Interdisciplinary course of

Design and Robotics

6° edition, 2018

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Abstract

The purpose of this report is to describe the entire development process to create a robot prototype capable of expressing emotions, from the starting design phase to the final implementation. The first part of this document explains the conceptual part of this process, in particular, our inspirations, ideas and impressions to create an emotive robot. The second part contains details about the development of our robot, all the different steps taken while building the structure, realizing the shape and mechanism, and organizing electronics. In the final part, we added all the technical drawings such as the 3D representation of mechanics and shape and diagrams, like the electronic schematics and the flowchart.

Description

The aim of the sixth edition course of "Robotics and Design" is to design and realize a robot capable of expressing as clear as possible five basic emotions: Happiness, Sadness, Anger, Disgust, and Fear. Each of these should be arbitrarily reproduced using different combinations of movements, lights and sounds.
The choice that we made was to create a robot with a shape mixed between a flower and an alien creature, called SIID. This shape enables different layers of expressions employing different speeds in the closure of the petals, which hide the eye and the “heart” of our SIID. Moreover, the heart is a little sphere that can change color depending on the emotional state in which the robot is in. Other interactive elements are the wheels, sensors and a speaker. In this way, the robot can exploit vibration, movements, lights, sounds, and closure of the petals to create an interactive cycle with humans and reveal all the emotions required.

Research

State Of Art

Initially, we started gathering impressions about what each emotion means to us in terms of colors, sounds and actions associated with it. Therefore, we had a brainstorming during which we put together the thoughts of each person of the group and, in particular, we tried to map each idea on paper creating connections between them.
After that, each of us collected videos that display emotions through a cartoon character, a robot or an animal using YouTube and we searched keywords related to each emotion such as scared, funny, happy, sad, angry or disgusted linked to the object. We noticed that even if the subjects of the videos were different, they shared some common behavior: for example, they shrink back if scared or unfolding if happy.
We kept in mind these common points and we thought about the best shape for expressing these emotions.

We gave the task to ourselves to draw a storyboard for each emotion with the shape that best fits each idea. After that, we met on Skype to explain and confront all the drawings. Everyone drew something different but mostly related to animals or a vegetable figure. Finally, we altogether choose the best sketch and the best representations of each emotions.

Concept

Inspiration

The first thing we all agreed on was the idea of doing something that shows an emotional opening to a third party, much like the opening of a seashell. On the beginning, we thought of a chest-like creature that decides to offer an hidden object to a human by literally opening up. Based on this, the original shape idea of our robot was a crab with an opening shell on its back that hides a little sphere representing the heart of our creature, inspired by the crabs of *"Pirates of The Caribbean",* with an opening shell on its back that hides a little sphere representing the heart of our creature .
Since the crab idea resembled too much an existing animal and could have had some limitation in movements to express emotions, we took a different direction into something new that combine reality and imagination.
We opted for a vegetal creature, inspired by hybrid monsters like pokemon: this final shape can exploit the opening of the petals to reveal its hidden self, since this still is the central point of our robot.
The evolution that took us to the final shared idea followed an inspiration flow that can be summarized as follow:

- ➔ ***Crab:*** starting point
- ➔ ***Seashell***: represent the idea of gifting something hidden inside its body
- ➔ ***Pokemon:*** recall the idea of something not completely real that uses an opening mechanism to expand its own body and a skirt to amplify the dancing movements
- ➔ ***Jibo:*** represent the usage of an eye to show emotions
- ➔ ***Lotus flower:*** represent the external shape idea of our robot
- ➔ ***Gorilla:*** recall the movements made by this animal when it is angry
- ➔ ***Snake:*** recall the inflation of its hood while preparing to attack

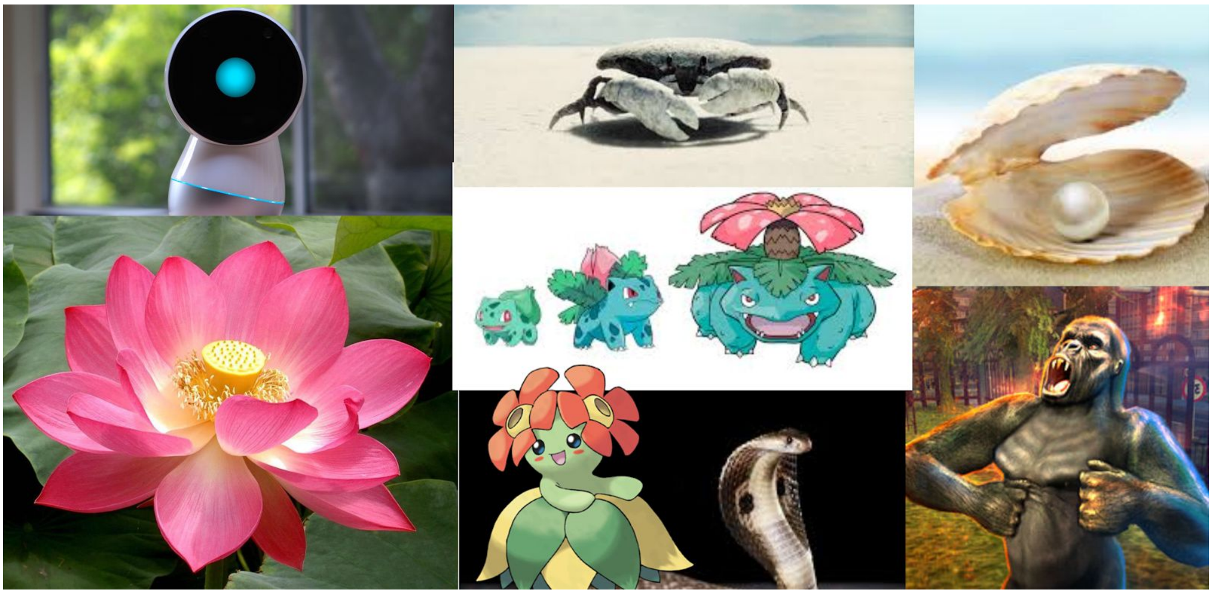


Figure 1: Inspirational Flow Images

Once arrived at the final shape idea, we produced an initial sketch by hand drawing a creature composed of an active and a passive part: the flower is the active part while the skirt represents the passive element.
Moreover, we initially designed the petals that compose the flower to be disposed on two independent levels as a double cover for the face of our robot: in this way, the idea was to control the opening process step by step allowing different movements to express emotion. In the end we had to finally settle on having only one petals level, so we decided to play more with the speed of the opening and closing to give additional value and expression to each emotion.

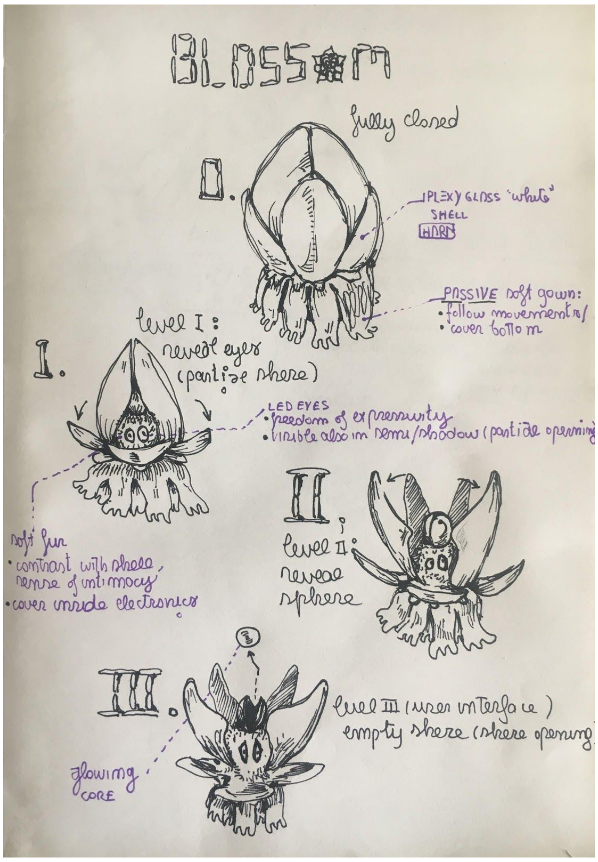


Figure 2: ***Final sketch idea***

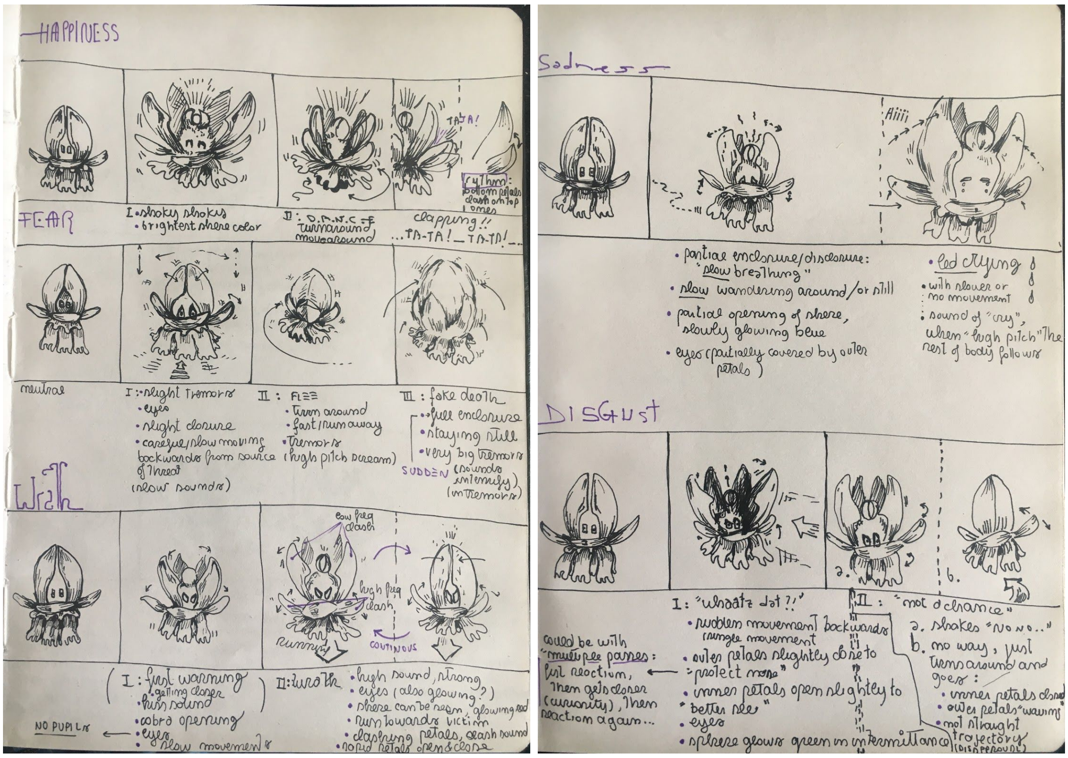


Figure 3: ***Storyboard of Emotions***

Development

Interaction

The design of the human-robot interaction process started from the definition of a set of reactions that represent all the possible states of our robot. Each of these displays an emotion choosing randomly from a predefined set of actions or a combination of them. In this way, we try to surprise the user expressing the same sensations with different multiple actions modes [Annex_Interactions].

Happy Reaction

- Turn on the spot for a random amount of time comprised in a range
- Make a random sound from a set of happy sounds
- Go around fast and squiggly
- Open and close rapidly the petals making 'clap' sound, the movement is fast but continuous
- Sphere with bright colors
- Eye with happy patterns

We added a supplementary interaction state that is a funny variation of the happy reaction that we called "*Giggle*" .

Giggle Reaction

- Eye with happy pattern
- Reproduce a laugh sound repeatedly

Angry Reaction

- Open petals with interrupted movements
- Reproduce an angry sound "Grrr"
- Eye with angry patterns
- Go forward with rapid and straight movements
- Go back slowly like to prepare the next attack
- Sphere with red colors that blinks

Sad Reaction

- Open and semi-close petals very slowly
- Go around slowly and squiggly
- Eye with sad patterns
- Make sound from a set of sad sounds
- Sphere of blue colors

Fear Reaction

- Closed and semi-open petals

- ❖ Tremors and vibrations with wheels movements
- ❖ Eye with fear patterns
- ❖ Reproduce a fear sound like a scream
- ❖ Go backward with fast and straight movement, then turn away from the danger
- ❖ Sphere of violet colors

Disgust Reaction

- ❖ Open and semi-closed petals with vibration
- ❖ Eye with disgust patterns
- ❖ Make sound from a set of disgust sounds like “bleah”
- ❖ Turn fast and then leave going backward
- ❖ Sphere of dark colors

Then, we started thinking about a series of trigger actions that the robot would be able to perceive. We exploited the usage of two types of sensor to design the interaction flow: the sonar to detect distances from objects and a thermosensor to determine proximity of a human.
Upon switching it on, the robot is in a neutral state during which it looks around searching for someone. If no one is detected, it becomes sad after a while, otherwise it becomes randomly happy or disgusted when an object of any kind is approaching near the robot.
Moreover if someone tries to touch its inside or its sphere it randomly triggers a Giggle, Fear or Angry reaction.

Shape

The choice of the hardware and materials to create our prototypes was not a simple process and required a lot of effort in researching the right ones.
The first thing we had to take in account was the material of the petals, a really fundamental part of our design. In the beginning, we opted for PVC material and we tried to realize a petal with 2 variant: one opaque and the other polished.

Figure 4: ***Initial material tests for the petals***

The result showed a better outcome for the polished material because it reflects lights and creates a nice visual effect. Unfortunately modeling just one petal required several hours and it was way too heavy to be used. Therefore we had to drop this option for the first prototype and think of other possibilities lighter and faster to create than this one.
So, for the first prototype, we decided to use wire material for the structure of the petals, all covered up by red silk fabric.

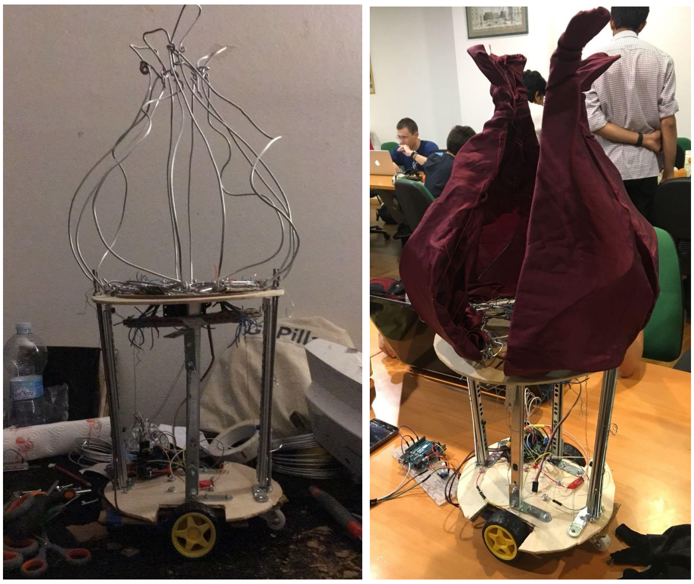


Figure 5:*Second material test for the petals*

Finally, we substituted the wire material with an iron network that on one hand allows to be easily molded and on the other reduced drastically the weight of the petals; the net is then covered with a sheet of expanded polyethylene, to make it safer and avoid cuts from the iron wires, and finally wrapped in white cloth.

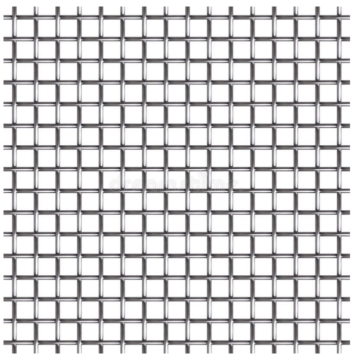


Figure 6:*Final material test for the petals*

Then, we organize the robot on two wood plane: an upper plane for the petals and a lower plane for the base. On the latter, there are the wheels that allows the robot to move around.

Internally we placed an RGB Led Matrix 8*8 as the eye of our robot, designing all the possible visible states and colors associated with it, depending on the emotion that the robot wants to show.

neutral				
{ 255, 246, 201 }	{ 255, 246, 201 }	{ 255, 246, 201 }	{ 255, 246, 201 }	{ 255, 246, 201 }
{ 255, 201, 177 }	{ 255, 240, 183 }	{ 180, 254, 198 }	{189, 224, 128}	{ 221, 175, 255 }
{ 255, 145, 133 }	{ 255, 236, 143 }	{ 137, 224, 255 }	{ 180, 214, 86 }	{ 165, 45, 255 }
{ 255,112, 97 }	{ 255, 231, 113 }	{ 91, 212, 255 }	{ 159, 198 , 48 }	{ 136, 0, 238 }
{ 254, 27, 0 }	{ 255, 215, 0 }	{ 0, 176, 240 }	{ 112, 141, 35 }	{ 75, 0, 130 }
angry	happy	sad	disgusted	afraid

Figure 7: ***Eye colors***

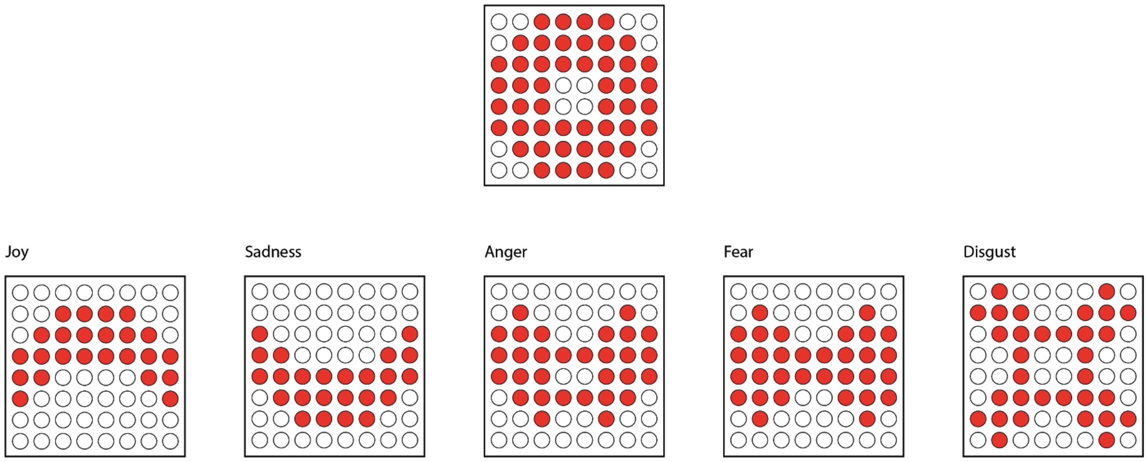


Figure 8: ***Eye shapes***

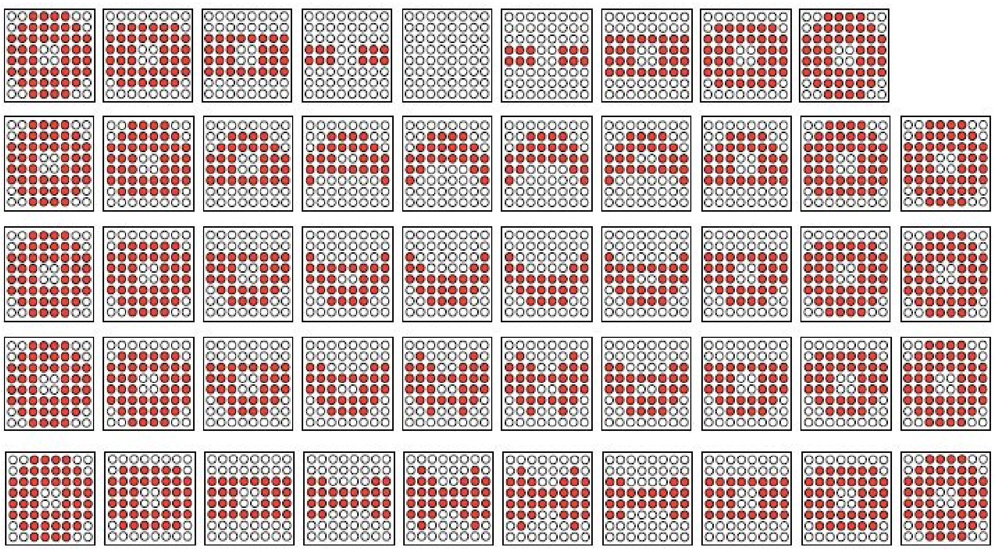


Figure 9: ***Eye Transitions***

First Prototype Result

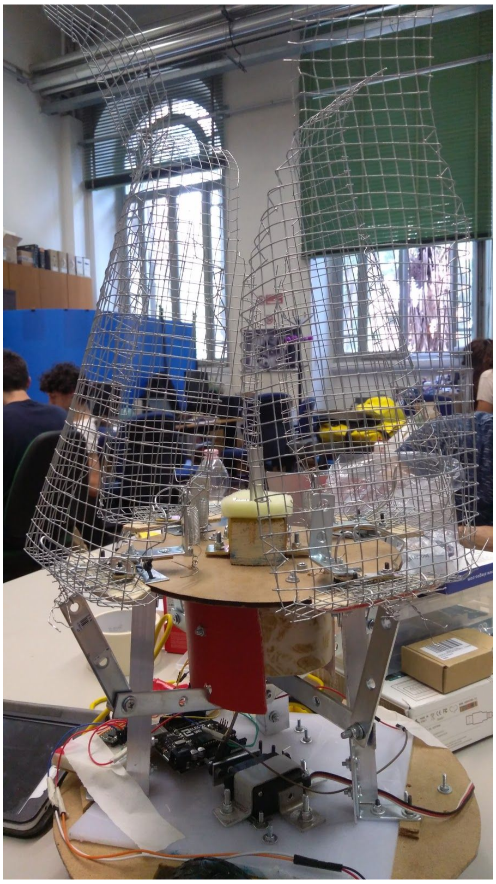


Figure 10: ***Middle-Term Prototype***

Final Prototype Result

During the development of the final version, we realized that wasn't feasible to reach all the initial objectives, and we decided to drop the idea of adding a second row of petals, since we couldn't afford the extra weight and we also didn't have enough space on the structure to add them. Therefore, for the final version, we decided to optimize the single row petals shape we already had.

One of the main problems with the first prototype was the weight, even if we already tried to reduce it. We firstly removed all the extra weight opting for lighter materials, such as aluminum to sustain the upper plane, and choose a lighter and flexible iron net, that was also easier to mold in petal shape, that we proceed to cover with two layers of papier-mache.

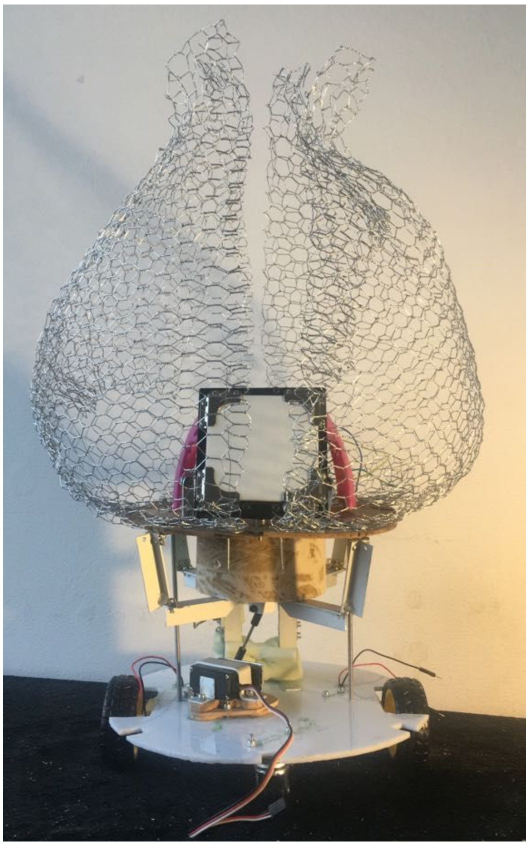
 

Figure 11: ***Petals process for the Final Prototype***

Once we had the final petals and shape, we decided the colors and textiles. We looked for a color that remembers a plant and at the same time results interesting for the users. Additionally, we wanted that when the robot was open, the user would notice it and instinctively had the impulse to get closer to touch it. Consequently, we chose a mauve color for the petals and a spotted cream fur for the internal covering. Then, we added a green skirt made of a combination of different textiles to recall foliage.

The final shape result of our robot was a combination between a flower and a mysterious but unique creature.

Figure 12: *Final-Term Prototype*

Mechanics

Petals Mechanics

The main mechanical component was the opening and closing mechanism of the petals. The process that lead us to the final one followed different phases.
During the first phase, we designed a 3D model with two concentric rings each of them maintained by three linear guides. The idea was to connect the petals both to the external and internal rings controlling them independently. So the petals move together with the rings opening when the ring goes up and closing when down.
To reach this goal, we thought to use two servo motors: one for the internal ring and the other for the external one, placing them on different planes behind the two rings. Then, we chose the crankshaft system to connect the servos with the rings.[Annex_Mechanics_1]

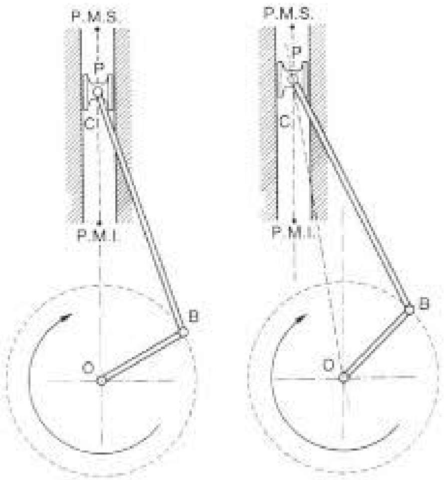


Figure 13: ***Crankshaft Mechanism***

Unfortunately, this mechanism did not work correctly in practice because the shape of the different planes was not precise and the structure was too heavy. In fact, the mechanism got stuck and could not move the plane. So, we dropped this idea keeping just the crankshaft and the servo motors usage. We also decide to drop the layer of the external petals because of technical reasons (weight, space, mechanism complexity, …) and time.

During the second phase, we tried to use the nylon wires. First, we created a wood plane fixing on it the petals and connecting the wire to each one.Then, the wires were attached to a DC motor using a circular guide. This mechanism exploit the rotation to pull and push the petals. The main problem with this idea was that the wires were not rigid so it was difficult to calibrate them, and sometimes even this mechanism got stuck.
To address this problem, we tried to fix the wires with springs to a central cylindrical guide able to slide up and down moving the wires in the process. This solution points us to other types of difficulties. In fact, the guide tended to rotate during the up and down movement resulting in the crisscross of the wires. Then, we substituted it with iron wires fixed to the cylindrical guide. These wires had two joint points to have more leverage and flexibility, but the deformation was unavoidable. Also, the control of the closure and opening of the petals was not precise, hence the entire wires idea was discarded.

Figure 14: ***Iron Wires Mechanism***

During the last phase, we resolved all these issues by keeping the central cylindrical guide, but we fixed on it four external rigid mechanical arms of iron material. We attached them to each petal and to the servo motor using the usual crankshaft system. [Annex_Mechanics_2]

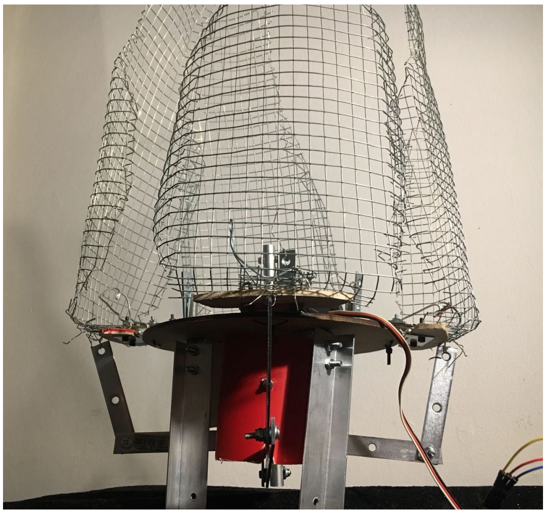


Figure 15: ***Four Mechanical Arms Mechanism***

Wheels Mechanics

We choose to use a platform equipped with four wheels: two motorized *fixed wheels* and two *caster wheels*. This configuration allows us to have a small oscillation while moving because the system is hyperstatic.

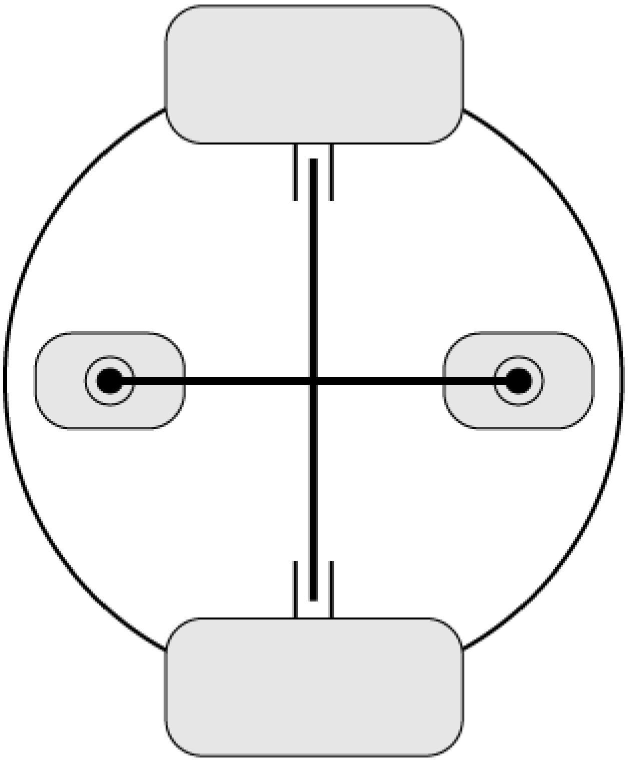


Figure 16: ***Wheels Mechanism***

Electronics

The electronic components include a set of sensors and mechanic parts, each one with a specific role.
In particular, we needed two ultrasound sensors to detect object distances, one placed behind and one on the front of the robot, and a thermosensor to perceive human proximity. Then, we used a servo motor to open and close the petals, one speaker with a mini Mp3 player for the sounds, one RGB led to change the color of the internal sphere, and one matrix RGB led for the eye. Moreover, we required two DC motor to move the wheels fixed on the base of the robot.

As introduced the robot is organized on two different level: the base and an upper level with the petals fixed on it. So the electronics had to be adapted consequently.
Accordingly, we decided to use four separate stripboards for each module. Moreover, on the upper level of the robot, we placed one small stripboard for each element that requires an independent circuit such as the Mp3 Player, the thermosensor, and the RGB led. Instead on the base level, we used a unique stripboard for the Arduino Mega, where we attached the wheels motors and all the pins to connect all the components and the battery.
One of the main problem encountered was the supply. In fact, we decided to use one battery for everything but each module requires a precise voltage between 3.3V and 8V. The solution applied was to create a circuit on another stripboard with two voltage regulators of 5V and one of 8V that receive the supply and produce a fixed voltage. Then, we added also a bi-directional logic converter to switch the charge from 5V to 3.3V for the module that requires it.
To reach the final outcome, we made a technical drawing for each module and then we reported it on a schema using the Fritzing Tool. We did not use this tool immediately because it was faster and more intuitive to design the pattern on paper.

Bill Of Materials

ELECTRONICS	
RGB Led Matrix	€ 11,18
Elegoo Mega	€12.99
UltraSound x5	€ 8.99
MP3 Mini	€ 9.70
Strip Board x5	€ 8.87
Thermo Sensor	€ 18
Bidirectional Logic Converter	€ 7.50

TOT. € 77.23	
MECHANICS	
Motor Driver	€ 5.36
Hobby GearMotors	€ 4.39
Wheels	€ 7.29
Wheels for rotation	€4.36
TOT. € 21.40	
MATERIALS	
Lastre PVC 5 mm / 2.5 mm	€ 20,71
Hinges,L, and Rails	€ 11.40
Wire and Iron Network	€ 5.60
Plywood Disks	€ 3.20
Bolts, L, plywood	€ 12,48
Support for Servo Motor	€ 9.20
Paint	€ 10.00
TOT. 72.59	

Informatics

The strategy used to design the Informatics part was a Finite State Machine. We created a set of states that includes the emotional states and neutral states of our robot. Moreover, we organized the code on different files: one for each electronic component, one to manage the animations and one to handle the updating of the state machine.

The main Arduino file called *Siid* has only the setup function and the loop function. The setup function calls the settings of all the other files, while the loop function continuously updates the state of the robot and plays the associated animations.

The *Animations* file depending on the emotion set manages the sequence of actions concerning the eye, the sphere, the audio and the servo motor with the usage of timer and delays. In fact, each electronic components file makes available a set of functions that enable it.

The *State* file defines the different robot states and the transition between them over time. The possible states are:

- *LOOK_AROUND* :It is a neutral phase that depending on the distance received by the sonar sensors changes the current state, or set a “Looking” animation trying to search an object around it.

- *SPOT_ROTATION* : It is a neutral state of the robot when it is waiting to interact with an object around it.

- *RANDOM_SAD* : When the robot does not detect any object randomly express the sad emotion.

- *JOY_STATE* : When the object detected is near the robot then randomly enter this state with a probability of 1/7.

- *DISGUST_STATE*: When the object detected is near the robot then randomly enter this state with a probability of 1/3.

- *ANGRY* : When an object is near the robot and the thermosensor reveal that someone is trying to touch it, then it enters randomly this state.

- *EXCITEMENT_STATE* : When an object is at a medium distance from the robot, it enters this state.

- *WAIT_INTERACTION* : After an emotion state is fully performed the robot enters this state waiting for the next interaction.

- *COLLISION* : When an object is too near the robot, the it enters this state.

- *FEAR_STATE* : When an object is near the robot and the thermosensor reveal that someone is trying to touch it, then it enters randomly this state.

- *GIGGLE_STATE* : When an object is near the robot and the thermosensor reveal that someone is trying to touch it, it enters randomly this state. In particular, the robot expresses some funny behavior that represent a variation of the JOY_STATE.

Each state sets the associated animation and defines a set of actions to move the wheels of the robot. In this way, we ensure a parallelism between the actions made in the *Animation* file and the one done by the *State*.

The interaction between the states is shown in the following diagram:

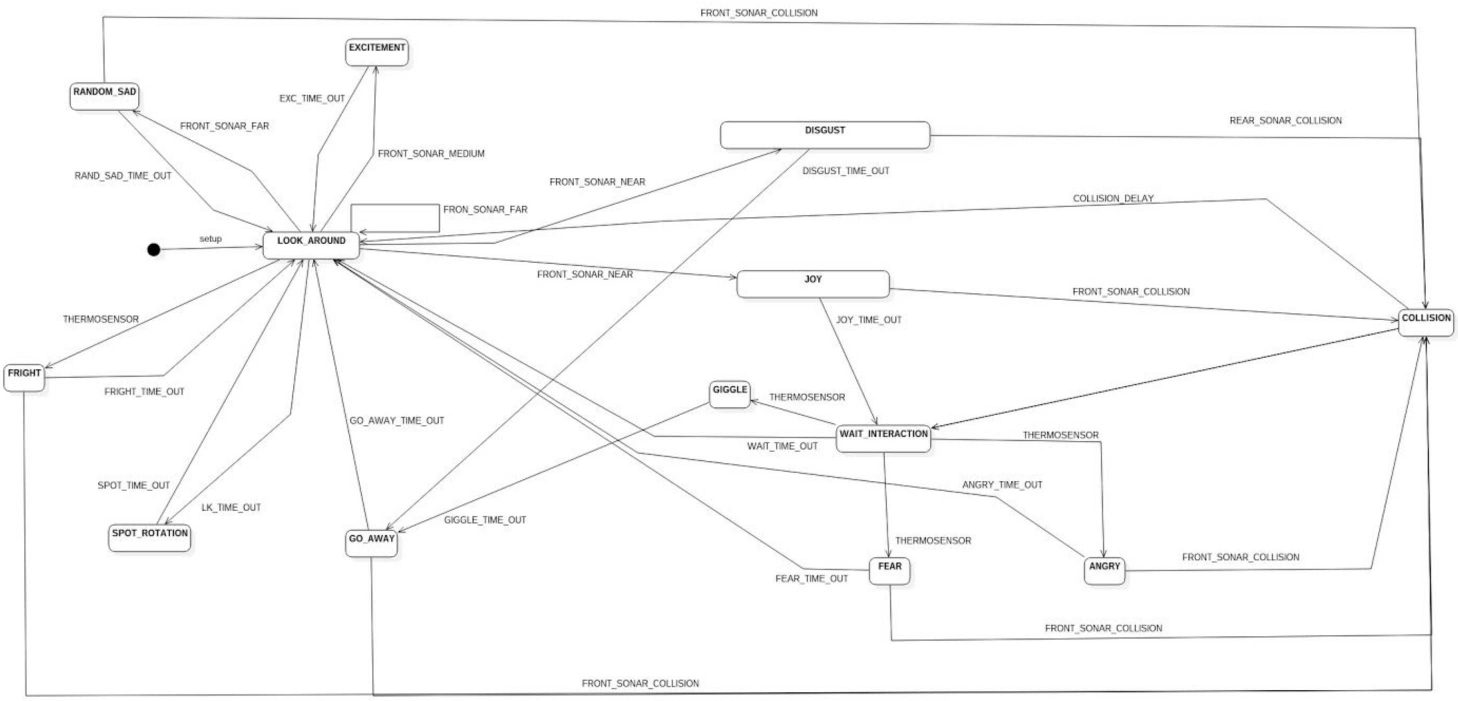


Figure 17: ***State Machine of the Robot***

For some electronic component we used predefined libraries:

LIBRARIES USED	
Wheels Motors	*SparkFun_TB6612*
Matrix LED	*Adafruit_NeoPixel*
	Adafruit_NeoMatrix
	Adafruit_GFX
MP3 Player mini	*SoftwareSerial*
	DFRobotDFPlayerMini
Sonar	*NewPing*
Thermosensor	*Adafruit_MLX90614*

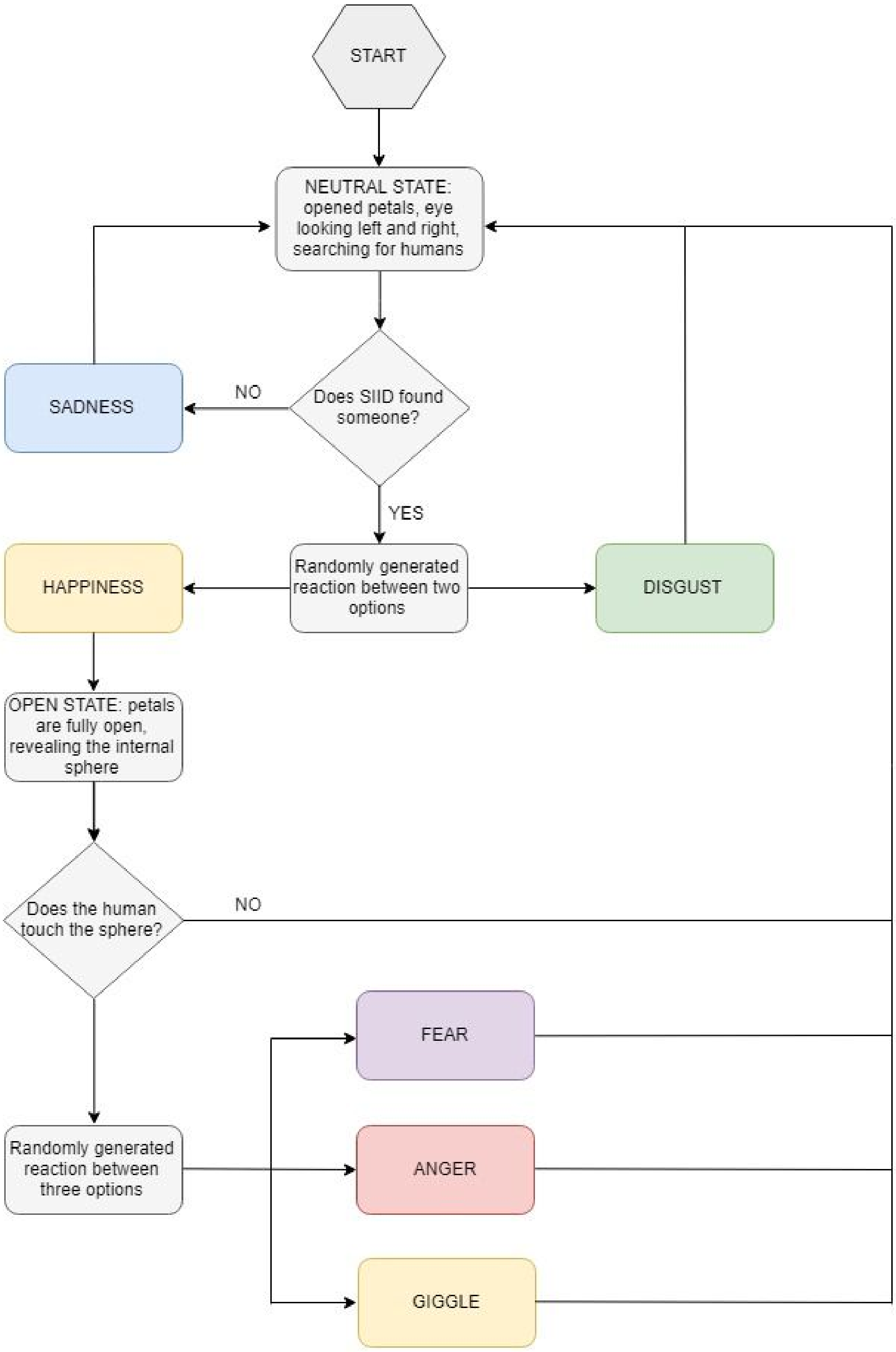
Conclusion

The more complicate problems we encounter with the robot was the weight of the petals and the mechanism. We wanted to realized a structure which would allow us to open and close all the petals together at the same time and with a single servomotor. We are conscious that our current mechanism is still not perfectly optimised and it could be a little rethought of. For example, it would probably have been better to manage the flower opening using one servo per petal.

Teamwork-wise, if every member of the group had a journal to write down and explain the work done, it would have been easier to continue and build up on each other’s work.

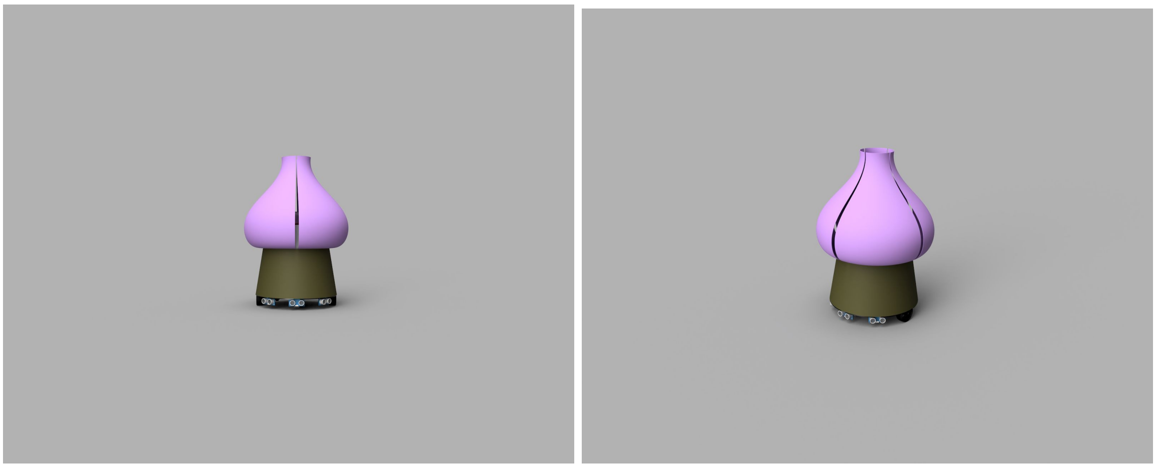
All in all, we had a very good experience working with each other, everyone contributed as they could to the project and we kept exchanging ideas and opinions through the very end.

Interaction



[1] ***Interaction Flow Diagram***

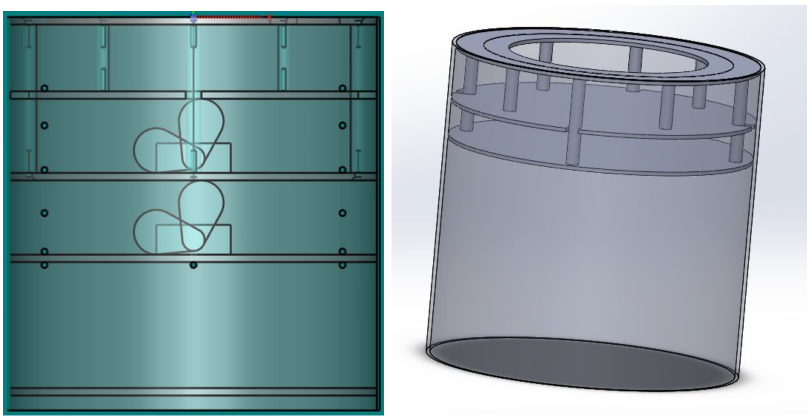
Shape



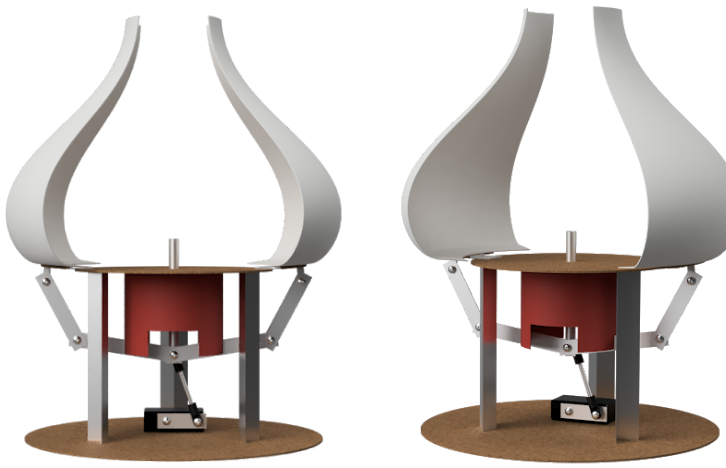
[1] ***3D External Shape***

Mechanics

Opening and Closing Mechanism

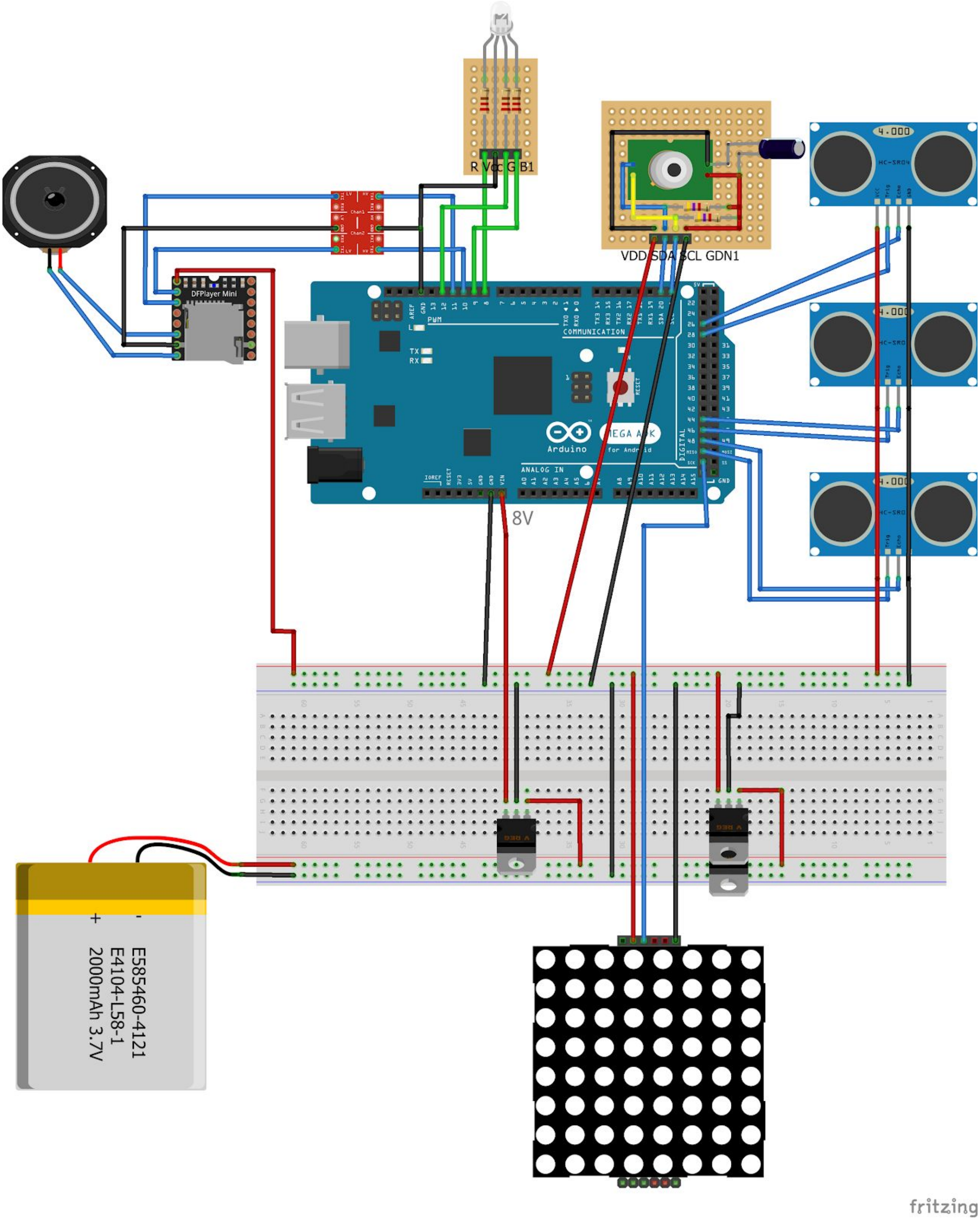


[1] ***First idea of the Mechanism for two layer of petals***

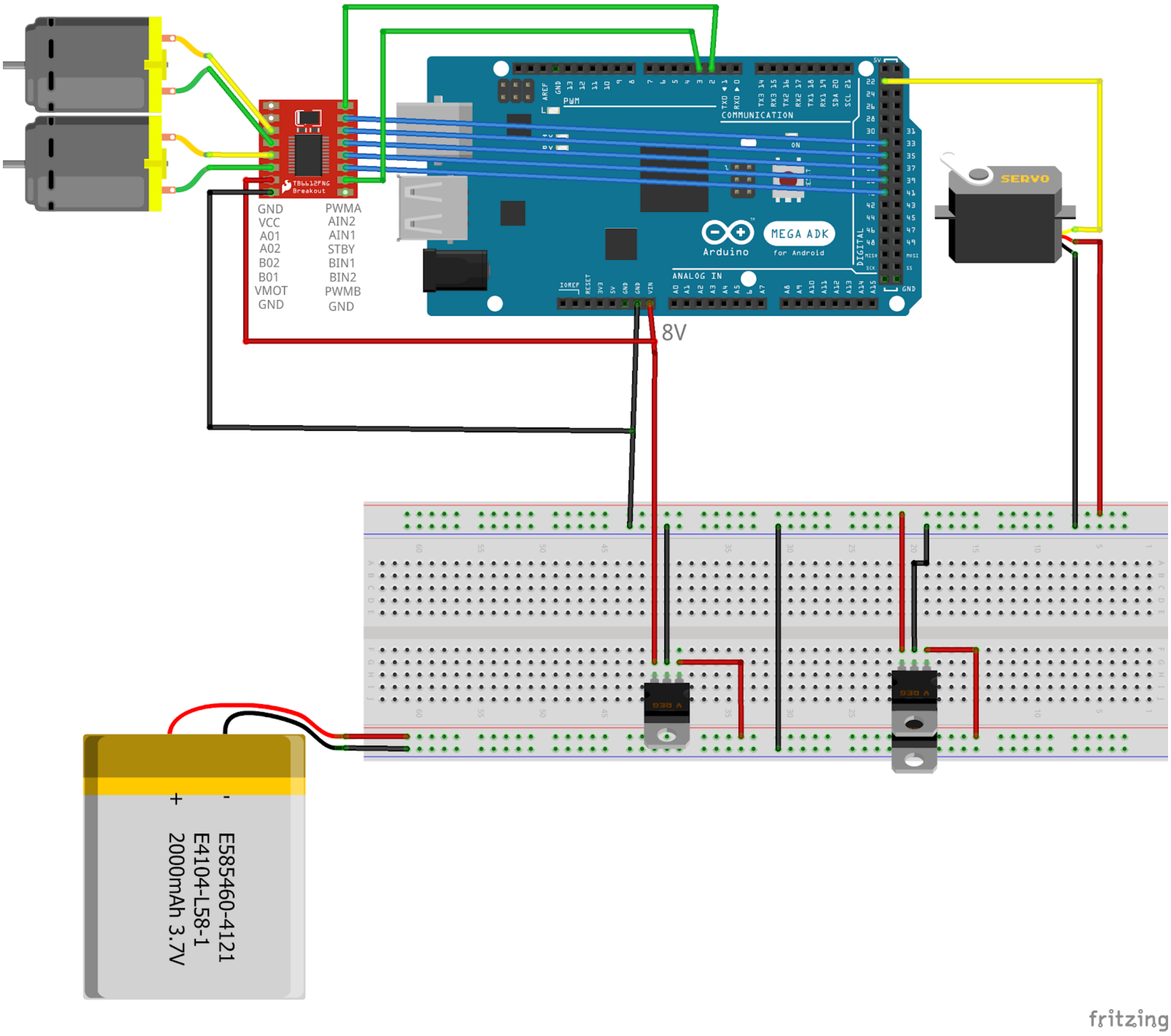


[2] *Four mechanical arms Mechanism for just a layer of petals*

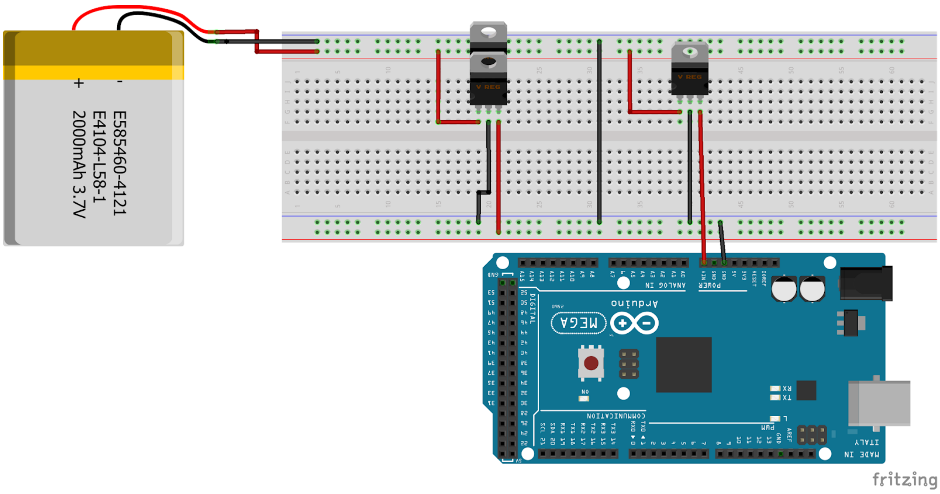
Electronics



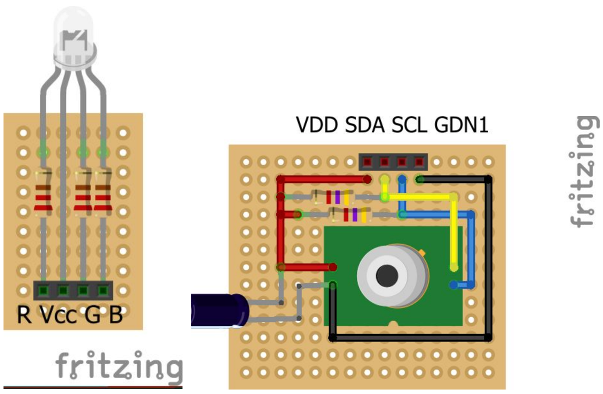
[1] ***Connections between all the sensors and the Arduino Mega board***



[2] *Connections between the actuators and the Arduino Mega board*



[3] Details of the power supply board



[4] *Details of the RGB Led and the thermosensor board*

Informatics

Source Code and Libraries:

- https://github.com/ricber/group3_robotics_and_design