DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

TRABAJO FIN DE GRADO PARA LA OBTENCIÓN DEL TÍTULO DE GRADUADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

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Index

RESUMEN DEL PROYECTO ........................................................................................................ 4
Contexto ................................................................................................................................. 4
Objetivos ............................................................................................................................... 4
Etapas .................................................................................................................................... 5
    Concepción y desarrollo de los productos ..................................................................... 5
    Concepción y desarrollo del utillaje .............................................................................. 6
Problemas encontrados ....................................................................................................... 7
Marco económico ................................................................................................................ 7
Organización del proyecto .................................................................................................. 8
Conclusión ............................................................................................................................ 8
Presentación de la Universidad de acogida ..................................................................... 9
Study Context ....................................................................................................................... 10
    Global Introduction ........................................................................................................ 10
    Chain presentation ......................................................................................................... 10
    Pallets presentation ...................................................................................................... 11
    Robots presentation ...................................................................................................... 11
    Client’s Requirements .................................................................................................. 12
Technical report .................................................................................................................. 13
    Designing the product ................................................................................................. 13
        Introduction ............................................................................................................... 13
        Criteria and restrictions ......................................................................................... 13
        Deciding on the three products .............................................................................. 13
        Design Approach .................................................................................................... 16
        Conclusion ............................................................................................................... 18
    Designing the casing of the products ........................................................................... 18
        Importance of a good product casing ...................................................................... 18
        Criteria of the product casing ................................................................................. 18
        Design approach ..................................................................................................... 19
        Conclusion ............................................................................................................... 23
    Designing the component holders .............................................................................. 24
        Introduction ............................................................................................................... 24
        Criteria ....................................................................................................................... 24
        Design approach ..................................................................................................... 24
        Conclusion ............................................................................................................... 27
Designing the support ........................................................................................................ 28
Introduction ..................................................................................................................... 28
Criteria .............................................................................................................................. 28
Design Approach .............................................................................................................. 28
Conclusion ......................................................................................................................... 30
Designing the Robotic Gripper .......................................................................................... 31
Introduction ..................................................................................................................... 31
Criteria .............................................................................................................................. 32
Design Approach .............................................................................................................. 32
Conclusion ......................................................................................................................... 36
Costs’ interpretations and calculs ................................................................................... 37
Calculus .............................................................................................................................. 38
Materials’ cost .................................................................................................................. 38
Supports ........................................................................................................................... 39
Holders ............................................................................................................................... 39
Product .............................................................................................................................. 39
Robots’ Hands .................................................................................................................. 39
Costs ................................................................................................................................. 39
Cost repartition .................................................................................................................. 40
Human cost ....................................................................................................................... 41
Conclusion ......................................................................................................................... 41
Gestion of the project ...................................................................................................... 42
Time Organization ............................................................................................................. 42
Initial Gantt and utilization final of the time .................................................................... 42
Gantt diagram utilization ................................................................................................. 42
Feedback from the experience ......................................................................................... 42
Organization of the resources .......................................................................................... 43
Final organization .............................................................................................................. 43
Feedback from the experience ......................................................................................... 43
Methods used .................................................................................................................... 44
Logiciels ............................................................................................................................ 44
Technologies ..................................................................................................................... 44
Global feedback from the experience .............................................................................. 44
Conclusion of the project .................................................................................................. 45
Future development ......................................................................................................... 45
Annex 1: Arduino Codes .................................................................................................. 47
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

Thermometer .................................................................................................................. 47
Timer with a Relay ............................................................................................................. 48
Annex 2: Arduino Scheme for trying the programming with the Arduino kit from the university....... 51
  Thermometer ............................................................................................................ 51
  Automatic Lamp ........................................................................................................... 52
Annex 3: Demand form for material purchase ..................................................................... 53
Annex 4: Specifications of the electronic components ....................................................... 54
Annex 5: CAD Models ..................................................................................................... 57
  Support ....................................................................................................................... 57
  Holders ....................................................................................................................... 59
  Casing ......................................................................................................................... 61
  Gripper ....................................................................................................................... 63
Annex 6: Information about the robots ............................................................................... 68
RESUMEN DEL PROYECTO

Contexto
El trabajo desarrollado se ha llevado a cabo para uno de los laboratorios del Departamento de Robótica del ENSE3 (Escuela de Ingeniería de la Energía, Agua y Medioambiente, perteneciente a la Universidad Politécnica de Grenoble). Dicho laboratorio es una plataforma de enseñanza donde los alumnos de tercer año de Ingeniería Mecánica de la Universidad Politécnica llevan a cabo las prácticas de la asignatura de Robótica. Durante el año pasado se trasladó el citado laboratorio a la Universidad para que estuviera cerca de los alumnos y facilitar el desarrollo de las prácticas y la adquisición de conocimientos, a la vez que se modernizó la plataforma de prototipos, cambiando los robots que estaban obsoletos. Junto con estos cambios se decidió modificar los trabajos prácticos que cada año los alumnos tienen que realizar para cursar los créditos de esta asignatura.

Dentro de este laboratorio se planteó para el curso 2016-17 el montaje en serie de unos productos a través de la programación de robots. Para ello se necesitaba desarrollar previamente los nuevos productos y a su vez terminar la cadena de montaje. Es a raíz de esta problemática donde surge mi Proyecto de Fin de Grado.

El proyecto se llevó a cabo en la Universidad “Génie Industriel”, una de las escuelas del Instituto Politécnico (INP) de Grenoble (Francia) que cuenta con una gran plataforma de creación de prototipos (el GI-NOVA).

Objetivos
Los objetivos principales del proyecto fueron los siguientes: i) diseñar y desarrollar tres productos modulables (un termómetro, una Cuenta Atrás y una lámpara automática) realizados a partir de tecnología Arduino, que pudieran ser montados en tres etapas consecutivas (debido al número de robots que hay en la plataforma). Además todos estos productos deberían incorporar un módulo Wi-Fi de forma que pudieran ser controlados a distancia. ii) diseñar y desarrollar los utillajes de los tres robots necesarios para poder ensamblar los mencionados productos.

Figura 1: Ejemplo de uno de los productos (termómetro)
Figura 2: mano del robot cogiendo uno de los componentes de su soporte
Etapas
El proyecto estuvo dividido en dos etapas correspondiendo cada una de ellas con los objetivos planteados.

Concepción y desarrollo de los productos
La primera parte consistió en el diseño y posterior desarrollo de los productos. Para ello se llevó a cabo un estudio del tipo de productos que podían desarrollarse bajo las especificaciones del cliente, buscando siempre que tuvieran una utilidad práctica. Las ideas seleccionadas para llevar a cabo el proyecto fueron un termómetro, una cuenta atrás y una luz automática.

- **Termómetro**: utilizando un sensor de humedad y de temperatura el producto es capaz de medir la temperatura del aire y encender una luz (LED) cuando la temperatura sobrepasa un valor fijado por el usuario. Se puede utilizar para avisar al operario que la máquina que está utilizando está sobrecalentándose.

- **Cuenta Atrás**: este producto enciende una luz y un relé cuando ha pasado un cierto tiempo. De esta forma se le da un aviso luminoso al operario de que el proceso ha terminado y se puede encender la máquina correspondiente a la siguiente etapa del proceso.

- **Lámpara automática**: utilizando un captador de luminosidad y un sensor de movimiento, este producto encenderá una luz cuando alguien esté en la sala y la luminosidad del entorno sea baja.

Una vez seleccionados los tres productos que se iban a llevar a cabo se hizo otro estudio para encontrar los mejores componentes para poder fabricarlos. Se buscó que fueran lo más pequeños posibles (debido a las limitaciones de espacio del proceso de fabricación en la cadena de montaje) y además que no fueran muy caros, para reducir el coste global del proyecto.

Cuando los componentes fueron encargados a la Universidad se empezó con la programación de los productos (esta parte fue secundaria ya que no era un requisito primordial del proyecto que los productos funcionaran perfectamente). Aun así se consiguió programar todos los productos con éxito. Se hizo un primer acercamiento a la programación de los productos utilizando un kit de Arduino que tenía la Universidad y posteriormente, se terminó con los componentes solicitados.

La parte más compleja fue encontrar la forma correcta de colocar todos los componentes para que los productos fueran modulables (tenía que encontrar una forma para que los tres productos tuvieran una base común). Después de hacer muchas pruebas y de encontrar la manera correcta de colocarlos hubo que soldar ciertas partes de la tarjeta Arduino así como colocar cables en su parte inferior para lograr las conexiones correctas que harían funcionar el producto debidamente. También se soldaron los conectores necesarios sobre los cuales se colocarían los componentes. Cabe destacar que estos conectores no estarán siempre ocupados por componentes, algunos quedaran vacíos en función del producto que se vaya a fabricar.

Durante esta parte del proceso se hizo evidente que si se requería que la cadena de fabricación funcionara no bastaba con desarrollar el producto, tenía que encontrar además una forma eficaz de hacer que éste se moviera sobre los pallets de la cadena de montaje para poder ensamblarlo. Es por esto que hubo que desarrollar un soporte que se colocará y fijará sobre los pallets (la fijación se hace con unas varillas metálicas que se hacen pasar por los agujeros del soporte y del pallet, y se fijan con tuercas). Este soporte además eleva el producto
evitando así las zonas conflictivas del pallet (solo se puede usar la zona central del pallet ya que la parte trasera es utilizada para colocar un chip que permite conocer la posición de la pieza durante todo el proceso de fabricación. Algo similar pasa con las partes laterales, que tampoco son útiles ya que las utilizan los robots para agarrar los pallets en las zonas de ensamblaje de los componentes). Con este soporte conseguimos no sólo una forma de fijar el producto a la cadena de montaje, sino además recuperar el espacio que habríamos perdido de montarlo todo directamente sobre la superficie del pallet. El soporte se hizo a partir de plexiglás, un material que puede resistir perfectamente los esfuerzos a los que estará sometido cuando el robot ejerza presión sobre él para ensamblar los componentes. Se utilizó el corte láser como método de fabricación debido a la simplicidad de las formas del diseño.

También se tuvo que diseñar una caja sobre la que montar el producto de manera que una vez terminando se pudiera coger todo en su conjunto evitando así que los componentes pudieran dañarse por estar desprotegidos. La parte inferior de la caja iría montada sobre el soporte previamente mencionado, y sobre ella se fijaría la placa Arduino para permitir el montaje. La “tapa” se pondrá al final del proceso de ensamblaje una vez terminado el montaje. La parte inferior de la caja fue hecha con impresión 3-D, ya que el diseño de esta parte contenía diversas alturas y ángulos complejos que imposibilitaban su fabricación con otro tipo de tecnología más rápida (el diseño fue complejo ya que la caja tenía que ser válida para todos los productos por lo que tenía que tener la forma adecuada para contener a todos los componentes). Mientras que la tapa, cuya geometría era mucho más simple, pudo hacerse de nuevo con plexiglás que fue curvado después para darle la forma necesaria.

Concepción y desarrollo del utillaje
Durante el desarrollo de la primera parte se empezaron a realizar estudios de distintos tipos de utillajes para un robot. Una primera preselección dio como resultado que las mejores opciones eran usar un sistema de agarre por absorción (utilizando ventosas por ejemplo) o una garra que simulara una mano humana. Finalmente debido al tamaño y a la forma de los componentes la solución elegida fue la de la garra. Fue en este momento cuando se planteó como el robot iba a coger los componentes para poder colocarlos posteriormente sobre la placa Arduino. Este proceso llevó a diseñar una serie de “soportes” para los componentes, que se colocaron al lado del robot permitiendo que éste pueda cogerlos con precisión.

A la hora de desarrollar estos soportes se buscó que el robot utilizara los movimientos más sencillos posibles (evitando que tuviera que llevar a cabo rotaciones para colocar los elementos debido a la gran precisión que se necesita para colocar componentes de este tipo). Los soportes se desarrollaron con la impresión en 3-D debido a sus geometrías complejas.

Para finalizar se estudió todos los tipo de garras posibles para el robot, tomándose la decisión de que una con dos dedos sería suficiente para este proyecto. Se realizó una búsqueda de los diferentes modelos en internet, y se rediseñó la garra más adecuada para el proyecto. Los distintos elementos de la garra se hicieron con plexiglás debido a su sencillez, y se diseñaron también, específicamente para la garra, los tornillos y tuercas, que se realizaron con impresión en 3-D. Por último se diseñó un soporte de unión entre el robot y la garra, la cual se abre y se cierra con el accionamiento de un rotor. Para evitar que los componentes agarrados pudieran resbalar o girar mientras están siendo trasladados por el robot, se diseñó una pieza que se coloca al final de la garra con una ranura, de manera que el componente queda perfectamente sujetado. Esta pieza además se hizo con impresión 3-D, que utiliza un material más rugoso que el plexiglás, reduciendo así el coeficiente de rozamiento entre el componente y la garra y evitando que los componentes pudieran resbalar.
Problemas encontrados

Varios problemas surgieron durante el desarrollo del proceso que hubo que ir solv...
diferentes y varios de cada tipo, el precio finalmente fue elevado. En contraposición, se puede observar que el desarrollo de la garra del robot es bastante asequible, lo único que hay que comprar es el rotor necesario para su accionamiento.

También cabe destacar que el proyecto no tiene una retribución económica, ya que tanto los productos como el utillaje del robot van a ser utilizados en el ámbito del aprendizaje, por lo que una parte importante del proyecto fue encontrar los métodos de fabricación más económicos posibles, así como los más rápidos.

**Organización del proyecto**

En el ámbito de la organización se puede observar que el proyecto era muy extenso, subdividido en dos grandes partes, que a su vez podían subdividirse en otras, sobre todo la parte de desarrollo del producto. Se realizó un diagrama de Gantt al principio del proyecto para repartir el trabajo, el cual se intentó seguir de manera más o menos exacta. Los problemas que fueron surgiendo en el proceso (como el desarrollo de los soportes) fueron retrasando el proyecto. Es cierto también que una vez familiarizada con las distintas tecnologías de creación de prototipos presentes en la plataforma y con el programa para desarrollar los diseños, el proyecto avanzó más rápidamente.

**Conclusión**

El proyecto ha abarcado mucha de las fases del desarrollo de un proceso. Parte de la fase cero (diseño de los productos y utillajes del robot) y termina con la fabricación de los prototipos. Todo esto me ha servido para poner en práctica los conocimientos adquiridos durante los años de estudio del Grado de Ingeniería desde un enfoque práctico. El proyecto está enfocado a la mecánica, pero tiene también un fuerte punto de vista de electrónica debido a la naturaleza de los productos.

Cabe destacar que además de tratar temas puramente ingenierriles, como todo proyecto tiene una parte económica y organizativa importante convirtiéndolo en un proyecto completo.

**Figura 3:** Producto terminado colocado dentro de su caja sobre el soporte y el pallet
Presentación de la Universidad de acogida

El proyecto de fin de grado ha sido realizado en la Universidad Politécnica (INP) de Grenoble (Francia), que cuenta con seis escuelas de Ingeniería cada una de ellas especializada en un campo diferente de ingeniería. Ésta universidad tiene más de 100 años de antigüedad y actualmente cuenta con más 5300 estudiantes y una plantilla de 1100 personas, entre los que se encuentran profesores e investigadores, personal de laboratorio y otro personal de apoyo.

Concretamente el trabajo se llevó a cabo para la escuela ENSE3 (Escuela de Ingeniería de la Energía, Agua y Medioambiente) donde se encuentran los laboratorios del Departamento de Robótica. El proyecto se encuentra dentro del marco de asignaturas de otra de las escuelas del INP, el Génie Industriel, que ha sido la escuela en la que he realizado mi año de estudios (esta es la Escuela especializada en Mecánica y Organización Industrial).

Esta Escuela cuenta con dos ramas de estudio, una para cada especialidad. La rama relacionada con la especialidad de Mecánica es la de desarrollo del producto, enfocada sobre todo en la fabricación de procesos, teniendo una gran importancia para ellos el aspecto económico. Es por esto que el proyecto a pesar de ser enteramente mecánico, cuanta con una parte organizativa y económica importante.
Study Context

Global Introduction
This project is separated into two parts and aims to design a modular product that will be assembled on a production chain with robots. This project will be conducted on the CIM platform, presented subsequently, for Mr. Quoc Bao DUONG and Thierry Henocque customers.

The first part of the project is therefore to take care of the design and the development of the products to be assembled. Being modular, the latter feature will depend on the components chosen for its assembly. Therefor the adaptability of the product will be more interesting than its functionality.

The second part will be to find solutions to assemble our products with the 3 robots that are on the platform. We will take care of the design of the grippers of the robots as well. These grippers must be adapted to the different components that are going to be assembled.

Chain presentation

The products assembled on this line move on the pallets that are placed on treadmills. The pallets enter the system by the outside loop n ° 1. They are then put in movement to successively face the 3 different robots through which the components of the product are assembled. To change the loop, pallets pass first through a central loop and then are pushed by automatons (in blue) on the external loops (where the robots are).
Pallets presentation

It is on these pallets where the products are going to be assembled.

The edges of the gray brackets are used during the assembled phase by robots to prevent the pallets from moving (it is where the robots will hold the pallets while the assembly process is being done).

The assembly area is limited by the required placement of a chip in the bottom part which will track the progress of the assembly of the piece on the assembly line. In the up part, the overflow is impossible because of a material constraint when changing the loop. On the sides, setting the required pallet during the assembly of the parts by the robot, prevents it to exceed.

Robots presentation

Three poly-articulated six-axis robots (detailed information about the robots can be found in the annex 6) are part of our assembly line and will enter the components of our various products and assemble them on a plate moving on the conveyor of the working platform. The articulated robot arm must be fitted with a gripping system allowing it to adapt to the seizure of the various components it will have to handle.
The grip which is the faculty or the action of grasping objects and breaks down into several aspects. For grasping being effective it is necessary that the robot has the opportunity to be placed in different positions allowing him access to the components to enter and place them at their assembly positions. It must also be able to exert pressure for the maintenance and installation of objects to manipulate. Therefore arises both issues of congestion and technological solutions to generate a pressure to the seizure of objects.

**Client’s Requirements**

**Clients:** Mr Quoc Bao DUONG and Thierry Henocque.

**Context:** In an educational setting a practical session to work on an assembly line will be offered to students in the CIM platform.

**The existing reminder:** The CIM platform is equipped with a conveyor, pallets moving on the conveyor as well as robots poly articulated 6-axis.

**Needed:** Reproduce an assembly line, in the CIM platform, using the conveyor as well as poly articulated robots to assemble a product whose dimensions are of the order of magnitude of the pallets moving on the conveyor.

**Requirements:** To respect the demand of the customer, Quoc Bao Duong, a product running right out of the chain assembly should be develop. They have to be composed by electronic elements and an Arduido plate. The product must also be able to be programmed remotely, therefore it is also necessary to use a Wi-Fi module in our product. Robots are devoid of gripping systems. So for each robot a gripper should be delivered, being able to manipulate the components of the product in order to assemble them.
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

Technical report

Designing the product

Introduction

I was tasked by the client to develop three modular products based on the Arduino architecture with the requirement being that these three products must be have a Wi-Fi module attached.

Given the scope of this project, which is that the products are to be assembled with three robotic arms, the aim was to create simple products that have practical uses, products that help us improve on the daily problems we face in life.

Criteria and restrictions

1. Each product must have a practical purpose.
2. The 3 products are to be powered by Arduino and have a Wi-Fi module attached.
3. The 3 products are to have similar components as well as similar number of them.
4. The Arduino Shield used is to be small enough such that it is suitable for use on the conveyor and pallet specified by the client.
5. The components used for the product are to be small enough such that they can be fit into the Arduino Shield.
6. The 3 products are to be modular, meaning that components can be added or removed in order for them to function differently.
7. It is to be possible to assemble the products in 3 steps as we are provided with 3 six axis robots.
8. The 3 products are to work as expected, meaning they must be within our capability to program.
9. The positions of the components on the Arduino shield are to be similar across the 3 products.
10. Attachment of the components on the Arduino Shield must be such that they are easily attached and removed.

Deciding on the three products

In order to come up with products with practical purpose, I thought about daily situations that annoys us, situations we wish that there is a simple device we can use to mitigate it.

I came up with various products that have the potential for further development. In order for selecting the three most feasible ones, a comparative table was made, in which the products were compare with respect to the list of attributes as stated on the table.
As indicated from the table above, there are three products which fulfil all the desired attributes. They are the ones we chose to develop:

1. **Thermometer with LED indicator**: Using a temperature and humidity sensor, this product will measure the temperature of the air. We are to program this product in such a way that when the temperature gets higher than the input temperature, the LED would be switched on, giving the user a visual aid indicating that the machine he is using is overheating. Since this product is modular, a buzzer or a relay could be attached should they be necessary.

2. **Timer with a Relay**: The function of the product is to have an LED light up and turn the relay on when a certain timing has passed. It can be used to give the user a visual indicator that a process is finished or it could be programmed such that another machine be started.

3. **Automatic Lamp**: This product is to detect movement and luminosity of the environment and to turn on/off the light accordingly. A timer could be attached and the product can be programmed according to the user's specific needs.
Looking at the three images at the same time we can see clearly the modularity of the product that has been explained before. The three products have the same number of connectors placed in the same positions, the only difference is the component that has been placed on those connectors. It is obvious that all the products have an Arduino Nano card and a Wi-Fi module (that was a specification of the client). Furthermore it is important to highlight that the three of them turn on a relay (component that looks like a blue box) when they are working, the reason of putting a relay in all of them is very simple: this relay is an example of all the kinds of machines that we can connect to the product and that will be turn on once the different conditions of each of the product is achieved (in the case of the thermometer the relay will be turn on once the temperature is higher than the one fixed, and this could turn on an emergency stop of the working machine or turn on a fire alarm). The rest of the components of the products are different in order to fulfil the end they were built for.

Another important remark is that the three products can be assembled in three steps. During the first one the Arduino card and the Wi-Fi module will be assembled. The second corresponds to the attachment of the rest of the components, while in the third one the cover...
of the box (explain later) will be placed. The components are placed in a different step from the Arduino card and the Wi-Fi due to their differences in the geometry (they are much thinner so they will need a gripper with a different finalisation that the Wi-Fi and the Arduino card).

I have been able to come up with different situations where these products can be useful. One situation is that we could have a device that turns off the light automatically when we are fast asleep. This device helps to save electricity and would also improve the quality of sleep. Another situation is the difficulty of maintaining the temperature of the food during simmering and we wish that there is a simple device readily available in giving us visual aids on the temperature so that we could adjust the fire necessarily or to even control the stove automatically.

Design Approach

General steps

I thought about the different situations we faced in our lives that gives us inconvenience and thought about the possible solutions, with Arduino, to improve on it. Then a list of possible products was analysed for deciding the three various products to develop as explained in the previous section.

I was able to come up with the algorithms for these products (the programming codes using Arduino can be find in the annex 1) and tested the programs using the Arduino kit from the university. Repeated iterations of debugging are done in order to have the product to work as expected.

After which, diverse ways of positioning of the different components on the shield were tested, as well as the circuitry of the product itself. After the final positioning was decided, the connectors on the Arduino Shield were soldered, which aids the attachment and detachment of the electronic components on the Arduino Shield.
Problems faced

A particular difficulty faced while developing the project was that it took several weeks to order and receive the components required to build the products. In order to deal with delay, the Arduino Kit from the university was borrowed to design the circuitry of the products and to also, design the program of the products, making sure that the algorithms are working as expected.

Furthermore, once the components have arrived, finding the ideal position for every component in the Arduino Shield was difficult. I had to consider the functionality of the components, for example the light sensor or the movement captor must face the exterior of the product to work properly.

Moreover, the common components had to be assembled in the same position across the three products, and this poses as a challenge as the components unique to a product are of varied sizes and many iterations of “trial and error” has been done to arrive at the ideal position.

I have tried to attach the modules directly on the Arduino Shield but found it was quite difficult to do so. As such, connectors have been used to aid the attachment of the components on the Arduino Shield.

There was also an uncertainty on the longevity of the product, particularly, the connecting pins of the electronic components. This poses as a cause of concern due to the repeated attaching and detaching of the components with a robot. Since the robots weren’t ready for testing the
durability of the connecting pins, I have attached and detached the components on the Arduino Shield a thousand times by hand. The results show that the connecting pins are durable enough as it could go through this test without any noticeable damage.

Machines used

For developing the product I did not need to use a lot of machines of GI-NOVA, in fact I just had to use the soldering iron in order to do some connections in between the points of the Arduino Shield, and fixed some wires between the points that needed to be connected but were far between each other. These wires where fixed on the under part of the Shield so they will not interfere with the assembly of the components. This was a consideration that needed to be taking into account while designing the casing of the product (there had to be space for the wires on the bottom part).

Conclusion

Time management was key for overcoming the lead time of several weeks of ordering the electronic components. It was crucial that I worked with whatever that was available on hand, such as designing and testing the algorithms using the Arduino Kit, as otherwise, other parts of the project would have been delayed, causing a domino effect.

The final design of the electronic part of the product gives many design cues to the product casing such as its final shape, dimension and also special factors to be considered such as the usage of a motion sensor.

Designing the casing of the products

Importance of a good product casing

The casing of the product is one of the most, if not the most, essential part of the product. Other than, first and foremost, protecting the product, the casing of the product gives the consumer an idea of the overall quality of the product and a well-built product, at least on the outside, would give consumers the added confidence in using it. For example, a MacBook by Apple is often touted as a quality product as it feels sturdy compared to a generic laptop despite having similar internal parts and computing power\(^1\).

As such, the design of the product casing has been taken very seriously as I put myself in the shoes of product developers, with the aim of selling and giving the consumers that confidence in using our product.

Criteria of the product casing

\(^1\) http://www.laptopmag.com/reviews/laptops/macbook
1. The casing has to be transparent as a motion detector is used in one of the product, the Automatic Lamp.
2. The casing has to be sturdy as it protects the product, which consists of delicate components such as the Wi-Fi module.
3. The casing has to be of a regular shape, in our case, a cuboid, as it promotes visual weight\(^2\), meaning that the product would appear heavier and sturdier.
4. There must be a way to easily open the product casing as the product is modular and users may, at time, change the modules of the product in order for it to cater to his needs.

**Design approach**

**General steps taken**

While the placement of the components on the Arduino Shield were being finalised, I carried on with the initial design of the product casing with reference to the length and breadth of the Arduino Shield. With the limited information on the final dimension of the electronic part of the product, I have carried on with designing the first prototype, a cuboid shaped casing, with a dimension of 13cm x 9cm x 8cm.

Having the general dimension of the first I decided to use the laser cutter in the fabrication of the first prototype, in which the considerations taken will be elaborated later on this report.

![Figure 10: The final prototype of the product casing](image)

Only when the final placement of the components on the Arduino Shield finalised was done, I proceed with designing final dimensions and details, which is essential in securing the electronic part of the product in the casing, on PTC Creo its fabrication, and this time, with both the laser cutter and 3D printer due to its more intricate shape.

\(^2\) Visual weight is a measure of the force that an element exerts to attract the eye. [https://www.smashingmagazine.com/2014/12/design-principles-visual-weight-direction/](https://www.smashingmagazine.com/2014/12/design-principles-visual-weight-direction/)
Problems faced

Upon finalising the positioning and design of the electronic part of the product, some problems have surfaced. The first problem is that the wires are being soldered at the underside of the Arduino Shield, as shown in the picture below. This causes the wires to be exposed, making the product unsightly due to the casing being totally transparent. Furthermore, the electronic part would not sit stably in the casing as it then, sits on the cable.
This problem was solved by creating a component to house the cables, and having a more sophisticated shape of the base such that the electronic part of the product could fit properly. Since the shape is more intricate, we have to 3D print the base of the casing as using a laser cut plastic would be infeasible then. Moreover, using a 3D printer means that the base of the casing is then, opaque, hiding the exposed cabling.

![Figure 12: Cabling at the underside of our product](image)

**Materials and Machines Used for the Prototype Fabrications**

I decided to use plastic as the primary material of the product casings as it is transparent, fulfilling criterion (1), it is sturdy since the plastic sheets at our disposal are of greater than 5 mm, fulfilling criterion (2) and it can easily be molded into a cuboid, fulfilling criterion (3).

<table>
<thead>
<tr>
<th>Laser Cutter</th>
<th>3D Printer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Precise</td>
<td>Not Precise</td>
</tr>
<tr>
<td>Can only work with sheets of material</td>
<td>Able to print different shapes</td>
</tr>
<tr>
<td>Plastic, which is transparent can be used</td>
<td>Transparent feed not readily available</td>
</tr>
</tbody>
</table>

*Table2: Comparing the usage of laser cutter and 3D printer*

As noted from the table above, a laser cutter has to be used as transparent 3D printer feeds are not readily available. Which means that criterion (1) cannot be fulfilled with 3D printer. As such, we would use a laser cutter.

A big disadvantage of using laser cutter is that it can only work with sheets and it is necessary to work around this limitation. The main idea, for fabricating the first prototype, is to attach 6 sheets of plastic to achieve the cuboid shape. We have drawn our inspiration from a simple puzzle cube, with which we would design edges on the 6 sheets of plastic and have them attached together. 5 of these sheets would be glued together, acting as a lid and the last sheet would act as the base. Since there is a base and lid system, criterion 4 is fulfilled.
As for the final prototype, it was decided to 3D print the base of the casing due to its intricate shape and it is not feasible to use laser cut plastic. Finally the laser cut plastic was used for prototyping the lid, but this time, it is done by bending a bigger sheet of plastic, using a thermal bending machine, rather than attaching different sheets of plastic as done during for the first prototype.

Rationale of the Dimensions and Measurements

For the first prototype, measurements were based on the length and breadth of the Arduino Shield as it is the largest component of the electronic part of the product. I decided for it to have a height of 8 cm to make sure all components fit as the rationale of the first prototype is to visualise the design considerations of our final prototype. The thickness of the plastic sheet used is 5 mm as it is readily available and it is thick enough such that it does not break easily.

As for the final prototype, the base was 3D printed with a thickness of 3mm. This is so as the thinnest available plastic sheets to be used for laser cutting have a thickness of 3mm and as discussed in Part 2.3.3, laser printing is a very slow process and we aim to minimise the thickness of materials to be printed as much as possible to save time. To ensure that 3mm thickness of base is sufficient, I conducted a break test where we try to, forcefully, break the 3D printed base by hand as this is done to simulate the product being used by the most abusive users. The results have shown that the base of the casing has passed the break test.
With this result, I carried on with the laser cutting of the 3mm thick plastic sheets for the casing cover. A similar test for the cover was done and also, it has survived the break test. As such, a 3mm thickness of material gives us the best balance of speed of production and durability.

Conclusion

Through the process of creating the product case, I have learnt the importance of iterative prototyping. This is evident in the final prototype being vastly different from the initial prototype. I was initially trying to decide between 3D printing and using a laser cutter and only after the first prototype was done, I learnt that a combination of both would be ideal as the weaknesses of each method could be overcome.

By understanding the importance and checking the above criteria of a good product casing, a robust casing that serves its practical purpose in protecting its inner component has not only been created, but also a casing that gives an impression a well thought and a well-built product. (The components bought for developing the products can be found in annex 3)
Designing the component holders

Introduction

Robots are not cognitive and uses coordinates when it comes to spatial tasks such as picking an object. The approach is to design a holder that keeps the different components in specific positions and orientations in order for the robots to pick them up and attach it on the Arduino Shield during the assembly process. (The information and specifications of each of the components used can be found in annex 4)

Criteria

1. The electronic components\(^3\) must be positioned such that the pins are facing down. This will ease the attachment of these components to the Arduino Shield by the robotic gripper since they need not be programmed to be rotated.
2. The holder must be able to hold the components in a fixed position.
3. The components must be placed such that it is easily detached from the container.
4. The container must be sufficiently sturdy to withstand the force applied by the robots when picking up the components.

Design approach

General steps

I have, firstly, measured all the dimensions of the components, taking particular notice of the thickness of their connecting pins. This is so as I have to fulfil criterion (1) and (2) with the holders securing the connecting pins of the components. I have also studied the components and decide on the parts which is crucial to secure as I have to minimise the materials to be printed since there are many holders for different components to be printed and, as explained earlier, 3D printing is a very slow process.

With these considerations in mind, I have, with the use of PTC Creo, created compartments in which the pins may be inserted. Holding the pin alone may not be secure enough for some of the modules, and we have created sophisticated shapes in order to keep these modules in place.

\(^3\) This refers to the components that will be connected to the Arduino shield

Figure 17: Components on their holders
I have then 3D printed these holder, test if the components fit and fulfil the 4 criteria above, and repeat iterations of the adjustment of drawing and printing procedure until the ideal holders were created.

![Flowchart](image)

**Figure 18: Process flow diagram of the design of the component holders**

### Problems Faced

The first problem that I had was taking the measures off all the components. As all of them are pretty small with some complex parts it was officially to take the exact measures, this lead at the end, to the problem that some of the models that were printed were not accurate enough and we had to repeat them.

The components used are small and with irregular shapes, making vernier callipers the most suitable tool for measurement. Furthermore, a vernier calliper has a precision of 0.01mm,
which is important as there would be some holes of precise diameter at specified positions of the product casing in order for it to be attached to the shaft of the manufacturing platforms.

Particular attention was given to the measurements of the pins\(^4\). For components with 2 rows of pins, I have taken the measurements of the combined width of the pins and the gap between the 2 rows of pins.

Another problem that had arisen was having to design the components holder without having the final prototype of the robot hand. Visualizing how a robot hand is to grip the components from their respective holders was necessary. I tried simulating the gripping process with my hands and found that gripping them with two fingers, thumb and index, was the most effective. This has provided me with the design cues for the robot hand.

\[\text{Machine Used}\]

I decided to use a 3D printer to fabricate the containers. This is so as the shapes that were designed are specific and irregular. Furthermore, the containers of the product are small, making it feasible and fast for it to be 3D printed.

\[\text{Measurements}\]

3D printers are subjected to 0.2mm of error. This means that if we were to specify the dimensions for printing as measured with the vernier callipers, the components would not fit into the holder. It is necessary to give an allowance and we have decided that 0.2mm of allowance would be the most ideal as it allows the components to fit nicely into the holder, meaning that it would be secure, but not so tight such that it takes a lot of effort to detach the components from the holder. With that, criterions (2) and (3) are fulfilled.

Given that 3D printing is a very slow process, and that there were several holders to print, I had to work around the design process such that amount of material required for printing was reduced, speeding up the printing process. The thickness of material for the holder is about 2 mm, which is the thinnest possible in order to survive our break test, similar to part 2.3.4. As such, it was found this figure to be the sweet spot between rigidity, fulfilling criterion (4) and speed of printing.

\(^4\) Pins refer to the electronic pins on the components which would be attached to the Arduino Shield
Conclusion

The designing of the holders involved a rigorous process of detailed measuring of the components which is crucial for the holders to function as design. The inaccuracy of the 3D printer has to be taken into account, leading to numerous iterations of redesigning, printing and testing. 3D Printing, being very slow process, has also shown the importance of the efficiency of the usage of the material as I have to find ways to minimize the amount of material used while not compromising the integrity of the holders. This will not only lead to time saved during printing, but also, leads to the saving of materials used should these holders be mass produced for future use.

*Figure 21: The holders for the components*
Designing the support

Introduction
One of the requirements for the project is to have the products assembled at a specific workshop in Polygon ENSE3, with the robots and conveyor system as prescribed by our client. Given the width of the conveyor, it is insufficient for our project, due to the size of the Arduino Shield and the product casing, and a method of increasing this space constraint is necessary. I have, thus, created a support which is, a raised platform on the palette that will allow for assembly in a wider space.

Criteria
1. It should be sturdy enough to last over a course of repeated usage
2. Its surface area should be within the dark green area marked in the picture above, showing the limits due to the width of the conveyor and due to the sensors present at the manufacturing line.
3. It has to be able to be fixed on the palette and to the product casing, using the shaft on the palette.

Design Approach

General Steps
Firstly the client was consulted on how the conveyor works and the specification of the robots and as such, it was decided that a method of increasing the surface area for the assembly process was necessary. Then detailed measurements of the pallet provided by the client were made and I came up with designs for the proposed support, analysing the different ways of producing it. I have then come up with a CAD drawing with PTC Creo, fabricated the support with laser cut plastic and checked if the prototype of the support is suitable for the project.
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

Figure 24: Process flow diagram for the designing of the support

Figure 25: CAD drawing of the prototype of the support
**Problems Faced**

The main challenge is to have the holes of the support we were to create, as marked in yellow in the picture below, to have the exact same size and be completely aligned with the holes on the palette. This is so as to be able to attach the support to the palette by screw. This task was made even more difficult by holes in the palettes being too small, making it impossible to use a Vernier calliper to have its diameter measured accurately. This problem was overcome by using a fine string to measure the circumference and compute the diameter of the holes.

![Figure 26: Holes used on the palette](image)

**Machines Used**

Given the shape of the support I have proposed, using a 3D printer, without printing by parts and have them attached together, would not be possible. As such, the advantage of using a 3D printer is lost and I have opted to use laser cut plastic instead as it offers a greater precision in terms of dimension, combined with the fact that laser cutting is a much faster process than 3D printing. Moreover, the resulting support being much sturdier than its 3D printed counterpart makes the usage of laser cut plastic a better choice than to 3D print the support.

**Conclusion**

To be able to find alternative solutions is key for a smooth work flow and it was being demonstrated with the difficulty in getting the accurate diameter measurement of the holes of the palette. One can find the easy way out of using a ruler to estimate the diameter of the holes but it would lead to the inaccuracy of the size of the holes of the prototype, leading to another iteration in the editing and prototype fabrication process, highlighting the importance of being able to work around a problem without compromising quality.
Designing the Robotic Gripper

Introduction

Along with the products, according to our client’s requirements, it was needed to come up with a design of a robotic gripper that will assemble the products I have already generated. The products will have 3 steps of assembly as the client requested, 3 robot hands are required.

In order to make the hands adaptable for all the products, the plan is to have the same design for all 3 robot hands, with each having different gripping tips.

Figure 27: Robots’ detail given by the client
Criteria

1. It should be sturdy enough such that it would not break during the movements and have enough strength to hold and assemble the components.
2. It should grab the parts tightly, there should be no slipping.
3. It should move easily in the desired directions.
4. It should be able to last over a course of repeated usage, which means that it should not break in a short period of time and be able to use more than our client’s desired usage.
5. It should be adaptable to the end of the robotic arms that our client already has.
6. As it will be for future robotic practical exercises for the students, it should be easily reparable, easily reproduced at a relatively low cost.

Design Approach

General Steps

A research was done on the start of art on the current design of the robotic hands, looking at the current designs techniques being applied for these hands to function. Due to the shape of the components, it was found that the most effective way to grip and assemble the components on the Arduino Shield is to use a robotic gripper as shown in the picture below.

The specifications of such an electronic gripper, with a strength rating of up to 200N, are too high for our needs. Furthermore, they are too expensive for our project, costing anywhere between 700€ to 900€. Hence, I have decided to produce our own prototypes at GI-Nova.

Use existing templates online and making some adaptations according to the robot dimensions, I was able to come up with the first prototype drawing on PTC Creo and have them fabricated using laser cut plastic. One big modification that was done is to have the gripper operate with a motion similar to that of an automatic door rather than a pinching motion as found in most templates.

![Figure 28: Example of a gripper](image)
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

Figure 19: Process Flow Diagram on the design of the robot hands

Problems Faced

The design found online was generic and protected, meaning that it was not possible to add or edit anything on it, so all the hand needed to be redesigned.

These are the three points were critical in redesigning the hand:
- The tip of the gripper that has actual contact, has to be modular.
- The mechanical hand has to be accurate. More than in the Makers platform due to the size of our products.
- It is important to take note of the design of the rotating parts as these parts could easily wear out with extended usage.
With the design found online, the tip of the gripper was straight and this would be problematic due to the size and the shape of the components. The first prototype could not have a firm grip on the components. In order to have a better grip, I decided to have a small groove on the robotic hand. This is done by having a groove on an external piece, which is 3D printed, attached to the tip of the robotic hand. By having the piece 3D printed, I could have different layers printed with different materials. This way, a softer material could be used, for the part that is in contact with the electrical components being handled, increasing grip without compromising on durability. This groove will be different for the first and second robot due to the differences between the geometry of the components assembled in each station.

The first prototype I came up with was not very steady due to its size, it was too big for the components. It was difficult to control the gripper since the screws we used are bigger than the holes on the parts. In addition, the grippers on the tip of the hand was not closing properly and it was difficult to hold the products firmly. Therefore, a healthy result from the first prototype was not achieve.

The main problem was to minimize looseness around the axles. To overcome it, I decided to use smaller plain bearings and axle to make the hand more stable. Using the EGB40 plain bearings for the robotic hand reduces friction and hence increases longevity of the hand. However, it also requires the reduction the size of the hand for the next prototype. To produce the axles, we used Zortrax 3D printing which was, after testing, (+/-0.03mm) accurate enough for our final prototype. Metal axles are preferred due to them having a slower rate of wearing off than their plastic counterparts. Moreover, ball bearings are designed to be assembled with metal axes as oil or other lubricants can be added to reduce friction. Also, metallic circlips are easily available.

Then the second prototype, I came up with a smaller design for the hand to grab the components more easily. The gap between bearing, axles and arms has been greatly reduced and from our tests, it was easy to prove that this prototype is functional.
It the picture above we can see the first and second prototype, and like it has been already explained the differences are obvious. Firstly, the first one is too big to take such small components, and as well is not robust enough. Furthermore, the second one is smaller and more robust and compact, which make it be more accurate. In addition, the final parts have been redesign so the groove is now located at the end of the gripper making easier the process of picking up a component for the robot.

The fact that the six axis robots was not available was a problem for ensuring that the hand is compatible. I have, however, simulate the assembly process by holding the robot hand manually, and operate its main screw, using a hex key, to simulate the rotation function of the Six Axis robots. During the tests, I was successful in removing the components from its holder and to assemble them in their respective positions on the Arduino Shield. Furthermore, the joints of the robotic hand did not sustain much noticeable damage, indicating that the mechanism for the robotic hand is appropriate.

Lastly, there is a recurring problem of the side movements of the gripper, making it not very accurate. The possibility of adding a guiding axle to prevent this problem was been thought, although this is not implemented on the prototype.
Machines and Materials Used

For the manufacturing of the product, it was decided to use laser cutting in GI-NOVA. The reason why laser cutting machine was chosen instead of 3D printer was since the hand was requiring numerous parts, it would take a lot of time to print the whole hand. In addition, as it has been mentioned before, the hand needs to be sturdy. The outcome of the 3D printer has more error margin and less endurance. That’s why I only used 3D printer for the gripper parts on the tip of the hand, in order to hold the materials more smoothly and prevent slipping.

The reason why plain bearings were used is to prevent the cracking of the hand from the joints and make the product more durable.

Conclusion

Designing and creating the robotic gripper was one of the main aspects of the project and it is imperative that they are able to function as designed. A lot of thoughts and considerations have been put into the designing and conception of the robot hands. Despite not having the Six Axis robots at my disposal, I am confident that our robot hand will work on the robots as it operates by the tightening and loosening of the main screw. Furthermore, I have tested the hands by controlling the robotic hands manually, using a hex key to simulate the robotic hand being operated by the six axis robots. I have also factored in the longevity of the robots by considering the appropriate materials for the joints. As such a stunning robotic hand that is also functional and long lasting has been created.
Costs’ interpretations and calculations

Strategic, economic and financial objectives of the project

The problem is that the goal of the project is not to profit financially. Indeed, it is to develop the technological platform to improve the teaching of different subjects that relies on (automatic, robotics...)

The overall project is to make the platform. The conveyor remains the same but the robots are changed to install new ones and products are also modified. This project has a cost (cost of robots and cost of our project, which is interested in the products and in the hands of robots), but no income, knowing that the products are not marketed or sold to a customer.

The goal is to improve the training of students who have access to this platform.

Analyze the consequences of our solution in terms of use of the product

The project can be broken down into two very different parts: the design of the new product including its assembly on the chain and the design of the hands of the robot that will be used to assemble this new product. There are therefore two products.

In terms of the assembled product, I have, by following the specifications, designed a modular product, based around an Arduino board. Its use is therefore very varied, but the basic idea remains the same: the chosen client modules that he wishes to incorporate into its product, then it can be programmed through a Wi-Fi module. Its use therefore requires basic knowledge of programming Arduino. For the rest of the life of the product, there are too many different use to analyze them all. In the project, I developed a countdown driving an electrical outlet, for example, or even a presence and brightness sensor related to lighting for example. It can be used by anyone.

However, it should not be forgotten that these products are often designed to be disassembled to be up again under different practical work on the platform.

Estimated costs and potential gain caused by the solution

Still, the project generates no gain.

However, a cost study can be achieved. They are of several different types:

- The cost of raw materials (plates of Plexiglas, plastic used in 3D printers)
- The cost of components (hardware, electronic components, elements of transmission of efforts, modules to animate the hands of robots)
- The human cost (working time)
- Cost machine (3D printer and laser cutting)

For what concerns the maintenance, the products are flexible and therefore easy to remove, just a change of the defective parts would be needed if a component stops working properly. The maintenance is done easily and should be considered in the costs.

Regarding the hands of robots, the question is more complex because different parts that compose them are subject to efforts (even if they are not very important face to what materials
are able to withstand) repeated, and so are likely to break. Change of parts is not difficult but it must create them again (in laser cutting or 3D printing). In addition, as for the products, modules or different electronic components may stop of work.

Anyway, to estimate a lifetime of the components to know the costs they generate when it should be changed. It is interesting to note that if the products were sold, maintenance costs related to the latter only would be not taken into account in our calculations but as we keep them (the goal being teaching Robotics and Automation), in our case, they have to be considered.

Calculus

Materials’ cost

Two technologies have been used for developing this project: laser cutting and 3D printing

For these two technologies, two costs has been considered: a material and machine costs, which correspond respectively to the cost of the materials used, which depend on the mass for the 3D printer and the surface for laser cutting and the costs of the use of machinery (energy consumption).

The calculations to determine the values in the following table are based on several assumptions. Firstly at the level of the power of the machines. It has been assumed a power of 60W for laser cutting and 400W for the 3D printer. In addition, for laser cutting, I consider that 5 mm thick plates, to 3 mm, the cost is € 32 / cm3.

<table>
<thead>
<tr>
<th>Time cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser cut</td>
</tr>
<tr>
<td>3D printing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser cut (€/m²)</td>
</tr>
<tr>
<td>3D printing (€/kg)</td>
</tr>
</tbody>
</table>

I have calculated the total cost of our project from these costs and costs of the various components. As a reminder, here is the list:

<table>
<thead>
<tr>
<th>Supports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holders</td>
</tr>
<tr>
<td>Products</td>
</tr>
<tr>
<td>Base</td>
</tr>
<tr>
<td>Battery case</td>
</tr>
<tr>
<td>Support plaque</td>
</tr>
<tr>
<td>Plaque</td>
</tr>
<tr>
<td>Common components</td>
</tr>
</tbody>
</table>
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

<table>
<thead>
<tr>
<th>Components</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Nano</td>
<td></td>
</tr>
<tr>
<td>Wi-Fi Module</td>
<td></td>
</tr>
<tr>
<td>Piles</td>
<td></td>
</tr>
<tr>
<td>Modules</td>
<td></td>
</tr>
<tr>
<td>Casing</td>
<td></td>
</tr>
<tr>
<td>Robots’ Hands</td>
<td></td>
</tr>
<tr>
<td>Modules</td>
<td></td>
</tr>
<tr>
<td>Conception</td>
<td></td>
</tr>
<tr>
<td>Supports</td>
<td>0.94 €</td>
</tr>
<tr>
<td>Holders</td>
<td>0.86 €</td>
</tr>
<tr>
<td>Product</td>
<td>68.88 €</td>
</tr>
<tr>
<td>Gripper</td>
<td>51.27 €</td>
</tr>
<tr>
<td>Total</td>
<td>364.11 €</td>
</tr>
</tbody>
</table>

**Supports**

The supports are only designed by laser-cut parts. For calculating the manufacturing costs is as simple as measuring their surface and estimate the time of manufacturing.

**Holders**

For the holders, the method is the same, with the difference that the technology used is 3D printing.

**Product**

Most of the components of the products are bought (electronic components). The only parts we have designed are the boxes (in laser cutting) and support for the plate.

**Robots’ Hands**

It was needed again to buy some components (module allowing to move the robot’s hands). For the rest, the majority is designed in laser cutting and fingers have a modular parts done by the 3D printer.

**Costs**

Below are the individual cost of each part of our solution. Remember that hands and products are produced three times each in the project.

It is important to ask ourselves how to lower these costs, by analyzing the origins.
Cost repartition

Taking a look to the graph, we can notice that the final cost of the project is shared between the cost of the hands and mostly the cost of products. As it has been said before the products of the project are produced three times. But taking a global look of the logistic chain it is obvious that in the platform there are going to be more than three products. Therefore it would be very interesting to find a way of lower the cost of this products to a minimum.

One option would be buying all the components on wholesale, which is a cheaper way of getting all the components needed. And having some extra ones in case a failure occurs in any of them.

In addition, it is interesting to notice that less than 15% of the cost of a product is the raw material which it is made. With this idea on mind it is clear that one of the best ways to bring down the cost of the project we should follow the idea mention before. It would be possible as well trying to minimize the quantity of raw material used in the casing of the product. But this topic is more focused in reducing the time of production of the product that's its cost.
Human cost

Human cost has not been taking into account in this study, but being realistic it is obvious that there is one. It should be measured the time I have spent working on it as well as the time the client and the different teachers have been working with in order to arrive to a successful solution. Furthermore it should be taken into account, if we look at the project in a global way, the time that will be spent in fixing the possible failures that will occurred as well as the installation and programming of the robots in order to have to platform working properly.

Conclusion

This project costs seem high, but most of the components are robust enough to not be changed often, especially for the Arduino modules, which are known for having very long service life, although I haven’t been able to find a good source that gives a specific life span. To determine this, some tests could be done, that includes of accelerated aging, to see when the components are expected to be changed.

In addition, the parts of the hands of the robots have been designed from the perspective of a long service life, using the most possible of plates of Plexiglas (rather than the plastic of 3D printing) and facilitating movements when it was needed using plain bearings. Therefore, if the acquisition cost of items useful to our project is important, the cost of maintenance, low. It can be observed as well that the holders, casing and support, do not work on extreme conditions so there wouldn’t be a reason either for them to break until a long time has passed.
Gestion of the project

Time Organization

Initial Gantt and utilization final of the time

The Gantt chart that I drew up at the beginning of the project turned out to be pretty close to what I finally realized. I opted for a diagram just relatively blur (little detailed steps, only the main lines of the project appear on the diagram) so some modification of the time programing could be done during the development of the project. The reason of this was the little experience I had working in designing products or working with robots in general. Thanks to this I was able to change how I wanted the project to develop when the different problems were faced.

Gantt diagram utilization

It’s especially at the beginning of project that this chart was helpful. Indeed, once the project has picked up speed, and everything that needed to be done was clearly specified it was less used. It has still allowed me to keep the cap during difficult passages as at the beginning of the design and the precise definition of the specifications, because without this tool, it would have been really hard to fulfil the project.

Feedback from the experience

If I had to develop the project again I think I will try to set up a more specific diagram, where I could actually see everything that is needed to be done. Especially I would have used it to further detail the more complicated parts of the project, such as the developing of the products, where a lot of thing were meant to be done. It would have help me to better plan myself and stop me for trying to do many different things at the same time, which finished being a little chaotic. I have found this tool very useful, above all, as a reminder of all the things that are needed to get done so you do not forget any detail.
Organization of the resources

Final organization

As it has explained above the task were not very define in the begging of the project clearly. The main reason of this was the little knowing I had about some of the task that I was asked to develop. Therefore I found a lot of intermediate steps, on the different tasks that needed to be done, that I didn’t expected. All of this made the project much longer and harder of what I have planned and the beginning.

The first step was understanding the customer needs and on the definition of the specifications which would strongly influence in the future of the project.

Once everything was clear I quickly realized the project must be divided into two completely different parts: the modular product design, and the design of the robot hands. In the beginning this separation seems as an easy way for developing the project. But finally it make it harder because once I finished the first part I had to start the second one from zero (start again doing research) which made the project kind of tedious at the end. This was one of the biggest problems that I found with the project, the big difference between its parts.

Logically, I started working on the product, because it was its form and its components the ones that needed to be known in order to find the technologies and solutions that will be used for developing the robots’ hands. This task was split in different steps: a part that involves mechanical design (designing of the support of the products) and a part that involves electronic design (programming and assembly of electronic components of the product).

Once I had estimated that the design of the product was sufficiently advanced (in agreement with what it has been planned in the Gantt chart), I started, in parallel, working on the hands of robot design (meanly doing some research to start speaking with the client about it, so once the product was finished I could start directly working in the development of the hand). At the same time the programming and welding for the electronics components were done, and I finished all the holders and the support.

Finally while writing the final report the prototyping of the hand of the robot was done once all the designs were approve by the client.

As it can be notice clearly the project involve a great number of very difference tasks, which of course, were difficult to handle, but allow me to deal with a great number of different technologies and make the project quiet original and no repetitive at all.

Feedback from the experience

Even though the organization at the beginning was not very precise, as the project develop and I become more familiar with it was easier to plan which task to make every week, and the time I expected that this tasks will take become more realistic. In conclusion at the end the project was well organized with the objectives well defined.
Methods used

Logiciels

For mechanical design, I chose to use the PTC Creo software because it is the CAD software that I had been using during the last semester so it was the one I had the best competences at the beginning of the project. It was in all the steps of the project with a big range of different purposes.

For electronics, the modular product was based on an Arduino shield. It is in this language that I had to program. The software was used for programming the three product that were develop, and took a great time of the begging of the project.

Technologies

For achieving at having the prototypes, several technologies and machines were used, all of them were found at the GI-NOVA Laboratories.

For what is the mechanical part, I especially used laser cutting for all parts in two dimensions and the 3D printer when more complicated pieces were needed. I also think on using leaning on the tour, for our robot hand axes, but finally did not use it due to it cost for just doing a prototype. 3D printing is then imposed for it’s very low cost, both in material first and machine usage time (the problem is that the time spent for doing every piece is very long, so you have to be very sure your design is going to work before prototyping it). For a more advanced solution of the hand, it would however more interesting to use the tour, especially for life time that has the metal has against plastic that is much higher.

For electronics, we also welded, in order to make the necessary connections the Arduino shield that were needed to test our finished product.

Global feedback from the experience

As it has been explained above, a lot has been learned from a technical point of view during the development of the project. Therefore I believe I have mastered designs such as PTC Creo software and technologies of prototyping.

From the point of view of the organization, the same point can be done. I hadn’t really had a course of how to organize a project, so this work has given me the experience of how to do it in a practical way.

If I had to redo this project, or one kind of similar, I firmly think that the work would be done faster and more efficient. First of all, the designs would have been done faster, and less mistakes will be done because I already know the characteristics of the different technologies of prototyping. The programming part will be done faster as well because of the knowledge I have acquired. Finally I really think the big difference will be notice in the organization of the tasks of the project. Knowing what to expect and different common problems that I will have
to faced would have made of course the project goes better. Anyways, in an overall, I think I handle pretty well how to develop a project and I learned from the mistakes that were done in order to improve during the project and of course for the next ones.

Conclusion of the project

For this project I had to meet the needs of our customer Mr. Quoc Bao DUONG and Thierry Hencoque. The goal was to reproduce an assembly line to the CIM platform which would then serve as a work practice for students.

The work consisted in designing and manufacturing three the products that needed to be assembled as well as the grippers that will be implemented into three poly-articulated robots. Almost all the requirements of the specifications have been reached with the realization of the project. The product to be assembled is a functional and complete product meeting the requirements of the customer, it is modular, mountable and detachable hundreds of times and reproducible. Indeed, thanks to the CAD files and the means of production used to produce the product, (which are fast and cheap prototyping tools), it is possible to reproduce quickly and easily in case of wear parts. Finally the computer part that makes activate and operate the products is available and works.

The "holders" to place accurately the components near the articulated robots are also provided with their CAD file as well.

Regarding the gripper, the work has resulted in a sufficiently advanced prototype that allows to already to perform tests. Including tests seized the components in order to verify the accuracy of the gripping system. The CAD of all the pieces that composed the gripper (including the clips and axes) is given as well. (Annex 5)

One important fact about this project is its lifetime in the future. Having all the designs and knowing the components that are used it is easy to assure a long life time to the process, just having to change a specific part if there is a failure.

An interesting aspect of the project was its variability. Apart from being a really mechanical project, it had as well a very strong point in electronics and a huge study in economics. All of this makes it a really complete project.

To sum up, the aim of the project has been reached and achieve successfully making the process reliable and feasible for the next year.

Future development

The project can be continue following different types of lines. The main one would be finding new products that can be done basing them in the modular product already existing. Furthermore this product could be sell and commercialized in order to win benefits with the project.

Also a deeper study in the grippers could be considered interesting in order to find a more suitable type of hand for the process or a more efficient way of developing it. In general the process leaves a lot of doors open for innovation and changes in the future.
The students should be able as well to program the robots making them work correctly with the gripper given. It would be interesting as well if they study how the product were design and develop giving them a deeper knowledge in the Arduino technology and its actual applications.
Annex 1: Arduino Codes

**Thermometer**

/*Program for reading the temperature of the air and turning on a LED if the temperature measured is bigger or smaller than the one fixed by the user

The circuit:

* LCD RS pin to digital pin 12
* LCD Enable pin to digital pin 11
* LCD D4 pin to digital pin 5
* LCD D5 pin to digital pin 4
* LCD D6 pin to digital pin 3
* LCD D7 pin to digital pin 2
* LCD R/W pin to ground
* LCD VSS pin to ground
* LCD VCC pin to 5V
* 10K resistor:
  * ends to +5V and ground
  * wiper to LCD VO pin
  * LED au pin 13
* Temperature sensor in pin A0
*/

// include the library code:
#include <LiquidCrystal.h>

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

// Declaration of the variables that measured the temperature
float volt;
float temp;

void setup() {
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);

  // Print a message to the LCD.
  lcd.print("Temperature : ");
}
// Initialisation des autres pins
pinMode(A0, INPUT);

pinMode(13, OUTPUT);
}

void loop() {
    // set the cursor to column 0, line 1
    // (note: line 1 is the second row, since counting begins with 0):
lcd.setCursor(0, 1);

    // Conversion of the signal received from volts to degrees Celsius
    volt = analogRead(A0);
    volt = 5*volt/1023;
    temp = volt/0.01;
    lcd.print(temp);

    // Turning on the LED in function of the temperature
    if (temp > 25){
        digitalWrite(13, HIGH);
    }else{
        digitalWrite(13, LOW);
    }

    // Delay for the stability
delay(1000);
}

Timer with a Relay

/* LiquidCrystal Library

The circuit:
* LCD RS pin to digital pin 12
* LCD Enable pin to digital pin 11
* LCD D4 pin to digital pin 5
* LCD D5 pin to digital pin 4
* LCD D6 pin to digital pin 3
* LCD D7 pin to digital pin 2
* LCD R/W pin to ground
* LCD VSS pin to ground
* LCD VCC pin to 5V
* 10K resistor:
  * ends to +5V and ground
  * wiper to LCD VO pin (pin 3)
* /

#include <LiquidCrystal.h>

// constants won't change. They're used here to
// set pin numbers:
const int buttonPin = 13;     // the number of the pushbutton pin
const int ledPin =  8;      // the number of the LED pin
float Nombre=15;
float Numero;
int flag = 0;
int j=0;

// variables will change:
int buttonState = 0;         // variable for reading the push button status

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

void setup() {
  // initialize the LED pin as an output:
  pinMode(ledPin, OUTPUT);
  // initialize the pushbutton pin as an input:
  pinMode(buttonPin, INPUT);
}

void loop() {
  // read the state of the pushbutton value:
  buttonState = digitalRead(buttonPin);
  lcd.begin(16, 2);
  // Print the number of seconds since reset:
  if (buttonState == HIGH){
digitalWrite(ledPin, LOW);
flag=1;
while (flag==1 && j<1) {
for (int i=0; i<= Nombre; i=i+1)
{
    lcd.clear();
    lcd.print(Nombre-i);
    delay(1000);
}
    j=j+1;
}
else {
    flag=0;
digitalWrite(ledPin, HIGH);
    lcd.clear();
    lcd.print("Finish; ");
    lcd.setCursor(0, 1);
    lcd.print("Press button");
    delay(1000);
    j=0;
}
Annex 2: Arduino Scheme for trying the programming with the Arduino kit from the university

This schemes were used at the beginning of the project while I was waiting for the components to arrive. It was used to have a visual aid of how to connect all the components in the Arduino kit of the university. It was not done in the Timer because of the great number of cables that were needed it was not possible to see anything clear in the drawing at the end so it was useless.

All this schemes were done with the program Fritzing.

Thermometer

We can see in the schema the LED (red circle) and the temperature sensor (blue circle). The LCD screen is not a real part of the product but was used to visualize if the measures that were taken by the sensor were correct. It was also a fast way of seeing if the product worked as expected.
Automatic Lamp

This one is the scheme of the Automatic Lamp. We can see the LED (red circle) that will turn on depending of the signals gotten by the movement sensor (green circle) and the luminosity sensor (yellow circle).
Annex 3: Demand form for material purchase

<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>DESIGNATION</th>
<th>Quantité</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ecran graphique LCD Arduino</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Carte de développement Seeed Studio WiFi Serial Transceiver Module 1MB Flash</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Capteur de lumière Iduino</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Capteur de température et d'humidité numérique DHT11 Velleman</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Module relais 5V Velleman</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Arduino Carte Nano</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Capteur de mouvement Velleman</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Module Led RGB Velleman</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Module Proto Shield seul Arduino</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Barrette femelle droite 40 pôles BKL Electronic</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Pile AAA</td>
<td>9</td>
</tr>
</tbody>
</table>

Réponse à la demande

Montant

Délai

Signature de l'enseignant responsable :

(obligatoire)
## Annex 4: Specifications of the electronic components

<table>
<thead>
<tr>
<th>Components</th>
<th>Specifications</th>
<th>Price</th>
<th>Quantity</th>
</tr>
</thead>
</table>
| **LCD Liquid Screen Arduino**   | 1. 54 digital I/O contacts (14 can be used as PWM outputs)  
2. 16 analog inputs  
3. 4 UART  
4. 16 MHz crystal oscillator  
5. 5 V power supply  
6. Memory 256 KB Flash  
7. 8 KB SRAM  
8. 4 KB EEPROM  
9. USB connection  
10. Connector power jack  
11. Connector, ICSP  
12. Reset button  
13. Automatic selection of power supply  
14. Compact dimensions: 102 x 53 mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 30€   | 1        |
| **Module Wi-Fi**                | 1. Protocols supported: 802.11 b/g  
2. Wi-fi Direct (P2p), Soft Access Point  
3. PLL, integrated controllers and power steering units  
4. Output power: + 19.5dBm in mode 802.11b  
5. Integrated temperature sensor  
6. Lower consumption in low-power mode: &lt; 10 uA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 13€   | 3        |
| **Luminosity sensor Iduino**   | 1. Can detect the brightness and intensity of ambient light (compared with photo-resistance, this module has a better directivity, can sense light in fixed direction)  
2. Adjustable sensitivity (use blue digital potentiometer to adjust)  
3. Operating voltage: 3.3 V and 5 V  
4. Output format: Outputs digital switching (0 and 1) and AO analog output voltage  
5. Affixed bolt for easy installation holes  
6. PCB size: 3.2 cm * 1.4 cm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 3€    | 1        |
| **Temperature and Humidity sensor DHT11 Velleman** | 1. Voltage: 5 VDC  
2. Temperature range: 32°F - 122°F (0 - 50 °C , error of +/- (2 °C)  
3. Humidity: 20 - 90% RH +/- 5% RH error  
4. Interface: Digital                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 5€    | 1        |
<table>
<thead>
<tr>
<th></th>
<th>Specifications</th>
<th>Price</th>
<th>Quantity</th>
</tr>
</thead>
</table>
| **Relay 5V Velleman**     | 1. Operating voltage: 5 VDC  
2. Relay current rating: 10 A at 250 VAC, 10 A at 30 VDC (non inductive)  
3. Relay contact: C, NO, NC  
4. Connections: GND, +5 VDC, control input (5 to 12 VDC)  
5. Dimensions: 40 x 27 x 18 mm | 6€    | 3        |
| **Arduino Nano Cart**     | 1. 54 digital I/O contacts (14 can be used as PWM outputs)  
2. 16 analog inputs  
3. 4 UART  
4. 16 MHz crystal oscillator  
5. 5 V power supply  
6. Memory 256 KB Flash  
7. 8 KB SRAM  
8. 4 KB EEPROM  
9. USB connection  
10. Connector power jack  
11. Connector, ICSP  
12. Reset button  
13. Automatic selection of power supply  
14. Compact dimensions: 102 x 53 mm | 28€   | 3        |
| **Movement sensor Velleman** | 1. Detection distance: 7 meters  
2. Detection angle: 120 °  
3. Power: 5V to 16V DC  
4. Analog output: 3.3V (High) 0V (Low)  
5. Detection distance: 7 meters  
6. Detection angle: 120 °  
7. Delay: adjustable  
8. Operating temperature: -20 °C to 70 °C  
9. Dimensions: 3.2x2. 4 x 2. 4 cm | 5€    | 1        |
| **Arduino Shield**        | 1. IEEE802.3af compliant  
2. Low output ripple and noise (100mVpp)  
3. Input voltage range 36V to 57V  
4. Overload and short-circuit protection  
5. 9V Output  
6. High efficiency DC/DC converter: typ 75% @ 50% load | 8€    | 3        |
<table>
<thead>
<tr>
<th><strong>LED</strong></th>
<th>7. 1500V isolation (input to output)</th>
</tr>
</thead>
</table>
| 1. FR4 material.  
2. Module LED RGB application made by one full colour LED plugin.  
3. Adjusting three primary colours (red / blue/green / ) force in order to achieve an effect of mixing colour by B three pins of voltage R / G / PWM input. | 3€ 3 |

| **Connectors 50 pins** | 1. Straight female bar 50 poles BKL Electronic 10120606  
2. Size: 1.27 mm 2 x 25-pole 1 pc (s) - female  
3. Strip suitable for male bar 1.27 mm pitch.  
4. Dimensions product, height: 3.0 mm  
5. Dimensions product, width: 6.7 mm  
6. Dimensions product, length: 32.13 mm  
7. Divisible: construction of the connector non  
8. Form: Barrette | 8.60€ 3 |

| **Piles AAA** | 1. Height: 45 mm  
2. Weight: 7.7 g  
3. Diameter: 10 mm  
4. Volts: 1.5V  
5. Brand: Powergee  
6. Type: Lithium  
7. Equivalent references: FR3 FR03, AAA, LR03, LR3, R3, MN2400, R03P, SUM4, LR3, HP16, 824, AM4, 4003, E92, K3A  
8. Form: Cylindrical  
9. Frequent uses: PDA, toys, portable cd player, radio, smoke detector | 8€ 9 |
Annex 5: CAD Models
Support

1. **Inferior and superior parts**: is on this parts were the support gets in contact with the pallet on one side (inferior part), and the case of the product on the other one (superior part).

As it can be seen the shape of the support is the same as the pallet. Furthermore we can see the two holes design for fixing the support to both the pallet and the case. As it has been explained before in the problems faced while designing the support we can see the first hole is bigger than the second one, this was the way of making it coincide with the hole of the pallet.
2. **Side part:** This piece appears two times on the support (one for each side) and its main function is to lift up the product so we can have more useful space during the production process.

3. **Middle part:** This part puts together the two sides parts and the inferior and superior part giving robustness to the design and allowing the final piece support the efforts that it is going to have to tolerate when the robots is assembling the components.
Holders

The main criteria for designing all this holders was that all the pins should be upside-down (looking to the ground). The reason for this is making the robot avoid having to rotate them for their assembly (it was demanded that the robot make the most simply movements).

Following this criteria the design of the holders for the components changes depending of the geometries they have. As we try to make the gripping the most simple as possible the thicker ones were placed horizontal (parallel to the ground) while the thinnest ones were place vertical if their geometry was regular, or a little bit bend in case their geometry was complicate (so they would not fall).

1. Wi-Fi Module:

![Wi-Fi Module Image]

2. LED:

![LED Image]
3. Temperature and Humidity sensor:

4. Relay:

5. Luminosity sensor:
6. **Movement sensor:**

This picture corresponds to the Automatic Lamp product (the product that has most components). As it can be seen the case has been design not only to move the product easily but to protect the components and make them stay in their place during the production chain (tall components such as the relay or the luminosity sensor tended to swing while the pallets were moving).

The position of the relay will be the same in all the products, the only significant change will be in the thermometer were the luminosity sensor will be changed for the temperature and
humidity sensor, but like they both were chosen with almost the same geometry and size the case fits perfectly in the two cases.

In this picture we can see the design made with PTC Creo and we can appreciate that the bottom part has the same holes that the support for fixing them easily. It is important to highlight the elevation (red circle) that this case has for the Arduino Shield (we have one in each corner) so it doesn't stand on the cables of the bottom part but on the sides.

The case was made with 3-D printing because of the different heights that it has.

2. **Cover part:**

This piece will be bend creating a cube without it is inferior face in order to cover the product. As the geometry was very simple it was made with laser cutting.
1. Plier:
   a) Number of pieces needed for one gripper: (Union between central and up parts)

   b) Number of pieces needed for one gripper: 2 (Up part)
c) Number of pieces needed for one gripper: 2 (central part)

d) Number of pieces needed for one gripper: 2 (central part)

e) Number of pieces needed for one gripper: 2 (central part)
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

f) Number of pieces needed for one gripper: 1 (Bottom part)

![Diagram of a gripper](image1)


g) Number of pieces needed for one gripper: 2 (Bottom part)

![Diagram of a gripper](image2)

h) Number of pieces needed for one gripper: 1 (Bottom part)

![Diagram of a gripper](image3)
i) Number of pieces needed for one gripper: 1 (Support for fixing the ripper and the robot)

2. **Groove**: Number of pieces needed for one gripper: 2
3. **Axis:** Number of pieces needed for one gripper: 12

![Axis](image)

4. **Clips:** Number of pieces needed for one gripper: 12

![Clips](image)
Annex 6: Information about the robots

Figure 2.1

© Stäubli 2015 – D29092801C
TX80
2.1. IDENTIFICATION

Robots fabriqués par

Stäubli Faverges SCA
Place Robert Stäubli
74210 Faverges France

et identifiés par une plaque apposée sur le contrôleur et sur le bras (voir figure 2.2).

Figure 2.2

Pour toute demande de renseignement, commande de pièces de rechange, ou demande d'intervention, veuillez préciser le type et le numéro de série de la machine concernée, situés sur la plaque signalétique.

Figure 2.3

Etiquette non contractuelle. Merci de vous référer à l’étiquette apposée sur votre machine.
2.2. PRÉSENTATION GÉNÉRALE

Le bras est constitué de segments ou membres reliés entre eux par des articulations (figure 2.1).

Les mouvements des articulations du bras sont générés par des servomoteurs couplés à des capteurs de position. Chacun de ces servomoteurs est équipé d’un frein de parking.

Cet ensemble fiable et robuste associé à un système de comptage innovant permet de connaître en permanence la position absolue du bras.

L’ensemble bras est suffisamment universel pour pouvoir effectuer une grande variété de travaux.

Exemples : Manipulation de charge, assemblage, process, application de cordon de colle, contrôle/vérification et application salle blanche. Cette liste n’est pas exhaustive : pour plus de précision, nous consulter.

Les différents éléments du bras sont le pied (A), l’épaule (B), le bras (C), le coude (D), l’avant-bras (E) et le poignet (F) (figure 2.1).
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

Figure 2.4
Bras standard - Sortie câbles arrière
Figure 2.5
Bras standard - Sortie câbles verticale
Figure 2.7
Bras long - Sortie câbles verticale
2.3. DÉSIGNATION DES BRAS DE LA FAMILLE TX SÉRIE 60

| (1) | Bras de la famille TX |
| (2) | Rayon maximum de travail entre l’axe 1 et l’axe 5 sur la version standard, exprimé en décimètres : cote A + cote B (figures 2.4 et 2.5) |
| (3) | Nombre d’axes actifs : |
| | 0 = 6 axes actifs, |
| (4) | Lettres pour indiquer une option. |
| | • L = version longue. |
| | • cr = application salle blanche. |
| | • scr = application salle blanche ultra propre. |
| | • he = application en environnement humide. |
| | • steri = application en environnement bio-contaminé |

Ces lettres peuvent être combinées. Exemple : L cr = bras rallongé application salle blanche.

Dans le manuel, on désigne par :

- **Bras standard** : bras de géométrie standard :
  - Sortie câbles arrière (figure 2.4).
  - Sortie câbles verticale (figure 2.5).
- **Bras L** : bras de géométrie différente où l’avant-bras et le bras sont rallongés :
  - Sortie câbles arrière (figure 2.6).
  - Sortie câbles verticale (figure 2.7).
2.4. CARACTÉRISTIQUES GÉNÉRALES

2.4.1. DIMENSIONS
Voir figures 2.4, 2.5, 2.6 et 2.7.

2.4.2. AMBIANCE DE TRAVAIL
Température de fonctionnement : +5°C à +40°C

ATTENTION :
L’obtention des performances nominales peut nécessiter un cycle de chauffe. Une température ambiante élevée peut aboutir à une limitation des performances dynamiques du robot.

- Humidité : 30% à 95% maxi sans condensation
- Altitude : maxi 2000 m.
- Vibration : Nous consulter.
- Protection du bras IP65 et du poignet IP67 avec prises électriques ou bouchons connectés.

ATTENTION :
En cas d’utilisation du robot dans une zone poussiéreuse ou de projection de liquides, il est vivement conseillé d’utiliser l’appareil de pressurisation décrit chapitre 2.10.

ATTENTION :
Les dégâts éventuels dus au non respect des préconisations inhérentes aux environnements ci-après ne sont pas garantis.

Application environnement salle blanche :
- cr : classe de propreté ISO 4 selon norme ISO 14644-1.
- scr : classe de propreté ISO 2 selon norme ISO 14644-1.
- Le nettoyage du robot peut être effectué avec des lingettes imbiber d’alcool isopropylique dilué avec 30% d’eau (IPA 70).

Application environnement humide (he) :

- Limites d’application :
  - 4,5 < pH < 8,5
  - Tenue au brouillard salin : 300 heures suivant norme NS EN 60068-2-11
  - L’utilisation de produits chlorés pour le nettoyage est interdit.
  - La pressurisation du bras est obligatoire. Il est vivement conseillé d’utiliser l’appareil de pressurisation décrit chapitre 2.10. Celui-ci doit être protégé de l’environnement humide (he).

ATTENTION :
Pour chaque bras de robot, un appareil de pressurisation est nécessaire.

- La visserie de l’interface mécanique du poignet, la visserie de fixation du robot, le dessous du pied, la plaque porte prise ainsi que le matériel implanté dessus ne sont pas qualifiés pour un environnement humide (he), et doivent par conséquent être protégés de celui-ci. Cette protection est à réaliser par le client, donc de sa responsabilité. Les dégâts éventuels ne sont pas garantis.
Chapitre 2: Description

- En cas d'utilisation d'un système de butées mécanique optionnel, suivant l'environnement, le système peut avoir une tenue chimique limitée. Vérifier régulièrement le bon état de celui-ci (voir aussi le chapitre 4.4.4). En cas de dégradation, le système peut être remplacé. A noter que, du fait de sa technicité, le système de butées rend moins aisé le nettoyage et la désinfection du bras de robot.

- Sortie câbles verticale : Configuration standard
- Voir également le chapitre 3.2 pour les particularités d'installation des robots he.

- Sortie câbles horizontale : En option uniquement.
- Voir également le chapitre 3.2 pour les particularités d'installation des robots he.

Application environnement bio-contaminé (steri) :

- Limites d'application :
  - $4.5 < \text{pH} < 8.5$
  - Tenue au brouillard salin : 300 heures suivant norme NS EN 60068-2-11.
  - Bio-décontaminable avec du peroxyde d'hydrogène à la lingette (concentration 35 %) ou en phase vapeur.
  - L'utilisation de produits chlorés pour le nettoyage est interdit.
  - La visserie de l'interface mécanique du poignet, la visserie de fixation du robot, le dessous du pied, la plaque porte prise ainsi que le matériau implanté dessus ne sont pas qualifiées pour un environnement bio-contaminé (steri), et doivent par conséquent être protégées de celui-ci. Cette protection est à réaliser par le client, donc de sa responsabilité. Les dégâts éventuels ne sont pas garantis.
  - En cas d'utilisation d'un système de butées mécanique optionnel, suivant l'environnement, le système peut avoir une tenue chimique limitée. Vérifier régulièrement le bon état de celui-ci (voir aussi le chapitre 4.4.4). En cas de dégradation, le système peut être remplacé. A noter que, du fait de sa technicité, le système de butées rend moins aisé le nettoyage et la désinfection du bras de robot.
  - Le nettoyage du robot peut être effectué avec des lingettes imbibées d'alcool isopropylique dilué avec 30 % d'eau (IPA 70).
  - Il ne doit pas exister de différence de pression entre l'intérieur du robot et l'environnement extérieur du robot.

- Sortie câbles verticale uniquement :
- Voir également le chapitre 3.2 pour les particularités d'installation des robots steri.

2.4.3. POIDS

<table>
<thead>
<tr>
<th>Bras standard</th>
<th>Bras long</th>
</tr>
</thead>
<tbody>
<tr>
<td>51.4 kg (113.3 lb)</td>
<td>52.5 kg (115.71 lb)</td>
</tr>
</tbody>
</table>

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2.4.4. CONSEILS DE NETTOYAGE ET DE DÉSINFECTION

Surfaces externes des robots STÄUBLI standard, cr et scr

- Pièces en métal non peintes :
  - Utiliser une lingette humidifiée avec un produit recommandé dans le tableau de compatibilité ci-après.
- Pièces métalliques peintes ou en plastique :
  - Utiliser une lingette humidifiée avec une solution savonneuse de pH neutre (Par exemple, l’un des produits figurant dans le tableau de compatibilité ci-après).
  - Rincer à l’aide d’une lingette humidifiée à l’eau claire.
  - Sécher à l’aide d’une lingette.

L’intervalle de nettoyage ou de désinfection dépend du niveau de saleté du robot (Périanocité typique : 1 semaine).

Surfaces externes des robots STÄUBLI “he” (Application environnement humide) :

- Utiliser un produit aqueux de pH 4.5 à 8.5 (Par exemple, l’un des produits figurant dans le tableau de compatibilité ci-après).
- Rincer à l’eau claire.
- Sécher à l’aide d’une lingette.

Surfaces externes des robots STÄUBLI “stericlean” (Application environnement bio-contaminé) :

- Utiliser un produit aqueux de pH 4.5 à 8.5 (Par exemple, l’un des produits figurant dans le tableau de compatibilité ci-après).
- Rincer à l’eau claire.
- Sécher à l’aide d’une lingette.

ou

- Utiliser d’autres produits recommandés dans le tableau de compatibilité ci-après (par exemple IPA 70, peroxyde d’hydrogène à 35% sur une lingette ou en phase vapeur) sans rinçage à l’eau.

L’intervalle de nettoyage ou de désinfection dépend du niveau de saleté du robot (Périanocité typique : À la fin de chaque production).

**ATTENTION :**

Les informations données dans les présentes ne dispensent pas de vérifier la propreté du robot après le nettoyage et la désinfection. STÄUBLI ne pourra être tenu responsable d’aucun dommage lié à la persistance de résidus après la procédure de nettoyage décrite ici.

**ATTENTION :**

L’utilisation de produits chlorés pour le nettoyage ou la désinfection est interdite. L’utilisation d’autres nettoyants ou désinfectants que ceux spécifiés ici peut endommager les surfaces externes du robot. Dans ce cas, il est conseillé de protéger le robot en le recouvrant d’une housse de protection.
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

Chapitre 2: Description

**ATTENTION:**
En cas de nettoyage ou de désinfection avec projection de liquide ou avec un jet de liquide à basse pression, le bras du robot doit être pressurisé (voir manuel d'instruction).

**ATTENTION:**
L'action mécanique répétitive de l'essuyage peut altérer le brillant de la peinture.

Consulter STÄUBLI si les produits nettoyants ou désinfectants ne sont pas conformes aux spécifications.

<table>
<thead>
<tr>
<th>Type de produit</th>
<th>Désinfectant</th>
<th>Nettoyant</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>Neutre</td>
<td>8,5</td>
</tr>
<tr>
<td></td>
<td>Neutre</td>
<td>Neutre</td>
</tr>
<tr>
<td>pH</td>
<td>2 à 4</td>
<td>-</td>
</tr>
<tr>
<td>pH</td>
<td>8,5</td>
<td>Neutre</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nom du produit nettoyant ou désinfectant</th>
<th>P3-alcoodes</th>
<th>P3-topaz 990</th>
<th>H2O2</th>
<th>Alcool isopropylique à 70% (IPA 70)</th>
<th>P3 aquanta tin</th>
<th>ELPON</th>
<th>Alcool isopropylique à 70% (IPA 70)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabricant</td>
<td>ECOLAB</td>
<td>ECOLAB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concentration</th>
<th>100%</th>
<th>3%</th>
</tr>
</thead>
<tbody>
<tr>
<td>35% sur un chiffon ou en phase vapeur</td>
<td>100%</td>
<td>0,2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pièces non peintes</th>
<th>√*</th>
<th>Non</th>
<th>Non</th>
<th>√*</th>
<th>Non</th>
<th>Non</th>
<th>√*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pièces peintes ou en plastique</td>
<td>Non**</td>
<td>√</td>
<td>Non</td>
<td>Non**</td>
<td>√</td>
<td>√</td>
<td>Non**</td>
</tr>
<tr>
<td>Pièces non peintes</td>
<td>√*</td>
<td>Non</td>
<td>Non</td>
<td>√*</td>
<td>Non</td>
<td>Non</td>
<td>√*</td>
</tr>
<tr>
<td>Pièces peintes</td>
<td>√</td>
<td>√</td>
<td>Non</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Pièces non peintes</td>
<td>√</td>
<td>√</td>
<td>√*</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Pièces peintes</td>
<td>Non**</td>
<td>√</td>
<td>Non</td>
<td>Non**</td>
<td>√</td>
<td>√</td>
<td>Non**</td>
</tr>
</tbody>
</table>

Utilisable dans l'industrie alimentaire

Prendre contact avec le fabricant du produit pour définir la procédure de nettoyage ou de désinfection.

**ATTENTION:**
* : Utiliser uniquement des lingettes humidifiées du produit.

** : Pour les pièces peintes, le produit peut néanmoins être utilisé en essuyage doux, sans prolongement de l'application. L'action mécanique répétitive de l'essuyage peut altérer le brillant de la peinture.
DESIGNS REQUIRED TO MANUFACTURE A PRODUCT AND THE HANDS OF A ROBOT FOR ITS ASSEMBLY

Figure 2.9