SoroSim: Multi-Finger Soft Robotic Hand Gripper Design & Simulation Study

Group 11: Jose Parra

March 28, 2025

Abstract

This report discusses the design and simulation of a multi-finger soft robotic hand gripper using a custom simulation environment called **SoroSim**. Each finger is modeled as a hyperelastic actuator that bends under internal pneumatic pressure. We present the gripper geometry, relevant hyperelastic material properties , the applied boundary conditions, and our overall simulation approach. The results demonstrate that moderate pressures provide adequate flexion for the fingers to gently and reliably grasp various objects.

Contents

1 Introduction

Soft robotic grippers have garnered attention in recent years, especially due to their ability to handle delicate items with minimal risk of damage. Traditional rigid grippers often either require sophisticated linkages or risk harming fragile objects. By contrast, soft robotic actuators rely on highly deformable materials, which naturally distribute contact forces more evenly [**?**, **?**].

In our work, we focus on simulating a **multi-finger soft hand gripper** within **SoroSim**, which is our specialized simulation tool for large-strain continuum robotics. Each finger inflates internally, similar to a biological finger curling motion, and easily conforms around an object. This approach offers a gentle yet stable grasp for various tasks that require care and compliance.

2 Design Concept

Our gripper design features two **identical soft fingers** connected to a central rigid palm (Figure 1). When pressurized, each finger's upper channel expands more than the lower region, inducing a curling (flexion) that wraps around the object at the center.

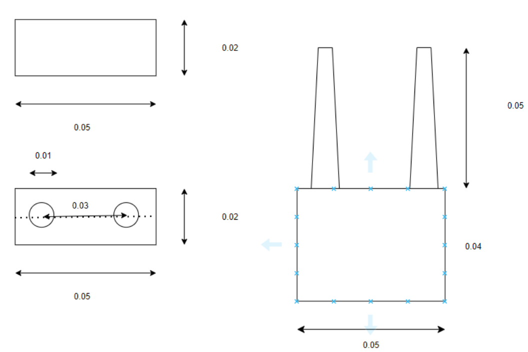


Figure 1: Conceptual layout of a 2-finger soft robotic hand gripper. Each finger bends inward upon inflation to grasp a central object.

3 Modeling in SoroSim

3.1 Geometry

In SoroSim, each soft finger is represented by:

- **Length:** $L = 0.04\,\mathrm{m}$
- **Cross-section:** $W = 0.05\,\mathrm{m}$, $H = 0.02\,\mathrm{m}$
- **Internal channel:** Occupies the top half of the cross-section, running the full length.

All fingers attach radially around a rigid palm (or base). The geometry can be imported from a STEP file or generated directly within SoroSim's CAD utilities.

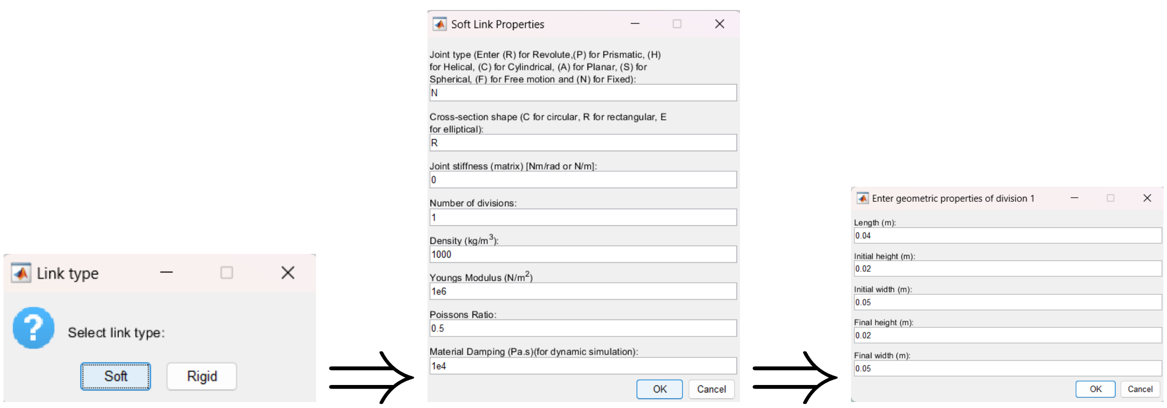
3.2 SoroSim Functions

Before we begin modeling, it's worth noting a few crucial SoroSim commands. These are fundamental building blocks for constructing and analyzing soft robotic systems within the simulation environment:

- `SorosimLink`: Creates a single *Link* in the MATLAB workspace (e.g., a rod, rectangular prism, etc.).
- `SorosimLinkage`: Merges multiple Links into a combined model.
- `dynamics`: Executes a time-stepped simulation, generating a video or real-time view of how the structure deforms.
- `statics`: Solves for the equilibrium state of the model, reporting physical properties and final deformations.

4 Modeling the Simulation

All the steps described below are carried out using SoroSim's command-window prompts and pop-up interfaces. Figure sets help illustrate the workflow.



4.1 Step 1: Palm Geometry

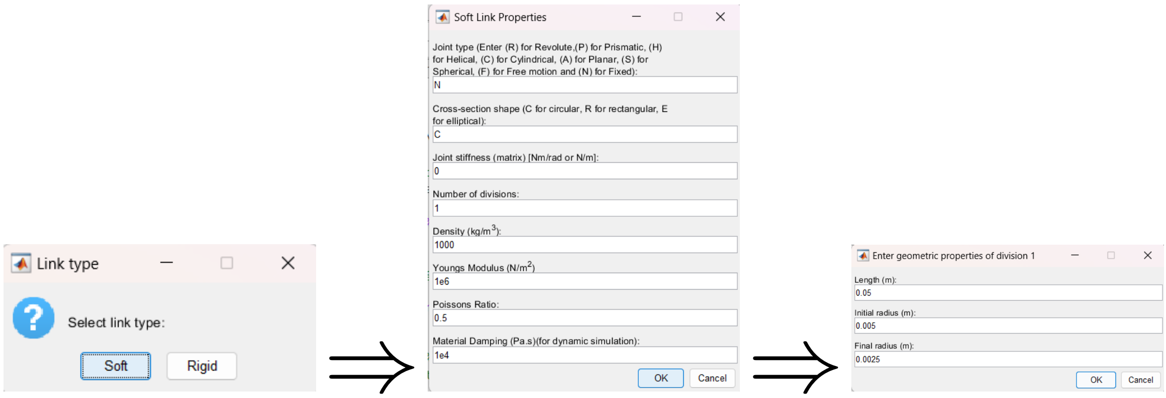
We begin by creating the rigid `Palm` Link. In the command window, type:

```
Palm = SorosimLink;
```

When prompted:

1. Select **Soft** as the Link type (yes, we can still define a stiff material under "Soft").
2. In the "Soft Link" window, change `C` (cylindrical) to `R` (rectangular).
3. Input the following geometry:
    - Length: 0.05 m

- Initial radius: 0.005 m
- Final radius: 0.0025 m



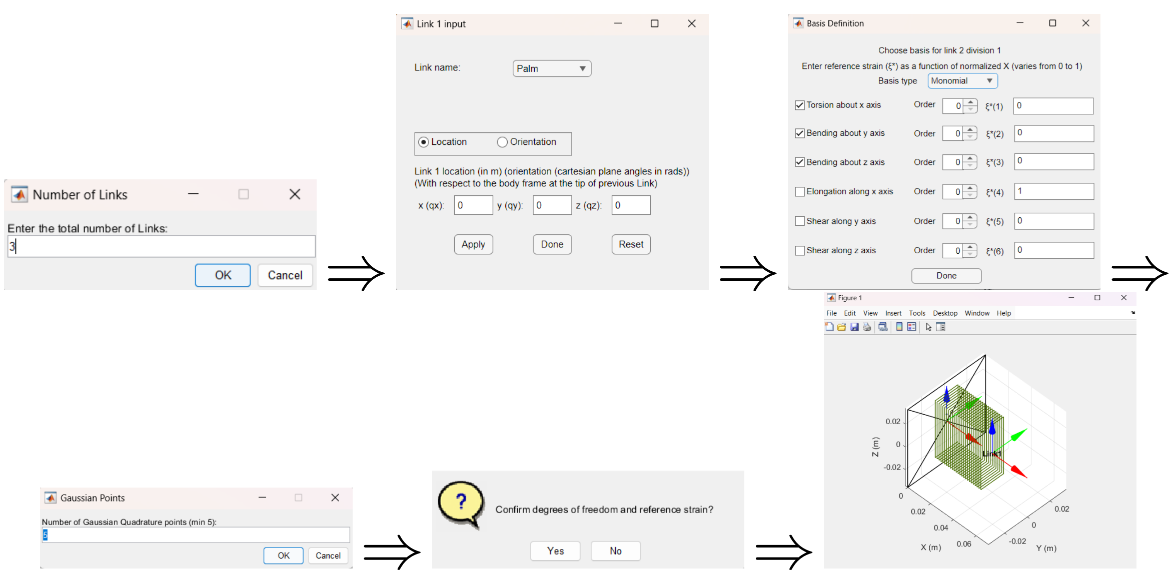
4.2 Step 2: Finger Geometry

Next, we build a `Finger` Link:

`Finger = SorosimLink;`

Follow similar GUI steps:

1. Choose **Soft** as the Link type again.
2. Retain `C` for a cylindrical shape.
3. Input:
   - Length: 0.04 m
   - Initial height: 0.02 m
   - Initial width: 0.05 m
   - Final height: 0.02 m
   - Final width: 0.05 m



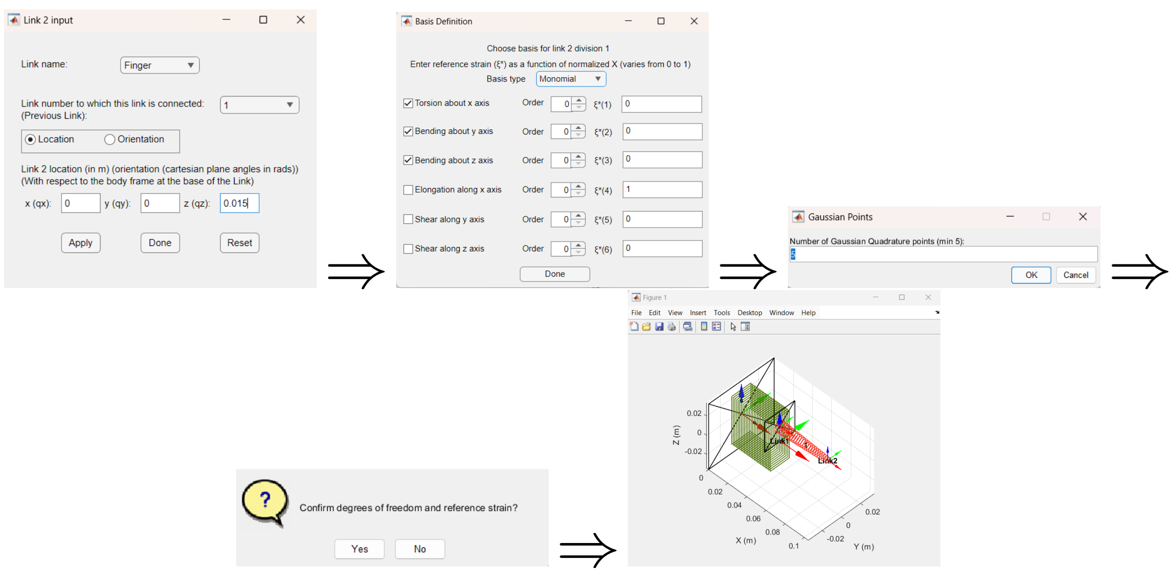
4.3 Step 3: Linking Palm and Finger

To combine the `Palm` and `Finger`:

```
Hand = SorosimLinkage(Palm, Finger);
```

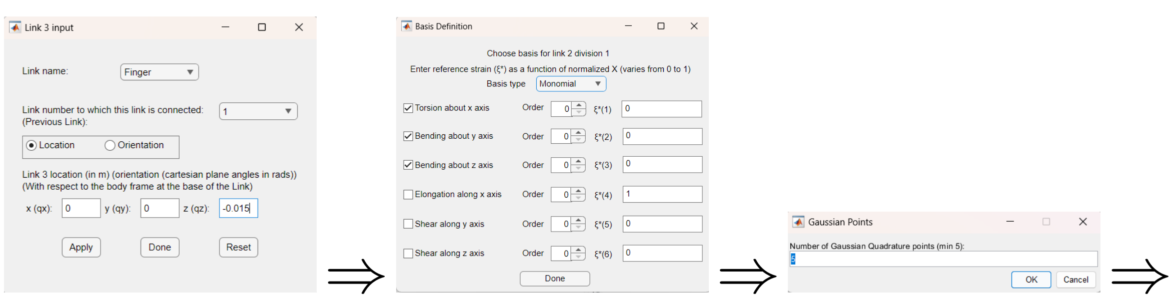
When prompted:

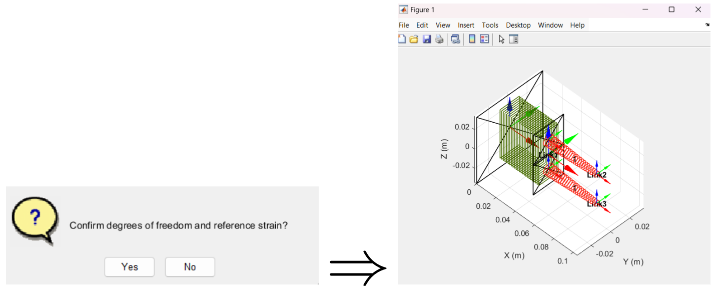
- Specify **3 Links**, since we plan to create one palm and two finger Links (the second finger repeats the first).
- For Link 1 Input, simply accept defaults and press `Done`, as the palm orientation remains as is.
- In the Basis Definition window, check the boxes for Torsion (x-axis), Bending (y-axis), and Bending (z-axis). Use order 0 for quicker computation, `Monomial` basis, and 5 Gaussian points.



4.4 Linkage Finger 1

A prompt will appear for positioning `Link 2`, named `Finger`. Select **Location**, then apply a translation of `+0.015` in z to move the finger above the palm. In the following windows, keep Torsion/Bending checked, order 0, `Monomial` basis, and 5 Gaussian points. When you confirm, the new link is added to the model.





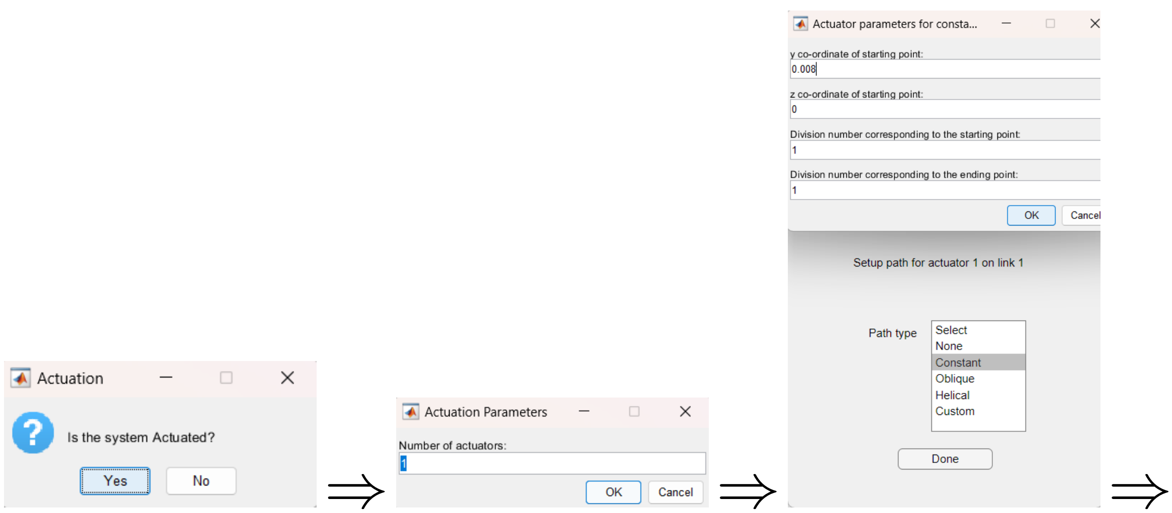
4.5 Linkage Finger 2

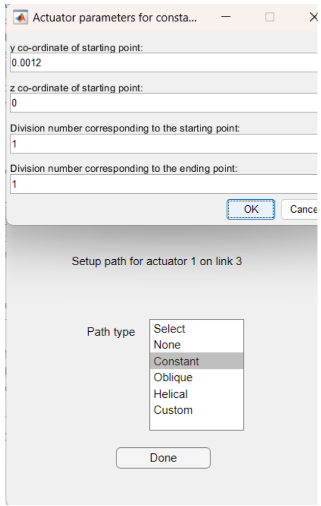
The process repeats for the second finger. Translate it by `-0.015` in z, then confirm the same basis settings. The second finger appears in mirror symmetry.

4.6 Actuator Placement

When prompted about actuation:

1. Select **Yes** for "System is actuated" and input `1` actuator.
2. For the palm actuator parameters, set $y = 0.008$, $z = 0$, and divisions = 1.
3. For both fingers, adjust the starting point's y-coordinate to $0.0012\,\mathrm{m}$.





4.7 Structure Stress and Dynamics

Once the geometry and actuators are set, you can solve for the structure's equilibrium state via:

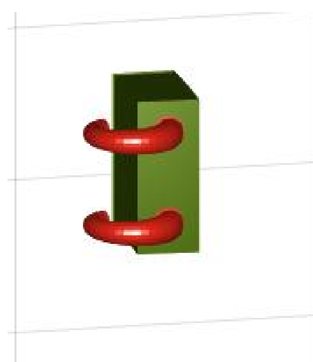
```
Hand.statics
```

To store results in a variable:

```
HandStatics = Hand.statics;
```

For a real-time or animated view of how the fingers pressurize:

```
Hand.dynamics
```



5 Advantages and Limitations

Soft robotic hands offer several benefits, but also come with a few drawbacks:

- **Advantages**:
  - Gentle handling of fragile objects

  - Compliance with uncertain geometries
  - Fewer moving parts compared to rigid grippers

- **Limitations**:

  - Slower response than electric motors
  - Reliance on an external air pressure source
  - Silicone materials can exhibit creep or fatigue over time

References

[1] Mathew, A. T., Ben Hmida, I., Armanini, C., Boyer, F., & Renda, F. (2023). *SoRoSim: A MATLAB Toolbox for Hybrid Rigid–Soft Robots Based on the Geometric Variable-Strain Approach*. IEEE Robotics & Automation Magazine, 30(3), 106–122. doi:10.1109/MRA.2022.3202488

[2] Mathew, A. T., Feliu-Talegon, D., Alkayas, A. Y., Boyer, F., & Renda, F. (2025). *Reduced order modeling of hybrid soft-rigid robots using global, local, and state-dependent strain parameterization*. The International Journal of Robotics Research, 44(1), 129–154. Harvard Soft Robotics Toolkit, `https://softroboticstoolkit.com/`.