Soft Robotic Gripper

Santhosh Kanaga Sabapathy

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1 Introduction

Soft robots have a number of advantages over rigid robots, including significantly more degrees of freedom and structures that enable the controller to offload morphological computation to the body [1]. Apart from this, the structural flexibility enables soft robots to continuously alter their shape as they behave, enabling them to perform tasks that rigid bodies are incapable of, such as amplifying or dampening vibrations, complying to uneven terrain, evolving to achieve specific tasks, and efficiently transferring stress. However, the field of soft robotics faces several challenges, including the lack of design automation and simulation tools [2].

Due to their numerous degrees of freedom and nonlinear geometric deformations, the dynamics of soft materials are computationally expensive and complicated to simulate. Standard nonlinear finite element solvers fall short of quantitatively simulating all deformations except for those of relatively small magnitude. To overcome this, Hiller, and Lipson [3] constructed a computationally effective system based on nonlinear relaxation and released Voxelyze, an open-source voxel-based soft matter physics engine, and VoxCAD, the resulting GUI. Voxelyze simulates elastic voxels using an internal lattice of distinct points connected by spring-like beam elements, resulting in realistic and potentially very large deformations when forces are applied.

In this report we design and analyse a soft gripper using the VoxCAD software. The designed gripper is simulated to conform to the objects shape and thus grasp two different objects with minimal control.The objects to grasp is defined as two cube with dimensions of x=2, y=2, and z=5 and x=3, y=3, and z=5. We will discuss the performance of the gripper for two objects through evaluating the total energy consumed per distance moved in the following sections.

2 Design and Materials

The soft gripper (Figure 1) was constructed using the same concept as a two-claw mechanical gripper, due to the fact that it generated forces parallel to the motion of the grip fingers hence resulting in a much dexterous and more versatile mechanism [4]. The soft gripper is made up of three different types of silicon, the material properties are mentioned in Table 1. Since the material used is silicon the Elastic Modulus for the materials are set to be 0.2 MPa. The Poisson Ratio is the ratio of a material's change in width per unit width to its change in length per unit length as a result of strain, and it is set to be 0.35 for all tree materials. The density is set to 0.95 Kg/m^3 for all materials. The only variable that is not constant between the three material is the Coefficient Of Linear Thermal Expansion(CTE) which is a material property that indicates how much a material expands when heated, more the CTE value the more the expansion and vice versa. The expansion and contraction for each material due to temperature change is shown in Figure 2.

Material 1 with the highest CTE value is placed in the gripper's corners to provide a more effective hold on the object. Materials 2 and 3 surround material 1 to provide damping and support when temperature variation is applied.

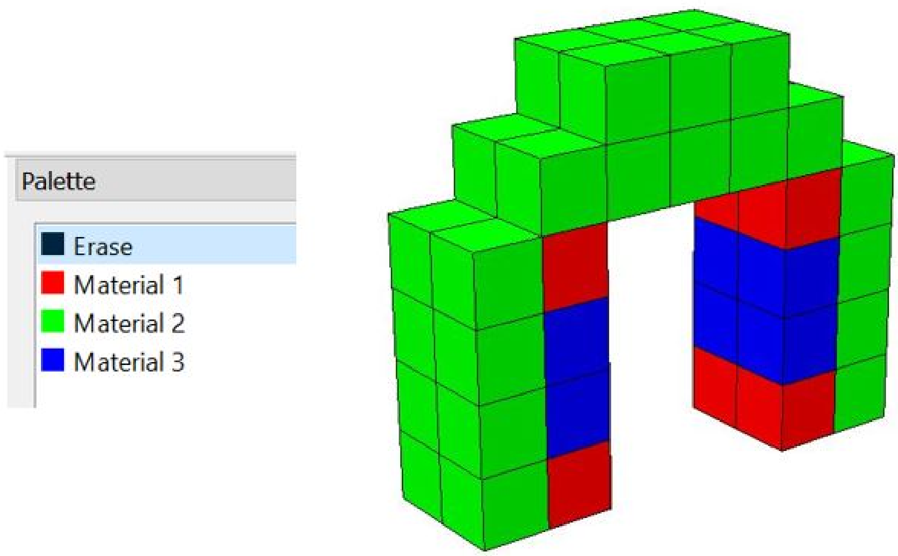


Figure 1: Design of Gripper

Table 1: Material Properties

Material Properties				
$Materials$	$ElasticModulus(MPa)$	$PoissonsRatio$	$Density$	$CTE(1/degC)$
Material 1 (RED)	0.2	0.35	950	0.06
Material 2 (GREEN)	0.2	0.35	950	0.01
Material 3 (BLUE)	0.2	0.35	950	0.02

Boundary conditions are applied to the gripper's top surface to ensure that it remains in position while lifting the object. Finally, the object is placed in between the gripper and the simulation is run. The temperature is varied this expands and contracts the voxels causing the gripper to grasp and lift the object.

3 Results

The performance of the gripper is determined by dividing total energy by the displacement. The maximum total energy for the cycles is shown in the trace sub-tab under the simulation. This data is downloaded in form of a text file and then imported to excel to plot graphs and

Expanded

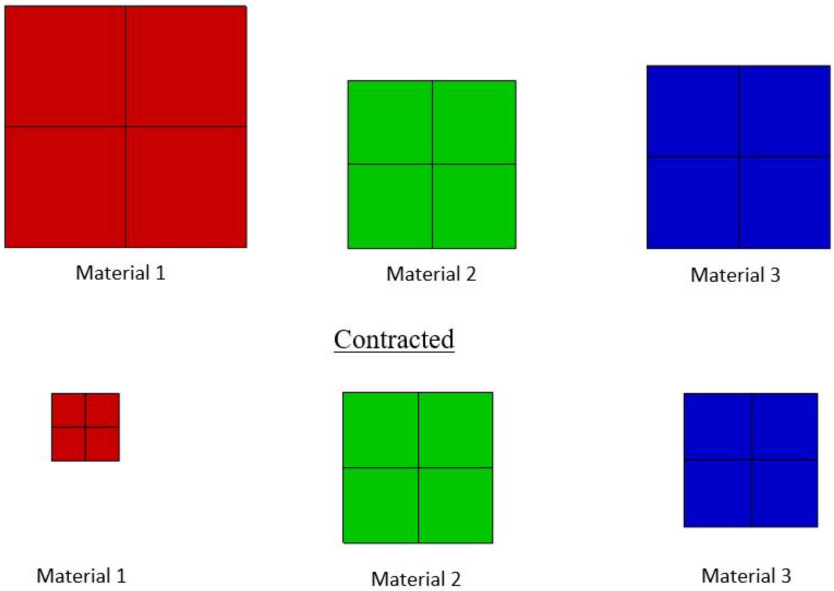
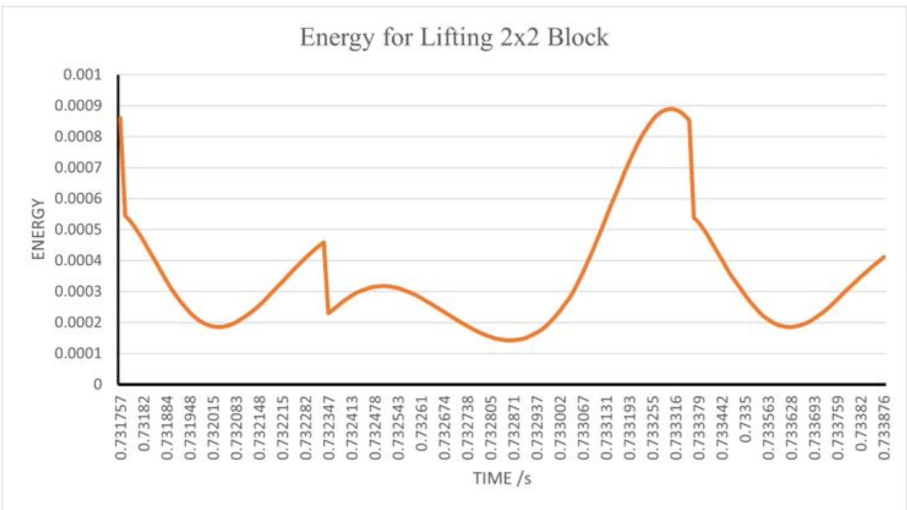


Figure 2: Expansion and Contraction of Materials

perform calculations. To estimate the displacement, the simulation is paused at the maximum movement the object is off the ground and measured as a percentage of one voxel size. Yellow voxels are places to aid with the measurement.

3.1 2 x 2 x 5 Object

From the data collected on maximum total energy we have plotted a graph for the 2x2x5 object. Using the graph we have calculated the average total energy required to move a 2x2x5 object as shown in Figure 3.



Average ENERGY	0.00034794
Total ENERGY	7.3729E-07
Max Peak ENERGY	0.00088967

Figure 3: Total and Max Peak Energy values for Lifting 2x2x5 object

The displacement of the 2x2x5 object is shown in Figure 4

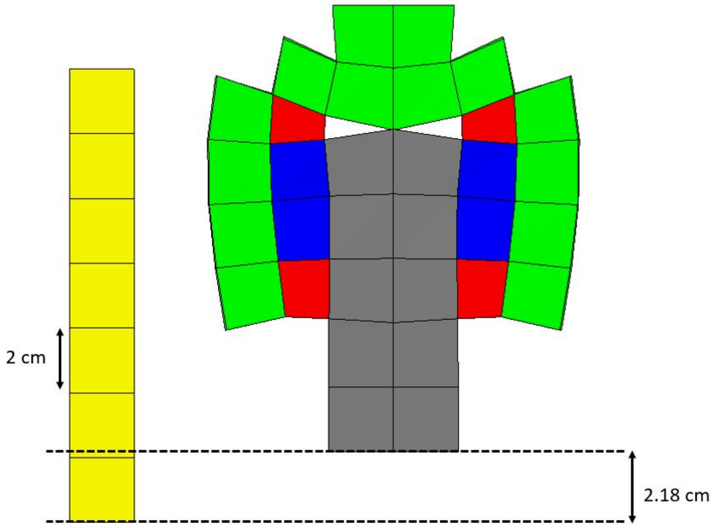


Figure 4: Displacement of 2x2x5 object

Now using the the average total energy and displacement the performance of the gripper is estimated to be **3.382E-5 energy unit/m**.

3.2 3 x 3 x 5 Object

From the data collected on maximum total energy we have plotted a graph for the 3x3x5 object. Using the graph we have calculated the average total energy required to move a 3x3 object as shown in Figure 5.

Average ENERGY	0.000206849
Total ENERGY	2.88347E-07
Max Peak ENERGY	0.000400106

Figure 5: Total and Max Peak Energy values for Lifting 3x3x5 object

The displacement of the 3x3x5 object is shown in Figure 6.

Now using the the average total energy and displacement the performance of the gripper is estimated to be **1.442 energy unit/m**.

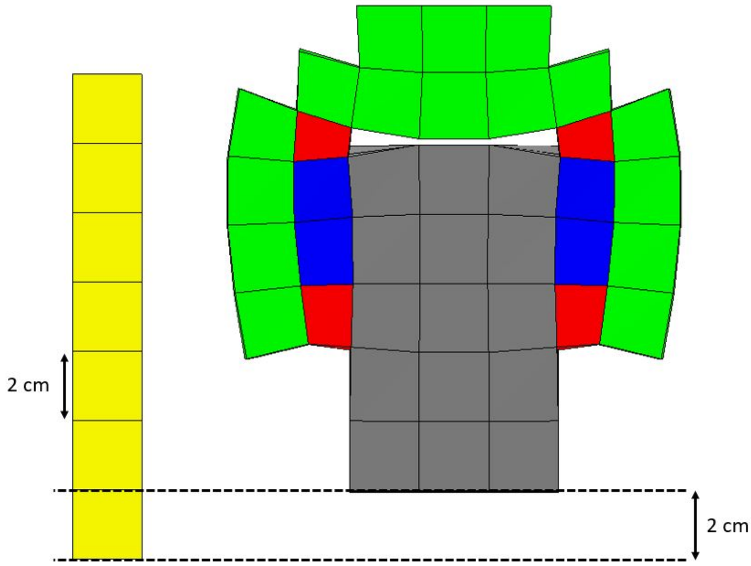


Figure 6: Displacement of 3x3x5 object

4 Discussion

The results indicate that the gripper performs better when a 3x3x5 object is used, as the average energy dissipated per displacement is less than when a 2x2x5 object is used. As a result, we can deduce that the larger the surface area of the object, the easier the gripper will be able to lift it. The current proposed design makes use of eight vovels (RED) with a high CTE value; these are the primary voxels that provide the lifting movement. Performance can be improved by increasing the CTE values, allowing the objects to have a much greater displacement and thus perform better.

The VoxCAD software is a simple to understand and use program, but the issue is that it frequently crashes and does not save open files automatically, forcing us to redo the work from the beginning. VoxCAD requires a software update to address these issues, as the most recent update occurred in 2012. Another disadvantage of VoxCAD is the inability to perform stress and strain analysis; in this case, we could have evaluated the stress and strain around the gripper's corners to determine whether the design is appropriate. However, because no other application with a proper graphical user interface exists for simulating soft robots, I would definitely use VoxCAD for future projects.

References

[1] H. Hauser, R. M. Füchslin, and R. Pfeifer, "Opinions and outlooks on morphological computation," 2014.

[2] H. Lipson, "Challenges and opportunities for design, simulation, and fabrication of soft robots," *Soft Robotics*, vol. 1, no. 1, pp. 21–27, 2014.

[3] J. Hiller and H. Lipson, "Dynamic simulation of soft multimaterial 3d-printed objects," *Soft robotics*, vol. 1, no. 1, pp. 88–101, 2014.

[4] R. Alqasemi, S. Mahler, and R. Dubey, "A double claw robotic end-effector design," *Recent Advances in Robotics*, pp. 1–6, 2007.