Joint Industry Research Consortium on Formation Evaluation

Software Update on Finite Element Simulation of DC/AC Borehole Resistivity Measurements

D. Pardo, C. Torres-Verdín, M. J. Nam, M. Paszynski

hp-FE TEAM: D. Pardo, Ch. Michler, M.J. Nam, M. Paszynski,
R. Abdollah-Pour, L. Demkowicz, C. Torres-Verdín

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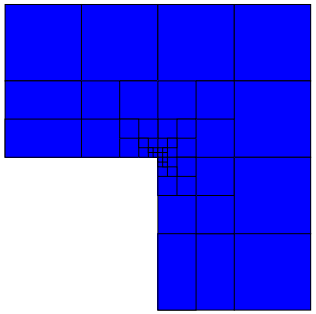
Department of Petroleum and Geosystems Engineering

THE UNIVERSITY OF TEXAS AT AUSTIN

OVERVIEW

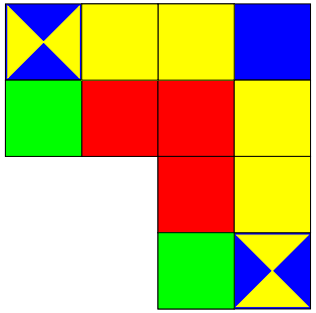
1. 2D Resistivity hp-Finite Element Software —β version— (D. Pardo).
2. 3D Resistivity hp-Finite Element Software —α version— (D. Pardo).
3. 2D Sonic hp-Finite Element Software —β version— (Ch. Michler).
4. 2.5D Sonic hp-Finite Element Software —α version— (Ch. Michler).
5. 2D Multi-Physics and Inverse Problems Software — work in progress — (D. Pardo).

2D hp-FEM



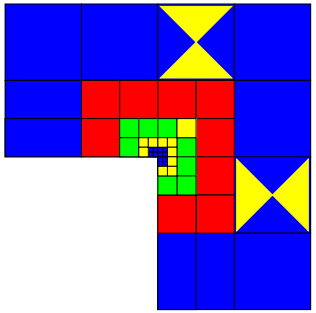
The h-Finite Element Method

1. Convergence limited by the polynomial degree, and large material contrasts.
2. Optimal *h*-grids do NOT converge exponentially in real applications.
3. They may "lock" (100% error).



The p-Finite Element Method

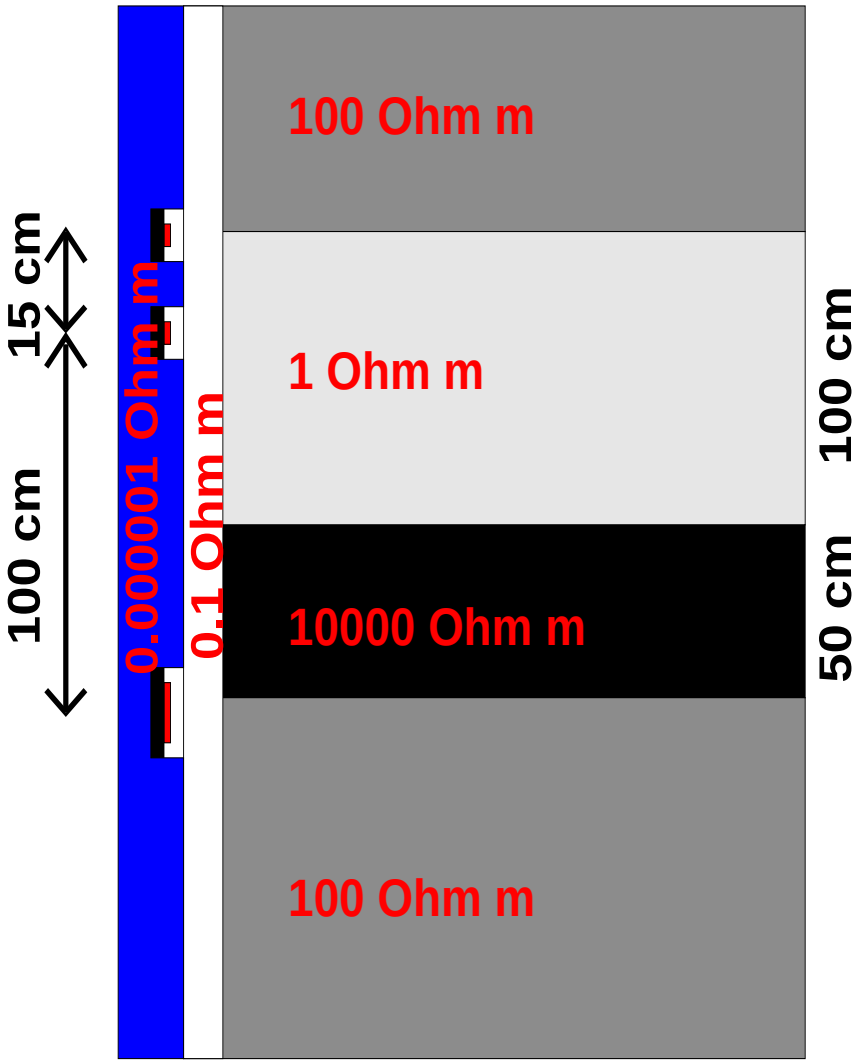
1. Exponential convergence feasible for analytical ("nice") solutions.
2. Optimal *p*-grids do NOT converge exponentially in real applications.
3. If initial *h*-grid is not adequate, the *p*-method will fail miserably.



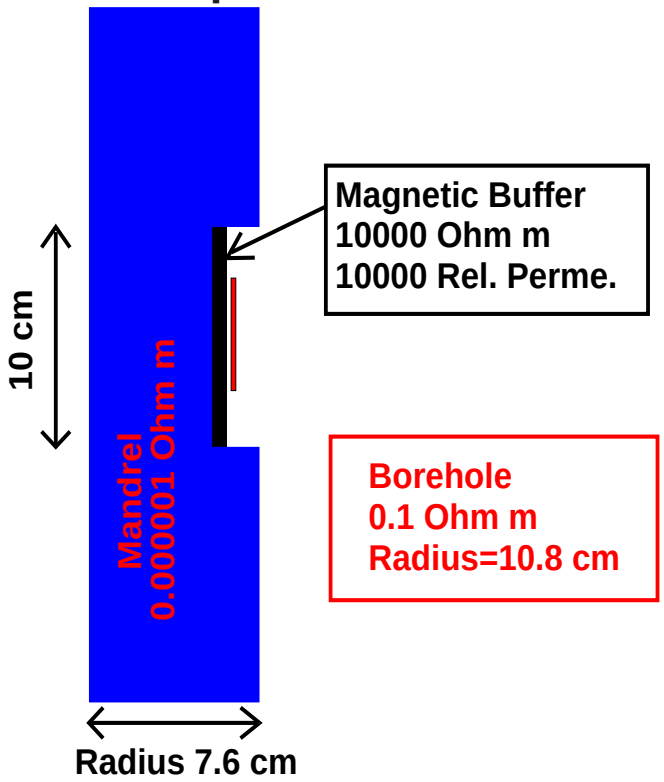
The hp-Finite Element Method

1. Exponential convergence feasible for ALL solutions.
2. Optimal *hp*-grids DO converge exponentially in real applications.
3. If initial *hp*-grid is not adequate, results will still be great.

2D hp-FEM



Description of Antennas

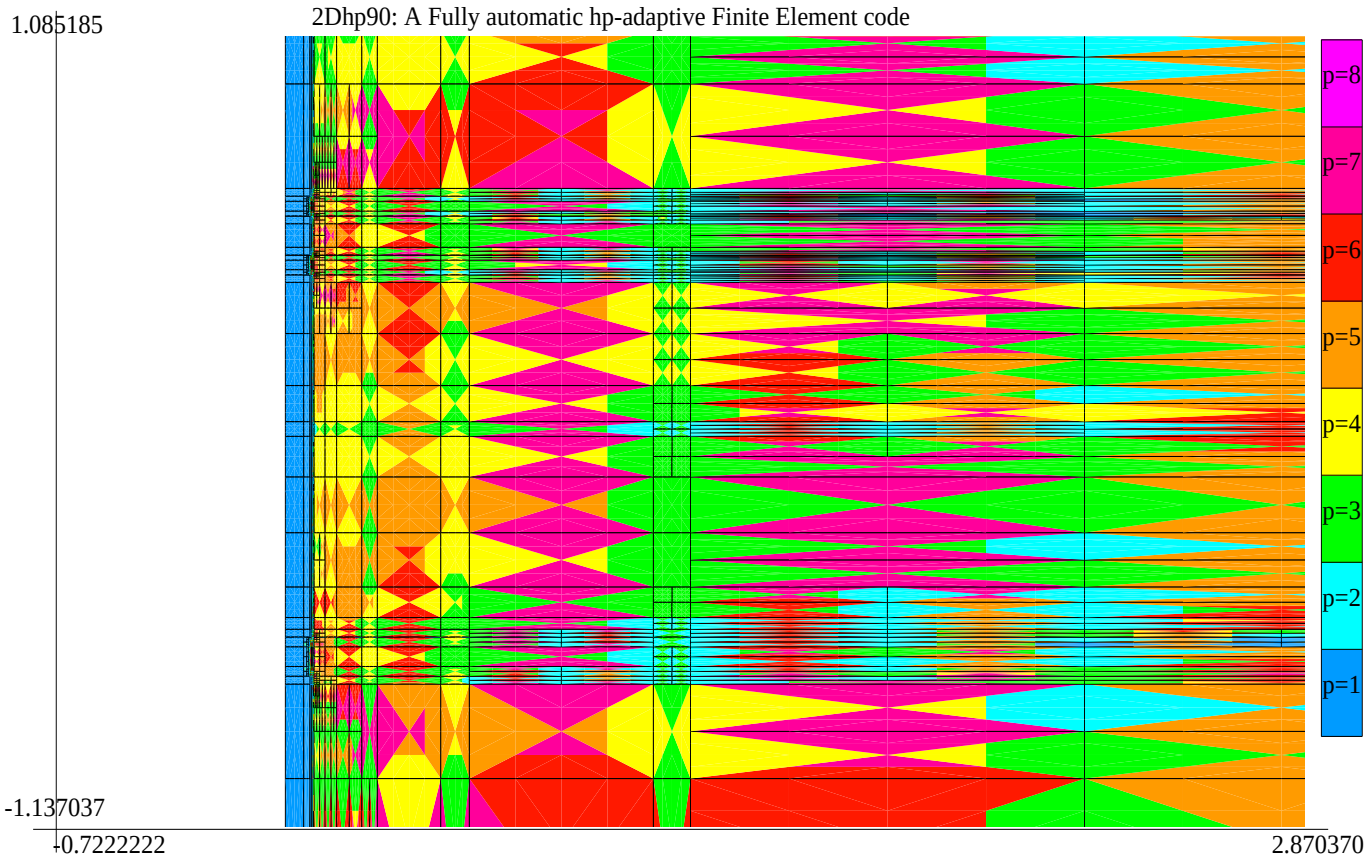


Goal: To Study the Effect of Invasion, Anistotropy, and Magnetic Permeability.

2D hp-FEM

First. Vert. Diff. E_ϕ (solenoid). Position: 0.475m

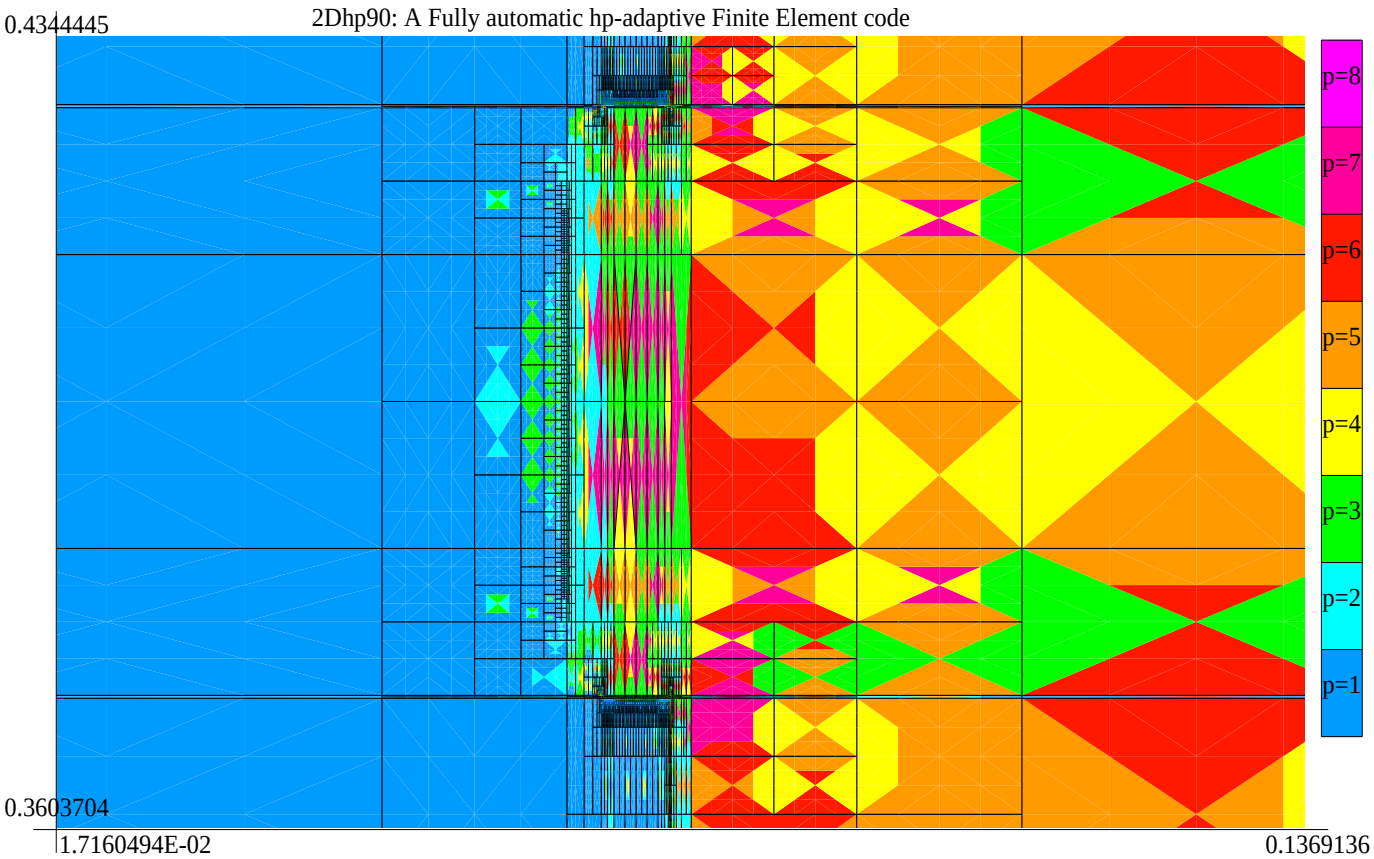
GOAL-ORIENTED HP-ADAPTIVITY (Quadrilateral Elements)



2D hp-FEM

First. Vert. Diff. E_ϕ (solenoid). Position: 0.475m

GOAL-ORIENTED HP-ADAPTIVITY (ZOOM TOWARDS FIRST RECEIVER ANTENNA)



2D hp-FEM

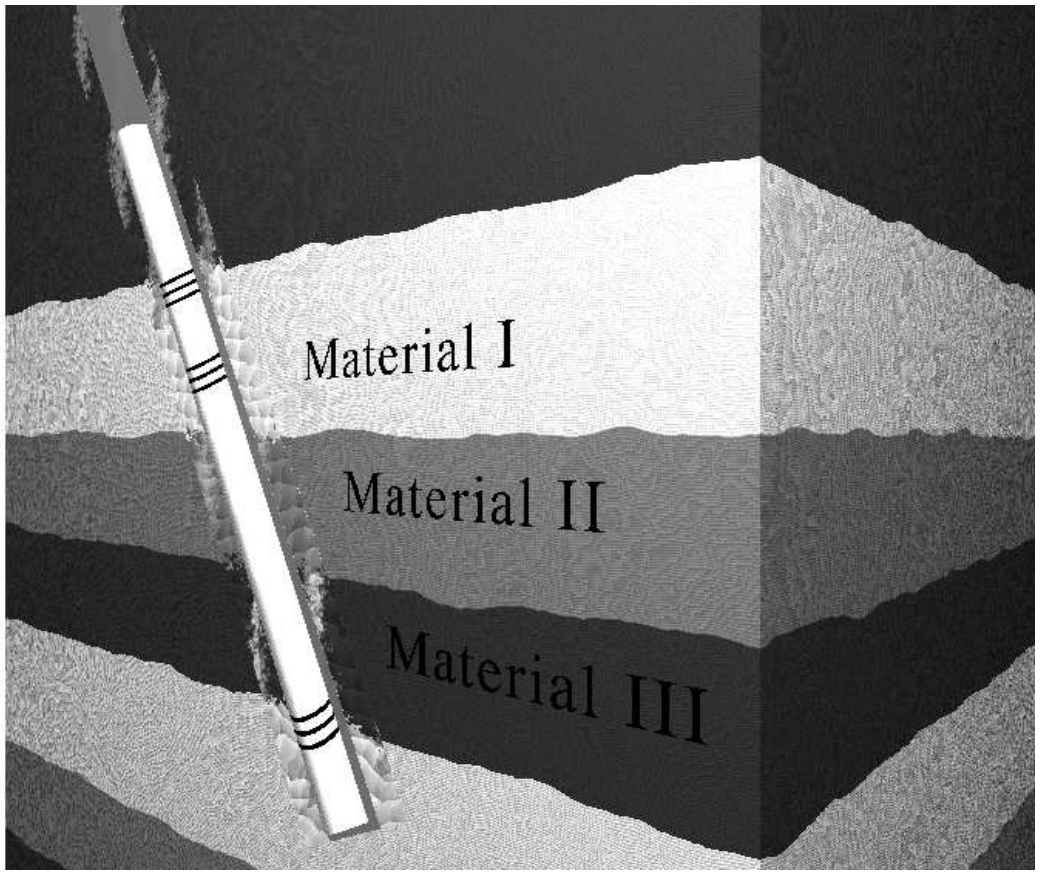
Type of Problems We Can Solve with 2Dhp90

Physical Devices	Magnetic Buffers	Insulators	Displacement Currents
	Casing	Casing Imperfections	Combination of all
Materials	Isotropic	Anisotropic	
Sources	Toroidal Antennas	Solenoidal Antennas	Dipoles in Any Direction
	Electrodes	Finite Size Antennas	Combination of All
Logging Instruments	LWD/MWD	Laterolog	Normal
	Induction	Dielectric Instruments	Cross-well
Frequency	0-10 Ghz.		
Invasion	Water	Oil	etc.

ALL AXISYMMETRIC RESISTIVITY LOGGING PROBLEMS

3D hp-FEM

Deviated Wells (Forward Problem)



- Dip Angle
- Invasion
- Anisotropy
- Different Sources (Triaxial Induction)
- Eccentric Logging Instruments
- Laterolog
- Through-Casing
- Induction-LWD
- Induction-Wireline

Results on the 3D DC/AC software will be presented on Friday.

SUMMARY AND FUTURE WORK

2D hp-FEM

- We have available a 2D hp-FE software that automatically generates optimal grids.
- It utilizes a version system and the interface is based on a single file.
- FUTURE WORK: Develop a user-friendly graphical interface.

3D hp-FEM

- The 3D code includes the 2D code and is multi-processor compatible.
- It will be available for your use within the next few months.
- The interface is based on a single file.
- FUTURE WORK:
  - Develop a user-friendly graphical interface.
  - Develop an iterative solver.

ACKNOWLEDGMENTS

Sponsors of UT Consortium on Formation Evaluation

Joint Industry Research Consortium on Formation Evaluation

Software Update on Multi-Physics Simulation and Inversion of Borehole Measurements. Work in Progress.

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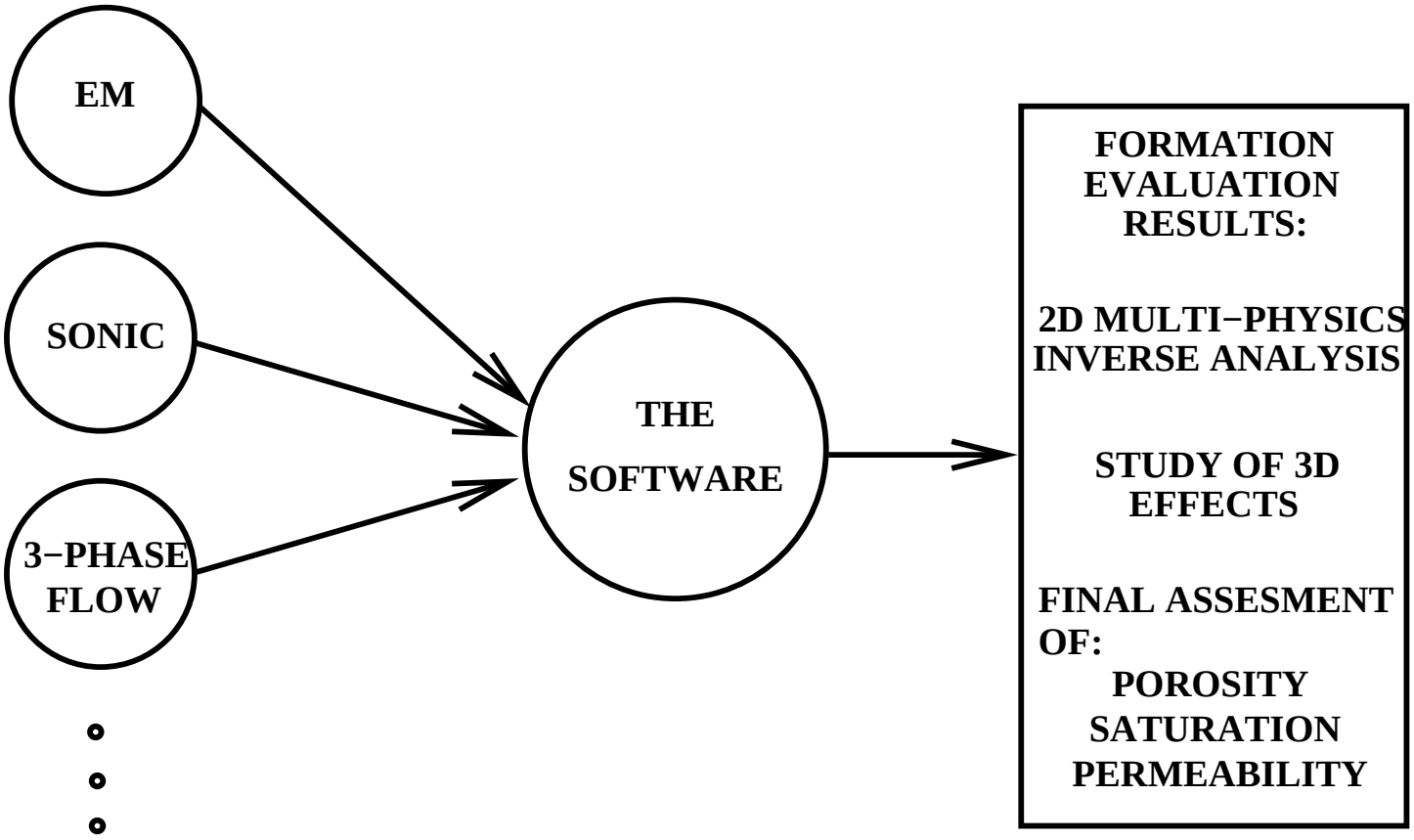
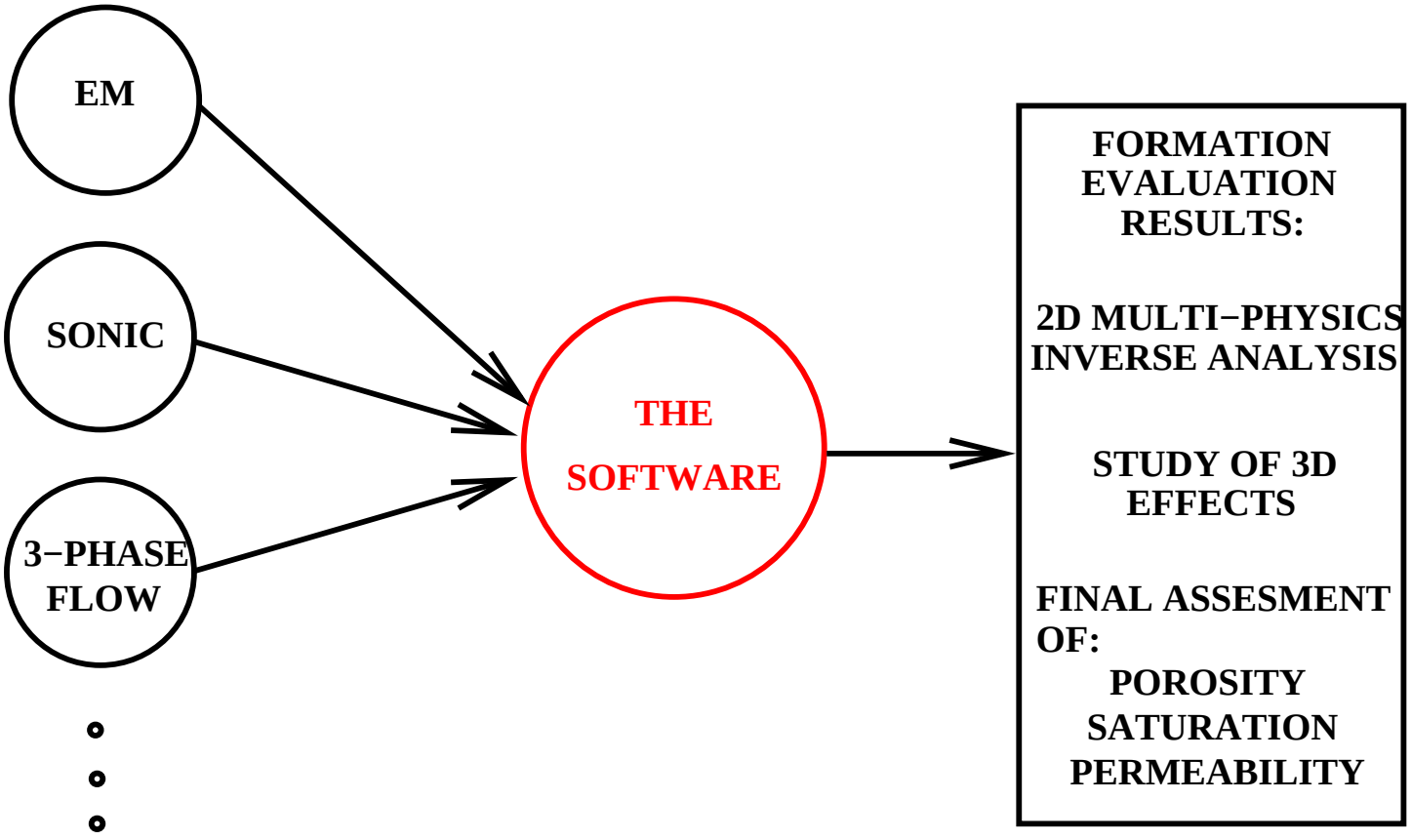
INTEGRATED APPROACH TOWARD FORMATION EVALUATION

ONE software FOR ALL the formation evaluation



INTEGRATED APPROACH TOWARD FORMATION EVALUATION

What software can we use?



INTEGRATED APPROACH TOWARD FORMATION EVALUATION

What software can we use?

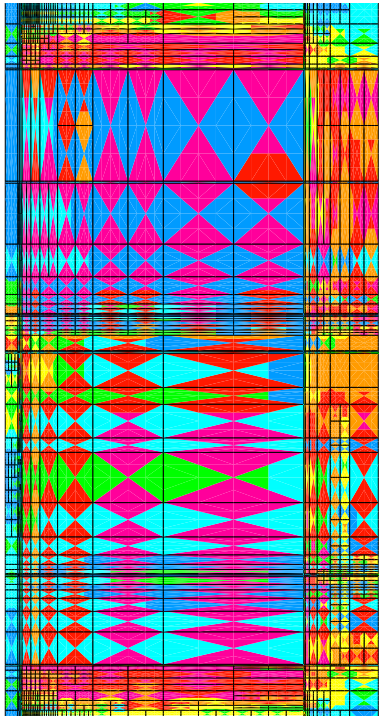
A Self-Adaptive Goal-Oriented hp-Finite Element Method (FEM)

We have developed a new hp-FE KERNEL using object-oriented programming concepts (including encapsulation, linked lists, dynamic memory allocation, etc.). The main advantages are:

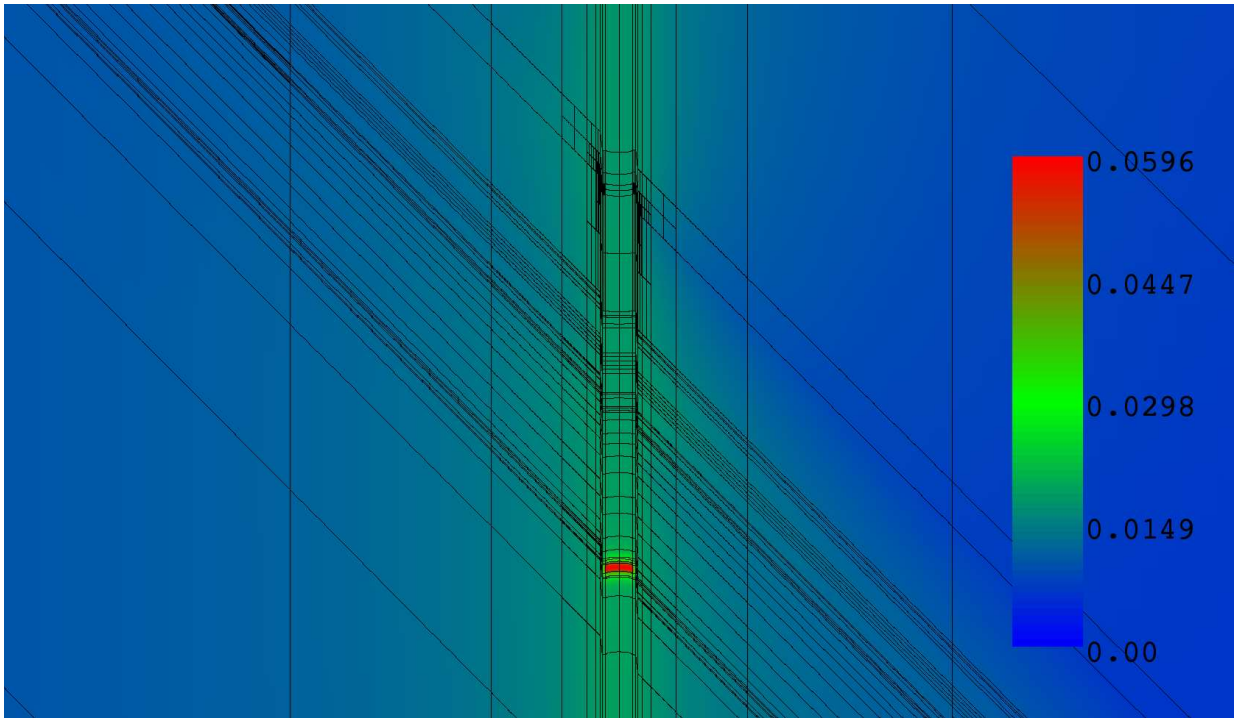
1. **It naturally supports the "de Rham" diagram.**
2. **It enables solution of multi-physics problems (multiple equations).**
3. **It is designed for parallel machines (including multi-core processors).**
4. **It enables solution of time-dependent problems.**

INTEGRATED APPROACH TOWARD FORMATION EVALUATION

2D and 3D Resistivity Logging (Electromagnetics)



2D hp-mesh

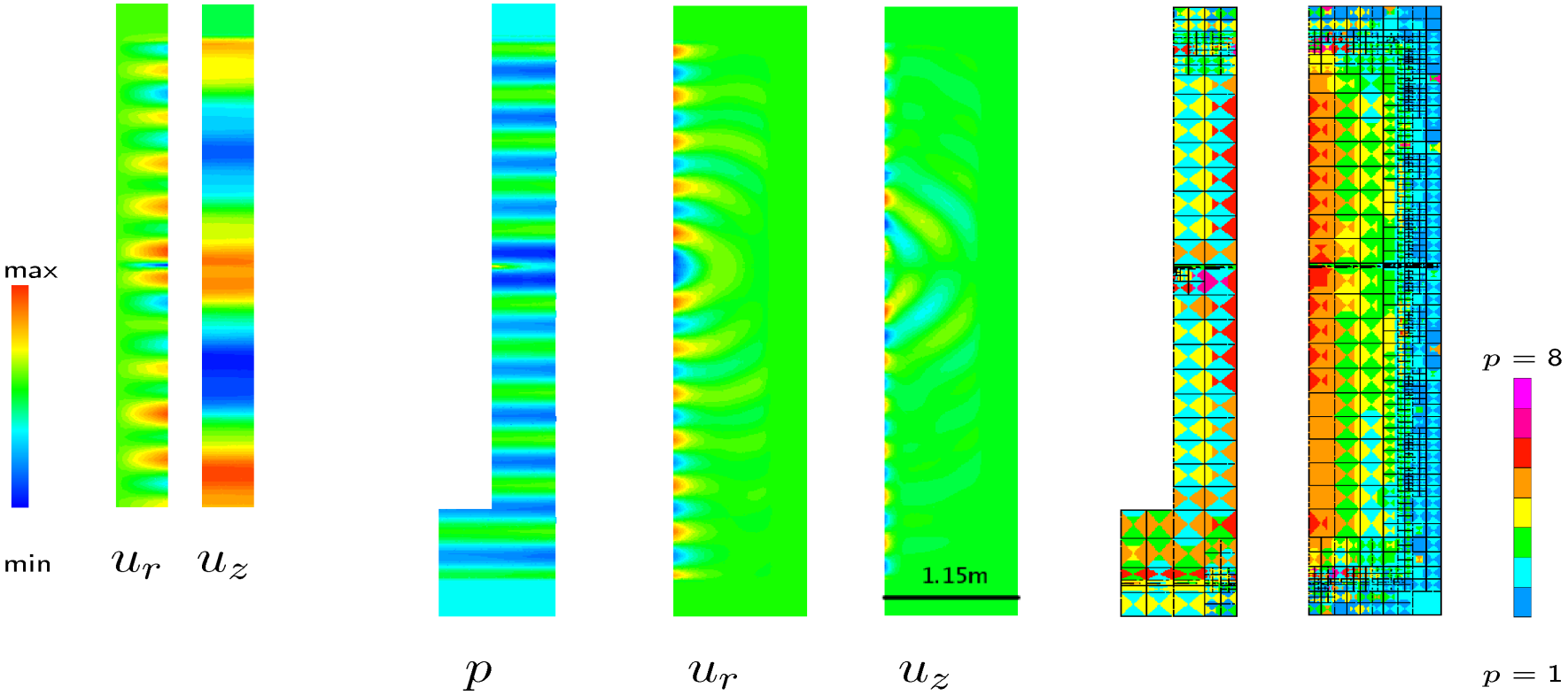


3D TCRT Solution (Dip Angle = 60 degrees)

INTEGRATED APPROACH TOWARD FORMATION EVALUATION

2D Sonic Logging (Acoustics/Elasticity)

Monopole source at f = 2 kHz



Tool Borehole Fluid Rock formation

INTEGRATED APPROACH TOWARD FORMATION EVALUATION

Work Plan

- 2D DC/AC simulator (2005).
- 3D DC simulator (2006).
- 2D sonic simulator (2006).
- 3D parallel AC simulator (2007).
- 2.5D sonic simulator (2007).
- 1D kernel for inverse and multi-physics problems (2007).
- 2D/3D inverse DC-AC simulator (2008).
- 2D fluid-flow simulator (2008).
- 2D AC-sonic inverse simulator (2008-2009).
- 2D inverse fluid-flow simulator (2008-2009).

ACKNOWLEDGMENTS

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