Tech Xplore

A plant-inspired controller that could facilitate the operation of robotic arms in real-world environments

June 5 2023, by Ingrid Fadelli

The robot explores the workspace through plant-like oscillations to gather information from the environment and build a knowledge base. By mean of a greedy search approach, the robot can identify the point of interest and implements reaching through plant-like tropism. Credit: Donato et al

Many existing robotics systems draw inspiration from nature, artificially reproducing biological processes, natural structures or animal behaviors to achieve specific goals. This is because animals and plants are innately equipped with abilities that help them to survive in their respective environments, and that could thus also improve the performance of robots outside of laboratory settings.

Researchers at the Brain-Inspired Robotics (BRAIR) Lab, BioRobotics Institute of Sant'Anna School of Advanced Study in Italy and National University of Singapore recently developed a plant-inspired controller that could improve the performance of robotic arms in unstructured, real-world environments. This controller, introduced in a paper presented at the conference IEEE RoboSoft 2023 in Singapore and selected among the finalists for the best student paper award, specifically allows robot arms to complete tasks that involve reaching specific locations or objects in their surroundings. This paper was part of a broader research project called GrowBot.

"Soft robot arms are a new generation of robotic manipulators that take inspiration from the advanced manipulation capabilities exhibited by 'boneless' organisms, such as octopus tentacles, elephant trunks, plants, etc.," Enrico Donato, one of the researchers who carried out the study, told Tech Xplore. "Translating these principles into engineering solutions results in systems that are made up of flexible lightweight materials that can undergo smooth elastic deformation to produce compliant and dexterous motion. Due to these desirable characteristics, these systems conform to surfaces and exhibit physical robustness and human-safe operation at potentially low cost."

While soft robot arms could be applied to a wide range of real-world problems, they could be particularly useful for automating tasks that involve reaching desired locations that might be inaccessible to rigid robots. Many research teams have recently been trying to develop controllers that would allow these flexible arms to effectively tackle these tasks.

"Generally, the functioning of such controllers relies on computational formulations that can create a valid mapping between two operational spaces of the robot, i.e., task-space and actuator-space," Donato explained. "However, the proper functioning of these controllers generally relies on vision-feedback which limits their validity within laboratory environments, restricting the deployability of these systems in natural and dynamic environments. This article is the first attempt to overcome this unaddressed limitation and extend the reach of these systems to unstructured environments."

As most existing controllers for soft robot arms were found to primarily perform well in laboratory environments, Donato and his colleagues set out to create a new type of controller that could also be applicable in real-world environments. The controller they proposed is inspired by the movements and behavior of plants.

"Contrary to the common misconception that plants do not move, plants actively and purposefully move from one point to another using movement strategies based on growth," Donato said. "These strategies are so effective that plants can colonize almost all habitats on the planet, a capability lacking in the animal kingdom. Interestingly, unlike animals, plant movement strategies do not stem from a central nervous system, but rather, they arise because of sophisticated forms of decentralized computing mechanisms."

The control strategy underpinning the functioning of the researchers' controller tries to replicate the sophisticated decentralized mechanisms underpinning the movements of plants. The team specifically used behavior-based artificial intelligence tools, which consist of decentralized computing agents combined in a bottom-up structure.

"The novelty of our bio-inspired controller lies in its simplicity, where we exploit the fundamental mechanical functionalities of the soft robot arm to generate the overall reaching behavior," Donato said. "Specifically, the soft robot arm comprises of a redundant arrangement of soft modules, each of which are activated through a triad of radially arranged actuators. It is well-known that for such a configuration, the system can generate six principle bending directions."

The computing agents underpinning the functioning of the team's controller exploit the amplitude and timing the actuator configuration to reproduce two different type of plant movements, known as circumnutation and phototropism. Circumnutations are oscillations commonly observed in plants, while phototropism are directional movements that bring a plant's branches or leaves closer to the light.

The controller created by Donato and his colleagues can switch between these two behaviors, achieving the sequential control of robotic arms spanning across two stages. The first of these stages is an exploration phase, where the arms explore their surroundings, while the second is a reaching phase, where they move to reach a desired location or object.

"Perhaps the most important take-away from this particular work is that this is the first time redundant soft robot arms have been enabled reaching capabilities outside of the laboratory environment, with a very simple control framework," Donato said. "Furthermore, the controller is applicable to any soft robot arm provided a similar actuation arrangement. This is a step towards the use of embedded sensing and distributed control strategies in continuum and soft robots."

So far, the researchers tested their controller in a series of tests, using a modular cable-driven, lightweight and soft robotic arm with 9 degrees of freedom (9-DoF). Their results were highly promising, as the controller allowed the arm to both explore its surroundings and reach a target location more effectively than other control strategies proposed in the past.

In the future, the new controller could be applied to other soft robotic arms and tested in both laboratory and real-world settings, to further assess its ability to deal with dynamic environmental changes. Meanwhile, Donato and his colleagues plan to develop their control strategy further, so that it can produce additional robotic arm movements and behaviors.

"We are currently looking to enhance the capabilities of the controller to enable more complex behaviors such as target tracking, whole-arm twining, etc., to enable such systems to function in natural environments for long periods of time," Donato added.

More information: Enrico Donato et al, Plant-inspired behavior-based controller to enable reaching in redundant continuum robot arms, *2023 IEEE International Conference on Soft Robotics (RoboSoft)* (2023). DOI: 10.1109/RoboSoft55895.2023.10122017.