

Researchers at Nanyang Technological University Singapore have developed a seed-sized surgical robot that can switch between five different functions in less than a second. The device offers a potential new tool for minimally invasive medical procedures.

Credit: NTU

The robot measures just 4.4 millimetres long and is controlled wirelessly using weak magnetic fields. Despite its small size, it can move across soft surfaces, cut biological tissue, release drugs, grip and store tissue samples, and generate heat remotely.

Scientists say the device addresses a longstanding challenge in miniature robotics by fitting multiple functions into a single tiny robot without sacrificing control or manoeuvrability. The team demonstrated these capabilities in laboratory experiments using biological tissues and soft-tissue models.

Unlike most miniature magnetic robots that perform only one or two tasks, the new device can rapidly switch between multiple tools. Associate Professor Lum Guo Zhan led the study. Lum said the long-term goal is for doctors to use these mini robots in the body, navigate them to a targeted location, and use them to perform treatments. The study was published in the journal *Advanced Materials*.

The robot is made from soft silicone-based materials known as PDMS and Ecoflex. Microscopic magnetic particles that respond to external magnetic fields are embedded throughout the structure.

At the heart of the system is a magnetic module that can be magnetised, demagnetised, and remagnetised in different directions. Each magnetic orientation activates a different function, allowing the same robot to deploy various tools on demand.

The researchers also engineered different regions of the robot to respond independently to magnetic signals. This prevents the entire device from moving as a single magnet, which is a common limitation in many existing miniature robotic systems.

The design introduces a sixth degree of freedom known as rolling, which allows the robot to spin around its long axis. The added movement provides greater control when navigating narrow and irregular spaces inside the human body.

To evaluate its performance, the team tested the robot on chicken liver and gelatin-based materials designed to mimic soft biological tissue. The robot successfully cut tissue, released particles representing drugs, collected and stored tissue samples, and generated localized heat through magnetic induction.

Researchers said the heating capability could support magnetic hyperthermia approaches being explored for cancer treatment. The team also assessed the safety of the materials by exposing them to human skin cells.

More than 99% of cells remained viable after exposure, indicating low toxicity under laboratory conditions. Researchers are now investigating how the robot could be integrated with medical imaging systems, sensors, and artificial organ models.

The team members are also working with surgeons to understand how such systems might fit into future clinical workflows. Lum noted that to move closer to practical use, researchers must understand how the robots can be guided, monitored, and controlled in realistic medical settings.

- Nanyang Technological University Singapore researchers developed a 4.4-millimetre surgical robot controlled wirelessly by weak magnetic fields.
- The device can rapidly switch between five functions, including cutting tissue, releasing drugs, collecting samples, and generating heat, in less than one second.
- The robot utilizes a reconfigurable magnetic module and independent regional responses to overcome common maneuverability limitations of miniature robotics.

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