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Ph.D. subject proposal

Towards new algorithms for structural health monitoring

Localization : IRISA Rennes - Academic year 2006-2007

Team : Sisthem

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Objective : Developing new methods for the design of structural health monitoring algorithms which exploit new sensoring, networking and computing architectures.

Subject : The new architectures of sensors, data transmission networks and computing which appeared these last years are drastically renewing the health monitoring problems for civil engineering structures. On the one hand, new sensing technologies - e.g. laser - give access to a distributed state and not only to a few selected degrees of freedom. On the other hand, the development of wireless networks allows synchronized recording of distributed measurements (very large number of degrees of freedom) and remote monitoring. Finally, recent advances in scientific computing, and specifically the development of grid computing, allow considering sensor data processing algorithms associated with multi-physics finite elements models, involving thermal, hydrodynamic, and aerodynamic phenomena interacting with the dynamics of the structure itself. Structuration and reduction of those finite elements models are then mandatory for a statistical approach to monitoring.

Exploiting these advances for structural health monitoring requires the design, tuning and development of methods and algorithms fully different from those currently available. The proposed topic consists in exploring one or several of those directions.

Economical, technical and strategic challenges : The emergence of stronger safety and environmental norms, the need for early decision mechanisms, together with the widespread diffusion of sensors of all kinds, result in a thorough renewal of sensor information processing problems. In particular, efficient and robust methods for structural analysis, non destructive evaluation, integrity monitoring, damage diagnostics and localization, are necessary for fatigue and aging prevention, and for condition-based maintenance. The structural health monitoring research activity is less developed and supported in Europe (except in Great Britain, Italy and Greece) than in America (US, Canada) and in Asia (Japan, and also China). Moreover, the French research effort on these issues has not yet been sufficiently developed, compared with the associated scientific and socio-economic challenges.

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Framework : The Sisthem project-team has a long standing experience on identification and change detection for parameterized dynamical systems. The team has a strong expertise in designing and developing statistical inference methods for vibration-based identification and health monitoring of civil engineering and aeronautic structures: Euréka projects Sinopsys, FliTE and FliTE2, Constructif project of the French national program on Computer and Security. Our approach is as follows. The vibration-based identification of a structure's dynamics is achieved with an output-only covariance-driven subspace-based algorithm [1] [2]. The health monitoring problem is decomposed into two tasks of damage detection and localization. The first task is addressed as a problem of detecting changes in the eigenstructure of a linear system [3]. The solution to the second task handles modes and mode-shapes sensitivities w.r.t. the structural parameters of a design finite elements model [4].

The team works in tight connection with the Metrology and Instrumentation Department of LCPC (Laboratoire Central des Ponts et Chaussées) and the Laboratoire Mécanique des Sols, Structures et Matériaux (LMSSMat) of École Centrale Paris, within the project Constructif.

Moreover, major research activities on distributed systems supervision and on grid computing are coordinated within IRISA.

Required skills : Mathematics and engineering sciences, or mathematics engineering and computer science, or statistical signal processing, or civil engineering.

[1] M. Basseville, A. Benveniste, M. Goursat, L. Hermans, L. Mevel, H. Van der Auweraer (2001). Output-only subspace-based structural identification: from theory to industrial testing practice. *ASME Jal of Dynamic Systems Measurement and Control*, vol.123, no 4, pp.668-676.

[2] L. Mevel, A. Benveniste, M. Basseville, M. Goursat (2002). Blind subspace-based eigenstructure identification under nonstationary excitation using moving sensors. *IEEE Trans. Signal Processing*, vol.SP-50, no 1, pp.41-48. *Version préliminaire.*

[3] M. Basseville, M. Abdelghani, A. Benveniste (2000). Subspace-based fault detection algorithms for vibration monitoring. *Automatica*, vol.36, no 1, pp.101-109. *Version préliminaire.*

[4] M. Basseville, L. Mevel, M. Goursat (2004). Statistical model-based damage detection and localization: subspace-based residuals and damage-to-noise sensitivity ratios. *Journal of sound and Vibration*, vol.275, no 3-5, pp.769-794. *Version préliminaire.*