Critical Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Working with machinery and specialised equipment

Workgroup: University of Cagliari

University of Cassino and Southern Latio

This document is the Critical Design Review of the technical competence “Working with machinery and specialised equipment”. Its details the complete program/realization of small components for the use with the pneumatic/electropneumatic test bed..

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1.1 Scope

This module focuses on developing practical and theoretical skills in the field of **Fused Deposition Modeling (FDM)** using the **Original Prusa MK4 3D printer**. Students will gain hands-on experience with the complete 3D printing workflow, from preparing digital models to operating and maintaining the machine.

Throughout the activities, learners will acquire essential competences that align with the requirements of modern digital fabrication environments, including troubleshooting, software use, and understanding mechanical and electronic components.

A1.3DP – Additive Manufacturing Technology

which related skills are (see Table I):

Table I. Skills

S1.1.	Prepare and calibrate the Prusa MK4 for a successful print
S1.2.	Import and process a 3D model using the slicing software (PrusaSlicer)
S1.3.	Execute a print operation to produce a functional or demonstrative component
S1.4.	Evaluate print quality and make necessary adjustments based on observed performance

1.2 Preliminary definition

This experimental platform can be widely used for teaching and prototyping purposes. It is composed of:

- n.1 Original Prusa MK4 3D printer (FFF technology);
- n.1 PLA filament spool (Prusament, 1.75 mm diameter);
- n.1 CAD 3D model (STL format – example: 3DBenchy);
- n.1 PrusaSlicer software for slicing and G-code generation;
- n.1 USB storage device for file transfer;
- n.1 PC workstation for modeling and slicing;
- n.1 Set of printed models (test prints in PLA);
- n.1 Flexible build plate (textured or smooth);
- n.1 3D printed support base (optional, for printer positioning or accessories).

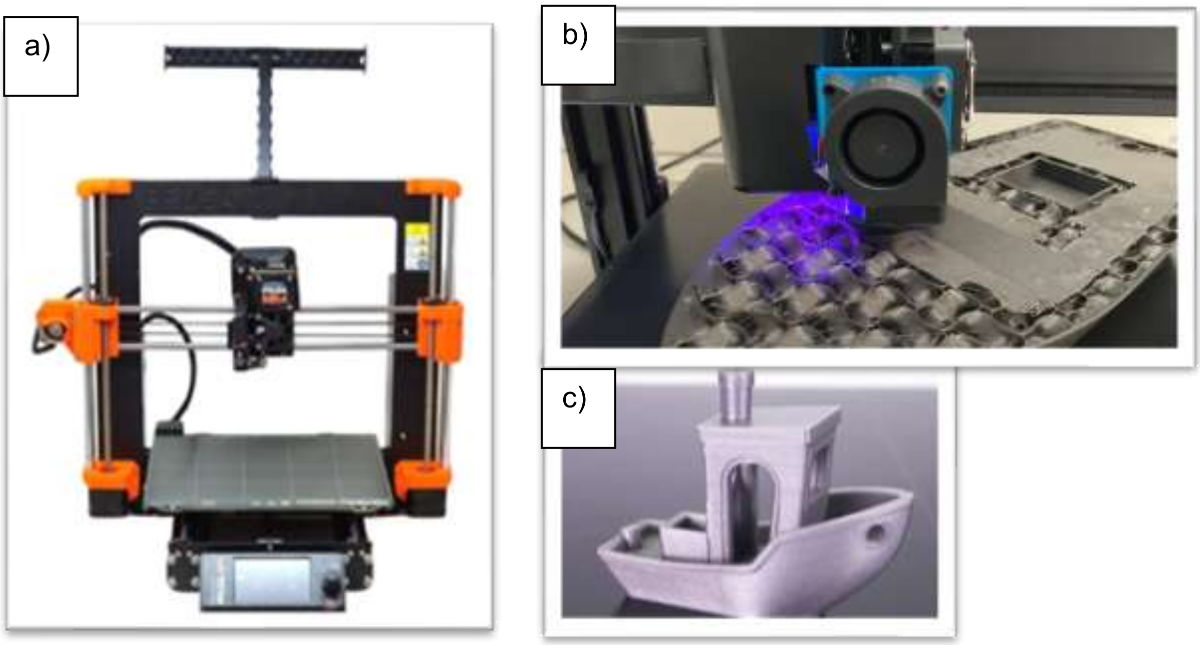


Figure 1. a) Original Prusa MK4 3D printer; b) Running process; c) Printed model

This proposal (see Figure 1) requires either the physical test-bed setup or the use of a digital environment that simulates the slicing and manufacturing workflow (e.g. through preview mode in PrusaSlicer or 3D CAD environments).

The main advantage of this setup lies in its accessibility and clarity: the additive manufacturing process can be easily visualized, manipulated, and adapted to different educational levels. Furthermore, the process of creating a tangible model from a digital file introduces core concepts of Industry 4.0 such as digital twin, parametric design, and rapid prototyping.

1.3 Technical requirements

The main advantage of this platform lies in its versatility and suitability for a wide range of educational activities, both theoretical and practical. In addition, the 3D printing process—being visible, sequential, and easy to follow—provides a very illustrative way to introduce students to the fundamental skills of digital modelling, rapid prototyping, and additive manufacturing.

1.3.1 Prusa MK4 3D printer

The 3D printer used in this educational context is the **Original Prusa MK3.9**, one of the most refined models in the Prusa Research lineup. It is an **FFF (Fused Filament Fabrication)** technology printer designed to offer **high precision, reliability, and ease of use**, making it particularly well-suited for both home and academic environments. The MK3.9 incorporates several advanced features inherited from the newer MK4 model, ensuring stable and efficient prints with common materials such as **PLA, PETG, and ASA** (see Figure 2).

Figure 2 Prusa MK4 3D printer

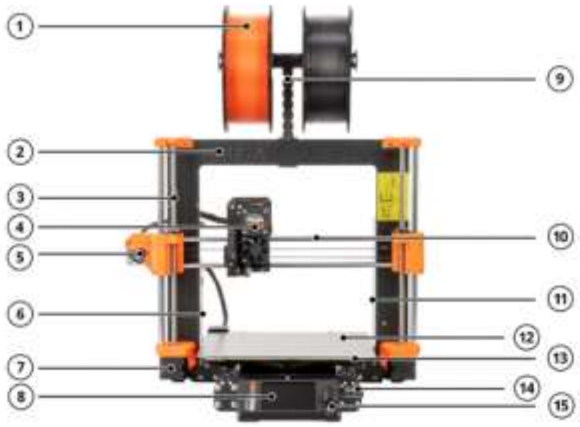
The following table summarizes the main technical specifications of the **Original Prusa MK3.9**, including its **physical dimensions**, **print volume**, **recommended operating conditions**, and **extruder features**. These values provide a clear understanding of the system's capabilities and its optimal operating environment (see Table II).

Table II Technical specifications of the Original Prusa MK3.9 3D printer

Name:	Original Prusa MK3.9
Manufacturer:	Prusa Research a.s., Partyzánská 188/7a, Holešovice, 170 00, Prague, Czech Republic
Contact:	Phone: +420 222 263 718, e-mail: info@prusa3d.com
EEE Category:	3 (IT and/or telecommunication equipment), Device intended for indoor use
Power Supply:	100–240 VAC, 2.8 A max, 50–60 Hz
Operating Temperature Range:	18 °C – 38 °C
Maximum Air Humidity:	85%, non-condensing
Printer Dimensions:	Width: 460 mm Depth (bed centered): 420 mm Height (without or with spool): 385 mm
Print Volume:	250 × 210 × 220 mm
Nozzle Diameter Installed:	0.4 mm
Filament Diameter	1.75 mm
Weight (without packinging)	7.6 kg

To better understand the functioning and structure of the Original Prusa MK4 3D printer, it is useful to explore its main components. Each part plays a crucial role in the additive manufacturing process, contributing to precision, stability, and ease of use. From the motion system and extruder to the electronics and user interface, the MK4 integrates several optimized features aimed at improving the overall printing experience.

The following list describes the key mechanical and electronic parts of the MK4, highlighting their respective functions within the system. This overview is particularly useful for educational purposes, technical documentation, and training activities involving 3D printing technology (see Figure 3).



1. **Filament Spool** – The MK4 is compatible with 1.75 mm filament;
2. **Frame;**
3. **Z Axis** – Vertical, made of threaded and smooth rods; moves the Nextruder up and down;
4. **Nextruder** – Our new-generation extruder with planetary gear and load cell sensor;
5. **X-Axis Stepper Motor** – Moves the Nextruder left and right;
6. **Electronics Enclosure** – Housing for the xBuddy board. Ethernet and Wi-Fi ports are accessible from the rear.Z-Axis Stepper Motor – One of two total;
7. **Z-axis** motors move the Nextruder up and down;
8. **LCD Screen** – Used to control and configure the printer;
9. **Spool Holder;**
10. **X Axis** – Generic name for the horizontal group composed of two smooth rods, an X-axis motor, a belt, and plastic parts. The Nextruder moves left to right along the X axis;
11. **Power Supply Unit;**
12. **Print Sheet** – Easy to maintain, held in place by strong magnets integrated into the heated bed.Heated Bed – Proven MK52 heated print bed;
13. **USB Port and USB Drive** – Uses a USB drive to print G-code (print files) and flash firmware;
14. **Control Knob** – The main control knob with reset button located just below the screen.

Figure 3 Labeled overview of the MK4 3D printer components

1.3.2 PLA filament

Polylactic Acid (PLA) is one of the most widely used thermoplastic materials in 3D printing, particularly in educational and prototyping environments. Derived from renewable resources such as corn starch or sugarcane, PLA is a **biodegradable and environmentally friendly material**. It is characterized by its **low extrusion temperature**, typically between **190 °C and 220 °C**, **minimal warping**, and **low emission of odors**, making it safe and easy to use even in closed or classroom environments.

PLA offers **excellent dimensional stability**, **vivid colors**, and a **smooth surface finish**, which makes it ideal for aesthetic models, visual prototypes, and general-purpose parts. However, it has **limited mechanical strength** and **low heat resistance** (typically softening above 60 °C), which means it is not suitable for outdoor or high-stress applications.

In the context of this project, **PLA was selected as the preferred filament** due to its simplicity, print reliability, and the quality of surface finish it delivers—perfectly suited for test models such as the **3DBenchy**. The following procedure describes how to load PLA filament into the **Original Prusa MK4**. This is a fundamental part of the 3D printing process, and understanding it ensures consistent print quality and avoids issues such as clogging or filament tangles (see Figure 4).

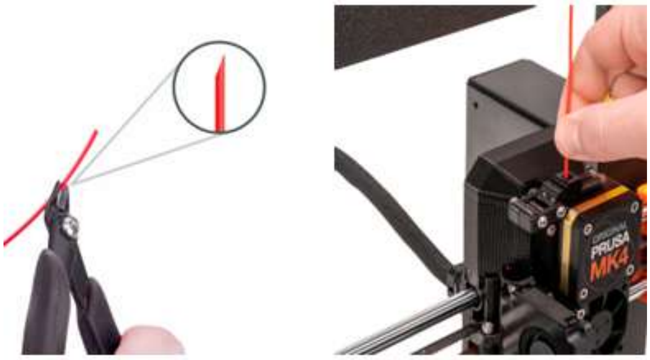


Figure 4 Loading the PLA filament into the Nextruder

Before starting, prepare a spool of PLA filament. Prusa strongly recommends PLA for its ease of use and stable behavior during printing. Place the spool on the holder located at the top of the printer's frame and carefully unwind the filament, keeping tension to prevent tangling.

1. **Cut the tip** of the filament at an angle to form a sharp point.
2. Insert the filament through the filament guide hole and into the **Nextruder's top opening**.
   - If the filament sensor is **enabled**, the filament will load automatically.
   - If **disabled**, manually proceed to the next step.
3. On the LCD screen, go to: **Menu** → **Filament** → **Load Filament**, and confirm.
4. The **Preheat Menu** will appear. Select the filament material (PLA) and confirm.
5. Wait until the **nozzle reaches the required temperature**.
6. Press the knob to begin feeding the filament. Slightly push the filament in until the extruder gears grab it.
7. The extruder gear will push the filament forward and begin **extruding material through the nozzle**.
8. The printer will ask whether the extruded filament color is correct:
   - Select **Yes** if the extrusion is clean and the color is correct.
   - Select **Purge More** if there is color contamination or inconsistent extrusion.
   - Select **Retry** if nothing extrudes or the process needs to be repeated.

This loading step ensures the filament is properly inserted and the nozzle is clean, guaranteeing high print quality from the first layer onward.

1.3.3 Test model

The 3D printing process begins with the creation of the three-dimensional model, which can be designed using CAD software (Figure 5) and subsequently exported in .STL or .3MF format, both supported by slicing software (see Figure 6).

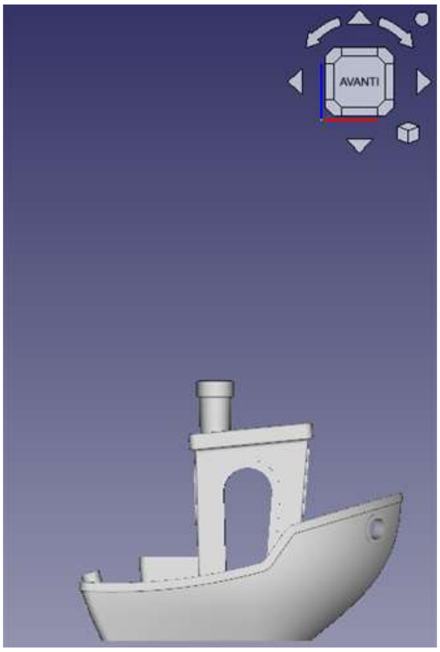


Figure 5. 3D Model

Once the model file is prepared, it must be imported into PrusaSlicer, the slicing software officially provided by Prusa Research Within PrusaSlicer, the model is positioned on the virtual print bed, correctly oriented, and configured with the desired print parameters (layer height, infill density, supports, etc.). The software then generates a G-code file containing all instructions required by the Prusa MK4 printer. This G-code file is transferred to the printer via USB drive, SD card, or network connection. Once the file is loaded onto the machine, the print process is initiated by selecting the file from the printer's interface; the printer will automatically heat the necessary components (heated bed and extruder) and begin the deposition of material according to the defined toolpath. It is recommended to monitor the initial layers to ensure proper adhesion to the build plate.

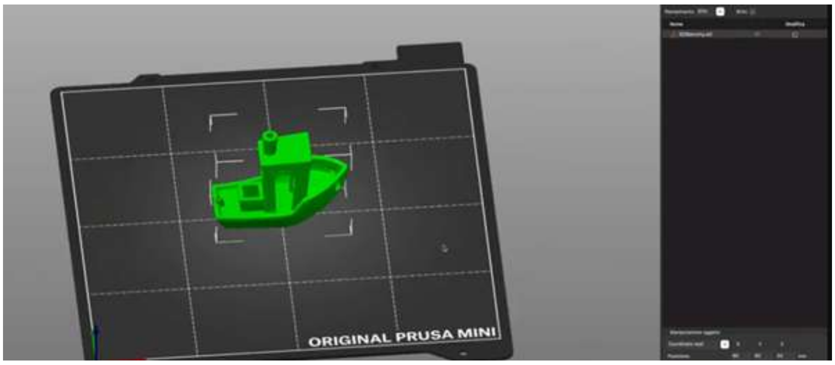


Figure 6. PrusaSlicer

2 Hardware Design

The hardware design includes some functional parts that can be easily acquire in the market.

2.1 Functional Parts

The necessary hardware therefore includes:

- Printer;
- PLA;
- Cleaning cloth and isopropyl alcohol.

2.2 Hardware Overview

The hardware used in this activity is centered around the **Original Prusa MK4**, a desktop 3D printer that integrates all key components into a compact, preassembled unit. This system was selected for its ease of use, consistent reliability, and the availability of spare parts and accessories—making it especially well-suited for educational use.

While no custom mechanical design is required, users can enhance the system by **3D printing auxiliary parts** such as cable guides, storage trays, or sensor holders, directly using the printer itself. This hands-on approach supports the teaching of core principles in digital manufacturing, self-sufficiency, and iterative design.

The setup includes the printer itself, a **PLA filament spool**, the **extruder in action during the printing process**, and the **completed model (3DBenchy)**. This sequence provides a complete view of the workflow from preparation to production, and illustrates the practical implementation of the additive manufacturing process in a classroom setting (see Figure 7).

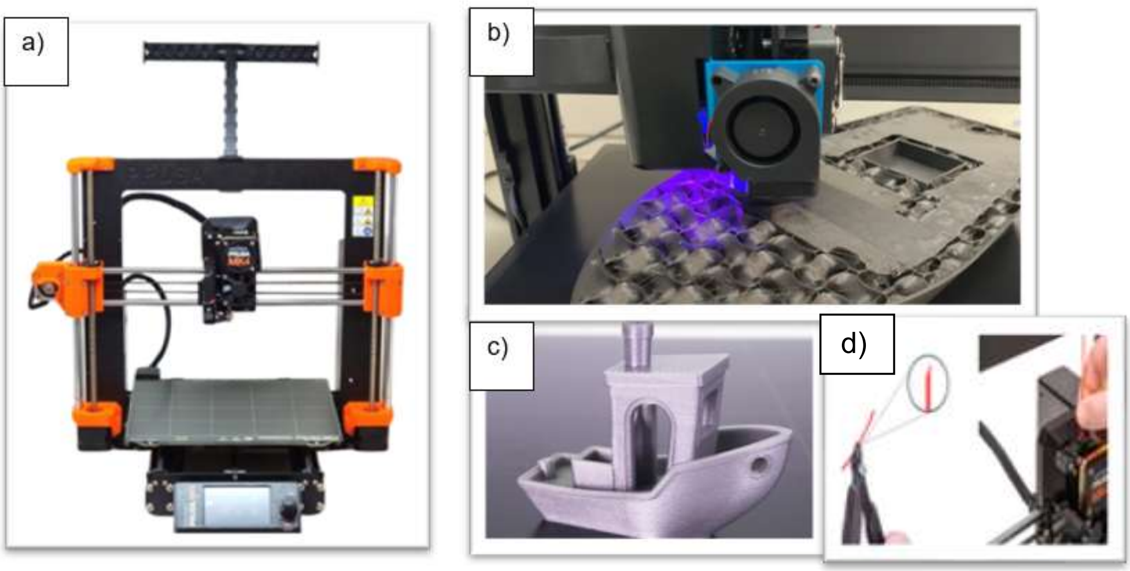


Figure 7 of the educational 3D printing system with Original Prusa MK3.9:
(a) Full view of the printer; (b) Extruder during the printing process; (c) Final printed model (3DBenchy) in PLA; (d) PLA filament spool mounted and ready for use

3 Software Design

The software tools used in this educational activity were selected to be intuitive and accessible for both teachers and students. The design and printing process relies on two main software environments: a **3D modeling tool** and a **slicing software**.

For 3D modeling, **FreeCAD** was used, a free and open-source parametric CAD program suitable for educational use. Once the 3D model was completed, it was exported in **STL format** and then processed using **PrusaSlicer**, the official slicing software developed by Prusa Research. PrusaSlicer allows users to set print parameters, visualize the layer-by-layer structure of the object, and generate the necessary G-code for the 3D printer.

Both applications are available on most desktop and laptop computers and are compatible with Windows, macOS, and Linux systems (see Figure 8).

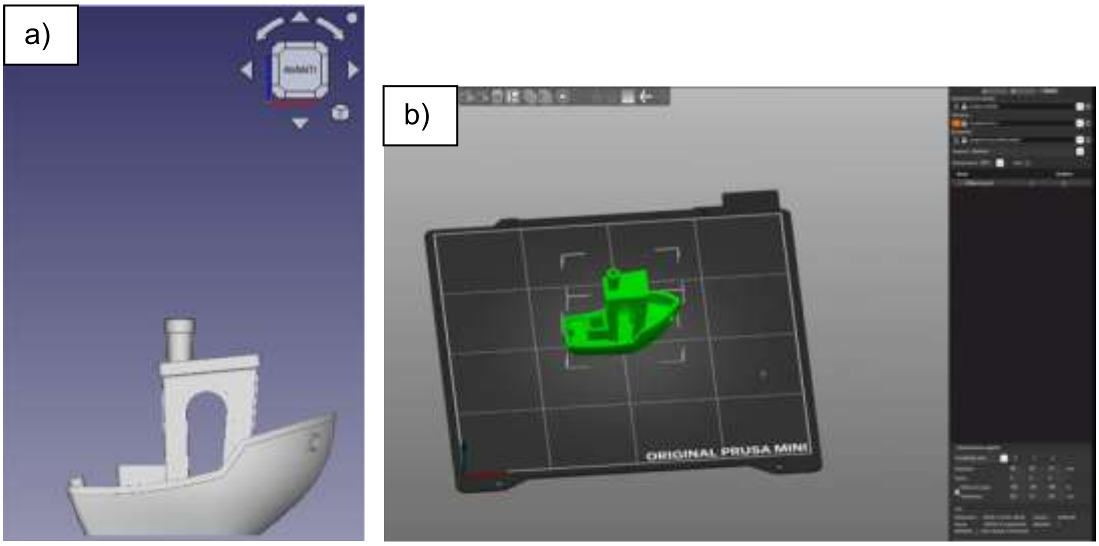


Figure 8 shows the overall software workflow.a) FreeCAD; b) PrusaSlicer

3.1 FreeCAD

FreeCAD was used to design the 3D model used in this activity. Its parametric design capabilities and modular interface make it particularly suitable for technical education. The model created for this project is the well-known **3DBenchy**, often used to evaluate printer accuracy and quality (see Figure 9).

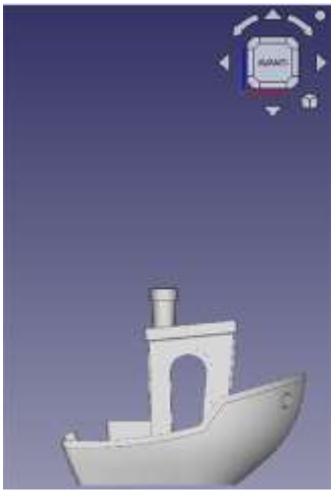


Figure 9 3D model of the Benchy loaded in FreeCAD

3.2 PrusaSlicer

The STL file exported from FreeCAD was processed in **PrusaSlicer**. This software allows the user to define key print parameters such as layer height, infill density, nozzle temperature, and print speed. It also provides a visual simulation of the print process layer by layer, which is valuable for understanding how the printer builds the object in real time.

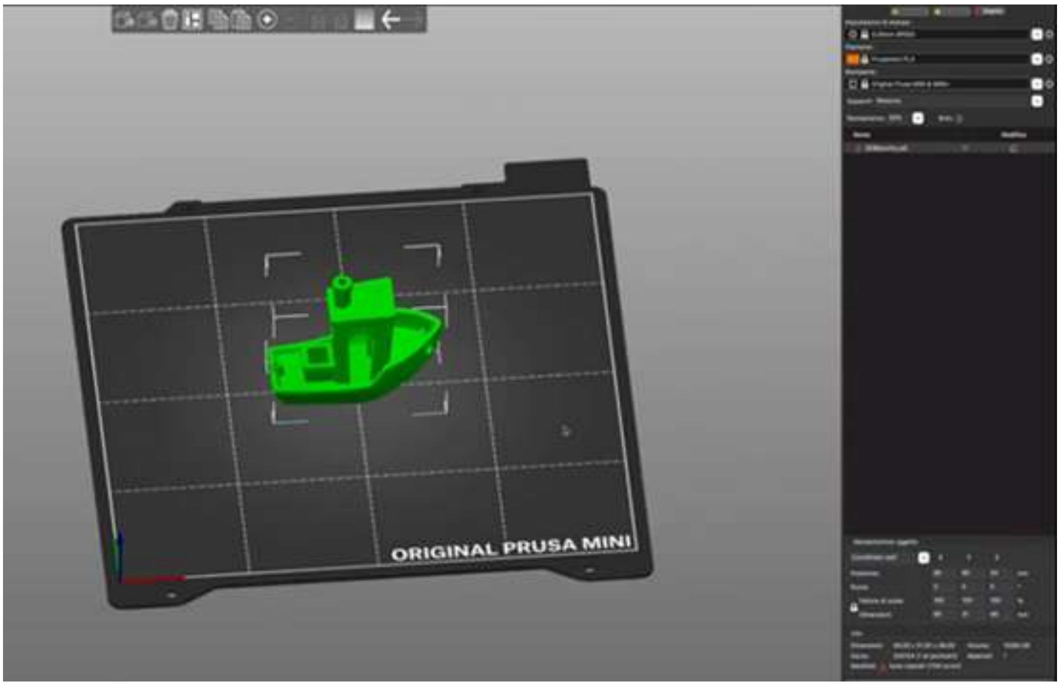


Figure 10 Model sliced and prepared for printing in PrusaSlicer