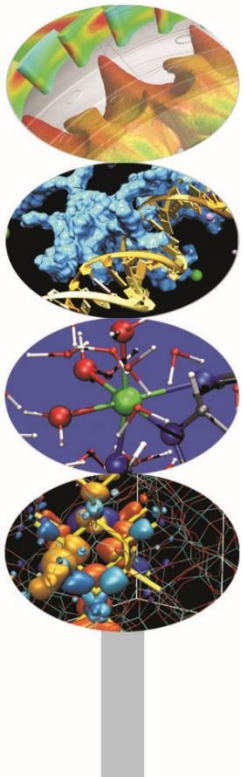
CINECA SCAI
SuperComputing Applications and Innovation

Cineca TRAINING High Performance Computing 2016

HPC enabling of OpenFOAM® for CFD applications

HPC-based simulation tool for motorcycle helmets design and development



07 April 2016, Casalecchio di Reno, BOLOGNA

Matteo Longoni
matteo.longoni@moxoff.com
Moxoff Srl

MOX-OFF MATHEMATICS FOR INNOVATION

PRACE

CINECA

About us

MOX-OFF
MATHEMATICS FOR INNOVATION

Ottavio CRIVARO
MOXOFF CEO

Alfio QUARTERONI
EPFL CMCS Director

Piercesare SECCHI
PoliMI Math Department Director

Luca FORMAGGIA
PoliMI MOX Director

Management team

Engineers & Data scientists

POLITECNICO MILANO

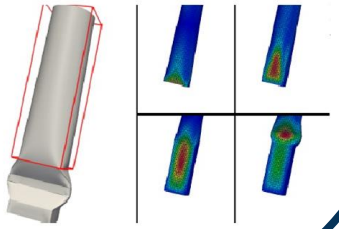
MOX

Spinoff of Politecnico di Milano MOX Lab

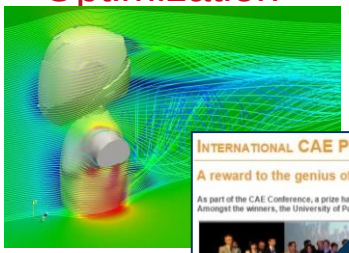
- Technology & Know-how transfer
- Innovative product development
- Solutions & software provider

Our skills

Modelling Intelligence



Simulation & Optimization



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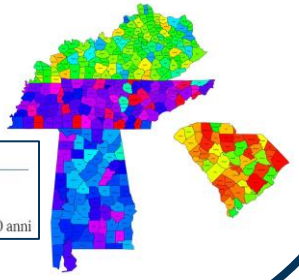
Data Intelligence

Software Engineering



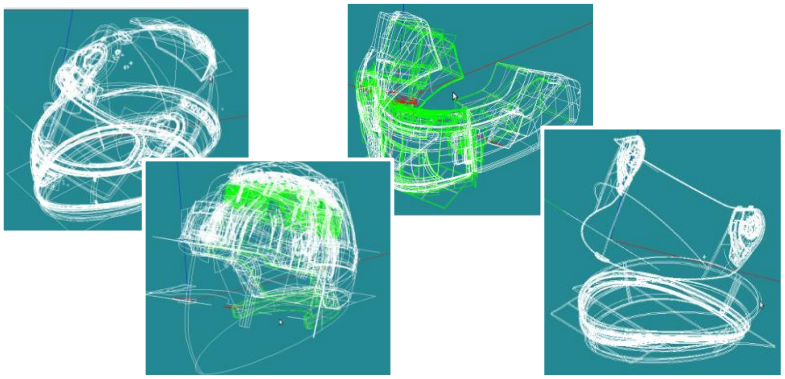
Where's math?

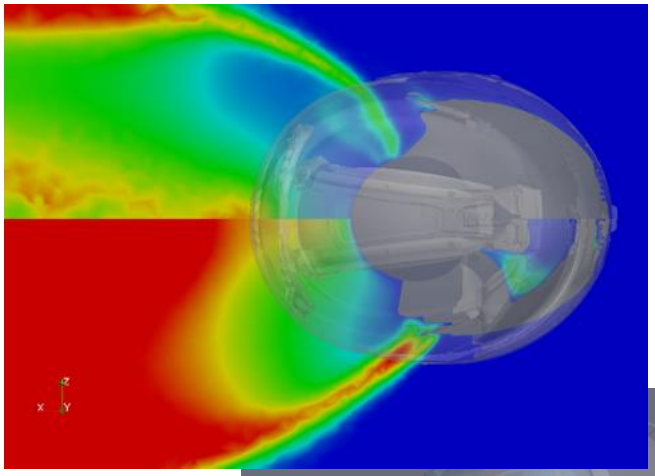
DeLonghi
Sealed Air
Re-imagine
POLTI
NATURAL HOME FEELING
FIPAV
Federazione
Italiana
Pallavolo
POLIHUB
ZAKSA
Whirlpool
SIEMENS
saipem
PROTECTS
Tetra Pak
WHAT'S GOOD
Eni
NOLAN
EDISON
ZUCCHETTI
CENTRO SISTEMI
pixartprinting
saes
ETC
INGV
cavanna
Packaging Group
energeya
Enixs
DELCONCA
Il Pavimento in Ceramica
Filippi
RADICI
GROUP
aiutare i bambini
IWT
TECNIPLAST
STARA
GLASS
Real service
desmet ballestra
BLM GROUP
TECNIPLAST
IMS
beintoo
Terre des hommes
Proteggiamo i bambini insieme
VOLLEY
1984
FINNISH VOLLEYBALL
ASSOCIATION
PALLAVOLO
LVGANO

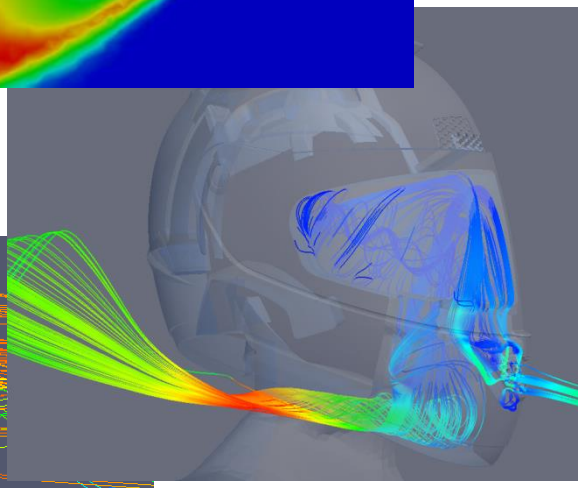
Where's math?

OpenFOAM® for Aerodynamics

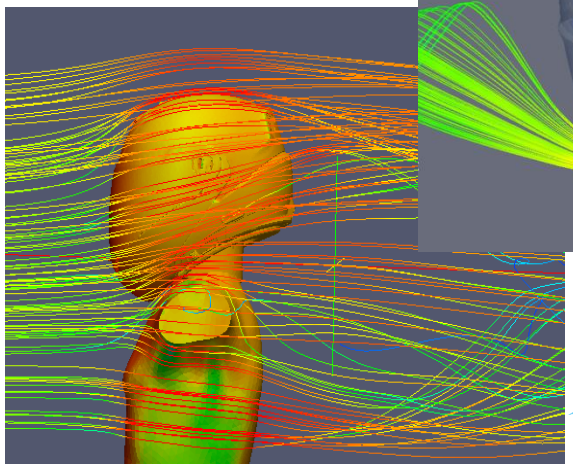
- Handling of real complex geometries (full detail production drawings)





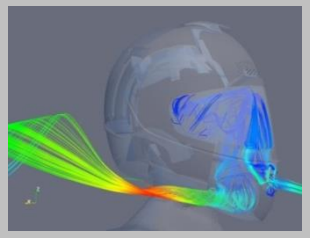


- Mesh criteria definition and **conformity checks** to ensure quality
- Dedicated **simulation worflow** and settings
- The results are input for thermofluid dynamics and vibroacoustics simulations



Multiphysics workflow coupling

AERODYNAMICS wf



3D simulations output to:

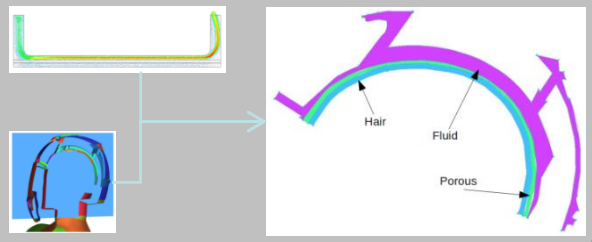
- Real geometry
- Simulation results

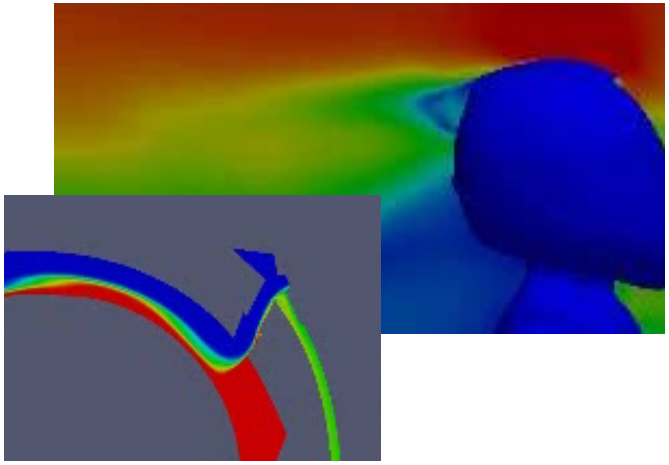
Vibro ACOUSTICS wf

Coupling through aerodynamic **pressure**

THERMO-FLUIDO wf

Coupling through ventilation 3D **inflow/outflow**

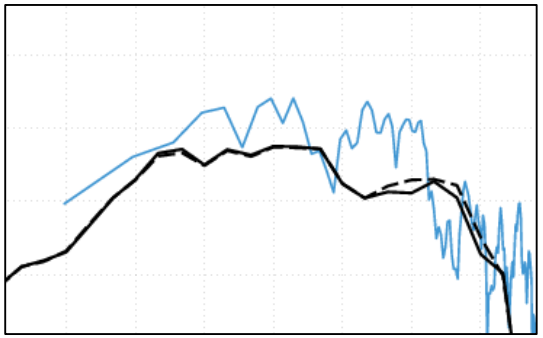




- Multiphysics coupling
- Automatic WF interface
- Customer oriented
- User friendly

A "mathematically" comfortable helmet

Vibroacoustic model for noise propagation



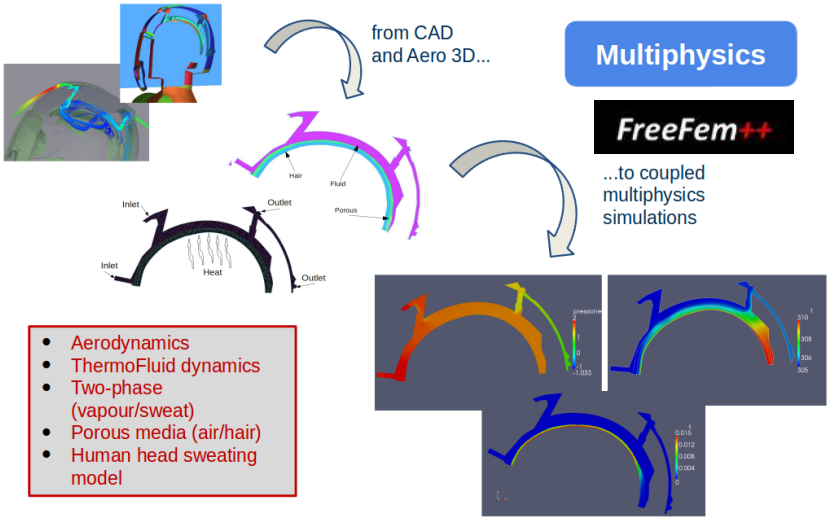
SPEED

P.F.Antonietti, I.Mazzieri, A.Quarteroni,F.Rapetti: Non-conforming high order approximation of the elastodynamics equation, CMAME, 2012

http://speed.mox.polimi.it/SPEED/Home.html

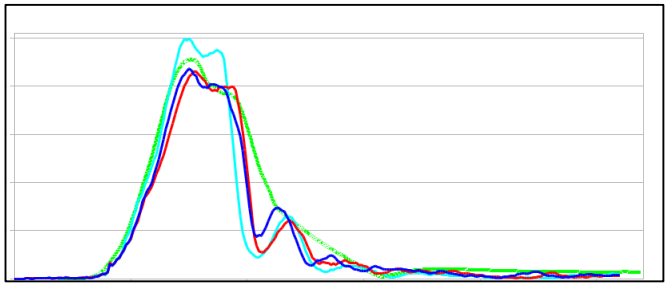
Projects carried out in collaboration with

Thermofluid dynamics model for ventilation system



- Aerodynamics
- ThermoFluid dynamics
- Two-phase (vapour/sweat)
- Porous media (air/hair)
- Human head sweating model

LS-Dyna



Non-linear structural dynamics model for crash

The challenge
Some numbers

Aerodynamics simulations on OpenFOAM®:

- **≈ 10M** elements per mesh
- **≈ 200h** (overall) simulation time per helmet
- **≈ 45** typical configurations per helmet (inclination, speed, style, etc)

Workflow	Solver	h/sim	Config.
Thermofluid	Steady/time-dep.	24	25 + parametric
Vibroacoustics	Time-dependent	1500	25
Crash	Time-dependent	60	25

≈ 50K hours of simulation time per helmet!

Next Step: HPC

The FORTISSIMO project

Factories of the Future Resources, Technology, Infrastructure and Services for Simulation and Modelling

FORTISSIMO

SEVENTH FRAMEWORK PROGRAMME

MOX-OFF
MATHEMATICS FOR INNOVATION

- Porting of the platform on a HPC framework
- Simulation & analyses speed-up
- Development of a web-based, on-demand SaaS

Partnership

CINECA

- HPC expertise
- HPC resources

Nolangroup®

- Industrial motivation
- End-User validation

Enabling Innovative Products & Services

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OpenFOAM® for glass melting furnaces

- **flameletSimpleFoam**[1]
  - Thermo + fluid dynamics
  - Combustion (flamelet model)
  - Steady state

Mesh size	≈ 2M hex
Processors *[#]*	3
Computational time (average)	≈ 1.5gg

OMISSIS

[1] *Developed by Dr. Holzmann and Prof. A. Cuoci from Politecnico di Milano*

OpenFOAM ® for polymerization oven

- **buoyantPimpleFoam**
  - Thermo + fluid dynamics
  - Gravity
  - Time dependent

Modified to:

- buoyant**Dyn**PimpleFoam
  - Moving mesh

Mesh size	≈ 3M
Processors *[#]*	12
Computational time (average)	»14gg

OMISSIS

OpenFOAM® for laser cutting

- **rhoCentralFoam**
  - Gasdynamics
  - Supersonic flow
  - Steady state

Mesh size	≈ 5M
Processors *[#]*	48
Computational time (average)	≈ 10gg

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Contacts

- matteo.longoni@moxoff.com
- info@moxoff.com

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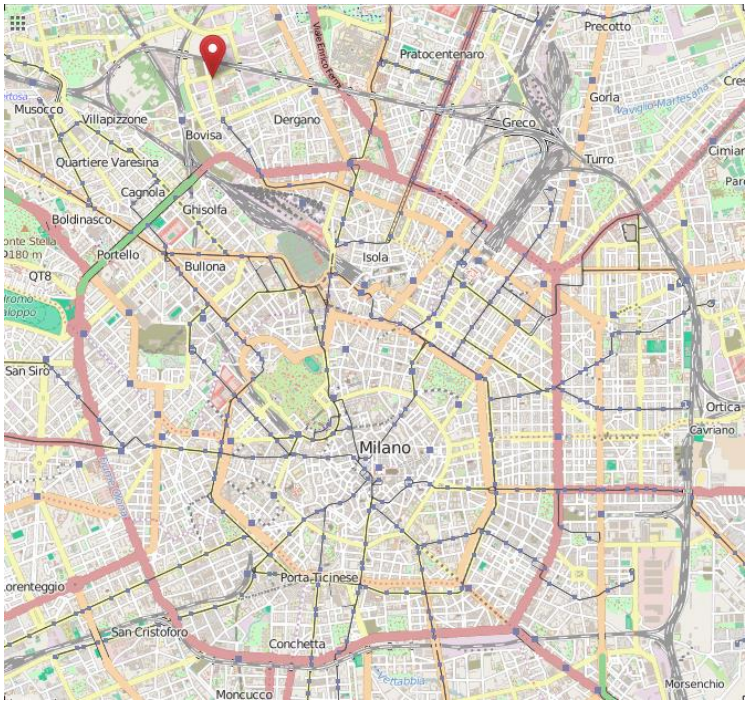

Via Giovanni Durando 38/A, Milan
Ph: +39 02 2399 2966

Thank you for your attention!