MpCCI – A general Solution for Multidisciplinary Code Coupling

Klaus Wolf

Overview

- Fraunhofer Institute for Algorithms and Scientific Computing (SCAI)
- MpCCI - The basic Principles
- MpCCI - Interpolation Schemes
- MpCCI - Communication
- MpCCI - System and Environment (Portings, Tools, ...)
- MpCCI - and Commercial Simulation Codes
- MpCCI - Coupled Applications
- Conclusion

Fraunhofer Society

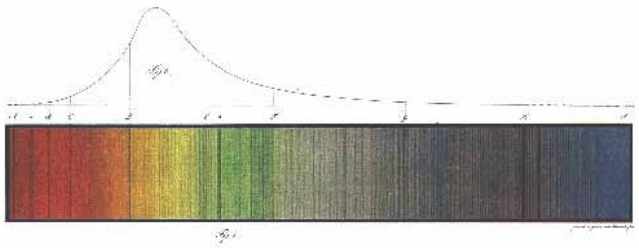
- Founded in 1949, non-profit organization
- Focus on application-oriented basic and industrial research
- 56 Research Institutes thoughout Germany
- Staff of approximately 11000 people, majority of qualified scientists and engineers
- Annual research volume around 900 Million EURO

Joseph von Fraunhofer (1787 - 1826)

Researcher
discovery of “Fraunhofer Lines“
in the sun´s spectrum

Inventor
new methods of lens processing

Entrepreneur
head of royal glass factory



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Fraunhofer Society – Groups and Consortia of Institutes

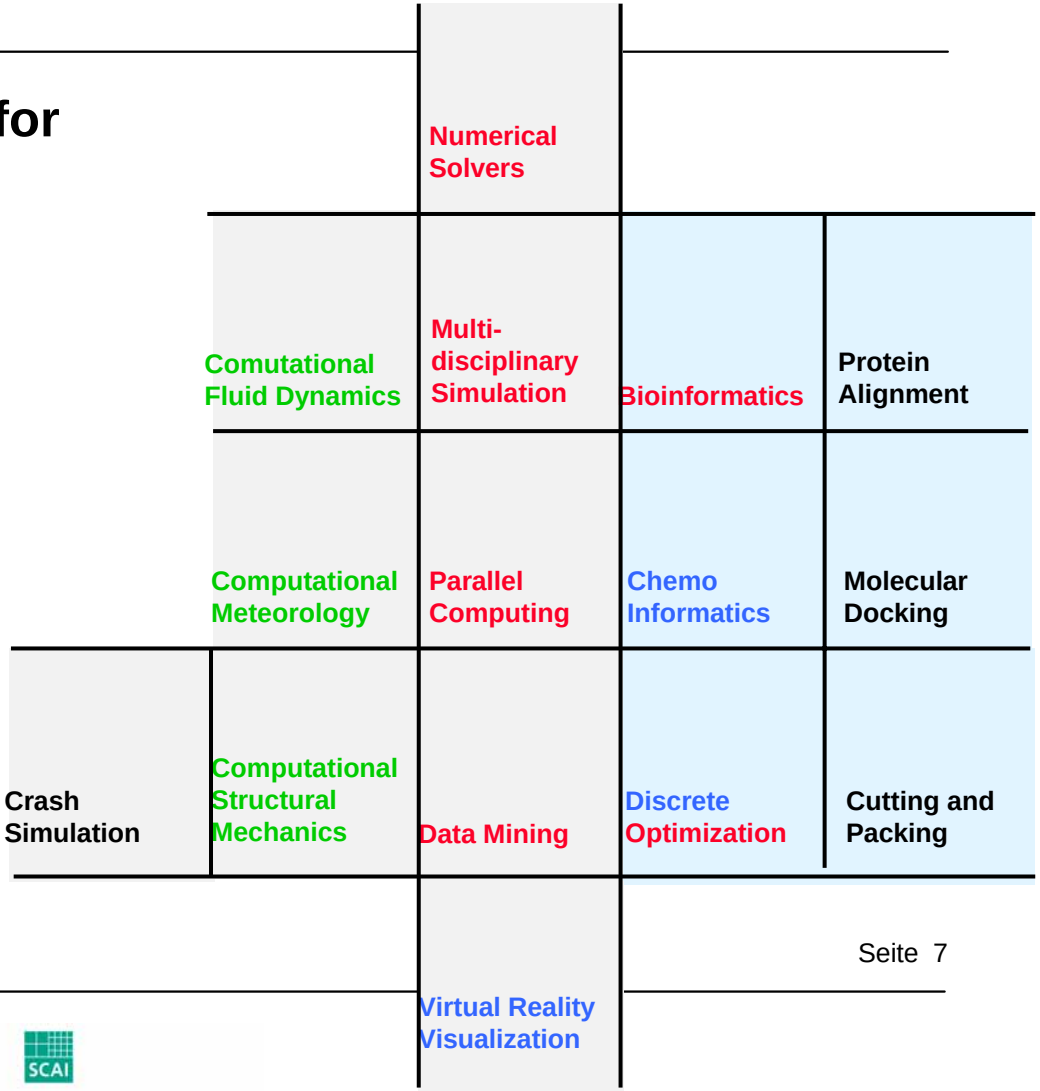
Pooling expertise and services in...

- Information and Communication Technology (ICT Group)
  15 Institutes, Staff of around 2000, Budget volume 160 Million US$
- Life Sciences
- Microelectronics
- Surface Technology and Photonics
- Production
- Materials and Components
- Polymer

Fraunhofer Schloss Birlinghoven

Innovative SW Technology for Fast Simulation

Technologies and Competence



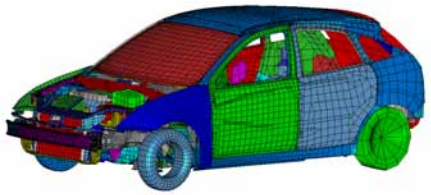
Staff: ~ 100 People
Master and Ph.D. students: 25

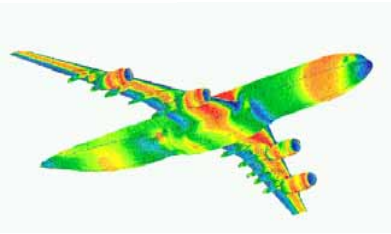
Budget: 6 Million € institutional
4 Million € third party

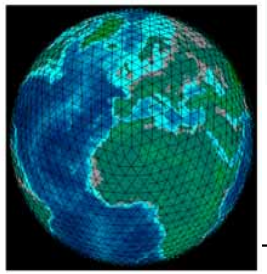
Simulation Engineering

Target Areas

- **MpCCI – coupling interface, algorithms and library**
- **CAE data integration**
- **Multidisciplinary simulation and mapping**
- **Grid Computing**
- Computational fluid dynamics
- Numerical methods in meteorology and climate research







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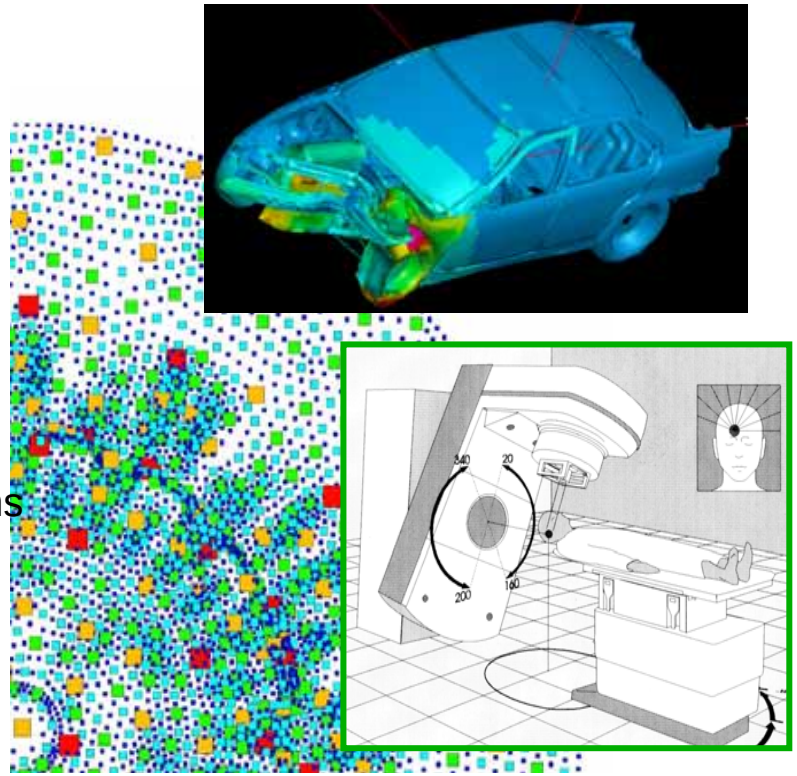
Simulation Methods

Target Areas

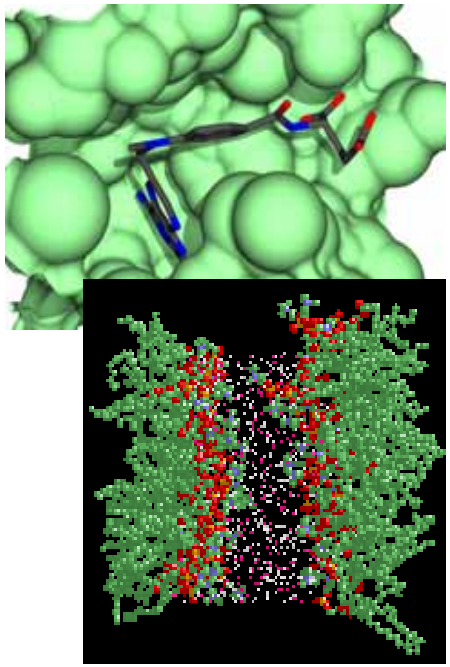
- Fast solvers (e.g. Algebraic Multigrid)
- Parallel computing (e.g. load balancing)
- **Parametric optimization**
- **Stability analysis of crash simulations**
- **Data mining in engineering applications**
- Compiler technology for data parallel systems



Bioinformatics

Target Areas

- Bioinformatics
- Database-Management for BioInformatic
- Workflows for Bio



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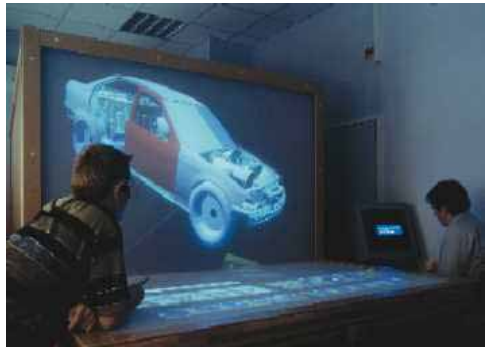
WebServices

Target Areas

- Scheduling
- Intelligent postprocessing
- VR and visualization tools



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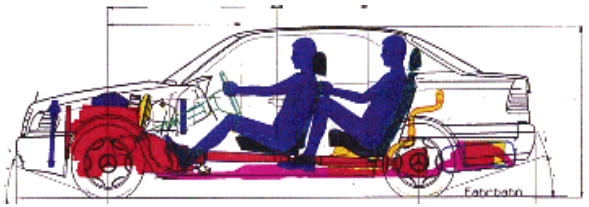
Optimization

Target Areas

- Discrete optimization
- Cutting and packing problems



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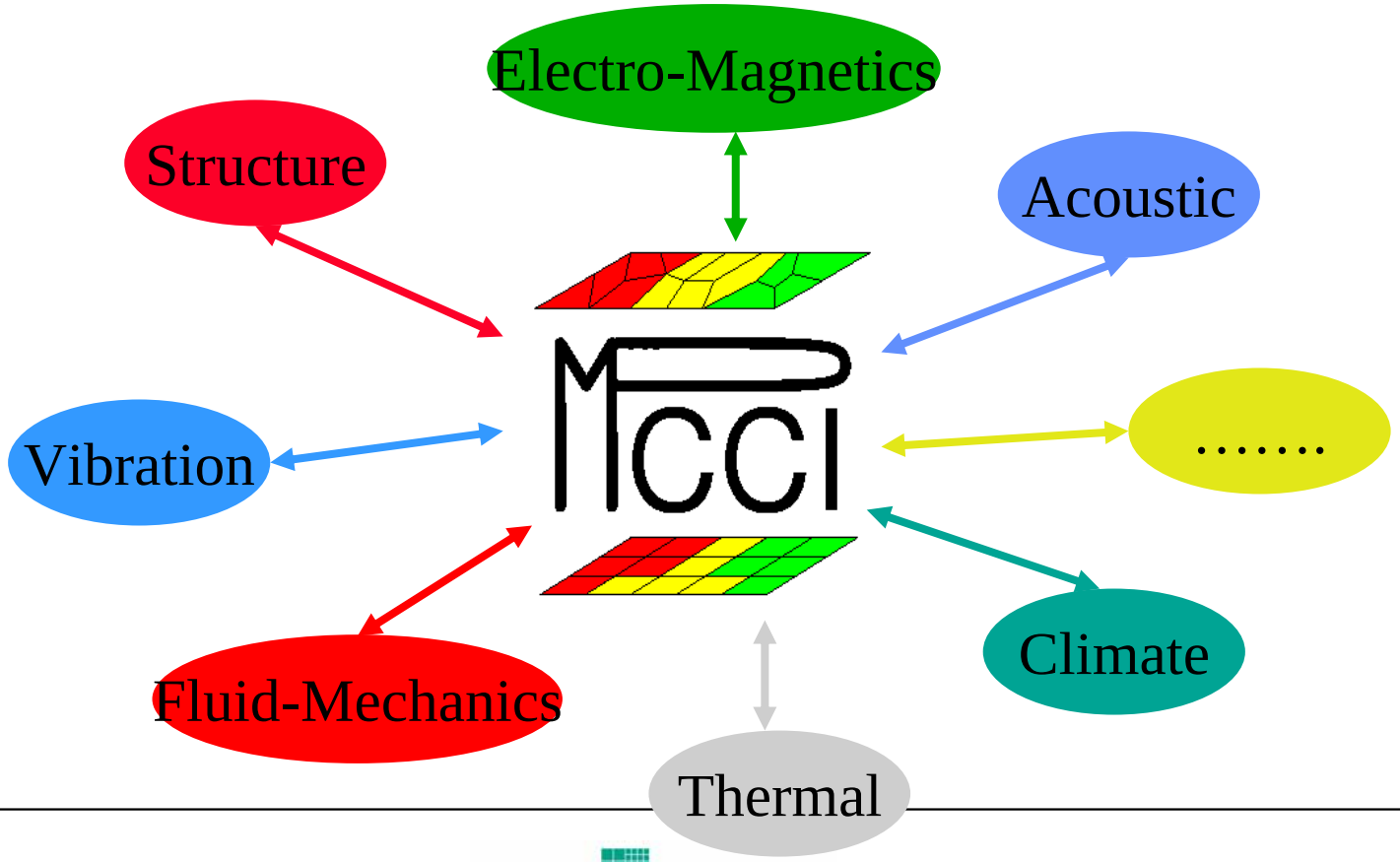
Standard Interface for Coupling of Simulation Codes



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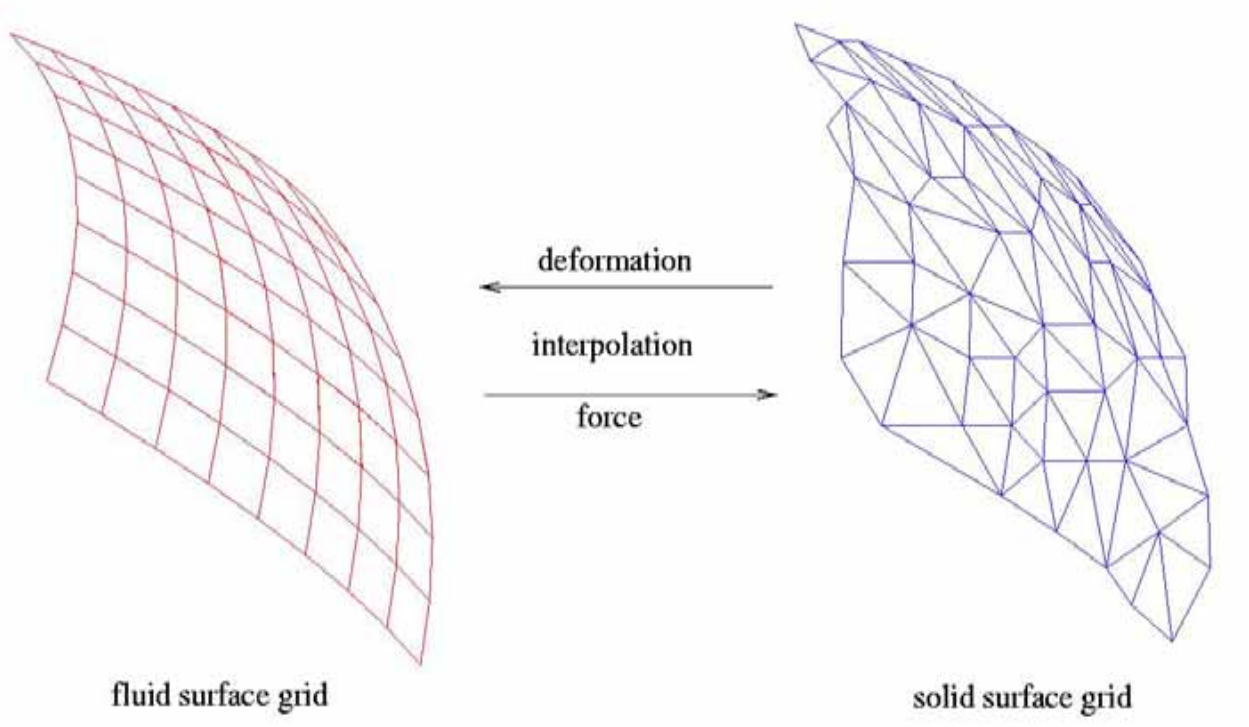
MpCCI Tasks



- Neighborhood search
- Interpolation
- Data transfer of coupling values

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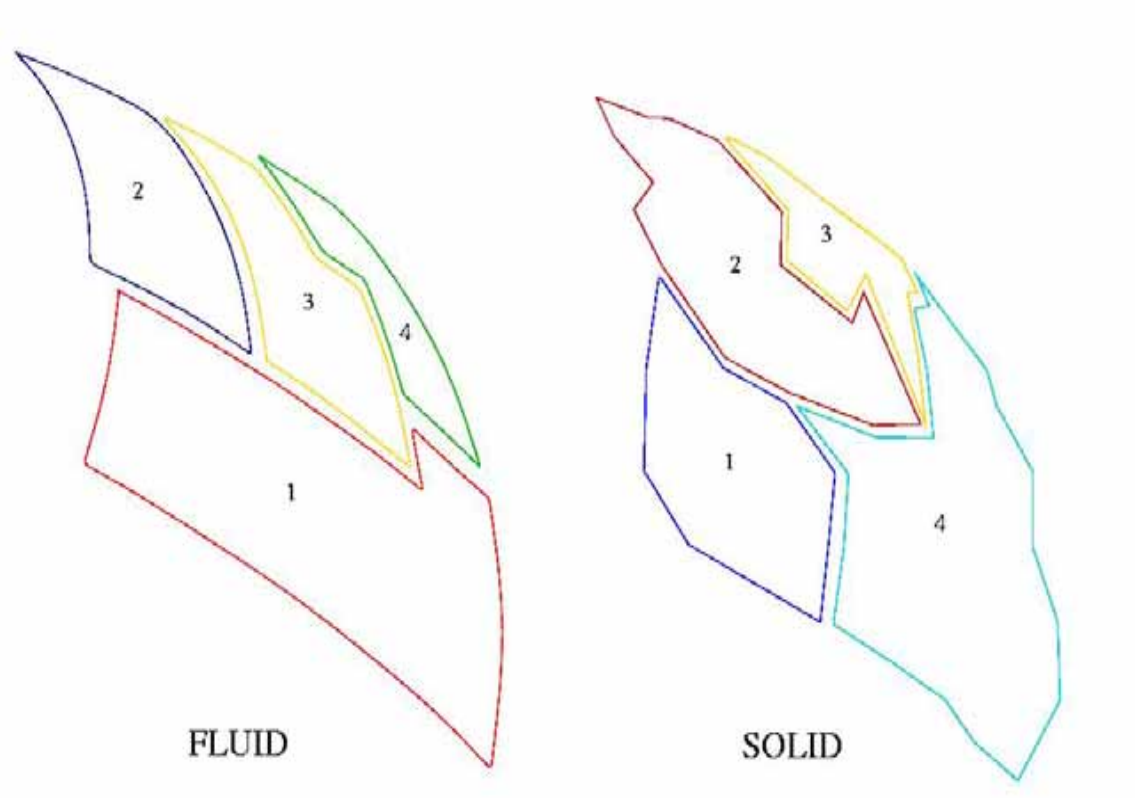
MpCCI Tasks

Coupling Regions

distributed over several

parallel processes



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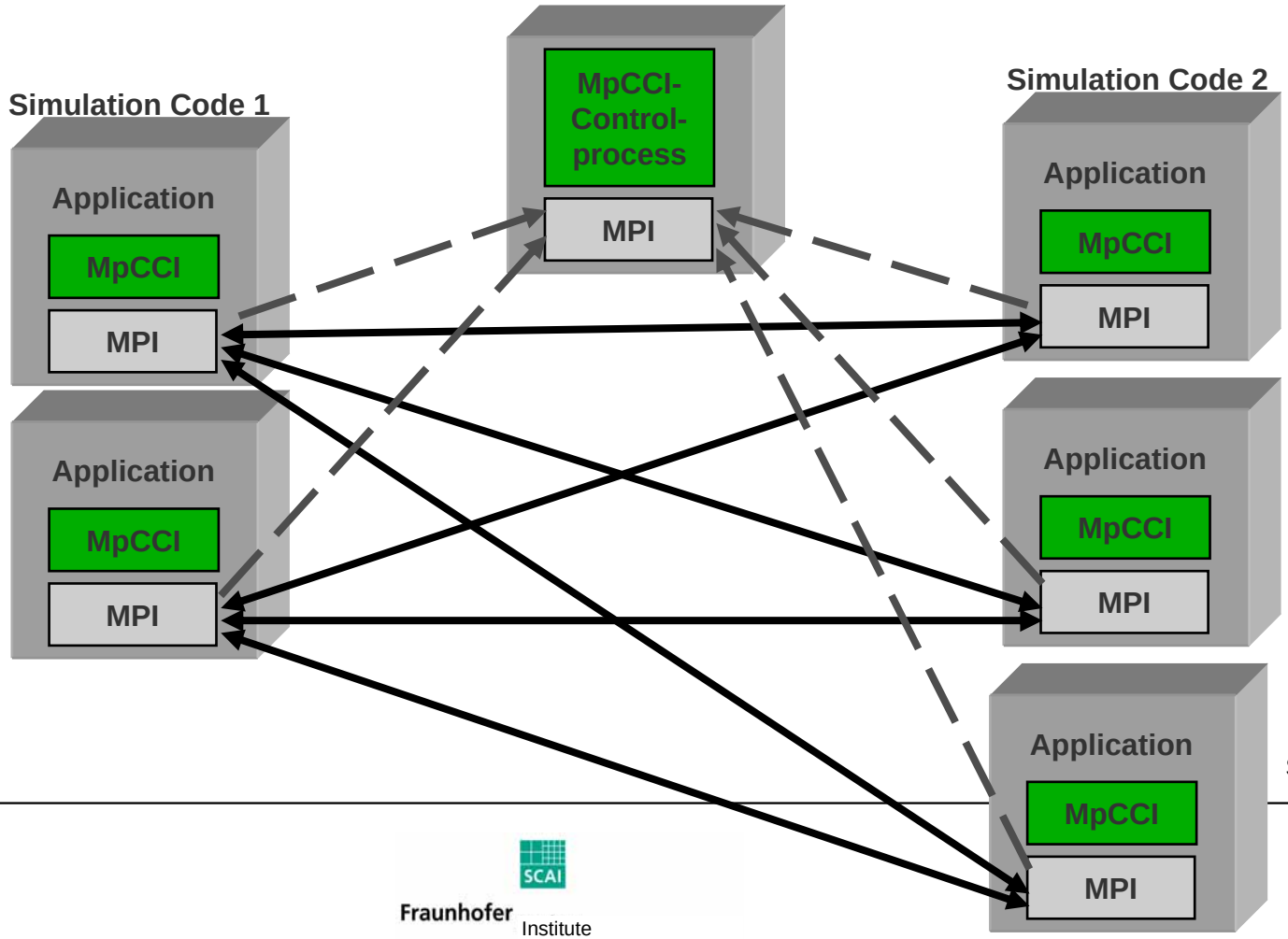
MpCCI Parallel Implementation



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Technical Requirements

MpCCI is fully implemented in C++

Procedure Calls in C and Fortran (F77, F90)

Instalation Requirements :

- C++ runtime environment
- MPI

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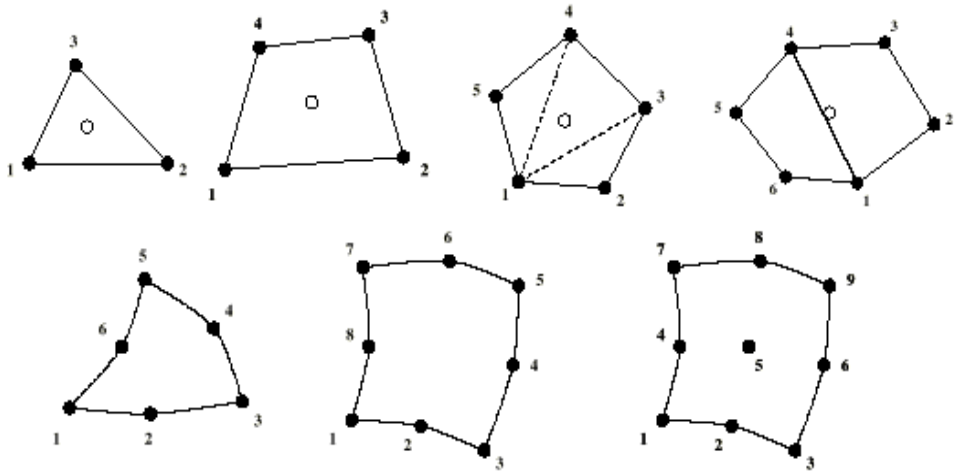
MpCCI 1.3 / Interpolation Survey

MpCCI 1.3

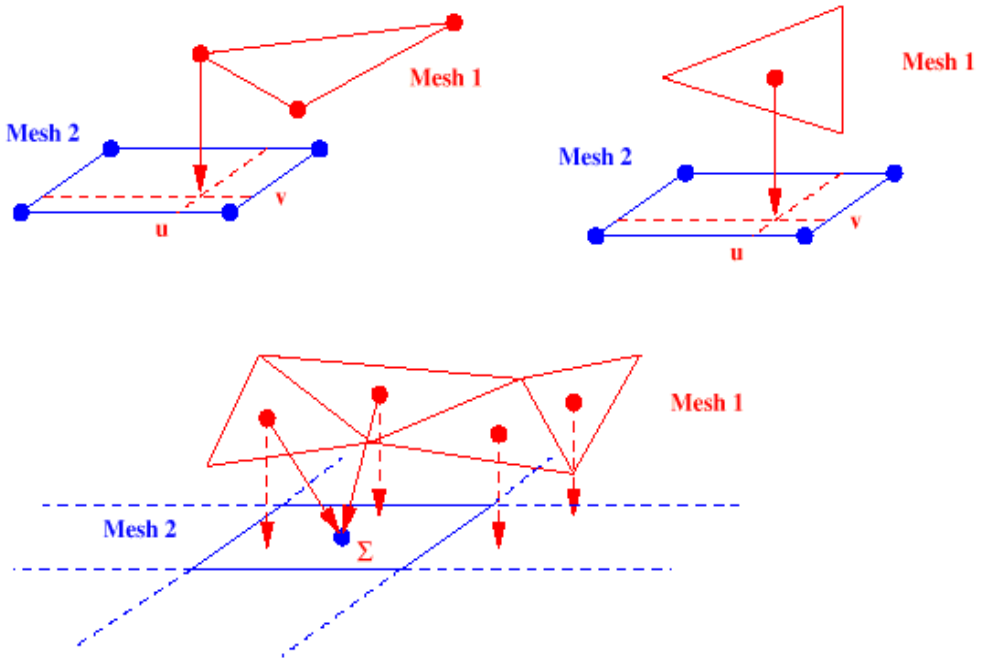
- Two dimensional coupling regions in the three dimensional space
- Element types with linear or quadratic interpolation



MpCCI 1.3 / Interpolation Survey

MpCCI 1.3

- Simple conservative mappings



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MpCCI 2.0 / Intersection computations in 2D

The method

- is based on the determination of the area of the overlap region of the elements of two grids.

The reason

- for implementing a new method for the conservative data transfer from elements on elements is, that the present mapping
  - ⋆ is based on the position of the midpoint of an element of one grid w.r.t. the elements of another grid and
  - ⋆ does not depend on areas/volumes of the elements.

  This may cause a lack of accuracy for the data transfer from a coarse to a fine grid.

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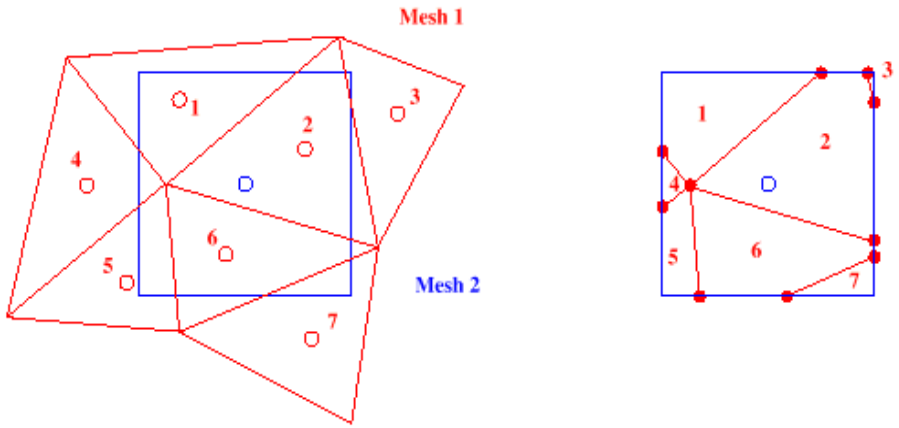
MpCCI 2.0 / Intersection computations in 2D

The status

- is, that an intersection method for surface coupling is currently implemented.



The aim

- is to offer intersection methods for all kind of coupling regions which are supported by MpCCI.

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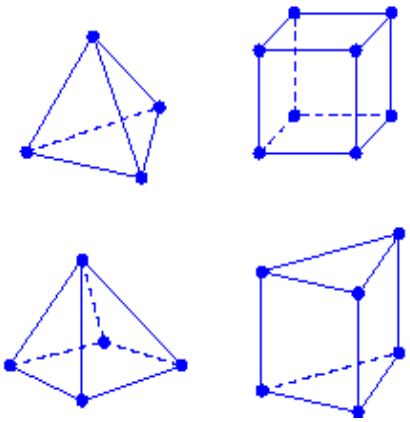
MpCCI 2.0 / Volume Interpolation

Volume elements

- Three dimensional coupling region
- Non-conservative interpolation: linear or lesser accuracy
- Simple mappings of conservative quantities
- Tetrahedron, hexahedron, prism and pyramid



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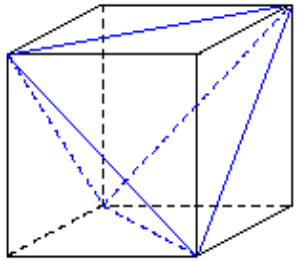
MpCCI 2.0 / Volume Interpolation

The neighborhood computation

- is based on the decomposition of the elements into tetrahedrons.



The reduction

- of the number of elements for the computation of the local coordinates is done with the help of a bucket search algorithm.

The matching criterion

- for the neighborhood search is based on the local coordinates of the nodes of one mesh w.r.t. the other mesh.

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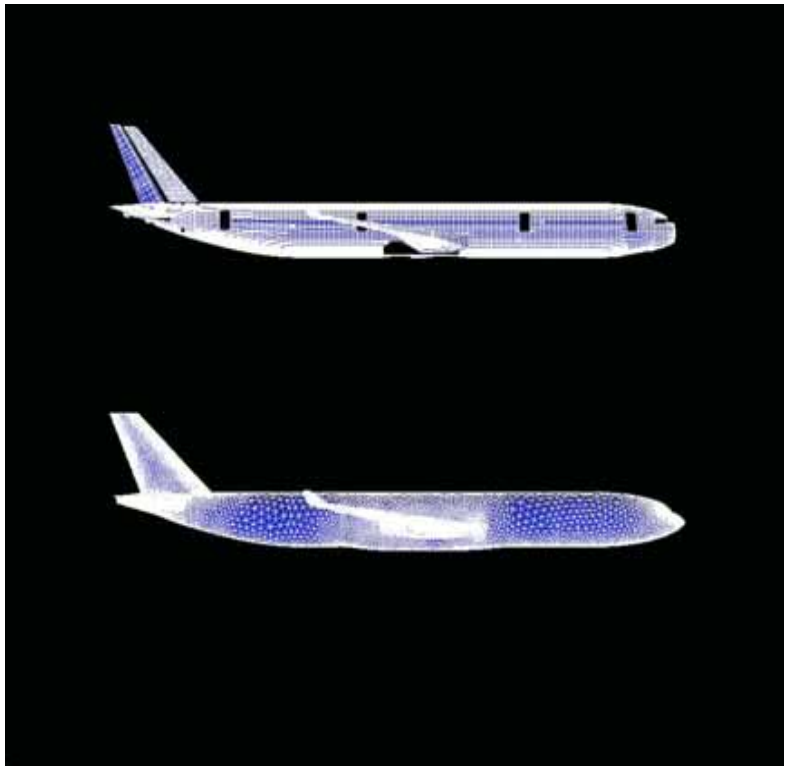
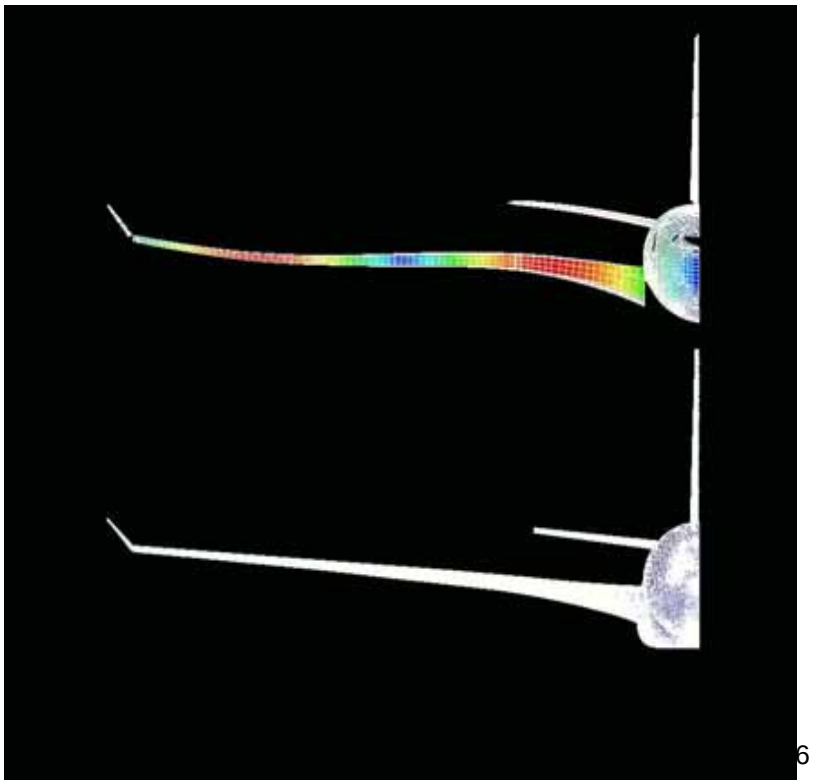
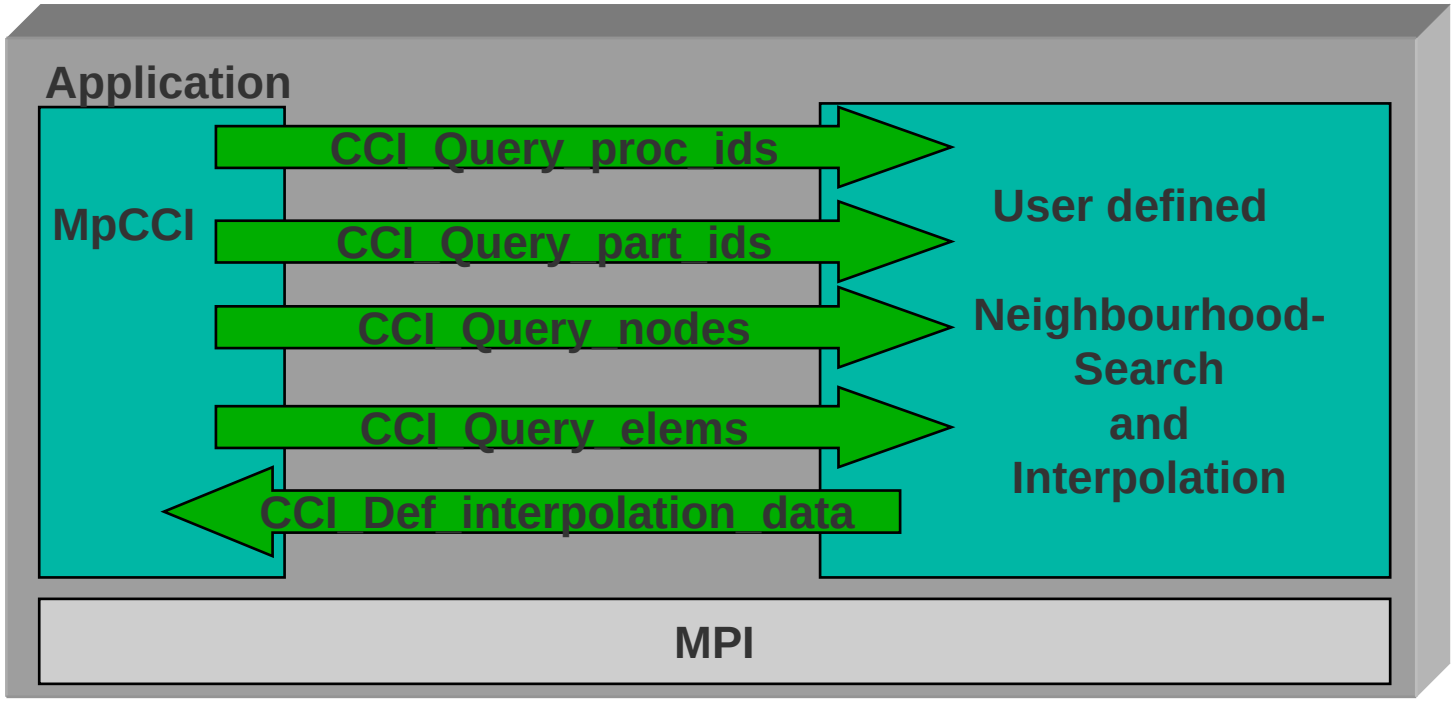
MpCCI 2.0 / Customising for Aeroelastics





MpCCI 2.0 Internal Interface for User Defined Interpolation



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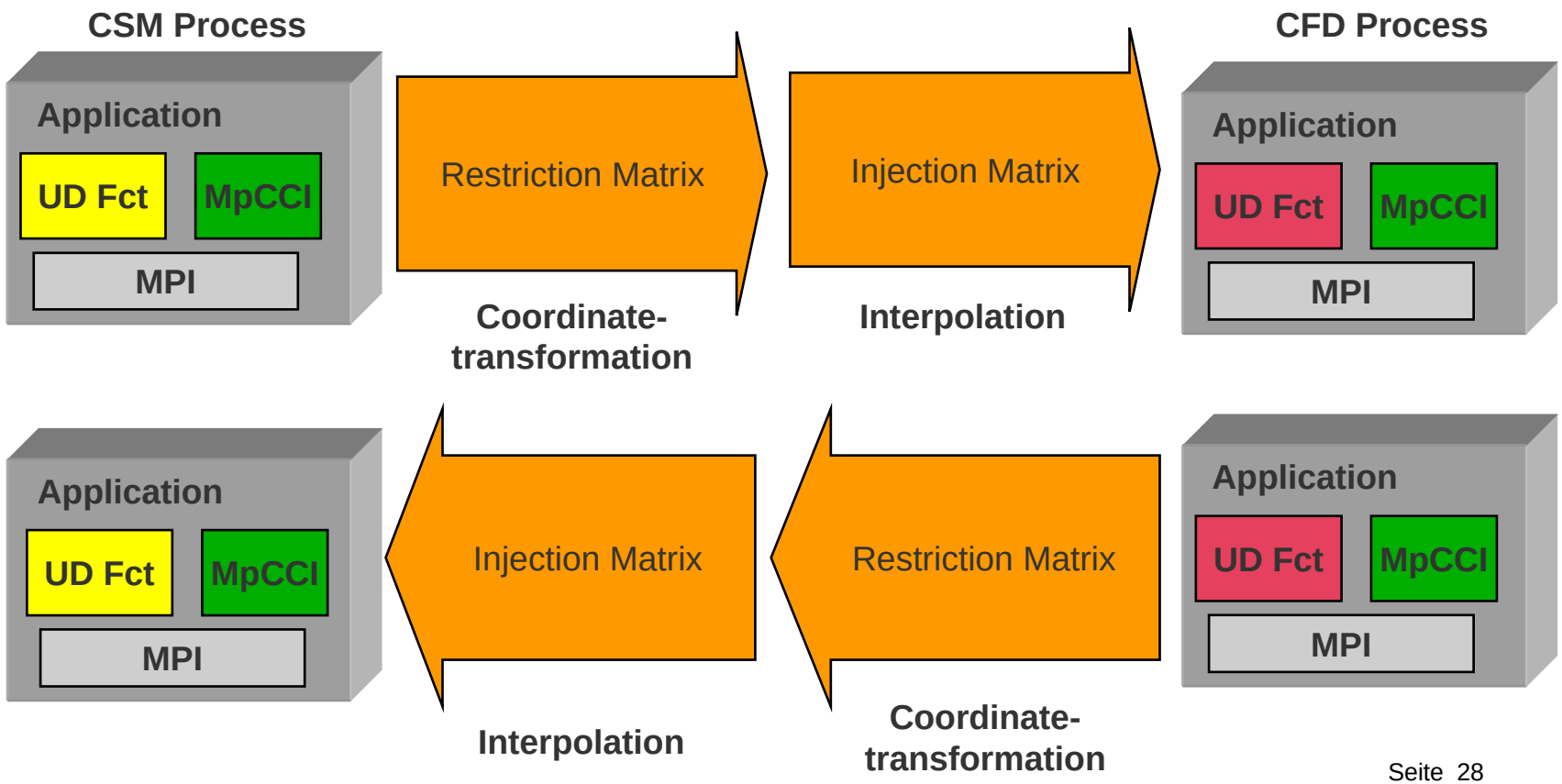

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MpCCI 2.0 / Extensions for Radial Basis Functions

Thin Plate Spline Funktion

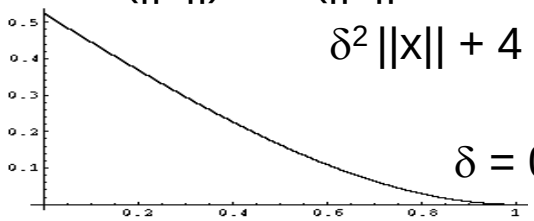
$\Phi(||x||) = ||x||^2 \log ||x||$

Volume Spline Funktion

$\Phi(||x||) = ||x||$

Euclid's Hat Funktion

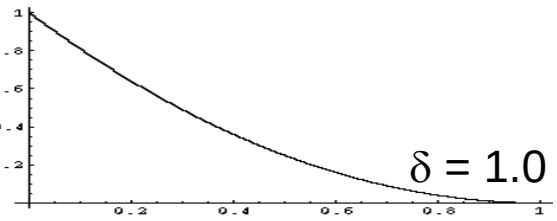
$\Phi(||x||) = \pi\ (||x||^3 / 12 - \delta^2\ ||x|| + 4\ \delta^3 / 3)$



$\delta = 0.5$

Wendland's Funktion 1

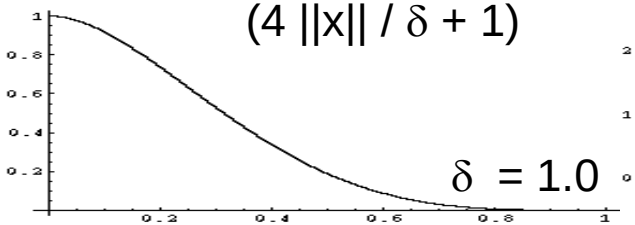
$\Phi(||x||) = (1 - ||x|| / \delta)^2$



$\delta = 1.0$

Wendland's Funktion 2

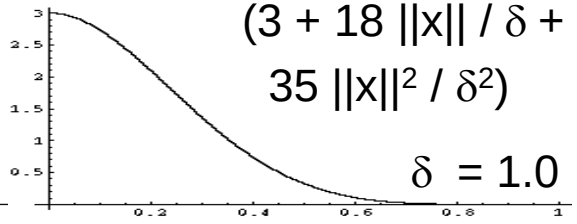
$\Phi(||x||) = (1 - ||x|| / \delta)^4\ (4\ ||x|| / \delta + 1)$



$\delta = 1.0$

Wendland's Funktion 3

$\Phi(||x||) = (1 - ||x|| / \delta)^6\ (3 + 18\ ||x|| / \delta + 35\ ||x||^2 / \delta^2)$



$\delta = 1.0$

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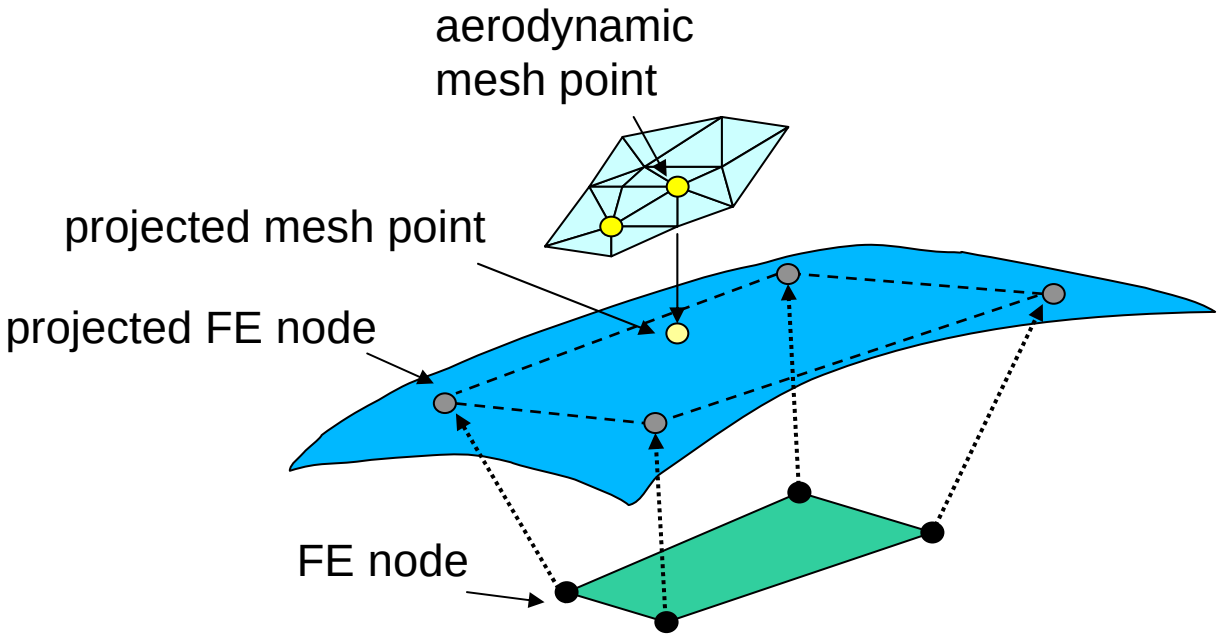
MpCCI 2.0 / Extensions for NURBs based Neutral Interface



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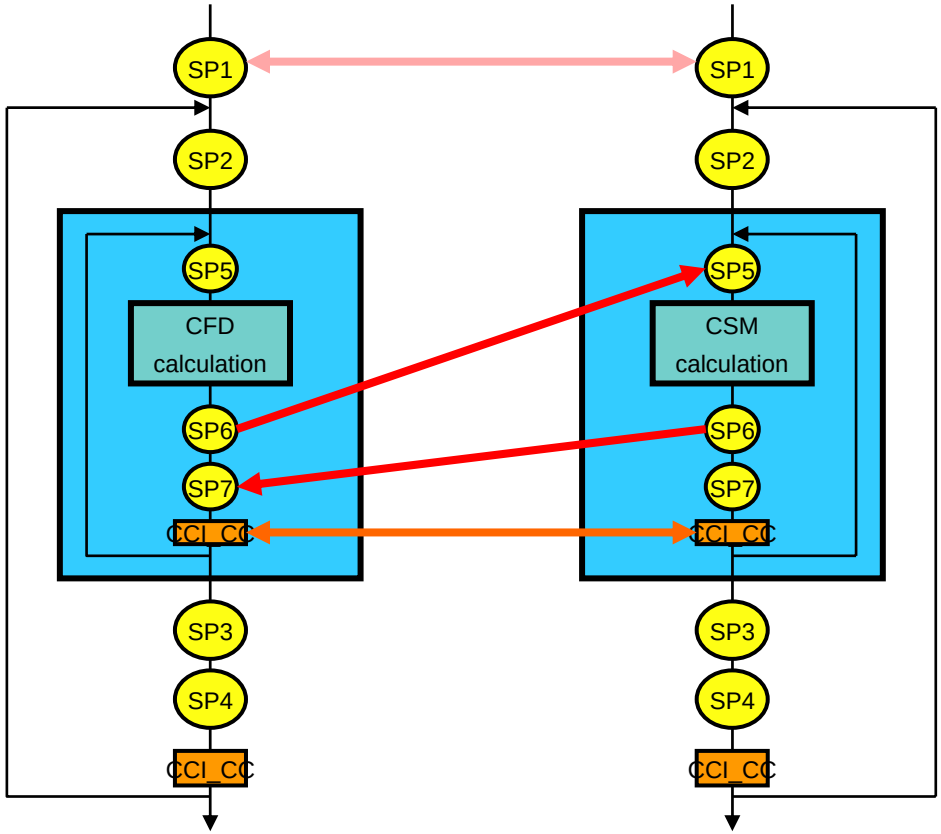
MpCCI Synchpoints



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MpCCI Synchpoints

idea

- Make the coupling configurable
  → well-suited for commercial codes
- Syncpoints are central points in the coupling algorithm where communication with the remote code makes sense
- A step towards general coupling capability of a code (independent of a specific remote code)

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MpCCI Synchpoints

handling

- The end-user puts the syncpoints of the individual codes together
- The end-user defines in the MpCCI input file, what quantities are to be exchanged at what point
- one syncpoint of code A can be mapped to several syncpoints of code B

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MpCCI Synchpoints

```
coupling

  ...

  syncpt myCodeA( 5 )   : send( force         / "leftBorder",
                                heat          / "rightBorder" ),
                          recv( displacements / "upperBorder",
                                timestep      / "global" );

  ...

  match_syncpt   myCodeA(  5,  6,  7,   - )
               = myCodeB( 21, 21,  -,  22 )
               = myCodeC( 41,  -, 41,  42 );

end
```


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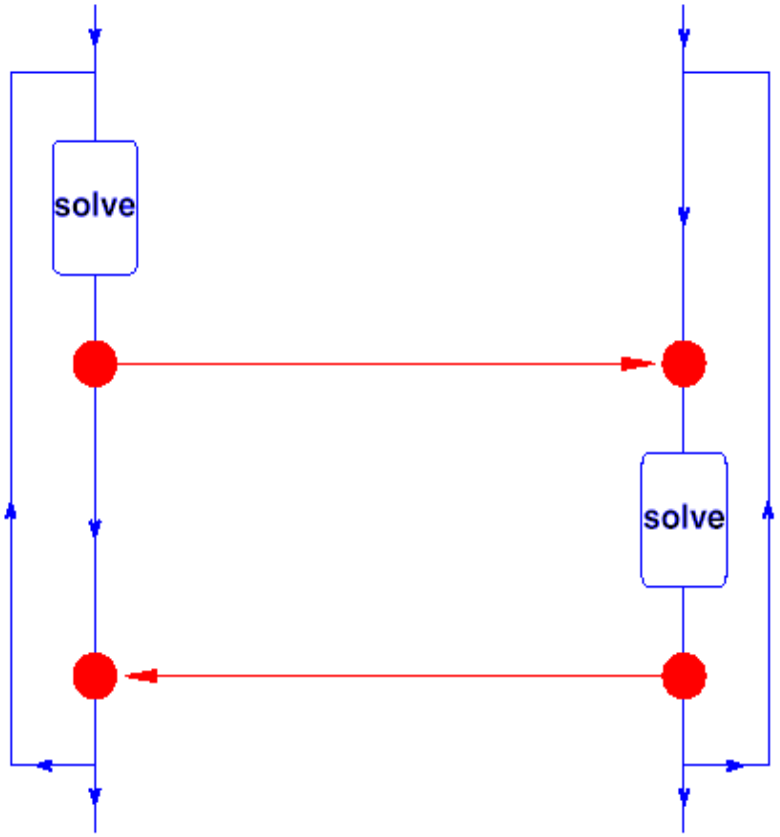
MpCCI Synchpoints

Gauss-Seidel coupling algorithm



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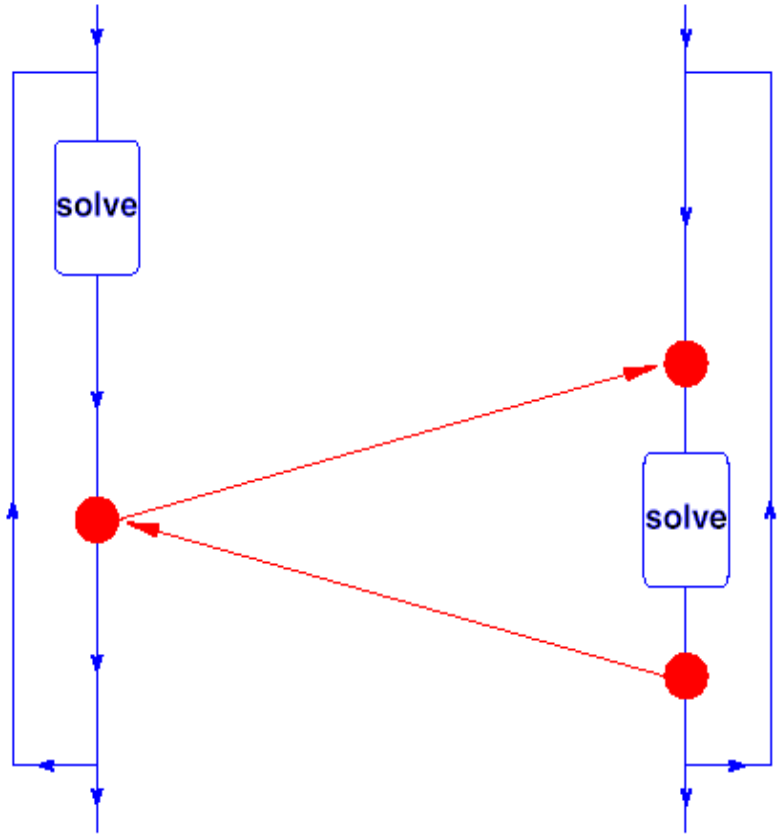
MpCCI Synchpoints

Gauss-Seidel coupling algorithm

map one syncpoint to two



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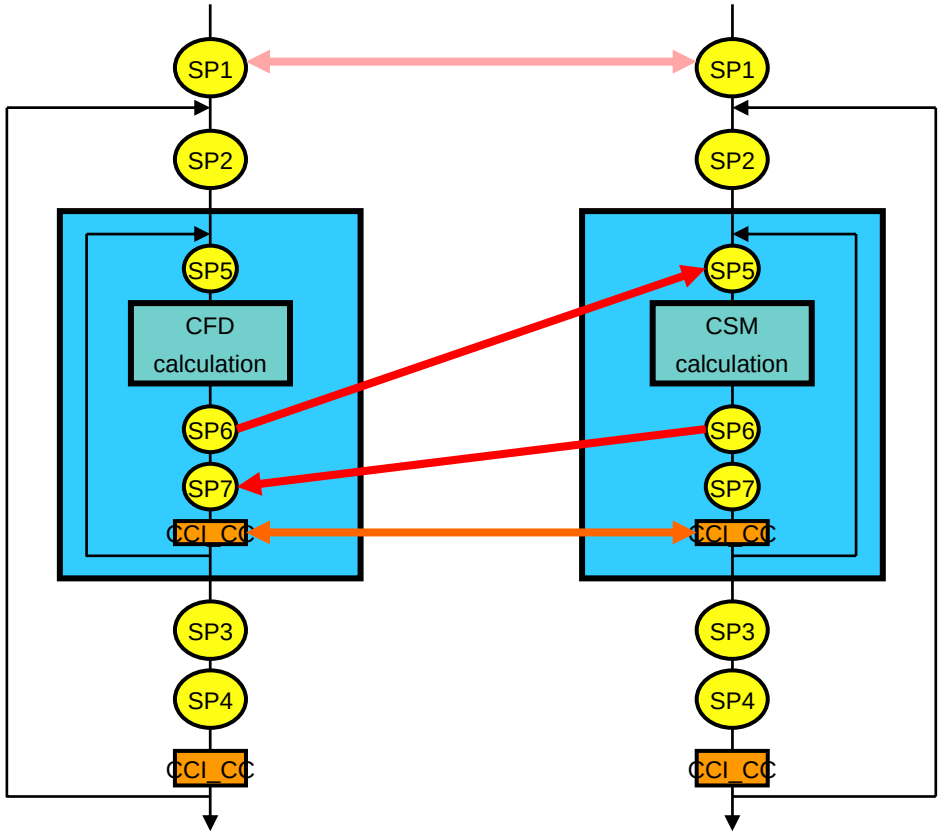
MpCCI Synchpoints



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MpCCI Version 1.3 (April2002)

major new features

- extended syncronization point concept
- remeshing
- GUI for setup
- revised tracefile format for MpCCI-Visualizer
- 2D coupling along a line
- licence key (date, system id)
- many minor improvements

environment

- MPICH 1.2.3

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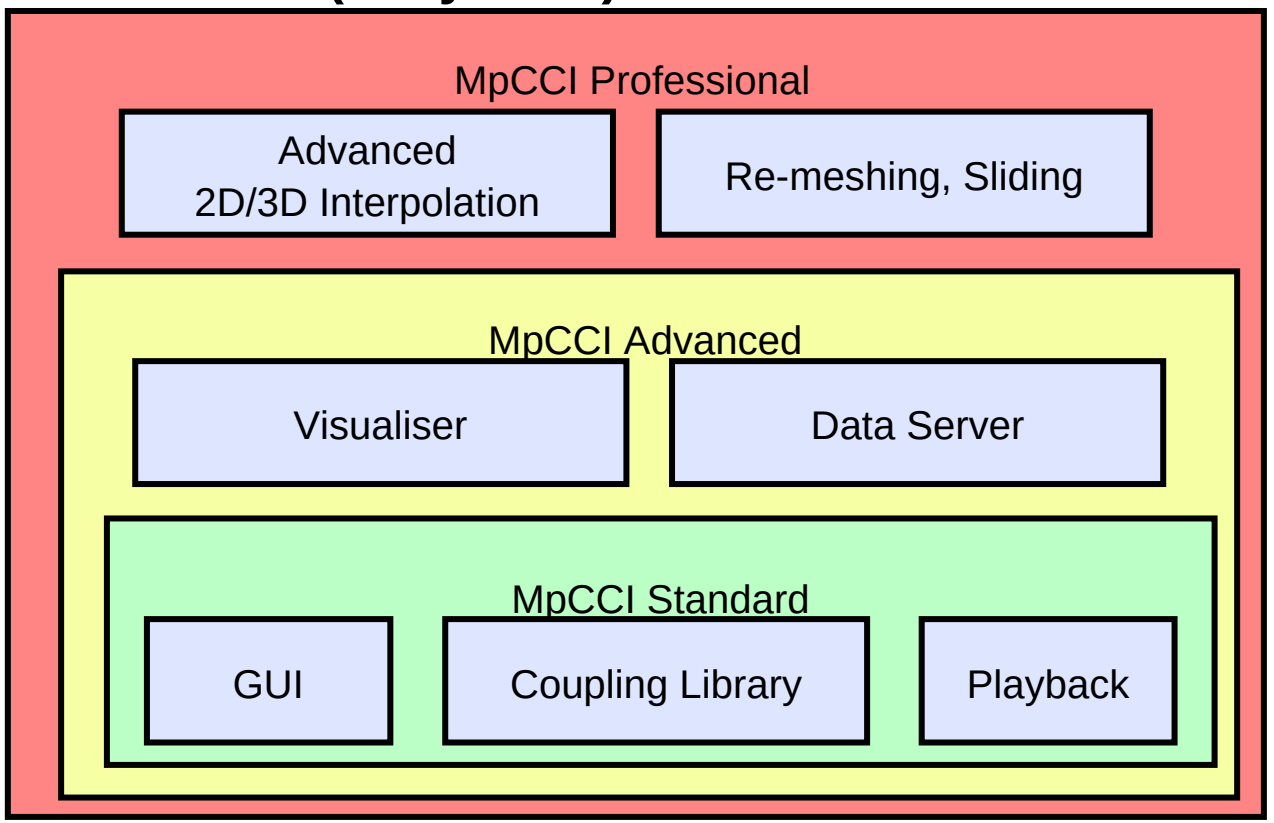
MpCCI 2.0 Levels (early 2003)



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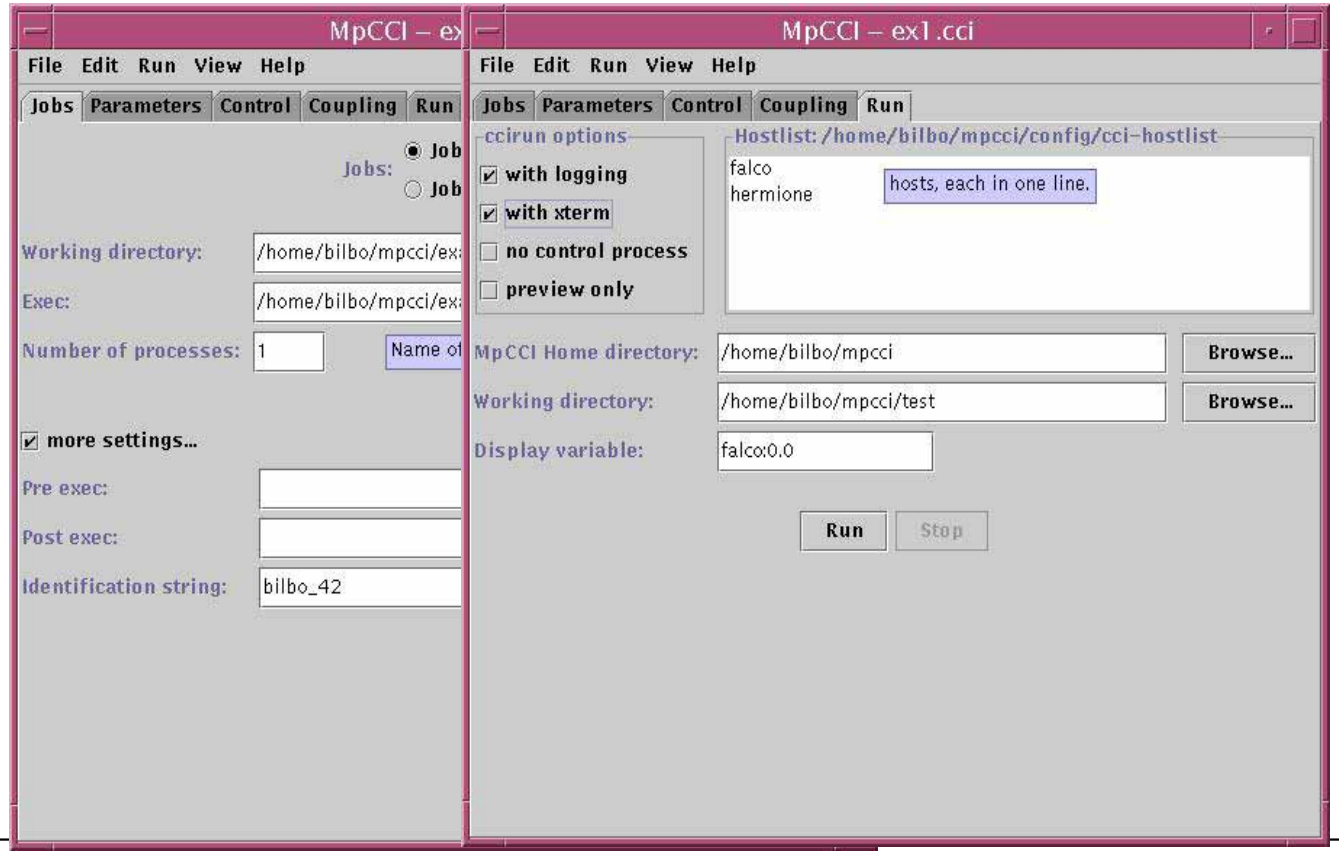
MpCCI 2.0 Standard / GUI



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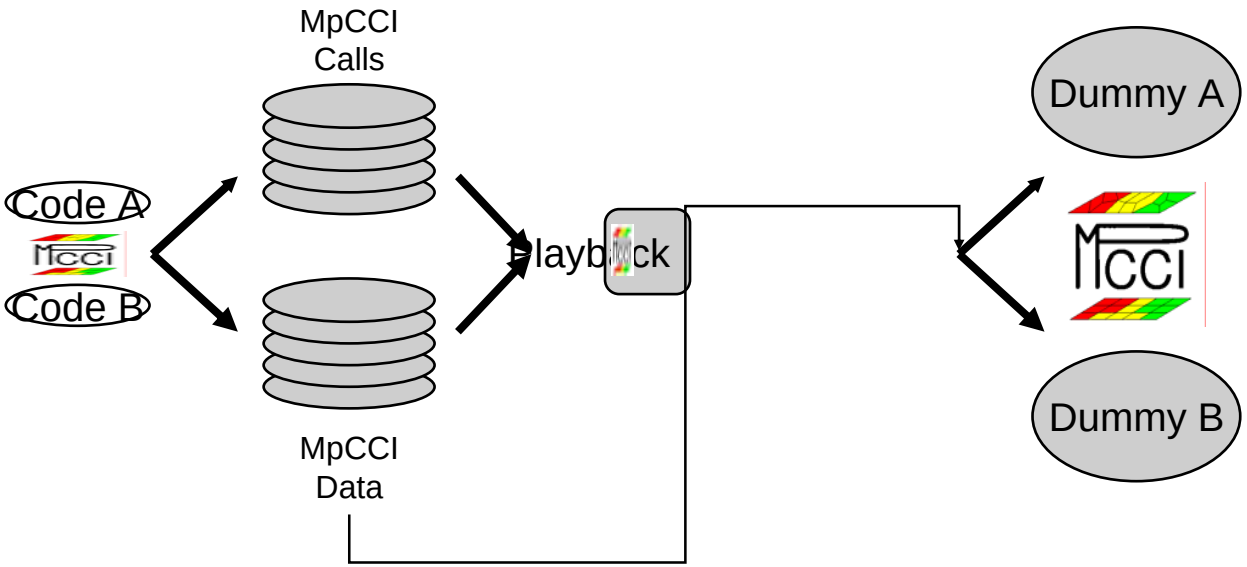
MpCCI 2.0 Standard / Playback



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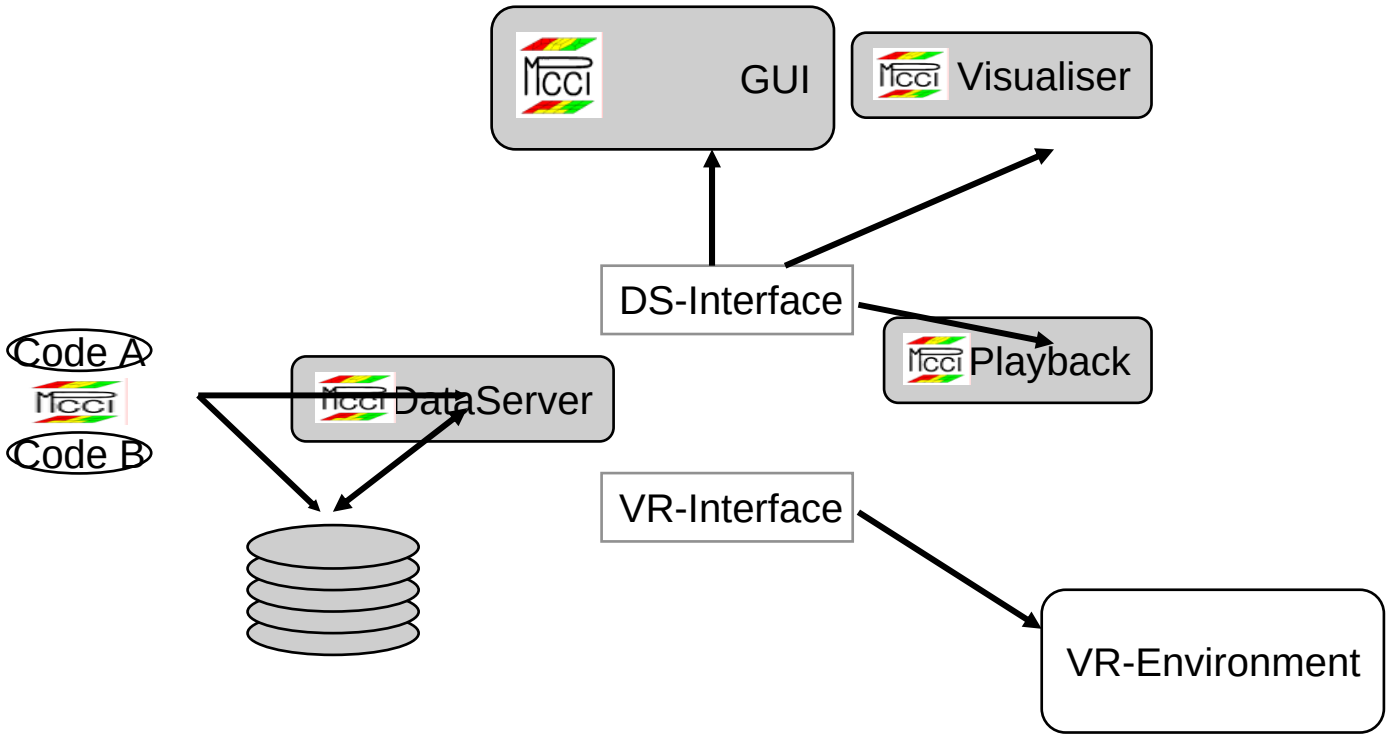
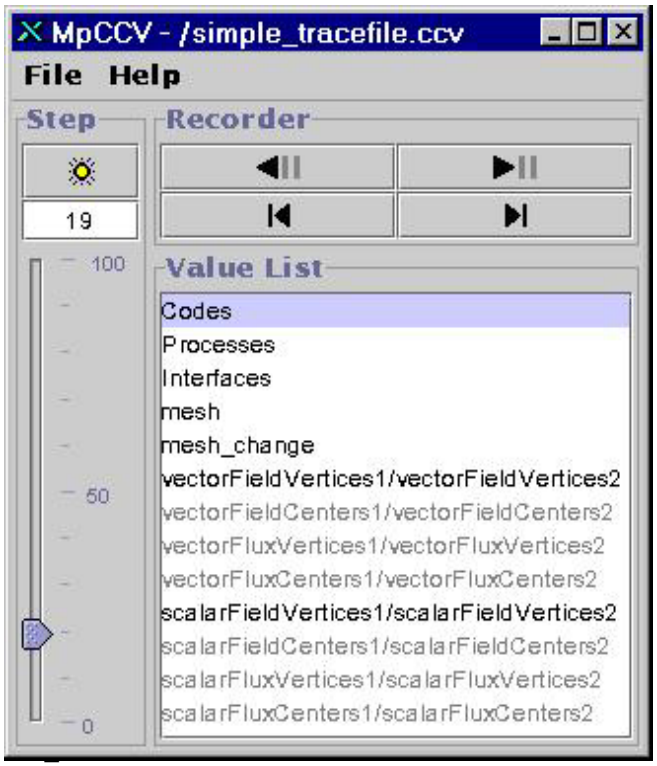
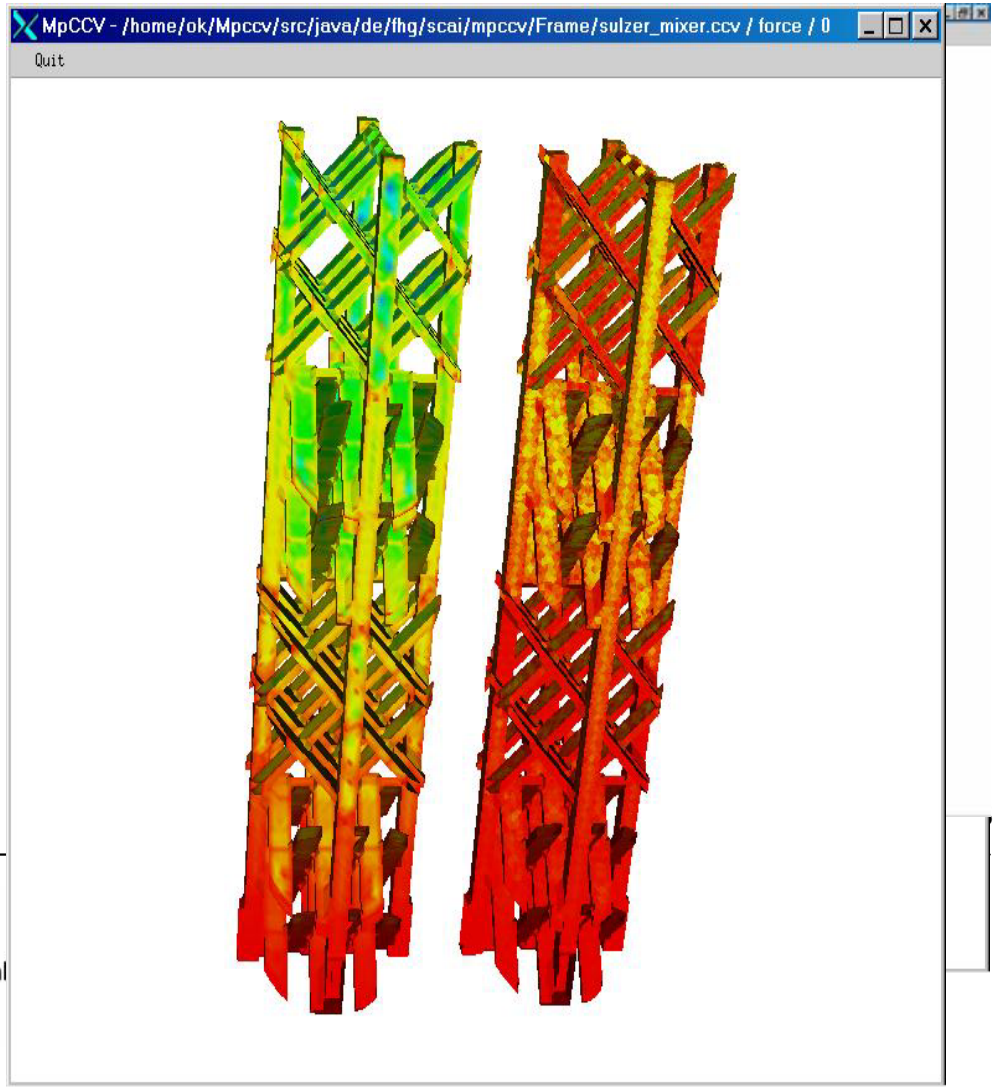
MpCCI 2.0 Advanced / Architecture



MpCCI 2.0 Advanced / Visualiser





MpCCI 2.0 Professional

- Numerical Extensions
- Sophisticated Support for 3D-Coupling Areas
- New Interpolation Schemes
  - 3D Linear and Bi-Linear Interpolation
  - 2D and 3D Intersection of Elements
- Fast Remeshing Support
- Coordinate Transformation

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Portability

SUN	Solaris	CC/gcc	MPICH/MetaMPI
SGI	IRIX	CC/gcc	MPICH/SGI-MPI
IBM	AIX	xlC/gcc	IBM-MPI/STAMPI
HP	HP-UX	aCC/gcc	MPICH
Cray T3E/T94	Unicos	CC/KCC	Cray-MPI/MetaMPI
Hitachi SR8000	HI-UX	KCC	Hitachi-MPI
NEC SX4	SUPER-UX	c++	NEC-MPI/STAMPI
PC	Linux	gcc/g77/pgf90/lf95	MPICH/SCAMPI
PC	Windows	VisualC/BorlandC	WMPI/MPICHNT
Compaq			
Fujitsu			

Overview

- Fraunhofer Institute for Algorithms and Scientific Computing (SCAI)
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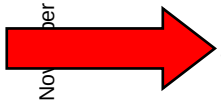
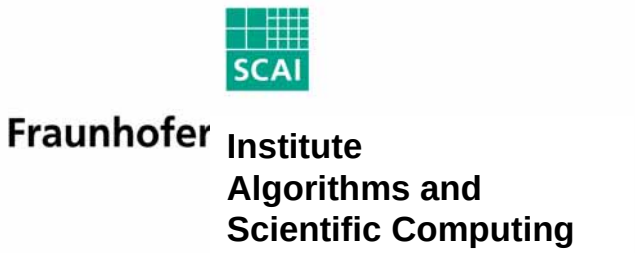
- MpCCI - and Commercial Simulation Codes
- MpCCI - Coupled Applications
- Conclusion



Cooperations with Software Vendors

- AEA Technology: ***CFX-5***
- ANSYS: ***ANSYS*** (***FLOTRAN)***
- CD-adapco: ***STAR-CD***
- Intes: ***PERMAS***
- MSC.Software: ***MSC.Marc,*** ***MSC.Nastran***
- Fluent: ***Fluent***
- AVL: ***Fire, Swift, Boost, …***
- ESI: ***PAM-Flow, PAM-Crash***
- EXA: ***PowerFLOW***
- HKS: ***Abaqus***
- ***CFDRC, ITASCA, MAGMA, Access/Cast***

MpCCI – Commercial Distribution



- Owner of all Rights
- Further Development of MpCCI and Coupled Applications
- Creation of new Multidisciplinary Tools

- Exclusive Distribution Partner
- Support and Services around

- Sub-Distribution Licence under Negotations

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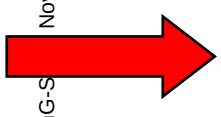
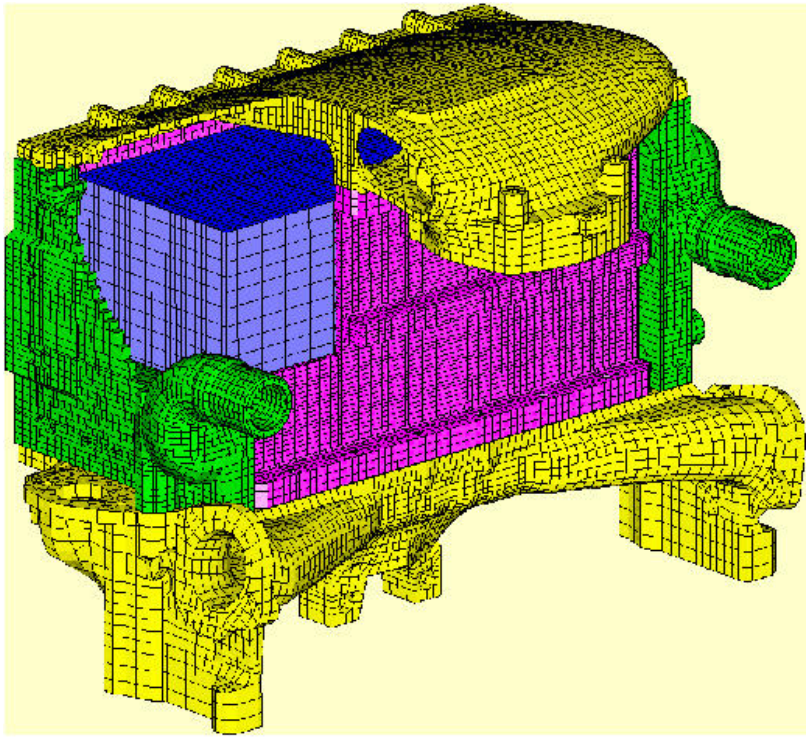


Fluid Dynamics and Thermal Analysis



INTES

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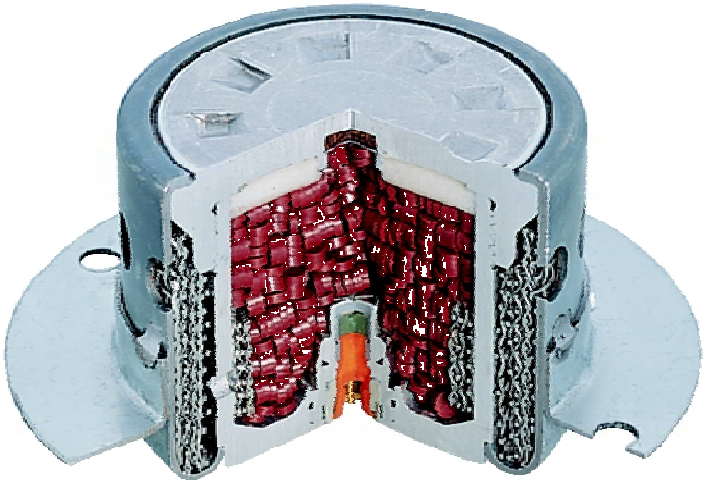
Gas Generator (TRW Airbag Systems)



AEA TECHNOLOGY
ENGINEERING SOFTWARE

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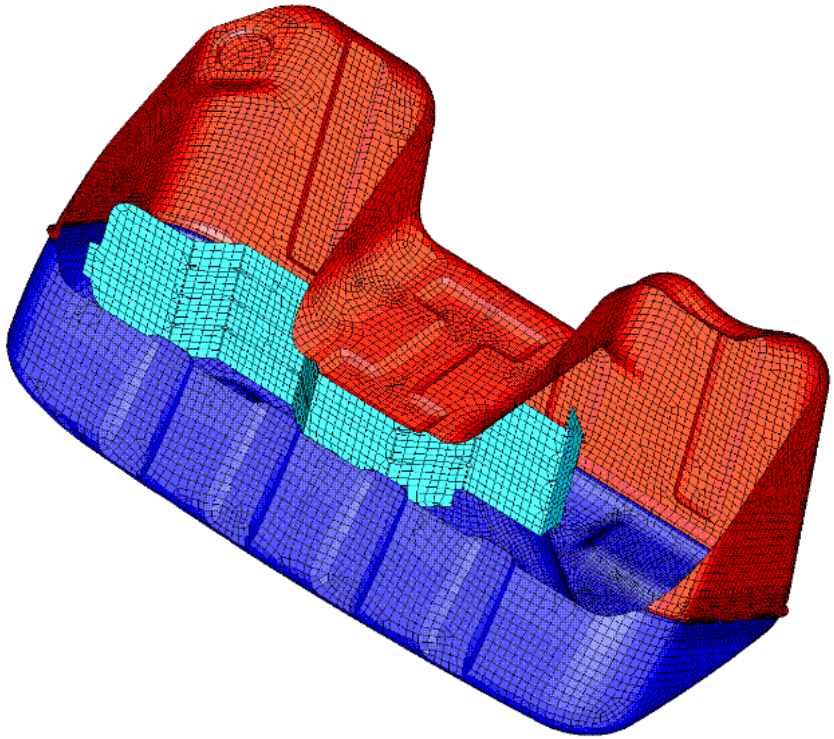
Sloshing in Tanks (DaimlerChrysler)



CD adapco Group

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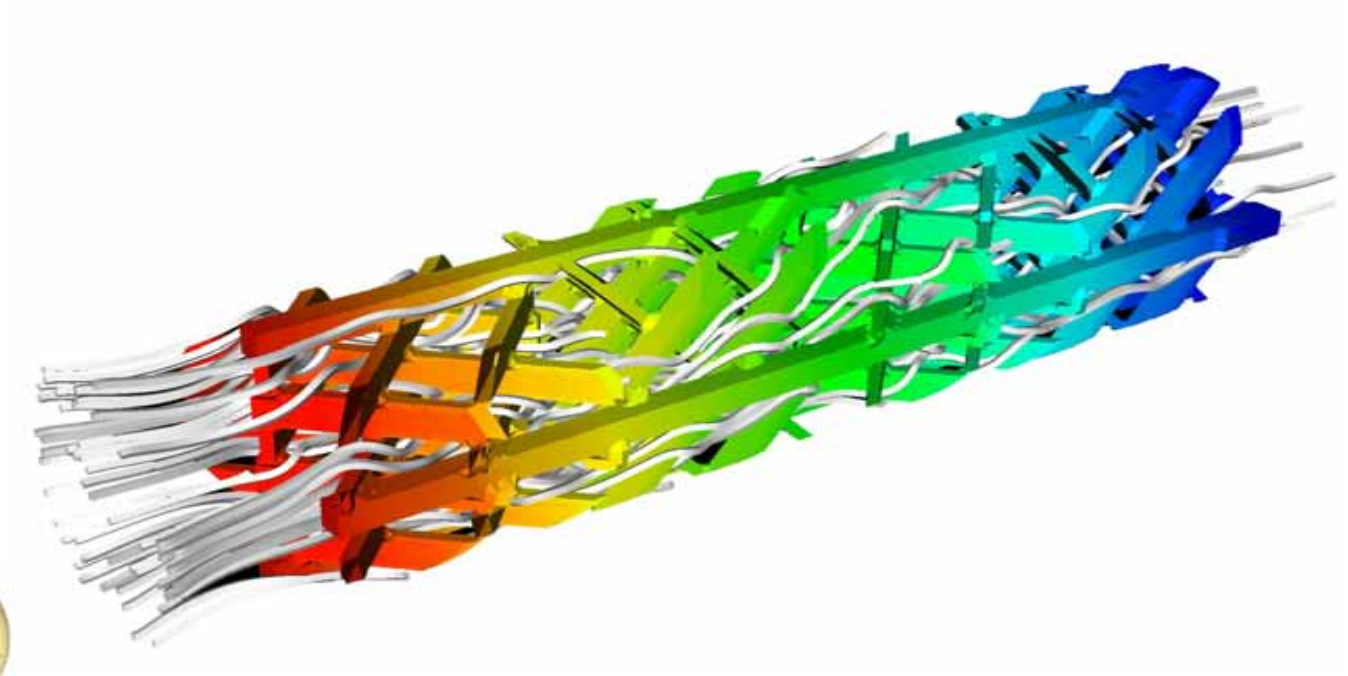
Polymer Mixer(Sulzer Innotec)



CD adapco Group

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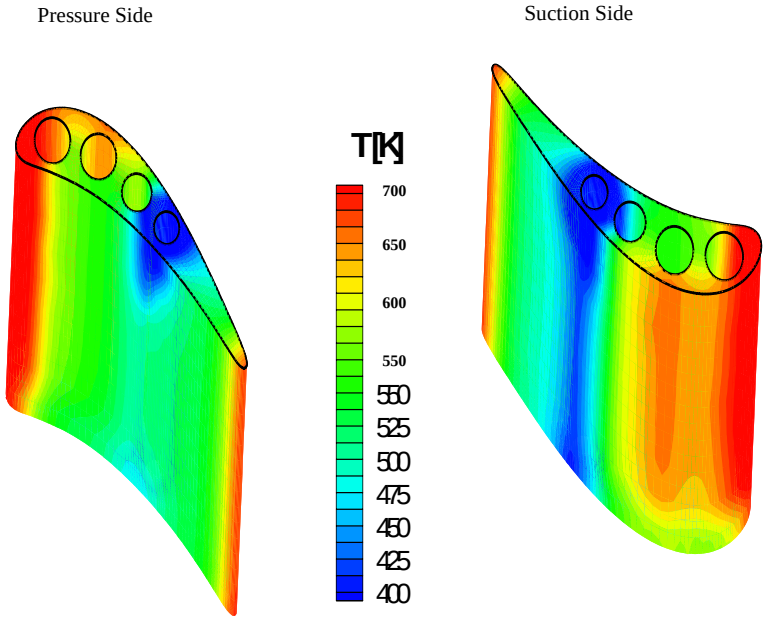
Heat Transfer in Turbines



DLR

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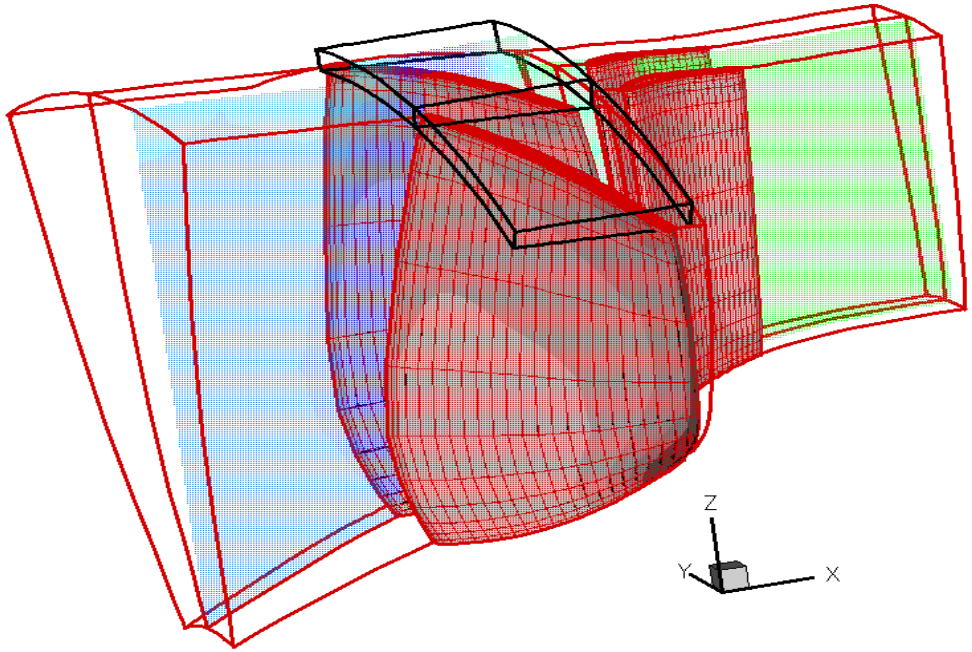
Fluid-Fluid-Coupling in Turbines (MTU Turbo Engines)



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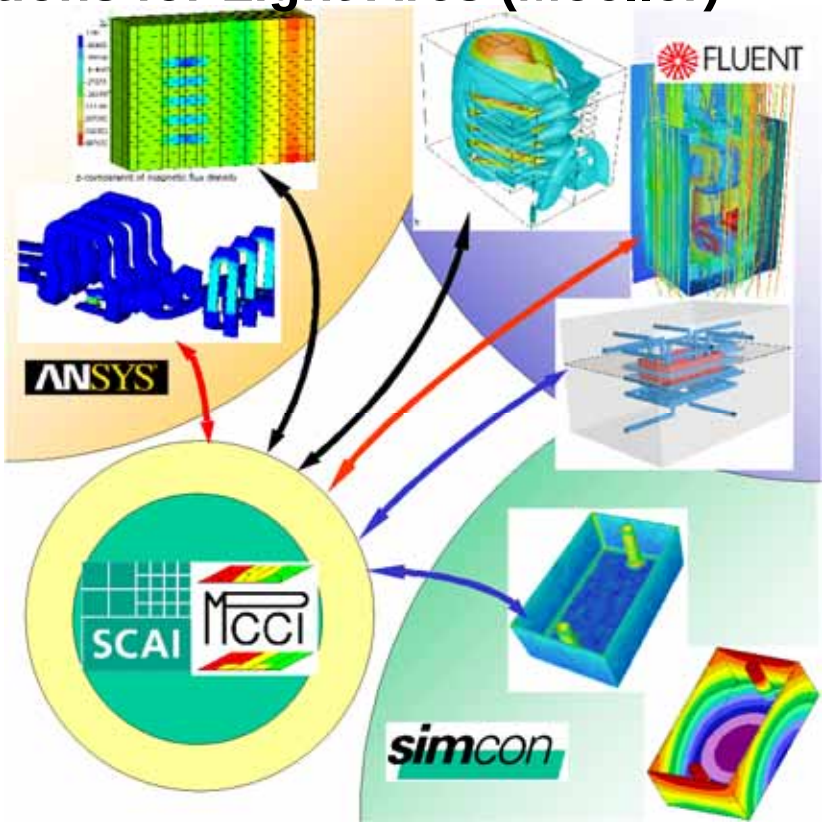
Coupled Simulations for Light Arcs (Moeller)



MOELLER

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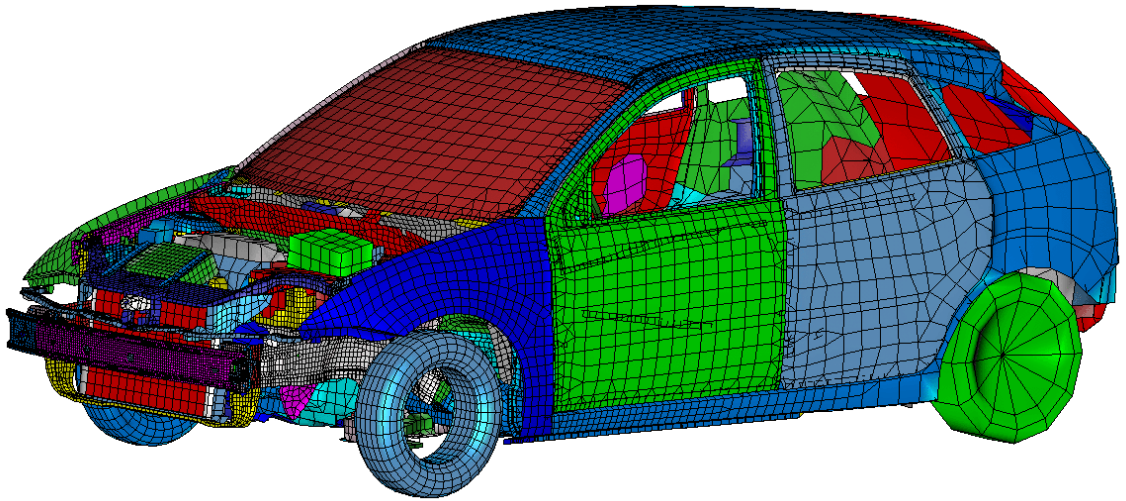
Coupled Stamping-Crash-Simulation (Ford)



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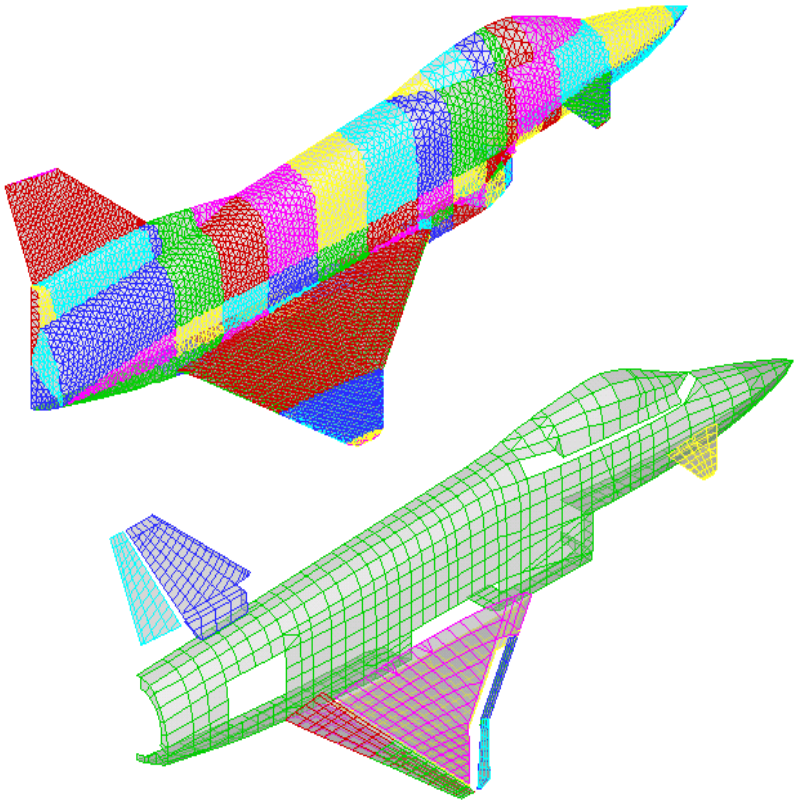
Aeroelastic Simulations (EADS)



EADS

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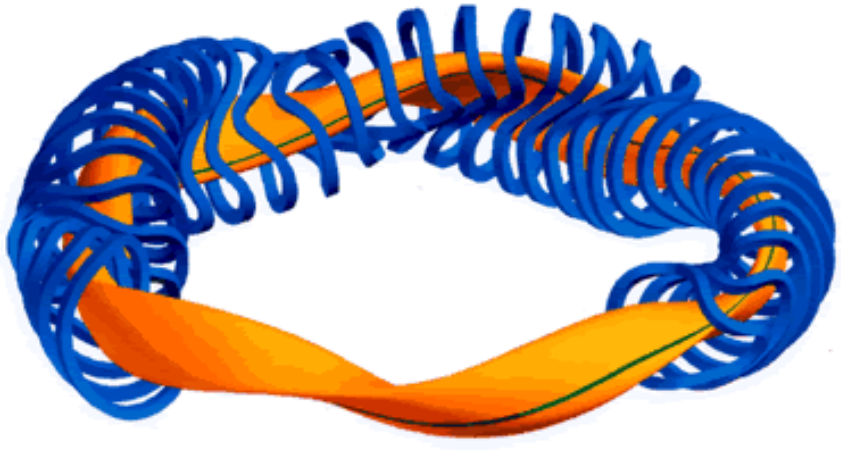
Electrodynamic-Structure-Coupling (University of Rostock)



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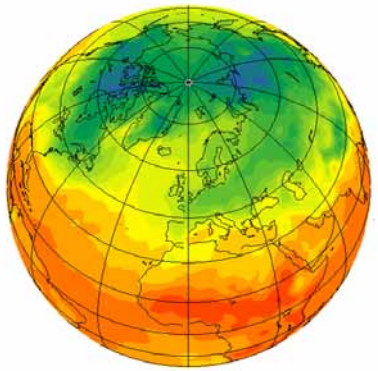
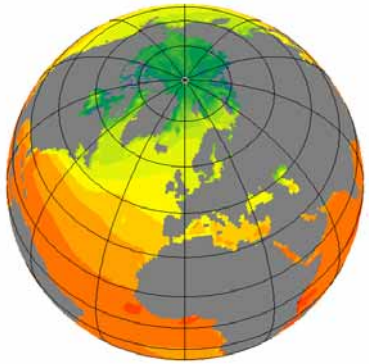
Fraunhofer Institute Algorithms and Scientific computing

Coupled Climate Models





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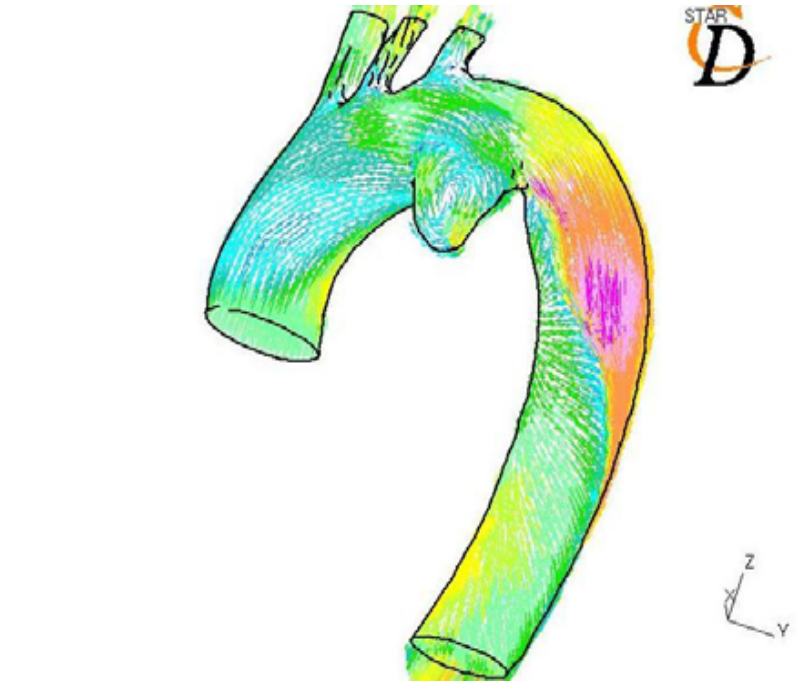
Simulation of Arterial Biomechanics (JAERI)



JAERI

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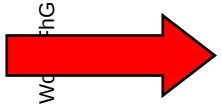

Conlusion

- MpCCI is an accepted industrial standard for code coupling
- MpCCI is not limited to any application areas
- MpCCI provides solution for communication, spatial interpolation and coupling control
- MpCCI provides an increasing set of additional tools .

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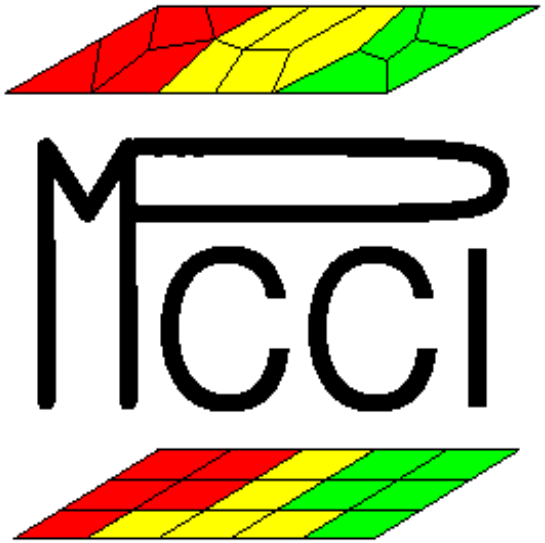
Outlook

There are upcoming new application types

- Coupling of simulation and experimental data
- Coupling of mesh-based and mesh-less codes (e.g. CSM and MBS)
- Increasing requirements for mapping and geometry processing facilities



http://www.mpcci.org
http://www.scai.fhg.de

Thank You very much for Your Audience!!

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