Open-Source Software Framework Integrates Data Analysis

PAGES 261–262

An open-source software framework suitable for integrating many research tasks could be advantageous in various areas of geophysics. Two examples of the most successful and broadly used of such frameworks are the Seismic Un*x, which is used in seismic reflection data processing (SU) [*Stockwell*, 1999], and Generic Mapping Tools (GMT), used to produce various map projections in PostScript [*Wessel and Smith*, 1995]. Such large, shared projects bring clear benefits of versatile and uniform software support to the research community yet require decades of consistent development effort. However, SU and GMT are still limited to their respective application areas, and their interactive visualization capabilities are limited.

This report outlines our open-source software framework [*Morozov and Smithson*, 1997; *Chubak and Morozov*, 2006], which is called IGeoS (Integrated Geoscience, formerly referred to as SIA) and which has been in development for more than 12 years. Started as a seismic (reflection and wide-angle) processing package, the system uses dynamically linked custom binary executable codes for each task, similar to commercial seismic processing packages and unlike SU. Very few restrictions are imposed on the system's data types (seismic, borehole logs, gravity, Earth models, and so forth) and processing logic, which results in broad functionality. The system has been used in a variety of tasks, including signal processing in earthquake and wide-angle refraction; reflection seismology; seismic ray tracing, tomography, and migration; potential fields; visualization; interactive modeling and inversion; real-time data management; and Web services (such as data processing and delivery via the Internet).

The system now has reached substantial maturity and includes more than 200 plug-in tools, a full-featured graphical user interface (Figure 1a), support for parallel computations, and a 3-D/2-D visualization component. The system incorporates seamless interfaces to SU, GMT, and other software, and it includes a global seismic travel time calculator, 2-D ray-tracing programs, and seismic waveform modeling in one, two, and three dimensions. The IGeoS design framework is also convenient for developing new geophysical applications, with built-in tools for community collaboration and automatic code updates. Because of the system's object-oriented design, the incorporation of new and existing (including legacy) algorithms is typically easy, with benefits including common parameterization, input/output, parallelization, integration with other tools, and uniform code maintenance.

Integration of 3-D/2-D Visualization With Data Analysis

Visualization is the key to modern interpretation; however, interactive visualization also requires programming skills and efforts that are rarely available in focused research projects. Different data types also use different display methods, and multiple data sets often need to be combined in common 3-D displays. Our solution to these challenges was to build a single, all-purpose visualization server based on OpenGL graphics libraries, which provides 3-D/2-D displays for many tools in the system. With this component, interactive graphical displays can be built for various data analysis/interpretation tasks (Figures 1 and 2).

Seismic travel time modeling represents perhaps the most impressive improvement arising from this software integration approach. Wide-angle seismic ray tracing and inversion is the key operation used in the interpretation of deep crustal structures. The ray-tracing code "rayinvr" by *Zelt and Smith* [1992] appears to be the most broadly used such code, and several interactive interfaces [e.g., *Song and ten Brink*, 2004] were created for it. However, these interfaces are still limited in their capabilities and, most important, in their ability to incorporate other types of data.

By using the object-oriented rayinvr ray tracer in our system, the power and convenience of analyzing crustal structures improve dramatically (Figure 2). Model depths, velocities, and densities can be displayed in color and edited by using the computer mouse. Velocity columns and contours at any points can be analyzed interactively, and waveform synthetics can be produced for the selected columns. Rays are traced, and the changes in travel times and amplitudes are displayed during model editing, instantly. Reflection travel times and stacked sections can be incorporated in common displays (Figure 2b). Two-dimensional gravity is modeled concurrently with the seismic properties (Figure 2a, top). Teleseismic receiver functions can also be modeled and analyzed in the same ray-tracing session (Figure 2c). Finally, the model can be displayed and ray traced in full 3-D geometry (Figure 2d). The ray tracer also offers several technical enhancements for crooked-line and marine-land recording, and it supports travel time and attenuation tomography and migration.

Note that the various displays in Figures 1 and 2 are created entirely by the user, by describing the sequences of processing tools and their parameterizations (similar to those used in SU or GMT) and without computer coding. The displays are constructed by combining the objects posted by the selected tools, including 3-D geographical base maps obtained directly from GMT databases (Figure 2d). Other types of data (such as heat

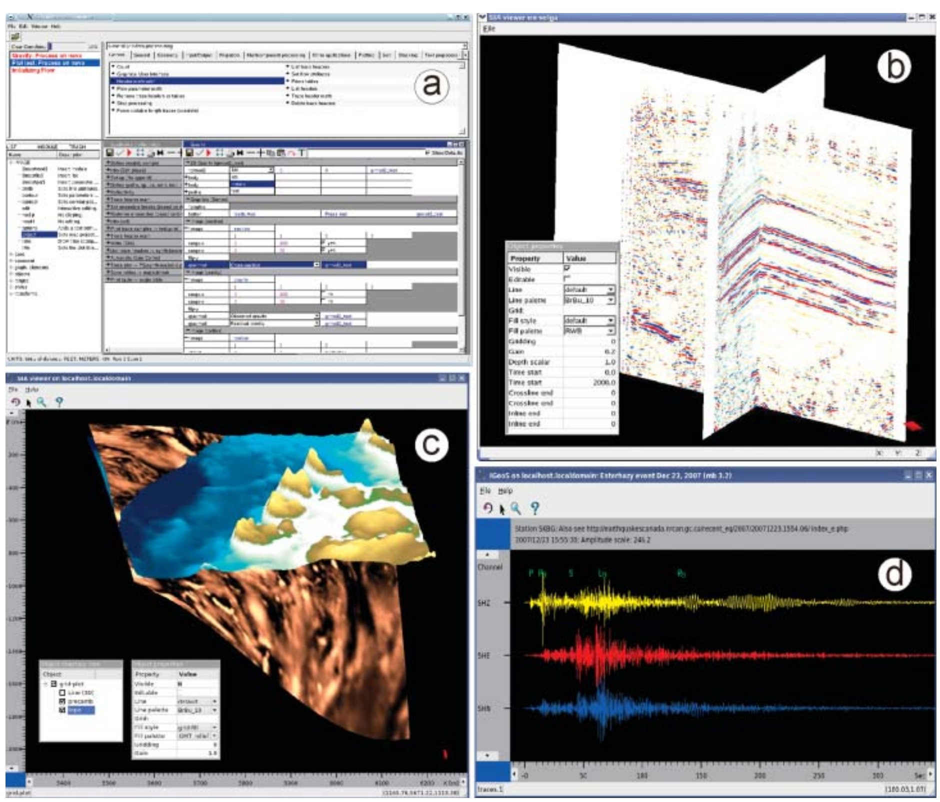

Fig. 1. Examples of interactive graphical displays: (a) user interface; (b) three-dimensional (3-D) reflection seismic sections; (c) 3-D potential-field data; and (d) real-time earthquake data display. Many display options can be selected from the menus.

flow, resistivity, magnetotelluric, and well log) can be included in the displays to produce a complete interpretation environment. Recently, access to external PostgreSQL databases was included in the system.

In summary, IGeoS is an advanced data processing and analysis system that could be of interest to researchers in several areas of geophysics. Its strengths are its versatility, broad scope, modern interface, robust core, very general visualization system, and parallelization capabilities. Because of its data abstraction, the system could be particularly useful as a data handling and code integration framework in various application domains. The display system seamlessly handles both 2-D and 3-D data and allows for the creation of specialized, interactive applications by the user. A code distribution system provides automated access to software updates and allows researchers to share their work. The system was used under IRIX and Solaris computer operating systems, with most of the recent development done under Linux. The system's documentation, distribution, usage examples, and other services can be accessed at http://seisweb.usask.ca/igeos/.

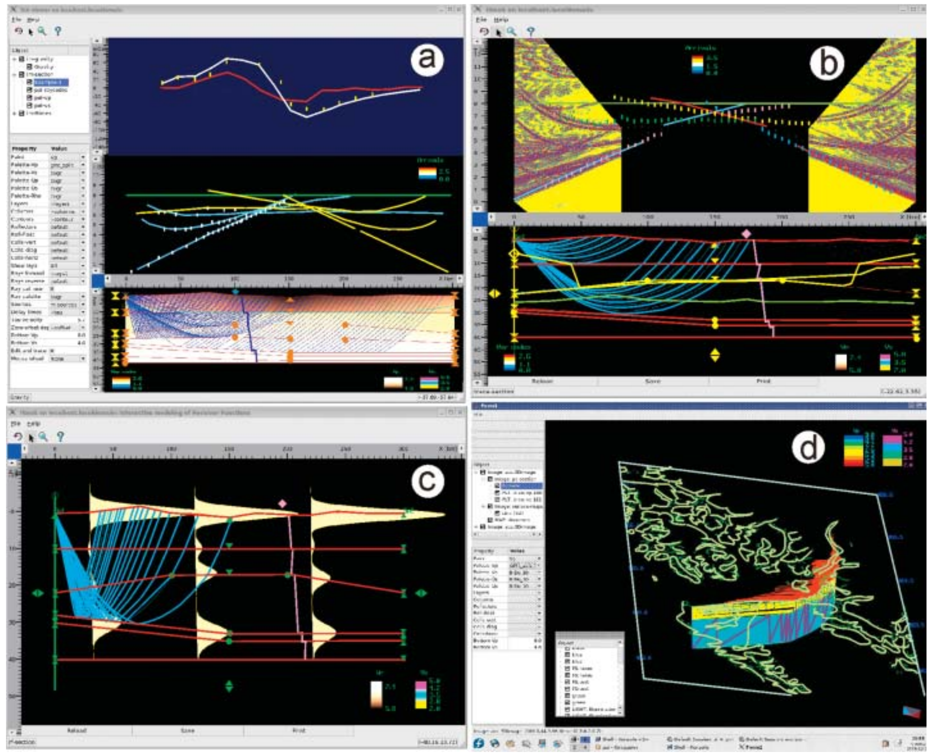

Fig. 2. Seismic ray tracing–related applications: (a) interactive 2-D seismic ray tracing and gravity modeling; (b) ray-tracing and travel time analysis using seismic data; (c) modeling and 2-D ray tracing of receiver functions in the same velocity structure; and (d) crustal seismic velocity model in true 3-D view. Smaller screenshot elements were redrawn for print clarity.

Acknowledgments

Glenn Chubak wrote the user interface (Figure 1a), and several students at the University of Wyoming and University of Saskatchewan contributed to the codes described in this article.

References

Chubak, G., and I. Morozov (2006), Integrated software framework for processing of geophysical data, *Comput. Geosci.*, *32*, 767–775.

Morozov, I. B., and S. B. Smithson (1997), A new system for multicomponent seismic processing, *Comput. Geosci.*, *23*, 689–696.

Song, J. L., and U. S. ten Brink (2004), RayGUI 2.0—A graphical user interface for interactive forward and inversion ray-tracing, *U.S. Geol. Surv. Open File Rep.*, *2004-1426*, 33 pp.

Stockwell, J. W., Jr. (1999), The CWP/SU: Seismic Un*x Package, *Comput. Geosci.*, *25*, 415–419.

Wessel, P., and W. H. F. Smith (1995), New version of the Generic Mapping Tools released, *Eos Trans. AGU*, *76*, 329.

Zelt, C. A., and R. B. Smith (1992), Seismic travel-time inversion for 2-D crustal velocity structure, *Geophys. J. Int.*, *108*, 16–34.

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G E O P H Y S I C I S T S

Honors

PAGE 263

The Committee on Space Research (COSPAR) of the International Council for Science presented awards to a number of AGU members. **George Gloeckler** of the University of Michigan and the University of Maryland received the COSPAR Space Science Award for his outstanding contributions to space science. The citation noted Gloeckler's leadership in his scientific discipline and in scientific cooperation between Europe and the United States. **Marvin Geller** of the State University of New York at Stony Brook received the COSPAR International Cooperation Medal for distinguished contributions to space science and work that has contributed significantly to the promotion of international scientific cooperation.

Mangalathayil Abdu of the Instituto Nacional de Pesquisas Espaciais, Sao Jose dos Campos, Brazil, received the Vikram Sarabhai Medal (a joint award of COSPAR and the Indian Space Research Organization) for outstanding contributions to space research in developing countries. **James Burch** of the Southwest Research Institute, San Antonio, Tex., received the Jeoujang Jaw Award (a joint award of COSPAR and the Chinese Academy of Sciences), which recognizes scientists who have made distinguished pioneering contributions to promoting space research, establishing new space science research branches, and founding new exploration programs. **Jonathan Makela** of the University of Illinois, Urbana-Champaign, was named a recipient of a Zeldovich Medal (a joint award of COSPAR and the Russian Academy of Sciences), which is conferred on young scientists for excellence and achievements.