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Singapore researchers pioneer neural blueprint for human-like intelligence in soft robots

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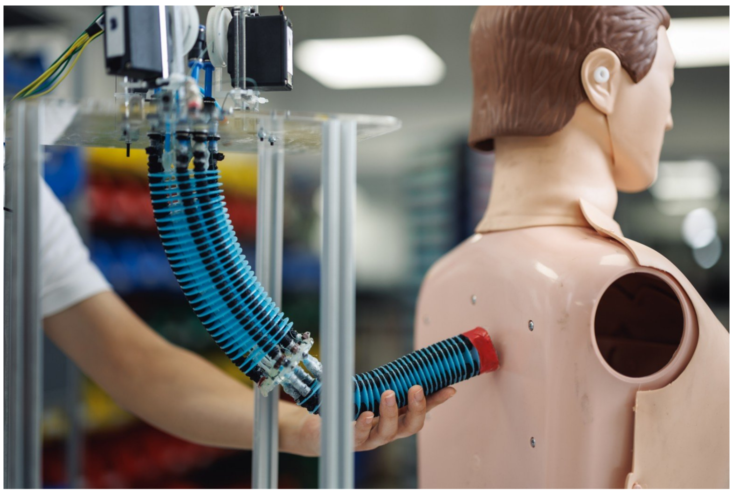
SMART and NUS develop AI control system using neuron-inspired learning enables soft robotic arms to learn a broad set of motions once and adapt instantly to changing conditions without retraining



Singapore-MIT Alliance for Research and Technology's (SMART) Mens, Manus & Machina (M3S) interdisciplinary research group, and National University of Singapore (NUS), alongside collaborators from Massachusetts Institute of Technology (MIT) and Nanyang Technological University (NTU Singapore), have developed an AI control system that enables soft robotic arms to learn a wide repertoire of motions and tasks once, then adjust to new scenarios on the fly without needing retraining or sacrificing functionality. This breakthrough brings soft robotics closer to human-like adaptability for real-world applications, such as in assistive robotics, rehabilitation robots, and wearable or medical soft robots, by making them more intelligent, versatile and safe.

Unlike regular robots that move using rigid motors and joints, soft robots are made from flexible materials such as soft rubber and move using special actuators – components that act like artificial muscles to produce physical motion. While their flexibility makes them ideal for delicate or adaptive tasks, controlling soft robots has always been a challenge because their shape changes in unpredictable ways. Real-world environments are often complicated and full of unexpected disturbances, and even small changes in conditions – like a shift in weight, a gust of wind or a minor hardware fault – can throw off their movements.

Despite substantial progress in soft robotics, existing approaches often can only achieve one or two of the three capabilities needed for soft robots to operate intelligently in real-world environments: using what they've learned from one task to perform a different task, adapting quickly when the situation changes, and guaranteeing that the robot will stay stable and safe while adapting its movements. This lack of adaptability and reliability has been a major barrier to deploying soft robots in real-world applications until now.

“This new AI control system is one of the first general soft-robot controllers that can achieve all three key aspects needed for soft robots to be used in society and various industries. It can apply what it learned offline across different tasks, adapt instantly to new conditions and remain stable throughout — all within one control framework,” said Associate Professor Zhiqiang Tang, who was a Postdoctoral Associate at M3S and at NUS when he carried out the research, is the first and co-

corresponding author of the paper, and is now Associate Professor at Southeast University (SEU China).

The system supports multiple task types, enabling soft robotic arms to execute trajectory tracking, object placement and whole-body shape regulation within one unified approach. The method also generalises across different soft-arm platforms, demonstrating cross-platform applicability.

This breakthrough opens doors for more robust soft robotic systems to develop manufacturing, logistics, inspection and medical robotics without the need for constant reprogramming – reducing downtime and costs. In healthcare, assistive and rehabilitation devices can automatically tailor their movements to a patient’s changing strength or posture, while wearable or medical soft robots can respond more sensitively to individual needs, improving safety and patient outcomes.

The researchers plan to extend this technology to robotic systems or components that can operate at higher speeds and more complex environments, with potential applications in assistive robotics, medical devices and industrial soft manipulators, as well as integration into real-world autonomous systems.

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