Soft Actuators for a New Generation of Soft Bodied Robots

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Abstract

Because of the challenges that traditional robotics based on rigid connections confront in many applications, soft materials are increasingly being used in robotics. A soft body brings up hitherto unexplored robotics possibilities, which are now difficult to exploit yet are a source of rich behaviours. To attain this aim, new soft mechatronics concepts, particularly soft actuation concepts, are necessary. Despite the fact that numerous steps must be taken, they are already demonstrating the potential for a dramatic technological shift in a variety of application sectors.

Keywords: *Soft robotics, Soft manipulators, Soft actuators*

INTRODUCTION

Robotics has advanced rapidly, but it still requires basic research and radical innovation to achieve its great potential. When presented with regular life activities and complex tasks in a real-world, poorly ordered environment, there is a technological gap between expected and actual behaviour of robots. A new design paradigm highlights how the body impacts behaviour through interaction with the environment. This robotics strategy is based on significantly altered bodyware that is intended to use and embrace compliance and deformability rather than fight it. This is the little revolution caused by soft robotics, which is described as the use of soft and pliable materials to create new mechatronic technologies with unrivalled capabilities. This novel technique handles the development of all robot components, with no influence on overall system compliance. In the mechatronic paradigm, these components include power supply, sensors, actuators, and mechanics. For this reason, new transduction concepts, notably for (but not limited to) soft actuators, have recently been introduced.

SOFT ACTUATORS

Actuators are divided into two types: active actuators that can exchange both positive and negative work (that is, they can raise or lower the energy level of the regulated system) and semi-active actuators that can only exchange negative or null work (i.e. they can only dissipate energy during the mechanical interaction with the controlled system).

Table I. Active Soft Actuation Technologies Comparison

Actuation technology			*Scaling of dimensions*	*Strain*	*Stress*	*Response velocity*
Cable-driven	electromagnetism		low due to driving motors	high	medium / low	high
SMA	temperature change		high	wires: very low springs: high	wires: high springs: medium / low	medium / low
SMP	light, electric current, magnetic field, chemical stimuli		high	medium	medium	low
EAP	electric field	electrons	medium / high	medium / high	medium	high
		ions	medium / high	axial: low bending: medium / high	medium / low	high
Flexible fluidic actuators	pressurized fluids	liquids (hydraulic)	medium / low due to hydraulic pumps	high	high	medium / high
		gases (pneumatic)	medium due to pneumatic pumps	high	medium	high

Active soft actuators

Flexible fluidic actuators are a broad category of soft actuators based on an elastic bladder, the expansion of which is pushed in favored directions by geometrical asymmetries, various material characteristics, or braided architectures. As a result, these actuators can convert fluidic pressure into tensile-compression force (e.g., McKibben actuators) or bending movement (e.g. Pneunets). They are quite adaptable and have a high energy density in general, although substantial fluidic sources are required.

Shape Memory Alloys (SMAs) are metal alloys that, when heated, may regain apparent plastic deformations. This technology may be used in soft robots due to its high force-weight ratio, small size, sensing capabilities, and noise-free operation.

However, they often demand rather strong currents, and the transduction process is inefficient. Furthermore, because to the substantial non-linearity and hysteresis associated with material activation, SMAs are extremely difficult to accurately manage. Shape Memory Polymers (SMPs) use the same idea as SMAs but with chemical, thermal, optical, and magnetic fields as stimulus. They have a faster reaction time but a slower transduction efficiency.

Electro Active Polymers (EAPs) are a new and promising class of technologies that have already shown the potential to bridge the gap between natural and artificial muscles. The majority of them are based on elastomeric matrices triggered by various processes, but they all have the capacity to change size and form when an electric stimulus is applied. They offer higher power densities than biological muscle, are easily scalable and free-form fabric able, and are perfect for biomimetic soft robotic applications. However, depending on the exact EAP technology, poor reaction times or excessive voltage requests may restrict its utility. Furthermore, dependability and robustness should be increased.

Cable-driven actuation is not a soft concept in and of itself, but when utilised to operate soft (mostly slander) robots, it may take use of a classic driving scheme's benefit of having continuous, extremely dexterous, and flexible behaviour. In comparison to other actuation systems, cable actuation provides minimal inertia, weight, and volume, as well as quick reaction times and long-range transfer of force and power. On the other hand, friction losses caused by the cables along the robot may diminish the system's controllability.

Semi-active soft actuators

Semi-active actuators are mostly employed as variable stiffness mechanisms in soft robotics.

Magneto- and electro-rheological materials may vary their stiffness from that of low viscosity fluids to that of solid materials by applying magnetic or electric fields, respectively.

The primary disadvantages are control concerns and the high fields required.

The jamming transition is a fluidic concept in which granular, fibrous, or laminar material trapped in an elastic membrane behaves as a liquid at air pressure and as a solid when driven into a vacuum.

This transition is quick and causes stiffness to grow in preset directions (depending on the filler material used).

Low melting point materials have a low melting temperature, which may be used to cause a phase shift (from solid to liquid and back) by heating and cooling.

This process is typically quite successful in stiffening change, but it is also relatively sluggish and wasteful.

Table 2 Semi-Active Soft Actuation Technologies Comparison

Actuation technology	Controllability	Response velocity	Stiffening range
Low Melting Point materials	low (through temperature)	seconds	up tp 10^4x
Magnetorheology	medium (through magnetic field)	milliseconds	16x
Electrorheology	high (through electric field)	milliseconds	10x
Jamming transition	medium (through vacuum level)	fraction of second	up to 40x

APPLICATION CASE STUDIES

Despite its youth, soft robotics is already proving its worth in areas where dexterity and inherent safety are critical.

In this paper, we describe three case studies in which soft actuators were integrated with flexible structures to satisfy the needs of distinct jobs.

OCTOPUS

We created an artificial arm in the OCTOPUS project that is based on the unusual muscle arrangement of the genuine octopus (muscular hydrostat). This was achieved by combining SMA springs positioned longitudinally and transversally along the arm with wires flowing from the base to various lengths of the arm [5]. The arm displayed the ability to mimic all of the basic actions of an octopus, including extension (40%), shortening (10%), omnidirectional bending, and local or global stiffening. A combination of these fundamental motions resulted in more sophisticated and natural behaviours (Fig. 1a). Despite not being aimed towards a single purpose, the robot inspired a number of application-driven robots, including STIFF-FLOP and I-SUPPORT.

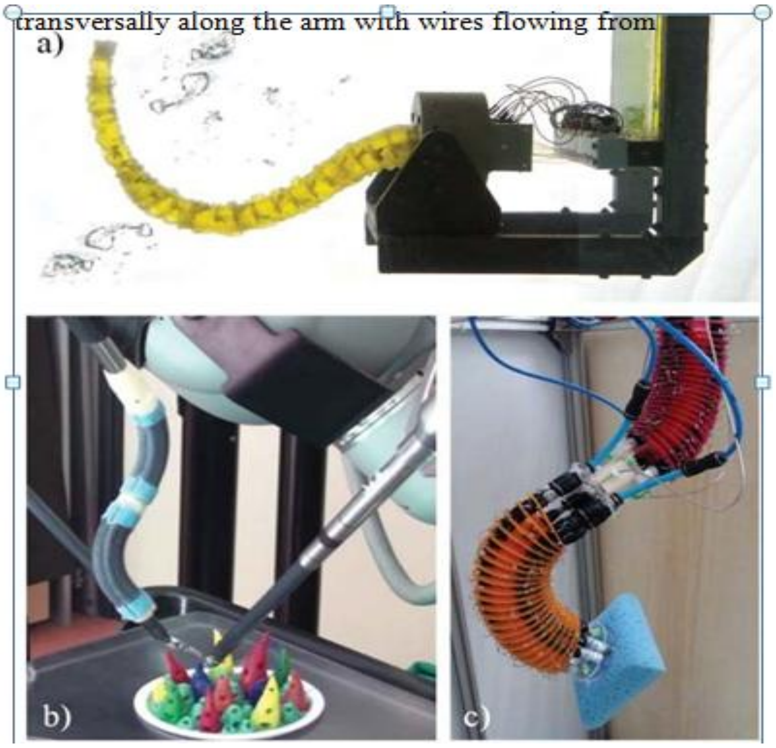

Fig. 1 Soft manipulators based on soft actuators developed within the OCTOPUS (a), STIFF-FLOP (b) and I-SUPPORT (c) European projects.

B. STIFF-FLOP

Although there are certain basic limits, minimally invasive surgery has become the gold standard in the majority of abdominal surgeries. Because of the restricted dexterity, flexibility, and manoeuvrability of equipment, many laparoscopic surgeries need up to 5 trocar accesses. A new surgical device has been designed that is based on a mix of soft actuators (Fig. 1b). Flexible fluidic actuators were embedded to provide high dexterity (omnidirectional bending capability with 120° angles and 86 percent elongation), but a granular jamming system was also integrated to increase manipulator stiffness (up to +36 percent), increasing stability and allowing the application of tunable forces.

I-SUPPORT

Soft robotics technology has shown to be beneficial in the field of assistive robotics. As part of the I-SUPPORT project, a soft robotics shower was constructed. The basic concept arises from the previous two studies: a soft manipulator that can move dexterously around the user, securely come into contact with the skin, and engage in bathing activities (including pouring water and brushing). Elongating fluidic actuators and Bowden cables are used by the robot to offer elongation, shortening, omnidirectional bending, and modular stiffening.

It has a maximum possible workspace of 60x70x35 cm3 and an effective workspace of 30x30x20 cm3 (Fig. 1c). Its location precision isn't exceptionally high (about 15-20 mm), but clinical testing proved that it's enough for the task at hand.

CONCLUSIONS

Soft actuator research is already allowing the development of soft-bodied robots and devices. Their intrinsic abilities open up new options, demonstrating their value as a complement to regular robots.

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