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Design of a final effector applying soft robotics TPU patterns

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***Abstract*—This project addresses the limitations of current soft gripper end effectors that do not rely on compressed air and struggle to handle fragile foods and solid objects. The lack of research on ”soft grippers” based on shape and materials hinders their industrial use and prevents cost savings from eliminating compressed air. To overcome this, a two-finger gripper with a TPU interior will be developed, using the V-**
21 **Model methodology for structured development and validation. Initial prototypes will be created with PLA, followed by TPU for behavior analysis, with extrusion and line width adjustments to enhance strength and adaptability. A textured surface will be applied for optimal non-slip grip. The results demonstrate that the structure can withstand prolonged use with minimal wear and deformation, even when handling fragile or weighted objects. The project concludes that leveraging 3D printing and the honeycomb principle for soft gripper prototypes significantly improves industrial processing capabilities, offering a cost-effective and**
23 **efficient solution with potential for future enhancements and diverse applications.**

***Index Terms*—Additive manufacturing, soft robotics, soft**
19 **gripper, gripper design, claw**

I. Introduction

24 This research will focus on the design and prototyping of an end effector, using additive manufacturing technology for its manufacturing and using appropriate materials to ensure maximum efficiency and adaptability. Programs such as FUSION 360 will be used for the digital design of each part of the end effector, and prototypes will be made using
26 polylactic acid (PLA) and thermoplastic polyurethane (TPU) filaments. The processes and tests that this project will undergo will be shown to ensure a completely mechanical soft grip end effector, which will be flexible and adaptable to ensure its efficient grip on objects of different shapes and sizes. This project aims to evaluate various pattern designs for a soft gripper to determine their performance in terms of grip strength and object protection. Each design undergoes simulations and physical testing to assess its adaptability and effectiveness with objects of varying shapes, weights, and textures. Special attention is given to the handling of fragile and heavy objects, optimizing the designs to balance flexibility and resistance. The ultimate goal is to ensure a safe, efficient, and adaptable gripping solution suitable for diverse industrial and commercial applications.

A. *Additive Manufacturing*

Additive manufacturing (AM), also known as 3D printing, has transformed modern manufacturing by enabling the production of complex and customized components with high precision. Techniques like fused filament fabrication (FFF) and material extrusion (ME) are widely employed to deposit thermoplastic materials layer by layer, forming intricate structures with minimal waste [1]. This technology has found applications in industries such as aerospace, automotive, healthcare, and consumer goods, thanks to its versatility and efficiency in prototyping and production [2].

Materials such as polylactic acid (PLA), polyethylene terephthalate glycol (PETG), and thermoplastic polyurethane (TPU) are commonly used in AM due to their unique properties [3]. Continuous advancements, such as the integration of carbon fibers into polymers, have improved the mechanical performance of printed components, making them suitable for high-strength applications [4]. Despite these advancements, challenges like low resolution and surface quality persist, particularly in ME-based methods [5].

AM has also revolutionized the research and development cycle by enabling rapid prototyping, reducing costs, and accelerating innovation. For example, multi-material additive manufacturing allows for the creation of functional prototypes with embedded sensors and actuators, which is particularly valuable in robotics and biomedical fields [6].

B. *Role of Additive Manufacturing in Soft Robotics*

Soft robotics has benefited significantly from additive manufacturing technologies, which facilitate the creation of flexible and adaptable robotic components. There are several models that demonstrate the efficiency of these developments, such as bio-inspired designs that can adapt to various shapes of objects [7]. Robotic grippers capable of manipulating delicate objects, such as fruits, vegetables, and irregularly shaped devices [11], have benefited from TPU [8] and other polymers [9], [10]. In addition, conductive TPU can be used to detect stresses, providing real-time information to improve control and adaptability [12]. These innovations have expanded the use of soft robotics in different areas where adaptability is critical [13].

C. Advances in Robotic End Effectors

Unlike traditional rigid grippers, soft grippers use materials with variable stiffness to achieve a conformable grip, allowing for the manipulation of fragile and irregularly shaped objects [14]. This capability has revolutionized applications in manufacturing, where precision and adaptability are essential [15]. Furthermore, this adaptability must be measured in terms of productivity according to the process being implemented [16]. Soft grippers are also inspired by biological systems, mimicking the mechanics of natural organisms to achieve superior adaptability and precision [17]. They perform complex tasks in dynamic environments, making them indispensable in industries ranging from logistics to healthcare [18].

II. Methods

The study follows a qualitative, iterative process aimed at optimizing the soft gripper design through continuous testing and refinement. Using a V-shaped development methodology, the project progressed systematically from conceptualization to experimental validation, covering steps such as lattice pattern design, CAD modeling, simulation, and material integration. This approach ensured traceability between specifications and outcomes, enabling early flaw detection and informed design adjustments for effective and safe gripping performance.

Prototypes were fabricated using accessible materials—primarily thermoplastic polyurethane (TPU) and polylactic acid (PLA)—through Fused Deposition Modeling (FDM). For the PLA Figure 1 shows the design of the traditional gripper, which was used as the basis for adding the frames. The patterns used were printed using TPU and are shown in Figure 2.

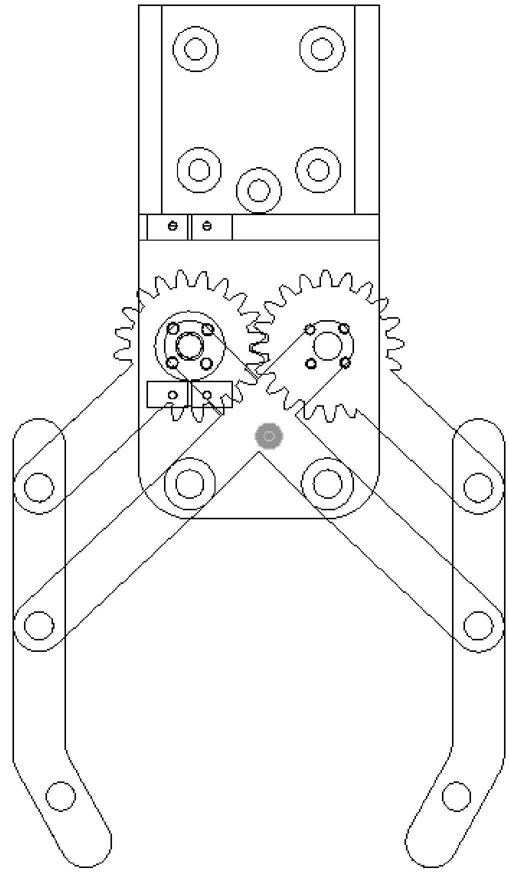

Fig. 1: Exploded view of the soft gripper assembly, illustrating the modular structure and key mechanical components.

A. Instruments and Techniques Applied

1) 3D Design Software::

- SolidWorks: Used for precise computer-aided design (CAD) of gripper patterns, such as hexagonal, triangular, cubic, linear, and grid designs. Simulations were conducted to analyze deformation and stress under various forces, facilitating optimization before fabrication.
- Autodesk Fusion 3D: Applied for the detailed design of individual gripper components, including external mechanical parts, gears, and internal structures based on the beehive principle.

2) 3D Printing Software::

- PrusaSlicer: Enabled preparation of design files in G-code format, optimizing printing parameters like infill density and speed for TPU material.
- Bambu Slicer: Utilized for processing designs intended for the Bambu Lab P1S printer, ensuring seamless integration into the manufacturing process.

3) Control Systems::

- Arduino IDE: Programmed control boards to manage servomotors and actuators, ensuring precise and synchronized grip and release movements.

4) Materials and Components::

- 3D Printer: Bambu Lab P1S, used to manufacture mechanical components.

5) Filaments::

- Polylactic acid (PLA) for external components such as frames and couplings.

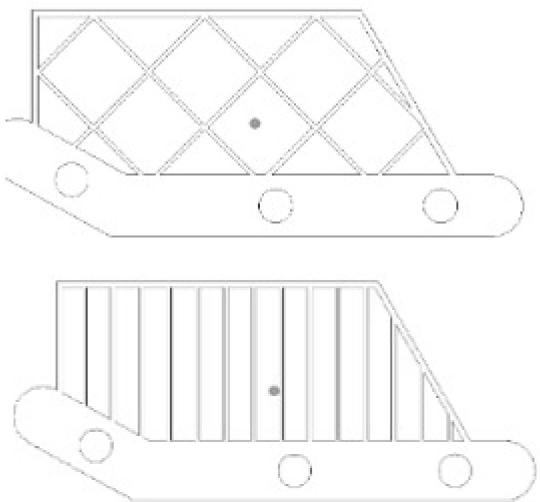

Fig. 2: Exploded view of the soft gripper assembly, illustrating the modular structure and key mechanical components.

- Thermoplastic polyurethane (TPU) for the internal flexible mesh, ensuring adaptability to object shapes and sizes.

6) Actuation and Control::

- MG996R servomotor to drive the effector clamps.
- ESP8266 microcontroller for processing activation commands.
- 12V power source to power the servomotor.

B. Programming

The robotic system completed over 1,000 pick-and-place cycles, demonstrating consistent coordination between the SCARA i450L and a 3D-printed end-effector. The figure 3 shows the SCARA robot where the end effector used to develop the tests was installed. The robot was programmed to send actuation signals at predefined path points, using a digital output to trigger a gripper controlled by an ATMega328P microcontroller.

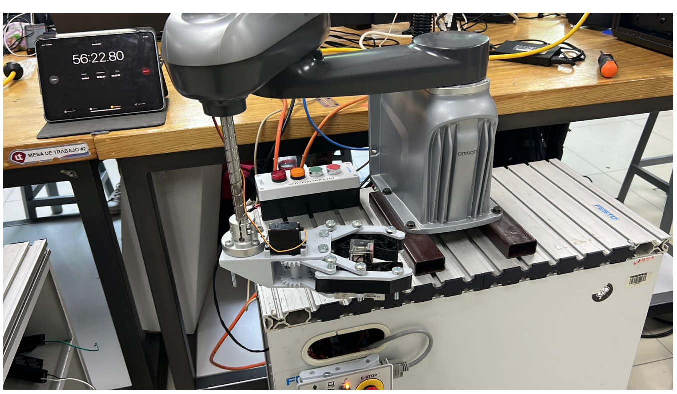

Fig. 3: Experimental testing of the end-effector grip

This integration ensured precise object handling, with gripper actions synchronized to the robot's trajectory. Even after extended operation, minimal wear was observed on the gripper's lattice, confirming the system's durability and repeatability for industrial tasks.

The control code implemented on the ATMega328P uses a servo motor actuated by a push-button. The servo toggles between 40° (open) and 130° (closed) based on a boolean state variable. A 300 ms delay is introduced to mitigate mechanical debounce effects, enabling reliable manual actuation. The system's simplicity and low hardware requirements make it suitable for scalable robotic applications requiring basic yet effective actuation control.

III. Results obtained

The soft robotic end-effectors were tested on a SCARA i4-450L robot over extended periods (8–24 hours) to evaluate durability, grip precision, and resistance to mechanical stress. All prototypes maintained structural integrity and operational functionality, even when handling loads up to 168g. However, surface wear, filament buildup, and minor deformations were observed across different lattice designs, indicating opportunities for design and printing optimization.

1) Linear pattern: During the evaluation phase, one of the tested lattice designs was discarded due to its inadequate mechanical performance. Although the vertical bar configuration was geometrically straightforward and easy to fabricate, it exhibited excessive flexion under load, resulting in insufficient gripping strength. This deformation limited the gripper's ability to conform to object geometries and maintain stable contact, ultimately compromising functionality. Consequently, this pattern was excluded from subsequent iterations in favor of configurations with improved stiffness, force distribution, and structural resilience.

2) Cubic pattern: The cubic lattice exhibited good structural stability during prolonged testing, withstanding up to 16 hours of operation while gripping a 168g relay. Despite some surface roughness and filament strands caused by suboptimal retraction settings, the internal structure remained intact. Improvements in extrusion speed and temperature could mitigate these imperfections and enhance finish quality. Figure 4 shows evidence of the adaptability of this proposed end effector through the use of cubic patterns.

Fig. 4: Cubic grid after extended use.

Table I summarizes the results of grip and durability tests performed on a cubic grid structure using three different objects. The relay, weighing 168g, underwent 2,400 repetitions over 16 hours, showing only minor wear on the lattice edges and some filament buildup, while maintaining structural integrity. The fragile egg was successfully handled without damage over 1,800 repetitions, with only slight lattice deformation observed. Lastly, the 150g wheel test lasted 10 hours and 1,500 repetitions, resulting in minor deformation in high-load areas but stable grip performance throughout.

IV. Discussion

While significant progress has been made, challenges persist in the fields of AM and soft robotics. Achieving precise stiffness control in soft robotic components without compromising flexibility remains a key research area [19]. Additionally, integrating multiple functions, such as actuation and sensing, into untethered soft robots poses technical difficulties that require innovative solutions [20].

Future developments will likely focus on improving the material properties of soft robotic components, enhancing the resolution of AM techniques, and designing smarter control systems. The combination of AM and soft robotics holds promise for breakthroughs in industrial automation, personalized medical devices, and advanced human-robot interaction systems [21].

V. Conclusion

In this work, the mechanical performance and reliability were evaluated. Repeated grip and durability tests with various types of objects evaluated the end effects of the cubic network. The results show that structures can withstand long- term use and minimize wear and deformation, even in the hand Lifting of delicate or weighty objects. These findings validate the effectiveness of lattice-based design for lightweight,adaptable robotic grip applications and highlight the potential of cost-Effective and scalable robotic systems.

- The project succeeded in achieving the objective of optimizing the 3D printed soft gripper by evaluating different gripper frames to determine which ones were more effective in terms of grip strength and hand damage prevention for manipulable objects. The study identified the optimal balance between flexibility and strength models, which are essential characteristics for a safe and non-destructive grip in soft robotic applications.
- Pattern geometry has had a significant impact on the performance of the griffon. The cube and triangular frames prove to be the most flexible and effective,confirming that correct geometric designs are key to achieving solid support without damaging fragile objects.
- TPU material proved to be ideal for soft-touch applications due to its ability to deform and resist moderate loads. However, its performance under extreme load conditions requires further adjustments in the design of the pattern.
- The filling density plays a key role in the efficiency of handling and directly affects the bending capacity and handling force. Low-filling patterns tend to be deformed excessively, and higher-filling patterns achieve better grip.

TABLE I: Summary of Grip and Durability Tests Across Grid Types

Grid	Object	Time (h)	Reps	Comments
Cubic	Relay (168g)	16	2,400	Minor wear to lattice edges; structure intact. A certain accumulation of filaments was observed.
Cubic	Egg (fragile)	12	1,800	It was successfully managed without damage. A slight deformation of the lattice.
Cubic	Wheel (150g)	10	1,500	Minor deformation in high-load zones. Grip remained stable.

References

[1] Kladovasilakis, N., Sideridis, P., Tzetzis, D., Piliounis, K., Kostavelis, I., & Tzovaras, D. (2022). Design and Development of a Multi-Functional Bioinspired Soft Robotic Actuator via Additive Manufacturing. Biomimetics, 7(3), 105. doi: 10.3390/biomimetics7030105.

[2] Bingham, K. C., Hessler, M., Lama, S., & Deemyad, T. (2023). Design and Implementation of a Compliant Gripper for Form Closure of Diverse Objects. Applied Sciences, 13(17), 9677. doi: 10.3390/app13179677.

[3] Ma, X., Chen, L., Gao, Y., Liu, D., & Wang, B. (2023). Modeling Contact Stiffness of Soft Fingertips for Grasping Applications. Biomimetics, 8(5), 398. doi: 10.3390/biomimetics8050398.

[4] Tu, Y., Tan, Y., Zhang, F., Zou, S., & Zhang, J. (2024). High-Throughput Additive Manufacturing of Continuous Carbon Fiber-Reinforced Plastic by Multifilament. Polymers, 16(5), 704. doi: 10.3390/polym16050704.

[5] Hwang, S.-R., & Park, M.-S. (2021). Property Analysis of Photo-Polymerization-Type 3D-Printed Structures Based on Multi-Composite Materials. Applied Sciences, 11(18), 8545. doi: 10.3390/app11188545.

[6] Georgopoulou, A., Vanderborght, B., & Clemens, F. (2021). Fabrication of a Soft Robotic Gripper With Integrated Strain Sensing Elements Using Multi-Material Additive Manufacturing. Frontiers in Robotics and AI, 8, 615991. doi: 10.3389/frobt.2021.615991.

[7] Galley, A., Knopf, G. K., & Kashkoush, M. (2019). Pneumatic Hyperelastic Actuators for Grasping Curved Organic Objects. Actuators, 8(4), 76. doi: 10.3390/act8040076.

[8] M. A. Cáceres-Suazo and A. M. Reyes-Duke, "Design and Development of Soft Actuator for Handling Chemical Laboratory Instrumentation and IoT Monitoring," 2023 IEEE Central America and Panama Student Conference (CONESCAPAN), Guatemala, Guatemala, 2023, pp. 139-144, doi: 10.1109/CONESCAPAN60431.2023.10328432.

[9] Sierra, E.M.; Ordoñez-Avila, J.L. Mathematical Modeling of a Multi-Chamber Pneumatic Soft Actuator. Actuators 2022, 11, 221. https://doi.org/10.3390/act11080221

[10] J. L. Ordoñez-Avila, A. Hernández and M. Cardona, "Design of a Final Effector using Modular Molds for Soft Robotics," 2022 IEEE Central America and Panama Student Conference (CONESCAPAN), San Salvador, El Salvador, 2022, pp. 1-6, doi: 10.1109/CONESCAPAN56456.2022.9959636.

[11] Ganguly, S., & Margel, S. (2023). Fabrication and Applications of Magnetic Polymer Composites for Soft Robotics. Micromachines, 14(12), 2173. doi: 10.3390/mi14122173.

[12] Wang, D., Wu, X., & Chen, Y. (2023). Soft Actuators and Robots Enabled by Additive Manufacturing. Annual Review of Control, Robotics, and Autonomous Systems, 6, 31-63. doi: 10.1146/annurev-control-061022-012035.

[13] Licardo, J. T., Domjan, M., & Orehovački, T. (2024). Intelligent Robotics—A Systematic Review of Emerging Technologies and Trends. Electronics, 13(3), 542. doi: 10.3390/electronics13030542.

[14] Zhao, P., Xiong, C., Gao, Z., Liu, X., & Zeng, Y. (2024). Design and Experiment Investigation on Soft Grippers with Modular Variable Stiffness Structure. Micromachines, 15(1), 88. doi: 10.3390/mi15010088.

[15] Kitamura, T., Matsushita, K., & Nakatani, N. (2023). Analysis of Contact Force and Shape Change on Grasping a Square Object Using an Actual Fin Ray Soft Gripper. Sensors, 23(24), 49827. doi: 10.3390/s23249827.

[16] Maldonado, J. S., & Ordoñez-Avila, J. L. (2022). End Effector´s productivity simulation test based on Honduran textile and food production processes. https://laccei.org/LACCEI2022-BocaRaton/meta/FP700.html

[17] Iqbal, Z., Pozzi, M., Prattichizzo, D., & Salvietti, G. (2021). Detachable Robotic Grippers for Human-Robot Collaboration. Frontiers in Robotics and AI, 8, 644532. doi: 10.3389/frobt.2021.644532.

[18] Manns, M., Morales, J., & Frohn, P. (2018). Additive Manufacturing of Silicon-Based PneuNets as Soft Robotic Actuators. Procedia CIRP, 72, 328-333. doi: 10.1016/j.procir.2018.03.186.

[19] Zhan, S., Guo, A. X. Y., Cao, S. C., & Liu, N. (2022). 3D Printing Soft Matters and Applications: A Review. International Journal of Molecular Sciences, 23(7), 3790. doi: 10.3390/ijms23073790.

[20] Jia, B., Liu, C., Zhang, Y., Tan, Y., Tian, X., Cui, Y., & Deng, Y. (2024). Light-Responsive Soft Robot Integrating Actuation and Function Based on Laser Cutting. Micromachines, 15(4), 534. doi: 10.3390/mi15040534.

[21] Riddervold, A., Nesheim, O. S., Eikevåg, S. W., & Steinert, M. (2024). Electrical Resistance Response to Strain in 3D-Printed Conductive Thermoplastic Polyurethane (TPU). Applied Sciences, 14(9), 3681. doi: 10.3390/app14093681.