Infinity, Genetics and Oil
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What do you do when you have more choices than atoms in the universe? You develop computer software to make the best decision… and not just any software but the type that is modeled after life itself. Enter Genetic Algorithms (GA), a class of computer programs that mimic the process of biological genetics in order to find the best possible solvent-steam recipe for getting the most oil out of a reservoir.

"For the last 15 years researchers have been trying to get the optimal amount of oil out of various geologic formations, by injecting different combinations of solvents and steam," explains Laricina Energy Ltd.'s Neil Edmunds, Vice President Enhanced Oil Recovery. "The very first time we used this new software, it ran for two weeks and produced results that were superior to all the best techniques that human beings had written down over the last 15 years."

The use of solvent and steam is preceded by technologies that injected only steam, a common extraction approach of in-situ oil sands operators today. With hard sticky bitumen deep below the surface in oil sands geologic formations, the steam heats it enough so that it can be extracted like conventional oil. This is often done through a process called steam assisted gravity drainage (SAGD), which is one of the most well known in-situ techniques. Latin for "in place", in-situ technology recovers bitumen from deep below the earth's surface using wellbores. In-situ operators use various approaches to loosen the viscosity of the bitumen enough so that it can flow up through a production well. In the case of SAGD technology, steam is injected into one horizontal well and the softened bitumen flows down into a parallel production well where it is pumped to the surface.

SAGD requires energy and water (mostly non-potable groundwater from deep saline aquifers) to generate the steam needed to heat the bitumen. Industry has been improving the efficiency of SAGD with engineering and better technology that continues to reduce oil sands water and energy use which not only improves the economics but reduces greenhouse gas emissions. For companies like Imperial Oil, Laricina and EnCana, one solution is using solvents which act as diluents for bitumen. On one end of the solvent-use spectrum, there is the cold solvents approach, which basically involves no steam and injecting a solvent like propane into the oil to make it thin enough to be pumped. While this approach requires minimal energy and has no emissions or water usage, it is also comparable to the speed at which molasses flows on a cool January morning.

"If the process is too slow, you end up needing to drill too many wells," explains Edmunds, "which impacts your rate of return and efficiency". As it is right now, the cold-solvent extraction approach is too slow to be efficient. Of course, on the other end of the spectrum is the previously discussed SAGD approach in which no solvents are used at all. The gamut of possibilities that sits between the two extremes is astronomically large.

"The problem with using solvents is the number of choices you can make," explains Edmunds. "If you have a certain amount of steam and two types of solvents, for example, and let's say we're going to allow for a different injection rate every few months, and you do that for five years, you end up with more possibilities than the number of atoms in the universe."

Making Choices

So how exactly does it all work and why are there so many changing variables involved? Basically, a solvent combination with a low boiling point is injected together with the steam, Edmunds explains. As the steam mixture moves out into the reservoir the steam condenses at a higher temperature than the solvent, causing the solvent vapour to move ahead of the steam, essentially "beating the steam to the punch." Ultimately this allows the entire steam front to move through the reservoir quicker as the solvent mobilizes the oil in regions that are cooler than the steam zone. "At the end of the day we're draining the same oil using half the steam and therefore half the water and half the carbon emissions."

Of course the term "half" in all of these contexts is variable depending on the choices an engineer makes on a project. And it's not just the solvent types, mixes and quantities that make for an expansive array of possibilities, but other variables as well, such as the shape, size and characteristics of a reservoir or the steam and solvent injection rate. Even economic factors such as market prices of solvents can exponentially increase the number of variables in a given operation.

"If there are 60 possible variables, and each one of those variables can have 10 values, the total number of different options is 10^{60}," explains Edmunds, likening the optimization process to finding the highest peak of a mountain, which is usually obscured by clouds. "In this sense, the surface to be optimized on cannot be seen (only sampled at different points), it exists in many, many dimensions, it is very nonlinear and therefore the same action often generates different or opposite effects when applied in different situations." In other words, it makes advanced calculus look like a game of duck-duck-goose.

But that hasn't stopped companies from trying to nail down an optimal process. In the end, the sheer enormity of possibilities explored on a pencil-to-paper basis was enough to drive throngs of engineers crazy, making the transition from wetware to software an inevitable part of the technology's evolution.

Using Smarter Software

"Genetic Algorithms is a program for automating the process of optimizing complex and nonlinear problems," explains Edmunds, adding that GA is basically an implementation of some of the basic mechanisms of biological evolution. And it seems to make sense. Genetic variation is, after all, a process that also optimizes outcomes that are best suited to organisms' environments and also deals with a vast selection of seemingly infinite variables.

Sticking with the analogy, the engineer creates a 'genome' that defines an arbitrary number of variables to be investigated, each with a finite range and specified number of possible values. Using the software, the genome is a simulation that reflects the particular values encoded in an arbitrary bit string of a certain length. The engineer could input an 'objective

Canadian Centre for Energy Information 800 - 6 Avenue SW, Suite 1600, Calgary, Alberta T2P 3G3
T: 403.263.7722 F: 403.237.6286 Toll Free: 1.877.606.4636 E: infoservices@centreforenergy.com www.centreforenergy.com

function' for a given simulation, such as 'minimize supply cost', as one example out of many. The program would then calculate the 'score' based on economic evaluation.

"Essentially, we're just borrowing from nature itself to find ways to get the most amount of oil for the least amount of cost and environmental impact," concludes Edmunds who also teaches as Adjunct Associate Professor in the Department of Chemical and Petroleum Engineering at University of Calgary's Schulich School of Engineering.

So far, Laricina has conducted a series of tests with solvents in its carbonate Grosmont Formation at Saleski, southwest of Fort McMurray. As GA software continues to simulate and model various solvent-steam combinations, the company expects commercial production to begin in 2014 and grow steadily for 10 to 15 years, all the while improving recovery techniques, lowering operating costs and reducing greenhouse gas emissions.