TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	September 23	September 24	September 25	September 26	September 27
09.00 - 09.45	Registration	de Saxcé	Serban	de Saxcé	Serban
09.45 - 10.30	Terze	de Saxcé	Serban	de Saxcé	Serban
11.00 - 11.45	Müller	Boyer	Serban	Terze	Boyer
11.45 - 12.30	Müller	Boyer	de Saxcé	Terze	Müller
14.00 - 14.45	Boyer	Terze	de Saxcé	Boyer	
14.45 - 15.30	Boyer	Terze	de Saxcé	Boyer	
16.00 - 16.45	Serban	Müller	Terze	Müller	
16.45 - 17.30	Serban	Müller	Terze	Müller	
18.00	Welcome aperitif				

ADMISSION AND ACCOMMODATION

The course is offered in a hybrid format giving the possibility to attend the course also by remote (on Microsoft Teams platform). On-site places are limited and assigned on first come first served basis.
The registration fees are:

- **On-site participation, 600.00 Euro + VAT***
This fee includes a complimentary bag, five fixed menu buffet lunches, hot beverages, downloadable lecture notes.
Deadline for on-site application is August 23, 2024.

- **Live Streaming Online participation, 250.00 Euro + VAT***
This fee includes downloadable lecture notes.
Deadline for online application is September 11, 2024.

Application forms should be sent on-line through the following web site: http://www.cism.it
A message of confirmation will be sent to accepted participants.

Upon request a limited number of on-site participants can be accommodated at CISM Guest House at the price of 35 Euro per person/night (mail to: foresteria@cism.it).

** where applicable (bank charges are not included)*
Italian VAT is 22%.

CANCELLATION POLICY

Applicants may cancel their registration and receive a full refund by notifying CISM Secretariat in writing (by email) no later than:
- August 23, 2024 for on-site participants (no refund after the deadline);
- September 11, 2024 for online participants (no refund after the deadline).
Cancellation requests received before these deadlines will be charged a 50.00 Euro handling fee. Incorrect payments are subject to Euro 50,00 handling fee.

GRANTS

A limited number of participants from universities and research centres who are not supported by their own institutions can request the waiver of the registration fee and/or free lodging.
Requests should be sent to CISM Secretariat by **July 23, 2024** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

For further information please contact:
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Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

ACADEMIC YEAR 2024
The G. Del Piero Session

COMPUTATIONAL AND GEOMETRIC MECHANICS OF DISCRETE AND CONTINUUM SYSTEMS

Advanced School
coordinated by

Andreas Müller
Johannes Kepler University
Linz, Austria

Zdravko Terze
University of Zagreb
Croatia

Udine *September 23 - 27* 2024

COMPUTATIONAL AND GEOMETRIC MECHANICS OF DISCRETE AND CONTINUUM SYSTEMS

Rising interest in non-holonomic mechanical systems has initiated a large body of research that exploits what is often called 'non-holonomic' geometry. More precisely the geometric setting is that of (principal) bundles, which serve as configuration space, and the connection on the bundle plays a key role as it encodes constituent kinematic and dynamic relations. This not only provides a beautiful holistic approach to multi-physical systems it also gives rise to consistent compact and efficient computational formulations for complex systems. Renewed interest in concepts from geometric mechanics for modelling and computation arises in various scientific and engineering communities. In robotics, geometric mechanics approaches have become a corner stone of what is sometimes called 'modern robotics', where Lie group formulations are now established for kinematics and dynamics modeling, and the bundle view is central for locomotion planning and control of floating-base systems, e.g. humanoids, legged robots, and space robots. Computational multibody dynamics is another area that has embraced geometric methods for the consistent modeling of constrained systems comprising rigid and flexible bodies, and also geometric integration schemes are now established for the numerical analysis of such systems. In the last decade, significant progress was made in the field of computational geometric approaches to discrete and continuous mechanical systems, in particular for the dynamics simulation and control of articulated rigid body systems, and of solid and fluid systems in a consistent geometric framework as well as fluid-structure interaction and particle methods.

Recently geometric modeling of discrete and continuous systems find their fruitful application also in the domain of artificial intelligence, where manifold learning, structure-preserving integration schemes, and computational Lie group formulations enhance efficiency and robustness of learning methods. Geometry based reduced-order modeling of complex systems, especially nonlinear dimensionality reduction techniques exploiting the topology of the underlying manifolds, provide new perspectives in this emerging field. Hybrid surrogate models of continuum and discrete systems, merging physics-based sub-models and data-driven representations, are combined to co-simulate complex mechanic and thermodynamic phenomena by incorporating the geometric structure of information manifolds. Contemporary machine learning algorithms start using methods originated from physics and statistical mechanics even on the conceptual level as geometrical structures and principles provide insight into formulations and algorithms used in artificial intelligence. This course will introduce attendees to fundamental concepts and mathematical formulations of geometric mechanics and provide a panoramic overview of current state of research and applications of geometric modeling. It covers theoretical and mathematical foundations, computational methods that allow for practical application to multibody system dynamics, as well as cutting-edge multidisciplinary research.

PRELIMINARY SUGGESTED READINGS

Z. Terze et al. Reduced coupled flapping wing-fluid computational model with unsteady vortex wake. Nonlinear Dynamics 109, 975–987, 2022.

A. Müller, Z. Terze, 2014. Modelling and Integration Concepts of Multibody Systems on Lie Groups. In: Z. Terze, (eds) Multibody Dynamics. Computational Methods in Applied Sciences, Springer.

A. Müller: Screw and Lie group theory in multibody dynamics – Recursive algorithms and equations of motion of tree-topology systems, Multibody System Dynamics, 42(2), 219-248, 2018.

A. Müller: Hamel's Equations and Geometric Mechanics of Constrained and Floating Multibody and Space Systems, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, Vol. 479, 2023.

H. Goldstein, C. P. Poole, and J. L. Safko, Classical Mechanics, 3rd ed. Pearson, 2001. (Chapter 2: Variational principles and Lagrange's mechanics).

J. C. Simo and L. Vu-Quoc, "On the dynamics in space of rods undergoing large motions – A geometrically exact approach," Computer Methods in Applied Mechanics and Engineering, vol. 66, no. 2, pp. 125 -161, 1988.

G. de Saxcé and C.Vallée: "Galilean mechanics and thermodynamics of continua", book series «Mechanical Engineering and Solid Mechanics», ISTE- Wiley, London (2016).

G. de Saxce: Symplectic and variational formulations of compressible and incompressible Navier-Stokes equation, arXiv:2306.04405v1

M. Anitescu, "Optimization-based simulation of nonsmooth rigid multibody dynamics," Math. Program., 105(1):113–143, 2006.

D. Violeau and B.D. Rogers, "Smoothed particle hydrodynamics (SPH) for free-surface flows: past, present and future," J. Hydraulic Research, 54(1):1-26, 2016.

INVITED LECTURERS

Géry de Saxcé - University Lille, France
7 lectures on:
The geometric modelling of continuum mechanics and thermodynamics, principle of relativity with Galileo symmetry group, principles of the thermodynamics in geometric form, symplectic and variational principles for dynamics of viscous fluids.

Frédéric Boyer - LS2N Nantes, France
7 lectures on:
Modeling Cosserat media and applications, fundamentals of Cosserat rods using Lagrangian reduction on Lie groups, geometrically exact finite element method, new parametrization of Cosserat rods with strain fields, modelling, simulation and control of continuous and soft robots.

Andreas Müller - Johannes Kepler University, Linz, Austria
7 lectures on:
Geometric foundations, Lie group formulations for the kinematics and dynamics of stationary and floating-base rigid body systems, computational formulations applied to legged/walking robots, mobile platforms, zero-gravity floating-base system (e.g. satellites, space robots).

Radu Serban - University of Wisconsin-Madison, Madison, USA
7 lectures on:
Particle methods and their applications, granular dynamics and fluid-solid interaction in a Lagrangian framework, large-scale granular flow problems with frictional contact, smooth and non-smooth contact formulation, numerical solution techniques, Smoothed Particle Hydrodynamics, applications to large-scale simulations in terramechanics, terrestrial and extra-terrestrial vehicles and robots.

Zdravko Terze - University of Zagreb, Croatia
7 lectures on:
Geometric modelling of Euler and viscous fluid, dynamics of multibody systems and fluid-solid interaction in Lie group setting, coupled ('multi-physics') systems, structure-preserving integration schemes for Hamiltonian systems, applied to multibody systems immersed in fluid, aerospace case-studies, flapping-wing drones and locomotion systems.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants.