Mechatronics, a key impulse in Upper Austria for bridging scientific research and industrial application.

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AGENDA

- LCM – the company
- MECHTRONICS: Bridging Science and Industry
- MECHTRONICS: Bridging Industrial Branches
- WHERE Bridges are built
- EXAMPLE: Software tool HOTINT
LCM – THE COMPANY

• R&D cooperations and services from applied basic research to the final product

• Continuous more than 100 employees, who work in projects for our customers - small enterprises, SMEs to large international groups

• International partner network

• Access to latest findings of applied basic research through our integrated K2 project trail

• International projects – H2020
Industry driven projects: customer – supplier conditions

Projects with international funding (e.g. H2020): partner structure

COMET K2 project trail: national regulations, have to be accepted by all partners, “ACCM project” is running till 12/2017
Mechatronics: Briding Industrial Sectors

- Operators and manufacturers of plant, machinery and equipment
- Suppliers of components for plant, machinery and equipment

...from the following sectors...
Where bridges are built

- Simulation of components, systems & processes
- Customized control systems
  - Model based
- Drive Technology
  - Electrical + Hydraulic
- Sensors and Communication
  - Condition Monitoring, positioning
- Noise and Vibration
  - Fault detection, vibration reduction
EXAMPLE: HOTINT - Open Source Multibody Simulation Software

Why this example in the context of bridging Science and Industry

- HOTINT: “History” and Today
- Basics
- Numerical Solver
- Scientific topics investigated with HOTINT
- Recent industrial applications
- Outlook on future developments

For details see: [www.hotint.org](http://www.hotint.org)

1 Alexander Humer, Johannes Gerstmayr: ECCOMAS Thematic Conference on Multibody Dynamics 2015, Barcelona, Spain
HOTINT - Yet another multibody simulation tool?

„History“ of HOTINT

„father“ of HOTINT:
Prof. Johannes Gerstmayr (full professor at university of Innsbruck) started the tool with his diploma thesis 1996

HOTINT Today

• Object-oriented multibody / mecha(tro)nic simulation software for
• Windows implemented in C++
• Focus: complex mechanics, deformable bodies, mechatronic systems
• Open-source software since 2013 (complete code available)
• Pre-compiled freeware version & installer (www.hotint.org)

For details see: www.hotint.org
HOTINT - Basics

• Redundant coordinate formulation: bodies & constraints
• Object-oriented:
  ➢ Each component (rigid body, solid/beam/shell element, connector, IO-Element, . . . ) is represented by an element object
  ➢ Elements contribute equations (ODEs, algebraic) to multibodysystem (object based model denition)
  ➢ Service objects: loads, nodes, sensors, . . .
• Synthesis of rigid & flexible members: merge MBS & FE
• Modularity: independent core modules implemented as libraries
  ➢ HOTINT kernel, object libarary, numerical solvers, math libararies, GUI, script parser, etc.
• Efficient model setup & manipulation: GUI & script language
• Open-source framework: designed for efficient development

For details see: www.hotint.org
HOTINT – Numerical Solver

• Three basic computations modes (sparse & full matrices):
  ➢ Static analysis: Newton solver, fixed-point, return-mapping, etc.
  ➢ Dynamic solver for DAEs: general implicit Runge-Kutta schemes
    (acronym: High-Order Time INTegration)
  ➢ Eigenvalue problems: direct & iterative solvers

• Optimization & parameter identification: genetic algorithm
• Automated parameter variation & sensitivity analysis

For details see: www.hotint.org
**HOTINT – Scientific Topics**

- Structural mechanics: Large deformation beam elements
- Modal reduction: Generalized Component Mode Synthesis
- Fluid-Structure Interaction: SPH & co-simulation

**Structural mechanics:**

**Absolute Nodal Coordinate Formulation (ANCF)**

- Orientation of cross-sections represented by slope vectors
- Large deformation beam and shell elements

For details see: [www.hotint.org](http://www.hotint.org)
Modal reduction: Generalized Component Mode Synthesis (GCMS)

- Modal reduction based on components modes
- Rigid-body motion and flexible deformation relative to inertial frame

\[ \mathbf{u} = \mathbf{u}_t + (\mathbf{A} - \mathbf{I}) \mathbf{x} + \mathbf{u}_f \]

Key ingredients of GCMS:

- Co-rotationally linearized strain tensor
- Linear configuration space

\[ \mathbf{u}(\mathbf{x}, t) = \mathbf{N}(\mathbf{x})\mathbf{q}(t) \]

- Appropriate shape functions for rotational motion and flexible deformation

For details see: [www.hotint.org](http://www.hotint.org)
Modal reduction: Generalized Component Mode Synthesis (GCMS)

Equations of motion in GCMS:

\[ M\ddot{q} + K q_{\text{flex}} + f_{n1}(q) + \left( \frac{\partial C}{\partial q} \right)^T \lambda = f_{\text{ext}} \]

\[ K = A_{bd}K_{\text{red}}A_{bd}^T, \quad f_{n1} = \sum_{i,j=1}^{3} (q_{\text{flex}})^T A_{bd}K_{\text{red}} \frac{\partial A_{bd}^T}{\partial A_{ij}} q_{\text{flex}} \frac{\partial A_{ij}}{\partial q} \]

- Constant mass matrix, no gyroscopic terms
- Co-rotated but otherwise constant stiffness matrix & computationally inexpensive non-linear term
- However, 9 generalized coordinates per local mode shape

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Fluid-Structure Interaction: Smoothed Particle Hydrodynamics (SPH)

- Particles represent fluid domain ⇒ Lagrangian, meshless approach
- Non-conventional CFD: changing fluid domains, free surface, . . .
- Partitioned approach: solid (HOTINT) ⇔ Fluid (LIGGGHTS)
- Force-displacement coupling: via surface mesh
- Co-simulation: data exchange via TCP/IP

HOTINT – Scientific Topics close to Industry (1)

Fluid-Structure Interaction: Smoothed Particle Hydrodynamics (SPH)

- HOTINT: implicit solver, large timesteps
- LIGGGHTS: fully parallelized, explicit solver
- General purpose interface design
- Coupling realized for: rigid bodies, structural elements, solid-finite elements, modally reduced MBS, . . .
HOTINT – Scientific Topics close to Industry (1)
**HOTINT – Industrial Application (1)**

Desing and Simulation Tool for large Power Transformers

- Modeling and simulation of transformer core
  - Core sheets in frictional contact! compression essential
  - Homogenized material model of core sheets in frictional contact

- Tool for tank design and peripherals (radiators . . . )
  - ANCF plate and beam elements

- Layout of reinforcements
- Earthquake loads on pipes
Sheet Metal Forming

- Optimization of an automatic sheet panel bender
- Complex simulation model (total machine, process)
- Model reduction strategies
- Highly nonlinear: large deformations, plasticity, contact
- Automatic identification of material properties (online)
  - Adaptive fully automated one piece flow production

source: http://www.salvagninigroup.com
Summary

• Mechatronics is not an industrial branch but a scientific discipline

• However, Mechtronics is a fundamental basis for many engineering activities in industry

• Therefore Mechatronics is bridging Science and Industry by its nature

• Furthermore, Mechatronics is bridging many industrial sectors/branches due to its technological approach

• Example of Software tool HOTINT was shown to demonstrate this
Thank you for your kind attention

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