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A survey on open source codes for computational acoustics

Takuya OSHIMA (Niigata University)
Takashi Ishizuka (Institute of Technology, Shimizu Corporation)

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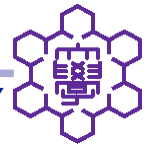
Agenda

- Why do we survey open source codes?
- List of open source codes for acoustics
- Investigated codes: Code_Aster and Elmer
- Code_Aster
  - Overview
  - Capabilities in acoustics
  - Installation / Usage
- Elmer
  - Overview
  - Capabilities in acoustics
  - Usage
- Summary

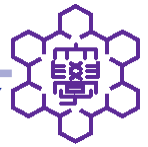
Why do we survey open source codes? (1)



- Rapid and broader acceptance of open source engineering in recent years
  - Especially in major areas - CFD, structural analysis
  - For cost reduction in industrial usages
  - As academic platforms to share model developments and cases
    - Fast path from model developments to industrial applications

- However, not so many codes are known for acoustics

Why do we survey open source codes? (2)



- We are about to start a project for open source acoustics
  - Under funding by Architectural Institute of Japan
  - Meant to create an introductory code that covers main numerical techniques such as BEM, FEM, FDTD

- In order for our product to be original and innovative, we have to know
  - What open source codes are now on the net
  - What they can do
  - What degree of usability they have
  - Their strengths and weaknesses

- The survey is still an ongoing work, hence this presentation is not conclusive

List of open source codes for acoustics (1)

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List of open source codes for linear acoustics classified by development status and intended usages

- Acoustic education

Name	Lambda
Developer	Institut für Hörtechnik and Audiologie, Fachhochschule Oldenburg/ Ostfriesland/Wilhelmshaven (Institute of Hearing technology and Audiology, The University of Applied Sciences Oldenburg/Ostfriesland/ Wilhelmshaven), Germany
Solution technique	2-D transmission line matrix method
Project URL	http://www.hoertechnik-audiologie.de/web/file/Forschung/Software.php

List of open source codes for acoustics (2)

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•Preliminary, education for multiphysics

Name	DelFEM
Developer	Nobuyuki UMETANI (A graduate student of The University of Tokyo)
Solution technique	2-D FEM
Project URL	http://ums.futene.net/
Remarks	There is a citation of ASJ AA2006-5 (N. Okamoto et al.) in the developer's blog

List of open source codes for acoustics (3)

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•Production-level, multiphysics

Name	Elmer
Developer	CSC - IT Center for Science Ltd., Finland (Non-profit company administered by the Ministry of Education)
Solution techniques	2-D/3-D BEM (non-FMM) Helmholtz 2-D/3-D FEM Helmholtz
Project URL	http://www.csc.fi/elmer
Core feature	CFD and structural analysis with chemistry and thermophysics

Name	Code_Aster
Develper	Électricité de France (EDF), France (The main electricity generation and distribution company in France)
Solution techniques	2-D/3-D FEM Helmholtz
Project URL	http://www.code-aster.org/
Core feature	Structural analysis with thermo-/hydro-physics

List of open source codes for acoustics (4)

(continued)

Name	OpenFOAM
Developer	OpenCFD Ltd., UK (Independent company)
Solution technique	3-D FVM (FVTD) (*Requires customized solver*)
Project URL	http://www.opencfd.co.uk/openfoam/
Core feature	CFD for multiphysical/multiphase phenomena

Name	ESP-r
Developer	Department of Mechanical Engineering, University of Strathclyde, UK
Solution techniques	Empirical formulae (reverberation formula etc.)
Project URL	http://www.esru.strath.ac.uk/Programs/ESP-r.htm
Core feature	A whole building simulation software (CFD, lighting, energy simulation)

List of open source codes for acoustics (5)

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•Production-level multiphysics code that is *not* capable of acoustics

Name	Adventure System
Developer	The University of Tokyo
Solution technique	-
Project URL	http://adventure.sys.t.u-tokyo.ac.jp/

List of open source codes for acoustics (6)

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•General-purpose multiphysics toolkits that may, or may not, have acoustics capability (to be investigated)

Name	OpenLB
Developer	Jonas Latt (Tufts University, USA) et al.
Solution technique	Lattice Boltzmann Method (LBM)
Project URL	http://www.openlb.org/

Name	FiPy
Developer	National Institute of Standards and Technology, USA
Solution technique	FVM
Project URL	http://www.ctcms.nist.gov/fipy/

Investigated codes: Code_Aster and Elmer

•Two of the listed codes are being investigated further:

Code_Aster Elmer

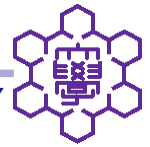
•Because both have

- ➢a lot of features and application domains (multiphysics, multiphenomena)
- ➢built-in acoustics capability (no customization required)
- ➢FEM as a solution technique

• And are developed under extensive institutional involvements

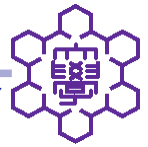
- ➢by the main electricity company in France (Code_Aster)
- ➢by the largest IT/supercomputing resource provider in Finland (Elmer).

Code_Aster: Overview



- A multiphysics code developed by EDF, the main electricity company in France
- Core feature: Structural analysis including fatigue analysis
- License: GPL
- Current version: 9.4
- Supported platforms: Linux, (Windows – a bit outdated version 9.1)
- Certification: ISO 9001 for the code development process
- Contains 1.2 million lines of code written in Fortran and Python
- Has 12,000 pages of documents (*in French*), many of which are about validations
- Project started in 1989 (has 20 years of history)
  - ➢ Has been developed and used in-house for the maintenance of EDF's own power plants
  - ➢ To assess the lifetime of nuclear components that are operated but not designed by EDF

Code_Aster: Capabilities in acoustics (1)



- Solution technique: 2-D/3-D FEM Helmholtz (frequency domain)
- Available finite elements
  - Types of elements: "`ACOUSTIQUE`," "`MECHANIQUE`," 2D (planar), 3D, axial
  - Orders: 1st order, 2nd order
  - Element shapes in planar 2D (number of nodes in 1st/incomplete/complete 2nd orders):
    - Linear: segment (line) (2/3)
    - Planar: triangle (3/6), quadrangle (4/8/9)
  - Element shapes in 3D
    - Surface: triangle (3/6), quadrangle (4/8/9)
    - Volume: tetrahedron (4/10), pentahedron (prism) (6/15), hexahedron (8/20/27)

Code_Aster: Capabilities in acoustics (2)

•Boundary conditions: rigid, complex acoustic impedance, velocity, pressure, open boundary

•Acoustic sources: complex velocity in boundary elements

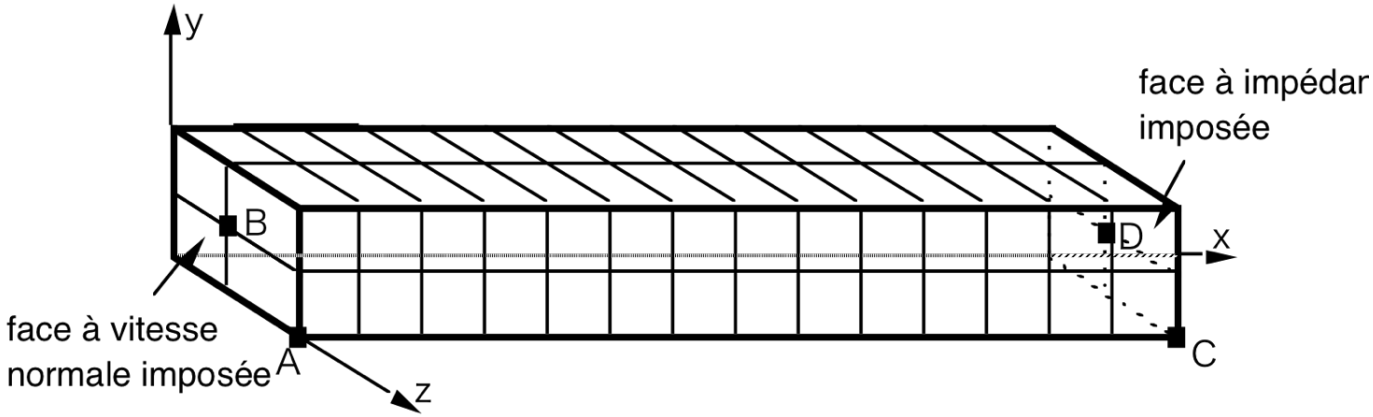
•Eigenfrequency analysis

•Coupled/chained problems: possible (acoustics-structural vibration)

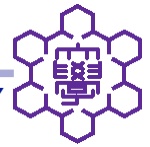
•Parallelization: either OpenMP or MPI

•Sample cases: an acoustic waveguide problem with different element shapes

•16 cases in total (one of which is shown below)



Code_Aster: Installation



•Windows: a binary distribution is available (NB: a bit outdated)

•Linux: binaries distributed with CAELinux and Salome-Meca (integrated environment with Salome pre/postprocessor)

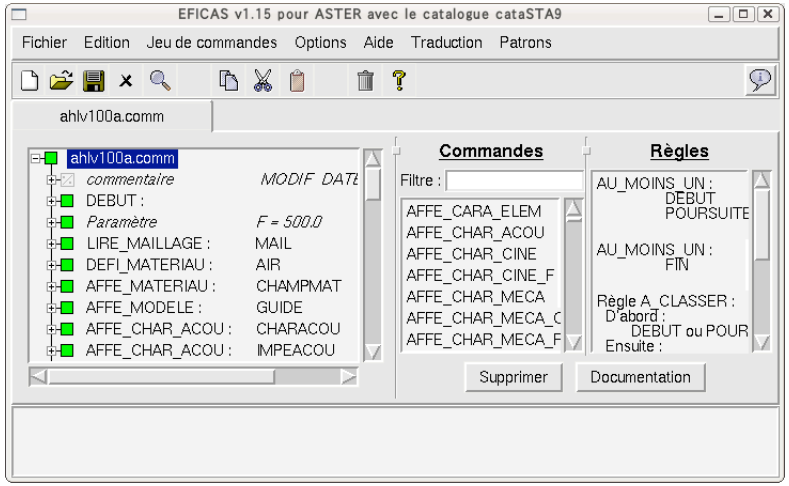
•Compilation on Linux:

- Main prerequisites: `bison`, `flex`, `nedit`, `lapack`, `gfortran`, `python-dev`, `python-qt-dev`, `python-qt3`, `tkinter`, `grace`, `xmgrace`
- Python-style installation: "`python setup.py install`"
- Requires careful network and X display manager settings to run the ASTK GUI (mandatory)

Code_Aster: Usage (1)

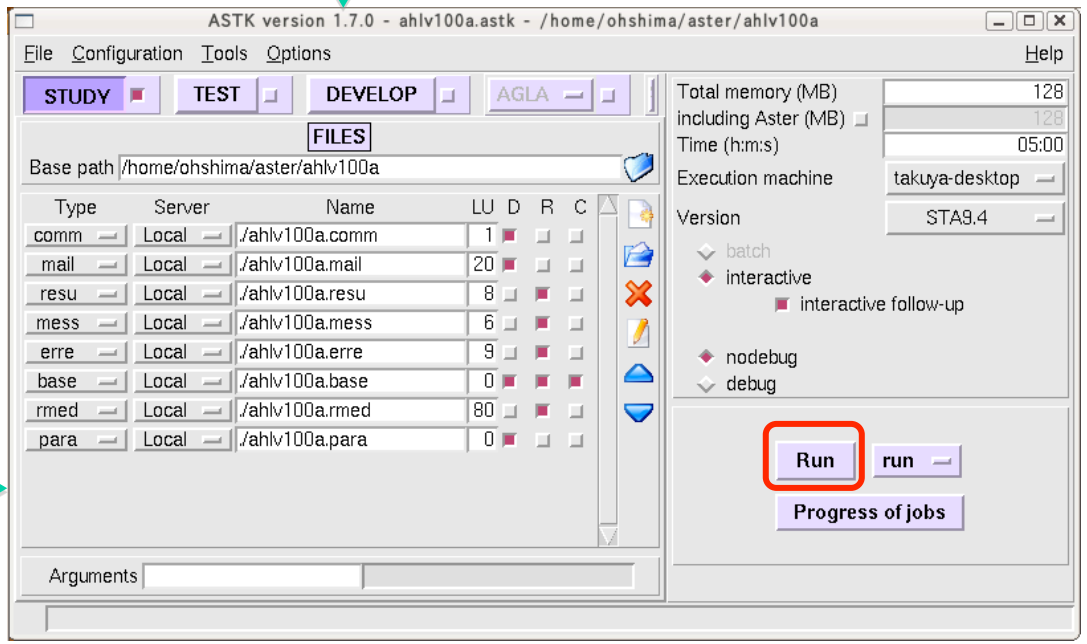
Text editor

Command file (.comm)
- Python code fragment
- Define type of problem
- Define materials
- Define BCs



EFICAS (command file editor)

Mesh file
- Gmsh format (.msh)
- GIBI format (.mail, .mgib)
- I-DEAS format (.msup)
- MED format (.mmed)



ASTK GUI (job manager)

Code_Aster: Usage (2)

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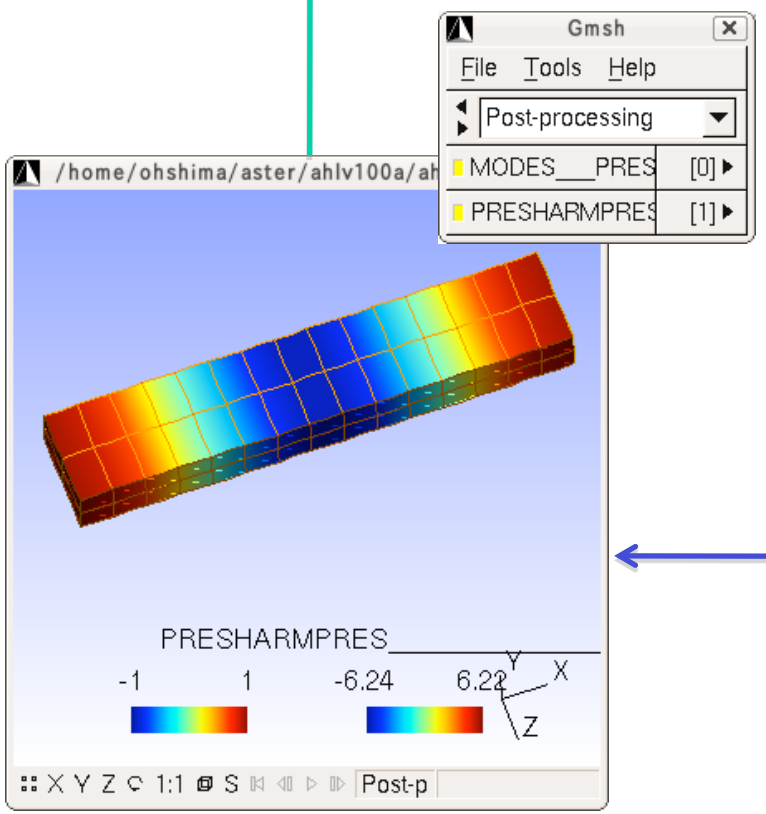


Pre/postprocessor (Gmsh etc.)

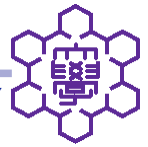
Result database

- Aster result format (.resu)
- CASTEM format (.cast)
- Ensight format (.ensi)
- I-DEAS format (.unv)
- Gmsh format (.pos)
- MED format (.rmed)

Messages

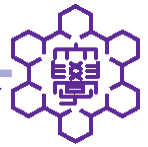
- Info (.mess)
- Error (.erre)

Elmer: Overview



- A multiphysics code developed by CSC Ltd., the largest IT/supercomputing resource provider in Finland
- Core features: CFD and structural analysis with chemistry and thermophysics
- License: GPL
- Current version: 5.4.1
- Supported platforms: Linux, Windows, OS X
- Project started in 1995
  - As a part of national CFD technology program
  - Development consortia includes CSC and Helsinki University of Technology

Elmer: Capabilities in acoustics (1)



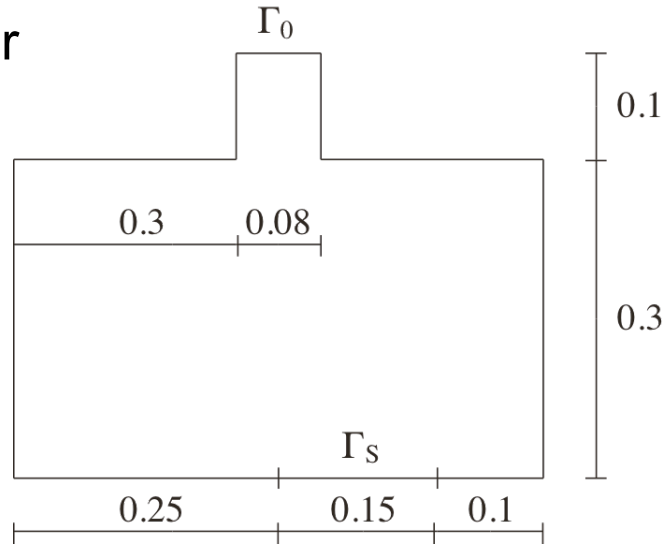
•Solution techniques: 2-D/3-D FEM/BEM Helmholtz (no FMM acceleration), 2-D transient

•Available finite elements

- Element dimensions: 1-D, 2-D, 3-D
- Orders: 1st order, 2nd order, 3rd order, higher degree approximation using p-elements
- Element shapes: triangle, quadrangle, tetrahedron, pyramid, prism, hexahedron

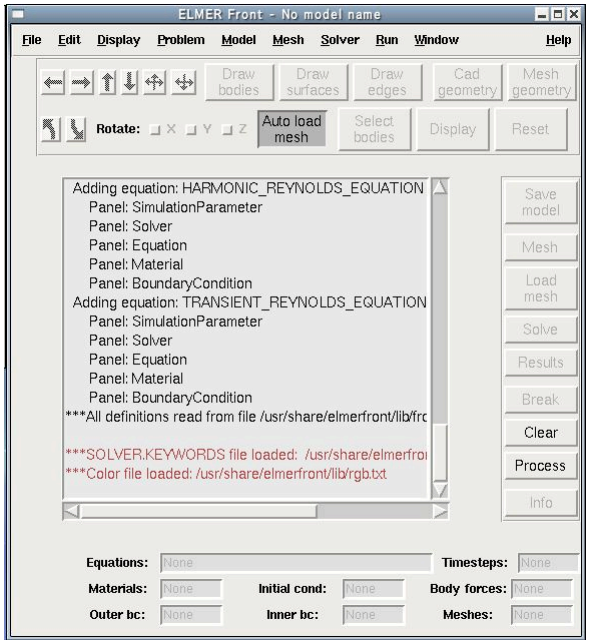
Elmer: Capabilities in acoustics (2)

- Boundary conditions: rigid, complex acoustic impedance, velocity, pressure
- Acoustic sources: complex velocity in boundary elements
- Damping medium
- Eigenfrequency analysis
- Coupled/chained problems: possible (acoustics-structural vibration)
- Parallelization: MPI
- Has better GUI (pre/postprocessors) than Code_Aster
- Sample case: A resonator



Elmer: Usage (1): Overview

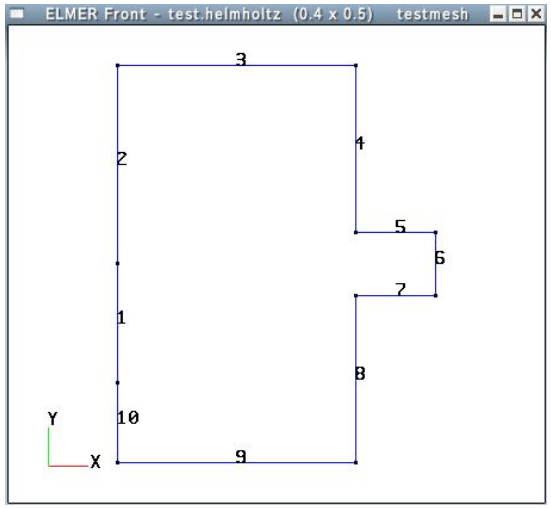
- Elmer cases are handled by ElmerFront, a GUI preprocessor
  - Another better GUI, ElmerGUI, is now under development



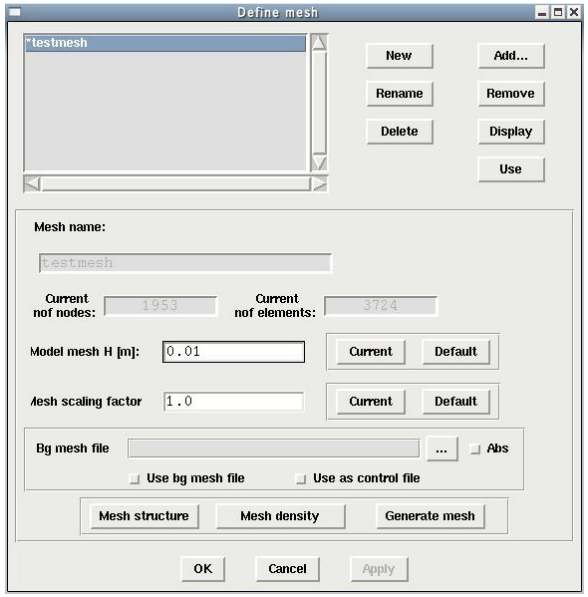
- Import geometry/mesh
- Define type of problem
- Define materials
- Define BCs
- Control mesher/solver/postprocessor

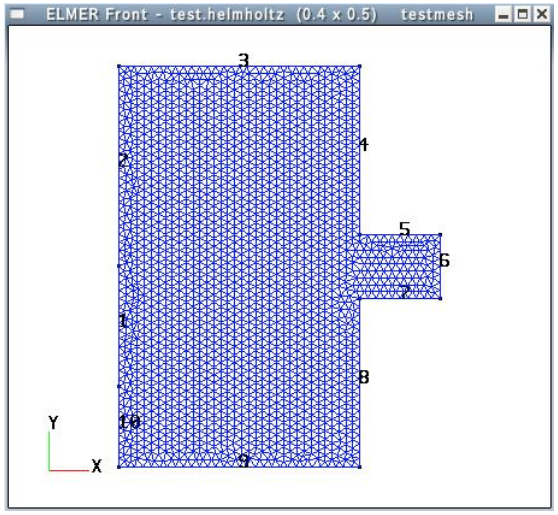
Elmer: Usage (2): Import geometry/generate mesh

- Import geometry



- Generate mesh





Elmer: Usage (3): Define problem, materials and BCs

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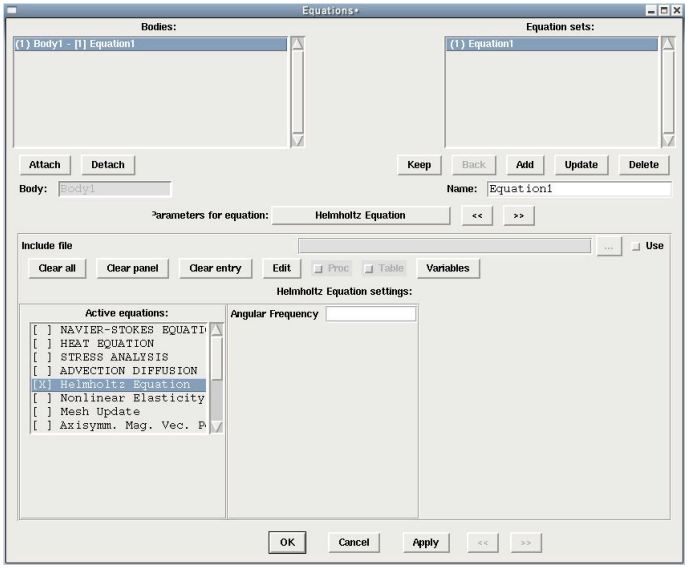
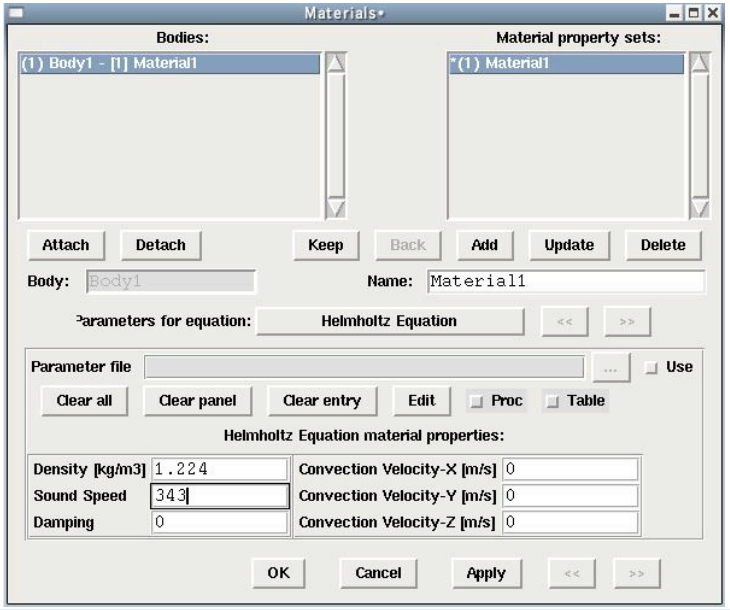
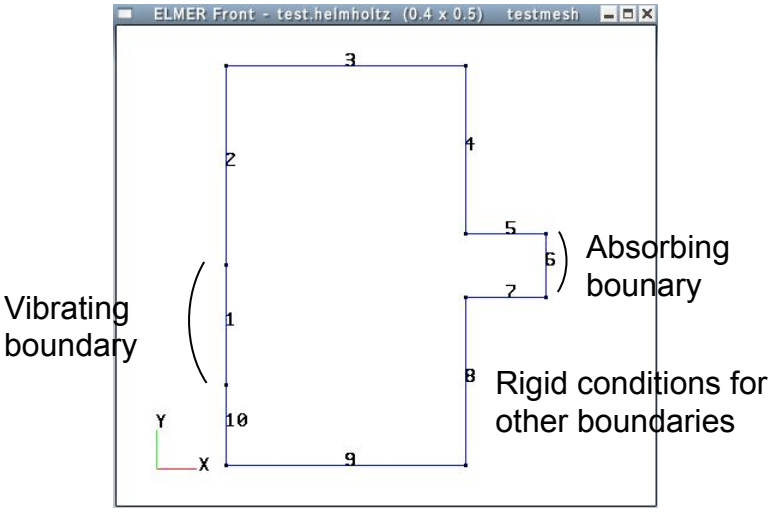
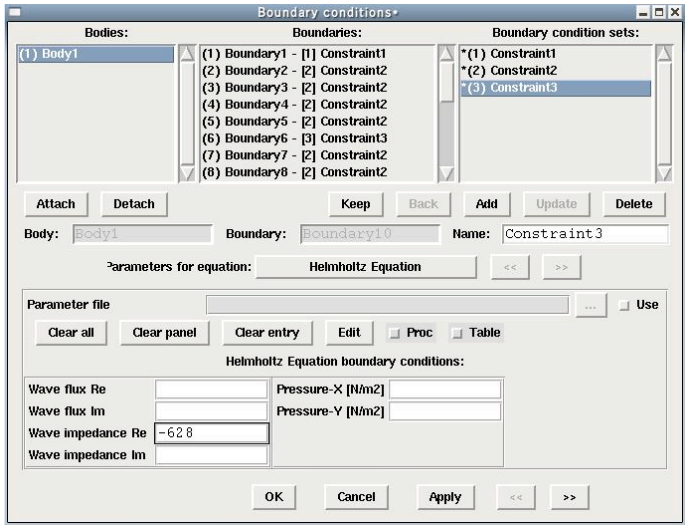
- Define problem and materials





- Define boundary conditions





Elmer: Usage (4): Solve

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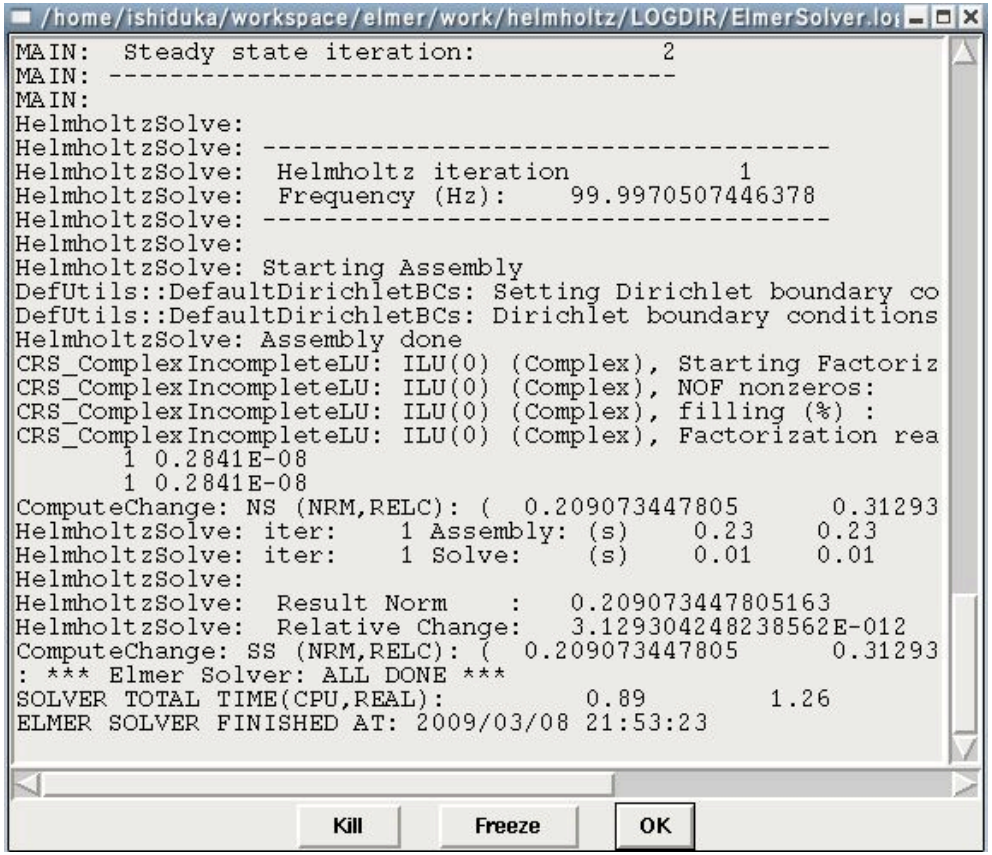
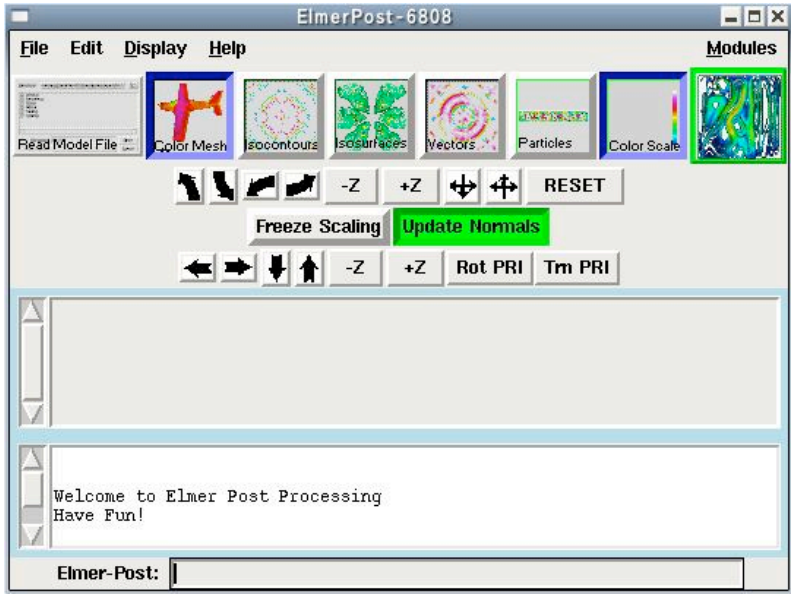
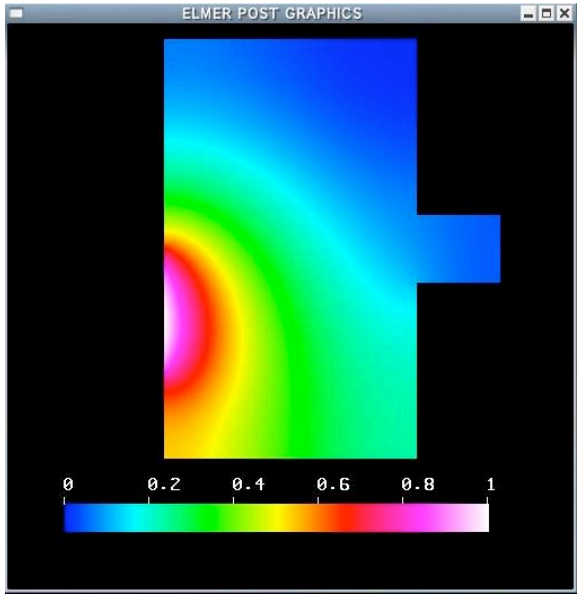


Elmer: Usage (5): Postprocessing





Summary

- Presented overview about current open source codes for acoustics
- Presented overview and capabilities in acoustics for Code_Aster and Elmer
- Future works
  - Test and validate the solutions of benchmark problems by Code_Aster and Elmer
  - … and eventually, our product!