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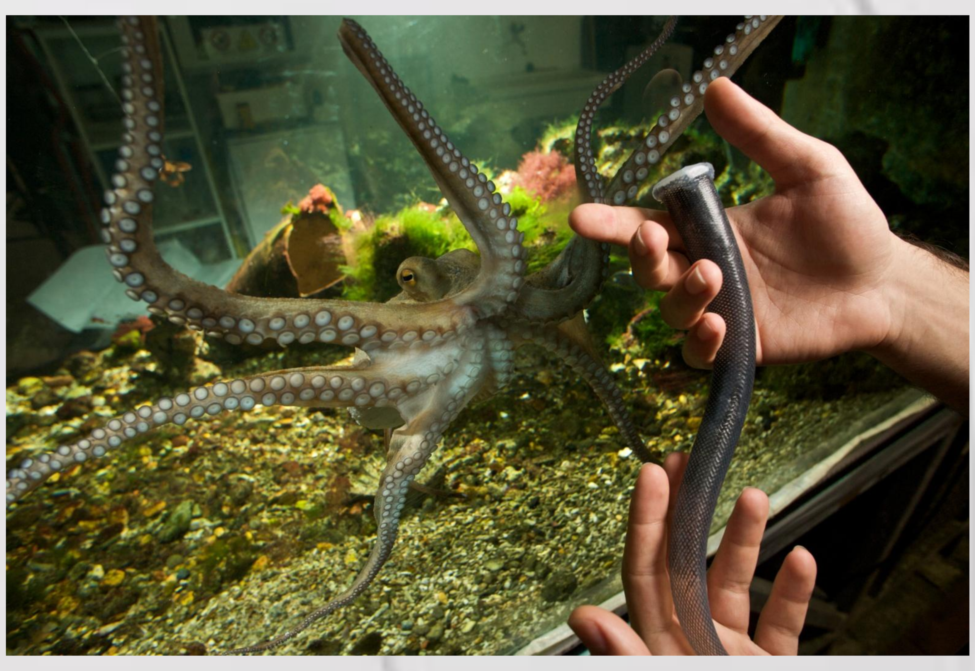
Novel Design Principles and Technologies for a New Generation of High Dexterity Soft-bodied Robots Inspired by the Morphology and Behaviour of the Octopus

From biology to robotics

The first soft arm prototype has been developed using the biological specifications appropriately translated into novel design principles.

The **results of the anatomical and neurophysiological investigation** and of the **biomechanical measurements** have been properly translated into specifications, as **structural advantages inspired by the biological model**, and relevant for the development of the **soft octopus-like robotic arm prototype**.



- Anatomy:
  Ultrasound imaging
  Histological analysis
- Biomechanics: in vivo biomechanical measurements of arm capabilities
- Neurophysiology and Modelling

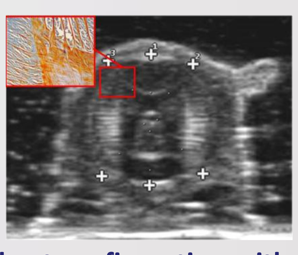
Mechatronic structure of artificial muscular hydrostat

Artificial muscular hydrostat performance

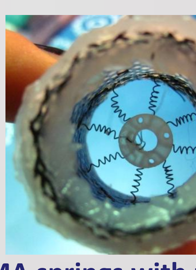
Control

The features of the octopus arm, as the muscular, nervous and connective tissue arrangement and biomechanics, have been replicated for the **soft actuators, electrical cables and mechanical interface structure and performance**.

Transverse muscles design and mechanical performance



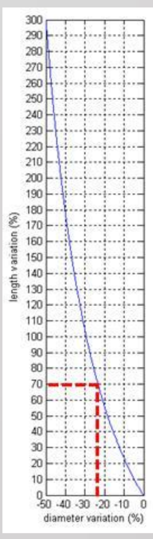
- Radial net configuration with straight interweaving of transverse muscle fibers
- Key-role of the trabeculae in maintaining circular the transverse section during contraction



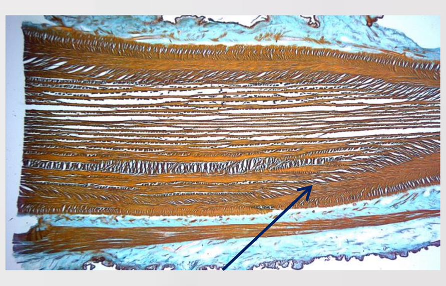
- SMA springs with radial configuration for a more efficiency in the reduction of the diameter

Measured 70% of arm strain during elongation obtained with 23% diameter reduction, which has been used as specification input in the model for the design of the SMA helical characteristics

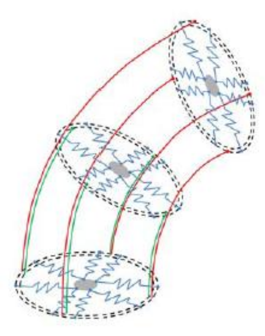
- NiTi Alloy mechanical properties
- Wire diameter
- Average spring diameter
- Number of coils
- Heat treatments

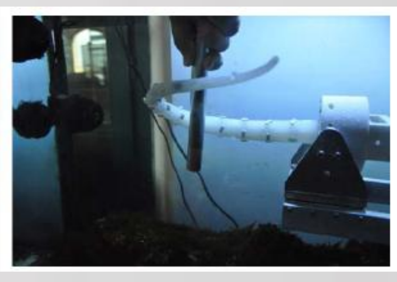


Longitudinal muscles design and mechanical performance



- Longitudinal muscles with insertion points along the arm allow multiple point bending

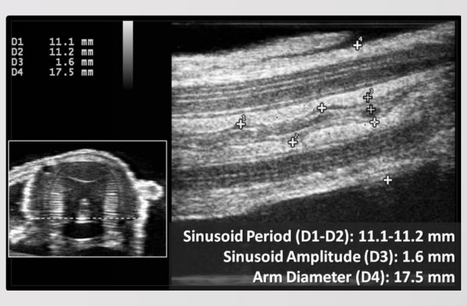


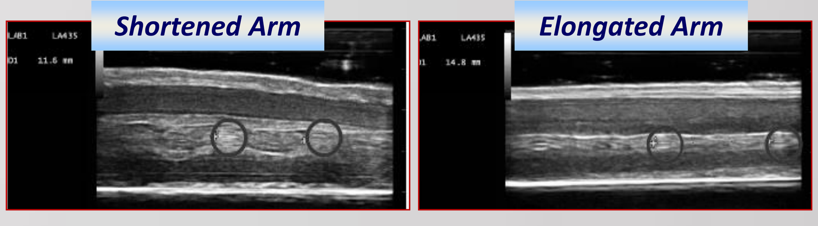


- The arm prototype rely on additional longitudinal cables from the base of the arm and fitted to several points along the arm length, thus improving bending capability

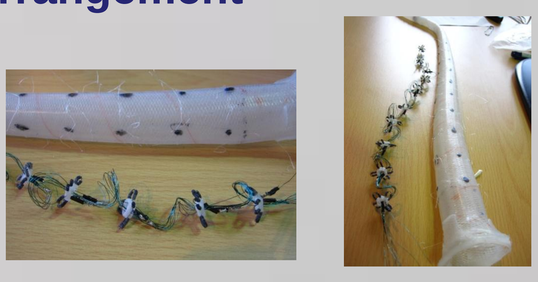
- Results of the force measurements (40 N mean, 1-2 sec contraction time) are used as specification in setting the longitudinal actuators of the robotic arm prototypes
- Cables have been covered with sheaths to reduce friction and avoid silicone damages
- The grasp point position at a 0.75 of total length has been used to allow grasping during the arm prototype pulling tests

Structural design specifications from octopus nerve cord arrangement



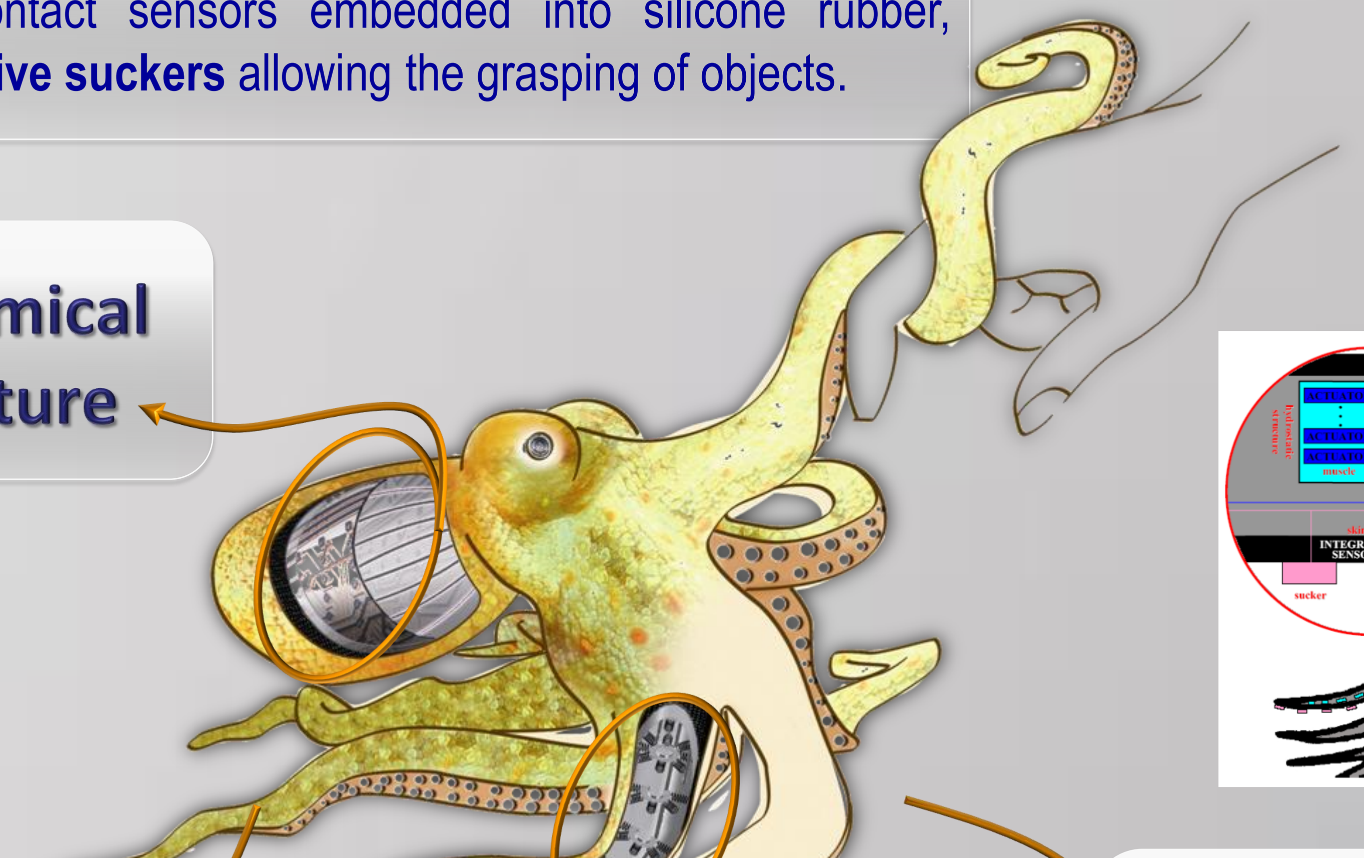


- Nervous tissue of the arm nerve cord has a sinusoidal arrangement at the arm rest length while is extended during elongation

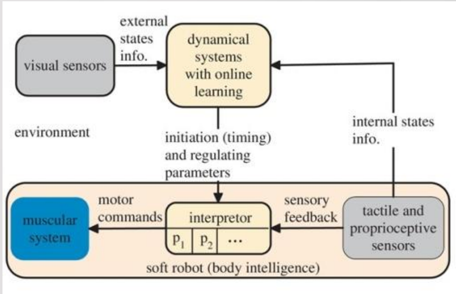


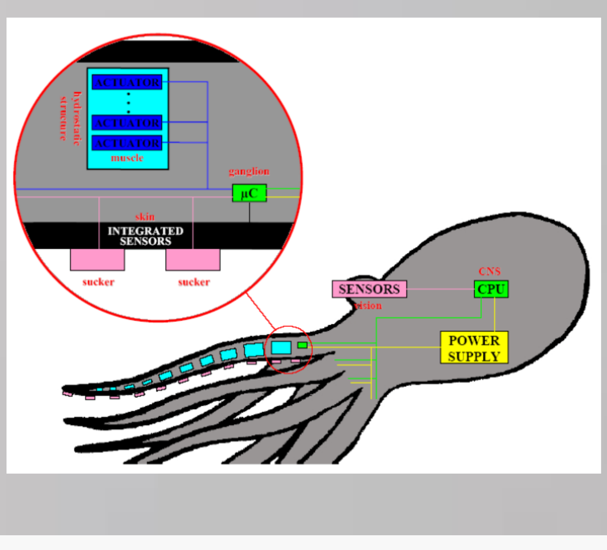
- Large elongations can be achieved using a sinusoidal arrangement for cables

Longitudinal cables and transverse SMA substitute muscle fibres, controlling contractions as soft actuators within the robot arm.
A **sensitive skin**, with contact sensors embedded into silicone rubber, surrounds the arm with **passive suckers** allowing the grasping of objects.



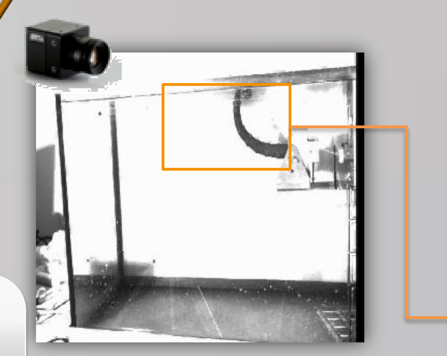
Behavioural dynamical systems architecture

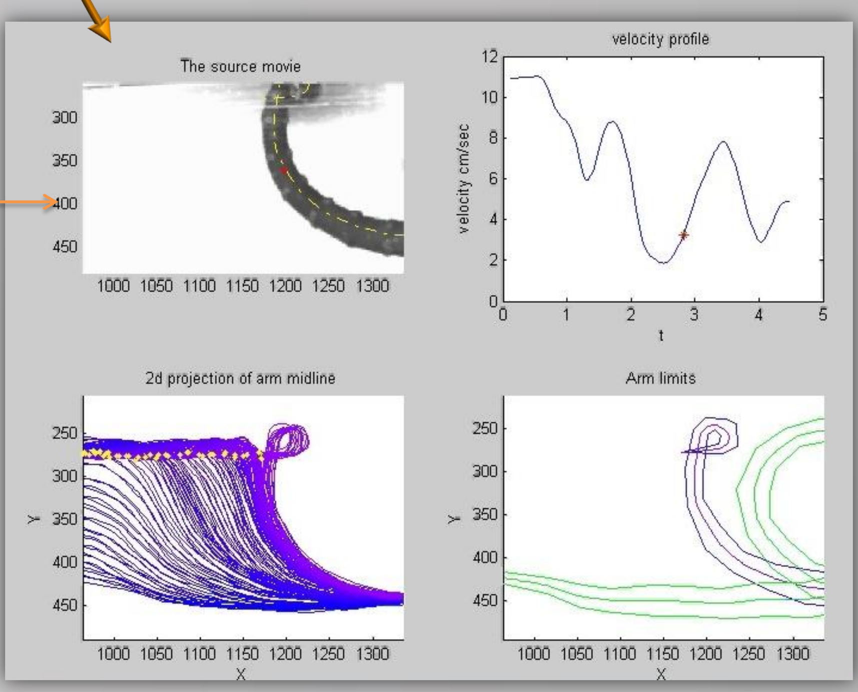




Sensorized skin with suckers

Robotic arm 3D movements recontruction tools

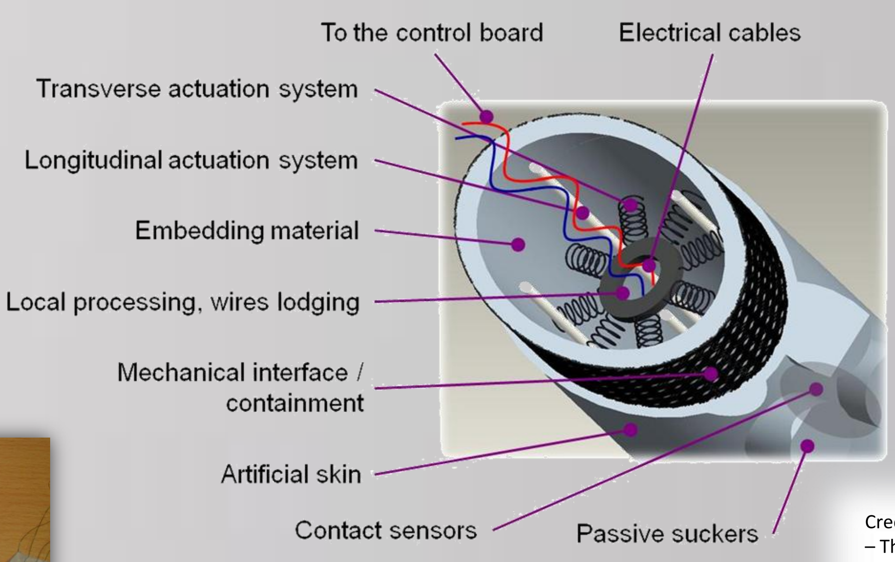




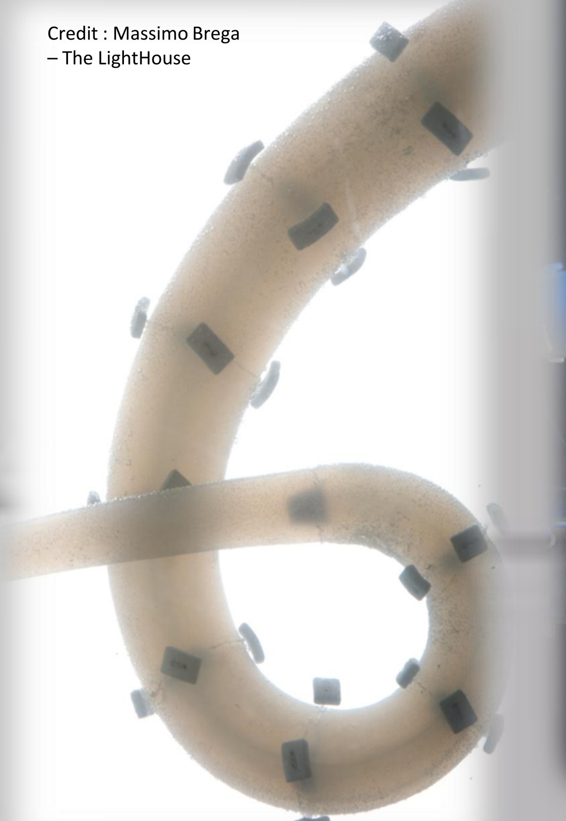
Robotic octopus-like arm prototype

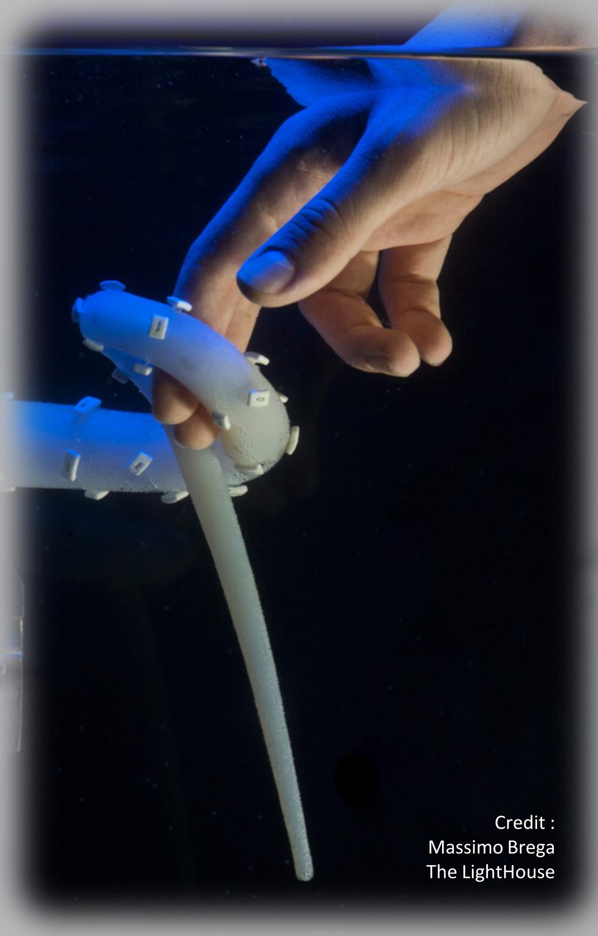
Technical data

Length: 457mm
Base Diameter: 30mm
Actuators: 4 longitudinal cables, 12 transverse SMA modules (8 SMA springs each)
Degrees of freedom: 16
Switch contact sensors
Passive silicone suckers



Credit : Massimo Brega – The LightHouse





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