Website address:
https://www.gesundheitsindustrie-bw.de/en/article/press-release/magnetic-microrobot-swarms-enable-contactless-manipulation-objects-through-fluidic-torque

Magnetic Microrobot Swarms Enable Contactless Manipulation of Objects Through Fluidic Torque

In a study, a team of researchers show that groups of magnetic microrobots can generate fluidic forces strong enough to rotate objects in different directions without touching them. These microrobot swarms can turn gear systems, rotate objects much larger than the robots themselves, assemble structures on their own, and even pull in or push away many small objects. The work was now published in Science Advances.

Researchers from the Max Planck Institute for Intelligent Systems (MPI-IS), the University of Michigan, and Cornell University have demonstrated a breakthrough in microrobotics: swarms of magnetic microrobots can manipulate objects without physical contact by harnessing fluid-generated torque. This discovery opens new pathways for precision manufacturing, biomedical applications, and microscale assembly.

In their study titled "Fluidic Torque-Enabled Object Manipulation by Microrobot Collectives" published in Science Advances, the research team showed that rotating microrobot collectives generate controllable fluid flows that can exert torque on surrounding objects. By carefully adjusting parameters such as spin rate, number of robots, and spatial arrangement, the group of tiny microrobots together rotate, assemble, transport, and reorganize objects many times larger than themselves.

"Fluidic torque provides a fundamentally new way to manipulate delicate objects that are only a few millimeters small," says Gaurav Gardi, one of the lead authors of the study, who is a postdoctoral researcher in the Physical Intelligence Department at MPI-IS.
Instead of pushing or pulling directly, microrobot collectives use fluid motion to generate forces that can rotate gears, move structures, and even assemble complex configurations. A video demonstrates just how well the robot collectives work.

Non-contact manipulation and programmable motion

The microrobots, each approximately 300 micrometers in diameter, spin under an externally applied magnetic field. Their rotation creates circular flow fields in the surrounding fluid, which generate torque. Experiments demonstrated that the torque can be precisely tuned and amplified by increasing the number of microrobots or their spin frequency, reaching torque levels up to 3.6×10^{-9} newton-meters.

This mechanism enables programmable motion in passive objects. For example, the researchers show how they rotate gear wheels, rotating them in the same or opposite direction depending on how the microrobots inside are positioned relative to the wheels. This programmable rotation illustrates how fluidic torque can transfer mechanical work without physical contact.

Driving gears, rotating large objects, and enabling self-assembly

Beyond simple rotation, the microrobot collectives demonstrated the ability to actuate gear trains, rotate three-dimensional objects weighing more than 45,000 times the mass of a single microrobot, and dynamically assemble structures through coordinated fluid flows.

"Hydrodynamic drag has been an important mechanism in enabling diverse behaviors in microrobot collectives, but here, we use those same fluid-mediated interactions to control objects at a distance. This is incredibly exciting because it opens an avenue of remote manipulation at small scales where we can use the microrobots' surrounding environment to our advantage," says Steven Ceron, one of the lead authors of the study, who is now an assistant professor in the Robotics Department at the University of Michigan.

The researchers also observed emergent collective behaviors. At certain operating conditions, microrobot swarms transitioned between dispersed rotation and "crawling" motion along object surfaces. These adaptive behaviors allow microrobot collectives not only to manipulate objects but also to reorganize themselves depending on the environmental conditions and task requirements.

Toward microscale manufacturing and biomedical applications

Unlike traditional micromanipulation approaches that rely on direct contact or external mechanical tools, fluidic torque provides a scalable, programmable, and contactless mechanism for controlling objects. This approach reduces the risk of damage when handling delicate structures and enables simultaneous manipulation of multiple objects.

The findings could have significant implications for future technologies, including microscale manufacturing, packaging, and biomedical engineering. For example, microrobot swarms could one day assemble miniature devices, transport biological samples, or perform targeted manipulation inside fluid environments such as the human body.

“By understanding and controlling fluidic torque, we are moving toward programmable microrobot systems capable of complex, coordinated tasks,” Metin Sitti added. He was the head of the Physical Intelligence Department at MPI-IS and is now the President of Koç University in Istanbul.

Reference:
“Fluidic Torque-Enabled Object Manipulation by Microrobot Collectives”
Steven Ceron, Gaurav Gardi, Kirstin Petersen, Metin Sitti
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Further information

- Max Planck Institute for Intelligent Systems