RESEARCH NEWS

Seismic reflection method

Seismic imaging provides an insight into the Earth's subsurface

The seismic reflection method involves sending acoustic waves thousands of meters under the Earth's surface. The reflected signals provide scientists with information about the characteristics of the subsurface. This is how oil and gas deposits can be discovered. While these will eventually no longer be extracted as we move away from fossil fuels, accurate knowledge of rock structures is important for better understanding known reservoirs. The Earth's subsurface could be a key place to store greenhouse gases. With improved machine learning algorithms and new high-performance computing concepts, researchers at the Fraunhofer Institute for Industrial Mathematics ITWM are now able to process seismic data in greater detail. The technology could also be useful for constructing wind farms.

Seismic reflection is an efficient, non-destructive method of exploring the subsurface and amongst other applications is used to search for oil, gas and hot water reservoirs. It involves transmitting acoustic waves into the ground and recording the signals reflected back. The results indicate the composition and structure of the subsurface, helping to locate reservoirs. The technology works on land as well as offshore on areas within the continental shelf. The key to producing meaningful results is the processing and analysis of the data recorded. The Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern has further developed the data processing method. With this improved seismic imaging, the raw data undergoes multiple processing stages to create an extremely detailed image of the seabed and its complex subsurface structure.

Fraunhofer experts are using the SF GRT (Statoil Fraunhofer "Generalized Radon Transform") process developed during contract research. Dr. Norman Ettrich, one of the section heads for High-Performance Computing and Seismic team leader, and his team have used innovative machine learning (ML) algorithms to refine the software package to a higher level of detail and optimized the underlying computer architecture. It now provides detailed and precise images of rock structures under the seabed. This makes it possible to identify the size, structure and shape of oil and gas reservoirs under the surface — to within a few meters of accuracy. For this project, Fraunhofer ITWM pooled its expertise in geophysics, mathematics and information technology.

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Specialist ships equipped with hydrophones collect data

Discovering new oil and gas deposits under the seabed is by no means the main focus, though. Norman Ettrich explains: "Due to the move away from fossil fuels, there is waning interest from European countries in discovering new oil and gas deposits. They are more concerned with better understanding and examining known reservoirs and those already in use." After all, the technology can also be used to find suitable locations for greenhouse gases such as CO_2 to be deposited underground.

Researching the surface and subsurface of the seabed requires specialist ships that often cover thousands of square kilometers in straight lines. They drag airguns and hydrophones behind them. Typically, the airguns send an acoustic pulse down every 25 meters. In the water, the sound waves travel at a speed of 1,480 m/s, penetrating the rock layers under the seabed. In extreme cases, the acoustic waves can travel through 3,000 meters of water, before passing through another 11,000 meters below the seabed.

The signals reflected are then detected on the sea surface by highly sensitive hydrophones. "In this way, each pulse creates a seismic trace. These traces provide information about how much time elapses between emission and reception. This propagation time is also influenced by the composition and size of each rock layer. Because the acoustic signal is picked up by multiple hydrophones, the seabed can be analyzed from multiple angles. The strength, propagation time and angle of the signal provide crucial information about the features, structure and thickness of the rock formation. This includes information about whether a particular layer is very porous and whether the pores are filled with oil or gas, for example.

Data volumes in terabytes

During a typical exploration, a specialist vessel will travel along hundreds of parallel lines across the area to be investigated. Along each line, thousands of airgun pulses are emitted, and each pulse is captured as a reflected signal by thousands of hydrophones. The result of this is hundreds of millions of data traces collected, which amounts to numerous terabytes of information. To manage this enormous quantity of data, computing experts in Kaiserslautern have developed special high-performance computing (HPC) concepts (see box).

The data are first filtered, edited and presorted, then the subsurface can be mapped out using the seismic migration method. To improve data processing quality further after migration, more and more fully automated ML processing algorithms are being introduced. "The particular strength of our method, which is enhanced by ML algorithms, is that it no longer uses abstractions in the analysis of the data that would end up compromising the accuracy of the analysis," explains Ettrich. The result being a detailed visual representation of the complex subsurface structure.

Seismic reflection method as a tool for planning wind parks

The optimizations make it possible for the first time to detect diffraction or fault zones and render them visible in the image created. These are relatively small areas in which the characteristics of a rock layer change suddenly, for example by the occurrence of faults in an otherwise sealing layer. "This would indicate an area from which oil or gas has long since escaped. It could also indicate that the layer is too porous to function as a CO_2 reservoir or that a hot water reservoir is present and the formation would therefore be suitable for geothermal systems," Ettrich continues.

Identifying such diffraction objects with the seismic reflection method can also be very useful for wind turbine placement in offshore wind parks. The Fraunhofer technology analyzes the subsurface, thereby flagging sites with particularly hard rock that would hinder the installation of the turbine mast in the seabed. This helps to avoid expensive problems later on.

Data processing with high-performance computing
The abbreviation SF GRT stands for Statoil Fraunhofer "Generalized Radon Transform." The method for processing seismic reflection data was developed by the Fraunhofer Institute for Industrial Mathematics ITWM in collaboration with the Norwegian energy company Statoil ASA (now Equinor ASA). It has been used in practical applications for the past 10 years and continues to be improved by Fraunhofer researchers.
The raw data collected during seismic investigations amounts to several terabytes of data. In order to construct the subsurface image from the data collected above ground — using an acceptable level of energy and computing power without compromising the quality — the experts have developed a unique high-performance computing architecture. The key to it is the in-house GPI parallelization library (GPI, Global Adress Space Programming Interface), which ensures that multiple computing nodes can be connected in a cluster in which each individual computer can access the entire data set and use its full processing power for its tasks. This computer structure allows all raw data to be processed without any loss or compromise, creating a high-resolution visualization of highly complex structures.

Website:
[Seismic Reflection Method]
[Programming Interface]

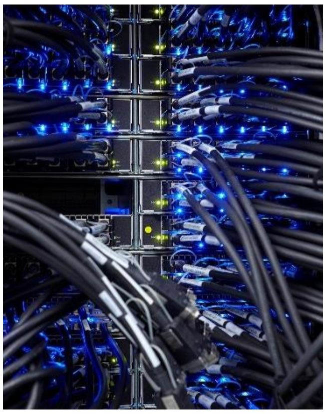

Figure 1: To manage the enormous volume of data that the seismic reflection method produces, Fraunhofer researchers have applied machine learning algorithms and high-performance computing processes to optimize massively parallel computing on computer clusters.

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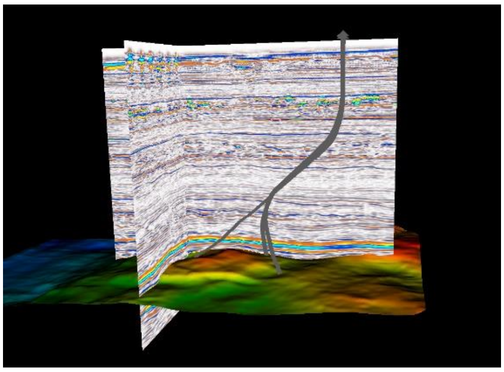

Figure 2: Typical seismic subsurface representation with borehole paths and the surface of a rock layer.

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