Robotic Aerial Door Manipulator

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SUMMER RESEARCH PROGRAM

Introduction

- 90% of Canadian firefighter time-loss claims were attributed to traumatic injuries sustained while on duty.[1]
- During emergencies, doors could possibly be concealing dangerous hazards such as backdrafts, explosives, and toxic gases. As a result of this, first responders put their lives at risk everyday when entering these doors.[1]
- To help to alleviate this problem, Tenaci Innovation, a student capstone group, has designed a drone-mounted arm and gripping end effector[2] with the following requirements:
  - produce 5 Nm of torque
  - push or pull a door open by 30 centimetres
  - exert 100 N of gripping force to grip both knob and lever style door handles.
- This project specifically focuses on constructing and testing a prototype of the gripping end effector.

Project Objectives:

- Construct prototype of end effector capable of exerting 100 N of gripping force.
- Test prototype to validate design and propose modifications, if needed.

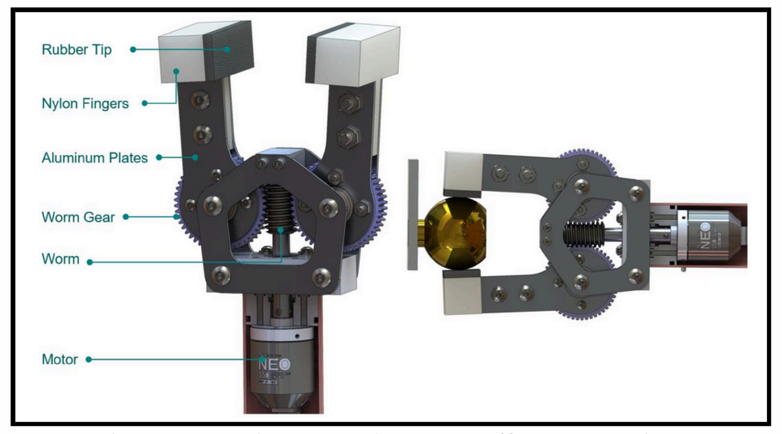

Fig. 1: Tenaci Innovation End Effector Design[1]

Methods

- Some modifications were made to the original design for ease of prototyping and assembly.
- Through the use of the software programs SOLIDWORKS and PrusaSlicer, and a 3D printer, 16 pieces of this prototype were printed using PLA filament.
- The remaining pieces were purchased as off-the-shelf components.

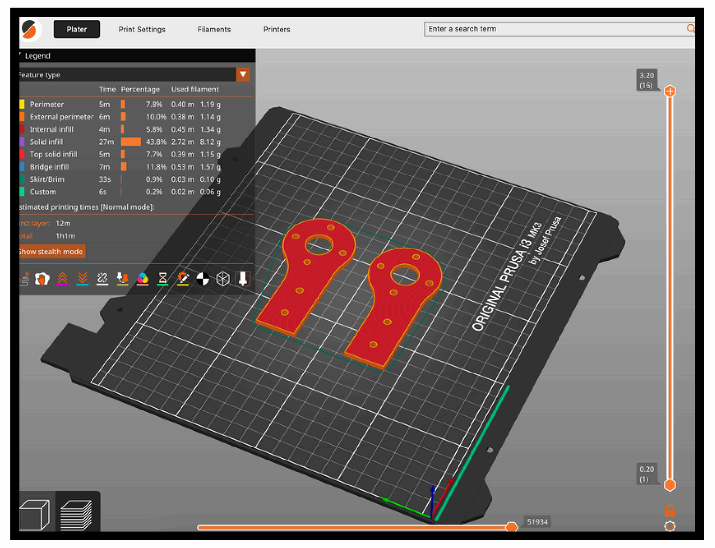

Fig. 2: Printing Format in PrusaSlicer Software Program

- The PrusaSlicer software program was used to format the part files before transferring them to the 3D printer (Figure 2).
- SOILDWORKS was used to model and visualize the overall assembly of the prototype (Figure 3), and the sub-assemblies (Figures 4, 5, & 6).

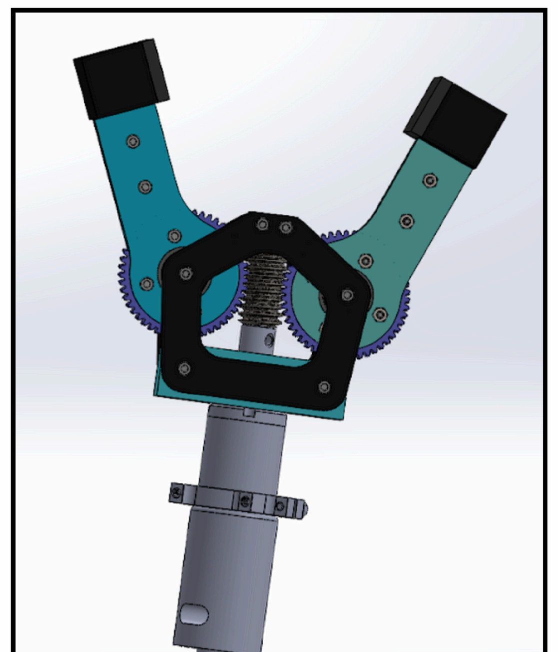

Fig. 3: SOLIDWORKS Full Assembly

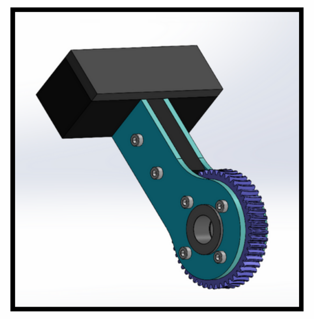

Fig. 4: SOLIDWORKS Finger Assembly

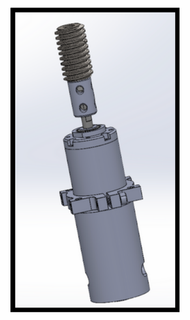

Fig. 5: SOLIDWORKS Motor Assembly

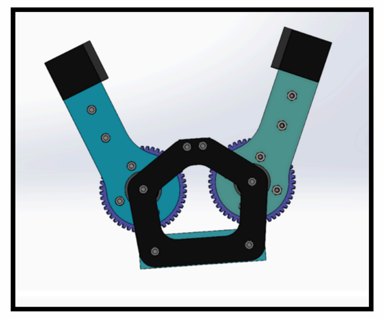

Fig. 6: SOLIDWORKS Body Assembly

Manufacturing

Process of Building End Effector Prototype:

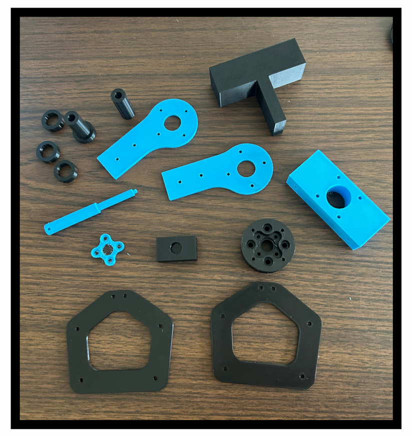

Fig. 7: 3D Printed Parts of Prototype

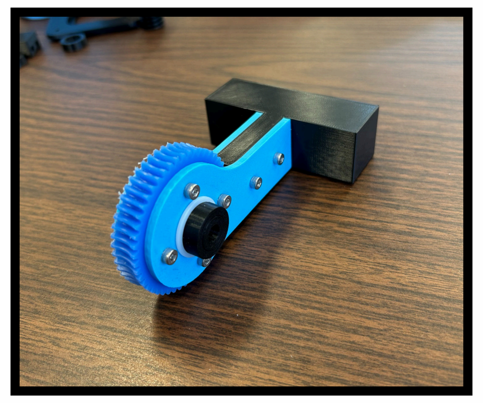

Fig. 8: Assembled Finger Assembly

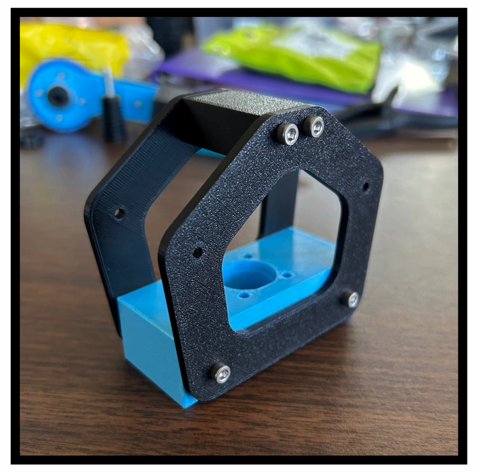

Fig. 9: Assembled Body Assembly

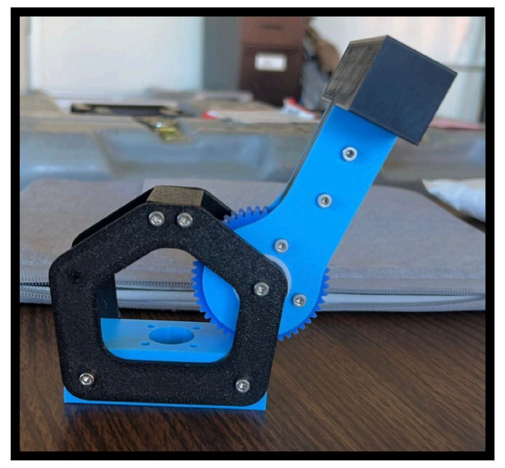

Fig. 10: First Steps of Assembling Full Prototype

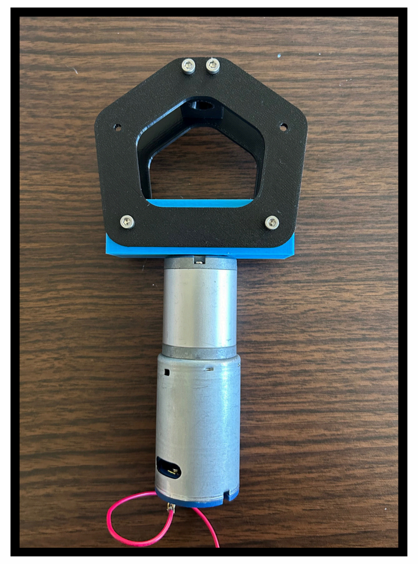

Fig. 11: Attachment of Motor and Body Assemblies

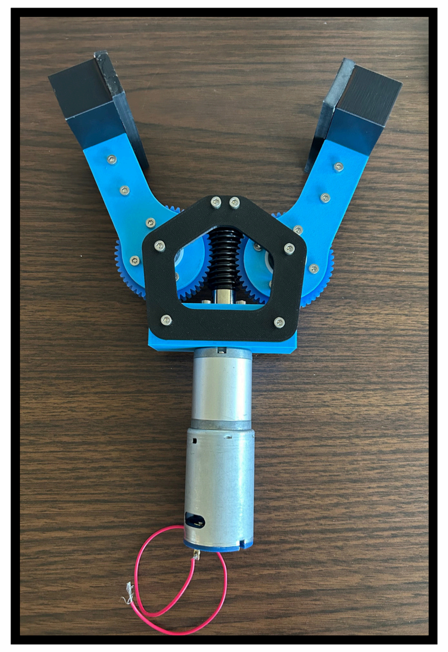

Fig. 12: Completed End Effector Prototype

Testing Results

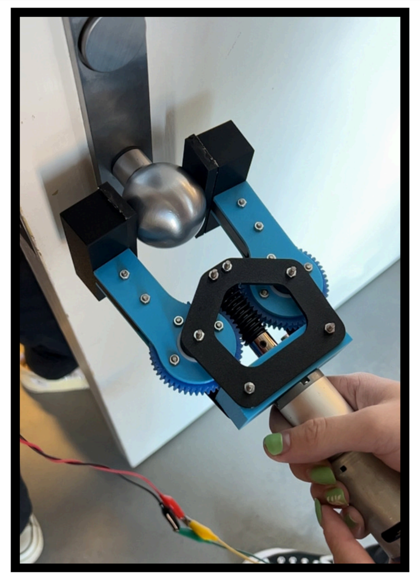

Fig. 13: Proof of Concept Test

- First, a proof of concept test was completed to show that the device was capable of gripping a door knob successfully (Figure 13).
- Next, validation tests were completed using a force gauge to measure the gripping force.
- The setup was organized to test the force of one finger assembly at a time, assuming that each finger assembly applies half of the force needed to grip a door knob (Figure 14).
- Validation tests proved one finger assembly had an overall higher performance because of better gear meshing between the worm and worm gear (Figure 15).

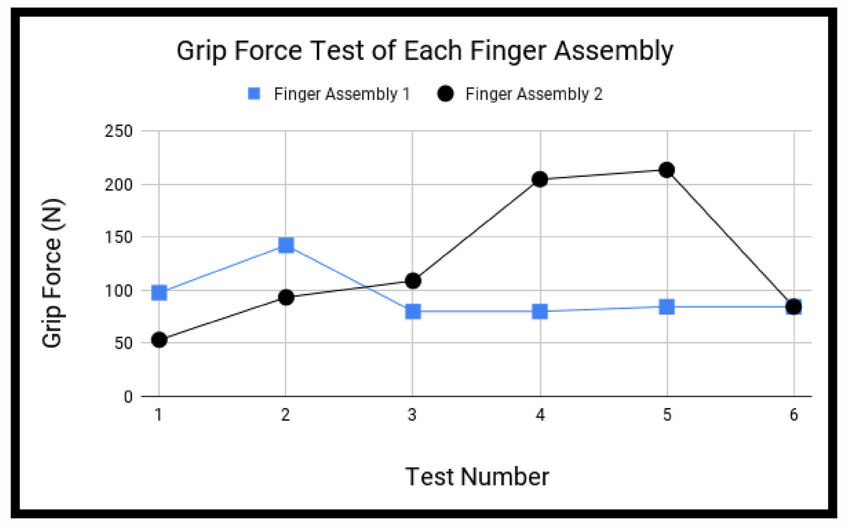

Fig. 15: Graph of Grip Force Test Results

- Slipping occurred on the motor and worm shafts during tests. A groove was made to help increase friction to prevent this issue.

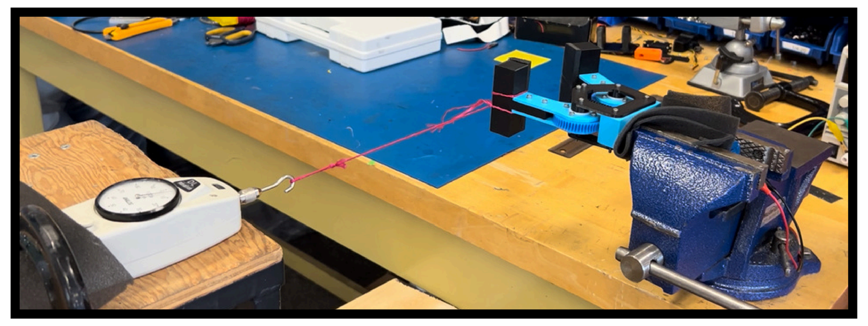

Fig. 14: Setup for Grip Force Tests

Conclusion

- Gripping end effector prototype was successfully built as a self-contained device available to be mounted onto a mobile robot.
- The prototype was tested for proof of concept and grip force of each finger assembly, proving that it surpassed design requirements.
- There were also failures found within the original design, such as:
  - Slipping between worm, motor shaft, and coupling due to lack of friction.
    - *Solution*: Use a key shaft to avoid slipping issue.
  - One finger assembly performed better in tests due to better gear meshing.
    - *Solution*: Improve gear meshing by reducing finger spacing.
- The motor chosen for this prototype was tested and proved that it produces approximately double the amount of force required by the design.
- The motor chosen was also oversized for this device. Downsizing the motor chosen would save costs.

Future Work

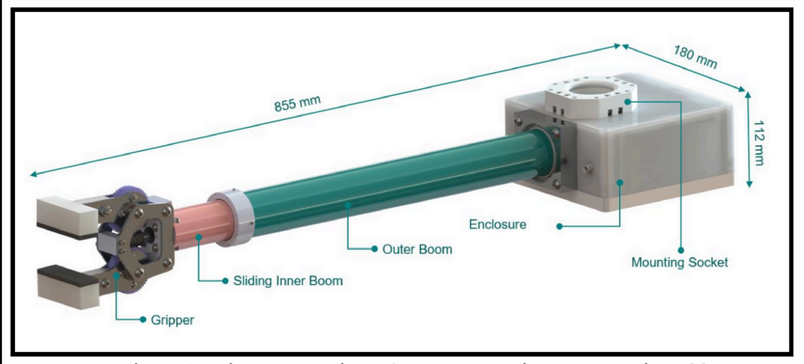

Fig. 16: Final Design by Tenaci Innovation[1]

- Implement design recommendations for gripping end effector and evaluate performance.
- Test and modify final design prototype and attach to drone.

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References

[1] C. Bashir, M. Joh, M. Nowlan, I. Saeed, J. Schmitt, and S. Zednhgl "Robotic Manipulator End Effector Phase III Report," Tenaci Innovations, University of Alberta, Edmonton, Alberta, Canada, PH III , April 11, 2024.

[2] C. Bashir, M. Joh, M. Nowlan, I. Saeed, J. Schmitt, and S. Zednhgl "Door Opening End Effector Drawing Group 12," unpublished.