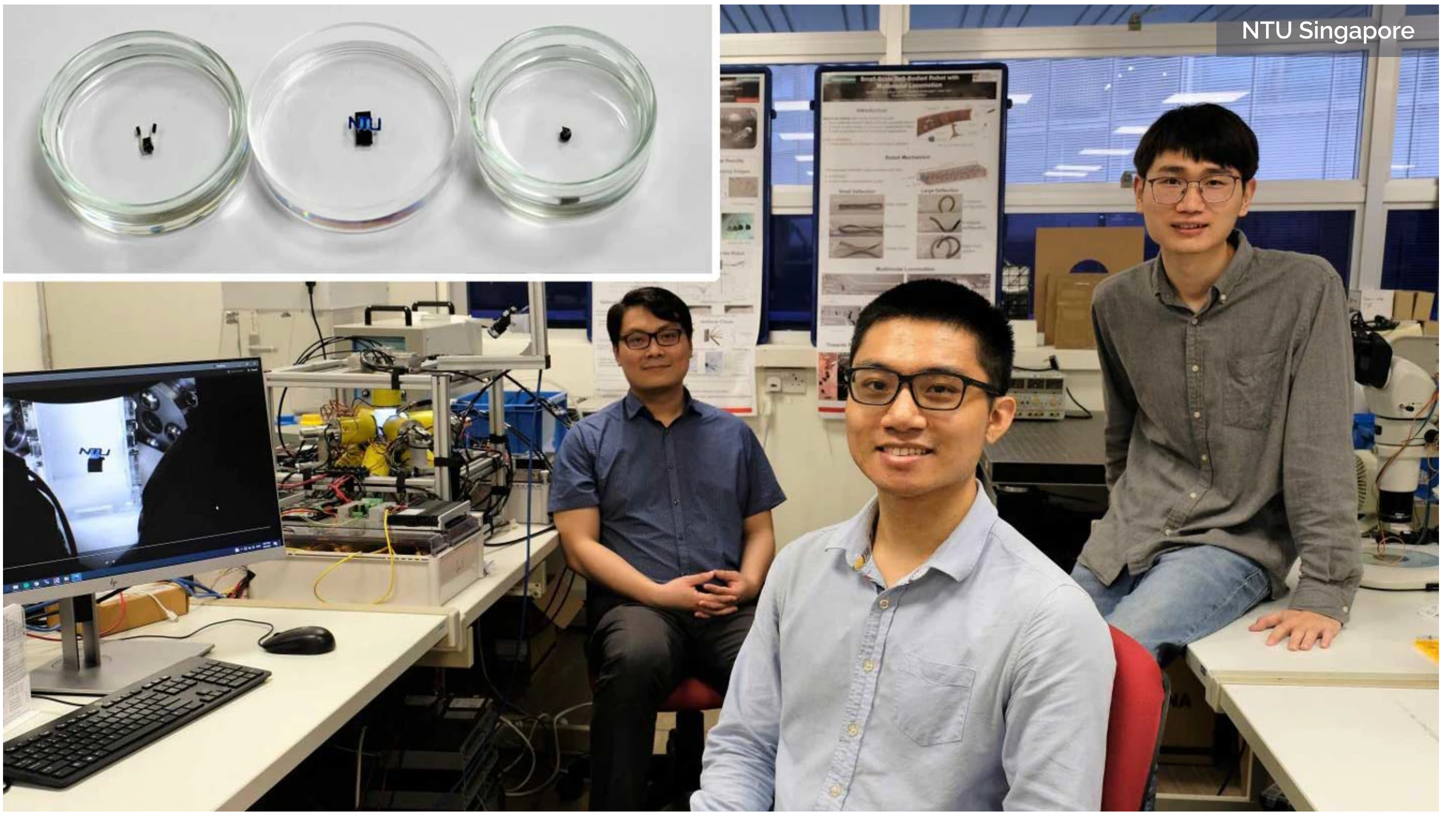


MEDICAL DESIGN

Miniature Robots with Six Degrees of Freedom

Six DoF miniature robots can rotate 43 times faster than previous renditions. They can move like jelly sh and pick and place miniature objects with precision.

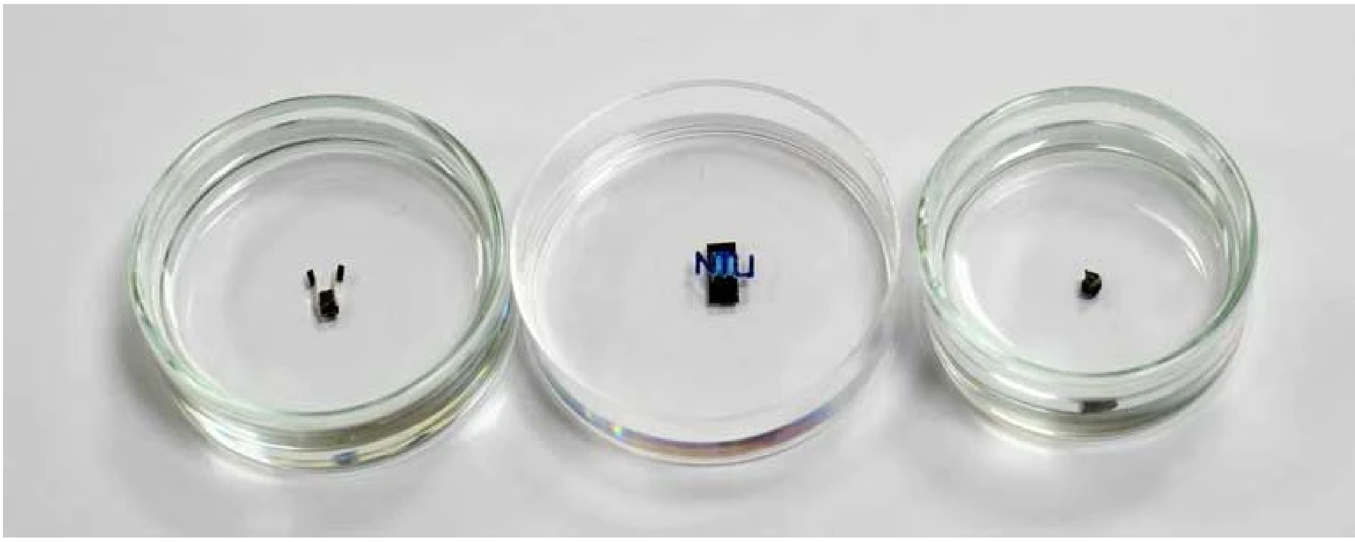
Rehana Begg
JUN 16, 2021

Biomedicine and manufacturing are two industries that have unlimited use for technologies that can access hard-to-reach spaces.

Catering to the need, scientists at Nanyang Technological University, Singapore have developed miniature robots that can be controlled using magnetic fields to perform highly maneuverable and dexterous manipulations.

Triggered when magnetic fields are applied, these robots improve on existing small-scale robots by optimizing their ability to move in six degrees-of-freedom (DoF), noted the scientists in a paper titled “Small-Scale Magnetic Actuators with Optimal Six Degrees-Of-Freedom,” published online in *Advanced Materials*, June 2021 issue. DoF is translational movement along the three spatial axes, and rotational movement about those three axes, commonly known as roll, pitch and yaw angles, noted the authors.

Six DoF miniature robots are not a new creation; what’s new about the NTU miniature robots is that they can rotate 43 times faster than previous iterations in the critical sixth DoF when their orientation is precisely controlled. Another distinction is that the robots may be fabricated with “soft” materials. This is a significant distinction because these robots can replicate important mechanical qualities. For example, the scientists noted that one type can emulate the locomotion of jellyfish, and another has a gripping ability that can pick and place miniature objects with precision.



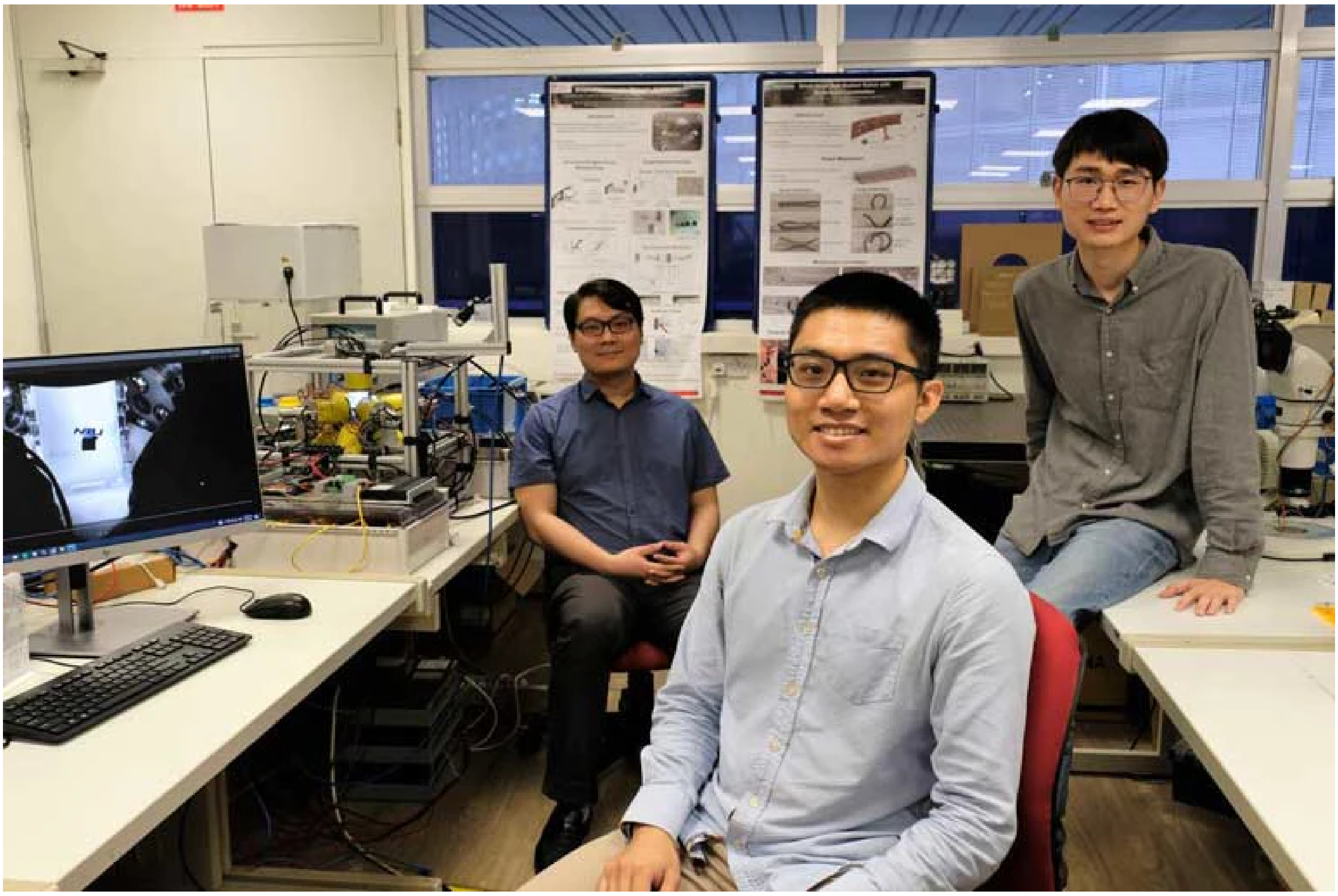
The NTU millimeter-sized robots measure about the size of a grain of rice and can be controlled using magnetic fields.

NTU Singapore

Critical Distinction

The discovery of the “elusive” third principal vector of these magnetic fields was critical for controlling the miniature machines, said Assistant Professor Lum Guo Zhan from the School of Mechanical and Aerospace Engineering at NTU Singapore.

“My team sought to uncover the fundamental working principles of miniature robots that have six-DoF motions through this work,” explained Zhan. “By fully understanding the physics of these miniature robots, we are now able to accurately control their motions. Furthermore, our proposed fabrication method can magnetize these robots to produce 51 to 297 folds larger six-DoF torques than other existing devices. Our findings are therefore pivotal, and they represent a significant advancement for small-scale robotic technologies.”



The NTU School of Mechanical and Aerospace Engineering team behind the millimeter-sized robots include (l-r): Assistant Professor Lum Guo Zhan, Ph.D. students Yang Zilin and Xu Changyu.

NTU Singapore

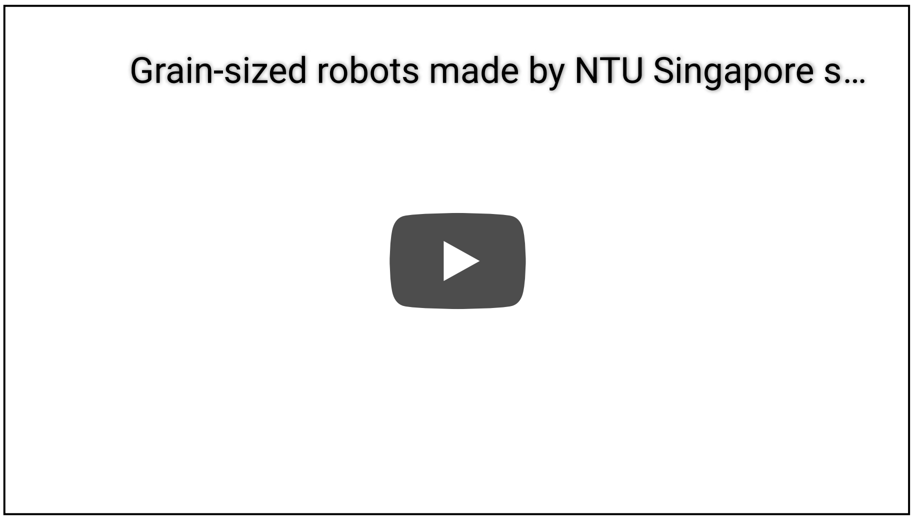
Suitable for Surgical and Manufacturing Use

The NTU team’s invention demonstrated several advantageous features. Firstly, the miniature robots measure about the size of a rice grain, which make them suitable for reaching confined and enclosed spaces and therefore useful in the field of medicine.

A computer programme varies the strength and direction of magnetic fields generated by an electromagnetic coil system.

The NTU team also said the miniature robots may inspire novel surgical procedures for "difficult-to-reach" vital organs such as the brain. However, more work and testing are needed before the miniature robots can be used for targeted medical applications.

"Besides surgery, our robots may also be of value in biomedical applications such as assembling lab-on-chip devices that can be used for clinical diagnostics by integrating several laboratory processes on a single chip," noted co-authors and Ph.D. students Xu Changyu and Yang Zilin from the School of Mechanical and Aerospace Engineering.



Negotiating Barriers and Assembling 3D Structures

The miniature robots demonstrated dexterity and speed in lab experiments. In one scenario, the NTU team demonstrated how a jellyfish-inspired robot could swim speedily through a tight opening in a barrier when suspended in water. The experiment suggested the robots' ability to negotiate barriers in dynamic and uncertain environments, noted the team.

Under precise orientation control, the miniature robots could execute full six-DOF motions reliably and achieve six-DOF angular velocities of 173 degrees per second. These movements exceed the fastest rotation that existing miniature robots have achieved, which is four degrees per second for their six-DoF motion.

The scientists further described how a gripper robot could assemble a 3D structure consisting of a bar sitting atop two Y-shaped stilts in less than five minutes. That's about 20 times faster than the speed of existing miniature robots. According to the NTU team, this proof-of-concept demonstration shows promise that the miniature robots may one day be used in "micro factories" that build microscale devices.

Follow-up work for the NTU team will include making the robots even smaller, on the scale of a few hundred micrometers, and ultimately making the robots fully autonomous.

The research was published in the peer-reviewed scientific journal *Advanced Materials* in May 2021 and is featured as the front cover of the June 10 issue.