Politecnico di Torino

Dipartimento di Ingegneria Meccanica e Aerospaziale

DIMEAS SEMINAR

IN SILICO TOOLS FOR THE DESIGN, OPTIMIZATION, AND VALIDATION OF DEVICES AND PROCEDURES FOR DIAGNOSTICS AND SURGERY OF THE GASTROINTESTINAL TRACT

SPEAKER

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Abstract

Gastrointestinal (GI) diseases represent a major global health burden. Nevertheless, GI bioengineering has historically received much less attention and investment, with substantial efforts emerging only in the last decade. As a result, many diagnostic and surgical devices and procedures are still developed mainly through experimentation on animal model and clinical trials, often involving high economic and ethical costs, limited adherence to the 3R principles, and suboptimal outcomes. In this context, in silico methods offer a powerful framework for a more rational, quantitative, and patient-oriented approach to GI diagnostics and surgery. This seminar will present recent advances in computational modelling of the gastrointestinal tract, focusing on the design, optimization, and validation of devices and procedures.

Recent studies have enabled the development of models of different GI regions. One example concerns the diagnosis of esophageal motility disorders through High Resolution Manometry (HRM). Conventional interpretation relies on clinical assessment of pressure maps, which may be affected by operator experience and subjectivity. Bioengineering approaches have led to biomechanical models whose parameters can be associated with specific disorders. Patient-specific parameters can be automatically identified by processing HRM data, and compared with statistical databases, supporting autonomous and objective diagnosis.

A second application concerns bariatric surgery, often performed according to standardized protocols without assessing gastric mechanical functionality. Computational tools can evaluate the mechanical stimulation of the gastric wall under different surgical configurations. Since this stimulation is related to brain regions involved in satiety, these tools may support patient-specific planning aimed at promoting adequate fullness after a meal, contributing to weight loss and well-being.

Further applications involve the intestine, where computational models have been used to optimize robotic devices for minimally invasive diagnosis and to design artificial sphincters for continence restoration.

To fully exploit the potential of GI computational modelling, key challenges include patient-specific tissue constitutive characterization and rigorous mathematical descriptions of the mechanisms underlying organ functionality. The long-term goal is to develop tools for in silico trials, patient-specific surgical planning, and functional simulators for pre-operative decision-making

BIO

Emanuele Luigi Carniel is Associate Professor of Industrial Bioengineering at the Department of Industrial Engineering of the University of Padova, Italy, and Head of the Centre for Mechanics of Biological Materials. He obtained his Ph.D. in Bioengineering from the University of Padova in 2007. His scientific activity is primarily devoted to the constitutive investigation of biological tissues and to the development of advanced in silico methodologies for biomedical applications. His research integrates experimental mechanics, constitutive modelling, and computational simulation to support the design, optimization, and validation of devices procedures for diagnostics and surgery. He is the author of more than 120 publications in peer-reviewed international journals.