Interdisciplinary course of

Design and Robotics

10° edition, 2022

Project:

Hato

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Index

Abstract

Hato is an educational toy for kids aged 4 to 8 years.
The idea is to teach them how to **solve a fight** and **respect each other** in a fun way, **helping the educator** in his/her difficult role.
The main idea is to teach them how to **respect shifts**, **not talk over each other**, **listen** to the **other's opinion** and speak politely.
The robot has an octopus-like shape and is worn like a hat, coming alive and reacting to the child's actions.

Team Organization

Our team is composed of:

Agnese Azzola, design & engineering
Jody Roberto Battistini, computer science engineering
Giuseppe Epifani, computer science engineering
Gabriele Pagano, computer science engineering
Giovanni Sassone Massari, product design

The team leader is: **Agnese Azzola**

Our responsibilities are:

- **Agnese Azzola**, synthesize and report the work, design internal structure, 3d modeling of components to 3d print, design external cloth cover, design eyes expressions, high level flowchart, prototype sewing and organize, language and interaction defining, movement defining, take care of report and presentations

- **Jody Roberto Battistini**, low level flowchart and high level flowchart, tentacles movement programming and calibration, mp3 player and speaker testing, eyes testing and programming, robot programming, user maintenance, firmwares and libraries, take care of report

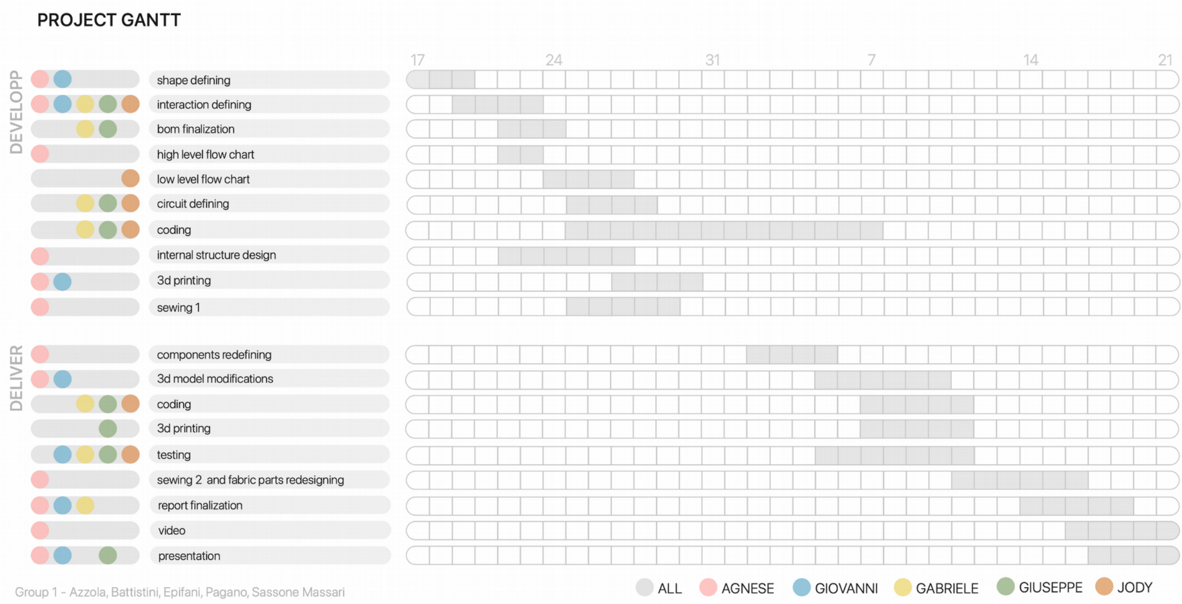
- **Giuseppe Epifani**, sensors and materials defining, design electrical circuit, 3d printing, mp3 player and speaker testing, soldering, architectural model of the robot software, filled out the final bill of material, robot programming, take care of report

- **Gabriele Pagano**, tentacles movement programming and calibration, take care of programming part of the report, final bill of material, Arduino components ordering, refund responsible, robot programming, final flow chart, firmwares and libraries, user manual, user maintenance, take care of report

- **Giovanni Sassone Massari**, sketch for the storyboard, to represent the product functionalities and to visualize the steps for the final video,design internal structure, 3d modeling of the internal structure and sensor case, rendering, presentation and report development, human robot interaction, make the final presentation.

Project Management

The work during the four phases has been divided between members, in order to proceed in an autonomous way.
At least once a week the group met to take stock of the situation and plan what to do before the next meeting.
As regards the definition of the concept, each member worked to find an idea that would respond to the initial brief of creating a social robot that was able to communicate with third parties, we then compared ourselves to arrive at a solution that would satisfy everyone, from that moment on, the designers have mainly developed the behavior of the robot, the human-machine interaction and defined and developed the formal and use requirements of Hato.
The engineers instead focused more on the research part of the sensors and actuators to be used and on the programming part to make the robot work.
In the first place (during the discover and define part) we weren't using a gantt, and we realized we needed more organization in order to respect the timelines.
So the gantt we followed for the final part of the course was:

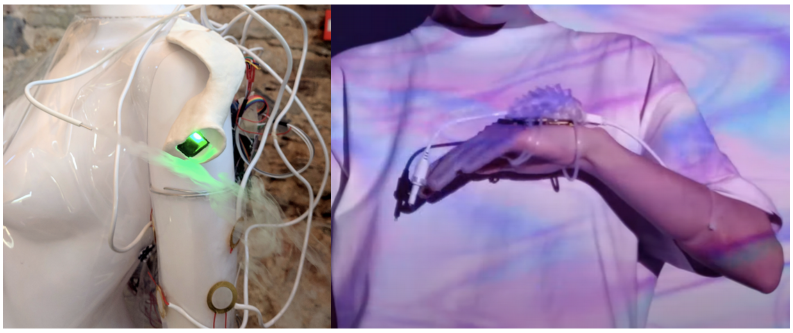


Phase 1: Discover

In this phase we start to organize ourselves, the team management, the tools we will use to communicate and we start to develop a common language.
We discussed each other's skills and areas of knowledge, defining which were our possibilities.
The goal of this phase was to find a scenario that could work in order to define the robot behavior and functionalities.

First research

Our first research focused on the search for keywords such as *fashion tech*, *wearable devices*, *wearable robot*, during this phase we collected many ideas in particular from the experiments of fashion in the field of technology, it was from these researches that we came up with the idea of an "animated character" to interact with the user and with other people.

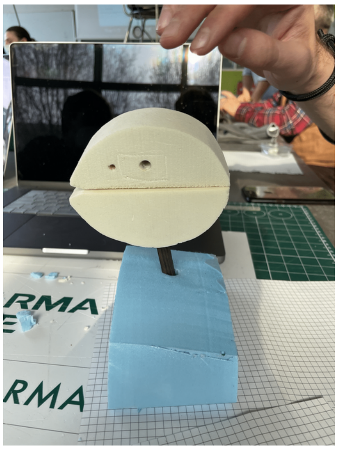


Brainstorming

We started thinking and brainstorming in order to develop the first concept of the robot, so we gathered suggestions on Miro and thought about possible solutions.

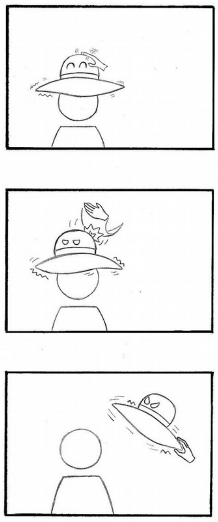
First idea

We started to define scenarios in which it could be useful to have a sort of "character" to communicate with others, than we thought of different typical situations, the user could for example be in the subway or in the bus and if he wanted to be alone, the hat would have made it clear to any other people not to disturb him.
In other situations, however, such as at the park, the hat could have allowed the user to socialize with other people.
Then we thought of sensors able to understand the emotional state of the user, communicate with the latter and with other people.



Second idea

This one was our second idea, a normal hat that could move based on the external stimuli, it could be "scary" if there are strong lights or sounds in the area, "sad" if the user is sad, "angry" if the hat is taken from the user's head, "bored" if someone smash it and "happy" if someone caress him.



We later discarded these ideas to focus on something for which it made more sense to have a wearable robot that could be used by children.

Second research

-We interviewed psychologists and teachers:

- We verified our concept speaking with primary school teachers, who told us that using a toy can really help the child to focus and spend time in an action that won't normally interest him.

- Speaking with a psychologist we defined that such a game is suitable for kids aged 4 to 8 years. They need to have a certain awareness of theirs and others emotions, and they need to be able to follow the rules and interact with the robot. On the other hand, they have to be young to find the toy interesting and useful.

-We searched for a scientific paper that described the impact of a social robot on humans.

- https://en.wikipedia.org/wiki/Social_robot#Social_Interaction
- https://link.springer.com/article/10.1007/s12369-018-0488-1
- https://link.springer.com/article/10.1007/s12369-013-0178-y

-We did research on social robots and pet robots on the market in order to verify what has previously been made and to understand the strengths and weaknesses of existing robots.

- https://en.wikipedia.org/wiki/Paro_(robot)
- https://en.wikipedia.org/wiki/Keepon

Interaction strategies

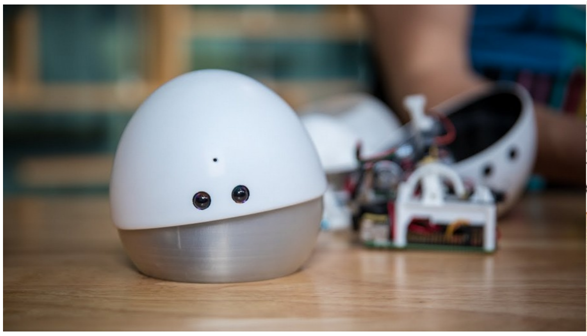
There are several reasons for which we chose to place the robot on the head:

-A hat is placed on the head, our first and main area of interaction, in this way, the third user can easily interact both with the other kid and with the robot, seeing their emotion and actions.

- Wearing a hat, even if big and eccentric is not something so uncommon, especially for kids. Everyone wore a funny hat at least once in his life. What one doesn't expect is for it to move and speak, and this is also helpful to bring attention to the interaction point.

Inspiration

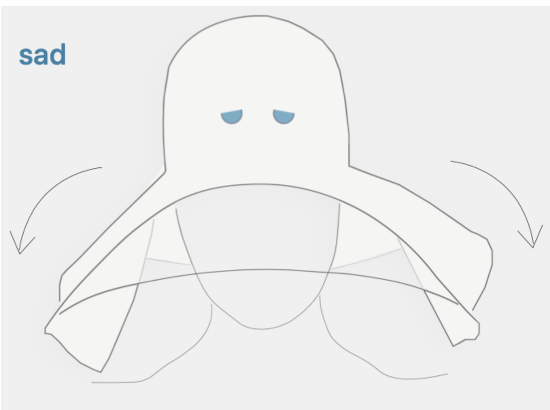
We took inspiration from existing robots, concepts about wearable robots, and concepts about fashion tech.

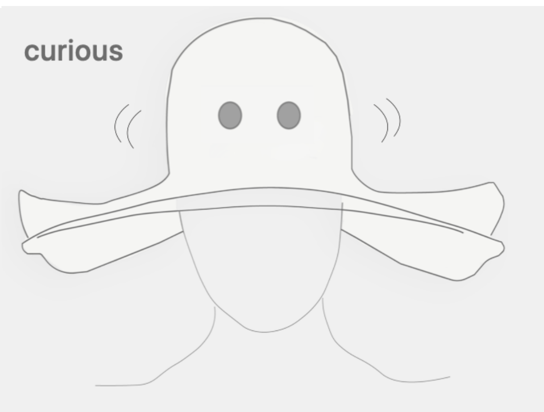


Third concept

Dealing with kids, we thought that an animal with a funny appearance could be the right choice.

At the same time, we thought that a hat itself has great expressing properties:





Phase 2: Define

After a broad research we started to define specific goals. Our goal was to understand how to design the behavior of the robot to help supervisors (teachers, parents and similar) to let their children make peace after an argument.

Strategy

We started to define scenarios to design the behavior of Hato.
Then we thought of sensors able to understand the emotional state of the user, communicate with the latter and with other people and finally to find ways to move the visor of the hat.

Moodboard



We have based the shape and the appearance of Hato based on the images we found to build the moodboard.

Storyboard

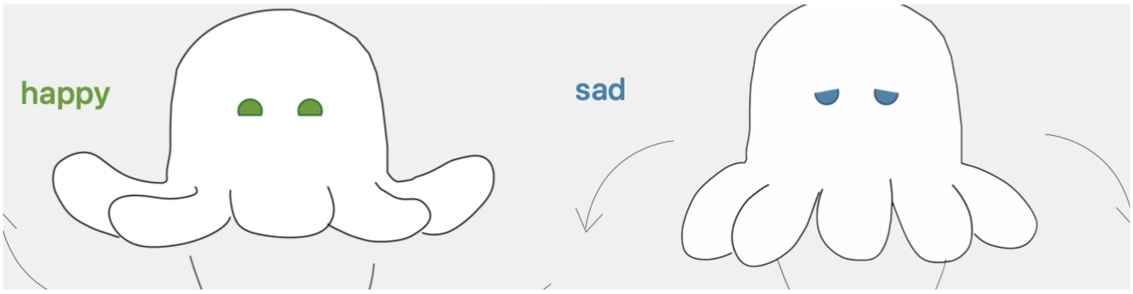
The best way to understand how the robot could have acted was to create a storyboard, through which all the key steps were highlighted:

This was our first storyboard, here we thought about a situation in which the two users, the children, were having a discussion. The teacher would have taken the hat in order to make peace for the children, so the teacher would have put the hat on the child's head.
The hat would have been happy to have touched the child's head and would have asked him to explain what happened by activating a timer, if during this time the other child had screamed, then the hat would have been angry.
The same procedure would have been for the other child, who would have to put on the hat and explain the situation.
During this phase the hat would be sad whenever the timer ran out.
The next step would be to make each child understand the other's point of view, the hat

would then be placed on the head of one of the two children and the latter would explain the other's point of view. The same thing would have been for the second child.
In the final stage, if both children, solving the matter, had to stroke the hat, that would have been happy.

Shape

We thought that mixing the shape of the hat with the one of a cute octopus could convey a similar expressiveness and be more interested for the kids:



From a movement point of view the main focus was the one of the tentacles, the main way to convey emotion. The second were the eyes. The speaking feature is supporting the flow of the game, but wasn't the center of the expressivity of the robot.

Functionalities

We decided to implement various functionalities through a series of components:

FUNCTION	COMPONENT	DETAILS
Head detection	**Capacitive sensors**	According to the game rules and field settings, we need to identify when the robot is on the head, because it needs to start the timer and at the beginning smile and greet the child. To achieve this, Hato was at first provided with a capacitive sensor to detect the skin of the child, but we had some problems with these sensors because sometimes it did not detect the touch
Volume detection	**Sound sensors**	The robot needs to tell the kids not to scream, so a microphone is fixed to the internal structure in order to detect if the level of the voice goes up to a certain threshold, if it take place, Hato will try to calm the kids saying the phrase "*Don't be mad, just tell me what happen*".
Speaking	**Mini**	To make Hato able to speak, it is provided with a mini

	Speakers	speaker. It repeats some mp3 recorded messages to clarify when the time is over, to calm the kids,to try to make the children understand the other point of view and to congratulate the children for their good job.
Feedback reading	**Buttons**	There are two buttons the children have to press together to make peace, the robot will react being happy and telling them they did a good job.
Tentacles moving	**Servo motors**	The tentacles move through two rods attached to two servo motors, the rods move based on one of the five emotions we provided the robot. If the robot is happy it moves the rods up, while if it's sad it moves them down, when Hato is angry or excited, it quickly moves the rods up and down, then it keeps them up or down for a while, before returning in the static condition. At the first attempt we noticed that the rods were too long and risked moving the fabric showing the servomotor mechanism.
Eyes expressions	**Led matrices**	We decided to use leds matrixes (8x8) to make the eyes. The main problem is that we couldn't use rgb ones because they required too much energy, but among the ones with a single color we only found the red ones.
Time counting	**Coding**	In order to define when it is time for the other child to speak, the robot starts counting time since the force sensor detects it is on the head, and when one minute passes he alerts him by moving, Hato could be interrupted during the time the child speaks.

Electronics

For the electronics, we opted right from the start to use an Arduino, because even our first ideas for the robot didn't require too much computational power.
We looked for two servo motors that would allow the movement of the tentacles; the motors needed to be strong enough to hold the resistance of the tentacles. Also we chose servos in particular because we needed their precision.
For the eye expressions we choose to use two LED RGB matrices, in order to have freedom in expressing all kinds of emotions.
Our first idea was to use some capacitive sensors to detect if the robot was put on the head. There are essentially two kinds of capacitive sensors: "Homemade" and bought; we tried the former but it was too noisy and difficult to control, so we opted for the latter.
For the external noise detection, we chose to use a pair of microphones.

At first, the selection of the battery was impossible as we didn’t have a final list of components and we couldn’t know the power consumption.
For the first tests, we hooked each component individually to test them, using a breadboard.
Then, we started to work with multiple components simultaneously.

Structure

We had thought the structure had to be able to accommodate the internal components including sensors and electronics and had to allow the movement of the visor and, at the same time, to be comfortable and lightweight.
We found it difficult to develop a way to move the visor without weighing down the structure

First attempt
This was our first attempt to understand what the dimensions of the robot would be, moreover through this print we realized that the structure should have been less high as it could annoy the ears and could also be uncomfortable for the given user. That would cover his eyes most of the time.
Another problem encountered was to find a way to keep the sensors still on the structure, as it did not have horizontal parts.

To move the flaps of Hato we had thought of using a lever attached with a screw to the servomotor, initially this lever would have to be inserted in three different tentacles, but this would have compromised the movement.
We then thought of inserting a wire that would have passed along all the tentacles, to be inserted inside much smaller levers, which would have been interlocked each of the two in a single tentacle, in this way the structure would have been lighter and we would have overcome the problem of the movement of the lever.

Emotions

Starting from the storyboard and the flowchart, we defined the emotions necessary for the robot to communicate with other users, as soon as Hato is put on his head, the capacitive sensor understands it and sends a signal that makes Hato happy, once the child begins to tell the story, if the other interrupts it, the sound sensor perceives it and Hato gets angry.
As soon as the child's time to talk is over, hato becomes sad, but when the two children make peace, Hato becomes excited.
Normally Hato is in a state of continuous curiosity, when he does not receive stimuli in fact, he will look around waiting for user feedback.

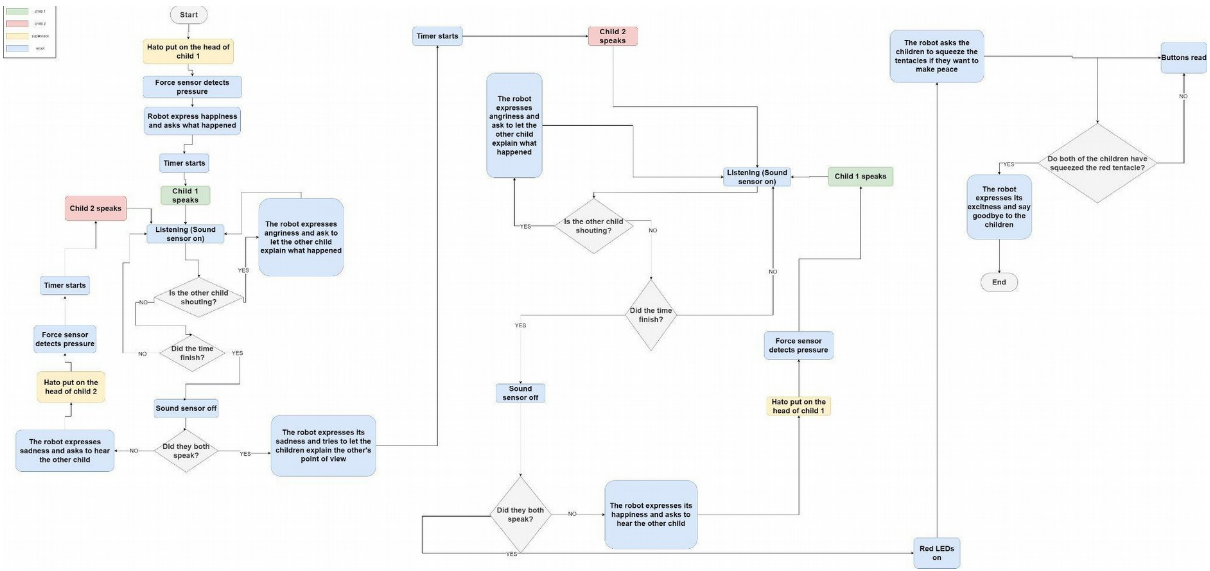
Phase 3: Develop

After the first prototypes, we thought about some things that needed to be changed.

Storyboard

In this phase we realized that the interaction process could be excessively long and boring, so we changed the storyboard and the related flow chart, in this new version the children no longer have to try to say something nice to the other because they have explained it their point of view, they will simply have to say they agree by pressing the two tentacles of Hato.

High Level Flowchart

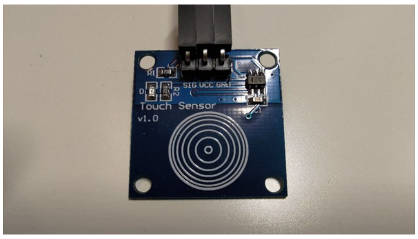
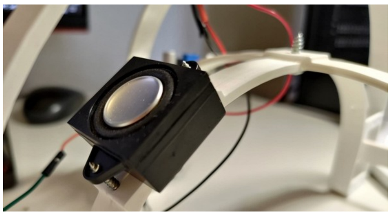
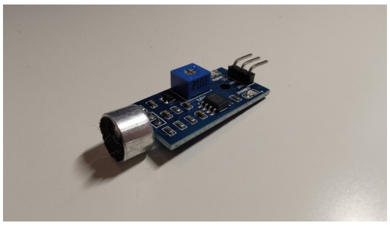
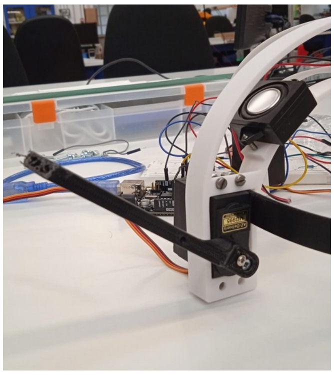
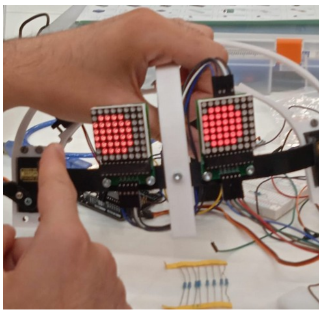


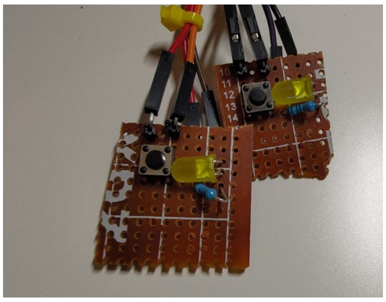
Electronics

Deeper in the development, we found some problems dealing with the different components:

- The capacitive sensor was not working as expected, as it was resetting itself randomly, so we looked at alternative solutions
- RGB LED matrices are really hard to find, and require high amount of energy
- We needed to reduce the voltage of the batteries, using a voltage regulator.

We started working on soldering on the protoshield to reduce the space of the circuits.
Another difficulty was in making sure that all the components were synchronized and that they responded in the right way. The engineering team worked through the code to make sure everything was in sync.

	Capacitive sensor
	Speaker
	Sound Sensor
	Servo Motor
	LED matrices

	Buttons and Leds

Coding

We started the programming phase by defining the architectural model of the robot. We opted for the Finite State Machine model in which each state corresponds to a particular phase of the interaction.
During the programming part the most of the issues we found were about letting the machine return in the correct states with the correct variables setting. We solved these problems by declaring some flags, checking their values in some if-else conditions and going to the correct state accordingly.
Moreover, pursuing the purpose of letting the robot be ready for a new interaction after the end of an older one, we also implemented a function that resets all the global variables and is called after the old interaction is finished.

The main problems we have faced during coding were:

-The calibration of the tentacles movement (i.e. Servo Motors Calibration) because of the limited angles in which they can move and the diversity of the environments in which we have tested them, with and without the fabric structure.

```
//Movimento di entrambi i motori, ogni volta che termina un'emozione torna alla posizione di base
void movementHappy(int finalPosition, int middlePosition, int transPosition, int myDelay, int numberOfMovement){

  while(count < numberOfMovement) {
    for (posLeft = 180 - finalPosition, posRight = finalPosition; posLeft >= middlePosition + 10 && posRight <= middlePosition; posLeft -= 1, posRight += 1) {
      myServoLeft.write(posLeft);
      myServoRight.write(posRight);
      delay(myDelay);
    }

    for (posLeft = middlePosition + 10, posRight = middlePosition; posLeft <= 180 - finalPosition && posRight >= finalPosition; posLeft += 1, posRight -= 1) {
      myServoLeft.write(posLeft);
      myServoRight.write(posRight);
      delay(myDelay);
    }

    count++;
  }
  count = 0;
  for (posLeft = 180 - finalPosition, posRight = finalPosition; posLeft >= middlePosition + 10 && posRight <= middlePosition; posLeft -= 1, posRight += 1) {
      myServoLeft.write(posLeft);
      myServoRight.write(posRight);
      delay(myDelay);
  }

  //Torna alla posizione base dopo 2 secondi
  delay(2000);

  for (posLeft = middlePosition + 10, posRight = middlePosition; posLeft <= 180 - finalPosition && posRight >= finalPosition; posLeft += 1, posRight -= 1) {
      myServoLeft.write(posLeft);
      myServoRight.write(posRight);
      delay(myDelay);
  }
```

-The calibration of the sound sensor and consequently the selection of a threshold for it, because it doesn't have an output value, so we have to do this calibration manually with a screwdriver.

-We have been able to stay within the number of pins given by the Arduino Uno, so we saved a lot of space because we don't use an Arduino Mega board.
In the next image are shown the libraries and the pins that we're using:

```
#include <StateMachine.h>
#include <LedControl.h>
#include <Servo.h>
#include <Arduino.h>
#include <SoftwareSerial.h>
#include <DFRobotDFPlayerMini.h>

#define STATE_DELAY 2000
#define PIN_LED0 0
#define PIN_LED1 1
#define PIN_MATRIX_LOADCS 2
#define PIN_MATRIX_CLK 3
#define PIN_MATRIX_DATAIN 4
#define PIN_SERVOLEFT 5
#define PIN_SERVORIGHT 6
#define PIN_FSR 7
#define PIN_BUTTON1 8
#define PIN_BUTTON2 9
#define PIN_MP3PLAYERRX 10
#define PIN_MP3PLAYERTX 11
#define PIN_MICROPHONE 13
```

As you can see we tried to use the pin 0 and the pin 1 from the Arduino, but we later discovered that this two pins may have some hardware conflicts because they are used for serial communications and it's normal for them both to be a steady high when there is no actual data being sent, that is the default stop condition for serial data.
We also changed the FSR pin from 7 to an analog pin (A0).
In definitive we have:

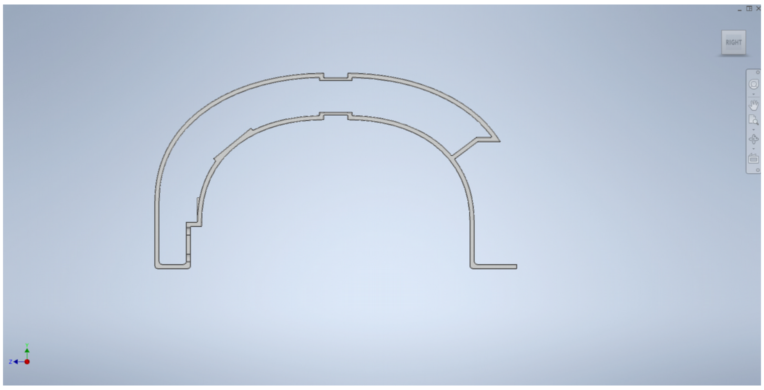
```
#include <StateMachine.h>
#include <LedControl.h>
#include <Servo.h>
#include <Arduino.h>
#include <SoftwareSerial.h>
#include <DFRobotDFPlayerMini.h>

#define STATE_DELAY 2000
#define PIN_LED0 7
#define PIN_LED1 12
#define PIN_MATRIX_LOADCS 2
#define PIN_MATRIX_CLK 3
#define PIN_MATRIX_DATAIN 4
#define PIN_SERVOLEFT 5
#define PIN_SERVORIGHT 6
#define PIN_FSR A0
#define PIN_BUTTON1 8
#define PIN_BUTTON2 9
#define PIN_MP3PLAYERRX 10
#define PIN_MP3PLAYERTX 11
#define PIN_MICROPHONE 13
```

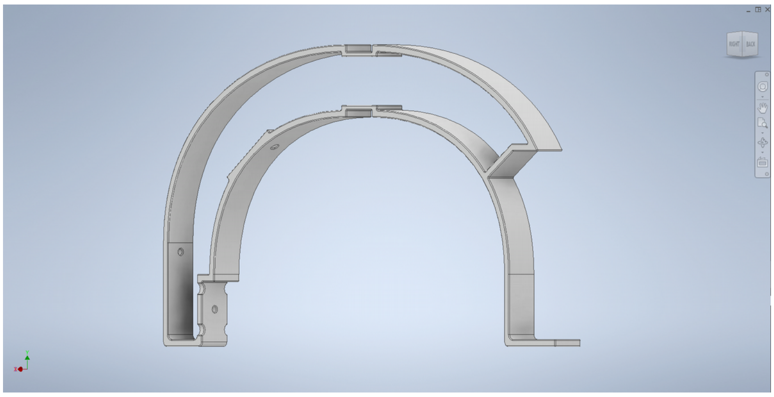
Structure

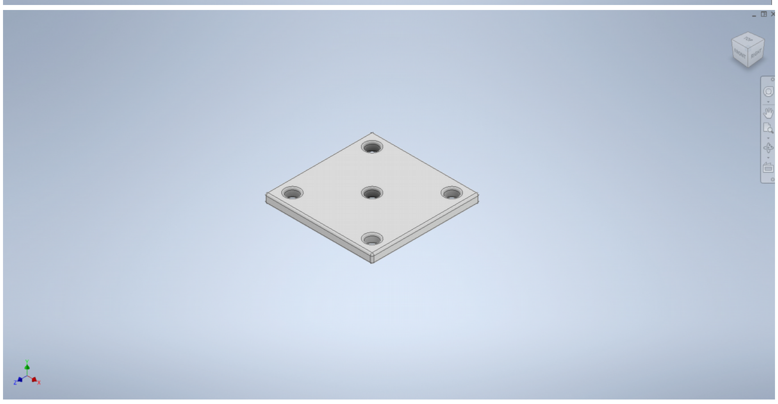
The difficulty was making sure that the structure was light and at the same time had enough space to accommodate all the components, another difficulty encountered was that of the correct positioning of the LED matrices inside the structure.
We therefore worked to create a structure that was comfortable and at the same time used in as little material as possible and also we worked on how to be in such a way that the sensors were fixed to the structure without having to use more material, to do this we made use of self-tapping screws and molded the structure with holes already inside.
For the structure we made two 3D printed arches on which to put all the components and the battery, these arches, compared to the previous ones, were much less high, so as not to

annoy the ears and not always cover the user's view, a difficulty encountered was however that of designing a comfortable shape for the two lower arches of the two structures, these were in fact too square to be comfortable once worn.



The front structure, compared to the previous one, had a base where to fit the capacitive sensor, it had therefore been modeled to house a plate to be screwed between the structure and the sensor, the problem was, however, to find screws that were not too long.
Furthermore, that part of the front structure that was going to rest on the user's forehead was very uncomfortable due to both the non-ideal dimensions of the arch and the excessively squared shape.
Due to these problems we made the front and bottom of the front structure rounder.

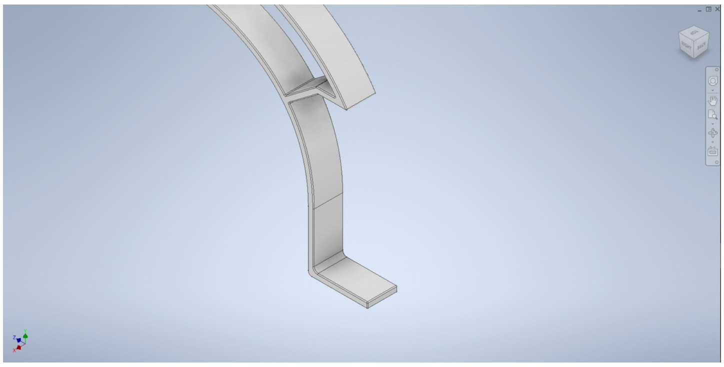




On the front we then created the housing for the sound sensor, we then made a part of the structure flat and inserted a hole to screw a screw and a bolt to hold the sensor still.

The same procedure performed for the capacitive sensor was done to accommodate the arduino, between the structure and the component there is in fact a plate with five holes, the control unit attaches only to the structure, the other four outermost instead are made to fix the Arduino plate.

The frontal structure was also modified to allow the housing of the battery, the upper arch of the structure was then cut and connected via an oblique axis to the lower arch, a hole was then drilled on the latter to allow embedding the battery case to the frame, but we quickly realized that the screw could scratch the battery cell, so we thought it would be safer to attach the case to the frame with glue.
A further problem was that of the battery plate to be connected to the structure in some way and then find somewhere to insert the on off button.



As for the side structure, we have created horizontal parts with two holes on each of the parts in order to house the speakers.

As for the LED matrices of the eyes, we initially thought of a mask in which to insert the LED matrices, to be fixed to the structure through a joint, but we had the problem of having to fold this mask in such a way that it was not visible under the fabric.
The mask would first have had to be folded after being heated while hot, then the LEDs would have had to be inserted and finally everything would have had to be tarred to the front structure.
So we have decided to create an additional horizontal rod that fits into two holes made in the lateral arch at the height of the servomotors, the lateral arch has therefore been widened in such a way as to allow the housing of the joints.
The horizontal rod is then attached to the front structure by means of a screw.

Once we tried to assemble the structure inside the fabric, we realized that the metal wire to pass along the tentacles, was difficult to assemble and was also too evident inside the fabric, having seen that the tentacles moved enough even with only the levers thanks to the movement of the fabric, we decided to leave the levers exclusively.

As for the button and the LED to put on the tentacles, we thought of attaching it to the levers for the movement of the tentacles, attaching them with screws and bolts, but we had the problem of having to press the button, the first idea was to print 3d a structure to be placed on the button that was flexible, but it would have been almost impossible to keep still on the button.
The second idea was to create an additional lever to be fixed on the first and to be pressed

when you wanted to press the button, in this way the flexibility of the Pla would be exploited.

In general, assembling the 3d printed structure with the components and the fabric, we realized the dimensions of the printed components had to be changed, making it larger to be more comfortable and taller to fit the arduino better.
The final structure is one centimeter larger and longer in order to be more comfortable, moreover it is four centimeter higher in order to fit the arduino.

Shape:

The shape was designed to enhance the movement of the tentacles and to allow users to see eye expressions through the fabric.
One difficulty we encountered was that of allowing the tentacles to function properly without showing the internal structure, this last problem is being studied, a solution could be to use additional fabric exclusively for the part where the flaps move.
Last prototype was made with a softer fabric compared to the previous one, the problem is that it shows the structure and the matrixes, so the round and cute shape is ruined. We understood that either we use a tougher fabric or we add another layer of padder.
We understood that it is important to sew after the internal structure is complete, in order to draw the paper pattern precisely. The problems we are facing are due to the fact that the fabric was sewed before the structure was assembled, so we couldn't check.

Phase 4: Deliver

During this phase we have filed any imperfections and corrected all those aspects that, during the development phase, seemed to us to be improved.

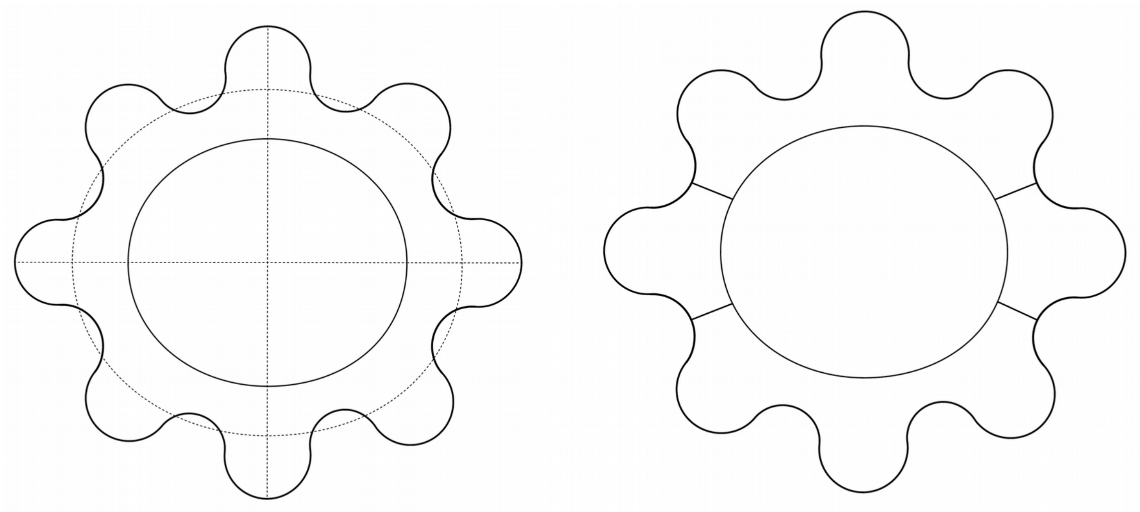
Final Robot description

Shape

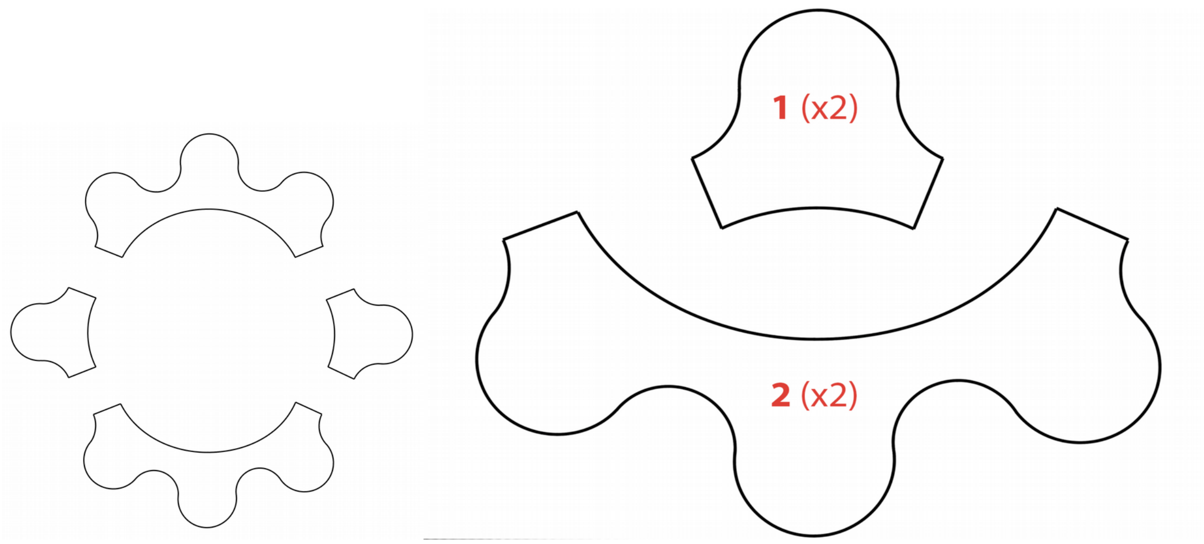
For the realization of the external fabric covering paper patterns were created, they were used to cut the fabric, and then a strategy has been applied for sewing the complex structure around the internal one.
Two fabrics have been used: felt - strong and rigid, to maintain the shape on the top- and a lighter, softer, elastic one - for the bottom layer, in order to easily open and stretch the

structure to insert the internal components.

1) creating the tentacles shape considering the head diameter

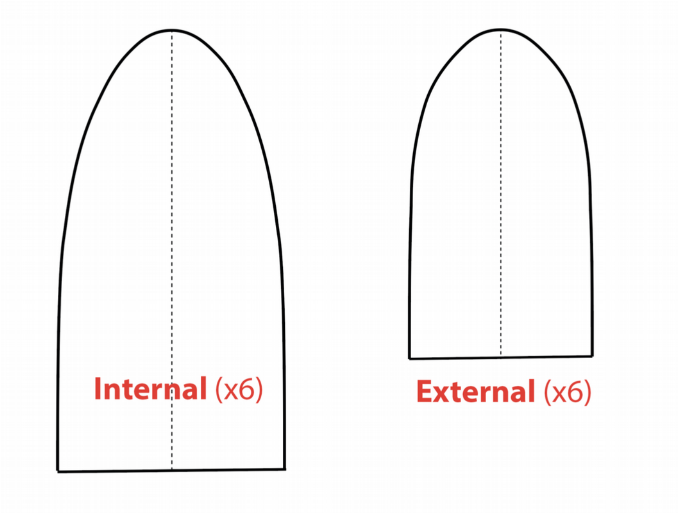


2) they were divided to have one specific in which insert the moving component

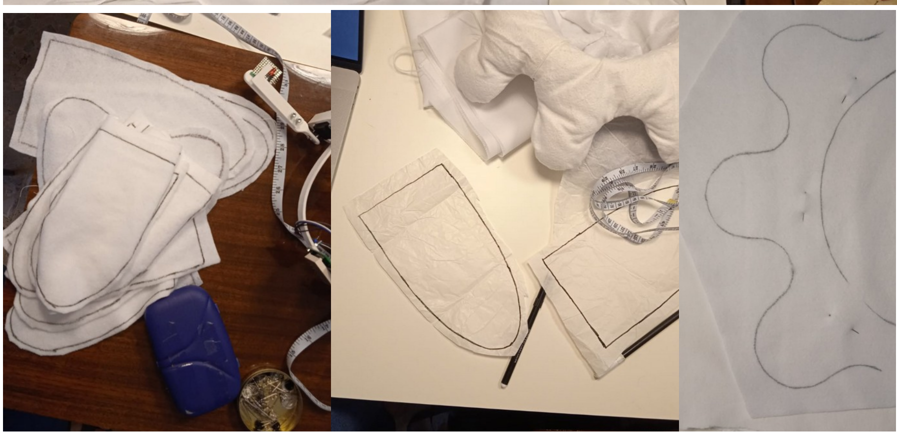


Considerations: the tentacles have been subdivided in this way since the "solitary" tentacles will be the one in which we insert the structure for the movement. We noticed that along the stitching the movement was transmitted strongly, so we wanted to apply the maximum possible there.

3) designing the cloves for the head part, considering one internal shell and one external

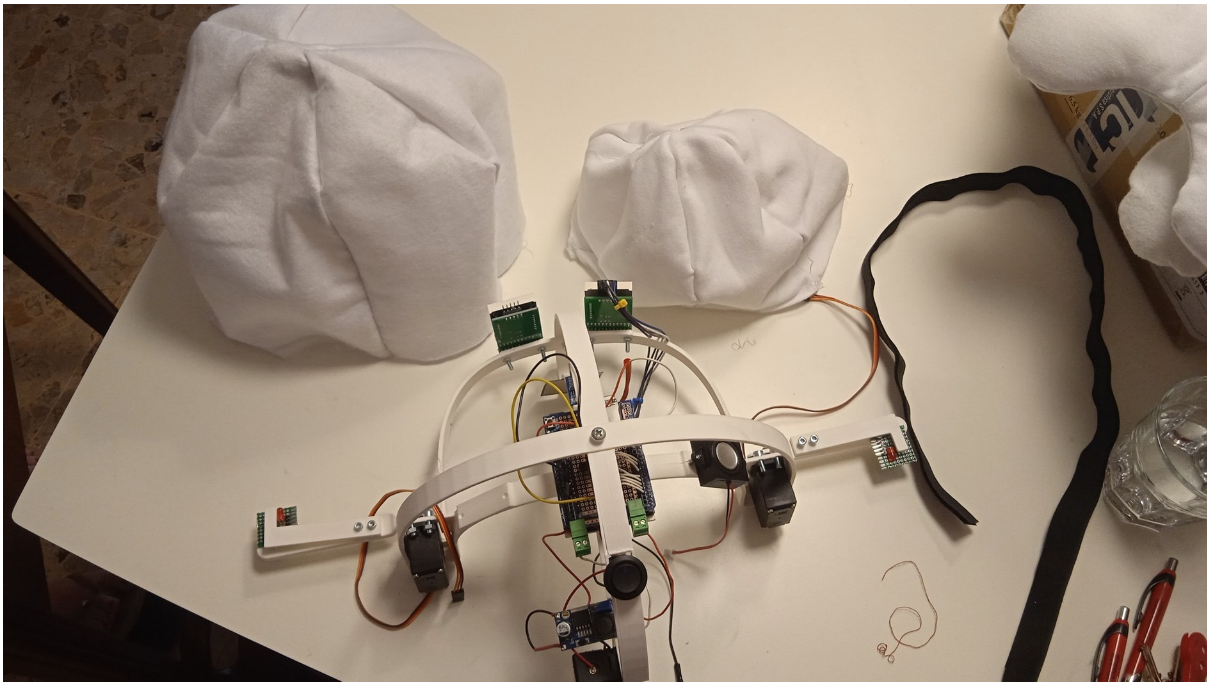


4) Paper patterns have been transferred to the fabric and bastings have been made. 12 cloves for the head part and 8 parts for the tentacles have been cutted-

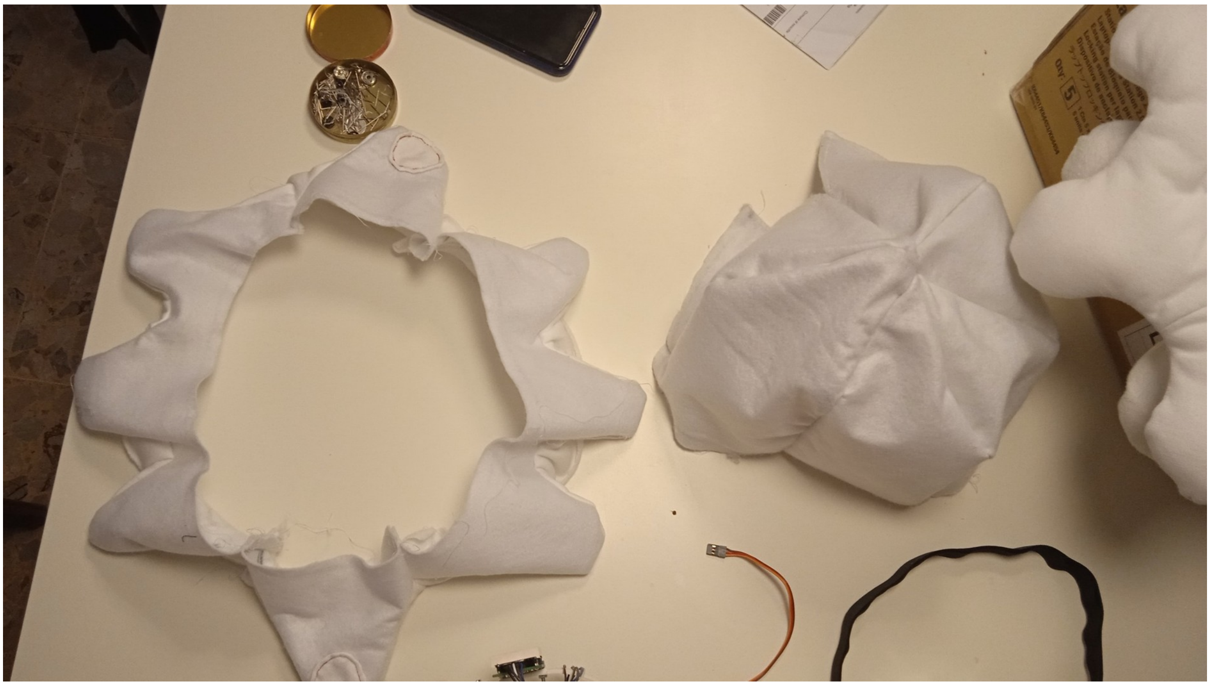


5) The two layers of the tentacles (made of two different materials) have been sewed together.

6)Then the two caps - internal and external - of the hat were sewn



7) Following step was putting them together:



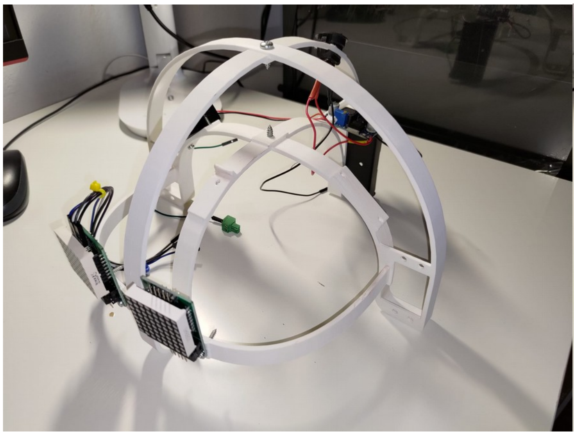
We made three different fabric prototipes, this one was the only one that was tailored on the structure

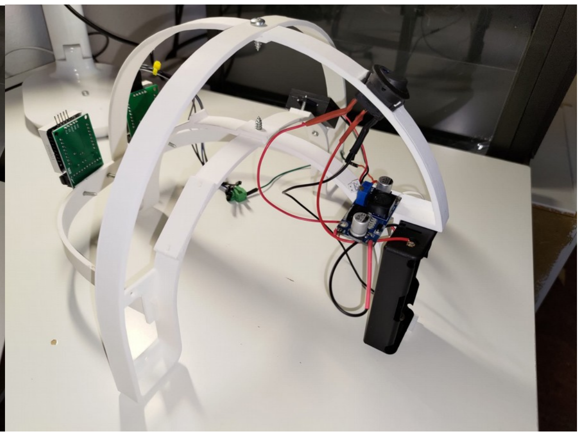
8) To suggest where the user has to press we added two circles on the pressing tentacles:

Conclusions: it took 48 hours total of two people sewing to realize the hat. Some parts were very thick and difficult to sew by machine so they needed to be handmade. Also the circular shapes didn't make the job easier.
We learned that this should always be the last thing to make and needs more time than the one we saved for it. This is because it has to be tailored to the internal structure, and sometimes you realize that the combination of the two isn’t working, so you need time to redo and correct.

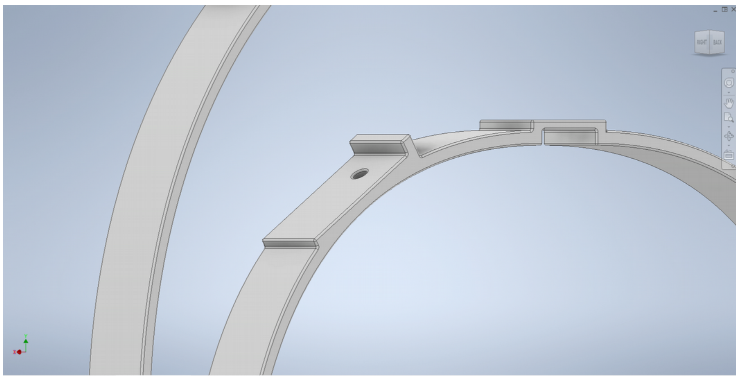
Mechanics and structure

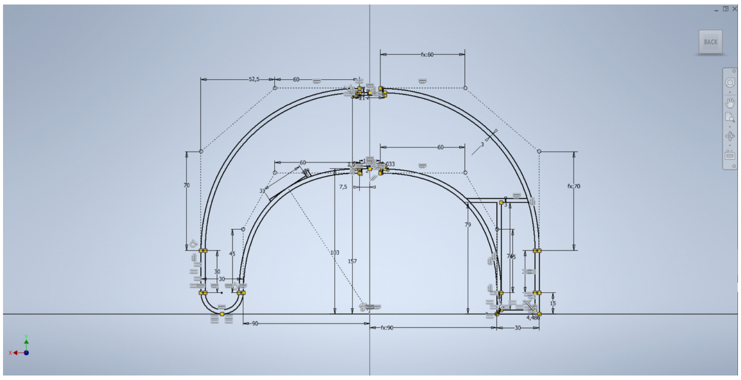
The final structure consists of three arches in Pla.
The two main arches are those that rest on the head, compared to the previous structure, these arches are one centimeter wider and one centimeter longer, furthermore in the front part the arch has been completely modified, no longer hosting the capacitive sensor, a "U" shape was chosen to make the structure more comfortable.



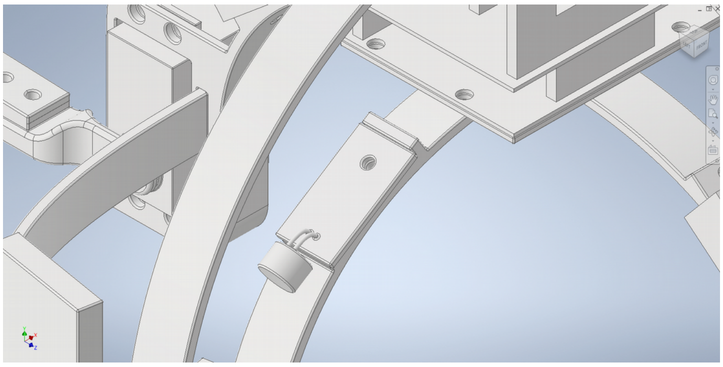


The front arch was then modified also because it no longer had to house the mask for the LED matrices, so a hole was made that would allow the coupling with the horizontal arch for the LED matrices, the housing of the arduino and the wiring; the part of the arch that instead rests on the head has also been raised in the middle in order to obtain a more comfortable shape to rest the hat on the head.

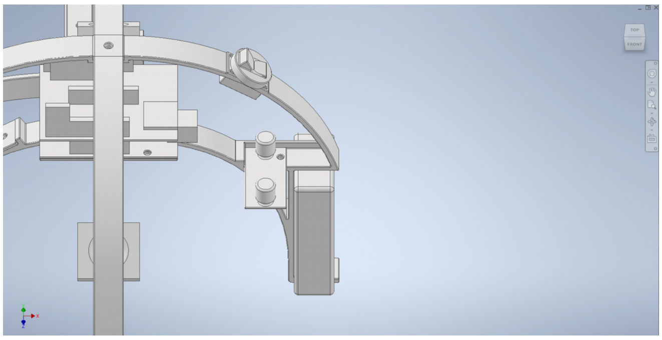


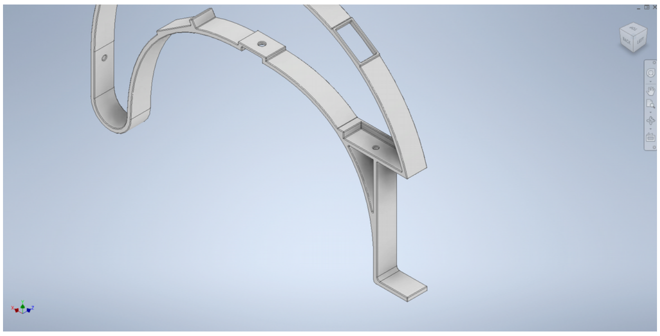


On the front arch, where there is the housing for the sound sensor for noises, an additional step has been created to prevent the sensor from rotating around the screw.

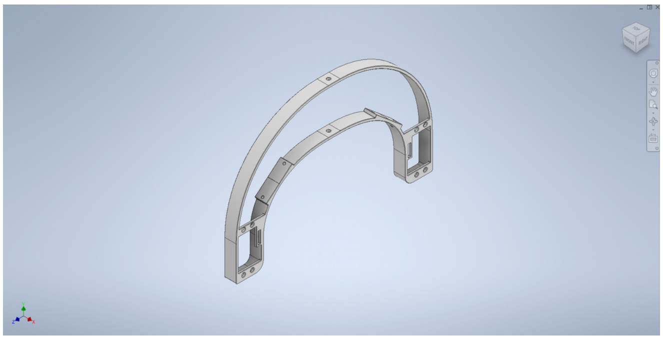


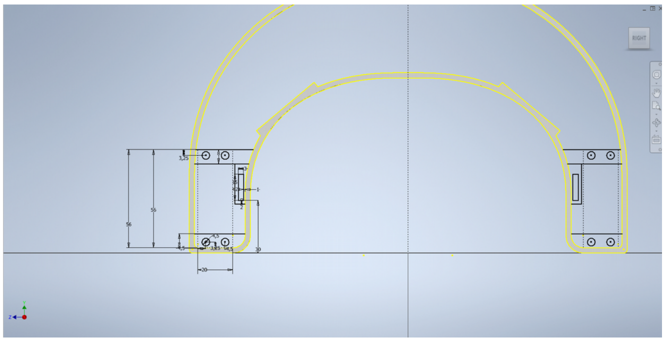
The last final change made to the structure is frontal was the one concerning the battery part and switch on and off.
As for the battery, it has been done in such a way that its case almost fits inside the structure. To avoid that the screws used to fix it to the structure could somehow scratch the battery, we decided to glue the case to the structure .
The battery then needed a plate to be connected to the on off switch, to put it on the structure the same procedure was used as with the microphone, a horizontal part was then modeled that goes from the lower arch of the front structure to the upper one, on this a hole was made to tar the plate to the structure with a screw and a bolt and, to prevent it from rotating around the axis of the screw, a vertical wall of a few millimeters was created that would have touched one side of the plate, preventing it from moving.
On the upper arch of the front structure, a rectangular section hole was instead made to allow the accommodation of the on-off switch.



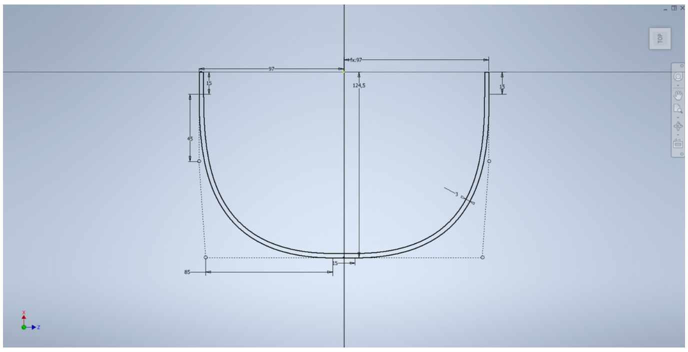


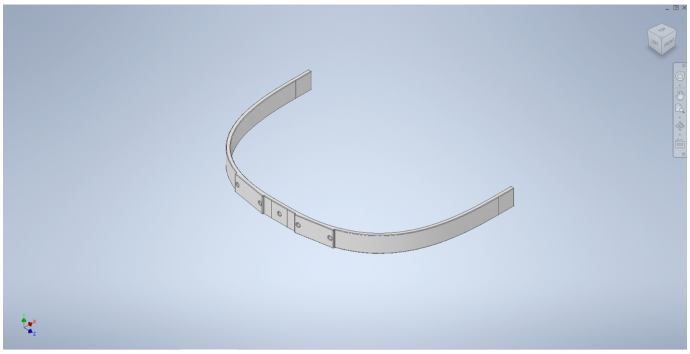
As regards the lateral structure, this has been widened in such a way as to allow the joint with the horizontal structure as well as for the servomotors, there is also a double flat part on which two holes have been made, so as to be able to host the speakers.
also the lateral structure, as well as the front one, has been raised by half a centimeter as regards the lower arch, in order to create a more comfortable shape for the head and by four centimeters to allow the accommodation of the arduino and the wiring.



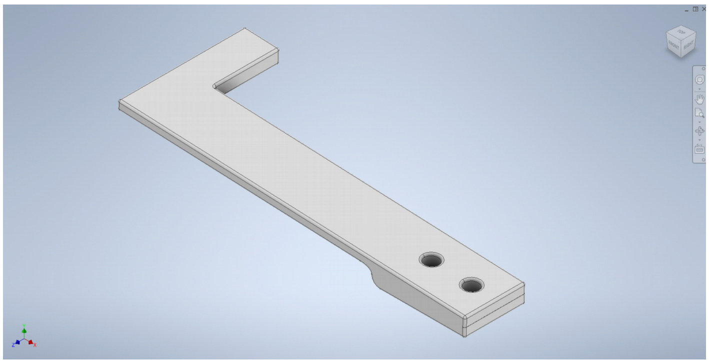


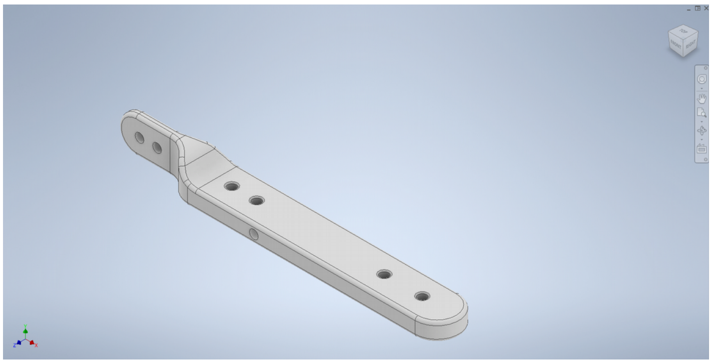
The horizontal structure has been specially designed to allow the housing of the LED matrices, this structure therefore has two horizontal parts, both with two holes, to ensure that the screws and bolts keep the LED metrics hooked to the horizontal structure, it hooks to the front one by means of an additional screw and to the side one by means of a joint.
It was then decided to make sure that the horizontal structure would be hooked to the other more, as the whole structure would have risen by a few centimeters, resulting larger and higher, it was done to avoid that the matrices were too close low and did not send Hato's expressiveness well.





We thought of adding shorter levers to the servo motors, onto which the board with the button and the LED above it using two screws, to ensure that the button was pressed, we created an additional lever to be positioned on the existing ones, with the difference that this would have been only two millimeters wide, in order to take advantage of the flexibility of the PLA to repeatedly press the button.



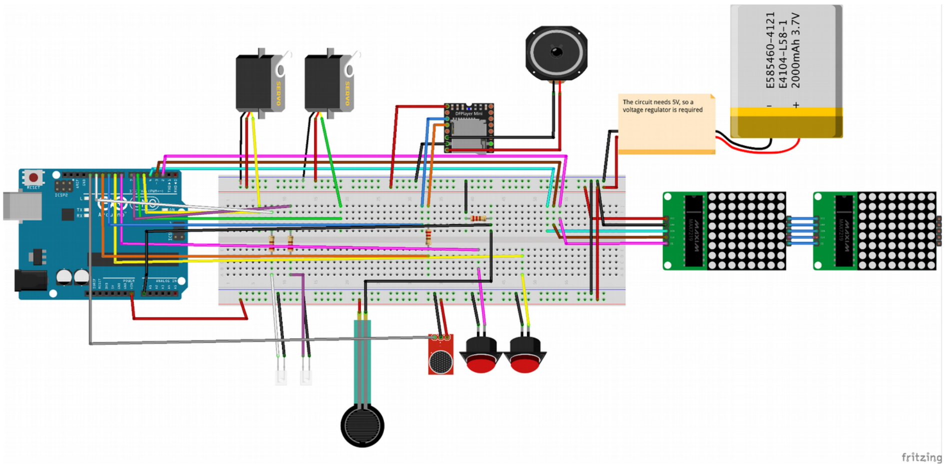


Electronics

The robot runs all of his logic on an Arduino board, with a proto shield installed on top for easier cable management.
The main components are:

- 2 servo motors, that are used to make the robot arms move up and down
- A micro SD card reader and a speaker, to play mp3 audio files
- A pair of 8x8 led matrices, used to make different eyes expressions
- A sound sensor
- A force sensor, to detect the pressure when the robot is put on the head.

The robot runs on 2 18650 LiPo batteries, which are put in series by a battery holder.
The batteries give on output 7.4V, so we used a voltage regulator to step this value down to 5V; attached to the battery holder there is also a simple switch, used to turn on and off the robot.
For most of us this was the first serious project involving electronics, and it was a really interesting challenge to overcome: the choice of the components to meet the objectives, the testing and the trial and error.
We also chose to do some soldering on the proto shield and the battery components to save some space; in particular, soldering was needed to connect all the components to the same 5V and Ground lines. We chose to not solder the component's cables directly, but to use a female connector, in order to be able to remove and swap components easily. The soldering part was not easy as it was our first time, but it turned out great.
One of the first and main problems we had was about power management: after compiling the first list of materials, we calculated the mean and peak power consumption, and they were over our expectations; we had to remove some components and change some others, in order to reduce the power consumption. For example, we scrapped the idea of having multi-colored led matrices, because apparently they consume a lot of power.
Another difficult task was the calibration of the sound sensor trigger threshold.
Our main objective was to have a working circuit in the smallest possible space; space was the most critical feature of the circuit and in general of the project. Having to build a wearable robot meant that it needed to blend in with the wearer, and to not be bulky or heavy. The soldering and the right choice of sensors and actuators were the two main tools that helped us archive a relatively small circuit that could fit in a wearable robot.



Informatics

The robot runs all of its logic on an Arduino board, so we implemented the code with Arduino IDE. We decided to use a modular approach, thanks to the **StateMachine.h** library that allows us to define the code as a state-machine diagram and lets us implement the transition between states.
To accomplish this task we used a bunch of libraries:

- **LedControl.h:** manages the eyes of Hato (i.e., led matrices) with some animations of the leds of the matrixes,

- **Servo.h:** manages the movement of the tentacles of the robot (i.e., servo motors) to let it show emotions,

- **Arduino.h:** standard Arduino libraries used for some standard things, like analog and digital I/O

- **SoftwareSerial.h:** used to manage the serial monitor, useful for calibrations and testing during the programming phase

- **DFRobotDFPlayerMini.h:** used to manage Hato's speeches, first loaded into a micro SD and then played by means of the MP3 player

Those are the links for downloading the code:

- **Whole code**: https://github.com/giuxlb/Robotics-Design-Project-2022

- DFRobotDFPlayerMini.h, Servo.h, LedControl.h can be downloaded directly from the Arduino IDE.

```
void state6(){
  //stato angry, fa movimenti angry mentre dice di non urlare
  myDFPlayer.play(3); //"Don't be mad, just tell me what happened"
  displayImage(0, IMAGESLEFT[6]);  //Occhio sinistro address == 0
  displayImage(1, IMAGESRIGHT[6]); //Occhio destro address == 1
  movementAngry(45, 5, 5, 4, 3);
  delay(500);
  machine.transitionTo(S5);
}

void state7(){
  // stato excited quando uno dei due spiega
  Serial.println("stato 7");
  displayImage(0, IMAGESLEFT[8]);
  displayImage(1, IMAGESRIGHT[8]);
  movementExcited(45, 85, 85, 4, 4);
  delay(500);
  machine.transitionTo(SINIT1);
}

void state8(){
  // stato excited con led accesi
  Serial.println("stato 8");
  displayImage(0, IMAGESLEFT[8]);
  displayImage(1, IMAGESRIGHT[8]);
  movementExcited(45, 85, 85, 4, 4);
  delay(500);
  digitalWrite(PIN_LED0, HIGH);
  digitalWrite(PIN_LED1, HIGH);
  machine.transitionTo(S9);
}
```

In the next image are show some examples of the states in the code:

Conclusion

We can say that the creation of Hato was a unique experience for the entire group: working with people that come from really different backgrounds improved our skills of team working, but most of all let us to acquire certain types of knowledge that would have been hard to gain otherwise: indeed, while working, we took care to both let everyone learn from the experience of the others and at the same time let every member handle the part in which he feels more secure and experienced.

Moreover, for engineers it was important to do the experience of dealing with a practical project with physical components, while for the designers it was important to deal with a project that also comprehends some electronics.

During the working phase we had some little problems, like the initial huge power requirement and the consequent hardness to find the proper batteries with a limited dimension, but at the end by constantly working at the project during the months, both via WhatsApp video callings and in person, we solved all of them.

APPENDIX

Github Push

Here is the list of all the pushes we made:

- 10/05: kick-up.
- 16/05: Reorganized functions and general updates.
- 17/05: first calibration of servo motors; animation of the eyes; kick-up of the states.
- 21/05: calibration of servo motors.
- 24/05: update some states and add others.
- 25/05: update some states.
- 28/05: calibration of movements and merged the various parts in a unique script.
- 30/05: update some states.
- 17/06: little changes in some states and added some more phrases.
- 18/06: final changes.

Minutes of the Meetings

Meeting 29/03/2022

Time: 10:30 - 17:30
Venue: Bovisa policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- Presentations and discussions of everyone's skills.
- First phase of brainstorming e generation of the first ideas.

Meeting 5/04/2022

Time: 60 minutes
Venue: Whatsapp
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- Review of first ideas, personal considerations, brainstorming.

Meeting 11/04/2022

Time: 46 minutes
Venue: Whatsapp
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We discussed the first form of the robot and we decided to address the idea of a hat that could also be a toy for kids.
- We decided in which scenarios to use the robot, which ones could be more and less feasible

Meeting 13/04/2022

Time: 25 minutes

Venue: Whatsapp
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We discussed furthermore our ideas and we went deeper on the hat idea with some details.
- here we reached the final idea of a robot that would help children to make peace

Meeting 26/04/2022

Time: 9:30 - 18:00
Venue: Bovisa policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- For this lesson/meeting we built our firsts prototypes and we have seen each other's prototype and the ones from the other groups.
- We decided on the firsts and most importants sensor, like the sound sensor or the capacitive sensor (lateral force sensor).
- We started looking for sites through which to find the various sensors

Meeting 30/04/2022

Time: 55 minutes
Venue: Whatsapp
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We discussed some other ideas for the environment of the robot, whether it has to be a mediator robot or a very toy robot.
- Later, we discussed more in detail the sensors and the other components like the Leds and the Led matrices.
- We started thinking about the best shape to give the robot
- we created storyboards to understand in more detail how it should work

Meeting 03/05/2022

Time: 9:30 - 18:00
Venue: Bovisa policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We start to prototype the 3d structure for the 3d printing.

- We start to code and to calibrate the sensors.
- We start the low level flowchart and the high level flowchart.
- At the end of the day we made a TODO list with the tasks that everyone has to finish for the next lesson/meeting.
- We built an initial circuit, with the components and sensors previously defined.

Meeting 09/05/2022

Time: 16:00 - 19:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We made some decisions for which sensors we have to buy and which components, like an RGB matrix or a red one, we opted for the last one, because of the high power consumption of the first one.
- We studied the type of batteries that could allow the robot to work for an adequate period of time

Meeting 10/05/2022

Time: 9:30 - 18:00
Venue: Bovisa policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We went more in detail in the coding and calibration part, in particular for the matrix controller and for the eyes.
- We made some changes to the interactions so we also changed the flowcharts.
- We changed the storyboard to be consistent with the flowchart

Meeting 16/05/2022

Time: 16:00 - 19:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We finished the flow charts part and we defined almost all the interactions and the phrases the robot should use.
- We have created the fabric form with which to cover the structure.

Meeting 17/05/2022

Time: 09:30 - 18:00
Venue: Bovisa policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We finished the Led Matrices part and we started the implementation and calibration of the other sensors.
- We started to weld and we noticed that there were some changes to do in the 3d structure, because there wasn't room for the additional board on the arduino.

Meeting 24/05/2022

Time: 09:30 - 18:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We continued the welding part and we noticed that there were some changes to do in the interactions part so we simplified the procedure a bit, because of a too long mediating part for the robot.
- We registered some phrases and took some videos for the semi-final presentation.
- We managed a serious problem with the LiPo batteries, i.e. they burned up some cables and they runned out.

Meeting 31/05/2022

Time: 09:30 - 13:00
Venue: Bovisa policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We did the presentation and at the end we made a TODO list with all the tasks and the corresponding person that were left.

Meeting 06/06/2022

Time: 17:30 - 20:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We edit some details in the code and in the flow chart.
- We bought the new batteries and we tested the whole robot again.
- The designer made another prototype for 3d printing that is the last one.

Meeting 12/06/2022

Time: 10:00 - 15:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We built the robot with the new 3d printed parts and tested the whole code.
- We start to sew the final fabric structure thanks to the new 3d printed parts.
- We decided to use a force sensor instead of a capacitive sensor, because we noticed that this one has a problem of recalibration after 4 seconds of continuous contact.
- We finished the BOM.

Meeting 14/06/2022

Time: 14:00 - 19:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- We made some changes in the code, in the circuit and also in the 3d printed structure.
- We developed the presentation and the videos

Meeting 17/06/2022

Time: 09:00 - 19:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- Final changes and final general corrections.
- Final tests and registration of the phrases.
- Finalized the report.

Meeting 18/06/2022

Time: 09:00 - 19:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- Final changes and final general corrections.
- Final tests.
- Took some videos of the assembly part and of the interaction part.
- Finalized the report.

Meeting 19/06/2022

Time: 09:00 - 19:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- Final changes and final general corrections.
- Final tests and took some more videos.
- Finalized the report.

Meeting 20/06/2022

Time: 09:00 - 19:00
Venue: Leonardo policampus
Attendees: Agnese Azzola, Jody Battistini, Giuseppe Epifani, Gabriele Pagano, Giovanni Sassone Massari

- General tests and presentation

Bibliography

-We searched for a scientific paper that described the impact of a social robot on humans.

- https://en.wikipedia.org/wiki/Social_robot#Social_Interaction
- https://link.springer.com/article/10.1007/s12369-018-0488-1
- https://link.springer.com/article/10.1007/s12369-013-0178-y

-We did research on social robots and pet robots on the market in order to verify what has previously been made and to understand the strengths and weaknesses of existing robots.

- https://en.wikipedia.org/wiki/Paro_(robot)
- https://en.wikipedia.org/wiki/Keepon

Attachments

To Deliver
Working Robot
Printed report:

- Moodboard
- Interaction Flowchart (storyboard or state diagram if needed)
- Circuit
- Bill of materials with providers link and cost, eventually data sheets
- User instruction (1 page to explain how to:
    - power supply
    - switch ON
    - provide Music
    - Interact with.
    - Maintain (change battery, solve problems, access to boards)

Files:

- Report (on-line)
- Firmwares and libraries
- 2D or 3D models (in DXF or STEP files)
- Short video

To fill

- Self evaluation form (same to the enrollment)
- Peer evaluation