Final Review ME-320

GROUP 38

1 Overall view

The proposed gripper consists of two main subsections. The first part comprises a 3D printed paddle connected through a special adapter to a DC motor. The motor is then secured to the second section of the gripper using PETG supports. The second section consists of a distinctive wooden box. The box has been designed to allow the paddle to slide beneath two of the box's walls. Additionally, it features a compartment *-called Small box in the Bill of Materials-* reserved for all the electronic components and for a camera, which has been programmed using Python to detect and recognize cutlery items.

The elaborated gripper proposal exhibits strengths in the simplicity of its governing mechanism, the precision with which the system detects objects, and its versatility to catch a wide range of objects.

Regarding the mechanism selection, the decision was driven by the desire to avoid using motion transmission mechanisms like 3D-printed gearwheels or similar components. These are small parts that require an *ULTRADETAIL* 3D printing quality, which is time-consuming and expensive due to potential trial and error process. Therefore, it was evaluated that a 180-degree rotation of the DC motor could suffice if the mechanism was appropriately designed to be direct. In practice a 160-degree rotation was sufficient. Ultimately, the choice of the mechanism was to directly connect the motor to the rotating plate through a circular male adapter inserted into a concentric female adapter. While the most complex components are precisely described by the 2 engineering drawings *Spinning Plate* and *Left motor support*, the whole rendering of the gripper is presented in the .step file *".step FINAL ASSEMBLAGE 3D"*. Furthermore, given that the rotating plate measures 20 cm in length at the base, the torque exerted on the connection between the motor and the adapter could have been excessive. To address this issue and reduce the force arm of the torque, the motor was positioned as close as possible to the ground level.

As for the implemented sensors, the choice was made to ensure effective and highly versatile object detection capability. Even in the case of providing a non-metallic cutlery item, our implemented recognition mechanism would still be able to identify it. The responsibility lies with a camera mounted on the roof of the box within the electronics area. This camera has been trained using Python code supported by a freely available online library of predefined objects called *YoloV8* from *ultralytics*. Moreover, the camera's objective was precisely positioned at the center of the projection of the square area covered by the gripper. Through this arrangement, the choice of the rotating paddle's color (white) and the incorporation of four white LED lights, the camera can proficiently recognize objects. The characteristics of the circuit implemented are part of the electronics diagram *CIRCUIT*. The camera has been connected to the Arduino Uno in order to be capable of exchanging bilateral digital signals.

To conclude, the choice of materials played a pivotal role in our engineering design and production process. All components that remain static were crafted from wood using laser cutting. The advantage of this choice lies in the ease of assembling the box walls, which do not require screws or bolts but are designed to interlock effortlessly and fastened with wood glue. Additionally, utilizing wood allowed us to efficiently design the honeycombs within the box, thereby conserving materials. On the other hand, the motor supports were produced using PETG due to the specific shape requirement and the need for increased thickness. This considerable thickness is essential to withstand the motor's torque, and the supports were fixed to the box walls using four screws and four inserts per side. Lastly, the rotating paddle was 3D printed with *ULTRADETAIL* quality because it needs to slide beneath objects for gripping. It also features a 4-degree inclination, which could not be replicated using laser cutting techniques.

2 Reflection on the design

To analyze the challenges encountered during the assembly and usage of the gripper, three critical observations have been identified:

2.1. **Chip breakage:** the only setback experienced during the official gripper test on December 20th regarded breakage of a chip while being picked up. The rapid closure of the spinning plate caused the chip to collide with an internal wall. Despite the extreme fragility of the object, this incident has inspired potential improvements. One proposed solution involves applying *sponge skirting boards* along the inner base of the box walls. These skirting boards should be made of a sponge material, approximately *1 cm* in height and $0.5cm$ in thickness, applied at the ground level. They could absorb impacts and prevent the breakage of certain objects. Additionally, this may address the gap issue analyzed later on.
Alternatively, reducing the rotational speed of the DC motor and compensating for torque loss by applying a lubricating

liquid *-such as the vaseline available within the SPOT-* might offer an effective solution.

2.2. **Honeycombs:** The load-bearing walls of the primary grip box feature numerous honeycomb-shaped perforations distributed across the entire surface, as evidenced in the *".step FINAL ASSEMBLAGE 3D"* file. The initial purpose of this design choice was primarily material conservation and secondary enhancement of the end effector's lightweight and maneuverability. However, the saved material comprises many small hexagons, proving difficult to efficiently reuse. It might have been more prudent to alter the wood incision geometry into larger strips or rectangles. Moreover, the honeycombs caused peculiar light penetration within the box, casting multiple shadows that affected the camera's performance. Eliminating the honeycombs might have solved the need for the four LEDs, potentially reducing the overall cost of the gripper.

2.3. **Direct Motor-Spinning Plate Connection Issue:** The direct link between the motor and spinning plate resulted in a slight downward flexion of the gripper. Consequently, even when the gripper was closed, lifting it revealed a $1.5cm$ gap due to this flexion. This did not compromise the gripper's performance, but an object less than $1.5cm$ in height capable of rolling might fall after being picked up. As mentioned earlier, we believe the implementation of sponge skirting boards could potentially resolve this issue.

3 Sustainability and Scalability

Before critically analyzing sustainability and scalability issues of the product, it is necessary to recognize that we overspent in the trial and error process. As shown in the *Team Budgets - Group 38* Excel, our design only costs around 23-. not considering mistakes and trials. Regarding the sustainability of our product, it could be enhanced by reducing the use of wood glue or hot glue, which, in some cases, were necessary to ensure product solidity. This solidity could, instead, be improved by optimizing the selection of dimensional tolerances of the part in line with the machine used for production. This approach would make the interlocking assembly for box walls 100% efficient and replicable across various assembly components. Instead, the use of PETG for the spinning plate is essential because the desired shape cannot be achieved with DMF.

Considering a mass production scenario for the gripper, scalability is already deemed competitive due to the ease of assembling the boxes and the absence of sophisticated motion transmission mechanisms. However, two enhancements could further improve it. Firstly, providing protection for exposed electronic cables exiting from the top of the small box and directly connecting to the DC motor is essential. These cables are undoubtedly one of the product's most vulnerable features and significantly diminish the *Life Cycle Assessment (LCA)* of our gripper. Additionally, it would be prudent to merge the side walls of the big box with those of the small box. In other words, creating a single box with an upper compartment resembling an *"attic in a house"* would be beneficial. This approach would require producing four fewer side walls, thereby increasing scalability.

4 Scientific Literature and Papers

After accurate research in scientific literature, three robotic papers that resemble our product are proposed. For each one, it is underlined how it differs from our design.

- *Paper 1:* ***Omnidirectional Nonprehensile Manipulation Using Only One Actuator***, published by *MDPI*. In this paper one actuator -a devices that produces linear motion- is *directly* linked to a flat plate to generate vibrations and use it as an end effector, for instance to hold objects. Apart from the obvious differences, our product is similar, indeed it uses a DC motor -a device that generates spinning motion- to make a directly- linked plate rotate. **Reference:** *https://www.mdpi.com/2218-6581/7/3/34*.

- *Paper 2:* ***Design and Development of a Tomato Picking Soft Robotic Gripper with a Separator and Mechanical Iris Based Pedicel Cutting Mechanism***, published by *Springer*. In this paper a robot uses an iris mechanism to pick various types of tomatoes (different size and shapes) before carrying them to a specified bin. After having noticed the similarities of tasks that have to be accomplished, a simpler variation of the *Iris Mechanism* was devised, consisting in catching the objects by passing under them. We performed our Kinematic Analysis on *Fusion 360.*
Reference: *https://link.springer.com/chapter/10.1007/978-3-031-16281-7_27*

- *Paper 3:* ***Computer Vision-based Robotic Arm for Object Color, Shape, and Size Detection***, published by *Universitas Muhammadiyah Yogyakarta*
In this paper the robotic arm is automated by the *Computer Vision* program, paired with Pixy Mon 2.0.9 to detect colors. One difference is that in our case the *Computer Vision* works separately from the Arduino. Moreover, an already existing library with *OpenCV* for our specified set of objects was implemented.
Reference: *https://journal.umy.ac.id/index.php/jrc/article/view/13906/7229*