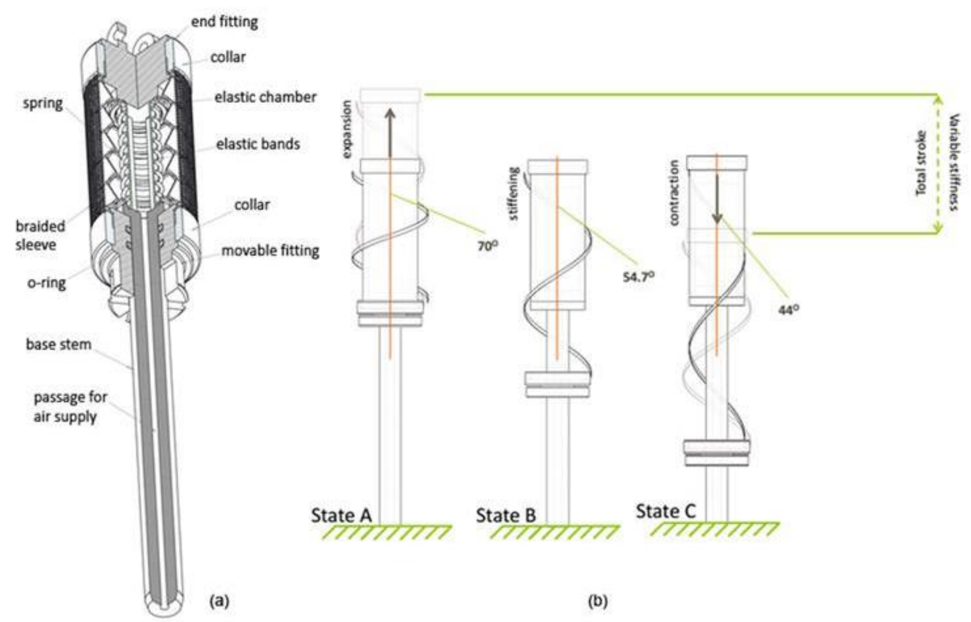
BI-DIRECTIONAL PNEUMATIC BRAIDED MUSCLE ACTUATOR

ABSTRACT

Our concept



(a) CAD rendering showing the schematics of the design. (b) Actuator working concept. A single braid fiber is shown instead of the whole outer braided sleeve for clarity. State A

The device offered is a pneumatic braided muscle actuator, able to produce bi-directional force and motion, and variable stiffness. Pneumatic muscles are generally preferred thanks to their high power to weight ratio, light weight, easy to install, hazard-free use and inherent compliance. The existing/traditional pneumatic muscle actuator has a fixed braid fiber angle and is usually able to produce a pulling uni-directional force when actuated. Conversely this actuator is able to achieve variable stiffness depending on the braid angle.

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Biorobotics,
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braided pneumatic muscle.

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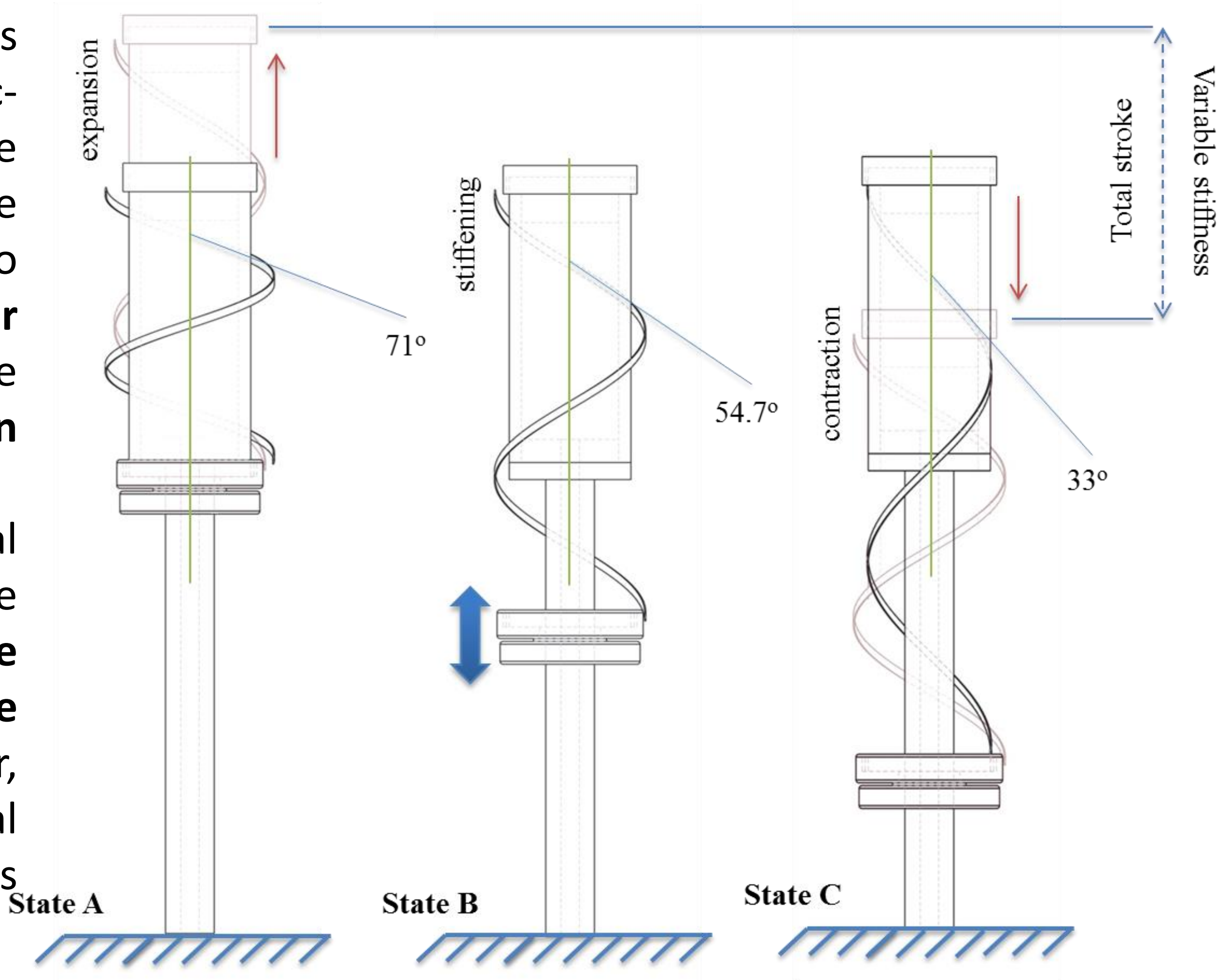
BI-DIRECTIONAL PNEUMATIC BRAIDED MUSCLE ACTUATOR

ABSTRACT THE WORKING CONCEPT

The pneumatic braided muscle is based on the traditional Mc-Kibben actuator but some fundamental changes to the design, enables the user to **change the initial braid fiber angle θ** independently, hence **achieving bi-directional motion and force upon actuation.**

The ability to change the initial braid fiber angle enables the actuator to **achieve variable stiffness at each point along the total stroke** of the actuator, whereas the traditional Pneumatic Artificial Muscles (PAMs) lack this ability.



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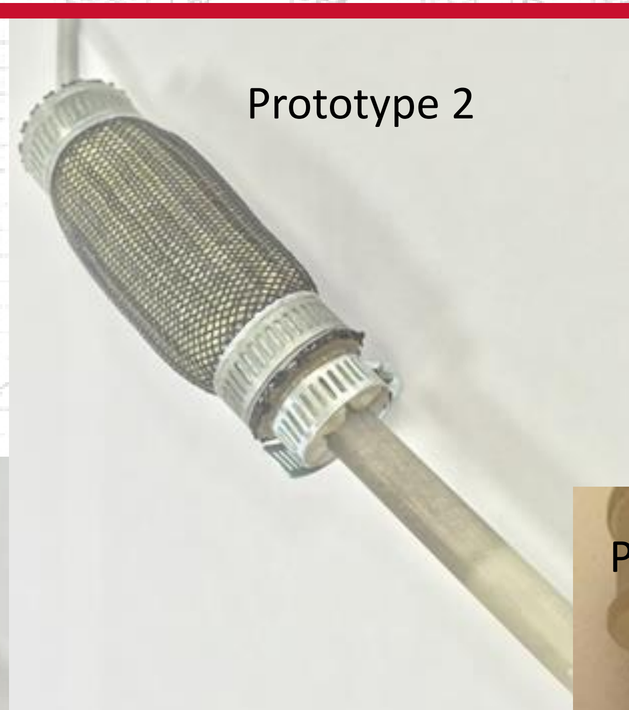
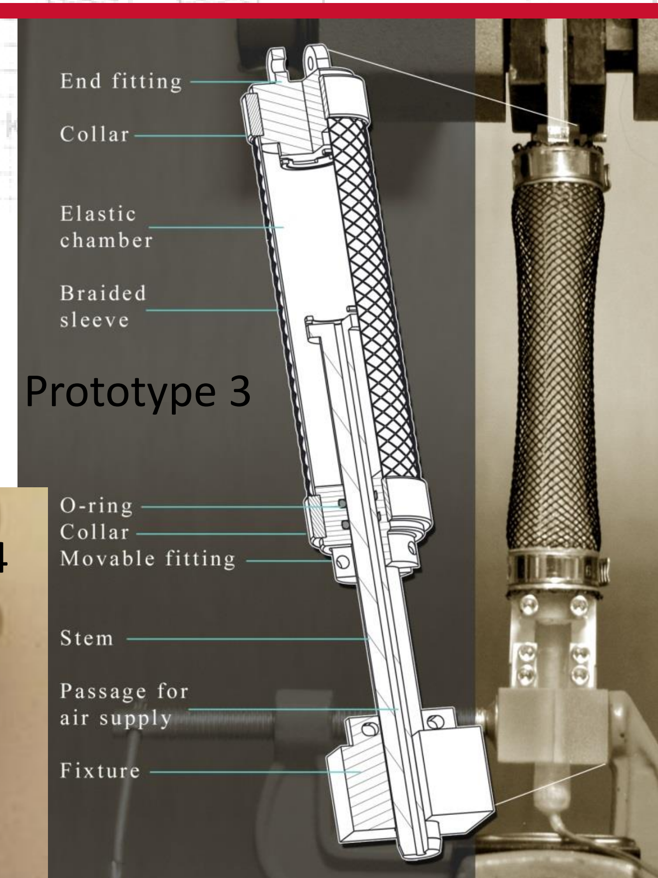
TEST & PROTOTYPING





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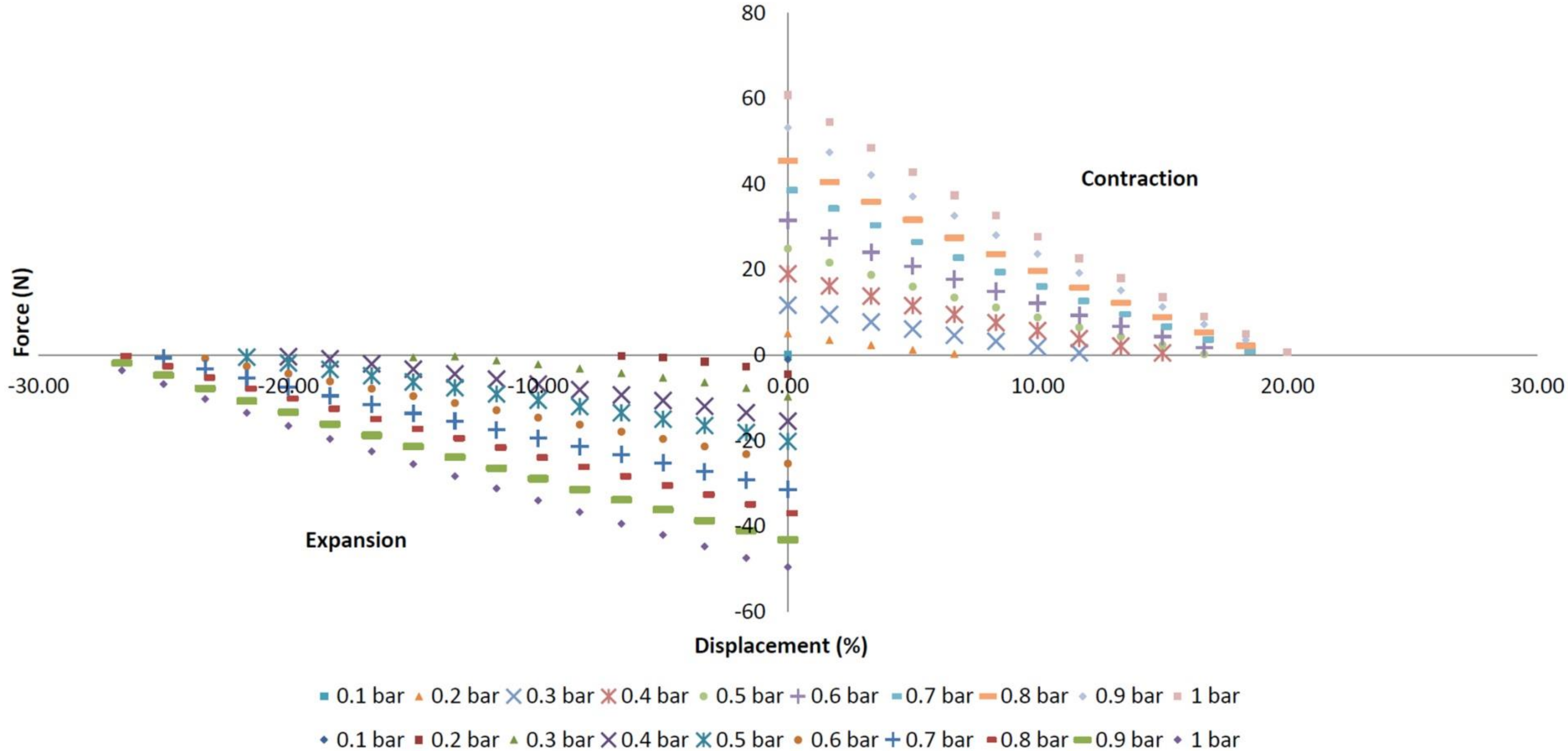
TEST & PROTOTYPING



Testing Prototype 3

Force-displacement characteristics of the actuator at different pressure values.

(x axis : displacement % , yaxis: force)

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TEST & PROTOTYPING

- Prototype 3 was tested in lab environment and through Finite Element Modeling (FEM), a 40/80N Force was exherted, in terms of expansion and contraction, in response to 1bar pressure.
- In terms of displacement, an overall stroke of of >40% of the total length of the actuator was obtained.
- Such Force displacement is compatible with the force exerted by a couple of antagonistic pneumatic actuator, to support 10 kg of a robotic arm of an exoskeleton that assists a worker, *e.g.* in the automotive sector.
- It was also tested as a main driver for a variable stiffness joint based on a 4-bar mechanism, able to convert the linear motion of the muscle into rotational motion of the joint. In this configuration the bi-directional muscle acts simultaneously as the main driver for the mechanism and as a damper *-energy dissipating medium-* in case of an impact loading on the joint.

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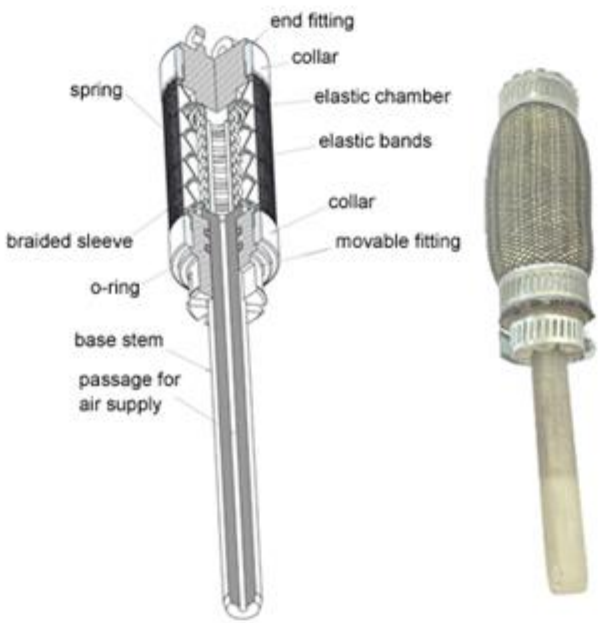
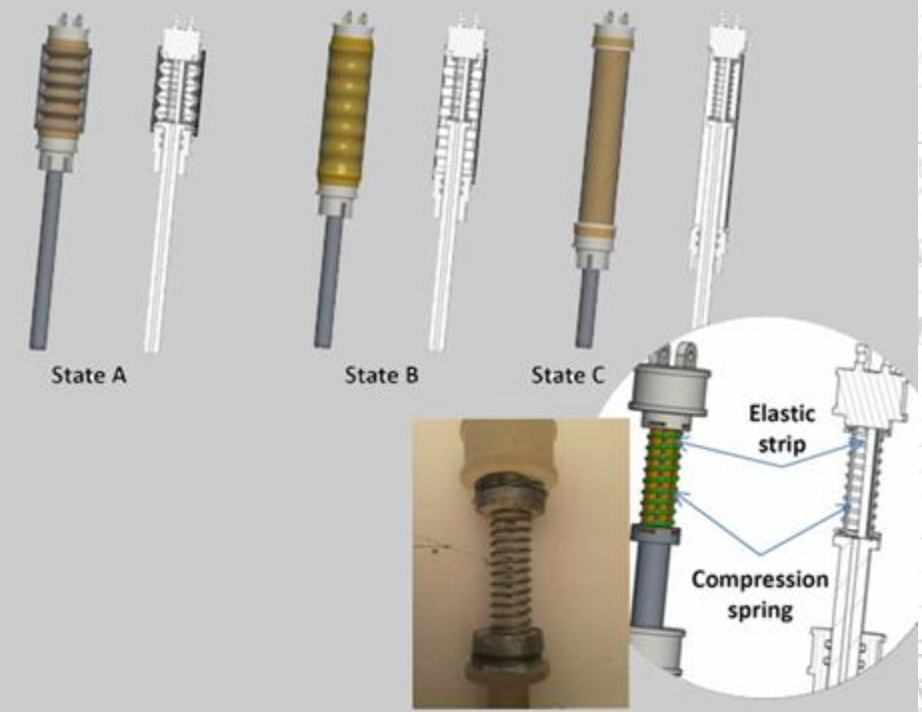
CAD RENDERING OF THE ACTUATOR IN 3 DIFFERENT STATE



Actuator design schematics. Physical prototype and sectioned CAD rendering.



Actuator shown in different states. In state A the actuator works as an extensor while in state C the actuator works as a contractor. In state B the actuator stiffen only upon actuation. A close-up of the internal components is also shown.

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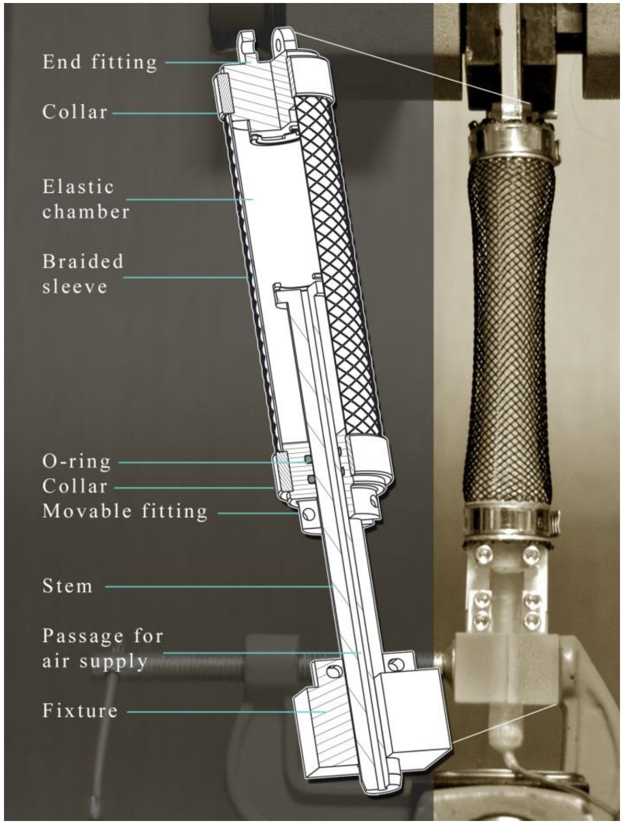
ADVANTAGES & APPLICATIONS



ADVANTAGES:

- Inherently compliant (good for human/ machine interaction from safety point of view).
- High power to weight ratio.
- Bi-directional force and motion.
- Able to achieve max and variable stiffness at each point along the total stroke of the actuator.
- No precise alignment required during installation due to the flexible body of the actuator.

APPLICATIONS:

- Rehabilitation robotics: robotic prosthesis or rehabilitation devices,
- human machine interaction, exo-skeletons
- manipulation, locomotion, industrial automation,
- automatic control of valves,
- single revolute joint resulting in light weight designs, where the muscle can also be used to control the stiffness of the revolute joint.

DESCRIPTION:

Pneumatic artificial muscles usually consist of a hollow cylindrical elastomeric chamber covered by an outer braided sleeve, consisting of fibres made of un-stretchable material and arranged in an anti-symmetric helical configuration. The hollow internal chamber and the braided sleeve are tightly sealed and attached to rigid end fittings, a passage is provided through one of these end fittings for pressurizing the elastic chamber. The mechanical work done is transferred to an external system through these end fittings. The working principle of the Bi-directional actuator is based on the traditional pneumatic muscles but some fundamental changes enables the user to change the initial braid fiber angle independently. Depending on the braid angle, the actuator is able to produce extension and contraction upon pressurization, moreover the ability to change the initial braid fiber angle enables the actuator to achieve variable stiffness at each point along the total stroke of the actuator, whereas the traditional pneumatic muscles lack this ability.

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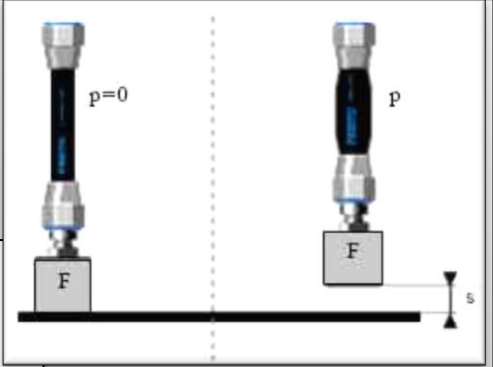
COMPETITOR ANALYSIS

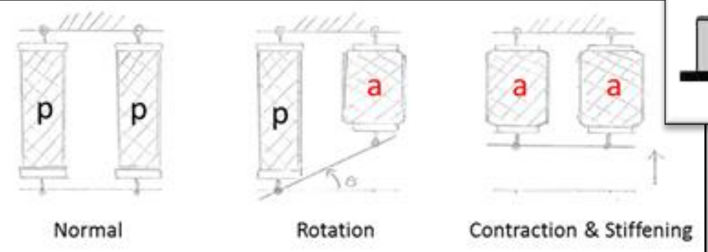
Example of Actuator

- Pneumatic artificial muscle (PAM)
- Mc-Kibben actuators
- Fibers Reinforce Elastomeric Enclosures (FREE's)
- Spring Over Muscle Actuator (SOM)

Limitations

- UniDirectional force&motion
- 1 degree of stiffness
- Invariable stiffness

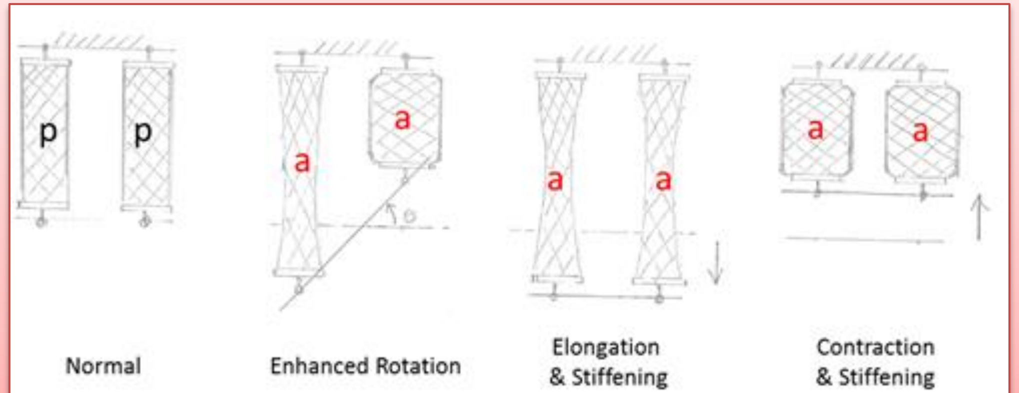




Normal Contractile Muscles

Braided pneumatic muscle Actuator (BPM)

Our Solution



Bi-Directional Muscles

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COMPETITOR ANALYSIS & BI-DIRECTIONAL PNEUMATIC BRAIDED MUSCLE ACTUATOR

	PAM	SOM	BPM
Bi-Directional force& motion	X	V	V
Overall size of a Bi-Directional mechanism	big	big	small
Weight	V	X	V
Equal F&M of extension & contraction	V	X	V
Antagonistic motion	2 muscles	2 muscles	1 muscle
Differential stiffness along the total stroke	X	V (at least 2 springs meaning increased size)	V

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PATENT FAMILY SPECIFICITIES

- On 29.12.2016 The patent received the International Search Report. No relevant objection emerged (only «A»). It was filed patents in EP, CN, US. The patents are now under the revision of the national patent office.
- Inventors: Cianchetti Matteo; Laschi Cecilia; Dario Paolo; Shah Syed Taimoor Hassan; Mazzolai Barbara
- Applicants: Scuola Superiore Sant'anna; Istituto Italiano Di Tecnologia

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SOFT ROBOTICS AREA AND SOFT MECHATRONICS FOR BIOROBOTICS LAB

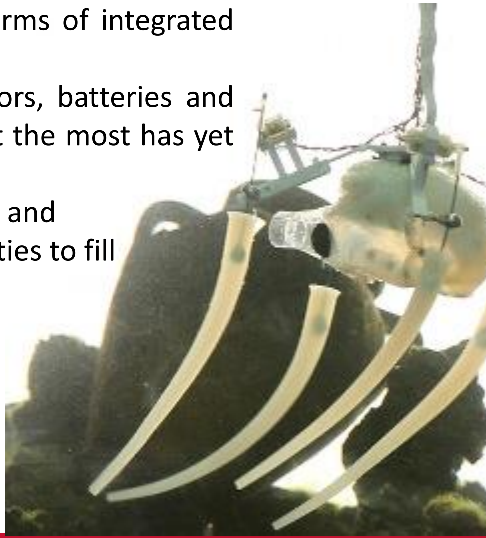
The growing need for robots in service tasks, in unstructured environments, in contact with humans, is leading to release the basic assumption of rigid parts in robotics. The role of soft body parts to increase adaptability and robustness appears clear in natural organisms. Compliance, or softness, are also needed for implementing the principles of embodied intelligence, or morphological computation, a modern view of intelligence, attributing a stronger role to the physical body and its interaction with the environment. **Soft robotics** is an interdisciplinary field in robotics that deals with robots built out of soft and deformable materials capable to actively and safely interact with humans and the environment. Soft robotics is not just a new direction of technological development, but a novel approach to robotics, unhinging its fundamentals, with the potential to produce a new generation of robots, in the support of humans in our natural environments.

Soft, elastic and deformable systems with variable stiffness are key factors for safe and effective interactions with physical unknown environments, opening to robots a wide range of application possibilities.

Soft robotics can show all its potentiality only if all the components of the system are contextually taken into consideration, going beyond even the biomechatronic approach in terms of integrated design.

Several efforts have been focused on the development of new sensors, actuators, batteries and mechanisms that are based on soft, flexible or variable stiffness technologies, but the most has yet to be done.

In particular, actuators represent the real bottle neck, but in the last few years new and promising soft mechatronics technologies are emerging thus offering new possibilities to fill the gap between natural and artificial muscles.



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