13:30  3-minute presentations:
   Timo, Thijs, Saman, Pieter, Nilgoon, Michael

14:00  Xunxun  *Preconditioners for the discrete Cahn–Hilliard equation*

14:15  Kris  *Diffuse-interface tumor-growth modeling and simulation*

14:30  — break —

14:40  3-minute presentations:
   Jonas, Göktürk, Faisal, Clemens

15:00  Gertjan  *Toward a high-level finite element toolkit: Design decisions, development status, and what it will look like*
Airbag modeling: domain decomposition approach

volumetric meshing
[Saksono et al '07]
[Hashimoto et al '10]

uniform pressure
[MADYMO]

(images: courtesy of upholstery journal and daimler)
Feasible fluid discretization in folds

Boundary element method
▲ Complex geometries
▲ Large displacements
▲ Solve only at interface
▼ Linear fluid models

/multiscale engineering fluid dynamics section
FEM with Cohesive zones for arbitrary crack growth in bulk material

Three point bending

Four point bending

Notched three point bending
Topology Optimization

A 99 line topology optimization code written in Matlab
O. Sigmund
Struct Multidisc Optim 21, 120-127

Google: topopt
Topology Optimization

- Python (CPU)
- Split Optimization and FEM
- Describe errors in original paper
- Remove Grey
- Apply for 2D Rim (URE)
Numerical simulation of failure mechanisms in composites

Saman Hosseini, Joris. J. C. Remmers, Clemens C. Verhoosel, René de Borst

Department of Mechanical Engineering
Numerical Methods in Engineering group
Failure mechanisms in composites

- Delamination (1cm – 10cm)
- Transverse crack (0.1 mm – 1 cm)

Interaction of delamination and transverse cracking.
Suiker and Fleck (2004)
Goal

Develop a set of numerical tools for the simulation of failure mechanisms in layered composite materials which has a:

- **Precise finite element model**
  - Solid-like-shell element equipped with gradient damage model
  - Isogeometric solid-like-shell element

- **Robust solver**
  - Energy dissipation arc-length solver
Energy dissipation arc-length solver

Mode II delamination
Isogeometric analysis

- Exact geometry representation.

- Direct usage of geometry parameterization for the analysis.

- Piece-wise higher order continuity of the shape functions.
Isogeometric analysis

Pinched hemisphere with isogeometric solid-like-shell

undeformed

deformed
Elevator Pitch
Introduction and Overview

Pieter Barendrecht
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March 14, 2012
Introduction

Info

- Name: Pieter Barendrecht
- Age: 24
- Started with NME mastertrack in 2010

Interests

- Making music! (Percussion, Piano, ...)
- Playing boardgames
- Pewter casting (Pewter = ±90% Tin)
- Helpdesking (Fixing Linux and \LaTeX\ problems)
Open Space: Subdivision Surfaces with IGA

Subdivision schemes (e.g. Catmull Clark)

Limit surface and applications with IGA
Combine IsoGeometric Analysis (IGA) with Marc
Internship at Philips (2)

Change of Basis ( = Bézier extraction)
Introduction

Hydrogen embrittlement

The reduction of the mechanical properties in metals due to the absorption of hydrogen. As a result materials fail at load levels that are very low compared to those that a hydrogen-free material can sustain.

Two main questions:

- How $H_2$ atoms enter the metal?

$$J = -\frac{DCL}{RT} \nabla \mu(\sigma, T)$$

- What happens after they enter?
  - Hydrogen-induced phase changes
  - Hydrogen-enhanced localized plasticity
  - Hydrogen-reduced cohesive energy
How HE coupled problem looks like?

Solve the BVP for stress fields

Solving for diffusion equation:
Finding Hydrogen concentration

"Hydrogen-reduced cohesive energy":
Finding the the new $\sigma_{max}(C_H)$

updating the boundary conditions,
time increment & dislocations pattern
Diffusion Equation

One equation and two unknowns!

\[ \frac{\partial}{\partial t} \int_V (C_L + C_T) dV + \int_S J \cdot n dS = 0 \]

What can be done?
Assuming local equilibrium between $H_2$ in traps and lattice sites:

\[ C_T = C_T(N_T, \ldots) \quad C_L = C_L(C_T, \ldots) \]
\[ \frac{\partial C_L}{\partial t} + F(C_L) + G(N_T) = 0 \]
What has been done?

Coupling continuum plasticity with

\[ \frac{D}{D_{\text{eff}}} \frac{\partial C_L}{\partial t} - \nabla \cdot (D \nabla C_L) + \nabla \cdot \left( \frac{D C_L \bar{V}_H}{RT} \nabla \sigma_h \right) + \theta_T \frac{dN_T}{d\epsilon_P} \frac{\partial \epsilon_P}{\partial t} = 0 \]

\[ \log N_T = 23.26 - 2.33e^{-5.5\epsilon_P} \]

But are dislocations really that important?

To be or not to be, that is the question! :)

\[ H_2 \text{ in lattice sites} \]
\[ H_2 \text{ in trap sites} \]
What have we done?

1) We perform a Discrete Dislocation stress analysis. Why is that?

- In this way we capture the real stresses arising from dislocations.
- We may show $C_T$ as $C_L$ trapped in very high stresses.

Figure: Stress field arising from a group of dislocations.
What have we done?

2) A quasi-static stress assisted hydrogen concentration formulation: Assuming equilibrium between $H_2$ in lattice sites and far field $H_2$.

\[ \mu^0 + RT \ln C_0 = \mu^0 + RT \ln C_L + \mu_\sigma \]

\[ C_L(x) = C_0 \exp \left( \frac{\sigma_h(x)V_H}{RT} \right) \]

3) A cohesive law depending on hydrogen concentration:

\[ \frac{\sigma_{max}(\theta)}{\sigma_{max}(0)} = 1 - 0.67\theta(C_L) \]
Introduction

- Theory:
  Numerical approximation of the Boltzmann Equation

- Application:
  Modeling of rarefied gas flows
Rarefaction Effects

- Molecular Dynamics
- Direct Simulation Monte Carlo (DSMC)
- Boltzmann equations
- Collisionless Boltzmann
- Euler equations
- Navier-Stokes equations

continuum

molecular flow

$Kn = \frac{\lambda}{L}$
A generic kinetic equation: the Boltzmann equation

\[ \partial_t f + \mathbf{v} \cdot \nabla_x f = C(f) \]

where \( f = f(t, \mathbf{x}, \mathbf{v}) \) is the density function and \( C(f) \) is an interaction term between particles acting only on the \( \mathbf{v} \) dependance of \( f \).
1. Moments.
Let $\mathcal{M}$ be a linearly independent finite set of functions of $\mathbf{v}$ with vector basis $\mathbf{m}(\mathbf{v})$

2. Integration upon $\mathbf{v}$.

$$\partial_t \int \mathbf{m}(\mathbf{v}) f \, d\mathbf{v} + \nabla_x \cdot \int \mathbf{v} \mathbf{m}(\mathbf{v}) f \, d\mathbf{v} = \int \mathbf{m}(\mathbf{v}) \mathcal{C}(f) \, d\mathbf{v}$$

3. Closure relation: $f(.,.,\mathbf{v}) \rightarrow G(.,.,\mathbf{v}) = \exp(\alpha(t, \mathbf{x}) . \mathbf{m}(\mathbf{v}))$ with

$$\int \mathbf{m}(\mathbf{v}) \exp(\alpha . \mathbf{m}(\mathbf{v})) \, d\mathbf{v} = \int \mathbf{m}(\mathbf{v}) f \, d\mathbf{v}$$

$\alpha$ are the Lagrange multipliers of the moments of $f$ with respect to the entropy functional $H(f) = \int (f \ln f - f) \, d\mathbf{v}$
Goals

- Closure and analysis
- Numerical approximation
- Modeling and simulation
Thank You!
Numerical modelling of textile composites

Compressive behaviour of woven textile composites

Jonas Freund, March 2012
Problem description

“Investigation on the compressive behaviour of woven textile composites at the ply-scale”

- What: textile composites behave differently in tension and compression (Young’s moduli, strengths)
- Why: laminate’s nature enables many material degradation modes
- How: numerical material modelling at ply scale and experiments (coupon tests)
Compressive behaviour

Woven textile composite:

Compressive behaviour is influenced by:

- Textile architecture and layup
- Boundary conditions and loading
- Micro-cracks
- Failure modes (may interact):
  - Micro-buckling / kink-bands
  - Delamination
  - Matrix crushing
  - Etc.

Fibre micro-buckling (Fleck, 1997)
Numerical modelling

Aspects to develop and implement:
• Failure criterion (damage initiation)
• Damage evolution law (material degradation)
• Possible occurrence of delamination

Numerical predictions will be compared to experimental data
Thank you for your attention
Adaptivity in Isogeometric Analysis

Göktürk Kuru
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March 13, 2012
Isogeometric Analysis

Adaptivity

Adaptive IGA?
Outline

Isogeometric Analysis

Adaptivity

Adaptive IGA?
Isogeometric Analysis

Adaptivity

Adaptive IGA?
Isogeometric Analysis

What? Using the geometry basis functions for the trial space.
Isogeometric Analysis

What? Using the geometry basis functions for the trial space.
Isogeometric Analysis

What? Using the geometry basis functions for the trial space.

Why? Bunch of nice properties:

- Exact geometry representation for the analysis of CAD objects.
- Arbitrary order of continuity across elements, by construction.
- Extra possibility of refinement, called k-refinement, in addition to hp.
Isogeometric Analysis

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Adaptivity

What? Modifying the solution space based on a localised error indicator.
Adaptivity

What? Modifying the solution space based on a localised error indicator.

Why? Meshing the solution, not the domain. 

- Better efficiency per d.o.f. by restoring the ideal convergence rate.
- (Usually) getting an estimate of the discretisation error for free.
Adaptivity

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Adaptive IGA?

Usually geometry representation of a CAD object is too coarse for analysis, requiring a preprocessing step as in conventional FEM.

Challenges?

- Local refinement of spline bases.
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- Compatibility with conventional FEM implementations after refinement.
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- Compatibility with conventional FEM implementations after refinement.
- Local error indicators suitable for basis functions with wide support.
Adaptive IGA?

Usually geometry representation of a CAD object is too coarse for analysis, requiring a preprocessing step as in conventional FEM.

Challenges?

- Local refinement of spline bases.
- Compatibility with conventional FEM implementations after refinement.
- Local error indicators suitable for basis functions with wide support.
- Complying with problem-specific constraints on the adapted mesh. (e.g. as in divergence-free elements for incompressibility constraints)
Effect of fluid on crack propagation in porous media

Faisal Irzal

Eindhoven, March 14, 2012
Motivation

To simulate crack propagation and to study the effect of microfluid flow in the cavity to the cracking behaviour of soft porous media

Application:

Hydraulic fracturing

Herniated Disc
Macro model

- Fully saturated mixture consists of solid \((u)\) and fluid \((p)\)
- Inertia and body force are neglected
- Fluid: Incompressible
- Solid: Hyperelastic, isothermal, and isotropic
- Properties of the medium are averaged by mixture theory
Discretised weak formulation

\begin{align*}
\mathbf{f}^{\text{int}}_{\hat{a}} & := \int_{\Omega} \mathbf{B}^T \sigma \, d\Omega \\
\mathbf{f}^{\text{int}}_{\hat{b}} & := -\int_{\Omega} \mathbf{H}^T \mathbf{m}^T \nabla \cdot \mathbf{v}_s \, d\Omega + \int_{\Omega} k_f \nabla \mathbf{H}^T \nabla p \, d\Omega \\
\mathbf{f}^{\text{int}}_{\tilde{a}} & := \int_{\Omega} \mathbf{H}_{\Gamma_d} \mathbf{B}^T \sigma \, d\Omega + \int_{\Gamma_d} \mathbf{N}^T (\mathbf{t}_d - \rho \mathbf{n}_d) \, d\Gamma \\
\mathbf{f}^{\text{int}}_{\tilde{b}} & := -\int_{\Omega} \mathbf{D}_{\Gamma_d} \mathbf{H}^T \mathbf{m}^T \nabla \cdot \mathbf{v}_s \, d\Omega + \int_{\Omega} k_f \nabla (\mathbf{D}_{\Gamma_d} \mathbf{H})^T \nabla p \, d\Omega \\
& \quad + \int_{\Gamma_d} \mathbf{H}^T \mathbf{n}_d^T \mathbf{q}_d \, d\Gamma
\end{align*}
Micro model - solid

Cohesive zone model

\[ \mathbf{n}_d \cdot \mathbf{\sigma} = \mathbf{t}_d - \rho \mathbf{n}_d \]

\[ \mathbf{t}_d = f(\kappa, \mathbf{u}_d) \]
Assumptions

- Small opening of the cracks
- Viscous-Newtonian flow
- Monophasic

By applying local balance of momentum and integrating them over the cross section of the cavity, we get:

\[
\mathbf{n}_d \cdot \mathbf{q}_d = n_f \left( \frac{2h^3}{3\mu} \frac{\partial^2 p}{\partial \zeta^2} + \frac{2h^2}{\mu} \frac{\partial p}{\partial \zeta} \frac{\partial h}{\partial \zeta} - 2h \frac{\partial v_f}{\partial \zeta} - 2 \frac{\partial h}{\partial t} \right)
\]
Effect of fluid on crack propagation in porous media

Faisal Irzal
Integration of CAD and FEA

GMSH example with geometry imported from CAD package

/ department of mechanical engineering
Integration of CAD and FEA

Spline-based geometry parametrization

Discretization with $C^0$ piecewise polynomials
Integration of CAD and FEA

Spline-based geometry parametrization

Discretization with $C^0$ piecewise polynomials

**IsoGeometric Analysis**
Unification of CAD and FEA by using the same spline basis functions for both geometry and analysis
Advantages of IGA

“Design-through-analysis”
- Elimination of meshing procedures
- Elimination of geometry clean-up procedures
- Efficient geometry parametrization
- Exact representation of e.g. conic sections

Shape function properties
- Inter-element continuity control
- Efficient discretization of smooth fields
- Enhanced discretization stability
- Solenoidal discretizations