Optimizing Cyclic Steam Oil Production With Genetic Algorithms

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Cyclic Steaming Process
- Trying to produce heavy, viscous oil from diatomite – like trying to get roofing tar out of a brick
- Need to inject steam to:
  - fracture the rock
  - reduce the viscosity of the oil
- We do this using a cyclic process:
  - Inject steam for 3-4 days
  - Let it soak in for 2-3 days
  - Produce oil for ~30 days (production declines exponentially with time)
  - Repeat

Optimization Opportunity
- Maximize cycle time (inject steam less frequently) because there is no production during steam and soak periods
- Minimize cycle time (inject steam more frequently) because oil production is highest immediately after returning the well to production, then declines rapidly
- There is an optimum cycle length (OCL) for every well that results in maximum productivity

This is a formidable optimization problem
- Large number of wells
- Multiple objectives – Production, Profit, Steam efficiency
- Multiple constraints –
  - Steam availability
  - Steam loop balancing
  - Facility constraints
- Special situations
  - Steam generator maintenance
  - Well shutdowns due to maintenance
  - Communicating / Gassy wells
- A Scheduling tool would be very helpful
Cyclic Steam Optimization Project

- **Objective**
  - Develop a tool to optimize the steam injection schedule to increase oil production and decrease steam-oil ratio

- **Project Challenges**
  - Complex combinatorial problem
  - Pockets of feasible space
  - Data quality is not very good
  - Well performance models are not readily available
  - Work process will change significantly
  - Operators must buy into the new tool & work process

- **Scheduler has 3 components**
  - **Visualizer** – Reconciles data & predicts future performance for individual well
  - **Simulator** – Simulates field-wide performance for a given steaming sequence
  - **Optimizer** – Uses Genetic Algorithm to optimize steaming sequence

- **Why is GA suitable for this problem**
  - Optimize over a long period of time
  - Discrete / integer variables
  - Pockets of feasible space
  - Computation time not an issue
  - Some constraints can’t be expressed in a mathematical form
  - Multiple solutions are preferred by the user

- **GA Features**
  - Chromosomes
    - Enumerated chromosomes
    - Literal representation
    - Sequential representation – Preferred
    - Sequence length – Heuristic based
  - Seeding Algorithm based on Optimum Cycle Length
  - User defined operators – insert, delete, swap
  - User controlled termination criteria
  - Inclusion of both hard & soft constraints
**Closed loop test**
- Conducted during July – November 2001
- One gauge setting - 21 wells
- Similar constraints as the whole field
- Objective was to maximize oil production over next 60 days
- Compared the performance against pre-selected baselines

**Closed loop test proved the feasibility**
- Production during closed-loop test increased by 4 - 18% (depending on which baseline you used for comparison)
- Steam injection also increased by 11 - 41% (was this fair?)
- The field operators & engineers made the new work process a success
- Project is economically viable and technologically feasible

**Challenges / Strategies for scale up**
- Risk mitigation – Phased development
- Retain performance – Heuristics, New GA operators
- Robust optimization – Breeding pool
- Evaluating the success of the project - ?
- Project management – Constant tracking and communication

**Project economics are very attractive**

**Project Economics**
- NPV (@10%) = $5.8MM
- DPI (@10%) = 5.25
- Payout = 9 months
- Total Investment = $1.4MM
• **Lessons Learned**
  
  - GA can be effectively used for production optimization
  - Technology implementation is as much about right people as it is about right technology
  - External peer review resulted in selecting software that is better suited for field-wide implementation
  - Design of a pilot for a complex facility is not an easy task but very critical
  - Measurement accuracy / frequency very important for optimization

• **Questions?**