S&N Microfactory

PROJECTS INITIATIVE 2023-24

Final report

PROJECT SUMMARY

1. **Project no. and title:**

   P14 - Foldable grippers for drones

2. **Brief description of the project (max. 100 words):**

   The idea behind the project was to create a foldable gripper for drone applications which was inspired by origami. The gripper should be able to handle a versatile set of objects and should not hamper the aerodynamics of the drone. The gripping mechanism should not be very heavy to not add further load and possibly drag to the drone. The mechanism should be executed using minimal active power by the use of simple but sophisticated mechanisms. The objective is to enable the drone to be able to pick/deliver objects through narrow and deep enclosures.

3. **Project objectives and corresponding achievements (3-5 points, add rows if needed):**

Sr. no.	Objective	Achievement
1	Origami-Inspired	Scissor Mechanism
2	Versatile Gripper	Specific curvature of gripper
3	Minimum Active Power	Utilized only 2 servos

DESIGN & DEVELOPMENT

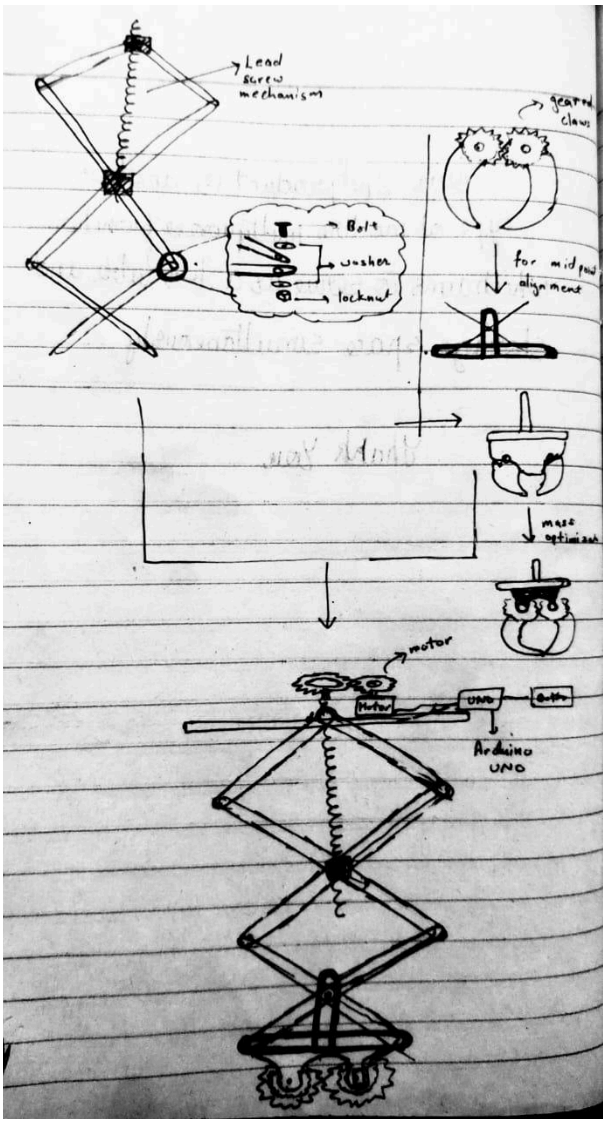
1. **Summary of relevant academic / commercial literature reviewed (max. 100 words):**

   Our first iteration of the gripping mechanism was inspired by a South Korean research paper that focused on fabricating a gripper for a drone based on a tendon actuation mechanism and then analyzing its performance. The gripping mechanism was composed of several modules which had inbuilt Sarrus linkages which enabled the module to collapse upon itself at the time of retraction. Lockers were put in place which used the principle of perpendicular folding to lock the module once expanded completely using neodymium magnets and a wire ("tendon") to unlock the module so that it could collapse.

Although we have now moved on from this idea and are implementing a different mechanism, this research paper helped us greatly to get started with this project.

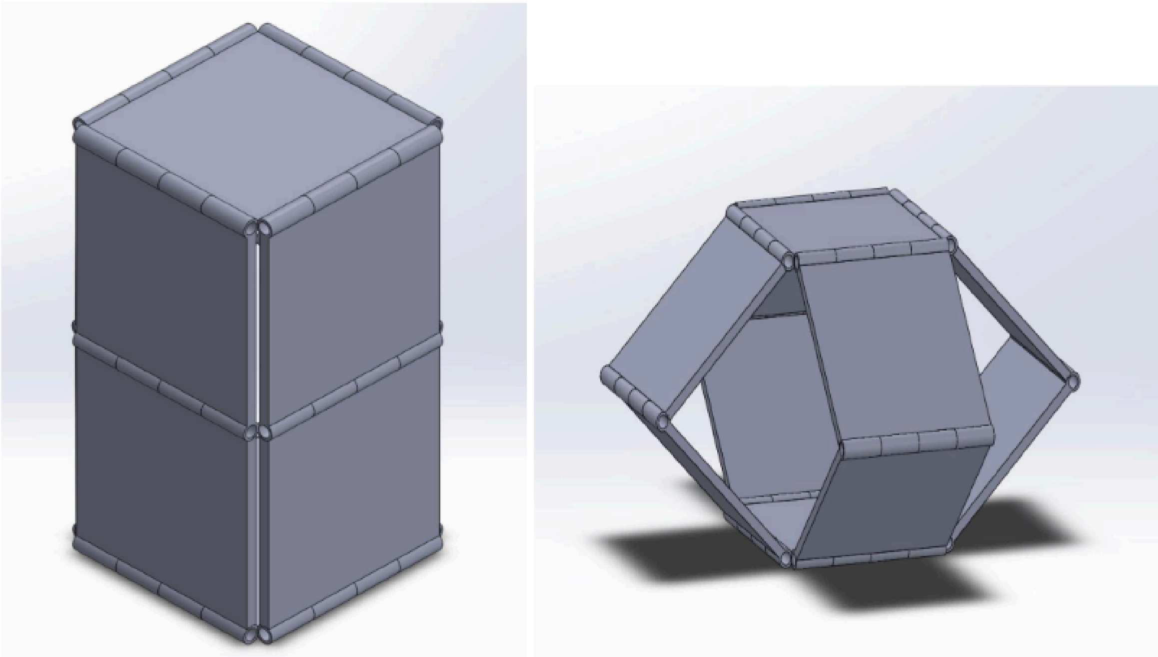
2. **Design constraints identified. e.g. size, shape, weight, etc. (3-5 bullet points):**
    - We had to operate within a designated clearance between the legs of the drone for which we took appropriate dimensions and made the entire gripping mechanism planar.
    - The mechanism should retract back into the drone frame in its entirety and its compressed length should be lesser than that of the drone legs.
    - The gripper should be versatile enough to be able to pick up objects of various sizes and shapes.

3. **Working of the standalone assembly or the sub-assembly designed to be part of the bigger assembly (use flowcharts or block diagrams):**



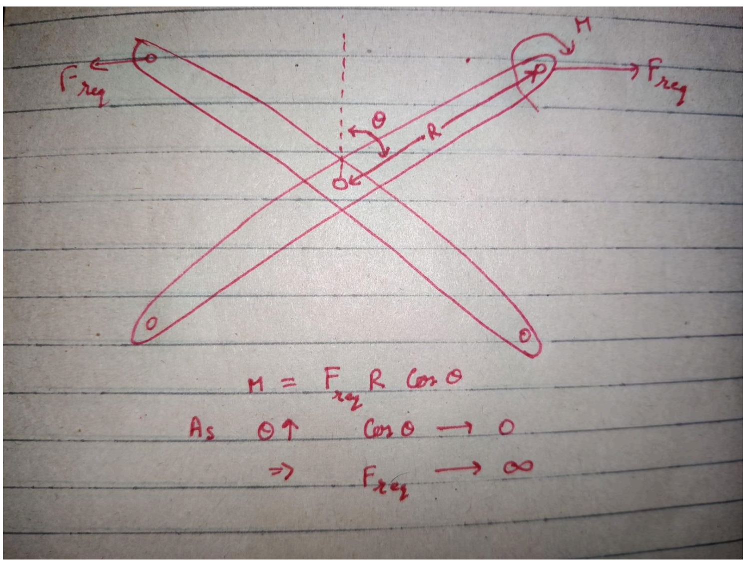
4. **Design iterations (3-5 images of different versions, max. 100 words for explanation):**

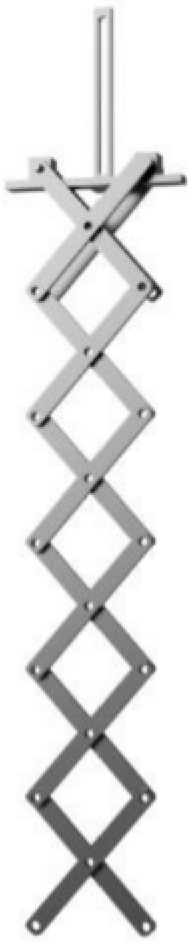
   As mentioned earlier, our first iteration was inspired by the Tendon Actuation mechanism proposed and tested by the South Korean research paper. We created a prototype of the collapsible module being used and were in the process of choosing between permanent neodymium magnets vs electromagnets when we realized the impractical nature of the design due to its large weight, unnecessary locking feature and discrete nature of its movement.

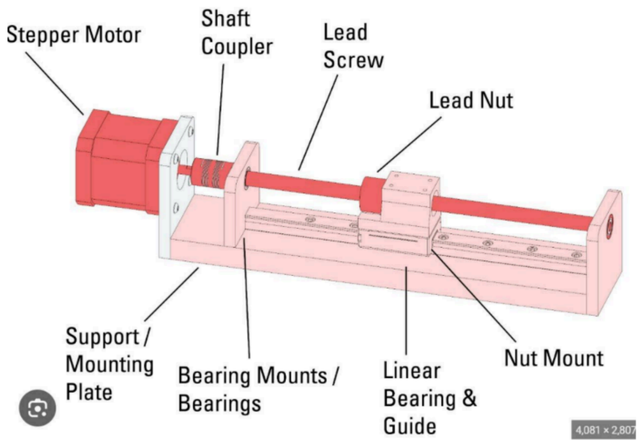


Collapsible Module

Then we switched to the aforementioned scissor mechanism. But we soon encountered another problem. We had planned to operate a lead screw between two scissor links in the horizontal plane. Though this was kinematically possible, we soon realized that the kinetics of this mechanism simply do not work. The reason for this is that when actuated in the horizontal plane, after a certain displacement, the component of force offered by the lead screw tends to zero thereby not being able to apply sufficient torque to efficiently lift the object.

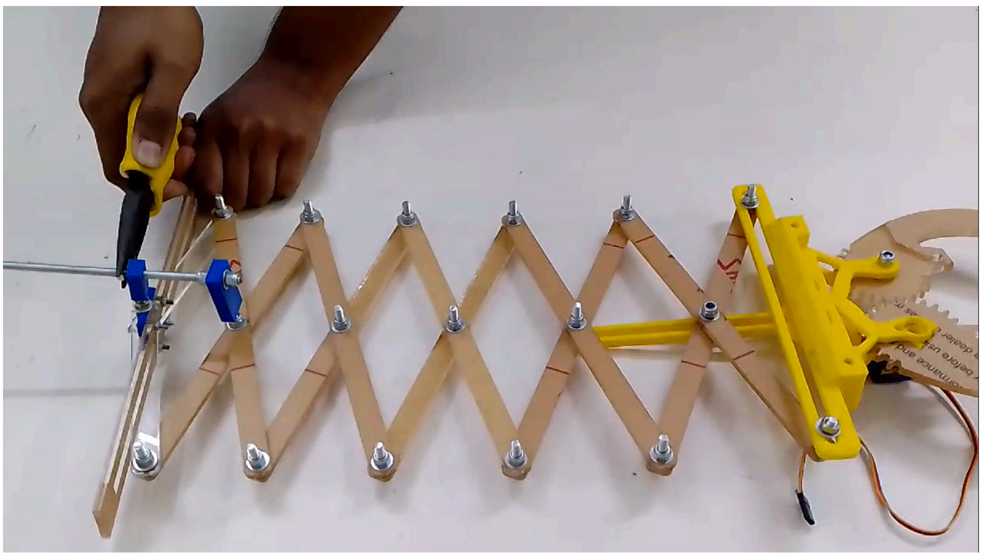






Lead Screw Mechanism

To fix the above issue, we integrated a vertical lead screw mechanism between the center mark of two adjacent scissor links. This considerably reduced the force required to actuate the gripping mechanism.



4. **Technical challenges encountered and corresponding solutions implemented during the development (3-5 points, add rows if needed):**

Sr. no.	Challenge	Solution
1	Heavy weight of mechanism	Utilizing acrylic sheets (laser cut)
2	High power requirement	Lead screw mechanism
3	Weak nature of 3D printed parts	Printing in different orientations and parts, assembling them at a later stage with nuts and bolts

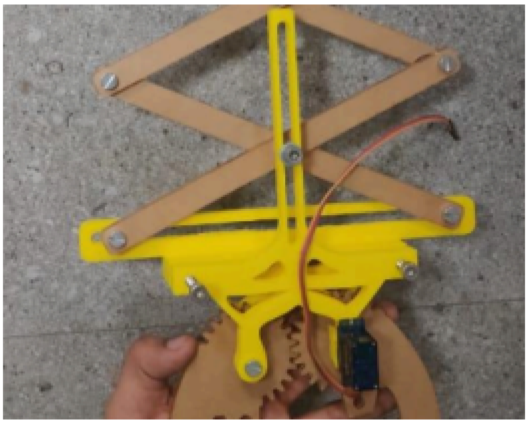
FABRICATION & ASSEMBLY

1. **Microfactory equipment for which training has been completed (1 row per student):**

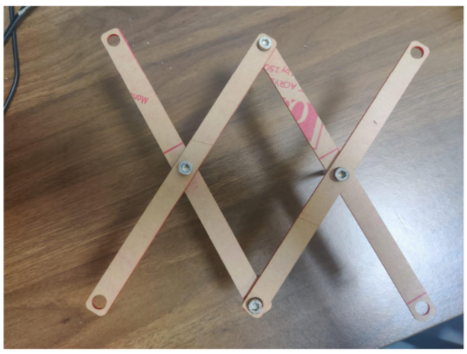
Sr. no.	Student	Machine(s) trained on	Machine(s) used for fabrication
1	Rohan Mekala	Single Nozzle 3D printer Laser Cutter	Single Nozzle 3D printer Laser Cutter Angle Grinder Power Drill
2	Jaskaran Singh	Single Nozzle 3D printer Laser Cutter	Single Nozzle 3D printer Laser Cutter Angle Grinder Power Drill

2. **Detailed description of all components of your assembly, including custom-fabricated and commercially-purchased components (1 bullet point per component, 3-5 labelled images of the components / sub-assemblies / assembly):**
   - **Grippers**: We have laser-cut acrylic grippers with specific curvature to lift various types of objects.

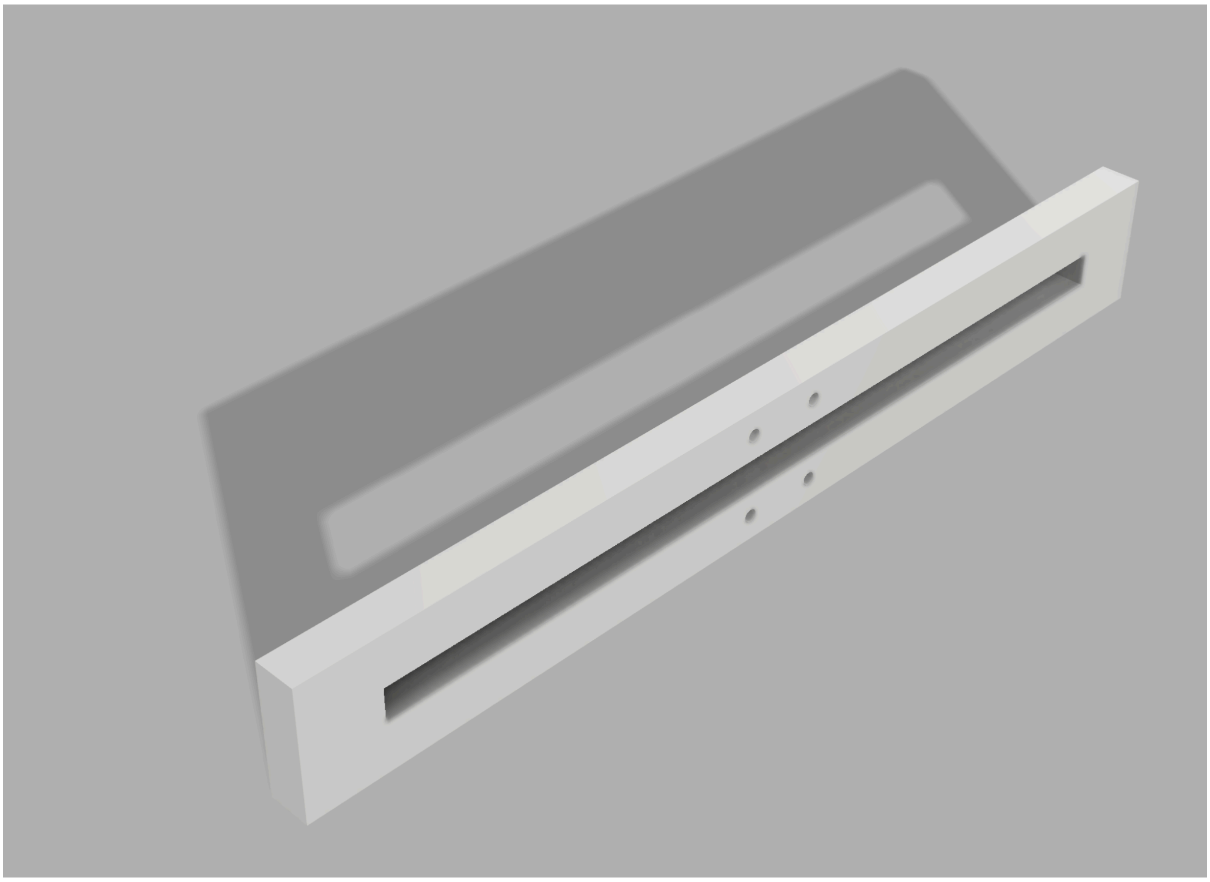
   - **Gripper Mount**: We have 3D printed an asymmetrical mount that can fit a servo to one of the grippers thereby allowing it to actuate the other as well. The mount has two slits, one horizontal and the other vertical, which together create a midpoint constraint for the scissor links to actuate about.



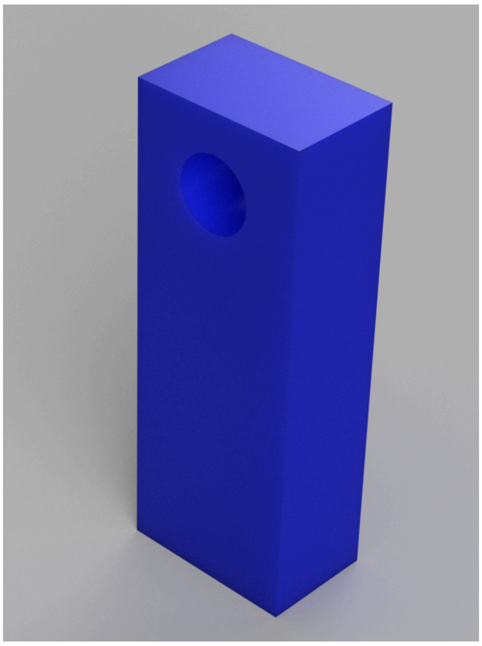
   - **Scissor links**: These 10 links form the crux of our mechanism allowing the gripper to retract and expand on command efficiently.



- **Base Plate**: We had made various iterations for this and in the end, we settled upon a plate with a slit to allow for the unrestricted movement of the scissor links.



- **Lead Screw mounts**: We 3D printed two mounts and attached them to the bolts of two adjacent scissor links to facilitate the movement of the lead screw.



- **Lead Screw**: We have utilized a threaded steel rod (5mm diameter and 1m length) for the lead screw.

- **Servo**: We have used a 9g micro servo to actuate the gripper.

- **BLDC motor**: We have used a BLDC motor to actuate the scissor links.
- **Arduino Microprocessor**: We have utilized an Arduino Uno to program the servo.

3. **Machine, material and technique used for custom-fabricated components (1 bullet point per fabricated component):**
    - Grippers - Laser Cutter - Acrylic - Subtractive Manufacturing
    - Gripper Mount - Single Nozzle 3D printer - PLA - Additive Manufacturing
    - Scissor links - Laser Cutter- Acrylic - Subtractive Manufacturing
    - Base Plate - Laser Cutter - Acrylic - Subtractive Manufacturing
    - Lead Screw mounts - Single Nozzle 3D printer - PLA - Additive Manufacturing

4. **List of commercially-purchased hardware components used in the project. e.g. microcontroller, motors etc.:**
    - 9g micro servo
    - Arduino Uno
    - BLDC motor
    - 3D Printing PLA
    - Lock nuts, washers and bolts

5. **List of software used in the project:**
    - Arduino IDE
    - Solidworks and Fusion 360
    - Fracktory
    - Laser Cad

TESTING & VALIDATION

1. **Final results following testing (max. 100 words, use graphs / figures where possible):**

    We were successfully able to actuate the scissor links and the gripper with the help of a BLDC motor and a 9g micro servo programmed using Arduino microcontroller. We were able to test the lifting ability of the gripper on objects of different sizes and shapes. The lead screw was successful in reducing the load on the motors and in turn, has helped in reducing the active power. We were able to code in the allowable values for rotation into the servo to allow the gripper to accurately grip objects without damaging them or the mechanism itself.

2. **Comparison with similar existing products / designs (max. 100 words, cite references):**

As mentioned before, we had taken inspiration for our first prototype from the South Korean research paper which focussed on implementing a tendon actuation mechanism to actuate a foldable gripper using various collapsible modules and a Sarrus linkage based locking mechanism which works on the concept of perpendicular folding. The team at Seoul University was successfully able to craft and test their gripper on a drone. Though we have made various modifications based on our problem statement and availability of resources, at the core level, our thought process and implementation match that of the Seoul Univ project.

LEARNINGS & FUTURE SCOPE

1. **Potential areas for improvement in design or fabrication (max. 100 words):**

    During our ideation phase, we had thought of a design for a robotic arm that would have 6 degrees of freedom enabling the gripper to be more mobile but we were unable to implement it due to the lack of time and resources. We had planned on using soft robotics for the gripper itself to make it more versatile and were planning to use threads and a chain sprocket mechanism to use minimum servos and achieve maximum mobility. Another issue that we faced with the fabrication was the poor strength of 3D-printed parts. A great way of improving the current design is to implement SLA 3D printing in place of FDM 3D printing which results in much stronger and robust components.

2. **Plan for the project beyond the Projects Initiative, including potential applications (max. 100 words):**

Beyond the Projects Initiative, we plan on integrating the assembled mechanism with a drone. We intend to use an orange cube controller and a Raspberry Pi 4 module to make the drone completely autonomous and set appropriate gain values in the ardupilot firmware to integrate the mechanics of the gripper into the drone to enable the scripts running on the Raspberry Pi 4 module to actuate the gripping mechanism autonomously. Once we can achieve this, the drone will be well equipped to be used in various disaster relief missions to supply medical and other care packages to victims stuck under rubble or debris in case of earthquakes or aid victims stuck in narrow enclosures inaccessible to humans.

3. **Key technical and/or non-technical takeaways from the project (3-5 bullet points):**
    - We learned about the intricacies of 3D printing and laser cutting.
    - We understood the importance of modeling the entire mechanism (in Solidworks or Fusion 360) before proceeding with the manufacturing phase to avoid any contradictions of constraints or any errors in the motion linkages.
    - We focused more on the kinematic analysis, but in doing so, we overlooked the kinetics of the mechanism which resulted in some mistakes in the design which we had to rectify later.

COMMUNICATIONS & INTERACTIONS

1. **List pros and cons of your group dynamics (3-5 bullet points):**

Pros :-

- Working in a group has enabled the sharing of ideas allowing us to learn from each other.
- Repeated and rigorous constructive criticism of each other's designs has helped us to come up with the most efficient and optimal design.

Cons :-

- There have been instances of lack of understanding and conflict of ideas between the team members.

- The different schedules of each member made it difficult to find a common time to work together on the project.

2. **Frequency and details of meetings with the faculty involved (max. 100 words):**

   We had meetings with Prof. Ambarish roughly twice a week during the winter and once a week once the semester started. However, we couldn't have frequent meetings once the semester started because of the academic load and the schedule. However, we continued to work on the project during this period and completed the manufacturing phase. Prof. Ambarish's insights were critical in helping us understand the flaws of our initial prototype and he has been instrumental in suggesting various alternatives. Towards the end of the project tenure, we were not able to have a meeting with Prof. Ambarish because of having multiple quizzes throughout the last 2 weeks but we ensured that this would not slow down our project and were able to complete the manufacturing and testing of the gripper mechanism.

3. **Learning key points from your interaction with the mentors at the Microfactory (3-5 bullet points):**
   - We learned how to efficiently use the machines at the Microfactory, especially the 3D printer and the laser cutter.
   - We were facing some issues with the lead screw mechanism and the mentors were instrumental in helping us to ideate and develop a solution.
   - The mentors helped suggest which materials we should use for various applications in the mechanism.

UPLOAD CHECKLIST

1. **Final report (using the template)**
2. **Video(s) of the final working prototype**
3. **Technical drawings, CAD files of parts/sub-assemblies/assembly, circuit diagrams, codes and datasheets**
4. **Photos of the team while working on the project**

References:

1. South Korean Research Paper on Tendon Actuation mechanism: https://www.science.org/doi/10.1126/scirobotics.aar2915

