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

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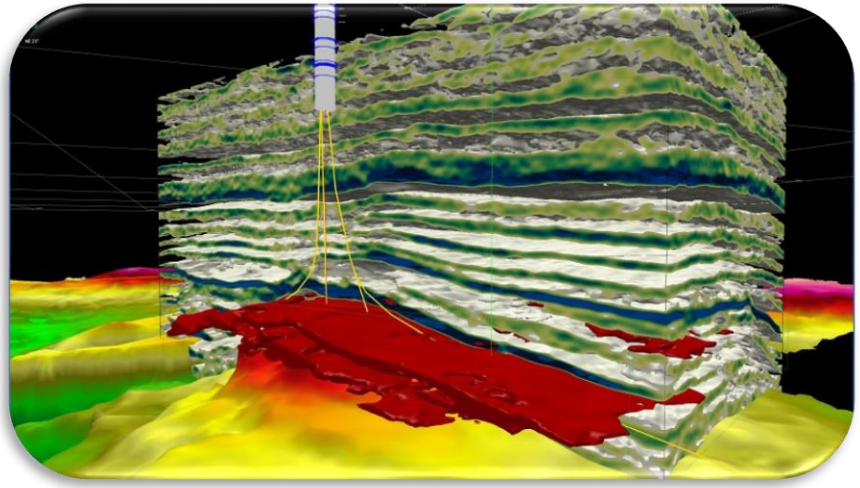
Biography – Klemens Katterbauer

- AI/Robotics Specialist at Saudi Aramco
- PhD, King Abdullah University of Science & Technology
- Focusing on artificial intelligence for deep reservoir monitoring
- Robotics for subsurface downhole evaluation

Background



Example of reservoir section

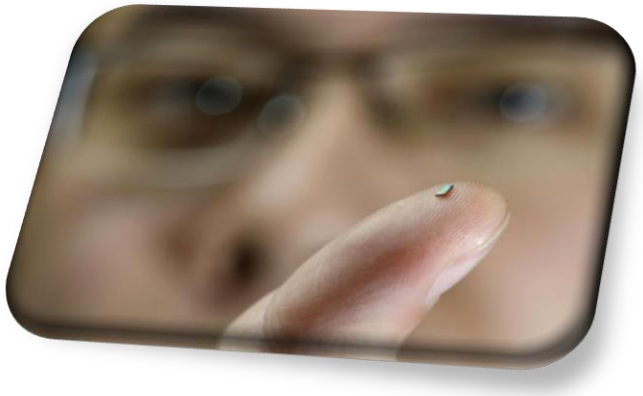
Reservoir fracture illustration

- 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

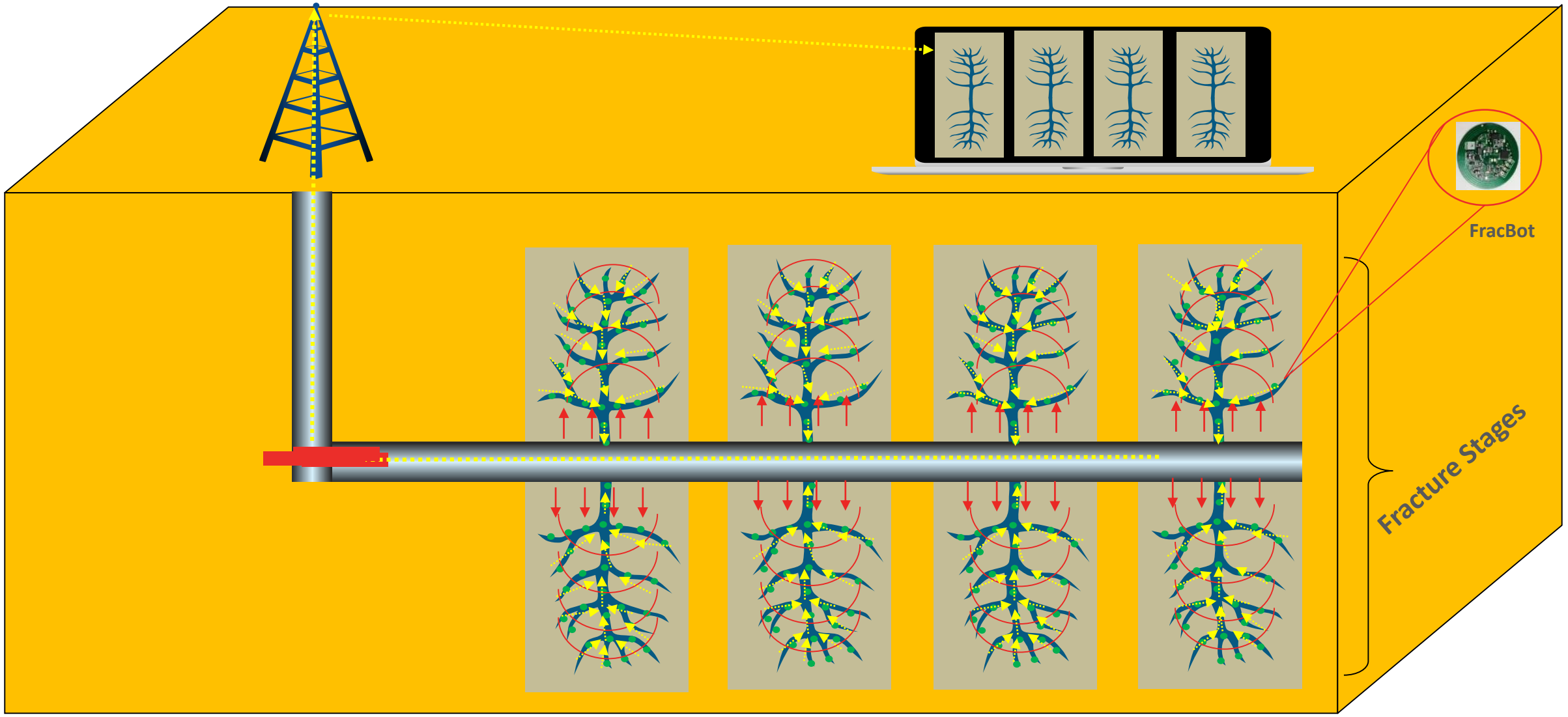
Miniaturized sensor

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



Challenges - Sensing

In-situ reservoir sensing is quintessential with several sensors available to operate in reservoir conditions

Challenges → **Solution**

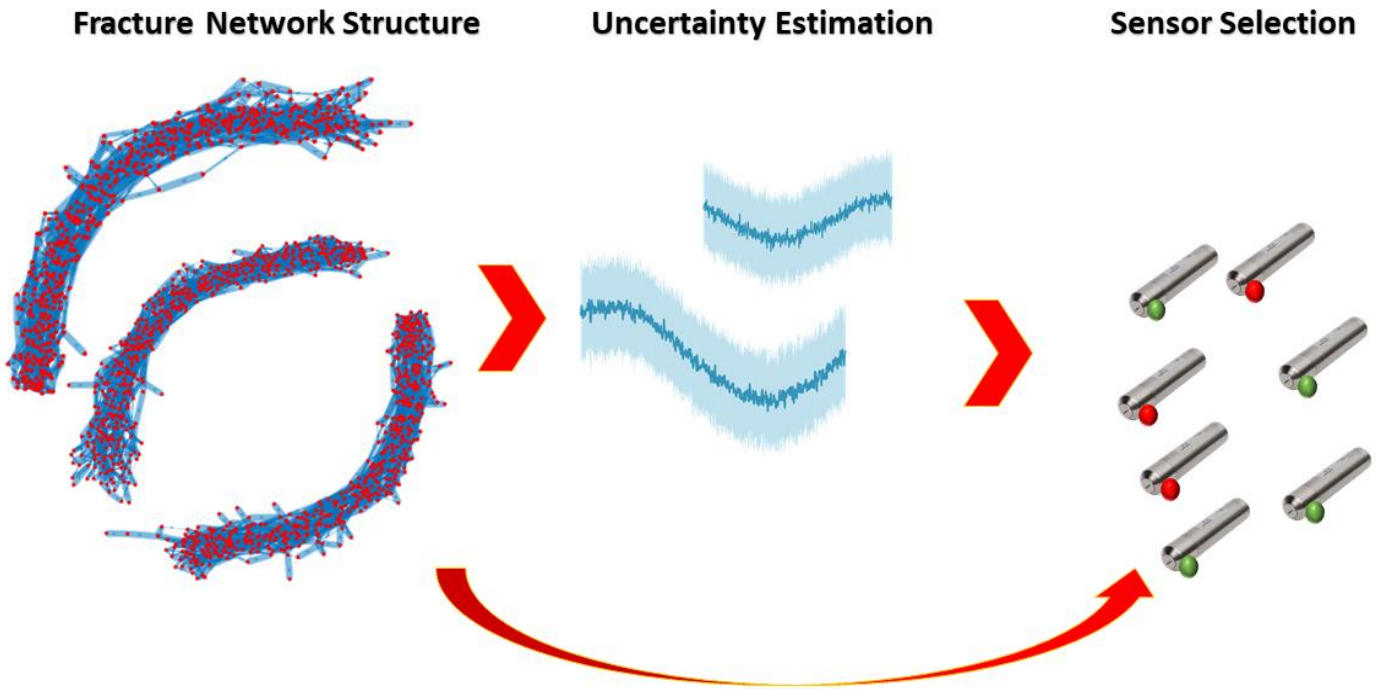
Sensing data quality

Power requirements

Data transmission quality

Optimally select sensors to maximize coverage while maintaining data quality

Framework Illustration



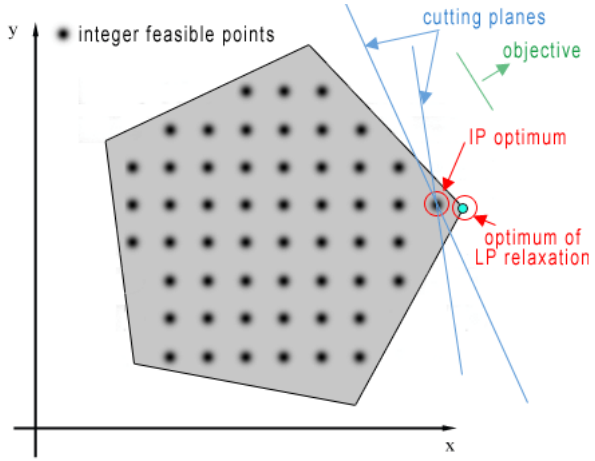
From the fracture network to the uncertainty and selection of sensors.

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).

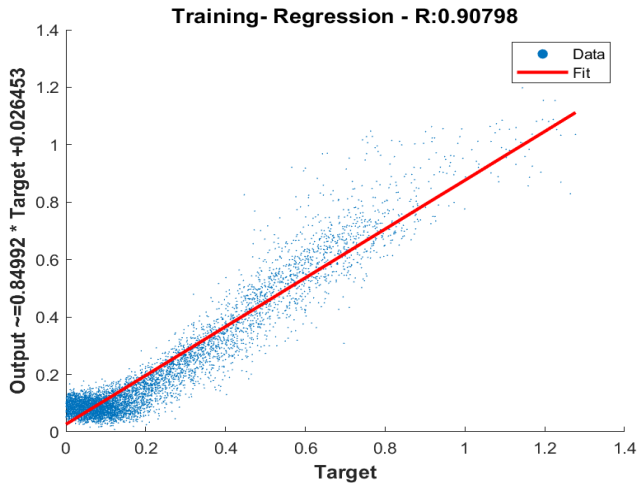
$$\min f'z$$
$$s.t.\ Cz > 0, \forall i \in N$$
$$Uz \leq b_u, \forall i \in N$$
$$z_i \in \{0,1\}, \forall i \in N$$

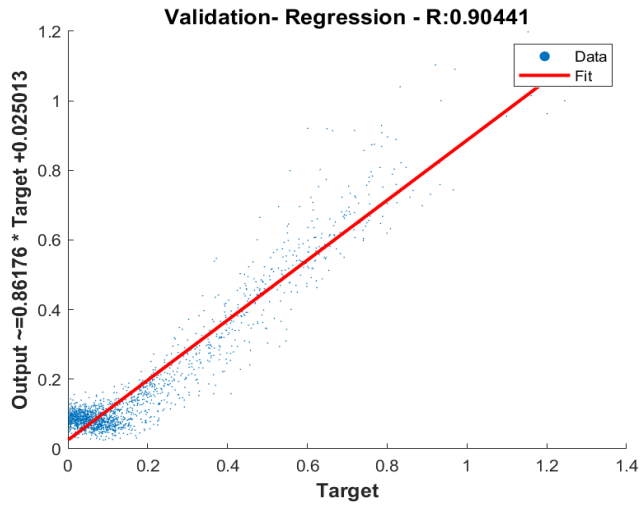


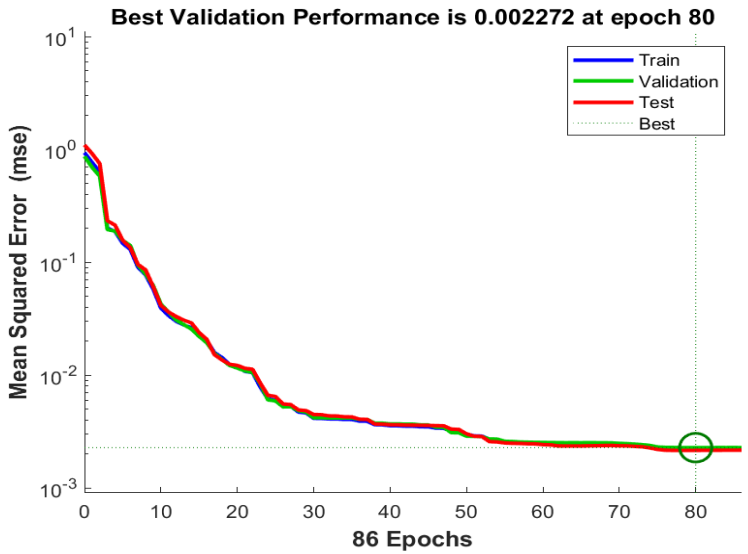
Solver

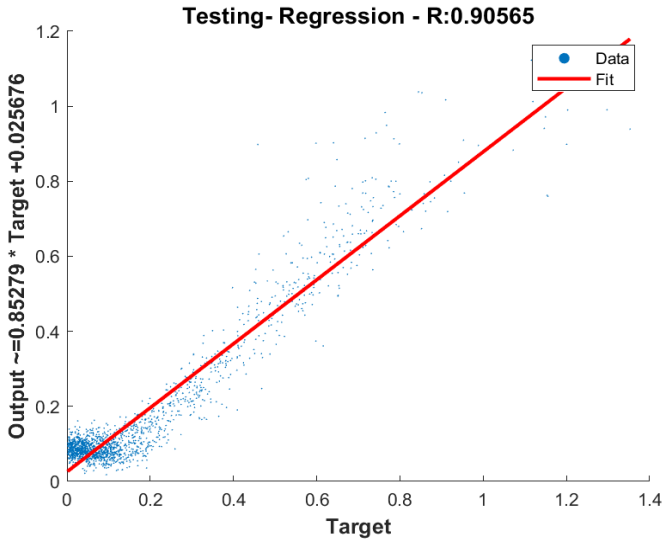
We utilized a fast and efficient branch and bound solver for fast convergent to optimum for the integer optimization problem.

Network Estimation Performance

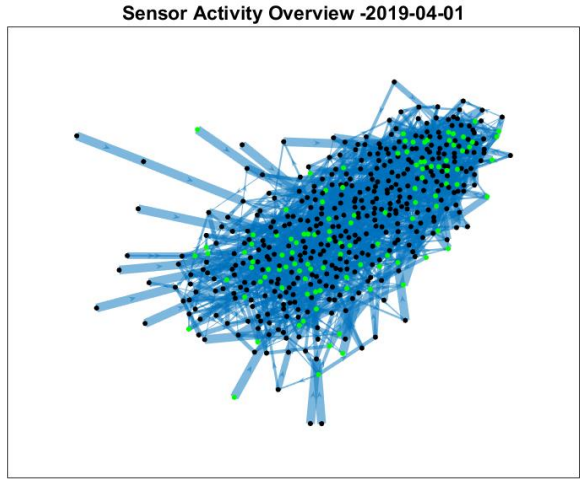


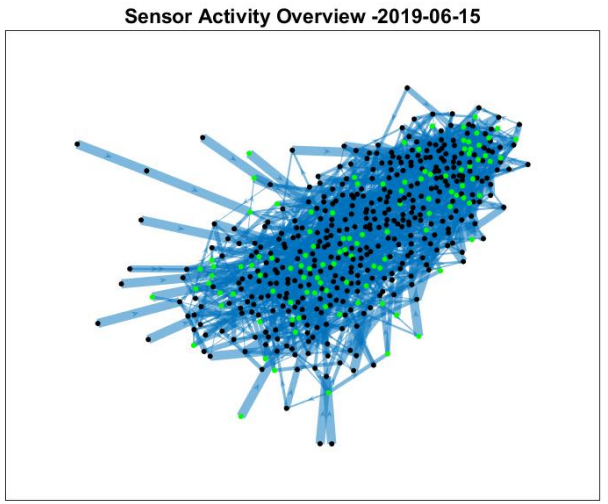


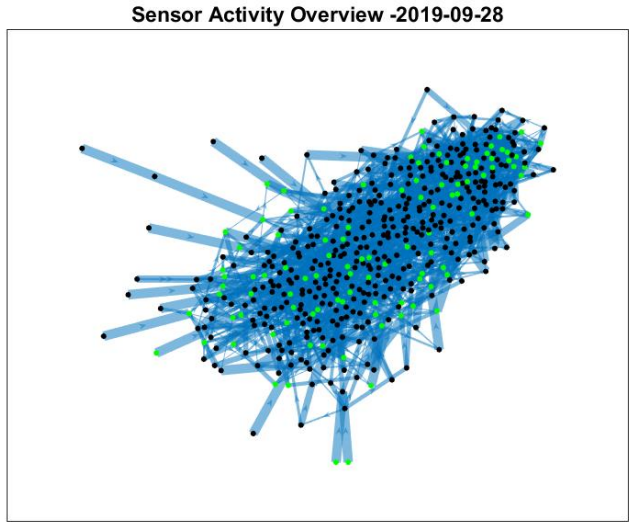


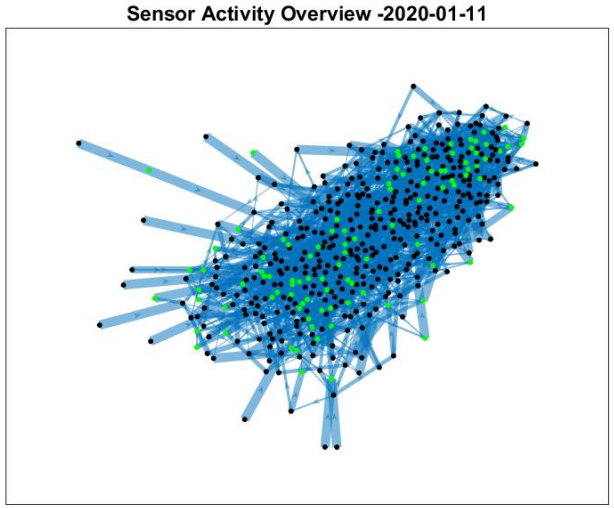


Sensor optimization

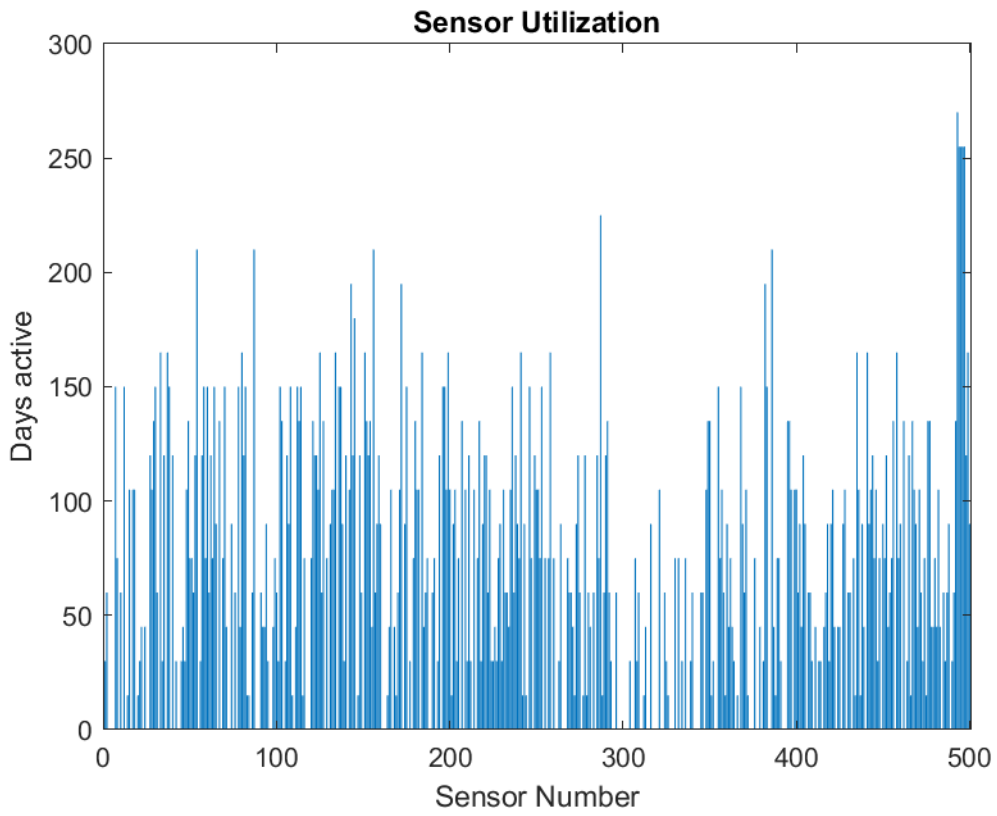


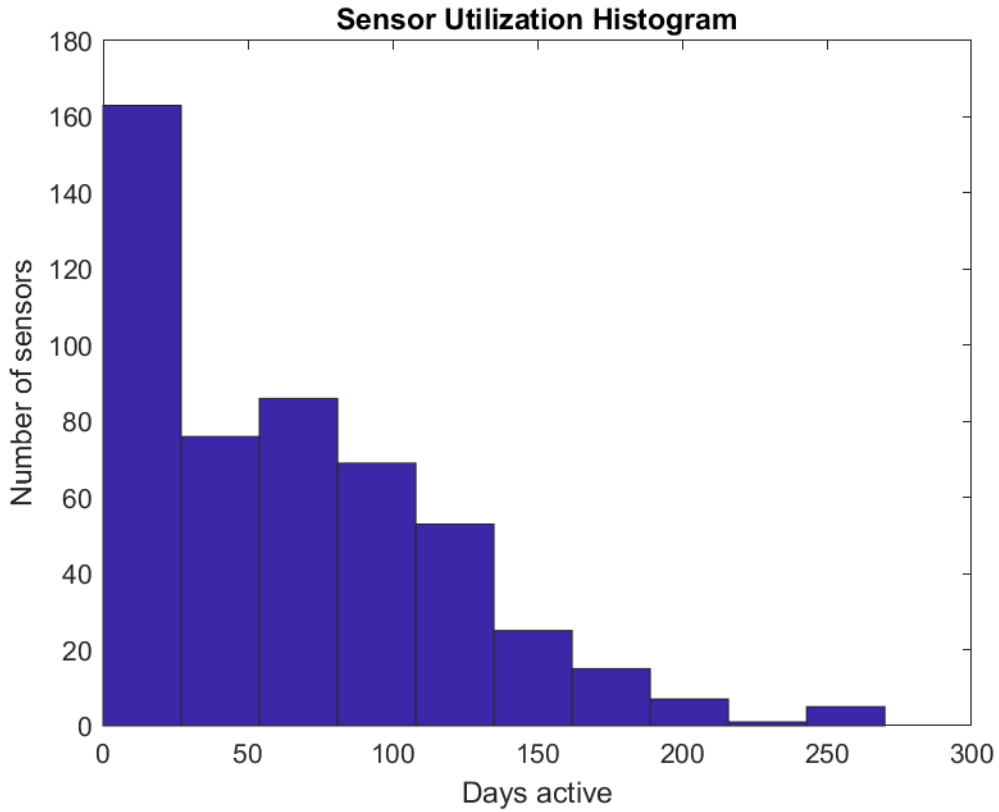






Sensor Activity Overview





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