Report Gripper

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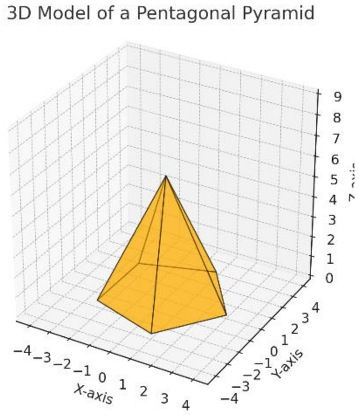
Development of a Three-Finger Gripper for Manipulating a Pentagonal Pyramid

The task involves designing a gripper capable of handling a hollow, wooden pentagonal pyramid with the following dimensions:



- **Base:** 3-5 cm
- **Height:** 6-8 cm
- **Wall Thickness:** 4 mm

We selected a **three-finger gripper** as the optimal design for this project due to its effective gripping capability. Adding soft padding to the gripper fingers ensures even pressure distribution and minimizes the risk of damaging the object.

Reasons for Choosing a Three-Finger Gripper:

1. **Stability:** The three-finger mechanism provides secure and balanced gripping of the pentagonal structure.
2. **Flexibility:** Suitable for irregular geometries like the pyramid's shape.
3. **Pressure Distribution:** Soft padding helps distribute the gripping force evenly, reducing the risk of deformation.

Selection of the Robotic Arm: Universal Robot UR3

For the robotic arm, we chose the **Universal Robot UR3**, a compact and versatile model with 6 degrees of freedom (DOF). The UR3 is well-suited for tasks such as pick-and-place and precise manipulation, which align with our project's requirements. **Key Features of the UR3:**

1. **Compact Size:**
    - Weight: 11 kg
    - Payload Capacity: 3 kg
      These specifications make the UR3 ideal for handling the lightweight pyramid without adding unnecessary bulk.
2. **High Precision:**
    - Repeatability: ±0.1 mm
    - Wrist Joint Rotation: 360°
      These features ensure the accuracy required for delicate tasks like gripping a hollow wooden structure.

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UR3 Technical specifications

Item no. 110103

6-axis robot arm with a working radius of 500 mm / 19.7 in

Weight:	11 kg / 24.3 lbs
Payload:	3 kg / 6.6 lbs
Reach:	500 mm / 19.7 in
Joint ranges:	+/- 360° Infinite rotation on end joint
Speed:	All wrist joints: 360 degrees/sec. Other joints: 180 degrees/sec. Tool: Typical 1 m/s. / 39.4 in/s.
Repeatability:	+/- 0.1 mm / +/- 0.0039 in (4 mils)
Footprint:	Ø128 mm / 5.0 in
Degrees of freedom:	6 rotating joints
Control box size (WxHxD):	475 mm x 423 mm x 268 mm / 18.7 x 16.7 x 10.6 in
I/O ports:	Controlbox / Tool conn. Digital in 16 / 2 Digital out 16 / 2 Analog in 2 / 2 Analog out 2 / -
I/O power supply:	24 V 2A in control box and 12 V/24 V 600 mA in tool
Communication:	TCP/IP 100 Mbit: IEEE 802.3u, 100BASE-TX Ethernet socket & Modbus TCP
Programming:	Polyscope graphical user interface on 12 inch touchscreen with mounting
Noise:	Comparatively noiseless
IP classification:	IP64
Power consumption:	Approx. 100 watts using a typical program
Collaboration operation:	15 advanced adjustable safety functions
Materials:	Aluminum, PP plastic
Temperature:	The robot can work in a temperature range of 0-50°C*
Power supply:	100-240 VAC, 50-60 Hz
Cabling:	Cable between robot and control box (6 m / 236 in) Cable between touch screen and control box (4.5 m / 177 in)

*) At high continuous joint speed, ambient temperature is reduced.

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Key Calculations for the Gripper Design

Here are the main calculations that were essential for designing the gripper. These calculations helped us choose the appropriate components and ensure the system meets performance requirements:

Assumption

Edge length of the base, $a = 4\,cm$

height of Pyramid, $H = 7\,cm$

Wall thickness $t = 0.4\,cm$

Density of wood, $\rho_{wood} = 0.6\,g/cm^3$

gravity $g = 9.81\,m\,s^{-2}$

coefficient of friction $\mu = 0.5$

Hollow wooden, mean outer volume minus inner volume

1. Base area of regular Pentagon

$$A = \frac{5}{4} a^2 \cot\left(\frac{\pi}{5}\right)$$

Using $a = 4\,cm$,

$$A = 27.53\,cm^2$$

2. Volume of outer pyramid

$$V_{outer} = \frac{1}{3} AH = \frac{1}{3} \times 27.53 \times 7 = 64.42\,cm^3$$

3. Inner Pyramid Dimensions:

Inner edge $a_{inner} = a_{out} - 2t = 4 - 0.8 = 3.2\,cm$

Inner height

$$H_{inner} = 7 - 0.8 = 6.2\,cm$$

4. Base Area of inner Pentagon

$$A_{inner} = \frac{5}{4} a_{inner}^2 \cot\left(\frac{\pi}{5}\right)$$

$$A_{inner} = 17.61\,cm^2$$

5. Volume of inner Pyramid

$$V_{inner} = \frac{1}{3} A_{inner} H_{inner} = 36.43\,cm^3$$

6. Final volume

$$V_{obj} = V_{outer} - V_{inner} = 64.42 - 36.43 = 27.99\,cm^3$$

Mass and weight of Pyramid

1. Mass

$$m = V_{obj} \times \rho = 16.79\,g$$

2. Weight

$$W = m \times g = 16.79 \times 9.81 = 1.647\,N$$

Friction Force per finger

1. Total friction required:

$$f_{total} = W = 1.647\,N$$

2. Friction Force per Finger

$$f = \frac{f_{total}}{3} = 0.549\,N$$

Normal force Required per Finger

$$f = \mu F$$

$$F = \frac{f}{\mu} = 1.098\,N$$

Total force gripper need to applied

$$F_{gripper} = 3 \times F = 3.294\,N \quad (3\ \text{Fingers})$$

Inertia force Calculation

$F_{inertia} = m.a$

$= 0.01679 \cdot 1 = 0.01679\,N$

Total force including Inertia

$F_{total} = F_{gripper} + F_{inertia}$

$= 3.3 + 0.01679$

$= 3.31679\,N$

Force per Finger

$F_{per\ finger} = \frac{F_{total}}{3} = \frac{3.31679}{3} = 1.1056\,N$

Torque Calculation

Assume arm length $r = 0.05\,m$

$T_{per finger} = F_{per\ finger} \cdot r = 1.1056 \cdot 0.05 = 0.05528\,Nm$

$T_{total} = 3 \cdot T_{per\ finger} = 3 \cdot 0.05528 = 0.16584\,Nm$

Gripper speed and Motor Rpm

For gripping distance of 5cm. (the arm length) in 1s.

angular velocity, $\omega = \frac{distance}{arm\ length} = \frac{0.05}{0.05} = 1\ rad/s$

Convert to RPM, $RPM = \omega \cdot \frac{60}{2\pi} \approx 9.55\,RPM$

Acceleration during motion:

Assume a = 1m/s^2

Assume the lever arm length r = 0.05 m (distance from the motor axis to the gripping point on each finger).

Inertia force is small due to the lightweight object, but it must still be added to the total gripping force.

For our gripper, we have selected high-quality components to ensure optimal performance and precision. Below is a detailed overview of the components we plan to use:

1. Touch Sensors

- **Tekscan FlexiForce**

These sensors will allow the gripper to accurately detect and adjust to the force applied, ensuring safe and reliable manipulation of the wooden pyramid.

2. Distance Sensor

For distance sensing, we have selected the **Lidar-Lite v3**.

- This sensor is known for its compact size, low power consumption, and high accuracy.
- It will be used to measure distances and assist in positioning the gripper correctly, particularly during the approach to the object.

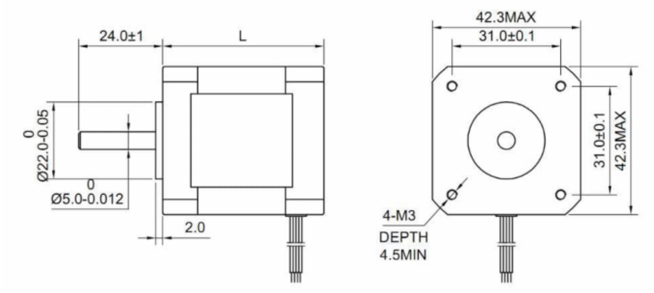
3. Motors and Drivers

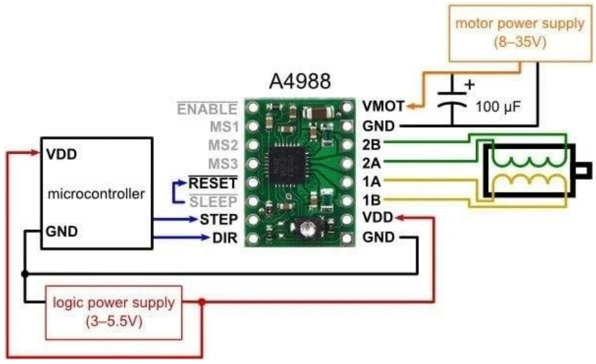
Individual Motors for Each Finger
Each finger of the gripper requires a torque of **0.055 Nm**. Based on this requirement:

- **NEMA 14 or NEMA 17 stepper motors** with torque ratings around **0.1 - 0.2 Nm**, which are sufficient for the task.

Drivers for Control:

- **A4988** or **DRV8825 drivers** are excellent choices for microstepping and precise control.
- Both options are small, efficient, and capable of delivering the required performance.





Decision to Use a Belt-Driven Gripper

At this stage, we have decided to implement a **belt-driven gripper** for our design. This decision is based on its several advantages, which make it highly effective for our specific application:

Why a Belt-Driven Gripper is Effective:

1. **Smooth and Precise Movement:**
   - A belt-driven system allows for consistent and accurate motion, which is crucial for handling delicate and lightweight objects like the wooden pyramid.
2. **Efficiency:**
   - Belt-driven mechanisms are known for their high efficiency in transferring power, minimizing energy loss during operation.
3. **Compact Design:**
   - The belt system enables a compact and lightweight setup, which is ideal for integration with the Universal Robot UR3.
4. **Flexibility:**
   - The belt system can accommodate adjustments in the range of motion, making it adaptable for gripping objects of varying sizes

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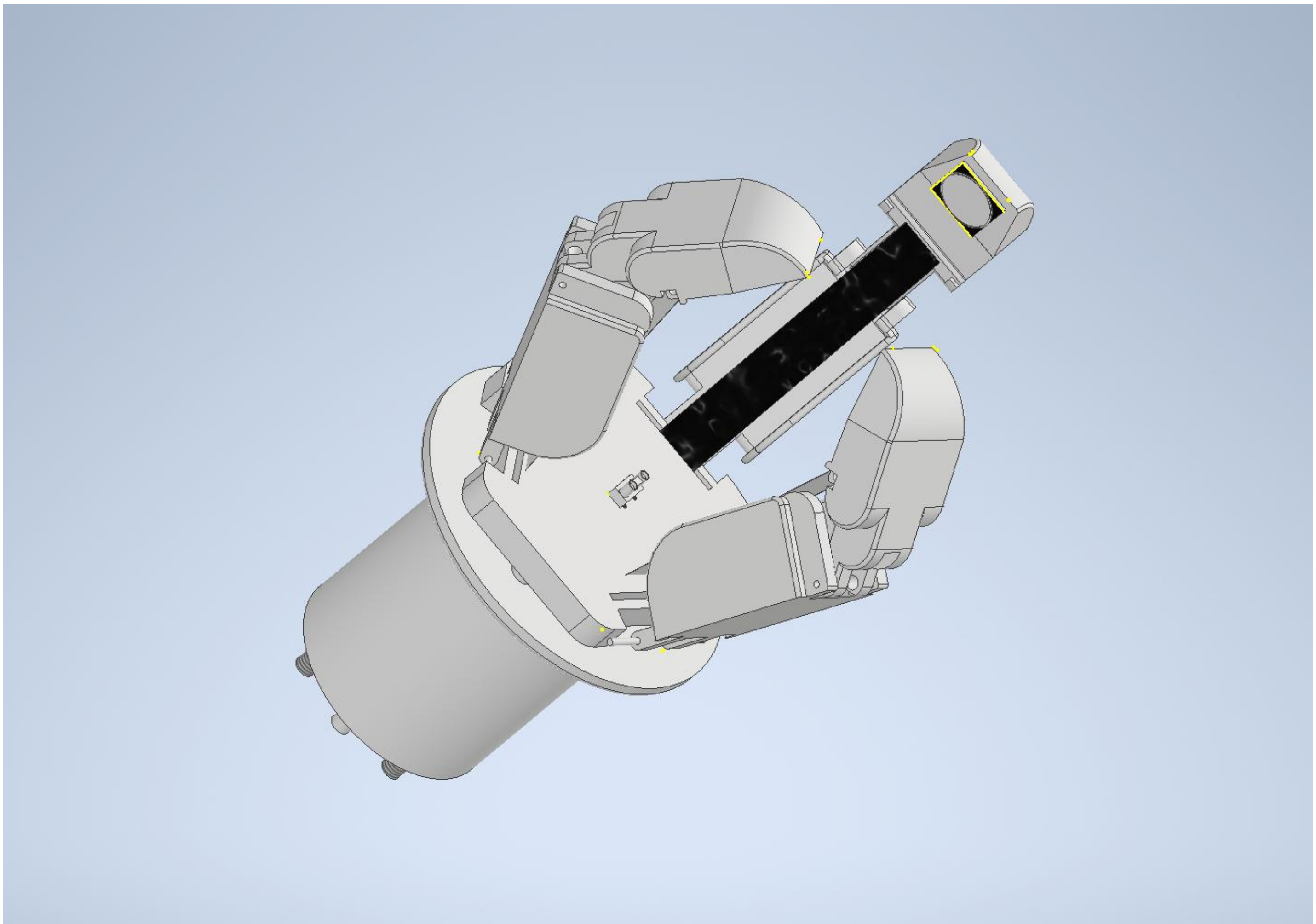
Initial Model of the Gripper

Below is the preliminary model of our belt-driven gripper design.



Instructional Essay for Assembling Robotic Gripper Components

Assembling a robotic gripper involves a series of methodical steps to ensure that all components are properly connected and function as intended. This essay provides detailed instructions on how to assemble the key parts of a robotic gripper, including the platform, palm, fingers, sensors, and wiring. The goal is to achieve a functional and stable gripper that can perform reliable and efficient tasks.

1. Platform Connection

The platform serves as the foundation of the gripper, linking it to the robotic arm or mounting fixture. It is crucial that this component is securely attached to prevent instability in the overall structure. Begin by aligning the platform with the base of the gripper. To connect them, use screws or bolts to fasten the platform firmly. Ensure that the alignment is precise to avoid misalignment, which could lead to operational issues or instability during use.

2. Attaching the Palm Platform

The palm platform acts as a middle layer connecting the fingers to the base. This component is integral in ensuring that the fingers operate smoothly. Once the base is secured, attach the palm platform to the central structure using bolts. It is essential that the palm platform has cutouts or mounting points for the fingers. If necessary, use spacers to provide additional room for internal mechanisms like belts or wiring, which will be routed through this section.

3. Mounting the Palm

The palm plays a critical role in providing support to the fingers and sensors. When attaching the palm to the palm platform, ensure that it aligns with the finger slots for accurate positioning. Secure the palm using screws or inserts to fasten it properly to the platform. It is important to leave sufficient space for the placement of the distance sensor, which will later be mounted at the center of the palm.

4. Connecting the Fingers

The fingers are the primary components for gripping objects, so they must be able to move freely and effectively. Begin by attaching pivot joints at the base of each finger. These joints will allow the fingers to articulate and perform gripping actions. The pivot joints should be secured to the palm or palm platform using screws or pins, depending on the design. If belts are used for finger actuation, ensure that the finger mounts have designated points for connecting the belt system. The belts should be routed through pulleys attached to both the fingers and the palm platform, providing the necessary movement for the fingers.

5. Installing Belts for Finger Movement

Belts are used to control the movement of the fingers. To connect the belts, loop them through the pulleys that are attached to the fingers and the palm platform. Ensure that the belt's fixed ends are connected either to the base or to a motorized actuator that will drive the movement. Tension on the belts should be carefully adjusted to ensure smooth operation without any slippage. Improper tension can lead to inefficient finger movement or excessive wear on the system.

6. Touch Sensors on Fingertips

Touch sensors on the fingertips are essential for providing feedback when the gripper makes contact with objects. These sensors should be embedded or adhered to the rubber pads on the fingertips. It is crucial that the sensors are placed in such a way that they are not obstructed by the rubber pads, allowing for proper contact detection. Once the sensors are in place, route the sensor wires carefully through the fingers, securing them along internal channels that lead to the base of the gripper. This ensures that the wiring remains organized and does not interfere with the movement of the gripper.

7. Securing Rubber Pads on Fingertips

Rubber pads on the fingertips provide grip and prevent slippage during object manipulation. The rubber pads should be attached using either adhesive or screws, depending on the design. Ensure that the rubber pads are securely fixed to the fingertips, but also make sure that they do not obstruct the touch sensors. The rubber pads must allow for proper contact with objects while providing sufficient friction to prevent the object from slipping out of the gripper.

8. Mounting the Distance Sensor on the Palm

The distance sensor is a vital component for detecting objects before they are gripped. It is typically mounted at the center of the palm to allow for a clear line of sight. The sensor should be installed using screws or adhesive, depending on the design. Ensure that the sensor is positioned in such a way that it is not obstructed by the fingers or other components. Once mounted, route the sensor's wiring to the base of the gripper, where it will be connected to the control unit.

9. General Wiring Considerations

One of the most important aspects of assembling a robotic gripper is ensuring proper wiring management. The wires for the sensors and actuators must be routed neatly through internal channels to avoid interference with the moving parts. Use cable ties or clips to secure the wires and prevent them from tangling or becoming damaged during operation. Pay close attention to prevent the wires from being pinched or overstressed, as this can lead to malfunction or failure. Proper cable management is essential for long-term reliability and performance.
