Enhancing the locomotion of small robots with microwheels

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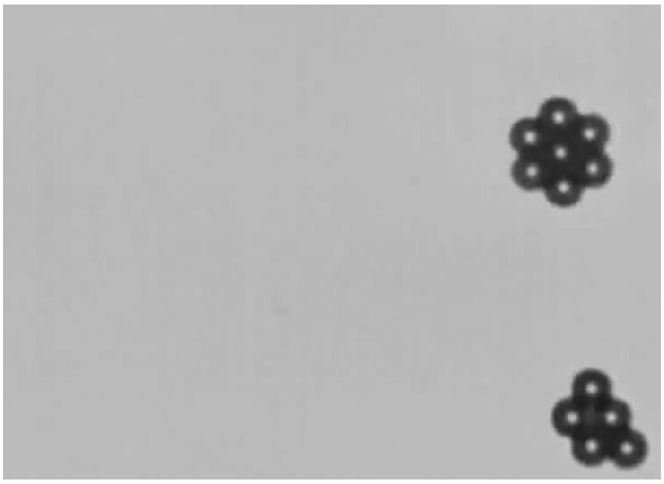

Microbots could have several useful applications, particularly within biomedical and healthcare settings. For instance, due to their small size, these small machines could be inserted within the human body, allowing doctors to remotely carry out exams or operate regions affected by diseases.

Developing approaches that enable the effective locomotion of microrobots in medical contexts, however, is a challenging task due to patterns in the flow of fluids inside the human body. To overcome this challenge, past studies have proposed the use of wheel-shaped machines that can roll on surfaces, as their structure allows for enhanced propulsion and faster translation speeds.

Despite their promise, research findings suggest that these robots do not move well on flat surfaces and often slip. In an interesting new study featured in *Science Robotics*, a team of researchers at Colorado School of Mines and the University of Colorado Denver have proposed a new approach that could help to enhance the locomotion of microrobots on wet surfaces.

"Due to fundamental limitations in fluid dynamics at small scales, it is difficult for small machines to swim, a limitation we have tried to overcome by developing methods based on wheels and driving on available surfaces," Professor David Marr, one of the researchers who carried out the study, told TechXplore. "These methods are relatively effective, [but] because surfaces within the body are wet, our wheels tend to slip and travel at about 10 percent of their theoretical maximum. The idea of this work was to develop an approach that prevents slip with wheels that fit like gears onto the surface of travel, in effect removing slip and leading to significantly faster translation."

Prof. Marr and his colleagues drew inspiration from the mathematics behind roads and wheels, applying these calculations to small wheel-shaped robots. They found that specific changes to the topography (i.e. physical features) of the 'microroad' where the robot is operating allow the microwheels to reach far higher velocities.

The researchers observed that periodic bumps on the microroad traveled by the robots can improve the traction between the tiny wheels and nearby walls. While on wet flat surfaces, the wheels tend to slip. Therefore, bumpier roads result in a locomotion pattern composed of rotations with slip and nonslip flips. This enhances the wheels' translation velocity significantly, with the robots moving up to four times faster than they would on flat surfaces.

"Wheels of specific shape and size fit roads of a particular designed shape perfectly," Prof. Marr explained. "While a round wheel and a flat road match, non-round wheels match surfaces with specific bumps in the road. One eventual goal is to develop wheels that better match surfaces in vivo, leading to faster therapies in diseases where treatment must be administered quickly, for example."

Putting square wheels on a car might seem like a counterintuitive and inefficient way of improving its locomotion. However, as Prof. Marr explains, adequately paving the surfaces on which microbots operate is often difficult, hence, in these cases, a non-circular wheel design can actually be beneficial.

"Our work revealed the important hydrodynamic interaction between microwheels and non-smooth surface, while most work in literature have primarily focused on the propulsion of micro-robot on flat surfaces," Professor Ning Wu, another researcher involved in study, told TechXplore. "One application of our findings will be separation of microscopic object based on symmetry rather than size."

The findings gathered by Marr, Wu and their colleagues could have several practical implications. For instance, the researchers observed that square and diamond-shaped microwheels roll at similar speeds on a flat surface but at very different ones on a bumpy road.

This simple observation could inform the strategic design of surfaces on which microbots will operate, ultimately enhancing their locomotion based on the shape of their wheels. Achieving faster rotation of these small machines on bumpy surfaces could also simplify their manipulation while they are traveling in specific regions of the human body, such as partly obstructed vascular networks.

The recent paper by Marr, Wu and their colleagues offers new insight that could guide the development of more efficient microbots for biomedical purposes. In their future work, the researchers plan to explore two further research directions that could yield additional valuable observations.

"First, we will utilize the topographically patterned substrates to separate micro- and nanoscopic particles on both symmetry and size, since we have demonstrated that they can roll with different speeds," Prof. Wu said. "The separated particles can then be used as building blocks for making photonic structures with interesting light-matter interactions. Another direction will be making microwheels of soft materials such as droplets that can encapsulate drugs. Our ultimate goal is to maneuver these soft wheels within complex vascular networks and use them to deliver drugs."

More information: Tao Yang et al. Microwheels on microroads: Enhanced translation on topographic surfaces, *Science Robotics* (2019). DOI: 10.1126/scirobotics.aaw9525