Innovation in Oil & Gas: Impacts of Digitalization on Operations

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1. Modeling Strategies for O&G fields
Simulation, Analytical and Data-driven Models

- Heuristics, Correlations and Analogues (PVT models, Recovery Factor,)
- Statistical & Signal Processing methods (Regressions, Wavelets, Laplace, ...)
- Machine Learning and Neural-networks (Linear, recurrent, deep learning, ...)
- Simple analytical models (Material balance, Decline Curves, Buckley-Leverett, ..)
- Simple numerical models (Capacitance-Resistance, Parametric, Streamlines, ...)
- Full-physics reservoir simulation (Black-Oil, Compositional, Dual-Porosity, ...)
Data-driven models vs Physics (?)

Example: Modeling oil production rate for pseudo-steady state flow circular reservoir

Darcy’s law, integration in cylindrical coordinates:

\[ Q_o = \frac{2\pi KK_o h}{B_o \mu_o \left( \ln \left( \frac{r_o}{r_w} \right) - 0.75 + s \right)} (P - P_{wf}) \]

- **K** and **h** can be (partially) characterized by the location of a well
- **B_o** and **µ_o** are function of the average reservoir pressure
  - Average reservoir pressure is a strong function of the cumulative production, reservoir properties and drainage area
  - The drainage area of a well is determined by reservoir characteristics, cumulative production and number of wells in the field.
- **K_{ro}** is a function of the oil saturation, which is strongly related to the cumulative production.
- **P_{wf}** and skin factors are the most likely time-dependent and are usually hard to quantify

- Let data speak too!
- Build from physics...
- .. but don’t restrict to textbook models and assumptions
- Data-driven models can capture underlying physics under right framework.
- AI + engineering context can provide optimum solution
Example: Determining OWC

**Example:** Reduce the Risks of Excessive Water Production in Infill Drilling Campaign

- Generalized Material Balance Equation
- Determine Reservoir Drive Mechanisms & $S_{avg}(t)$
- Creating WOC & GOC Matching and Including $S_{avg}(t)$, Historical BT & Coning

- Data-driven models must be combined with fundamental, engineering understanding of reservoir behavior (!)
Considerations to Select Right Modeling Strategies

i. Do we really know our reservoir?
ii. Do we have data?
iii. What is the time frame to solve the problem?
iv. Context: reservoir management?
2. Automation Opportunities in RM
A Systematic Approach to Machine Learning Modeling

1. **Clearly understanding the goals** of the problem we want to model

2. **Data pre-processing** (data gathering, exploration/visualization, transformation/reduction)

3. **Determine the machine learning task** (i.e., translate step 1 into a more specific statistical question).

4. **Apply machine learning algorithm** (e.g., ANN, Random Forests, SVM...)

5. **Interpret results** of the machine learning algorithm

6. **Deploy the model** (integrate model into operational system).
I/O view of the modeling problem

Input → Run Model/s → Output

This is easy to automate!
Modeling Execution Process

Reservoir Management
- Recovery Design (e.g., D&C design)
- KROs
- Pressure Maintenance
- Depletion
- Reserves
- Surveillance
- Workovers
- Economics
- ....

Can we automate the whole thing?
Organizational Capabilities for Automation

i. Good problem framing (Mgmt&Engineering&Quants)
ii. Allow lateral thinking when it comes to automation
iii. Agile/Lean Development
iv. Emphasize knowledge mgmt
3. Machine Learning and AI applications
Application 1: Eagle Ford

Eagle Ford

- Client owns land in Eagle Ford; first wells show disappointing results.

- Client is considering 3 options:
  I. Change operator
  II. Sell entire position
  III. Be patient and wait for technology to improve

- Want quantitative answers
Application 2: FDOs in non-economical Mexico field

- **Objective**: Opportunity identification in very large tight-oil field

- **Timeframe**:
  - Preliminary data collection
  - 3 weeks of focused work
  - 1 week of meetings, reviews and workshops

- **Approach**:
  - Top-down workflow focused on value creation
  - Speed provided by fast Quantitative Analysis
  - Guidance provided by experienced engineers & geoscientists
  - Analysis accelerated by proprietary technologies
  - Diversified modeling approaches
  - Strong Knowledge Management foundation
  - Thousands of opportunities identified using QRI AI and Machine Learning Algorithms and Workflows.
Application 3: Well Target Identification

Problem: To identify new well targets using AI in complex fractured carbonate

BASIC WELL DATA

X=489610.9; Y= 1995589; Z=3784.7; Length = 12m

OFFSET WELL DATA

Ring 1
Ring 2
Ring 3
Ring 4

GEOLOGICAL DATA

PRESSURE DATA

PRODUCTION DATA

PVT DATA
Application 3: Well Target Identification

Problem: To identify new well targets using AI in complex fractured carbonate.

VALIDATION SET: True values vs predictions

MAPE analysis (MAPE = Mean Absolute Percentage Error):

- MAPE validation set = 34%
- MAPE for 97% percentile = 30%

Potential good locations for new producers derived from AI.
Application 4: Drilling

SDS - SpeedWise® Drilling Solutions

- **Problem:** Analyzing drilling performance (and opportunities) for field with > 200 wells

- Advanced technology to improve drilling efficiency.
- Rapid and intelligent analysis of drilling data.
- SDS automates metrics (NPT, DEI, ROP) and analytics
- Value creation (NPV) by optimizing rig schedule, drilling practices, etc

SDS - SpeedWise Drilling Solutions

- Automatically extract hole size and depth for the daily description
- Overview of each field/asset
- Well book for each well
- Online interactive visualization
- Drill performance analytics
- Dual drilling and reservoir management event & automated insights

Major activities during D&C: Drilling (76.4%), Casing (7.8%), Completion (6.9%)

Major NPT causes: LostCirculation (10.8%), Logistics (10.4%), WellControl (10.1%)

Highest completion capital was spent in 2015: 46.4 MMUSD

Highest completion capital was allocated to FA field during the past 7 years: 107 MMUSD

Average completion cost per 12 month cum. increased from 2.4 to 9.4 USD/bbl in the past 6 years

Lowest recent completion cost per 12 month cum.: field FA
AI frameworks to solve problems in specialized domain that typically requires human expertise

AI solutions will draw upon the our worldwide knowledge of reservoirs + technology applications.

Knowledge Base Systems, Expert Systems, Machine Learning and Heuristics to generate:

- Insights
- Business optimization
- Process automation