REGION BOURGOGNE FRANCHE COMTE

EIPHI-BFC GRADUATE SCHOOL CROSS DISCIPLINARY SCIENCE AND TECHNOLOGY

L'Europe s'engage en Bourgogne-Franche-Comté

PhD Thesis - ECOBOT project

Job title	Modeling and control of deformable robots (soft robots) based on electroactive polymers: a Hamiltonian approach to ports
Job type (PhD, Post-doc, Engineer)	PhD
Contract	36 months 1600 € net/month
Qualifications (Master, Ph.D ...)	Master
Job hours (full time/ part time)	Full Time
Employer	UBFC Université Bourgogne Franche-Comté
Financing Institutions	Graduate School EIPHI & Region Bourgogne Franche Comté
Host Laboratory	FEMTO-ST
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Job description	In this thesis we are interested in the modeling and control of deformable robots, or soft robots powered by electroactive polymers. Polymers electroactive or Dielectric Electo-Active Polymers (DEAP) have experienced a particularly boom these last years. They caught the attention of the robotics community with their different advantages: large deformation, fast response, energy efficiency, low cost [1, 2]. Many robotics applications use these dielectric polymers. The more recent are: an insect robot with low actuating voltage [3], a stretch pump for flexible robotics [4], a conformable gripper using electro-adhesion [5]. The Technologies for manufacturing these polymers have evolved well [6, 7, 8] and it is now possible to make flexible electrodes by simple inkjet printing [9], making possible the realization of complex configurations. The objective of this thesis is the design, modeling and control of structures deformable robotics for the rapid pick-up and drop of objects of varying shapes. The structure robotics initially envisaged is based on the use of wound actuators to the robotic arm and HASEL-type actuators for the conformable gripper. The multi-physical, non-linear and distributed-parameter characters (the system is governed by Partial Differential Equations (PDE)) of the studied systems motivates the use of Hamiltonian formalism with ports, both for the modeling and for the synthesis of laws of ordered. Indeed, the Hamiltonian formalism with ports is particularly adapted for the modeling and control of complex and nonlinear multiphysics systems such as electro-mechanical systems. This formalism is based on the principle of conservation of energy and allows a clear and coherent interpretation from a physical point of view

control law synthesis problems. Initially proposed for systems (not linear) open of finite dimension, the Hamiltonian port formalism has been extended to distributed parameter systems governed by PDEs in [10]. It allowed the representation of phenomena such as wave propagation, convection and scattering as well as many other phenomena distributed in space.

With regard to dynamic properties, the Hamiltonian approach has been advantageously used for the analysis of the well-posed character and the stabilization of systems linear with distributed parameters in [11, 12]. In a way identical to the case of the finite dimension, it has been shown that internal energy exchanges and interactions with the environment can be represented using a geometric structure called the Dirac structure. This geometric structure, resulting from an appropriate choice of state variables and stress variables (especially at the border), reflects the energetic properties of the system and the existing links between driving forces, dynamics and energy. This structure is of great interest when the dynamic properties of the system as well as its stability and / or stabilization are studied. In effect, the techniques of synthesis of control laws for nonlinear systems and / or with distributed parameters mainly use Lyapunov theory whose foundations are based on the concept of energy. The Hamiltonian approach to port is therefore naturally suitable for this type of synthesis. These consist mainly of a formatting energy function (Energy shaping) or power (Power shaping). It is also possible modify the structure of closed-loop equations, as well as the dissipation function, so as to obtain a dynamic system with the desired behavior. These methods are known under the name IDA-PBC, Interconnection and Damping Assignment Passivity Based Control [13]. They were developed within the framework of the finite dimension and recently extended in the framework of 1D systems of infinite dimension controlled at the border [14]. A first extension to border-controlled 2D and 3D systems is under study in [15]. In the case of distributed parameter systems they use state feedbacks or observers [16,17].

Objectives and progress of the thesis:

This thesis has three main objectives:

• Modeling: Initially we will focus on the development of reliable models allowing the taking into account of the multi-physical, non-linear character and distributed parameters of soft robots based on DEAP actuators. The models will be developed for systems based on: wound actuators to serve as arms robotics and HASEL-type actuators for the conformable gripper.

• Robot design: We then focus on determining the best geometric configuration for the design of flexible robots with the main purpose is to maximize the actuation capacities (contraction forces and variable stiffness)

• Summary of control laws: Finally, control methods adapted to the Hamiltonian approach to port will be developed with the aim of responding to the initial specifications while ensuring the minimization of the energy consumed (frugal order). A secondary objective is to make the robot completely soft the fastest in the world for picking up and dropping objects of varying shapes.

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Candidate profile	See Job description
Keywords	Systèmes Hamiltoniens à ports ; robots mous ; les actionneurs DEAP ; modélisation multiphysique ; synthèse de commande frugale
Application deadline	15/06/2021
Application Depending on the type of position	The doctoral fellowship is 3-year fellowship funded by EUR-EIPHI and BFC-Region Interested candidates may send their application to yongxin.wu@ens2m.fr Applications must contain: • An academic CV • A cover letter/statement of purpose • At least two letters of recommendation • A transcript of records for the past two years

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