How Much Information is Enough?
Value-of-Information for IOR Operations.

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Information gathering is one of the most important activities in an operating company.

- The oil and gas industry spends billions of dollars each year on collecting and analysing information.

- The value of information lies in its ability to potentially reduce uncertainty.

- Yet we seldom ask questions such as:
  - How much uncertainty reduction is enough?
  - How do we know when to stop?
If the goal is to reduce uncertainty, there is no obvious and consistent stopping rule as we can always further reduce the uncertainty by gathering more information.
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- When is the history match good enough?
- How much uncertainty reduction is enough?

Graph: Production vs. Time for History Match 3: Extensive
Stopping criteria

■ Common stopping criteria
  – Running out of time
  – Decision must be made now
  – Engineering/scientific intuition
  – Good enough for …

■ Better stopping criteria
  – Stop when further uncertainty reduction
    1. does not add value
    2. cannot change the decision at hand

But how can we know that?
VOI analysis allows us to distinguish between constructive and wasteful information gathering

- Value-of-information (VOI) analysis evaluates the benefits of collecting additional information *prior to collecting the information*.

- Such information gathering may be worthwhile if it holds the possibility of changing the decision that would be made without further information.

- The VOI is *defined* as the most the decision maker should pay for additional information on the event of interest:

\[
\text{VOI} = \text{Expected value with additional information} - \text{Expected value without additional information}
\]
VOI Intuitively

Throw a die and hide top face. What is the probability of a 3?

Now get information. Has the top face changed? No. Has the probability that it’s a 3 changed? Yes! What is the probability of a 3 now? 1/3

Is this information valuable if you were making a betting decision? How much would (should!) you pay for it?
VOI Example: How much should you pay to see center of top face.

Betting Game

- Win $100 if it is a 3. Lose $10 if it is not.

How much are you willing to pay to look at the center?
**VOI Example: Base Bet**

Ev = \((1/6)\times\$100 + (5/6)\times(-\$10)\) = \$8.33
**VOI Example: Option to Acquire Information**

EV = \((\frac{1}{6}) \cdot 100 + (\frac{5}{6}) \cdot (-10)\)  
= $8.33
VOI Example: Required Probabilities

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VOI Example: Required Probabilities

Base Bet

Bet
- 3
  1/6
  +$100
- 3'
  5/6
  -$10

Don't Bet
- $0

Look at Center
- Spot
  - 1/2
  - $0

- Spot'
  - 1/2
  - $0

Bet
- 3 | Spot
  - 1/3
  - $100

- 3' | Spot
  - 2/3
  - -$10

Don't Bet
- 2/3
  - $0

Bet
- 3 | Spot'
  - 0
  - $100

- 3' | Spot'
  - 1
  - -$10

Don't Bet
- 1
  - $0

EV = \( \frac{1}{6} \times 100 + \frac{5}{6} \times (-10) \)

= $8.33
VOI Example: Solving the Tree

\[ EV = (1/6)\times 100 + (5/6)\times (-10) = 8.33 \]

\[ EV = (1/3)\times 100 + (2/3)\times (-10) = 26.67 \]

\[ EV = 0\times 100 + 1\times (-10) = -10 \]
**VOI Example : Solving the Tree**

- **Base Bet**
  - **Bet**
    - 3
      - 1/6
        - +$100
    - 3'
      - 5/6
        - -$10
  - **Don’t Bet**
    - $0
  - **Look at Center**
    - **Spot**
      - 1/2
        - $26.67
    - **Spot’**
      - 1/2
        - $0

\[
EV = (1/6) \times 100 + (5/6) \times (-10) = 8.33
\]
VOI Example: Solving the Tree

```
| 3       |
| 1/6     |
| +$100   |
| 3'      |
| 5/6     |
| -$10    |
```

Bet: $EV = (1/6)*$100 + (5/6)*(-$10) = $8.33

Don't Bet: $EV = (1/2)*$26.67 + (1/2)*$0 = $13.33

**VOI** = $13.33 - $8.33 = $5

Therefore pay anything up to $5 to see the center.
Modeling Information Gathering

- When gathering information, we should be concerned with two uncertainties:
  1. The uncertainty we hope to learn about
     - The event of interest
  2. The test result
     - The observable event

- We use Bayes’ theorem to infer the event of interest based on the test results.
IOR Information Gathering - Example

- The oilfield Chemo is currently being water flooded and has reached a water cut of 90%.
- The operator is considering implementing a polymer flood (PF) into a portion of the field.
- Uncertainty as to whether the PF will be viable and profitable.
- Using historical data as well as expert knowledge they identify the following possibilities and probabilities for IOR resulting from the PF:
  - 50% chance of success resulting in incremental profit of $165 MM
  - 50% chance of failure resulting in incremental loss of -$105 MM
Example -- continuation

PF Decision – Main Uncertainty is the Profitability

Prior Information

a) \( P(\text{PF is successful}) = 50\% \)

b) The pay-offs (NPVs) are
   
   \[ \begin{align*}
   &\text{If Success (S):} & \$165 \text{ MM} \\
   &\text{If Failure (F):} & \$-105 \text{ MM}
   \end{align*} \]

This tree represents the decision without additional information on the success of the PF.

\[
EV = (0.5)(165) + (0.5)(-105) = \$30 \text{ MM}
\]
Can conduct a core flood test to investigate the viability of a polymer flood (PF), which again gives information about the possible increase in recovery resulting from a PF.

Based on past experience, combined with expert input:

- Test will indicate “success” with probability 0.75 if the PF is a success, $P(\text{"success"} | \text{success}) = 0.75$, and
- “failure” with probability 0.85 if the PF is a failure, $P(\text{"failure"} | \text{failure}) = 0.85$

These metrics are not reported directly by the core flood itself but rather through the interpretation of the core flood by experts.
Modeling Information Gathering - Example

Likelihood function:

The inferential tree is calculated from the assessed tree via Bayes’ theorem.

- This is often referred to as "flipping the tree"
Example -- continuation

VOI on Core Flood

If the core flood can be conducted at a cost less than $24 million, it will add value

\[
\text{VOI} = \$54 - \$30 = \$24 \text{ MM}
\]
There are four criteria that information (or a test) must meet in order to be worthwhile (or value creating).

1. **Observable.** You must be able to view the results of the test before deciding.

2. **Relevant.** The information must change your beliefs about another uncertainty.

3. **Material.** The information must have the ability to change decisions you would otherwise make.

4. **Economic.** The cost of the information must be less than its value.
We often forget that the goal is to make good decisions which will lead to good outcomes – *not to reduce uncertainty*

- **Quantifying or reducing uncertainty** creates no value in its own right.
  - We cannot value information or uncertainty reduction outside of a particular decision context
  - If the best course of action is clear, it is a waste of resources to further reduce uncertainty
  - This could imply that no further information gathering to reduce uncertainty is warranted even though it is possible

*There is nothing so inefficient as to very efficiently do the wrong things.*

-- Peter Drucker
The VOI concept forces us to ask the important questions ...  
- What is the prior uncertainty, quality of the information, value of the information, etc.?  

... and informs us when enough is enough  
- Stop when VOI < Cost of reducing the uncertainty  

Without such a stopping criterion, we continue to use unclear and inconsistent stopping rules which leads to suboptimal use of corporate resources.