(1C) End Effector Design

Team Kerbals

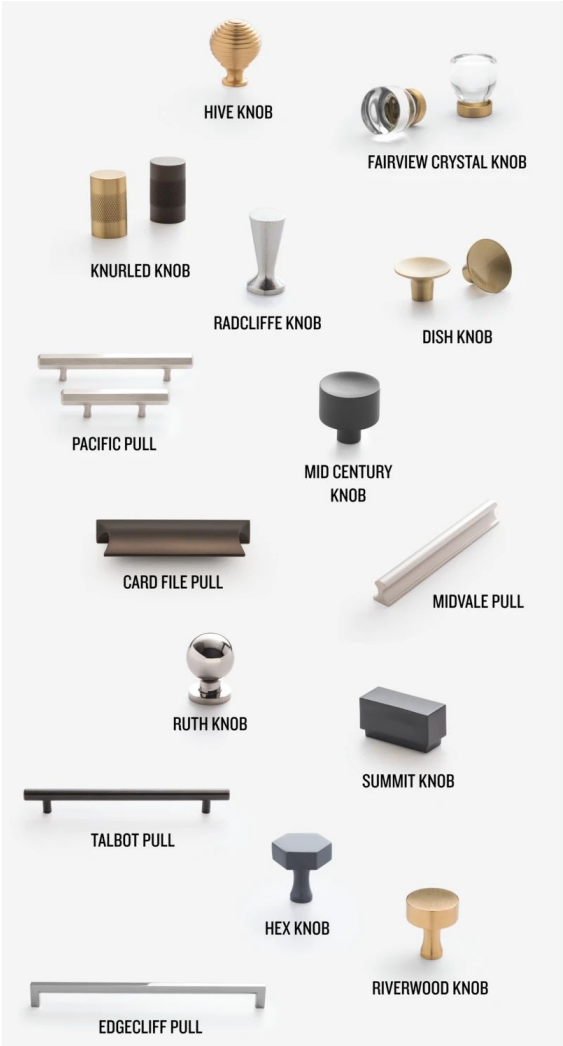
Problem Statement

Design the **end effector** of a robotic arm, having **3 degrees of freedom**.

- The arm must be **capable of**:
  - Typing on a keyboard
  - Opening a drawer
  - Lifting a rock with maximum radius of 20 mm and mass of 1 kg
- What are some **design constraints** you would have to consider when designing the end effector?
- What would the **characteristics** of the optimal end effector be?
- What **materials** would you use to manufacture the different parts of the end effector?

Task Specifications

1. **Typing on a keyboard**
2. **Opening a drawer**
   - In general, 3 structural types [1]:
     1. Handle
     2. Knob
     3. Card file pull
3. **Lifting a rock with maximum radius of 20 mm and mass of 1 kg**



Optimal End Effector Characteristics

1) **Functionality**
   - Able to complete all tasks
2) **Performance**
   - Tasks are optimised and completed with high performance according to certain metrics (i.e. weight, complexity of mechanism, time, precision)
   - Fulfill design constraints

Design Constraints

1. **Financial Constraints**
   - Items procured must be less than $5000
   - Aim for items to be as low-cost as possible
2. **Physical Constraints**
   - Weight of system → design a light system as higher weight, more energy expended to move
   - Size of system → design a system that's as compact as possible
3. **System Constraints**
   - System simplicity → reduce number of new systems introduced (such as pneumatics system)
   - Manufacturing simplicity → create a design that's easy to manufacture

Gripper Design Inspirations

Traditional Designs

Parallel Motion Two-Jaw [2]

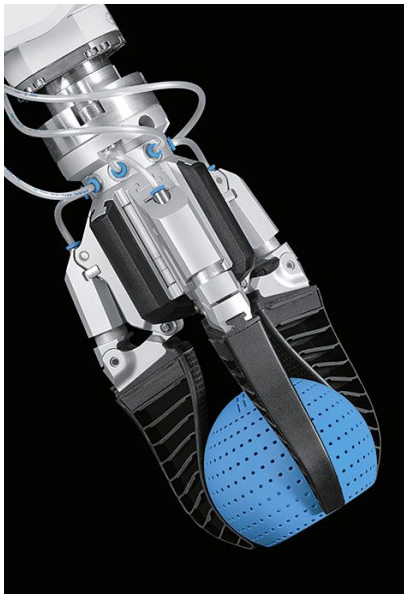
Three-Jaw Gripper [3]

Wide Stroke Adaptive Gripper [4]

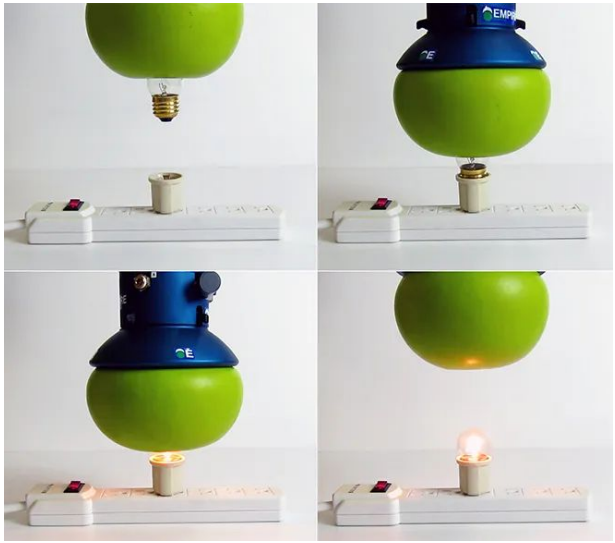
Gripper Design Inspirations

Modern Design

FESTO Tentacle Gripper [5]



FESTO Multichoice Gripper [6]



Beanbag Gripper [7]

Comparison

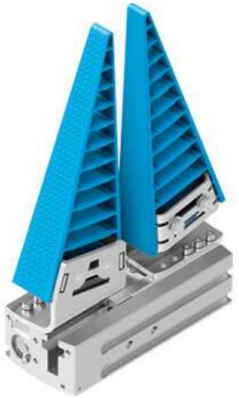
Functionality / Performance	**Typing /5**	**Drawer /5**	**Lifting rock /5**	**Pros**	**Cons**
2-Jaw [2]	5	5	4	Simple mechanism	Needs to compensate grip with adding more force - not suitable for brittle items
3-Jaw [3]	5	3	5	Stable in picking up things	More complex design
Wide-stroke Parallel [4]	5	5	4	Simple mechanism	Very commonly used in rovers
Tentacle Gripper [5]	2	5	4	Very innovative	Still in research stage, not commercialised
Multichoice Gripper [6]	5	4	5	- Good for brittle items - Has high friction grip	More complex design
Beanbag Gripper [7]	1	2	5	Innovative and new	Complex system (uses air compressor)

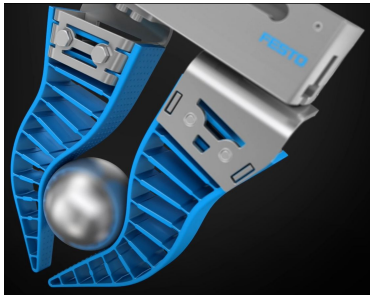
FESTO Adaptive Gripper

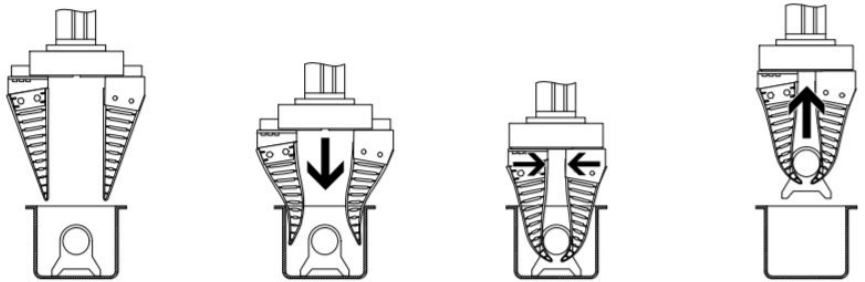
Basic Proof of Concept

Gripper fingers' interface [8, 9]:

- Designed so that both parts can be easily slid together to form a positively-engaged and friction-based adapter while the fingers can flex
- **Reliable gripping** of different shapes and with different surfaces (i.e. rock shapes, drawer handles/knobs/openings)
- Gripper is made from TPU
  - Easy to manufacture
  - Light
- Relatively simple design

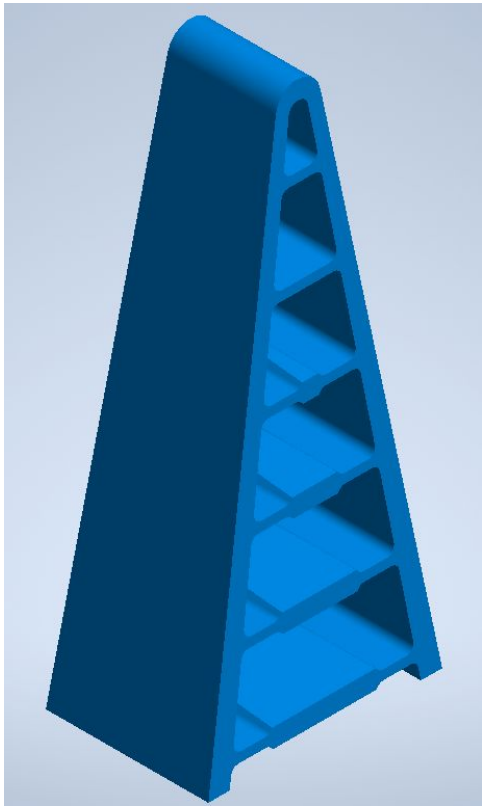


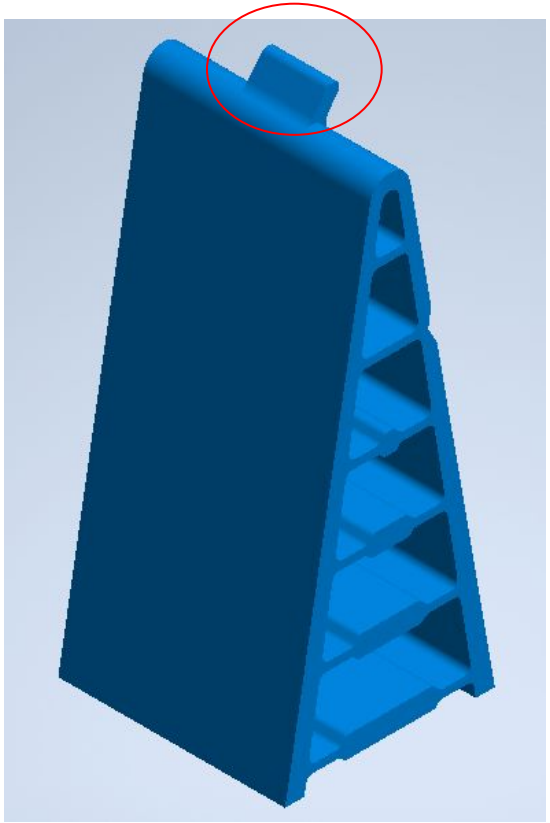


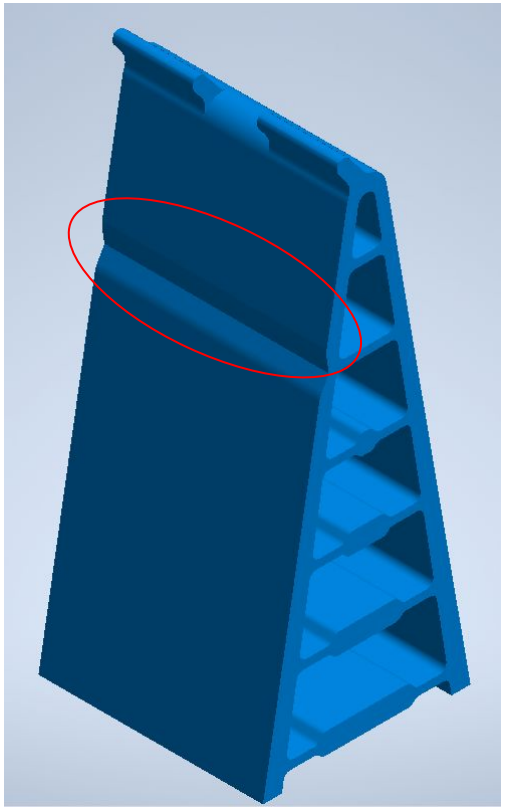


Modified Adaptive Gripper Finger

CAD Design







Modified Adaptive Gripper Finger

Basic Proof of Concept + Modifications

To improve **performance**:

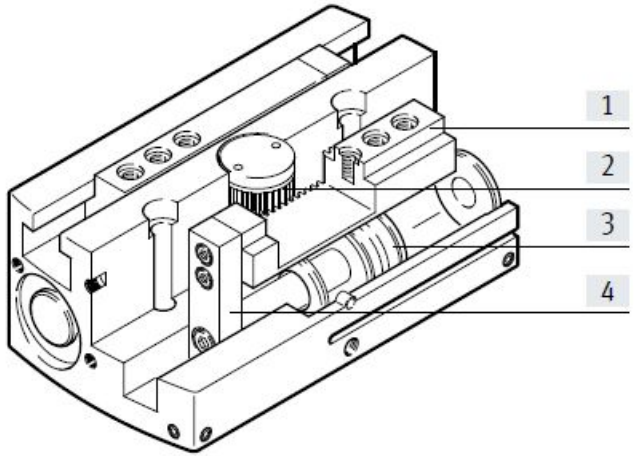
1. **End/tip gap** for enclosing
   - Allows better securement of large objects (task 3)
2. **Groove** at gripper
   - Allows thin objects to fit better (e.g. thin drawer handles) (task 2)
3. **Make the gripper hold a Laser stylus** to help aim designated key on the keyboard(task 1)
   - Allow user or sensors to have better aim
   - Groove at grip ensured laser is secured at the same position every time
   - A smaller finger which eliminates the chance of accidentally pressing a neighbouring key

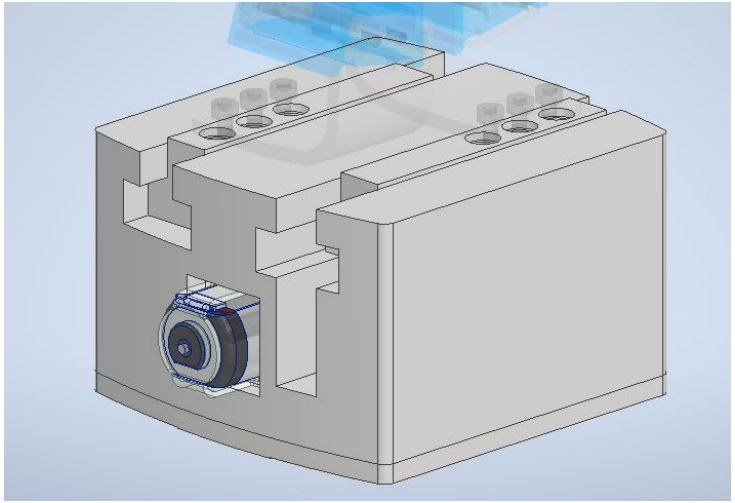
Modified Parallel Gripper Actuator

	Pneumatic piston system	**Gear system**	**Hydraulic system**
Pros	- Easily bought off-the-shelf, no need to manufacture - Has precise positional control	- Lighter - Can withstand greater force VS pneumatic piston with stepper motors with gear reduction - Has precise positional control - Highly customisable depending on need	- More sustainable VS pneumatic piston
Cons	- Complex system → More things added causes higher probability of something failing - Not sustainable → requires constant servicing of the pneumatic pistons - Requires heavier system to withstand equivalent force VS Gear system	- Slower VS pneumatic piston - Not off-the-shelf purchase (less convenient)	- Heavier VS pneumatic piston - Introduces a new system

Modified Parallel Gripper Base

Basic Proof of Concept + Modifications





FESTO HGPL-25-20 [10]

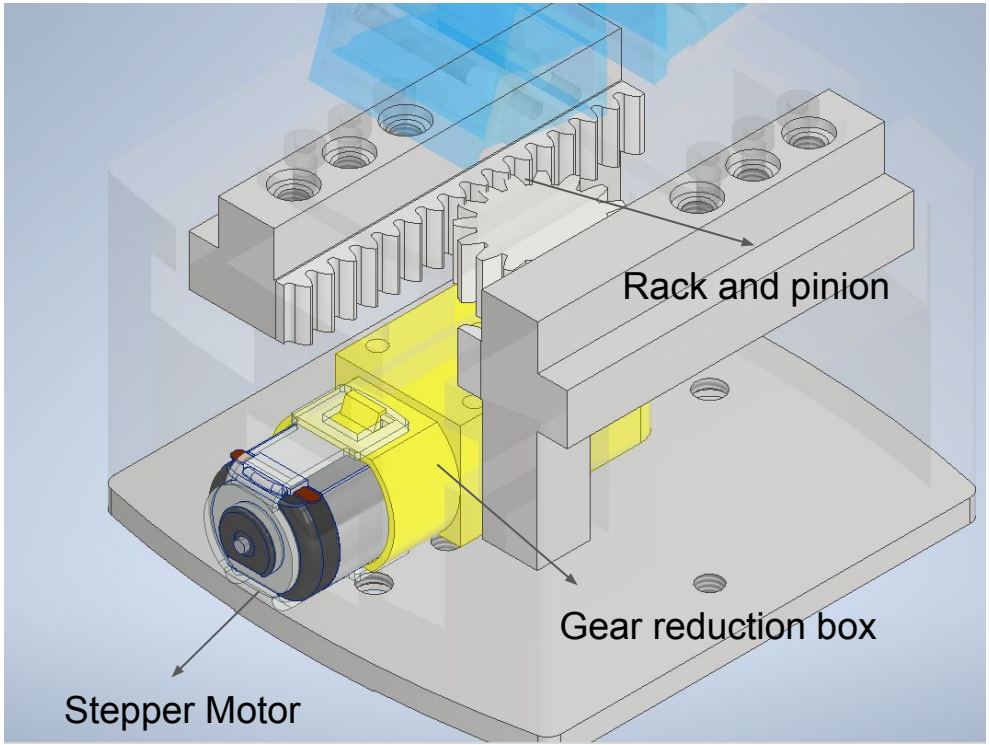
- Uses Pneumatics
- Metal-alloy based (heavy)
- Difficult to manufacture
- High cost

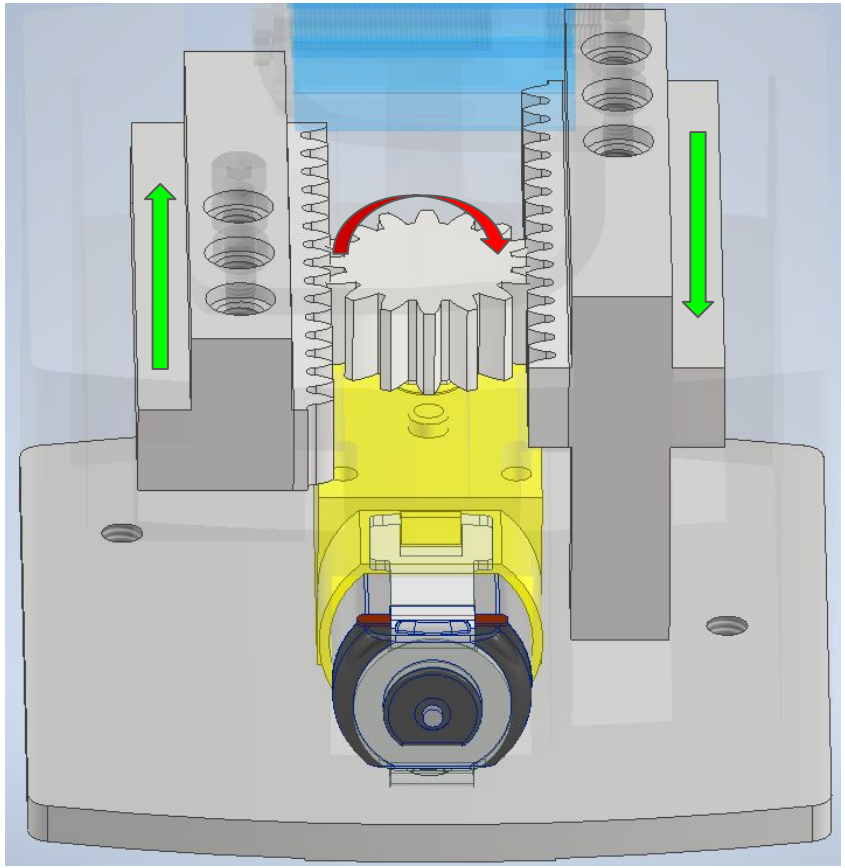
Adapted System

- Uses high-torque stepper motor and gears (rack and pinion)
- Onyx based (3D printed)
- Easy to manufacture
- Low cost

Modified Parallel Gripper Base

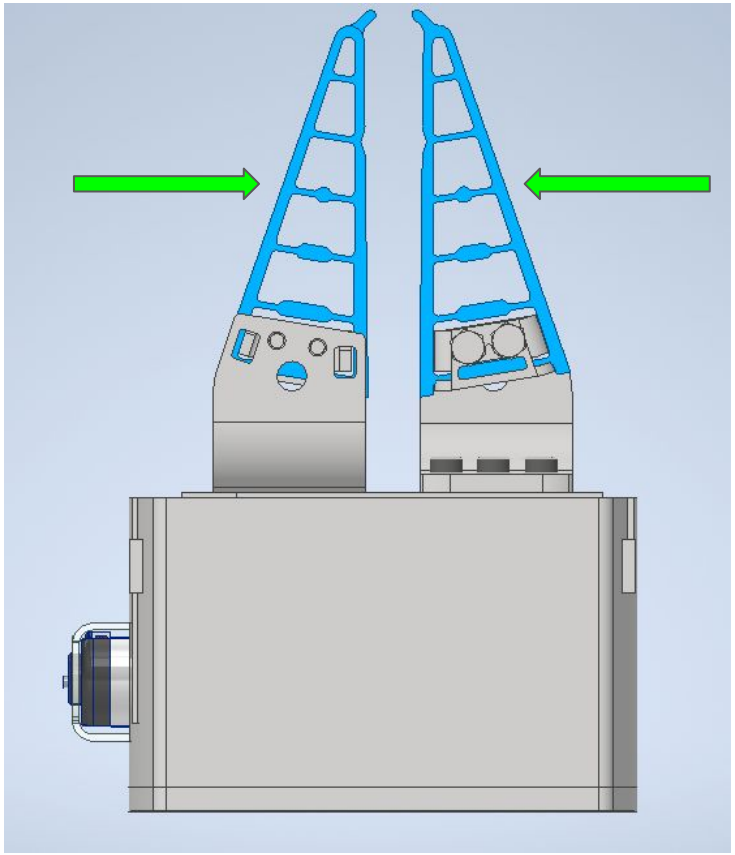
Basic Proof of Concept + Modifications

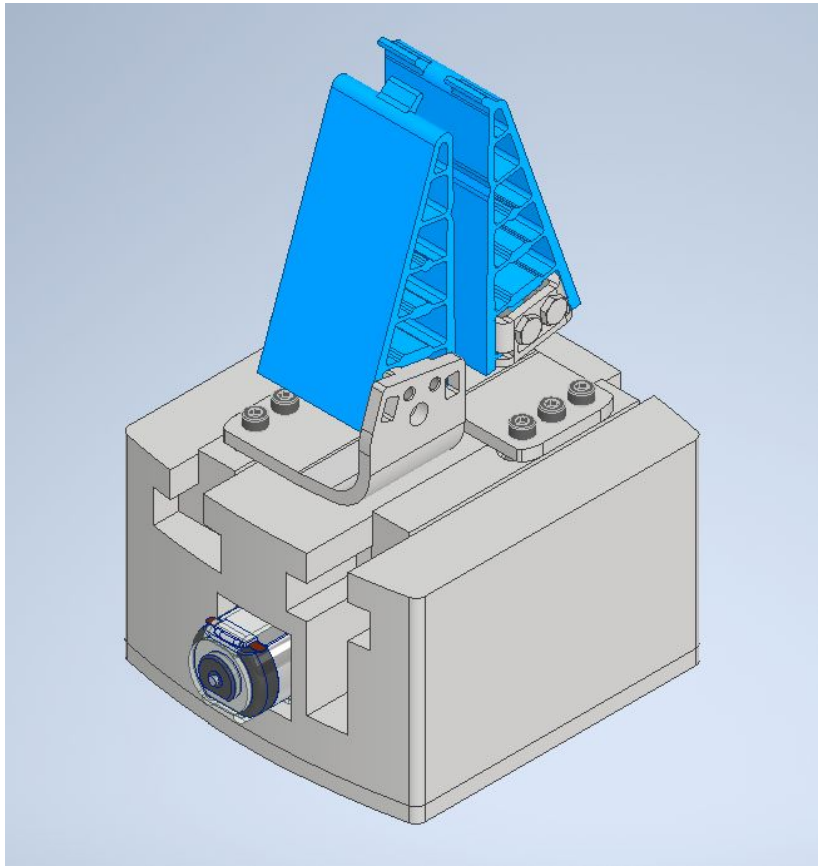




Modified Parallel Gripper Base

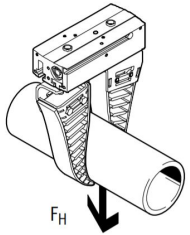
CAD Design

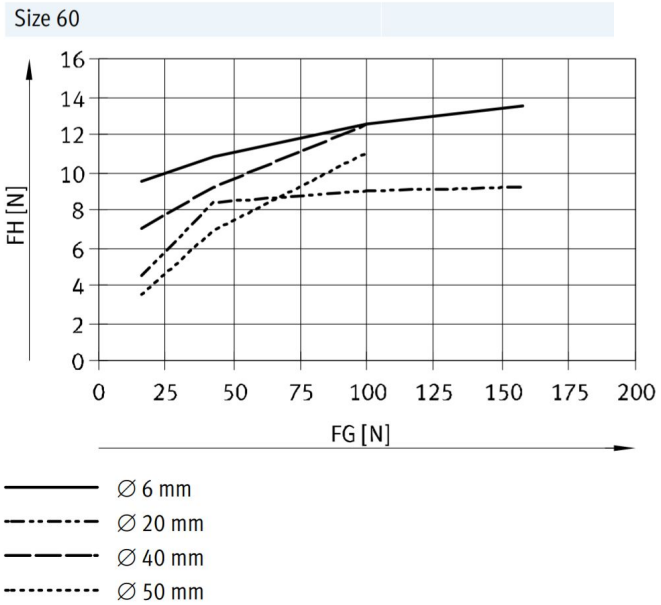




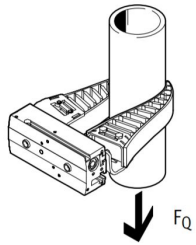
Technical Feasibility [11]

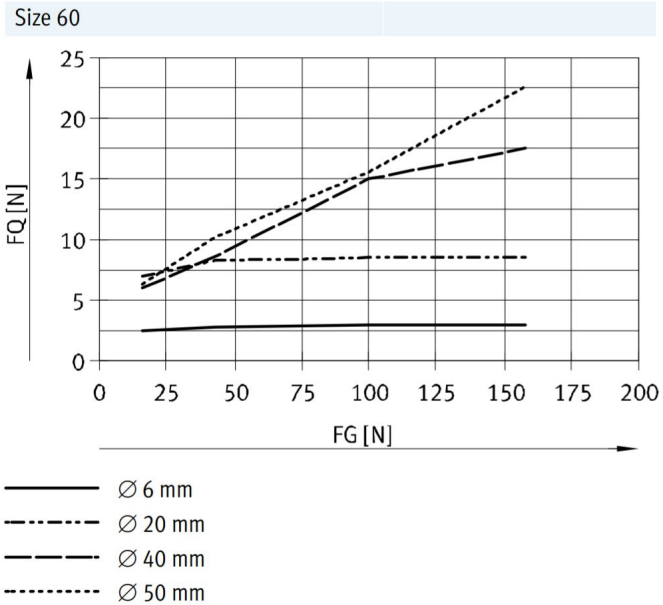
Retention force (pulling handle, pulling knob, etc.)





Lateral force (holding stylus, lifting rock, etc.)





Technical Feasibility

Rough Technical Calculations

Max Weight: 1 kg or 9.81 N

Max Diameter: 40mm

From Lateral Force graph, Fg required = 50 N

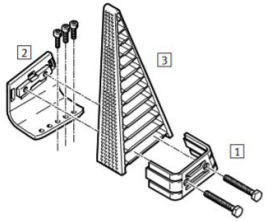
Since gear diameter = 25mm, Torque of motor required = 1.25 Nm

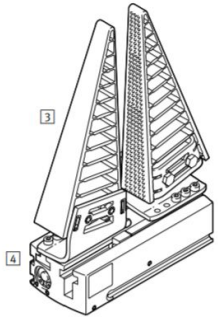
With safety factor of 4, Torque recommended = 4 Nm

Average Stepper motor torque ~ 0.5 Nm

Gear reduction required for system is **8 : 1**

Bill of Material





1 Mounting kit
DHAS-ME
2 Mounting bracket
DHAS-MA
3 Adaptive gripper finger
DHAS
4 Parallel gripper
HGPL-14

Part	**Details**	**Material / Weight**	**Procurement**
Mounting Bracket DHAS-MA-B6-60 [12]	Mounting of adaptive gripper finger together with the mounting kit and parallel gripper	High-alloy stainless steel / 23g	Off-the-shelf purchase [13]
Mounting Kit DHAS-ME-H9-60 [14]	Mounting of adaptive gripper finger	High alloy steel, non-corrosive / 7g	Off-the-shelf purchase [15]
Modified Adaptive Gripper Finger	Adapted from FESTO DHAS-GF-60-U [16]	Polyurethane (TPU) / 39g	3D printed

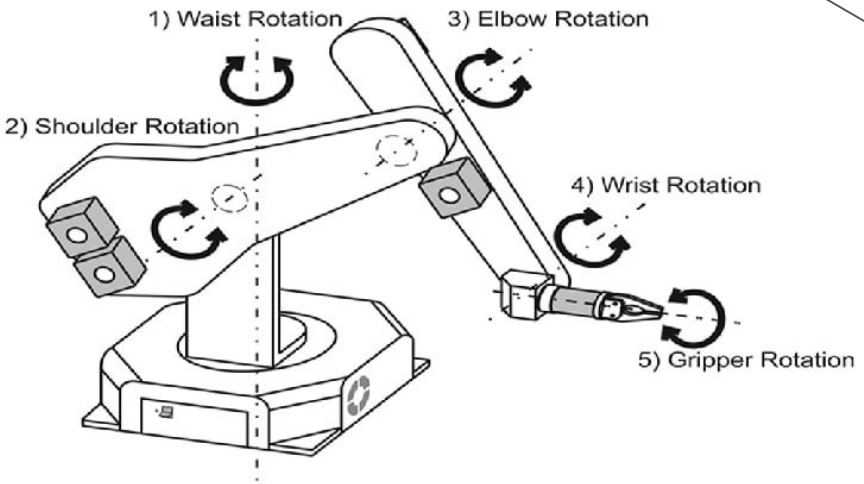
Bill of Material

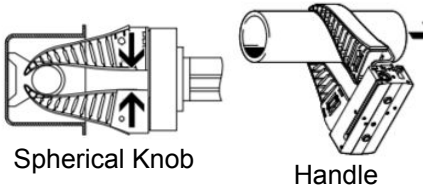
Part	**Details**	**Material / Weight**	**Procurement**
Modified Parallel Gripper Frame	Custom frame	Onyx Material / ~250g [17]	3D printed
Stepper Motor	Motor to drive the jaws	Metal Alloys 160 g	Off-the-shelf purchase [18]
Laser pen	Laser pen to guide Task 1	Plastic ~ 30 g	Off-the-shelf purchase [19]

Future Improvements:

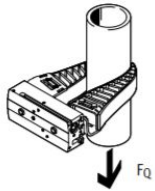
To improve **functionality**:

- **Additional rotor** for additional degree of freedom [20]

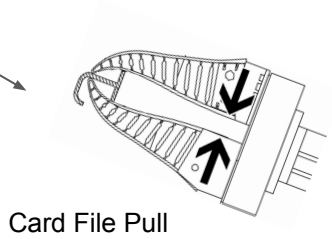




Gripper rotation (perpendicular)



Gripper rotation (parallel)



Wrist rotation (angled)

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