

Seismic mitigation using advanced control strategies

PI: Ovidiu PRODAN
Structural Mechanics Dept.

Motivation

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- Development of better vibration mitigation techniques of structures is an on-going challenge
- Proposed approach: an emerging control strategy
- Fractional order controllers advantages: robustness, efficiency, few research in civil engineering applications up to date

Summary

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- Design and construction of a laboratory scaled steel structure
- Design and implementation of novel control strategies for seismic mitigation based on fractional calculus (comparisons with classical control strategies)
- Experimental testing and validation of results
- Extension to adjacent fields (Smart Beam, Airplane Wing)

Challenges

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- Implementation problems (numerical issues related to Fractional Order Elements approximations)
- Controller tuning: based on complex nonlinear equations
- 2D laboratory structure design, scaling and construction
- Structural parameter identification

Research Team

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- Interdisciplinary project:
 - Automation Dept.:
 - Silviu Folea
 - Cristina I. Muresan
 - Structural Mechanics Dept.:
 - Ovidiu Prodan

Previous research

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- Research grant TUCN 2013-2014:
 - Efficient use of energy in reducing the structural response to exceptional loading using viscoelastic dampers and advanced fractional order control methods
 - Director: Cristina I. Muresan (Aut. Dept.)
 - Research Team:
 - Ovidiu Prodan (Struct. Mech. Dept.)
 - Silviu Folea (Aut. Dept.)

Results

1. Muresan, C.I., Dulf, E.H., Prodan, O. (2014), A Fractional Order Controller For Seismic Mitigation Of Structures Equipped With Viscoelastic Mass Dampers, *Journal of Vibration and Control*, DOI:10.1177/1077546314557553 (**ISI impact factor 4.355**)
2. Muresan, C.I., Prodan, O., Folea, S. (2014), Tuning Method of Fractional Order Controllers for Vibration Suppression in Smart Structures, *Applied Mechanics and Materials Journal*, Vol. 598, pp. 534-538, paper selected at the 4th International Conference on Mechanics, Simulation and Control, 21-22 June, Moscow, Russia (**ISI PRO**)
3. Muresan, C.I., Prodan, O. (2014), Vibration Suppression in Smart Structures using Fractional Order PD controllers, IEEE International Conference on Automation, Quality and Testing, Robotics AQTR, ISBN: 978-1-4799-3731-8, pp. 1-5, DOI: 10.1109/AQTR.2014.6857907, 22-24 May, Cluj-Napoca, Romania (**ISI PRO**)
4. Prodan, O., Muresan, C.I. (2014), Seismic mitigation via fractional order active control, Eurosteel, 10-12 September, Naples, Italy (**International Conference**)
5. Muresan, C.I., Prodan, O., Folea, S. (2015), Robustness evaluation of an optimal fractional order controller for vibration suppression, *Structural Control and Health Monitoring*, under review (**ISI impact factor 2.133**)
6. O. Prodan, I. R. Birs, S. Folea, C. Muresan (2015), Seismic mitigation in civil structures using a fractional order PD controller, The 3rd International conference on Control, Mechatronics and Automation, Barcelona, Spain, December 21-22, 2015 (**ISI PRO**)
7. Design and implementation of an active fractional order control strategy for a three floor steel structure - *Journal of Process Control*, under review (**ISI impact factor 2.653**)

Results

Conferences:

- 4th International Conference on Mechanics, Simulation and Control, 21-22 June, Moscow, Russia (**ISI PRO**)
- IEEE International Conference on Automation, Quality and Testing, Robotics AQTR, 22-24 May, Cluj-Napoca, Romania (**ISI PRO**)
- Eurosteel, 10-12 September, Naples, Italy (**BDI**)
- The 3rd International conference on Control, Mechatronics and Automation will be held in Barcelona, Spain during December 21-22, 2015 (**ISI PRO**)

1 invited lecture:

- “Fractional calculus in control applications”, University of Cambridge, UK, April 7-10, 2015

1 research mobility:

- Swiss Federal Institute of Technology, EPFL, Lausanne, Earthquake Engineering and Structural Dynamics Laboratory EESD, February - December 2014
- **EPFL Internal Grant (16.000 CHF)**

Student Involvement

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1 Bachelor thesis, Automation Dept., July 2014

- Title: Active vibration control strategies, student: **Robert Balan-Rus**

2 Bachelor theses, Automation Dept., July 2015

- Title: Active vibration control strategies for one story structures, student: **Remus Bizu**
- Title: Vibration suppression of a smart beam with integer and fractional order controllers, student: **Izabela Birs**

Student Involvement

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Bachelor thesis due in June 2016:

- Active vibration control strategies for three storey structures: **Boca Diana, Greta Han**, Automation Dept.
- Vibration mitigation in aeroplane wings: **Andrei Molnar**, Automation Dept.

Master thesis due in June 2016:

- Monitoring system for three story structures against seismic phenomena: **Balan-Rus Robert**, Automation Dept.
- Building seismic response and structural health monitoring: **Serban Ursu**, Structural Mechanics Dept.

Master thesis due in June 2017:

- Fractional order active control strategies for vibration suppression in smart beams: **Isabela Birs**, Automation Dept.

Associated Results

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Associated events:

- FSS 2015 International Conference (<http://fss-conference.com/organizing-committee.php>)

2 Research grant proposals UEFISCDI:

- Novel Fractional Order Control Strategies for Vibration Supression in Aeroplane Wings, score: 94.5
- inQuake – Instability of Reinforced Concrete Walls to Earthquake Loading, score: 79

Current research grant

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TE86/2015 Novel Fractional Order Control Strategies for Vibration Supression in Aeroplane Wings, 1.10.2015-30.09.2017, 534980 LEI

Research team:

Automation Dept.: Cristina I. Muresan, Silviu Folea, Eva Dulf, Gabriel Harja

Structural Mech. Dept.: Ovidiu Prodan, Cristian Miculas

Current research grant

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Objectives:

Objective 1: Development of a complete and up-to-date study of the state of the art regarding vibration suppression in aeroplane wings (construction, modelling, control);

Objective 2: Design and construction of an experimental unit for the study of vibration suppression;

Objective 3: Development of a dynamic model for aeroplane wings (using fractional calculus and experimental identification);

Objective 4: Development of novel robust fractional order control strategies for vibration suppression.

Publication:

- Eva-H. Dulf, Cristina I. Muresan, Robust controller design using fractional calculus and Hinf norm, International Journal of Robust and Nonlinear Control, under review (ISI impact factor 3.176)
- Cristina I. Muresan, Silviu Folea, Ovidiu Prodan, Design and Experimental Validation of an Optimal Fractional Order Controller for Vibration Suppression, paper submitted at The International Conference on Control, Decision and Information Technologies, Malta, April 6-8, 2016 (BDI)

THANK YOU!