The challenges of Oil and Gas data interpretation

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Schlumberger Background

- The world’s leading oilfield services provider.
- Employs ~77,000 people of 140 nationalities working in ~80 countries.
- $27B revenue in 2008, investing more than $800M in research.
Oil Exploration Lifecycle

Exploration

The initial phase in petroleum operations that includes generation of a prospect, and drilling of an exploration well.
Oil Exploration Lifecycle

Appraisal

The phase of petroleum operations that immediately follows successful exploratory drilling.

During appraisal, delineation wells might be drilled to determine the size of the oil or gas field and how to develop it most efficiently.
Oil Exploration Lifecycle

Development

The phase of petroleum operations that occurs after exploration has proven successful, and before full-scale production.

A plan to fully and efficiently exploit the field is created, and additional wells are usually drilled.
Oil Exploration Lifecycle

- Explore
- Appraise
- Develop
- Produce

Production

The phase that occurs after successful exploration and development and during which hydrocarbons are extracted from an oil or gas field.
What Oil Companies Want to Know…

Where is the oil?
How much oil is there?
Will it flow?
What’s the best way to produce it?

“Can this reservoir profitably produce oil or gas?”
Oil Companies Like Data…
…But Want Insight

Drill here…
How Oil Companies Find Out…

To answer these questions…

• From *seismic data*, we interpret a structural model.
• From *borehole data*, we interpret physical properties of the rocks
• Integrating the structural model with the physical properties of the rocks, defines a property model.
• The property model is used for fluid flow simulations, financial estimates, drilling planning, etc.
Seismic Data: Acquisition

- Horizons
- Faults
- Structure
- Salt and other bodies
- Amplitude anomalies
- Fluid presence
- Traps
- Rock properties
Seismic Data

Seismic data is like weather radar.

- Coarse-grained.
- Covers a large volume that we cannot measure in detail everywhere.
- Is a fairly simple measurement.
Seismic Data: Characteristics and Processing

- 500 samples per second per trace
- ~20,000 traces per shot, every 10 seconds
- Up to 160 shots/km², 100 – 2,000 km² per survey
- ~ 45 surveys being processed at any one time
- ~30 separate steps in processing each survey
- Seismic, the largest consumer of computers-worldwide
- Online storage: 38 petabytes: ~ 120 million DVDs
- CPU capacity >200TFlops: ~ 90,000 x 3GHz PCs
  ... this week
Geco Eagle over Oslo

Seismic Towing Configuration
1999
Outer Separation: 1350 m
Streamer length: 6000 m
Monowing Deflector

Foto: Fjellanger Widerøe AS, Dag Myrstrand (Blå)
Seismic Data: Interpretation
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Seismic Data: Interpretation

- Rio de Janeiro
- Shallow
- Deep
- Campos Basin
- Santos Basin
- Espírito Santo Basin

Distance Scale: 0 - 100 km
Seismic Data: Time Lapse – Permanent Monitoring

1985  1996  Changes

HC indicator

0  1

No Change  Significant Change
Seismic Data: Challenges

- **Acquisition**
  - Sampling bandwidth: 100 MB/sec
  - Extremely large amounts of data
  - Multi-component data

- **Processing**
  - Terabytes of data
  - Algorithmic complexity (physics $\otimes$ programming)
  - I/O efficiency

- **Architecture**
  - Scalability
  - Reliability

- **Multiple versions!**
Borehole Data: Acquisition

- Lithology & Petrophysical Properties
  - Sand/Shale discrimination
  - Porosity (sonic, nuclear)
  - Density (nuclear)
  - Permeability (electrical)
  - Water/Oil/Gas Saturation

- Geomechanical Properties
  - In-situ stresses (sonic)
  - Seismic velocity calibration

- Geology
  - Sub-seismic bedding (electrical, nuclear)
Borehole Data

Borehole data is like data from a weather station.

- Lots of precise measurements.
- Sparse areal coverage
- Fronts are like faults—discontinuities between air masses
Borehole Data: Interpretation

Shale

HC-saturated sandstone
Borehole Data: Challenges

- **Acquisition**
  - High sampling rate
  - Noise
  - Extremely difficult borehole environments

- **Processing**
  - Mega to Giga bytes of data
  - Algorithmic complexity (physics $\otimes$ programming)
  - Disparity in data types
  - I/O efficiency

- **Architecture**
  - Scalability
  - Reliability
Seismic Data + Borehole Data = Shared Earth Model
Getting to the insight is a multi-disciplinary effort…

Drill here…
Multidisciplinary Data Integration

Geologist
Reservoir Engineer
Drilling Engineer
Production Engineer
Economist
Geophysicist
Exploration
Appraisal
Development
Production

Depth Conversion
Complex Fault Modeling
Petrophysical Modeling
Facies Modeling
Gridding
Data Analysis

Fault Analysis
Uncertainty
Upscaling
Fluid Flow
Simulation
History Matching

Well planning

Seismic Interpretation
Seismic Volume Rendering
Surface Imaging
Mapping Well Correlation
Pre-stack workflows

Economics
Project Valuation

Production

Production

Drilling Engineer

Reservoir Engineer

Geologist

Geophysicist

Exploration
Appraisal
Development
Production
Computer Science Challenges
Data Interpretation Challenges: Horizon Detection
Data Interpretation Challenges: Horizon Detection

Automatically interpreted and interpolated horizon
Data Interpretation Challenges: Fault Detection
Data Interpretation Challenges: Scalability
Data Interpretation Challenges: Properties

Volumes
- Cartesian, Corner point
- PEBI, Tetrahedra
- Unstructured

Surfaces
- Height fields: simple and compact, but limited
- Triangle meshes: flexible, but complicated
- Hybrid: best of both, but more complicated
Data Interpretation Challenges: Visualization
Usability

Interpretation requires a computational infrastructure that:

- Makes routine work easy and quick,
- Makes extraordinary work possible (e.g., is extensible)
- Takes advantage of local knowledge and past experience, and
- Allows for experimentation with alternative hypotheses.
Extensibility

Application extensibility requires:
- A robust, secure component framework
- A comprehensive data access API
- Domain API extensibility
- UI extensibility

We want to support *emergent behavior*: allow users to exploit component interactions in unforeseen ways.
Summary of Oil & Gas Data Interpretation Challenges

- Diverse data types
- Extremely large data volumes
- Complex mathematical algorithms
- Enormous range of feature sizes: mm to km
- Complex data structures
- High-performance 3D geometric modeling, visualization and simulation
- What if scenarios and uncertainty management
- Robust calculations and error handling

- Highly efficient parallel computing, need it everywhere!
- Growing functionality and complexity requires extensive software verification
- Growing functionality and complexity requires high developer productivity
- Maintenance and re-engineering of legacy code
- Exponential code base growth
- High performance over the web
- Usability
Thank you!

Questions?

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