



## **MATERIALS & SURFACE SCIENCE INSTITUTE**

### **PRESENTATION BY**

**Professor Stéphane P. A. Bordas**  
**University of Luxembourg and Cardiff University**

### **PRESENTATION TITLE**

**Cutting in Real-time in Co-rotational Elasticity and  
Perspectives on Simulating Cuts**

### **ABSTRACT**

We focus on the simulation of surgical acts of types similar to cutting and needle insertion in soft tissue, in real time (500Hz), where the scale of the surgical instrument is several orders of magnitude smaller than that of the organ. We provide review of the state of the art and make propositions to address some of the main difficulties in this area: complex geometries - implicit boundaries, XFEM, meshless, advanced meshing; multiple scales (large gradients) - domain decomposition and model reduction; error control and adaptivity; parallel implementation Graphical Processing Units (GPUs). We then describe a series of contributions in the field of real-time simulation of soft tissue biomechanics. These contributions address various requirements for interactive simulation of complex surgical procedures. In particular, we present results in the areas of soft tissue deformation, contact modelling, simulation of cutting, and haptic rendering, which are all relevant to a variety of medical interventions. The contributions we describe share a common underlying model of deformation and rely on GPU implementations to significantly reduce computational expense. Since the commencement of the ERC RealTcut Starting Research Grant, we have made a number of advances, in particular in the area of real-time simulation of cutting. We have started implementing a novel cutting algorithm and investigating co-rotational elasticity to non-linear materials. We have shown that it is possible to cut non-linear solids formulated within a co-rotational formalism in real-time

with a tetrahedron subdivision method and a Sherman-Morrison update. The next steps include assessing the error associated with the single Newton iteration, extending to non-linear materials, and investigating the improvements enabled by enriched approximations. These results will form the basis of the real-time work.

## **ABOUT THE PRESENTER**

In 1999, Stéphane Bordas joined a joint graduate programme of the French Institute of Technology (Ecole Spéciale des Travaux Publics) and the American Northwestern University. In 2003, he graduated in Theoretical and Applied Mechanics with a PhD from Northwestern University. Between 2003 and 2006, he was at the Laboratory of Structural and Continuum Mechanics at the Swiss Federal Institute of Technology in Lausanne, Switzerland. In 2006, he became permanent lecturer at Glasgow University's Civil Engineering Department. Stéphane joined the Computational Mechanics team at Cardiff University in September 2009, as a Professor in Computational Mechanics and directed the institute of Mechanics and Advanced Materials from October 2010 to November 2013. He is the Editor of the book series "Advances in Applied Mechanics" since July 2013. In November 2013, he joined the University of Luxembourg as a Professor in Computational Mechanics. The main axes of his research team include (1) free boundary problems and problems involving complex geometries, in particular moving boundaries and (2) 'a posteriori' discretisation and model error control, rationalisation of the computational expense. Stéphane's keen interest is to actively participate in innovation, technological transfer as well as software tool generation. This has been done through a number of joint ventures with various industrial partners (Bosch GmbH, Cenaero, inuTech GmbH, Siemens-LMS, Soitec SA) and the release of open-source software. He has been collaborating with over 110 academic partners over the last 10 years. In 2012, Stéphane was awarded an ERC Starting Independent Research Grant (RealTcut), to address the need for surgical simulators with a computational mechanics angle with a focus on the multi-scale simulation of cutting of heterogeneous materials in real-time.

**DATE:** Monday, 10 February 2014  
**TIME:** 15h30

**VENUE:** MSB-012 MSSI Building

**REFRESHMENTS WILL BE PROVIDED AT 15h15**

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