with rechargeable batteries or even solar panels to complement the energy supply.

Conclusion

The goals of this project were to come up with a new helmet that, in addition to protect a user from falls, would also protect his eyes against wind, rain and sun automatically. To conclude, we achieved the main goals by looking for existing similar types of device that helped us proposing several solutions and, by comparing them, choosing one final solution. Then, the work was mainly dedicated to design a prototype that would implement all the functions mentioned above. The prototype satisfies all the metrics we stated at the beginning of the project. Indeed, our innovative helmet can sense and deploy in less than 2 seconds, weights only 580g and does not require any operations from the user. Moreover, the visor, which is gradually tinted, modulates with respect to the level of brightness.

References

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Appendices

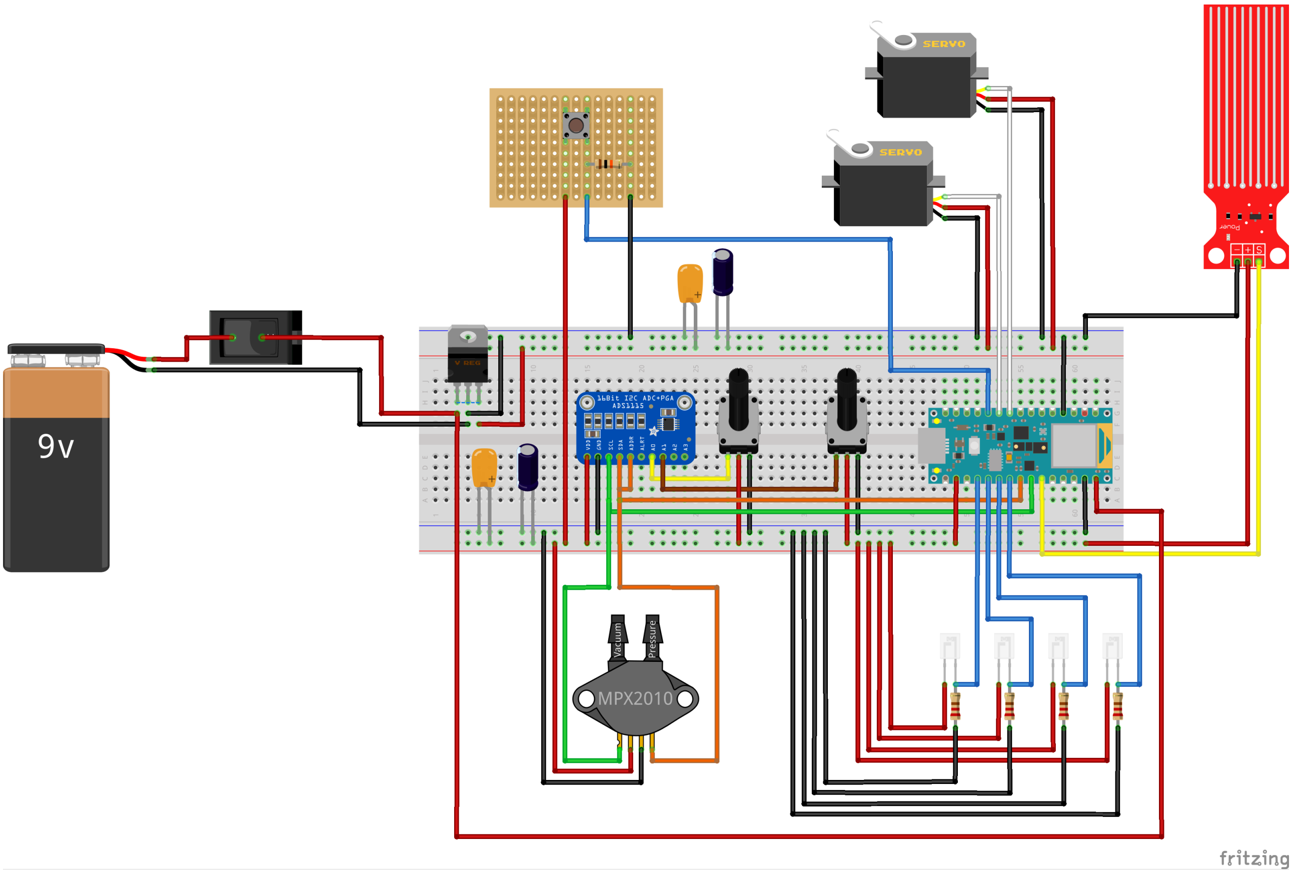

Figure 10: Electrical wiring diagram

Link to the code of our Supervisor: https://github.com/ChristopherJulien/SuperVisors