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ROBOTS THAT TICKLES INTO DEEP SEA

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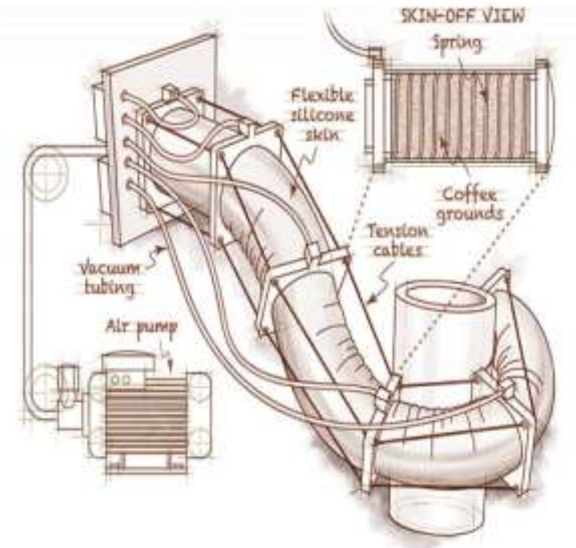
ABSTRACT---Humans can't safely scuba dive beyond 330 feet (100 meters) of water, so it's important that Squishy Fingers can dive deeper and retrieve hard to reach creatures, Wood told National Geographic. So far, the joystick-controlled squishy robot has successfully completed a dive at about 0.6 miles (1 kilometer) depth, but the researchers hope to design an upgrade that can reach 3.7 miles, or 3,168 feet (6 km). "Squishy Arms" robot that has a greater capacity to collect deep-sea organisms. Researchers have designed the first application of soft robotics for the non-destructive sampling of fauna from the ocean floor. Their recent expedition in the Red Sea successfully demonstrated the new technology, which could enhance researchers' ability to collect samples from largely unexplored habitats thousands of feet beneath the ocean surface, areas that scientists believe are biodiversity hotspots teeming with unknown life. The soft grippers also could be useful in underwater archaeology.

I. INTRODUCTION:

It is a new soft and squishy robot and it's ready for some serious underwater business. Meet "Squishy Fingers," a new remotely operated vehicle designed to delicately grab and take samples of coral study in the journal Soft Robotics, will collect specimens from deep underwater reefs without damaging the corals' fragile bodies. Until now, coral researchers used clunky and rigid ROVs originally developed for the oil and gas industries. These vehicles stiff arms were made to do heavy work, such as turning pipes off and on, rather than plucking tiny organisms off a coral reef. According to the Researchers the arms can generate lifting and gripping forces up to 500 lbs.-force [227 kilograms-force] and are not optimal for delicate specimen collection. Enter soft robotics expert Robert Wood inspiration from sea creatures, such as the tube worm and the snake (which can wrap itself about things). The final fingers are largely made of memory foam, silicone rubber, fiber glass and Kevlar fibers.

II. STRUCTURE OF SQUISHY ROBOT:

Soft robotic gripper is attached (lower left) to the remotely operated vehicle (ROV) as it is lowered into the Red Sea for a test dive. Credit: Kevin Galloway, Wyss Institute at Harvard University. During a 2014 talk on his exploration of deep-sea coral reefs, Baruch College marine biologist David Gruber showed a video of clunky robotic hands collecting fragile specimens of coral and sponges from the ocean floor. Harvard engineer and roboticist Robert J. Wood was in the audience—the two scientists were being recognized as Emerging Explorers by the National Geographic Society—and a lightbulb went off. The rigid Jaws of Life-type grippers designed for the oil and gas industry that were totally overpowered. In the months that followed, the pair collaborated to design, fabricate, and test soft robotic grippers for deep-sea collection of fragile biological specimens. Their recent expedition to the Gulf of Eilat in the northern Red Sea, a unique marine ecosystem that houses one of the world's largest and most diverse coral reefs, marked the first use of soft robotics for the non-destructive sampling of fauna from the ocean floor. The new technology could enhance researchers' ability to collect samples from largely unexplored habitats thousands of feet beneath the ocean surface, areas that scientists believe are biodiversity hot spots teeming with unknown life. The soft grippers also could be useful in underwater archaeology.



III. DESIGN OF THE ROBOTS:

Designing involves two types hands to replace the ROV's factory-furnished metal gripper, each capable of gently recovering objects of different sizes and shapes, inspired by the coiling action of a boa constrictor, can access tight spaces and clutch small and irregular-shaped objects. Then a bellows-style model, features opposing pairs of bending actuators. To facilitate rapid in-field modification and repair, the team emphasized simple construction, inexpensive materials and a modular design. This meant they could try multiple configurations and make them in quantity. Harvard's Office of Technology Development has filed a patent application on the team's method for the manufacture of bellows-type soft actuators. The method is scalable, opening up a wide range of commercial, biomedical and industrial applications for this type of actuator.

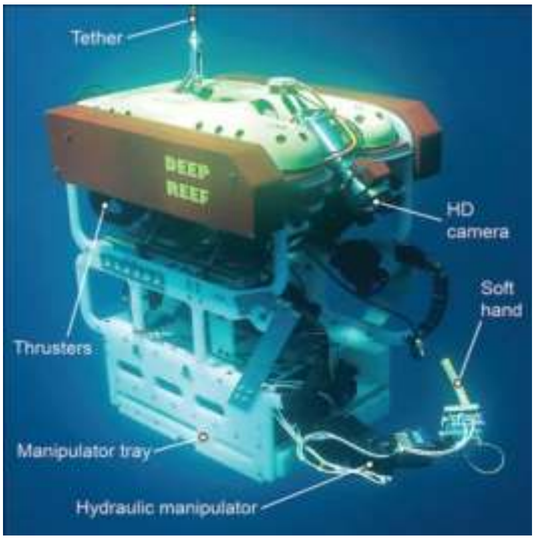
To approximate likely specimens, brought the assortment of vegetables—celery, radishes, carrots and bok choy—tied them to a metal grate, and dropped them into a test tank at the University of Rhode Island. After exhaustive tank tests, the devices were put through their paces at depths greater than 800 meters off the Rhode Island coast.

IV. TESTING OF SQUISHY ROBOTS:

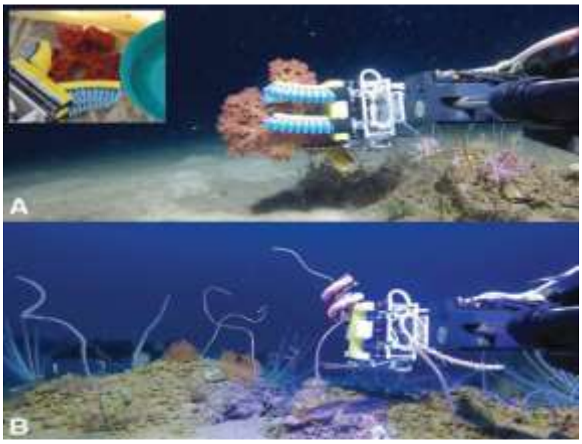
Field testing took place in the northern Red Sea in May 2015. There were conducted more than a dozen dives ranging from 100 to 170 meters (558 feet—or as deep as the Washington Monument is tall). Most dives involved "catch-and-release" maneuvers to test system performance. But the manipulation of the grippers to retrieve samples of delicate red soft coral, as well as difficult-to snag coral whips, bringing them to the surface undamaged in the ROV's cargo tray. Simply collecting hard-to-harvest samples isn't the end game. Researchers like Gruber hope to apply these techniques to conduct in situ measurement of organisms, and eventually, gene expression and transcriptomic analysis. Conducting this work on the seabed floor rather than bringing samples to the surface, means that organism are not exposed to stress from 4dchanges in temperature, pressure, and light and there is less disturbance to the reef system. On the robotics side, Wood has a list of performance enhancements he hopes to pursue. Current-generation ROVs rely exclusively on visual feedback—a live video feed from an onboard camera - but he'd like to add tactile feedback, applying his lab's expertise in soft sensors to let an operator actually "feel" what the gripper is touching. He is also interested in experimenting with bilateral, rather than single-arm manipulation to achieve improved dexterity. Finally, the team wants to go deeper—literally. During the Red Sea dives, the system operated at depths under 200 meters. They envision conducting field work in unexplored worlds 6,000 meters below the surface.

V. WORKING OF THE ROBOT :

The best part about scuba diving is being able to see all kinds of amazing animals, plants, animals that looks like plants, and plants that look like animals. The worst part about scuba diving is not being able to squidge any of these things it is occasionally important for sea creatures to be aggressively groped in the name of science. Researchers at Harvard have endowed undersea robots with some squishy robotic fingers that allow them to non-destructively collect underwater specimens from under the sea. Custom-made deep sea sampling robots and submarines use what are basically underwater vacuum cleaners to suck up fragile samples, which works pretty well. For economy-class ROVs, you're usually stuck with leftover robotic arm and hand hardware from the oil and gas industry.



The biggest design challenge was a lack of precise specifications. They weren't designing a robotic arm to repetitively attach doors to car bodies in an auto assembly plant. The team had no way of knowing the size, shape, or stiffness of the objects they would be sampling on the ocean floor. To approximate likely specimens, they visited the produce aisle and brought back an assortment of vegetables – celery, radishes, carrots, bok choy – tied them to a metal grate, and dropped it into a test tank at the University of Rhode Island. After exhaustive tank tests, the devices were put through their paces at depths greater than 800 meters off the Rhode Island coast.

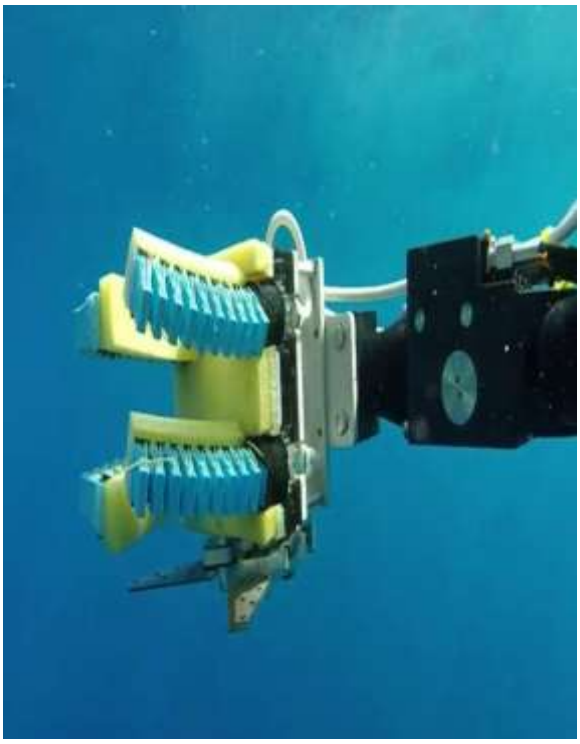


The grippers themselves work well enough, but the sampling technique could be improved, since it's just oceanographers peering at monitors and remotely groping at stuff. The soft grippers can incorporate haptic feedback, which would help this non-destructive sampling be significantly less destructive. The study was funded by the National Geographic Society, and in future experiments the researchers hope to test dual arms on robots that can go down 20,000 feet under the sea.To study deep-sea corals, scientists have to collect small samples in order to examine DNA and other characteristics. This presents a problem: The animals grow beyond the reach of human divers. A remotely operated vehicle could dive that deep, but most robotic arms are too powerful and awkward to handle the delicate coral without damaging it. Their squishy robotic hands can gather coral samples more delicately than robots, and in places humans can't reach. Developed with support from a National Geographic Innovation Challenge Grant, the hands were first tested in tanks in March 2015 and then taken to the Red Sea in May. After a successful expedition, Wood and Gruber hope the technology may have even broader applications. We spoke with Wood, who also founded the Micro-robotics Lab at Harvard University, about the innovation, which is also described in a new paper in the journal Soft Robotics.

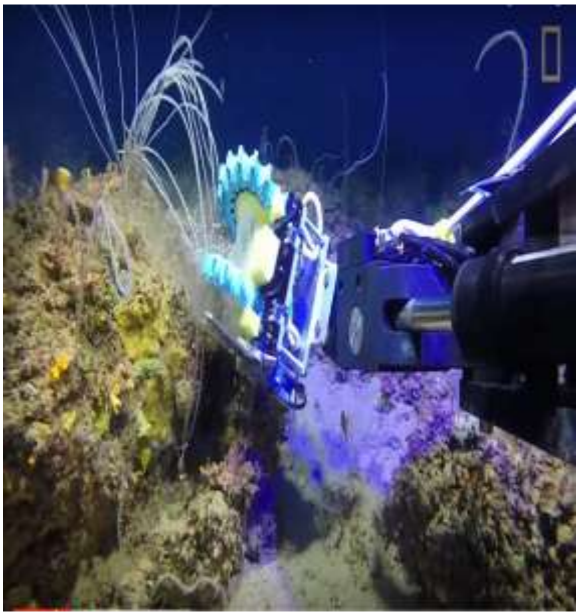
VI. CHALLENGES OF WORKING UNDER WATER :

Deep and mesophotic coral reefs, as well as other deep sea ecosystems in general, are hotspots for unique biological diversity and genetic adaption. Although the existence of coral reefs down to 128 m was noted by Darwin in 1889it was not until the recent advent of technical diving, remotely operated vehicles (ROVs) and submersibles that researchers have been able to access and examine them *in situ*. In the few decades since, the field of mesophotic reef biology has expanded significantly with the increased access. Concurrently, the scientific community is presented with estimates that 19% of the world's shallow coral reefs have recently been lost, with a further 35% expected to disappear in the next 40 years. However, reefs occurring at depths greater than 30 m are somewhat buffered from human and natural disturbances and represent a potential refuge. These, deep reefs remain dramatically under studied compared to other highly diverse habitats. Although major advances have been made in accessing this environment, biological collection and the molecular biology and biochemical analysis of these habitats are still highly challenging. Intervention almost always involves a robotic manipulator, and the industrial nature of existing technology causes a major challenge for researchers valuing delicate collections. Deep reefs are known to have slow growth rates and experience seasonal bleaching events, so it is of interest for scientists to take steps to study these ecosystems with as great care as possible. Commercially available deep sea manipulation systems are designed to perform heavy mechanical work (i.e., construction or pipeline maintenance) and are not geared to perform delicate tasks, such as the collection of fragile biological specimens. For example, high-end systems incorporate sophisticated force feedback to minimize damage from their rigid jaws.

These arms can generate lifting and gripping forces up to 500 lbf and are not optimal for delicate specimen collection. Furthermore, more economical grippers typically lack force feedback and an intuitive user interface. Hence, many biologists work to modify research design and collection methods and tools as best possible to suit their needs and consider getting the sample to the surface, regardless of condition, as a success. Recently, the field of soft robotics has erupted as an alternative to hard-material robotics, providing a safer alternative for robots to interact, in proximity, with living organisms. By using soft materials instead of more traditional metals and hard polymers, robotic components can closely mimic the properties of natural systems. This can allow marine and molecular biologists to delicately handle an organism while in its natural setting and perform more complicated tasks while on location underwater. It's a composite, made mostly of silicone rubber, with some fiberglass and Kevlar fibers for reinforcement. We pressurize it with seawater to turn it on and off and so we can get it to close like fingers or curl like a snake. We made an array of different shapes. It has to be robust because the consequences for failure are worse, since you have to bring the whole thing up and start over if you have a problem. The rubber-like material itself is basically indestructible. You can freeze it, run your car over it, light it on fire, and it doesn't matter. They are also very cheap, costing around $2 each. We took 20 or 30 in a duffel bag on the expedition to test them out. They worked very well. We used them to collect samples on deep reefs, down to about 150 meters (500 feet). Previously, we had tested the fingers down past 800 meters (2,600 feet) and that was no problem. Human beings can't really scuba dive past 100 meters (330 feet), so we wanted to push it beyond what people are capable of on their own.

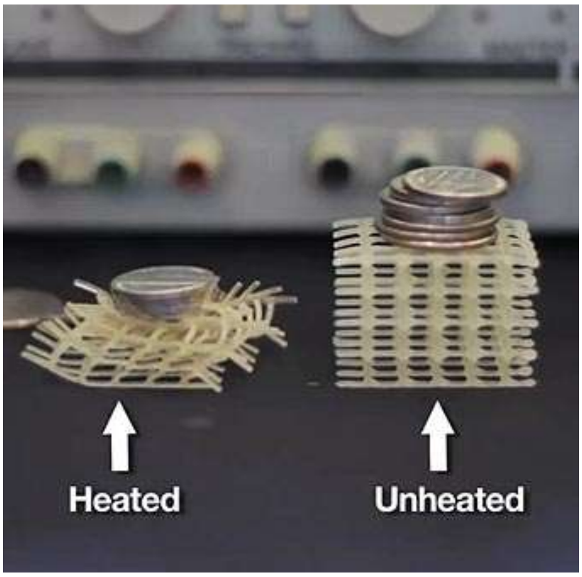


VII. APPLICATIONS OF SQUISHY ROBOTS :



There are other underwater applications, such as archaeology, in which it's important to be gentle, perhaps even more so. There are also above-water applications, such as agriculture and biological sampling, in which you need to handle delicate materials but you don't want to spend a lot of time setting something up. You want to turn it on, grab it, and go. Examples could include picking fruit or leaves. An international collaboration has developed a material made from wax and foam that is capable of switching between hard and soft states. Its developers say it could result in low-cost robots that can squeeze through small spaces and then regain their shapes. The material could be used to build deformable surgical robots that could move through the body to reach a particular point without damaging organs or blood vessels along the way. It was developed by Massachusetts Institute of Technology mechanical engineering professor Anette Hosoi and her former graduate student, Nadia Cheng, alongside researchers at the Max Planck Institute for Dynamics and Self-

Organization in Göttingen, Germany, and Stony Brook University in New York.



squishy robot fingers. After learning that deep-diving robots often damage corals while taking samples for research, a roboticist realized that advances in "soft robotics" could help. Along with a marine biologist, he designed squishy gripping hands made of silicon rubber that inflate when pumped full of seawater, described in a paper in Soft Robotics. This invention allowed the researchers to safely collect coral samples at a depth of 2600 feet—8 times deeper than a scuba diver can reach. The technology may also be useful for underwater archaeology, where a soft touch could make all the difference.

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