PhD Proposal 2017

School - Location: Ecole Centrale Lyon, Ecully, France

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Title: Wireless Sensor Networks for dynamic adaptative control of vibrations

Scientific field: mechatronic, embedded systems, IoT

Key words: active control, distributed computation, adaptative and dynamic control, Wireless Sensor Networks; energy harvesting
Background, Context:
Active Vibration Control (AVC) systems are involved in many engineering fields, ranging from Structural Health Monitoring to the automotive field including industrial applications: they provide efficient solutions for vibration and noise damping systems. Regenerative-power laws have proved their efficiency in the control of vibration based on hydraulic or piezoelectric components [1] and Wireless Sensor Networks (WSNs) have been demonstrated [2] to be efficiently used in AVC with some restrictions: implementation of the AVC in a WSN is a challenge for designers: the entire vibration control system must be designed in order to pass very stringent requirements of the WSN and control law [3]. Wireless Sensor Networks (WSNs), since their introduction in the control active systems during the last decade, have been extensively studied for their wireless connectivity and their remote sensing capacities. Yet, WSNs are far from being implemented to their full potential: the energy harvesting capacity of each individual node requires improvement, the computation power of every sensing node is currently under-exploited and despite their distributed architecture, WSNs are still mainly used in centralized paradigm. Distributed approach has been used reduced to the sensing part in SHM [4]. Depending on the application, the spatial distribution of such a WSN can generate a large amount of data and time-consuming processes to ensure the scope and the analysis of the entire system. Such applications on large structure like in civil engineering [7] is driven by the need of a sharp description of the structure response. WSN have been used for distributed active control but time delay is a serious problem that requires considerably more attention: time taken for real-time acquisition from sensors combined to time taken for data processing and control force signal calculation by controllers and finally added to time taken by actuators for the generation of control force [5]. Complete distributed approach for AVC is still a promising domain to be explored.

Research subject and scientific bottlenecks:
Previous works from the thesis of M.Zielinski [6] have resulted in the design of an AVC-dedicated WSN node permitting to fulfil simultaneously measurement, vibration damping and energy harvesting from a vibrating plate (cf. Figure 1).

The objective of this thesis is to develop a dynamically adaptative control for vibrations structure based on the WSN hardware developed in [3]. In this thesis we will consider an AVC adaptative system composed of two elements:
• a Wireless Sensor Network composed of a decade of nodes able to measure vibrations, to perform a local damping on vibrations and to harvest energy from their environment for their autonomous self-powering.
• a wired piezoelectric power network (WPPN) linked to the collector node of the WSN composed of medium-sized piezoelectric with a separate power system that enable drastic vibration reduction.

In a common approach, the WSN is used for measurement and the wired network is used for vibration damping driven by a central common law implemented in the head of the wired network. In our approach, the WSN is enhanced so as to be able to proceed to local damping in a distributed way and the WPPN is used only when the distributed damping isn’t sufficient. However, local semi-active vibration control clusters in closed-loops would hence enable a more efficient and a faster reaction to the vibrational environment’s changes. Transient and propagative phenomena could, if any compensated, at least followed and tracked. This shift from a centralized paradigm to a distributed paradigm will be explored during the thesis so as to open interesting perspectives in active control with distributed/centralized repartition of the control and adaptive strategies where this ratio (local damping or global damping) that can dynamically be adapted depending on the vibration environment. At that stage, the prior knowledge of the structural properties of the sensor-equipped system shall be considered. Indeed, in order to identify the most suitable spots where either energy sources or sensitive reaction places, the embedding of the WSN in combination with the WPN shall be optimized. Relative shades in mechanical properties (stiffness, mass density, electromechanical abilities …) between neighboring areas of the structure will be combined in order to assess the advantage of an optimized distribution and optimized WSN settings.

In a second phase, suboptimal active control vibration will be addressed: indeed, in a classic approach, the position of every node and piezoelectric is calculated so as to fit to physical positions on the vibration structure corresponding to specific vibrations modes. Suboptimal approach consists in deploying nodes and piezoelectric in a random distribution without the preliminary knowledge the mechanical modes of the plate. However, the design of the controlled structure will be taken into account. Its architecture in terms of components, connections and interfaces will define area types and domains where the efficiency of a random distribution will be analyzed. Numerical simulations will emphasize specific features of such a combined

**Work plan of the thesis**
The thesis will be conducted through the following milestones:
• Getting started with the existing experimental setup and update of the bibliography: improvement of the setup and specifications tuning
• Definition of characteristic scenari to address the bottlenecks of the thesis
• Development of a distributed control law for the WSN
• Development of a dedicated control law for the WPPN that can be integrated in the distributed control law of the WSN
• Extraction of design parameters and development of control law working both on WSN and WPPN: exploration of the design space to define dynamic scenario and adaptative situations.

**Collaborations**
This thesis will be conducted in the context of a collaboration between 3 internationally recognized laboratory of Lyon: Laboratory of Tribology and Dynamic Systems UMR CNRS 5513, Ampere Lab UMR CNRS 5005 and Institute of Nanotechnology of Lyon UMR CNRS 5270
References:


