Friday	October 11	Gerstmayr	Gerstmayr	Romero	Romero				
Thursday	October 10	Lew	Lew	Betsch	Betsch	Cardona	Cardona	Arnold	Arnold
Wednesday	October 9	Cardona	Cardona	Arnold	Arnold	Gerstmayr	Gerstmayr	Romero	Romero
Tuesday	October 8	Gerstmayr	Gerstmayr	Romero	Romero	Lew	Lew	Betsch	Betsch
Monday	October 7	Lew	Lew	Betsch	Betsch	Cardona	Cardona	Amold	Amold
TIME		9.00 - 9.45	9.45 - 10.30	11.00 - 11.45	11.45 - 12.30	14.00 - 14.45	14.45 - 15.30	16.00 - 16.45	16.45 - 17.30

(Registration on Monday at 8:30)

TIME TABLE

ADMISSION AND ACCOMMODATION

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through our web site: <u>http://www.cism.it</u> or by post.

ACADEMIC YEAR 2013

The Troger Session

Centre International des Sciences Mécaniques International Centre for Mechanical Sciences

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A message of confirmation will be sent to accepted participants. If you need assistance for registration please contact our secretariat.

The 700,00 Euro registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday not included), hot beverages, on-line/downloadable lecture notes and wi-fi internet access.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered board and/or lodging in a reasonably priced hotel. Requests should be sent to CISM Secretariat by **July 20, 2013** 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.

Information about travel and accommodation is available on our web site, or can be mailed upon request.

Please note that the centre will be closed for summer vacation the first three weeks in August.

For further information please contact:

CISM

Palazzo del Torso Piazza Garibaldi 18 33100 Udine (Italy) tel. +39 0432 248511 (6 lines) fax +39 0432 248550 e-mail: cism@cism.it STRUCTURE-PRESERVING INTEGRATORS IN NONLINEAR STRUCTURAL DYNAMICS AND FLEXIBLE MULTIBODY DYNAMICS

Advanced School coordinated by

Peter Betsch University of Siegen Germany

Udine, October 7 - 11, 2013

STRUCTURE-PRESERVING INTEGRATORS IN NONLINEAR STRUCTURAL DYNAMICS AND FLEXIBLE MULTIBODY DYNAMICS

The course focuses on structure-preserving numerical methods for flexible multibody dynamics, including nonlinear elastodynamics and geometrically exact models for beams and shells. Starting with early developments in the eighties, structure-preserving timestepping schemes are nowadays well-known to possess superior numerical stability and robustness properties.

Originally, energy-momentum conserving schemes have been mainly developed in the framework of nonlinear elastodynamics and structural dynamics. In this connection, nonlinear finite elements are typically used for the discretization in space. Moreover, the parametrization of finite rotations and their impact on the discretization in space and time plays a crucial role. Due to their success in the field of nonlinear structural dynamics, the energy-momentum method, as well as energy-decaying variants thereof, have been extended to the framework of flexible multibody dynamics. In fact, the nonlinear finite element approach to flexible multibody dynamics has been strongly supported by the availability of structure-preserving discretization methods.

Concerning the discretization in space of nonlinear beams and shells, the course will address two alternative approaches. Firstly, geometrically exact formulations which are typically used in the finite element community and, secondly, the absolute nodal coordinate formulation which is quite popular in the multibody dynamics community. The semi-discrete equations of motion resulting from the discretization in space of flexible multibody systems in general assume the form of differentialalgebraic equations.

Concerning the discretization in time, the energy-momentum method and energy-decaying variants thereof will be treated. In addition to that, the newly emerging class of variational integrators as well as Lie-group integrators will be dealt with.

In the wake of the structurepreserving discretization in space and time a number of issues arise that will be addressed as well. Among them are the parametrization of finite rotations, the incorporation of algebraic constraints and the computer implementation of the various numerical methods. The practical application of structure-preserving methods will be illustrated by a number of examples dealing with, among others, nonlinear beams and shells, large deformation problems, long term simulations and coupled thermo-mechanical multibody systems. In addition to that the novel time integration methods are linked to frequently used methods in industrial multibody system simulation.

The target audience of this summer school are research scientists, postgraduate and graduate students from universities, research institutes and industry, who are interested in the theoretical background and the practical application of computer methods in nonlinear structural dynamics and flexible multibody dynamics.

INVITED LECTURERS

Martin Arnold - Martin Luther University of Halle-Wittenberg, Germany *6 lectures on:* Lie group integrators for constrained systems: Theory and practical aspects such as index reduction, modified starting values in the index-3 case and variable time step sizes. Generalized- α time integration method for constrained mechanical systems. Dynamical simulation of geometrically exact rods.

Peter Betsch - University of Siegen, Germany

6 lectures on: Energy-momentum integrators for flexible multibody dynamics. Discrete null space method for constrained mechanical systems. Multibody dynamics in terms of natural coordinates. Nonlinear finite element methods for geometrically exact beams and shells.

Alberto Cardona - Universidad Nacional del Litoral-Conicet, Santa Fe, Argentina

6 lectures on: Generalized- α algorithms for flexible multibody dynamics. Time-step-size-independent conditioning of equations in index-3 DAEs in flexible multibody dynamics. Energy conserving and energy decaying algorithms for rigid bodies and flexible mechanisms. Lie-group time integrators in multibody dynamics.

Johannes Gerstmayr - Austrian Center of Competence in Mechatronics, Linz, Austria

6 lectures on: Absolute nodal coordinate formulation: basic concepts, some popular and easy-to-implement formulations on two-dimensional beams. Continuum mechanics formulation and hybrid (structural mechanics) formulation of work of elastic forces. Application to three-dimensional beams. Notes on implementation and numerical examples.

Adrian Lew - Stanford University, CA, USA

6 lectures on: Lagrangian and Hamiltonian mechanics for finite dimensional systems. Discrete mechanics and variational integrators for finite dimensional systems, Conservation and accuracy properties. Lagrangian mechanics for continuous systems. Formulation of variational integrators for continuous systems.

Ignacio Romero - Universidad Politecnica de Madrid, Spain *6 lectures on:* High frequency numerical dissipation in nonlinear problems: the EDMC method. Extension of structure-preserving methods to coupled thermo-mechanical multibody systems: viscous, frictional, and other sources of dissipation. Description of symmetries and conservation laws for dissipative systems, and Energy-Entropy-Momentum methods.

LECTURES

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

PRELIMINARY SUGGESTED READINGS

M. Geradin, A. Cardona, Flexible multibody dynamics: A finite element approach, John Wiley & Sons, 2001.

O. Bauchau, Flexible Multibody Dynamics, Springer-Verlag, 2011. A.A. Shabana, Dynamics of Multibody Systems, 3rd edn., Cambridge University Press, 2005.

E. Lens, A. Cardona. An energy preserving/decaying scheme for constrained nonlinear multibody systems. Multibody System Dynamics, Vol. 18 (2007), 435-470. J. C. García Orden, I Romero. Energy-Entropy-Momentum Integration of Discrete Thermo-Visco-Elastic Dynamics, European Journal of Mechanics - A/Solids, Vol. 32 (2012), 76-87. A. Lew, J.E. Marsden, M. Ortiz, M. West. Variational time integrators. Int. J. Numer. Meth. Engng, Vol. 60 (2004), 153-212.

STRUCTURE-PRESERVING INTEGRATORS IN NON-LINEAR STRUCTURAL DYNAMICS AND FLEXIBLE

MULTIBODY DYNAMICS

Udine, October 7 - 11, 2013 Application Form (Please print or type)

Surname _____

Name _____

Affiliation_____

Address_____

E-mail

Phone ______Fax_____

Method of payment upon receipt of confirmation (Please check the box)

The fee of Euro 700,00 includes IVA/VAT tax and excludes bank charges

I shall send a check of Euro _____

- □ Payment will be made to CISM Bank Account N° 094570210900, VENETO BANCA - Udine (CAB 12300 - ABI 05035 - SWIFT/BIC VEBHIT2M - IBAN CODE IT46 N 05035 12300 09457 0210900). Copy of the receipt should be sent to the secretariat
- I shall pay at the registration counter with check, cash or VISA Credit Card (Mastercard/Eurocard, Visa, CartaSi)

IMPORTANT: CISM is obliged to present an invoice for the above sum. Please indicate to whom the invoice should be addressed.

Name
Address
C.F.*
VAT/IVA* No
(*) Only for EU residents or foreigners with a permanent business activity in Italy.

Only for Italian Public Companies

□ I ask for IVA exemption (ex law n. 537/1993 - art. 14 comma 10).

Privacy policy: I understand that data received via this form will be used only to provide information about CISM and its activities, within the limits set by the Italian legislative decree no. 196/2003 and subsequent amendments. Complete information on CISM's privacy policy is available at www.cism.it.

I have read the "Admission and Accommodation" terms and conditions and agree.