Introduction

Seismic modeling is the key to understanding seismic wave propagation in a heterogeneous Earth. The methods and tools integrated in the PGS proprietary seismic modeling and survey design package Nucleus, stand alone as the premier seismic modeling package in the industry. Nucleus has been the industry standard for marine source modeling and survey design for more than 15 years and is continuously being developed and extended. It handles any streamer, ocean bottom cable (OBC) or land geometries along with any acquisition or hardware system, including all major manufacturers of recording instruments, streamers, hydrophones, geophones, and air guns. The package is installed in all PGS offices and PGS Vessels as well as most of the major contractors and oil companies.

Modeling methods such as source modeling, ray-tracing and finite difference modeling can be combined with processing to allow the data quality to be examined with respect to acquisition parameters or processing flows.

New techniques are continuously being investigated and developed for repeat modeling, anisotropy or increasing the efficiency of the seismic acquisition through the combination of different modeling methods.

The modeling algorithms include 1D reflectivity, 2D and 3D ray tracing, and finite difference for 1D, 2D and 3D models. All modeling is frequency dependent accounting for attenuation and anisotropy.

Besides application in survey design, seismic modeling is also a fundamental tool used in feasibility studies for reservoir characterization and seismic monitoring.

Lately, the core functionality of Nucleus has been ported to a new framework called Nucleus+ introducing greater flexibility for the users (Figure 1, over page).

Summary

The well known marine source modeling and seismic modeling software Nucleus is now available in a brand new GUI with even more functionality. A large scale project to redesign and implement a new development framework has provided a flexible, integrated and easily extendable software platform. Efficiency is increased and with a new project based structure allowing both interactive and workflow-based usage. Computational and memory intensive algorithms, such as ray-tracing or finite difference modeling have all been parallelized. The end result is a faster, more efficient and, easy to use survey design and modeling package. We look at the new project based modeling environment and the enhanced features in more detail.

Nucleus+ will replace Nucleus very shortly.

Nucleus+
Nucleus+

The new environment enables geoscientists to view, process, and integrate widely different data types and formats. These include survey layouts, navigation data, source and vessel configurations, seismic data, well logs, horizon surfaces and Earth models. All the functionality is accessed and utilized through a single software platform, so integration is immediately apparent to the user. To help achieve this level of integration, both object-oriented and component-oriented software technologies have been employed at various levels.

Uniformity in the appearance and common functions in the software user interfaces contribute to more efficient handling, reducing the challenges often faced by users in acquiring and maintaining expertise in a variety of applications. Likewise, consistent, comprehensive user help documentation (Figure 2) with a uniform layout throughout all software components, and rich cross-referencing, is a key element. This is particularly true for acclimatization of new users.

Nucleus+ is project-based, but data can be shared between projects and between users creating a common library. The different data elements are listed in a tree structure allowing for fast and flexible browsing of all data types from all available projects. Access rights can be defined for projects in order to protect the data.

The new software can be used interactively (as with the former version of Nucleus) or in a workflow-based manner. The user is given the possibility to define a series of actions and store it as a job. The job can later be copied, edited and finally run. This is a great advantage for repetitive tasks such as source modeling or filter design. This is also a major step in QC of modeling exercises. Annotation and comments can also be added to a job. All parameter pages and fields in the page tree are easily accessible at any time by clicking at the corresponding node in the job tree. Parameters changed by user are highlighted. Queries for data parameters can be done across all available projects.

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The new project structure has been designed specifically to support access to a wide range of data types. The local visibility of the data remains controlled by the end user. Other improvements afforded by the new model for storing and manipulating data, are a flexible hierarchy for project organization and a search feature allowing the user to browse and sort the data.

- Features to enhance integration and efficiency include:
  - Sharing data between users
  - Large-scale job generation and launch on clusters
  - Additional tools to support data-parallel job processing and easy specification of the same by users

The current features include:
- Advanced marine source modeling application
- Advanced signal processing toolkit including maintained history datasets
- Complete integration with the NORSAR-3D and NORSAR-2D applications allowing survey definition, synthetic data generation and target illumination analysis

- Forward modeling applications including reflectivity modeling, ray tracing and finite difference (Figure 5, over page)

The introduction of Nucleus+ dramatically increases efficiency by redesigning the system from the ground up by using modern hardware, as well as updated programming languages and tools. The application runs on Linux (32 and 64 bit) but users will not miss their office applications because these run either from a remote application server or directly on the desktop, using a virtual machine software technology.

The Nucleus+ JobBuilder application is the interface.
that separates the software and hardware resource layers. It improves the efficiency by allowing the user to distribute jobs over a massive cluster in an easy way.

Development strategies

Nucleus+ is built with an architecture based on the Model-View-Controller pattern, using Qt for its presentation part (GUI), and having an inner core mainly written in C++. With a well defined separation between user interface and program core, the geophysicist is enabled to write new modules without having to know the Qt mechanisms.

Computationally intensive algorithms like ray-tracing, 2D and 3D finite difference modeling and true amplitude pre-stack time migration analysis have all been parallelized over shot. Furthermore, the memory intensive 3D finite difference module has been parallelized within a shot using threading. This allows the user to speed up the modeling, by utilizing today’s multi-core CPU’s.

In practice, developers were teamed up with selected representatives of the geoscientist user group. This model has worked well, thanks to the quality of the personnel involved on all sides and the well-defined scope of the porting effort.

Issues often encountered with legacy systems, such as efficient management and use of modern hardware, easy data integration, new user acclimatization, management of modern large data sets, software support, and portability, have all been addressed.

Conclusions

A large scale project to redesign and implement a new development framework has been undertaken. The result is an easily extendable software platform which has taken the development of Nucleus+ to new levels of flexibility and greater functionality which will maintain Nucleus as the premier marine survey design software.