CS-358 Making Intelligent Things

Knitting Robot Project Proposal

Group Members:

Wiktoria Rozkosz, Bogdan Cîrje, Imane Raihane,
Lorie Xu, Yasmine Hidri, Victor Zablocki
EPFL, Lausanne, Switzerland

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1 Introduction

1.1 High-Level Description of the Project

The main aim of this project is the development of a **Knitting Robot** capable of knitting simple patches. The robot will consist of an Arduino-based system that controls actuators to manipulate knitting needles (or hooks), allowing it to produce knitted fabrics autonomously. The final result is expected to be a functional prototype that demonstrates the ability to knit given patterns, such as scarves or scalable fabrics. Further, the project can be extended to more complex knitting patterns with further development.

Figure 1: Existing design of a single axis knitting robot

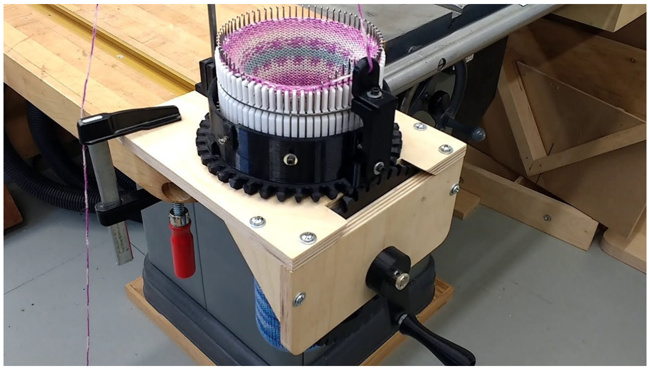


Figure 2: Round knitting machine. Creating round pattern can also be done by combinating two moving beds of needles.

1.2 Related Projects and Resources

Our project is not the first initiative in the realm of automated knitting. Several existing projects and companies have made significant steps in this field, which can serve as inspiration and points of reference for our development:

- **OpenKnit Project**: An open-source initiative that developed a digital knitting machine (`http://openknit.org/`). The project has the benefit of providing good insights into mechanical designs and control systems for knitting automation.
- **Kniterate**: A commercial digital knitting machine (`https://www.kniterate.com/`) created by OpenKnit developer, that automates knitting with computer-controlled patterns. While it's a more advanced system, studying its functionality can inspire potential future features for the project.
- **Hand-Cranked Knitting Machines**: Designs of traditional knitting machines (e.g. Brother KH series machines) provide foundational knowledge on the mechanics of knitting that can be adapted for automation.
- **Arduino Knitting Machine Conversion**: Projects where hobbyist have converted manual knitting machines into automated ones using Arduino microcontrollers (`https://youtu.be/-AjIKjxDDHE`).
- **Knitify**: Knitify is a notable startup that focuses on automating knitting processes using an innovative approach. Their platform allows users to create and customize patterns digitally, which are then executed by their knitting machines. This project exemplifies how technology can enhance traditional knitting and offers insights into user interface design and pattern generation.

These projects offer mechanical designs, control algorithms, and software that can be referenced and adapted for this project. Their strategies and resolved challenges can be studied to implement our one efficient solution of knitting automation.

2 User Stories

- **Hobbyist Knitter**: As a hobbyist knitter, I want a device that can knit simple patterns automatically so that I can produce scarves and fabrics without spending hours of manual labor.
- **Educational Tool**: As a prestigious teacher in robotics and automation, I want a demonstration project that showcases the integration of mechanical design, electronics, and software to inspire students about the possibilities of engineering.
- **EPFL Demonstrations**: As a member of the EPFL IC public relations team, I want a compelling demo that can attract prospective students by showcasing an innovative project combining computer science and mechanical engineering.
- **Business Owner**: As an owner of a knitting business, I find it useful to explore new solutions in hope of upgrading our factories.
- **Future Developers**: As a developer interested in advancing knitting automation, I want a modular and open-source project that I can build upon to create more complex knitting patterns or improve efficiency.

3 Product Management

From a long-term perspective, this project has the potential to evolve in several ways:

- **Educational Kits**: The Knitting Robot can be developed into an educational kit for teaching robotics, programming, and automation concepts in schools and universities.
- **Open-Source Platform**: By making the design and software open-source, we can create a community of developers and makers who contribute to improving and expanding the project's capabilities.
- **Basis for Startups**: With further development, the project could lead to the creation of affordable, consumer-friendly knitting machines, filling a niche in the crafting and DIY market.
- **Future Course Projects**: The mechanical and software components can be reused or expanded upon in future CS-358 projects, allowing students to work on pattern recognition, advanced motion control, or integration with computer vision for pattern customization.

4 Software

The software for the knitting robot will center around a web app that serves as the main interface for users to interact with the machine. Through the app, users can upload knitting patterns, select different project styles, and customize settings. The app will allow for versatile choices, such as knitting a scarf, beanie, and hopefully a pullover, with adjustable parameters like size, color, and patterns.

Inspired by the AYAB project (https://www.ayab-knitting.com/) , the knitting robot will accept pattern formats such as bitmap images or text files. The software will digitize these patterns by interpreting each pixel as a specific stitch, enabling the creation of different textures or patterns. The robot will then convert the digital designs into precise row-by-row instructions for the needles.

The knitting robot will have an LCD screen to provide real-time feedback on the knitting process. It will display essential information, such as the progress of the current project, the number of completed rows, and any detected errors. If an issue occurs, such as yarn tension problems or motor stalls, the screen will show an alert, allowing users to pause the machine and resolve the problem before continuing.

5 Bill of Materials

This section provides a detailed breakdown of the components required for the Knitting Robot project, along with reasons for their inclusion and links for sourcing.

- In order to test different patterns and produce more complex items, we need differently colored and weighted materials for knitting, e.g., special *heavier* yarn.
- **Switch Sensors:** We will use switch sensors instead of the initially planned ultrasonic sensors, which may not perform as expected (e.g., detecting unintended movement from other components, such as yarn). These sensors will act as "end stops" for the carriage to prevent it from moving beyond its intended range. This is an implementation of a safe-to-fault default.
- **USB Isolator:** For additional safety, a USB isolator and a camera will be used to monitor operations. The USB isolator will capture any energy spikes that may result from the operation of the NEMA motors, and the camera will allow both the user and us to observe any anomalies during the machine's operation.
- **Stepper Motors and Motor Drivers:** Stepper motors will provide precise movements for the knitting machine's needle beds and carriage. The motor drivers, including A4988 drivers, will control the motors, and it is crucial to adhere to safety protocols due to the associated risks.
- **CNC Shield:** To facilitate a safer and simpler electronics setup, a CNC shield has been provided for use with the NEMA 17 stepper motors and A4988 motor drivers.
- **Rotation Sensor:** Initially, a rotation sensor similar to the one used in the OpenKnit project was chosen. If this sensor proves unsuitable, we will switch to an AS5600 rotation sensor for enhanced accuracy.
- **Skateboard Ball Bearings:** By reducing friction, these bearings will ensure smooth movement for all mechanical parts of the machine. We plan to use six skateboard bearings: two on each flatbed and two in the carriage.
- **SG90 Servo Motors:** We will initially use smaller SG90 servos for specific parts of the carriage to select needle positions and manage yarn feeders.
- **Multiplexer:** We will use a multiplexer to incorporate all the elements using just one Arduino and Wemos.
- **Voltage Converter:** Since our design integrates 12V stepper motors and 5/6V servos, a voltage converter is required.
- **LCD Screen:** This will provide real-time feedback to the user.
- **ESP32 CAM:** The ESP32 CAM will provide camera functionality and Wi-Fi capabilities for wireless communication, allowing for remote monitoring and control. An FTDI USB-to-serial converter will facilitate communication between the ESP32 CAM and the computer.
- **MPU-6050 (IMU):** This sensor will help us track the carriage's movements, making it easier to control and stabilize.
- **Aluminum Bar:** This bar will serve as a base for securely mounting all components.

Total Estimated Cost: 239 CHF

Material	**Quantity**	**Price (CHF)**	**Links**
Normal yarn (50g/135m)	4	1.95 (total: 7.8)	Ecru: Click here Rose: Click here Bleu-Clair: Click here Rouge: Click here Lilas: Click here
Needles	1	50	Click here
HC-SR04 ultrasonic sensor	2	2 (total: 4)	In stock
Microcontroller ESP32-CAM	3	4 (total: 12)	In stock
FTDI USB-to-serial	3	2 (total: 6)	In stock
Arduino Uno	1	5	In stock
Nema motor + driver (17HS4401 + A4988)	3	15 (total: 45)	In stock
Servo DMS15 (Needle Chooser)	4	5 (total: 20)	In stock
Servo DMS15 (Yarn Feeder)	1	5	In stock
LCD screen	1	6.20	Click here
Skateboard ball bearing	8	1 (total: 8)	In stock
PCA9685 16-channel PWM Multiplexer	1	12	In stock
Belts (2 meters)	1	2	In stock
Bourns PEC11R-4020K-S0012	2	1.75 (total: 3.50)	Click here
8-channel logic-level converter	2	1 (total: 2)	In stock
USB isolator	1	15	In stock
Aluminium bar	3 meters	—	From mechanical shop
Power supply 120 W	1	29.70	Click here
LM2596 buck converter	1	4.45	Click here
MPU-6050 (IMU)	1	5	In stock
Power connector	1	0.653	Click here

Table 1: Bill of Materials for the Knitting Robot Project

6 Risk Management

In this section, we identify the potential risks that could affect the successful completion of the Knitting Robot project and outline strategies to mitigate them.

- **Risk 1: Hardware Component Failure**
  - **Description**: Components such as the Arduino microcontroller, motors, or sensors might malfunction or be faulty.
  - **Impact**: High – A malfunctioning component could prevent the knitting robot from functioning correctly, causing delays.
  - **Probability**: Medium – While unlikely, it is possible for hardware components to fail, particularly if they are not tested thoroughly.
  - **Mitigation**: Thorough testing of individual components before integration will be carried out. Backup components will be bought in advance to ensure quick replacement if needed.
- **Risk 2: Integration of Software and Hardware**
  - **Description**: The integration of the Arduino programming with mechanical components might lead to unforeseen issues, such as synchronization failures or inaccurate knitting patterns.
  - **Impact**: Medium – Inconsistent communication between software and hardware could result in a malfunctioning prototype or poor performance.
  - **Probability**: Medium – Software bugs or mechanical misalignment could occur during integration.
  - **Mitigation**: Use step-by-step testing during development to ensure each subsystem (e.g., needle control, motor movement) works independently before integrating them. Unit testing of code and simulations of movements will be performed to catch errors early in the process.
- **Risk 3: Budget Overrun**
  - **Description**: The estimated costs may exceed the available budget due to unexpected component requirements or additional parts needed for repairs.
  - **Impact**: Medium – Exceeding the budget could limit the ability to acquire necessary parts and delay completion.
  - **Probability**: Medium – The current cost estimate leaves ample room for unforeseen expenses, but unexpected costs could still arise.
  - **Mitigation**: We will adhere closely to the budget estimate, only purchasing additional components if absolutely necessary. Additionaly we will try to accuire components from different suppliers for best price possible.
- **Risk 4: Difficulty in Achieving Desired Knitting Accuracy**
  - **Description**: The knitting robot may not achieve the level of precision required to create high-quality fabrics, especially for more complex knitting patterns.
  - **Impact**: High – Inaccurate knitting could lead to poor-quality outputs or failure to meet project goals.
  - **Probability**: Medium – Ensuring consistent and precise needle movement is technically challenging.

  - **Mitigation**: Focus initially on achieving accurate knitting of simple patterns before scaling to more complex designs. Best precision motor controls will be used to increase precision.

- **Risk 5 Sustainability and Environmental Risks**
  - **Description**: The project could lead to environmental impact through the use of non-recyclable materials or energy consumption during operation.
  - **Impact**: Moderate to High – The use of non-recyclable materials could contribute to environmental degradation, while high energy consumption could increase the carbon footprint, potentially damaging the project's sustainability goals and public perception.
  - **Probability**: Medium – While it is feasible to use sustainable materials, constraints like cost or availability may lead to compromises on eco-friendliness.
  - **Mitigation**: The design will prioritize the use of sustainable materials wherever possible, such as recyclable or biodegradable components. Additionally, the power requirements of the system will be assessed to minimize energy consumption during operation, and we will explore options for using renewable energy sources.

Effective risk management ensures that potential challenges are anticipated and mitigated, helping the project stay on track and within budget.

7 Encountered Problems

During the initial stage of development of the Knitting Robot, we encountered several challenges that have required adjustments to our initial plans:

- **Circular Knitting Challenge**: We initially aimed to create circular objects, such as beanies, using a single-axis machine. However, we discovered that the current machine design only supports straight-line knitting, which makes it difficult to achieve seamless circular patterns. We are exploring the possibility of modifying the design by combining two beds of needles to simulate a circular motion.
- **Affordable Needles**: Another issue has been sourcing affordable and appropriate needles for the project. Easily available specialized knitting needles for automation are either too expensive or difficult to find within our budget constraints. To mitigate this, we are considering using fewer needles or opting for wooden alternatives for the prototype phase. We also plan to explore using wood or metal cutting to fabricate custom knitting tools, allowing us to continue development while waiting for the delivery of proper needles.

We are continuing to explore alternative solutions to these problems while ensuring the project stays on track.

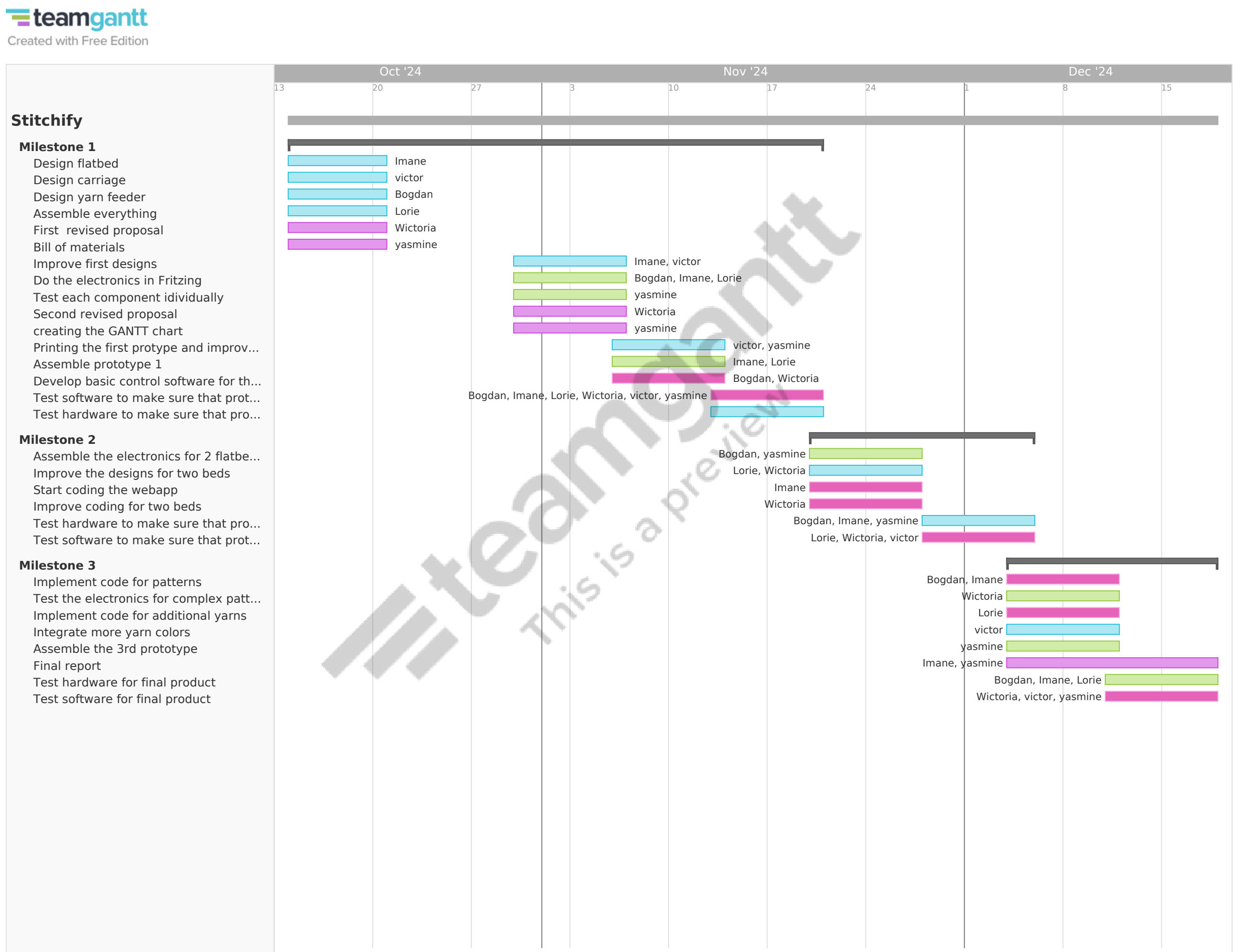
8 Milestones

Throughout the development of the Knitting Robot project, we have outlined the following key milestones to track progress and ensure that each stage of the project is completed on time:

- **Milestone 1: Create a Smaller Prototype with One Bed and Two Yarn Colours**
  The initial milestone involves building a smaller prototype version of the knitting robot that uses one bed of needles and supports knitting with two different yarn colours. This prototype will serve as a proof of concept, allowing us to validate the basic knitting mechanics, including for example yarn manipulation. This milestone also includes testing the integration of the hardware and software components.
- **Milestone 2: Build a Larger Version with Two Beds of Needles**
  In this stage, the design will be expanded to a larger version of the knitting machine featuring two beds of needles, allowing for more complex knitting patterns and increased knitting efficiency. The two beds will make it possible for example to explore the creation of circular patterns, and this milestone will include the testing and improving of the new mechanical setup.
- **Milestone 3: Implement a Moving Bed, Add More Yarn Colours, and Create Patterns**
  The final milestone will involve adding the capability of a moving bed, enabling the machine to knit with multiple yarn colours beyond two, allowing for more complex patterns and designs. The moving bed will allow for a broader range of designs, enhancing the versatility of the knitting robot.

9 Gantt Chart

In our proposal, we used a Gantt chart to effectively manage tasks and project timelines. This approach will help us to monitor progress, anticipate potential delays, and provide efficient time management as well as smoother project execution. The Gantt chart serves as a central reference, helping us stay on track with our project goals.



10 Electronics and Components

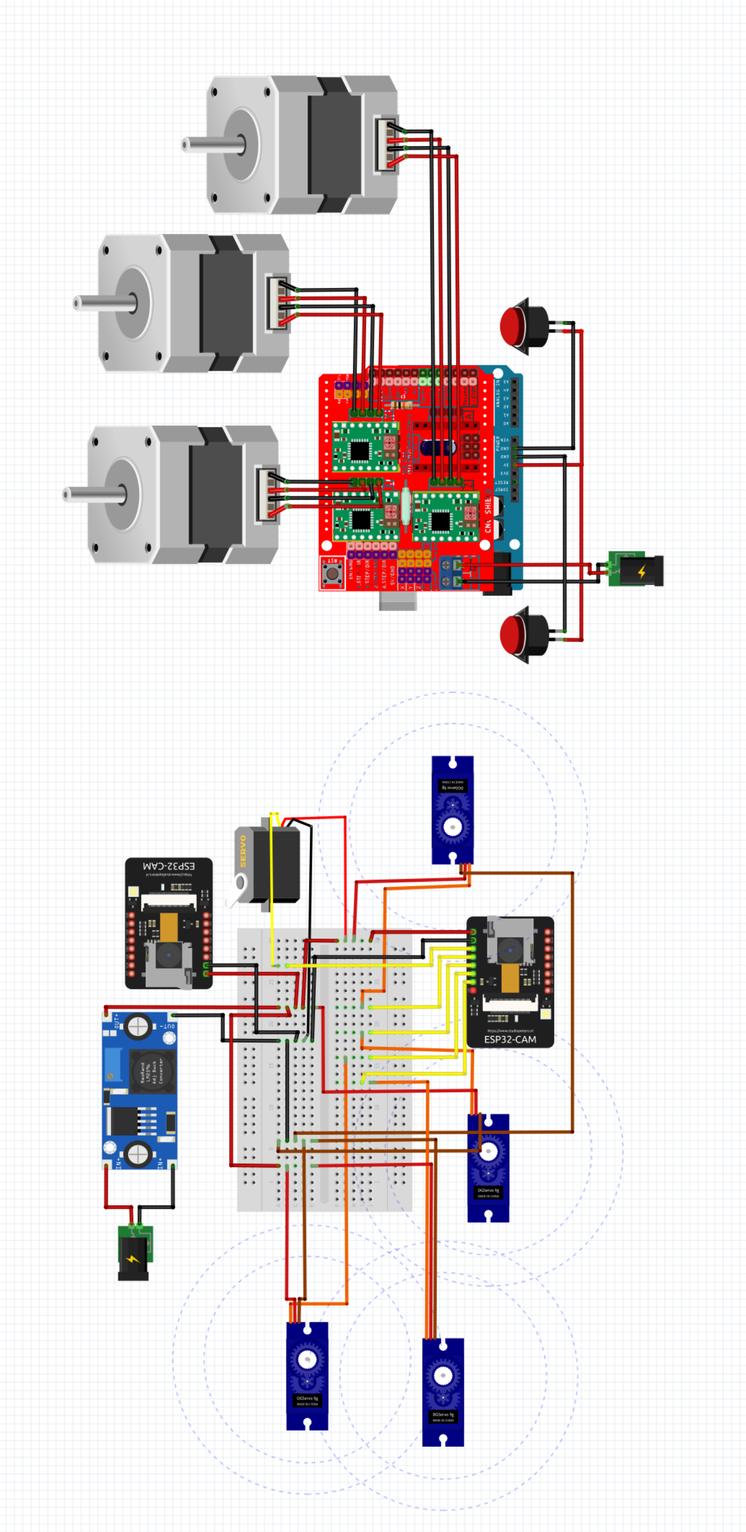


Figure 3: Electronic assembly

11 CAD designs and dimentions

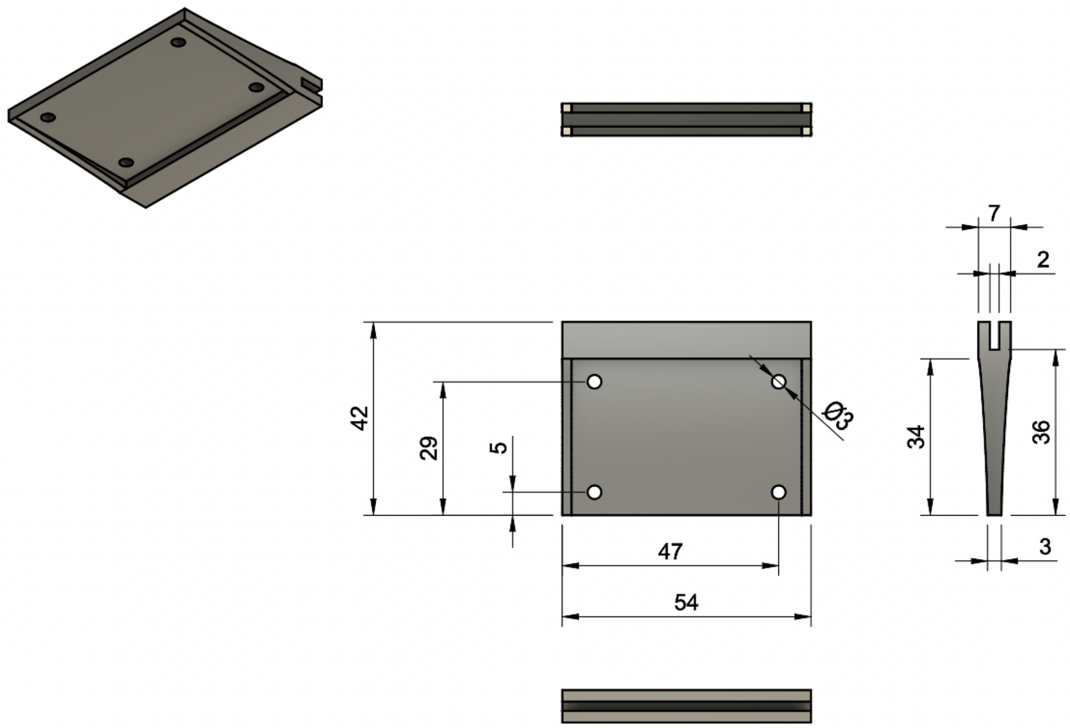


Figure 4: The belt pincher

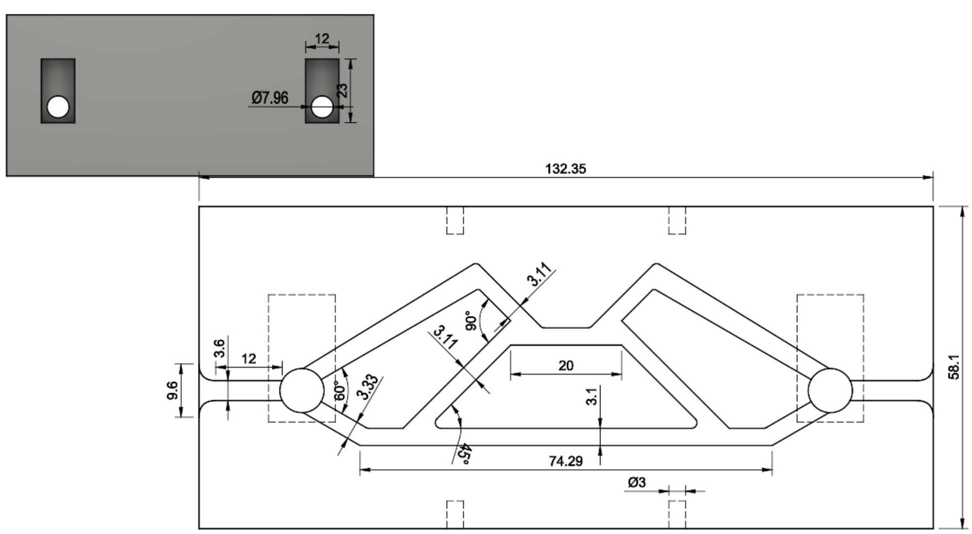


Figure 5: Carriage

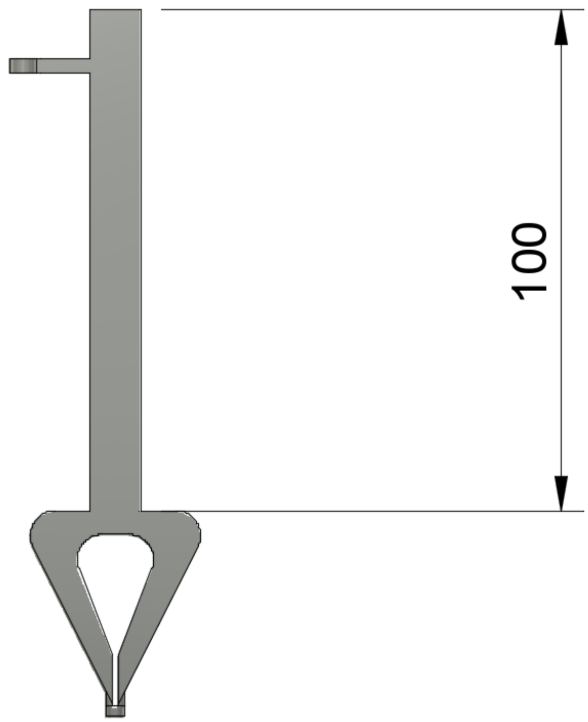


Figure 6: Yarn Fidder

12 Conclusion

The Knitting Robot project aims to automate the traditional craft of knitting. By taking inspiration from existing projects, applying robust risk management, we plan to deliver a fully functional knitting robot prototype that could serve as a foundation for further academic, commercial, and educational purposes.

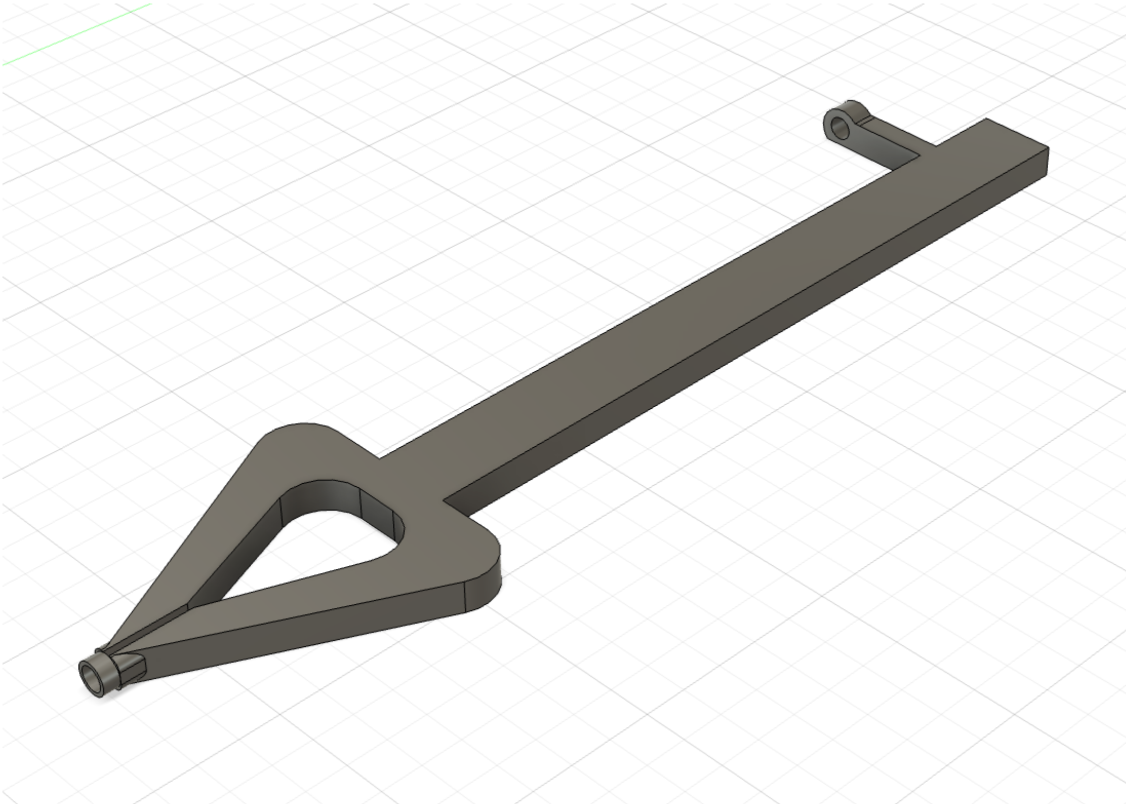


Figure 7: Yarn Fidder

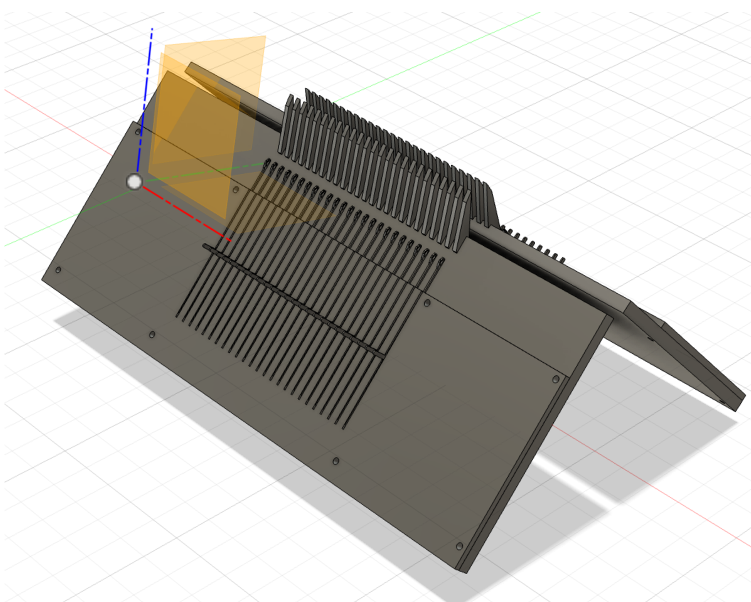


Figure 8: Flatbed

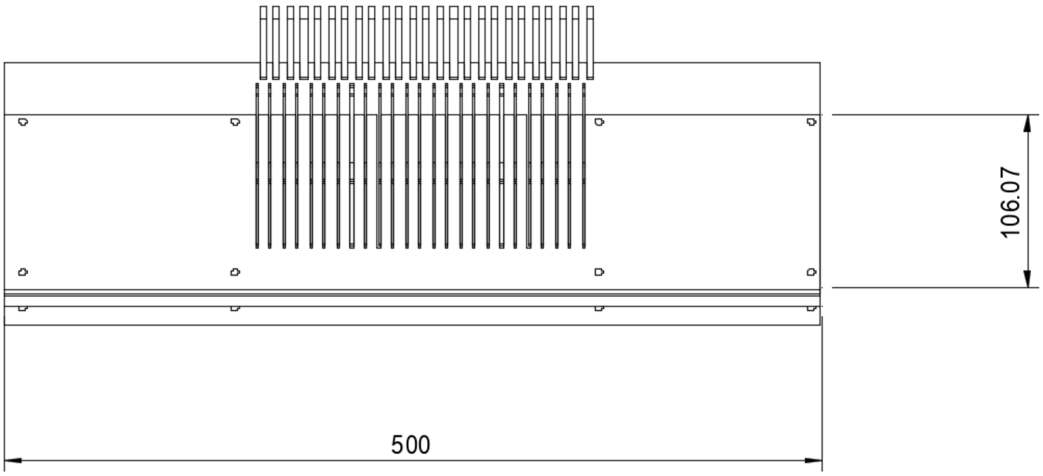


Figure 9: Flatbed

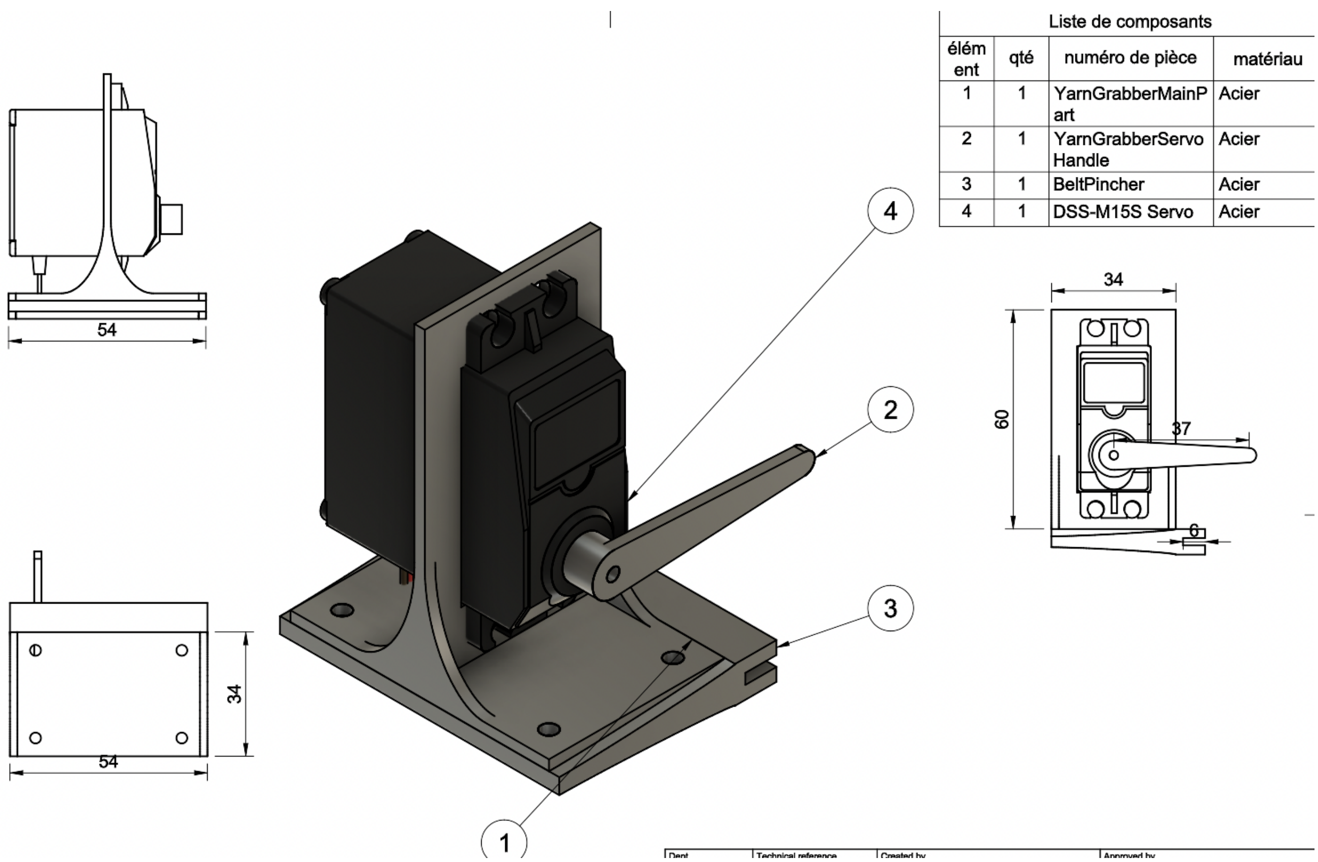


Figure 10: Yarn Grabber