Pump powers soft robots, makes cocktails and opens the door for soft robotic applications

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A compact, soft pump with adjustable pressure flow is versatile enough to pump a variety of fluids with varying viscosity, including gin, juice, and coconut milk. Credit: Harvard Microrobotics Lab/Harvard SEAS

The hottest drink of the summer may be the SEAS-colada. Here's what you need to make it: gin, pineapple juice, coconut milk and a dielectric elastomer actuator-based soft peristaltic pump. Unfortunately, the last component can only be found in the lab of Robert Wood, the Harry Lewis and Marlyn McGrath Professor of Engineering and Applied Sciences at the Harvard John A. Paulson School of Engineering and Applied Sciences.

At least, for now.

Wood and his team designed the pump to solve a major challenge in soft robotics—how to replace traditionally bulky and rigid power components with soft alternatives. The research was published in *Science Robotics*.

Over the past several years, Wood's Microrobotics Lab at SEAS has been developing soft analogs of traditionally rigid robotic components, including valves and sensors. In fluid-driven robotic systems, pumps control the pressure or flow of the liquid that powers the robot's movement. Most pumps available today for soft robotics are either too large and rigid to fit onboard, not powerful enough for actuation or only work with specific fluids.

Wood's team developed a compact, soft pump with adjustable pressure flow versatile enough to pump a variety of fluids with varying viscosity, including gin, juice, and coconut milk, and powerful enough to power soft haptic devices and a soft robotic finger.

The pump's size, power and versatility opens up a range of possibilities for soft robots in a variety of applications, including food handling, manufacturing, and biomedical therapeutics.

Peristaltic pumps are widely used in industry. These simple machines use motors to compress a flexible tube, creating a pressure differential that forces liquid through the tube. These types of pumps are especially useful in biomedical applications because the fluid doesn't touch any component of the pump itself.

"Peristaltic pumps can deliver liquids with a wide range of viscosities, particle-liquid suspensions, or fluids such as blood, which are challenging for other types of pumps," said first author Siyi Xu, a former graduate student at SEAS and current postdoctoral fellow in Wood's lab.

Building off previous research, Xu and the team designed electrically powered dielectric elastomer actuators (DEAs) to act as the pump's motor and rollers. These soft actuators have ultra-high power density, are lightweight, and can run for hundreds of thousands of cycles.

The team designed an array of DEAs that coordinate with each other, compressing a millimeter-sized channel in a programmed sequence to produce pressure waves.

The result is a centimeter-sized pump small enough to fit on board a small soft robot and powerful enough to actuate movement, with controllable pressure, flow rate, and flow direction.

"We also demonstrated that we could actively tune the output from continuous flow to droplets by varying the input voltages and the outlet resistance, in our case the diameter of the blunt needle," said Xu. "This capability may allow the pump to be useful not only for robotics but also for microfluidic applications."

"The majority of soft robots contain rigid components somewhere along their drivetrain," said Wood. "This topic started as an effort to swap out one of those key pieces, the pump, with a soft alternative. But along the way we realized that compact soft pumps may have far greater utility, for example in biomedical settings for drug delivery or implantable therapeutic devices."

The research was co-authored by Cara M. Nunez and Mohammad Souri.

More information: Siyi Xu et al, A compact DEA-based soft peristaltic pump for power and control of fluidic robots, *Science Robotics* (2023). DOI: 10.1126/scirobotics.add4649

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