Real-time intelligent sensor selection for subsurface flow and fracture monitoring

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Focusing on artificial intelligence for deep reservoir monitoring

Robotics for subsurface downhole evaluation
Background

- Measuring properties in the reservoir represents a major **challenge** due to the **sparsity** of measurements and **lack of direct measurements**
- In-situ reservoir measurements are key to obtain a greater insight farther of the wellbore
- **Solution:**
  - Small-scale reservoir sensors are transported into the reservoir and will provide temperature and pressure data
What are subsurface reservoir sensors?

- **In-house out-of-the-box idea**
- Tiny devices with wireless communication, and sensing capabilities
- Real-time mapping of fracture networks
- Real-time reservoir information
How subsurface sensing technology works
In-situ reservoir sensing is quintessential with several sensors available to operate in reservoir conditions.

Challenges

- Sensing data quality
- Power requirements
- Data transmission quality

Solution

Optimally select sensors to maximize coverage while maintaining data quality.
From the fracture network to the uncertainty and selection of sensors.
Sensor Optimization Problem

**Problem Statement**

Select the minimum numbers of sensors in each step the cost function (which is inversely proportional to the remaining power) subject to maintaining sufficient data quality and ensure that each fracture is covered by a sensor (NP-hard).

\[
\begin{align*}
\min & \quad f'z \\
\text{s.t.} & \quad Cz > 0, \forall i \in N \\
& \quad Uz \leq b_u, \forall i \in N \\
& \quad z_i \in \{0,1\}, \forall i \in N
\end{align*}
\]

**Solver**

We utilized a fast and efficient branch and bound solver for fast convergent to optimum for the integer optimization problem.
Network Estimation Performance

Training - Regression - R: 0.90798

Validation - Regression - R: 0.90441

Best Validation Performance is 0.002272 at epoch 80

Testing - Regression - R: 0.90565
Sensor optimization

Sensor Activity Overview -2019-04-01

Sensor Activity Overview -2019-06-15

Sensor Activity Overview -2019-09-28

Sensor Activity Overview -2020-01-11
Sensor Activity Overview

Sensor Utilization

Sensor Utilization Histogram

Days active

Sensor Number

Number of sensors

Days active

0 50 100 150 200 250 300

0 20 40 60 80 100 120 140 160 180

0 50 100 150 200 250 300

0 100 200 300

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Conclusions

Optimum selection of sensors essential for long-term reservoir monitoring

Good reservoir coverage and accurate measurements by the sensors

Longevity of operation depends on reservoir fracture network structure