Doctoral Dissertation
Doctoral Program in Mechanical Enginering (37th cycle)

# Pneumatic Soft Robotic System for Actuation and Sensing

## Novel sustainable solutions for Service Robotics

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# Summary

Service Robotics is the branch dedicated to the development of robotic technologies aimed directly at serving humans. Today, service robots must be efficient and safe in order to interact in unstructured environments where humans or other living creatures are present.

This thesis presents two pneumatic technologies, namely an actuator and a sensor, for Service Robotics applications. To this aim, the research context is first provided, outlining the evolution of pneumatic robotic systems over the past two decades. The main application areas of Service Robotics will then be described, including their challenges, design requirements, and how the scientific community has responded to these needs with pneumatic-based solutions. Additionally, the rise of Soft Robotics will be discussed, with a particular focus on the materials and methodologies currently employed for the fabrication of soft pneumatic robots.

The thesis will then explore the development of a linear soft pneumatic actuator that exploits the principle of antagonistic chambers to achieve bidirectional behavior. Design methodologies, prototyping techniques, and static performance in terms of stroke, exerted force, and energy consumption will be described. Particular attention will be paid to the evaluation of control methods for energy savings. The experimental phase will include not only the characterization of the actuator but also its implementation in the development of a lightweight compliant soft gripper.

The final chapter will address the development of a sensing unit based on a soft pneumatic chamber connected to an auxiliary electro-pneumatic circuit. The approach will follow the same process as the actuator, from the theoretical formulation of the geometry and system outputs to its prototyping and experimental characterization. Particular attention will be devoted to the reliability quantification of the system. The anticipated applications of this concept include the development of a tactile sensing system to enhance the exteroceptive capabilities of robotic grippers, as well as the creation of a lightweight, untethered haptic device for active finger tele-rehabilitation, which has led to a patent application.