The People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

8 May 1945 University of Guelma

Faculty of Science and Technology

Department of Electronics and Telecommunications

End of Studies Project Report (PFE)

For the award of the Master's degree in Telecommunications a startup / a patent innovation.

Option:

« Networks and Telecommunications »

Title:

Machine conception and realization

Mesh generation from a cloud of points

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Academic Year: 2023/2024

Appreciation

I would like to express my profound gratitude to the Almighty God, without whose blessing this modest work would never have seen the light of day.

The meticulous and careful preparation of this work was carried out with the invaluable assistance of my supervisor, **Mr. Kheireddine ABAINIA**, whom I particularly thank for proposing such an interesting topic, through which i was able to gain enriching experience on all levels.

I would also like to thank the members of the defense jury for the honor they have done me by evaluating my work.

I do not forgetmy classmates and friends, with whom I shared the best moments during my academic journey, as well as the most difficult moments, which will remain etched in the book of memories.

Finally, I return to the source of my existence, my dear parents, to whom I express my profound gratitude and dedication; I thank them for instilling in me the importance of education and knowledge, and for teaching me that the most difficult choice is often the most fruitful. I hope to bring some joy and pride to your hearts through this personal achievement.

I would also like to thank my siblings very much, for their support, as well as everyone who contributed to this work, whether near or far.

Dedication

إهداء

إلاهي لا يطيب الفرح الا بشكرك ولاتطيب اللحظات الا بذكرك ولا يطيب النجاح الى بطاعتك الحمد لله حبا شكرا وامتنانا ما علونا ولا تفوقنا الا برضاه واليه ينسب الفضلو

اهدي تخرجي هذا وثمرة جهدي وحصاد ما زرعته خلال السنين في سبيل العلم الى التي تقر عينها لرؤيتي في يوم كهذا، الى شمس حياتي وملاذي الدافئ، الى العطاء الدي لا ينفد امي الغالية

الى رمز العطاء و التضحية ،حبيبي ومعلمي ، من أسهر لياليه وعمره في سبيل راحتي وتحقيقأحلامي،الى روح القوة و السلام التي تملأ حياتي، إلى قائدي وقدوتي أبي العزيز

الى من شد عضدي بهم ، إخوتي الأعزاء، أهدي تخرجي وأعبر عن شكري العميق لكم كنتم الدعم الثابت والسند الموثوق

و اخيرا الى من تطيب صحبتي بهم صديقاتي العزيزات والى ابنة اخي وعزيزتي "رويا"

...

حموشي إكرام

Dedication

إهداء

بسم الله الرحمن الرحيم، الحمد لله الذي بنعمته تتم الصالحات، وبتوفيقه يتحقق النجاح. ما كان لهذا العمل أن يرى النور لولا عون الله ورحمته، فله الحمد أولاً وآخراً على ما أنعم به من توفيق وعلم وصبر.

إلى والديَّ العزيزين، اللذين كانا دائماً مصدر دعمي وقوتي، أقدّم لهما هذا العمل تقديراً لما بذلاه من تضحية ودعاء وتشجيع.

إلى إخوتي وأخواتي الأعزاء، وإلى ابنة أختي العزيزة "رزان"، الذين رافقوني وسندوني في كل خطوة، كنتم دائماً العون والمساندة.

إلى أساتذتي الأفاضل، الذين بذلوا جهدهم ووقتهم في تعليمنا وتوجيهنا، ولكل من ساهم في إنجاح هذا المشروع من قريب أو بعيد.

وأخيراً، إلى زملائي وأصدقائي الذين شاركوني في هذه الرحلة الطويلة، أهديكم هذا العمل اعترافاً بفضل دعمكم ومساندتكم.

اللهم لك الحمد والشكر على كل نعمة، وعلى كل نجاح تحقق بفضلك وكرمك.

...

سلمي جيهان

Abstract

This project focuses on the development of a low-cost, high-precision 3D scanning machine designed to transform physical objects into detailed 3D models. The study begins with an exploration of mesh generation and 3D scanning technologies, examining their history, applications, challenges, and recent innovations. The project then delves into the technical design of a specific 3D scanner, detailing the electronic and mechanical components. Point cloud data is generated and processed through a series of phases, from scanning to mesh reconstruction. A Python program is employed to convert raw data into 3D coordinates and visualize the resulting point cloud. The final stage involves transforming the point cloud into a 3D mesh. This innovation aims to provide accessible 3D scanning solutions for industries like digital design, film production, mechanical construction, and 3D printing, with the potential to significantly reduce modeling time and cost.

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List of acronyms

3D: Three-Dimensional

AI: Artificial Intelligence

ML: Machine Learning

CAD: Computer-Aided Design

CAE: Computer-aided engineering

EMS: Engineering and Manufacturing Services

CMM: Coordinate Measuring Machine

NEMA: National Electrical Manufacturers Association

DC: Direct Curren

RMS: Root Mean Square

DIR: Direction

Vmot : Voltage to Motor

GND: Ground

VDD: Voltage Drain Drain

Vin: Voltage In

SCL: Serial Clock

SDA: Serial Data

GPOI: General purpose output/input

XSHUT: External Shutdown

SHDN: ShutDowN

IDE: Integrated development environment

LED: Light Emitting Diode

SRAM: Static Random Access Memory

EEPROM: Electrically Erasable Programmable Read-Only Memory

USB: Universal serial bus

CNC: Computer Numerical Control

TLS: Terrestrial laser scanning

ALS: Airborne laser scanning

TOF: Time-of-flight

General Introduction

General introduction

Many industries face challenges related to the need for precise measurements, remanufacturing parts, historical documentation, and surgical planning. 3D scanning technologies offer an effective solution to these issues by enabling the creation of accurate digital models of real-world objects. These models help improve processes, save time and costs, and enhance accuracy in various applications.

This project aims to provide a comprehensive overview of mesh generation and 3D scanning technologies, highlighting their importance in solving numerous practical problems.

In the first chapter, we define mesh generation and 3D scanning, review their history, and explore various applications. The chapter also discusses the challenges and innovations within this field.

The second chapter details the design of a specific 3D scanning device, including its electronic and mechanical components, and explains the design process for various parts such as the rotating disk and sensor holder.

In the third chapter, we focus on the process of transforming point cloud data into a 3D mesh, highlighting the key techniques and algorithms involved in mesh reconstruction. This chapter explains the methods used to acquire point cloud data, process it, and generate a cohesive 3D mesh, allowing for the detailed representation of scanned objects. Additionally, we discuss the results of testing the prototype on different objects, analyzing the device's performance, limitations, and potential improvements to enhance precision and expand its capabilities.

Through this exploration, the project provides a strong foundation for understanding the evolving capabilities of 3D scanning and mesh generation technologies, highlighting their potential for further development and application in diverse fields.

Chapter I: Overview of mesh generation and 3D scanning

1. Introduction

3D mesh models are a crucial element of 3D modeling, and it is a technique used to create and visualize three-dimensional objects, scenes and spaces. 3D modeling, and by extension, 3D mesh models, are commonly used in construction, architecture, interior design, product design, film production, video games, medical imaging (devices, diseases, treatments, etc.), scientific research and analysis [1].

Mesh generation in 3D modeling encompasses various techniques, including those involving 3D scanning. The latter serves as a fundamental step, capturing real-world objects or environments to generate a cloud of points (or data) used to create meshes.

In this chapter, we will give an overview and discuss the mesh generation concept and 3D scanning principles.

2. History

Mesh generation involves computational science and engineering, and has been developed significantly since its inception in the 1950's. Early methods were rudimentary, but structured grids in the 1970's and 1980's facilitated efficient calculations. Unstructured grids in the 1980's and 1990's revolutionized the mesh generation, enabling arbitrary geometries' discretization, where the adaptive mesh refinement in the 1990's enhanced simulation accuracy. Automatic mesh generation in the 2000's streamlined the process, where the progress in hybrid methods and parallel computing in the 2010's further accelerated the mesh generation capabilities. Future trends point towards adaptive and dynamic meshing techniques integrated with artificial intelligence and machine learning algorithms, promising real-time simulations and optimization. Throughout the mesh generation evolution, it is considered as fundamental, enabling numerical simulations and scientific discoveries across diverse disciplines [2].

3. Meshgeneration

The mesh generation considers the whole process from data collection to final 3D product including data visualization (point clouds), data cleaning, filtering, creation of complex surface models.[3]

3.1. Definition of 3D mesh model

A 3D mesh model is a collection of vertices (3D points), edges, and faces that form a three-dimensional object. The vertices are the coordinates in three-dimensional space, the edges each connect two adjacent vertices, and the faces (also called polygons) enclose the edges to form the surface of the object. The most commonly used polygons in 3D mesh models are triangles and quadrilaterals [1].

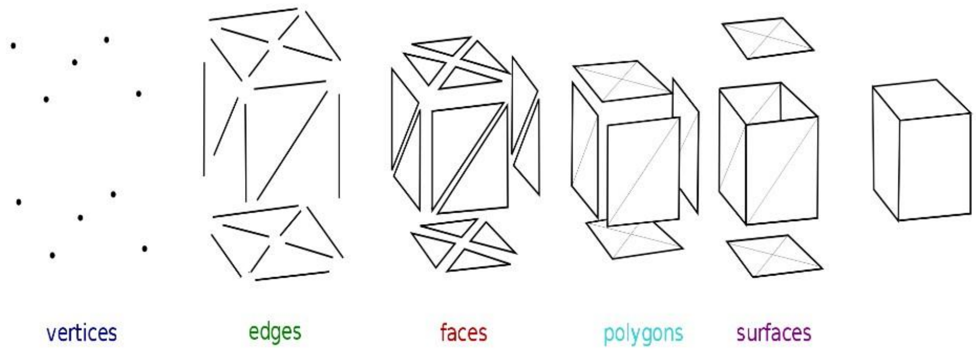


Figure I.1. Example of mesh construction [4]

3.2. 3D mesh model creation

The creation of 3D mesh models can be done in several ways, such as modeling, sculpting, procedural modeling and 3D scanning. Below, we will give an overview about each one [1].

3.2.1. Modeling

This involves creating and editing the vertices, edges and faces of the mesh model manually or using advanced tools in 3D modeling software. Some of the most popular 3D modeling softwares are Blender, Cinema 4D, SolidWorks, Autodesk Maya, Fusion 360 and 3DS Max [1].

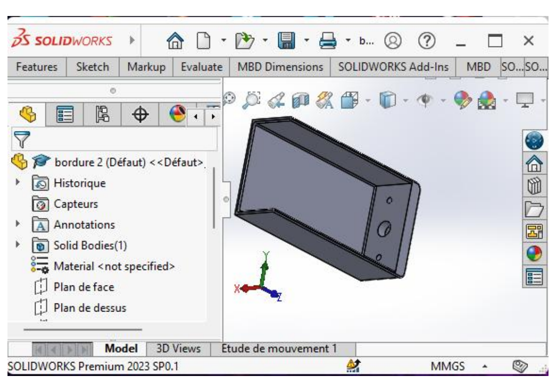


Figure I.2. Screenshot of SolidWorks

3.2.2. Sculpting

In this method, the mesh model is shaped similar to *clay or mud* by directly manipulating the surface of the object. Sculpting is often used in combination with other modeling techniques to create realistic and complex models [1].

Figure I.3. Sculpted object [5]

3.2.3. 3D scanning

3D scanning is a technique that converts a physical object into a 3D digital model. It involves a 3D scanner to capture the surface of the object and create a digital mesh model. This process is particularly well suited for capturing real objects and reproducing them in detail in the digital world [1].

Figure I.4. Example of 3D scanner [6]

3.2.4. Procedural modeling

Procedural modeling generates the 3D mesh models using algorithms and mathematical functions. This method is particularly useful for creating complex and detailed models that are difficult to model manually, such as natural landscapes, clouds, or fluids [1].

4. 3D scanning technologie

4.1.Definition

3D scanning is a quick and precise method for capturing the physical measurements of an object and transferring them to a computer as data. This data is typically represented as a scaled digital model or 3D graphical rendering. Once digitized, all dimensions of the object, such as length, width, height, and surface area, can be measured.

3D scanners can be utilized for various purposes, including reverse engineering, inspection, creating CAD models, and supporting computer-aided engineering (CAE) applications. The data captured by 3D scanners is typically represented as free-form, unstructured three-dimensional data in the form of a cloud of points or a triangular mesh. The collected data is then merged into a complete model through alignment or registration processes, either during scanning or as a post-processing step [7].

4.2. History and assessment of 3D scanning

Three-dimensional laser scanning technology evolved during the latter half of the 20th century with the goal of accurately reproducing objects and environmental surfaces. The earliest iterations emerged in the 1960's, employing lights, cameras, and projectors. By the mid-1990's, these scanners progressed to full-body scanning capabilities. In 1994, 3D scanners introduced REPLICA, enabling rapid and precise scanning of detailed objects.

Concurrently, Cyberware developed high-detail scanners capable of capturing object colors. However, achieving true three-dimensional scanning with high speed and accuracy remained challenging. Digibotics introduced a 4-axis machine for 3D modeling, but it was slow and couldn't digitize colored surfaces. While optical scanners were costly, Immersion and Faro Technologies introduced affordable manually operated digitizers. In the 1980s, Cyberware Laboratories pioneered head scanners for the animation industry. In 1996, 3D scanners integrated manual arm and laser stripe 3D scanner technologies in ModelMaker, the world's first reality capture system, capable of producing complex models and coloring them within minutes [8].

4.3. Types of 3D scanning

There are many types of 3D scanners and scanning technologies.

Structured light scanning a prevalent methodology, employs the projection of patterns onto an object followed by capturing their deformations to ascertain its form. Renowned for its impressive precision, structured light scanning excels at detecting intricate details and textures on objects ranging from small to medium sizes. It is especially effective for non-industrial applications, including the scanning of the human body, artwork, and cultural relics.[9]

Laser scanning constitutes another favored technique. This method involves directing a laser beam towards an object that reflected light is subsequently analyzed to generate a three-dimensional representation of the subject.[9]

Laser scanners provide speed and versatility, making them ideal for tasks that require high precision in industrial applications. They are particularly effective for scanning objects like engine piping, lost foam molds, and planet carrier gears.

Photogrammetry represents an alternate approach that leverages multiple photographs taken from varying angles from which software synthesizes into a 3D model.

A cost-effective and convenient solution, photogrammetry proves particularly beneficial when tasked with large objects like fuselage, engine blade, wind power hub.[9]

4.4. Applications of 3D scanners

3D scanners play a vital role across various industries, offering a multitude of applications:

Engineering and Manufacturing: They accurately map object geometry, aid in prototype design, facilitate the creation of new tools, and ensure quality control in production processes [10].

Figure I.5. Quality control using 3D scanning [11]

Architecture and Construction: 3D scanners digitize existing buildings and monuments, enabling analysis and reconstruction. They are also used to create mockups for architectural projects [10].

Medicine: In the medical field, 3D scanners are used to create anatomical models for surgical planning, design orthoses and prostheses, and prepare orthodontic appliances [10].

Figure I.6. Example of a 3D dental scanner[12]

Entertainment: They are utilized to create realistic characters and objects for computer and video games, enhancing visual experiences for users [10].

3D Printing: Objects scanned by 3D scanners can be replicated through 3D printing, allowing for the production of exact replicas with precision and accuracy [10].

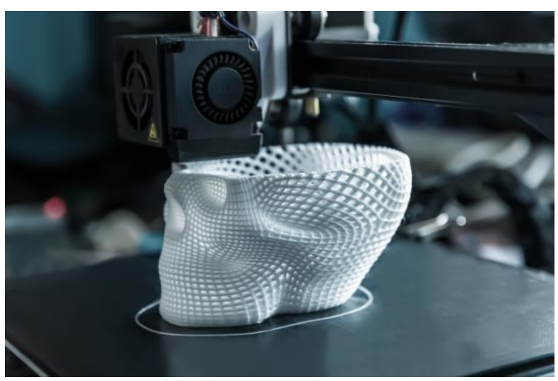


Figure I.7. Example of 3D printing [13]

Automotive: 3D scanners are used to recreate components that are no longer available in the market, such as vintage car parts. They also play a crucial role in scanning traffic accident scenes to recreate the sequence of events for forensic analysis [10].

5. Conclusion

In summary, 3D mesh generation and 3D scanning technologies have significantly advanced, playing a substantial role in various industries such as architecture, medicine, entertainment, and manufacturing. The evolution of 3D scanning from the early optical devices of the 1960's to the sophisticated scanners of today highlights the technological strides made in capturing and reproducing detailed three-dimensional models. Despite their transformative potential, these technologies face challenges such as high costs, limitations in scanning complex or concealed geometries, and sensitivity to ambient light interference. Nevertheless, with ongoing advancements and increasing accessibility, 3D mesh generation and scanning are poised to revolutionize the way we design, analyze, and interact with the digital and physical world, offering precise and efficient solutions across multiple sectors.

Chapter II: Design and Construction of a 3D Scanner

1. Introduction

The meticulous design of electronic components and the integrated mechanical structure are crucial factors in constructing a 3D scanner with high accuracy and reliability. Each component plays an essential role in ensuring the synchronization of movements and the accurate collection of data, ultimately producing a comprehensive and detailed 3D model.

In this chapter, we will delve into the electronic components and mechanical design of a 3D scanning device.

2. Description of electronic components and mechanical design of a 3D scanner

In this section, we describe different parts used to construct our 3D scanner, as well as the mechanic design

2.1. Description of electronicschematic setup for a 3D scanning machine

The 3D scanning machine designed for 3D mesh generation, based on the depicted schematic, employs an Arduino board (Arduino UNO) as the central controller to precisely manage the movements of two stepper motors, each connected via motor drivers (A4988 driver). The stepper motors are responsible for moving the scanning platform and the sensor (VL1680X sensor) in a controlled and accurate manner. This setup enables the system to capture multiple viewpoints of the object being scanned. The Arduino sends step and direction signals to the motor drivers, which then translate these signals into high-power outputs to drive the stepper motors. The motors' precise movements allow for the systematic scanning of the object’s surface.

As the Arduino coordinates the motors movements, the scanning sensor collects data at each position, which is then processed to generate a 3D mesh. The integration of these electronic components ensures the smooth operation of the 3D scanning process, resulting in accurate 3D models for various applications.

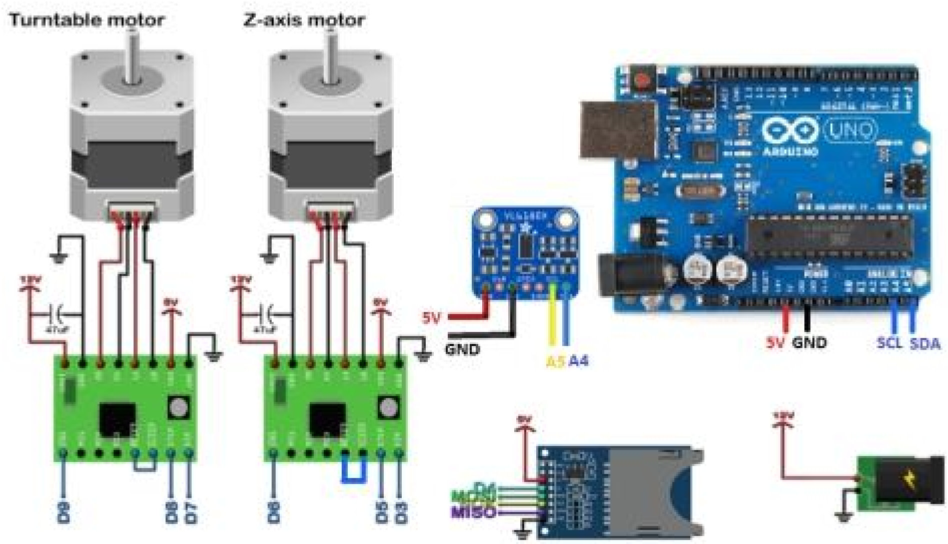


Figure II.1. Schematic illustrates the electronic setup for a 3D scanning machine

2.1.1. Description of electronic components

A. Stepper motor

A stepper motor is a type of brushless synchronous motor that rotates at precise angular steps, dividing a full rotation into a different number of steps. Unlike many other motors, it does not necessitate a feedback mechanism for control [14].

a. Constitution

A stepper motor typically consists of a rotor and a stator. The former contains a permanent magnet, while the latter has multiple coils wounded around it. These coils are energized in a sequence to generate electromagnetic fields, causing the rotor to move in precise angular steps. Stepper motors can come in various designs, such as bipolar, unipolar, or hybrid depending on the arrangement of the coils and magnets [14].

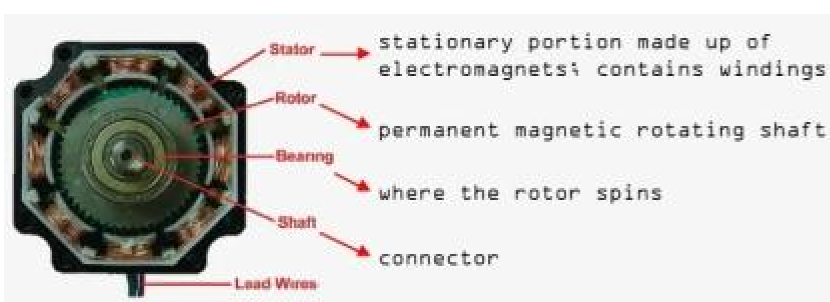


Figure II.2. Structure of a stepper motor [14]

b. Principle of operation of the stepper motor

Stepper motors receive an ordered sequence of square-wave signals or pulses and convert them into a rotational mechanical movement made up of a series of increments called “steps” [15].

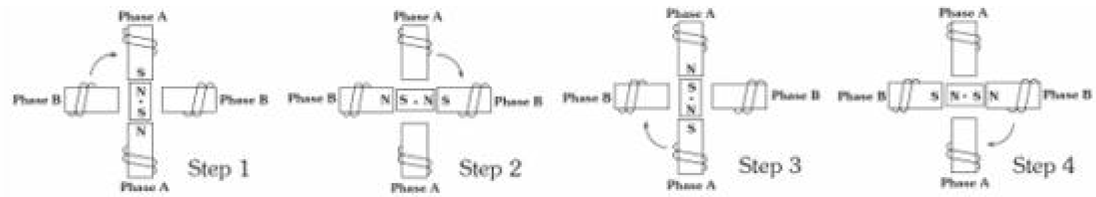


Figure II.3. Step sequence for a two-phase motor [15]

Energizing a coil winding creates an electromagnetic field with a north and south pole. The magnetic field created by the winding will cause the magnetized rotor to align itself with the magnetic field, since unlike poles attract [15]. The direction of the magnetic field can be altered to create rotation of the rotor.

c. Stepper motor driving and control

Stepper motors require some external electrical components in order to run. These components typically include a power supply, logic sequencer, switching components and a clock pulse source to determine the step rate [16].

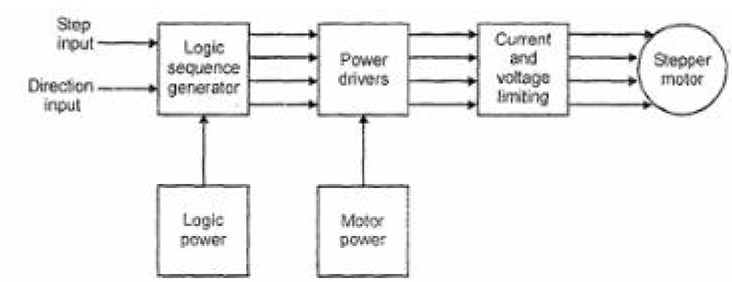


Figure II.4. Block diagram of the stepping motor driver [16]

It involves a series of electrical pulses, which determine its movement. These pulses are generated by a controller or a microcontroller in the form of square waves with a specific frequency and duration.

The electrical pulses are then directed to the stepper motor coils through a driver circuit. The sequence of pulses, timing between pulses, and control logic determine the motor's movement[16].

d. Driving mode

There are four different driving modes for stepper motors:

- Wave drive (full step): Energizes one phase at a time, moving in full steps. Simple but may vibrate and have lower torque[14].

- Two phases on (full step): Both phases energized together for full step movement. Better torque and smoother than wave drive[14].

- Phases on (half step): Alternates phases for half-step movement. Finer resolution and smoother motion than full step[14].

- Microstep: Energizes coils at varying levels for fractional steps. Highest resolution and smoothest motion, but needs more complex control[14].

e. Step angle and motor speed

$$\beta = \frac{N_s - N_r}{N_s \cdot N_r} \times 360$$

$$\beta = \frac{360}{mN_r}$$

Step angle is defined as the angle through which the stepper motor shaft rotates for each command pulse. It is denoted as ***β***. and computed as follows:

Where N_s is the number of stator poles or stator teeth, N_r is the number of rotor poles or rotor teeth and *m* is the number of stator phases [16].

f. Motor speed

The motor speed of velocity is computed by the following formula:

$$n = \frac{\beta \times f}{360^\circ} \text{rps}$$

Where β is the step angle, f is the stepping frequency (or pulse rate in pulses per second) and *rps* is the rotation per second [16].

g. Nema17 stepper motor

Standard Nema17 motors typically have the following characteristics[17]:

- Step angle: 1.8 degrees per step, resulting in 200 steps per revolution.
- Phases: 2 (bipolar).
- Wire Configuration: 4-wire cord.
- Voltage: 2 volts DC.
- Current: 1.2 amperes.
- Phase resistance: approximately 1.7 ohms with a tolerance of ± 10% at 20 degrees Celsius.
- Phase inductance: around 4.5 milli-henries with a tolerance of ± 20% measured at 1 kHz and 1 volt RMS.
- Holding torque: Minimum of 0.4 Newton meters (Nm).
- Shaft diameter: 5 millimeters or 0.188 inches (3/16 inches).
- Shaft length: 22 millimeters.
- Motor body height: 40 millimeters.

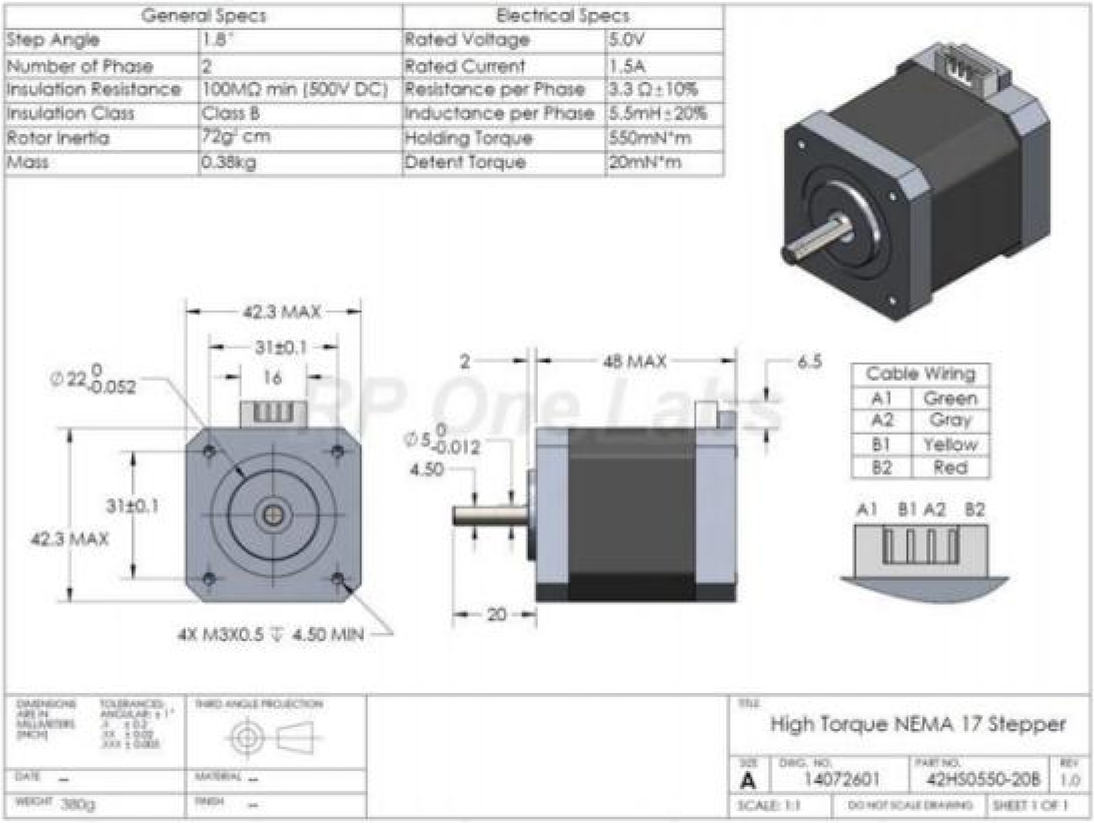


Figure II.5. Features of Nema17 stepper motor [17]

B. Stepper driver A4988

The operation principle of stepper motor drivers involves the efficient control of the motors, using only two control signals STEP and DIR. The number of pulses sent to the driver corresponds to the number of steps taken, with the frequency of the pulses dictates the motor's speed, and the DIR signal determines the motor's direction [18]. The A4988 driver manages sending the sequence to the motor coils based on the received input commands.

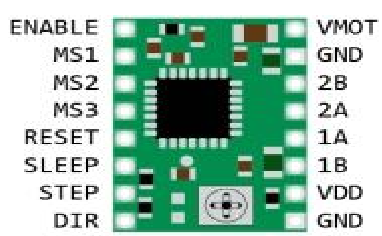


Figure II.6. Stepper driver A4988 [18]

The assembly of the A4988 driver requires understanding its various pins and their functionalities:

- **Enable pin :** Inverted logic. It enables or disables the motor. When in a high state, the motor is active, locking the axis between steps. In a low state, the axis is completely free[19].
- **MS1, MS2, MS3 pins :** Used for selecting the Step/ MicroStep configuration. These pins have Pull-Down resistors that bring the potential to 0V when they're not connected [19].
- **Reset pin :** Inverted logic. It resets the module and is typically connected to the "sleep" pin [19].
- **Sleep pin :** Inverted logic. It's typically connected to the "Reset" pin of the module [19].
- **Step pin :** Sends a clock signal (High then Low) to advance the motor by one step [19].
- **DIR pin :** Indicates the direction of motor rotation. A high state turns the motor in one direction, while a low state turns it in the other direction [19].
- **V Mot pin :**Motor power supply voltage, typically 12V for stepper motors, with a voltage range between 8V and 12V [19].
- **GND pin :** Ground for the motor supply, usually connected to the logic control ground [19].
- **2B 2A pins :** First coil of the bipolar stepper motor [19].
- **1A 1B pins :** Second coil of the bipolar stepper motor [19].
- **VDD pin :** Logic control power supply, typically between 3V and 5.5V, commonly set at 5V [19].
- **GND pin :** Ground for the logic control, often connected to the motor power supply ground [19].
- **The adjustment potentiometer**: used to adjust the output current of the driver Max.Current= V ref x 2.5 [18].

C. VL6180X distance sensor

The VL6180X is based on Time of Flight technology, and it contains a very tiny invisible laser source, and a matching sensor. It can detect the "time of flight", or how long the light has taken to bounce back to the sensor. Since it uses a very narrow light source, it is good for determining distance of only the surface directly in front of it. Unlike other distance sensors, the VL6180X is much more accurate and doesn't have linearity problems or 'double imaging' where you can't tell if an object is very far or very close [20].

Figure II.7. VL680X sensor [20]

The VL6180X uses I2C protocol to interface it, which means it uses the two I2C wires (data & clock) available on most microcontrollers. We summarize the sensor pins as follows:

- **Vin :** the power pin with 3-5 VDC [20].
- **GND :** common ground for power and logic[20].
- **SCL :** I2C clock pin, connected to the microcontroller I2C clock line [20].
- **SDA :** I2C data pin, connected to the microcontroller I2C data line [20].
- **GPIO :** is used by the sensor to indicate that data is ready. It's handy in the case of continuous sensing [20].
- **XSHUT/SHDN :** the shutdown pin for the sensor. By default it's pulled high, and when the pin is pulled low, the sensor goes into shutdown mode [20].

D. Microcontroller

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip [21].

a. Arduino

Arduino is an open-source platform used for building electronic projects. It consists of both hardware and software components. The former includes a microcontroller board, which is essentially a small computer on a single integrated circuit, along with various input and output pins for connecting sensors, actuators, and other electronic components. The software involves an integrated development environment (IDE) that allows users to write, compile, and upload code to the Arduino board [21].

Arduino IDE supports a simplified version of the C and C++ programming languages, making it accessible to users with different levels of coding experience. Users can write code to interact with sensors, control motors, communicate wirelessly, and perform a wide range of other tasks [21].

Arduino Uno is a popular microcontroller board based on ATmega328P microcontroller. It's an open-source platform for building a variety of electronic projects, from simple blinking LED experiments to complex roboticsand automation systems [21].

Figure II.8. Arduino Uno Rev3 [21]

Arduino Uno uses the ATmega328P microcontroller running at 16MHz that has 32KB of flash memory for storing code, 2KB of SRAM, and 1KB of EEPROM. It has has 14 digital input/output pins configured as inputs or outputs, as well as it has 6 analog input pins (labeled A0 to A5) used to read analog voltages from sensors and other devices [21]. The Uno is compatible with a wide range of sensors, shields, and other accessories designed for the Arduino platform.

2.1.2. Components calibration

The A4988 stepper driver, will interrupt the motor's current if it overheats. If the motor current is not properly tuned, the motor may exhibit incorrect movement or pulsating behavior.

This issue can be resolved by reducing the current via the potentiometer, indicating the need for fine-tuning the motor current.[22]

To calibrate the A4988 stepper driver using the formula :Vref = Max Current / 2.5,

Where : Max Curent = 1.7A,

A. Calculate Target Vref

Calculate the target Vref voltage using the formula

Vref = Max Current / 2.5

Vref = 1.7/2.5

Vref =0.68 V

B. Adjust Vref

Turn the potentiometer incrementally to adjust the Vref voltage to match the calculated value.

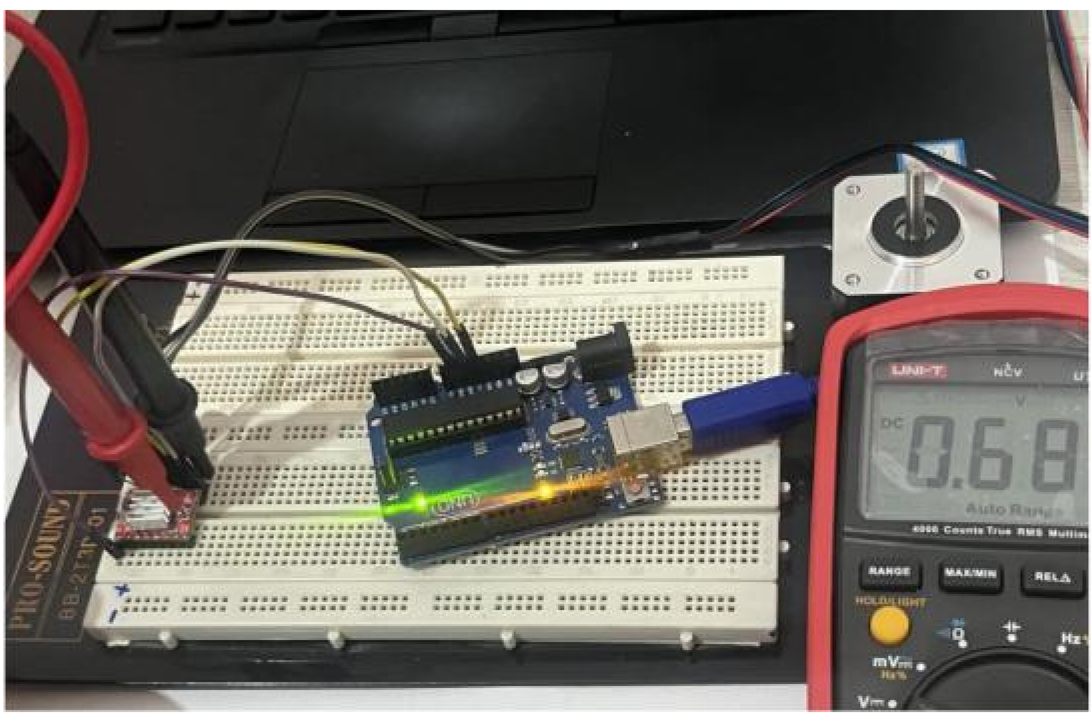


Figure II.10. Driver A4988 calibration

2.2. Mechanical design of thedevice

The device has been designed using SolidWorks, a CAD (Computer-Aided Design) software used for precise and efficient design of parts and assemblies. Indeed, the device requires two stepper motors as motion generators. The first rotational motion is utilized to rotate the intended object for scanning 360 degrees between the X and Y axes. Meanwhile, the second rotational motion is mechanically converted into linear motion using specific components. This linear motion is used to lift the distance sensor along the Z-axis. It's worth to note that these two motions are interdependent; each affects the other. There is a deliberate and programmed synergy between them, which will be further elaborated upon in chapter 3.

2.2.1. Design of different spares

A. Rotating disk

The rotating disk, also known as the turntable or base, is where the object to be scanned is placed. It is called the rotating disk, because it acquires the first rotational motion, allowing the object to rotate 360 degrees.

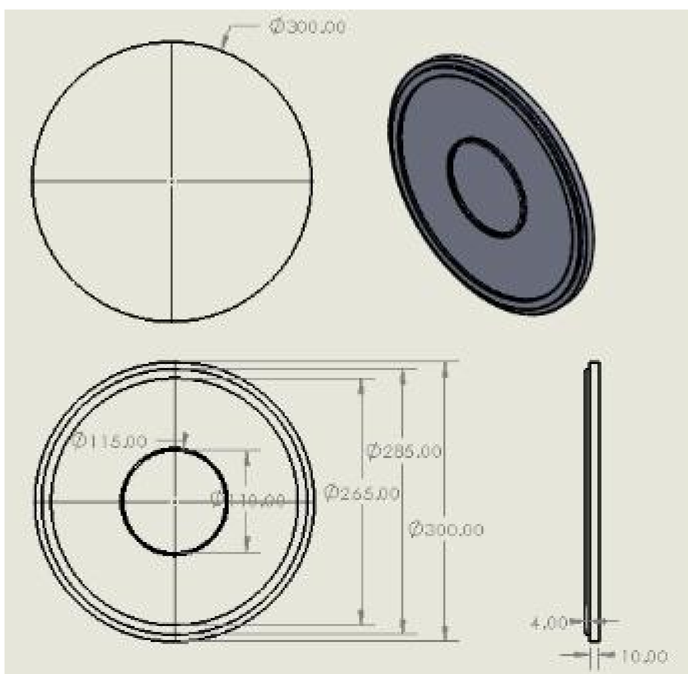


Figure II.11. Rotating disk CAD model.

B. The base

The base is the fundamental part of the device, serving as the starting point of the device assembly, where it represents a solid and stable foundation that accommodates the rest of the components and provides the necessary stability for the operation.

The base offers the necessary support and stability, while the disk, driven by a motor. The disk, or turntable, mounted on the base, rotates around a central axis, driven by a stepper motor. This rotational movement allows the distance sensor to capture measurements from all angles, facilitating a comprehensive 3D scan of the object placed on the disk. The base's stability is vital for maintaining measurement accuracy, preventing any vibrations or movements that could introduce errors. Together, the base and disk ensure smooth, precise operation, enabling accurate data capture for 3D modeling.

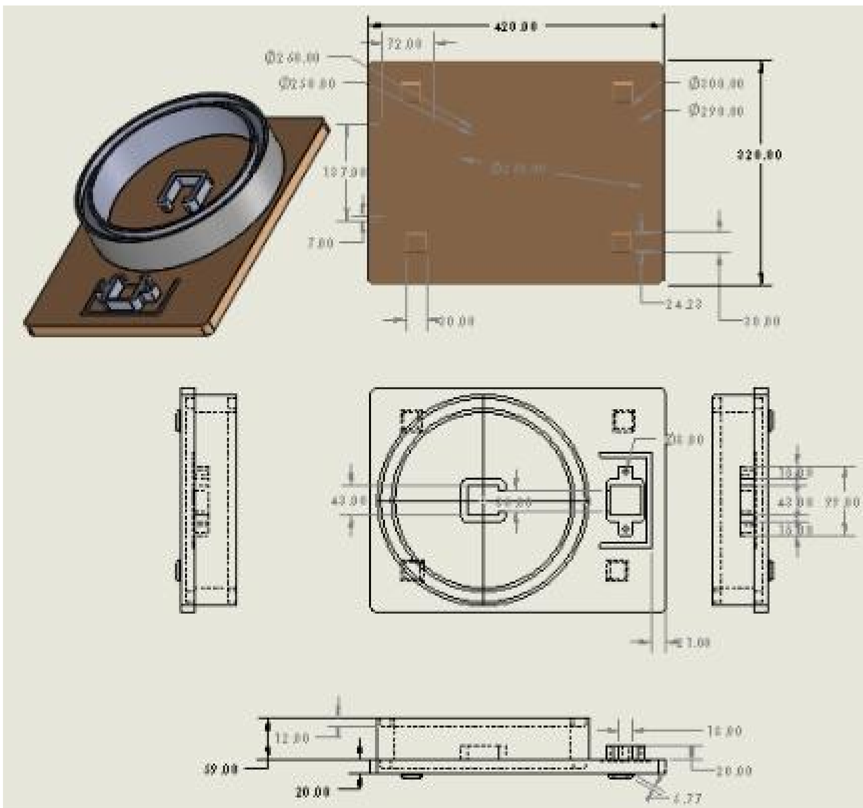


Figure II.12. Base CAD model

C. Sensor holder

This part is a key component designed to mount the sensor onto it, which is then fastened onto a screw. In addition, it provides space for attaching linear bearing blocks for an easy motion.

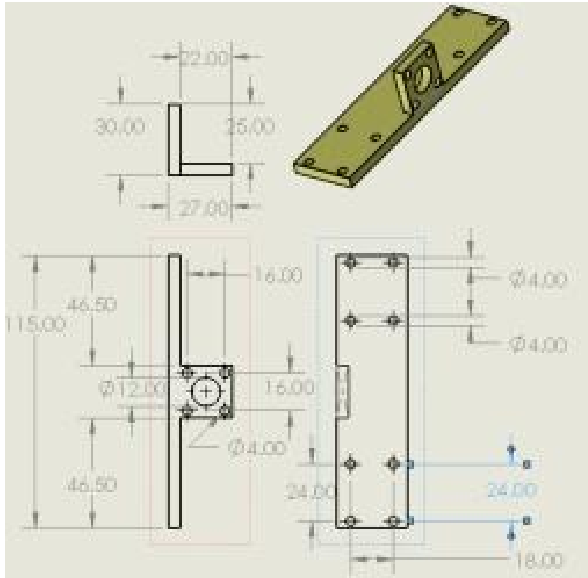


Figure II.13. Sensor holder CAD model

D. Support of rods

Its primary function is to provide sturdy support for columns from the top to prevent any vibration or tilting. Additionally, it surrounds the motor and sensor from the sides to protect them.

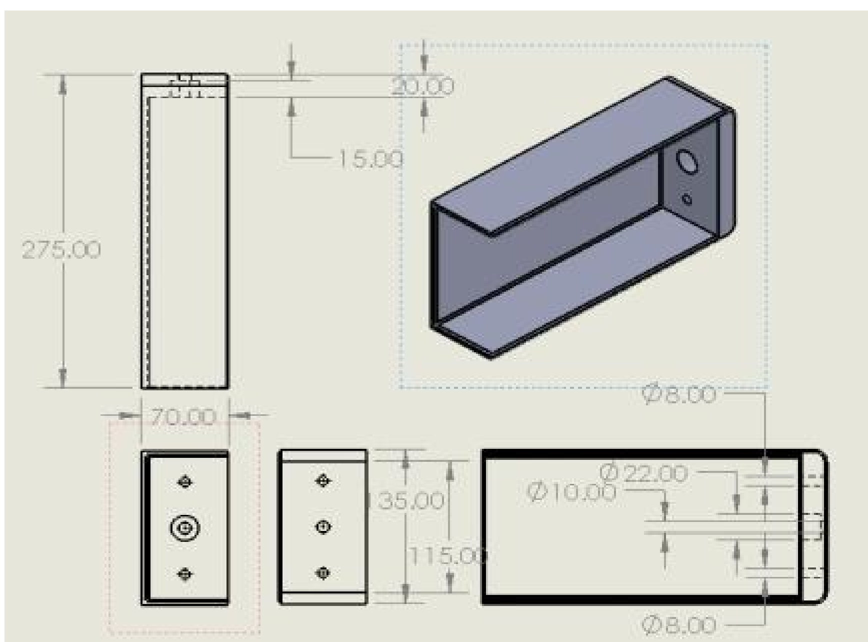


Figure II.14. Support of rods CAD mode.

E. Motor coupler

An intermediary piece between the motor and the turntable, and it is fixed to the rotating shaft of the motor, and the disk is attached to it. It allows the motor to turn the turntable. The shape of the coupler fits the shaft's shape.

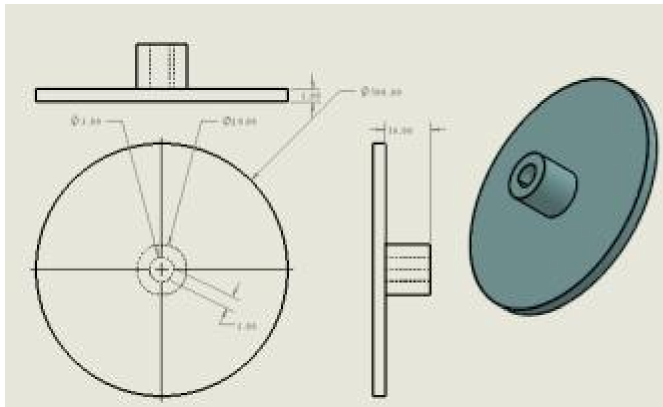


Figure II.15. Motor coupler CAD model

2.2.2. Off-the-shelf components

A. Trapezoidal lead screw

The trapezoidal lead screw with an 8mm diameter is a common component used in 3D printers, CNC machines, and other linear motion applications, these lead screws typically have a lead (pitch) of 8mm, meaning the screw will move 8mm per full rotation [24]. The lead is the linear distance the screw travels axially in one complete rotation (360 degrees) around its axis.

The lead screw is attached to the stepper motor with a flexible coupler and the sensor holder, in order to move up and down the sensor.

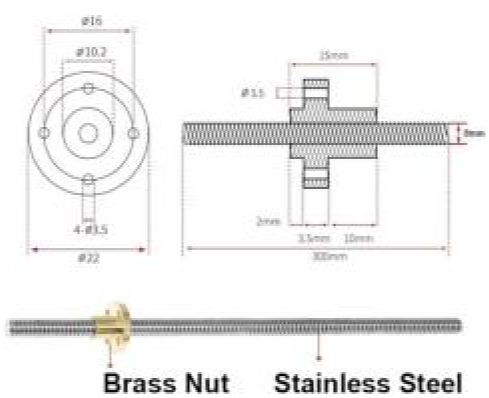


Figure II.16. Example of T8 trapezoidal lead screw [24]

B. Linear Motion Ball Bearing Slide Unit (SCS8UU)

The SCS8UU linear bearings are ideally suited as a guide for many projects such as the construction of a 3D printer. There are four threads in the bearing block with which the bearing can be fastened comfortably[25].

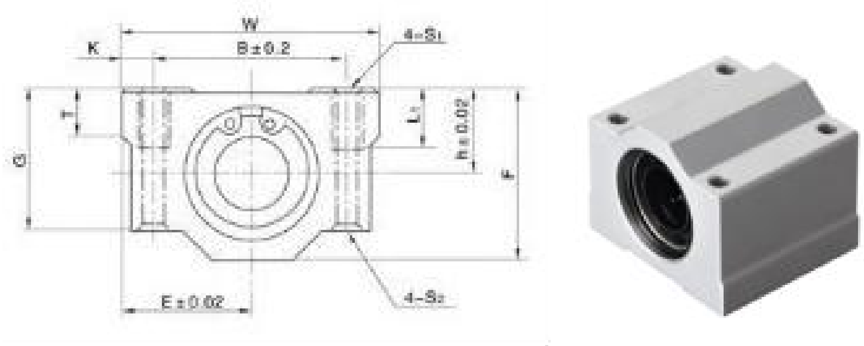


Figure II.17. SCS8UU block [25]

C. Smooth linear rod

High quality 8mm linear rod for CNC, 3d printer and Laser Engraving for efficient, smooth, fast and precise movement. It's Available in various lengths kindly select one from variation section[26].

Figure II.18. Smooth linear rod[26]

2.2.3. Rotation to linear motion conversion

When the motor rotates, it transmits rotational motion along the axis of the lead screw (Trapezoidal), which in turn affects thesmooth rods due to the coupling mechanism with the lead screw. When the rotational motion of the T8 nut is canceled, it transits into a transnational motion induced by the pushing force of the screw threads.

This cancellation of rotational motion is facilitated by the linear smooth rods and the linear bearing, an integral linkage with the T8 nut, where allowing only the smooth sliding on the two vertical shafts fixed on the base.

This cancels out the rotational motion of the T8 nut, enabling the conversion of rotational motion into linear motion. Thus, the rotational motion is utilized along with the pushing force of the screw threads to achieve linear motion, leads in the linear movement of the conveyor.

2.2.4. Mechanical considerations

Accuracy in 3D scanning is highly sensitive to even minor deviations or tilts. Therefore, it is crucial that the design remains stable and secure to ensure precision [27]. Some of the mechanical problems that affect the stability of the device and the accuracy of the results include are described below.

2.2.5. Structural imbalance

A. Rotary disk tilt during movement

The tilt of the rotary disk during its movement is usually attributed to the nature of the disk itself, as it pivots entirely on the motor shaft, as well as due to the imbalance of the heavy object placed upon it.

As a result, the disk tends to lean towards the side bearing the greater mass, even if this tilt is not visibly apparent to the naked eye. However, it significantly affects the accuracy of the results.

Based on that, an integral part of the base has been designed, which is a circular wall surrounding the center of rotation of the disk and extending beneath the disk's edge. Its function is to act as a support for the disk to prevent it from tilting, withstand heavy weight and also serve as a protector for the motor.

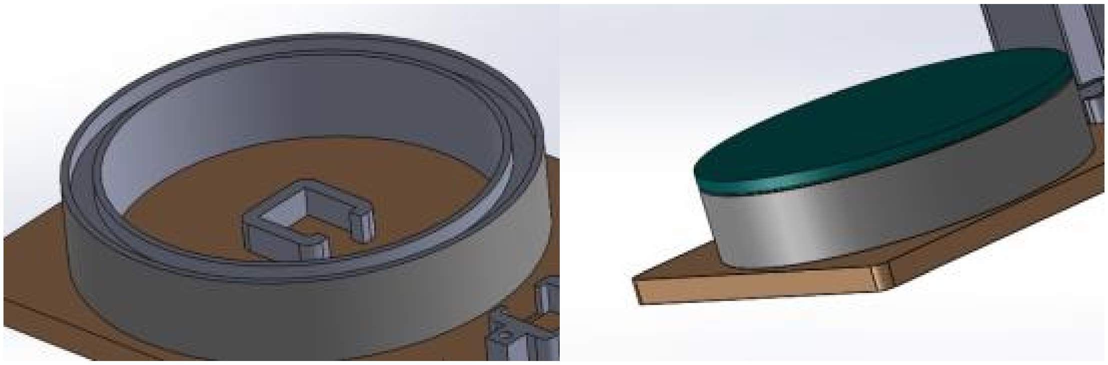


Figure II.19. Circular wall supporting the turntable

B. Rods tilt during movement

To ensure proper rod stabilization, we designed a chamber that fits around the rods, featuring a surface with three holes, wherein the rods are inserted from the top to secure them and prevent any tilting. The rods are in turn anchored from the bottom onto the base using the same principle.

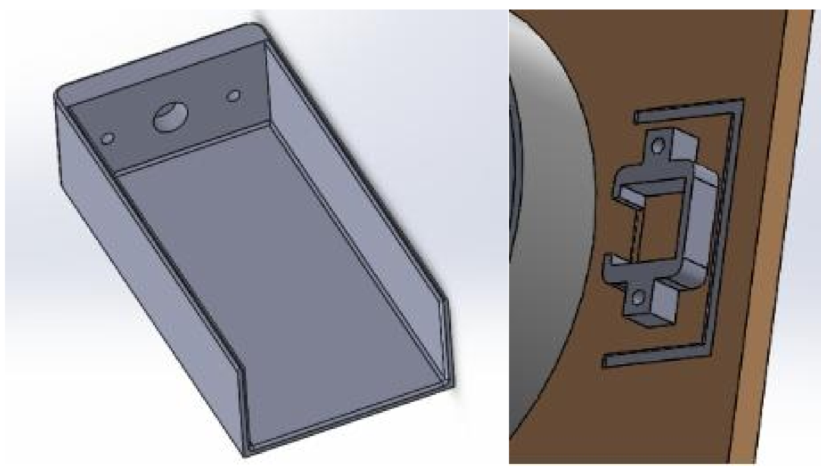


Figure II.20. Rod hole.

C. Motor tilt during movement

By placing the motors in these two parts, we ensure that the motors does not vibrate during the movement, because their dimensions are designed according to the size of Nema17 stepper motor.

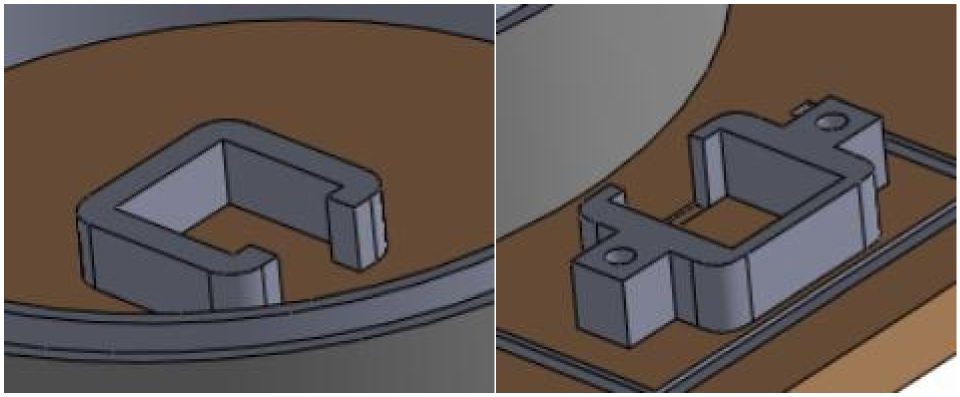


Figure II.21. Place of stepper motors in our 3D scanner.

2.2.6. Friction during motion

A. Types of friction

There are two main types of friction such as static friction and kinetic friction. Static friction is the one present between two objects that are not moving with respect to each other, in liquids, friction is the resistance between moving layers of a fluid better known as viscosity [28]. Force of kinetic friction = (coefficient of kinetic friction) (normal force)

$$F_k = \mu_k \ \eta$$

Where,

- F_k = force of kinetic friction
- μ_k = coefficient of kinetic friction
- η = normal force (Greek letter "eta")

B. Friction during motion of the disk

When the disk rotates and touches the supporting wall surface, the contact generates kinetic friction, which leads to wear and tear on both surfaces due to the heat produced [28]. To avoid this mechanical problem, we employed the principle of bearings, which is one of the best mechanical solutions to prevent friction. This principle was applied to the design by removing material along the middle of the wall surface, creating a path.

Then, placing metal balls in this path allows the rotating disk to touch the balls instead of the wall surface. Consequently, as the disc moves, the balls roll, significantly reducing friction.

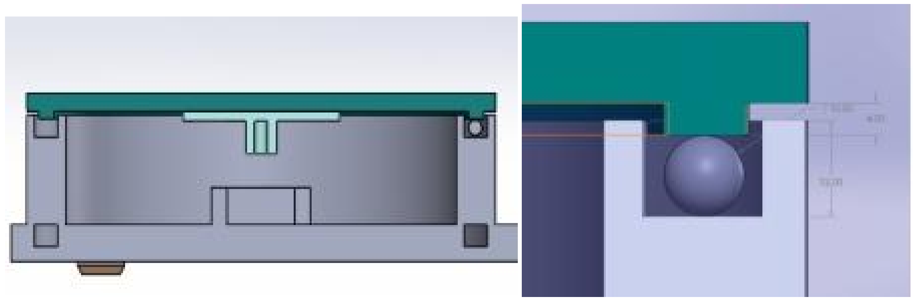


Figure II.22. Metallic ball to reduce the disk's friction

C. Friction during rotation of the trapezoidal lead screw

Using 608-ZZ-ABEC-7 type roller bearings is the optimal solution to prevent friction between the metal rod and the hole on the surface of the chamber, especially since the rod is metallic and the chamber is made of a type of polymers. Friction in this area leads to slight hindrance in the movement of the rod, causing wear on the plastic material and consequently the hole loses its function after wear, which affects the accuracy of the device.

2.2.7. Lightweight and simplicity of the design

Lightweight and simplicity of the design are also important factors in mechanical device design. Lightweight construction helps reduce energy consumption and improve the device efficiency, while also making it easier to move and install.

Simplicity of design facilitates manufacturing and maintenance, reducing production and maintenance costs in the long run [29]. Therefore, lightweight materials were carefully chosen, and component dimensions were optimized only as needed, with a focus on simplicity and ease of disassembly, assembly and maintenance.

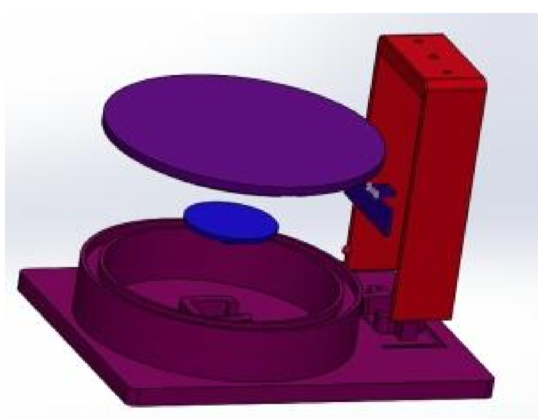


Figure II.23. Assembly schema in CAD.

3. Conclusion

In this chapter, the design process and key mechanical considerations for a 3D scanner were discussed. However, preceding this, significant emphasis was placed on the electronic components, which constitute the vital core of the device. Components such as the stepper motor, stepper driver, VL6180X sensor, and the Arduino Uno microcontroller were meticulously explained and detailed as they form the fundamental elements driving the system. Through this, the paramount importance of these electronic components in achieving reliable and precise device performance was highlighted.

Subsequently, attention was shifted to the mechanical aspect of the design, detailing components such as the rotating disk, base, sensor holder, and rod supports. Off-the-shelf components and innovative solutions were proposed to address mechanical challenges like structural imbalance and friction during motion.

In conclusion, it was underscored that the actual success of the device relies on the seamless integration of both electronic and mechanical components, emphasizing the significance of understanding each part and its role in the complete system.

Chapter III: Mesh reconstruction from a 3D point cloud

1. Introduction

In the realm of 3D modeling and visualization, a point cloud serves as a foundational representation, capturing the intricate geometry and spatial characteristics of objects or surfaces through a multitude of (x, y, z) coordinates. These coordinates are meticulously obtained via advanced technologies like laser scanning, terrestrial scanning, or photogrammetry, preserving the essence of the scanned subject matter.

The journey from a point cloud to a three-dimensional mesh encompasses various methodologies and technologies, each contributing unique nuances to the transformation process. Techniques like triangulation play a prominent role in forging cohesive mesh structures that mirror the underlying geometry accurately.

In this chapter, the focus is on the intricate process of transforming point cloud data into three-dimensional meshes. Point clouds, consisting of numerous points in space, serve as the raw material for generating detailed representations of objects. The transition from a point cloud to a mesh entails a series of techniques and algorithms, each playing a crucial role in crafting a solid and continuous surface structure.

2. Point Clouds

2.1. Definition

A point cloud is a collection of 3D data points in Euclidean space, where each point is defined by x, y, and z coordinates representing a position on the surface of a 3D object. These points, organized into a common coordinate system, capture the geometric information of the object. In addition to spatial coordinates, each point can have attributes such as intensity, RGB color, and semantic information. Dense point clouds provide a rich representation of an object's geometry and attributes, which can be used in 3D modeling, particularly in applications like building reconstruction [30].

2.2. Methods of acquiring and processing 3D point cloud data

2.2.1. Data acquisition

Point cloud data are captured using three-dimensional technologies, enabling the collection of precise geometric and characteristic information about objects or environments. Various sensors and techniques are employed for acquiring 3D point cloud data, especially in construction applications. These commonly used methods include[30]:

3D Laser Scanning: Captures high-resolution geometric data by measuring the time it takes for a laser to reflect off surfaces.

Photogrammetry: Utilizes multiple 2D images taken from different angles to create 3D models.

Videogrammetry: Extracts 3D data from video sequences by analyzing motion and changes in perspective.

2.2.2. Data processing procedures

When using point cloud data in construction applications, a series of processing steps is necessary to transform raw data into useful outputs. These procedures include four main stages[30]:

Data cleansing: This step removes noise and erroneous data from the raw point cloud, which is often collected in complex construction environments. Algorithms are employed to filter out irrelevant data and retain only the points of interest.

Data registration: Involves aligning multiple point clouds collected from different locations into a common coordinate system. This is necessary for large construction sites, where scanning from multiple positions is required to capture all parts of the target object.

Data segmentation: The point cloud is divided into meaningful segments or clusters. These segments may represent distinct objects or geometric primitives, helping to streamline further processing.

Object recognition: This step identifies specific objects from the point cloud data, such as walls, windows, and doors, which are essential for creating semantically rich 3D models of buildings.

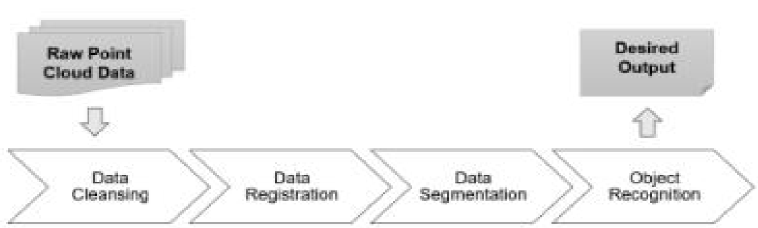


Figure 3.1. Typical processing procedures of point cloud data [30].

3. Meshreconstruction

Mesh reconstruction from a 3D point cloud involves creating a 3D mesh composed of vertices, edges, and faces based on the point cloud data. This process transforms discrete data points into a continuous surface representation, enabling detailed analysis and visualization of 3D objects.

One of the most common approaches to convert a point cloud into a mesh is by triangulation. This process involves generating connected triangles between neighboring points, creating a mesh structure [31].

4. Prototype test and results

In this section, we present the prototype and outline the different steps used to generate a three-dimensional mesh from a point cloud.

4.1. Prototype presentation

The prototype developed for this project is a 3D scanning system specifically designed to scan various physical objects and generate precise digital models. The primary objective of the prototype is to systematically capture point cloud data by moving the sensor in a controlled manner, collecting data from multiple angles to ensure comprehensive coverage of the object's geometry.

Key Functions

Controlled scanning: The prototype utilizes a VL1680X sensor and stepper motors, controlled by a microcontroller, to execute precise movements during the scanning process. This approach enables the acquisition of dense point cloud data that accurately reflects the object's surface details.

Data reconstruction: The collected point cloud data is processed using Python software to reconstruct a 3D mesh. This transformation facilitates detailed analysis and visualization.

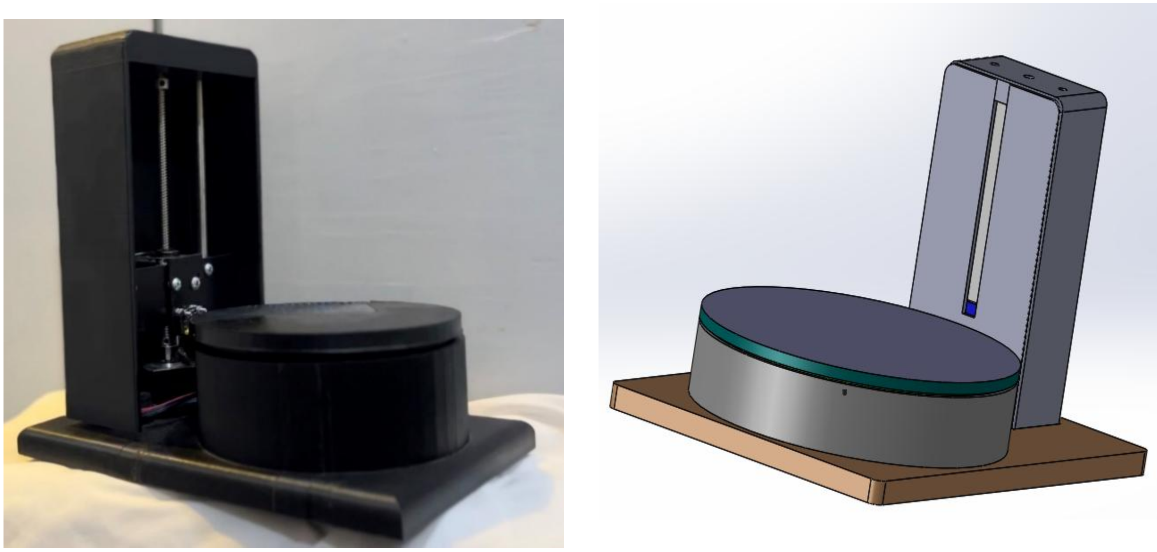


Figure 3.2. The prototype

4.2. Processing

4.2.1. Generate a point cloud (scan phase)

The first phase of the Procedure consists in the 3D scanning and the processing of the acquired data. The objects are scanned from various positions, in order to

acquire the full shape.

Point cloud data are obtained via time-of-flight scanner that use the VL1680X sensor to capture the surface structure of objects.

The 3D scanning process based on the depicted schematic, employs an Arduino UNO as the central controller to precisely manage the movements of two stepper motors. The first stepper motor is responsible for moving the scanning platform or the turntable, and the second one is responsible for moving the VL1680X sensor in the Z-axis. The motors' precise movements allow for the systematic scanning of the object's surface with multiple viewpoints.

As the Arduino coordinates the motors' movements, the scanning sensor collects data at each position.

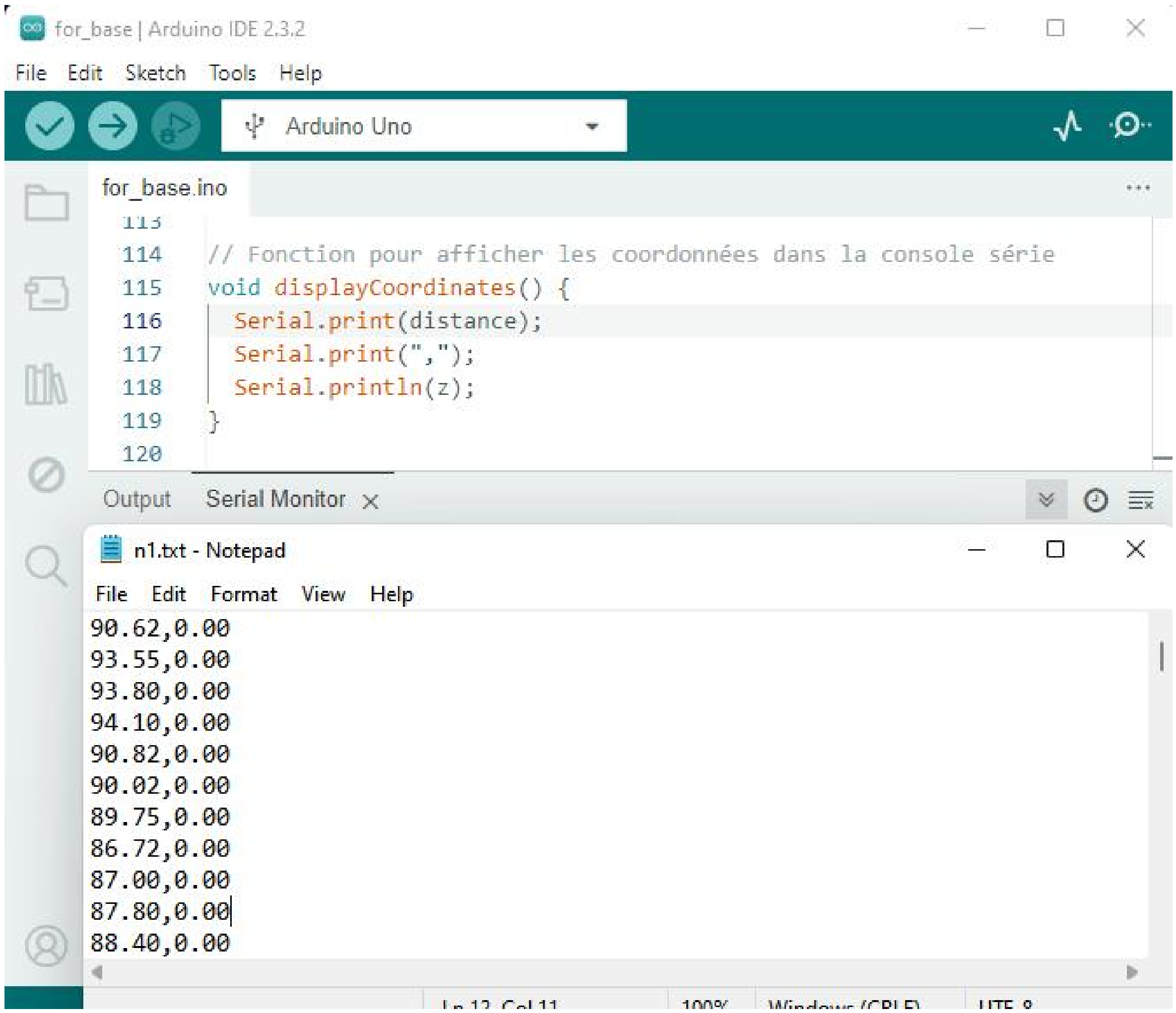


Figure 3.3. Data collection.

4.2.2. Data conversion

In the data conversion phase, raw data from the scanning sensor is transformed into precise (x, y, z) coordinates representing the 3D positions of points on the scanned object. This transformation is achieved using a Python program, which imports and processes the raw data, organizing it into a structured format. The program ensures that the coordinates are accurate and ready for further analysis and 3D mesh generation.

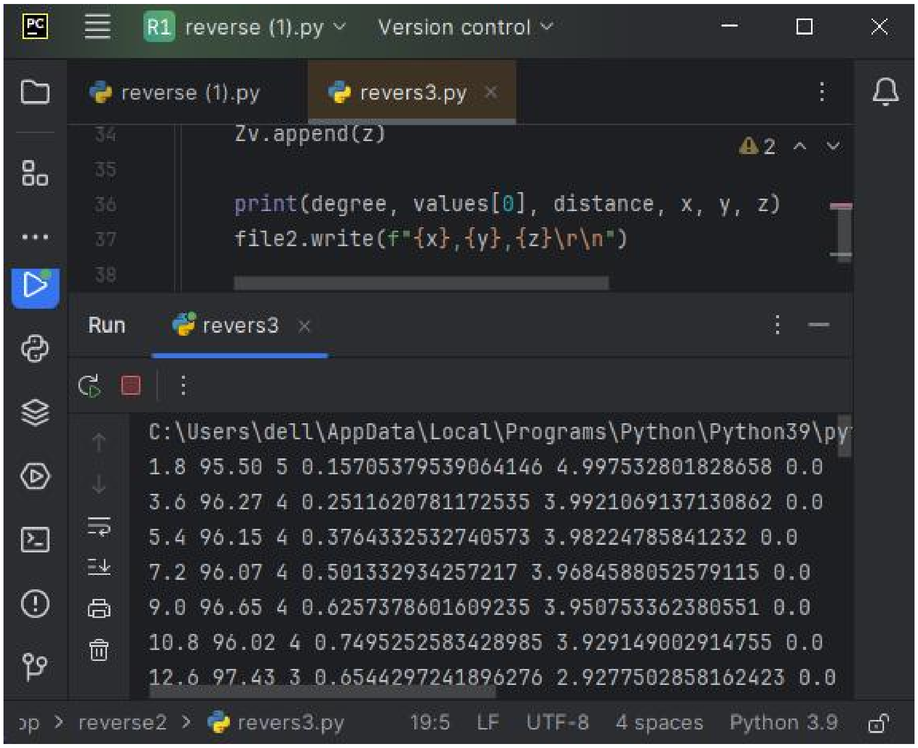


Figure 3.4. (x, y, z) coordinates data

4.2.3. Plotting and visualization

In the plotting and visualization phase, a visual representation of the 3D point cloud data is created using a Python program to facilitate analysis and interpretation.

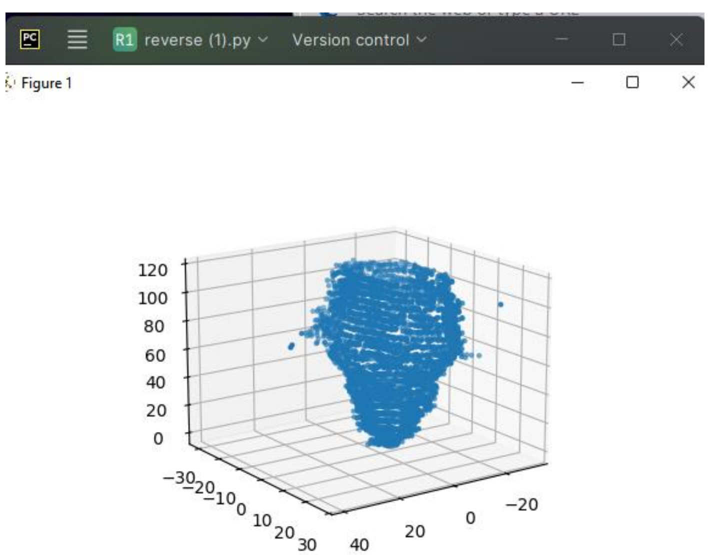


Figure 3.5. Result.

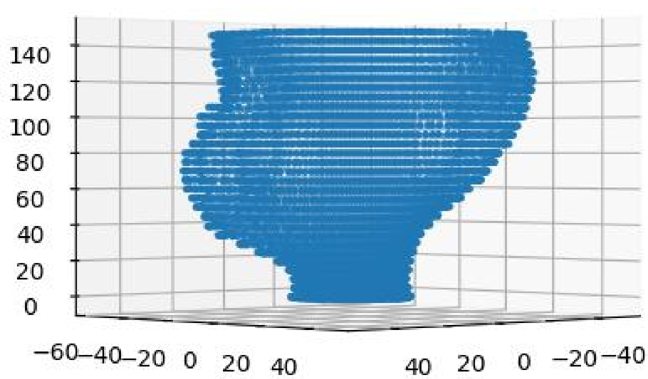
4.3. Test results and analysis

During the testing phase, the prototype was evaluated using three different objects: a doll head, a Lego structure, and half of a bottle. The results varied significantly based on the object's shape and size

A. Results

a. Scanneddollhead

Figure 3.6. Scanned doll head.



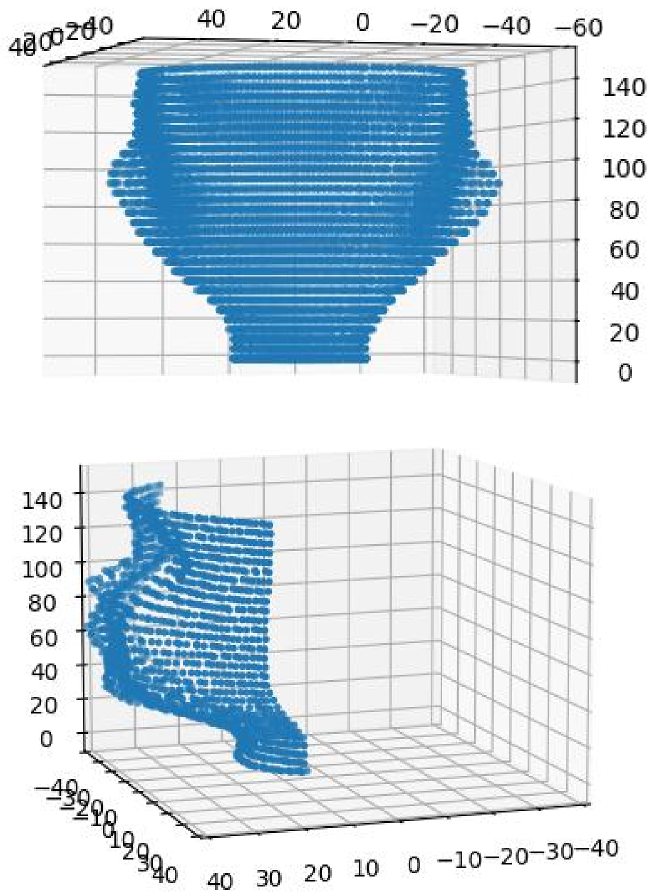


Figure 3.7. Doll head scanned results.

b. Scanned Lego

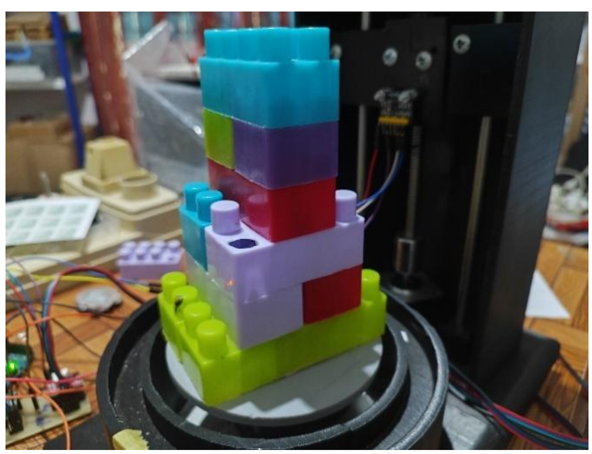


Figure 3.8. Scanned lego.

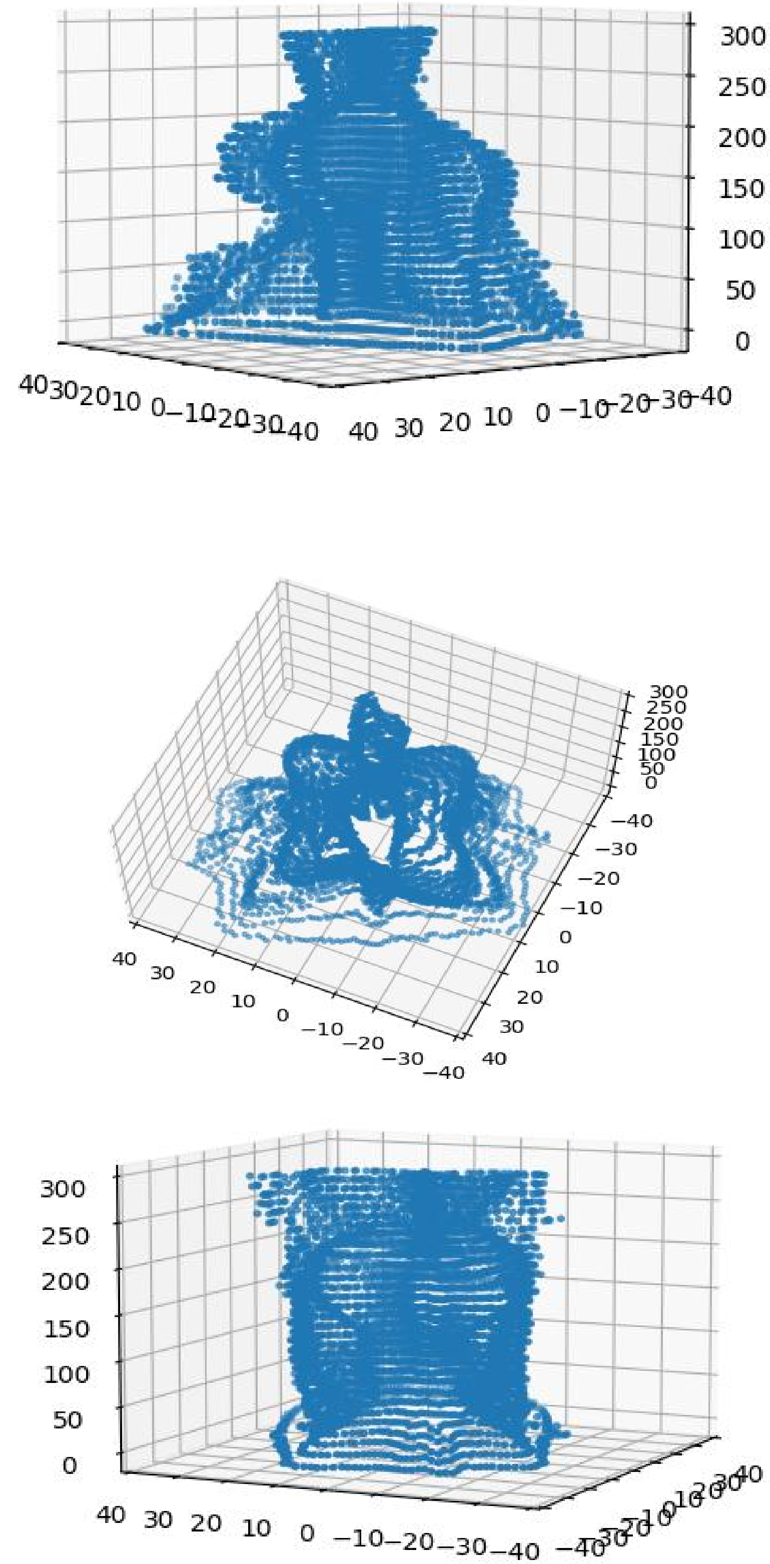


Figure 3.9. Lego scanned results.

c. Scannedbottle

Figure 3.10. Scanned bottle.

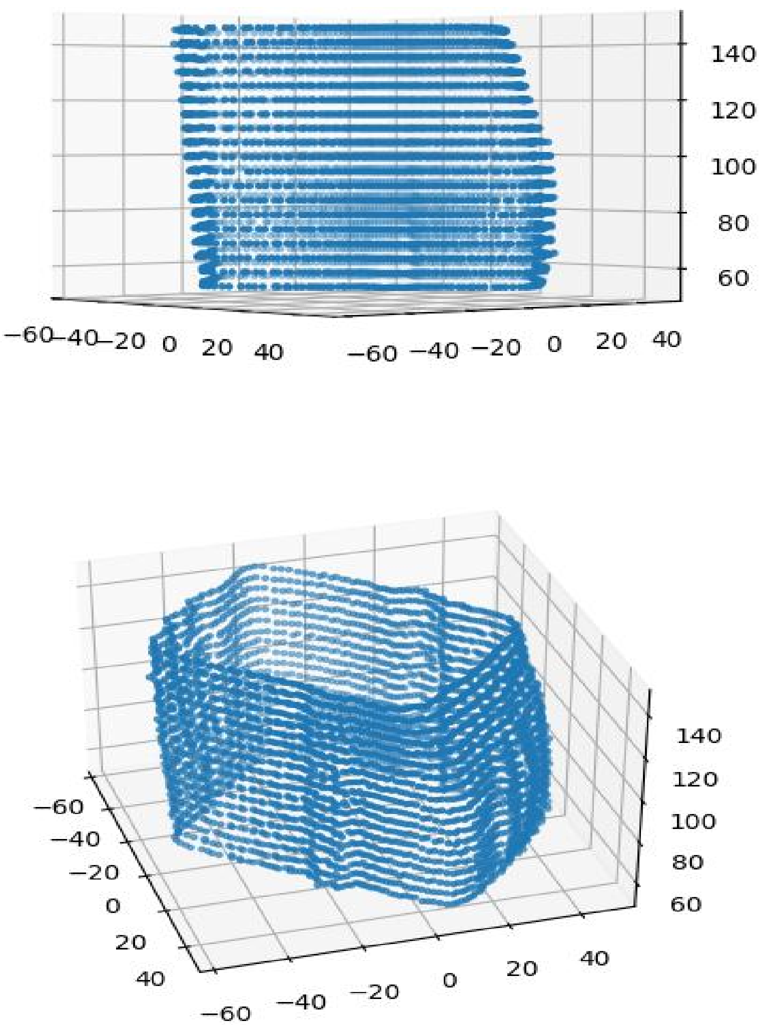


Figure 3.11. Bottle Scanned results.

B. Resultsinterpretation

Doll head and bottle: The scanning results for both the doll head and the half bottle were satisfactory. The system successfully captured the details and contours of these rounded objects, demonstrating good precision and accuracy.

Lego structure: The results for the Lego structure were notably poor. The prototype struggled to capture the sharp edges and fine details of this rectangular, small-sized object, leading to a distorted and incomplete scan.

4.4. Limitations

The primary limitations observed in the current version of the prototype include:

Inability to scan rectangular objects: The machine had difficulty accurately scanning objects with sharp angles and flat surfaces, as demonstrated by the poor results from the Lego structure.

Challenges with small objects: Smaller objects, such as the Lego structure, posed significant challenges. The machine's precision in capturing fine details diminishes when working with smaller-scale items.

Capture field limitation: The current capture field of the scanner restricts its ability to scan certain object shapes and sizes. This limitation impacts its effectiveness when dealing with objects that have sharp edges or are particularly small.

Missing areas: The scanning process often misses parts of the object, particularly the top and bottom surfaces. This limitation is caused by the difficulty in reaching these areas due to the current scanning setup and object positioning.

Missing software options: The current 3D scanning software lacks several features that would significantly enhance usability and precision. This limitation can hinder the overall effectiveness of the scanning process.

4.5. Future improvements

To address the limitations, future versions of the prototype should focus on:

Expanding the capture field: Enhancing the capture field will improve the machine’s versatility and effectiveness for various object shapes and sizes.

Upgrading software features: Incorporating additional features into the 3D scanning software like noise filtering, and other features to enhance usability and precision.

Improvements for missing areas: (object Repositioning) rotates or reposition the object throughout the scan to ensure that all surfaces, including the top and bottom, are captured accurately.

Reducing motor vibrations: through dampeners and optimizing motor control will improve scanning smoothness.

5. Conclusion

This chapter detailed the process of transforming point cloud data into a 3D mesh, a key step in creating accurate digital models. Beginning with the methods of point cloud acquisition, the chapter outlined the necessary data processing steps for effective mesh reconstruction. Prototype testing demonstrated that the system performs well with rounded objects; however, limitations were noted, including difficulties with rectangular shapes, small objects, and incomplete surface coverage. These findings highlight the potential for further enhancements, particularly in expanding capture capabilities and refining software features, to optimize the overall mesh reconstruction process.

General Conclusion

General Conclusion

In this project, we have presented our approach to creating 3D mesh models using a scanning device, focusing on data collection, preparation, and model evaluation. We discussed the process of converting point clouds into 3D meshes and analyzed experimental results to illustrate the efficiency of the current device and identify areas for improvement.

As these technologies continue to evolve, they promise more sophisticated solutions to challenges in diverse fields such as manufacturing, healthcare, and historical preservation. This study provides a solid foundation for understanding the current state and future potential of 3D mesh generation technologies, paving the way for ongoing innovation and development in this dynamic and impact field.

This study represents a significant step towards developing 3D mesh generation techniques using a scanning device. The applications of this project in daily life are numerous, including part replication in manufacturing, precise reconstruction of historical artifacts, and advancements in healthcare technologies such as designing custom medical devices. While our proposed approach has shown effectiveness, further research and refinement of algorithms are needed to enhance final performance. Expanding the data set and exploring rule-based algorithms will be crucial for achieving more accurate and efficient classifications in the future.

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Annex

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First section: Project presentation

1. Project idea (proposed solution)

Amid the significant economic transformations occurring in Algeria, aimed at boosting local industry and reducing reliance on imports, there is a pressing need for innovative technologies to support this shift. This is a particularly opportune moment, as the art and design sector are experiencing notable growth, including areas such as digital design, film making, and device design. Based on thorough market research and the identified lack of competition in this field, we recognized a key opportunity to launch our project. Our goal is to provide products and services that contribute to this development and align with the national strategy for infrastructure modernization and innovation.

In the field of 3D design, companies and designers in Algeria, as well as globally, face numerous challenges and issues. These include the high cost of available technologies, the innovative challenges that demand a high level of skill and creativity from designers, and the difficulty of delivering projects on time, among other obstacles.

The project focuses on developing a low-cost, high-precision 3D scanning machine that can generate accurate 3D models from scanned objects. This innovation addresses the market gap wherein existing solutions are expensive or lack of precision. Under the guidance of Doctor AbainiaKheireddine from the University of 8 Mai 1945 (Faculty of Sciences and Technology), the project aims to reduce 3D modeling time and costs. It targets sectors such as digital design,quality control, film creation, mechanical construction, game development, and architecture. The goal is to design and realize a 3D scanning machine that can scan objects and generate accurate models for applications in 3D printing, gaming, cinematography, etc. The innovation lies in creating an affordable machine without compromising on quality or precision. It is proposed by our superviser due to its significant potential impact and absence in the current market, the project will be executed by Master 2 students in Networks and Telecommunications, with the ultimate goal of delivering a working prototype.

Our project enables a wide range of users to access 3D scanning and replication technology, not limited to industrial companies but extending to craftsmen and individuals. The ability to produce precise models at low cost will empower designers and craftsmen to easily translate their ideas into tangible realities. Moreover, it opens new horizons for innovations, allowing this technology to launch new projects in fields such as education, arts, and even small businesses.

Thanks to its flexibility and capability to produce accurate models quickly, this technology will contribute to enhancing innovation and creativity across various sectors. It represents a significant step towards empowering the community to utilize advanced technology for progress and development in Algeria.

2. Suggested values

The 3D scanner and mesh generation project are fundamentally driven by a commitment to delivering exceptional customer value. By carefully examining market needs and target segments, as well as analyzing competitors' strengths and weaknesses, the project aims to meet and exceed customer expectations while addressing prevailing market demands. The values proposed to our customers are the result of a thorough and insightful study, which ensures that our solutions are not only effective in solving customer issues but also position us for success in a competitive business environment. This focus on understanding and addressing customer needs underpins our strategy to provide high-quality, cost-effective solutions that resonate with our target audience.

The proposed values delivered to customers can be identified according to the following elements:

A. Innovation: Introduce a cutting-edge solution in the 3D scanning market that is both affordable and highly precise.

B. High precision: Ensure the highest level of accuracy in 3D model generation, meeting the exact needs of industries such as digital design and film creation.

C. Cost-effectiveness: Offer a cost-effective alternative to existing high-priced 3D scanners without compromising on quality.

D. User-friendliness: Design the machine to be intuitive and easy to use, even for users with minimal technical expertise.

E. Versatility: Provide a versatile tool that can be used in various fields such as 3D printing, gaming, cinematography, and mechanical design.

F. Customization: Allow for customization and flexibility to adapt to different customer requirements and applications.

G. Time efficiency: Significantly reduce the time required for 3D modeling processes, enhancing productivity for users.

H. Broad accessibility: Make advanced 3D scanning technology accessible to a wider range of users and industries.

I. Reliability: Ensure the scanner is robust and reliable, providing consistent performance over time.

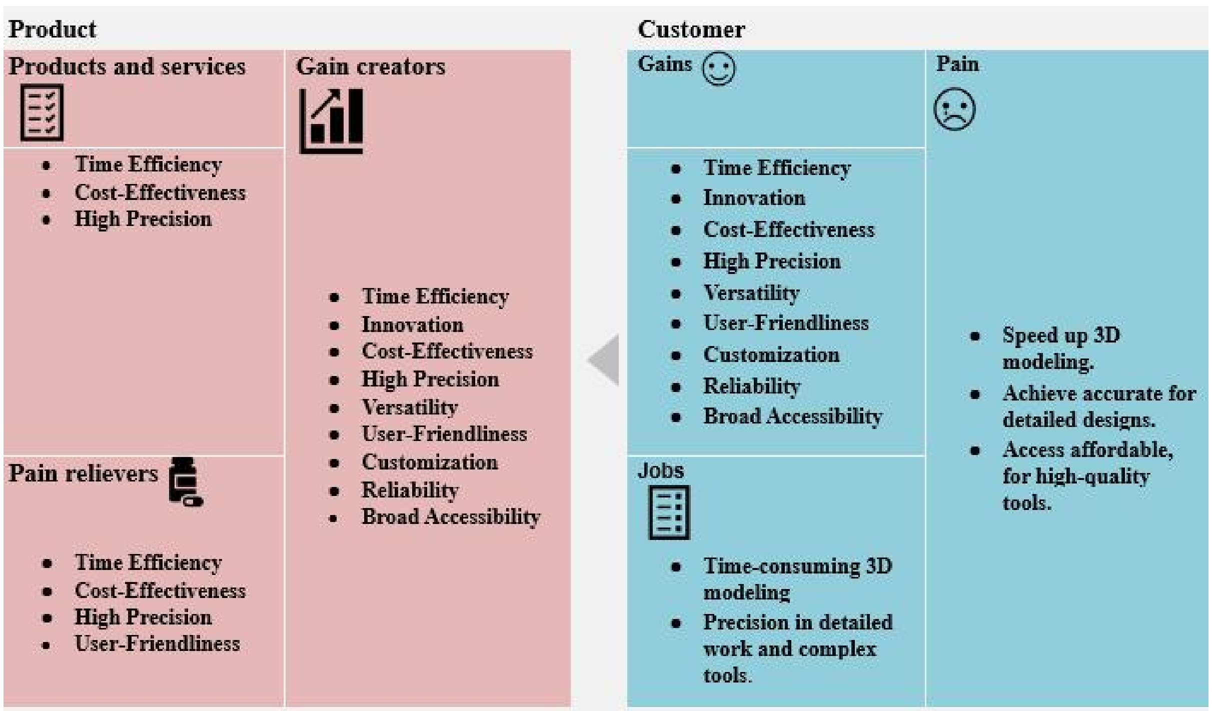


Figure 1.1: Suggested values diagram

3. The team

The success of this project relies on the collaboration of highly skilled team members, each bringing their unique expertise to ensure the effective design, development, and implementation of the 3D scanning machine. Coupled with a strong sense of responsibility, discipline, and a constant drive for development and innovation, the team members leverage their diverse backgrounds in networks, telecommunications, mechanical design, and electronics. This synergy enables a comprehensive approach to tackling technical challenges and design complexities, propelling the project toward success.

3.1. Team members and their skills

Student 01: Hammouchi Ikram: a student specialized in networks and telecommunications at the Faculty of Sciences and Technology, University of 8 Mai 1945 Guelma. She is experienced in machinery design and equipment along with two years of experience in mechanical engineering and CAD software proficiency

Student 02:Selmi Djihane: a student specialized in networks and telecommunications at the Faculty of Sciences and Technology, University of 8 Mai 1945 Guelma. Electronics and telecommunications engineer, with a deep background in electronic circuits design and control systems. She has gained significant experience in developing electronic hardware for industrial applications.

3.2. Work organization

A. Mechanical design: Hammouchi Ikram is responsible for the design of a stable and accurate mechanical structure that supports the scanning process. She has used *SolidWorks* for the conception of different spares, ensuring the project's durability and smooth operation.

B. Printing parts: This step involves printing the designed components using appropriate technology to ensure accuracy and fit.

C. Electronic part: Selmi Djihane is responsible for the integration of electronic components needed for the operation of the machine. Driving the system and ensure synchronization between the movement system and data acquisition. She has used the Arduino platform as a software for its simplicity of reproduction.

D. Device assembly: This step includes assembling the mechanical and electronic parts of the device, ensuring proper connection and readiness for actual operation.

E. Software development: This part is undertaken by Selmi Djihane and Hammouchi Ikram. It consists of developing the software for data processing and 3D model generation. It includes developing control software to manage the scanning process, handle data acquisition, and perform initial processing of the cloud of points using python programming language.

F. Test and debug: This task is done by Dr. Abainia (supervisor) to ensure the best workflow of the machine and correct any bugs occurred during the implementation process.

The team collaborates to review the progress, identify challenges, and make strategic decisions. Additionally, they collectively undertake market research, marketing activities, and prototyping the project.

3.3. Organisation chart of the corporation

The organizational structure of the startup outlines the roles and responsibilities of the team members based on their expertise and skills, ensuring smooth coordination and successful achievement of the project's goals.

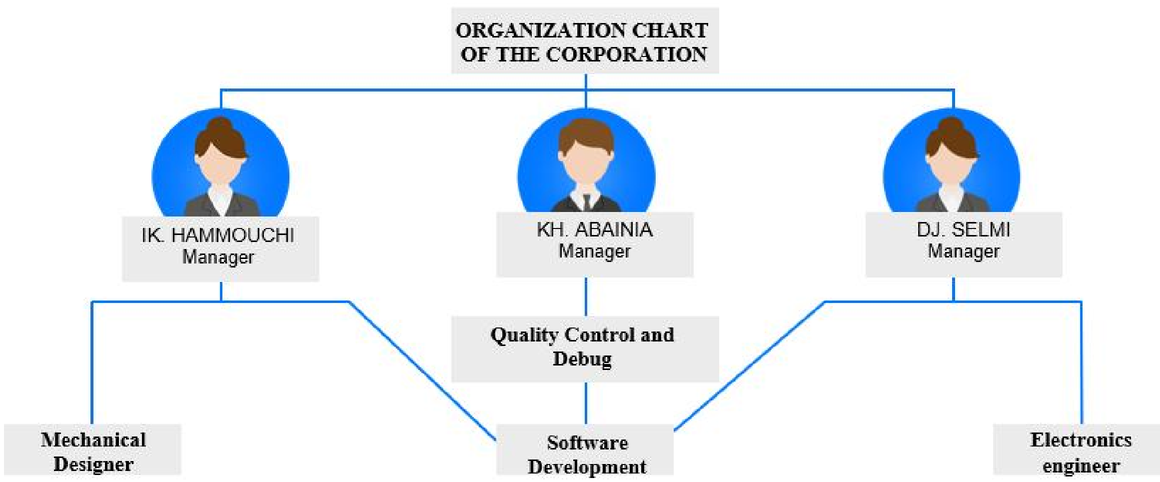


Figure 1.2: The organizational structure diagram

The startup also requires additional organizational structures to ensure its success and sustainability, such: a marketing and sales department, research and development (R&D), finance, technical support and customer service, and operations and production. However, we will initially rely on the current organizational structure and aim to expand our knowledge and develop skills in these areas over time. Additionally, we may outsource certain services or expand the structure as needed to meet future demands.

4. Project objectives

Defining project goals is crucial for guiding efforts and ensuring success. Our project aims to meet customer needs and achieve their full satisfaction by developing innovative solutions. The primary objective is to establish a strong presence in the Algerian market for 3D scanning and mesh generation technology, offering high-quality, cost-effective products that drive innovation across various industries.

- Meeting customer needs and ensuring satisfaction.
- Developing a low-cost, high-precision 3D scanning device.
- Raising awareness about the importance of 3D scanning technology.
- Empowering designers to easily turn ideas into tangible models.
- Providing innovative solutions for diverse industries.
- Enhancing time efficiency and productivity.
- Creating opportunities for future innovation.
- Continuous investment in research and development.
- Increasing sales and expanding into new markets.

5. Project implementation plan

For our project, we have divided the main objective into several tasks, determined the time required for each task.

Tasks	Month 1				Month 2				Month 3				Month 4				Month 5				Month 6				Month 7			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	3	3	4	1	2	3	4
Research and Analysis	06 weeks																											
Choosing Economic Partners					04 weeks																							
Choosing and Setting Up the				10 weeks																								
Choosing and raw Material							03 week																					
Product Design and Development									16 weeks																			
Administrative and Paperwork												04 weeks																
Digital Platform Development																					08 weeks							
MVP Testing and Validation																	12 weeks											

Table 1.1: Project implementation plan

Second section: Innovative aspects

1. Nature of innovations

The project incorporates a blend of incremental and technological innovations, with an eye on market innovation. It addresses both technological and market uncertainties by aiming to provide a cost-effective and a high-precision 3D scanning solution. This approach not only enhances the existing technology, but also has the potential to create new market opportunities, making it a comprehensive and innovative project in the 3D scanning and modeling domain.

A. Ttechnological Innovation

This is because it involves the development and enhancement of 3D scanning technology by improving precision and reducing costs, making the technology more accessible and efficient.

B. Market Innovation

It targets a new segment of users who may not be able to afford expensive devices, there by expanding the market to include more designers and artists.

C. Incremental Innovation

Rather than introducing a radical change in how 3D scanning is used, it improves upon existing technology by increasing efficiency and accuracy while lowering the cost.

D. Radicalmarket innovation

Since this innovation will target Algeria market where these devices are not locally available, it can be considered a radical market innovation within the Algerian context. The reasons are as follows:

- **Radical Innovation for the Local Market**: This innovation introduces new technology that is currently unavailable in the Algerian market, fundamentally changing how local designers and artists work, providing them with new tools and opportunities that were previously inaccessible.
- **Technological Innovation in Algeria**: The introduction of this advanced technology, which doesn't exist locally, will enhance Algeria's technological capabilities and foster growth in this sector.

- **Marketing Innovation**: Bringing this technology to the Algerian market will require innovative marketing strategies to attract new users who have not previously interacted with such devices.

2. Areas of innovation

The innovation in our 3D scanning and mesh generation project spans across multiple domains to ensure comprehensive improvements and advancements.

A. New Processes

Our project introduces streamlined processes for 3D scanning and data processing, which significantly increase the efficiency of operations modelling and reduce production costs.

B. New Features (Offering improved products and services)

The 3D scanning machine incorporates advanced features, such as high precision scanning and real-time data processing, providing users with superior quality models and faster results.

C. New Customers

We aim to expand our customer base by offering our 3D scanning solutions to new segments, including digital designers, film producers, mechanical engineers, advertisers, game developers, and architects.

D. New Offerings (Providing innovative products)

The project introduces a new, cost-effective 3D scanning machine that meets the market demand for high-quality, affordable 3D scanning technology.

E. New Models

We are exploring new business models, such as offering subscription-based access to our 3D scanning software and providing cloud-based services for 3D model storage and processing, enhancing the overall value creation system.

3. Name and logo

Name: 3D ScanCloud

3D scan refers to the technology of 3D scanning and ‘cloud’ to the cloud of points of the object.

Logo: the logo was designed in a simple, clear, and expressive manner that is pleasing to the eye.

Figure 2.1: Our brand logo.

Third section: Strategic market analysis

1. Market segment

1.1. Potential market

This include industries such as digital design, film production, mechanical spare parts manufacturing, gadget design, publicity and design agencies, game development studios, engineers, and architects, all of which require 3D scanning capabilities for various applications.

1.2. Target market

The target market for this project focuses on professionals and businesses in the arts and design sector, including digital artists, graphic designers, animators, filmmakers, architects,and others involved in creative industries. We have choosed this sector, because it represents a significant portion of the overall demand for 3D scanning technology. By offering accurate and cost-effective solutions tailored to their needs, we position our product as a valuable tool for enhancing creativity and streamlining workflows.

2. Intensity of competition measurement

To succeed in the Algerian 3D scanner market, it is essential to conduct a thorough competitor analysis and develop a clear differentiation strategy. Providing strong local technical support and competitive pricing will be crucial for attracting and retaining customers.

2.1. Direct competitors

In Algeria, and specifically in Guelma, there are no brands or companies that manufacture 3D scanners locally. However, our main competition comes from distributors of international brands who supply 3D scanners from international manufacturers.

2.2. Indirect competitors

CAD designers: a few individuals and companies offering design services using CAD software such as AutoCAD, SolidWorks, and others.

Competitors	Product / Service	Advantages	Disadvantages
Distributors of international brands	3D scanners from international brands.	- Advanced features and high precision. - Time efficiency.	- High cost - Less accessibility.
CAD designers	3D modelling service	- Established technology. - Wide application across various industries.	- Manual modeling can be time-consuming. - Less precision compared to 3D scanning.

Table 3.1. Table of project competitors

Project SWOTanalysis	
Strengths	**Innovative technology:** Offers cutting-edge 3D scanning technology that is currently unavailable locally. **Cost-effectiveness:** Provides a more affordable solution compared to high-end international brands. **High precision:** Delivers accurate and detailed 3D models, enhancing quality and reliability. **Local production:** Addresses the gap in local manufacturing and reduces dependency on imports. **Market opportunity:** First mover advantage in the Algerian market with limited local competition.
Weaknesses	**Initial investment:** Requires significant investment in development, production, and marketing. **Limited awareness:** Potential customers may have limited knowledge of the benefits and uses of 3D scanning technology. **Post-processing needs:** Scanned data may require additional processing and refinement. **Technical challenges:** Development and calibration of the technology might face technical hurdles.
Opportunities	**Growing market demand:** Increasing interest in digital design, film production, and gaming in Algeria creates demand for 3D scanning. **Expanding industries.** **Government support:** Potential for support from local government initiatives aimed at promoting technology and innovation. **Collaborate with industry and companies:** influence for the share the technology.

Threats	**Increased market competition:** The entry of new competitors can heighten market rivalry, potentially leading to a loss of market share and reduced profit margins. **Economic Fluctuations.**

Table 3.2. Project swot analysis

3. Marketing strategy

To maximize the chances of success for the 3D scanning and mesh generation in our machine project, we have targeted the following strategies:

- **Development of advancedtechnology:** Investing in research and development to design innovative and efficient 3D scanning technology, offering high precision and rapid mesh generation.
- **Competitive pricing:** Adopting a competitive pricing strategy to make the technology accessible to a wide range of customers while maintaining a viable profit margin.
- **Market segmentation:** Identifying key market segments such as designers, manufacturers, architects, etc., and adapting marketing and sales strategies accordingly to meet their specific needs.
- **Targeted marketing:** Using targeted marketing channels such as social media, industrial events, and strategic partnerships to promote the 3D scanning and mesh generation machine to potential customers.
- **Quality management:** Implementing rigorous quality controls at each stage of the manufacturing process to ensure the reliability and precision of the machine.
- **Continuous innovation:** Continuing to innovate and improve the technology based on customer feedback and market trends to remain competitive and meet the evolving needs of users.

4. Payment and delivery methods

Our project follows specific payment and delivery strategies to streamline operations and ensure customer satisfaction.

4.1. Clear Communication Channels

Office: Implement an efficient office-based system to manage orders, payments, and deliveries, ensuring quick resolution of any issues.

Website: Offer an online platform for ordering and payment, enhancing customer convenience and streamlining the process.

4.2. Reliable delivery options

Service: Utilize a dependable courier service to ensure timely and secure delivery of products to customers' homes, offices, and other locations as needed.

Tracking: Offer tracking information through your website or app to keep customers informed about the status of their delivery.

4.3. Secure paymentmethods

Offer various payment options, including:

- Advance Payment: Requires customers to pay the full amount before product delivery.
- Payment on Delivery: Allows customers to pay upon receiving the product.
- Payment CCP: Offer payment through the CCP.
- Payment BaridiMob: Provide payment options via BaridiMob.

Fourth section: Production plan and organization

1. Production process

The production process for our 3D scanning machine involves several key stages, each is critical to ensure the quality and efficiency of the final product. Below, we describe each step on detail.

1. Product Design	2. Raw Materials	3.Manufacturing	4.Product conditioning	5. Packaging and labeling
- Designing essential parts of the machine using CAD software to ensure precise and functional components.	- Choosing Materials. - Printing Designed Components. - Acquire hardware components (optical components, electronic components, mechanical components) from reliable suppliers. - Software Licenses	**- Assembly:** Assemble mechanical and electronic parts of the 3D scanner. - **Software Development:** Develop the software required for scanning and processing. - **Software Integration:** Install and synchronize the software with the hardware components to ensure smooth operation and precise scanning.	- Quality control and testing: conduct thorough tests to verify functionality and reliability, and address any issues.	- Packaging: prepare the product for shipment with protective packaging to prevent damage. - Labeling: add labels,manuals, foruser guidance.

Table 4.1. Production process.

1.1. Product design

Focusing on designing the device structure in an innovative and efficient manner, ensuring high accuracy and ease of use and maintenance. We aim to provide a robust and flexible device that meets the needs of different users.

1.2. Raw materials

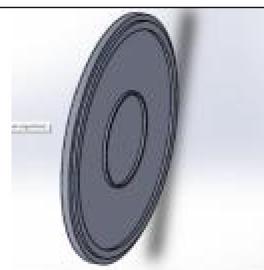
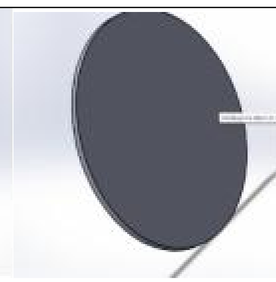
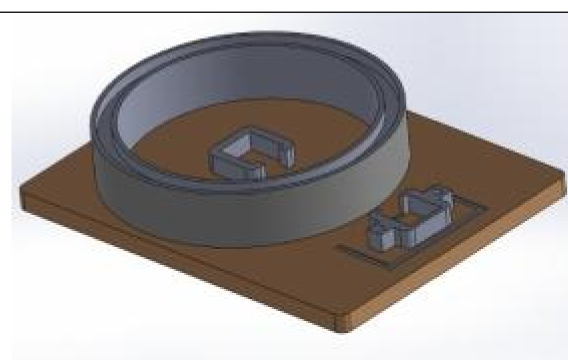
For the effective production of our 3D scanning machine, we carefully select high-quality raw materials, including optical, electronic, and mechanical components, as well as designed-printed parts. We also utilize essential software licenses, such as Arduino IDE and SolidWorks, Python to design, develop, and process the scanning data. This combination ensures that our product is reliable, precise, and up to industry standards.

Electronic components	
Arduino Uno	The central microcontroller that controls the entire setup
Stepper motors	Two NEMA 17 stepper motors - one for the turntable and another for the Z-axis movement
Motor drivers (A4988)	Two motor drivers to control the stepper motors
VL6180X sensor	A distance sensor to measure the distance of each point of the scanned object
SD Card adapter	To save the scanned data
Power supply	Provides power to the motors and other components

Table 4.2: Electronic components.

Mechanical elements	
Trapezoidal threaded rods (8mm)	
T8 Smooth rods	
Linear Motion Ball Bearing Slide Unit (SCS8UU)	
Metalic ball (10mm)	
Flexible coupler 5-8 mm	

Table 4.3: Mechanical elements.

Designed structural elements	
Turntable	 
Base	

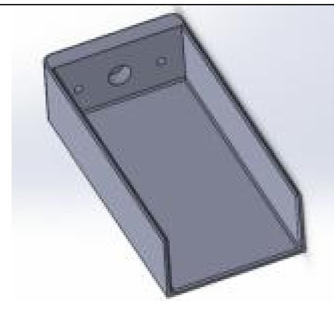
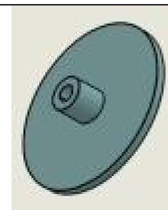
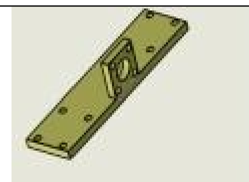
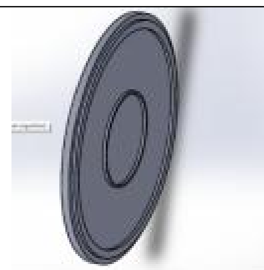
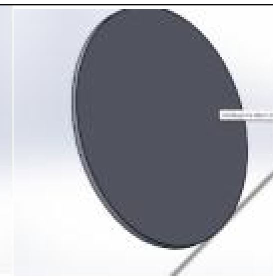
Rods support	
Disk holder	
Sensor holder	
Turntable	 

Table 4.4: Designed structural elements

1.3. Manufacturing

Once we have all the necessary raw materials, we proceed with the manufacturing phase, which involves:

A. Assembly: Combining optical, electronic, and mechanical components to build the 3D scanner. This process requires precision and expertise to ensure all parts fit and function correctly.

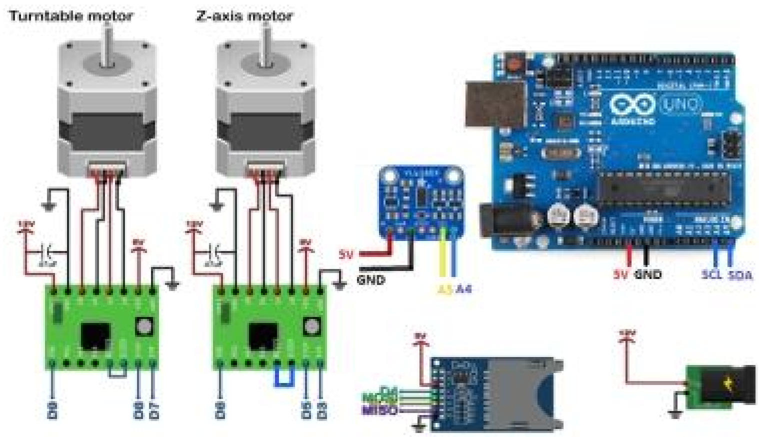


Figure 4.1: Schema of the electronic setup of our 3D scanner.

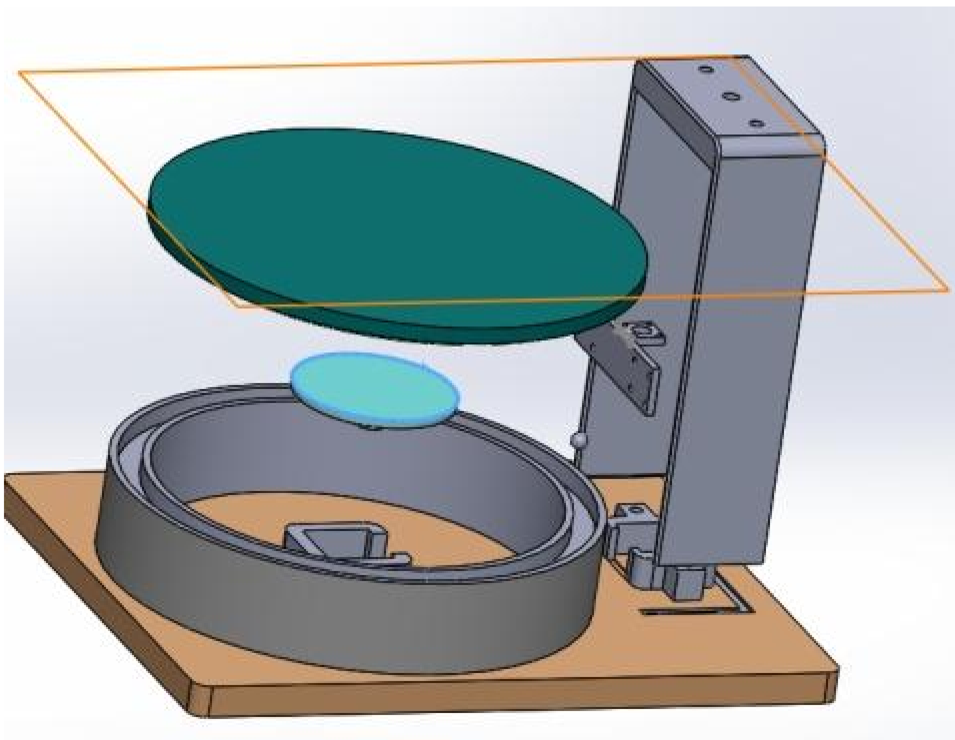


Figure 4.2: Assembly schema of different spares.

B. Calibration: Calibrating the scanner to ensure it captures accurate and high-resolution 3D models. This involves fine-tuning the sensors and motors movement.

C. Test: Each unit undergoes rigorous testing to check for any defects or issues. We perform various tests to ensure the scanner meets our quality standards and specifications.

D. Software and algorithms: Specialized software for processing and converting scanned data into 3D models.

E. Software installation: Installing the necessary software and drivers that enable the scanner to communicate with computers and other devices.

1.4. Product conditioning

After manufacturing and initial test, we prepare the product for final use. This step includes:

Quality Assurance: Conducting final quality checks to ensure the scanner operates perfectly. This involves additional testing under different conditions to guarantee reliability.

1.5. Packaging and labeling

The final step includes packaging the product securely to prevent damage during shipping and labeling it by adding product labels and including user manuals for proper guidance and setup.

- Designing and manufacturing appropriate packaging for products, including boxes and inner protective cases.
- Placing products in carefully designed packaging and securing them to ensure their safety during shipping, storage, and delivery.
- Adding labels, manuals, for user guidance.

2. Supplies and supply chain

To effectively manage resources and budget constraints while ensuring product quality, our purchasing policy focuses on sourcing high-quality components and efficient distribution. Collaborating with key suppliers ensures a smooth and cost-effective production process. Here are some effective policies for our project:

A. Identifyingneeds and priorities

We start by identifying the essential materials and components required for production. This involves determining critical items such as sensors, electronic boards, and key mechanical parts. We prioritize these components based on their importance and impact on the initial phase of production.

B. Establishing a network of reliablesuppliers

We focus on building relationships with reputable suppliers who can meet our quality, quantity, and pricing needs. Our goal is to partner with suppliers that provide components consistently and reliably, ensuring the quality and performance of our 3D scanners.

C. Effective negotiation

We negotiate the best possible terms and prices with our suppliers. This includes securing minimum order quantities, favorable payment terms, and flexible delivery schedules to maintain a continuous flow of materials and components without interruption.

D. Enhancing supplier collaboration :

We aim to establish long-term strategic partnerships with our suppliers. By exchanging information and expertise, we enhance the quality of our products and services. This collaboration fosters continuous innovation and improvement over time.

E. Monitoring and evaluating performance :

We implement a system to regularly monitor supplier performance to ensure they adhere to our quality standards. We use key performance indicators to measure supplier efficiency and take necessary improvement actions when needed.

F. Flexibility and continuousimprovement:

We adopt a flexible policy capable of adapting to changes in the supplier market and our project's evolving needs. We focus on continuous improvement of our purchasing processes to ensure the quality of components and materials, maintaining smooth production operations.

G. Cost management

Our procurement policy focuses on cost control, ensuring we get the best value for the money invested in materials and components. We utilize techniques such as supplier comparisons and effective negotiations to secure competitive prices and achieve cost savings.

3. Labor force

Our 3D scanning machine project has the potential to create multiple job positions in various departments. These positions will be essential to ensure the successful development, production, and marketing of our 3D scanning machine. As the project progresses and scales, additional positions may be created to support increased production and customer service needs.

A. **Electronics engineer:** Responsible for designing, testing, and overseeing the electronic components of the device.

B. **Software developer:** Develops software and applications necessary for operating scanners and processing scanned data.

C. **Maintenance engineer:** Ensures the proper functioning and maintenance of the equipment and machinery used in the production process.

D. **Mechanical engineer:** Designs and oversees the mechanical aspects of the device, including its structure and moving parts

E. **Financial analyst:**Analyzes the project's financial aspects, including cost estimation, budgeting, and financial forecasting.

F. **Customer relations officer:** Handles customer inquiries, feedback, and ensures customer satisfaction throughout the sales process.

G. **Transportation and shipping officer:**Manages logistics and oversees the transportation and shipping of products to customers, ensuring timely delivery and proper handling.

H. **Security guard**: Responsible for securing and protecting the facility, ensuring the safety of equipment and personnel.

4. Key partners

The key companies in our project were pivotal in its success as they were important partners in determining prices and supplying the required quantities to meet production needs, additionally, we benefited from the expertise of dr.abainia and Business Incubator at 8 May 1945 University of Guelma provides training, educational courses, and consultations in the fields of management and marketing. As economic partners, we have *Annaba Robotics inc.* that will supply as with different mechanical and electronic spares, as well as *Cloud Pi inc.* who will help as to distribute our product nationally and worldwide.

Fifth section: Financial plan

1. Charges and cost

In this section, we detail the financial plan and costs to realize our project (Table 5.1), where the stated costs are subjective to increase or decrease in futur depending on the international market of different spares. It is worth mentionning that the prices (in DZD) are got from our sponsor *Annaba Robotics*, and they may differ in other stores and distributors. Moreover, the prices are excluded from the value added tax (*VAT*ou*TVA* in French).

N°	Product	Price in DZD
1	Arduino Uno Atmega328 16-DIP	2 400,00
2	Stepper driver A4988	300,00
3	Stepper motor Nema17 4Kg.cm^2	3 400,00
4	Distance sensor VL6180X	1 300,00
5	Breaboard 830p	700,00
6	Jumper wires 20cm (pack)	700,00
7	Trapezoidal T8 with screw	3 000,00
8	Smooth rod 8mm 50cm	900,00
9	SC8UU block	600,00
10	Metalic ball (10mm)	100,00
11	Flexible coupler 5-8 mm	500,00
12	608-ZZ-ABEC-7 roller bearing	250,00
13	Printing service	5 000,00
14	Collar T8	300,00
15	Power supply 12v 5A	1 000,00

Table 5.1. Relative costs invested in our project

As initial test of our prototype, we have chosen PLA filament to print different spares, because it is easy to print and does not require a high temperature and more time, respectively. Conversely, it is not strength and maybe broken easily. In the final and commercial product, we will use ABS filament, which is more rigide, but requires more time to print and a special 3D printer to get well finished product.

The first plan to get recognition of our product, and as a marketing strategy to start our startup, we will contact some mechanical manufacturing enterprises to fund our startup and

release the first series of 3D scanners. In return, we will give a free 3D scanner to use and test in their industries. Subsequently, these enterprises will have special coupons on later subscriptions.

	Achievement			**Expectation**				
	N-2	**N-1**	**N**	**N+1**	**N+2**	**N+3**	**N+4**	**N+5**
Product quantity	1	3	5	20	30	40	50	70
Price VAT excl.	130000,00	150000,00	170000,00	185000,00	185000,00	200000,00	200000,00	250000,00
Selledprodct	1	3	5	10	17	25	35	55
Total revenue								

Table 5.2. Detail of our incomes

2. Revenue

The startup is planned to start in the next commercial year on January 21, 2025.
Firstly, we do not expect selling a large quantity of the product until it gets recognition. On the other hand, we will focus on the scanning service, where we will target the rare automatize mechanical spares in Algeria, because this field is still unloched.

2.1. Revenuestreams

N°	Service	Price in DZD
1	Sell the 3D scanner machine	50 000,00
2	Sell a software subscription for one year	70 000,00
3	Sell a software subscription for two years	130 000,00
4	Scanning service for one hour of work	2 000,00

Table 5.3. Revenue plan from selling the product (DZD currency)

As illustrated in Table 5.2, our incomes are divided into two parts, i.e. selling the 3D scanning machine and selling a software subscription for one or two renewable years. We offer an additional service to our customers, which consists of a scanning service dedicated to occasional customers who cannot buy the machine and pay the subscription.

	Achievement			**Expectation**				
	N-2	**N-1**	**N**	**N+1**	**N+2**	**N+3**	**N+4**	**N+5**
Number of hours	661	661	800	1000	1000	1300	1300	1500
Price VAT excl	2000,00	2000,00	2000,00	2000,00	2300,00	2300,00	2300,00	2400,00

Worked hours	490	490	600	1000	1000	1300	1300	1500
Total revenue	980000,00	980000,00	1200000,00	2300000,00	2300000,00	2990000,00	2990000,00	3600000,00

Table 5.4. Revenue plan from the scanning service (DZD currency)

3. Treasury plan

In this section, we detail the investment plan and revenue plan during the first commercial year.

Month	Local Rent	Electricity	Allocation	Stock Supply	Service income	Selling Income	Tax (0.5%)
1	15000,00	4000,00	2000,00	48000,00	50000,00	0,00	
2	15000,00	4000,00	2000,00	0,00	50000,00	0,00	
3	15000,00	4000,00	2000,00	48000,00	125000,00	0,00	
4	15000,00	4000,00	2000,00	0,00	125000,00	0,00	
5	15000,00	4000,00	2000,00	0,00	125000,00	170000,00	
6	15000,00	3000,00	2000,00	0,00	125000,00	170000,00	
7	15000,00	2000,00	1000,00	0,00	50000,00	0,00	
8	15000,00	2000,00	1000,00	0,00	50000,00	0,00	
9	15000,00	3000,00	2000,00	48000,00	125000,00	0,00	
10	15000,00	4000,00	2000,00	0,00	125000,00	170000,00	
11	15000,00	4000,00	2000,00	48000,00	125000,00	170000,00	
12	15000,00	4000,00	2000,00	0,00	125000,00	170000,00	
Total	***180000,00***	***42000,00***	***22000,00***	***192000,00***	***1200000,00***	***850000,00***	***10250,00***

Table 5.6. Treasury plan for the first year (DZD currency).

Sixth Section: Experimental prototype

1. Prototype presentation

The prototype design emphasizes the integration of electronic and mechanical components. The electronic design incorporates a high-precision sensor, a microcontroller, and stepper motors to ensure accurate scanning and synchronized movement. The mechanical design, developed using SolidWorks, features a robust frame and rotating platform that provide essential stability and precision. Together, these components form a reliable and efficient 3D scanning machine.

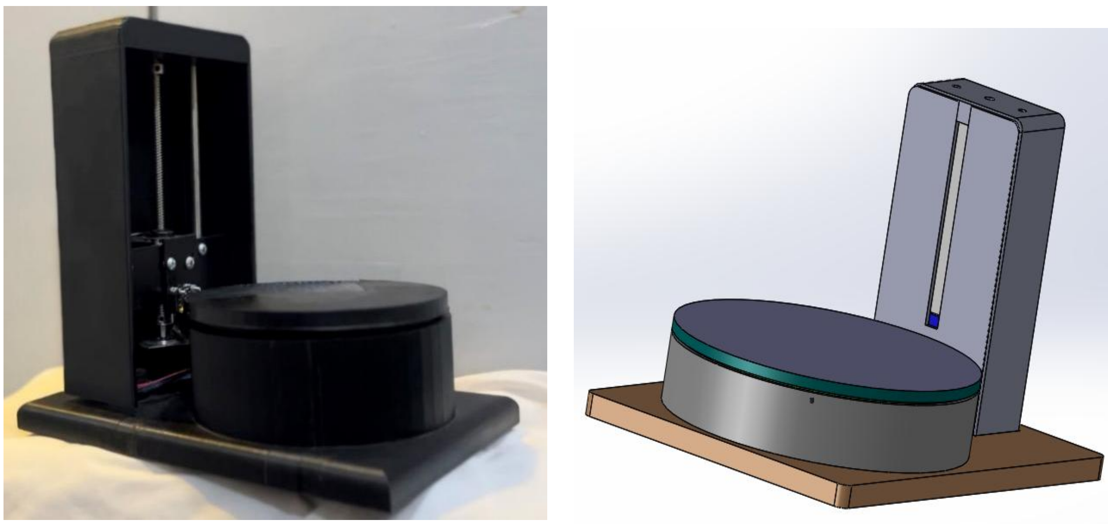


Figure 6.1. prototype presentation.

2. Prototyping process

The prototyping process for our 3D scanning machine involves several crucial steps to ensure a functional and efficient device.

A. **Mechanical design**: Create a stable and accurate mechanical structure to support the scanning process using SolidWorks for designing the parts, ensuring durability and smooth operation.
B. **Printing parts**: Print the designed components using the appropriate technology to ensure they are accurate and fit together properly.
C. **Electronic part**: Integrate electronic components, including sensors and controllers, to manage the system and synchronize movement with data collection
D. **Device assembly**: Assemble the mechanical and electronic parts, ensuring everything is properly connected and ready for operation.

E. **Software development**: Develop software for processing data and generating 3D models. This includes control software to manage the scanning process, handle data acquisition, and process point clouds using Python.
F. **Software integration**: Integrate the developed software with the hardware to ensure smooth operation and functionality.
G. **Testing and debugging**: Test the device to ensure it functions correctly and resolve any issues or bugs encountered during the implementation process.

3. Components and materials

For the initial testing of our prototype, we selected PLA filament as printing material for printing various parts. PLA is preferred due to its ease of use, as it requires lower printing temperatures and less time compared to other materials.

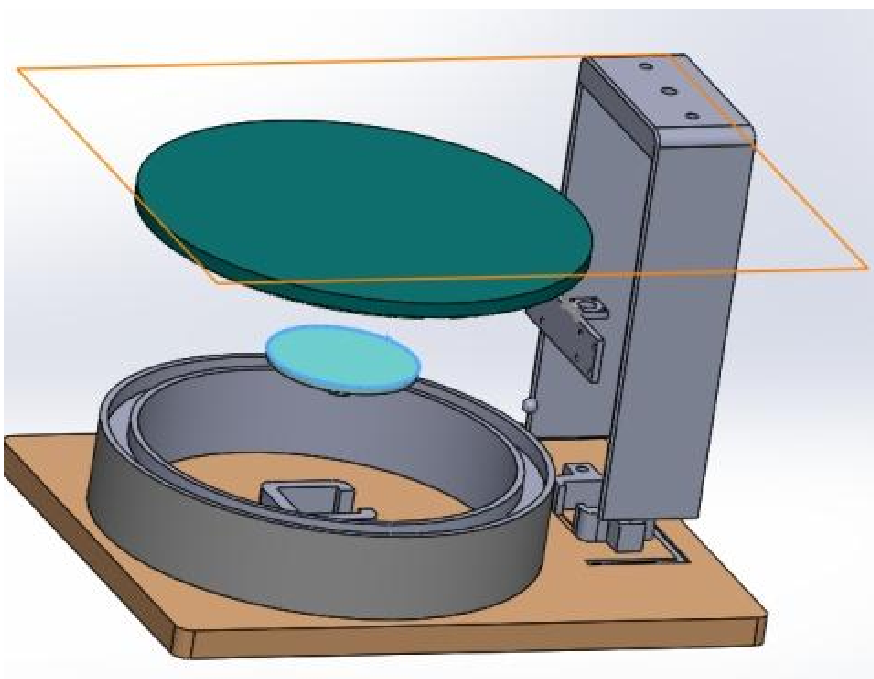


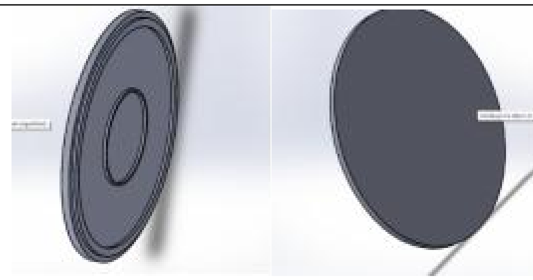
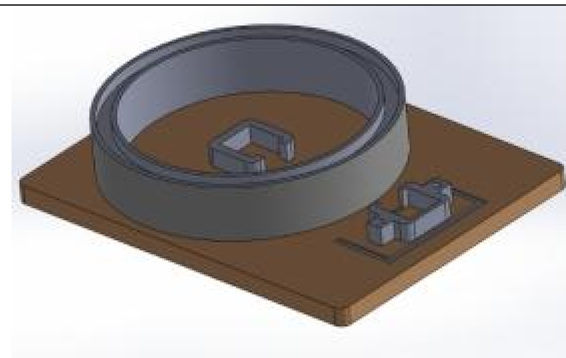
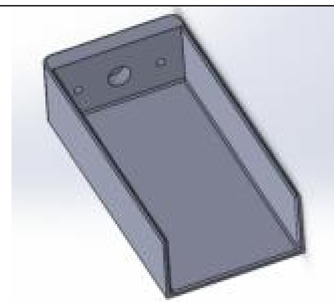
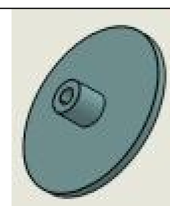
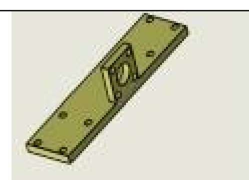
Figure 6.2: designed and printed elements

Electronic components	
Arduino Uno	The central microcontroller that controls the entire setup
Stepper motors	Two NEMA 17 stepper motors - one for the turntable and another for the Z-axis movement
Motor drivers (A4988)	Two motor drivers to control the stepper motors
VL6180X sensor	A distance sensor to measure the distance of each point of the scanned object
SD Card adapter	To save the scanned data
Power supply	Provides power to the motors and other components

Table 6.1: Electronic Components.

Mechanical elements	
Trapezoidal threaded rods (8mm)	
T8 Smooth rods	
Linear Motion Ball Bearing Slide Unit (SCS8UU)	
Metalic ball (10mm)	
Flexible coupler 5-8 mm	

Table 6.2: Mechanical elements.

Designed structural elements	
Turntable	
Base	
Rods support	
Disk holder	
Sensor holder	

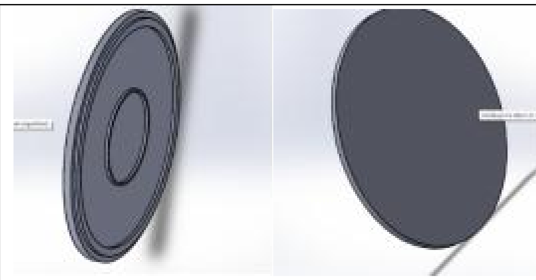
Turntable	

Table 6.3: Designed structural elements

Annex

<table>
<tr><th colspan="5">The Business Model Canvas</th></tr>
<tr><th>Key partners</th><th>Key activities</th><th>Value propositions</th><th>Customer relationships</th><th>Customer segments</th></tr>
<tr>
<td rowspan="3">•Annaba Robotics Inc:Supplies mechanical and electronic parts.
•Cloud Pi Inc:Assists with the distribution of our products.
•Printing service company.
•University incubator:supports startups and innovation through resources and mentorship.
•NESDA: Offers investment loans to support the financial needs.
• Delivery channels: manages product delivery.</td>
<td>•Product development and manufacturing.
•Production, marketing, and sales.
• Providing various services: (Selling 3D scanning machines, offering software subscriptions, providing 3D scanning services).
• Technical support and Customer Service.
•Partner and company collaborations.
•Research and Development.</td>
<td rowspan="3">•Providing accessible 3D scanners that can make thetechnology available and affordable to a wider segment of thecustomers.
• Quality and precision.
•Continuous development ofproducts and services to keeppace with modern technologies and market trends.
•Regular technical assistance and after-sales service.
•Ease of use and speed: the simplicity and efficiency of your 3D modeling technology compared to traditional CAD software.</td>
<td>•Deep understanding ofcustomer needs.
• Association and loyalty: encourage the user to associate with a particular serviceand offer specialdiscounts.
•Directcustomer relationship via website pages and online chat support.
• Interactive relationship and feedback: gather feedback that helps to develop the products and services.
• Specific Services: Provide services based on each customer need.</td>
<td rowspan="3">•Companies and designersin Algeria across various industries, including digital design, quality control, film creation, mechanical construction, game development, architecture, media and entertainment, and 3D printing.</td>
</tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr>
<td>•Physical Resources:
- Manufacturing Equipment: includes microcontrollers, stepper motors, drivers, power supplies, sensors, and other components.
- Office Space and Equipment: Workspaces and necessary office furnishings and tools.
- Technology Infrastructure: Computers and related technology for design and development.
•Human Resources: Skilled team members including engineers, designers, and support staff.</td>
<td>•Direct communication at our Guelma office.
•Company online platform : the website offers information about the company, services, and online sales.
•Social media marketing (Algeria was home to 24.85 million social media users in January 2024).
•Collaborations with Design, Architecture, and Engineering companies.
• Participation in exhibitions and events.</td>
</tr>
</table>

	•**Financial Resources**:Aligning with project needs through support and funding bodies.			

Cost Structure	Revenue Streams
•Product development. •Manufacturing. •Physical resources.•Human resources. •Marketing.•Printing service. •Distribution. •Research and development. •Partnerships and collaborations. •Legaland compliance. •Insurance. •Contingency fund.	•Selling 3D scanning machines. •Selling software subscriptions. •Scanning services.