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JELLYPHANT: A SOFT, ELEPHANT TRUNK-INSPIRED ROBOTIC ARM THAT CAN GRAB OBJECTS

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YOUNG REVIEWERS:

ATTE
AGE: 14

HARRY
AGE: 15

JONATAN

Many animals, such as elephants and octopuses, can change the stiffness of their limbs and trunks. This allows them to move around their environments as well as grab things and move them around. We would love our soft robots to be able to do the same! We can do this using a technique called jamming, in which the materials in the trunk are packed together to change its stiffness. Jamming has been used in all sorts of soft robots, like robotic hands for gently picking up fruits and vegetables, exoskeleton suits, and surgical instruments. In this article, we will talk about the three main types of jamming that are used in soft robotics, and show how they can be used in real life. And guess what? At the end of the article, we will describe the use of jamming to build a robotic elephant trunk that can change its stiffness, just like a real elephant's trunk!

WHAT ARE SOFT ROBOTS?

SOFT ROBOTICS

An area of robotics that study the design, creation, and control of robots made of flexible materials.

Soft robotics is a field in which robots are made from soft materials instead of hard ones. Soft robotics scientists use things like silicone, rubbers, and gels, which let robots change shape similar to the way living creatures can bend and stretch. Think of Baymax, the friendly inflatable healthcare robot in Big Hero 6 — that is a soft robot!

Some of the most useful soft robots are based on real animals. Soft robots therefore need to copy what real animals can do. This means being flexible so they can move well, pick up objects, and interact with the world. For example, an octopus tentacle or an elephant trunk does not have bones but can become stiff when needed. Think of an elephant picking up food with its trunk (Figure 1)[1]. An elephant's trunk has over 90,000 bundles of muscle fibers, which let it control the trunk precisely to grab food [2] and use tools (like a branch) to scratch its body [3]. The complex network of muscles in the trunk work together by relaxing and contracting (shortening) to produce forces that move the trunk. The tips of their trunks have finger-like features, which they can stiffen to grab onto food before bringing it to their mouths [4]. In soft robotics, we use a method called **jamming** to allow robots to harden themselves, similar to what elephants do with their trunks.

JAMMING

A process which enables controllable stiffness in soft robotics.

Figure 1

Figure 1

Elephant trunks are normally flexible, but they can also stiffen to grab onto food or other objects.

A BRIEF INTRODUCTION TO JAMMING

Jamming allows robots to both change shape and change their stiffness. The robot can be unjammed, which makes the robot flexible for moving and exploring, or jammed, which makes the robot rigid and great for gripping. Next, we explain how the most popular jamming methods work. Then we will put theory into practice and describe how to make a soft elephant trunk!

Granular Jamming

Imagine you are in the supermarket, and you reach for a bag of beans. The vacuum-packed bag feels hard and rigid, with all the beans packed closely together in one solid block. Beans and grains sold in supermarkets are often vacuum sealed to ensure a longer shelf life. This is done by removing the air inside the package to prevent the growth of bacteria and to reduce the size of the package for transport and storage.

After buying the beans, you decide to tear the bag open. The seal holding the vacuum is broken and air returns into the bag. The bag feels a lot more compressible, and the beans can move freely, shifting around inside the bag when you squeeze it. This phenomenon is known as **granular jamming**, in which particle materials such as coffee grounds, beans, rice, gravel, and sand can reversibly change from a fluid-like state to a solid-like state when a pressure is applied [5]. When the granular substances can flow freely, the robot is soft and flexible. However, when a vacuum pressure is applied, these grains are compressed by a membrane and have nowhere to move, and hence they form a solid structure.

GRANULAR JAMMING

A process whereby granular particles in membrane pack-together and transition from a fluid to solid-like state after application of a vacuum.

LAYER JAMMING

A process whereby a stack of planar layers or sheets enclosed in a membrane are compressed together after application of a vacuum.

Layer Jamming

You can imagine **layer jamming** like making a sandwich! Instead of using normal bread, we use flat materials like stacks of paper or plastic sheets. We put these layers in an envelope or bag, similar to wrapping up a sandwich. If you do not wrap your sandwich tightly, the ingredients inside can spill out, so the wrapping needs to be tight enough to hold them in place. That is what we do in layer jamming—we compress these layers together using a vacuum, to create a rigid structure and stop the layers from sliding against each other. When unjammed (at normal pressure), the layers are free to slide and move against each other, because there are still air gaps between the layers (Figure 2). However, once a vacuum is applied to jam the structure, air is sucked out and the envelope forces the layers together, compressing the "sandwich" structure. The space between layers, which was previously occupied by air, shrinks down, and the layers pack tightly together. As more vacuum pressure is applied, the layers become closer and closer together, and the area of contact increases. The **friction** between the layers therefore prevents the layers from sliding against each other, effectively immobilizing the entire structure. The structure therefore becomes entirely rigid, like a solid block, which is difficult to bend.

FRICTION

A force that resists motion of two surfaces sliding against each other.

Fiber Jamming

Fiber jamming structures use of bundles of fibers enclosed within a cylindrical envelope (Figure 2). They are a bit like muscle fibers wrapped together by connective tissue sheaths. These fibers could be made of materials such as plastic, silicone, waxed cotton, and even leather [6]. When unjammed (at normal pressure), fibers in the bundle are free to slide against each other. However, when a vacuum is used to remove all the air, these fibers are forced together by the envelope, which increases contact area and friction between the fibers, and consequently increases their stiffness. This is similar to how muscles

FIBER JAMMING

A process whereby a bundle of fibers in a membrane transitions from a flexible to rigid beam after vacuuming.

Figure 2

The three main jamming methods used in soft robotics.

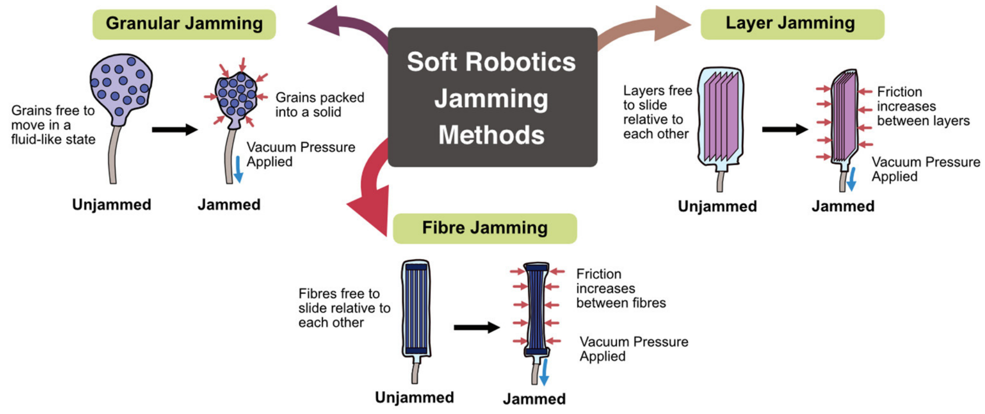


Figure 2

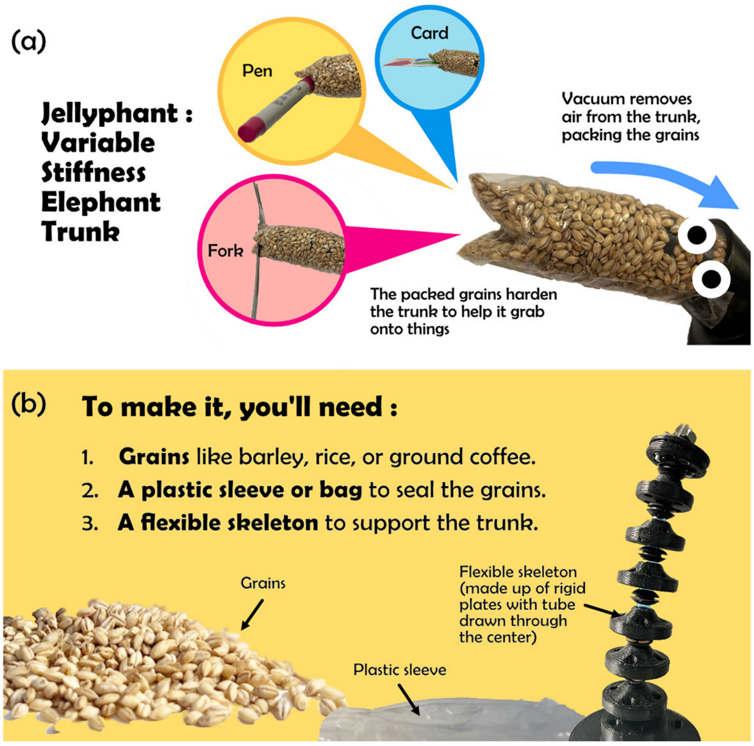
in the human arm tighten up and stiffen when we lift something heavy.

JELLYPHANT: A GRANULAR JAMMED ELEPHANT TRUNK

Now we will explain how we built a simple, soft robot based on jamming (Figure 3A). In this case, we used granular jamming to build a soft robot that mimics some characteristics of an elephant's trunk. Jamming has previously been used to make trunk-like robots with the freedom to move in many directions [7–10]. Additionally, granular-jamming systems can often be replicated at home, using easily available grains and a bit of creativity (or 3D printing if you are lucky enough to own a printer!). The membrane can be a balloon or a few wraps of cling film or Glad wrap.

Because we could call this artificial trunk whatever we wanted, we decided to call it Jellyphant! Jellyphant was constructed with a flexible skeleton, barley grains, and a plastic sleeve (Figure 3B). Unlike real elephant trunks, which do not have any bones or cartilage, some soft robots still need structural support to avoid a phenomenon called buckling (unwanted bending). Soft robots are often prone to buckling when they try to support weight. As in the Jellyphant, a support structure like a flexible skeleton is often required to maintain the overall shape of the soft robot, to make sure its body does not become too floppy. The skeleton is made up of rigid plastic plates with spacers and a vacuum tube drawn through its center. The vacuum tube is connected to a home vacuum, through a small nozzle. A plastic sleeve was then stretched over the skeleton and filled with barley grains.

In its unjammed state, Jellyphant is soft and flexible, as the grains can move and shift within the membrane and around the skeleton plates. Jellyphant can be easily deformed with little force in this state. However, when the vacuum is turned on and the structure is jammed,



To make it, you'll need :

1. **Grains** like barley, rice, or ground coffee.
2. **A plastic sleeve or bag** to seal the grains.
3. **A flexible skeleton** to support the trunk.

Figure 3

Figure 3

(a) Jellyphant, an elephant trunk-inspired soft robot capable of grabbing household objects, such as a fork, pen, and card, through granular jamming. **(b)** Jellyphant construction materials.

the structure becomes rigid and can grab onto objects. Figure 3A shows Jellyphant grabbing onto household items like a fork, pen, or a piece of card! This is possible because, by jamming, the grains are packed tightly together around the object, and they lock the object in place.

CONCLUSION

In a variable stiffness robot, a flexible state is helpful for delicate tasks, keeping the people around the robot safe, and preventing damage to the robot. On the other hand, a rigid state is helpful when the robot needs to lift heavy things and stay in a specific shape. In summary, soft robots are incredibly versatile, and can change their shapes and functions more easily than traditional, rigid robots. In the future, the Jellyphant could be scaled up to create a bigger robot, which might be used to help in medical surgeries. Because these robots are soft and flexible, they can easily move through tight spaces and are less likely to harm the human body. These kinds of robots a called **continuum robots**, and they can be controlled using wires or cables connected to motors, kind of like a puppet on strings.

CONTINUUM ROBOTS

Long and continuous robots, with many joints to allow them to bend and twist like animals.

Soft robotics is an exciting field that is reshaping the way we understand, build, and interact with robots, and it has the potential to improve human lives. The future of soft robots looks pretty "solid"!

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as a potential conflict of interest.

YOUNG REVIEWERS

ATTE, AGE: 14

Hello my name is Atte. I am 14 years old. I like Fortnite because I can full box the enemies and see them running to my walls and shout full boxed 200! I like to play football. I love technology and innovation and always want to learn more about it.

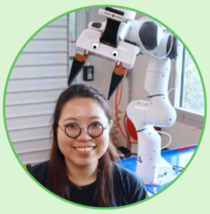
HARRY, AGE: 15

I am Harry, currently 15 years old. I enjoy a wide range of sports and games, and I am extremely interested in the different fields of science, especially biology and the biomedical sector, where I can see how applications of biochemistry and genetics are able to effectively solve real world problems!

JONATAN

I like to do sports and I am really interested in technology. For example, I have been building a couple of computers and now I have my own one. I am also really into video gaming, AI technologies, and robotics. Maybe I could make something useful in the future for the environment.

AUTHORS



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