SORTING ROBOTIC ARM FOR INDUSTRY 4.0

BOUDER Arthur[1], LE STANC Maxime
[1]Faculty:ERASMUS Students, INSA Rennes, France Year of study: 5, e-mail:arthur.bouder98@gmail.com (Corresponding author only)

Scientific Leader: **Bogdan ABAZA**, PhD
(e.g. Scientific Leader: Conf.dr.ing. **Ion POPESCU**)

SUMMARY: This paper is a report of a work project at the University Politehnica of Bucharest, regarding the Industry 4.0 module. This report is about the theoretical work on the application of a robotic arm in a context of industry 4.0. The main goal is to develop an application that could be evolved with more advanced components. So will be presented results that are likely going to change.

KEY WORDS: robotic arm, Industry 4.0, 3D printing

1. Introduction

This research explores the work in the Small and Medium Business. Currently, in some of them, they handle the sort and the sending by hand but they want to improve their competitivity. What's more, manual handling can expose workers to hazards resulting in musculoskeletal disorders. So the idea is to create a cyber-physical system that would automatize the sort and prepare the sending of their products in different areas in the country. They are looking for different benefits through our method such as: cheaper, faster, automatic and useful. The objective is to create a prototype of a sorting robotic arm able to identify the destination of a package and to sort it depending on this destination. This arm would allow for the possibility of getting to an industry 4.0. It's currently hard for the SMB to optimize their production, due to the price of the Cyber Physical System. Additive manufacturing will be used to reduce the cost of the machine. Because of its good mechanical characteristics, ABS plastic will be used to print the robot, but in real fatigue conditions, it should be updated to a more resistant material. Thanks to the flexibility of this technology the sorting arm will be adapted to each customer request as for example the shape of the gripper (the design of the gripper could be adapted depending on the demand and on its function) or the connectivity between the robot and the production line.

2. Business Strategy

On the factories there are many workers who make repetitive gestures, typical of assembly line work. This is the main reason of the appearance of musculoskeletal disorders. In France, in 2017, MSD represent 87% of professional diseases and their direct cost to companies is estimated to almost two billion euros. For employees, almost the half of this diseases have serious consequences with the risk of professional dissertation.

To deal with this workplace health issues, robots appeared during the 3rd industrial revolution. They are used intensively in factories to perform repetitive, arduous tasks and replace men. Nowadays, after several years of improvement, they are able to perform more precise and rapid movements. This project is to design and create a handling and sorting robot that can be used at the end of a production line. Each industry needs this kind of equipments in order to separate differents products and redirect them to the next operation. The Sorting Robotic Arm is a prototype which aims to attract potential customers in order to launch full-size production.

Obviously there are already similar solutions to the one developed in this report. Among the existing concepts two were selected.

The first one is the Zortrax Robotic Arm which is a pick and place device. This robot is able to lift part that weight up to 100g and all of the components are 3D printed. The user can also change the tool heads as he wants (sucker, electromagnet, drill…). However there are only three axes which are powered and the others are positioned by hand.

Fig. 1. Zortrax Robotic Arm

The second is the Little Arm which has a very simple design. The servo motors are basic components and we have already seen who to drive them during the mechatronics courses. “The LittleArm is a perfect miniature analog for large industrial robot arms.” according to his designer.

Fig. 2. Little Arm

The idea for this project is to keep the advantages of competing concepts and try to improve them in order to have a place on the market sector and a large customer base. In the next table there is the comparison between the two previous robotic arms and the Sorting Robotic Arm for Industry 4.0.

Table 1. Comparative table of projects

Project	3D printing	Interchangeable tool heads	Controlled remotely	Optimization of parts	Maximum mass liftable (kg)
Zortrax Robotic Arm					0.100
Little Arm					-
Sorting Robotic Arm					0.200

The robot will be fully created with 3D printing except for the mechatronics components (servo motors, wires, sensors…) and the fixing elements as screws. Thanks to this technology it’s possible to have the same mechanical characteristics as metal while reducing considerably the weight of each part. After have developed a first type of head tools it will be interesting to design some others in order to answer the market demand. The movement will be controlled remotely and the optimization of the parts will allow to increase the maximum mass liftable at the end of the arm.

3. External Functional Analysis

To understand the needs targeted by this robot had to be made a functional analysis. The goal of this functional analysis is to define precisely the principle and constraint functions that the robot will have to fill. It also introduces the technical solutions that could be used to answer this problems. This analysis leads mainly to three principle functions:

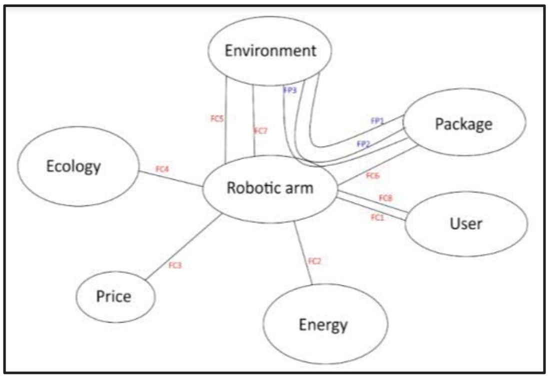

Fig. 3. Octopus of the Sorting Robotic Arm

FP1 : Be able to transport the package
To do it so, it was necessary to think of the best way to pick the package. Actually, there is plenty of technical solution to do it. The three principles that stood out to realize this function are a system of magnet (one on the arm and the other on the package), a grab device at the end of the arm that could pick the package and a sucking device, with a system of compressed air.
FP2 : Be able to access all the working areas
The distance from the robot to the working areas are a primordial factor in the design of the robot, and in the choice of its components. Indeed, to be useful for a large number of companies, it had to have a big working area. But actually, to keep the price as low as possible a compromise had to be found because this distance directly influences the value of the mass liftable by the arm.
FP3 : Be able to read the destination of the package
As it is explained previously, the aim of this robot is to sort the package depending on its destination. To do it so, the arm needs to detect specific criterias that could differentiate one package to another. Two solutions to fill this task were brought up. The first one is based on barcodes. It would require a barcode reader that would determine the destination of each box by simply reading the barcode on the package and isolating the associated information. The second is based on a color reader. The package would be equipped with color spot that would be read by the color sensor. This way, the robot would be able to sort the packages depending on this color.

To complete this functional analysis were added some criterias that were primordial to have a good final product. Here are some constraint functions added to the functional analysis:
FC1 : Must be easily usable, user-friendly
FC3 : Must not be expensive
FC8 : Must be safe
These different constraint functions are built to get a limit around the project. With these, it is possible to know what solutions are forbidden for example.

4. Competing Concepts

As it is explained in the previous part, to answer correctly the functional analysis, there is plenty of solutions available but only one was developed through the project. So, to understand the choice of solution will be discussed in this part the advantages and the inconveniences of each technical possibility.

First of all, will be chosen the solution that will permit the robot to lift the package. As it is said higher, three principal technicals solutions will be discussed.

The first one is a sucking device. On the technical part, it is pretty easy to implement, as there is no power transmission to think about. However, it remains a lot of problems caused by this choice. Indeed, the first one is a matter of space. To use such a device, a stock of compressed air is needed. Therefore it needs space to stock it and it involves a certain cost. What's more, the sucking device is not very versatile. Indeed, the sucking device will not be able to stick to any surface (dusty, smooth..).

The second solution that was mentioned is the grab. The main disadvantage of this system would be that it needs a servo motor to work. However, as the robot already uses three servo motors, and that the code for these is really simple on arduino, it is possible to overcome this problem. To this adds the fact that the grab has the huge advantage that it can be adapted depending on the type of application the user requires. Indeed, it is possible to think about different types of tool head. It is also 3D printable and therefore pretty cheap.

The last solution brought up was the system of magnets, but in this case, every package should have a system of magnet, and that would be very expensive after a while.

Now, the choice will be made about the system that will read and control the destination of the package. If the choice was pretty simple for the device of picking, it is more difficult for this one. Indeed, each solution have very good advantages.

The first solution mentioned higher is about the use of a barcode reader. The system of barcode is a really robust technical solution. Past the coding part, it is possible to stock many useful information in the barcode such as the size of the package, its weight, its destination and so on. The robot could easily adapt depending on these information. However, its principal inconvenience is its price. Indeed, as the robot is destined to be a prototype, this type of device is unaffordable.

That's why the second solution will be chosen. It is based on a color detector. This device will be used to detect the color of a spot placed on the box. Depending on this color, the robot will choose a zone in which sort the package. The device is so much easier to program, as there is less information accessible through it. However, it fills the function expected.

5. Selected Concept

The Sorting Robotic Arm is a prototype of a larger concept intended to move packages in the factories at a sorting area. The idea is to create a three axis robotic arm prototype that will be composed by five main parts: the base, the tower, the first arm, the second arm and the gripper. The objective of this robot is to be able to lift 0,200g. After studying the existing concepts, the length of the arms will be fixed at 120mm.

By taking in account the weight of the parts and the package that the robot will lift, the characteristics of the servo motors can be calculated. For the three axis of rotation a MG995 servo motor is necessary and the gripper solution requires a SG90 servo motor.

On the next figure there is the kinematics diagram of the project and the characteristics of the servo motors on the following table:

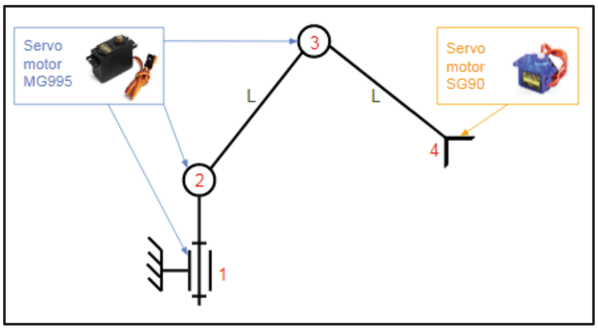

Fig. 4. Kinematics diagram

Table 2. Characteristics of servo motors

Servo motors	Weight (kg)	Torque (Nm)	Price (€)
MG995	0.055	0.83	7
SG90	0.015	0.24	2

After the components that will be used were determined, the next thing to work on was to design the global shape of the robotic arm. According with the rules imposed by the 3D printing technology, mainly not to create angles upper 45 degrees or avoid horizontal bridges, the following design was established, and it is currently the state of the project.

Remaining in the same optic as during the whole project, and as it is written higher, the goal is to reduce the price of production, by optimizing the volume of our parts. To do it so, it was necessary to work on topological and parametric optimizations, mainly on the arms. Indeed, the two arms are the more important parts because their weight define the mass liftable by the whole machine. It is also foreseen to optimize the base of the robotic arm because it is pretty massive.

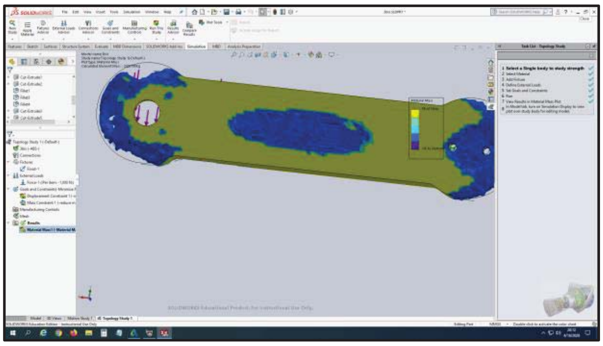

Fig. 6. Topological optimization of the first arm

In parallel, an application is developed and will come with the robotic arm. This application, that is designed with Labview [2], will allow the user to take the manual control of the arm, even if the goal is to implement an automatic mode.

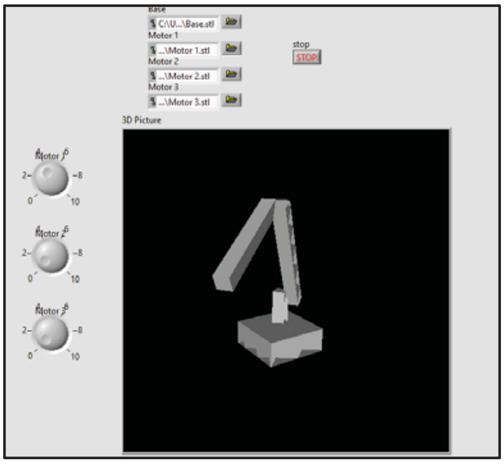

Fig. 7. Current state of the labview application

As we can see on the Fig.7, the application permits the user to control each articulation of the arm. It still misses some specific functionalities as the change of mode (between automatic and manual) or the display of the detected color. Nevertheless the core of the application has been built.

What's more, a simulation on how the circuit will work was built on TinkerCAD. Unfortunately, as some specific components (as the color sensor) are used, it is difficult to get a really realistic approach on it and the connexion with Labview is impossible. That's why some alternatives were found to be able to work on it whatever. For instance, the color detector is currently simulated by the use of a temperature sensor: each color corresponds to a specific range of temperature in the program. This temporary solution allows to see what problem could show up. To get something more realistic, a simulation of the color sensor could be created on LabView to generate a random sequence of color that would be sent to the arduino card. Nevertheless, the simulation is working pretty good in its current state. Indeed, the working modes and the main functions have been set to follow the "scenario d'action".
Finally, it remains to work on the manual mode : Some potentiometers will be added to control the servo motors by hand when the mode is switched from automatic to manual.

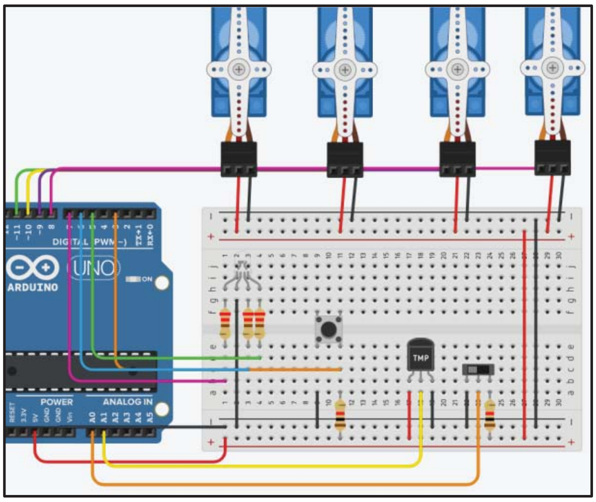

Fig. 8. Development of the circuit on TinkerCAD

6. Economic Analysis

As it was explained previously, the first goal of the robot is to be accessible by small companies. That's the main reason why the robot must be simple but efficient, and its price of production has to remain low. To justificate the use of additive manufacturing, a first comparison of prices is necessary. Indeed, here is an idea of the price the robot would have cost without the use of additive manufacturing.

So, the components would be used to build the exact same components that will be printed, among other things, two arms, one base and one tower. For the system of gripper, it is hard to have an idea of where to buy it.

Table 3. Components

Item	Picture	Quantité	Unit Price ($)
1202 Series Angle Pattern Mount (1-1)		3	5,99
1106 Series Square Beam (6 holes, 48mm Length)		4	1,79

1109 Series goRAIL (120mm Length)		2	3,49
1116 Series Grid Plate (5x7 Hole, 40x56mm)		1	1,59
Total Price		33,70$	

Of course, this list of components is just an idea of what could be taken to build the structure and it doesn't take in account components like screws, bolt or even servo motors. But actually, there would be another point to add to these : the weight. As said previously, the weight of the structure is one of the biggest advantage of the additive manufacturing. Indeed, the lower the weight is, the lower the torques of the servo motors have to be. If the components were made of metal, it would have been also necessary to change the servo motors chosen for stronger ones (and ineluctably more expensive ones).

Now, it is possible to put the designed parts in the software Cura Ultimaker to have an idea of what that would cost using additive manufacturing. The parameters set are just hypothetical, as there is still work to do on it.

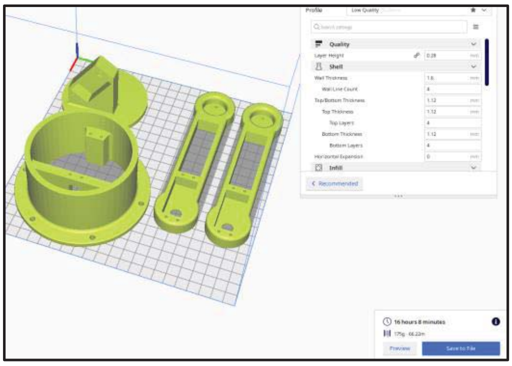

Fig. 9. Result of the printing simulation

As we can see, this printing is using only 175g of ABS to print the parts. Regarding the price of the raw material, that would be worth less than 4 euros. It is hard to put an exact price on the process because it takes 16 hours to print, and that should be taken in account in the calculation of the final price.

7. Conclusions

To finish this report with will be made a point about the current state of the project and what remains to improve.

Concerning the state of advancement of the project, if the general design of the robot is drawed, it remains to work on the design of the grab. As explained previously, it would be interesting to implement at least two types of grippers that the shapes still have to be determined. To reduce the cost of printing, the shape of the base will also be reviewed and optimized to get a less massive part.

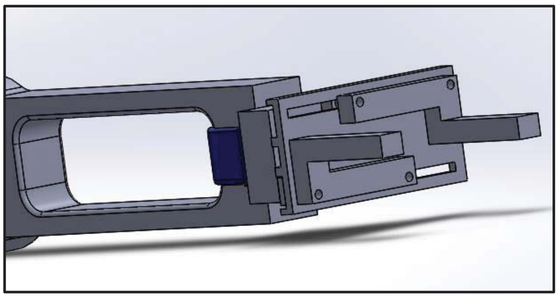

Fig. 10. Gripper of the robotic arm (work in progress)

For the software part, there is still functions to add to the application and the information exchanged between the arduino and the application have to be fully defined. The big works remaining concerning the software part will be to get a link between TinkerCAD and the Labview application. For example, it would be relevant to create a labview application able to read data written in a file by TinkerCAD circuit. The next steps are so to go further in the Labview application by creating a simulation of color detection and an exchange with the arduino.

The current results about the robot are pretty encouraging, as the mass liftable keeps increasing as optimization goes by. The robot is now capable to lift nearly 230g against 150 at the beginning of teh project. In the future, to improve the adaptability of this work, there is plenty of direction to explore. For example, there is an infinity of new gripper shapes to design. It is also possible to upgrade the current devices that are used to improve the capacities of the robot. This way, it could be able to either lift heavier packages, or to pick them at a further distance. To get the robot robuster, it would also be possible to replace the color detector by the barcode reader.

Concerning the robot developed in this study, it obviously remains a prototype because of the cost a real robot could cost. Due to the current world situation, this robot will likely not see the light of day, but all the main clues are studied to get it realistic.

8. Bibliography

[1].Grames E, “10 Best DIY / 3D Printed Robot Arms in 2020”, 2020 https://all3dp.com/2/10-best-robot-arms-to-3d-print-or-buy/

[2].Menelaos K , “myRoboLab : Custom design Robotic Arm”, 02/06/2015 https://forums.ni.com/t5/myRIO-Student-Projects/myRoboLab-Custom-design-Robotic-Arm/ta-p/3499870?profile.language=fr

[3].Fuster A.M.G, “Greaper design and development for a modular robot”, June 2015 https://upcommons.upc.edu/bitstream/handle/2117/79988/AnnaMariaGil-report.pdf

[4].ABAZA Bogdan, Industry 4.0 course