Ministry of Education
Superior And Scientific Research
*****
University of Carthage
*****
National Institute of Applied Science and Technology

Year-end Project Report

Developed by: MSEIBI Souha
JABRI Chaima
CHAABANI Elaa
JLASSI Wejden

Hand Motion Recognition

Supervisor: Mr. KETATA Raouf
Protractor: Ms. Ben Hatira Fafa

Academic year 2021/2022

Table of contents

Table of figures

General Introduction

Gesture recognition aims to interpret human movement using algorithms. Gestures can come from any movement or body condition, they typically come from the face or hand. Users can create simple movements to interact with devices without physically touching them. numerous approaches have been used using cameras and vision algorithms to interpret gestures. This type of system is very useful in the industry, let’s mention the following robot example: the robot of Amazon Astro- collaborative robots- humanoid robots. It is in this perspective that our work fits.

As part of our year-end project, we've developed a human gesture recognition system that interacts with a robotic hand. This robotic hand with its algorithm reads human gestures and repeats them in real-time using a camera. Indeed, our approach should increase and give more flexibility in interaction. It contains ways to segment the hand, detect the fingers and classify the gesture.

Our report is divided into three chapters, the first chapter «Project scope» will focus on the context of the project and its specifications, and after that, the second chapter «Requirement specifications and technological choices » carries the functional requirement and the hardware and the software choices. And finally, the third chapter «Development, Implementation and validation» will be devoted to the simulation, and to the setting up of our system

Chapter I: Project scope

Introduction:

This chapter presents the context of the project and its environment. The start will be a literature review, involving a brief description of the motion recognition fundamental concepts. Then, the scope of the project follows to explain the problem and outlines the main incentive of the project. Finally, we will give an idea about the steps to follow on the project.

I - Project presentation

This project is in the context of an end-of-year project, to validate the 4th year in the engineering cycle in industrial IT and automation of the National Institute of Applied Sciences and Technology for the academic year 2021/2022. The project is supervised by Mr. Ketata Raouf a Professor at the National Institute of Applied Sciences and Technology.

II - Generality Motion Detection

Movement recognition helps humans to communicate with the machine and interact without any mechanical devices or physical touch.

Regarding man-machine interaction, Kurtenbach and Hulteen define a gesture as follows: "A gesture is a movement of the body that contains information. Saying goodbye is a gesture. Pressing a key on the keyboard is not a gesture because the movement of a finger is neither observed nor meaningful, it is only important to know which key was pressed". On the other hand, Harling and Edwards renounced the obligation of movement and understood each other with a gesture and static postures. It is possible to distinguish the systems in which the necessary sensors the detectors are located directly on the body of the user and those in which the user is observed by external sensors. [1]

Characteristics of gesture recognition :

- More accurate
- High stability
- Saving time to unlock a device

The most known applications of gesture recognition are:

- Automotive industry
- Consumer electronics sector
- Transit sector
- Gaming sector
- To unlock smartphones
- Defense

- Home automation
- Sign language interpreting

III- The exciting solutions

The subject of automatic recognition of gestures is a field of research very active, especially in recent years, this subject has had success in the projects carried out using other technology in the field of robotics and intelligence. Through this various research, manufacturers realized to develop this field and test several techniques.

There are several methods used for hand tracking, namely, using for a project in “Faculty of Engineering and Natural Sciences, SabancıUniversity, Tuzla, İstanbul, Turkey”: the method proposed in this project includes the following steps: [2]

- Localization of hand-like regions based on learned skin color statistics, producing a BW image output.
- Perform region-based hand segmentation, eliminating small regions of false alarms that have been declared “hand-like” based on their color statistics.
- Calculate the center of gravity (COG) of the hand region and the distance farthest in the COG hand region.
- Build a circle centered on the GOC that crosses all active fingers in the count.
- Extraction of a binary signal by classifying the hand movements according to the number of active fingers in the signal.

In another system as “Model-based 3D Hand Tracking with on-line Hand Shape Adaptation”: [3] In this work, using an RGB camera, Mr. Alexandros and Mr. Antonis present an online method that simultaneously solves the problems of hand tracking and hand shape estimation. For laying estimation, the Bayesian hierarchical model (HMF) framework is used [10, 11]. Shape parameters are estimated using a new approach. Initially, the shape parameters are optimized by image using the PSO algorithm. A history of such image estimates is then introduced into a robust fit framework that estimates the best hand shape parameters in this image history. For this experiment, there is a clear advantage of the proposed approach in the case where the shape of the initial model differs from the shape of the hand followed.

Another method of motion detection was proposed this time without a camera but using smart gloves such as the project «Motion tracking glove for augmented reality and virtual reality» and «Glove for augmented and virtual reality». [4]

As a microcontroller of the glove, we have STM32 F413ZH. Also, they developed a device using the IMU sensors, the MPU6050 which has an accelerometer and a gyroscope on its card which
allows you to accurately calculate the angle and position of each finger phalanx. The MPU-6050 includes three 16-bit ADCs to scan the gyroscope outputs and three 16-bit ADCs to scan the accelerometer outputs. Communication with all device registers is done using the I2C communication protocol at 100 kHz or in 400 kHz fast mode. The microcontroller collects the data and sends the data packet to the computer via the USART DMA communication protocol. These are projects based on anatomical analysis, the hand skeleton model has 23 internal DOF, and each of the four fingers has four DOF. [5]

IV- The proposed solution:

The first objective of this project is to create a complete system to detect, recognize and interpret hand gestures through computer vision.
The second objective of the project is therefore to provide a new low-cost, high-speed robotic hand tracking system.

V- Project steps

Behind every successful project, there’s a good plan that explains clearly the inner and outer of the project. Our project realization is divided into 5 parts

1- Requirement specifications
2- Electrical and mechanical design
3- 3D Simulation interface
4- Software development
5- Implementation and validation of the result

Conclusion:

This chapter is the outline of the project. It explained the general notions needed to understand the context. After that, it described the problem and the aim of the project.
In the following chapter, an in-depth requirement specification will be elaborated, and the technological choices will be explained.

Chapter II: Requirement specifications and technological choices

Introduction:

This chapter starts with the requirement specifications to get a view of the necessary parts that must be approached. After that, a detailed description of the final solution will be given along with the technological choices.

I- Requirements specification:

I.1- Functional requirements:

Functional requirements describe in a simple way the main feature of the system.

- The user could use the 3D environment to simulate the hand gesture detection
- The data acquisition is done through a simple camera

I.2- Nonfunctional requirement:

Unlike functional requirements, non-functional requirements do not specify behaviors, but rather focus on the criteria of the system and its' quality attributes and they are as follows:

- **Speed**: the arm must respond in real-time
- **User-friendliness**: The simulation interface must be easy to handle and interactive
- **Economical**: reduced cost and low energy consumption

I.3-Modelization of the functional requirement:

In order to model the functional requirement of the system we have used the Use case diagram which is presented by the image bellow:

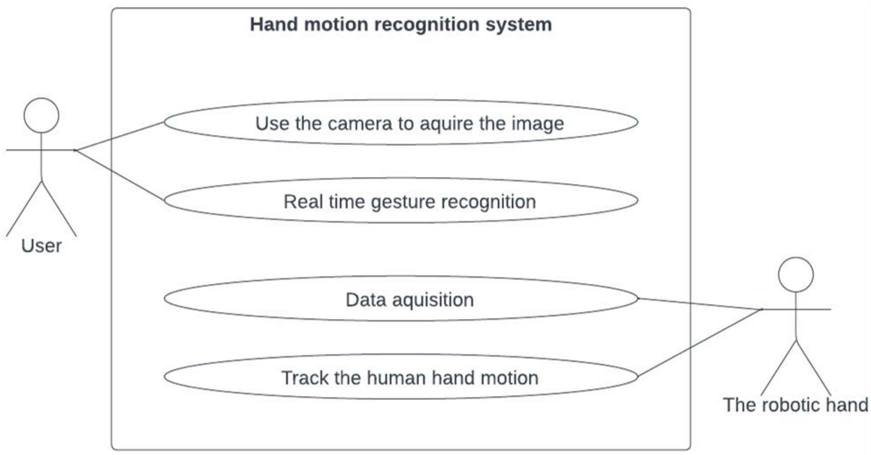


Figure 1:Global use case Diagram

I.4 -SADT Diagram:

Structured analysis and design technique (SADT) is a systems engineering and software engineering methodology for describing systems as a hierarchy of functions. SADT is a structured analysis modeling language, which uses two types of diagrams: activity models and data models.

The SADT diagrams developed for the system are presented in the following figures:

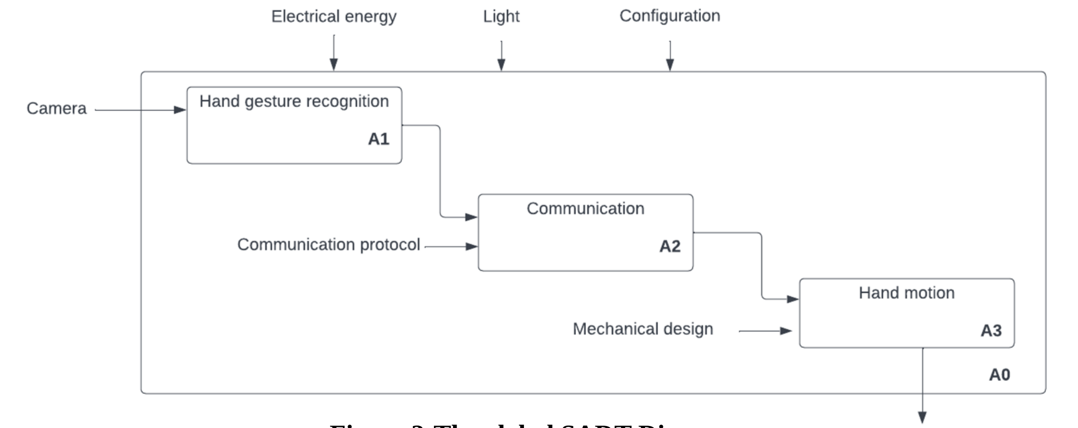


Figure 2:The global SADT Diagram

After that we present the diagrams of each level

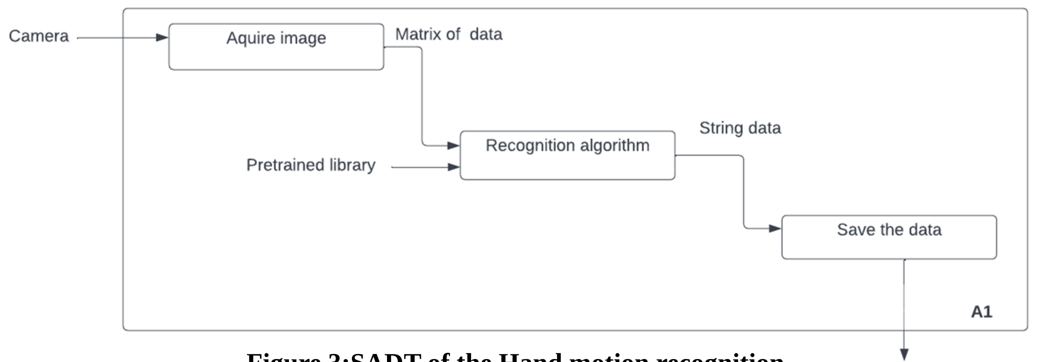


Figure 3:SADT of the Hand motion recognition

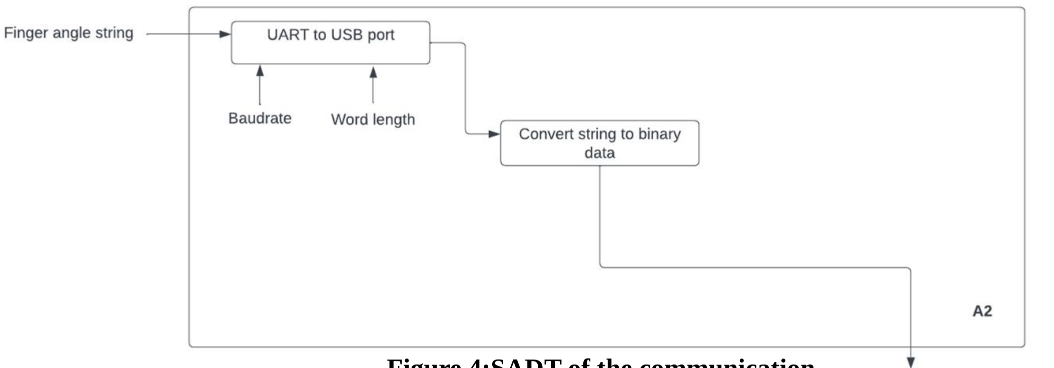


Figure 4:SADT of the communication

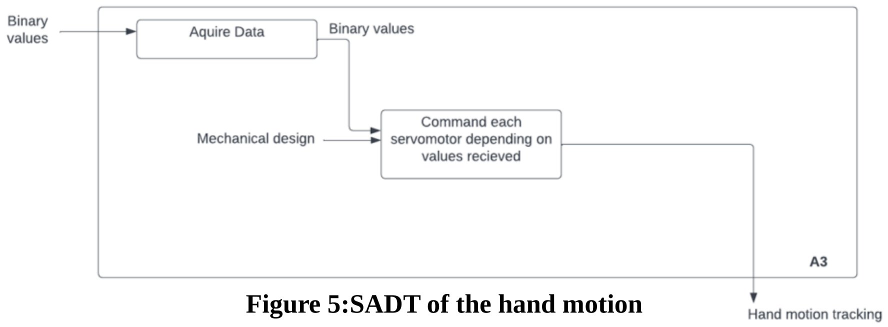


Figure 5:SADT of the hand motion

II- The technological choices:

II.1- The software choices:

STM32 CUBE IDE

STM32CubeIDE is a multi-OS development tool, which is part of the STM32Cube software ecosystem. It is an advanced C/C++ development platform with peripheral configuration, code generation, code compilation, and debug features for STM32 microcontrollers and microprocessors.

PYTHON

Python is a high-level, interpreted, general-purpose programming language. Its design philosophy emphasizes code readability with the use of significant indentation.
It supports multiple programming paradigms, including structured (particularly procedural), object-oriented and functional programming. It is often described as a "batteries included" language due to its comprehensive standard library.

JUPYTER

Jupyter is a web application used to program in more than 40 programming languages, including Python, Julia, Ruby, R, and Scala2. It is a community project whose objective is to develop free software, open formats, and services for interactive computing. Jupyter allows you to create notebooks, that is to say, programs containing both texts in markdown and code. These notebooks are used in data science to explore and analyze data.

Unity

Unity is a cross-platform game engine developed by Unity Technologies.
The engine can be used to create three-dimensional, two-dimensional, virtual reality, and augmented reality games, as well as simulations and other experiences. The engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering, and construction.

CATIA

CATIA is Three-Dimensional computer-aided design software that makes it possible to model any product according to its real behavior: design in the age of experience. System architects, engineers, designers, building professionals and all contributors can define, imagine and shape the connected world

FRITZING

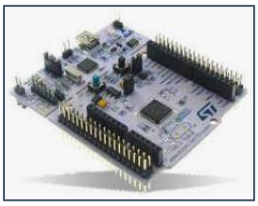
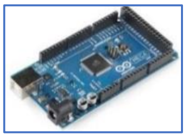
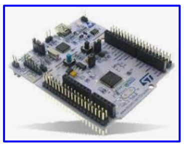
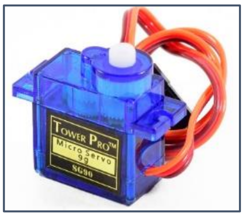
Fritzing is a free printed circuit design software that allows you to design the circuit entirely graphically and print the artwork.

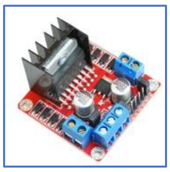
EasyEDA

IT is a web-based EDA tool suite that enables hardware engineers to design, simulate, share - publicly and privately - and discuss schematics, simulations, and printed circuit boards.
EasyEDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analog and digital circuits and the creation and editing of printed circuit board layouts, and, optionally, the manufacture of printed circuit boards.

II.2- The hardware choices:

In order to set up our project , we have to select the materials we need , the following decisions are based on cost , performance and energy consumption criteria .

Hardware	Possible solutions	Characteristics	Chosen solution
Microcontroller	**Arduino Uno** 	• Less expensive • Has a lot of modules to simplify the work • Available	In order to control the robotic hand efficiently: Real time data acquisition and better energy consumption we choose the STM32 microcontroller 
	Arduino Mega 	• A large number of I/O • Low computing power • Clutter	
	STM 32 	• More Professional • More powerful • Low-power, low-voltage operation • It can work in real time with an embedded OS STM32 F4	
Servo motor	**SG90 SERVO MOTOR** 	• Low cost • Small size and easy installation • High output power relative to motor size and weight. • Torque 2.5 (Km-cm) • Speed 0.1 sec	With a view to optimize the energy consumption and minimize the cost we have chosen the SG90 Servo motor 
	MG946R SERVO MOTOR FUTABA 13KG 360 DEG 	• Precise speed control • High cost • Speed : .20sec/60Deg • Torque : 12kg • Voltage : 4.8~6v	
	Stepper Motor 	• More precise • Heavier, • Consumes more energy	
Motor Driver	**LM2596 DC-DC Module** 	• Switching current maximum: 10A • Reverse polarity protection • Output power 20W, 15W	For the sake of cost optimization and control efficiency, we opt to use the DC-DC Converter

	L298N Module 	• Low cost • It can deliver up to 2A peak and 20W continuous. • Unable to control all the servo motors used	Module 5A 75W XL4015 
	DC-DC Converter Module 5A 75W XL4015 	• Better than 2596 • Short circuit protection • Overheat protection • It can deliver up to 4A peak and 50W continuous. • Unable to control all the servo motors used • Ability to control the five-servo motor used	
Camera	**Computer Webcam** 	• Low cost • Low resolution	The hand gesture could be controlled with a simple camera so that we opted to choose our computer webcam. 
	STM32F4DIS-CAM CAM MODULE STM 	• High cost • Resolution : Up to 1280 * 1024 • Up to 30 frames / second for VGA and CIF modes	

II.3- Budget:

Element	**Cost**
Servo Moteur SG90	**9.400 dt *2 =18.400DT**
Wires	**6.000DT**
DC-DC Converter Module 5A 75W XL4015	**24.000DT**

Conclusion:

This chapter explained further the requirement specifications. This allows us to get an in-depth view and understanding of the work required and the tasks to be performed. After that, the technological choices are highlighted. The next chapter will deal with the design and realization of the project.

Chapter III: Development, Implementation and validation

Introduction:

In this chapter we will focus on the steps of the project realization. First the 3D simulation environment will be presented. Then the electrical and mechanical design will be fixed.
After that the development process will be detailed using flowcharts. Finally, we will go through the implementation followed by the validation.

I- The mechanical design:

In this part of the project, we have established a solid model of our robotic hand using the CATIA software. The robotic hand is composed of four 3D printed fingers supported jointly by a 3D printed palm. A thread wire is used to connect the fingers with its corresponding SG90 servo motor, which will provide the fingers' movements according to the microcontroller's command.
The following images shows the different parts of the mechanical design

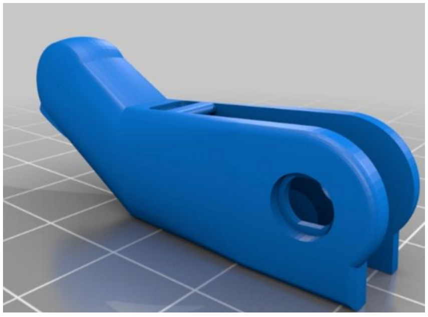


Figure 6:Finger design

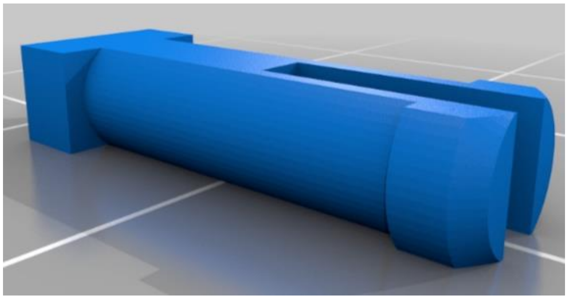


Figure 7:Pin design

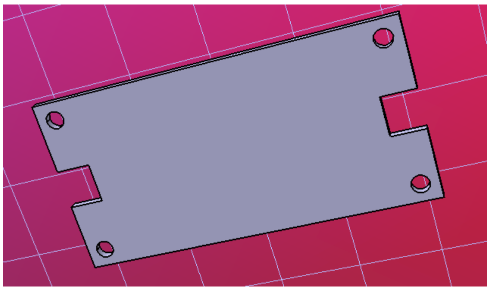


Figure 8: Plate design

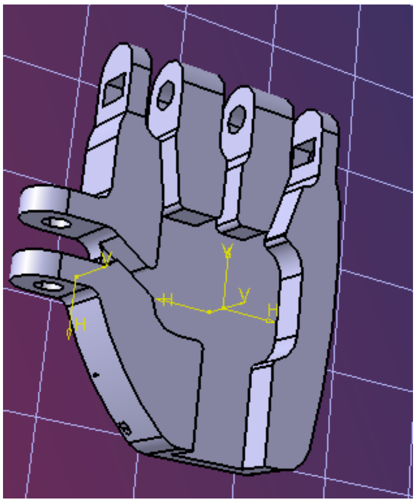


Figure 9:Palm design

II- 3D hand tracking environment:

In order to ensure the efficiency of our tracking model and the real time data acquisition it's important to simulate the operation through a 3D interactive environment.

We thought of using an open cv algorithm to track the hand and build a UNITY 3D hand tracking virtual environment which is the best used in application with real-time and big data.

the necessary steps of the model development are detailed below.

1-Strating from python script which allows us to identify the 21 hand landmarks on the cropped image of the hand. (Each landmark has three coordinates X, Y and Z).

The following image shows the 21 hand points that

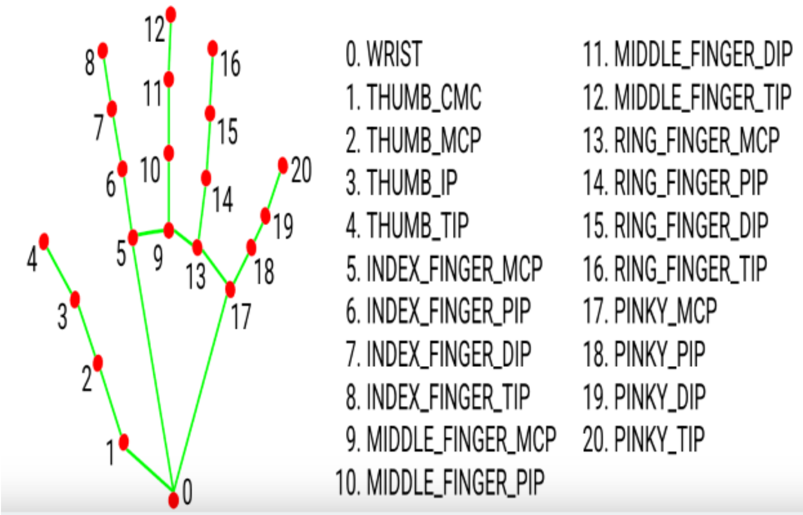


Figure 10:The Landmark

2-Followed by the design of the hand on unity

3-After that we have to write the C# code. In fact, the program was broken down into smaller modules each of which perform a certain function (the Data Receive, the lines, the Hand Tracking)

4-The final step is to test and validate the real time Hand tracking.

The interface of the simulation environment is shown in the following figure

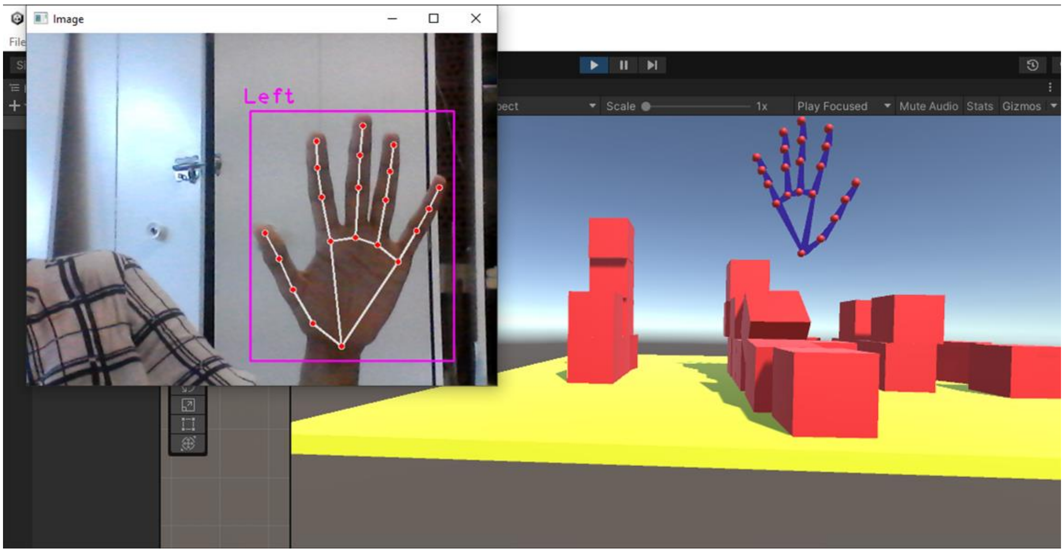


Figure 11:3D Virtual environment

III- The software development:

III.1- The hand recognition code:

- Hand recognition system can be divided into preprocessing, Feature extraction of the processed image, and real-time classification.
- This part of the project introduces the application using computer vision for hand gesture recognition. The camera records a live video stream. The media pipe library ensures the recognition of the hand motion. In fact, the system is trained for each type of count hand gesture after that a test gesture is given to it and the system tries to recognize it. The final step is to save the data from rendered results and send it to the system.
- The structure of the hand gesture detection is shown by the following flowchart

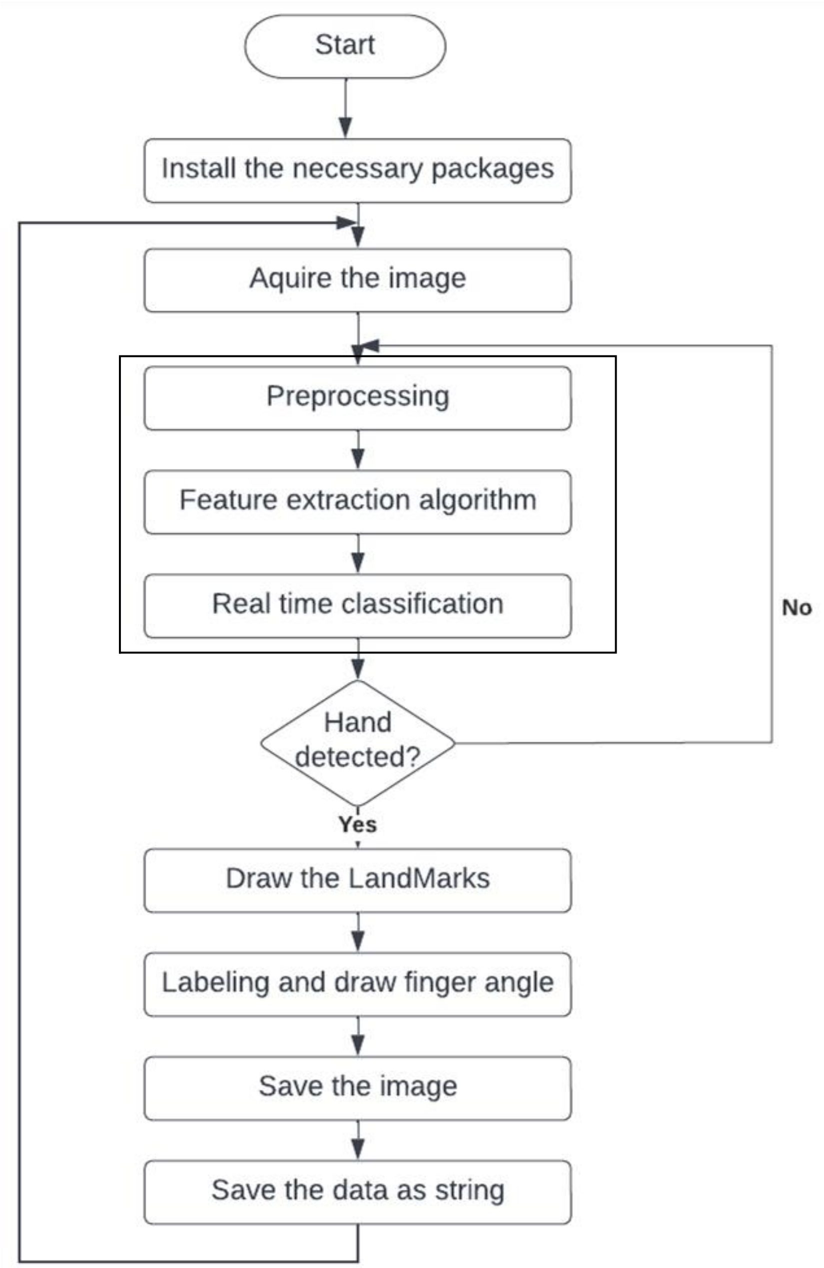


Figure 12:Python code organigram

III.2- The UART communication

UART (Universal Asynchronous Receiver/Transmitter) illustrates the hardware circuitry used for serial communication. UART is known as an integrated circuit within microcontrollers. UART hardware is devised into two forms:

- UART – Universal Asynchronous Receiver/Transmitter
- USART – Universal Synchronous/Asynchronous Receiver/Transmitter

The Synchronous transmitters generate the data clock and send it to the receiver which functions consequently in a synchronized way.

However, the asynchronous type generates the data clock internally. There is no incoming serial clock signal, so in order to achieve proper communication between the two ends, both of them must be using the same baud rate.

In this project, we have established USART communication between STM32H745ZI high-performance MCU and python. The module is used over a USB link which allows the transmission of data from python to the board. Accordingly, we have followed the next steps:

1. Enable USART3 from the connectivity tab
2. Put-on asynchronous mode
3. Set Baud Rate to 115200 Bits/s
4. Set Parity bit to None
5. Enable USART3 global interrupt
6. Configure pins PD9 and PD8 to USART3_RX and USART3_TX
7. Generate code

Microcontrollers have many ways to communicate with other systems. Typically, there is a serial link (UART), but there are also industrial buses like I2C, SPI or CAN For our project, we need a serial communication that retrieves data from the PC port, so A suitable solution is a UART, which is a serial link consisting of sending information bit by bit, with a delay between each bit

III.3- The STM program:

In this organizational chart, we have presented the microcontroller's process to send commands to servo motors in consonance with the identified hand's motions. The transmission of data is permitted by enabling the UART and unlocking the serial communication, which will receive the angles coordinates as a string of 1 and 0. The processed information will decide the rotation of the motors, therefore the fingers' movements.

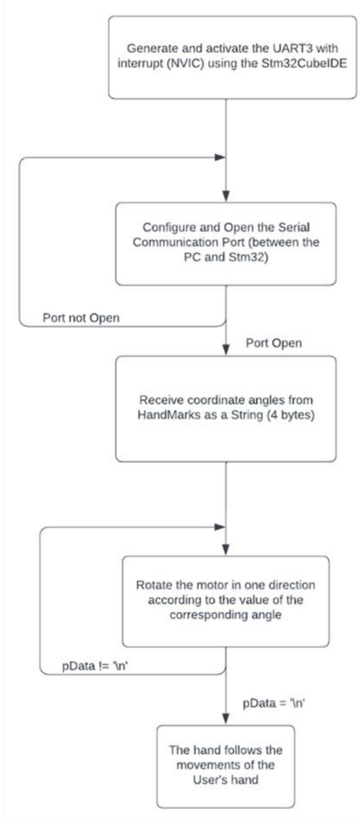


Figure 13 : The STM code chart

IV- Results verification and validation:

The main objective of our project is to create a system to detect, interpret hand gestures through computer vision and make hand tracking system.

As an achievement for our project, we successfully complete the next objectives:

1- Requirement specifications
2- Electrical and mechanical design
3- 3D Simulation interface
4- Software development

For the last objective “Implementation and validation of the result”, we encountered a voltage drop at the servo motor input which disable the servo motor and cancel its operation.

By measuring the servo motor input voltage, we find that it is 3.3V, or the motor requires 5v as an input to operate so the voltage interval is not adequate,

Our solution was to rescale the range of the voltage by adding a Level shifter, this circuit is used to translate signals from one logic level or voltage domain to another, allowing compatibility between integrated circuits with different voltage requirements, such as TTL and

CMOS. we can use 74AHCT125 Quad Level-Shifter (3V to 5V), will do everything you need, with better performances with respect to discrete solutions, but at a much higher price. [6]

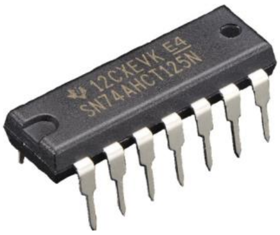
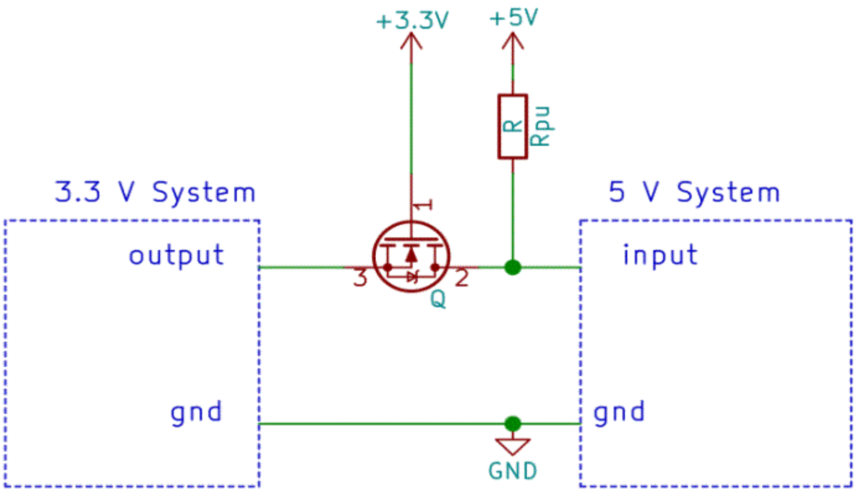


Figure 14: Level Shifter

In addition, we can use Single MOSFET level translator , the principal of operation is simple , when the output is 3.3 v , since VGS =0V , the MOSFET is off , so the output held at 5V by the pull-up resistor , when the output is low VGS is 3.3V .Assuming the MOSFET has a logic threshold (should be fully on when VGS=2.5V) the MAOSFET conducts the low



General conclusion

The main goal of this project is to create and set up a system of hand motion recognition allowing the user to detect and track the hand gesture in real-time using computer vision technology and adding IoT functionalities.

The project could be divided into three main phases: Hardware development, software development, and 3D virtual interactive environment development. This report deals with these three parts.

To initiate the project, we started by studying the literature review and the existing products in order to reshape the requirement.

After that, the new components were chosen carefully to bring maximum value with minimum price. Following that, the electrical and the mechanical design were fixed to satisfy the requirement.

Then a 3D virtual environment was developed rigorously in order to simulate the real-time hand motion tracking.

Finally, the software development was divided into two parts: A code for hand gesture

recognition and a code for the command of the hardware. The communication between the two parts was done through the UART protocol.

However, this project always remains open for evolution. We aimed to add functionalities to improve the system.

The functionalities that we estimate to add are summarized in adding a level shifter module in order to command the servomotors properly. In addition, we can add piezoelectric sensors allowing the system to manipulate objects in real time.

Webography

[1]: https://www.hisour.com/fr/gesture-recognition-42946/, consulted in 02/06/2022

[2]:https://research.sabanciuniv.edu/id/eprint/1225/1/malima_SIU06.pdf?fbclid=IwAR0WDWnclA6vXNd7stXIOyOssTf5KcSbZYGxNbO3YkW6Dy1dQLqEH96z3lc, consulted in 2/1/2022

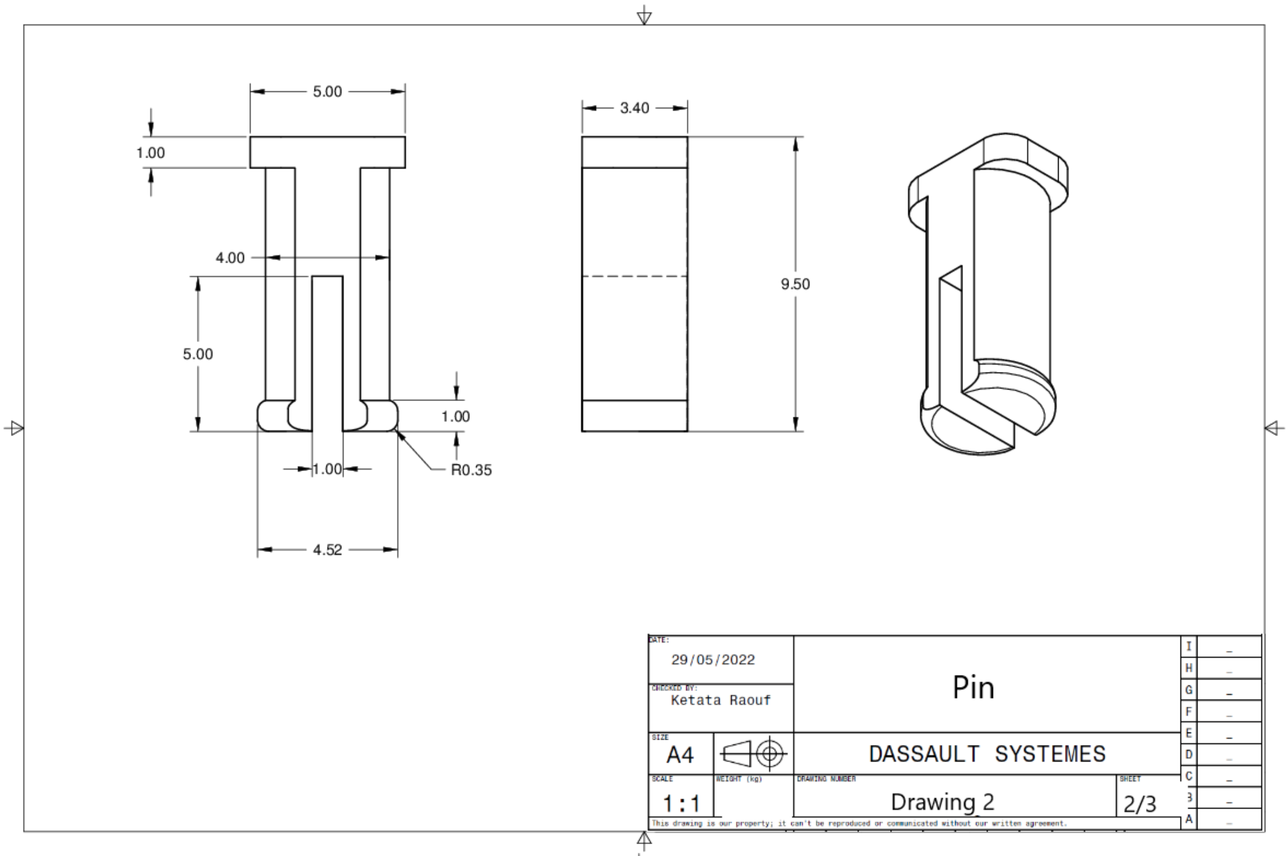
[3]:https://www.researchgate.net/publication/296970229_Modelbased_3D_Hand_Tracking_with_on-line_Shape_Adaptation, consulted in 2/1/2022

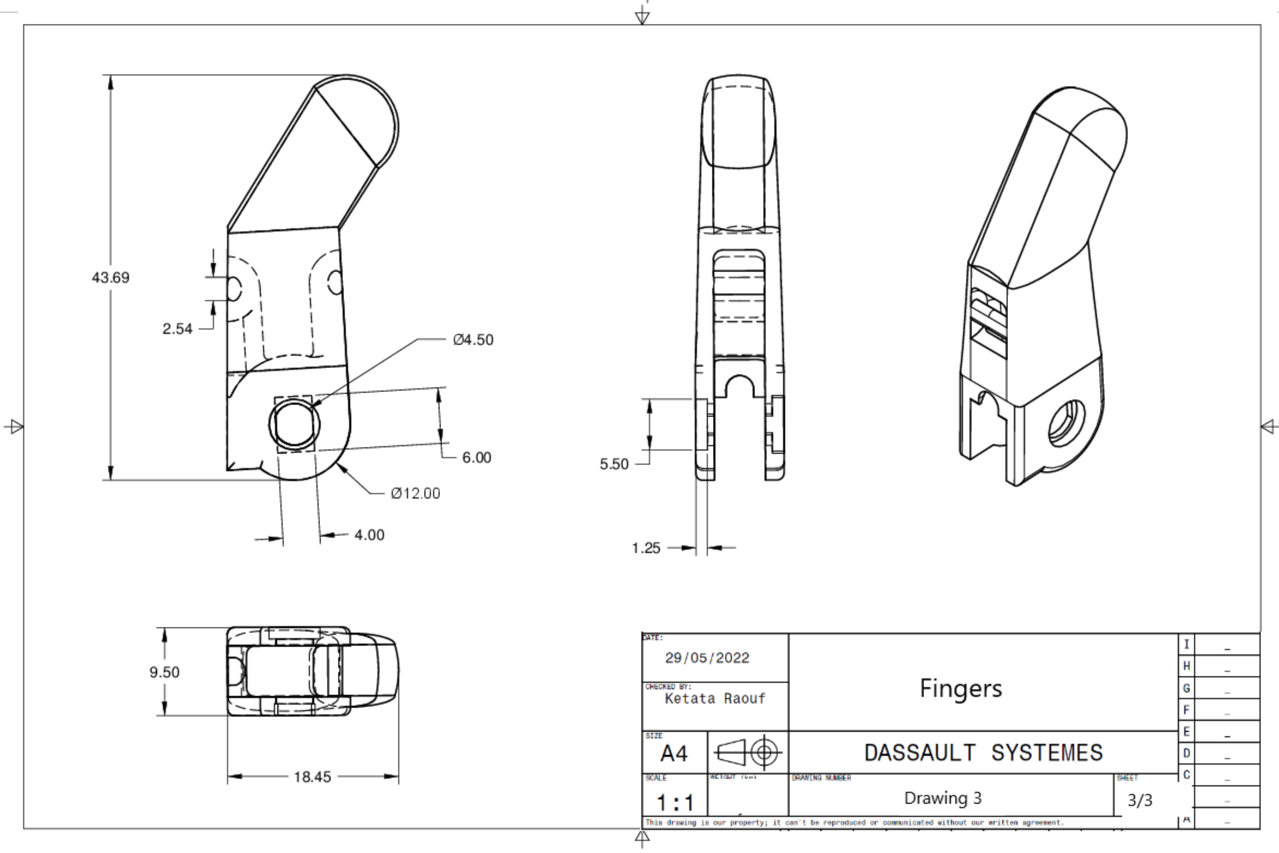
[4]: https://www.degruyter.com/document/doi/10.1515/pjbr-2019-0012/html, consulted in 02/06/2022

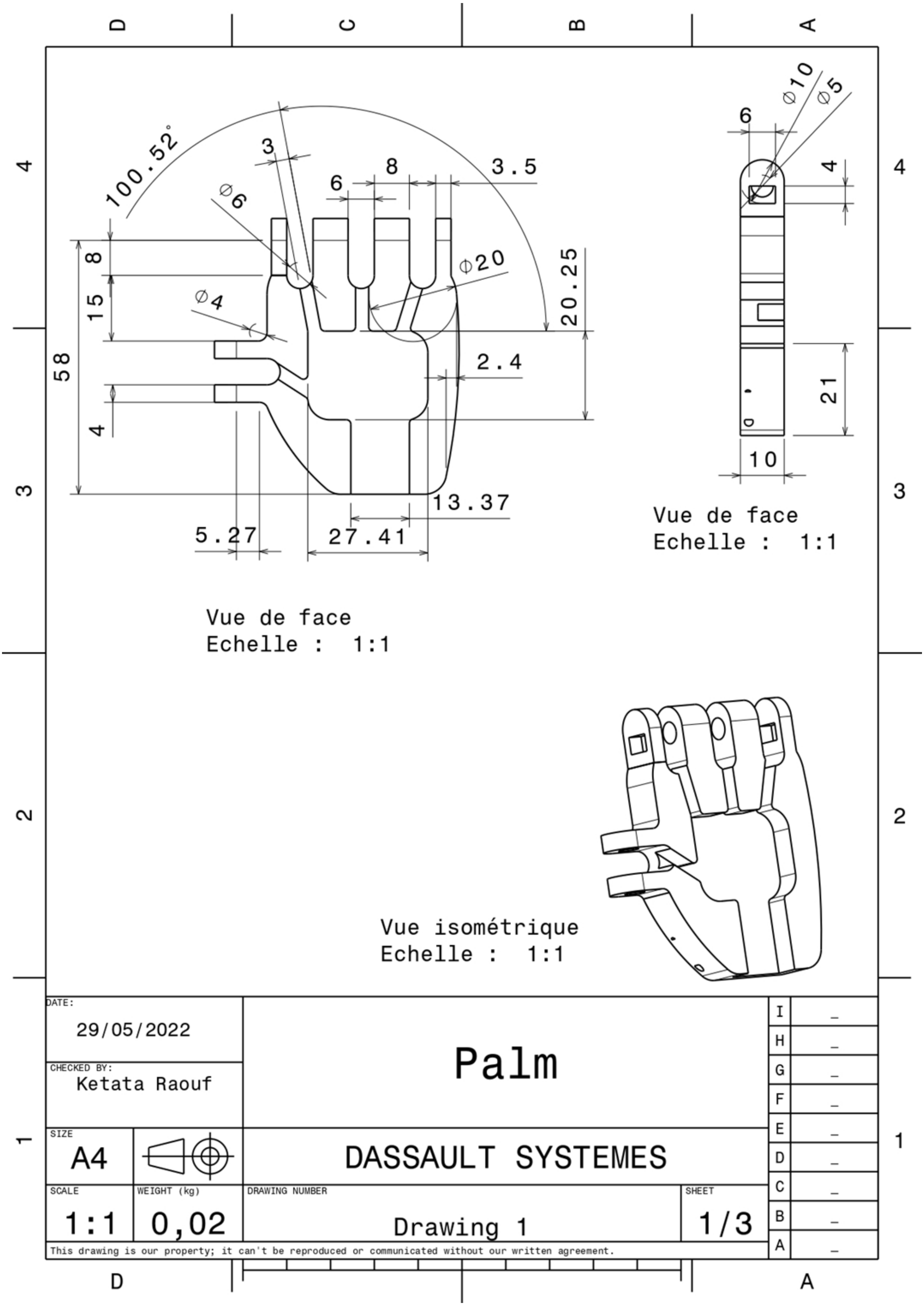
[5]: http://www.ijitis.org/index.php/ijitis/article/view/22/20, consulted in 01/06/2022

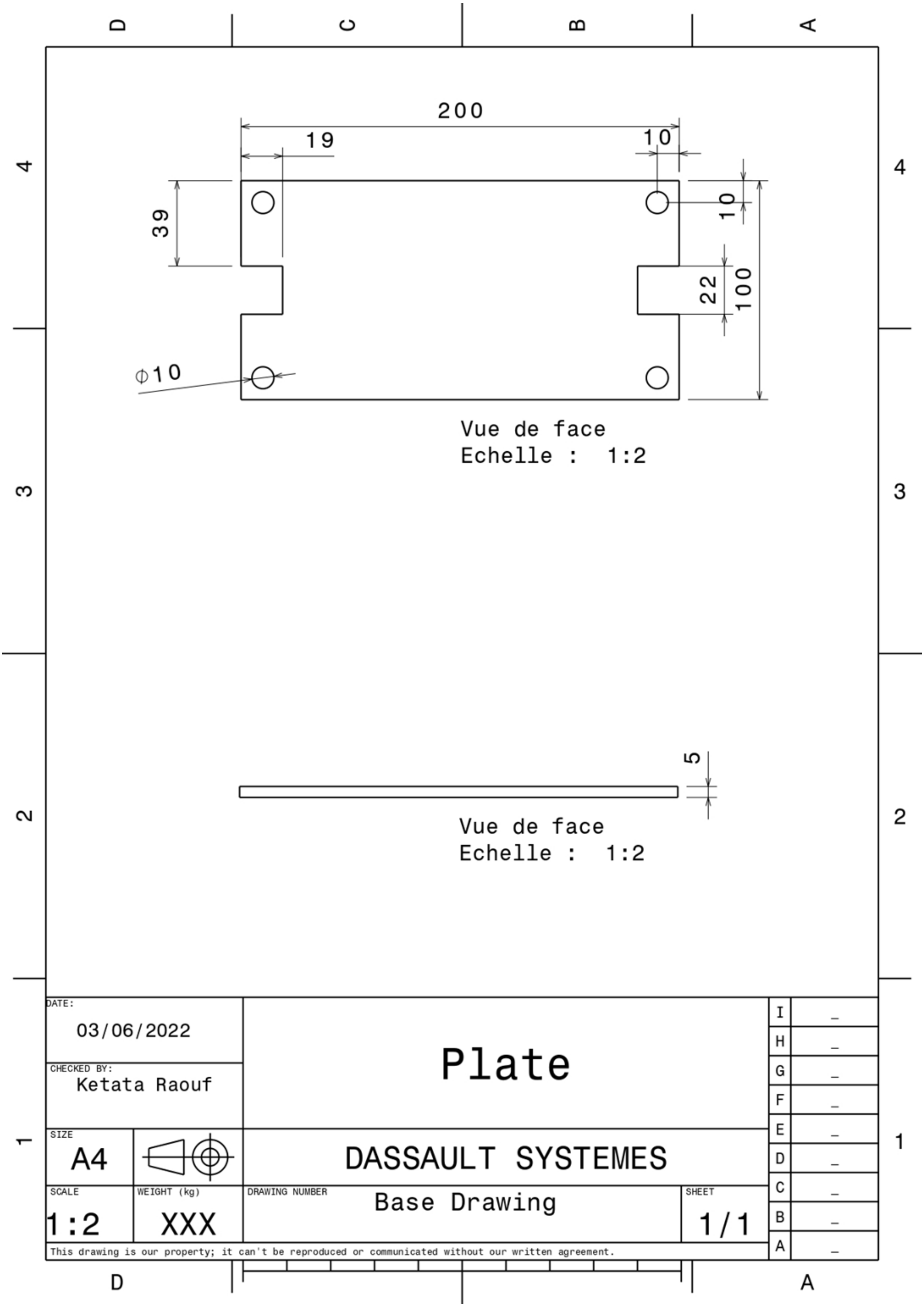
[6]: https://2betrading.com/cartes-de-developpement/5631-74ahct125-quad-level-shifter-3v-vers-5v-.html?fbclid=IwAR1Z-n0zQyJMcDUAbTtCGWz6w3wrVS5rBATuj54ih-kd5rwzYorKlKTSDIM, consulted in 03/06/2022

Appendix I: Mechanical design






100.52°
3
ϕ6
6
8
3.5
ϕ20
20.25
ϕ4
8
15
58
4
2.4
13.37
5.27
27.41
Vue de face
Echelle : 1:1
6
ϕ10
ϕ5
4
21
10
Vue de face
Echelle : 1:1
Vue isométrique
Echelle : 1:1
DATE:
29/05/2022
CHECKED BY:
Ketata Raouf
Palm
SIZE
A4
DASSAULT SYSTEMES
SCALE
1:1
WEIGHT (kg)
0,02
DRAWING NUMBER
Drawing 1
SHEET
1/3
This drawing is our property; it can't be reproduced or communicated without our written agreement.


D
C
B
A
4
3
2
1
200
19
10
39
10
22
100
ϕ10
Vue de face
Echelle : 1:2
5
Vue de face
Echelle : 1:2
DATE:
03/06/2022
CHECKED BY:
Ketata Raouf
Plate
SIZE
A4
DASSAULT SYSTEMES
SCALE
1:2
WEIGHT (kg)
XXX
DRAWING NUMBER
Base Drawing
SHEET
1/1
I
H
G
F
E
D
C
B
A
This drawing is our property; it can't be reproduced or communicated without our written agreement.

Appendix II: Electrical design