VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Pasquale Ferrentino**

The public defense will take place on **Tuesday 2nd July 2024 at 4:00 pm** in room **D.0.07** (Building D, VUB Main Campus)

To join the digital defense, please click here
Meeting ID: 365 411 609 836
Passcode: hyP9Yf

MATERIAL-BASED MODELING OF CONTINUUM SOFT ROBOTS

BOARD OF EXAMINERS

Prof. dr. Dimitrios Angelis

Dr. Ellen Roels

Prof. dr. Greet Van De Perre

Prof. dr. Cosimo Della Santina

Prof. dr. Christian Duriez

PROMOTORS

Prof. dr. Bram Vanderborght

Prof. dr. Seppe Terryn

Abstract of the PhD research

Continuum soft robots raise many challenges in the research field, from optimizing the material properties to being involved in the design to having accurate models that can be used for real-time control. Specifically, continuum structures are not easily described by the modeling strategies that characterize traditional robots. Furthermore, the materials used in this field are called elastomers, rubber-like materials with complex non-linear mechanics and time-dependent behavior.

This thesis places a significant emphasis on the material mechanical behavior of elastomers. It strives to incorporate non-linear elasticity and time-dependency into the modeling process of continuum soft actuators, following the material-based modeling strategy.

In particular, mechanical tests on elastomeric specimens examine the material's mechanical behavior. The tests conducted at the material level are always linked to the actuator's final working conditions. From this test, a constitutive mechanical equation of the material is retrieved, which is inserted in an open-source finite element analysis simulator called SOFA, where the authors of this thesis contributed to creating new algorithms that open new possibilities within the SOFA community, but in general to the soft robotics research field. The finite elements models are validated experimentally in quasi-static and dynamic conditions for single-material and multi-material robots. In addition, they are eventually inserted in real-time controllers directly involving the continuum mechanics equation.

This dissertation has as a material use case the self-healing elastomers, which represent a new avenue in the field, creating soft robots less susceptible to damages. Furthermore, their recyclability could make the production of soft structures more sustainable.

The material-based methodology presented in this thesis brings material mechanics concepts into soft robotics and can open new possibilities to optimize the mechanical performances of the elastomers and the soft actuator designs and, in future perspectives, have accurate models that can be used in real-time controllers and involves the complex mechanics of the elastomers.