Dynamic structural reconfiguration for structural control: development of new control algorithms and assessment of their efficiency

(description for the general public)

Objective of the project and the research to be carried out

This project is situated at the crossroads of structural mechanics and control theory, in the field of the so called smart structures. We intend to pursue a specific type of smart structures capable of a **dynamic self-reconfiguration**. We will develop methods and algorithms to employ the mechanisms of reconfiguration for the purpose of structural control. In particular, we will

- develop techniques, algorithms and methodologies of **structural dynamic self-reconfiguration**, including their coherent theoretical models and computationally efficient surrogates;
- numerically and experimentally asses their effectiveness in tasks of controlling
    - **self-stress state**,
    - **geometry** and
    - **modal and frequency-domain characteristics**

  of structures subjected to typical operational excitations.

By structural reconfiguration, we understand real-time control of

- structural supports and boundary conditions,
- local and nonlocal aggregation, deaggregation and coupling of selected degrees of freedom,
- dynamic modifications to structural topology.

Besides the development of control algorithms that employ reconfiguration, we aim at

- **optimization** of the developed dynamic structural reconfiguration systems (with respect to control strategies, type and placement of actuators, structural topologies);
- design of algorithms for **real-time adaptation of reconfiguration control laws**, to ensure control effectiveness even in case of changing structural parameters or environmental conditions.

Reasons for choosing the research topic

Reconfiguration and self-reorganization are typical natural adaptation mechanisms in biological structures of various types and in various time scales. They have been successfully mimicked in many areas of science and technology. However, in applications to structural control, they constitute a new and relatively unexplored research area, which is important theoretically and practically. This project is aimed at filling this gap: we plan to employ **untypical actuators to accomplish untypical control tasks**:

- In terms of *actuators*, instead of focusing on typical active actuators (which generate and directly apply control forces) or on semi-active actuators (with their locally controllable dissipative characteristics), we focus on **dynamic application of** various **kinematic and geometric structural constraints**, such as supports, boundary conditions, local and nonlocal aggregation/deaggregation and coupling of Dofs, and dynamic modifications to structural topology. This is a relatively **new and original research concept**.
- In terms of the *control objectives*, besides standard frequency-domain and modal characteristics of the structure, we aim at controlling structural self-stress state and geometry, including large displacements:
    - *Prestressing* is a standard technique in civil engineering, but its applications and the research in this area are effectively limited to the optimum static design of the initial prestress state. We will address the problem of a **fully dynamic control of the state of structural self-stresses**.
    - Control of *geometry*, in the form of trajectory tracking or path following is a standard problem in robotics and manipulator control, but it is performed there by means of direct force generation in actuators. Instead, we aim at the generation and accumulation of displacements in an externally excited vibrating structure by periodic short-time removal of constraints, treated as a mean to **affect global structural geometry**.

We believe that the developed optimal structural reconfiguration systems will contribute to the progress in modern, lightweight and cost-effective structures through increasing their safety and versatility.