Mimicking Adaptation and Plasticity in WORMS: the MAPWORMS Project

Linda Paternò[1], Ilaria Cedrola[1], Hasan Dad Ansari Mohammad[1], Veronica Iacovacci[1], Selene Tognarelli[1], and Arianna Menciassi[1]

[1] *The BioRobotics Institute, Scuola Superiore Sant'Anna, Pontedera (Pisa), Italy*

***Abstract*—The MAPWORMS project proposes a new paradigm of worm-inspired modular robots, able to operate in unstructured environments through the exploitation of stimuli-responsive shape-morphing materials.**

Keywords—Bioinspired robotics, shape-morphing robots, smart materials, soft robotics, worms

I. Introduction

The capability of living beings to perform tasks in response to environmental cues has inspired researchers to develop new technological solutions to allow robots controlling their structure, actively. In this regard, marine Annelida, which has adapted to all marine habitats, even the extreme ones, represents an intriguing source of inspiration [1].

In traditional robotics, precise position control is typically accomplished by central control of rigid structures. By contrast, nature puts in place a distributed control paradigm and exploits the elastic compliance of body parts (i.e., morphological computation). In this sense, soft robotics and material science have opened up new avenues for the development of bioinspired machines able to execute tasks in unstructured environments, in a safe and compliant manner, as nature does. Recently, a wide set of stimuli-responsive hydrogels have been proposed as promising building material candidates for signal-triggered shape-morphing devices, including medical ones. In particular, DNA-based hydrogels exploiting structural and functional information encoded in nucleic acids represent an attractive solution for reactive synthetic machines [2].

In this scenario, the MAPWORMS project proposes a radically new paradigm aimed at reproducing the complexity of living organisms and their capability to react to environmental cues without implementing a central control strategy as in traditional machines, but by relying on synthetic actuation units integrated into a smart shape-morphing and modular architecture with limited environmental impact.

II. Mapworms Paradigm

The target machines are intended as integrated systems inspired by the adaptation and plasticity of the body plan in marine Annelida and featured by shape-memory and self-healing hydrogels able to vary their shape and stiffness upon triggering. Thus, functional and morphological characterization of the case study worms is performed to deeply understand the mechanics enabling efficient surroundings exploration and to point out the key features allowing for shape changes (Fig. 1a). From a mathematical point of view, how a shape-morphing can be obtained by local modulation of rest- and stiff-state in an artificial system inspired by a fully characterised biological entity is carried out by mathematical modelling (Fig. 1b) [3].

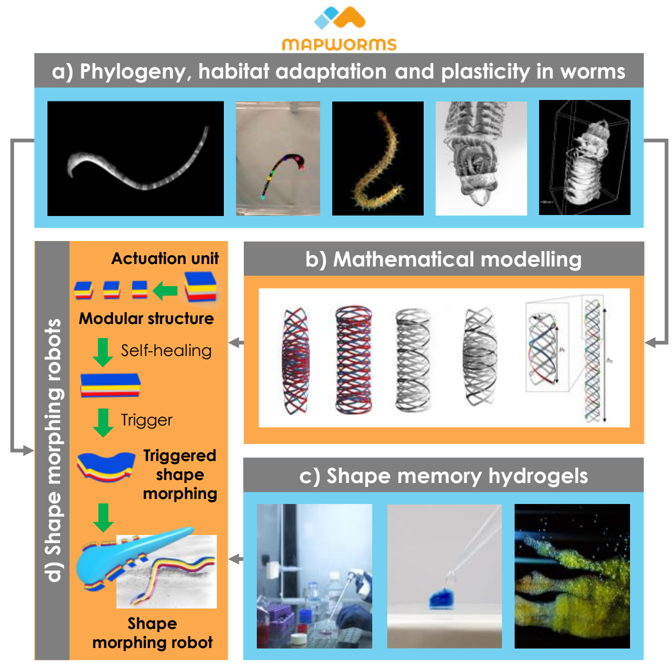

Fig. 1. Workflow of the biomimetic design of the modular shape morphing robots. Images in figure b are readapted from [3].

Stimuli-responsive DNA-based hydrogels undergoing cyclic hydrogel-to-liquid transitions are developed. In particular, smart materials embodying responsivity, or enzymes embedded in hydrogels, are under analysis to control their stiffness, shape-morphing, and self-healing capabilities (Fig. 1c). Different stimuli, such as light, pH, specific chemicals or biomolecules, are used to stimulate reversible hydrogel-to-solution phase transitions or to induce reversible stiffness variations of hydrogel matrices. By combining smart reactive hydrogels with non-reactive elements, actuation units able to transduce stiffness variation into geometrical changes are developed. The smart combination of actuation units and other passive parts leads to reconfigurable structures capable of self-adaptability, and to the development of robotic artifacts across different size scales (Fig. 1d). The potential employment of such morphing robots in selected medical applications will be investigated during the project development.

References

[1] S. Filogna, *et al*., "A Bioinspired Fluid-Filled Soft Linear Actuator," *Soft Robotics*, Nov. 2022.

[2] M. Vázquez-González and I. Willner, "Stimuli-Responsive Biomolecule-Based Hydrogels and Their Applications," *Angew. Chemie Int. Ed.*, vol. 59, no. 36, pp. 15342–15377, Sep. 2020.

[3] J. Quaglierini, *et al*., "Mechanics of tubular helical assemblies: ensemble response to axial compression and extension," *Acta Mech. Sin. Xuebao*, vol. 37, no. 2, pp. 173–186, Feb. 2021.

This work was supported by the European project MAPWORMS - Mimicking Adaptation and Plasticity in WORMS - Grant Agreement 101046846 (www.mapworms.eu).