UNIVERSITÀ DEGLI STUDI DI TRENTO
Dipartimento di Ingegneria Civile, Ambientale e Meccanica

PhD Course

Variational principles in structural mechanics, numerical solution strategies and advanced topics

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University of Trento, Italy

June 3, 2024 (Monday)	9:00-12:00
June 4, 2024 (Tuesday)	10:00-12:00
June 6, 2024 (Thursday)	9:00-12:00

The course introduces to the variational principles that emerge in structural mechanics and build up to numerical solutions of structural elements with emphasis to the case variable support.
The course starts with an introduction to variational analysis and calculus of variations. The notion of minimization problems is examined through basic examples from physics and mechanics.
Next, the Hamiltonian principle is discussed, and the Euler-Lagrange equations of motion are obtained. Then, the problem of variable support elements is introduced, and the equations of motion are obtained. This leads to the emergence of extra "interface" equations that are discussed in the context of configurational forces.
In the second part of the course, the numerical solution of the variable support elements is discussed. The notion of a reconstruction of field quantities from discrete Degrees of Freedom is presented and used to derive a Finite Element representation of the problem using the Galerkin method.

Course Delivery:
The course will be offered in a hybrid format. Synchronous, in-person lectures will be offered to PhD students at the University of Trento, Campus Mesiano. On-line video-streaming lectures will also be available to other students.

Topics & learning objectives

Topic:	**Students will be able to:**
Introduction to variational analysis	1) Calculate variational derivatives of functionals
	2) Solve minimization problems through variational calculus
Hamiltonian principle	3) Write the weak form of equations of motion by direct application of the calculus of variations
	4) Derive Euler-Lagrange equations of motion in mechanics

Introduction to structural elements of variable length	5) Derive the equations of motion of variable length structures
	6) Calculate configurational forces
Numerical solution of variable length structures	7) Derive discretized equations using reconstructed fields
	8) Use the Galerkin method to formulate the Finite Element model of variable length structures

Exams and assignments
Homework assignments can be given to the students wishing to obtain the type “A” credit.

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Recommended Textbooks:

Books:

1. Calculus of Variations, I.M. Gelfand and S.V. Fomin, Dover Publications, 2000.
2. Extremely Deformable Structures - CISM Lecture Notes No. 562, D. Bigoni, Springer, 2015.
3. Numerical Solution of Partial Differential Equations by the Finite Element Method, C. Johnson, Dover Publications, 2009.

Journal papers:

1. D. Bigoni, F. Dal Corso, F. Bosi and D. Misseroni, “Eshelby-like forces acting on elastic structures: theoretical and experimental proof,” Mechanics of Materials, 2015.
2. C. Armanini, F. Dal Corso, D. Misseroni, D. Bigoni, Configurational forces and nonlinear structural dynamics, Journal of the Mechanics and Physics of Solids, 2019.
3. P. Koutsogiannakis, D. Misseroni, D. Bigoni, and F. Dal Corso, “Stabilization against gravity and self-tuning of an elastic variable-length rod through an oscillating sliding sleeve,” Journal of the Mechanics and Physics of Solids, 2023.

Panagiotis Koutsogiannakis is a postdoctoral researcher at the Department of Civil, Environmental, and Mechanical Engineering at University of Trento since 2023. He completed his Ph.D. at the University of Trento from 2019 to 2022. He received his Diploma of Naval architecture and Marine engineering from the National Technical University of Athens in 2019. His research interests revolve around structural mechanics with a focus on the instabilities of structures and the dynamics of structures subjected to configurational forces.