05 MAY 2020

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SUPERVISOR: M. LUBRANO

TECHNICAL PROJECT COBOTIC

Final report

Group 7 – Subgroup 15

SCHEER SIMON - GIRAUD FANNY - BERTELLI FRANCESCO - GHIGINI ORIANE - RAJOT ROMAIN - SCHILLIO NICOLAS

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Summary

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TABLE OF ILLUSTRATIONS

TABLE OF APPENDIX

GLOSSARY

CAD: Computer Aided Design

FMECA: Failure Modes, Effects and Criticality Analysis

GDP: Gross Domestic Product, the growth rate of gross domestic product (GDP) per person employed is defined as the growth rate of output per unit of labour input.

KPI: Key Performance Indicator

LED: Light Emitting Diode

OS: Operating System

PC: Personal Computer

PLA: Polylactic Acid, material used during 3D printing.

ROS: Robot Operating System

RPi: Raspberry Pi

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Acknowledgment

We would like to thank all the people who helped us during this project with all the technical and managerial difficulties we encountered.

We especially would like to thank Mr. Porcedda, our customer, who believed in what we did, supported us, and helped us to find the best solutions.

We also would like to thank Mr. Lubrano, our supervisor, who always gave us good advices and motivated us.

Special thanks to our technical experts: Mr. Nisand and Mr. Turko, who helped us to find solutions to our technical problems linked to the 3D printing and the electronic part.

Thanks to Wandrille Würz who worked with us on the CAD file assembly of the robot and was pleased to help us when we had some questions about dimensioning and manual processes for the assembly of the robot.

Lastly, we would like to thank everyone who contributed to our project whether it was through an idea or a helping hand to progress.

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INTRODUCTION

Our project is part of the project group “Smart Factory”. This project aims to create a robot arm which does not need a physical barrier to work. It should work in symbiosis with the operator it is working with. The user must be able to pilot the robot directly from a touchscreen tablet. Our group work in collaboration with the Subgroup 14 working on the conveyor. Our robot must carry a minimum load of 1 kg and drop it on the trolley navigating on the conveyor belt. The customer wants a new robot that will replace the one in the laboratory 2.

The progress or our project will be explained in this report, as well as the difficulties we encountered.

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I. Project Management

1. The team management

For this project we used the Agile Methodology in order to be more efficient: it is a process by which the team can manage the project by breaking it up into several stages and involving constant collaboration with stakeholders and continuous improvement and iteration at every stage. It facilitates the coordination and implementation of the project.

The Scrum Master is Simon Scheer and the Product Owner is Fanny Giraud:

Figure 1- Our Team

The Scrum Master must establish an environment where the team can be effective, address team dynamics, clear obstacles and ensure a good relationship between the team and product owner as well as others outside the team.

The product owner must clearly identify and describe the product backlog items in order to build a shared understanding of the problem and solution with the product development team.

2. The Product Backlog

We made a Product Backlog: it is a list of all things that needs to be done within the project. The Product Backlog evolves as the product and the environment in which it will be used evolves. The Product Backlog is dynamic; it constantly changes to identify what the product needs to be appropriate, competitive, and useful. **(See annex 1)**

We made a system of story points to see if the distribution of tasks is fair between each member of the team.

Team Members	Story Points
Simon Scheer	56,00
Fanny Giraud	48,00
Francesco Bertelli	28,00
Oriane Ghigini	41,00
Romain Rajot	35,00
Nicolas Schillio	30,00

Figure 2 -Story Points values

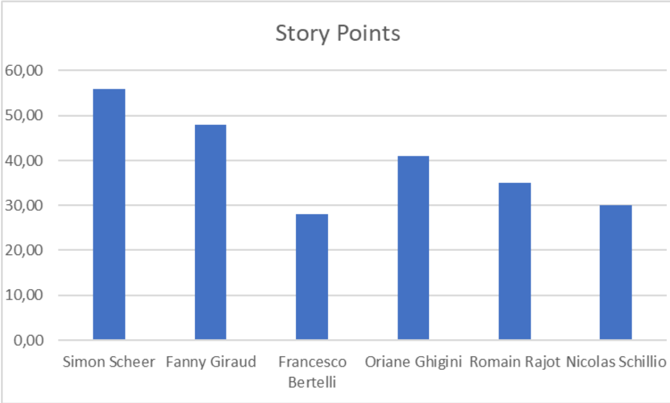


Figure 3 – Story Points repartition

For the moment, the repartition looks quite good knowing that the scrum master and the product owner are involved in many tasks.

3. The Sprint Backlog

Sprint 1:

(See annex 2)

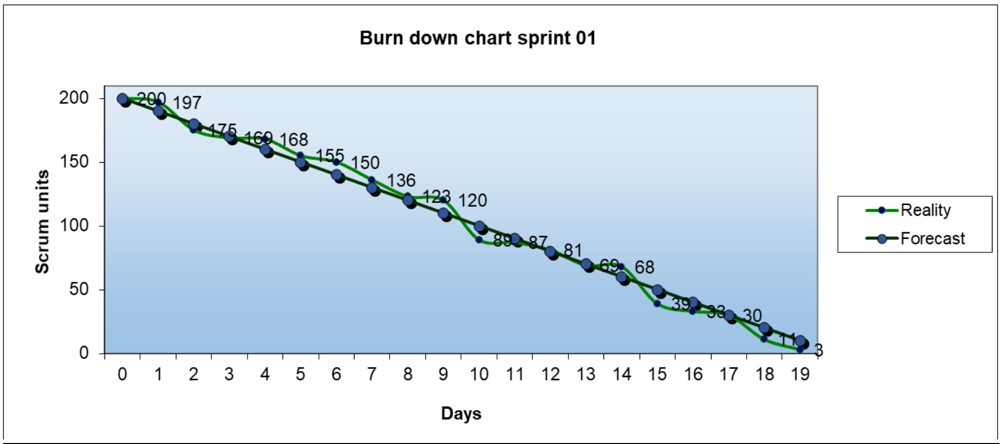


Figure 4- Burn down chart sprint 1

The first sprint was mainly dedicated to the redaction of the specifications. Many researches have been made about what were already existing and what could be a solution to our customer's specifications. We began on the 23^{rd} of September and ended up on the 18^{th} of October. At the end we presented our customer the complete specifications, requirements and what possible solution we could go with.

Sprint 2:

(See annex 3)

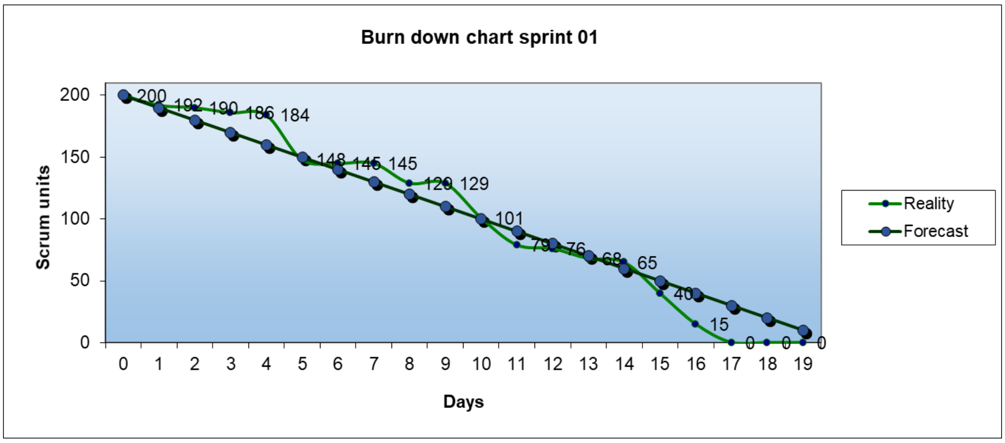


Figure 5- Burn down chart sprint 2

During the second sprint, the team worked on the inventory and what was already existing on the workstation. Tests were effectuated on the sensors and the electronical components to see what we needed to adjust or to modify to obtain the best possible result. It lasts a month from the 4th to the 29th of November.

Sprint 3:

(See annex 4)

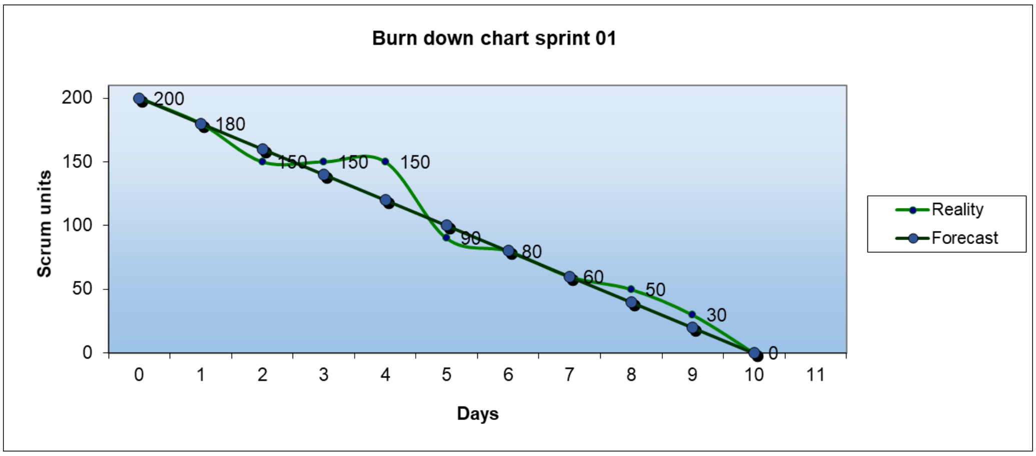


Figure 6- Burn down chart sprint 3

The third sprint was decisive for the team because it is the moment our project took a turn. Indeed, we stopped losing time researching more information and a final solution has been chosen by the team. At the moment this was done, an assembly CAD file was built, and a purchase sheet has been filled to buy the components as fast as possible to catch up the time requirements.

Sprint 4:

(See annex 5)

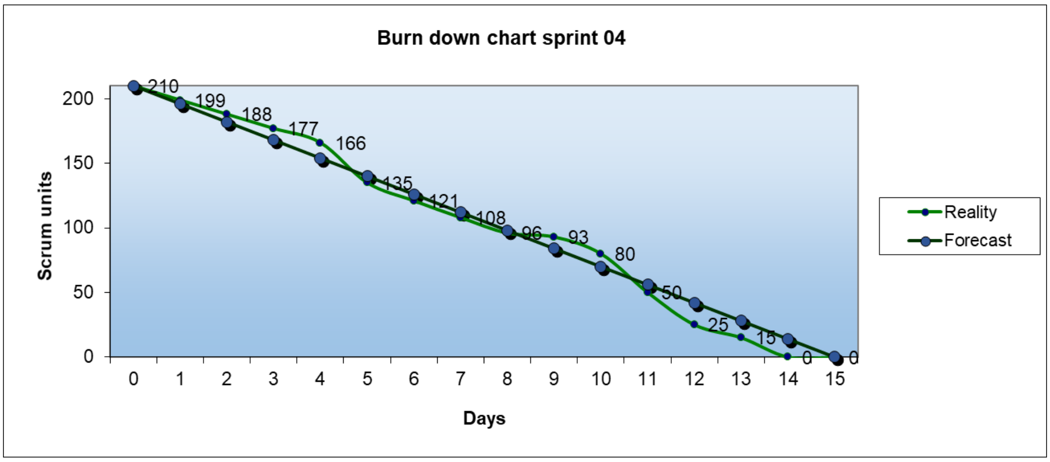


Figure 7 – Burn down chart sprint 4

During this sprint, we were able to show something concrete for the first time. Indeed, we had some parts of our robot which we printed in 3D at the ECAM. We made a point on how the rest of the project was going to unfold, and how we were going to proceed for the assembly.

Sprint 5:

(See annex 6)

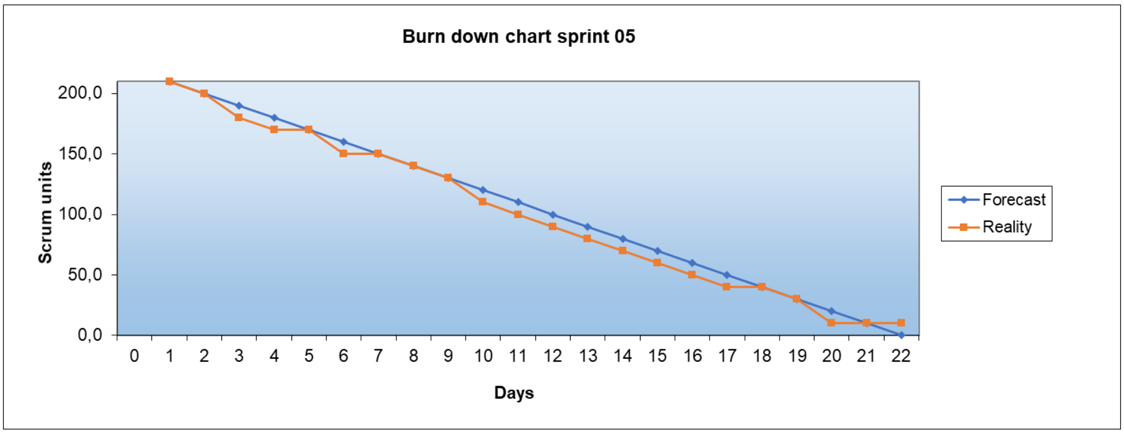


Figure 8 – Burn down chart sprint 5

After long hours of 3D printing and many orders placed with ECAM partner suppliers, we were able to present during this sprint several parts of our assembled robot. We were able to assemble the motors on the structure. We also discussed about the possible solutions for the sensor/security system.

Sprint 6:

(See annex 7)

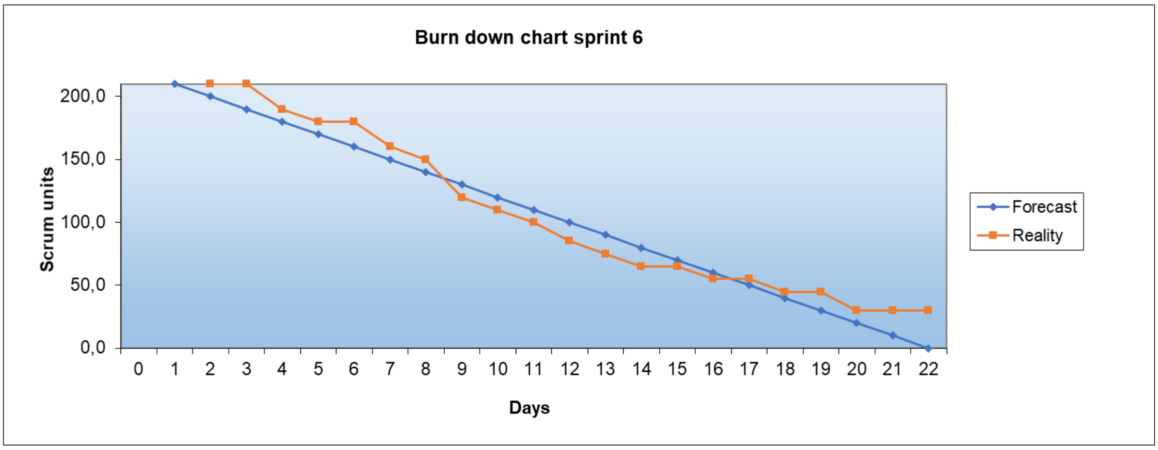


Figure 9 – Burn down chart sprint 6

Unfortunately, this last sprint was carried out on teams due to the current health crisis. We have not been able to make much progress on the assembly of the robot and we therefore talked about the report and an assembly manual which we must do to simplify the work of the next group.

4. The planning

(See annex 5)

Once the robot was chosen, the scrum master immediately raised a planning to split all the tasks through the time and assign them to the other members. This type of planning is usually used for a general purpose at the beginning of a project but here, it enables the team to inform the customer about the deadlines fixed in order to show the progress of the project.

5. The planner

We also used a planner because it is effective for the daily management of the tasks, we can clearly see the progress of the project, the deadlines, and therefore if we are late or not.

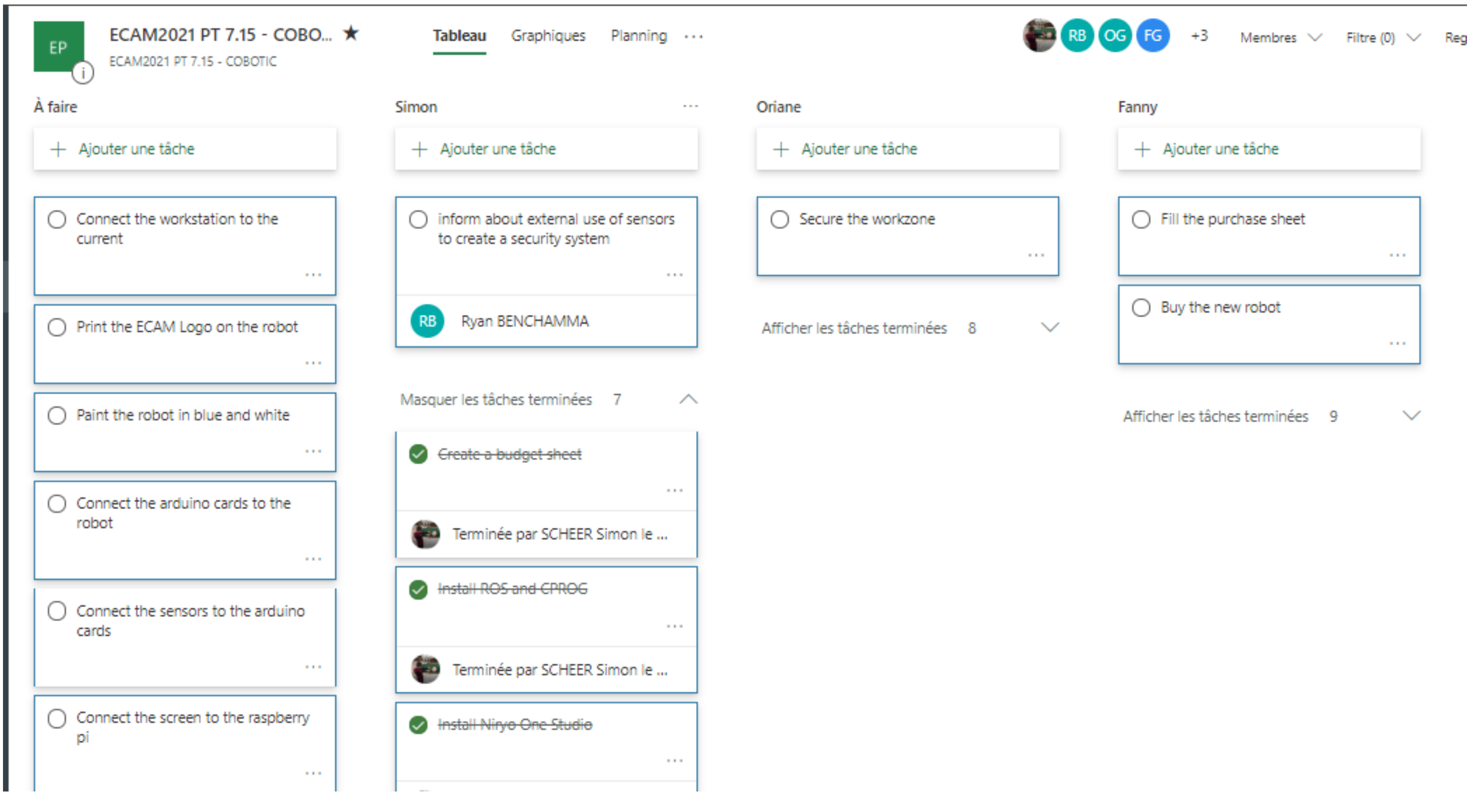


Figure 10 - Planner

With Planner, it is easier and more pleasant for the team to see which task they were assigned. Furthermore, the software disposes of a calendar functionality to match it with the personal member's one.

II. Specifications

1. Goals

The main goal of our project is to build a 6 axes robot arm which should work in symbiosis with the operator. Here are some other objectives/requirements for our robot.

- The robot has to be controlled by the tablet located on the station
- We want to be able to control the speed rate
- We want to be able to control the clamp pressure
- We want to be able to provide a BOM for all the components
- We want a 3D model of our robot in Solidworks
- We will integrate the robot in the workstation
- The final program will include a test part to fix the eventual issues
- The robot must be able to detect the piece
- The robot must be able to access the conveyor
- The robot will be entirely electronically automatized

- We want an intuitive control panel: it must be simple to understand and easy to use
- The robot must be eco-friendly in the conception process

2. Needs and constraints

About the aspect

- The robot must be a 6-axis robot
- The customer wants a completely new robot
- The colour of the robot: blue and white with the logo ECAM on the robot
- The robot could have a camera (option)
- The robot must have a clamp in order to take the components or the components could reach the robot in a surface (must be chosen)
- The size of the arm is not defined for the moment, but it must reach the conveyor on the side

Other points

- The robot must be located on a table
- The piece is in aluminium: max 1kg and the max size is 150x150x150 mm
- We must be able to control the speed rate of the robot
- We must have a tablet in order to begin the program, to stop and switch to manual mode
- We will have to code entirely the robot’s displacement with software

- The robot must respect the green plan
- The workstation will be secured, and the user will be prevented of all injuries
- The robot must be able to lift an aluminium component of 1kg with a maximal dimension of 150x150x150 mm

3. Functional analysis

Horn beast diagram

A goal was to define the environment and the technical solutions that could be brought to the project. We created a horn beast diagram: it allows to define the needs to which the system answers.

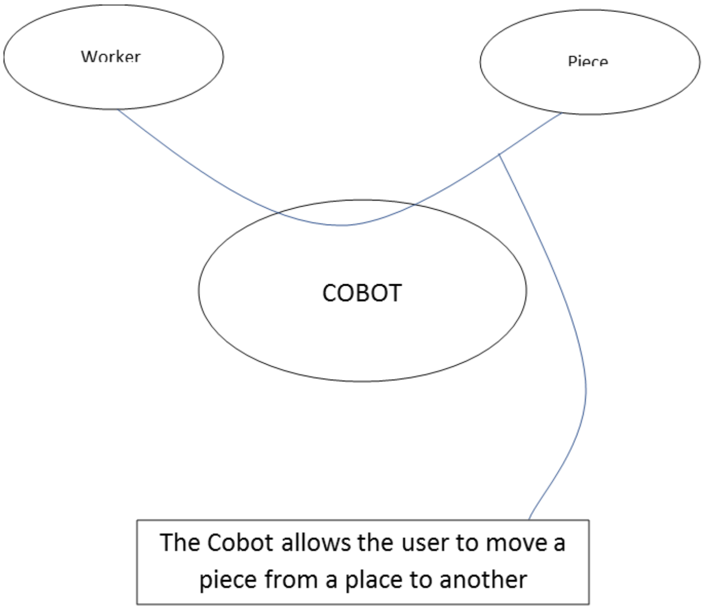


Figure 11 - Horn beast diagram

Octopus diagram

Then an octopus diagram has been created: a simple diagram that just describes what is the main function of this system and the constraints it will have to deal with while working.

The table that follows describes with more details the different functions and constraints.

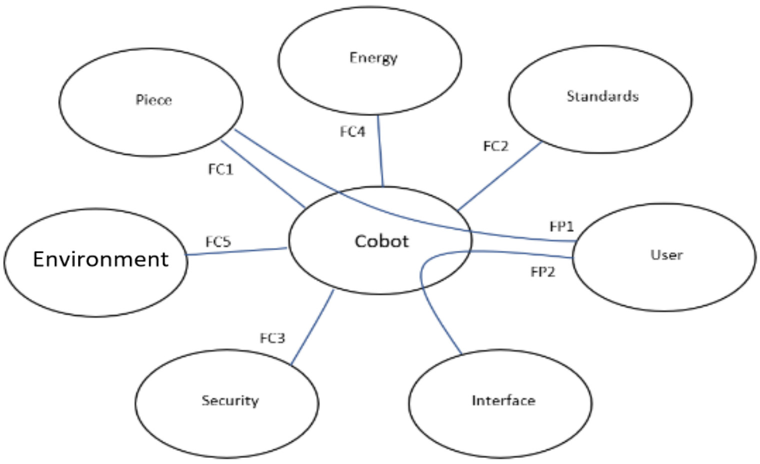


Figure 12 - Octopus diagram

Function		Criteria	Criteria Level	Level flexibility
ID	Description			
FP1	Help the user to move a piece from a point A to a point B	- Manage the pace of the robot - Control the handling system - Precision of the position P1 - Precision of the position P2	1 piece per minute Open/close the clamp ± 3 mm ± 5 mm	f2 f2 f1 f1
FP2	Allow the user to work with an interface	- Control the device with a touch screen - Use warning lights to warn the user - Use a robotic software to program the robot	USB port to connect PC and HDMI port Red LED: stopped Green LED: ready to launch Orange LED: processing Python and Blockly language	f3 f3 F0
FC1	Hold the piece	- Be able to take and release the piece	Size of the gripper: 150 mm	f0
FC2	Respect the standards	- Respect electrical constraints - Respect robotic constraints	Follow technical instructions In technical documentation (standards)	f0 f0
FC3	Protect the user from injuries	- Stop when a worker enters the work area	Automated stop system	f0
FC4	Power the device	- Connect the device to the electrical network	Power: 60 W Voltage: 230 V Intensity: 32 A 3-phase alimentation	f0 f0 f0
FC5	Resist the environment	- Resist to humidity - Resist to dust	-Max 70% -only superficially (not inside the robot)	f1 f1

Figure 13- Table of functional analysis

Fast Diagram

The team created a Fast Diagram, it is a technique to develop a graphical representation showing the logical relationships between the functions of a project, product based on the questions “How” and “Why”.

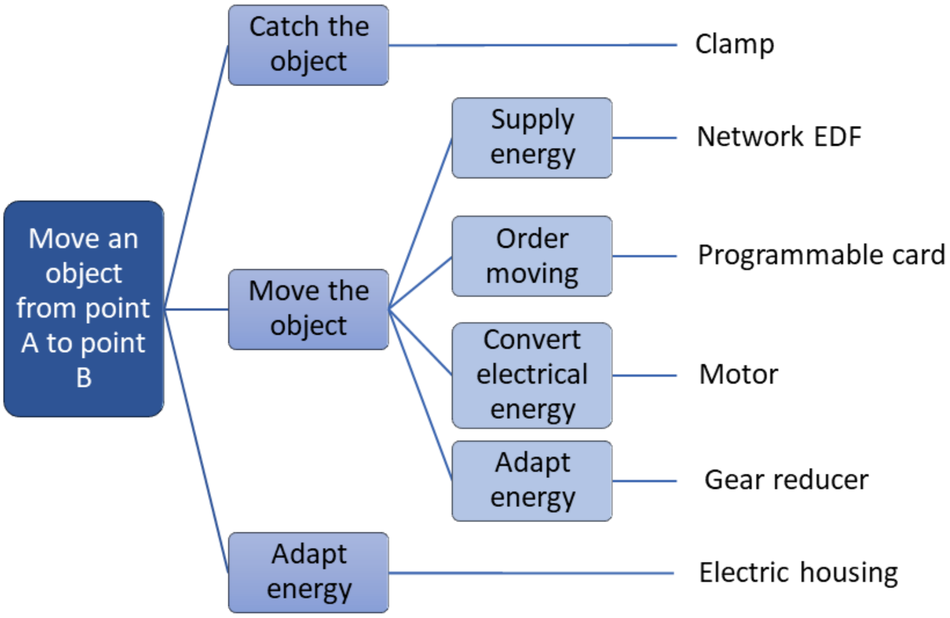


Figure 14 - Fast Diagram

This diagram enables us to fully understand and clarify the subject, splitting the main goal into several parts in order to find the best solution to fit the customer needs.

4. Security Risk Analysis

A security risk analysis identifies, assesses and implements key security controls for our project.

- A: Risks caused by a physical activity
- B: Risks of injuries on floor-level
- C: Risks due to mechanical manipulations
- D: Risks on resources
- E: Risks due to electricity
- F: Risk due to products, emissions and wastes
- G: Risks due to thermal environment
- H: Psychosocial risks

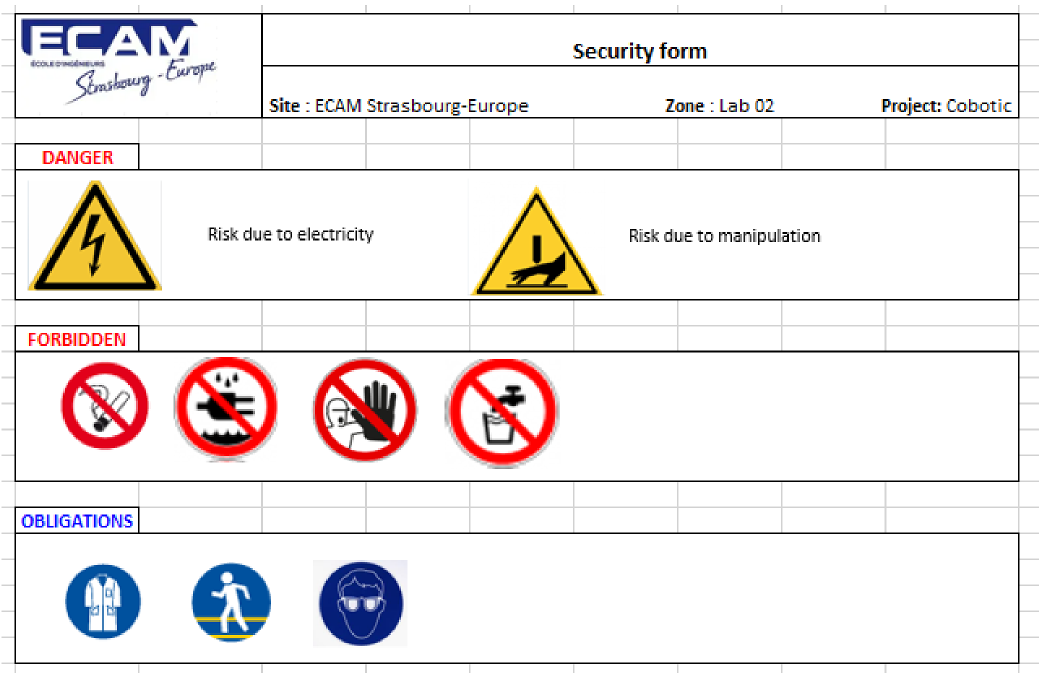
Probability / Seriousness	1. Painless	2. Limited	3. Important	4. Dramatic
1. Unlikely	B, D, H, F			
2. Occasional		A,G		
3. Ordinary			E	
4. Regular			C	

Unacceptable	
Permissible	
Insignificant	

Figure 15 - Risk Analysis table

The most likely risks are the risk due to mechanical manipulations and electricity. Indeed, the risk of injuries on the floor is almost unlikely because we do not need to reach any object in height. It is the same thing for risks due to thermal environment.

A security sheet was established to prevent measures for the two main risks.



Security form

Site : ECAM Strasbourg-Europe Zone : Lab 02 Project: Cobotic

DANGER

Risk due to electricity

Risk due to manipulation

FORBIDDEN

OBLIGATIONS

Risk identified	Preventative measure
Electricity	Do not use water in the lab
	Do not smoke
Manipulation	Wear a blouse
	Wear protective glasses

Figure 16- Risk analysis

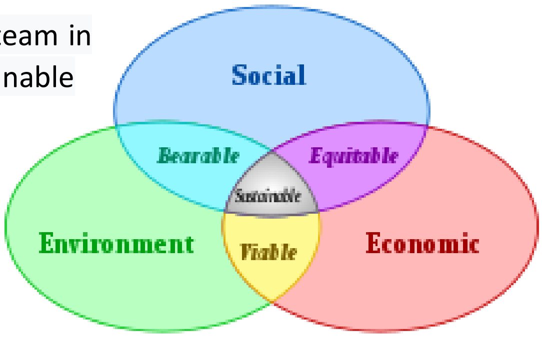
What to do in case of an accident?

- Due to electricity:
    1. Cut power
    2. Call the emergency
    3. If the victim is conscious: stay with him and talk to him
    4. If the victim is not conscious: Put him in lateral security position
    5. If the victim is not conscious and does not breathe anymore: start cardiac massage

- Due to manipulation:
    1. If the injury is shallow: just disinfect it
    2. If the injury is important: compress the wound and go the emergency

5. Green Plan

The Green Plan is a model strategy accompanying the team in the definition and implementation of the Sustainable Development approach.



A green plan has to be respected to pilot our project.

More precisely, the plan must follow 3 parts:

Social, Economic and Environmental:

Social	**About the product:** All the co-workers will have a good communication between them, we want the robot to be easy and pleasant to use for the user. They will feel good and have less workload **Indicator:** A pol can be used in google forms every month to check if each member is satisfied of the working atmosphere.
Economic	**About the product:** The supply chain will be automatized and therefore represent a gain of time in the whole process. We can therefore assign workers on other tasks more important and be more productive. **Indicator:** We can use some KPI in order to evaluate our money savings. For example, labour productivity: GDP per worker, GDP per hour of employment…
Environmental	**About the product:** We want the robot to consume energy only when it is functioning (with a button) and no sleep mode which could use some energy. And during the run we want to minimize his energy. For the 3D printing we want to use recyclable packaging and limit the quantity of material. We will use reusable and recyclable material to limit costs. **Indicator:** The consumption is around 60W. We can establish some KPI: for example, an EPI: Energy Performance Indicator (IPE in French). This will allow us to evaluate our energy savings.

Figure 17- Green Plan

6. Estimation cost

Materials	Price	Quantity
Touch screen 15 inches	150 €	1
Robot Niryo One kit	1399€ HT	1
Raspberry Pi 3 1,2 Go (in case of a new one is needed)	41 €	1
Sensor RPI HC-SR501	16 €	10
Filament de bobine Ø1,75, 1 Kg	36 €	1
Aerosol Neon fluorescent paint	11 €	1
Aerosol Neon shiny paint LUXENS, white	12 €	1
Aerosol paint Relook shiny	12 €	1
Adhesive tape SCOTCH BLUE 150m	10 €	2
Universal hinge inox for furniture	4 €	1
Glue mastic « Fixer sans percer » SADER	6 €	1
Cables male-male Conrad Pro 2	12 €	1
Cables male-female Conrad Pro 4	5 €	1

Figure 18 - Table of the estimation cost

Total estimation cost: 1714€

The total cost will decrease for sure after the inventory, because of the reusability of certain actual components.

Agreement statement

Signature of the customer:

Signature of the scrum master:

Signature of the product owner:

Date: 14/11/2019

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III. Solutions considered but abandoned

In this part, we will explain our approach in order to determine the robot that answers the best to our specifications. We changed robot many times during our project, we will here illustrate why.

After doing some internet researches, we made a list of all robots that could be a good solution to satisfy the client's need. **(See annex 6)**

1. Our first choice

The first robot we chose was the Niryo One robot.

It was indeed easy to set up, because the entire robot was available on sale in a kit containing all the elements needed to assemble it, and the cost of 1400€ of this kit was under our budget of 2500€.

However, we noticed a major problem concerning the capacity load of only 0.3 kg, much lower than the 1kg expected in our specifications. In a first time we contacted the manufacturer of the robot to ask him if this capacity could be increased by our own, but unfortunately it was not possible, and we decided to choose another solution.

Figure 19- Niryo One robot

Based on this conclusion, we focused our researches on a robot that respect this load capacity, because we understood that the hardest aspect was to find a robot that respect this criterion with our budget, and the choice was relatively limited.

2. Our second choice

The Thor robot, an open source printable robot available in kit, and with a free CAD given, that can lift to 0.75kg, not very far from our objective.

We decided to validate this robot with our customer after a sprint, but when we began the CAD in order to prepare the printing and the order of the components needed, we realised that the CAD files were not well defined, and the bill of materials wasn't exhaustive.

Moreover, the kits were not available on an ECAM's partner website and the pieces would have been difficult to machine; that is why it would have been perilous to continue in this direction.

Figure 20 - Thor robot

3. Our third choice

In accordance with the customer, another robot from our list has been chosen, the AR3 robot from Annin Robotics, that has a load capacity of 2kg, largely enough compared to the 1kg needed.

This robot is also an open source one, available for sale in many kits. Some of the parts are also printable, so we would have been able to get them at ECAM directly. Lastly, the entire CAD files ready to print are available for free.

However, when we started to work on the CAD files, we noticed that the files available for free were only in a printing format, and to get the CAD files that can be modified, we had to pay it to the robot manufacturer.

So there were two major problems: firstly, ECAM can't buy anything to a firm that is not a partner, so we were not able to get the CAD files that can be edited, and at any rate the payment method used by the robot manufacturer wasn't compatible with ECAM standards.

The second problem consisted in the components of the kits that were all coming from non-partner sites of ECAM, so we had to find them on right sites.

Figure 21- AR3 Robot

4. Our final choice

Finally, we chose the robot that we are working on the BCN3D Moveo robot.

This robot is entirely available for free on the manufacturer website, with the CAD files, and the bill of materials that contains all the elements needed to build it. We also can print all the parts of the robot ourselves, so the total cost of the robot is composed of the price of the components bought on the partner sites of ECAM and the price of the raw printing materials, and the criteria of the capacity load of 1 kg is respected.

The current work will be described in the next part.

Figure 22- BCN3D Moveo robot

To conclude this part, the choice of the robot was the major point of the project; this decision will have consequences all along the project. It was therefore a tricky part, because the solution had to fit all the specifications required, and this difficulty results in these many changes before our final choice.

IV. Our solution and the current state of our work

The robot we finally chose to work with is the **MOVEO from BCN3D**.

The BCN3D MOVEO is a robot with a complete 3D printed structure equipped with six stepper motors and controlled with an Arduino MEGA. It is an open source robotic arm, which means that it is easy to modify if we need to change something.
Thanks to the GitHub platform, a website where users from all over the world share their projects, we were able to get all the information we needed to assemble our own Moveo robot. Here is a picture of the CAD model:

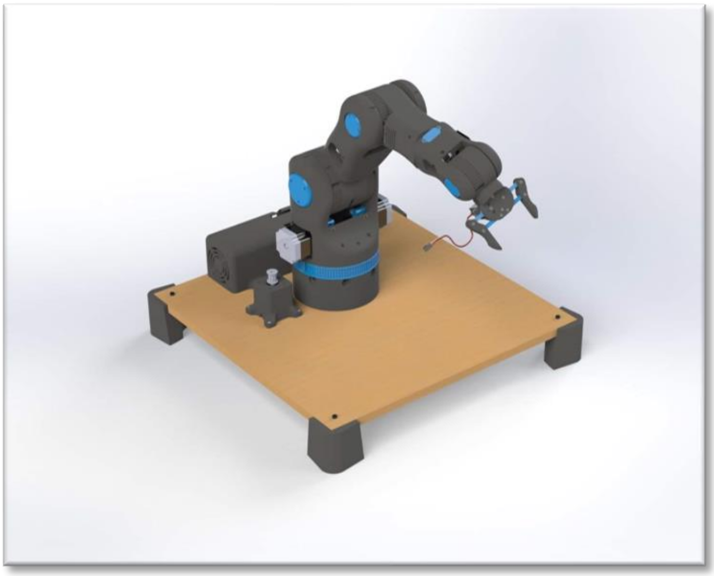


Figure 23 - Moveo Robot

The robot has been broken down into 4 parts to work more efficiently.

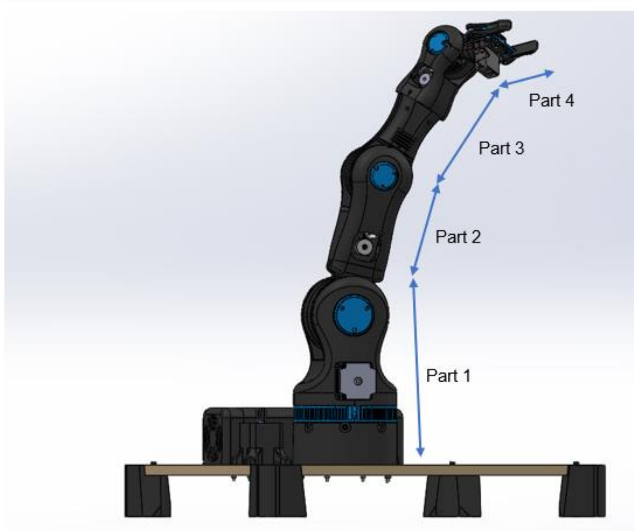
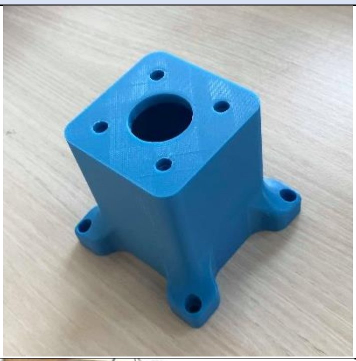


Figure 24 - Different parts of the Moveo Robot

All non-printable components have been ordered. We had to buy all the stepper motors, the fasteners, and the electronic components.
Concerning the printable parts, we used the 3D printers available at the ECAM. We decided to print in PLA it is affordable, and we already have some in stock. You will find below tables on the progress of their printing.

1. 3D printing

Part 1 :

Part 1		
Name	**Advancement status**	**Picture**
1M3A	Printed	
2M1D	Printed	
Tapa 2M1C	Printed	

T2M1BI	Printed	
T2M1BD	Printed	
1M1B	Printed	
1M2A	Printed	

Figure 25 – Printed parts of the robot's part1

Part 2 :

Part 2		
Name	**Advancement status**	**Picture**
2M2HA	Printed	
2M2MA	Printed	
3M1D	Printed	/
T3M1C	Printed	
Tapa 3M1	Printed	

Figure 26 – Printed parts of the robot's part2

Part 3 :

Part 3		
Name	**Advancement status**	**Picture**
3M2C	Printed	/
3M2CC	Printed	/
4M1D	Printed	/
T4M1E	Printed	/
Tapa 4M1D	Printed	
TBC	Printed	

Figure 27 – Printed parts of the robot's part 3

Part 4 :

Part 4	
Name	**Advancement status**
4M2B	Printed
4M2CB	Printed
Botton Plate C	Printed
Top Plate C	Printed
Gripper left	Printed
Gripper right	Printed
Cilinder	Printed
Idol Gear B	Printed
Servo Gear B	Printed
Pivot Arm B	Printed
Second gripper	Unstarted

Figure 28 – Printed parts of the robot's part 4

Two examples of the exploded views that have been established are reported in appendix **(Annex 7 & 8)**.

We then assigned to each component an index in order to be organized. Then from the established BOM, we searched for each component at the ECAM partners and established a purchase order.

Désignation		code fournisseur	P.U.H.T.	Qté	Total HT
32	M3 x 8 mm screw	280-997	15.63 €	1	15.63 €
25	M3 x 10 mm	660-4636	22.32 €	1	22.32 €
26	M3 x 12 mm	187-1229	17.15 €	1	17.15 €
27	M3 x 16 mm	281-013	17.22 €	1	17.22 €
28	M3 x 20 mm	483-8196	18.03 €	1	18.03 €
29	M3 x 25 mm	293-325	19.86 €	1	19.86 €
30	M3 x 35 mm	822-9066	51.06 €	1	51.06 €
36	M4 x 16 mm	281-041	15.01 €	1	15.01 €
37	M4 x 20 mm	290-102	18.64 €	1	18.64 €
72	M4 x 25 mm	281-057	20.26 €	1	20.26 €
38	M4 x 30 mm	290-118	22.32 €	1	22.32 €
39	M4 x 40 mm	293-347	28.00 €	1	28.00 €
43	M5 x 30 mm	483-9997	20.91 €	1	20.91 €
74	M5 x 40 mm	293-353	30.86 €	1	30.86 €
46	M8 x 65mm	124-7277	32.25 €	1	32.25 €
35	M4 Nut	189-579	7.28 €	1	7.28 €
24	M3 Nut	560-293	6.17 €	1	6.17 €
33	M4 locknut	524-304	5.68 €	1	5.68 €
41	M5 locknut	524-310	6.34 €	1	6.34 €
45	M8 locknut	521-951	25.47 €	1	25.47 €
75	Ventilateur axial ARX 24 V c.c., 61m³/h,	787-8948	14.42 €	1	14.42 €
76	Ventilateur axial ARX 24 V c.c., 61m³/h,	299-1504	23.50 €	1	23.50 €
77	Câble d'alimentation, Noir, Connecteur C7, CEI vers CEE 7 / 16, Europlug, 250 V /	626-6688	3.53 €	1	3.53 €
78	Câble USB Type USB 2.0 Noir, USB A mâle vers USB B mâle, longueur 1.8m	815-8450	3.15 €	1	3.15 €
79	Courroie synchrone Contitech 755 5M 15	474-6514	10.41 €	1	10.41 €
			Total H.T.		455.47 €
			remise		0.00 €
			Total HT remisé		455.47 €
délais de paiement : 30 jours fin de mois			T.V.A.		91.09 €
			TOTAL T.T.C.		546.56 €

Figure 29 – Purchase order

The clamp

We decided to keep the original clamp given with the original CAD of the robot, but in a first time we also decided to consider the case that this clamp isn't powerful enough to carry a piece with a maximum load of 1kg. To do so, we also worked on another type of clamp, to have an emergency solution, with a rack-pinion mechanism.

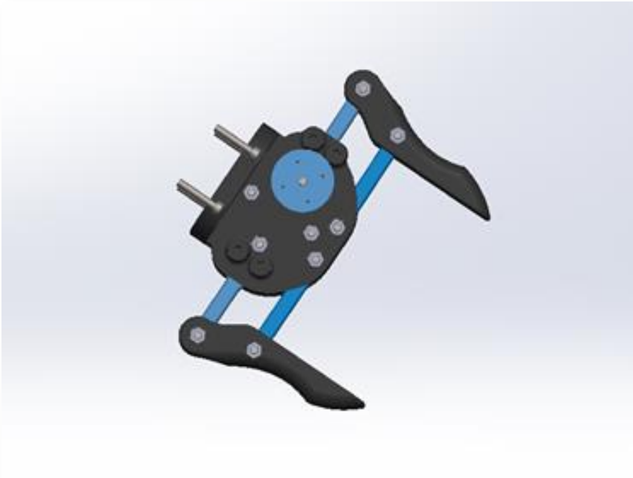


Figure 30 - Original clamp of the robot

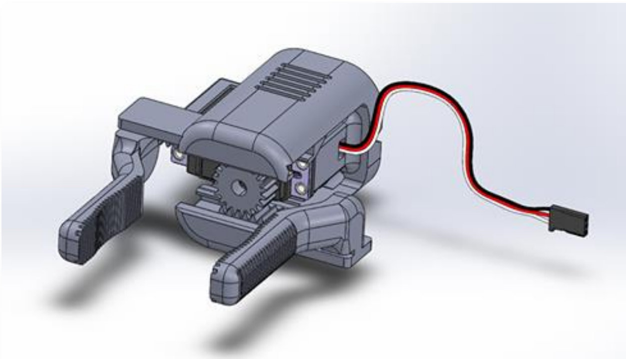


Figure 31 - The other solution of the clamp

After a meeting with our technical expert, we concluded that the best solution to respect the specifications was to put two paired clamps, that will work together. Each of them is powered by its own motor. This solution was for us the best because we didn't need to create a new clamp, that is able to carry the load, we knew that this one was already functioning, and we already had the CAD of the existing clamp so it was easy to modify the assembly to obtain our solution. We only had to create the support piece, on which we will set the two clamps. We made this piece on Solidworks and then we printed it, and we succeed to set the two clamps on it.

Figure 32 - Assembly of 2 original clamps

Driver Box

We decided to create a driver box in order to store our 6 drivers that will command our motors. We had to consider that the drivers are heating a lot during their use, and they will be connected to many other devices. We added a place for a fan to refresh the air into the box, and we placed on each side of the box a hole to allow the input and output cables to be connected to the drivers.

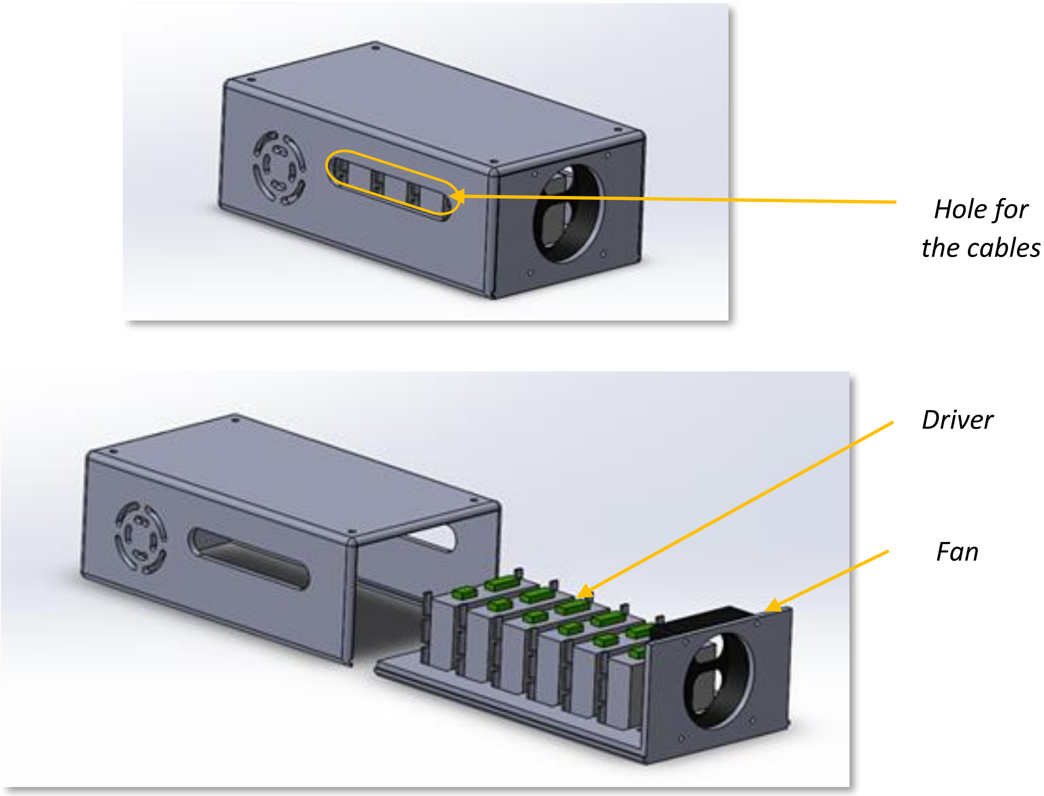


Figure 33 – Driver box

We designed the box with the idea that we will place it under the workstation, set with screws. To open it, the user has to pull the drawer, on which are placed the drivers. We also respected the constraint about the size of the box, because we decided to print it, we had to choose a length under the 300 mm of the largest 3D printer available at ECAM.

2. Assembly

The assembly part is the most important and the one that took us the most time. Before the quarantine period, we were able to print all the parts that make up the robot except the second part of the gripper.

We divided up the tasks so that some people started to assemble the parts in the order of the instructions, others cleaned some parts which had printing defects. Indeed, we had to make all the parts possible to assemble because we could not afford to leave parts with badly sized holes or filaments that could have prevented the rotation of the nuts for example.

Concerning the assembly, it was well advanced. The assembly between each part was not completely done.

Tasks	% CONSUMMATION	NOTES
Part 1	100%	
Part 2	100%	
Part 3	100%	
Part 4	50%	
Assembly	83%	

Total assembly progress	86,67%

Figure 34 - Assembly advancement

We started with the base: it is the simplest to assemble and we needed it as soon as possible considering that the whole assembly rests on this base.

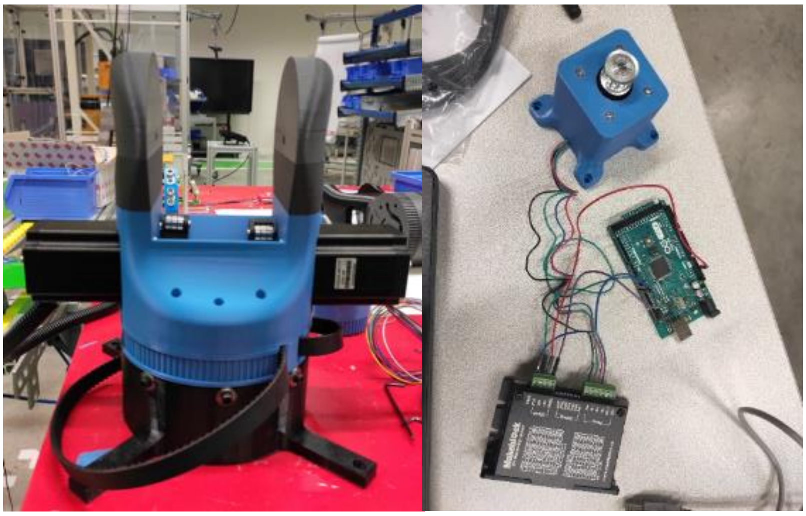


Figure 35 and 36 - Robot base and driver&motor

Tests on the engine were also carried out. Indeed, a big part of the assembly was also to test all the motors and motor brains (especially those of the pliers) to see if they worked well and if we could use them and also to test all the drivers.

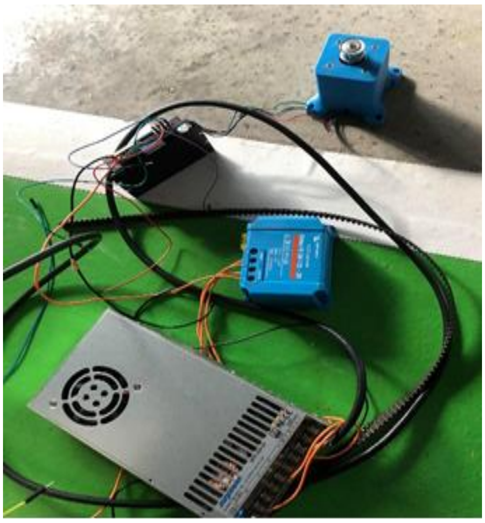


Figure 37 - Engine with driver

Once the base was finished, we started to assemble the other parts each on their own side, adding the motors as we can see on the picture above.

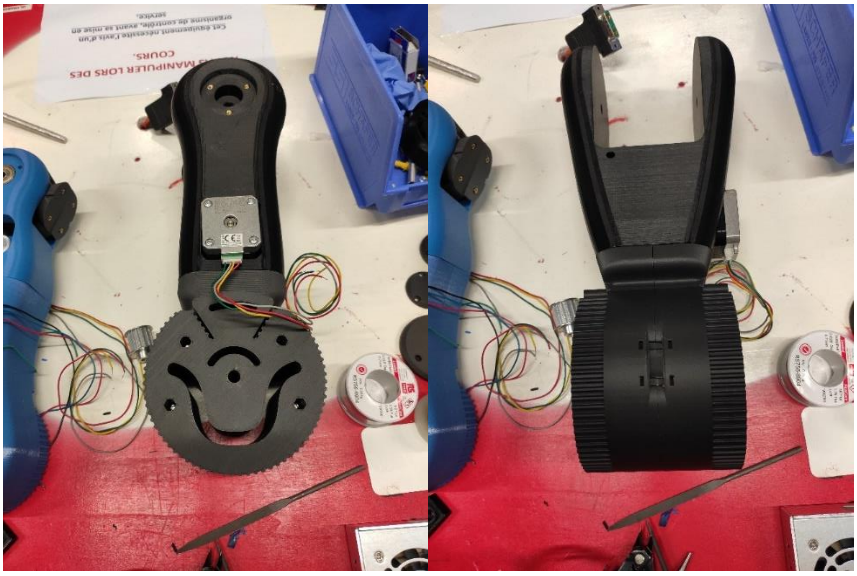


Figure 38 - Assembly of part 2

We were also thinking about the visual aspect of our robot in parallel of the assembly. We did not want the cables to be visible from all sides.

Figure 39 - Part of the robot with engine

Finally, due to the many problems we encountered with the 3D printer, we managed to almost completely assemble the robot just before the COVID19 problem we are still encountering today. Here above is the last picture we could take:

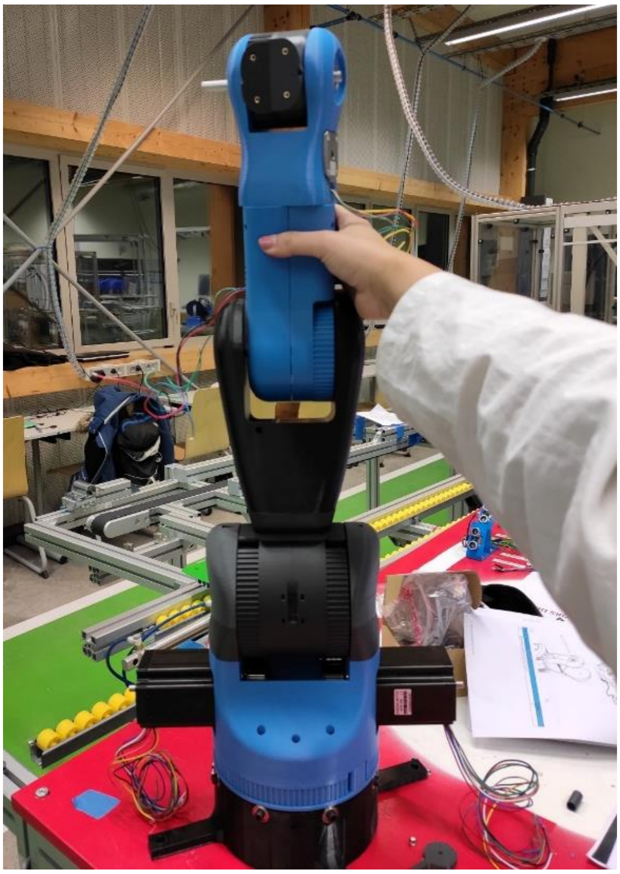


Figure 40 – Assembly of every parts

3. Wiring

We made some wiring diagrams to simplify the connection step when it will be done.

Driver – motor – Arduino card connection:

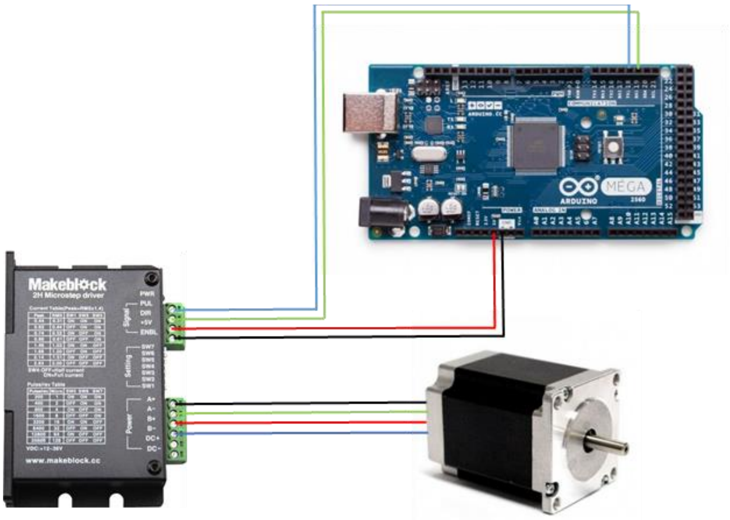


Figure 41 – Driver-motor-Arduino connection

Driver - power supply connection:

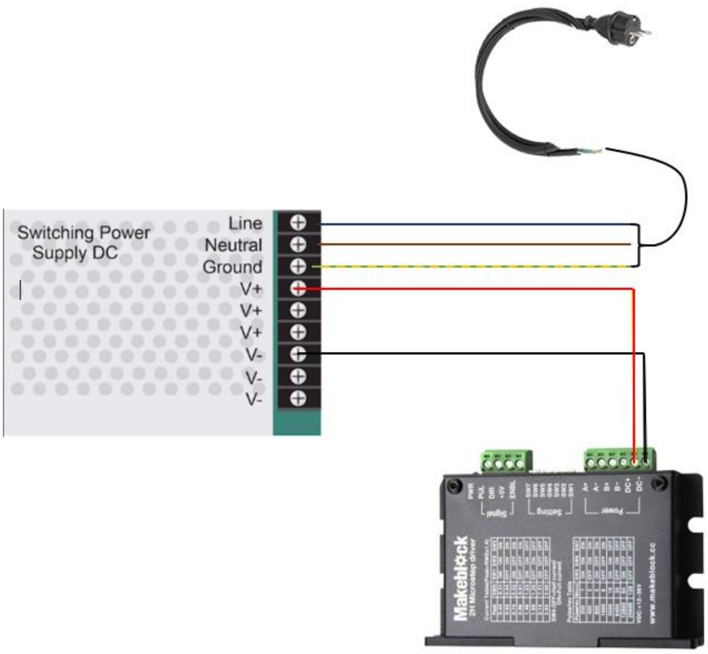


Figure 42 – Driver-power supply connection

4. Programming

The programming part is divided in three sub-parts:

- The sensors programming
- The robot movement program
- The LEDs of the control panel

This part is important because it is thanks to this code that when someone crosses the safety barrier that we are going to put in place, the robot will stop directly in emergency.

The difficulty is to succeed in coding the sensors so that they detect anything within the safety radius that we have set up and then to link it to the robot. The first step is to make the entire electrical system stop when the security barrier is franchised.

We contacted senior students to help us understand and code the sensors. We have this beginning of code:

```
#include <std_msgs/String.h>

void changingLEDState(const std_msgs::String& ledOrder){
  LEDGV = ledOrder.data[0];
  LEDGR = ledOrder.data[1];
  LEDPV = ledOrder.data[2];
  LEDPR = ledOrder.data[3];

  if(LEDGV.equals("1")){
    digitalWrite(pinLEDGV, HIGH);
  } else if(LEDGV.equals("0")){
    digitalWrite(pinLEDGV, LOW);
  }

  if(LEDGR.equals("1")){
    digitalWrite(pinLEDGR, HIGH);
  } else if(LEDGR.equals("0")){
    digitalWrite(pinLEDGR, LOW);
  }
```

Figure 43 – First part of the code

```
  if(LEDPV.equals("1")){
    digitalWrite(pinLEDPV, HIGH);
  } else if(LEDPV.equals("0")){
    digitalWrite(pinLEDPV, LOW);
  }

  if(LEDPR.equals("1")){
    digitalWrite(pinLEDPR, HIGH);
  } else if(LEDPR.equals("0")){
    digitalWrite(pinLEDPR, LOW);
  }
}

void setup() {
  pinMode(pinLEDGV, OUTPUT);
  pinMode(pinLEDGR, OUTPUT);
  pinMode(pinLEDPV, OUTPUT);
```

Figure 44 – Second part of the code

The actual code enables the signal LEDs when a sensor is activated.

- The robot movement program

This part is led thanks to a recommended firmware which is available on the GitHub of the robot.

With the software Pronterface normally used to move the head of a 3D printer, we will be able to perform movement tests when the robot will be completely assembled. This software is compatible with Arduino INO, enabling us to code the whole process directly on the card.

The fact that it runs on Arduino enables us to use a Raspberry Pi 3 to run the code and connect it to the touchscreen we ordered: the Raspad from Sunfounder.

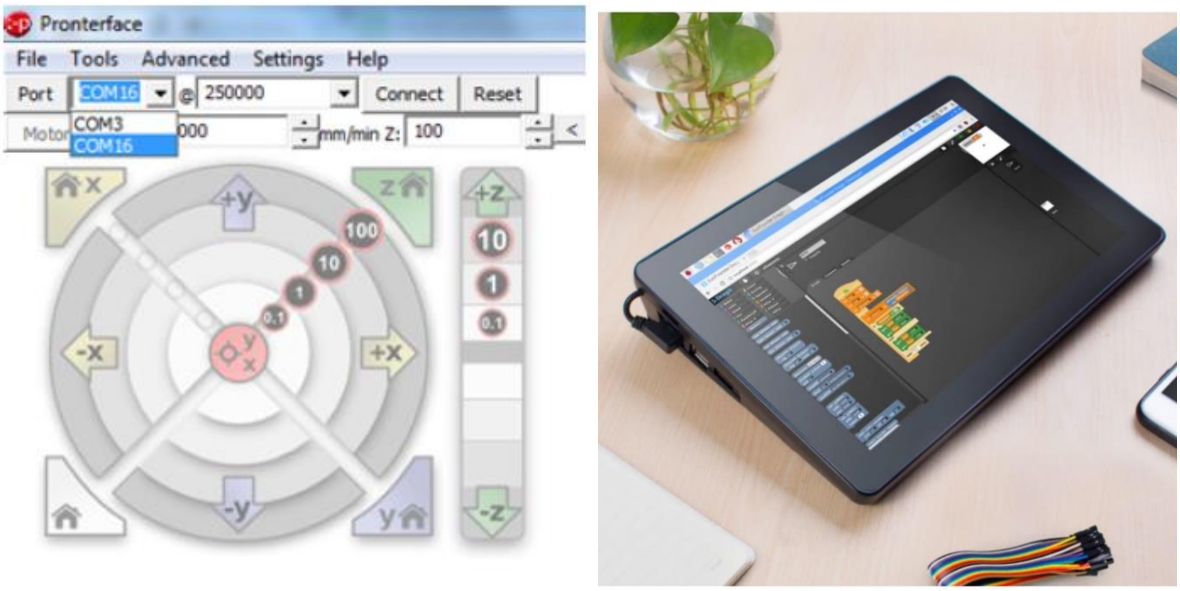


Figure 45 – Pronterface

Features of the touchscreen:

- 100% compatible with the Raspberry Pi 3B+
- A mobile workstation: lightweight frame, built-in battery, 10” touchscreen, and Audio In One
- Graphical User Interface Software available

Ports and buttons of the Raspad touchscreen:

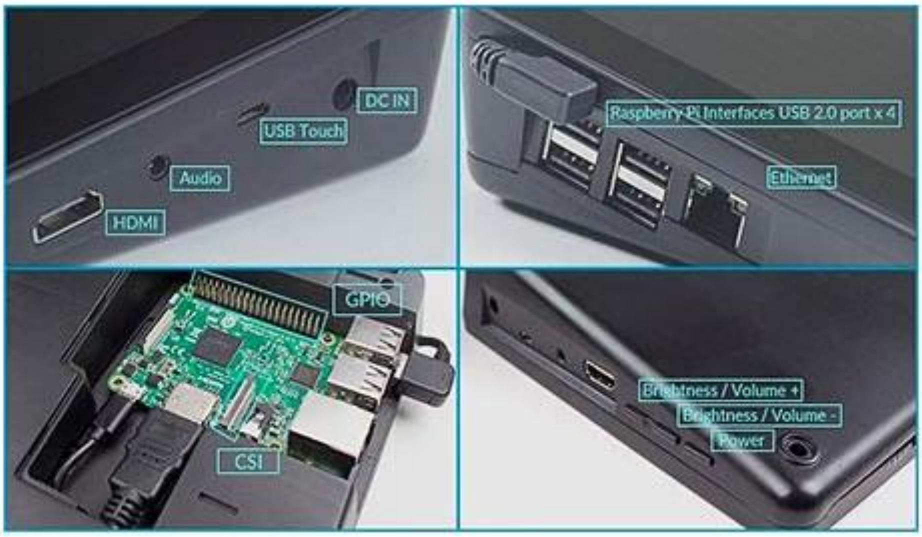


Figure 46 – Ports and buttons of the touchscreen

5. Workspace management

Regarding the workspace management, we first established a list of constraints and thought about the solutions we could provide.

First, let us remember the goal: we had to bring a piece from a conveyor going out of the Datron Neo machine to a carriage on the opposite side of the workstation.

Here are the constraints we had to respect:

- The arm must reach the conveyor
- The arm must reach the carriage
- The control panel must be accessible
- The robot must not collide with anything (environment, user…)
- The power supply must not be visible
- A security perimeter must be established around the robot

After measuring the total length of the arm, we were able to find a solution. Indeed, the robot arm length is around 44cm so the circle of action of the robot is an 88cm diameter zone. Knowing that, we found that the actual workstation disposition was not adapted. We decided to cut the table to integrate the conveyor. Indeed, The conveyor measures approximately 50 cm wide.

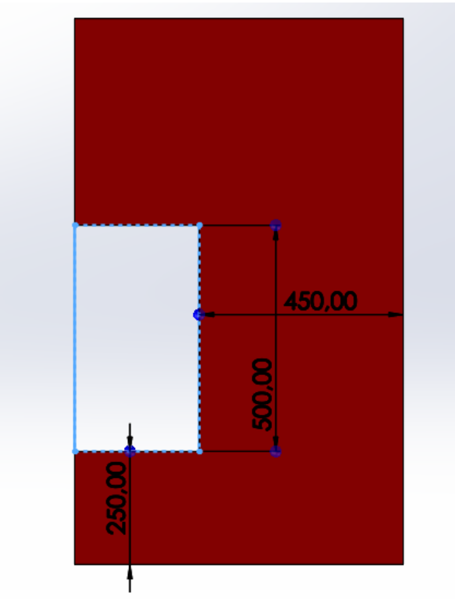


Figure 47 – Workstation dimensions

Thanks to this solution the robot arm can reach the conveyor and the carriage will have a large enough worstation to determine a safety perimeter. Moreover, this solution allows to keep the panel control box since the wide of the table is not modified.

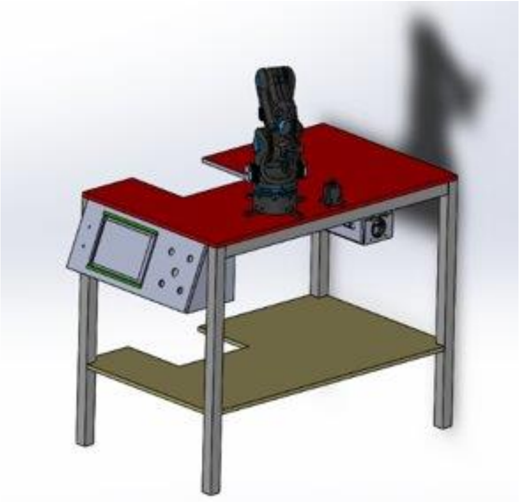


Figure 48 – Workstation

To avoid obstruction of the robot movement and to clear the workspace, we placed the power supply and the drivers' box under the table (Black box on the picture below).

Figure 49 – Under the workstation

6. Budget management

To carry out this project, we had 2500 euros available. We quickly reached this amount, due to the various orders made (Conrad, LDLC). On top of that, we had to add the cost of our 3D prints. Regarding this point, we are not sure of the exact amount, so we approximated it to around 300 euros. We got the following results:

Budget Cobotic

	BUDGET	REAL	BALANCE
Total incomes	2 500,00 €	2 500,00 €	- €
Total expenditures	2 231,38 €	2 431,09 €	- 199,71 €

	BUDGET	REAL	MOINS/PLUS
INCOMES			
Available budget	2 500,00 €	2 500,00 €	- €
TOTAL	**2 500,00 €**	**2 500,00 €**	
EXPENDITURES	BUDGET	REAL	
Order RS 1	547,00 €	546,56 €	- 0,44 €
Order RS 2	300,00 €	300,19 €	0,19 €
Order RS 3	83,71 €	83,71 €	- €
Order Conrad 1	509,18 €	509,18 €	- €
Order Conrad 2	324,46 €	324,46 €	- €
Order Conrad 3	101,14 €	101,14 €	
Order Conrad 4	65,89 €	65,89 €	
Order LDLC	200,00 €	199,96 €	- 0,04 €
3D printing	300,00 €	300,00 €	- €
TOTAL	2 231,38 €	2 431,09 €	

Figure 50 – Budget management

We spent a few more than what we had estimated: 2431.09 € instead of 2231.38 €. However, we did not spend more than 2500 € and are therefore in the budget.

7. Maintenance plan

We realized a Failure Mode and Effects Analysis (FMEA) and Failure Modes, Effects and Criticality Analysis (FMECA) are methodologies designed to identify potential failure modes for a product or process, to assess the risk associated with those failure modes, to rank the issues in terms of importance and to identify and carry out corrective actions to address the most serious concerns.

You can find our FMECA in annex 12.

V. Evolution of our project

For the pursuit of the project, much remains to be done. Indeed, a big part has been realized but the robot is not functioning for the moment.

1. Assembly instructions

To have every detail on the assembly, it is strongly recommended to check the User guide of the robot. You will find a Bill of Materials of the whole system, the assembly guide in case you need to disassemble a part, the wiring guide, and some programming advices to pilot the robot.

We strongly inspired from the guide of *Toglefritz* on the forum "*Instructables*".

Source : https://www.instructables.com/id/Build-a-Giant-3D-Printed-Robot-Arm/

2. Our solution for the clamp

We wanted to make a double clamp to have a better holding of the carried part.

The first part of the part is printed and mounted (unfortunately we do not have a picture) but the second part could not be printed.

Here is the 3D model of the clamp model:

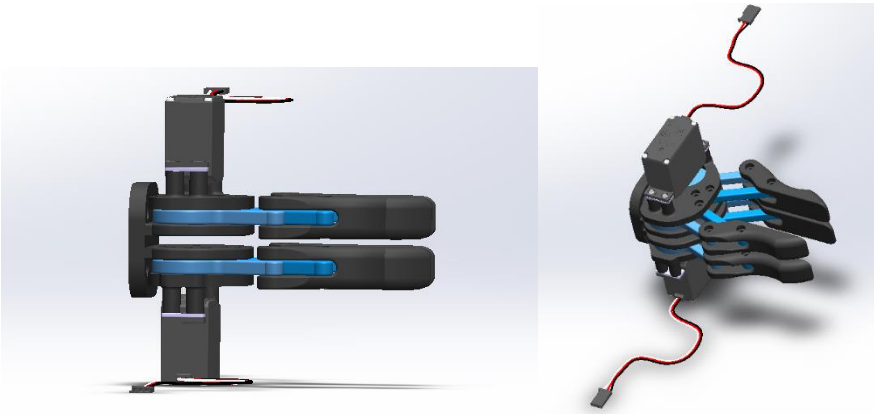


Figure 51 - 3D model of the clamp

This solution has not been tested yet and therefore may certainly be modified in the future.

3. Wiring

Indeed, once the robot is assembled, we must take care of the wiring part.

We must rearrange the actual sensor wiring system, taking care of keeping the workstation cleared, to avoid any problems during the robot displacements. Moreover, it is always pleasant to have something aesthetically correct at the end.

The wires will be protected with rubber sheaths to simplify the whole wiring. We want to divide the two wiring parts which are the engine wiring and the sensors wiring in two boxes: the first one will be fixed under the workstation in order to hide it from the user and the second one is hidden in the yellow control panel.

4. Programming

For the future of the robot, we can consider many points of views.

- Since the robot's motors are directly piloted from an Arduino MEGA 2650, it is possible to test and program the robot **from a PC** running on Windows OS using the ARCS software. Luckily, the development team released a Raspberry Pi adapted version! It is therefore possible to implement it on our tablet.

  The principle is easy: connect the Arduino board to the PC or the Raspberry Pi with a USB cable so that it is linked to the software and then begin to work on it. The owner of this application has uploaded some video tutorials to explain how to use entirely the program. It is initially made for his own robot, but he has expended the possibilities making it adapted to other robots using Arduino. If you go check his online tutorials, you will see that he realizes some tests on the Moveo robot from BCN3D, which is the robot we based all our work.

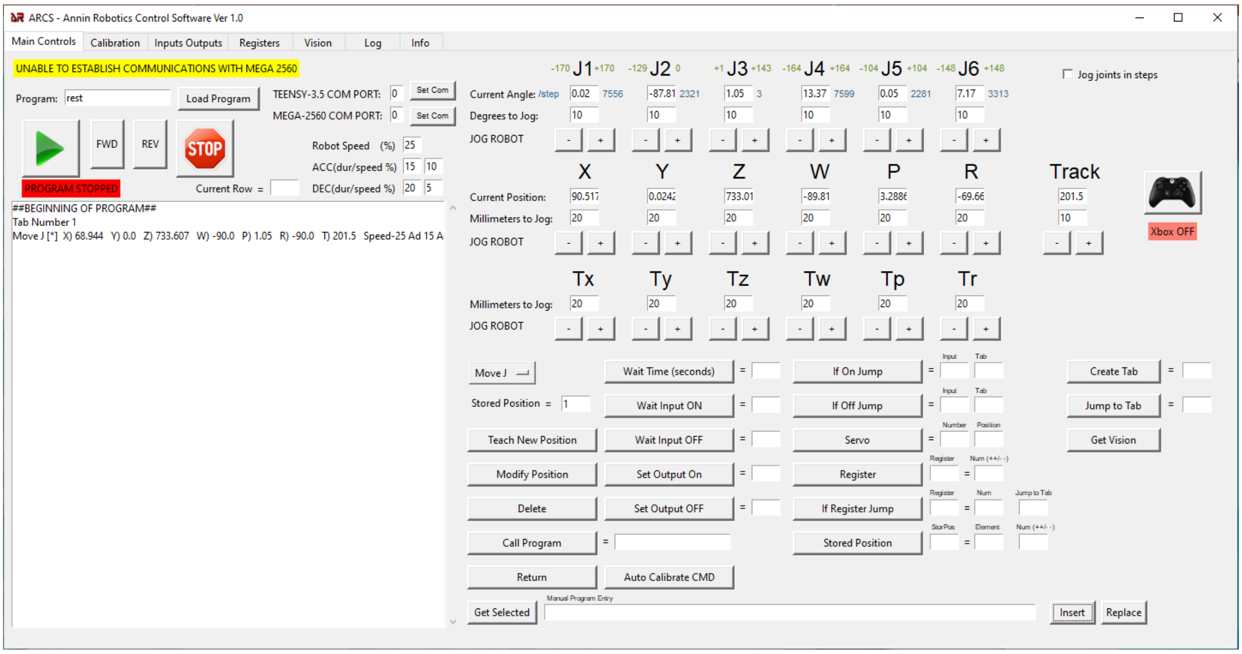


Figure 52 – Arcs software to pilot the robot

An Arduino program is available with the software, it is available on the GitHub of the project.

- Another solution would be to create then the same type of application for Raspbian. A simple app would be a clean panel where you can change the value of the angle direction of each motor with a simple + and – button. The clamp would be able to be closed or opened with 2 buttons and positions could be saved to create then an automatized path. We added a ZERO position button for each articulation. A homing rest position must be configured in order that the robot does not collapse when the power supply is not switched on. Moreover, a speed control command of the motors can be added as it is present in the ARCS software.

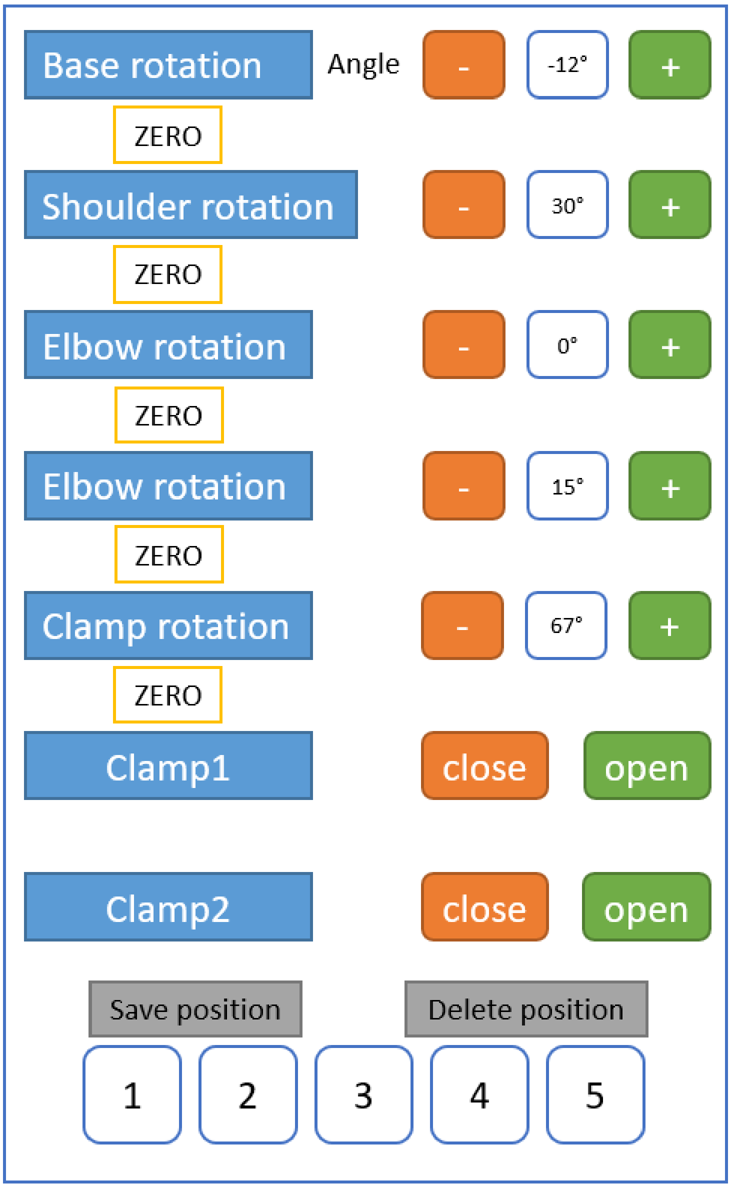


Figure 53 – App design for the robot

- The use of the **Marlin firmware**, generally used to program 3D Printers, could also be a solution. It works with Gcode with over 150 arduino commands. The thing with this method is that it isnt optimized for a 6-axis robot and would not be appropriated in our case.

- On the project of last year, the team worked with ROS. After some researches about a potential work on the moveo using ROS, we found this GitHub project: https://github.com/jesseweisberg/moveo_ros
  On this page, the owner explains step by step how to proceed with ROS and program the robot entirely.

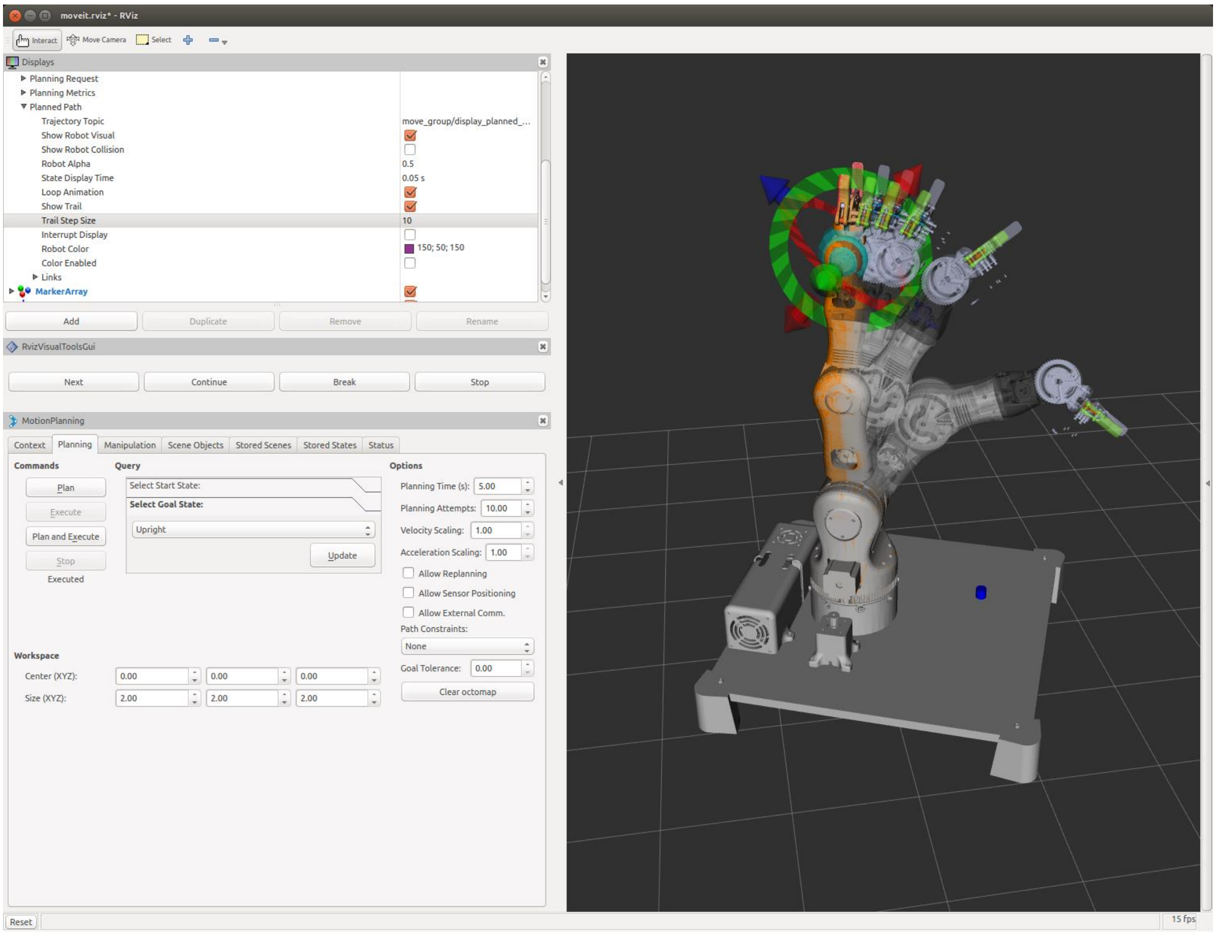


Figure 54 – Robot programming with ROS

The limit with ROS is that we cannot link the robot movements with the sensors' system if we want to work on it in the future.

Intentionally left blank.

Conclusion

This project will have been the longest and multidisciplinary project we have had so far. Indeed, this project was a good exercise to apply what has been studied during the ECAM courses. Each member of the group had the opportunity to work on many different fields and was not stuck to a unique type of task.
Staying focused and keeping a certain cohesion in the team throughout the year was difficult, but we were able to bounce back when we had difficulties in order to satisfy our customer.

At the beginning of the project, since we had to completely change the robot, we concentrated most of our time trying to find a robot that we could buy ready-made. Each robot we found on the internet did not meet all of our client's requirements: either the load that the robot could lift was too low, the price too high, or we found nothing on the ECAM partner sites. That is why we lost precious time during the first part of this project.

Otherwise, we took a major turn at the end of the year when we found our solution: the Moveo robot. The good about this is that it is fully open sourced, so we were able to easily modify everything we wanted to change. Thanks to the GitHub platform, we were able to get all the information we needed to assemble it. In fact, 77% of our initial objectives have been achieved and 23% are still unfinished. A comparative table has been created to sum up which goals were achieved, and which were not (cf. Goals analysis below). These 23% correspond to the programming part on which we have not been able to spend a lot of time. We dropped the security part to devote our time to the creation and assembly of the robot.

This project has brought us a great deal. Indeed, between the problems encountered within the team management, but also on another scale with the problems related to the health crisis, we will learn from it. We also lost a member of our group in the middle of the project. Group cohesion is a very important thing to carry out a project of this extent. We came out of it having learnt a lot of things that will be useful for our future business, and we also managed to create a close-knit group and a great cohesion between us.

GOALS ANALYSIS		
ID	GOALS	Achieved?
1	The robot has to be controlled by the tablet located on the station	x
2	We want to be able to control the speed rate	x
3	We want to be able to control the clamp pressure	x
4	We want to be able to provide a BOM for all the components	x
5	We want a 3D model of our robot in Solidworks	x
6	We will integrate the robot in the workstation	x
7	The final program will include a test part to fix the eventual issues	
8	The robot must be able to detect the piece	
9	The robot must be able to access the conveyor and the cart on the two sides	x
10	The robot will be entirely electronically automatized	
11	We want an intuitive control panel: it must be simple to understand and easy to use	x
12	The robot must be eco-friendly in the conception process	x
13	The robot must be a 6-axis robot	x
14	The customer wants a completely new robot	x
15	The colour of the robot: blue and white with the logo ECAM on the robot	x
16	The robot must have a clamp in order to take the components or the components could reach the robot in a surface (must be chosen)	x
17	The robot must be located on a table	x
18	We must be able to control the speed rate of the robot	
19	We must have a tablet in order to begin the program, to stop and switch to manual mode	x
20	We will have to code entirely the robot's displacement with software	
21	The robot must respect the green plan	x
22	The workstation will be secured, and the user will be prevented of all injuries	
23	The robot must be able to lift an aluminium component of 1kg with a maximal dimension of 150x150x150 mm	x
TOTAL	23	17

Figure 55 – Goal analysis

APPENDIXES

<u>Annex 1</u>: Product Backlog

Product Backlog

In green : completed / In Yellow: not completed / In Red: Cancelled(Covid19)

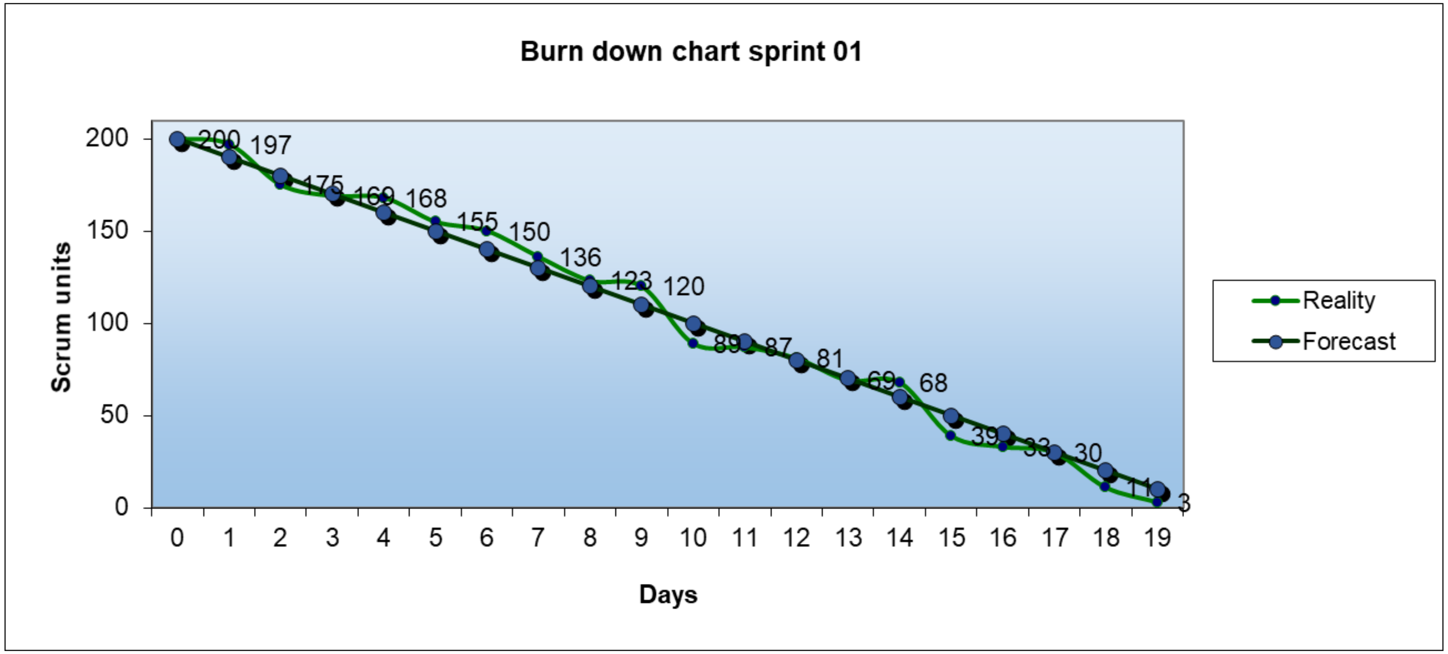
Edited by: SCHEER Simon **Last edited:** 30/03/2020 15:28

ID	Task	User story	Assigned to (Members)	Story points (1 to 5)	Domain	Priority	Date of beginning	Date of ending	Statut	Reference document	Plannified in Sprint
1	Analyse the subject	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Team	5	Need's analysis	High	09/23/2019	10/20/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	1
2	Appointment with the customer (to know the requirements)	As a customer, I want the robot to fully meet my expectations	Giraud	2	Need's analysis	High	09/18/2019	09/18/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
3	Define the requirements	As a customer, I want the robot to fully meet my expectations	Benchama	4	Need's analysis	High	09/23/2019	10/14/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
4	Define the goals	As a customer, I want the robot to fully meet my expectations	Ghigini	3	Need's analysis	High	09/23/2019	10/14/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
5	Analyse the risks	As a customer, I want the robot the robot arm to not hurt the worker	Rajot Schillio	4 2	Security	Medium	09/23/2019	10/14/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
6	Define a green plan	As a customer, I want the robot to have a green dimension	Ghigini Giraud	2 2	Need's analysis	Low	10/19/2019	10/21/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
7	Write the specifications	As a customer, I want the robot to fully meet my expectations	Giraud Scheer	3 3	Need's analysis	High	09/30/2019	10/20/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
8	Propose solutions	As a customer, I want the robot to fully meet my expectations	Scheer	3	Need's analysis	High	10/14/2019	10/20/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
9	Estimate the budget	As a customer, I want the robot to fully meet my expectations	Schillio Giraud	3 2	Need's analysis	High	10/14/2019	10/20/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
10	Study the robot	As a customer, I want to have the right documentation	Team	5	Need's analysis	High	10/21/2019	10/28/2019	100%	T715-COBOTIC/Ebp4ViYyXStPk	
11	Stocktake in order to know what we have and what we need	As a customer, I want to have the right documentation	Ghigini Rajot	4 5	Logistic	High	11/04/2019	11/18/2019	100%	https://ecamstrasbourg.sharepo	2
12	Test the components	As a customer, I want to have the right documentation	Benchama Scheer	5 3	Logistic	High	11/04/2019	11/18/2019	100%	T715-COBOTIC/EZ3GBjdQkmN	
13	Watch for a new robot	As a customer, I want a new 6-axis robot that brings a piece from point A to point B	Team	5	Need's analysis	High	11/04/2019	12/02/2019	100%	https://ecamstrasbourg.sharepo	
14	Make the wiring diagram of the available system	As an operator, I want a practical and efficient coding environment	Scheer	2	Electronic	High	11/11/2019	11/26/2019	100%	https://prezi.com/view/AZ5kfMTf	
15	Watch for a new screen	As a customer, I want to be able to control the robot from a tablet	Giraud Schillio	3 4	Need's analysis	Low	11/12/2019	11/17/2019	100%	prezi.com/view/AZ5kfMTfSm8CFt	
16	Study the file for 3D printing	As an operator, I want a practical and efficient coding environment	Ghigini Scheer	4 3	Mechanical	Medium	12/04/2019	12/16/2019	100%	/	3
17	Complete the exploded view	As a customer, I want to have the right documentation	Ghigini	5	Practical	High	12/16/2019	01/06/2020	100%	/	
18	Study the motors	As a customer, I want to have the right documentation	Bertelli	5	Mechanical	High	12/16/2019		100%	/	
19	Do the motor's calculation	As a customer, I want to have the right documentation	Bertelli	5	Mechanical	High	12/16/2019		100%	/	
20	Estimate the budget	As a customer, I want the robot to fully meet my expectations	Scheer	4	Need's analysis	High	12/16/2019	02/06/2020	100%	https://ecamstrasbourg.sharepo	
21	Fill the purchase sheet	As a customer, I want the robot to fully meet my expectations	Scheer	4	Logistic	High	12/16/2019	01/20/2020	100%	/	
22	Print the part 1 of the robot	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Giraud	5	Practical	High	12/16/2019	04/06/2020	100%		
23	Assemble the part 1 of the robot	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Giraud	2	Practical	High	01/13/2020	01/20/2020	100%		
24	Design a prototype for the control pannel	As an operator, I want a practical and efficient coding environment	Scheer	3	Programming	Medium	01/13/2020		100%	/	
25	Install the Raspberry Pi with the new screen	As an operator, I want an ergonomic workplace	Schillio	4	Electronic	High	01/20/2020		100%	/	4
26	Install OS on Raspberry Pi	As a creator, I want my programming system to be user-friendly	Scheer	1	Programming	Medium	12/16/2019	12/17/2019	100%	/	
27	Install CPROG and ROS	As a creator, I want my programming system to be user-friendly	Scheer	2	Programming	Medium	12/16/2019		100%	/	
28	Install ARCS.exe	As a creator, I want my programming system to be user-friendly	Scheer	3	Programming	Medium	12/16/2019		100%	/	
29	Print the part 2 of the robot	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Giraud	5	Practical	Medium	12/16/2019		100%		
30	Create a program to control the robot via the raspberry pi	As a creator, I want my programming system to be user-friendly	Scheer	5	Programming	High	02/01/2020	03/28/2020	100%		
31	Cable the motors to the drivers	As an operator, I want a practical and efficient coding environment	Giraud	2	Electronic	High	02/10/2020	02/13/2020	0%		
32	Cable the drivers to the arduino cards	As an operator, I want a practical and efficient coding environment	Giraud	2	Practical	High	02/10/2020		0%		
33	Create a sensors system for the security	As an operator, I want a practical and efficient coding environment	Ghigini	5	Electronic	High	02/01/2020	03/20/2020	0%	/	
34	Link the sensors system to the arduino	As an operator, I want a practical and efficient coding environment	Giraud	2	Electronic	High	02/13/2020	02/20/2020	0%	/	

35	Print the part 3	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Giraud	5	Practical	High	01/06/2020	01/14/2020	100%		
36	Print the part 4	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Scheer	5	Practical	High	01/10/2020	01/20/2020	100%		
37	Assemble part 2	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Ghigini	5	Practical	High	02/06/2020	02/15/2020	100%		
38	Assemble part 3	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Ghigini	5	Practical	High	02/06/2020	02/22/2020	100%		
39	Assemble part 4	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Bertelli	5	Practical	High	02/06/2020	02/29/2020	100%		
40	Create a coverbox for the drivers in solidworks	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Rajot	4	Mechanical	Medium	02/07/2020	02/10/2020	100%		
41	Make the system stop when the sensor bareer is crossed	As an operator, I want to be safe when I work with the robot	X	5	Programming	Low	02/10/2020		0%		5
42	Create a wiring plan of the sensors	As an operator, I want to be able to cable and modify easily when it's needed	Giraud	2	Electronic	Medium	01/27/2020	02/03/202	100%		
43	Create a wiring plan of the motors	As an operator, I want to be able to cable and modify easily when it's needed	Scheer	2	Electronic	Medium	02/06/2020	02/10/2020	100%		
44	Rectify and clean each printed piece	As a customer, I want my robot to work properly whithout any issue	Schillio	5	Practical	High	01/27/2020	02/13/2020	100%		
45	Print the drivers' box	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Rajot	2	Practical	Medium	02/11/2020	03/01/2020	100%		
46	Assemble the drivers' box	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Bertelli	2	Practical	Medium	02/13/2020	03/09/2020	100%		
47	Test phase 1	As a user, I want my robot to work perfectly	X	3	Programming	High	03/01/2020	03/10/2020	0%		
48	Test phase 2	As a user, I want my robot to work perfectly	X	4	Programming	High	03/10/2020	03/20/2020	0%		
49	Test phase 3	As a user, I want my robot to work perfectly	X	3	Programming	High	03/20/2020	03/30/2020	0%		
50	Create a 2nd version of the clamp on solidworks	As a user, I want to be sure that my robot can hold every pieces	Scheer	2	Practical	High	02/24/2020	03/10/2020	100%		
51	Print the clamp v2	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Scheer	2	Practical	High	03/09/2020	03/15/2020	100%		
52	Assemble the clamp v2	As a customer, I want a 6-axis robot that brings a piece from point A to point B	X	2	Practical	Medium	03/09/2020	03/20/2020	0%		
53	Modelize the screen support in solidworks	As a user, I want to be able to access the control panel easily and retire it when I wa	Rajot	4	Mechanical	Medium	02/24/2020	03/01/2020	100%		
54	Print the screen support	As a customer, I want a 6-axis robot that brings a piece from point A to point B	Bertelli	2	Practical	Low	03/02/2020	03/05/2020	100%		
55	Test the power supply	As a user, I want to be safe when using the system	Scheer	2	Practical	Medium	03/09/2020	03/09/2020	100%		6
56	Program a homing position	As a user, I want my robot to work perfectly	X	2	Programming	Low	x	03/30/2020	0%		
57	Define the initial position of the piece	As a user, I want my robot to work perfectly	X	4	Programming	High	x	03/30/2020	0%		
58	Define the final position of the piece	As a user, I want my robot to work perfectly	X	4	Programming	High	x	03/30/2020	0%		
59	Test the softwares we already have	As a user, I want my robot to work perfectly	Scheer	2	Programming	Medium	03/02/2020	03/02/2020	100%		
60	Write the final report	As a customer, I want the robot to fully meet my expectations	Giraud	5	Report	High	03/23/2020	04/06/2020	100%		
61	Report's part: write assembly instructions	As a customer, I want the robot to fully meet my expectations	Scheer	5	Report	High	03/23/2020	04/05/2020	100%		
62	Report's part: explain what we've done	As a customer, I want the robot to fully meet my expectations	Team	5	Report	High	03/23/2020	04/05/2020	100%		
63	Report's part: explain what remains to be done	As a customer, I want the robot to fully meet my expectations	Team	5	Report	High	03/23/2020	04/05/2020	100%		

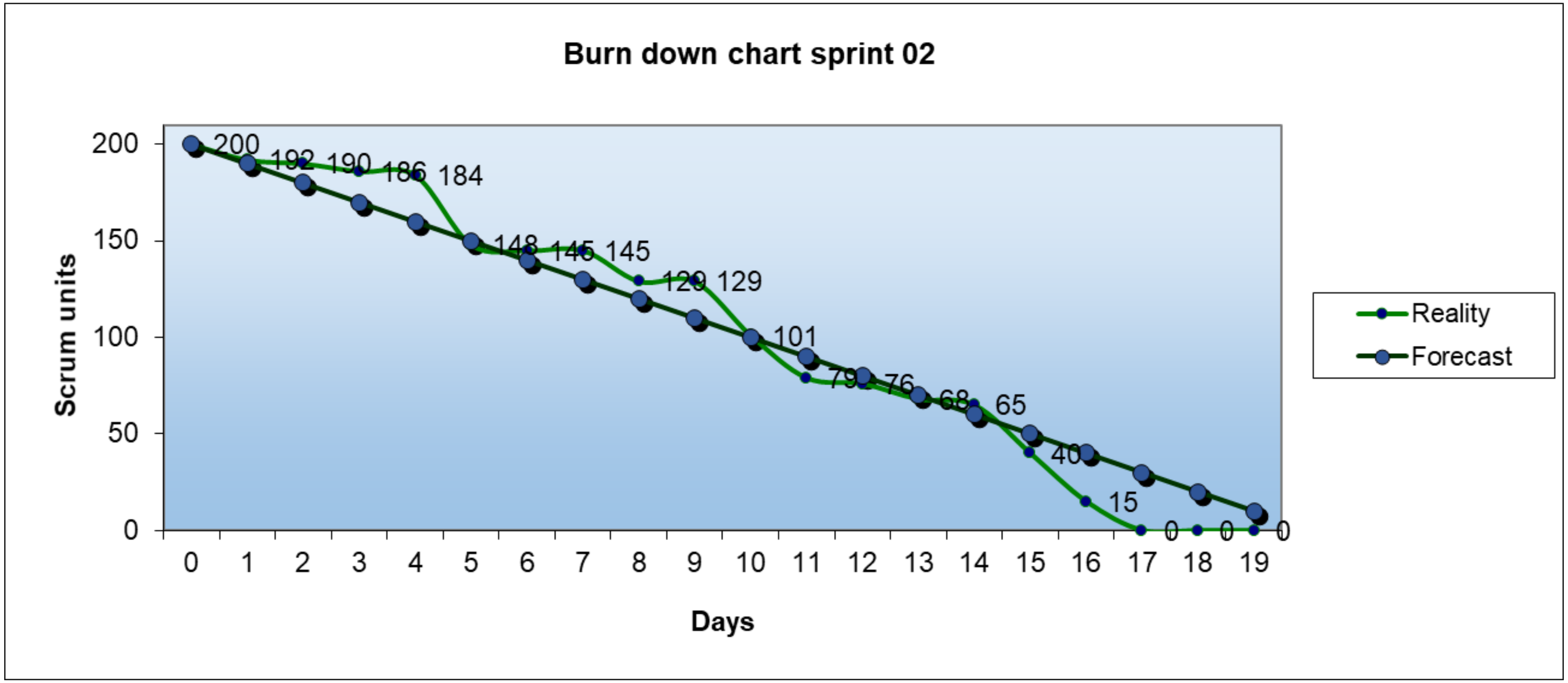
Annex 2: Sprint Backlog 1

ID	Short name	Value/Importance	Initial Estimate	23-Sep-19	24-Sep-19	25-Sep-19	26-Sep-19	27-Sep-19	30-Sep-19	1-Oct-19	2-Oct-19	3-Oct-19	4-Oct-19	7-Oct-19	8-Oct-19	9-Oct-19	10-Oct-19	11-Oct-19	14-Oct-19	15-Oct-19	16-Oct-19	17-Oct-19	18-Oct-19
1	Analyse the subject	0	**20**	20	18	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	0
2	Appointment with the customer (to know the requirements)	0	**20**	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Define the requirements	0	**20**	20	20	20	19	19	16	16	14	14	14	8	8	8	6	6	3	3	3	0	0
4	Define the goals	0	**20**	20	20	20	19	19	16	16	14	14	14	8	8	8	6	6	3	3	3	0	0
5	Analyse the risks	0	**20**	10	10	20	18	18	17	16	16	16	16	13	13	13	11	11	4	4	4	0	0
6	Define a green plan	0	**10**	20	20	10	10	10	10	10	10	10	10	10	10	10	10	10	8	6	4	2	0
7	Write the specifications	0	**30**	30	30	30	30	30	30	27	25	22	20	15	15	12	9	9	5	5	5	3	0
8	Propose solutions	0	**30**	30	30	30	30	30	25	25	23	20	20	10	10	10	9	9	5	5	5	3	0
9	Estimate the budget	0	**20**	20	20	20	20	20	20	20	15	10	10	10	10	9	8	8	4	2	2	0	0
10	Study the robot	0	**10**	10	9	9	8	8	8	8	8	7	7	7	6	5	5	5	4	3	3	3	3
			200	*200*	*197*	*175*	*169*	*168*	*155*	*150*	*136*	*123*	*120*	*89*	*87*	*81*	*69*	*68*	*39*	*33*	*30*	*11*	*3*
			Forecast	*200,0*	*190,0*	*180,0*	*170,0*	*160,0*	*150,0*	*140,0*	*130,0*	*120,0*	*110,0*	*100,0*	*90,0*	*80,0*	*70,0*	*60,0*	*50,0*	*40,0*	*30,0*	*20,0*	*10,0*



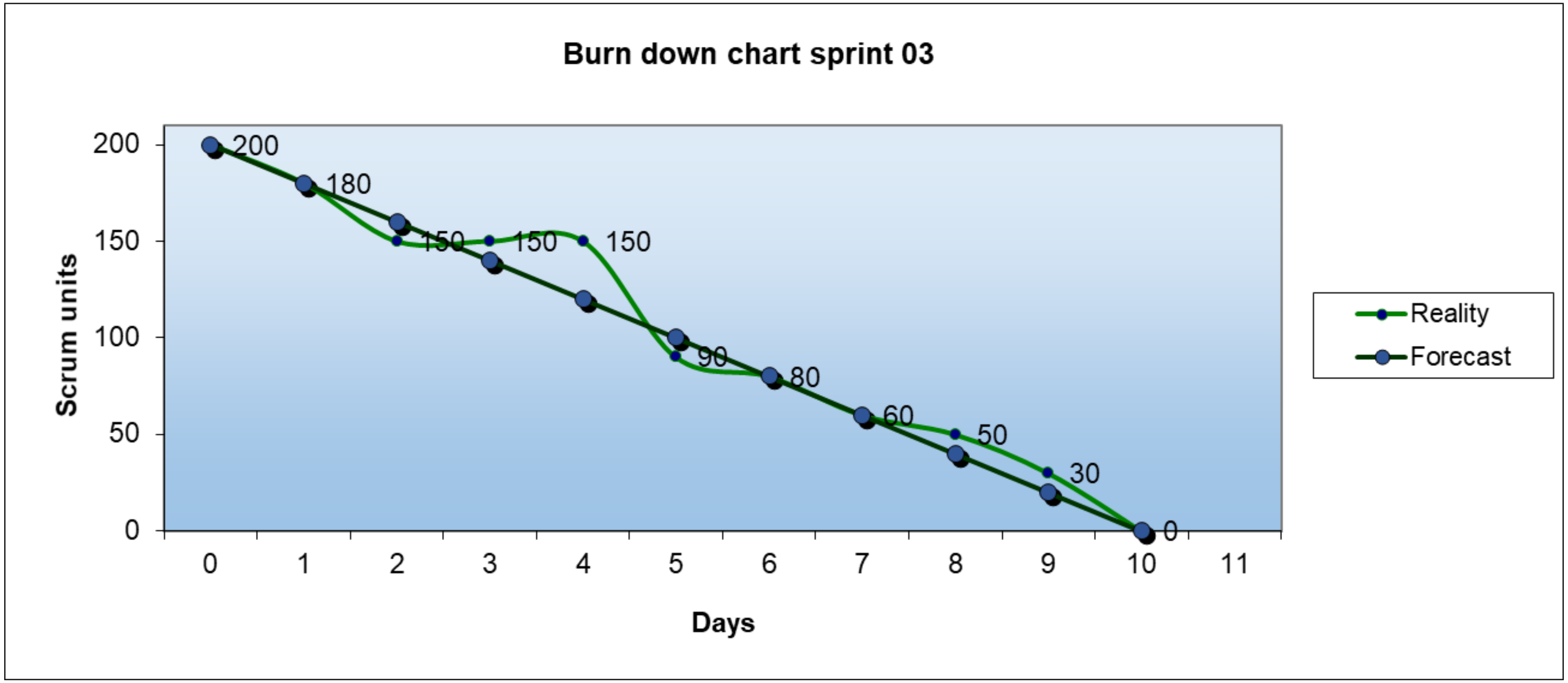
Annex 3: Sprint Backlog 2

ID	Short name	Value/Importance	Initial Estimate	4-Nov-19	5-Nov-19	6-Nov-19	7-Nov-19	8-Nov-19	11-Nov-19	12-Nov-19	13-Nov-19	14-Nov-19	15-Nov-19	18-Nov-19	19-Nov-19	20-Nov-19	21-Nov-19	22-Nov-19	25-Nov-19	26-Nov-19	27-Nov-19	28-Nov-19	29-Nov-19
11	Stocktake in order to know what we have and what we need	1	**40**	36	36	36	36	36	28	28	28	23	23	20	0	0	0	0	0	0	0	0	0
12	Design a prototype for the control pannel	0	**20**	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	10	0	0	0
13	Test the components	1	**40**	40	40	40	40	40	35	35	35	29	29	20	20	20	20	20	10	0	0	0	0
14	Watch for a new robot	1	**50**	50	46	44	40	40	38	38	38	36	36	25	23	20	18	15	7	5	0	0	0
15	Make the wiring diagram of the available system	0	**30**	30	30	30	30	28	27	24	24	21	21	16	16	16	10	10	3	0	0	0	0
16	Watch for a new screen	0	**20**	20	20	20	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			200	*200*	*192*	*190*	*186*	*184*	*148*	*145*	*145*	*129*	*129*	*101*	*79*	*76*	*68*	*65*	*40*	*15*	*0*	*0*	*0*
			Forecast	*200,0*	*190,0*	*180,0*	*170,0*	*160,0*	*150,0*	*140,0*	*130,0*	*120,0*	*110,0*	*100,0*	*90,0*	*80,0*	*70,0*	*60,0*	*50,0*	*40,0*	*30,0*	*20,0*	*10,0*



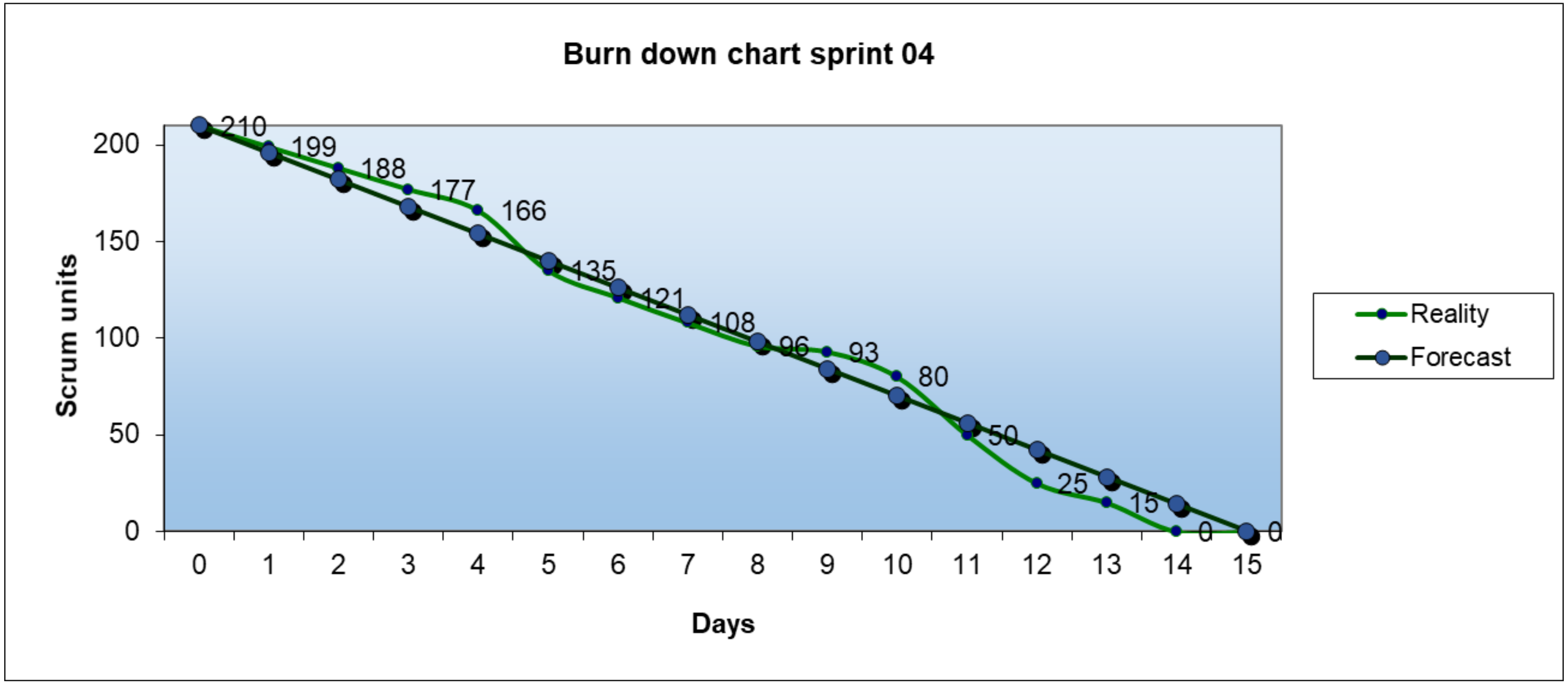
Annex 4: Sprint Backlog 3

ID	Short name	Value/Importance	Initial Estimate	2-Dec-19	3-Dec-19	4-Dec-19	5-Dec-19	6-Dec-19	9-Dec-19	10-Dec-19	11-Dec-19	12-Dec-19	13-Dec-19	16-Dec-19
18	Study the file for 3D printing	1	**20**	20	20	20	20	20	0	0	0	0	0	0
19	Choose the robot	0	**50**	50	30	0	0	0	0	0	0	0	0	0
20	Contact the company for the new robot	1	**40**	40	40	40	40	40	20	20	20	10	0	0
21	Estimate the budget	1	**30**	30	30	30	30	30	20	20	10	10	0	0
22	Fill the purchase sheet	0	**40**	40	40	40	40	40	30	30	20	20	20	0
23	Design a prototype for the control pannel	0	**20**	20	20	20	20	20	20	10	10	10	10	0
														0
			200	*200*	*180*	*150*	*150*	*150*	*90*	*80*	*60*	*50*	*30*	*0*
			Forecast	*200,0*	*180,0*	*160,0*	*140,0*	*120,0*	*100,0*	*80,0*	*60,0*	*40,0*	*20,0*	*0,0*



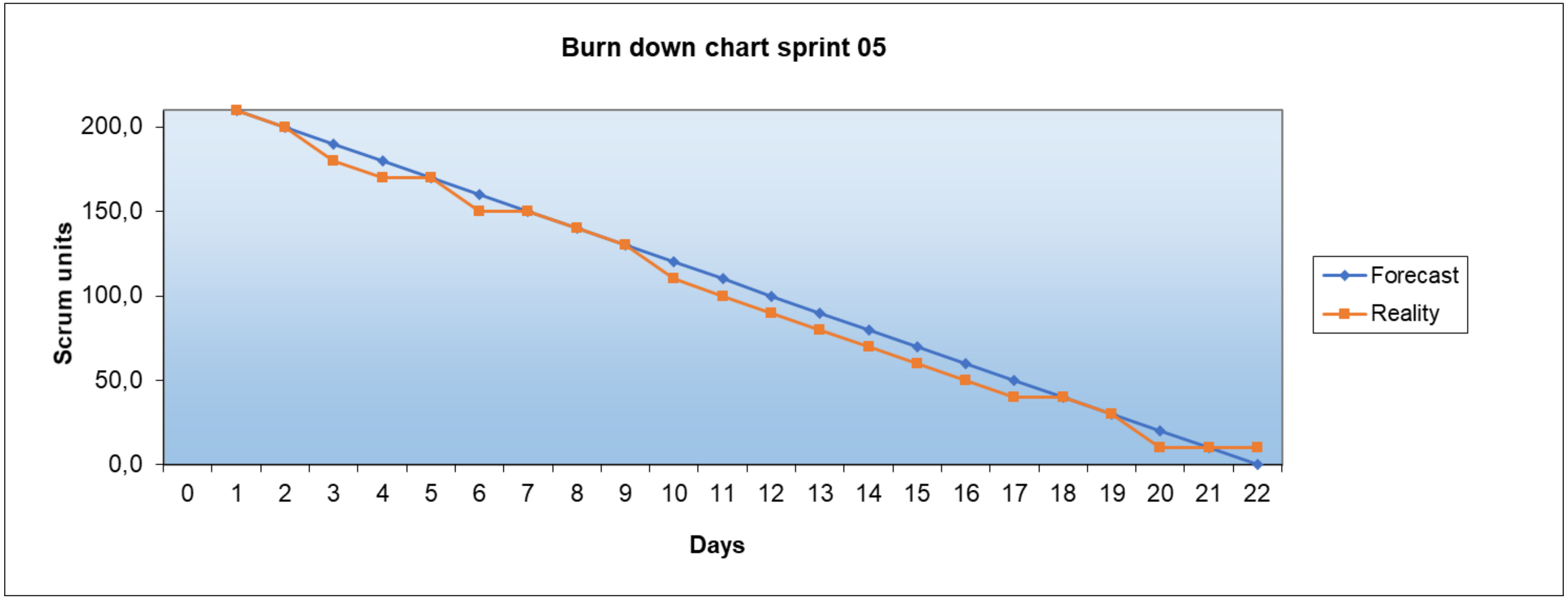
<u>Annex 5</u>: Sprint Backlog 4

ID	Short name	Value/Importance	Initial Estimate	16-Dec-19	17-Dec-19	18-Dec-19	19-Dec-19	20-Dec-19	6-Jan-20	7-Jan-20	8-Jan-20	9-Jan-20	10-Jan-20	13-Jan-20	14-Jan-20	15-Jan-20	16-Jan-20	17-Jan-20	18-Jan-20
18	Complete the exploded view	1	**20**	20	20	20	20	20	0	0	0	0	0	0	0	0	0	0	0
19	Study the motors	1	**20**	20	19	18	17	16	15	11	8	6	3	0	0	0	0	0	0
20	Print the part 1 of the robot	1	**40**	40	30	20	10	0	0	0	0	0	0	0	0	0	0	0	0
21	Print the part 2 of the robot	1	**40**	40	40	40	40	40	30	20	10	0	0	0	0	0	0	0	0
22	Print the part 3 of the robot	1	**40**	40	40	40	40	40	40	40	40	40	40	30	20	10	0	0	0
23	Fill the purchase sheet	1	**30**	30	30	30	30	30	30	30	30	30	30	30	20	10	10	0	0
24	Receipt of the order	1	**20**	20	20	20	20	20	20	20	20	20	20	20	10	5	5	0	0
														0					
			210	*210*	*199*	*188*	*177*	*166*	*135*	*121*	*108*	*96*	*93*	*80*	*50*	*25*	*15*	*0*	*0*
			Forecast	*210,0*	*196,0*	*182,0*	*168,0*	*154,0*	*140,0*	*126,0*	*112,0*	*98,0*	*84,0*	*70,0*	*56,0*	*42,0*	*28,0*	*14,0*	*0,0*



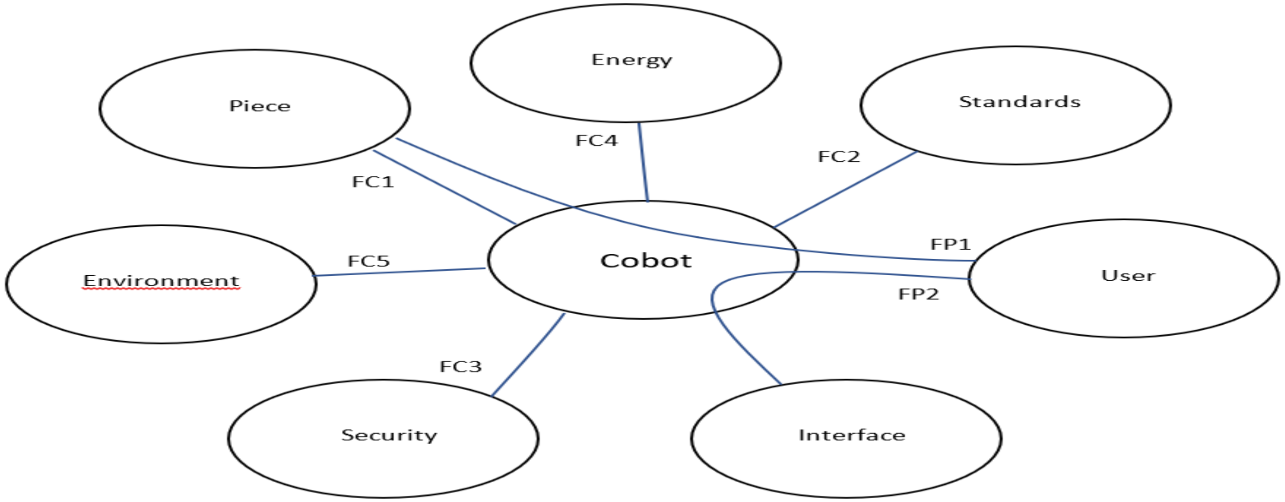
Annex 6: Sprint Backlog 5

ID	Short name	Value/Importance	Initial Estimate	20-Jan-20	21-Jan-20	22-Jan-20	23-Jan-20	24-Jan-20	27-Jan-20	28-Jan-20	29-Jan-20	30-Jan-20	31-Jan-20	3-Feb-20	4-Feb-20	5-Feb-20	6-Feb-20	7-Feb-20	10-Feb-20	11-Feb-20	12-Feb-20	13-Feb-20	14-Feb-20	17-Feb-20	18-Feb-20	19-Feb-20
37	Assemble part 2	1	**40**	40	30	20	10	0	0	0	0	0	**0**	**0**	**0**	**0**	**0**	**0**	0	0	0	0	0	0	0	0
38	Assemble part 3	1	**40**	40	40	40	30	30	30	20	20	10	**10**	**0**	**0**	**0**	**0**	**0**	0	0	0	0	0	0	0	0
39	Assemble part 4	1	**40**	40	40	40	40	40	40	30	30	30	**20**	**20**	**10**	**0**	**0**	**0**	0	0	0	0	0	0	0	0
40	Create a coverbox for the drivers in solidworks	0	**20**	20	20	20	20	20	20	20	20	20	**20**	**20**	**20**	**20**	**20**	**10**	0	0	0	0	0	0	0	0
42	Create a wiring plan of the sensors	0	**10**	10	10	10	10	10	10	10	10	10	**10**	**0**	**0**	**0**	**0**	**0**	0	0	0	0	0	0	0	0
43	Create a wiring plan of the motors	0	**20**	20	20	20	20	20	20	20	20	20	**20**	**20**	**20**	**20**	**20**	**20**	20	20	20	20	20	0	0	0
44	Rectify and clean each printed piece	1	**30**	30	30	30	30	30	30	30	30	30	**30**	**30**	**30**	**30**	**20**	**20**	20	10	10	10	0	0	0	0
45	Print the drivers' box	1	**20**	20	20	20	20	20	20	20	20	20	**20**	**20**	**20**	**20**	**20**	**20**	20	20	10	10	10	10	10	10
				220	*210*	*200*	*180*	*170*	*170*	*150*	*150*	*140*	*130*	*110*	*100*	*90*	*80*	*70*	*60*	*50*	*40*	*40*	*30*	*10*	*10*	*10*
			220	*220,0*	*210,0*	*200,0*	*190,0*	*180,0*	*170,0*	*160,0*	*150,0*	*140,0*	*130,0*	*120,0*	*110,0*	*100,0*	*90,0*	*80,0*	*70,0*	*60,0*	*50,0*	*40,0*	*30,0*	*20,0*	*10,0*	*0,0*
			Forecast																							



Annex 7: Sprint Backlog 6

ID	Short name	Value/Importance	Initial Estimate	27-Feb-20	28-Feb-20	2-Mar-20	3-Mar-20	4-Mar-20	5-Mar-20	6-Mar-20	9-Mar-20	10-Mar-20	11-Mar-20	12-Mar-20	13-Mar-20	16-Mar-20	17-Mar-20	18-Mar-20	19-Mar-20	20-Mar-20	23-Mar-20	24-Mar-20	25-Mar-20	26-Mar-20	27-Mar-20	30-Mar-20
46	Create a 2nd version of the clamp on solidworks	1	20	20	20	20	20	20	20	20	20	20	10	10	10	5	0	0	0	0	0	0	0	0	0	0
47	Print the clamp v2	1	30	30	30	30	30	30	20	20	10	10	10	10	10	10	5	5	5	5	5	5	5	0	0	0
48	Test phase 1	1	30	30	30	30	30	30	30	30	20	20	10	10	10	10	10	0	0	0	0	0	0	0	0	0
49	Modelize the screen support in solidworks	1	30	30	30	30	30	20	20	20	20	20	10	10	10	0	0	0	0	0	0	0	0	0	0	0
50	Print the screen support	1	20	20	20	20	20	10	10	10	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0
51	Test the power supply	1	20	20	20	10	10	10	10	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0
52	Do the notice	1	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	30	30	30
53	Write the report	1	30	30	30	30	30	30	30	30	30	20	20	20	20	20	20	20	20	10	10	0	0	0	0	0
				220	*220*	*210*	*210*	*190*	*180*	*180*	*160*	*150*	*120*	*110*	*100*	*85*	*75*	*65*	*65*	*55*	*55*	*45*	*45*	*30*	*30*	*30*
			220	*220,0*	*210,0*	*200,0*	*190,0*	*180,0*	*170,0*	*160,0*	*150,0*	*140,0*	*130,0*	*120,0*	*110,0*	*100,0*	*90,0*	*80,0*	*70,0*	*60,0*	*50,0*	*40,0*	*30,0*	*20,0*	*10,0*	*0,0*



<u>Annex 8</u>: Planning

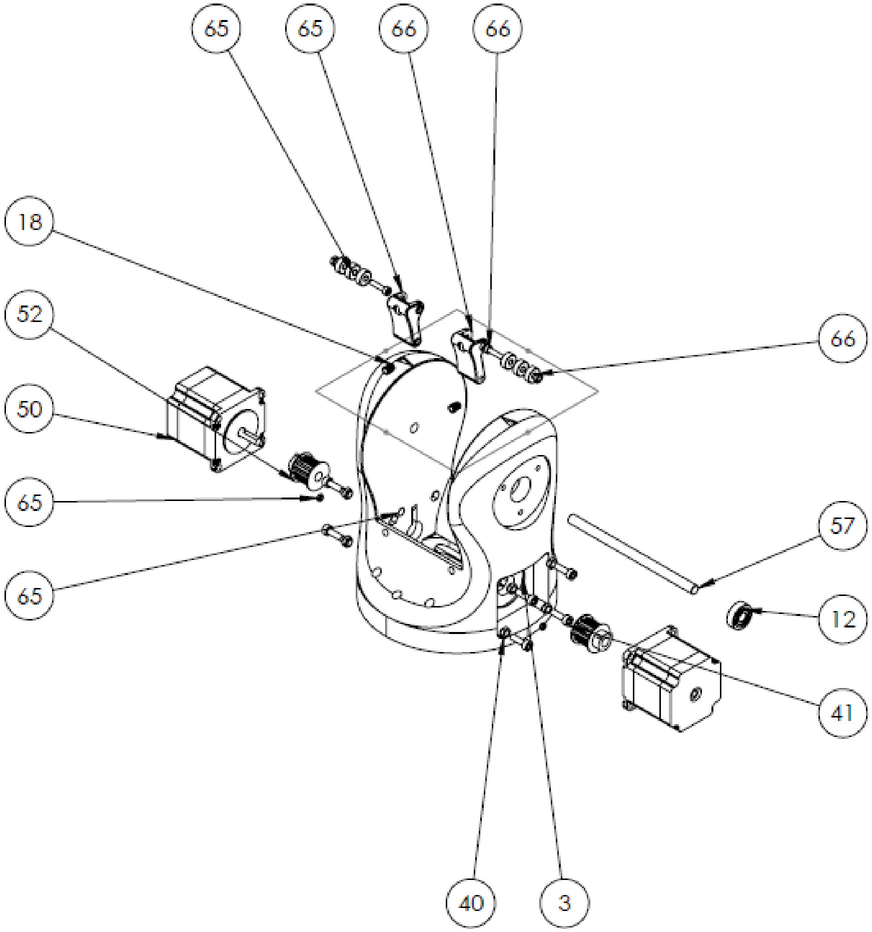
task id	Project's planification																									
	month	Dec				Jan				Feb				March				April				May				Members in charge
	week																									
A	**CAD Design**																									
	Download the CAD files				X																					Oriane & Fanny
	Assemble the robot on Solidworks				X																					
	Modify the assembly to adapt to the ECAM				X																					
	Create a simulation of movement				X																					
B	**Mechanical dimensionning**																									
	Estimation of the needed power				X																					Francesco & Nicolas
	Motors calculations																									
	Motors adaptation and implementation																									
C	**3D Printing**																									
	Print parts group 1					X																				Fanny&Simon
	Print parts group 2							X																		
	Print parts group 3																									
	Print parts group 4																									
D	**Buying**																									
	List and buy the components and fasteners needed				X																					Simon
	List and buy the motors					X																				
E	**Assembly**																									
	Follow the montage guide*																									Romain & Simon & Fanny
	Assemble part 1																									
	Assemble part 2																									
	Assemble part 3																									
	Assemble part 4																									
	Assemble tool																									
	Assemble box electronic and cover																									
F	**Programmation**																									
	Create a program to control the robot																									Ryan & Simon
	Cable the motors to the arduino cards																									
	Test the functionment																									
	Create a sensors system for the security																									
	Link the sensors system to the robot																									

blue shows the initial expected duration for tasks or process accomplishement	
green shows if process or task runs as smoothly as it was expected	
red shows a delay / a problem / trouble in the task or process running	

Annex 9: List of robots

Robot name	Capacity	Price in kit (€)	Components	Link	Software	Connectivity	Learning mode	Power (W)	Horizontal travel (mm)	Customizable ?
Niryo	300g	1400	All parts necessary to assemble the robot	https://niryo.com/fr/product/niryo-one-fr/	yes		yes			
BCN3D Moveo	1kg		https://github.com/BCN3D/BCN3D-Moveo	https://www.bcn3d.com/bcn3d-moveo-the-future-of-learning/	no specific software					
AR3 6 axis robot	4kg	1429	Aluminium parts, Hardware, drivers and power supply kit, complete SolidWorks assembly	https://www.anninrobotics.com	yes		yes, but by using the jog buttons of the software			
Thor robot	750g	<350	3D parts available online, list of components available on the site	https://hackaday.io/project/12989-thor	no specific software	USB	no		422	
Roboteurs 6 axis robot	Asked	750		https://roboteurs.com/collections/robots/products/rbx1-remix-3d-printed-6-axis-robot-arm-kit?variant=40314908751	SlushEngine Model D 7					
	2kg			https://hackaday.io/project/3800-3d-printable-robot-arm						
				https://www.usinenouvelle.com/expo/robot-collaboratif-industriel-robot-ur-p296431032.html						
Robot Anno V6	1kg	1950 - 2250	3D printed parts Control panel Controller and speed reducer USB cable	https://robotanno.en.alibaba.com/product/60804090386-813278424/6_Aixs_Robot_Arm_3D_Printed_Fully_Assembled_High_Precision_Mechanical_Robot_Arm_for_DIY_Education.html?spm=a2700.icbuShop.41413.11.4ae4744dq1biSA https://github.com/ps-micro/PROBOT_Anno	Graphical block programmation	USB, PC, Tablet, Mobile	Yes with a controller included	360	980	Yes
Robot Anno V6 Pneumatic	1kg	1100 (+130€ shipping)	3D printed parts	https://www.alibaba.com/product-detail/Pneumatic-Lightweight-Humanoid-Hydraulic-Telescopic-Robot_60821564273.html?spm=a2700.details.deiletai6.34.7adc120aD1Tvd6	Graphical block programmation	USB, PC, Tablet, Mobile	no	360	980	Yes
Robot CCR-45 MAKERFACTORY X641761	500 g	855€	Fully assembled	https://www.manomano.fr/p/bras-robotise-ccr-45-makerfactory-x641761-14835726						No
robot 6-axes Epson C4	4kg	21 100€		https://www.epson.fr/products/robot/epson-prosix-c4-a601s	EPSON RC+	1 emergency stop, USB	Yes			
Robot 6 axes VT6-A901S	6 kg	13 000€		https://www.epson.fr/products/robot/epson-6-axis-vt6-a901s-with-built-in-controller#specifications	EPSON RC+	PC	Yes			
Collaborative robots from classic robot manufacturers										
UR3	3 kg		CB3.1 controller	https://www.sysaxes.com/?gamme_ur=universal-robots-ur3	CB3.1	2 inputs, 2 TOR 12/24 V outputs, 2 analogic inputs			500	
TX2-60L	2 kg		robot + cs9 controller	https://www.staubli.com/fr-fr/robotics/gamme-produits/robots-4-et-6-axes/bras-robotises-6-axes/tx2-60/	CS9				920	

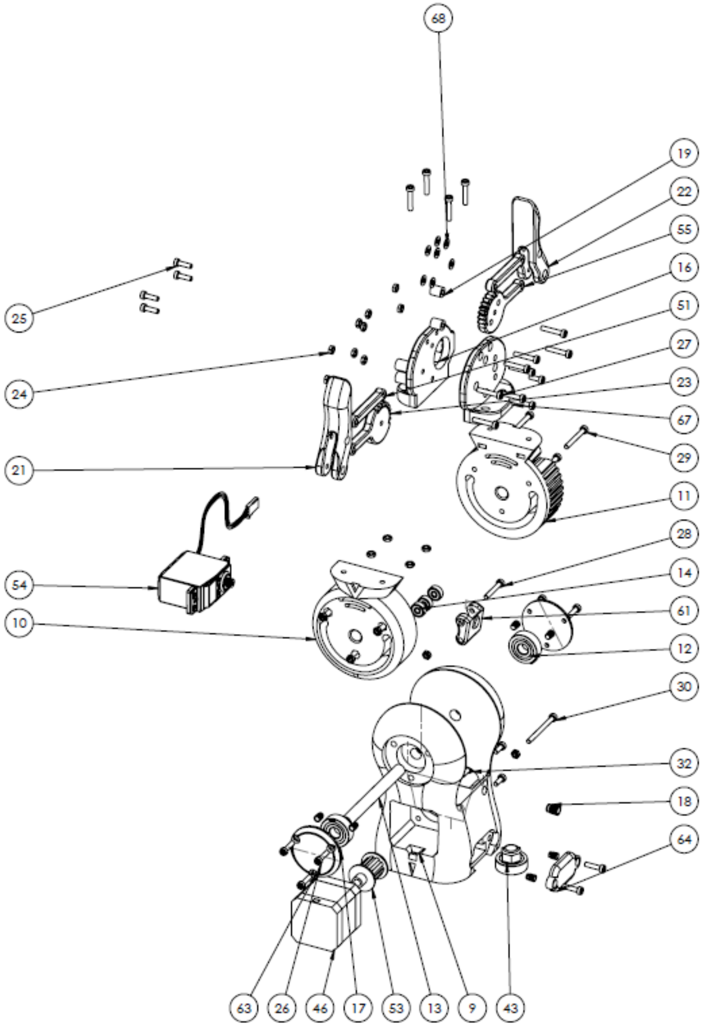
<u>Annex 10</u>: Exploded view of the assembly 2M1



No. ARTICLE	NUMERO DE PIECE	DESCRIPTION	QTE
40	M5 Lock		8
3	2M1D		1
50	Nema 23		2
41	M5x15		8
12	8mm Bearing		2
66	Tensor I		1
65	Tensor D		1
52	Pulley 8mm IGNIS		2
57	Smooth bar 8mm x 140mm		1
17	Brass insert M3		6
18	Brass insert M4		2
62	Tapa 2M1C		2
25	M3x10		6

SAUF INDICATION CONTRAIRE: LES COTES SONT EN MILLIMETRES ETAT DE SURFACE:	FINITION:	CASSER LES ANGLES VIFS	NE PAS CHANGER L'ECHELLE	REVISION

<u>Annex 11</u>: Exploded view of the articulation 4



No. ARTICLE	NUMERO DE PIECE	DESCRIPTION	QTE
9	4M1D		1
24	M3 Nut		18
46	Nema 14		1
32	M3x8		5
12	8mm Bearing		3
43	M8 Autoblocant		1
61	T4M1E		1
28	M3x20		1
14	Bearing 3Bore 10Ext 4Height		3
30	M3x35		1
53	Pulley M5		1
17	Brass insert M3		8
18	Brass insert M4		1
63	Tapa 4M1D		2
26	M3x12		8
64	TBC		1
10	4M2B		1
11	4M2CB		1
29	M3x25		3
13	Barra lisa 8mm x 80mm		1
16	Bottom Plate C		1
67	Top Plate C		1
19	Cilinder		2
21	Gripper Left B		1
22	Gripper Right B		1
23	Idol Gear B		1
51	Pivot Arm B		2
55	Servo Gear B		1
54	Servo Futaba S3003		2
27	M3x16		13
68	Volandera M3		7
25	M3x10		4

NOM | SIGNATURE | DATE

4M-eclatee

Annex 12: FMECA

FMECA

Cobot
Groupe 7, Subgroup 15
10/04/2019

Sévérité (S): de 1 impact négligeable à 5 impact catastrophique
Occurrence (O) : de 1 improbable à 5 presque inévitable
Détection (D) : de 1 détection presque certaine à 5 détection absolument incertaine
Criticité = S x O
Risque = S xO x D

Elements	Analysis of current failure modes									Recommandations		Results						Maintenance
	Potential failure mode	Effects of potential failure	Severity	Possible causes of failure	Occurrence	Current process controls	Detection	Criticité	Risk	Recommended actions	Bearer of the action	Severity	Occurrence	Detection	Criticality	Risk	Stopping the machine	Preventive/corrective
Clamp	Object not entered correctly	The object does not arrive on the conveyor	4	Wear or brake	3	Visual inspection	1	12	12	Reprint the pieces of the clamp and assemble a new one	Worker	4	3	1	12	12	x	Corrective
			4	Electrical problem	2	Visual inspection	1	8	8	Check the voltage	Worker	4	2	1	8	8	x	Preventive
Motor	The engine stops running or gives off smoke	Overheating	5	Electrical failure	2	Visual inspection	2	10	20	Buy a new one	Worker	5	2	2	10	20	x	Corrective
Belt	Belt is slidind	No operation, movement is not transmitted	3	Alignment problem or incomplete fixation	4	Visual and auditory inspection	1	12	12	Alignment adjustment	Worker	3	4	1	12	12	x	Corrective
	Belt is skipping	No operation, movement is not transmitted	4	The belt is broken	2	Visual and auditory inspection	1	8	8	Replace the belt by a new one	Worker	4	2	1	8	8	x	Corrective
The structure	The structure is broken (a piece or many pieces)	The robot can not work anymore	5	Too much weight applied on it	3	Visual inspection	1	15	15	Print some new pieces and assemble everything	Worker	5	3	1	15	15	x	Corrective

<u>Annex 13</u>: List of references

Guide of *Toglefritz* on the forum "*Instructables*":
https://www.instructables.com/id/Build-a-Giant-3D-Printed-Robot-Arm/

Moveo with ROS :
https://www.jesseweisberg.com/moveo-with-ros

Robot maker Moveo :
https://www.robot-maker.com/forum/topic/11216-bras-robot-bcn3d-moveo-de-donovan/
https://www.lesimprimantes3d.fr/forum/topic/7623-robotique-bras-robot-bcn3d-moveo/page/6/#comments

Nouvelle pince Moveo :
https://www.robot-maker.com/forum/topic/12354-nouvelle-pince/page-7

Annin Robotics :
https://www.anninrobotics.com/downloads

Makeblock driver:
https://www.makeblock.com/project/2h-microstep-driver

GitHub:
https://github.com/Chris-Annin/AR2/tree/master/RaspberryPi