The octopus as a paradigm for Embodied Intelligence and as source of inspiration for Soft Robotics

What is special in the octopus

The octopus has no rigid structures and it can flexibly squeeze into very small apertures or adopt the shape of its body and arm to the environment.

In the special muscular structure (muscular hydrostat) of the octopus arms, muscles are packed in a three-dimensional array, and have constant volume during movement.

By opening or promoting the movement, muscles serve as modifiable skeleton, allowing the octopus to actively control the stiffness of its arm.

The control of the large number of degrees of freedom is tightly distributed and is amplified by the use of stereotyped movements.

The octopus allows a rich behavioural repertoire, with also learning, memory and camouflage capabilities.

Need for quantitative data on the octopus anatomy, neurophysiology and biomechanics, to set the specifications for the design of the octopus-like robot

Bioengineering and biological methods are applied to study, measure and model octopus performance, with results of new scientific data beyond the state of the art, as well as novel design principles and specifications for robotics purpose.

Study of the organization of higher motor centers in the octopus brain

Ultrasound imaging is applied to investigate in vivo the arms morphology along the three planes

New ideas from the octopus neurophysiology for the design of control systems

Electrophysiological studies correlating kinematic with muscular activity, in order to understand dynamic degrees of freedom generation and control.

Characterization of elongation and bend along the arm length during reaching movement.

Hydrodynamics and elastodynamics models of the octopus arm

New insights on the octopus arm anatomy and biomechanics for soft robotics design

Novel design principles for soft robotics

New science and new knowledge on octopus anatomy, neurophysiology, mechanics, kinematic and dynamic modelling, and behavior

The 8 arms are a fascinating model of dexterity, with unique motor capabilities:

- No rigid structures virtually a whole number of DOF:

  - All-direction feeding
  - 70% of elongation of each arm
  - Variable and controllable stiffness
  - 45% pulling force (1 arm, 34% of length)
  - Manipulation capability with unexpected dexterity
  - Distributed control

Study of the organization of the motor and sensory peripheral nervous system of the arm

Hydrodynamics and elastodynamics models of the octopus arm

New bioengineering instruments and methods for the mechanical characterisation of the arms

- Measure of arms elongation, with strain gauges
- Measure of bending and longitudinal following
- Analysis of jet propulsion

Stress-strain and cutting tests on the arm skin

Octopus behavioural experiments to study arms use and motor coordination based on visual or tactile stimuli

Characterization of multi arms coordination and study of the octopus creating movement

Novel design principles for soft robotics

New science and new knowledge on octopus anatomy, neurophysiology, mechanics, kinematic and dynamic modelling, and behavior

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