Interdisciplinary course of

Design and Robotics

10° edition, 2022

Project:
CocoBot

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Abstract

Coco is a companion robot for users that will accompany them and interact with them in specific ways.
The goal is to keep people entertained while also preventing some undesirable behaviours.
The fundamental goals are :
1 - to encourage people to move their bodies more when they have been sitting for an extended period of time.
2 - connect with the third person by recognizing good and bad words.
3 - show positive feelings when pet..
The robot is shaped like a cat and can easily be carried on the shoulder. Being on the eye level of the third person helps people to interact better.

Phase 1: Discover

In this phase we start to organise ourselves, the team management, the tools we will use to communicate and we start to develop a common language. We also discussed the functionalities, shape and the way of communication of our robot.

Team Organization

Our team is composed of 3 science technology engineers and 2 designers: one from Design Engineer and one from the Product Service System Design field. The team leader is Giulia Riccardi (DE).

Project Management

Our team planned to solve the tasks according to the following GANTT chart. In order to have a clear idea of our path and being committed to the time table, we split the tasks in different weeks. Each week we tried to accomplish the tasks we needed to do, during class meetings and meetings outside the class time. We also broke assignments into little individual tasks and discussed them together after completing them. The work process is depicted in the diagram below.

Research

We collected data on the following topics related to the field:

1. Emotions; how to express emotion (colour, movement…)

Emotions are a vital aspect of our design for human communication and interaction. We wanted to communicate the emotions in the best way, we needed to be careful about that since it was the core of our communication. We started with the colours, we searched about how different colors could express specific emotions. We started from different characteristics of colours and tried to match each colour with the related emotions. We considered different emotions like Happy, Scared, Sad and Angry. We used Plutchik's wheel of emotions,one of the most influential classification systems for general emotional reactions is Robert Plutchik's psycho evolutionary theory of emotion. Anger, fear, sadness, disgust, surprise, anticipation, trust, and joy were eight primary emotions that he defined. Robert Plutchik also created a wheel of emotions. This wheel is used to illustrate different emotions and to define how emotions were related (Plutchik, 2001).

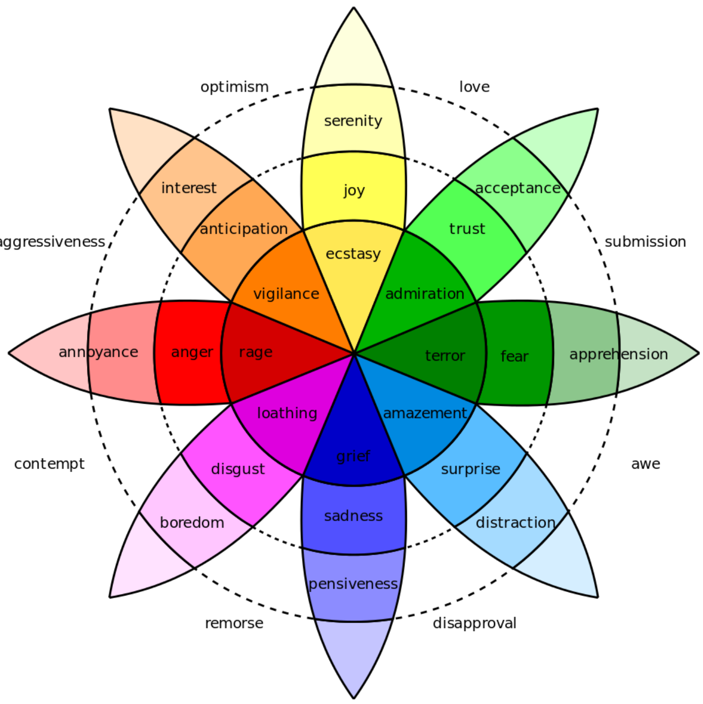


Figure x - Plutchik's Wheel of Emotions

It was not enough to know the emotions and have corresponding colours, we needed to define also the actions and reactions related to the emotion, and we needed some triggers for those emotions. So we started brainstorming and defining different actions for each emotion. Also, we added other actions to show emotion, like movements, sounds and vibration.

Color	Happy	Sad	Anger	Fear
Reaction to	people touch it on the head	stays too much time on the table	when staying too much time without moving	rapid movement
	when it is on the shoulder	hears bad words like "Horrible" and so on		
	hears positive words like "cute" and so on			

2. Ergonomics

We were thinking about how our design should be wearable from the beginning of ideation. Because one of the most critical criteria in our solution was that it should be wearable. We wanted an integrated shape that demonstrated its wearability perfectly. However, because this was an interactive robot, we needed something attached to a visible part of the body to communicate with the third person. In the initial idea which was an interactive crone for introverted people, we chose the head for wearing the robot, we used the forehead and ears for holding the robot (concept number 1). Then the idea changed to a personal Mascotte which was a small robot attached to the shoulder with a belt (concept number 2). But the visibility of the belt or robe was not fine, so we thought of a new shape and we came up with the idea of a cat. We used the tail and the shape of the cat for fixing the body (concept number 3).

Concept number 1


Concept number 2


Concept number 3

3. Action and results

For having a strong relationship with the user, we needed some levels of attention and care, for this reason, we were inspired by Tamagotchi toys. The creature grows through numerous phases and develops differently based on the level of care provided by the user; higher care results in an adult creature that is wiser, happier, and requires less attention (Allison & Cross, 2006).

We discovered that by observing all of the various technologies, we may implement a wide range of emotions and movements. On the other hand, we needed to establish a meaningful connection between our interactions. We wanted a robot that was useful and fascinating, not one that does a lot of actions without any concept behind that. We considered having hinting actions, such as when users talk loudly together or when the user remains motionless for a long time. Or the robot becomes enraged and signals the user to lower his voice or move his body. Another key factor for us was interaction; we defined specific actions that give life to the robot and give the user the impression of being a company; for example, when the user calls the robot's name, the robot becomes delighted and reacts by moving its head and changing the colour of the cheeks. Another element that makes the human-robot interaction more semantic is when the user pets the robot on the head and the robot responds by moving its head and becoming delighted. We used different elements for the communication of the robot. Elements like sound, colour lights, movements and vibration help the robot communicate with the user.

4. Functions (moving the eyes, the ears, which kind of sensor and mechanism) When this robot sits on the table for an extended time without moving, it becomes sad, drops its head and ears to the front, and its cheeks turn blue. When the user lifts it from the table and places it on their shoulder, the robot becomes animated, moving its head left and right, turning its cheeks yellow. Or when it is scared by some noise it starts to vibrate. At last when it’s upset move toward the user and vibrate to catch attention.

Why wearable?

Wearable assistive robotics is a new technology that has the potential to help people with sensorimotor impairments carry out everyday tasks. Individuals can be physically and socially active, accomplish things independently, and regain their quality of life with this aid (Martinez-Hernandez et al., 2021).

Social robots are artificial agents that can function independently within the physical and symbolic environment of human social interaction; they are programmed to mimic norm-guided human social conduct, including nonverbal and verbal communication (Seibt, 2021).
We researched some examples on the market or just concepts to better understand this social robot and how they expressed feelings.

Eilik

Paro

Dodo - Lisciani Giochi

Goosebumps robot

For example Eilik thanks to an LCD screen expressing his emotion, Paro moves his body and produces some sounds. The last one is a concept inspired by the goosebumps of the human being. So it reacts to different inputs using this skin and an LCD screen.

The project of this course aimed to facilitate the interactions between people. We didn't want a separate robot to interact with us, therefore a wearable social robot was the ideal option. Wearable robots have the sense of being connected with the user; in this situation, we chose a social wearable robot because the ultimate goal was to make communication easier.

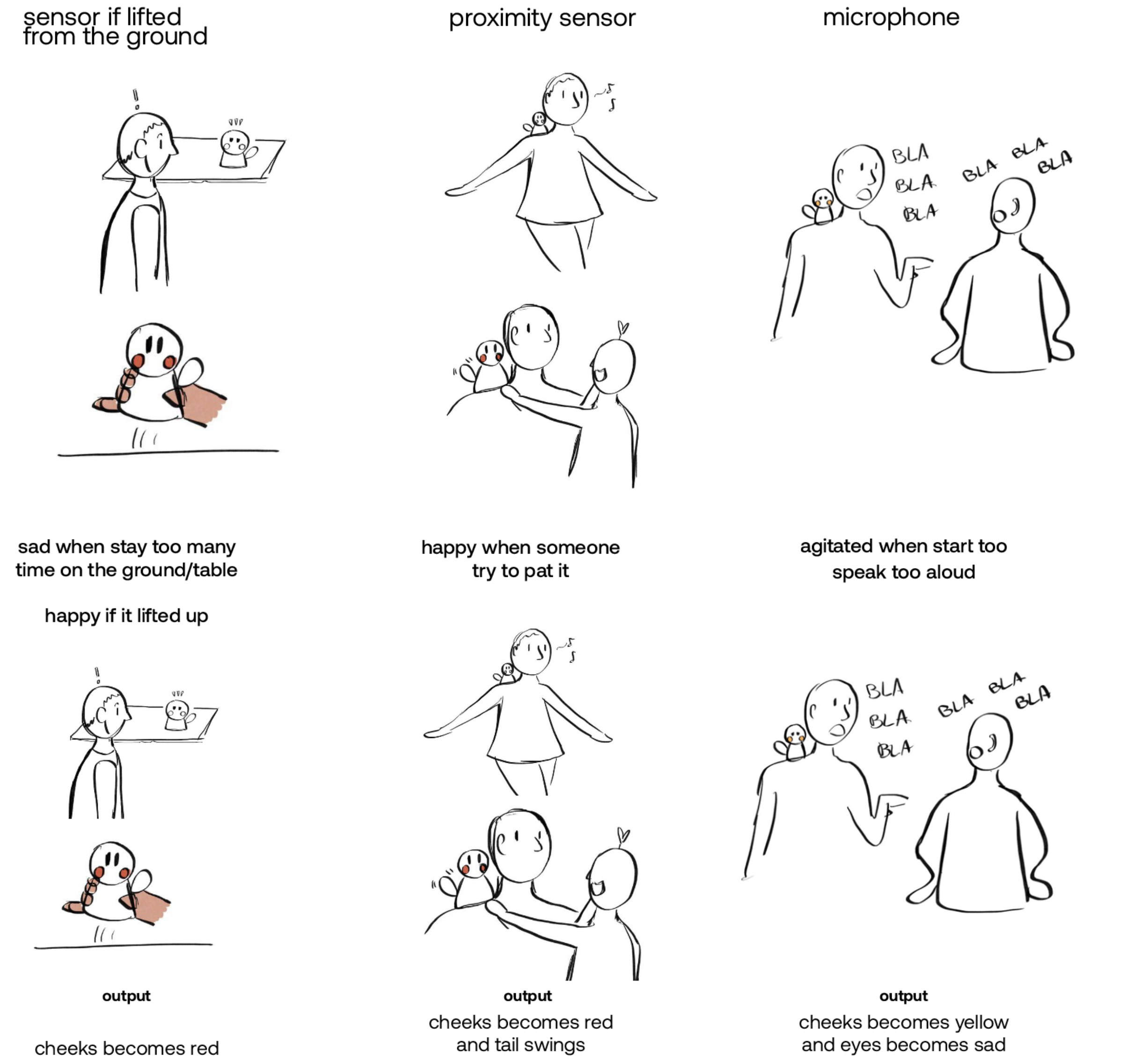
Functionalities

Movement mechanism

We have identified two main movements for our robot to help express better emotions:

- head movement
- ears movement
- Vibration and sound

We wanted to implement, also, the movement of a third part of the robot’s body in order to give the robot a more realistic behaviour.



Words recognition

A nice touch to the robot is the ability to recognize a predetermined set of words so that the robot can react to conversations around it.

Noise and touching recognition

The robot has, also, the ability to recognize loud noises around it and to detect if a person is touching it.

Position recognition

One of the most important features is that the robot has to be able to recognize if it is on the shoulder of its owner or if it is on the table. This distinction is needed in order to correctly implement its behaviour and how it reacts to external inputs.

Phase 2: Define

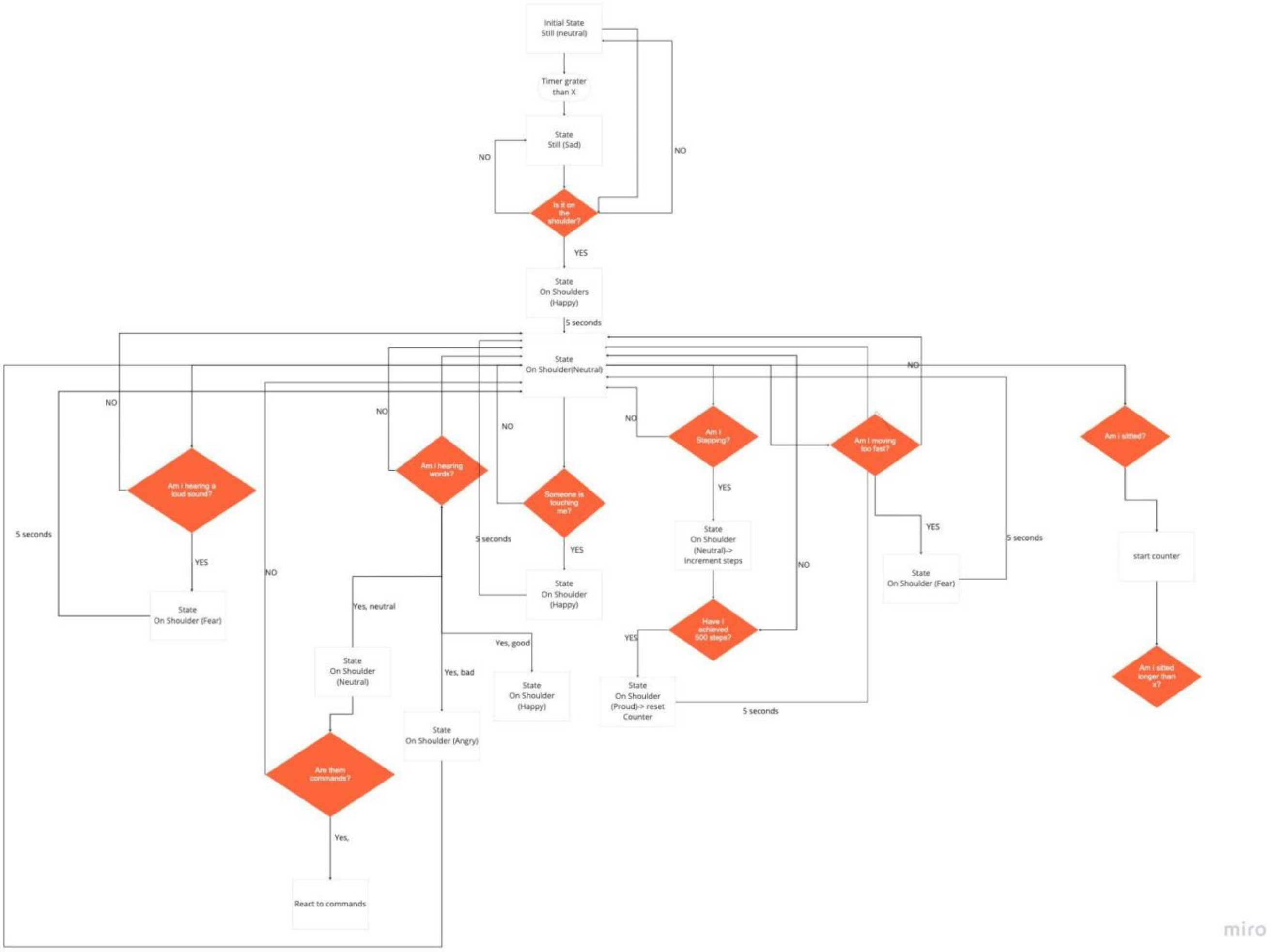
After the research, we start to define all interactions that we want to show with our robot. We made rough prototypes to test mechanisms, aesthetics and functionalities. We start defining the main interaction and all together we discuss the possible shapes and characters to give to the robot.

Concept

The idea is to create a trip mate, ready to follow you, on your shoulder, in all your adventures. You will live together with new experiences and new emotions that you will share with all people you will meet. Moving his head and thanks to colour/sound will be able to express his feelings. In this first part, we realised 5 prototypes with different shapes and references. For example 2 of them are more similar to animals, the other to a sort of machine robot.

Strategy

After defining the concept, we elaborate a draft of the flow chart of interactions (diagram below). The flowchart is a raw sketch of our idea, the final version will be displayed in the next phases.

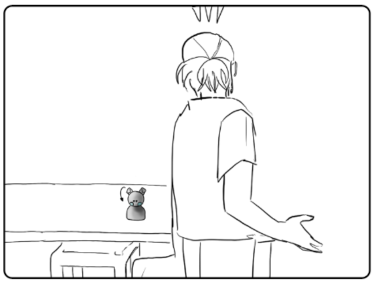


Functionalities

The main functionalities of our robot are:

- Recognize if it stays on the table or on the shoulder;
- Recognize if the user stay too many time without moving;
- Recognize some good, bad words and specific words as its name;
- Moving its head and the ears and vibrate to express its emotions;
- Recognize a loud noise;
- Recognize if someone is patting it.

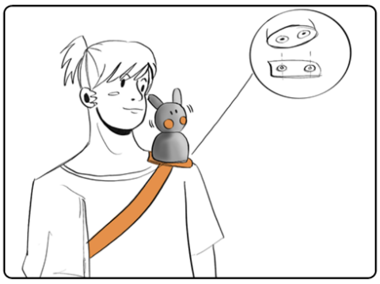
In the following pictures, we show all the interactions with the robot.



On the table

Input: If stay too much time on the table becomes sad

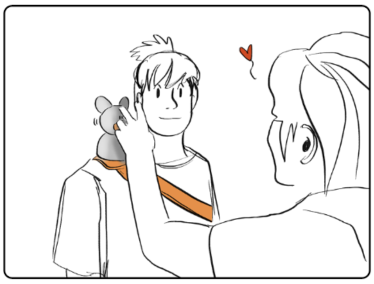
Sensor: accelerometer; timer



On your shoulder

Input: When put on the shoulder becomes happy

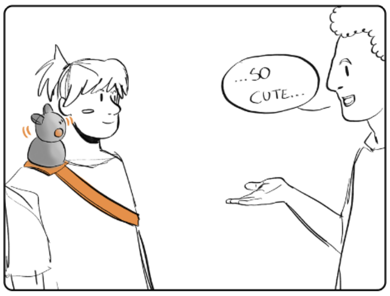
Sensor: accelerometer



Meet new friend

Input: When someone touch its head becomes happy

Sensor: tactile sensor



Sweet word

Input: When it hears some words as nice, cute, beautiful, it becomes happy

Sensor: microphone

Bad word

Input: When it hears bad words as stupid, idiot and shut up, it becomes sad

Sensor: microphone

Speak too aloud

Input: When someone speak too aloud it scares

Sensor: microphone
Attuator: vibration

Rapid movement

Input: If you start to jump or moving fast it scares

Sensor: accelerometer
Attuator: vibration

Let’s move!

Input: if you stand too still, robot on your shoulder becomes angry

Sensor: accelerometer; timer
Attuator: vibration

In the beginning, we thought of adding other features, for example, counting the steps and if the user reaches 5000 steps the robot becomes proud. Or a camera to recognize the expression (face recognition), or a sensor that understood if the robot stayed in a dark room and so on. But because of the complexity and because this feature wasn't so relevant for an interaction with a third person, we had preferred to avoid them. For instance, the recognition of the environment was quite useless because it communicated neither with the user nor with the third user.

Electronics

Sensors and Actuators

To discover new possible features for our robot we listed the Raspberry/Arduino sensors that could be involved in our project. Specifically, we looked for sensors that could help us to detect human interaction with Coco as motion sensors and others for expressing emotions as buzzers and LCD screens.
After listing all the possible components, we planned to choose only the relevant ones considering our interactions with the environment and third users.
At that time, we did not already know what kind of controller we could use between Arduino and Raspberry, so we researched components for both versions.

Arduino/Raspberry Sensors	Function
Sonar Sensor/IR Infrared Obstacle	This ultrasonic sonar sensor can measure distances from 2cm to 400cm with an accuracy up to 3mm.
Accelerometer sensor	Accelerometers measure linear acceleration. They can be also used for specific purposes such as inclination and vibration measurement. MEMS accelerometers embed several useful features for motion and acceleration detection, including free-fall, wakeup, single/double-tap recognition, activity/inactivity detection and 6D/4D orientation.
Microphone Sensor	This sensor is used for sound detection. This module has two outputs: AO (analog output), or DO (digital output). The digital output sends a high signal when the sound intensity reaches a certain threshold. The threshold-sensitivity can be adjusted via potentiometer on the sensor.
Tactile sensor	It can detect the change in capacitance when a finger is nearby.
Digital Barometric Pressure Sensor Board	You can use this module to measure the absolute pressure of the environment. By converting the pressure measures into altitude, you have a reliable sensor for determining the height of your robot or projectile, for example. This sensor also measures temperature and humidity.
SW-420 Motion Sensor Module Vibration Switch Alarm	This module can be used to trigger the effect of various vibration, theft alarm, intelligent car, earthquake alarm, motorcycle alarm, etc.
Passive Buzzer Module	A simple sound making module. You set high or low to drive this module. By changing the frequency you'll hear a different sound.
HC-SR501 Pyroelectric Infrared Sensor Module	A PIR sensor is a little module that allows you to detect movement from humans or pets when they are around making movement.
Raspberry Pi Cameras *	My bachelor thesis was using a camera sensor with Arduino in order to recognize faces but it was terrible as the camera modules for arduino are very poor. If we want to use it, we should consider Raspberry.

GPS NEO-6M Module/USB GPS Receiver*	The most common and best known GPS receiver is the NEO-6M module. All GPS position data can be determined with the help of the orbiting satellites.
MPU-6050 Gyroscope*	A gyroscope (circular instrument) is used to detect the rotation along the three axes. The MPU 6050 sensor also contains an acceleration sensor. This module can be used e.g. in robot arms to determine the angle of rotation.
DS1307 RTC*	If the Raspberry Pi is connected to the Internet, it can request the exact time. This could be a problem in applications where no (permanent) Internet connection is given, but the date and the exact time is important (car PC, weather station, etc.). A so-called Realtime Clock (RTC) module can help: Once initialized, it saves the current time – even if the power supply is not present – due to the small battery.
Heartbeat / Pulse Sensor*	With a pulse sensor, the heart rate can be read out on the Raspberry Pi. The analogously detected value changes, depending on the pulse beat. This is again converted with an ADC and the pulse is determined on the basis of the last measured values.
MAX7219 LED Matrix*	The square 8×8 LED matrices are available in red and green. It is possible to control each individual LED with the help of the MAX7219 IC. In addition, many of these modules can be plugged together, resulting in a large dot display. The signal is sent via SPI.
Photoresistors	In addition to conventional resistors and potentiometers, there are also photoresistors. These have a light-sensitive surface and have a different resistance value, depending on the light intensity.
LCD Screen	

Power supply

Regarding the power supply, two problems incomed:

- how to power the microcontroller
- how to power up all the sensors and actuators
- how to manage the power on and power off of the robot

To feed our electronic component, we used an 7.4V Rhino battery as a power supply, kindly lent by professor Bonarini.

The challenge consisted in how to use this single battery to supply the entire robot considering the tension limit of each component and the possibility of switching off and on Coco.

Coding

We proceeded using a bottom-up approach: testing sensors that we already had, one by one that for sure we could use for the robot as servo motors and others.
To organise the code in the best way possible, we created a GitHub repository at that link: https://github.com/LorisPanza/RoboticsAndDesign.git . In the folder Sensor Code, we test separately an initial list of actuators and sensors:

- Servo motors
- Big noise sensor
- Accelerometer (first test phase)
- Capacitive wires sensors
- Multicolor leds
- Vibration motor

We started thinking about how to manage the different states of the robot: searching on the internet we found a useful library for Arduino that implements the functionality of a state machine with transactions, states and other features.
At the same time, we started understanding Raspberry and its functionality as our group had already experience with Arduino.

Structure

The main idea for the structure is an arc shape to allow a comfortable positioning on the shoulder of the user. But this is not enough to guarantee stability. An additional element similar to a belt is thought to fix the robot and avoid falling from the side.
An important constraint has to be a rigid base in contact with the shoulder due to the presence of a vibration motor. Thanks to a fast test we understood the minimum thickness to transmit a good vibration (2 mm) and the minimum size of the vibration motor (8mm of diameter; 2,3 V)
The main components such as Arduino/Raspberry pi, battery, amplifier and so on will stay in the base box and just a few components in the head. For example, the LEDs for the cheeks, the capacitive sensor and a servo motor to move the ears. The head will have a spherical shape to allow its rotation on the 2 axes (right-left and front-back).
To give stability we thought to apply a low barycentre, so insert some weights in the feet. Unfortunately, this is not enough to guarantee the best stability so we decided to add a tail that passes under the arm and can be fixed on the feet (*Fig.1*)

Shape

As we said in the previous paragraph “concept”, each member of the team made a prototype in cardboard, plastic or wood. Even if the shape was very different, the concept to maintain all components in a “box” and the head free was common in all prototypes.

In the end, we decide to mix 3 of them to realise the final shape: a cat that lies on your shoulder. This shape came out because we tried to think about which kind of creature could stay on the shoulder in that way. The cat is the most realistic animal that could have the arc shape when lying on you. For this reason, the belt to fix the robot safely becomes a tail that arrives at the front feet and it stays in the middle of them, like a real cat

Fig.1

The final shape and finishing that we would like to apply is inspired by this kind of puppets:

Phase 3: Develop

In this phase we describe the development process, departing from the first prototype to the final improvements of interaction.

Strategy

In this part we split the work in two sections: coding and design. Loris, Giuseppe and Andrea worked on testing all components, meanwhile, Giulia and Elahe thought about the shape, which kind of fabric and the mechanism of movement. Giulia worked in parallel on the engineering part and design section.

Functionalities

Compared to the previous phase, we improved some interaction and also the way he expresses emotions.

On the table

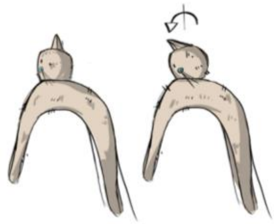
If stay too much time on the table becomes sad

Bad words

When it hears bad words as stupid, idiot and shut up, it becomes sad

Sad

- Cheeks becomes blue
- Move down head and ears
- Produce a sad sound

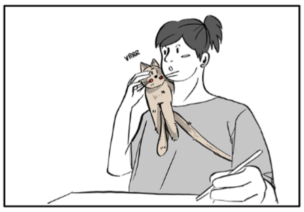


Rapid movement

If you start to jump or mov- ing fast it scares

Speak too aloud

When someone speak too aloud it scares

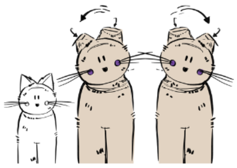


Let's move!

if you stand too still, robot on your shoulder becomes angry

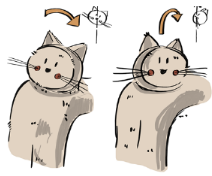
Scared

- Cheeks becomes violet
- Move head left and righ fast
- Vibration of all body
- Move down ears



Angry

- Cheeks becomes red
- First move head on the right
- Move head on the back
- Start to vibrate

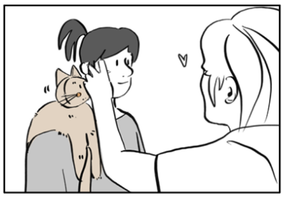


On the shoulder

When put on the shoulder becomes happy

Sweet words

When it hears some words as nice, cute, beautiful, it becomes happy

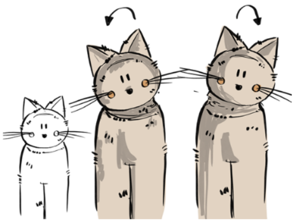


Pat on the head

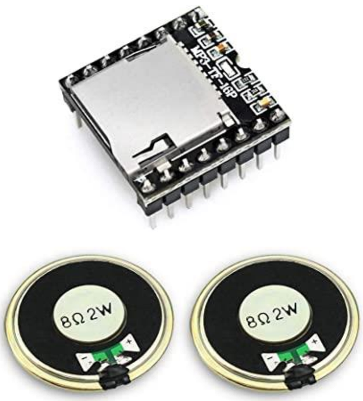
When someone touch its head becomes happy

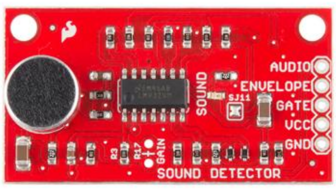
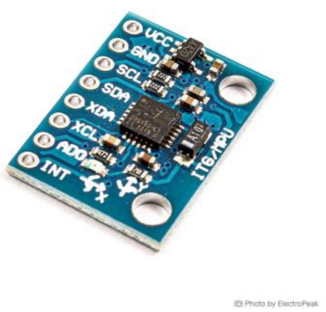
Happy

- Cheeks becomes yellow
- Head oscillate left and right
- Move ears
- Produce happy sound



Electronics

	Servo Motors x3	We already had
	Speaker	https://www.amazon.it/KeeYees-DFPlayer-Altoparlante-Compatibile-Lautsprecher/dp/B07X2CZZDJ/ref=sr_1_5?__mk_it_IT=%C3%85M%C3%85%C5%BD%C3%95%C3%91&crid=1D5F528SIOWHJ&keywords=arduino+mp3&qid=1651234362&sprefix=arduino+mp3%2Caps%2C139&sr=8-5

	Voice Recognition Module	https://www.amazon.it/gp/product/B07YX8VGDS/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1
	Vibration Motor	https://www.amazon.it/gp/product/B07QL8CMH7/ref=ppx_yo_dt_b_asin_title_o02_s00?ie=UTF8&psc=1
	Sound/Noise detector	https://www.amazon.it/SEN-12642-SparkFun-Sound-Detector-fba/dp/B06ZZGP9B4/ref=sr_1_2?__mk_it_IT=%C3%85M%C3%85%C5%BD%C3%95%C3%91&crid=1GLG8Q8MMJ308&keywords=sparkfun+sound+sensor&qid=1653061628&sprefix=sparkfun+sound+sensor%2Caps%2C92&sr=8-2
	Accelerometer & Gyroscope	https://www.amazon.it/gp/product/B07BVXN2GP/ref=ppx_yo_dt_b_asin_title_o03_s00?ie=UTF8&psc=1

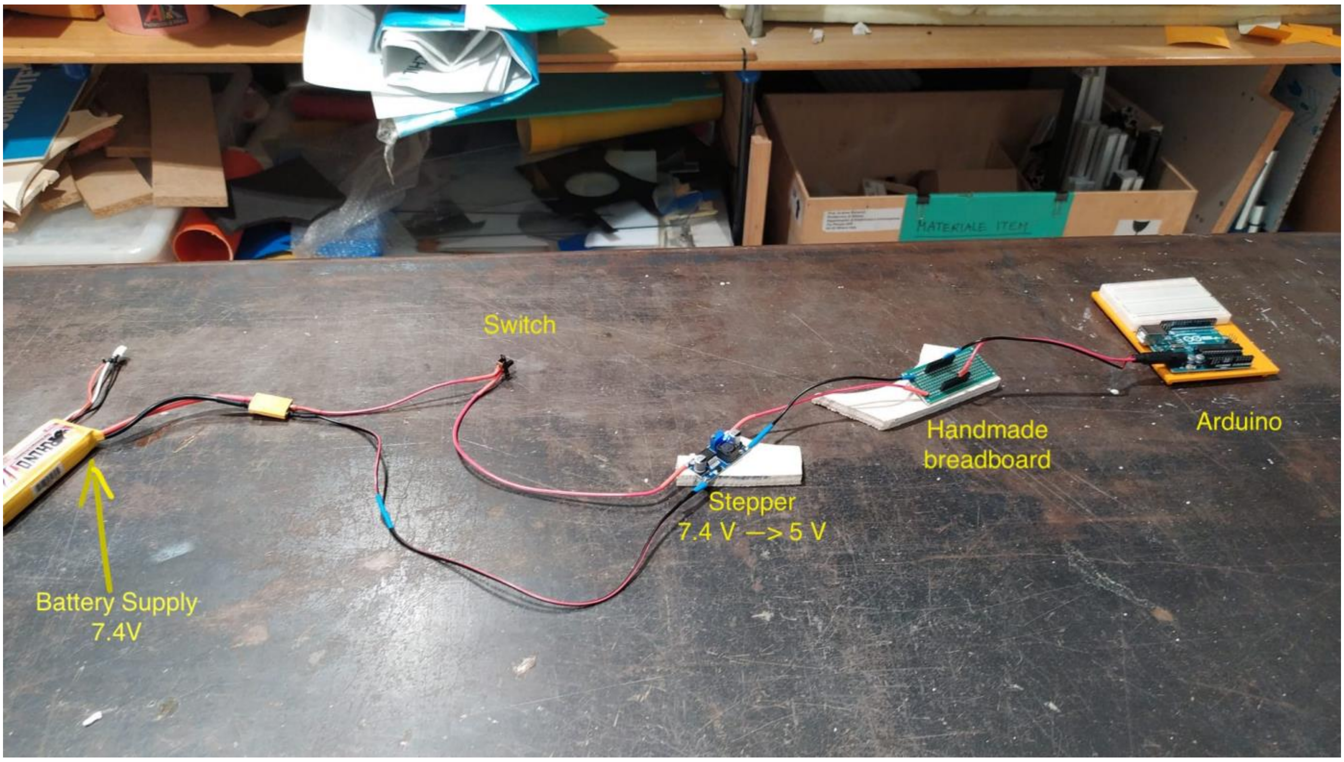
	Multicolor Led	

Capacitive sensors x2

As capacitive sensors we just used two jump wires connected to the analogical Arduino pin. If you touch the edge of the wire, the analog readings of that pin will vary allowing it to detect possible contacts.

Power supply

We connected the battery supply to a switch in order to control the power of Coco. We reduced the voltage output from 7.4V to 5V using a stepper that supplies a row of female pins that will be used to feed all the components (Arduino included).



Coding

In the development phase, we started adding together each sensor code and integrated them with the state machine (mentioned in the Coding paragraph of the Develop section).

State Machine Description

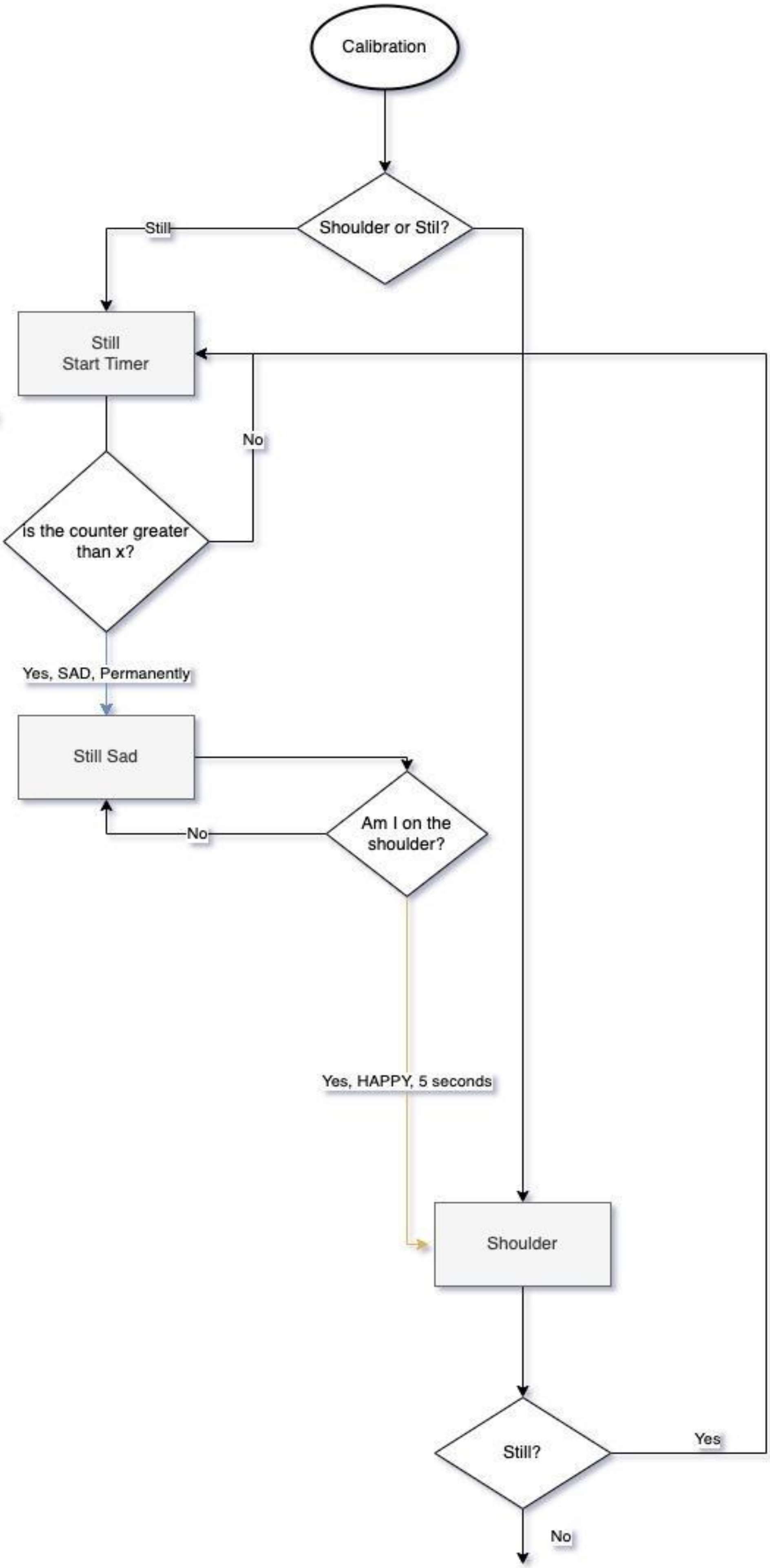
The state machine is divided in two main parts:

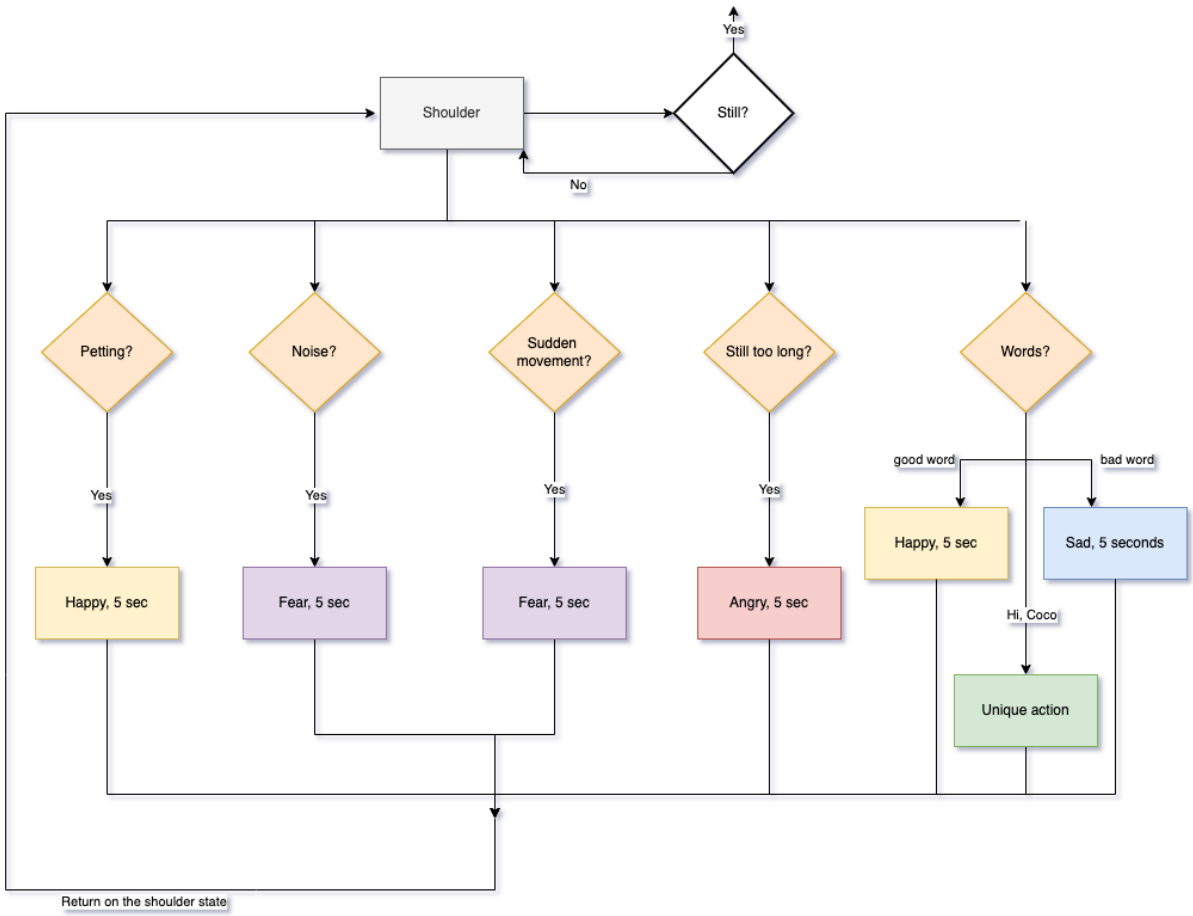
- table state
- shoulder state

This distinction is important because we want the robot to behave differently whether it is on the user's shoulder or on the table. In particular when on the shoulder it should be ready to process any meaningful input from the environment, instead when on the table it should go in an idle state where it waits to be picked up by the user.

Note

In that sequence of the flowchart the robot is continuosly checking if it has been picked up





Components Choices

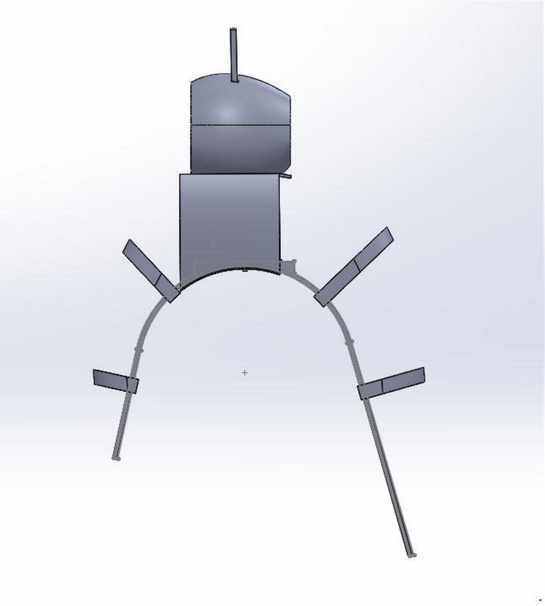
Concerning the accelerometer we made the decision to not use it in order to estimate the location of the robot (shoulder or table) because it didn't have the needed accuracy to perform such a task, instead we opted for a capacitive jumper wire to achieve this task: when the robot is on the shoulder the jumper should be in contact with the person wearing the robot and it will output high values instead when it is on the table the jumper shouldn't touch anything and it will output low values.

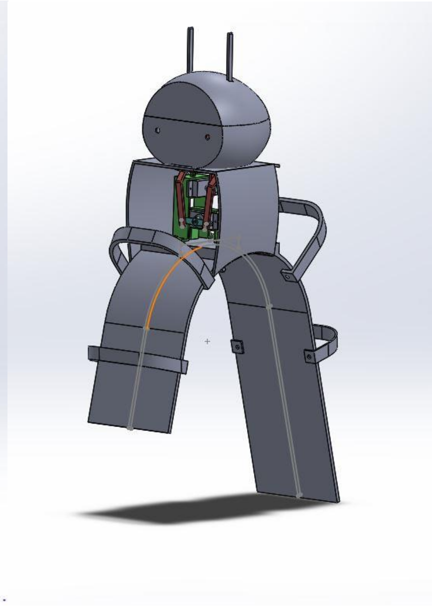
Another important development choice was to discard the Big Noise sensor which had a low accuracy and instead use the Sparkfun Sound Detector.

In this phase we also opted to use Arduino Uno instead of a Raspberry because Arduino has many analog pins whereas Raspberry lacks them completely, this choice made easier to use capacitive jumper wires, sound detector and accelerometer.

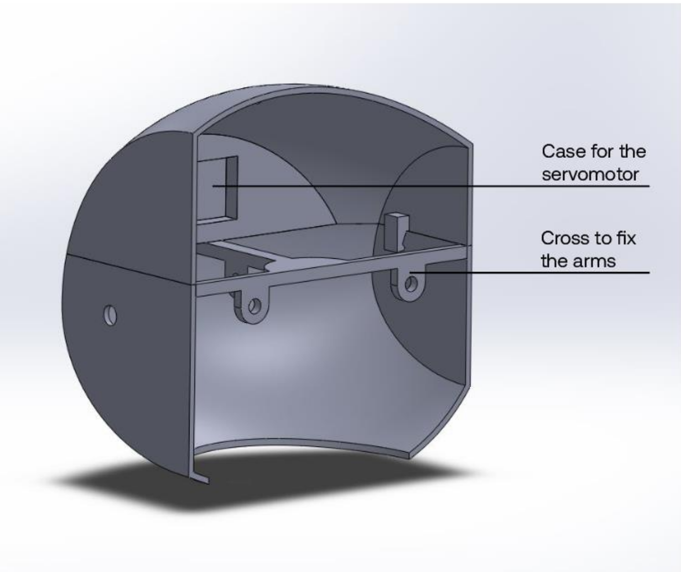
Structure

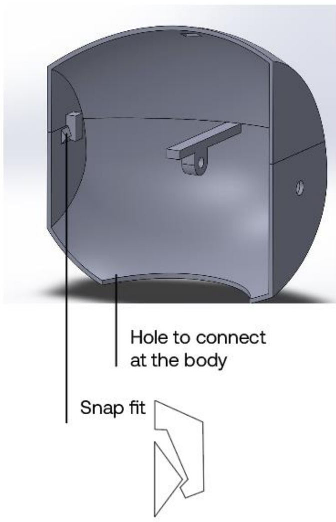
The final structure we thought to maintain a rigid curve base. In this way, we can easily manage the vibration motor and all components. Moreover, this offers a more strong idea of stability when it is put on the shoulder.
Then we added 4 “vertebrae” to protect the system and create the idea of a real cat with his skeleton.

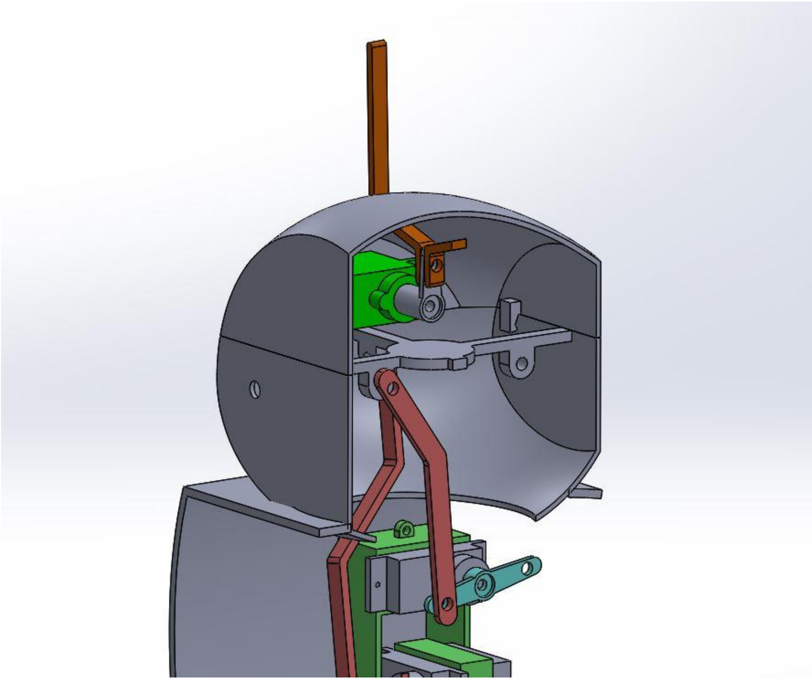




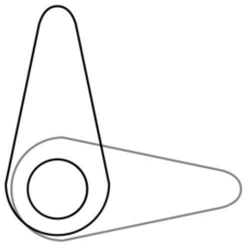
In the box, we insert the 2 servo motors to allow the movement of the head.
In the head, we add 2 LEDs, a tactile sensor and a microphone too and the last servo motor to move the ears. In the following images, we show the detail of this mechanism and how the 2 parts of the head are fixed to each other.



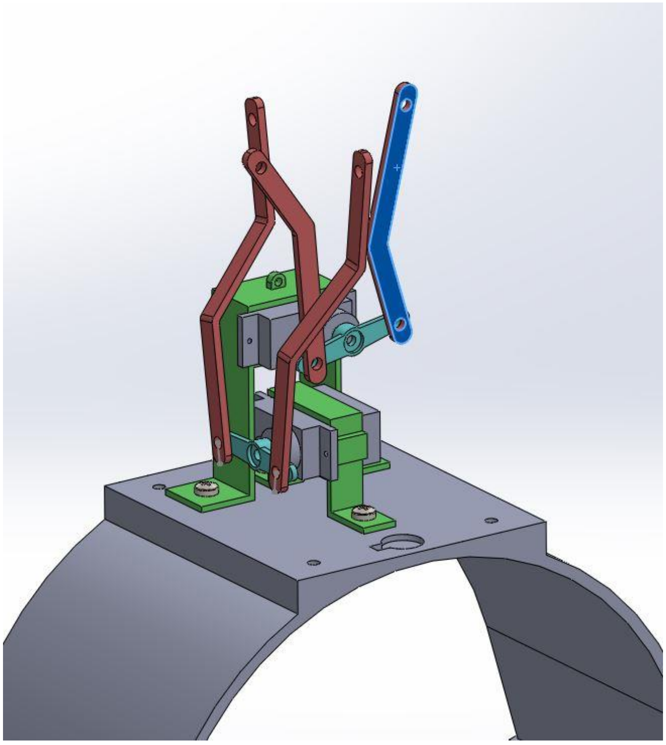


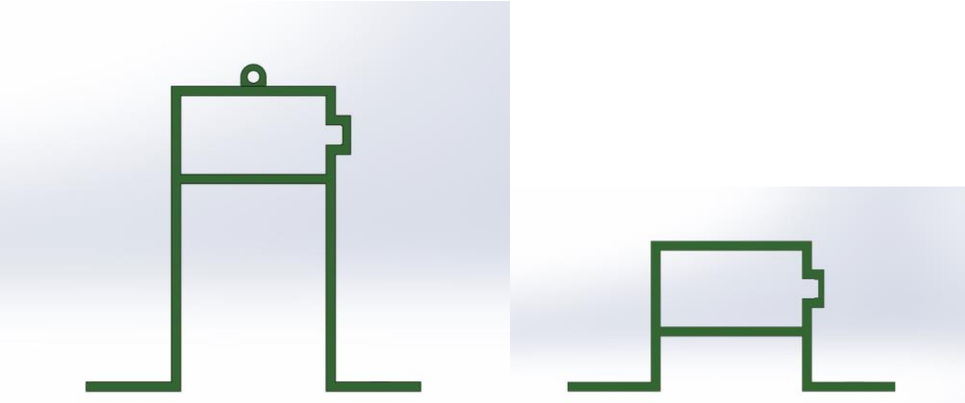


Section of the head where we can see the servo motor in his case and the 2 arms that come out from the hole in the top of the head. Thanks to a rotation from 90 degrees to 0 we can obtain the down movement of the ears.



The arms are linked to the structure with M3. The 2 servo motors on the base have a special case to host them at different heights to avoid interferences.





(Structure for servomotor front-back and for left-right)

Shape

For the final shape we tried to think about a fabric cover. We thought of a grey and soft colour. In that way, we would like to create a sort of puppet to wear on your shoulder.

The long tail is useful to fix the robot in a safe way. Because the weight of the components is not enough to guarantee stability.


This is what our CocoBot should be like. In these images, it’s just a rough prototype, without the eyes or moustache. The final version will be shown in the last chapter

Phase 4: Deliver

In this phase we describe the final robot. You can repeat some paragraphs from the development process if needed.

Final Robot description

Strategy

In this final step, we worked on improving the results shown in the prototype.
The coding was split between Giuseppe, Loris and Andrea who worked on assessing that the components worked properly both standalone and together with the rest of the system, while Giulia and Elahe focused their efforts, respectively, on the robot structure and coating.

Interaction

On the table

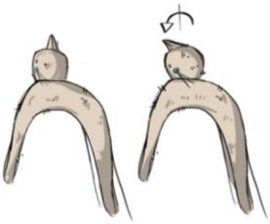
If stay too much time on the table becomes sad

Bad words

When it hears bad words as stupid, idiot and shut up, it becomes sad

Sad

- Cheeks becomes blue
- Move down head and ears
- Produce a sad sound

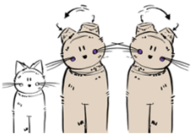


Rapid movement

If you start to jump or moving fast it scares

Scared

- Cheeks becomes violet
- Move head left and righ fast
- Vibration of all body
- Produce scared sound



Let's move!

if you stand too still, robot on your shoulder becomes angry

Angry

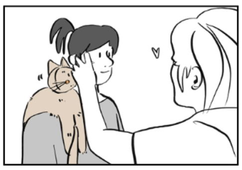
- Cheeks becomes red
- Move head on the right
- Start to vibrate
- Produce angry sounf

On the shoulder

When put on the shoulder becomes happy

Sweet words

When it hears some words as nice, cute, beautiful, it becomes happy

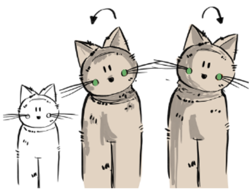


Pat on the head

When someone touch its head becomes happy

Happy

- Cheeks becomes green
- Head oscillate left and right
- Move ears
- Produce happy sound



Architecture

The final model is composed of a base in white "polistirolo colato" (3 mm of thickness). To model it and obtain the final shape we used a metal cylinder reference (diameter 150 mm), a hot gun to deform the material and many claps to fix it and give it the shape.

We chose polistirolo colato for his good mechanical properties and aesthetic finishing.
Even if it is quite difficult to deform because of the elastic spring back. For this reason, we need to maintain the clamps for 1 hour and a half.
After the base, we worked on the flat base for the support case. In this case, we modelled it first on Solidworks and then we 3d printed it with a Creality Ender 3. After that, we used a glue gun to fix the permanent way to the base. 3D printing was used for the principal body, the head, the ribs, the sticks, and the case for some sensors.

The body needs to create a support for the head and cover the most delicate part of the robot, the case for the servomotors. The body is fixed to the base by 4 M3 x 10 mm (fig.1) with hexagonal nuts (fig.2).

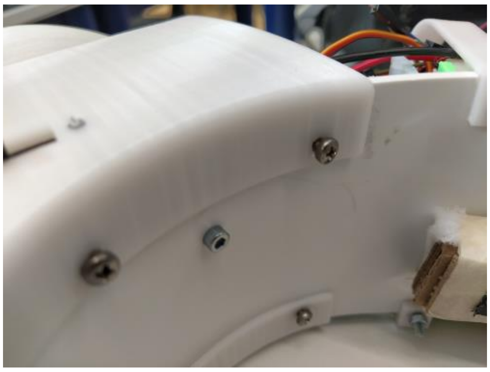


fig.1

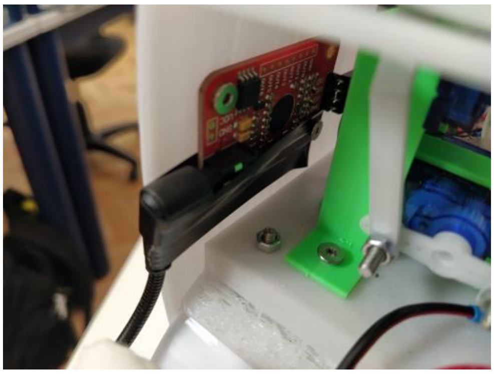


fig.2

The principal body has a case for the switch (fig.3) and two holes to fix the module of the microphone, always with 2 M3 x 10 mm and 2 hexagonal nuts (fig.4). On the same side of the body, we attached with a glue gun the case for the SD module (fig.5)

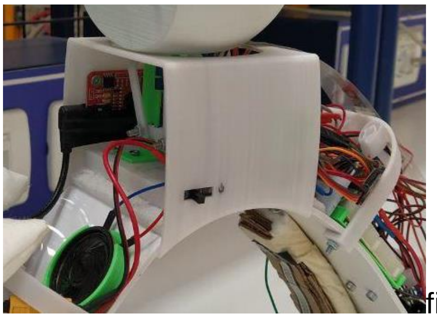


fig.3

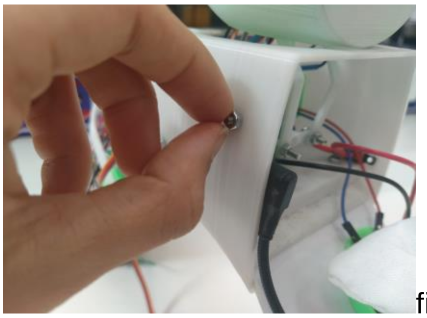


fig.4

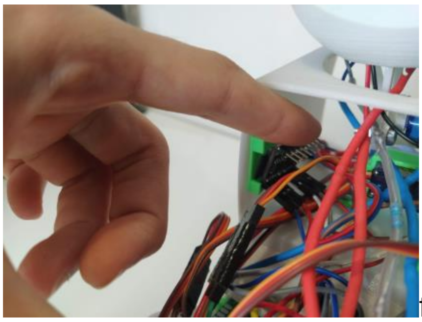
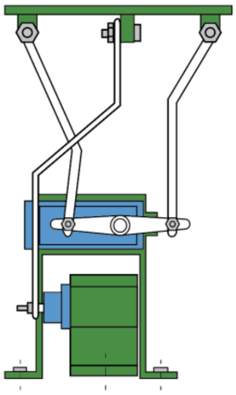
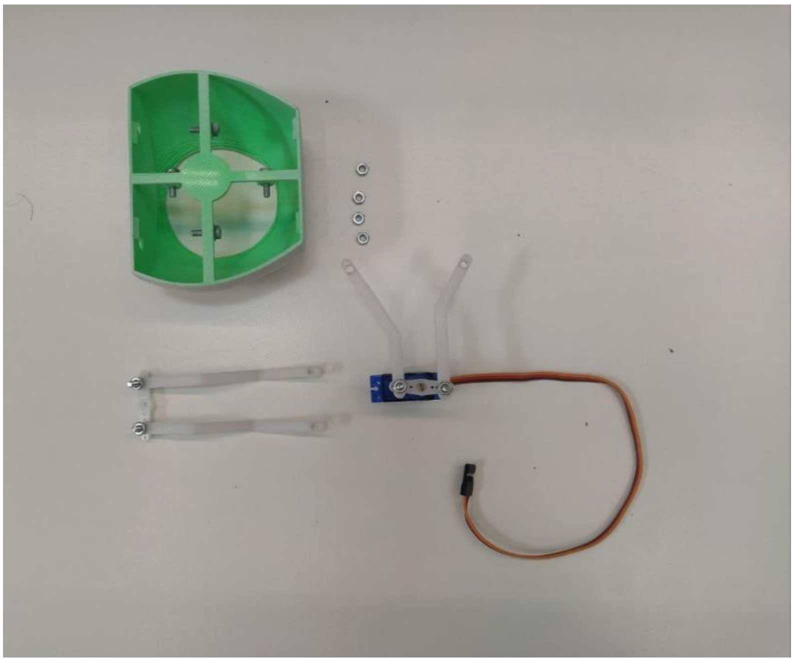


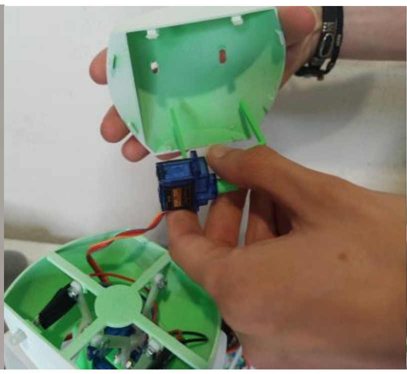
fig.5

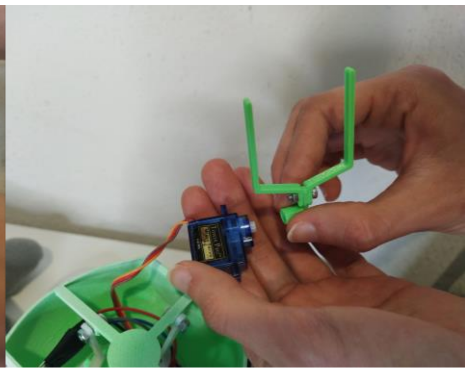
On the top of the body there is a hole to allow the stick to reach the bottom head and move it. Even the stick, as already said, is done with 3d printing. The sticks are symmetric but different for the left-right movement and front-back movement. For the second movement, we needed to switch the sticks and put them in a particular configuration like in the image below, to avoid any contact with the principal body.





The 2 sticks are fixed with 2 M3 x 10 mm and 2 hexagonal nuts to the servomotor. Same steps for the upper part. They are fixed to the cross. A similar process for the ears sticks. In this case, we have just one arm that connects 2 sticks to the servomotors with an M3 and nuts. The upper part of these sticks is free to move and comes out from the upper head.





The head is printed in the parts, upper and bottom and they are fixed to each other thanks to snap fits (fig.6). Inside the upper head, there is a case to host a servo motor to move the ears. While in the bottom head we create 2 holes for the LEDs. In this case, it is important to observe that the 2 LEDs must pass on the external part with respect to the left-right sticks (fig.7).

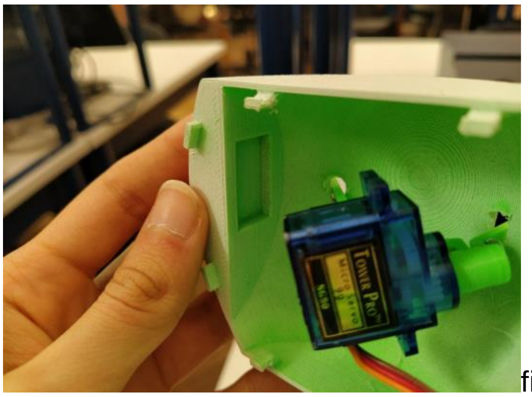


fig.6


fig.7

Other elements that we 3d printed are the case for the speaker, fixed with a glue gun in the front of the base (fig.8); the case for head servomotors (fig.9), the case for the breadboard (fig.10) and the ribs with some elements to fix the cables (fig.11).

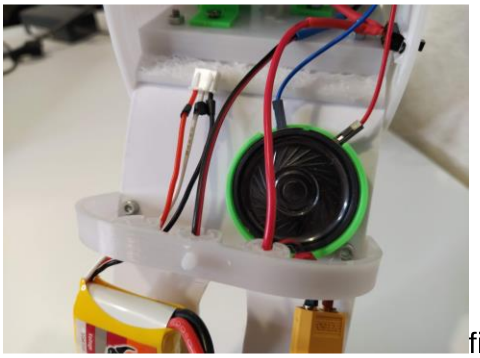


fig.8

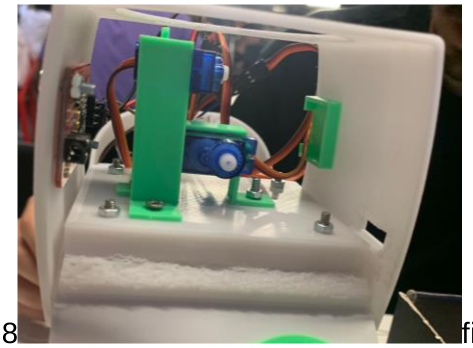


fig.9

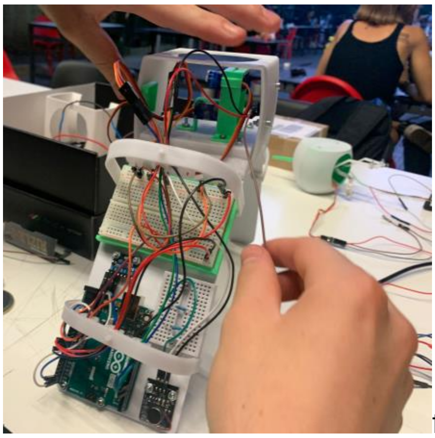


fig.10

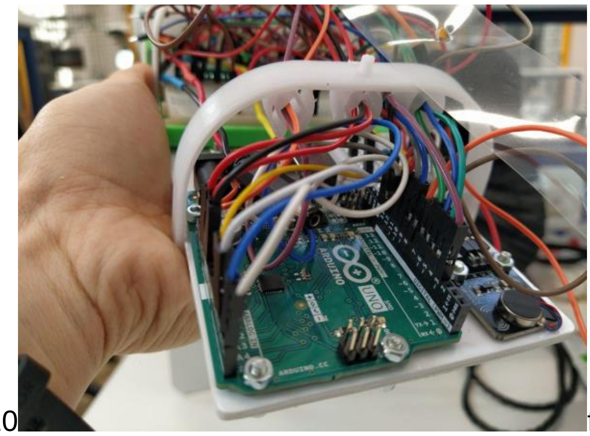
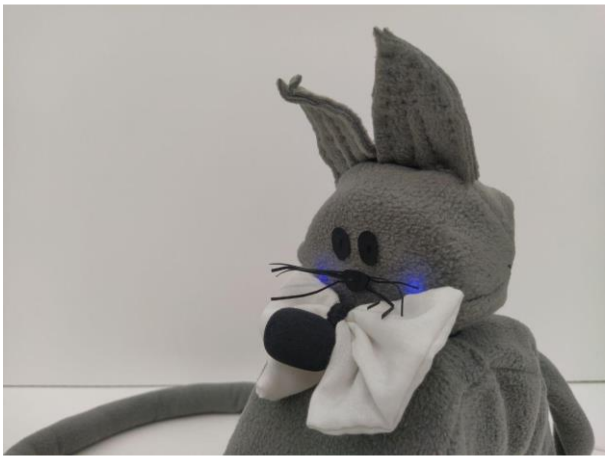


fig.11

aADD a PHOTO of the rib alone

For the rest of the sensors and Arduino we used M3 x 10 mm with nuts and we fixed everything to the base. In this way, we have more weight on the bottom to balance the robot.

Shape

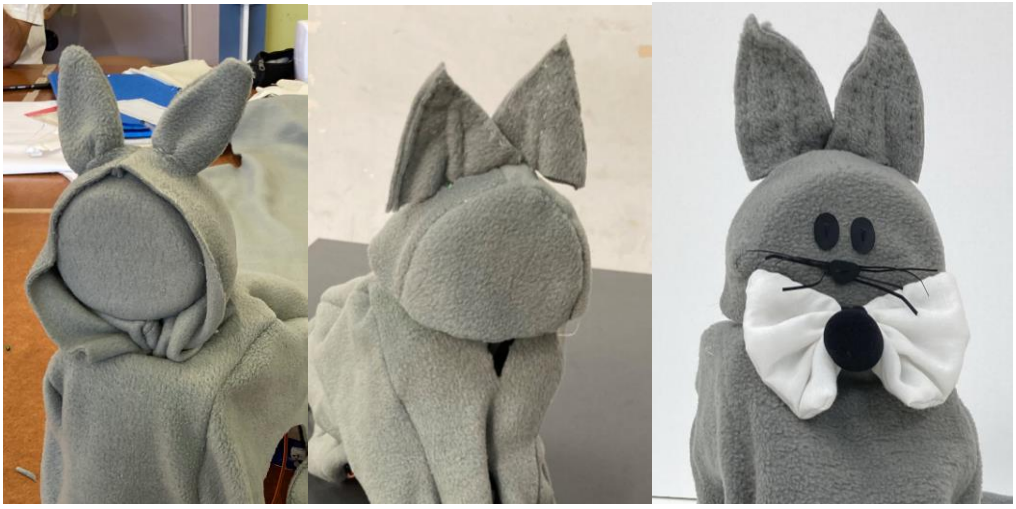


For the final shape maintained the idea of a cat. We divided it into 4 main components. The ears, the head, the body, the tail and a papillon. This last element is necessary to cover the microphone. Indeed it was impossible to maintain it inside the robot, otherwise, it didn't recognize the voice. So we move it outside, but from an aesthetic point of view it appears very rough, therefore we "hide" this problem by creating a papillon.

Fabric

For the tailoring we started with the paper patterns, the first step was to dimension each part and create a corresponding piece on the paper. After cutting the paper and double-checking the structure, we transfer the shape of each paper to the fabric. The most important part was to consider between 0.5 or 1 cm for each edge in order to have enough space to sew. At first, we were struggling with how to manage each part and how to start sewing. Elaheh passed the training course lab. moda and with the help and consultation of the lab moda staff, we came up with the idea of how to make paper patterns and do the fabric part. Since the fabric was the first thing that people could see, we had to have perfect skin for our robot.

One of the most challenging parts was doing the fabric for the head because the shape was not a perfect sphere. We tried different sewings for the face, the first one was glueing the fabric to the face and had something like a hat or a hoodie on top of that(first image). The second try was to create multiple pieces and sew them together to cover the head. The problem with this cover was that the sewing was visible around the face (second image). The final one that we came with was also a multi-piece fabric, but this time we planned that in a specific way in order to not have any visible sewing on the face (third image).



1 2 3

Hot press

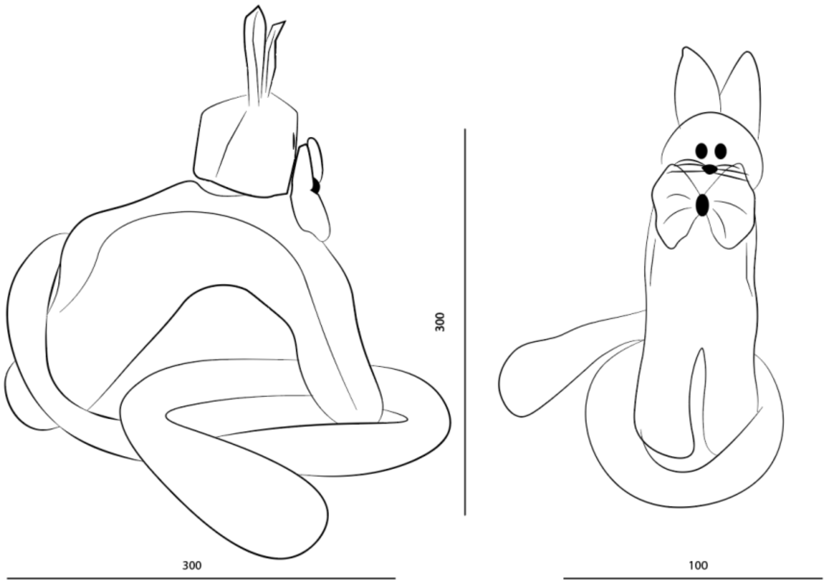
because of the fabric type we used, we had to press every single edge from the inside in order to have a smooth look on the surface part. Also, the hot press helped a lot with making the bulk with the fabric in order to stay straight and in sync with the structure.

Velcro attachments

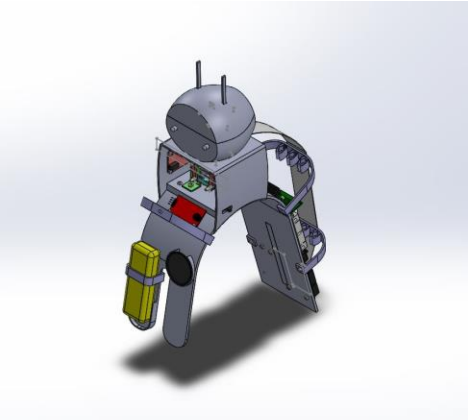
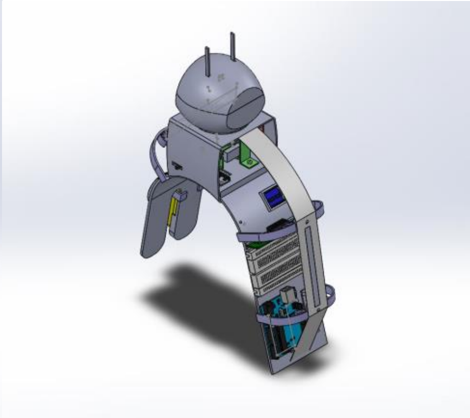
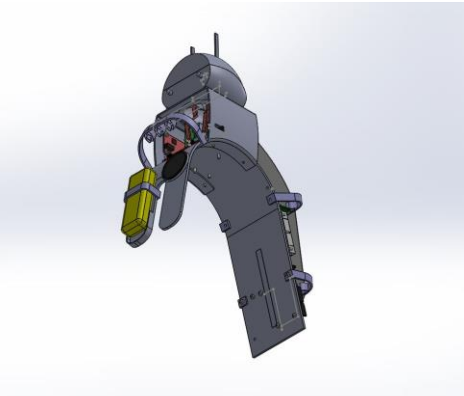
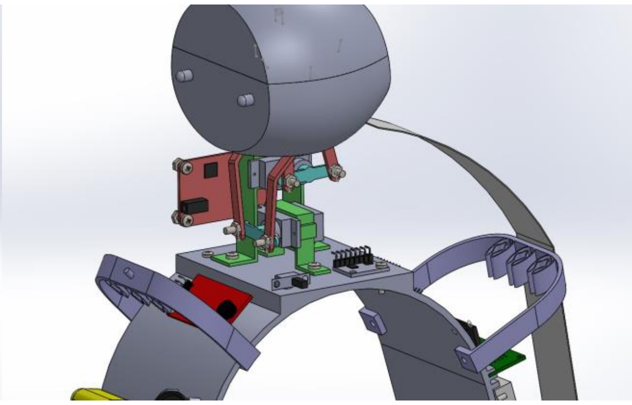
in order to facilitate assembling and disassembling of the components and structure, we decided to use velcro on the bottom side of the robot. using velcro helped us to easily remove the fabric and wear that.

Mechanics

To make all the components with 3d printed we realized a 3d model with Solidworks. In the image below you can see the maximum dimension of the robot.



To check the 3D model on google drive is available the google drive folder

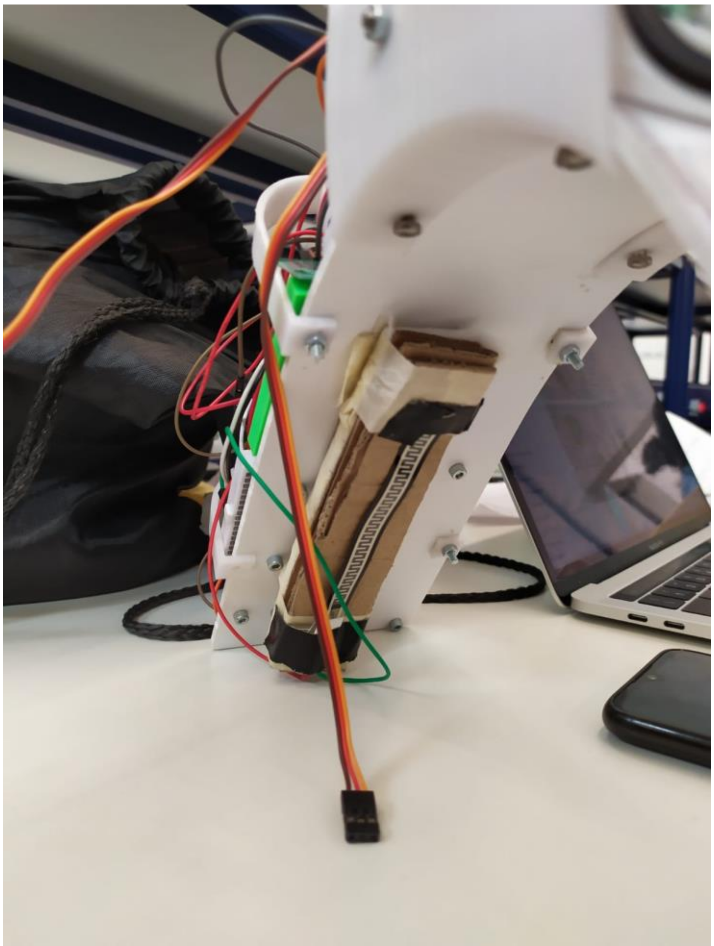





Electronics

Improvements

The previous touch sensors were a simple jumper attached to a tin paper that was able to detect a touch. We decided to improve it because the tin foil had a low sensitivity due to the presence of the fabric on our shoulders. We bought the FSR sensors which provide a better result in understanding the position of the robot and when someone touches it.

Even if that sensor works very well, it needs a consistent amount of pressure in order to have significant values and in addition, when it is curved the analog value red is not zero even if no one is touching it. We planned to put one of them in the point on contact between our shoulder and coco, so in the higher point of the arch. That solution was not possible as the sensor red values even if no one was touching it with the shoulder due its curvature. We solved the problem by putting a long piece in order to increase the intensity of the contact between the sensor and our shoulder.



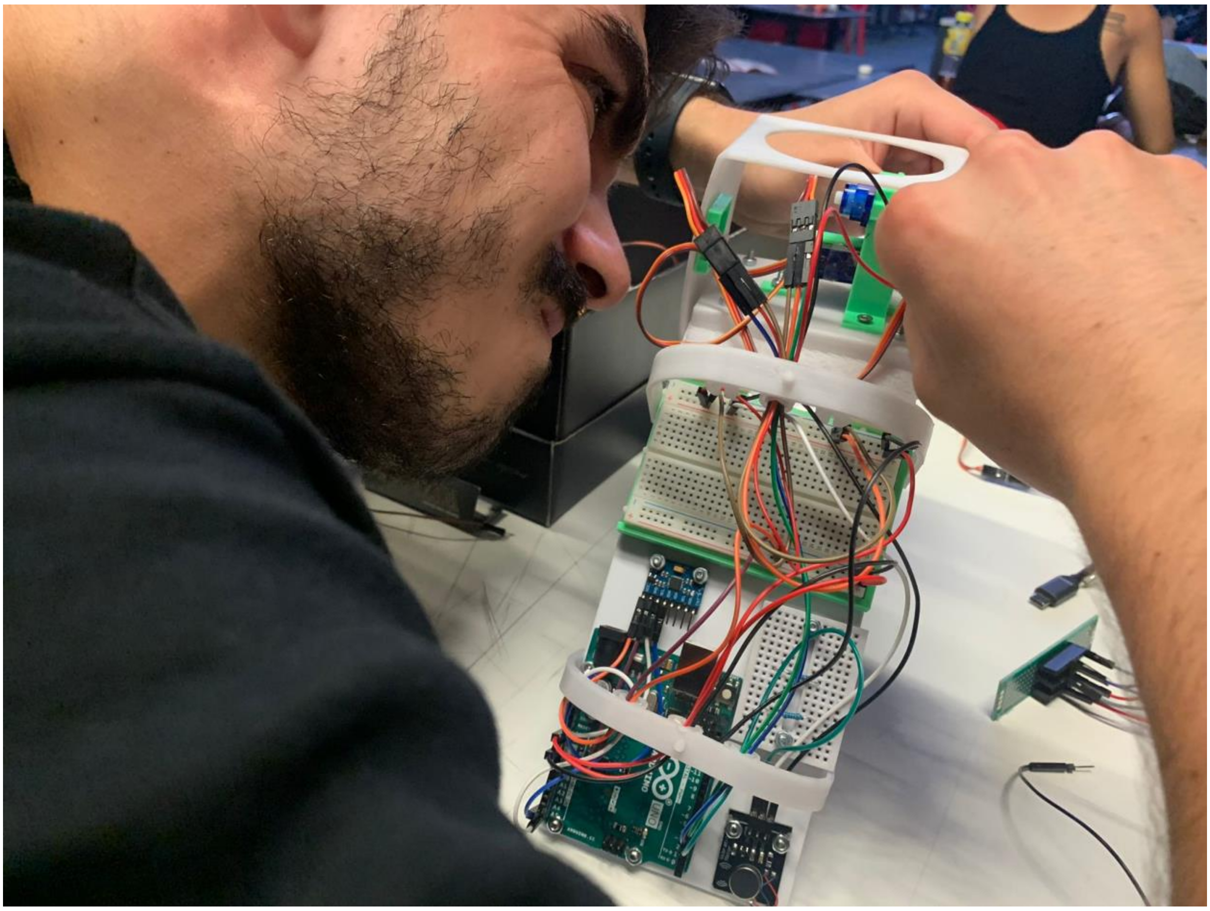
Problems

In the final testing of our components these problems arised:

1. The 5V voltage provided by Arduino cannot supply all the components
2. The voltage provided by the battery, through the stepper, does not work properly. We tested the sound detector using our “handmade” breadboard connected to the stepper but we burnt the sensor due to an unknown problem.
3. The servo motors often do not move in the right way, every now and then the motors move in a strange way or in different angles.
4. The speaker, due to the lack of voltage, does not recognize the sd card inside.
5. The microphone is not so sensitive in a noisy environment and it's able to better recognize the voice of the person who trained it.
6. The SparkFun noise sensor posed voltage problems regarding both the operation of the speaker itself and other sensors such as the servo motors.

Solutions

1. We manage the connection of the sensors using the breadboard trying to avoid voltage problems.
2. For the time being, we tried to rebuild the connection between Battery->Switch->Stepper->Handmade Breadboard->Arduino Pin but we discovered that the Arduino supplied with the jack input requires at least 7V. In this way we should have a battery that feeds at the same time all the sensors at 5V and the Arduino to 7V. This would require using two different switches for shutting down Arduino and the sensors. We chose to directly supply power to Arduino using the battery and then fed the sensors using the voltage in output from Arduino.
3. We figure out their pin layout position on the breadboard.
4. We figured out the lack of voltage for the speaker in point 1.
5. We tried to retrain the microphone in a noisy environment to give it more robustness, the performance is slightly improved but we reach a good trade off considering the value of the voice recognition module.
6. In the end we decided to remove the SparkFun noise sensor due to a voltage problem.



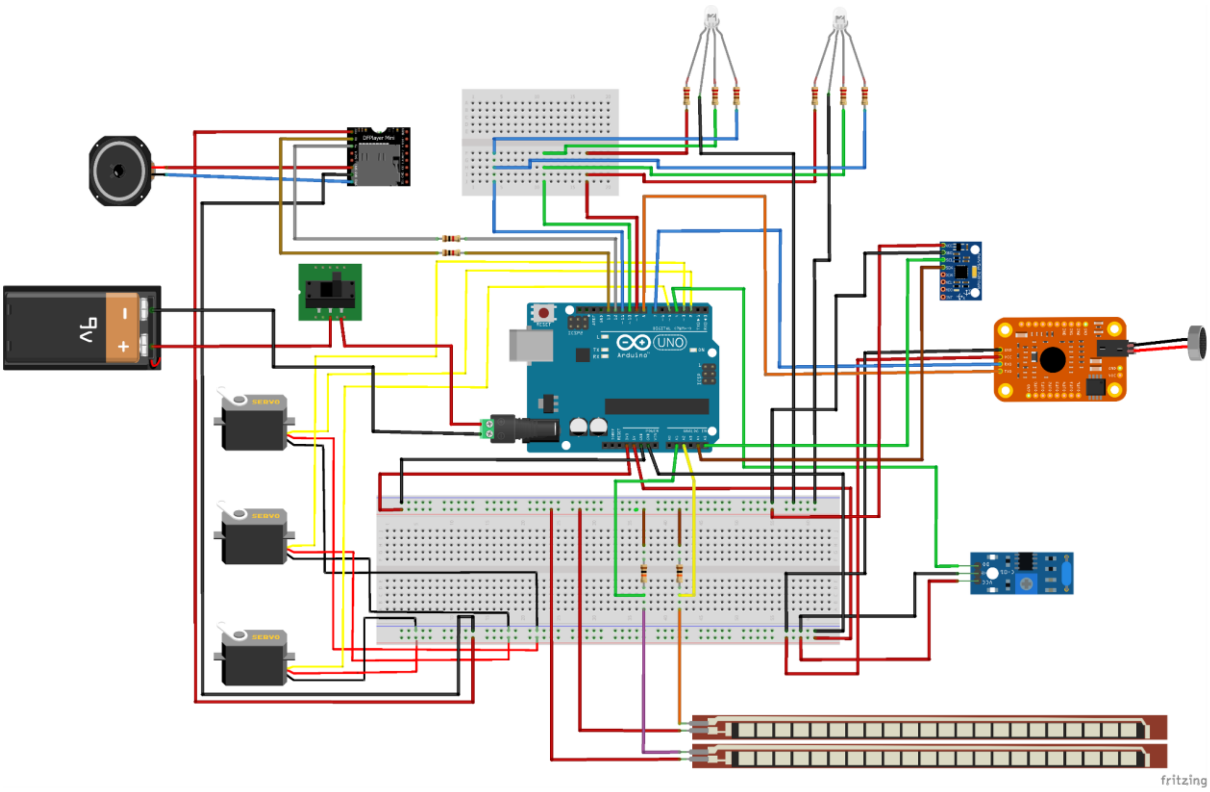
Bill of material

Arduino*	x1
Servo Motors*	x3
Battery*	x1

Step down converter	x1
Speaker*	x1
FSR Sensor*	x2
Multicolor Leds*	x2
Accelerometer/Gyroscope*	x1
Vibration Motor*	x1
Voice recognition module*	x1
Noise/Sound sensor	x1
Switch*	x1

The sensor signed with * are the ones that we will use in the final delivery in june.

Schematics



Informatics

The code is written around the idea of using a state machine, in particular, the code is divided into:

- state functions;
- transitions functions: check if a condition is met and eventually changes state;
- auxiliary functions;
- global variables.

The main problem we had was to make sure that the robot was able to recognize each input correctly and without any delay, the state machine approach helped us in achieving this because it can quickly check each transition of a state and gives a semi real-time behaviour.

We implemented different versions of the code where, incrementally, we added more and more features and corrected bugs, each version has been uploaded to our GitHub repository (https://github.com/LorisPanza/RoboticsAndDesign) under the Project folder.

The libraries we used are:

- StateMachine.h: to implement the state machine;
- ADCTouch.h: to read capacitive jumper wires;
- MPU6050_tockn.h: to manage the accelerometer;
- math.h: to use some mathematical functions such as 'abs';
- Servo.h: to control servo motors;
- SoftwareSerial.h
- VoiceRecognitionV3.h: to use the word recognition module;
- Wire.h: to establish a serial communication for debugging purposes;
- DFRobotDFPlayerMini.h: to use the SD card reader and the speaker.

Conclusion

From this experience we learnt to work in a team, where people have different qualities and skills, we learnt to work in such a way that everyone could be helpful in order to achieve the final result. The organisation inside the team was straightforward: Loris, Andrea and Giuseppe worked mainly on the code while Giulia and Elahe developed the structure of the robot, however, we met all together most of the time so that the two branches of the project could improve simultaneously. Moreover, the help of the professors was key in achieving some intermediate steps, for instance finding a way to balance the robot on the shoulder or understanding how to power Arduino Uno from a battery.
The workflow was altogether smooth from the first attempts to the final assembly, even though we had some setbacks, e.g., problems with the external power source or the accuracy of the accelerometer.

Engineers

We've learnt:

- how to weld, how to measure voltage and other practical instruments of the lab
- how Arduino framework works and how to use its libraries
- how to configure new sensors with Arduino
- how the external power supply works and the related risks
- how to forecast future issues
- how the bottom up approach is effective
- how a good team communication can lead to a successful work

Designers

we've learnt:

- how to weld
- how to use a little bit Library of Arduino to test simple action
- how to manage snap-fit with 3d printing
- Improved in the physical prototyping
- how to sew
- how to work with people from other fields

APPENDIX

Minutes of the Meetings

Meeting 29/03/2022 Class meeting

Time: 9.30 -18.30
Venue: Lab. Prototipi
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi, **Author**: Giulia Riccardi

- After the lecture, we discussed the brief “wearable robot” and we start to do a brainstorming
- We decide to work on the context “introvert at a party” and realized a mood board
- At the end of the day we thought to change the context because don’t express in a good way emotion to a third person

Meeting 08/04/2022

Time: 15.30 -16.30
Venue: Microsoft teams
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi
Author: Giulia Riccardi

- We tried to define a new concept and restarted with brainstorming, but first of all we tried to understand why to choose a wearable robot.
- We thought about doing a toy robot that can emulate the game “guardie e ladri”, or something that could be a sort of friend that follows you in your activities and interact with other people
- we split the research about how to express emotions with a robot
- we discussed about the email we received from Bonarini regarding a possible idea

Meeting 12/04/2022

Time: 12.30 -14.00
Venue: Microsoft teams
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi
Author: Giulia Riccardi

- We decided to work on the second idea
- We prepared a mood board and a storyboard to show our idea and with a brief bill of material

Meeting 15/04/2022

Time: 18.00 -20.00
Venue: Microsoft teams
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi
Author: Loris Panza

- We talked about our ideas of prototype to get some helpful hint from other ideas

Meeting 22/04/2022

Time: 18.00 -20.00
Venue: Microsoft teams
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi
Author: Loris Panza

- The people in the group that started to build the physical prototype start to share the shape of their robot

Meeting 26/04/2022

Time: 9.30 -18.30
Venue: Lab. Prototipi
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi, **Author**: Giulia Riccardi

- We started with the presentation of the paper prototype that every member of the group made
- We mixed 3 of them in one idea: the shape of a cat, with an arc structure and a belt to fix safely the robot to the shoulder
- Because of all interaction, was already decided we started to think about the materials to buy
- At the beginning because we need to have word recognition we thought to use a Raspberry pi. Indeed it is more suitable for this kind of interaction even if for other simple commands as servo motors and the using of accelerometer was not so good
- A draft of a flow chart was created
- A new rough prototype was realized to better understand if an arc shape with a low barycentre was enough to stay in the shoulder without the supports.

Meeting 03/05/2022

Time: 9.30 -18.30
Venue: Lab. Prototipi
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi, **Author**: Giulia Riccardi

- We discussed creating a more smooth shape for the cat, more natural.
- We thought about inserting some weights in the feet to balance the robot on the shoulder. For example we thought of inserting the battery in the front leg.

- We decided to use 2 servo motors to move the head and maybe add a spring to make the movement of the cat even more realistic if the servo motors don't work.
- we took the dimension of the principal components to understand better the maximum dimension and space required.
- we started to buy all components

Meeting 06/05/2022

Time: 16.30 -18.00
Venue: Airlab
Attendees: Giuseppe Chiari, Loris Panza, Andrea Razza,
Author: Loris Panza

- We start learning how to weld
- We start welding the components for the battery supply: switch, step down and the wiring

Meeting 10/05/2022

Time: 9.30 -18.30
Venue: Lab. Prototipi
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi, **Author**: Giulia Riccardi

- We finalized the final shape of the cat and created a rough prototype (body, head, feet and tail).
- We finalized the movement mechanism of the ears and how to divide the head and use the snap fit.

Meeting 11/05/2022

Time: 16.30 -18.00
Venue: Airlab
Attendees: Giuseppe Chiari, Loris Panza, Andrea Razza,
Author: Loris Panza

- We finished welding the battery supply infrastructure

Meeting 12/05/2022

Time: 16.30 -18.00
Venue: Airlab
Attendees: Giuseppe Chiari, Loris Panza, Andrea Razza,
Author: Loris Panza

- We finished welding the battery supply infrastructure

Meeting 17/05/2022

Time: 9.30 -18.30
Venue: Lab. Prototipi
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi, **Author**: Giulia Riccardi

- we decided the final shape and mechanism for the head movement without the spring
- we realized the snapfit to fix the head
- we tried testing the available sensors
- We understood that using the accelerometer for detecting the position of the robot was not efficient as using the capacitive sensor to check if it is on the shoulder or not

Meeting 18/05/2022

Time: 9.30 -18.30
Venue: Airlab
Attendees: Giuseppe Chiari, Loris Panza, Andrea Razza
Author: Loris Panza

- we merged the code of different sensor in the state machine trying to find the best way to represent the states and the relative transition

Meeting 21/05/2022

Time: 21.00 - 22.30
Venue: Lab prototipi
Attendees: Attendees: Elaheh Nabavi Nia, Giulia Riccardi
Author, Elaheh Nabavi Nia

- putting the sensors on the body's structure, testing the coding and movements We had good movement since the motors were operating well together. The voice recognition works, but it isn't very good, and we discovered that the microphone isn't sensitive enough, and we need a better one.
- testing the new speakers
- Modifying the 3D printed part of the head because the hole was a bit smaller and that prevented the good movement of the head.
- creation of the slides of presentation of 31th of May.
- Story board sketches of the video.

Meeting 24/05/2022

Time: 09.00 - 19.00
Venue: Microsoft Teams

Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi
Author, Elaheh Nabavi Nia

- We discussed the shape of the final structure of the body of the robot. We checked what we wrote individually for the final report, then we started to work together on a Figma file for the presentation of the delivery of 31th of May. Then we started to define the storyboard for the video.
- We decided to keep the base of the structure and attach other 3D printed parts on that. We came up with the idea of the flow of the slides and what we should do for the next presentation. We worked on slides together, we defined each slide's title and the components we wanted to add. For the video storyboard, we defined and wrote what we wanted to show in each scene.
- We tested the speaker and the servomotors fixed to the robot.

Meeting 27/05/2022

Time: 09.00 - 20.00
Venue: Moda lab, Air lab
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Loris Panza, Andrea Razza, Giulia Riccardi
Author, Elaheh Nabavi Nia

- Elaheh worked in the moda lab to create the fabric cover, the problem was that with a single cover it was not good to make the entire skin. We decided to have another solution to cover the head and the body.
- In the afternoon we moved to the air lab to work together on the design and the engineer parts. We wanted to test everything together, this time without a computer but with a battery. The first attempt failed because the components didn't work as before and we struggled a lot to try everything at the same time.

Meeting 28/05/2022

Time: 10.00 - 16.00
Venue: Loris house
Attendees: Giuseppe Chiari, Loris Panza, Andrea Razza
Author, Giuseppe Chiari

- tested different servo motors and tested the various transitions.
- While testing the external power source the step down converter burnt.
- Giuseppe and Loris wrote part of the report.
- Andrea made the Fritzing scheme.

Meeting 13/06/2022

Time: 10.00 - 17.00
Venue: lab prototipi, Lab Moda
Attendees: Elaheh Nabavi Nia
Author, Elaheh Nabavi Nia

- Redesign the paper pattern with different dimension for all the fabric parts(body, tail, head , ears)
- tailoring the new body fabric, tailoring all the parts. definition of a new way of sewing in order to not have the sewing on the area of the face.

Meeting 14/06/2022

Time: 10.00 - 16.00
Venue: lab prototipi, Lab Moda
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Giulia Riccardi
Author, Elaheh Nabavi Nia

- finalise the shape of ears and create the ears and tail by Elaheh.
- final decision on video making All together.
- test the pressure sensor by Giuseppe.
- Giulia finished the 3D model of the structure plus all the components on that.
- find the new different movement for the scared moment.

Meeting 16/06/2022

Time: 10.00 - 18.00
Venue: lab prototipi, Lab Moda
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Giulia Riccardi,Loris Panza, Andrea Razza
Author, Elaheh Nabavi Nia

- Reshape the structure of body with the hot gun.
- fixing the structure with screw
- new shape of ears
- we tried to test everything together
- decide to not use the noise sensor and finally decide to final pin configuration

Meeting 18/06/2022

Time: 10.00 - 18.00
Venue: Elaheh Residence
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Giulia Riccardi,Loris Panza, Andrea Razza , **Author**, Elaheh Nabavi Nia

- Record the video
- Fix the external shape of coco (papillon, moustaches)
- Discover a problem linked to the mic

Meeting 20/06/2022

Time: 10.00 - 18.00
Venue: AirLab
Attendees: Giuseppe Chiari, Elaheh Nabavi Nia, Giulia Riccardi, Loris Panza, Andrea Razza , **Author**, Elaheh Nabavi Nia

- Record the video related to the microphone
- Fix servomotors movement
- Tuned the parameters (accelerometer, touch sensors,..)
- Finished the report
- Finished user manual and maintenace manual

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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
- 3D models (in DXF or STEP files)
- Short video

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