BUILDING A LOW-COST 3D PRINTER WITH RECYCLABLE PARTS

Pupil: Jonas Fernando Schuh
Advisor: Miguel Alexandre Wisintainer

FURB
UNIVERSIDADE DE BLUMENAU

Script

- Introduction
- Goals
- Theoretical Background
- Related Works
- Requirements
- Specification
- Implementation
- Analysis of the Results
- Conclusions and Suggestions

Introduction

- The beginning started with the prototype of a 2D CNC router, developed as a hobby by the author who used low-cost recycled parts.
- One of the reasons was the use of the parts and structure: stepper motors, telescopic slides and recycled wood structure.
- The decision to make a 3D printer arose from the suggestion made by the future advisor at the time, professor of electronics at FURB, Prof. Ms. Miguel Alexandre Wisintainer.
- The idea was to make a laser engraver and take advantage of the entire structure of the CNC in 2D, but after studies, it was concluded that the 3D printer was the best option.
- Laser is dangerous. Ultraviolet rays that can cause serious vision problems during testing.
- The proposed work adheres to the Research, Innovation and Entrepreneurship axis.

Introduction

Roteador CNC 2D

Source: Prepared by the author (2023).

FURB
UNIVERSIDADE DE BLUMENAU

Introduction

- In the design phase, we were not aware of all the known problems in this work.
- As an example cited in related works, there were mechanical problems, heating, vibration, oscillation, lack of precision.
- This work is important because 3D printing and its operating structure is a current subject and contributed to the author acquiring knowledge on the subject.
- It is also expected to disseminate this knowledge to the academic community, in addition to contributing with this work to future academic works.

Objectives

- The main objective of this work was to assemble a 3D printer with low-cost materials, using the Arduino Mega 2560 microcontroller, Kit Ramps 1.4 and make it functional.
- The specific objectives were:
- a) Assembly of the mechanical part;
- b) Assembly of the electronic part;
- c) Make the printer functional;
- d) Evaluate whether the printer would achieve acceptable accuracy.
- Printing of a 20-millimeter calibration cube to measure the accuracy of the equipment;
- e) 3D printing of parts of the FURBOT project.

FURB
UNIVERSIDADE DE BLUMENAU

Objectives

Changes between the proposal and what was actually implemented:

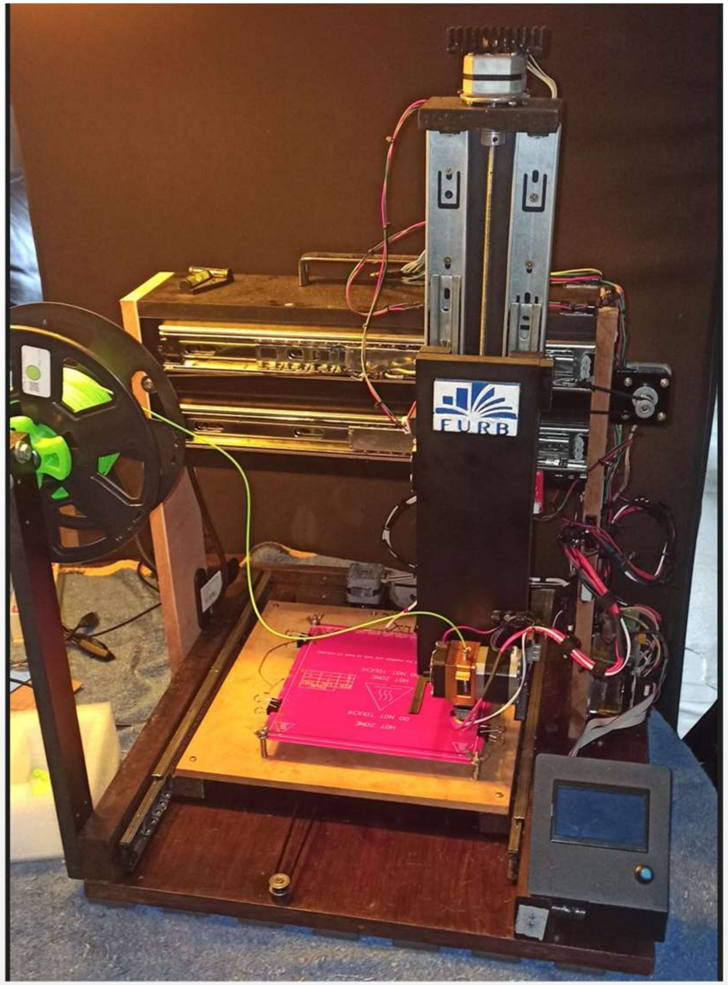
- Improved replacement of threaded bars with GT belts for X and Y axis movement.
- Benefits: Improved maintenance and increased print speed.

Objectives

CNC Router 2D

Source: Prepared by the author (2023).

3D Printer



Source: Prepared by the author (2024).

FURB
UNIVERSIDADE DE BLUMENAU

Theoretical Background

3D Printing

- Created in 1984, it was invented by Chuck Hull, an American physical engineer from the state of California.
- A sequence of automated manufacturing processes in sequential layers, which generate a physical model based on a digital object in three-dimensional format.
- There are several technologies for this type of printing and Cast Filament Manufacturing (FFF) stands out as the simplest and was the focus of this study.

Theoretical Background

Sustainability

- It consists of the principle of reusing electronic waste, reusing materials and parts that would be destined for common waste.
- Law 12.305 of 2010, which institutes the National Solid Waste Policy (Brasil, 2010).
- Scientific and technological research to stimulate the recycling of electrical and electronic products and their components.
- The idea is to reuse, promote the reduction of waste discarded in the environment and the reduction of costs applied in projects.

Theoretical Background

Marlin Firmware

- Firmware is low-level software that aims to communicate directly with the hardware.
- It is an open-source project and was created in 2011.
- It operates on ATMega2560 microcontrollers used in the Arduino Mega and are widely used in 3D printers.
- Among its features, excellent print quality and various configurations for all the components of a 3D printer can be highlighted.

Theoretical Background

Marlin Firmware

- It performs the interpretation of G-Code commands, a programming language that controls the direction of the movements of the 3D printer.
- It does in the conversion of control signals for the motors, heaters and other components of the printer.
- It must be parameterized according to the particular characteristics of each project for it to work properly.
- Example of configurations: Measurements of height, width, depth, sensors and actuators, type of plate used, calibration of distances traveled in millimeters, number of revolutions in the motors, thickness of the gears.

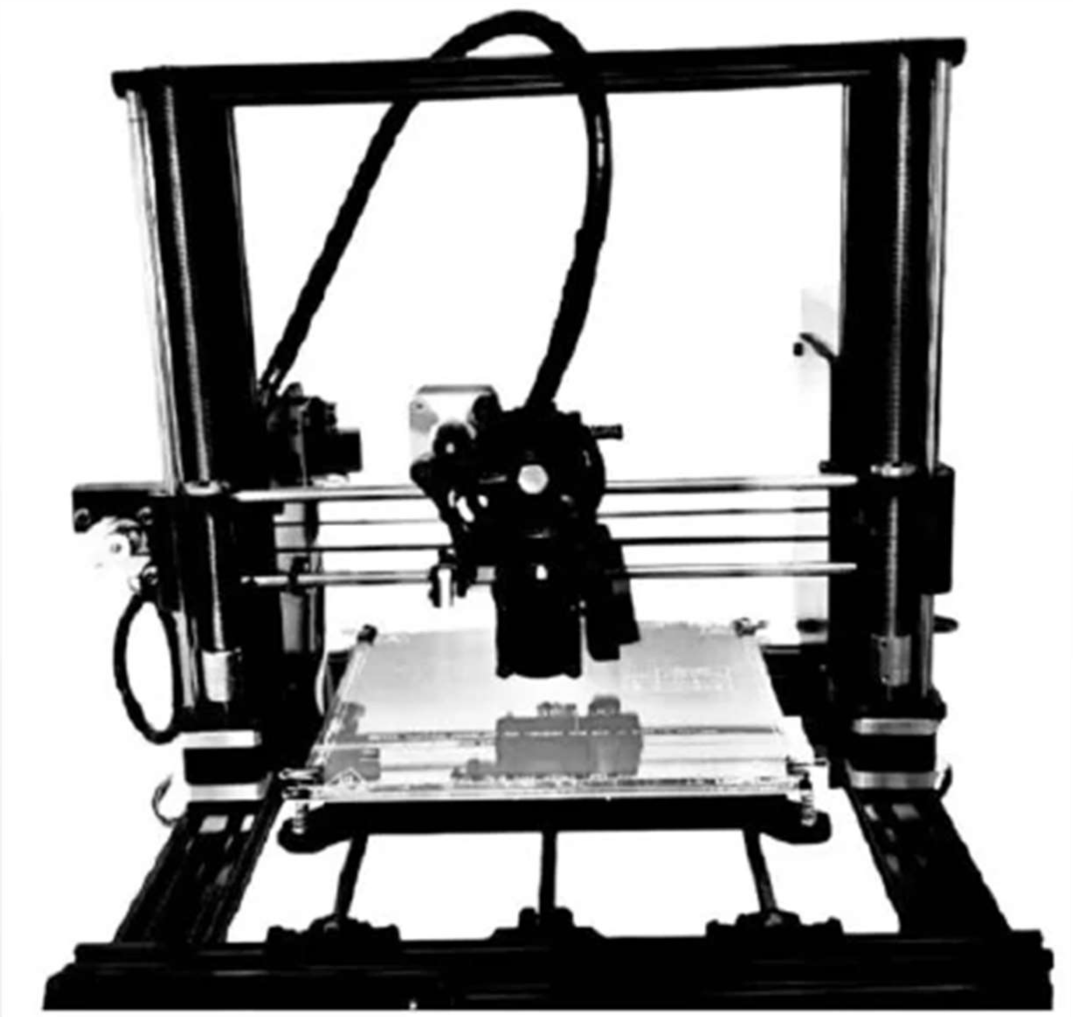
Related Works

The DIY Philosophy: repurposing electronic scrap for low-cost 3D printer construction

- It presents the creation of a 3D printer aimed at the reuse of electronic waste.
- Focus on sustainability, reuse and the issue of the Do It Yourself (DIY) philosophy, which translated from the English language, is understood as do-it-yourself.
- The firmware used was GRBL through the Arduino UNO platform.
- Performance comparison was made between the developed prototype in relation to a commercial printer.
- The results showed that it is possible to create a 3D printer with a low budget and satisfactory results.

Related Works

The DIY Philosophy: repurposing electronic scrap for low-cost 3D printer construction



Source: Level et al., (2022).

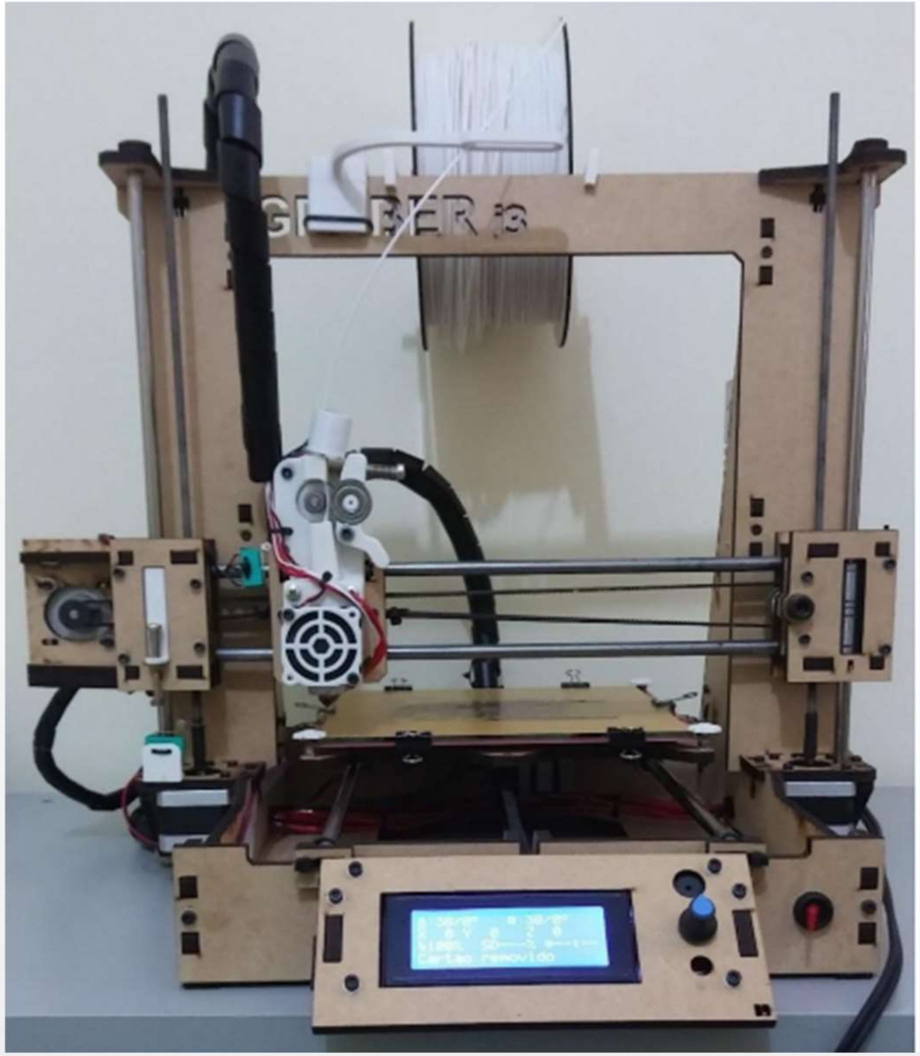
Related Works

Development of a low-cost 3D printer for prototyping parts for rural areas

- Focus for use in the development of parts, tools or prototypes in the agricultural environment.
- It used Marlin firmware, Arduino Mega 2560 and Ramps version 1.4 boards, extruder kit and heated board purchased.
- The X, Y-axis motors and their set of linear guides and belts were reused from old text printers.
- Performed quality comparison between the developed prototype in relation to a tested and certified commercial printer.
- Results were identical and showed as a quality alternative in relation to commercial printers with higher value.

Related Works

Development of a low-cost 3D printer for prototyping parts for rural areas



Source: Zucca e Machado (2019).

FURB
UNIVERSIDADE DE BLUMENAU

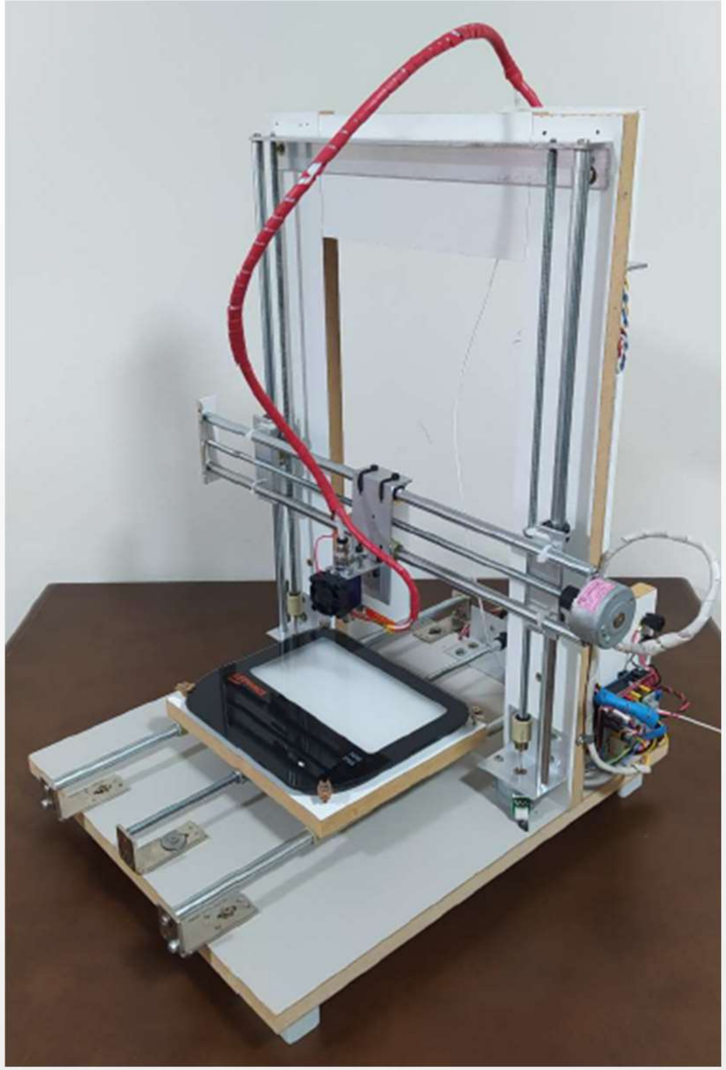
Related Works

Building a low-cost 3D printer with alternative material

- Low-cost 3D printer that largely used materials from disposal and electronic waste.
- They used parts taken from old printers and other obsolete equipment.
- Other parts used were acquired through an electronic kit, containing the Arduino UNO and CNC Shield boards and an extruder nozzle.
- The firmware used was Teacup which is free and open source.
- During assembly and use, there were several difficulties, among them, it was the excess of clearances that hindered the necessary precision.

Related Works

Building a low-cost 3D printer with alternative materials



Source: Batista (2021).

Requirements

a) be assembled with low-cost parts (Non-functional requirement – RNF);

b) use recycled components from other electronic devices (RNF);

c) use recycled wood (RNF);

d) use open source hardware, firmware and software (RNF);

e) promote the reuse of electronic waste for something useful again (RNF);

f) have the ability to operate for more than 10 hours without failure (RNF);

g) use the Marlin firmware (RNF);

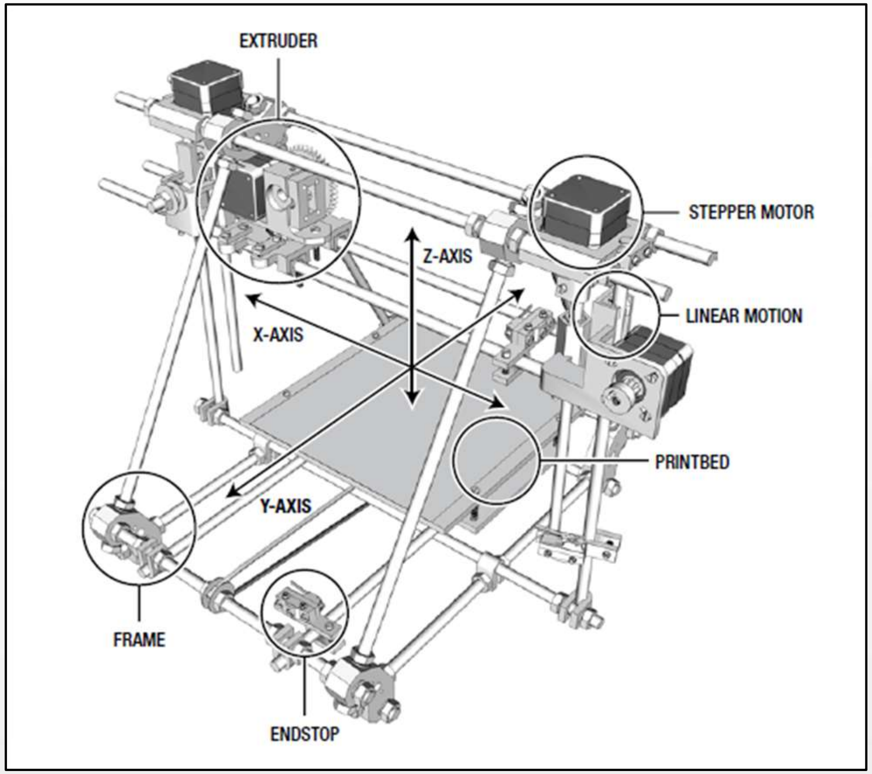
h) allow printing of a 20 millimeter calibration cube (RF);

i) evaluate whether the prototype generates 3D objects with acceptable accuracy (RF),

j) 3D printing of parts from the FURBOT project (RF).

Specification

- The initial idea arose from bibliographic research in foreign books, as there is little bibliography on this subject in the Portuguese language.
- Research in academic papers and scientific articles on the subject was also taken into account.
- The model is a Prusa-type 3D printer:



Source: Evans (2012).

Specification

- The basis began with the prototype of a 2D CNC router, developed as a hobby that was made with recycled parts.
- One motivation was the reuse of the pieces and structure.

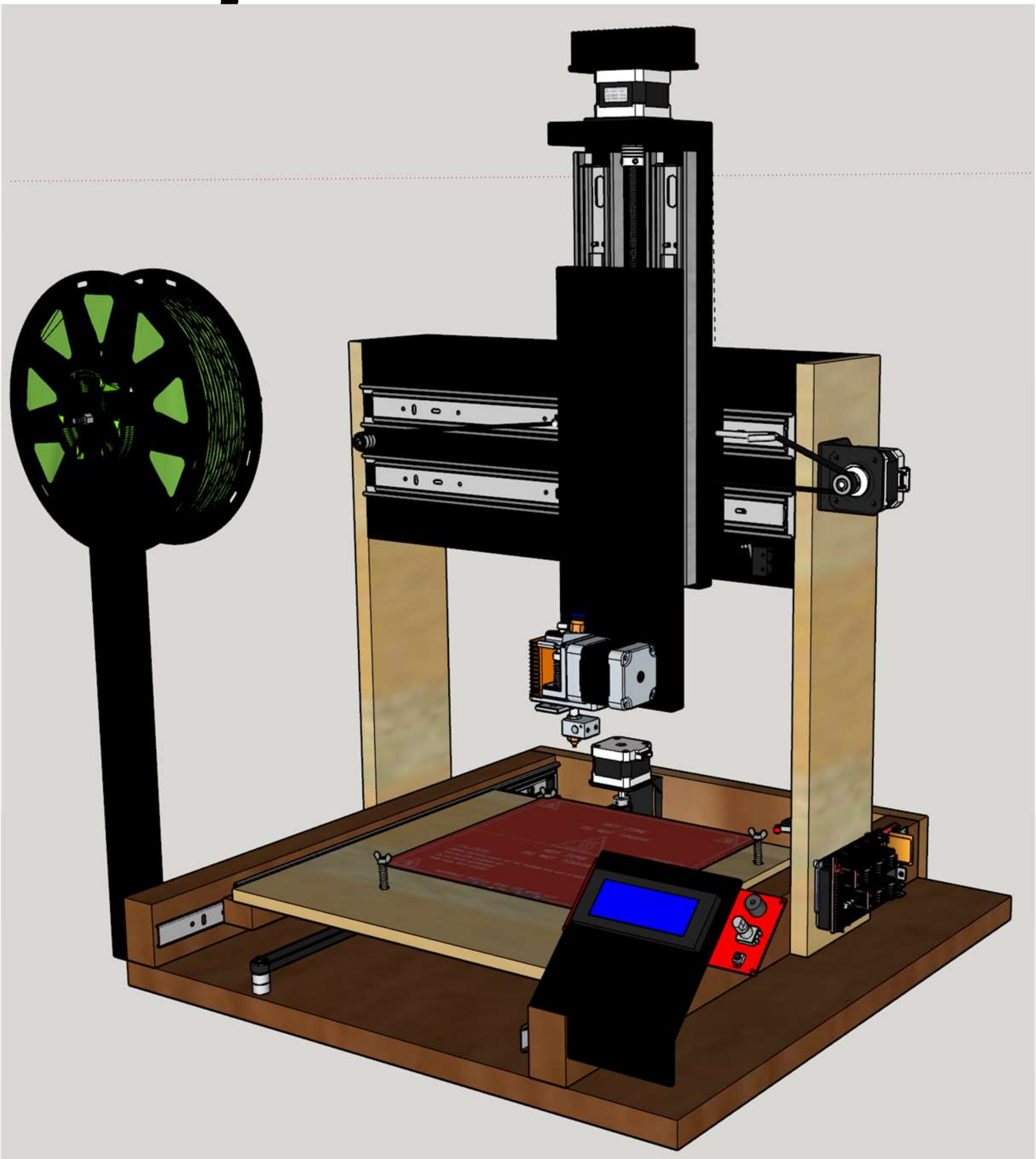
Source: Prepared by the author (2023).

Specification

Reverse engineering the built prototype

- The prototype was built incrementally.
- Reverse engineering was carried out through 3D models of what was built in all its stages.
- The construction of the technical drawing of the prototype structure in 3D was carried out with the SketchUp tool (Trimble Inc, 2023).

Specification



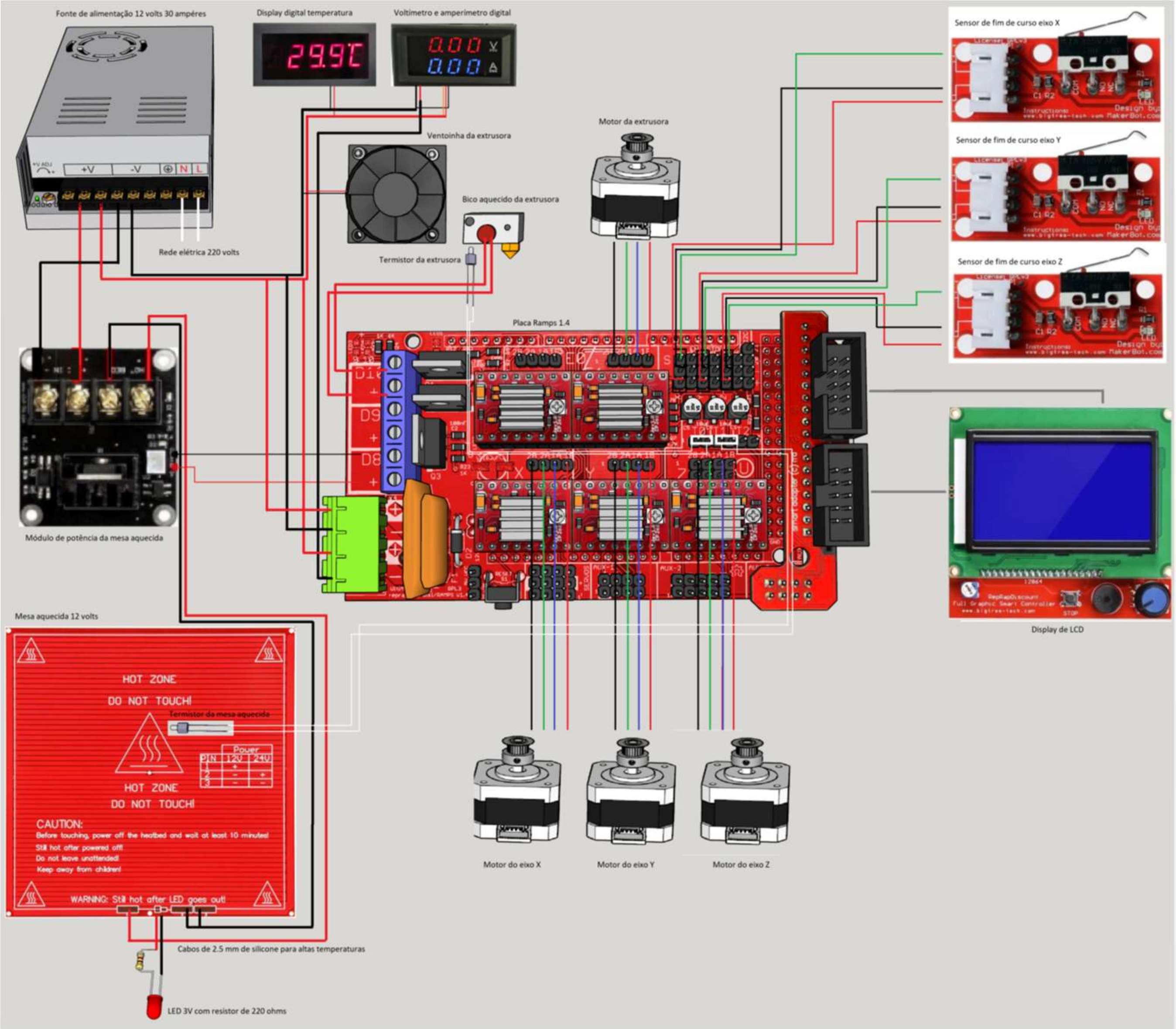
Source: Prepared by the author (2024).

Specification

Electrical schematic of 3D printer components

- The connection of the electrical components occurred incrementally.
- Reverse-engineered the functional version of the electrical schematic.
- Components were connected in isolation and as success was achieved, improvements were incorporated.
- In this phase there were several problems where the electrical scheme had to be changed and adapted.

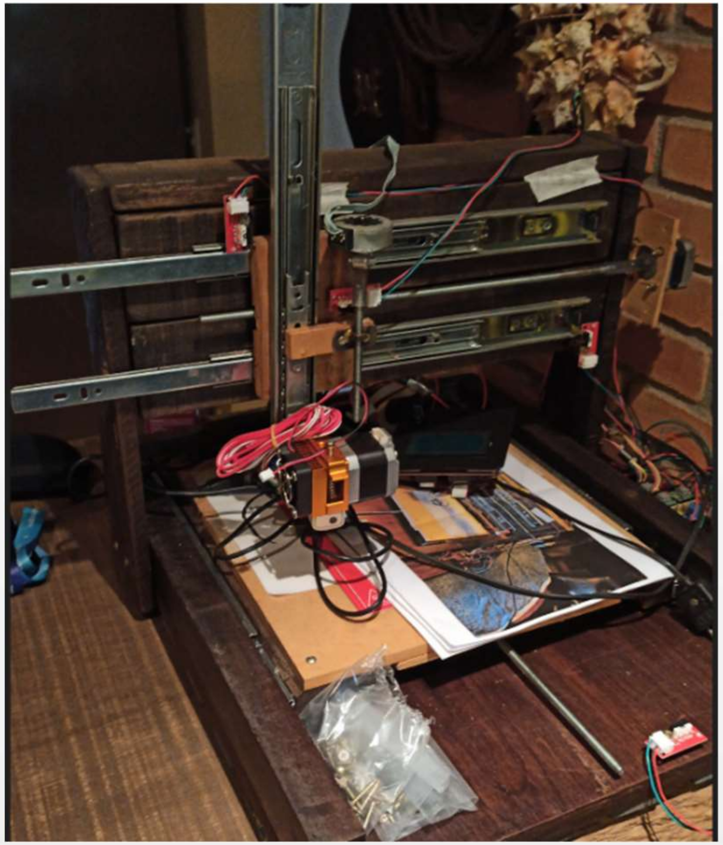
Specification



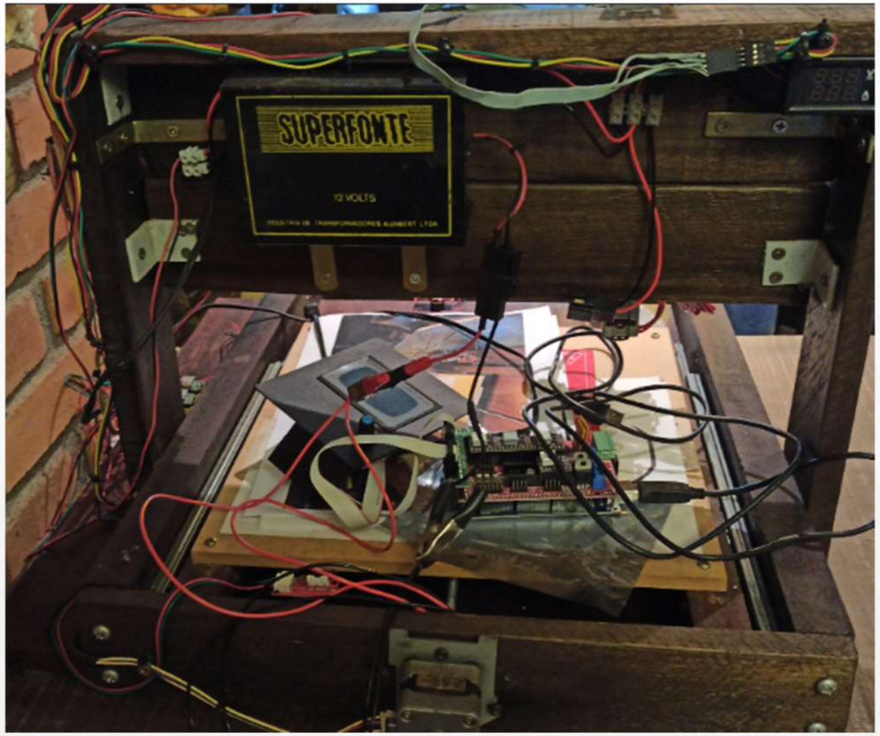
Source: Prepared by the author (2024).

Implementation

- The initial parts were used CNC router. Other components were purchased. Electronic kits, boards, screws, drills, cables.
- Tools for measuring level and square angles.



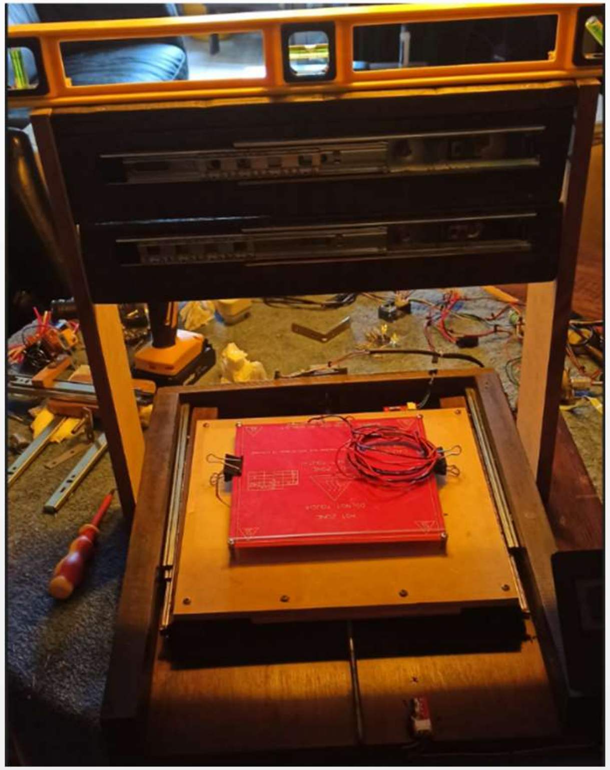
Source: Prepared by the author (2023).



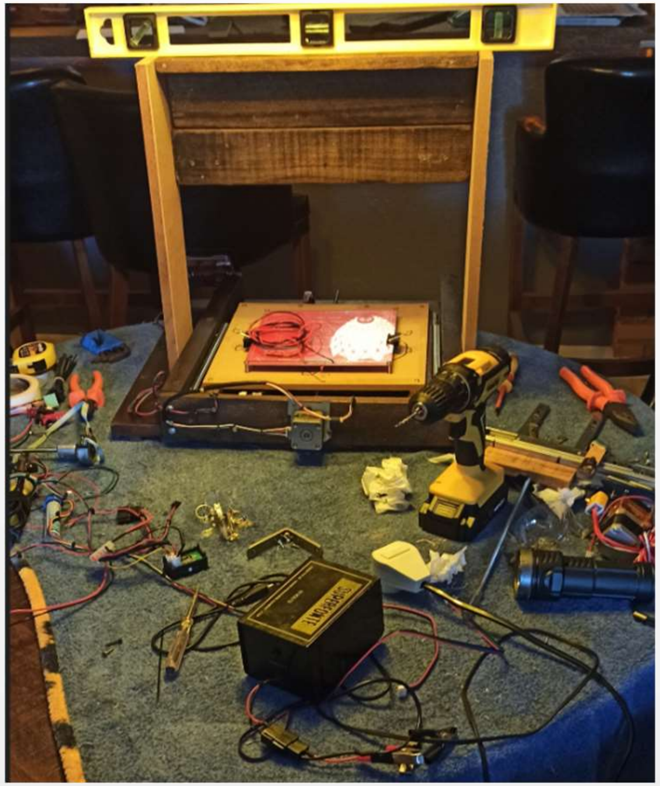
Source: Prepared by the author (2023).

Implementation

- The woods were cut by a professional machine by the company Compensados Keunecke located in the city of Blumenau, Santa Catarina.
- Perfect 90 degree angles. Various adjustments with the square.



Source: Prepared by the author (2023).



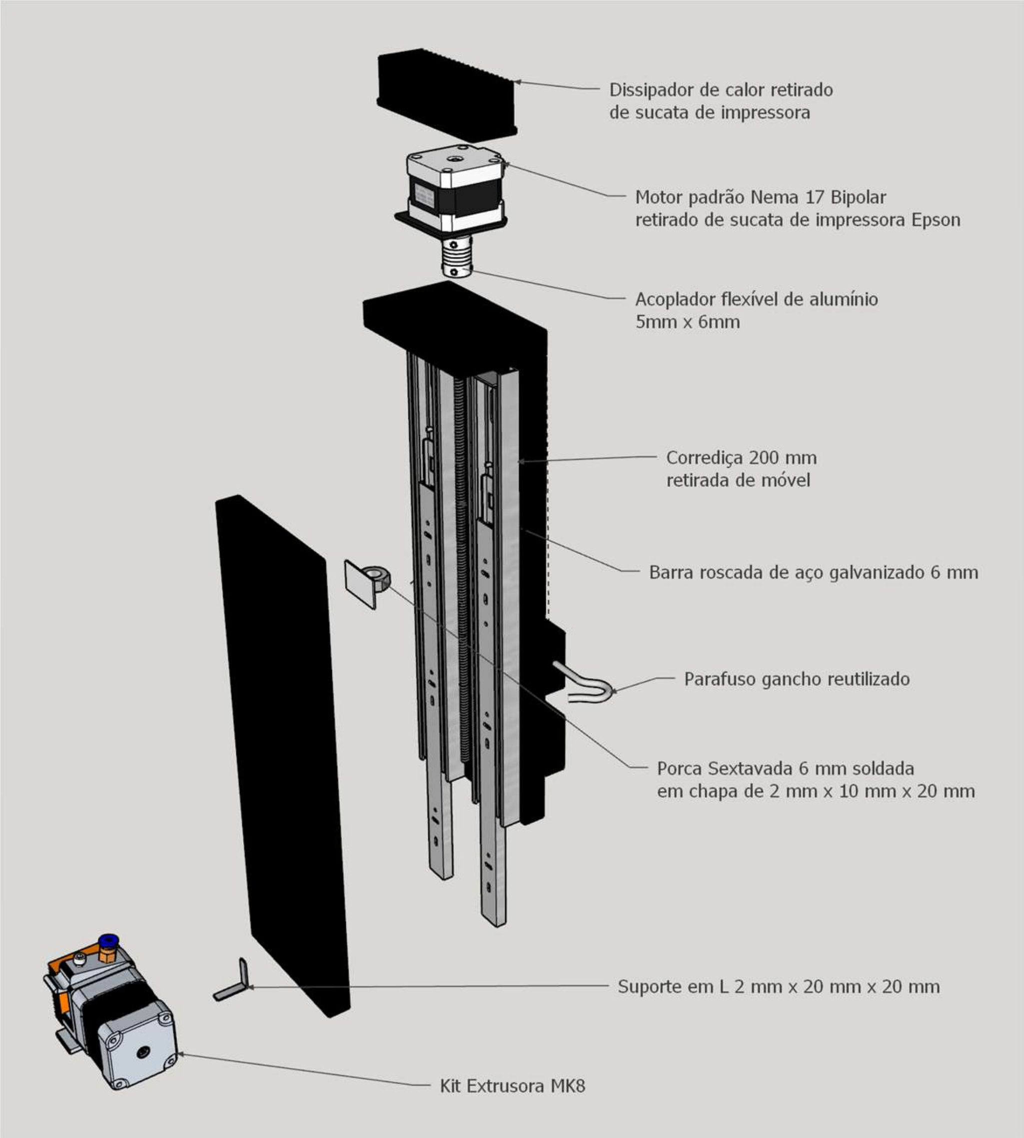
Source: Prepared by the author (2023).

FURB
UNIVERSIDADE DE BLUMENAU

Implementation

- The Z-axis concentrates the most complex moving structure.

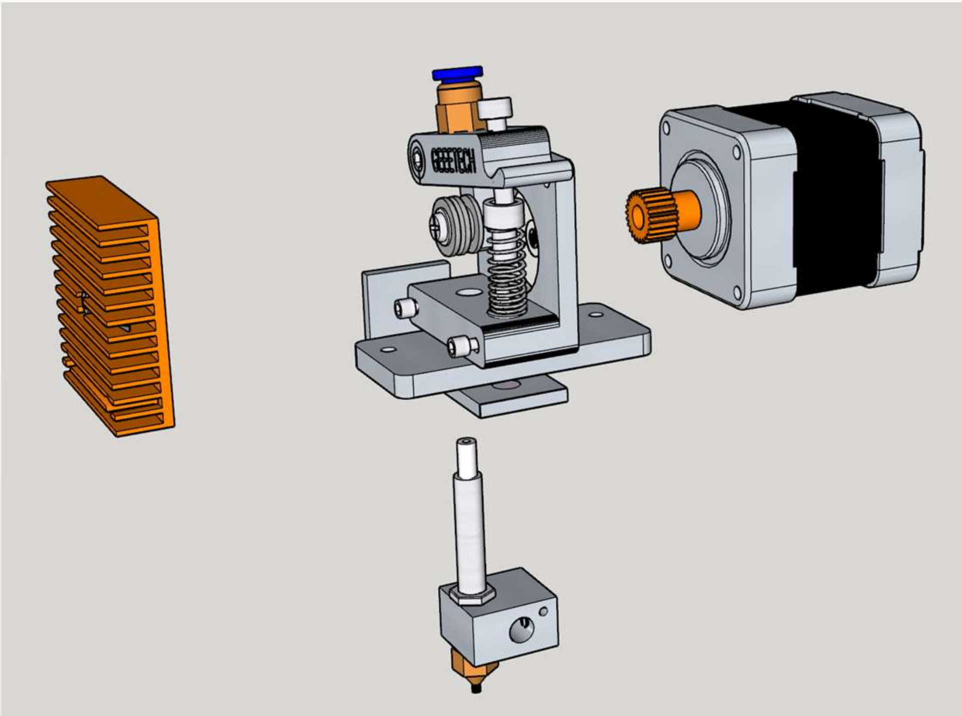
- In the illustration are all the pieces used in detail.



Source: Prepared by the author (2024).

Implementation

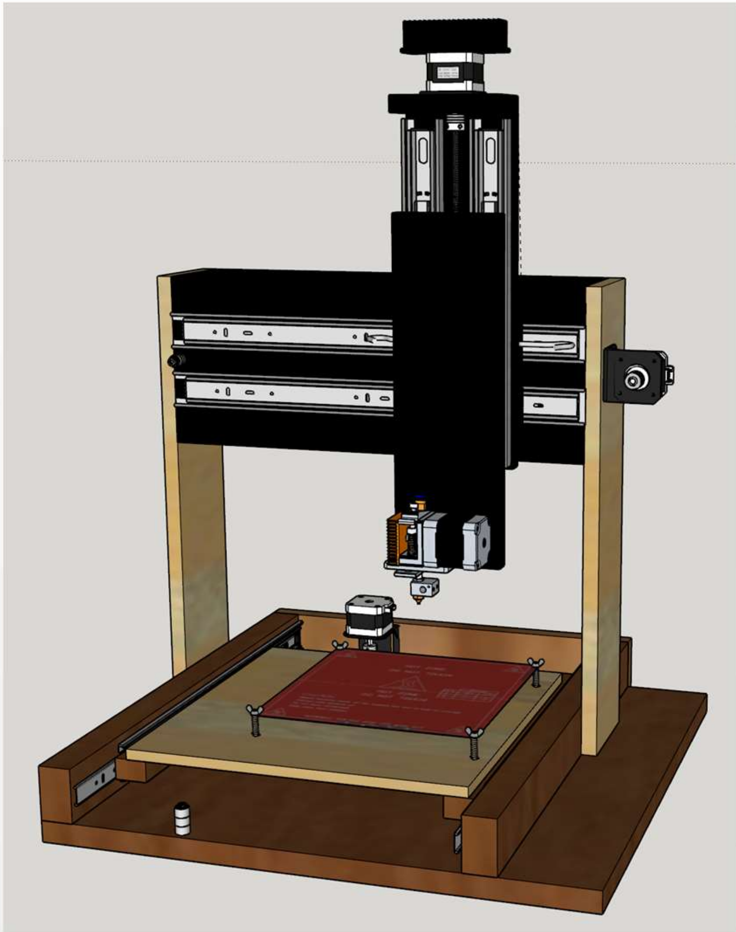
- The MK8 extruder was purchased manufactured.
- The filament is pulled by the motor and is driven to the bottom, called the HotEnd.
- When heated, it melts the filament, at the coordinates managed by the firmware that operates the microcontroller.



Source: Prepared by the author (2024).

Implementation

- After completing the assembly of the Z axis, the structure was coupled to the X-axis slides of the main structure.

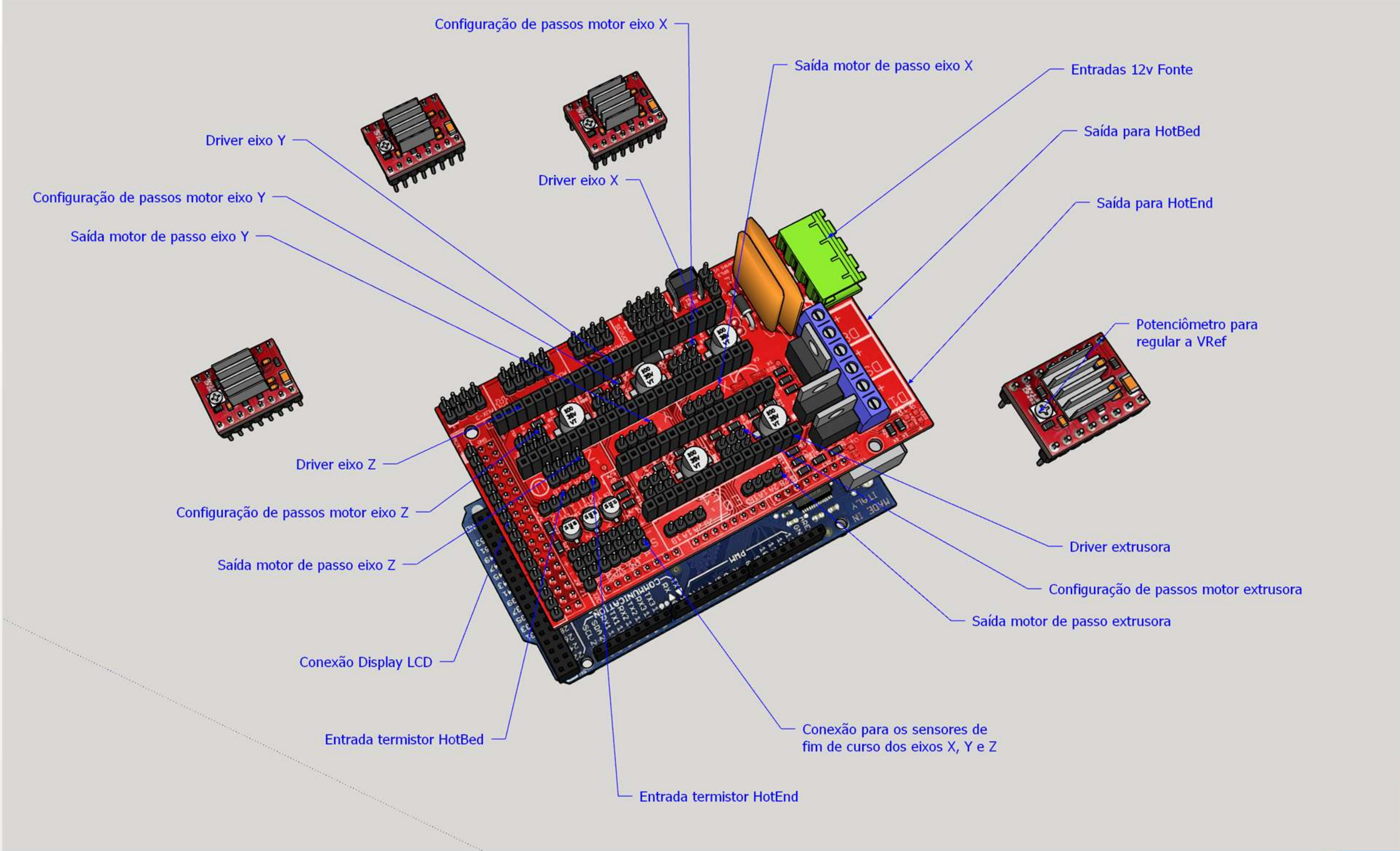


Source: Prepared by the author (2024).

FURB
UNIVERSIDADE DE BLUMENAU

Implementation

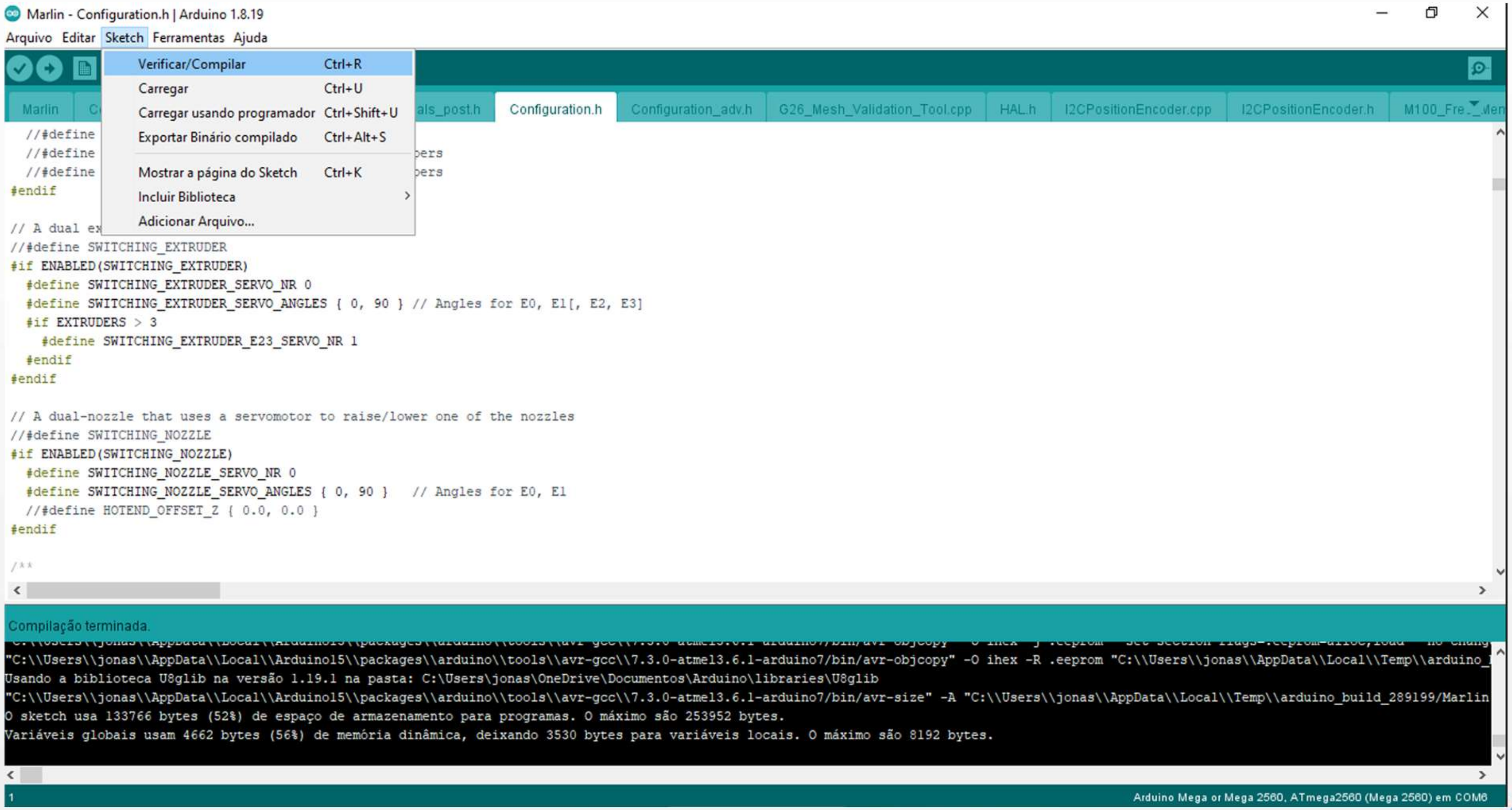
- Main connections used in Ramps version 1.4 that was coupled to the Arduino Mega 2560 board and the stepper motor controllers coupled to the Ramps board.



Source: Prepared by the author (2024).

Implementation

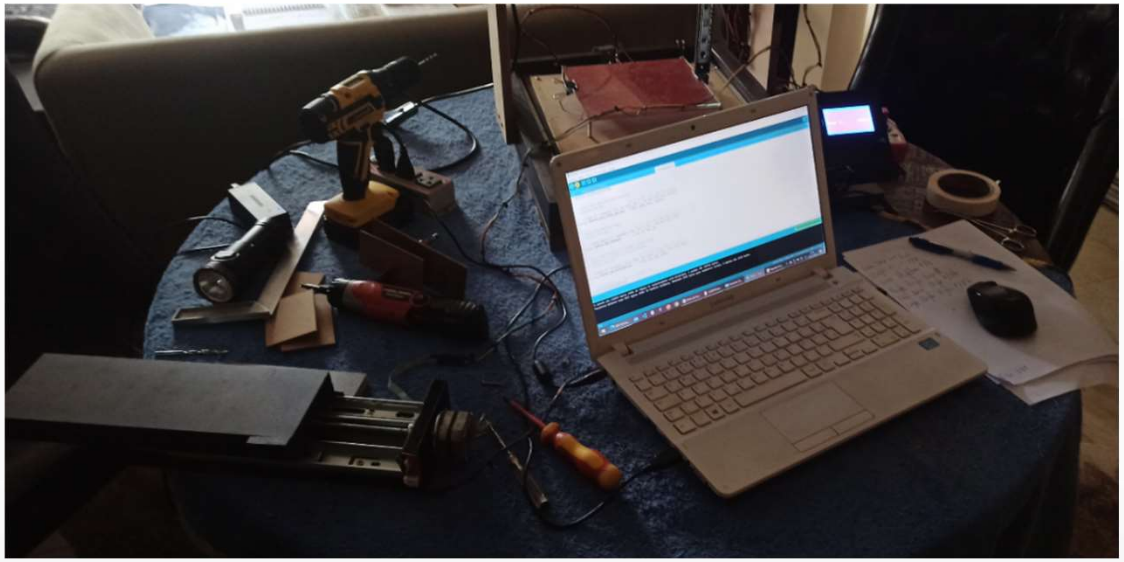
- Arduino IDE used for changes to the Marlin firmware. Written in C language.
- After compilation it is loaded to the Arduino Mega 2560 microcontroller.
- Connection between microcontroller and PC takes place through the USB port.

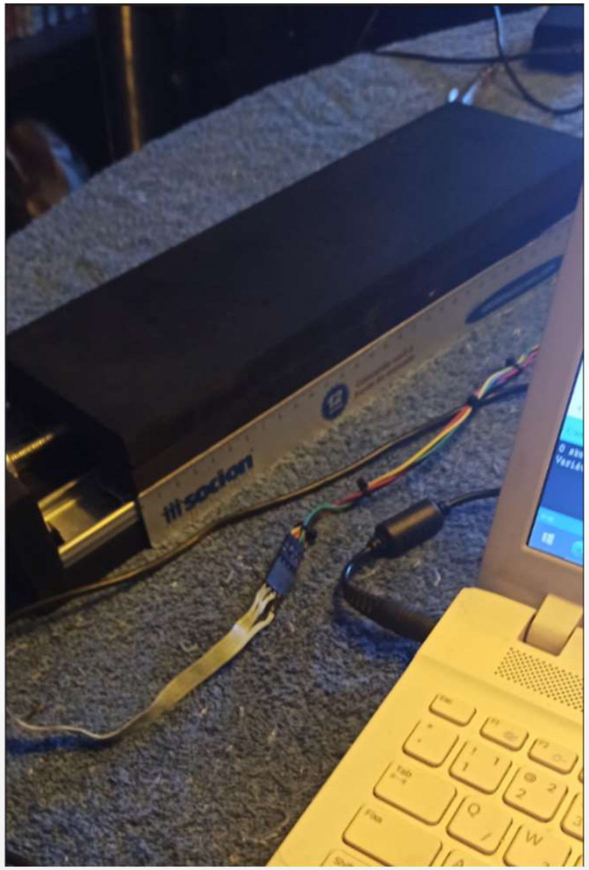


Source: Prepared by the author (2024).

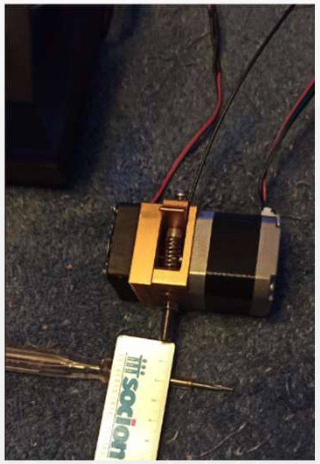
Implementation

- Calibration of the axes with ruler.





Source: Prepared by the author (2024).



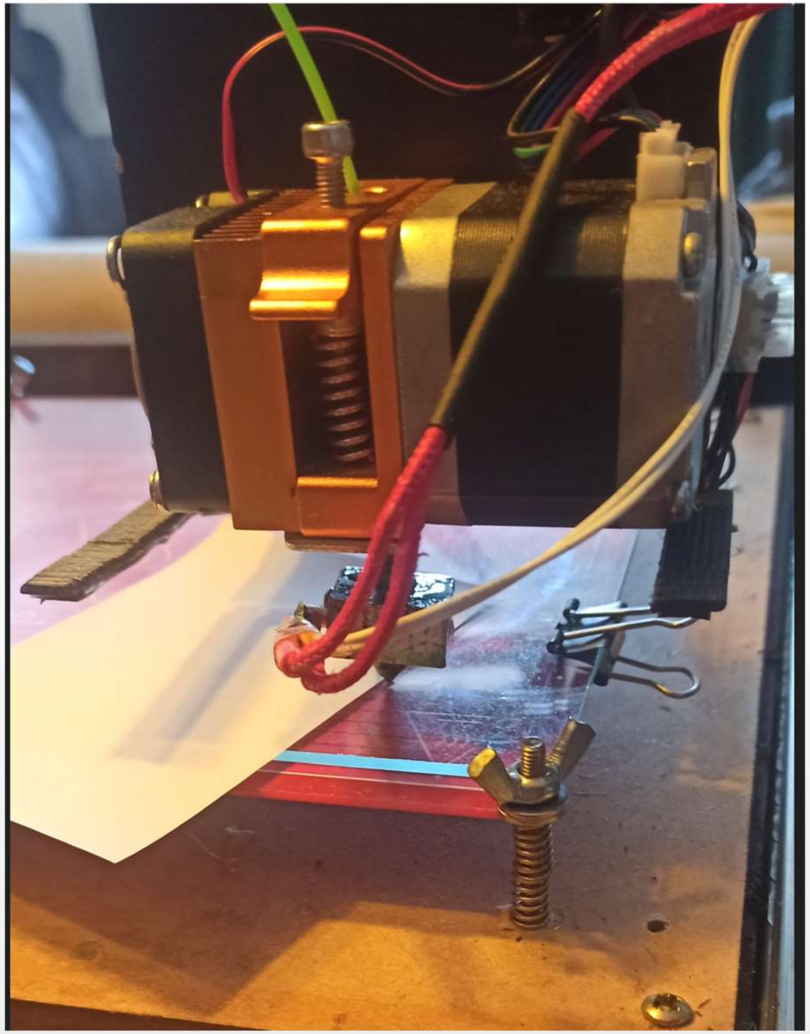
Source: Prepared by the author (2024).

Source: Prepared by the author (2024).

FURB
UNIVERSIDADE DE BLUMENAU

Implementação

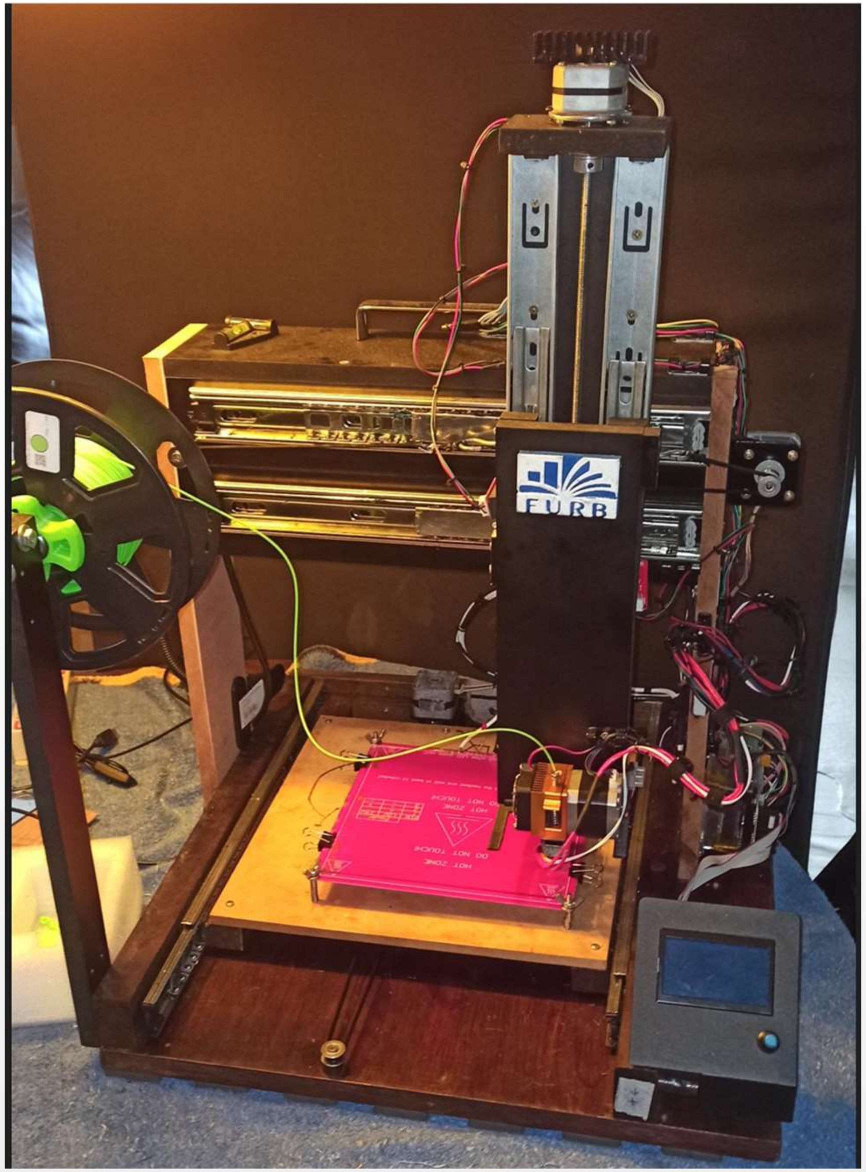
- Leveling heated table.



Source: Prepared by the author (2024).

Implementation

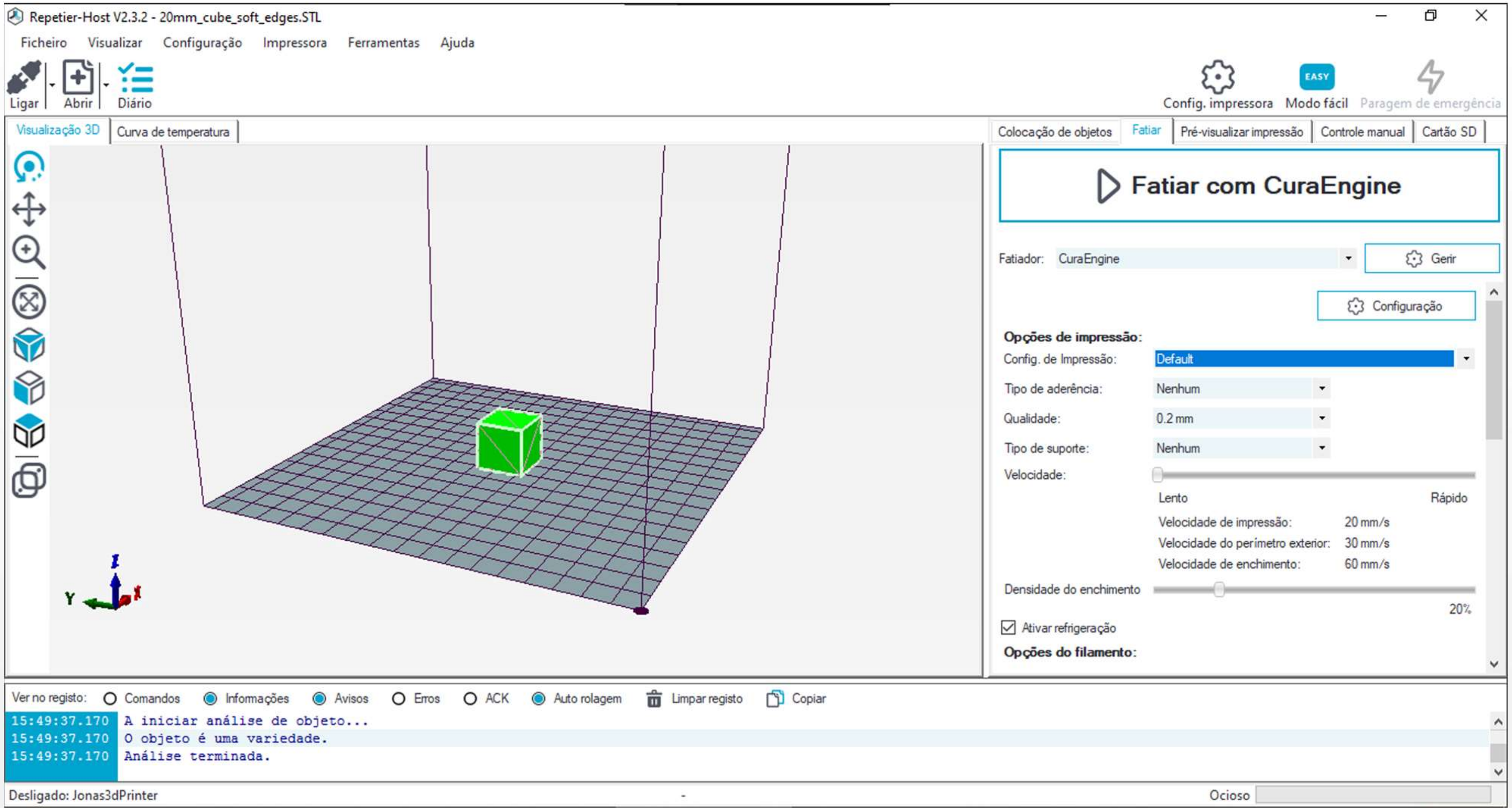
- Working version of the prototype.



Source: Prepared by the author (2024).

Analysis of the Results

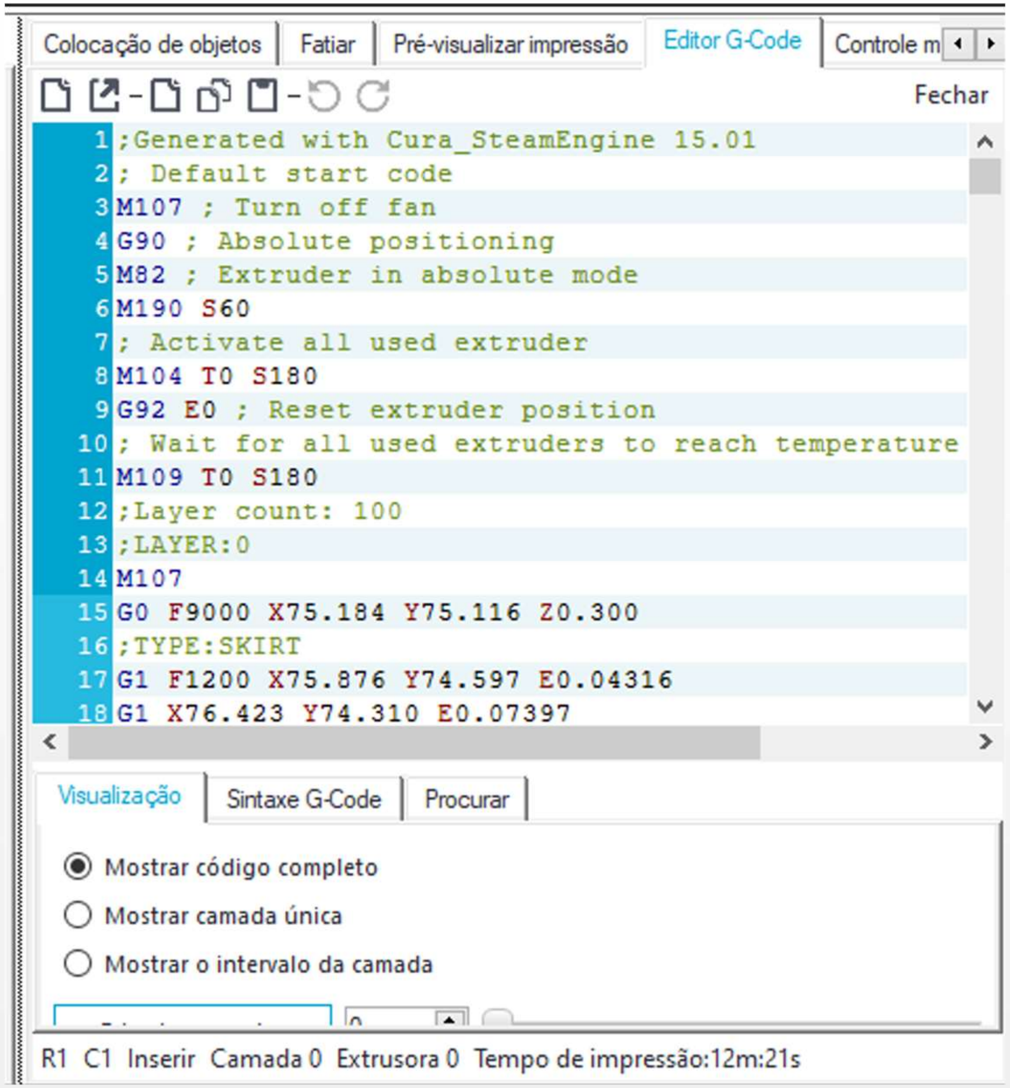
Software fatiador – Repetier Host



Source: Prepared by the author (2024).

Analysis of the Results

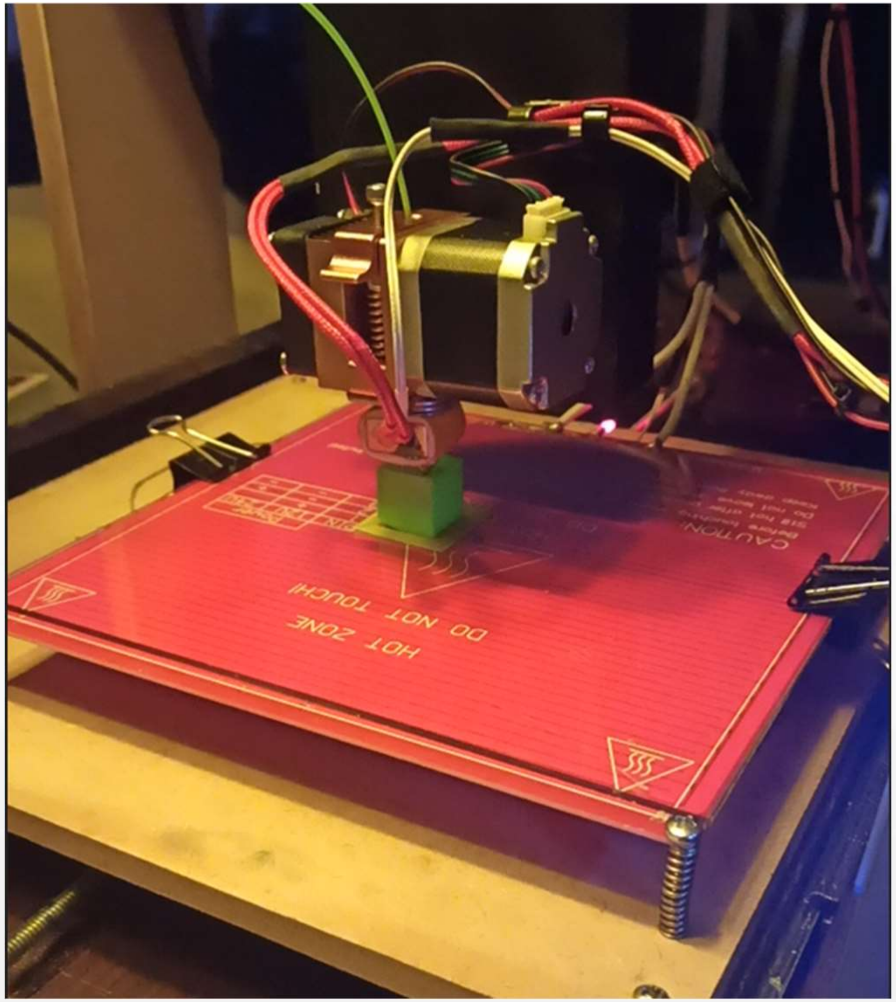
Example of the GCode generated by the slicer



Source: Prepared by the author (2024).

Analysis of the Results

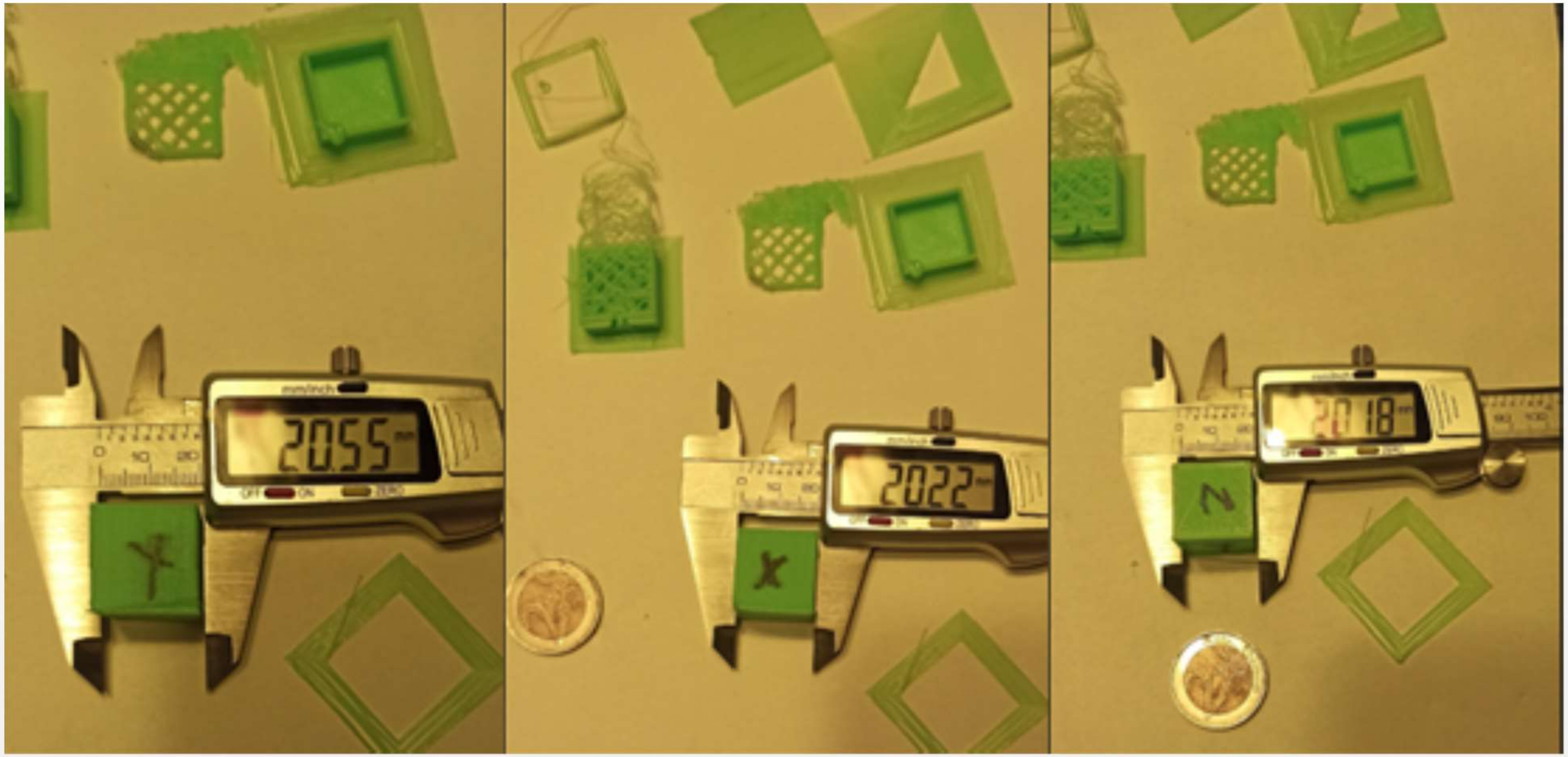
First impression made successfully



Source: Prepared by the author (2024).

Analysis of the Results

- Printing the first 20mm cube successfully. The main objective of the study was achieved.
- The material used was PLA.



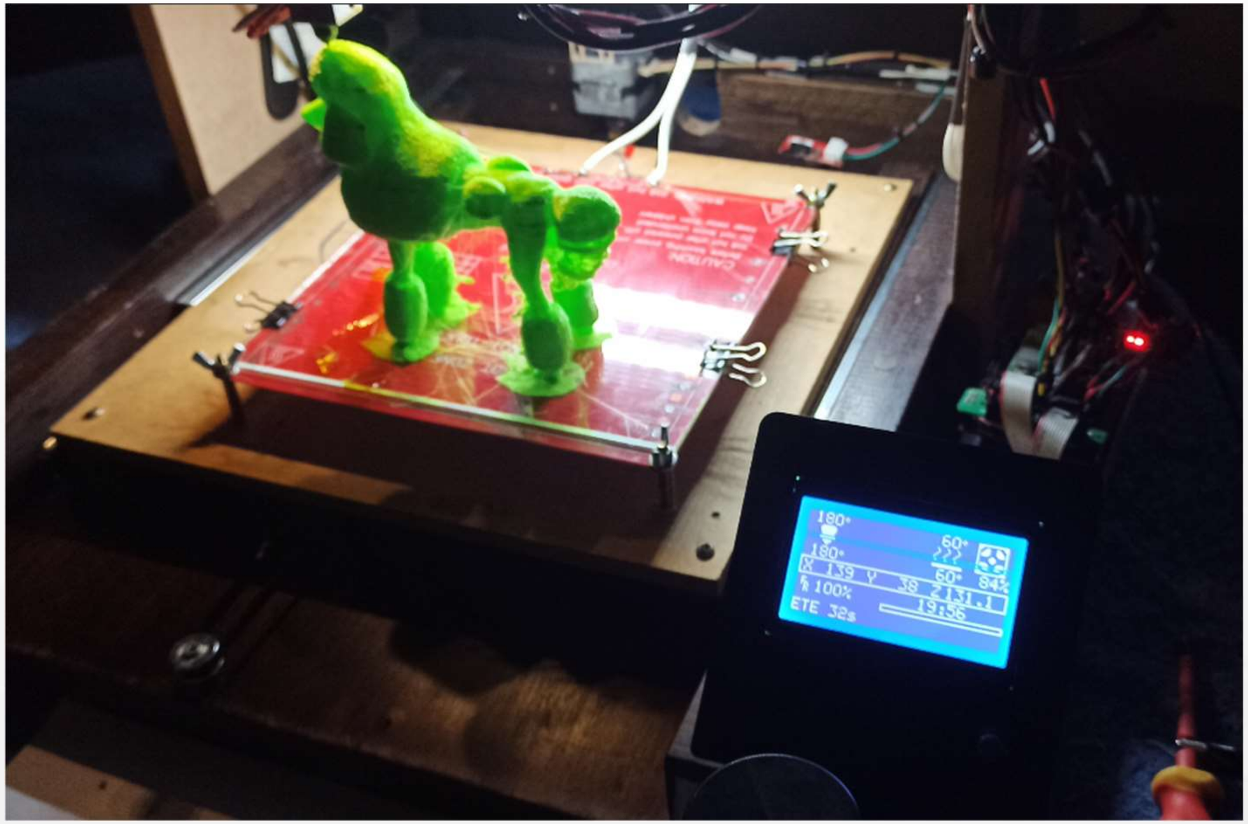
Source: Prepared by the author (2024).

FURB
UNIVERSIDADE DE BLUMENAU

Analysis of the Results

- New adjustments and tests to improve the accuracy of the calibration cube.
- Large organic shape printing to test prototype strength.

Source: Prepared by the author (2024).

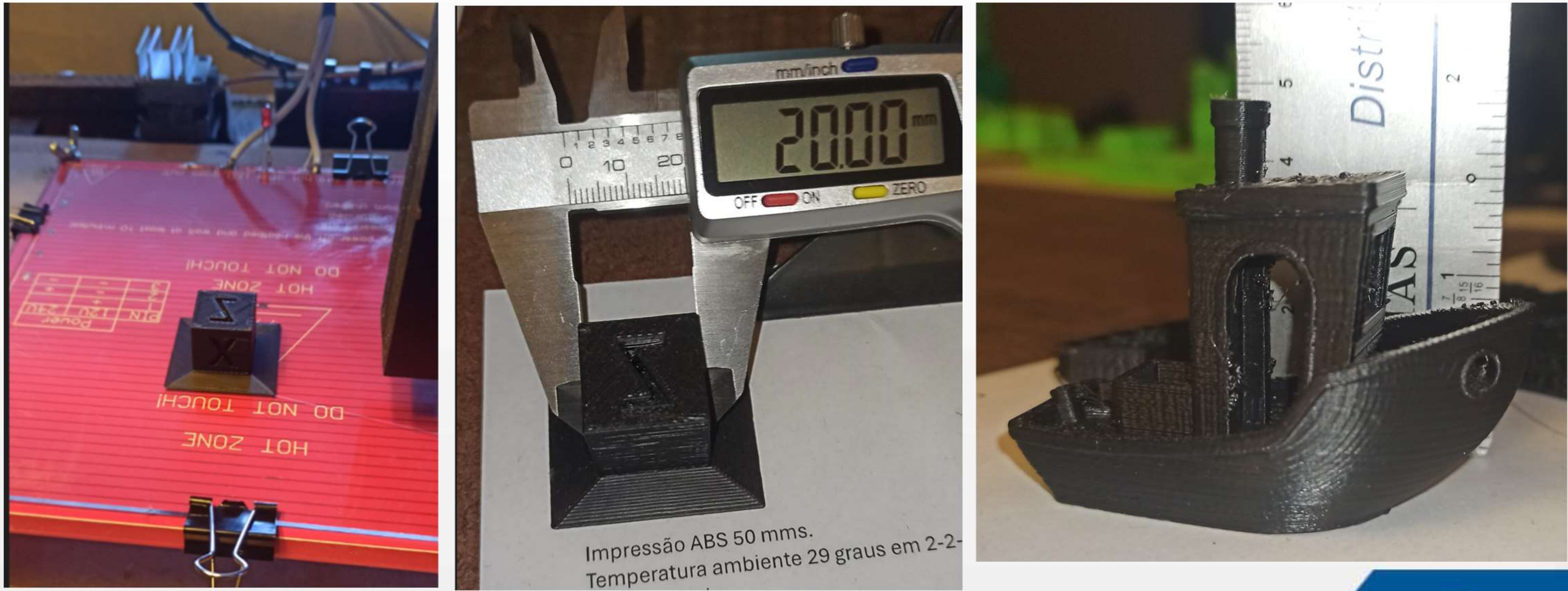


Source: Prepared by the author (2024).

FURB
UNIVERSIDADE DE BLUMENAU

Analysis of the Results

- Calibration hub in ABS material.
- ABS is more labor-intensive because it has different characteristics from PLA. It surprised in quality.
- Model 3DBenchy. These models are used worldwide to measure the capabilities of 3D printers.



Source: Prepared by the author (2024).

Analysis of the Results

- Large 3D model 30 centimeters high and 40 hours of printing.
- Approximately 200 hours of testing with different models, shapes, techniques and materials were carried out.

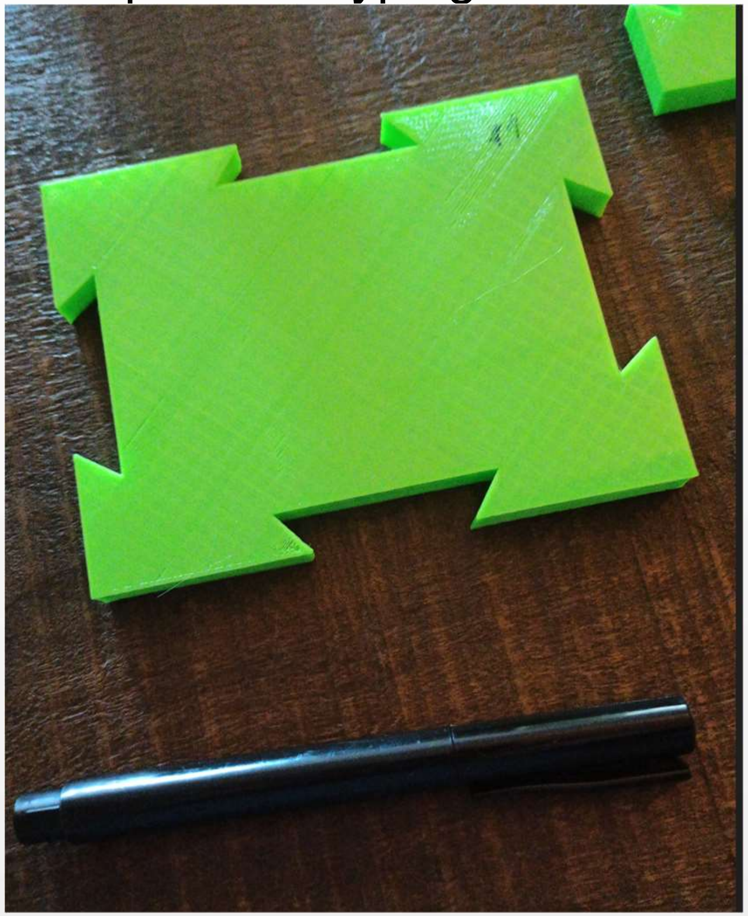
Source: Prepared by the author (2024).

Source: Prepared by the author (2024).

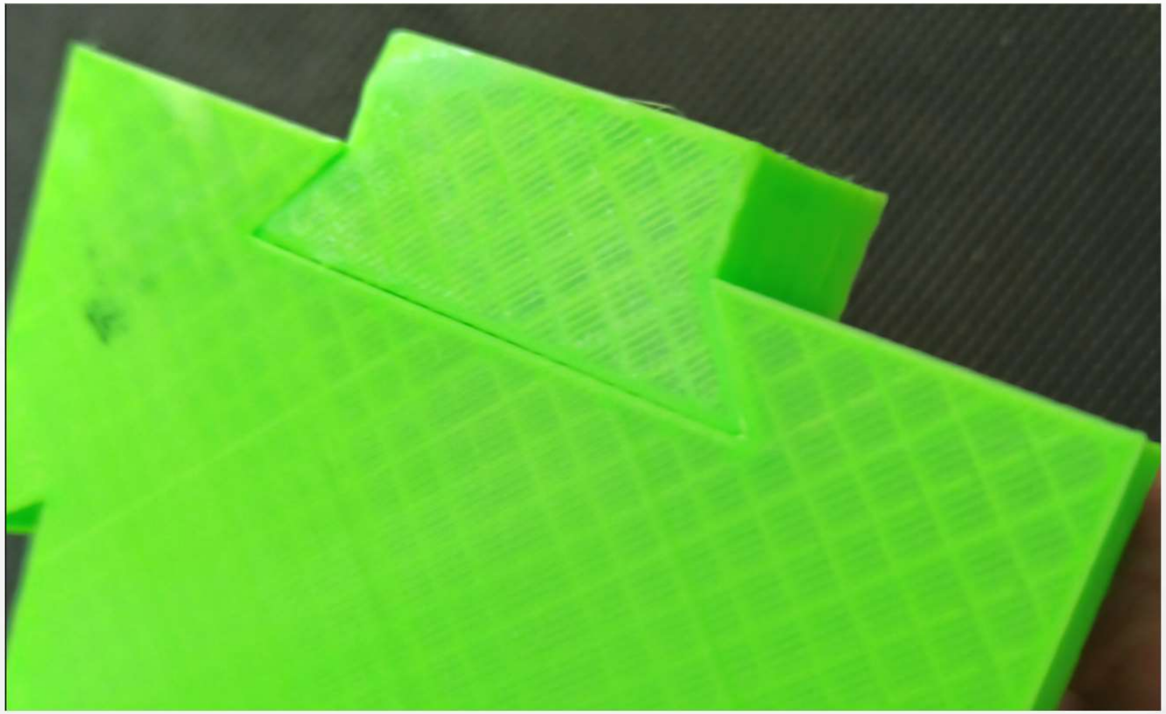
FURB
UNIVERSIDADE DE BLUMENAU

Analysis of the Results

- Testing of parts for FURBOT project.
- Multifunctional sheet size 130 mm x 100 mm x 10 mm.
- Plate corner fitting.
- Rapid Prototyping



Source: Prepared by the author (2024).



Source: Prepared by the author (2024).

FURB UNIVERSIDADE DE BLUMENAU

Analysis of the Results

FURBOT plate structure

- 24 plates of 10 x 13 cm (+- 6 hrs)
- 36 challenge connectors (+- 30 min)
- 12 edge connectors (+- 30 min)
- Hours of printing for walking:
- 48 + 6 + 2 hours = 56 hours
- 3 gaits = > 168 hours (estimated)
- NOTE: Printer maintenance.

Spending so far:

- GT Belts (R$ 80)
- Slides (R$ 50)
- Sandpaper 180 – 5 fls (R$ 25).
- 1 KG of PLA filament. (R$ 90) (335 m)
- Operating time: Approx. 200 hours. Total (R$ 245)
- Market: Cost of 30 to 50 reais per hour of printing.
- 168 hrs x R$ 30 = R$ 5040

Fonte: Elaborado pelo autor (2024).

FURB
UNIVERSIDADE DE BLUMENAU

Analysis of the Results

Key Issues and Solutions

- Pallets in terms of leveling and angle;
- Signal cables from induction limit switches;
- LCD display and voltage regulator burning;
- X and Y engines operating together;
- **Torque problems in the movement of the shafts;**
- RAMPS board burning;
- Fixing of heated table temperature sensor;
- Increased heating capacity of the heated table: damaged several parts of the circuit;
- Engine heating;
- Thermal protection via software;
- Problems of detachment of the glass parts;
- Threaded Bar x GT Straps;
- Configuration of PID AUTO TUNE for ABS;
- Filament shrinkage;
- Locking and knotting in the filament.

Analysis of the Results

Comparison with correlates

Characteristics	Level *et al.* (2022)	Zucca e Machado (2019)	Batista (2021)	Work developed
Z-axis motors quantities	2	2	2	1
Firmware	GRBL	Marlin	Teacup	Marlin
Board	Arduino Uno	Arduino Mega 2560 and Ramps 1.4	Arduino UNO e CNC Shield	Arduino Mega 2560 and Ramps 1.4
X and Y axis drive	Steel bar and linear guide	Stainless steel bar and linear guide	Steel bar and linear guide	Telescopic slides
Reuse of parts from other devices	No	Yes	Yes	Yes
Physical structure	Mounted	Bought	Mounted	Mounted
Limit Control	No	Yes	No	Yes

Source: Prepared by the author (2024).

Conclusions and Suggestions

- It exceeded expectations. In addition to the 20 mm calibration cube, several other parts with different shapes, techniques, materials with excellent quality were generated.
- All proposed objectives were achieved.
- Board Ramps with Arduino worked well with the recycled parts.
- The tools and equipment used met the needs of the project.
- RepRap, in addition to its low cost, will allow modularity for improvements.

Conclusions and Suggestions

- The assembly of the mechanical part was the most challenging.
- Mounting and dismounting several times until an acceptable level of print quality is reached.
- There were several adjustments in the issue of axle movement, such as locks, gaps in the slides and heating problems.
- Operation of a 3D printer is very different from a traditional 2D printer (abstraction).
- It is relevant and has proven the possibility of building a low-cost 3D printer with recyclable components, open-source hardware and software.
- It will contribute and encourage enthusiasts to use this technology to apply in more specific studies. Rapid prototyping for other areas, including architecture, medicine, engineering and electronics.

Conclusões e Sugestões

The main advantages observed in the work are:

a) low cost;

b) excellent cost-benefit;

c) Easy maintenance;

d) low coupling by using open source hardware and software;

e) ease of customization by not using proprietary hardware;

f) uses only one motor on the Z axis, which reduces cost, weight and complexity of the project.

The main limitations of the work are:

a) due to the prototype being open and low cost, it is not able to operate correctly with ABS material, as it would be necessary to readjust the entire set to achieve this goal;

b) aesthetic part due to the cables and gears being visible;

c) Prototype could be lighter and more compact.

Conclusions and Suggestions

To improve the features of this work or add new ones, the following extensions are suggested:

a) Develop a version of a closed 3D printer with a temperature-controlled heating cell system to operate correctly with ABS material;

b) Carrying out a study of this technology for civil construction: with a project to create a mortar extruder and later a large-scale 3D printer with the objective of generating a house with this technology;

c) Conducting a study to explore this low-cost 3D printer solution, for the creation of 3D prostheses to assist health areas and the community in general;

Conclusions and Suggestions

d) Conducting a study of this technology to disseminate teaching about 3D printing for purposes other than rapid prototyping of parts for projects or social programs;

e) Creation of a structure to generate 3D printing filament with the recycling of PET bottles and make necessary adjustments to the printer to use this type of filament that is ecologically friendly;

f) Develop a prototype of a heated table based on low-cost resistances with the objective of reaching 120 degrees in a stable way for use and improvement of this prototype.

FURB
UNIVERSIDADE DE BLUMENAU

Operation demonstration

3D Printer

https://www.youtube.com/watch?v=COdkKwUITvM

Old CNC 2D plotter 2D

https://www.youtube.com/shorts/ULowXKU8n5E

https://www.youtube.com/shorts/n5KCHaj6QJw

Playlist plotter 2D CNC

https://www.youtube.com/watch?v=sl_pvpyrn-M&list=PLpv83GdwnciMt2og577o_fMA764DJ-hFy&pp=gAQBiAQB

Playlist 3D Printer FURB Final Project

https://www.youtube.com/playlist?list=PLD1zFjMY56NA0T8d9giW4DUDWCh_5RUdH

FURB
UNIVERSIDADE DE BLUMENAU