The Delphi consortium: Overview of activities

Eric Verschuur
Delft University of Technology,
Delphi Consortium (www.delphi-consortium.com)
Delphi Studio for Imaging (www.delphistudio4imaging.com)

Seminar at EBN meeting, Utrecht
Thursday, February 20, 2014
Delft University of Technology:

- 1983: founding of PRINCEPS consortium on seismic inversion (spin-off: Jason, now part of CGG)
- 1986: addition of TRITON consortium on seismic imaging
- 1989: merge into DELPHI consortium (2014 is 25th anniversary)
**DELPHI consortium**

- **Advisory board**: sponsor delegates, on personal title
- **Written reporting**: once a year a progress report per project and PhD theses as they come out
- **Sponsor meetings**: twice a year, one in Houston in Feb., one in The Hague in June
- **Software**: interactive programs based on Seismic Unix and Matlab
- **Personnel involved**: 12 Ph.D. students, three full (emeritus) professors, two associate professors and support. In addition, we have Post-docs and visiting Ph.D. students
Delphi consortium projects

Delphi scientific coordinator: Guus Berkhout

• Acquisition & Preprocessing (A&P)
  Project director: Gerrit Blacquièrè (Appl. Earth Sci. / TNO)

• Multiple estimation & structural Imaging (M&I)
  Project director: Eric Verschuur (Lab. Acoustical Wavefield Imaging)

• Reservoir Characterization & Management (C&M)
  Project director: Guus Berkhout (Interim)
Sponsors of the Delphi consortium

<table>
<thead>
<tr>
<th>Sponsoring Companies</th>
<th>A&amp;P</th>
<th>M&amp;I</th>
<th>C&amp;M</th>
<th>Sponsoring Companies</th>
<th>A&amp;P</th>
<th>M&amp;I</th>
<th>C&amp;M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anadarko Petroleum Corporation</td>
<td></td>
<td></td>
<td></td>
<td>Petrobras</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BGP</td>
<td></td>
<td></td>
<td></td>
<td>Petronas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BHP Billiton</td>
<td></td>
<td></td>
<td></td>
<td>PGS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP</td>
<td></td>
<td></td>
<td></td>
<td>PSS-Geo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CGGVeritas</td>
<td></td>
<td></td>
<td></td>
<td>RWE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chevron</td>
<td></td>
<td></td>
<td></td>
<td>Saudi Aramco</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delft Inversion</td>
<td></td>
<td></td>
<td></td>
<td>Spectrum Geo Inc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMT Petrologic GmbH</td>
<td></td>
<td></td>
<td></td>
<td>Statoil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dolphin Geophysical</td>
<td></td>
<td></td>
<td></td>
<td>TEEC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eni</td>
<td></td>
<td></td>
<td></td>
<td>TGS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ExxonMobil</td>
<td></td>
<td></td>
<td></td>
<td>TNO-NITG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fairfield / Nodal</td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDF Suez</td>
<td></td>
<td></td>
<td></td>
<td>Tullow Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INPEX</td>
<td></td>
<td></td>
<td></td>
<td>Western Geco</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ION/GX Technology</td>
<td></td>
<td></td>
<td></td>
<td>Wintershall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OMV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Seismic value chain

• New capabilities in acquisition should inspire innovations in imaging as well as characterization (double feedforward loop)

• Characterization needs should drive both imaging and acquisition research (double feedback loop)
Acquisition & Preprocessing (A&P)

Acquisition & Preprocessing

Multiple Estimation & Structural Imaging

Reservoir Characterization & Management
Topics in Delphi A&P

• Blended acquisition

• Deblending algorithms

• Near-surface replacement

• Data reconstruction and interpolation

• Robotization – New acquisition techniques (separately sponsored project for additional fee)
Conventional vs. blended acquisition

Blended (or SimSrc) acquisition: start next shot before recording of previous shot is finished
Aiming at improved quality or reduced costs

In practice a combination may be preferred
Blended shot record (with sweeps)
Pseudo-deblended or fully deblended

Pseudo-deblended shot record 1

Estimate of shot record 1 in iteration 67

Shot record 1

Pseudo-deblended

Fully deblended

Original
Saudi Aramco line (EAGE 2005 workshop)
Field data results

Stack from input data

Results from Jan-Willem Vrolijk (Vrolijk et al., 2012, Journal of Applied Geoscience, 82, 30-45)
Field data results

Stack after redatuming with full-waveform operators (multi-datum)

Results from Jan-Willem Vrolijk (Vrolijk et al., 2012, Journal of Applied Geoscience, 82, 30-45)
Multiple Estimation & Structural Imaging

Acquisition & Preprocessing

Multiple Estimation & Structural Imaging

Reservoir Characterization & Management
Topics in Delphi M&I

• Multiple estimation:
  - Surface multiple estimation (SRME)
  - From multiple removal to primary estimation (EPSI)
  - Primary estimation for internal multiples
  - Extending closed-loop primary estimation to 3D

• Imaging:
  - Imaging of blended data and surface multiples
  - Full wavefield migration: including all internal multiples
  - Joint-Migration-Inversion: Automatic estimation of the background velocity model (including multiples)
Primary estimation: Marine field data

- Upgoing wavefield extracted from dual-sensor measurement
- Subset from 2D line for comparing SRME vs Primary Estimation (EPSI)
- State-of-the-art SRME-based method, including predictive tau-p deconvolution

Data courtesy PGS
SRME vs. EPSI: Marine field data example

Stacked section: input               SRME output                  EPSI output

Result from Rolf Baardman et al., SEG 2010

Data courtesy PGS
Sigsbee velocity model

Migration velocity model:

Depth [m]

Lateral location [m]
Conventional migration

Imaging with primary reflections only

Depth [m]

Lateral location [m]

Results from Mikhail Davydenko
Full Wavefield Migration (FWM)

Using primaries and internal multiples

Results from Mikhail Davydenko (SEG 2013)
Including velocity estimation in FWM

Results from Xander Staal (EAGE 2013)
Marmousi - Initial model

Results from Xander Staal (EAGE 2013)
Marmousi - Imaging only

Results from Xander Staal (EAGE 2013)
Results from Xander Staal (EAGE 2013)
Reservoir Characterization & Management (C&M)

- Acquisition & Preprocessing
- Multiple Estimation & Structural Imaging
- Reservoir Characterization & Management
Topics in Delphi C&M

- High-resolution full waveform inversion:
  - Local, reservoir-oriented FWI
  - FWI including geological scenarios

- Joint inversion-migration:
  - Include with JMI for overburden solution → JMI-res

- VSP full wavefield migration
  - Using all multiples to image away from the well
  - Integrate with surface seismic data

- Time lapse monitoring
  - Multi-physics (EM, Seismics, Remote Sensing)
Introduction: example for VSP

• Example of using multiples in VSP imaging (Work of Ph.D. student Alok Soni)
Introduction: example for VSP

Image with primaries-only migration

Full wavefield image, using all multiples

Results by Alok Soni, SEG 2013
3D VSP migration using multiples

First iteration of FWM
After 10 iterations of FWM

Result by Bouchaib El-Marhfoul
Spin-offs from Delphi Consortium

• 2008 : Delphi Studio for Imaging (DS4I)
  - Founded by Guus Berkhout and Eric Verschuur
  - One-to-one projects for sponsoring companies Delphi
  - Early applications of developed technology
  - Dedicated development of software products related to the research

• 2012 : Delft Inversion
  - Founded by Dries Gisolf, Peter Haffinger and Panos Doulgeris
  - Commercial entity (also for non-sponsoring companies)
  - Focus on high-resolution elastic inversion
Delphi Studio for Imaging

• Currently:
  - Guus Berkhout & Eric Verschuur founders
  - One employee (former M.Sc. Student)
  - One consultant (former M.Sc. Student)
Delphi Studio for Imaging

- One-to-one projects for Delphi Sponsoring companies
  - Demonstration of newly developed methods to client’s dataset (beyond capabilities of the involved Ph.D. project)
  - Further development of newly developed technology tailor-made for client (software development)
  - Consultancy to help client in using the Delphi tools (for in-house application → transfer of technology)
Delphi Studio for Imaging

• Selection of projects from last few years:
  - Deblending of SimSrc measurements
  - Primary estimation (EPSI) on marine data
  - Internal multiple removal on land data
  - Near-surface layer-replacement for land data
  - Developing interpolation software for specialized applications (3D marine, 3D land)
  - Imaging of 3D VSP data (software development)