COMILLAS
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GRADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES (GITI)

TRABAJO FIN DE GRADO

ROBOTICS FRENCH CUP

Autora: Blanca Ferrer Sánchez del Villar

Director: Emmanuel Boutleux

Madrid

Julio de 2022

I declare, under my responsibility, that the Project submitted under the title *Robotics French Cup* at the ETS de Ingeniería - ICAI of the Universidad Pontificia Comillas in the academic year *2021/2022* is of my authorship, original and unpublished and has not been previously presented for other purposes. The Project is not plagiarised from any other, either totally or partially, and the information that has been taken from other documents is duly referenced.

Fdo.: Blanca Ferrer Sánchez del Villar Date: 02/ 07/ 2022

The delivery of the project has been authorised

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To my parents and all my family,
thanks to whom I am who I am and who
have supported me during the academic stage
that today comes to an end

Acknowledgements

I would like to thank my family who have always supported me and have given me the possibility to access a double degree exchange with the French university École Centrale de Lyon where I have been able to carry out this project.

I would also like to thank my team of 14 students with whom I carried out the project as a whole, although this document only reflects my contribution to the project.

And to the professors of both the École Centrale de Lyon and the Universidad Pontificia Comillas. Thanks to the learning received in both centres, I have had the knowledge to carry out this project.

La Copa de Francia de Robótica : RESUMEN DEL PROYECTO

Autora: Ferrer Sánchez del Villar, Blanca
Director : Boutleux, Emmanuel
Entidad Colaboradora : École Centrale de Lyon

0.1 Introducción

El titulo de este TFG es "La copa de Francia de robotica". Dicho título coincide con la competición francesa de robótica que tiene lugar todos los años. El contenido de este documento explica la estrategia y el diseño de los robots del equipo de l'École Centrale de Lyon para la edición de mayo de 2022.

En este documento aparece detallada mi aportación al equipo de la universidad Centrale de Lyon. Dicho contenido es la estrategia seguida por el equipo para la obtención del máximo número de puntos, el diseño 3D de los robots para la realización de las tareas elegidas para la competición y el resultado final de dichos diseños, ya en su versión tangible.

El objetivo principal de este proyecto es presentar robots funcionales aptos para participar en la competición de robotica francesa. El objetivo de esta competición es que los robots de dos equipos se enfrenten en partidos de cien segundos en un campo definido por el reglamento. Los equipos obtienen puntos al completar tareas específicas. Este año, el proyecto también pretende mejorar la base de datos de los que dispone la universidad sobre proyectos anteriores con sus diseños y sus memorias.

Durante el proyecto se conceptualizaron y construyeron dos robots: Eve y Wall-E. Ambos están controlados por placas ARDUINO y están construidos con piezas LEGO y Mecano, así como con piezas impresas en 3D y piezas de madera hechas con las cortadoras láser del FABLAB CENTRALE LYON.

Dado que este año no se participará en el concurso, nos concentramos en el desarrollo y la experimentación de técnicas que puedan utilizarse en el futuro del proyecto, principalmente a través de la reestructuración de la Wiki y la comprensión de los tableros de programación y las tecnologías propuestas por la Fablab Centrale Lyon.

0.2 Contexto

La Copa de Francia de Robótica *(Coupe de France de Robotique)* fue creada en 1994 por *Association Planète Sciences* y la empresa VM Productions, ya que ambas querían organizar una competición de robots en Francia.

Cada año se publica un reglamento en el que se establecen las diferentes tareas que deben realizar los robots y la puntuación asociada a cada tarea. Estos eventos se basan en un tema común, siendo el de este año "La era de los robots" (figura 1). El diseño de los robots del proyecto se basará en dichas reglas.

Figure 1: Logo de la edición de 2022

El proyecto se articula en el contexto de esta competición. Pero su objetivo principal es el desarrollo y mejora del trabajo realizado por los alumnos que participaron en este proyecto los años anteriores. Esto está representado por el hecho de que los diseños realizados han sido concebidos de tal manera que resuelven los problemas propuestos para la edición de 2022 pero son exportables a futuros diseños. Y a que una de las tareas será la mejora de la base de datos de la universidad, a la que llamaremos la Wiki.

0.3 Estrategia

Antes de empezar el diseño de los robots necesitamos conocer cual va a ser la estrategia del equipo, que tareas se quieren priorizar para maximizar el número de puntos. Ya que cada juego tiene una duración de 100 segundos, por lo que no se pueden realizar todas las tareas sugeridas en el reglamento.

El reglamento tiene unas cincuenta páginas. A continuación se presenta un breve resumen que da una idea general de los puntos importantes y que me permitió establecer la problemática del proyecto, sus objetivos y finalmente las especificaciones funcionales.

0.3.1 Objetivos

El juego tiene una duración de cien segundos durante los cuales cada equipo debe realizar una serie de tareas, cada una de las cuales proporciona un número definido de puntos.

La primera tarea consiste en recoger las muestras de diferentes colores que se muestran en la figura 3 y transportarlas a las zonas de caída de muestras. Hay tres de estas zonas y el número de puntos que se obtienen varía según la posición de las muestras (boca abajo o boca arriba), como se muestra en la figura 2.

Area	Points	Action
Camp	1	Per sample removed from a dispenser (in the field half)
	1	Per sample in the camp
	1	Per sample face treasure + sorted in the camp
Galery	3	Per sample placed
	3	Per sample face treasure + sorted
Shelter	5	Per sample in the shelter

Figure 2: Puntos con respecto a las zonas

Figure 3: Muestras de color

A continuación, tendremos que dar la vuelta a los "cuadrados de excavación" situados en el borde del terreno y presentados en la figura 4a. Están colocadas de manera que puedan inclinarse hacia atrás. Hay tres tipos: amarillo, morado y rojo. Se reconocen por sus colores, pero también por dos placas conductoras conectadas por una resistencia, que varía según el color del cuadrado, cuyos valores son conocidos. Estos marcadores resistivos se muestran en la figura 4b. Un equipo gana cinco puntos por cada casilla de su color que se incline, y cinco puntos adicionales si al menos una de las casillas del equipo se inclina y la roja asociada al equipo no.

(a) Posición de los cuadros de excavación

(b) Marcador de resistividad

Figure 4: Cuadros de excavación

0.3.2 Restricciones

Los robots deben respetar una serie de restricciones. Éstas se dividen en dos, requisitos estáticos y dinámicos. Estas condiciones deben ser verificadas para que los robots puedan paticipar.

Los requisitos dinámicos son los siguientes:

- Tener un botón de parada de emergencia
- La batería no debe superar los 48V
- El robot no debe hacer contacto con otro robot
- El robot arranca con un cable de arranque que debe tener al menos 50 cm de longitud

- El robot debe detenerse después de 100 segundos de juego

Las condiciones estáticas se describen a continuación:

- La altura debe ser inferior a 35cm y el botón de parada de emergencia puede ir hasta 37,5cm (excluyendo el poste para la baliza)
- El soporte de la baliza debe ser lo más opaco posible (con grandes superficies planas) para que los sensores puedan localizar los robots
- El robot debe tener un lado en blanco de 10 cm por 7 cm para poner los logotipos de la copa y de los patrocinadores
- El robot debe tener un soporte de balizas con un área entre un círculo de diámetro 7 cm y un cuadrado de lado 10 cm

El robot también debe respetar las limitaciones de tamaño. Un equipo puede estar compuesto por uno o dos robots y esta elección influye en las dimensiones que deben respetarse. Estas dimensiones determinan el perímetro del robot. Además, un robot puede tener brazos articulados que pueden variar este perímetro, las reglas dan entonces condiciones de tamaño para el robot "Desplegado" y el robot "Desplegado". Estas condiciones se detallan en la tabla 1:

	Perímetro no desplegado	Perímetro desplegado
Un robot	<= 1200 mm	<= 1300 mm
Dos robots	A+B <= 2050 mm	A+B <=2200 mm

Table 1: Condiciones del perímetro del robot

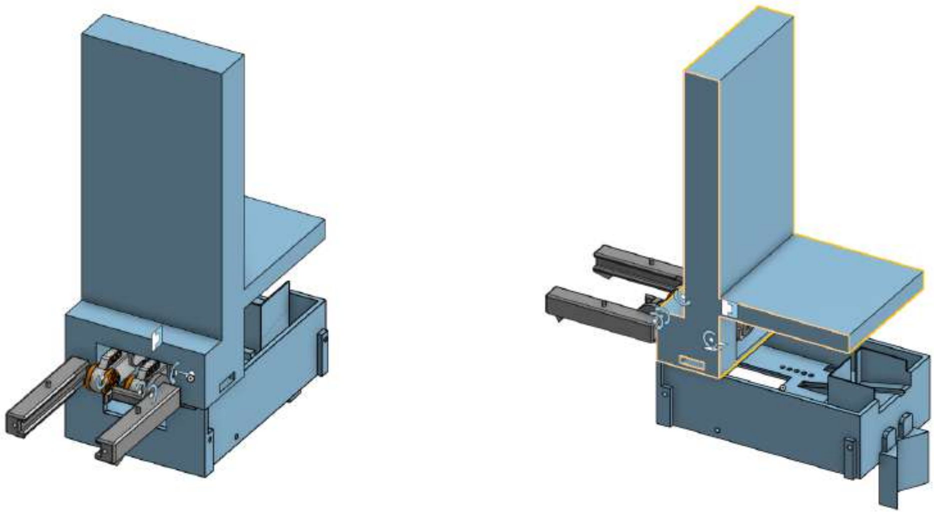
También hay que tener en cuenta que la proyección en la mesa del robot debe caber completamente dentro de su área inicial, lo que impone de nuevo una restricción de forma.

0.4 Desarrollo y resultados

0.4.1 Eve

El robot Eve, es el robot pequeño de los dos diseñados. Para el diseño empecé creando una forma general de la estructura, un borrador. A partir de este borrador creé la estructura precisa del robot en OnShape. El interés de esta estapa era tener una forma, y pensar en cómo acoplar y disponer las diferentes piezas electrónicas y mecánicas que ya teníamos. Estas piezas son, por ejemplo, los motores, las baterías, la placa de programación, las ruedas, los engranajes, la baliza y el eje de la rueda.

La pieza a construir está compuesta por una caja que será el cuerpo del robot (figura C.1), la torre (figura C.2) y los brazos (figura C.3) (Figuras en el anexo C).



(a) Vista 1

(b) Vista 2

Figure 5: Montaje teórico

El proyecto de construcción fue evolucionando a lo largo del año. La primera idea fue imprimir en 3D todas las piezas (después de diseñarlas en 3D CAO).

El cuerpo

Eve es un robot "pequeño". Por lo tanto, tiene una restricción de tamaño muy importante. El tamaño del robot debe reducirse al mínimo y al mismo tiempo tener espacio suficiente para albergar todos los componentes electrónicos y mecánicos del robot.

Por desgracia, la pieza es muy grande y la impresión nos llevó un día entero. Además, tuvimos que dividirla en tres partes para limitar la cantidad de material necesario para la impresión. Las tres partes son la parte superior, la parte inferior y el carro del robot. Sin embargo, el proceso de impresión sigue siendo muy largo, y el resultado de la figura 6a no es muy adaptable a las modificaciones que habrían sido necesarias ya que el resultado no era adecuado (errores de medición que se sumaban). Esta primera versión no era utilizable. En lugar de cambiar la versión 3D y volver a imprimir la pieza, decidí cambiar el método de construcción, utilizando las cortadoras láser y haciendo la estructura en madera.

Esta nueva solución tenía la ventaja de ser extremadamente rápida en comparación con la impresión y la madera es mucho más maleable. De hecho, hacer un agujero en ella, pegarla o serrarla es mucho más fácil. Fue necesario hacer tres intentos para obtener una estructura que nos convenía, es decir, una estructura sólida con las dimensiones adecuadas, donde las piezas encajan perfectamente.

(a) Versión de impresión en 3D

(b) Segunda versión con cortadora láser

Figure 6: Primeras versiones del cuerpo

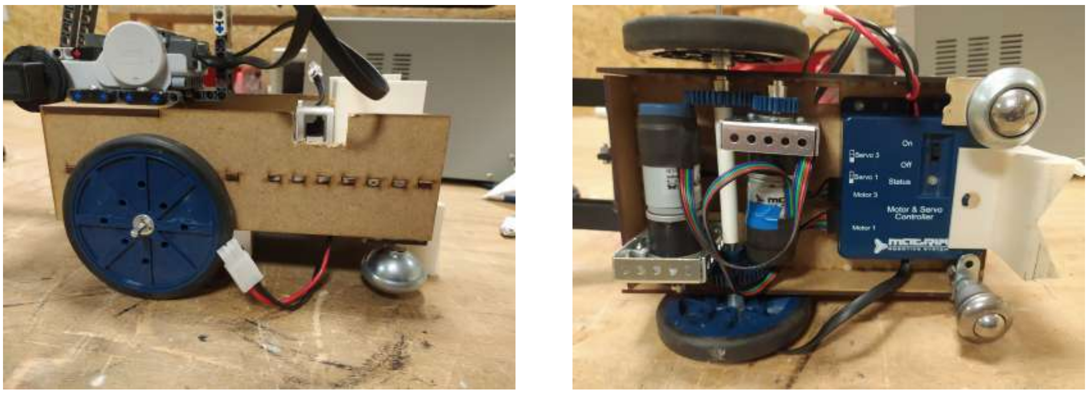
La versión final de la carrocería requirió algunos ajustes, pero éstos no supusieron ningún problema debido a la facilidad de manipular la madera. Por ejemplo, la perforación de los agujeros para atornillar el mástil. Además decidí imprimir algunas piezas en 3D porque estas piezas no existían en Lego, y tenían una estructura en 3D y no en 2D (por lo tanto no era factible con la máquina de corte). Pero la impresión de estas piezas sólo requirió unas pocas horas. Dichas piezas son :

- El soporte para el sensor de infrarrojos
- El carro en la parte trasera del robot

- El soporte de almacenamiento para la reliquia
- El estabilizador

El estabilizador es un cilindro hueco con un diámetro interior de 5 mm, un diámetro exterior de 8 mm y una longitud de 8 cm. El diámetro está diseñado para rodear los ejes de las ruedas sin fricción. El tamaño es muy grande en relación con el diámetro para garantizar la mejor conexión de pivote posible. No se sujeta a la carrocería sino a los ejes de las ruedas. Su objetivo es garantizar la coaxialidad de las ruedas sin perder potencia del motor por la fricción y evitar la hiperestaticidad en el posicionamiento de las ruedas. El estabilizador es visible en blanco en la figura 7b entre los dos motores.

La versión final del cuerpo se muestra en la figura 7. Se puede ver que se utilizan rodamientos laterales para que la estructura del robot sea estable durante su movimiento (más que las dos ruedas). Al final, tuve que poner dos de ellos cuando uno habría sido suficiente porque no había espacio para ponerlo en el centro en la parte trasera debido al carro y el controlador Matrix.



(a) Vista lateral

(b) Vista inferior con el montaje electrónico

Figure 7: Versión final de Eve

La torre

Debido a las reglas de la copa de robótica, es necesario tener un poste que sostenga un soporte para la baliza. Para la construcción del soporte, he utilizado Lego y he dividido la construcción en dos partes: el soporte base en la placa electrónica y el soporte recto. Esta parte es también un soporte para el botón de parada de emergencia.

El proyecto de imprimir en 3D el mástil se abandonó rápidamente porque la pieza era demasiado grande. Además, no había que tener en cuenta ninguna restricción de alineación en particular. La estructura final se muestra en la figura 8.

Esta parte del robot soporta la placa Arduino y su EVShield, la baliza y los motores de Lego que activan los brazos.

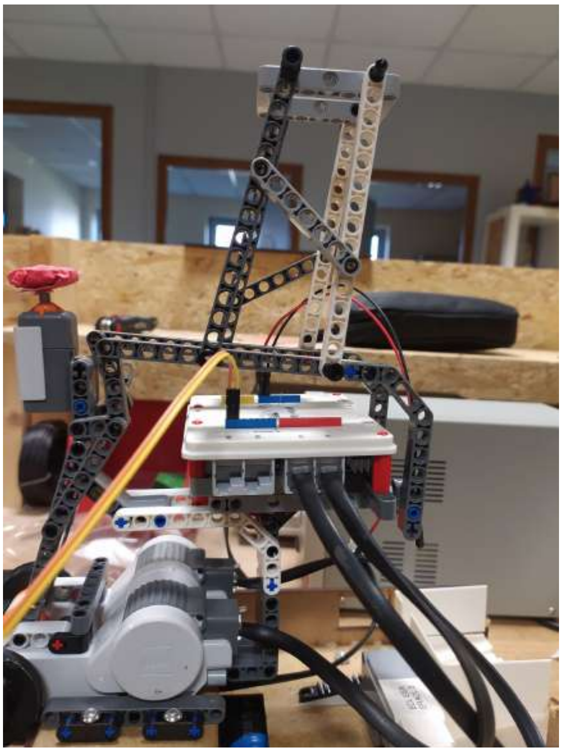


Figure 8: Diseño final de la torre

Debido a la asimetría de la placa electrónica, hemos tenido que construir una estructura asimétrica para permitir que las dos piezas horizontales del Lego sean coplanarias.

Para que el soporte de la baliza quedara lo más paralelo posible al suelo, utilicé cuatro piezas largas de lego para el soporte vertical y dos piezas laterales para evitar que la estructura girara y hacerla isostática.

Los brazos

Los brazos no presentaban ninguna tecnicidad mecánica, sólo era necesario dimensionar algunos aspectos de su uso. Además la primera versión de la figura 9 estaba bien dimensionada, así que la mantuve.

- Los topes superiores para sujetar la miniatura
- Los topes inferiores para poder empujar los hexágonos
- Los agujeros para poner los cables que sirven para medir la tensión de los cuadrados de las excavaciones
- Los agujeros para poner los accesorios de Lego, y su buena colocación para que sea coherente con los agujeros de los motores de Lego
- La barra para atornillar los dos brazos y que queden frente a frente

Figure 9: Resultado final de los brazos

0.4.2 Wall-E

De los dos robots este es el robot grande. Su tarea principal durante la competición era recoger las muestras hexagonales situadas en diferentes posiciones : horizontal en el suelo, horizontal en una plataforma y en una posición con una inclinación de 60º. Además de recoger dichas muestras el robot debía almacenarlas para poder optimizar los tiempos y así maximizar los puntos obtenidos.

Las pinzas

Siguiendo estos puntos, busqué una solución mecánica que lograra estos objetivos. Opté por un brazo que agarra las muestras presionando el contorno (de 1,5 cm de grosor) en tres puntos, recoge las muestras, las voltea, las deja caer, las vuelve a agarrar (se voltean) y luego las coloca en su posición final.

La FIGURA 10 muestra de forma esquemática cómo se realiza esta gestión de muestras. Vemos la zona oscura de la muestra que representa el lado del tesoro, que originalmente está boca abajo y al final boca arriba. Para dejar caer la muestra se utiliza un actuador hueco en su centro. Obsérvese que necesitaremos un actuador de agarre a presión, dos motores para el brazo y dos motores para el movimiento del robot, que debe estar orientado hacia la zona del depósito.

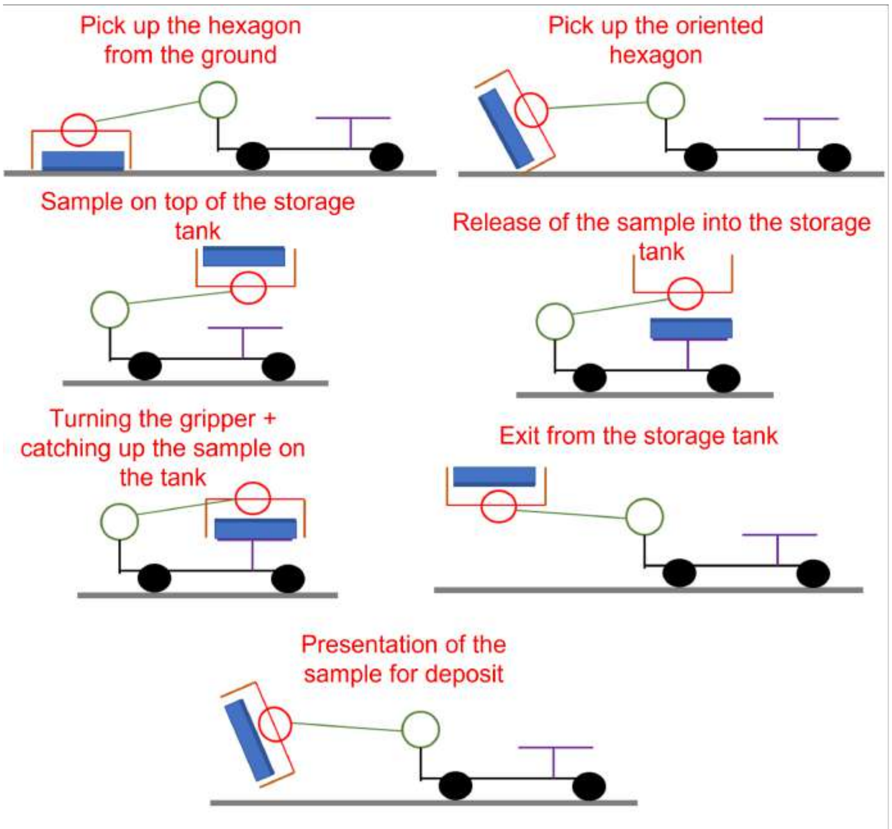


Figure 10: Muestra del funcionamiento del robot

Diseño de las pinzas

Con estas ideas bastante claras, primero pudimos hacer algunos bocetos a mano (presentes en el Apéndice B).

Una vez que el diseño está hecho y las condiciones de contorno (perímetro) se mantienen. Diseñé las piezas con *OnShape* en 3D y las ensamblé para crear un modelo 3D del brazo a construir, estudiar sus movimientos y las interacciones entre las piezas FIGURA 11.

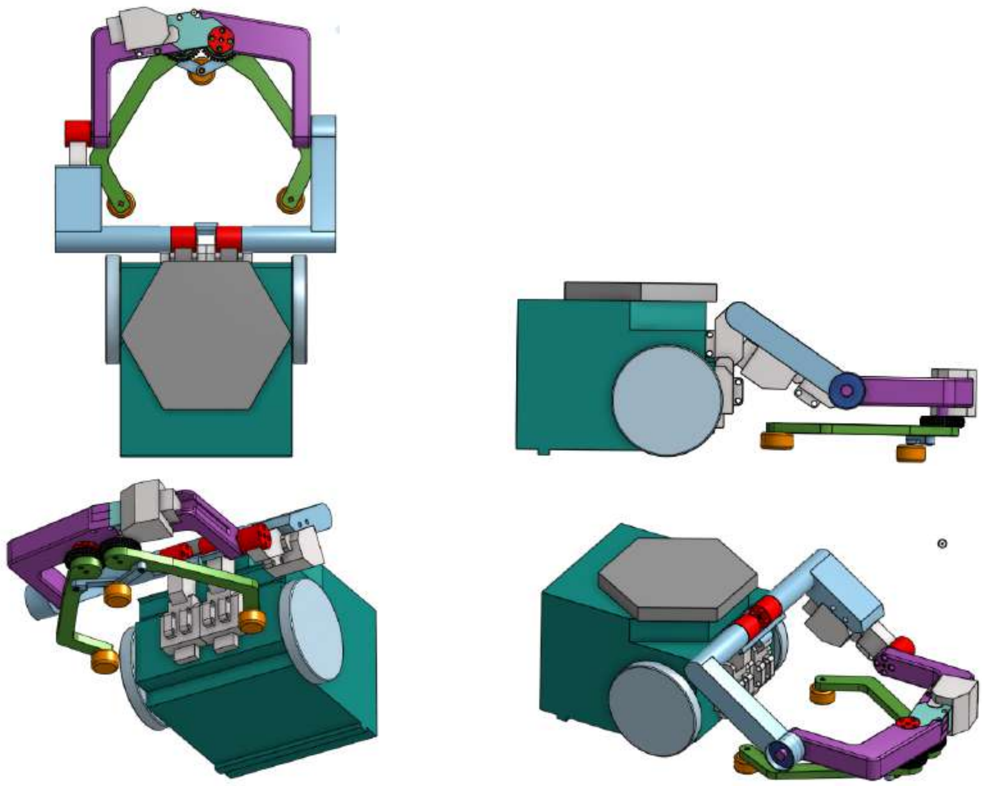


Figure 11: Modelo 3D de Wall-E

A continuación, pude imprimir en 3D todas las piezas, rehacer los detalles de bloqueo con las herramientas proporcionadas por el *Fablab*. Luego monté todo físicamente (sin el marco que es sólo una caja debajo del brazo en el robot).

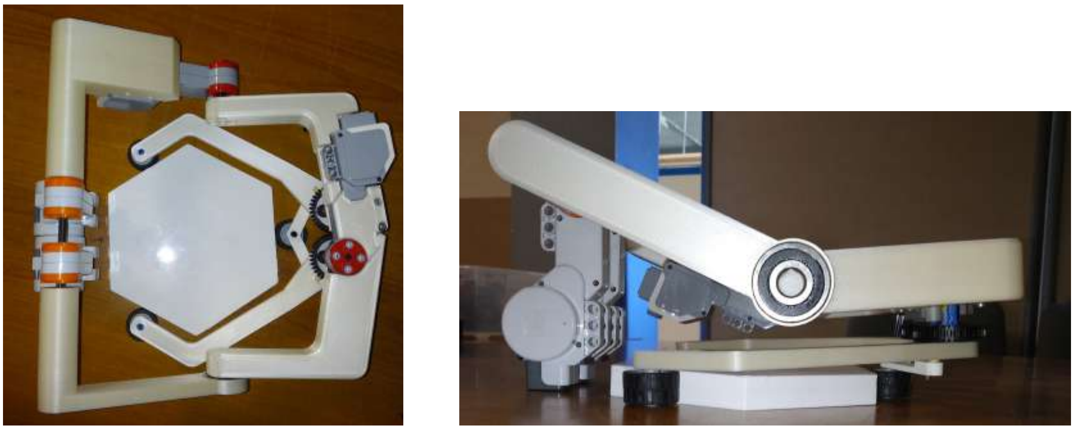


Figure 12: Primera versión de las pinzas

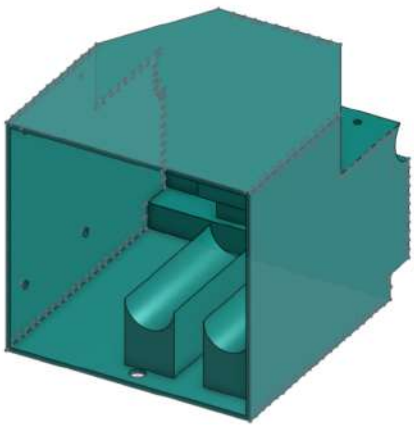
Ya tenemos la primera versión del brazo de Wall-E que aún tiene muchos problemas de ajuste para tener un brazo funcional.

Diseño del cuerpo

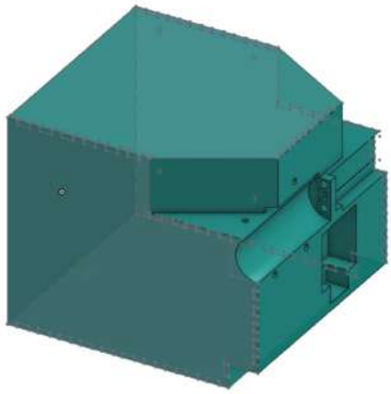
Para el diseño del cuerpo, había varios criterios que debían cumplirse:

- Todos los elementos de la placa Arduino, el VLSheald, los dos motores Matrix y las baterías tenían que caber dentro del cuerpo
- Debe tener el tamaño adecuado para albergar 3 muestras.
- Debe respetar los límites de perímetro impuestos por el reglamento del concurso
- Debe facilitar el crecimiento de los motores de la pinza

Después de algunas consideraciones, llegué al diseño que se muestra en FIGURA 13.



(a) Vista inferior



(b) Vista frontal

Figure 13: Cuerpo de Wall-E

Mejora empírica del diseño

Al realizar el primer diseño de las pinzas del robot vimos que pese a haber situado dos motores Lego en pararlelo la potencia administrada por ambos era suficiente para bloquear el brazo pero no para levantarlo.

Para superar este problema de par motor en la entrada del brazo, opté por utilizar un motor *Matrix* (que tiene un alto par). Todos los motores *Matrix* disponibles se utilizaron para las ruedas motrices de los robots Wall-E y Eve. Quedaba un motor extra, pero su codificador incremental está roto, lo que supone un problema para el control del brazo. Entonces opté por poner un motor *Lego* que se utilizará como sensor de posición en paralelo con el motor *Matrix* que se utilizará para la potencia.

A continuación, he modificado el formato 3D del robot para añadir el motor *Matrix* a la estructura. Quité un motor de Lego y añadí engranajes para transferir la rotación del eje del motor al brazo. También opté por una pieza de madera para reducir: el peso, el tiempo de producción de la pieza y el presupuesto de la nueva pieza del brazo. De este modo, la construcción fue más rentable que el equivalente en impresión 3D.

Podemos ver la nueva configuración del brazo en la FIGURA14, el motor *Matrix* no se muestra con su engranaje, pero hay una predisposición en el marco para fijarlo.

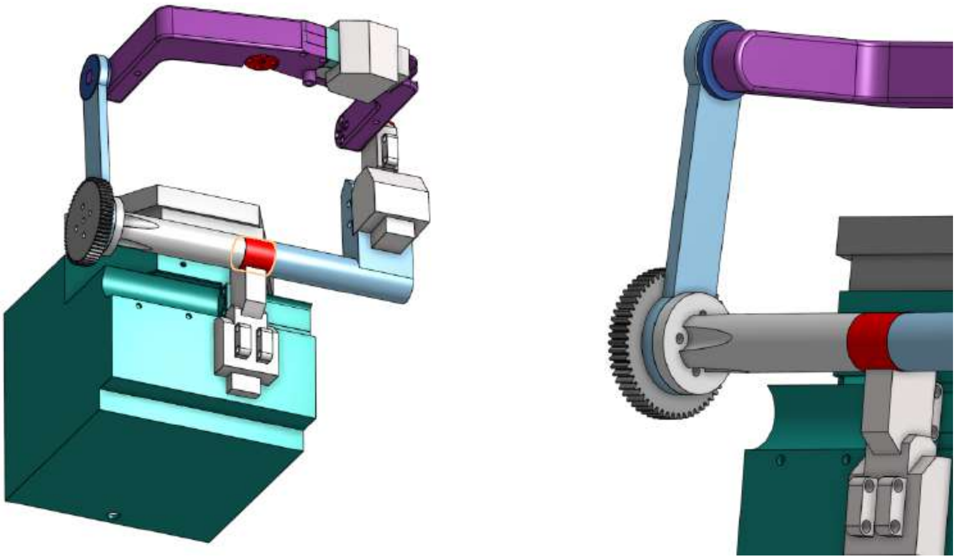


Figure 14: Segunda versión de las pinzas

0.5 Conclusión

Al final del plazo del proyecto, hemos conseguido tener una base de datos más intuitiva y el diseño en 3D de dos robots que podrían haber participado en la edición de 2022 de la competición y ganar los 168 puntos que diseñamos en la estrategia, lo que nos habría colocado en una de las posiciones típicas en las que acaba el equipo de la École Centrale de Lyon (en la mitad superior de la competición).

No conseguí terminar de construir el robot Wall-E (el más grande). Pero sí conseguí construir el robot Eve y probar su funcionamiento. Además, conseguí imprimir y montar las pinzas del robot Walle-E, que era la parte más exigente mecánicamente del robot, ya que lo que quedaba por crear era una caja que sirviera de cuerpo para guardar las baterías, las placas electrónicas y otros componentes.

A pesar de no haber podido participar en la competición debido a la falta de disponibilidad de los miembros del equipo para representar a la universidad en la competición. Creo que el trabajo será muy útil para las futuras generaciones del proyecto, ya que ahora dispondrán de una base de datos más accesible y los diseños de este año son exportables a los requisitos de futuras competiciones. Eve tiene brazos básicos para levantar objetos, y Walle-E tiene pinzas de tres puntos que se adaptan a cualquier tamaño y al sujetar los objetos en tres puntos pueden levantar objetos de diversas formas.

0.6 Blibiografía

Página web del concurso : https://www.coupederobotique.fr/.
Last accessed : July 08, 2022

Página web de la edición de 2022 : https://www.coupederobotique.fr/edition-2022/le-concours/.
Last accessed : July 08, 2022

Objetivos de Desarrollo Sostenible, ONU : https://www.un.org/sustainabledevelopment/.
Last accessed : July 08, 2022

French Robotics Cup : PROJECT ABSTRACT

Author : Ferrer Sánchez del Villar, Blanca
Director : Boutleux, Emmanuel
Collaborating Institution : École Centrale de Lyon

0.7 Introduction

The title of this project is French Robotics Cup. The given title matches the title French robotics competition that takes place every year. The content of this document explains the strategy and design of the robots of the École Centrale de Lyon team for the May 2022 edition.

This document details my contribution to the team of the École Centrale de Lyon. The strategy followed by the team to obtain the maximum number of points and my doing in it, the 3D design of the robots to carry out the tasks chosen for the competition and the final result of these designs in their tangible version, is what will be explained and proven in this final degree project essay.

The main objective of the project in place is to submit functional robots suitable for participation in the French robotics competition. The aim of this competition is for robots from two teams to compete against each other in 100-second matches on a field defined by numerous rules. Teams score points by completing specific tasks. This year, the project also aims to improve the university's database of previous projects with their designs and memories.

During the project, two robots - Eve and Wall-E - were conceptualised and built. Both are controlled by ARDUINO boards and were built with LEGO and Mecano parts, as well as 3D printed parts and wooden parts made with the laser cutters of the Fablab Centrale Lyon.

This year, we decided we would not formally participate in the competition. We concentrated on developing and experimenting with techniques that could be used in the future of the project, mainly through restructuring the Wiki and understanding the programming boards and technologies proposed by the Fablab Centrale Lyon. We focused on piling up knowledge for future use and development.

0.8 Context

The French Robotics Cup *(Coupe de France de Robotique)* was created in 1994 by *Association Planète Sciences* and the company VM Productions, as both wanted to organise a robot competition in France.

Each year a set of rules are published, delimiting and marking the different tasks to be performed by the robots, the score associated with each task... Every year, the competition has a common theme for all contestant groups, this year's being "The Age of Robots" (figure 15). The design of our robots were based on these rules.

Figure 15: Logo of the 2022 edition

The project is articulated in the context of this competition. But its main objective is the development and improvement of efforts and achievements previously carried out by students who had worked on this project on the years prior. This objective can be seen in the designs that were made given they solve problems that were noticed and proposed to be taken on my the 2022 edition. Nevertheless, those changes are exportable to future designs. One of the tasks will be the improvement of the university's database, which we will call "the Wiki".

0.9 Strategy

Before starting the design of the robots we need to know what will be the strategy of the team, what tasks we want to prioritise in order to maximise the number of points. Since each game has a duration of 100 seconds, it is not possible to perform all the tasks suggested in the rules.

The set rules fill up a fifty page long document. I have attached bellow only a brief summary of what I consider to be the most important giving a general idea of the most important requisites and allowed me to set up the project's problematic, its objectives and finally the functional specifications.

0.9.1 Objectives

The game has a duration of one hundred seconds during which each team must perform a series of tasks, each of which provides a defined number of points.

The first task is to collect the different coloured samples shown in the figure 17 and transport them to the sample drop zones. There are three of these zones and the number of points obtained varies according to the position of the samples (face down or face up), as shown in the figure 16.

Area	Points	Action
Camp	1	Per sample removed from a dispenser (in the field half)
	1	Per sample in the camp
	1	Per sample face treasure + sorted in the camp
Galery	3	Per sample placed
	3	Per sample face treasure + sorted
Shelter	5	Per sample in the shelter

Figure 16: Points with respect to zones

Figure 17: Colour swatches

Next, we will have to turn around the "digging squares" located at the edge of the terrain and presented in the figure 18a. They are positioned so that they can be tilted backwards. There are three types: yellow, purple and red. They are recognisable by their colours, but also by two conductive plates connected by a resistance, which varies according to the colour of the square, the values of which are known. These resistant markers are shown in the figure **??**. A team scores five points for each square of its colour that is tilted, and five additional points if at least one of the team's squares is tilted and the red square associated with the team is not.

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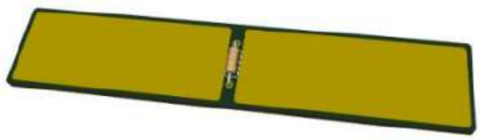
(a) Position of the excavation squares



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(b) Resistivity marker

Figure 18: Excavation squares

0.9.2 Restrictions

Robots must respect a number of constraints. These are divided into two, static and dynamic requirements. These conditions must be verified in order for the robots to be able to participate.

The dynamic requirements are as follows:

- Have an emergency stop button.
- The battery must not exceed 48V.
- The robot must not make contact with another robot
- The robot starts with a starter cable that must be at least 50 cm long.
- The robot shall stop after 100 seconds of play.

Static conditions are described below:

- The height must be less than 35cm and the emergency stop button can go up to 37,5cm (excluding the pole for the beacon).
- The beacon holder should be as opaque as possible (with large flat surfaces) so that the sensors can locate the robots.
- The robot should have a blank side 10 cm by 7 cm for cup and sponsor logos.
- The robot must have a beacon holder with an area between a circle with a diameter of 7 cm and a square with a side of 10 cm.

The robot must also respect size limitations. A team can be composed of one or two robots and this choice influences the dimensions to be respected. These dimensions determine the perimeter of the robot. In addition, a robot can have articulated arms that can vary this perimeter, the rules then give size conditions for the "Unfolded" robot and the "folded" robot. These conditions are detailed in the following table:

	Perimeter not folded	Perimeter folded
one robot	<= 1200 mm	<= 1300 mm
Two robots	A+B <= 2050 mm	A+B <= 2200 mm

Table 2: Robot perimeter conditions

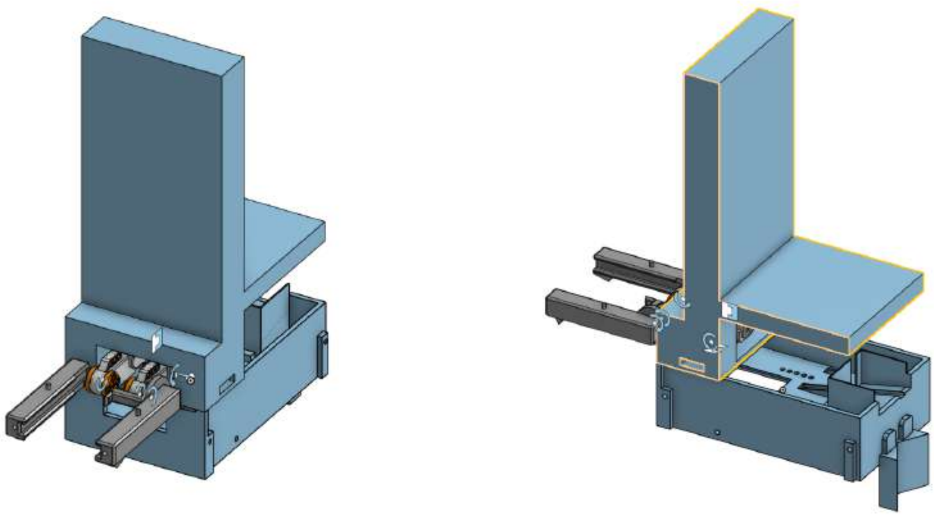
Also note that the projection on the robot table must fit completely within its initial area, which again imposes a shape constraint.

0.10 Development and results

0.10.1 Eve

The robot Eve, is the smaller of the two designed robots. For the design I started by creating a general shape of the structure, a rough draft. From this draft I created the precise structure of the robot in OnShape. The interest of this stage was to have a shape, and to think about how to attach and arrange the different electronic and mechanical parts we already had. These parts are, for example, the motors, the batteries, the programming board, the wheels, the gears, the beacon and the wheel axle.

The part to be built is composed of a box that will be the body of the robot (figure C.1), the tower (figure C.2) and the arms (figure C.3) (Figures in the annex C).



(a) View 1 (b) View 2

Figure 19: Theoretical assembly

The construction part of the project evolved over the course of the year. The first idea was to 3D print all the different pieces (after designing them in 3D CAD). First we printed the central body of the robot.

The body

Eve is a "small" robot. Therefore, it has a very important size restriction. The size of the robot must be reduced to a minimum and at the same time have enough space to house all the electronic and mechanical components of the robot.

Eve's central piece is very big and it took a whole day to fully print. In addition, we had to divide it into three parts to limit the amount of material needed for printing. The three parts are the upper part, the lower part and the carriage of the robot. However, the printing process is still very long, and the result of the 20a figure is not very adaptable to the modifications that would have been necessary as the result was not adequate (measurement errors that added up). This first version was not usable. Instead of changing the 3D version and reprinting the part, I decided to change the system and use laser cutters and make the structure with wood.

This new solution had the advantage of being extremely fast compared to printing and wood is much more malleable. In fact, drilling a hole in it, gluing it or sawing it is much easier. It took three jets to get a structure that suited us, i.e. a solid structure with the right dimensions, where the pieces fit together perfectly.

(a) 3D printing version

(b) Second version with laser cutter

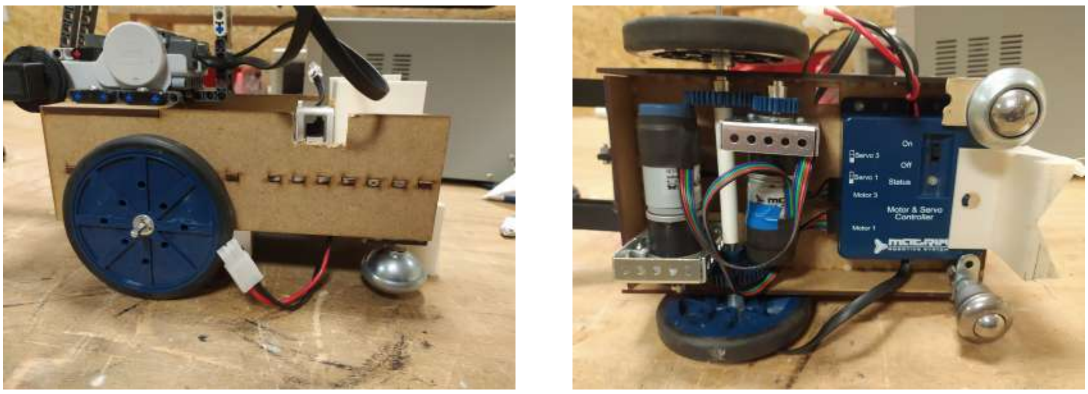
Figure 20: First versions of the body

The final version of the body required some adjustments, but these were no problem due to the ease of handling the wood. For example, drilling the holes to screw the mast. It was decided to 3D print some of the pieces because they did not exist within Legos, and they had a 3D structure and not a 2D structure (therefore not feasible with the cutting machine). The printing of these pieces only took a few hours. They are :

- The holder for the infrared sensor
- The trolley at the back of the robot
- The storage bracket for the relic
- The stabiliser

The stabiliser is a hollow cylinder with an inner diameter of 5 mm, an outer diameter of 8 mm and a length of 8 cm. The diameter is designed to surround the wheel axles without friction. The size is very large in relation to the diameter to ensure the best possible pivot connection. It is not attached to the body but to the wheel axles. Its purpose is to guarantee the coaxiality of the wheels without losing engine power due to friction and to avoid hyperstatic wheel positioning. The stabiliser is visible in white in the figure 21b between the two motors.

The final version of the body is shown in the figure. You can see that side bearings are used to make the robot structure stable during movement (rather than the two wheels). In the end, I had to put two of them when one would have been enough because there was no space to put it in the centre at the back due to the carriage and the MATRIX controller.



(a) Side view (b) Bottom view with electronic assembly

Figure 21: Final version of Eve

The tower

Due to the rules of the robotics cup, it is necessary to have a pole to hold a support for the beacon. For the construction of the bracket, I have used LEGO and divided the construction into two parts: the base bracket on the electronics board and the straight bracket. This part is also a holder for the emergency stop button.

The project of 3D printing the mast was quickly abandoned because the part was too big. In addition, no particular alignment constraints had to be taken into account. The final structure is shown in the figure 22.

This part of the robot supports the Arduino board and its EVShield, the beacon and the Lego motors that activate the arms.

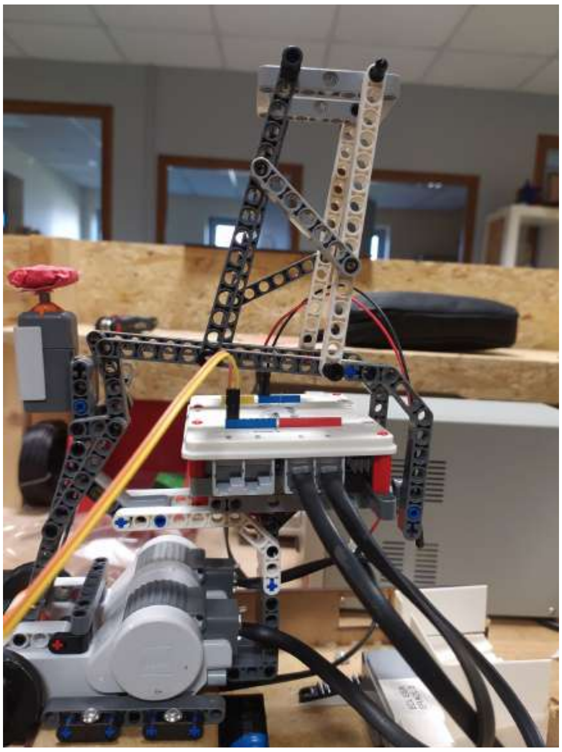


Figure 22: Final design of the tower

Due to the asymmetry of the electronic board, we had to build an asymmetrical structure to allow the two horizontal pieces of the LEGO to be coplanar.

To make the beacon support as parallel to the ground as possible, I used four long Lego pieces for the vertical support and two side pieces to prevent the structure from rotating and make it isostatic.

The arms

The arms had no mechanical technicalities, it was only necessary to dimension some aspects of their use. Besides, the first version of the figure 23 was well dimensioned, so I kept it.

- The upper stops to hold the miniature.
- The bottom stops to push the hexagons in
- The holes to put the cables that serve to measure the tension of the squares of the excavations
- The holes to put the Lego accessories, and their good placement so that it is coherent with the holes of the Lego motors.
- The bar to screw the two arms together so that they are facing each other


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Figure 23: Final result of the arms

0.10.2 Wall-E

Wall-E is a bigger robot compared to Eve. Its main task during the competition was to pick up the hexagonal samples placed in different positions: horizontal on the floor, horizontal on a platform and in a 60° inclined position. In addition to collecting these samples, the robot had to store them in order to optimise the time and maximise the points obtained.

The grippers

Following these points, I looked for a mechanical solution that would achieve these objectives. I opted for an arm that grips the samples by pressing the outline (1.5 cm thick) at three points, picks up the samples, flips them over, drops them, grips them again (they flip over) and then places them in their final position.

The FIGURE 24 shows schematically how this sample management is done. We see the dark area of the sample representing the treasure side, which is originally upside down and at the end upside down. A hollow actuator in the centre of the sample is used to drop the sample. Note that we will need a snap-grab actuator, two motors for the arm and two motors for the movement of the robot, which must be oriented towards the deposit area.

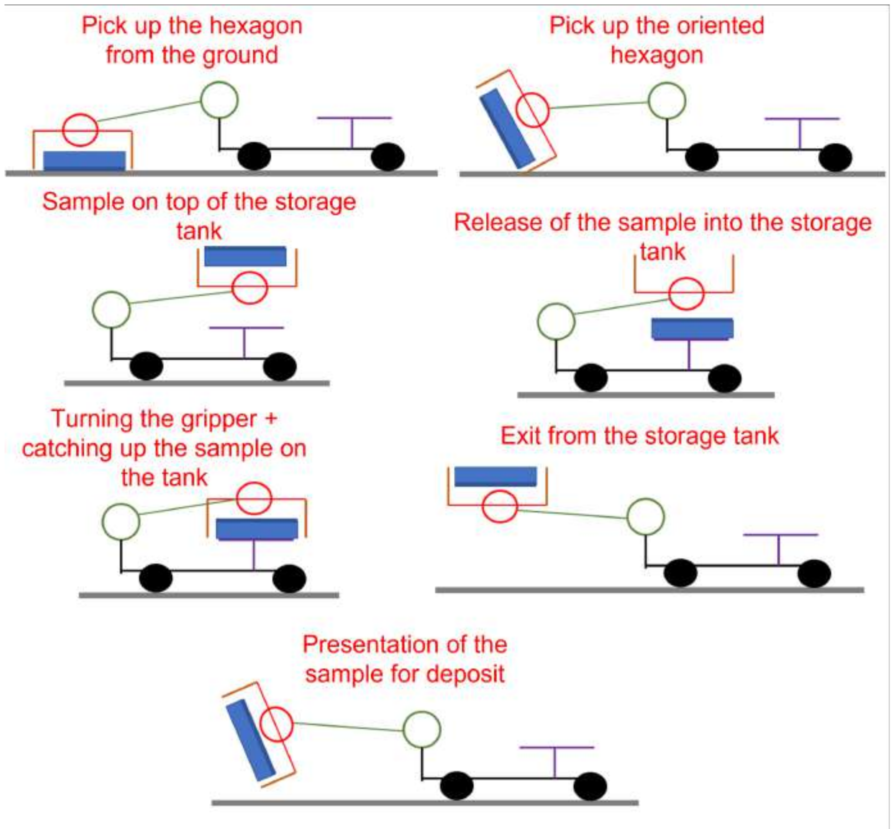


Figure 24: Sample of how the robot works

Design of the grippers

With these ideas in mind, we were first able to make some hand sketches (present in Appendix B).

Once the design was done and the outline conditions (perimeter) were maintained. I designed the parts with 3D *OnShape* and assembled them to create a 3D model of the arm to be built, study its movements and the interactions between the parts FIGURE 25.

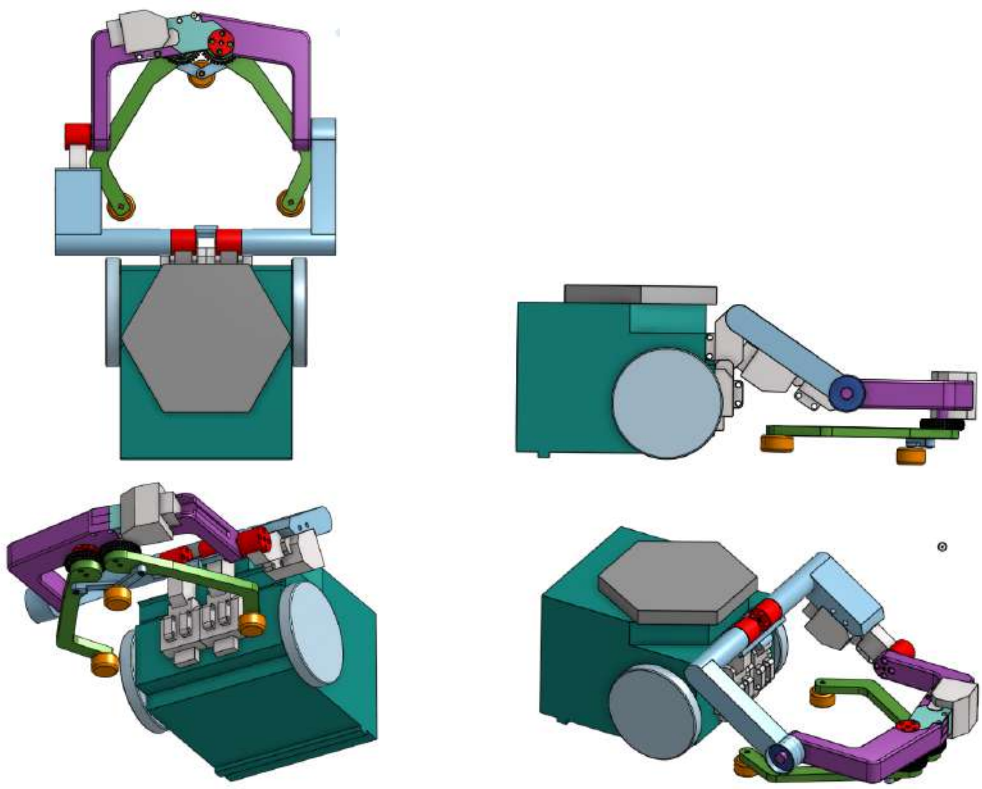


Figure 25: Wall-E 3D model

Afterwards I was able to 3D print all the pieces, redoing the blocking details with the tools provided by the *Fablab*. I then physically assembled everything (without the frame which is just a box under the arm on the robot).

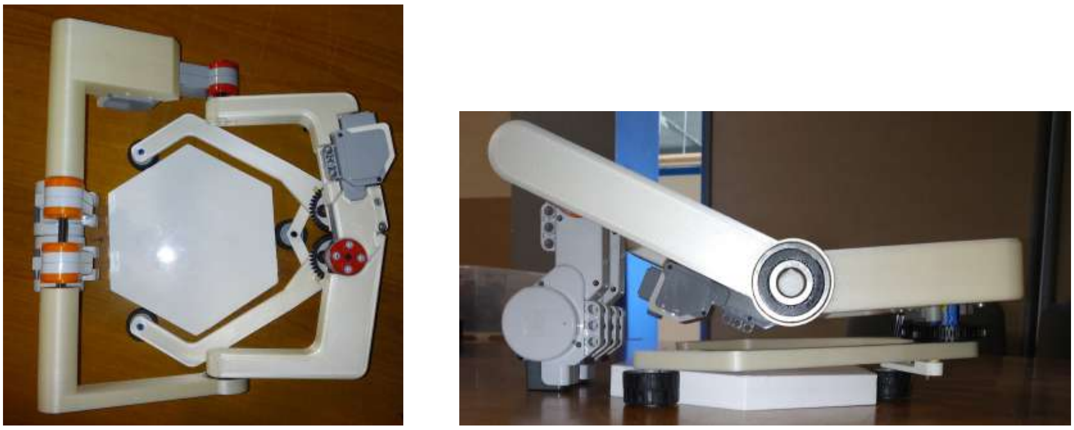


Figure 26: First version of the clamps

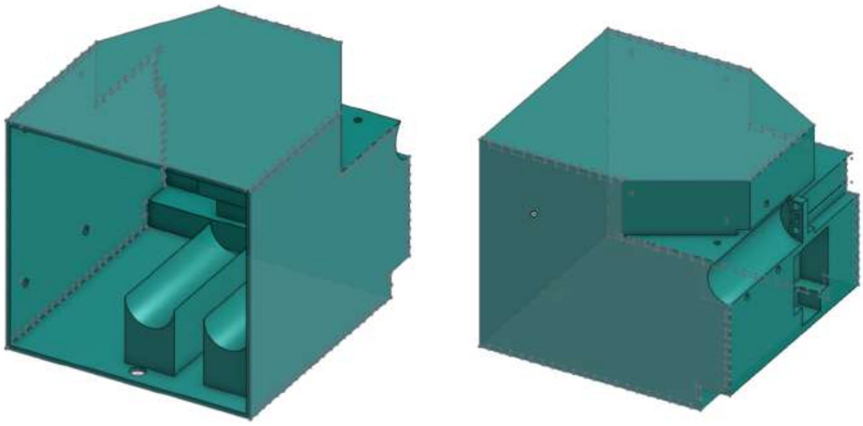
We already had the first version of Wall-E's arm which still had a lot of fitting problems to have a functional arm.

Body design

For the body design, there were several prerequisites that had to be met:

- All elements of the Arduino board, the VLSheald, the two Matrix motors and the batteries had to fit inside the body.
- It must be the right size to hold 3 samples.
- It must respect the perimeter limits imposed by the competition rules.
- It must facilitate the growth of the clamp motors.

After some consideration, I decided on the design shown in figure 27.



(a) Bottom view (b) Front view

Figure 27: Body of Wall-E

Empirical design improvement

When we first designed the grippers for the robot, we found that despite having two Lego motors in parallel, the power delivered by both was sufficient to lock the arm but not to lift it.

To overcome this problem of torque at the arm input, I opted to use a *Matrix* motor (which has a high torque) to control it. All the available *Matrix* motors were used for the drive wheels of the Wall-E and Eve robots. There was one extra motor left, but its incremental encoder is broken, which is a problem for controlling the arm. So I opted to put a *Lego* motor to be used as a position sensor in parallel with the *Matrix* motor to be used for power.

Next, I modified the 3D format of the robot to add the *Matrix* motor to the structure. I removed a Lego motor and added gears to transfer the rotation of the motor shaft to the arm. I also opted for a wooden part to reduce the weight, part production time and budget of the new arm part. This made the build more cost-effective than the 3D printed equivalent.

We can see the new arm configuration in the FIGURE 28, the *Matrix* motor is not shown with its gearing, but there is a predisposition in the frame to fix it.

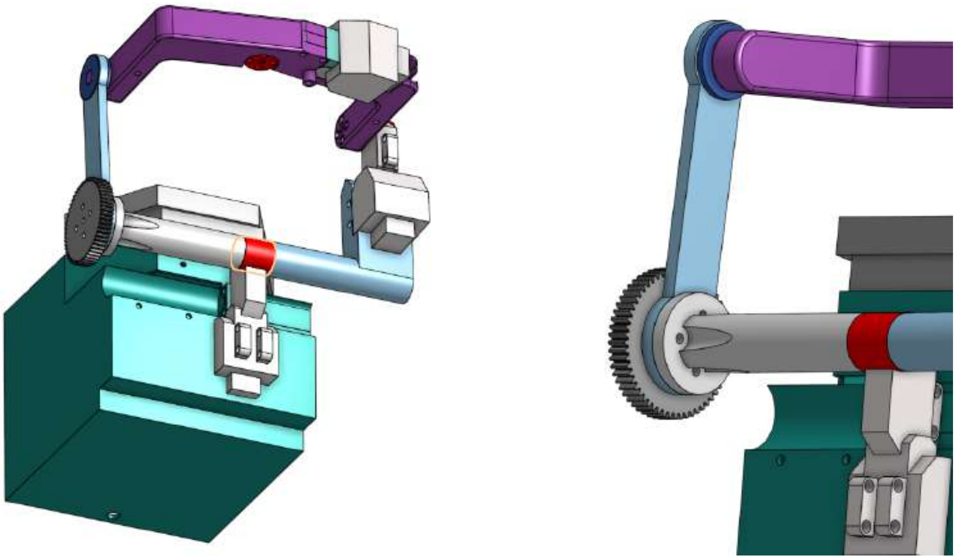


Figure 28: Second version of Wall-E's 3D arms

0.11 Conclusion

With this project we have managed to build a more intuitive database and design with the help of 3D printers two robots that could have participated in the 2022 edition of the competition. According to our calculations, our robots would have won up to 168 points, meaning it would have placed us in the top half of the competition, which is were the École Centrale de Lyon's team typically ends up in.

Walle-E, the biggest robot, unfortunately was not finished. Nevertheless, Eve was and I was able to test its great performance. I also managed to print and assemble the grippers of the Walle-E robot, which was the most mechanically demanding part of the robot. What was left to create was a box that would serve as a body to store the batteries, electronic boards and other components.

Despite not being able to participate in the competition due to the unavailability of the team members to represent the university in the competition, I believe that the work we have done will be very useful for future generations working on the project. They now have a more accessible database. Moreover, this year's designs are exportable to the requirements of future competitions. Eve has basic arms for lifting objects, and Walle-E has three-point grippers that adapt to any size and by gripping objects at three points can lift objects in a variety of shapes.

0.12 Blibiography

Competition website : https://www.coupederobotique.fr/.
Last accessed : July 08, 2022

Website of the 2022 edition : https://www.coupederobotique.fr/edition-2022/le-concours/.
Last accessed : July 08, 2022

Sustainable Development Goals, ONU : https://www.un.org/sustainabledevelopment/.
Last accessed : July 08, 2022

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Acrónimos

ICAI	Insitituto Católico de Artes e Industrias
PFC	Proyecto Fin de Carrera
TFG	Trabajo de Finde Grado
ERACL	Équipe de Robotique Association Centrale Lyon

Chapter 1

Introduction

This project is integrated in the 1003 project of the École Centrale de Lyon commonly called *French Robotics Cup (Coupe de France de Robotique)* which enables the university to participate in the event of the same name. This is an opportunity for the university to demonstrate its interest on this field.

The teams representing the school generally manage to obtain a ranking in the top half of the participants, among the 150 participating teams from engineering schools and universities throughout the country. However, in previous years, the school has been unable to participate in this event due to the global health crisis of COVID19. The aim is therefore to compete again and to contribute to the school's reputation.

Figure 1.1: Logo of the competition "French Robotics Cup"

This document details the mechanical development of the university's robots. For this purpose, this document will first detail the context in which the project evolves. Then, it will go on to explain the problematic around which the project was articulated as well as the mechanical resolutions implemented. Finally, it will show the structure of the different robots built in order to fulfil the objectives of this project. Moreover, it includes a section on how the documentation goal has been met, thanks to the improvement of the existing database from previous projects.

Chapter 2

Context

The French Robotics Cup *(Coupe de France de Robotique)* was created in 1994 and is part of a common desire of the *Association Planète Sciences* and the company VM Productions to organise a robot competition in France.

Each year, a set of rules are published, setting out the various tasks to be carried out by the robots that enter the competition, together with the way points for the final score would be attributed. These events are always based on a common theme. These year's theme was "Age of Bots" (figure 2.1). The design of the robots would be based on these set of rules.

Figure 2.1: Logo of the 2022 edition

My personal project, on which this essay is based on, is part of a bigger one articulated within the context of this competition. The main objective of this bigger project is the development and improvement of achievements previously carried out by students who had worked on this project on the years prior. This objective can be seen in the designs that were made given they solve problems that were noticed and proposed to be taken on my the 2022 edition. Nevertheless, those changes are exportable to future designs.

2.1 Resources

My team and I were given access to a room located in the university campus, but due to unexpected changes, we had to change locations to carry on with the development of the project. We were notified about this change for enough time in order to recover all the materials that we were using, such as Lego components, boards Arduino and Raspberry, and Matrix motors and controllers. The previous room in which we started the project had a large table similar to the competition table from previous years, shown in the figure 2.2, but we did not remove it from the room on to the next one.

Figure 2.2: Official game table

The project was subsequently developed in another room also located in the campus, near the FabLab (university room dedicated exclusively to 3D printing, laser cutting and welding of components). This change of location to work on the project made it a lot easier create the robots as I was physically a lot closer to the required machines. As I did not have access to the competition table, the robot tests had to be carried out on normal tables.

In terms of materials, all that were in the first room but the table were to my reach. For example, I had access to the Raspberry Pi3 in figure 2.3b which served as a programming board for the robot. I also had a Arduino (seen in figure 2.3a) and many Lego figures. It was important to have access to the electronic components in order to be able to foresee the space they would require and the consequent design of the robots. I also had access to the Fablab Centrale

Lyon (figure 2.3c) for the machining of parts that I had to develop myself.

(a) Arduino

(b) Rapsberry pi3

(c) FabLab Centrale Lyon

Figure 2.3: Resources

The Wiki (the data base) was another very important resource, especially at the beginning of the year while working on the project. It brought together the effort and development that had been done in previous years regarding the same project. There were explanations of the electronic components and codes and information about communication with the programming board. This Wiki allows to learn the knowledge that I will need for this project in an accelerated way.

2.2 Local scale

Within the École Centrale de Lyon and the set requirements, this project was taken on by a group of fourteen students. We had to coordinate our efforts meticulously in order to be as productive as possible and achieve the objectives of the project, given the large sized group. Working in a group of this size has been new for most of us and it has been a major challenge. Nonetheless, being 14 students gave us the possibility to work on the field we were most interested in, and to contribute with our individual knowledge to form a better project.

Moreover, participating in this competition is part of the university's pedagogical program as it contributes in two different ways. Firstly, this project provides experience, both in project management and in the field of robotics, the area of expertise of this project. Secondly, it gives us the possibility to draw on our past experiences. We learn how to use them to our advantage and how to extract knowledge from them that will be useful for this project.

2.3 Constraints

This project has faced several limitations:

- The first limitation is temporal. We were under time pressure and only had this academic year to work on the project. There were also a certain number of milestones that we had to meet, in particular, to reach the deadlines set by the monthly meetings with the project managers.

- The second limitation is imposed by the competition's rules. Whether or not you took part in the Cup, it was mandatory to deliver robots that were fit for the Cup. Therefore, we had to respect the competition rules.

2.4 Competition rules

The rules change every year. I have used them as a basis for the functional specifications. The competition is organised as a tournament, with two teams facing each other in a 100-second match. The team that earns more points by the end of the time limit, wins. The rules give us insight on the missions that must be completed and on how to collect points. It also includes a certain number of technical constraints (dimensions) and the prerequisites to be fulfilled by the robot to be approved to be able to participate in at least one match (static and dynamic tests...). Even if there were to be no participation in any match, the constraints must be respected.

The set rules fill up a fifty page long document. I have attached bellow only a brief summary of what I consider to be the most important giving a general idea of the most important requisites and allowed me to set up the project's problematic, its objectives and finally the functional specifications.

2.4.1 Objectives

A game lasts one hundred seconds during which each team must perform a number of tasks, each of which provides a defined number of points.

The first task is to collect the different coloured samples shown in the figure 2.5 and transport them to the sample drop zones. There are three such areas and the number of points earned varies according to the positioning of the samples (upside down or right side up) as shown in figure 2.4.

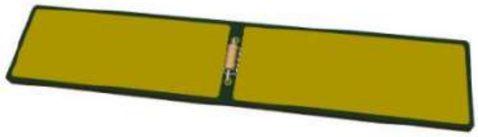
Area	Points	Action
Camp	1	Per sample removed from a dispenser (in the field half)
	1	Per sample in the camp
	1	Per sample face treasure + sorted in the camp
Galery	3	Per sample placed
	3	Per sample face treasure + sorted
Shelter	5	Per sample in the shelter

Figure 2.4: Table of points according to zones

Figure 2.5: Colour samples

Then, we would have to turn around the "excavation squares" located at the edge of the terrain and presented in figure 2.6a. They were positioned so that they could be tilted backwards. There were three types: yellow, purple and red. They were recognisable by their colours but also by two conductive plates connected by a resistor, which varied according to the colour of the square, the values being known. These restrictive markers are shown in the figure 2.6b. A team wins five points for each square of its colour that is tipped, and an additional five points if at least one of the team's squares is tipped and the red associated with the team is not.

(a) Position of the excavation squares



(b) Resistive marker

Figure 2.6: Excavation squares

2.4.2 Constraints

The robots must respect a number of constraints. These are divided into two, static and dynamic requirements. These conditions must be verified in order to approve the robots.

The dynamic requirements are the following:

- Have an emergency stop button.
- The battery must not exceed 48V.
- The robot must not make contact with another robot.
- The robot starts with a starter cable that must be at least 50 cm long.
- The robot must stop after 100 seconds of game.

The static conditions are described below:

- The height should be less than 35cm and the emergency stop button can go up to 37.5cm. (excluding the pole for the beacon)
- The beacon holder should be as opaque as possible (with large flat surfaces) to allow the sensors to locate the robots.
- The robot must have a blank side of 10 cm by 7 cm to put the logos of the cup and sponsors.

- The robot must have a beacon holder with an area between a circle of diameter 7 cm and a square of side 10 cm.

The robot must also respect the size limitations. A team can be composed of one or two robots and this choice influences the dimensions to be respected. These dimensions determine the perimeter of the robot. Moreover, a robot can have articulated arms that can vary this perimeter, the rules then give size conditions for the "Unfolded" robot and the "folded" robot. These conditions are detailed in the table below:

	Undeployed perimeter	Deployed perimeter
Single robot	<= 1200 mm	<= 1300 mm
Two robots	A+B <= 2050 mm	A+B <=2200 mm

Table 2.1: Robot perimeter conditions

It should also be noted that the projection on the robot's table must fit completely within its starting area, which again imposes a shape constraint.

Summary: Context

This project is part of the context of the *Coupe de France de Robotique*, even though if we did not formally participate. Our project set the objectives for us, mainly imposed by the rules, because were are acting as if we were participating.

In the context of continuing the work done previously (previous years with other students) within the project alongside the tutors who have been mentoring this project for some time, my personal project was born. The achievements and knowing that we could have scored points in the competition as well as our ability to build on what we have done this year marks our progress.

Now that the context has been defined, we need to determine the concrete objectives of the project and how I intended to achieve them.

Chapter 3

Background and objectives

3.1 Background

The main objective of the robotics project is to design autonomous robots on different devices (Arduino and Raspberry) for the purpose of participating in the French Robotics Cup. With this problem comes a multitude of objectives and constraints which are detailed in this report. Finally, another objective is to structure the Wiki at our disposal in order to facilitate the search for information. In any case, the inter-promotional continuity of this project is essential for the success of the future teams.

This year, we will not participate in the Cup because of the calendar (start of the engineering internships for the second year students in May), but we must have operational robots for the next cups and documented so that they can be taken in hand and easily improved by the next teams.

3.1.1 Decomposition of the project

In the next section I will explain the different decompositions of the project. Thanks to these decompositions we were able to make the synthetic GANTT of the project which can be found in the figure 4.3 in Chapter 4. It is important to mention that I will only present those decompositions that had an impact on my personal project, those tasks belonging to the programming part or to the other team of which I was not part are not reflected.

Within our project team, we decided it was best if we divided ourselves into two sub-teams, since we figured that working on a team of 14 people would constantly challenge our decision making and communication process which could potentially translate into poorer results. I was part of the sub-team made up of 6 students. We were in charge of the construction of the 2 robots with Arduino boards. And within this sub-team my task was to design the two robots taking into account the electronic elements to be used and the tasks to earn points for the competition. After the design was done there was a final phase of building the robots.

The project is therefore divided into the following decompositions:

1. **Project management**
   (a) Learning to use the previous year's robot": this first task was simply to be able to operate the robot. This is a starting point for the tutors to see our progress. Once this task is completed, task 2 can begin.
   (b) Maintaining and organizing the Wiki: this task is to be done continuously throughout the project. We will be in charge of rearranging the wiki and the previously written pages. We will also need to keep the wiki up to date while keeping it organized and readable
   (c) RVP1, RVP2 and Final defense: These milestones present the time constraints imposed by the institution. These milestones need to be prepared efficiently as they are control presentations for the directors to evaluate our evolution and work so far.
2. **French Robotics Cup**:
   (a) Organising participation in the Cup: this is the main theme of this project. However, due to the state of the robots on the deadline day for registration and the team's unavailability in May for attending the cup, we will not be able to participate
3. **Infrastructure**:
   (a) Understanding the structure of the previous year's robot: This task focuses on studying the structure of the robot and the organisation of the different components
   (b) Modelling & Building new structures for robots: the objective is to design infrastructure models that meet the specifications (weight, constraints, arrangement of components,...) so that the robots are able to accomplish the missions assigned to them
   (c) Adding sensors and actuators: once the structure has been established, the various actuators and sensors needed to carry out the missions are added

(d) Construction of the statuette: in this stage, we focus on the realization of the statuette which must be able to respect the criteria of dimensions, as well as the construction of the showcase which must accommodate it on a pedestal (the statueete and the pedestal are two specific elements chosen to gain points for the 2022 edition).

4. **Tests & Improvements**:

   (a) Testing the performance of the robots: this step consists of testing our robots in a real situation to see how they perform

   (b) Improve the robots following the test phases: this objective runs in parallel with the previous one, once the performance of the robots has been evaluated we focus on optimising the programs and structures to obtain the best possible results in the time available.

3.2 Objectives

At this point, our next objective is to identify the different functions and constraints necessary for our participation in the competition, which we will call "discriminating functions", and to realise them. These functions are independent of our scoring strategy. We have therefore drawn up a functional specification to list these discriminating functions, which we present in figure 3.1.

PF stands for Primary Function and CF stands for Constrained Function. The primary functions are the functionalities that the robots must have to be considered functionals. They are intrinsic to its operation and not to the constraints we listed earlier. These last ones come into play in the CF, which groups the functionalities that would be checked for the robot's homologation.

The notion of flexibility means how flexible or inflexible the level of assessment of the criteria is. A 0 means that no deviation from the associated criteria is allowed. A 1 means that the criteria is slightly adjustable. Flexibility is useful to know where we can play to make adjustments to the problems we will encounter throughout our project.

Functions	Explanation	Criteria of appreciation	Levels	Flexibility
PF1	Being able to move around	Accuracy	5 mm	1
		Distance	2000x3000 mm^2	0
PF2	Detect obstacles (other robots, background)	Range	> 80 mm	1
PF3	Avoiding obstacles	Safe distance	> 40 mm	1
PF4	Remote start with a rope	Range	> 500 mm	0
PF5	Having functions that earn points	Number	> 1	0
PF6	Have an automatic stop	Time	100 s	0
PF7	Braking without tipping	Braking distance	< 2 cm	0
CF1	Size of the robots within the standards	Robot perimeter	< 1200 mm at the start < 1300 mm deployed	0
		Robot height	< 350 mm	0
		Sum of the perimeters	< 2050 mm at the start < 2200 mm deployed	0
		Voltage	< 48 V	0
CF2	Have a suitable battery	Self-sufficiency	> 500 s	1
CF3	Have a reasonable preparation time	Time	< 180 s	0
		Emergency stop button	See Cup's rules	0
CF4	Have the required accessories	Beacon support	See Cup's rules	0
CF5	Easy to show its mechanism	Number of dismantling steps	3	1
CF6	Have a blank flat space on one side	Size	> 100x70 mm^2	0

Figure 3.1: Specification of requirements

Summary: Objectives

We have established the different objectives that we have set ourselves in order to be able to take part in the competition. These objectives can be presented in the form of a functional specification listing the **"discriminating functions"** of our project. These specifications are presented in figure 3.1.

Having set the objectives, it is now necessary to present how they can be achieved. To do this, we had to define the following strategies: first the organisational strategy and then the independent strategies of the robot teams

Chapter 4

Strategy

4.1 Finance

The expenses for the robot were mainly the materials needed to manufacture the different parts: the plastic from the 3D printer and the wood from the LASER cutter, as well as the robot's extensions (camera for example).

Most of the materials used for this projects came from the Fablab: PLA (80 euros) for 3D printing, which is necessary when the parts are too complex and cannot be made with the laser cutter; PMMA for the plexiglass of the showcase; and finally medium (180 euros) for the laser-cut wooden boards used for the robot's box.

	Spent
PLA	90 €
Pmma	80 €
Medium	100 €
Raspberry	60,02 €
Camera	27,90 €
Total	358 €

Figure 4.1: Finance

The funding of this project was made by the ERACL association, part of the École Centrale de Lyon.

4.2 General organisation

This part concerns the organisation adopted by the team during this year. Two different organisations were carried out in parallel, in order to fully meet the objectives. The first organisation is detailed in part 4.2.1 Responsibilities n which some members are responsible for the coordination of important tasks. The second organisation was created in order to be able to present two teams on the day of the competition. The latter is detailed in the section 4.2.2 Arduino team.

4.2.1 Responsibilities

The responsibilities were first established and then distributed among the different team members. In order for this distribution to be in line with the objectives set, it was decided not to leave any student without at least one responsibility. The figure 4.2 details the team's organisation chart.

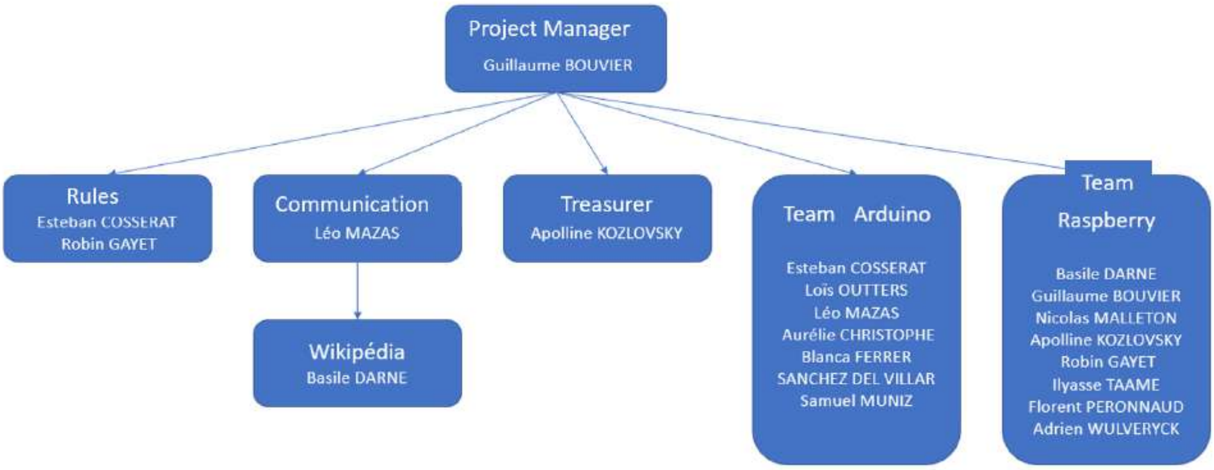


Figure 4.2: Distribution of roles

4.2.2 Arduino team

I will only explain the organisation of the team of students who were working on the Arduino team, as I belonged to it.

The second team consists of the two robots Eve (the "small" robot) and Wall-E (the "big" robot). The "big" robot is in charge of going to the front of the field to look for samples in the common area between the two teams. The "small" robot is in charge of retrieving samples near the starting area, lowering the digging squares or retrieving the relic.

This group was organised as follows :

- Léo is the Project manager of the Arduino Team
- Loïs, in charge the good working of the arduino library for the use of the block *Matrix*.
- Aurélie, in charge of the programming of the lego motors and *Matrix*.
- Blanca, in charge of writing, the documentation and the 3D design of the Wall-E's and Eve's robot parts
- Samuel, in charge of the assembly of Eve.
- Esteban, in charge of the chosen strategy, the assembly of Wall-E and the management of the sub-group.

Summary: Strategy

In order to carry out this project in an optimal way, the team decided to run two different organisations in parallel, one concerning the general organisation of the group and the other internal to the teams, allowing each of them to develop their own skills and bring their maximum to the group.
The simplified GANTT for my part of the project can be seen in the figure 4.3.

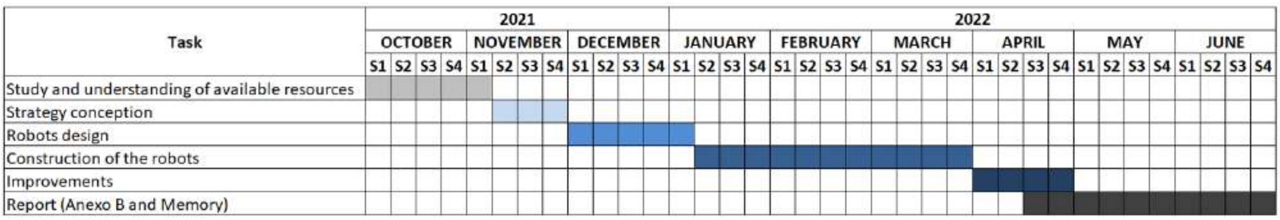


Figure 4.3: Simplified GANTT

The strategy used to achieve the objectives has now been presented. The remainder of this document therefore focuses on detailing how this strategy was implemented, describing the general structure of the robots and their strategy in play.

Chapter 5

Wall-E et Eve: Strategy

This idea of optimisation was first done by making the simple choice of which robot does which task, and how many points it earns. This distribution is presented in figure 5.1.Robot 1 being Eve and robot 2 being Wall-E. In addition, we studied the order of movement of the robots on the board, which is represented in figure 5.2.

Robot	Mission	Number	Points
1. Eve	Put 3 samples in the shelter	1	18
	Put the statue in the gallery (functional) + the relic on the pedestal	2	39
	Pushing the excavation squares	3	25
2. Wall-E	Collect 12 samples	4	6
	→ Put 9 samples, sorted, face up on the gallery	4'	54
	→ Put 9 samples, sorted, face up on the camp	4''	6
1 & 2	Finish the game with robot 1 in the camp and robot 2 in the excavation area	5	20
Total			**168**

Figure 5.1: Number of points

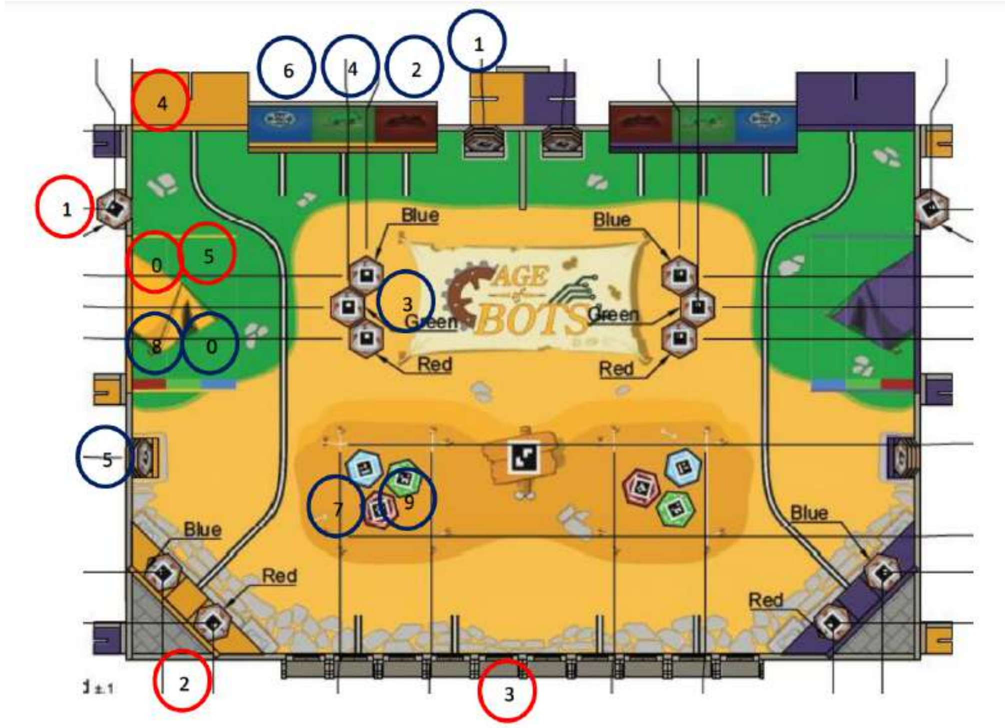


Figure 5.2: Robots' route

EVE

Eve must be able to pull the samples out of the 7 cm high location and push them under the 5.8 cm high shelter, so that three corners of a given sample are located in the shelter.

He also has to exchange the relic with the statuette. So you need a way to transport the relic, as well as a way to move the statuette. Finally, the excavation squares must be pushed while recognizing their colour (defined by the apparent resistances).

I decided to implement the majority of these features by creating two arms that are recessed between them like forks. They are close enough to each other to be able to grip the statuette that has to fit into a 12 cm cube, and wide enough to be able to pull the samples onto the pedestal with the tips provided. Their tips are conductive for measuring resistances on the digging squares, and they also allow the digging squares to be pushed. As for pushing the samples towards the shelter, it is the back of the robot that takes care of this thanks to a rake almost touching the ground and having a complementary shape to that of the samples.

Finally, the relics are stored in a sloping container at the rear of the robot. A jack or other similar solution would push the relic to place it in the appropriate place.

Wall-E

Wall-E, on the other hand, must be able to pick up the samples, store them, turn them around and place them at the various angles required.

His arm should allow him to pick up samples from the floor or from the sample holders at 60° and place them on the display case. It can also store up to three samples.

The ability to return samples, even if not mandatory, was an important feature for the team. It was indeed consistent with our desire to maximise the number of points to be performed.

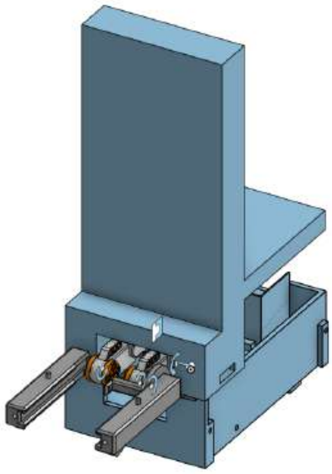
5.1 Construction of Eve

The aim of the Wall-E and Eve team was to create custom-made robots for the competition. This allowed us to have full control over the dimensions of the robots before they were built, and not have to buy back parts if we were short.

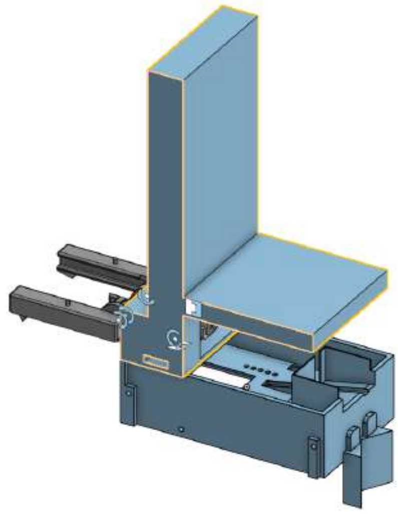
This idea, coupled with the fact that I had to work close to the FabLab (the works in the first building forced us to change rooms). So I decided to use the techniques available in the FabLab. These techniques are 3D printing, laser cutters, glues and tools. Thus I was able to really add knowledge about the FabLab tools for future students.

So I started by creating a general shape of the structure, a draft. From this draft I created the precise structure of the robot on OnShape, as if it was possible to print everything in 3D without necessarily considering different parts. The interest was to have a shape, and to think about how to attach and arrange the different electronic and mechanical parts that we already had. These parts are for example the motors, the batteries, the programming board, the wheels, the gears, the beacon and the wheel axis.

The part to be built is composed of a box which will be the body of the robot (figure C.1), the tower (figure C.2) and the arms (figure C.3) (Figures in appendix C).



(a) View 1



(b) View 2

Figure 5.3: Theoretical assembly

The construction project evolved over the year. The first idea was to 3D print all the parts (after designing them in 3D CAO). First we printed the body.

5.1.1 The Body

Eve is a "small" robot. It therefore has a very important size constraint. The size of the robot must be minimised while still having enough space to hold all the electronic and mechanical components of the robot.

Unfortunately, the piece is very large and the printing took a whole day. In addition, we had to split it into three parts to limit the amount of media that would have been required for printing. The three parts being the top part, the bottom part and the robot carriage. However, the printing process is still very long, and the result in figure 5.4a is not very adaptable to modifications that would have been necessary since the result was not suitable (measurement errors that added up). This first version was not usable. Instead of changing the 3D version and reprinting the part, I decided to change the system and use the laser cutters and make the structure in wood.

This new solution had the advantage of being extremely fast compared to printing and the wood is much more malleable. Indeed, making a hole in it, gluing it or sawing it is much easier. It was necessary to do three jets to obtain a structure that suited us, i.e. a solid structure with the right dimensions, where the pieces fit perfectly.

- The first version was too small. When switching between Onshape and the printing software, a scaling factor was incorrectly taken into account
- The second version was held with screws and the alignments and parallels were not checked (figure 5.4b)

(a) 3D Printing Version (b) Second version with cutting machine

Figure 5.4: Early versions of the body

The final version of the body required some adjustments, but these did not result in any re-cutting. For example the drilling of the holes to screw the mast. Moreover I decided to print some parts in 3D because these parts did not exist in Lego, and had a 3D structure and not a 2D one (therefore not feasible with the cutting machine). But the printing of these parts only required a few hours:

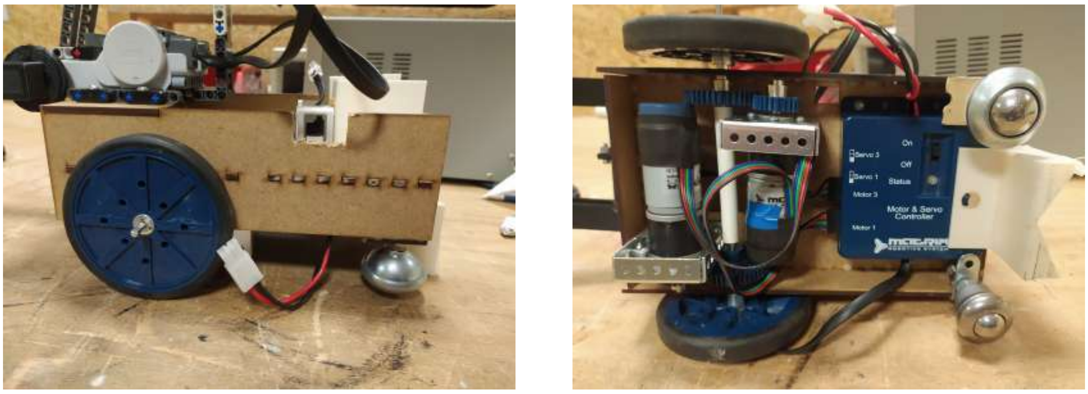
- The support for the infrared sensor
- The carriage at the back of the robot
- The storage support for the relic

- The stabilizer

The stabiliser is a hollow cylinder with an inner diameter of 5 mm, an outer diameter of 8 mm and a length of 8 cm. The diameter is designed to surround the wheel axles without friction. The size is very large in relation to the diameter to ensure the best possible pivot connection. It is not held by the body but by the wheel axles. Its purpose is to guarantee the coaxiality of the wheels without losing engine power through friction and to avoid hyperstaticity in the positioning of the wheels. The stabiliser is visible in white on the figure 5.5b between the two motors.

The final version of the body is shown in Figure 5.5. It can be seen that lateral bearings are used to make the robot structure stable during its movement (more than the two wheels). At the end, I had to put two of them when one would have been enough because there was no room to put it in the middle at the back because of the carriage and the controller MATRIX.

To attach them to the robot, I decided to use glue. However, due to some limitations of the structure, one of the bearings was not well fixed, so we decided to fix it with a metal plate and screws.



(a) Eve's side

(b) Eve's underside, and engine assembly

Figure 5.5: Final version of Eve

5.1.2 The Tower

Due to the rules of the robotics cup, it is necessary to have a pole that holds a support for the beacon. For the construction of the support, I used LEGO and divided the construction into two parts: the base support on the electronic board and the straight support. This part is also a support for the emergency stop button.

The project to 3D print the mast was quickly abandoned because the part was too big. I would have had to cut it in half and the printing time would have been much too long. Moreover, there were no alignment constraints to be taken into account in particular. The final structure is shown in Figure 5.6.

This part of the robot supports the Arduino board and its EVShield, the beacon and the Lego motors that activate the arms.

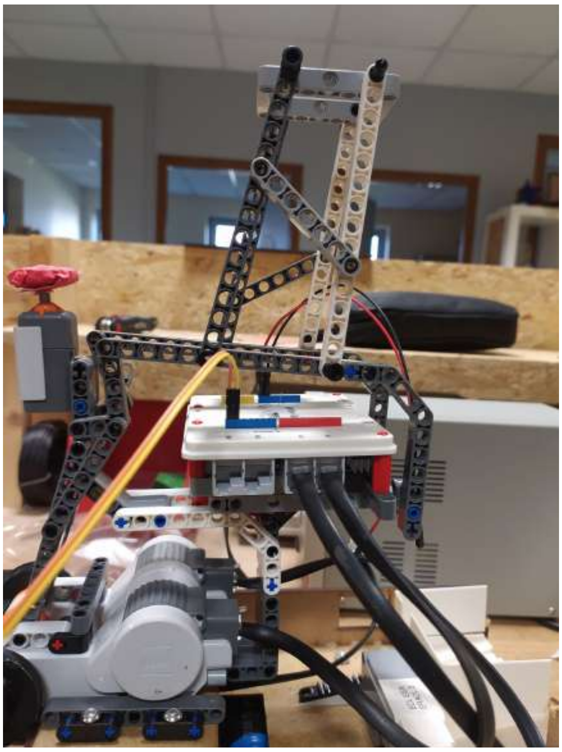


Figure 5.6: Final tower

Due to the asymmetry of the electronic board, we had to build an asymmetrical structure to allow the two horizontal pieces of LEGO to be coplanar.

To allow the beacon support to be as parallel to the ground as possible, I used four long lego pieces for the vertical support and two side pieces to prevent the structure from rotating and make the structure isostatic.

5.1.3 The Arms

The arms did not present any mechanical technicality, it was just necessary to dimension some aspects of their use. Moreover the first version in figure 5.7 was well sized, so I kept it.

- The upper stops to hold the miniature
- The lower stops to be able to push the hexagons
- A hole for the cables used to measure the tension of the squares of excavations
- The holes to put the Lego attachments, and their good positioning so that it is coherent with the holes of the Lego motors
- The bar to screw the two arms together and ensure that they are face to face

Figure 5.7: Gripper

5.2 Construction of Wall-E

As will be explained below, the main purpose of the Wall-E robot is to handle hexagonal samples, so I gave priority to the design of the grippers. This means that I started by designing grippers that met the pre-established requirements, and after obtaining functional ones, I designed the robot body so that it did not exceed the required diameter and make it impossible to use the grippers.

5.2.1 Objectives of Wall-E

The first step for this robot was to define well the specifications of its actuator to try to find the simplest solution. Its main task was to take samples from the dispensers (5 et 1 FIGURE 5.2) or from the floor (er et 9 FIGURE 5.2) and place them on the exhibition gallery (2, 4 et 6 FIGURE 5.2) or at the camp (0 et 8 FIGURE 5.2).

To do this we needed a way to capture and deposit these samples in different non-parallel planes, furthermore, to maximise the number of points we wanted to be able to flip the samples, the majority of which were originally rock-faced and had to be deposited treasure-faced in the correct area to get all the points. The figures FIGURE 5.8 and FIGURE 5.9 represent the expected final state of the gallery and the camp, given that the gallery is on a 60° incline.

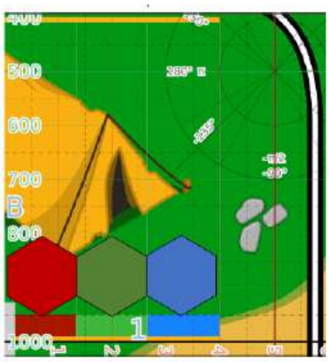


Figure 5.8: Final state in the the camp

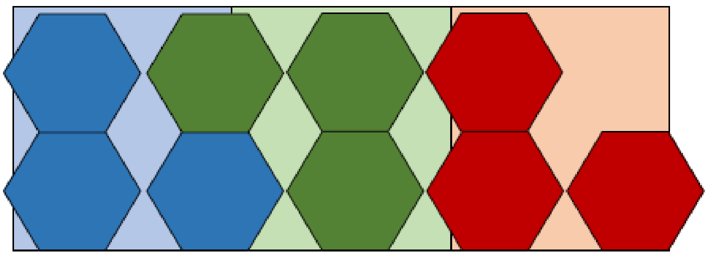


Figure 5.9: Final state of the gallery

5.2.2 Arm choices

Following these points, I looked for a mechanical solution that would achieve these objectives. I opted for an arm that grabs the samples by pressing on the contour (1.5 cm thick) at three points, picks up the samples, turns them over, drops them, grabs them again (they are then turned over) and then places them in their final position.

To save time during the competition (we only have 100 seconds the match), I decided to deposit the samples on the robot which will be able to store up to three samples before returning them.

The FIGURE 5.10 shows schematically how this sample management is done. We see the dark area of the sample which represents the treasure side, which is originally face down and at the end face up. Dropping the sample involves a hollow actuator in its centre. Note that we will need one pressure grip actuator, two motors for the arm and two motors for the movement of the robot which should face the deposit area.

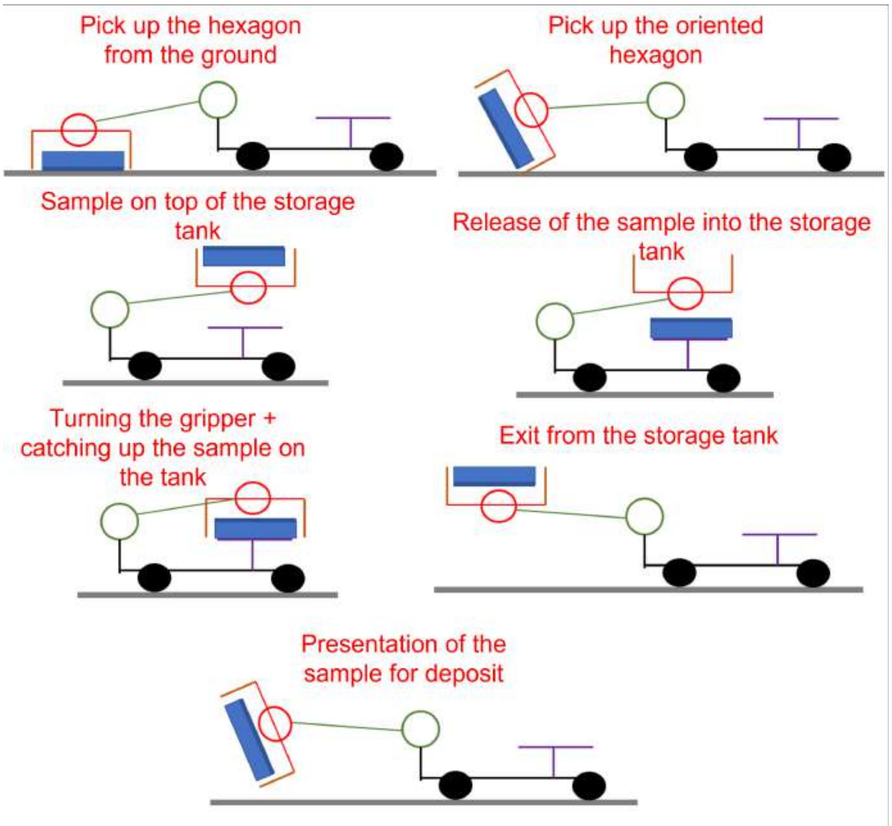


Figure 5.10: Sample management protocol

Another difficulty encountered when picking up the samples in the dispensers is that they are closed at the bottom. Our actuator would have to be open to catch them. One of the last constraints that we imposed on ourselves, as a team, for economic reasons was the use of Lego actuators available in the project room and used in large quantities in the Coupe de France de Robotique project every year. These motors are large and quite heavy, and I considered that putting mechanical power transmissions to lighten the arm at the end would be too costly in terms of design time to finish the robot in time for the cup. So I decided to attach them directly to their operating axes.

5.2.3 Arm design

With these ideas fairly clear, we were first able to make some hand sketches (present in the Appendix B).

Once the design is done and the boundary conditions (perimeter) are maintained. I designed the pieces with *OnShape* ein 3D and I assembled them to create a 3D model of the arm to be built, study its movements and the interactions between the pieces FIGURE 5.11.

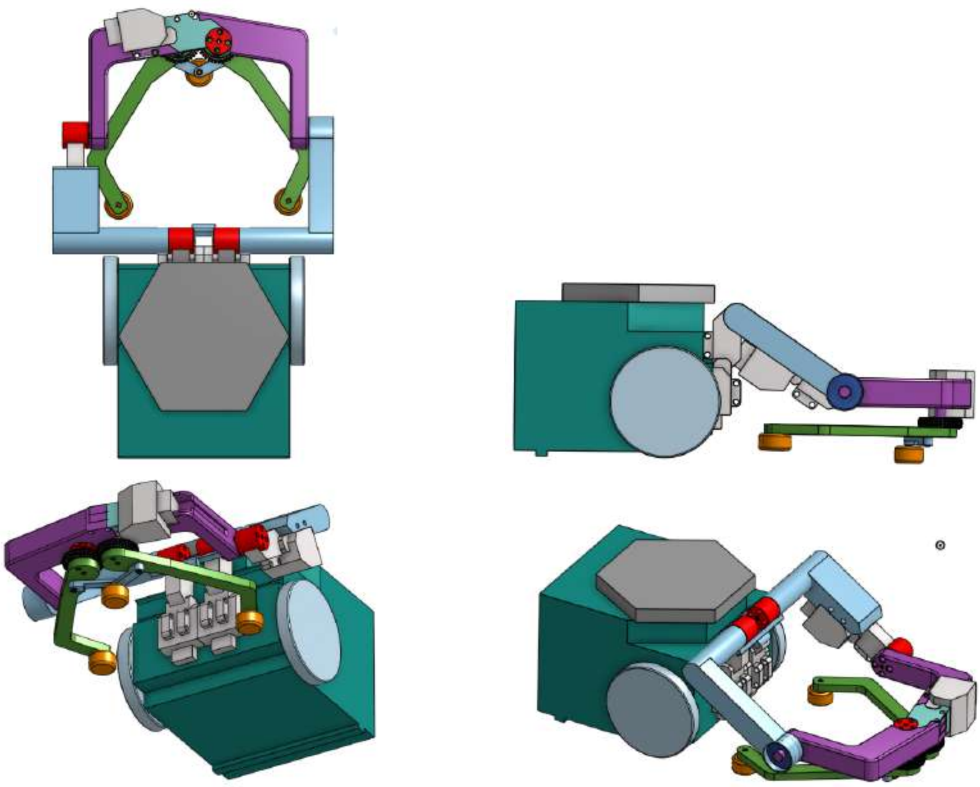


Figure 5.11: Wall-E 3D model

I was then able to 3D print all the parts, rework the blocking details with the tools provided by the *Fablab*. Then I physically assembled everything (without the frame which is just a box under the arm on the robot).

Figure 5.12: Bras Wall-E first version

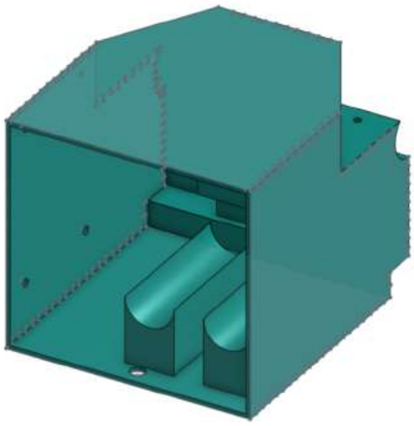
We now have the first version of Wall-E's arm which still has many problems to adjust in order to have a functional arm.

5.2.4 Body design

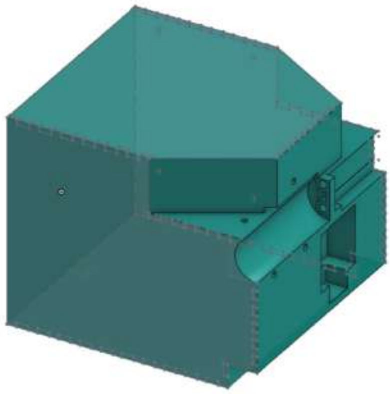
For the design of the body, there were several criteria that had to be met:

- All the elements of the ARDUINO board, the VLSHEALD, the two motors MATRIX and the batteries had to fit inside the body
- It must have the right size to hold 3 samples.
- It must respect the perimeter limits imposed by the competition rules
- It should facilitate the growth of the clamp's engines

After some consideration, I arrived at the design shown in FIGURE 5.13.



(a) Body seen from the back



(b) Frontal view of the body

Figure 5.13: Wall-E Robot Body

5.2.5 Empirical improvement of the design

I corrected the fine errors that were preventing assembly (tolerancing errors that prevented the different parts from fitting together) by sanding the parts where necessary, and identified the problems to be solved in the current situation:

- For the clamp (green part on the FIGURE 5.11), the motor has sufficient torque but the Lego clamp system that carries the clamps is too unstable and does not ensure that the clamp does not fall off during the manipulation of samples

- For the body (purple part on the FIGURE 5.11) apart from a little sanding to allow the motor to fit in correctly, there was no need to make any alterations. The motor that controls the body has a sufficient torque, we were not able to do a test with a worn sample, but its position makes a big dispersion of mass that could be a problem when controlling the robot frame

- For the arm (blue part on the FIGURE 5.11), the engines are not powerful enough, even when coupled. So this part of the plan had to be redesigned

To overcome this problem of motor torque at the arm input, I chose to use a *Matrix* motor (which has a high torque) to control it. All the available *Matrix* motors were used for the drive wheels of the Wall-E and Eve robots. There was one extra motor left, but its incremental encoder is broken, which is a problem for the control of the arm. I then chose to put a *Lego* motor which will be used as a position sensor in parallel with the *Matrix* motor which will be used for power.

I then modified the robot's 3D format to add the *Matrix* motor to the frame. I removed a Lego motor and added gears to transfer the rotation from the motor shaft to the arm. I also opted for a wooden part to reduce the weight, part production time and budget of the new arm part. As such construction was more cost-effective than the 3D printing equivalent.

We can see the new arm configuration on the FIGURE 5.14, the *Matrix* motor is not shown with its gear, but there is a predisposition in the frame to fix it.

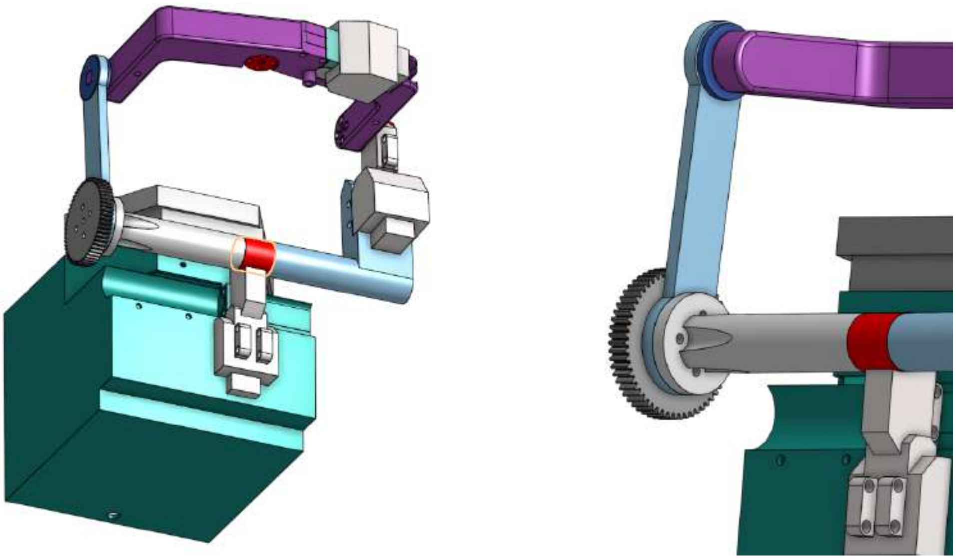


Figure 5.14: Second version of the 3D arms Wall-E

5.2.6 Update on the final state

Today, at the end of the time dedicated to the project, I am at the point where the arm has not yet been tested and the attachment with the frame has not been carried out, and therefore no sample recovery test has been implemented. Moreover, the Lego attachment between the two parts of the arm and the Lego motor is flexible and does not allow a good holding of the gear, which risks to cause jumps of step.

To get an idea of what the arm with the *Matrix* motor would look like, we quickly attached the *Lego* motor and *Matrix* to a plate and put it together.

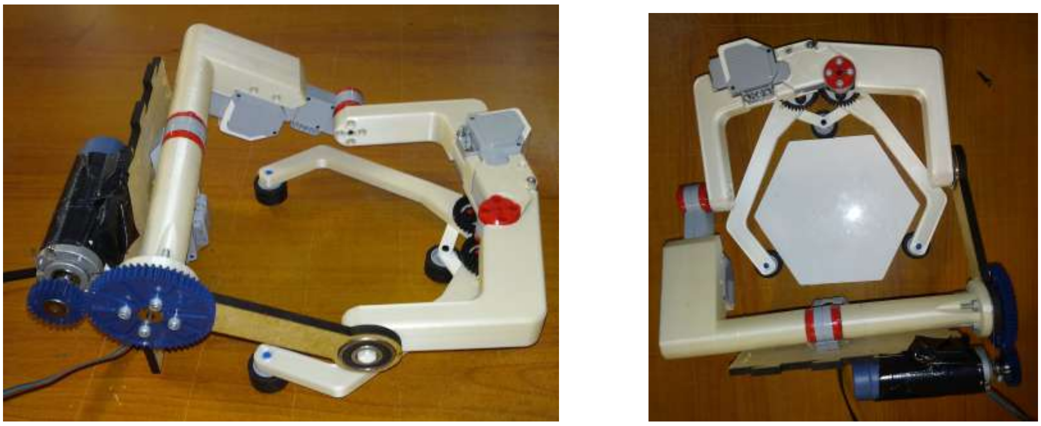


Figure 5.15: Last version of the 3D arms Wall-E

The project was ambitious with many material constraints (Lego motors and attachments) and a complex custom-made robotic arm structure for a rather short working time, which explains the unfinished final state of this robot. A lack of part control would also have held us back later, as would the lack of a second EvShield Arduino that allows communication with the *Lego* motors (the first being used by Eve). We could also have ordered a motor *Matrix* to avoid the problem of the incremental encoder on the control of the arm FIGURE 5.15.

5.2.7 Summary

Although the project was not completed, the work done was not insignificant for the design of two robots. The tasks performed for Wall-E were :

- Assimilation of the Cup rules
- Definition of a strategy and specifications for the robots
- Theoretical and then digital design of the robot tool
- Verification of the compliance of the 3D model with the specifications and digital visual tests of the desired movement possibilities (validity of the useful movements)
- Production and assembly of printed parts
- Motor power test for each connection
- Modification of the arm connection for a motor change

Thus, with more time, the project would certainly have been completed while respecting its objectives, objectives that would have been remarkable in the case of participation in the Cup.

In addition to the time spent on the various tasks mentioned above, the Wall-E robot required a certain amount of material:

- 1 *Matrix* motor (plus 2 for the chassis which has not been done)
- 3 large *Lego* motors
- 1 ball bearing
- 7 3D printed parts representing a total of over 150g of PLA
- 1 laser-cut wooden piece
- numerous *Lego* attachments
- a pair of *Matrix* gears
- 3 caoutchouc wheels (*Lego* tyres to grip the samples)

Chapter 6

Restructuring the wiki

As part of the internal communication and capitalisation of knowledge from previous years, one of the main objectives this year was to restructure and update the wiki (daya base). Indeed, the experience of the members who participated in the project last year showed that the wiki was not very intuitive to use and that some information was not up to date.

To address these issues, the first step was to analyse the information on the wiki and to identify exactly what was out of date. Then, to make the wiki more attractive, the main changes were made to the home page and the links between pages.

6.1 Redesign of the homepage

In order to make the home page more attractive, the choice was made not to put all the articles directly on this page but to adopt a tree structure as shown in figure 6.1. Another major change was to highlight the "Getting Started" (*"Pour Commencer"*) section containing essential information to get the project off to a good start, including guides to using the wiki.

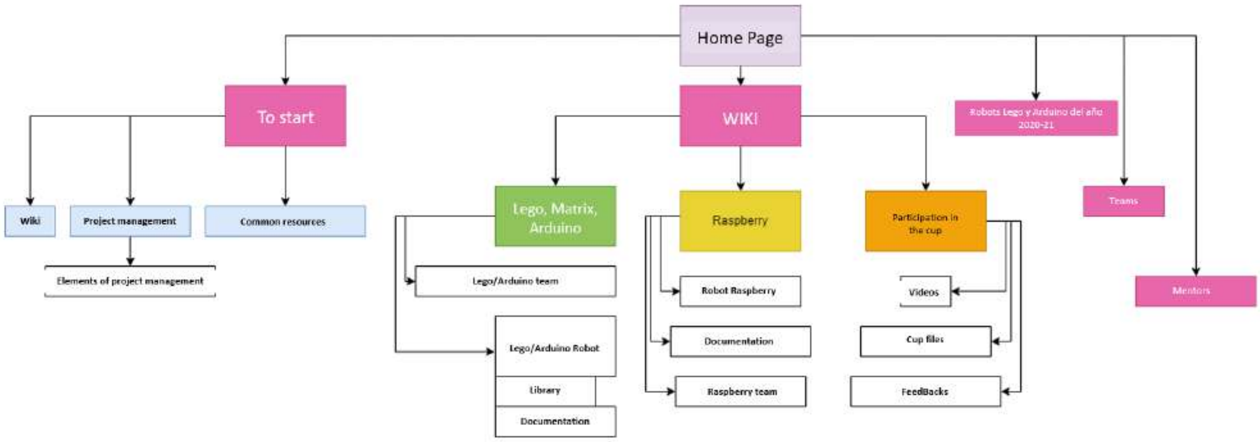
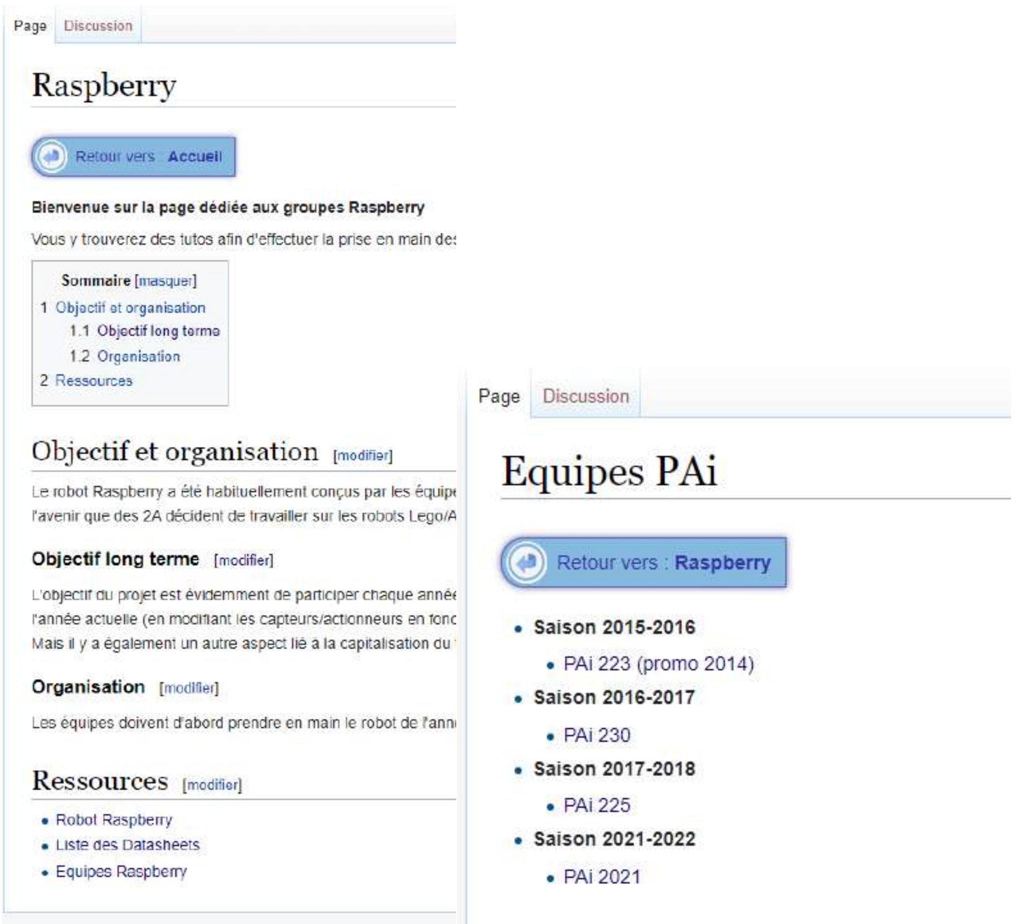


Figure 6.1: Wiki tree structure

6.2 Work on the wiki pages

As far as the existing wiki pages are concerned, three changes have been made: firstly, they have been re-read to check the validity of the information, then a link back to the previous page has been added, as shown for example in figure 6.2, in order to highlight the tree structure of the wiki and to facilitate navigation. Finally, an introductory paragraph has been added on each of them detailing the direction taken in previous years and the objective of these sub-projects. This makes it possible to better situate one's work in relation to that of previous groups and to insist on the importance of knowledge capitalisation.

It was also necessary to record the work done by this year's group, and to update some of the images, for example the photo of this year's team.



(a) (b)

Figure 6.2: Example of added backlink

Chapter 7

Conclusion

With this project we have managed to build a more intuitive database and design with the help of 3D printers two robots that could have participated in the 2022 edition of the competition. According to our calculations, our robots would have won up to 168 points, meaning it would have placed us in the top half of the competition, which is were the École Centrale de Lyon's team typically ends up in.

Walle-E, the biggest robot, unfortunately was not finished. Nevertheless, Eve was and I was able to test its great performance. I also managed to print and assemble the grippers of the Walle-E robot, which was the most mechanically demanding part of the robot. What was left to create was a box that would serve as a body to store the batteries, electronic boards and other components.

Despite not being able to participate in the competition due to the unavailability of the team members to represent the university in the competition, I believe that the work we have done will be very useful for future generations working on the project. They now have a more accessible database. Moreover, this year's designs are exportable to the requirements of future competitions. Eve has basic arms for lifting objects, and Walle-E has three-point grippers that adapt to any size and by gripping objects at three points can lift objects in a variety of shapes.

Appendix A

Harmonization with Sustainable Development Goals (SDGs)

The Sustainable Development Goals [3] elaborated by the UN that this project follows are :

- Goal 7 : Affordable and clean energies
- Goal 9 : Industry, Innovation, and Infrastructure
- Goal 11 : Sustainable cities and communities
- Goal 13 : Climate action

L'École Centrale de Lyon is a university that seeks a sustainable development of all its projects. That is why all the materials used for this project are intended to be reused from one year to the next. The ARDUINO boards, the LEGO and MATRIX motors, even a large part of the structure is kept fixed from one year to the next in order to reduce waste. In addition, rechargeable batteries are used for the robots instead of single-use batteries.

Appendix B

Sketch of Wall-E pliers

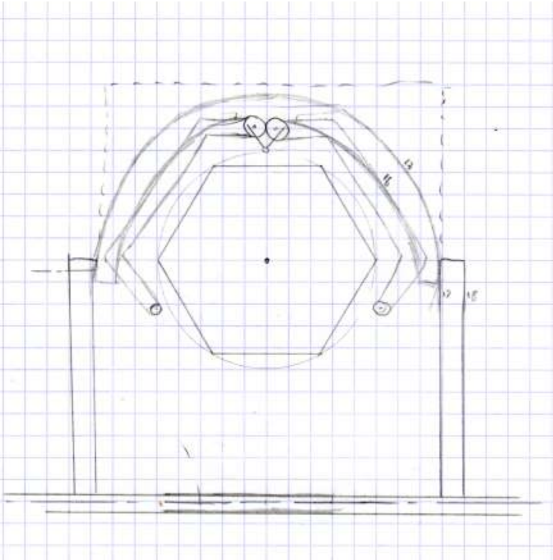


Figure B.1: Global idea sketch

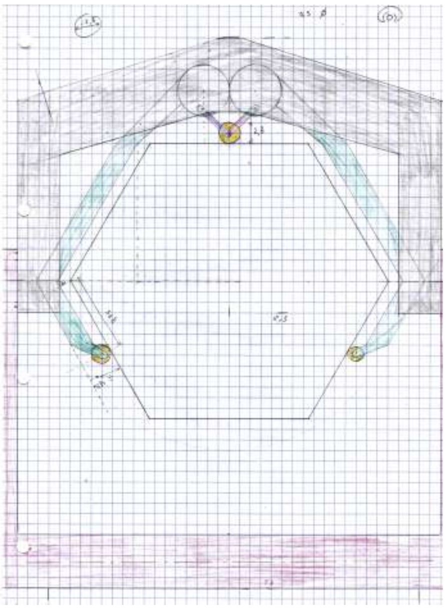


Figure B.2: Sketch complete idea top view

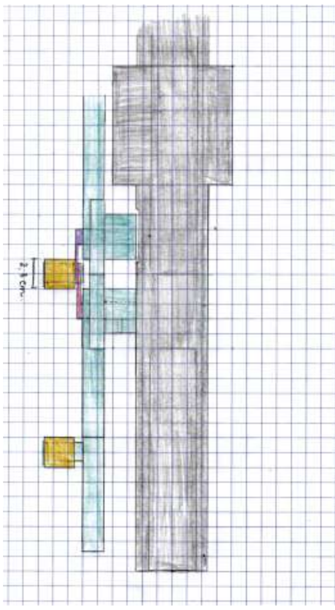
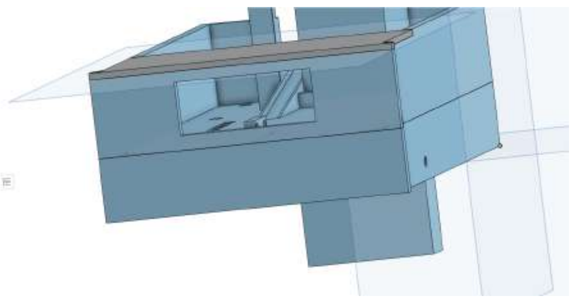


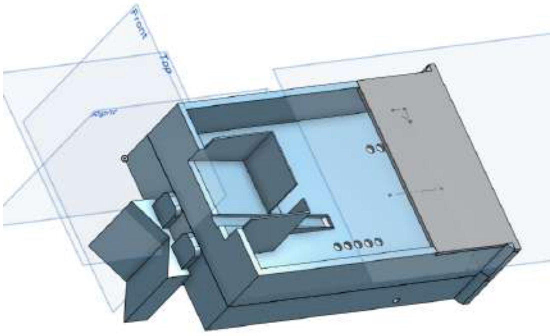
Figure B.3: Sketch complete idea side view

Appendix C

3D designs of Eve



(a) Front view of the body



(b) Top view of the body

Figure C.1: Eve's body

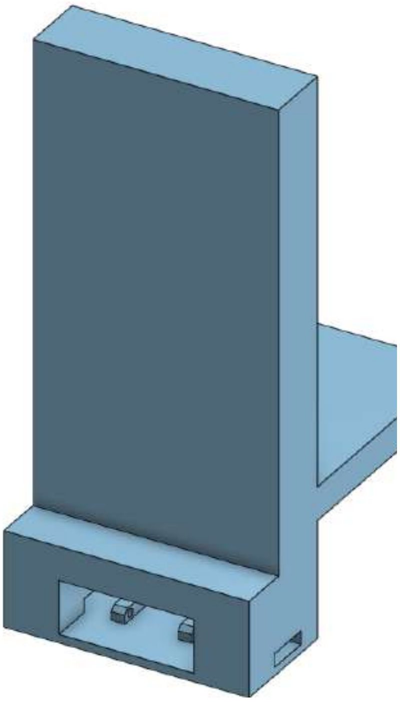


Figure C.2: Eve´s tower

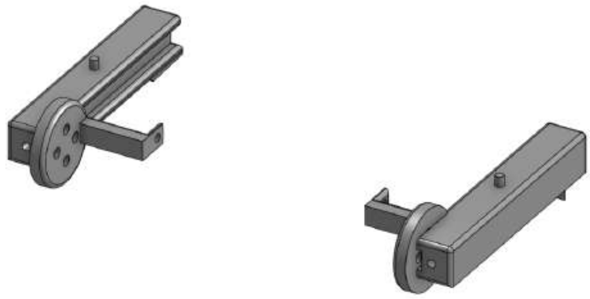


Figure C.3: Eve’s arms

Appendix D

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