Giving robots more muscle can help them lose weight

Bioinspired muscle design offers expanded robotic applications

By Terry Grant, ASU News
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The new heavyweight champions of robotics will be lighter, smaller and disconnected from a power source.

Researchers at Arizona State University are developing bioinspired robotic “muscles” that will enable robots to operate in boiling water, survive abrasive surfaces, bypass impediments that keep their motorized counterparts benched, and still lift up to 100 times their own weight.

Eric Weissman, a doctoral student in ASU’s Robotic Actuators and Dynamics Lab, was the lead author of a paper, “Versatile Artificial Muscles by Decoupling Anisotropy,” published on March 27. Lab Director Jiefeng Sun, an assistant professor at the School for Engineering of Matter, Transport and Energy in the Ira A. Fulton Schools of Engineering at ASU, was a co-author.

“Essentially, we developed a novel artificial muscle that mimics real muscles,” Weissman said. “While bioinspired muscles previously existed, we have made them more versatile, more lightweight and more powerful.”

Today’s quadruped robots, for example, are significantly limited in mobility because they are usually motor-based and tend to be very heavy and less flexible.

Weissman’s helical anisotropically reinforced polymer (HARP) actuators, on the other hand, mimic natural muscle contraction and expansion. These actuators are flexible, very lightweight and quiet for use in soft robotics — providing muscle that can lift far more proportionally than electrical-driven counterparts of the same weight.

“These muscles look like little tubes that are coiled like cavatappi, which is a hollow, ridged, corkscrew-shaped pasta,” Weissman said. “When we inflate them by applying a little bit of air, they expand and contract.

“Because of their versatility and adaptability, we were able to reduce that pressure requirement significantly, which enabled us to make a robot that could walk independently without any external power supply, carrying everything it needs on itself.”

The team's research goes beyond designing bioinspired muscles for individual, specific tasks. Instead, they have developed a broad framework that enables tailoring the technology for a range of lower-cost applications.

"In disaster response, soft robots will move through debris or collapsed buildings to search for survivors. Their flexible bodies allow them to squeeze into tight places without causing further damage," Weissman said. "At home, they could safely help older adults with daily activities, like reaching for items on shelves and assisting with simple chores."

Because HARP actuators can endure high levels of heat, they also can be used for tasks like industrial rinsing processes or marine exploration and sample retrieval near thermal vents where magma-heated water is released into the ocean. Its flexibility and ability to rotate and grasp makes it ideal for agriculture and industrial uses.

The team has a provisional patent through ASU's Skysong Innovations and recently was awarded an NVIDIA Academic Grant, which will provide hardware in continued support of the research.

Bionic elephant arm reaches over, around and under

Another project in Sun's lab is doctoral student Jiahe Wang's "bionic elephant arm," a soft robotic arm inspired by the flexibility and dexterity of an elephant trunk.

This bioinspired device enables the arm to reach over, under and around obstacles with ease, making it particularly well suited for inspection and manipulation tasks in industrial settings. Its lightweight structure and inherent compliance reduce the risk of damage to equipment and improve safety for nearby workers, especially in scenarios that require close human-robot interaction.

"In places like chemical plants or crowded production lines, equipment is often difficult to reach and sensitive to accidental bumps. As a result, even simple inspections may require stopping operations, leading to costly and time-consuming downtime," Wang said.

In agriculture, a thinner version could move through plants and help with pollination — a job that often requires long hours of manual work. Unlike drones, which create strong air movement that can disturb crops, a soft robot can work more gently. Thicker versions could be used in space, helping astronauts with maintenance or handing them tools. Because the robot is soft and flexible, it is safer to use around both people and delicate equipment, where even small collisions can cause problems.

"Crops like strawberries and tomatoes have dense leaf canopies, which are challenging for pollinators to navigate through," Sun said. "A soft robotic arm can get in there and perform the pollination functions, navigating around any obstacles it encounters."

A new kind of backup

Doctoral student Rohan Khatavkar, co-supervised by Sun and Associate Professor Hyunglae Lee, has developed a back support device (BSD) designed to mitigate overexertion while performing industrial tasks, like lifting heavy equipment or cargo. It also can provide support to individuals with weak back muscles and prevent falls.

“Typical active BSDs are motor-driven and can be tuned to specific task usage demands,” Khatavkar said. “However, they are bulky and heavy, making them uncomfortable, especially for those with physical limitations. Passive devices are lightweight and compact but cannot be tuned to task demands.”

In the latest version of its BSD, Khatavkar’s team strikes a balance by adding active and passive elements in parallel. This is accomplished with an elastic actuator and a pneumatic artificial muscle to provide a tunable mechanism.

“The new device is compact and lightweight yet has the capacity for tuning the assistive force,” Khatavkar said. “They can be tuned to specific task demands. ... Not only does the revised BSD that uses soft materials and offer a lighter-weight operating system, but it also has built-in, adjustable stiffness modes/force levels that can be turned off, instead of removing the BSD, when periods of assistance are not required.”

Bringing it all together for the future

Sun sees endless robotic applications for the bioinspired muscles, including agriculture, industry, health care and surgery, household and landscaping chores and, someday in the not-too-distant future, space exploration.

“Ultimately, we can use these softer, flexible and compliant muscle devices in a wide range of robots because they are smaller, more lightweight and don’t present the inherent pinching hazards of today’s rigid robots," Sun said.

“By using space-grade materials, we can provide mobility, agility and ease of motion in devices designed both for astronauts and the robots they bring with them to space.”

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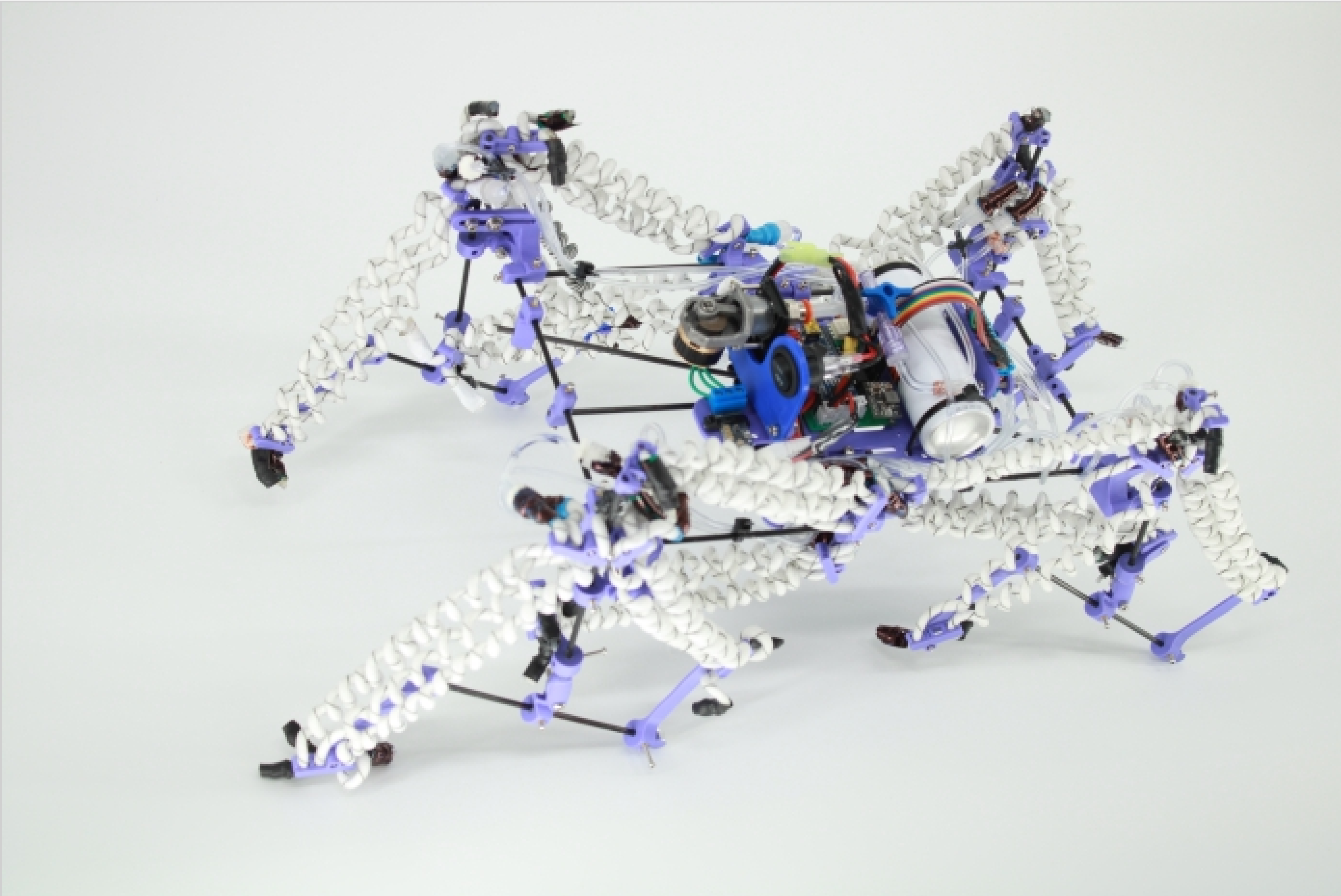
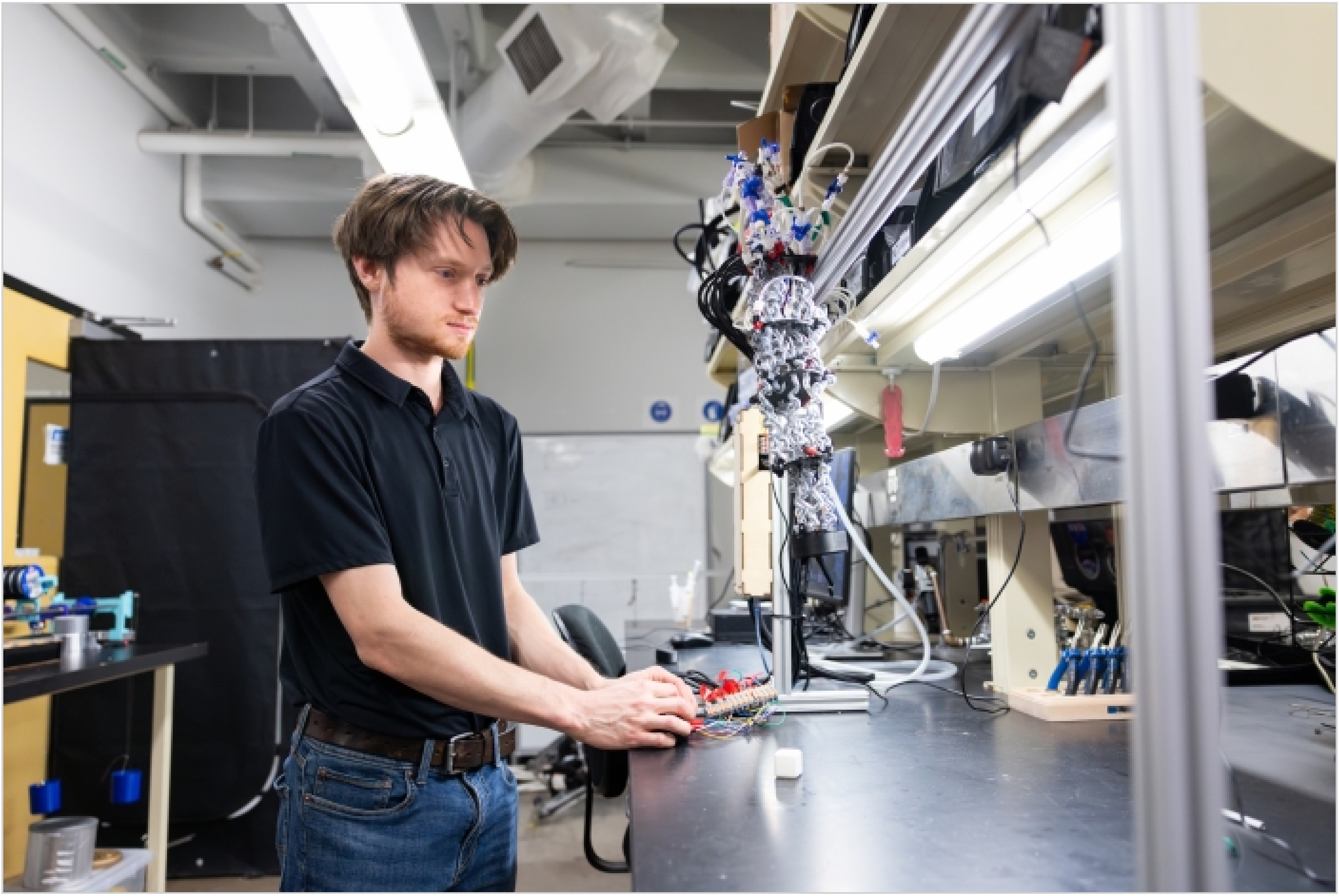
Main image

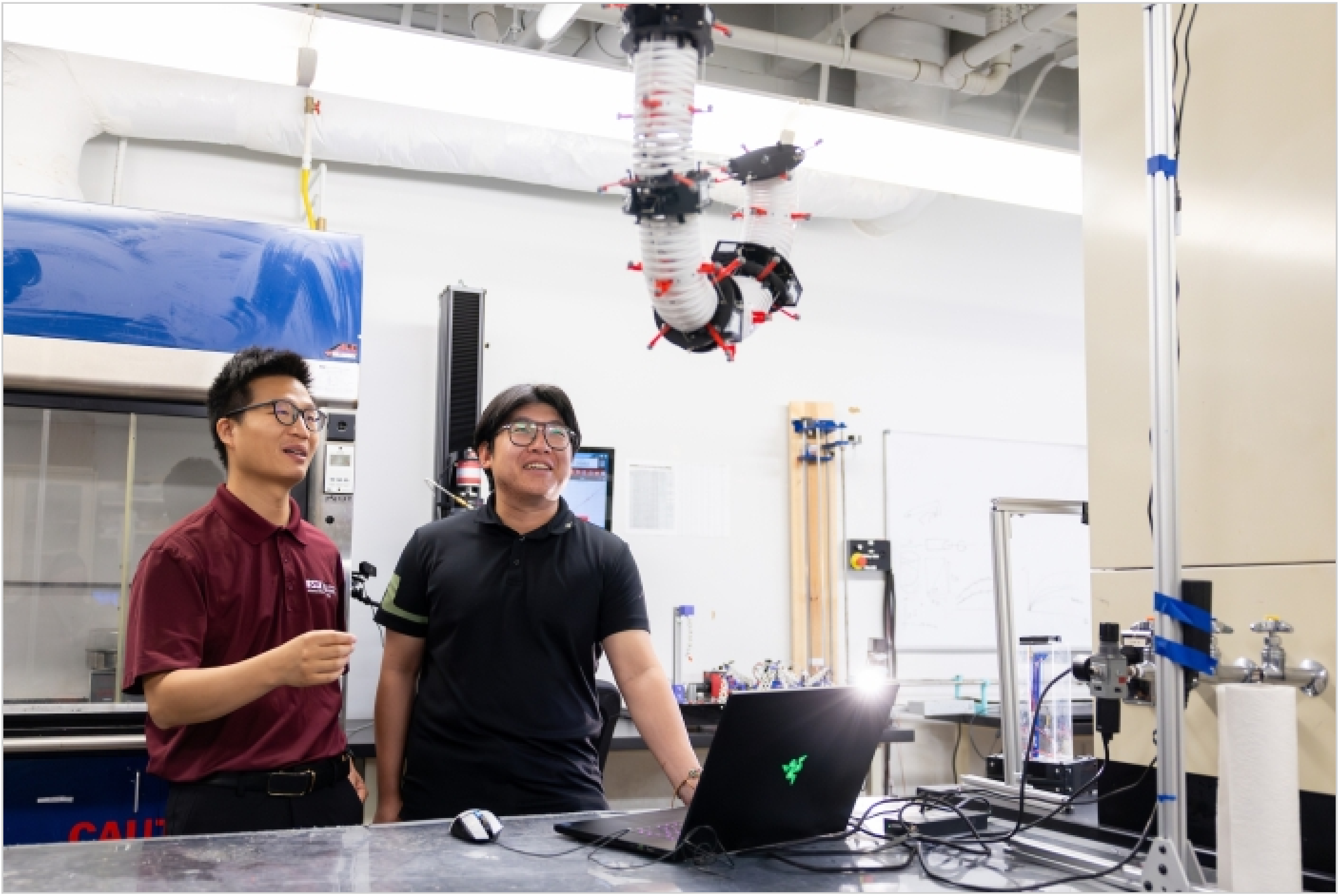


Leveraging the versatility of helical anisotropically reinforced polymer (HARP) actuators, this quadruped robot’s muscles can be tuned for high specific work and low stiffness, enabling fully untethered operation within a musculoskeletal architecture. The result is a faster, artificial muscle-driven quadruped capable of carrying its own power supply. Photo by Eric Weismann/ASU

Text image(s)

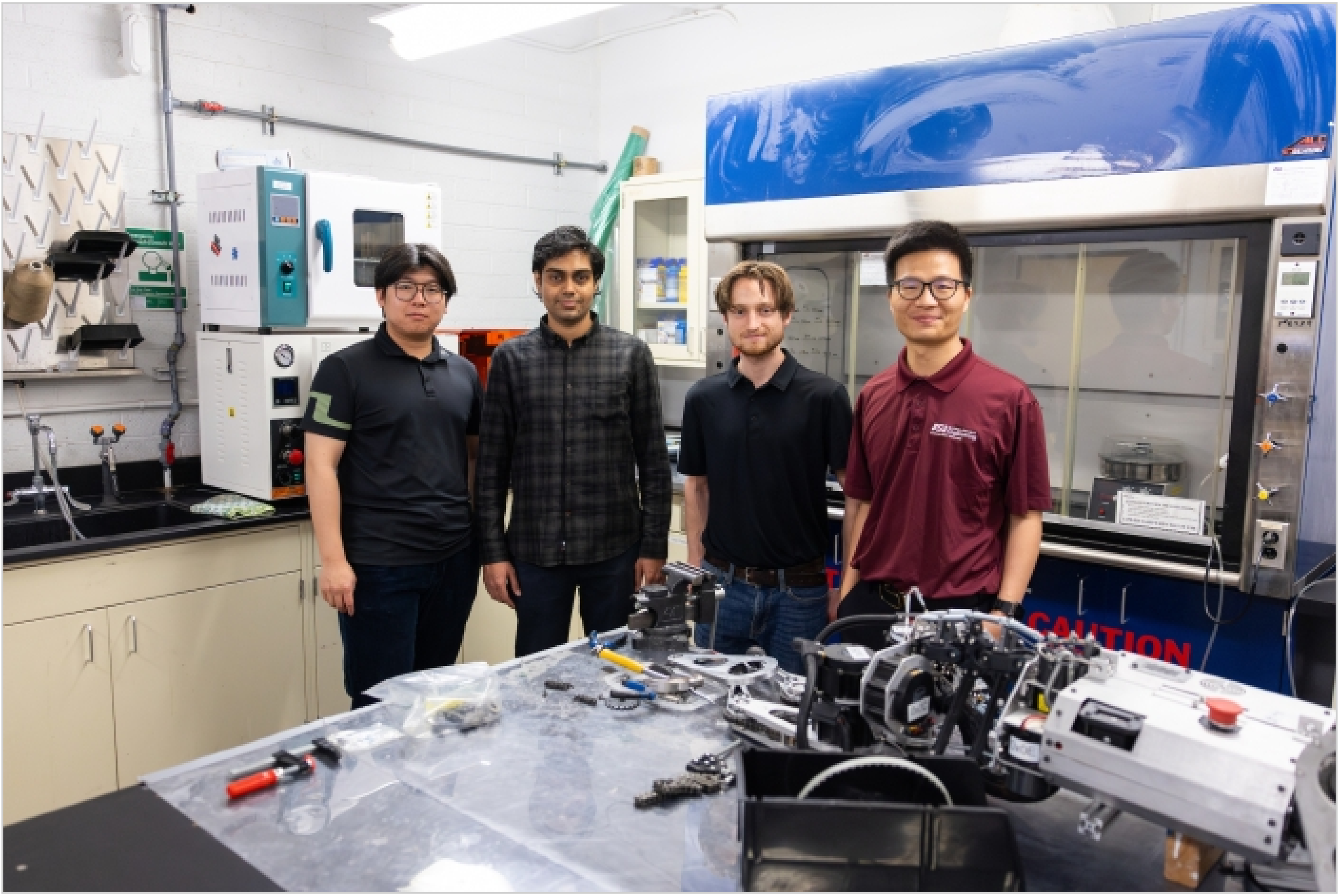


ASU mechanical engineering doctoral student Eric Weissman operates a robotic arm made of soft actuators, known as artificial muscles, at ASU Assistant Professor Jiefeng Sun’s Robotic Actuators and Dynamics lab in Tempe. Photo by Samantha Chow/ASU



ASU Assistant Professor Jiefeng Sun (left) and mechanical engineering PhD student Jiahe Wang operate a bionic, soft robotic arm that resembles an elephant’s trunk at Sun’s Robotic Actuators and Dynamics lab in Tempe on March 26. Photo by Samantha Chow/ASU

Mechanical engineering doctoral student Rohan Khatavkar does a treadmill test on the back support device his team designed in the Robotic Actuators and Dynamics Lab. Photo by Samantha Chow/ASU



ASU Assistant Professor Jiefeng Sun (right) poses for a photo with his team of PhD mechanical engineers (from left) Jiahe Wang, Rohan Khatavkar and Eric Weissman at the Robotic Actuators and Dynamics Lab in Tempe on March 26. Photo by Samantha Chow/ASU