Soft Mechatronics for Human-Friendly Robotics

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I. Introduction

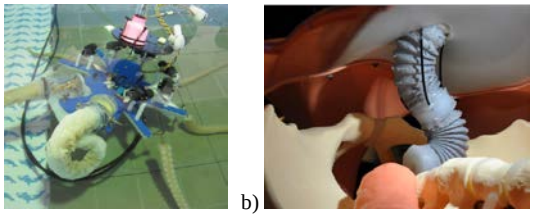
Bioinspiration in robotics is a consolidated approach that has contributed to the development of more robust control techniques, learning capabilities in robots, more friendly interaction with human beings, robot shapes more suitable for real-world applications. This responds to a growing need for robots in service tasks, in unstructured environments, in biomedical applications, in contact with human beings. By taking inspiration from the variety of organisms inhabiting our natural environment, the need for soft body parts appears clear, to increase adaptability and robustness.

II. The Octopus as a Paradigm for Soft Robotics

Roboticists who study biological systems look at the knowledge of the biological principles and their generalization, to take inspiration for the design of novel products. Looking at an octopus from the roboticist view point it is easy to understand why it is considered a paradigmatic example for soft robotics: its arms are soft and deformable, they can bend in any direction, at any point along the arm; however, they can stiffen when needed and they can grasp and pull objects with considerable strength; the octopus does not have a large brain, yet it can control this huge amount of possible movements and motion parameters. The abstraction which led to the understanding of the basic principles behind these capabilities pushed the development of new technologies for soft robot bodyware, soft actuators, soft tactile and proprioceptive systems, a stretchable skin, and suckers applied in the development of an octopus-like robot (Fig. 1a) [1].

III. New Frontiers in Surgery

A soft and flexible arm which is able to change its shape and modulate its stiffness: the biomedical field is probably one of the most sensitive to this breakthrough. In Minimally Invasive Surgery (MIS), for example, tools must be able to go through narrow openings and manipulate soft organs and they have to be able to move, deform, or change stiffness. Thus the experience and the knowledge gained from the study on the octopus natural model has been used to design a novel variable stiffness manipulator for surgery (Fig. 1b). This is based on a series of identical modules, each one consisting of a silicone tube with flexible fluidic actuators for enabling omnidirectional bending and elongation capability and one central channel for exploiting the granular jamming phenomenon for tuning the stiffness selectively. Moreover, it is worth mentioning that when in passive state, the module can be highly deformed and squeezed without affecting its functionalities (avoiding the risk of damaging both the manipulator and the organs) [2].



a) b)

Fig. 1. The eight-arm OCTOPUS robot (a); the STIFF-FLOP surgical manipulator (b).

IV. Advanced Realistic Biosimulators

New knowledge and availability of these new technologies allow the development of new tools and robots, but they also enable the possibility to move closer to the reproduction of the biological features at different levels. Expertise in soft materials, in actuation of soft parts and in modeling soft structures put the base for collaborations with clinicians for the possibility of producing physical simulators of different human organs. In this framework a robotic larynx is being developed with the similar purpose of providing a realistic physical model of the human organ to the otolaryngologists and for simulating and studying physiological behaviors and related pathologies.

V. Conclusion

The need for soft robots emerged in robotics, for facing unstructured environments, and in artificial intelligence, too. Using soft materials for building robots poses new technological challenges: the technologies for actuating soft materials, for embedding sensors into soft robot parts, for controlling soft robots are among the main ones. Though still in its early stages of development, soft robotics is finding its way in a variety of applications, where safe contact is a main issue, in the biomedical field, as well as in exploration tasks and in the manufacturing industry.

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