Developing General-Purpose Robotic Hand Systems

By Marwa El Diwiny

Nature is a source of inspiration when it comes to designing systems and machines. However, evolution is not always ideal. It has its own limitations, and its goal is to adapt to the environment. When it comes to designing a robotic hand, what are the directions we have to focus on? What are the missing pieces for designing a dexterous robotic hand that could perceive and manipulate different objects' shapes at fast response time and low-power energy?

Should we pursue a bio-inspired, biomimicry, or biohybrid approach? Or should we aim for something beyond that? Since we mention evolution isn't always ideal, the question is whether we can and should design a robotic hand that functions beyond the human hand and natural evolution. That depends on what kind of tasks and environment in which the robotic hand is going to work. One aspect to consider is designing a robotic hand that has redundancy. Imagine if the robot lost fingers: Could we design a robotic hand that can adapt to this damage or create new methods to handle objects with the new damaged hand morphology?

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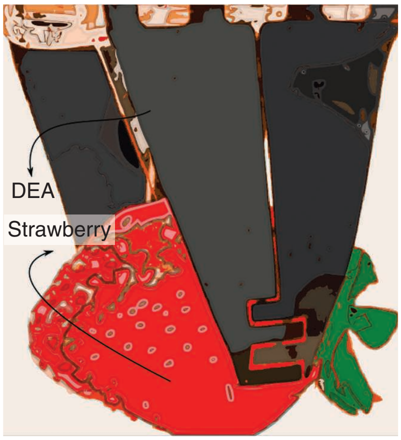

An example of a soft robotic hand.

Hoping to address some of these research questions, the Yale OpenHand Project is an initiative with the goal of advancing the design of robotic hands. The project focuses on creating an open source platform consisting of different models of existing robotic hands so that researchers can rapidly iterate and build upon previous designs, many of which don't mimic the design of a human hand.

When we look at the human hand, it is composed of rigid, soft, and fluid elements. However, the traditional design for robotic hands primarily incorporates rigid components, such as motors, tendons, and cables, and is sometimes challenging to efficiently assemble with sensing capabilities. Recently, engineers have explored the field of soft robotics (Figure 1). When it comes to designing soft robotics, one of the important questions is: How we can design materials that can actuate and replace servomotors? Should the focus be on developing passive materials that can be actuated pneumatically or cable-driven? Or on smart materials that can actuate and sense simultaneously?

Soft robotic hands can shift the paradigm since you don't have to deal with a control policy to adjust different objects sizes, as shown in Figure 1. Dielectric elastomers (DEAs) and electroadhesion methods developed by Prof. Herbert Shea's group at Ecole polytechnique fédérale de Lausanne (EPFL) demonstrated that DEAs grasp different objects and sizes and can adapt automatically. However, there is a tradeoff when it comes to soft robotics hands using smart materials like DEA, as it requires high-voltage sources to produce sufficient forces. The robotics community is working to solve this problem and reduce the energy supplied while maintaining reliable, safe, reproducible, and

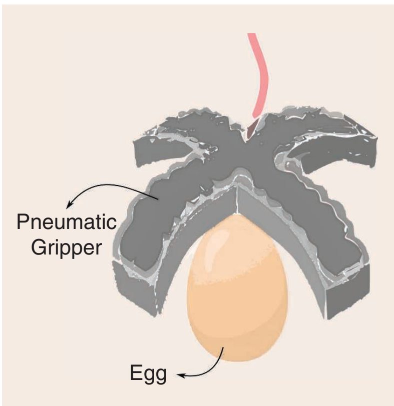

Figure 1. Illustration of a soft gripper based on DEAs and electroadhesion, similar to the one from Prof. Shea's group at EPFL.

desirable mechanical performance and speed.

An interesting emerging research direction in this area is the development of modeling theories and sim2real for open-ended environments. This leads to the question: How we can design general-purpose robotic hand systems? To begin to address this issue, OpenAI developed a method called Automatic Domain Randomization that generates a diverse environment in a simulation, which frees them to develop models about the environment and transfer the learned neural network in simulation to the real world. However, this approach has received criticism since it doesn't allow the robot to figure out things on its own in the open-ended environment. While many steps are being taken to move forward and shift the paradigm, maybe we are still not there yet.

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