

Stability of wave equation in one and multidimensional cases with and without geometric control conditions

Teacher

Mohammad Akil

Course description

The aim of the course is to explore the complex field of wave equation stability in the framework of control theory. Indeed, we will analyze the widespread applications of control theory in diverse scientific and engineering domains, such as noise reduction, structural vibration control against seismic waves, regulation of biological systems, and the design of robotic systems. Focusing on stability as a foundational concept in modern mathematical control theory, the course delves into the recent extensive studies on one-dimensional wave equations with various damping mechanisms. As waves are generated by vibrating sources disturbing the medium, the addition of different dampings becomes crucial for vibration restraint. The general form of the one-dimensional wave equation is:

$$\frac{\partial^2 u}{\partial t^2} - c \frac{\partial^2 u}{\partial x^2} = 0,$$

where u represents the displacement of the wave, t is time, x is the spatial coordinate, and c is the speed of the wave.

We will focus on the stability of these damped wave systems, emphasizing the importance of studying coupled systems for their potential applications. In multi-dimensional scenarios, the extension of the wave equation is explored, with a nuanced examination of stability both with and without geometric conditions. Participants will gain insights into controlling vibrations in dynamic systems and understand the practical implications of stability analyses in complex wave phenomena.

Course period

March 2023

SSD

MAT/05

Course References

- [1] Alabau, F., Cannarsa, P., Komornik, V.: Indirect internal stabilization of weakly coupled evolution equations. *J. Evol. Equ.* 2, 127–150 (2002)
- [2] F. Alabau-Boussouira, Indirect boundary stabilization of weakly coupled hyperbolic systems, *SIAM J. Control Optim.* 41 (2002), no. 2, 511–541.
- [3] F. Alabau-Boussouira, P. Cannarsa and R. Guglielmi, Indirect stabilization of weakly coupled systems with hybrid boundary conditions, *Math. Control Relat. Fields* 1 (2011), no. 4, 413–436.
- [4] Akil, M., Issa, I. & Wehbe, A. A N-dimensional elasticviscoelastic transmission problem with Kelvin–Voigt damping and non smooth coefficient at the interface. *SeMA* 80, 425–462 (2023).

- [5] Akil, M., Wehbe, A.: Stabilization of multidimensional wave equation with locally boundary fractional dissipation law under geometric conditions. *Math. Control Relat. Fields* 8, 1–20 (2018)
- [6] Wehbe, A., Issa, I., Akil, M.: Stability results of an elastic/viscoelastic transmission problem of locally coupled waves with non smooth coefficients. *Acta Appl. Math.* 171(1), 1–46 (2021)
- [7] Mohammad Akil, Ibtissam Issa, Ali Wehbe. Energy decay of some boundary coupled systems involving wave\ Euler-Bernoulli beam with one locally singular fractional Kelvin-Voigt damping. *Mathematical Control and Related Fields*, 2023, 13(1): 330-381. doi: 10.3934/mcrf.2021059 shu
- [8] Bardos, C., Lebeau, G., Rauch, J.: Sharp sufficient conditions for the observation, control, and stabilization of waves from the boundary. *SIAM J. Control Optim.* 30(5), 1024–1065 (1992)
- [9] Liu, K., Liu, Z.: Exponential decay of energy of vibrating strings with local viscoelasticity. *Zeitschrift Fur Angewandte Mathematik Und Physik ZAMP* 53, 265–280 (2002)
- [10] Liu, K., Liu, Z.: Exponential decay of energy of the Euler–Bernoulli beam with locally distributed Kelvin–Voigt damping. *SIAM J. Control Optim.* 36, 1086–1098 (1998)

Credits and Hours

1 lecture credit (8 hours per credit)

Exam Modality

The student will present a paper between two papers suggested by the teacher. No groups are allowed.

Teacher CV

CV attached.

Teacher Main Publications

See the attached list.

Curriculum di Mohammad Akil

PERSONAL INFORMATION

Family name, First name: Akil, Mohammad

Date of birth: 15/10/1991

Sex: Male

EDUCATION

- 2014 Graduated with a masters in Mathematics, Université Libanaise, École Doctorale des sciences et technologies, Hadath, Beyrouth, Liban.
- 2017 PhD in Mathematics, Université Libanaise, Faculté des sciences 1, Laboratoire KALMA, Beyrouth, Liban, et Université de Limoges, XLIM, France.

CURRENT AND PREVIOUS POSITIONS

- 2017-2018 Teacher Researcher in mathematics at the Lebanese University, Faculty of Sciences 1, KALMA Laboratory, Beirut, Lebanon.
- 2018-2019 Teacher Researcher at INSA in Rouen.
- 2019-2020 Teacher Researcher in mathematics at the Lebanese University, Faculty of Sciences 1, KALMA Laboratory, Beirut, Lebanon.
- 2020-2021 Associate Professor at the University of Savoie Mont Blanc and at the IUT-Chambéry
- Since 2021 Associate Professor at the Hauts-de-France Polytechnic University

PAPERS

Author of 1 and co-author of 23 papers published in international journals with referee and 3 papers submitted for publication.

SUPERVISION OF GRADUATE STUDENTS, PHD STUDENTS

- 2022/2023: Co-supervision of 2 PhD students in Mathematics
- 2020/2022 Supervision four Master's thesis
- Since 2023: Co-supervision 2 Ph.D. Students in Mathematics at *Université Polytechnique Hauts-de-France*

TEACHING ACTIVITIES

Lectures for PhD Schools

- 2023: 1 PhD course (University of Sheik Anti Diop -Senegal.)

ORGANISATION OF SCIENTIFIC MEETINGS

- Member of the organizing committee of 4 International Conferences
- Help with conference organization of 2 International seminars.

INVITATIONS FROM UNIVERSITY DEPARTMENTS

- 02-14/07/2023: Università degli Studi di Bari "Aldo Moro", Italie.
- 18-24/06/2023: Politecnico di Milano, Milan, Italie.
- 01-10/06/2023: Tuscia University, Viterbo, Italie.
- 02-07/10/2022: Brandenburg University of Technology, Cottbus, Germany.
- 02-08/05/2022. Université Libanaise, Beyrouth, Liban.
- 06-09/12/2021: Université D'Aix-Marseille
- 12-15/11/2019: Université Paris-Saclay.
- 24/07/2019: Université Paris-Saclay.

INSTITUTIONAL RESPONSIBILITIES

- Since 2021: Member of several examination committees in Hauts-de-France Polytechnic University.

COMMISSIONS OF TRUST

- Referee for one Ph.D thesis (2021)
- Since 2022: Review for Mathematical Reviews
- Since 2020: Referee for Mathematical Journals such as SIAM Journal on Control and Optimisation (SICON) in 2023, "Nonlinear Analysis: Real World Applications" in 2023-2024, "Journal of Mathematical Analysis and Applications (JMAA)" in 2022, "Mathematical Control and Related Fields (MCRF)" in 2020-2022, "Evolution Equations and Control Theory (EECT)" in 2021-2024, "Advances in Differential Equations (ADE)" in 2023, "Mathematical Methods in the applied sciences (MMAS)" in 2021-2023, "SeMA Journal: Bulletin of The Spanish Society of Applied Mathematics" in 2022-2023, "System And Control Letters" in 2023-2024.

SELECTED MAJOR COLLABORATIONS

Serge Nicaise (Valenciennes, France), V. Régnier (Valenciennes, France), Y. Chitour (Paris Saclay, France), G. Fragnelli (Viterbo, Italie), F. Dell’Oro (Milan, Italie), A. Soufyane (Sharjah, UAE), A. Özkan Özer (Kentucky, USA), Z. Liu (Duluth, USA), Zhong-Jie Han (Tianjin, Chine), Qiong Zhang (Pékin, Chine), M. Ghader (Beyrouth, Liban), A. Wehbe (Beyrouth, Liban),

MAIN INVITED SEMINAR AND TALKS

- Since 2017: 8 Invited Talks in International Workshop
- Since 2017: 9 Invited Participants in International Workshops and Conferences
- Since 2017: 16 Invited Seminars in French and foreign Universities.

FUNDED RESEARCH PROJECTS

- Project PEPS JCJC 2023 - FR2037 (FMJH), France.

10 main publications in the last 2 years by Mohammad Akil

1. M. Akil, H. Badawi and Z. Hajjej, Stability and instability of Kirchhoff plate equations with delay of the boundary control. *Electronic Journal of Differential Equations*. No. 68, pp. 1-18 Vol. 2023 (2023).
2. M. Akil and Z. Hajjej, Exponential stability and exact controllability of a system of coupled wave equations by second-order terms (via Laplacian) with only one non-smooth local damping, *Math. Meth. Appl. Sci.* 1-20, (2023)
3. M. Akil, M. Ghader, Z. Hajjej et M.A. Sammoury. Well-Posedness and Polynomial energy decay rate of a transmission problem for Rayleigh beam model with heat conduction. *Asymptotic Analysis*, vol. Pre-press, no. Pre-press, pp. 1-42, 2023
4. M. Akil, A. Soufyane, and Y. Belhamadia. Stabilization results of a piezoelectric beams with partial viscous dampings and under Lorenz gauge condition. *Applied Mathematics & Optimization*, **87**(2): Paper No. 26, 2023.
5. M. Akil et Z. Liu Stabilization of the generalized Rao-Nakra beam by partial viscous dampings. *Mathematical Methods in the Applied Sciences*, **46**(2):1479-1510, 2023.
6. M. Akil. Stability of piezoelectric beam with magnetic effect under (Coleman or Pipkin)-Gurtin thermal law. *Zeitschrift für angewandte Mathematik und Physik*, **73**(6):Paper No. 236, 2022.
7. M. Akil, H. Badawi, S. Nicaise, et V. Régnier. Stabilization of Coupled Wave Equations with Viscous Damping on Cylindrical and Non-regular Domains: Cases Without the Geometric Control Condition. *Mediterranean Journal of Mathematics*, **19**(6):Paper No. 271, 2022.
8. M. Akil, H. Badawi et S. Nicaise. Stability results of locally coupled wave equations with local Kelvin-Voigt damping: Cases when the supports of damping and coupling coefficients are disjoint. *Computational and Applied Mathematics*, **41**(6): Paper No. 240, 2022.
9. M. Akil et A. Wehbe, Indirect stability of a multidimensional coupled wave equations with one locally boundary fractional damping. *Mathematische Nachrichten*, **295**(12):2272-2300, 2022.
10. M. Akil, I. Issa et A. Wehbe, Energy Decay rate of the Euler-Bernoulli Beam and wave equations via boundary connection with one locally non-regular fractional Kelvin-Voigt damping. *Mathematical Control and Related Fields*, **13**(1):330-381, 2023.