Bi-objective optimization for seismic survey design
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Abstract

I applied a bi-objective optimization strategy to search the best seismic survey design in illumination and cost senses. Due to the conflicting goals of obtaining a good subsurface illumination at the lowest possible cost it is not possible to obtain an optimum survey in both senses simultaneously, but instead it is possible to get a set of surveys, called Pareto Front, that shows the trade-off between these conflicting objectives. As a result, the Pareto Front could be used as a decision tool to tune quality versus cost. I used the mixed-integer, free-derivative, nonlinear optimization algorithm called Particle Swarm Optimization and Mesh Adaptive Direct Search. The Particle Swarm Optimization part is used to escape local minima while the mixed-integer part is used to deal with integer aspects of a seismic survey design like the number of receivers and sources, to name but a few. I tested the optimization using a synthetic model and compared the final migrated seismic images. The results show good quality imaging and better cost.

Method

The survey design bi-optimization is composed of the following steps:

1. Choose a set of parameters that describe the acquisition with their upper and lower bounds. Some of these parameters could be integers while others are real numbers.
2. Define the illumination and cost objective functions.
3. These functions will guide the PSO-MADS algorithm in the search of seismic surveys with high illumination quality and low cost.
4. The Pareto Front that will be produced by the bi-optimization will show the trade-off between illumination and survey cost.

Illumination objective function

For each pair of specular rays I calculate their intersection points with the surface. If for a specular ray i these two points are x_i and y_i we measure the set of distances d(s_k, x_i) and d(r_j, y_i), where s_k is a source and r_j is one of the receivers in the spread s_k. The sum of the minimum of all these distances is the illumination objective function:

\[ \text{O}_I = \sum_i \min(d(s_k, x_i) + d(r_j, y_i)). \]

Cost objective function

To simplify, I assume that the cost of a seismic survey is proportional to the number of sources. The objective function is then defined as

\[ \text{O}_C = N_s \]

where N_s is the number of sources.

Pareto Front

If there are two surveys x^{(1)} and x^{(2)} with illumination and cost values \((O_I^{(1)}, O_C^{(1)})\) and \((O_I^{(2)}, O_C^{(2)})\), respectively, it is said that x^{(1)} dominates x^{(2)} if \(O_I^{(1)} \leq O_I^{(2)}, O_C^{(1)} \leq O_C^{(2)}\) and at least one of these relationships is a strict inequality. The Pareto Front is defined as the set of surveys that are not dominated by any other survey.

Example

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Bibliography
