Wireless origami-inspired microrobots for biomedical applications

By Andy Tay

Origami microrobots that can be wirelessly powered have the potential for use in biomedical applications like targeted drug delivery and minimally invasive surgeries because they can move in narrow spaces and morph their shapes. They can also be used to navigate complex environments for applications like disaster relief by detecting signals indicating signs of life. Unfortunately, there has been no origami microrobot that can operate efficiently both on-ground and in-water, and most physiological environments are complex and wet in nature. Additionally, most origami microrobots need multiple components to perform more challenging locomotion and functions.

In a recent paper accepted by *Nature Communications*, a team of researchers led by Professor Renee Zhao, Dr. Qiji Ze and Ph.D. student Shuai Wu, in the Department of Mechanical Engineering at Stanford University, reported a spinning-enabled amphibious microrobot that can be wirelessly controlled by magnetic fields for integrated capabilities of multimodal locomotion, delivery of liquid medicine, and cargo transportation. **Figure 1** demonstrates the controlled delivery of liquid medicine in an *ex vivo* pig stomach.

Figure 1 Image showing controlled delivery of liquid medicine by wirelessly controlled origami microrobots in an *ex vivo* pig stomach. Image credit: Zhao Lab, Stanford U.

"The design of the robot comes from the effective rotational motion that enables both on-ground rolling and in-water propelling. This work exploited geometrical features of the millimeter origami robot and its foldability for amphibious locomotion and delivery of liquid medicine," says Zhao.

A dexterous microrobot

The authors made use of the Kresling origami design, a triangulated hollow cylinder, which has high geometrical symmetry and can perform on-ground rolling and flipping around the axes parallel and perpendicular to its longitudinal direction, respectively. When the Kresling spins about its longitudinal axis, it also generates propulsion for in-water swimming.

The Kresling design enables the microrobot to display self-adaptive locomotion. This is a distinctive feature differentiating the Kresling microrobots from other existing robots that need to actively switch their configurations or control strategy (such as wireless magnetic fields) on different surface features like ridges and stairs. For instance, when the robot interacts with obstacles or rough surfaces, it can automatically switch between rolling and flipping motions to adapt to terrain features without the need to change the direction of the magnetic fields. As the Kresling microrobot is self-adaptive, it can navigate different terrains, hence enhancing its applications in complex biomedical environments.

Amphibious microrobot

The authors demonstrated that their microrobot can adapt to different environments such as on-ground, in-water and through transitional zones such as air-water interfaces, which enables broad use in applications like disaster rescue and resource exploration. For instance, the microrobot can be equipped with a temperature sensor to detect for body temperature indicating signs of life. The modified Kresling pattern has a hole in front and six radial cuts to serve as inlets and outlets for water flow, which enhanced the swimming performance of the microrobot. Models created using computational fluid dynamics simulations supported that the design with the hole and cuts enabled the robot to capture fluids which are then thrown from the cuts by centrifugal forces. Together with a decreased pressure in the front of the robot, this led to increased swimming speed. With the same magnetic field strength, the swimming speed of the modified microrobot was 23% faster (66.0 mm/s versus 81.2 mm/s), and the swimming speed also positively correlated with the rotating frequency of the magnetic field.

Interestingly, when in air and approaching the interface with water, the frontal hole of the robot could also trap air bubbles of increasing size which lowered the robot density for swimming and navigation at the air-water interface. The robot could also float in the water in absence of a magnetic field using the captured air bubble and surface tension at the water-air interface.

Microrobot for cargo transport

Using a spinning-enabled locomotion and suction, the authors showed that their robot could suck in cargo through the frontal hole due to naturally lower pressure in its internal space. When the hole of the robot faced the ground, the cargo could be released through its hole via gravity. In a further experiment, the authors filled an *ex vivo* pig stomach with viscous fluid. By manipulating the rotating magnetic field, the robot performed self-adaptive, on-ground rolling and flipping on the rugged stomach surface and swimming in the viscous fluid, which is useful for targeted drug delivery applications.

“Magnetic actuation separates the power source and control system out of the microrobot, which makes it feasible to further miniaturize the robot. We envision the robot’s agile navigation and cargo transportation capabilities facilitate its function to remove blood clot in complex vascular systems for treatment of stroke or heart attack,” adds Zhao.

Microrobots for the future of biomedicine

In this paper, the authors demonstrated how origami robots could exhibit different locomotion automatically. Through advanced fabrication methods, the robot can be scaled down further for navigating in complex biomedical environments, such as blood vessels and tissues, for cargo transport. The internal cavity of the robot can also house components like mini cameras and forceps for applications like endoscopy and biopsy. Such multi-functionalized microrobots can improve future biomedical diagnosis and treatment with greater efficacy and safety.

Source article

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