InterSis: a graphical interface for seismic modelling

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Abstract

INTERSIS is a graphical interface designed to interact with seismic modelling programs, generally available from academic or scientific environments, turning them friendly and comfortable to work with. Developed using the public-domain softwares GTK (Graphical Toolkit) and SU (Seismic Unix), INTERSIS is, in its present stage, able to be an effective platform for the well-established ray-tracing program SEIS88, that is an open software in 2-D and 2.5-D. Due to its general structure, however, INTERSIS can be well adapted to other modelling methods, such as, e.g., finite-differences. All that is needed is to adjust the i/o formats of INTERSIS to the formats required for running the chosen modelling program. As a particular feature, INTERSIS uses the information provided by SEIS88 to compute the parameters of the Common-Reflection-Surface (CRS) method. In this way, the proposed interface can be useful to imaging and inversion studies based on the CRS method.

Introduction

The design of graphical interfaces that enable full use and most benefit of the possibilities of complicated theories and methods are a very active topic of research in all fields of technology. Of particular importance is the development of interfaces that can help the use of computer programs that, although of great scientific or academic value, are restricted in their application because of an unfriendly environment.

One area that particularly requires great interactivity and visualization capabilities is seismic modelling. In fact, geophysicists have often a great need to systematically create and test seismic models for a variety of purposes. Even in simple 2D or 2.5D situations, well-designed, fast and accurate seismic modelling capabilities can be extremely useful for a number of applications. These include studies of specific wave propagation problems, validation or initial tests to guide for more complex and realistic modelling. In spite of these important needs, few among the available public-domain softwares have user-friendly interfaces and/or input/output data visualization. As a consequence, users have to find their own way to fix such shortcomings. For instance, one has to use other softwares to define the geologic model, as well as to fit the wavelet parameters. Only then, when all parameters are already set, the main modelling program can be started. After that, however, data visualization is needed and another program has to be employed to accomplish this task.

In view of the evermore specific needs of the various users in academic or industry environments, flexible and less expensive solutions can be achieved by means of the use of broadly available, public-domain tools, presented in unix-like operating systems, such as Linux. Two of these are the Graphical Toolkit (GTK) (available in the internet address `htpp://www.gtk.org`) and the software Seismic Unix (SU) (available in the internet address `http://www.cwp.mines.edu/codes`).

Here we combine the good features of GTK and SU to develop the graphic interface, INTERSIS, for seismic modelling purposes. The proposed interface aims in helping geophysicists in the design, management and evaluation of numerical experiments (namely synthetic seismograms), that are computed by well-established modelling codes.

In its present initial form, INTERSIS is able to act as a very convenient platform for the well-known 2D and 2.5D ray-tracing program SEIS88, available in the internet address `http://seis.karlov.mff.cuni.cz`).

In its original form, this excellent program is not easy to use, at least by a general practitioner. The main difficulties arise from a non-interactive selection of input parameters, as required for defining interfaces, layer velocities and source wavelets. The graphical interface is designed to overcome these difficulties, that are common to a number of available public-domain modelling softwares, in a simple and unified way. In other words, what is presently done for SEIS88 can be easily extended to other softwares.

INTERSIS software

INTERSIS has been conceived to, in principle, adapt its output to any seismic modelling program, keeping the same input data procedure. In other words, INTERSIS is used as a common first step to specify all the modelling parameters (e.g., velocities, densities, interface shapes and source wavelets). As a next step these modelling data are automatically transformed into the specific input format required by the program that will actually carry out the modelling task (synthetic seismogram). In reality, INTERSIS does not perform any modelling computations. Its main tasks are:

A. To exercise a clean communication with modelling programs.

B. To provide basic graphical and processing tools to manipulate SEGY-like datasets.

More specifically, INTERSIS provides a variety of graphical and interactive tools, such as menus, selection-box options, windows and so on, to help specifying the model as much as possible. After execution of the modelling program, INTERSIS also helps to display the results in a comfortable way. Moreover, the modelling outputs are also automatically transformed into SEGY-like formats, so as to be directly used by any general seismic processing package. INTERSIS has four distinct modules to input/output data control and geological model specification. These are:

(1) Source-wavelet selection,
(2) Configuration/acquisition parameterization,
(3) Depth-model construction and
(4) Data visualization.

A brief description of the above is provided below.

Source-wavelet selection

In this module (see Figure 1), there are four possibilities to specify the wavelet that will be used to build the seismogram, namely:

- Choosing from pre-assigned analytical wavelets: Gabor, Ricker and Berlage analytical formulas are available (see Červený (2001)), each one with its corresponding parameters.
- Constructing a band-limited spike: As well known, application of a suitable band-pass filter on a spike (unitary pulse signal, with value of one for null time and zero elsewhere) can give rise of a wavelet with very convenient characteristics. INTERSIS offers the possibility of specifying, in a simple interactive way, the frequency bands to be rejected and/or accepted, in the spike.
- Drawing a wavelet: A wavelet of arbitrary shape can be graphically constructed by selecting points on a Cartesian plane in which the vertical and horizontal axes are time and amplitude, respectively.
- Importing a file: A wavelet can be defined by simply importing an ascii, binary or SU-formatted file.

No matter under which selection mode is employed, the parameters of the given wavelet (such as time duration, sampling interval and time shift) are automatically computed and displayed, so as to reach the desired wavelet shape in time domain. Moreover, by means of the Fourier transform, the wavelet's frequency-domain characteristics are also displayed with the help of panels of phase/amplitude spectrum (see Figure 2). In particular, the Nyquist frequency for the acquisition is also provided in this analysis, so as to quantify and avoid temporal aliasing.

Configuration/acquisition parameterization

This module allows for specifying the acquisition/configuration (e.g., split-spread or end-on shooting) parameters of the envisaged modelling experiment. All relevant information such as type of spreads, gaps, shot and receiver locations, can be graphically and interactively given by suitable options (see Figure 3).

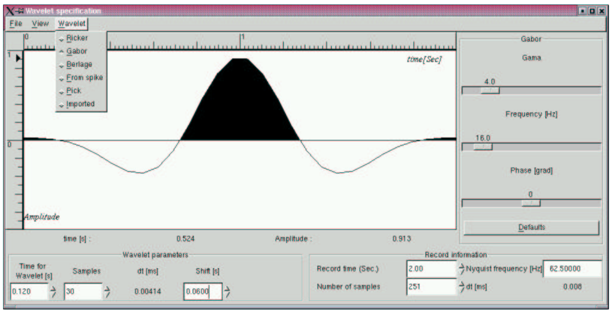
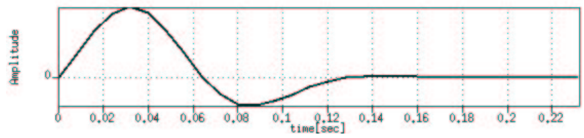
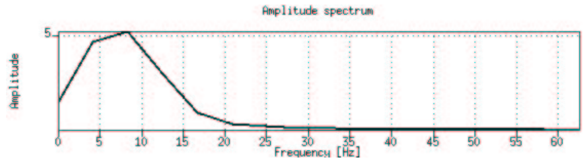


Figure 1: Source-wavelet selection module: wavelet display and menu



(a)



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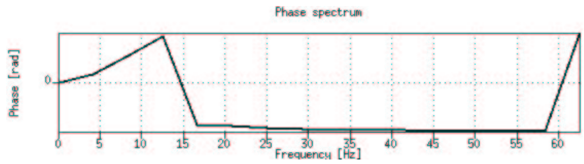

(c)

Figure 2: Source-wavelet selection module: wavelet analysis (a) Time domain; (b) Amplitude spectrum and (c) Phase spectrum

Shot points can be located, together with their depths, along the seismic line either individually or according to some step rule. It is also possible to import the seismic profile acquisition from an ascii file, where the location of sources and receivers are specified.

Depth-model construction

Design of the geological model that will be used in the synthetic seismograms to be computed is carried out by means of the depth-model construction module. In the present stage, INTERSIS accepts 2-D layered elastic isotropic models. Moreover, in each layer the density and velocities can be at most linear with arbitrary gradients. Interfaces are easily constructed with points linked by lines or curves using cubic splines, following the SEIS88 standards (see Figure 4). To input the medium parameters (densities and ve-

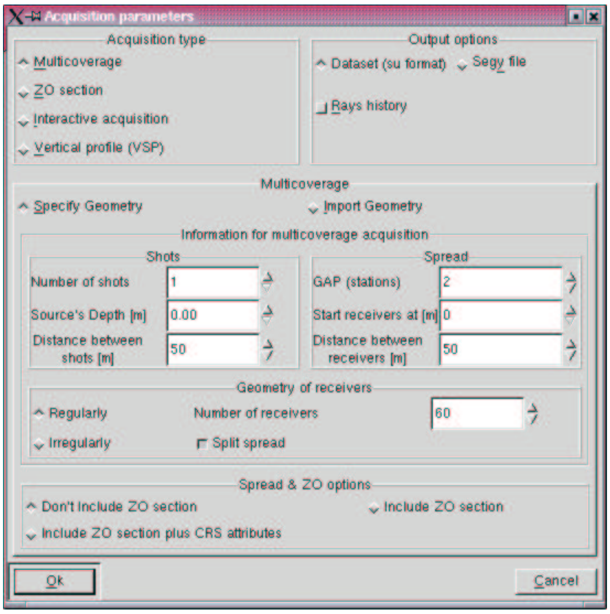

Figure 3: Configuration/acquisition module: Options include selection of multicoverage acquisitions, as well as computation of ZO sections and corresponding CRS parameters

locities) in each layer, the following three options are provided:

- Homogeneous layer: Density and P- and S-velocities are specified by single parameters (Figure 5a).
- Vertical gradient: following SEIS88, the user is allowed to select only one velocity field, either P- or S-velocities. The other one is automatically determined by built-in relationship. We consider the case of input of P-velocities. The user selects two values for the P-velocity, at the top and bottom of the layer. These values determine the required linear-vertical gradient distribution of the P-velocity in the layer. The density distribution also follows the rules prescribed in SEIS88, as a function of the given P- and S-velocities (Figure 5b).
- Vertical and lateral gradients: The procedure is identical for both P- and S-velocities. In each case, three values are necessary. One is a “reference velocity”, v_0, given at a given point, (x_0, z_0), within the layer. The other two are the lateral and vertical components, a_x and a_z, respectively, of the layer gradient. The velocity, v, for each point, (x, z) in the layer is computed by the simple formula $v = v_0 + a_x(x - x_0) + a_z(z - z_0)$. The reference point can be conveniently selected directly on the screen. (Figure 5c).

Data visualization

This module is a front-end for pre-processing tools available in the SU package. After the computations are performed by the modelling program, the obtained seismic

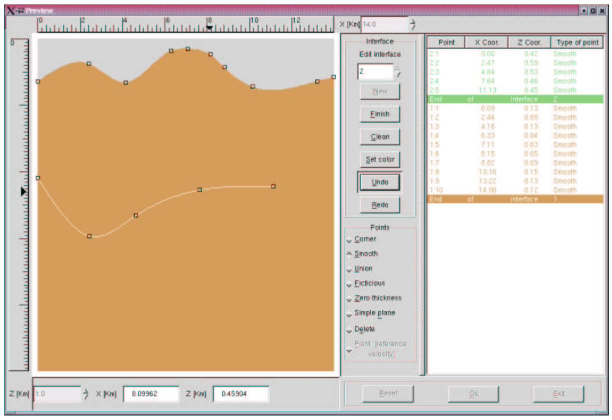

Figure 4: Depth-model construction module: a graphical tool to design of 2-D layered, elastic isotropic medium with curved interfaces. In the figure, note that the measurement (first) interface presents topography. Also the second interface is only partially constructed to show the module's interactivity.

synthetic data can be directly displayed or further processed using the built-in tools provided by the SU package. As well known, these processes include, among others: time data transformation into frequency domain, introduction of noise and gain functions, determination seismic attributes, header plotting, sorting and windowing. In this way, the visualization data module in INTERSIS acts as a convenient way to manage several of the useful processes available in the SU package.

As an example of the application of the data visualization module, we have used a shot gather available from the SU package (Figure 7a). To that data, we applied the SU time-domain Fourier transform to obtain its spectrum (Figure 7b) and the SU 2-D Fourier transform (FK-domain, see Figure 7c). All visualizations were easily managed by INTERSIS.

The visualization capabilities of INTERSIS can be particularly useful in designing modelling parameters, so as to avoid undesirable effects (such as, e.g., temporal and spatial aliasing, lack of illumination on target reflectors) in the results. As simple trial datasets can be quickly produced and checked, model parameters (such as, e.g., seismic profile configurations, location and shape of interfaces and choice of medium parameters) can be easily modified and adjusted to the user's needs.

Computation of CRS Parameters

INTERSIS has also a built-in capability to compute the CRS parameters of a ZO dataset, whenever the dynamical ray-tracing quantities (namely the propagation matrix along the ZO reflection rays) are determined by SEIS88. We recall that the ZO CRS parameters β, $K_{\rm N}$ and $K_{\rm NIP}$, stand for the emergency angle the ZO ray and the curvatures of N and NIP waves, respectively (see Hubral (1983)).

Fig 8a shows the ZO section, computed by SEIS88, for the model in Figure 5a. Correspondingly, Figures 8 b,c,d de-

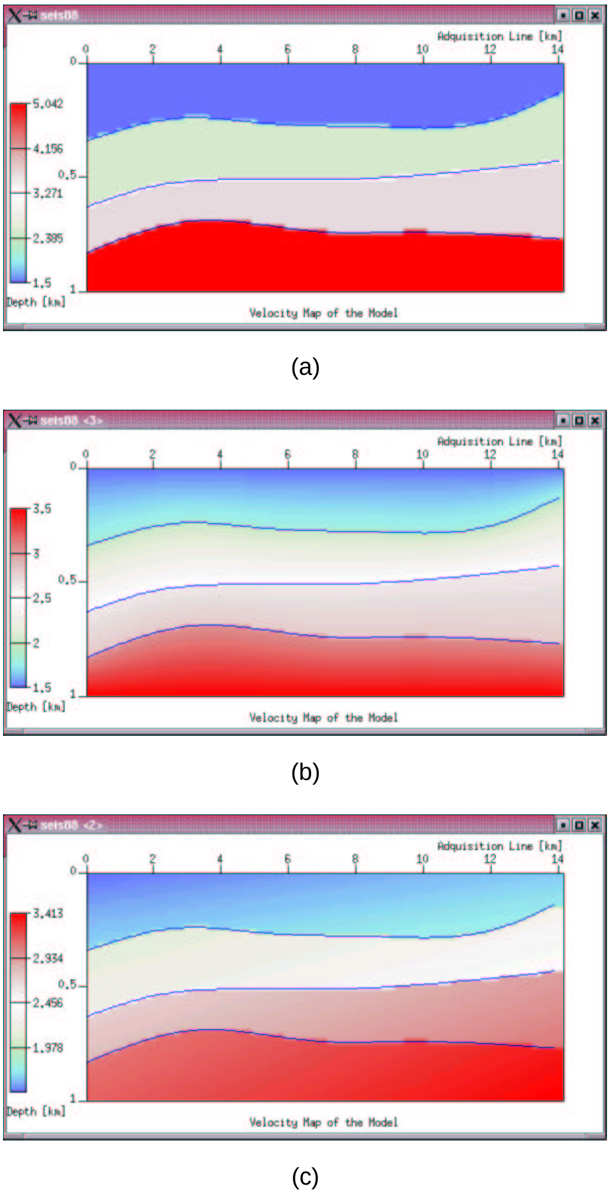

Figure 5: Velocity models: (a) Constant between layers; (b) Vertical gradient; (c) Vertical and Lateral gradients

pict the CRS-parameter sections that refer to that section. We note that the CRS-parameter sections were automatically computed by INTERSIS using the ZO dynamical information, provided as a byproduct by SEIS88.

Concluding remarks

We have presented the INTERSIS package, designed to be a common interface for various free/open seismic modelling programs. At this stage, INTERSIS operates with isotropic elastic layered models in 2-D and 2.5-D. The layers can be separated by arbitrarily curved interfaces. Within the layers, the velocities and densities can be at most linearly varying. The present version is able to interact, as a simple graphical front-end to the well-known ray-

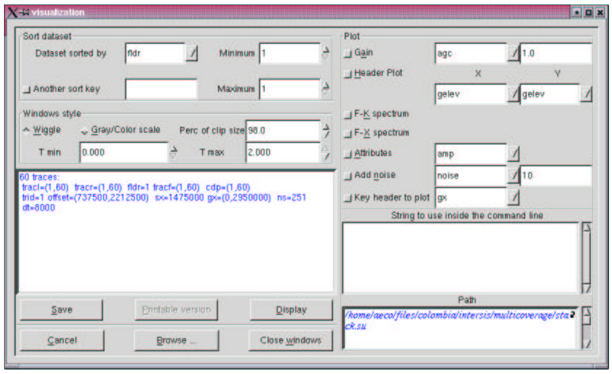

Figure 6: Module to display seismic dataset generated by INTERSIS or prexisting ones

tracing modelling program SEIS88, available, in the 2-D and 2.5-D situations, as a public-domain software. INTERSIS is, moreover, open to, in principle, adjust itself to any seismic modelling program. This can be done by just adapting the i/o formats of INTERSIS to the ones required by the chosen modelling programs. Besides being a convenient graphical interface, INTERSIS has additional features that provide more power and flexibility for the design and input of modelling parameters. These include, among others, tools for wavelet analysis, graphical and interactive input of depth models and easy data-display management as a front end of the public-domain SU package. A special feature, also related to SEIS88, is the direct computation of CRS parameters that relate to a modelled ZO dataset.

Acknowledgements

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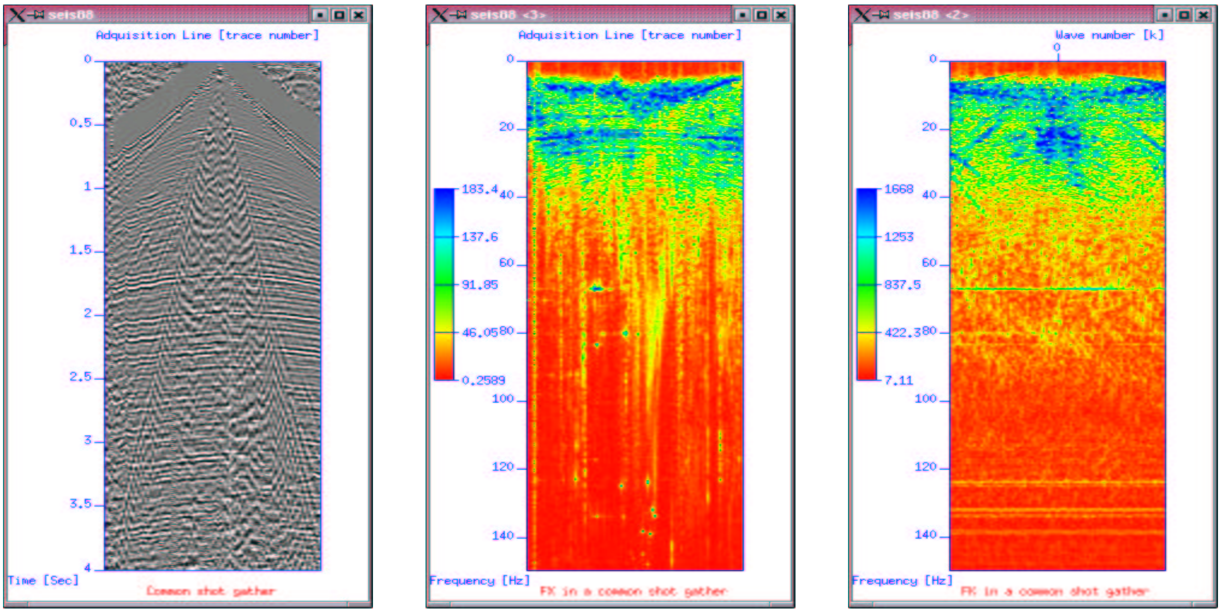
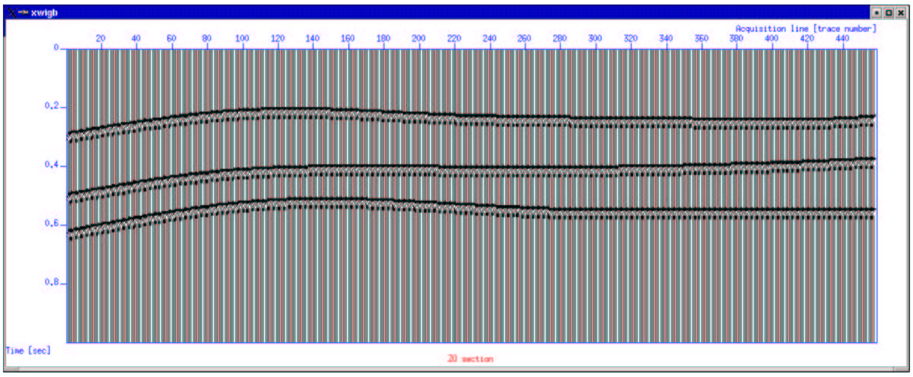


(a) (b) (c)

Figure 7: Data visualization module: Application on sample dataset of SU package (obtained from `http://www.cwp.mines.edu/cwpcodes/`).



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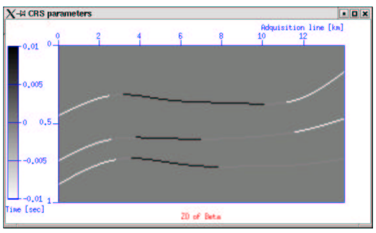

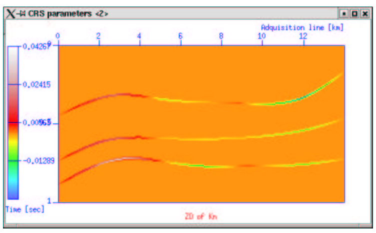

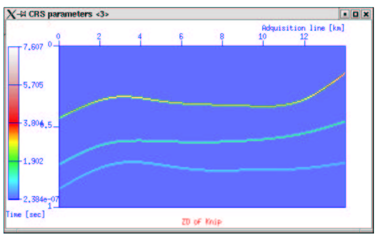

(b) (c) (d)

Figure 8: Computation of ZO section and CRS parameter sections for the depth model of Figure 5a: (a) ZO section, (b) β-section, (c) K_{N}-section and (d) K_{NIP}-section .