

TIME TABLE

| TIME          | Monday<br>October 12 | Tuesday<br>October 13 | Wednesday<br>October 14 | Thursday<br>October 15 | Friday<br>October 16 |
|---------------|----------------------|-----------------------|-------------------------|------------------------|----------------------|
| 9.00 - 9.45   | Registration         | Screen                | Screen                  | Evans                  | Oomens               |
| 9.45 - 10.30  | Avril                | Screen                | Screen                  | Evans                  | Oomens               |
| 11.00 - 11.45 | Screen               | Payan                 | Payan                   | Gasser                 | Avril                |
| 11.45 - 12.30 | Screen               | Payan                 | Payan                   | Gasser                 | Avril                |
| 14.00 - 14.45 | Payan                | Evans                 | Oomens                  | Oomens                 |                      |
| 14.45 - 15.30 | Payan                | Evans                 | Oomens                  | Oomens                 |                      |
| 16.00 - 16.45 | Evans                | Avril                 | Gasser                  | Gasser                 |                      |
| 16.45 - 17.30 | Evans                | Avril                 | Gasser                  | Gasser                 |                      |

### ADMISSION AND ACCOMMODATION

The registration fee is of 575,00 Euro + VAT taxes\*, where applicable (bank charges are not included).

The registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday subject to numbers), hot beverages, downloadable lecture notes and wi-fi internet access.

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

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

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email) no later than two weeks prior to the start of the course.

If cancellation occurs less than two weeks prior to the start of the course, a Euro 50,00 handling fee will be charged. Incorrect payments are subject to Euro 50,00 handling fee.

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 or students' dormitories, if available.

Requests should be sent to CISM Secretariat by *August 18, 2015* 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.

\* Italian VAT is 22%.

*For further information please contact:*

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 Piazza Garibaldi 18  
 33100 Udine (Italy)  
 tel. +39 0432 248511 (6 lines)  
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Centre International des Sciences Mécaniques  
International Centre for Mechanical Sciences

ACADEMIC YEAR 2015 The  
Villaggio Session



## MATERIAL PARAMETER IDENTIFICATION AND INVERSE PROBLEMS IN SOFT TISSUE BIOMECHANICS

Advanced School  
 coordinated by  
*Stéphane Avril*  
 Ecole des Mines  
 Saint-Etienne, France  
*Sam Evans*  
 Cardiff University  
 UK

Sponsored by:



*Udine October 12 - 16 2015*

# MATERIAL PARAMETER IDENTIFICATION AND INVERSE PROBLEMS IN SOFT TISSUE BIOMECHANICS

There are many fields in medicine and in biomedical engineering where accurate measurements of local soft tissue properties are needed. In general it is difficult to measure the mechanical properties of these materials directly and some kind of inverse approach is needed, where an experiment has to be simulated and the material parameters are adjusted until the model matches the experiment. Several open questions are raised by inverse approaches in soft tissue biomechanics:

- Experimental measurements on biological tissues present many practical and theoretical difficulties. Experimental and numerical errors also increase the uncertainty, as do inadequate constitutive models.
- An inverse problem requires a computational model that can be solved repeatedly with different

material parameters. This requires a model that can be solved quickly and reliably; these are not attributes one usually associates with computational models of biological tissues.

- Biological tissue mechanical behaviour exhibits special characteristics that may affect the mechanical response and disturb material identification, such as visco-elasticity, multi-scale properties, variability of properties and remodelling. Tissues often develop regionally varying stiffness, strength and anisotropy. Important challenges in soft tissue mechanics are now to develop and implement hybrid experimental - computational methods to quantify regional variations in properties in situ.
- Once the necessary experimental data and computational models are in place, it is essential to implement

an appropriate optimisation strategy to adjust the material parameters to give the best match with the experimental results, and to consider issues of uniqueness of the identified parameters.

- The question of uniqueness can be tackled by increasing the quantity of experimental data. To this purpose, tracking the full-field deformation of tissues using optical measurements or medical imaging techniques becomes quite commonplace but these novel measurement approaches have only been recently applied to material identification of biological tissues and they still have to be well calibrated and validated for them.
- It has also been identified that in certain situations useful patient-specific results can be obtained without precise knowledge of patient-specific properties of tissues. This situation arises for instance in image-guided surgery

and modelling and analysis of thin-walled biological organs. Learning skills in this multidisciplinary environment is challenging, and rarely addressed to a sufficient level within classical degree programs. The advanced school will gather the best worldwide specialists in hybrid experimental - computational methods applied to soft tissues, to teach a focused and highly original course in this area. The course is addressed to doctoral students and postdoctoral researchers in mechanical and biomedical engineering, materials science, biophysics and applied mathematics, academic and industrial researchers and practicing engineers. Attendees should have an engineering background with reasonable knowledge of mathematics; the necessary biology from will be taught from scratch.

## PRELIMINARY SUGGESTED READING

S. Avril, S.L. Evans Guest Edts. Inverse problems and material identification in tissue biomechanics - Special issue of the Journal of the Mechanical Behavior of Biomedical Materials, Volume 27, November 2013.

J.D. Humphrey. Review Paper: Continuum biomechanics of soft biological tissues. Proceedings of Royal Society London A, January 2003 vol. 459, no. 2029, 3-46.

J. Vincent. Structural Biomaterials: Third Edition. Princeton University Press, 2012.

S.A. Maas, B.J. Ellis, G.A. Ateshian, J.A. Weiss. FEBio: Finite Elements for Biomechanics. Journal of Biomechanical Engineering, 134(1):011005, 2012.

H.R.C. Screen. Hierarchical approaches to understanding tendon mechanics. Japan Society of Mechanical Engineers Journal of Biomechanical Science and Engineering, vol. 4, (4) 481-499, 2009.

M. Geerligs, L.C.A. van Breemen, G.W.M. Peters, P.A.J. Ackermans, F.P.T. Baaijens, C.W.J. Oomens,

In vitro indentation to determine the mechanical properties of epidermis, Journal of Biomechanics, 44, 1176-1181, 2011.

L. Dubuis, S. Avril; J. Debayle, P. Badel. Identification of the material parameters of soft tissues in the compressed leg. Computer Methods in Biomechanics and Biomedical Engineering, 2012, 15(1) pp 3-11.

G. Martufi and T.C. Gasser. Review: The role of biomechanical modeling in the rupture risk assessment for abdominal

aortic aneurysms. J. Biomech. Eng. 135:021010. doi: 10.1115/1.4023254, 2013.

R.B. Groves, S.A. Coulman, J.C. Birchall, S.L. Evans. An anisotropic, hyperelastic model for skin: Experimental measurements, finite element modelling and identification of parameters for human and murine skin. Journal of the Mechanical Behavior of Biomedical Materials, 18, 167-180, 2013.

## INVITED LECTURERS

*Stéphane Avril* - Ecole des Mines, Saint-Etienne, France

*5 lectures on:*

Introduction to inverse problems, Identification of material parameters from full-field measurements, Characterization of maps of material parameters at different scales.

*Sam Evans* - Cardiff University, UK

*6 lectures on:*

Advanced experimental approaches for soft tissue mechanics: full-field measurement techniques, imaging techniques, link between experiments and modeling.

*Christian Gasser* - Royal Institute of Technology, Stockholm, Sweden

*6 lecture on:*

Characterization of damage and failure mechanics of soft tissues, local analysis of rupture modes in soft tissues, experimental characterization and numerical implementation.

*Cees Oomens* - Eindhoven University of Technology, The Netherlands

*6 lectures on:*

What do the material parameters tell us about the soft tissues? Remodeling of tissues, inflammation, ulcers, ageing, diseases.

*Yohan Payan* - TIMC-IMAG, La Tronche, France

*6 lectures on:*

Finite Element modeling for soft tissues biomechanics, patient-specific model generation, in vivo estimation of the constitutive equations, examples of applications in the domain of computer-assisted medical interventions.

*Hazel Screen* - Queen Mary University of London, UK

*6 lectures on:*

Introduction to tissue biology and structure-function relationships in tissues. Linking multi-scale structure and mechanical properties, and reviewing multi-scale experimental characterization techniques

## 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.

MATERIAL PARAMETER IDENTIFICATION AND INVERSE  
PROBLEMS IN SOFT TISSUE BIOMECHANICS

Udine, October 12 - 16, 2015

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 is 575,00 Euro + 22% Italian VAT taxes, where applicable (bank charges are not included).*

I shall send a check of Euro \_\_\_\_\_

Payment will be made to CISM - Bank Account No. 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 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](http://www.cism.it).

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

Date \_\_\_\_\_ Signature \_\_\_\_\_