Development of an Intelligent Systems Approach for Restimulation Candidate Selection

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OUTLINE

• Introduction
• Objective
• Background
• Methodology
• Application
• Conclusion
INTRODUCTION

- In 1996, GRI began investigating potential for natural gas production enhancement via restimulation. Initial findings were:
  - Significant potential
    - >5 tcf incremental reserves in 5 years
  - Low reserve costs when successful
    - $0.10 - $0.20/Mcf
  - Critical success factors
    - Candidate selection (85/15 rule)
    - Problem diagnosis
    - Treatment strategy
INTRODUCTION

• Major obstacles are:
  – Industry’s (understandable) reluctance to restimulate “good” wells, which frequently are the best candidates.
  – Lack of “tools” or methods to cost-efficiently identify candidates and diagnose well performance problems.
OBJECTIVE

• Develop cost-effective, reliable methodologies to identify wells with high restimulation potential.

Several methods were investigated both simultaneously as well as in conjunction with one another. Intelligent Systems seems to be one of the better approaches.
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BACKGROUND

• Using virtual intelligence techniques to select restimulation candidates.
  • This method had been applied to restimulation candidate selection in a gas storage field in the past and had shown promise.

• Using a hybrid approach
  • Artificial Neural Networks
  • Evolutionary Optimization
  • Fuzzy Logic
VIRTUAL INTELLIGENCE

• A collection of several analytical tools that attempts to imitate life.
• Exhibit an ability to learn and deal with new and dynamic situations
• Possess attributes of reason such as generalization, discovery, association and abstraction.
VIRTUAL INTELLIGENCE

Conventional Computing
- Bivalent Logic
- Numerical Analysis
- Probability
- Differential Equations
- Functional Analysis
- Mathematical Programming
- Approximation Theory

Quantitative, Precise, Formal

Soft Computing
- Fuzzy Logic
- Neurocomputing
- Probabilistic Reasoning
- Genetic Algorithms
- Belief Networks
- Chaos
- Rough Sets

Qualitative, Imprecise, Informal

Precision and certainty carry a cost
VIRTUAL INTELLIGENCE

• Biologically Inspired

• Adaptive learning

• Parallel, distributed information processing

  _ _ P_NN_ _ S_V_D
  _ _ S _
  _ _ P_NN_ _ _ _RN_D
VIRTUAL INTELLIGENCE
• The metaphor underlying evolutionary optimization is that of natural evolution. In evolution the problem each species face is one of searching for beneficial adaptations to a complicated and changing environment. The “knowledge” that each species has gained is embodied in the makeup of the chromosomes of its member.
VIRTUAL INTELLIGENCE

- **NEW POPULATION**
- **FITNESS EVALUATION**
- **Convergence?**
  - **NO**
  - **SELECTION**
  - **MATING**
    - Crossover - Mutation
  - **YES**
    - Optimized Solution
- **INITIALIZATION**

Evolutionary Optimization
VIRTUAL INTELLIGENCE

Crossover & Mutation
VIRTUAL INTELLIGENCE

EVERYTHING IS A MATTER OF DEGREES

Paradox in modern math

Bit Value

1

1/2

0

Bit Value

Round Off

Round Off

Fit Values
2 people answering the following question?

Are you satisfied with your job?

1 = Totally satisfied
0 = Totally unsatisfied
VIRTUAL INTELLIGENCE

![Graph showing membership levels for oil price]

- **Low** membership range
- **Good** membership range
- **High** membership range

**Y-axis:** Membership

**X-axis:** Oil Price

- $5.00 to $10.00
- $10.00 to $15.00
- $15.00 to $20.00
- $20.00 to $30.00
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METHODOLOGY

• A three step process:

Step 1.

• Develop a reliable data set using well files and production data.
• Identify the production indicator (5 yr. cum. or Best 12 months production) to be used as model output.
• Build a representative neural model of the stimulation process in the formation.
• Test the neural model for accuracy.
METHODOLOGY

• A three step process:

Step 2.

• Identify the controllable (fluid type, sand concentration, ...) and uncontrollable (pay thickness, porosity) parameters in the neural model.

• Develop a multi-dimensional, evolutionary optimization process to find the best combination of controllable parameters that results in maximum output (5 yr. cum. ...)

METHODOLOGY

• A three step process:

Step 3.

• Using general engineering expertise and field engineers input to identify parameters that would have an impact on the decision making process. These parameters do not have to be precise in value.

• Build a fuzzy decision support system that incorporates the results from steps 1 and 2, and combine them with engineering expertise for final candidate selection.
METHODOLOGY

Data Set

Well Files

Production Data

Neural Nets

Genetic Algorithms

Engineering Expertise

Fuzzy Logic

Restimulation Candidates
## METHODOLOGY

<table>
<thead>
<tr>
<th>Category</th>
<th>Input Parameter</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>X</td>
<td>X coordinates of the well (east-west)</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>Y coordinates of the well (north-south)</td>
</tr>
<tr>
<td></td>
<td>KB Elevation</td>
<td>Kelly Bushing Elevation</td>
</tr>
<tr>
<td><strong>Reservoir</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Permeability</td>
<td>From Type Curve matching analysis</td>
</tr>
<tr>
<td></td>
<td>Drainage Area</td>
<td>From Type Curve matching analysis</td>
</tr>
<tr>
<td></td>
<td>Total Gas-Ft</td>
<td>Sum(Porosity * gas saturation * net pay) (all zones)</td>
</tr>
<tr>
<td><strong>Completion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total H Completed</td>
<td>Total completed thickness (all zones)</td>
</tr>
<tr>
<td></td>
<td>Total No. of Holes</td>
<td>Total number of perforation holes</td>
</tr>
<tr>
<td></td>
<td>Completion Date</td>
<td>Date of well completion</td>
</tr>
<tr>
<td></td>
<td>Number of Zones</td>
<td>Total number of zones completed</td>
</tr>
<tr>
<td><strong>Frac</strong></td>
<td>Frac Number</td>
<td>A well may have up to 7 frac jobs</td>
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<tr>
<td></td>
<td>Fluid type</td>
<td>Gelled oil, ungelled oil, linear gel, cross-linked gel</td>
</tr>
<tr>
<td></td>
<td>Fluid Volume</td>
<td>Total amount of fluid pumped in all fracs</td>
</tr>
<tr>
<td></td>
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Step 1. Neural Model Building.

**METHODOLOGY**

- Correlation Coefficient = 0.96

Training Data

- Actual 5 Yr. Cum. (mcf)
- Network 5 Yr. Cum. (mcf)
Step 1. Neural Model Building.

**METHODOLOGY**

- Correlation Coefficient = 0.72
Step 1. Neural Model Building.

**METHODOLOGY**

![Bar chart showing categories being eliminated with R square values.]

- None: R square = 0.95
- Location: R square = 0.82
- Reservoir: R square = 0.65
- Completion: R square = 0.52
- Frac: R square = 0.50

Well Based Analysis

Categories Being Eliminated
## METHODOLOGY

### Step 2. Evolutionary Optimization.

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<td>Total number of zones completed</td>
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### Frac

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### Uncontrollable Parameters

- Controllable Parameters
METHODOLOGY

Post-Optimization 5 yr. cum. — Pre-Optimization 5 yr. cum.

Potential 5 yr. cum.
### METHODOLOGY

<table>
<thead>
<tr>
<th>Fracs/Zone</th>
<th>Pressure</th>
<th>Potential Five Year Cum.</th>
<th>Pressure</th>
<th>Potential Five Year Cum.</th>
<th>Pressure</th>
<th>Potential Five Year Cum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Low</td>
<td>T</td>
<td>Medium</td>
<td>T</td>
<td>High</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>VT</td>
<td>T</td>
<td>Low</td>
<td>VT</td>
<td>Med.</td>
<td>VT</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>No</td>
<td>Medium</td>
<td>VT</td>
<td>Low</td>
<td>VT</td>
</tr>
<tr>
<td>Med.</td>
<td>Low</td>
<td>VT</td>
<td>Medium</td>
<td>VT</td>
<td>Med.</td>
<td>VT</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>No</td>
<td>Medium</td>
<td>VT</td>
<td>Med.</td>
<td>VT</td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>T</td>
<td>High</td>
<td>VT</td>
<td>Med.</td>
<td>VT</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>No</td>
<td>High</td>
<td>VT</td>
<td>Med.</td>
<td>VT</td>
</tr>
<tr>
<td></td>
<td>MayBe</td>
<td>MayBe</td>
<td>Low</td>
<td>Yes</td>
<td>High</td>
<td>VT</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>MayBe</td>
<td>Medium</td>
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<td>Med.</td>
<td>VT</td>
</tr>
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**A sample fuzzy rule.**

**IF**
- the well has a **HIGH** potential 5 yr. cum.  **AND**
- demonstrates **HIGH** pressure  **AND**
- the ratio of the number of fracs per number of zones is **LOW**

**THEN**
- the well **IS A CANDIDATE**

METHODOLOGY

Approximate Reasoning

<table>
<thead>
<tr>
<th>Truth Qualification</th>
<th>Fairly True</th>
<th>TRUE</th>
<th>Very True</th>
</tr>
</thead>
<tbody>
<tr>
<td>FT</td>
<td>T</td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>

The diagram illustrates the fuzzy logic approach to decision-making, where truth values range from 0 to 1, representing the degree of membership in the sets of Fairly True, True, and Very True.
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## APPLICATION

<table>
<thead>
<tr>
<th>Candidate Well</th>
<th>Ranking using the new approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRB 45-12</td>
<td>20</td>
</tr>
<tr>
<td>GRB 27-14</td>
<td>112</td>
</tr>
<tr>
<td>NLB 57-33</td>
<td>No Pressure Data</td>
</tr>
<tr>
<td>Wells in the analysis</td>
<td>123</td>
</tr>
</tbody>
</table>
APPLICATION
APPLICATION

GRB 27-14

Restimulation

Date

Gas Rate (Mscf/d)

WATER

Water Rate (Bpd)

0 10 20 30 40 50

0 100 200 300 400 500

01/01/1999 02/01/1999 03/01/1999 04/01/1999 05/01/1999 06/01/1999 07/01/1999 08/01/1999 09/01/1999 10/01/1999 11/01/1999 12/01/1999
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CONCLUSIONS

• Preliminary results indicate that intelligent systems demonstrate good potentials in selecting successful restimulation candidates.

• The tool developed in this study has the potential to learn and grow as the restimulation project in the field proceeds.