

Walking quadruped is controlled and powered by pressurized air

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Engineers at the University of California San Diego have created a four-legged soft robot that doesn't need any electronics to work. The robot only needs a constant source of pressurized air for all its functions, including its controls and locomotion systems. Credit: University of California San Diego

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legged soft robot that doesn't need any electronics to work. The robot only needs a constant source of pressurized air for all its functions, including its controls and locomotion systems.

The team, led by Michael T. Tolley, a professor of mechanical engineering at the Jacobs School of Engineering at UC San Diego, details its findings in the Feb. 17, 2021 issue of the journal *Science Robotics*.

"This work represents a fundamental yet significant step towards fully-autonomous, electronics-free walking robots," said Dylan Drotman, a Ph.D. student in Tolley's research group and the paper's first author.

Applications include low-cost robotics for entertainment, such as toys, and robots that can operate in environments where electronics cannot function, such as MRI machines or mine shafts. Soft robots are of particular interest because they easily adapt to their environment and operate safely near humans.

Most [soft robots](#) are powered by pressurized air and are controlled by [electronic circuits](#). But this approach requires complex components like circuit boards, valves and pumps—often outside the [robot](#)'s body. These components, which constitute the robot's brains and nervous system, are typically bulky and expensive. By contrast, the UC San Diego robot is controlled by a light-weight, low-cost system of pneumatic circuits, made up of tubes and soft valves, onboard the robot itself. The robot can walk on command or in response to signals it senses from the environment.

"With our approach, you could make a very complex robotic brain," said Tolley, the study's senior author. "Our focus here was to make the simplest air-powered nervous system needed to control walking."

The robot's [computational power](#) roughly mimics mammalian reflexes that are driven by a neural response from the spine rather than the brain. The team was inspired by neural circuits found in animals, called [central pattern generators](#), made of very simple elements that can generate rhythmic patterns to control motions like walking and running.

To mimic the generator's functions, engineers built a system of valves that act as oscillators, controlling the order in which pressurized air enters air-powered muscles in the robot's four limbs. Researchers built an innovative component that coordinates the robot's gait by delaying the injection of air into the robot's legs. The robot's gait was inspired by sideneck turtles.



The robot relies on a series of valves that open and close in a specific sequence to walk. Credit: University of California San Diego

The robot is also equipped with simple mechanical sensors—little soft bubbles filled with fluid placed at the end of booms protruding from the robot's body. When the bubbles are depressed, the fluid flips a valve in the robot that causes it to reverse direction.

The *Science Robotics* paper builds on previous work by other research groups that developed oscillators and sensors based on pneumatic valves, and adds the components necessary to achieve high-level functions like walking.

How it works

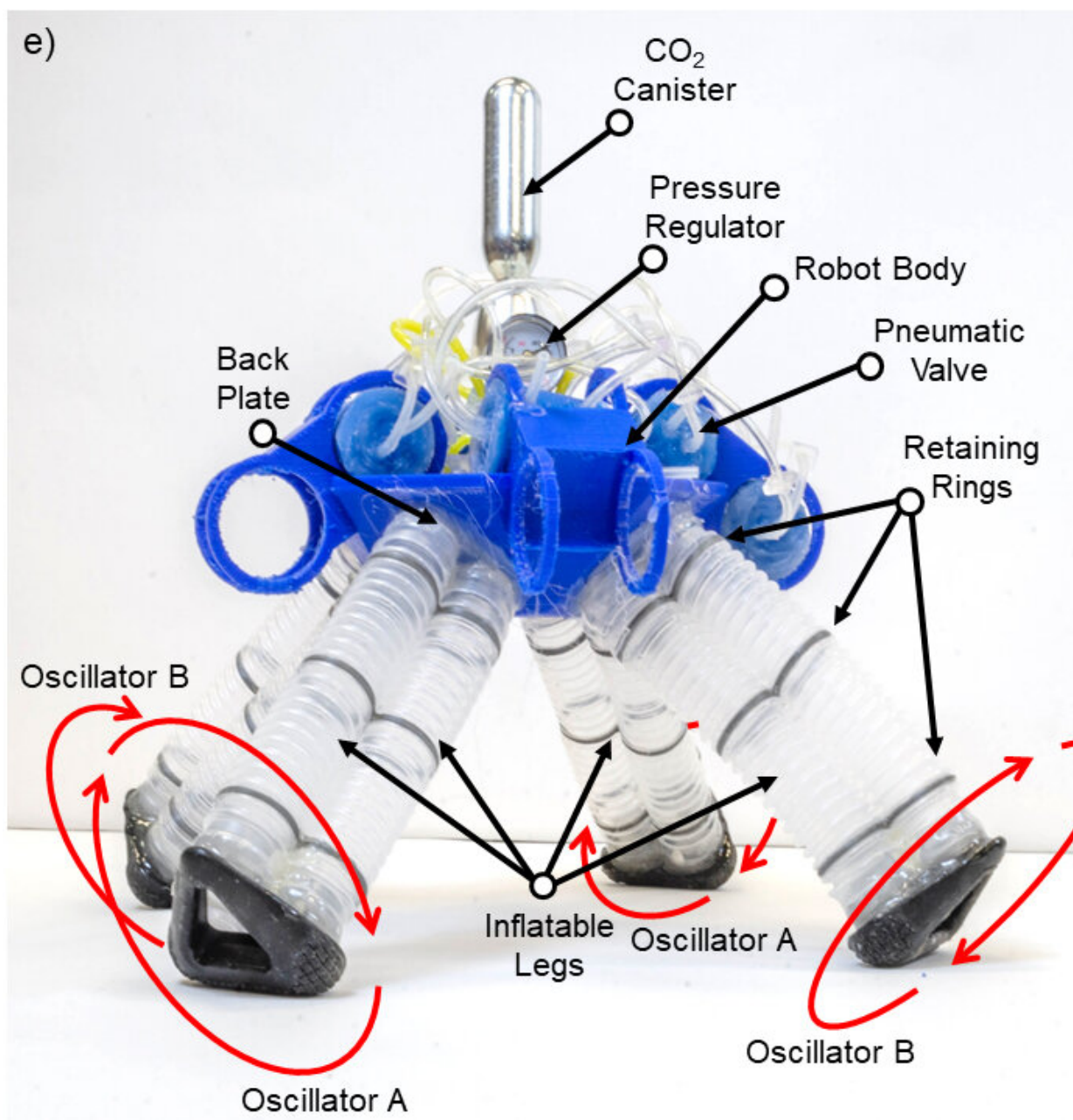
The robot is equipped with three valves acting as inverters that cause a high pressure state to spread around the air-powered circuit, with a delay at each inverter.

Each of the robot's four legs has three degrees of freedom powered by three muscles. The legs are angled downward at 45 degrees and composed of three parallel, connected pneumatic cylindrical chambers with bellows. When a chamber is pressurized, the limb bends in the opposite direction. As a result, the three chambers of each limb provide multi-axis bending required for walking. Researchers paired chambers from each leg diagonally across from one another, simplifying the control problem.

A soft valve switches the direction of rotation of the limbs between counterclockwise and clockwise. That valve acts as what's known as a latching double pole, double throw switch—a switch with two inputs and four outputs, so each input has two corresponding outputs it's connected to. That mechanism is a little like taking two nerves and swapping their connections in the brain.

Next steps

In the future, researchers want to improve the robot's gait so it can walk on natural terrains and uneven surfaces. This would allow the robot to navigate over a variety of obstacles. This would require a more sophisticated network of sensors and as a result a more complex pneumatic system.



The untethered soft quadruped robot with onboard soft valves powered by a pressure-regulated CO2 canister; key components are labeled, as are the directions of leg motions for forward walking. Credit: Drotman et al., *Sci. Robot.* 6, eaay2627 (2021)

The team will also look at how the technology could be used to create robots, which are in part controlled by pneumatic circuits for some functions, such as walking, while traditional electronic circuits handle higher functions.

More information: D. Drotman et al., "Electronics-free pneumatic circuits for controlling soft-legged robots," *Science Robotics* (2021).
robotics.sciencemag.org/lookup.../scirobotics.aay2627

Provided by University of California - San Diego

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