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Editorial for the special issue on biomimetic soft robotics: Actuation, sensing, and integration

The field of soft robotics has witnessed impressive progress in recent decades, driven by the necessity to develop robotic systems that are more adaptable, flexible, and user-friendly. Biomimetic soft robotics, inspired by nature and biological principles, has brought numerous benefits across various applications, ranging from industrial automation to underwater exploration. Advances in actuation mechanisms, sensing technology, and control systems have expanded the potential of these robots, enabling them to navigate complex, unstructured environments with unparalleled adaptability. This special issue on “Biomimetic soft robotics: actuation, sensing, and integration” includes seven research articles.

Wiranata et al. [1] present a do-it-yourself (DIY) ultra-high-voltage amplifier (UHV-Amp) tailored for educational purposes in dielectric elastomer actuators (DEAs). The research outlines the design process for the UHV-Amp, which is mainly based on a Cockcroft–Walton circuit and incorporates an Arduino microcontroller for control. The UHV-Amp effectively produced voltages of up to 4 kV, sufficient for operating DEAs at both low and high frequencies. By offering a flexible and affordable platform, this study enhances the accessibility of DEA technology for newcomers in the field and contributes to the development of soft actuators from a new educational point of view.

Peng et al. [2] present their work on the development and control of a soft robot that draws inspiration from the inchworm. The robot's design integrates the McKibben artificial muscles to facilitate axial and radial contractions, emulating the movement of the inchworm. The robot is divided into segments, each of which is governed by artificial muscles. The control system triggers the muscles to imitate the inchworm's motion, enabling the transportation of objects. Through experiments, the robot has demonstrated substantial improvements in transportation efficiency, being capable of transporting objects exceeding 100 g in weight and operating at a speed of 8.54 mm/s. The research contributes significantly by showcasing that an inchworm-inspired control pattern can notably enhance the transportation capabilities of soft robots.

Inspired by the biological adaptation observed in sand vipers, Li et al. [3] study the impact of anisotropic scales on enhancing the movement efficiency of soft undulatory robots. A pseudo-rigid-body dynamics model was developed to simulate the undulatory motion of the robot, accompanied by numerical simulations to scrutinize the influence of anisotropic friction. A prototype soft robot, drawing inspiration from the locomotion principles of biological snakes and incorporating anisotropic

scales, was tested within granular mediums to assess forward and reverse undulatory efficacy. The congruence between simulation outcomes and experimental data validates the accuracy of the model and underscores its applicability in practical scenarios. This research provides a significant contribution by demonstrating that introducing anisotropic friction via scale structures enhances the mobility of soft robots in granular environments.

Traditional underwater propulsion systems, such as propellers and jet systems, are effective in generating thrust but face challenges in miniaturization for small-scale swimmers and micro-robots. To address this, acoustic propulsion has emerged as a promising alternative, offering simplicity, biocompatibility, and scalability. The study of Kong et al. [4] introduces a novel submerged surface acoustic wave (SAW) propulsion system based on a SiO₂/Al/LiNbO₃ structure, optimized for high-power density and miniaturization. Through simulations and experiments, the system demonstrated efficient propulsion, achieving a maximum no-load speed of 177 mm/s and significant propulsion forces across various frequencies. The findings highlight the potential of submerged SAW systems to revolutionize small-scale underwater propulsion, with applications ranging from underwater drones to biomedical microbots.

Wang et al. [5] present a spider-inspired compliant leg design for mobile robots aimed at enhancing terrain adaptability, obstacle-crossing ability, and balance in search and rescue (SAR) operations. The innovative design integrates a semi-tendon-driven mechanism and compliant joints, enabling both passive and active adaptation to uneven terrains while reducing the number of required motors. By combining the speed of wheeled mobility with the flexibility of legged movement, the design offers a practical and cost-effective solution for SAR robots. Experimental results demonstrated that the leg could lift 1.3 times higher than the chassis height, support loads up to 1.5 kg, and cross obstacles up to 15.5 cm at speeds of 1 m/s. This research contributes to advancing SAR robot capabilities, particularly in challenging disaster response scenarios, by improving mobility and reducing production costs.

Zhu et al. [6] introduce a low-cost, easily manufacturable tendon-driven continuum robot (TDCR) utilizing a serial S-shaped backbone structure fabricated through Fused Deposition Modeling (FDM). Designed to mimic the flexibility and dexterity of biological structures, the TDCR minimizes plastic deformation during bending and incorporates a pseudo-rigid-body model (PRBM)

for accurate motion prediction. Experimental validation demonstrated the kinematic model's reliability, with minimal mechanical hysteresis and significant influence of structural parameters like line width on bending stiffness. A three-finger gripper prototype showcased the TDCR's practical applications in precise manipulation tasks. By significantly reducing manufacturing complexity and cost, this research provides a scalable solution for TDCR development, facilitating broader adoption in minimally invasive surgery, robotics, and industrial automation.

Hugo et al. [7] explore the application of neuroevolution algorithms—NEAT, HyperNEAT, and AFPO—for automating the design of soft actuators, focusing on medical devices like catheters for targeted drug delivery. Neuroevolution enables the optimization of actuator morphologies, prioritizing performance, robustness, and material efficiency. Using the Voxelyze physics engine, designs were simulated under real-world constraints and evaluated on metrics such as maximum bending displacement and control robustness. Among the algorithms, NEAT demonstrated superior performance by producing efficient designs with fewer voxels and enhanced robustness. This research highlights neuroevolution's potential to transform soft medical device development, providing an automated, scalable approach that minimizes reliance on manual prototyping while accelerating innovation in healthcare robotics.

Each article above has undergone a rigorous two-round review process to maintain the highest publication standards. The collective efforts presented in these articles underscore the critical role of bio-inspired and soft robotics in addressing global challenges. From navigating complex terrains to revolutionizing medical device design, these innovations are reshaping the possibilities for robotics in diverse domains.

The Guest Editors express their great thanks to all the authors and reviewers for their invaluable contributions to this special issue. Additionally, special thanks go to the journal editors for their unwavering support and dedication to the successful organization and publication of this issue. We hope this collection of papers serves as a valuable resource for researchers in advancing biomimetic soft robotics to benefit society.

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