Converted wave X-window tools (CXtools) – A practical working example

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Summary

A processing package (CXtools) has been developed for multi-component seismic data, based on the new theory of PS converted waves and the standard of Seismic Unix. This package can be used as a standalone package or as a plug-in to Seismic Unix. It extends the ability of Seismic Unix in processing real data. It provides GUI (Graphic User Interface) tools for parameter estimation and parallel prestack Kirchhoff time migration (PKTM) for migration on a PC cluster. It also provides tools for dealing with large datasets and geometry setting. Using this package, we have efficiently processed several marine and land multi-component (3D and 2D) datasets and obtained improved results at low cost.

Introduction

Multi-component seismic data has been widely acquired in recent years and the theory for processing multi-component data has also been developed (Li and Yuan, 2003, Li et al., 2004). However, due to lack of efficient tools to implement the theory, processing the PS-converted wave in multi-component seismic data is more difficult and expensive than processing the P-wave. There is a need for developing appropriate tools based on the new theory for processing multi-component seismic data. Here we present a processing package (Cxtools) we developed for this purpose. This package is intended for processing the PS-converted wave of multi-component seismic data, but it can also be used to process the P-waves. CXtools can be run as a standalone package or as a plug-in to Seismic Unix. In this paper, I will present the principles underlying the development of Cxtools, some examples of Cxtools and the results of processing a real dataset.

Motivation and principles for Cxtools development

The purpose of developing Cxtools is to implement the new theory of PS-converted waves so that we can provide a processing package on Unix/Linux platforms to process multi-component seismic data efficiently and economically. Because developing a complete processing package takes too much effort, we have developed only programs which are not available in other packages. These programs are developed using the same protocols as our chosen packages for I/O and communication, so that they can easily be used with other processing packages. That means the source code of subroutines or standards of the chosen packages for I/O and communication should be openly available. The necessary development tools (compiler and Libraries) should also be freely available. To satisfy these conditions, we chose Seismic Unix as the platform to develop Cxtools.

Seismic Unix (SU) is an open-source package for seismic research, which is developed at the Centre for Wave Phenomena at Colorado School of Mine. It provides the basic programs for researchers to test their ideas. In SU, routines can be connected by the UNIX pipeline facility to perform complicated jobs. Moreover, users can add their own routines into this pipeline. Because SU provides standard input, output and subroutines, researchers can easily develop their own programs according to the SU standard and use them with SU routines. However, since no interactive tools are available for estimating parameters in SU, it is not efficient for processing real datasets and it is difficult to verify the ideas and methods on real datasets. There is a need to extend its ability so that it can be used to process real datasets.

The functions and features of Cxtools

For processing real data, two sets of tools are needed. One set of tools is for processing, for example, tools to perform filtering, NMO, DMO, stacking, migration, etc. Another set of tools is for parameter estimation, for example, tools to estimate the velocity model. The job of estimating parameters is the most labor consuming, and generally needs interactive GUI tools which are not available in SU. Our main task is to develop these GUI tools. The velocity parameters obtained from GUI tools are then passed to the processing tools. Although velocity parameters can be shared in SU routines using the command-line method, it involves much manual editing work and is not efficient. To overcome this, we used a velocity file for sharing the velocity parameters Figure 1 shows the structure of CXtools.

The velocity file consists of the velocity model. For PS converted waves, there are four parameters: the PS converted wave velocity (V_{ps}), the vertical velocity ratio (γ_0), the effective velocity ratio (γ_{eff}), and the anisotropy parameter (χ). For P-wave, we can use the same structure but set γ_0=1.0 and γ_{eff}=1.0. The estimation tools can modify this file but the processing tools can only read it.

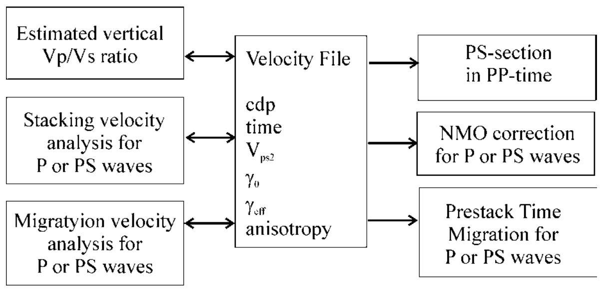


Fig 1. The relationship among the programs in Cxtools.

The Cxtools has the following functions for processing both 2D and 3D datasets:

(1) Estimate vertical Vp/Vs ratio;
(2) Stacking velocity analysis and ACP+NMO+Stacking processing for P and PS waves;
(3) Migration velocity analysis and prestack time migration;
(4) Parallel prestack time migration on PC cluster;
(5) Other routines for handling data, geometry, and velocity files.

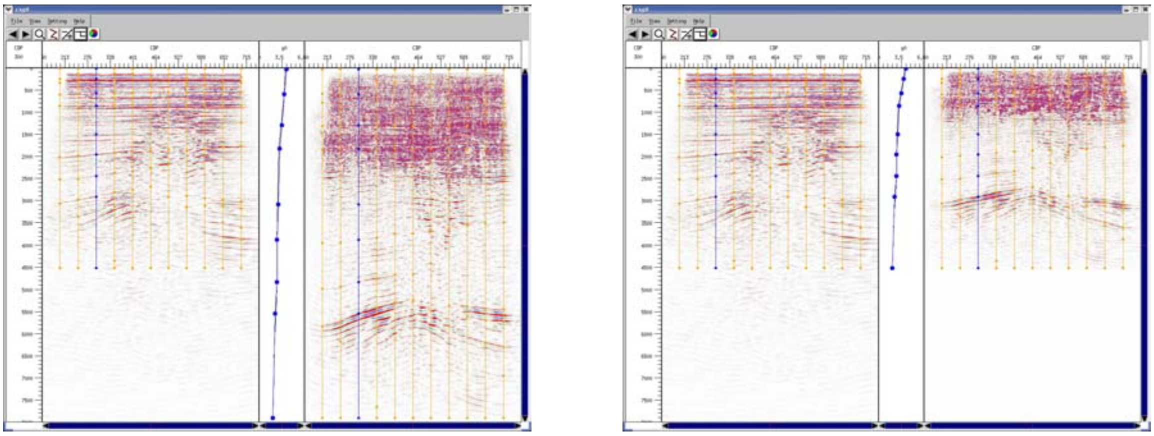
Estimation of velocity is performed using the interactive GUI tools and other functions are performed using non-GUI tools. The parallel version of the prestack time migration is performed on a PC cluster using a Message Passing Interface (MPI). All routines have the same format of input parameters and data I/O as the SU routines, so that the routines of Cxtools can be used with SU routines in the processing flow.

In Cxtools, the most important tools are the GUI tools which are used for estimating velocity parameters. Although one can estimate velocity parameters using SU routines, it is neither efficient nor economical because it involves a great deal of manual editing work. The GUI tools in Cxtools integrate the necessary steps and significantly reduce the processing time and costs. Also the parallel version of prestack time migration is a key routine for processing 3D datasets. It is not practical to perform the 3D prestack time migration for real datasets without the parallel migration programs.

GUI tools for estimating velocity parameters.

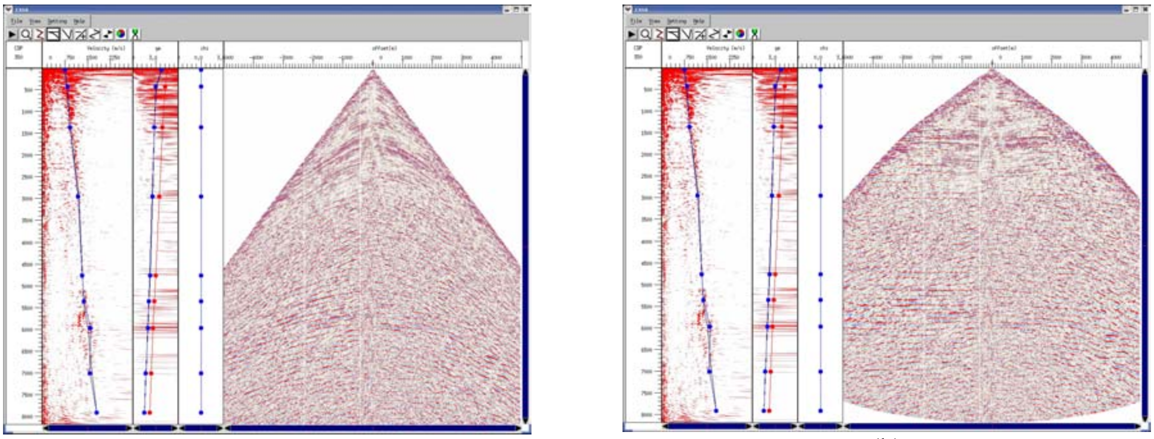
(1) *Estimation of vertical Vp/Vs ratio*. This tool interactively estimates the vertical Vp/Vs ratio (**γ_0**) by correlating events in the P and PS wave images. Figure 2 shows snapshots of this tool. Using this tool, when the values of γ_0 in the γ_0 panel are picked, guidelines are displayed in image panels to indicate the corresponding events in the PP and PS images. By comparing the events in both images, we can adjust the values of γ_0 so that the guidelines can match the events. The results are then automatically saved to the velocity file.

(2) *Stacking velocity analysis.* This tool interactively estimates the stacking velocity model by applying an anisotropic moveout analysis (Li and Yuan, 2003) to an ACP gather of PS-waves or to a CDP gather of P-waves. Figure 3 shows snapshots of this tool. The velocity spectrum and γ_{eff} spectrum are calculated using the current values of V_{ps}, γ_0, γ_{eff} and χ. When the mouse cursor is picked in the parameter panels, an NMO curve is displayed in the gather panel. We can adjust the values of the velocity parameters so that the NMO curves are matched to the events in the gather. The values of the velocity parameters are then saved to the velocity file. We can also see the results by applying the NMO correction to the gather as in Figure 3 (b). This tool can dynamically show the effects of parameter variation on the NMO correction results.



(a) (b)

Fig 2. Snapshots of the GUI tool for estimating vertical Vp/Vs ratio. The left panel displays the P-wave image and the right panel displays the PS-wave image, against on PS-time in (a) and PP-time in (b). The middle panel displays the values of γ_0 at a CDP location. The blue line indicates the ACP or CDP locations.



(a) (b)

Fig 3. Snapshots of the GUI tools for estimating the stacking velocity model. The left-most panel shows the velocity spectrum obtained from the ACP gather. The blue line indicates the picked velocity. The second panel shows γ_e and γ_0. The blue line shows both values of γ_e and the red line shows γ_0. The third panel shows the anisotropy. The right-most panel shows the ACP gather without NMO correction in (a) and after NMO correction in (b).

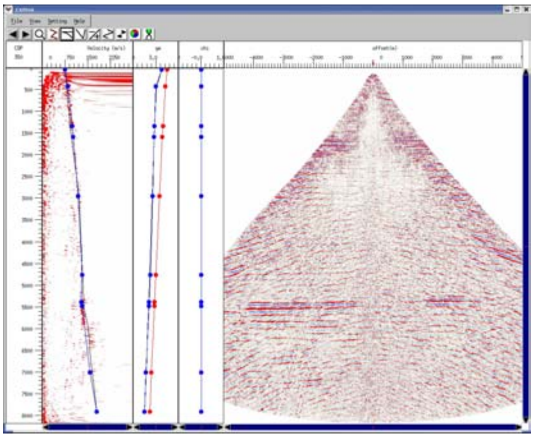
(3*) Migration velocity analysis.* This tool interactively updates the migration velocity model by applying a hyperbolic moveout analysis to an inverse NMO CIP gather obtained from anisotropic PSTM. Figure 4 shows snapshots of this tool. The interface of this tool is similar to the tool for estimating stacking velocity (Figure 3), but the gather is the CIP gather obtained from PSTM (Figure 4a) or the inverse NMO CIP gather (Figure 4b). If the events in the CIP gather are not flattened, we can adjust the velocity value according to the inverse NMO CIP gather and perform the PSTM again to flatten the events. This method is described in detail in Dai and Li (2002 and 2003).

Parallel version of Prestack Time Migration

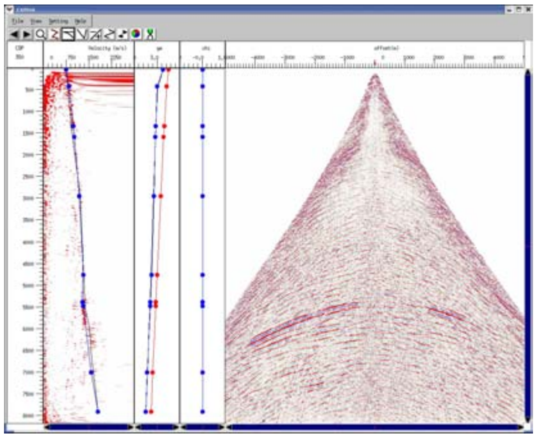
We also developed a parallel version of the PSTM that runs on a Linux PC cluster. The parallel version has the same I/O as the series version. Therefore we can test the data and parameters of PSTM on a single computer, and once satisfied, apply the parallel PSTM on the PC cluster. This parallel PSTM is vital for processing 3D datasets. The details of the method can be found in Dai (2005).

Applications and Conclusions

Cxtools extends the ability of Seismic Unix to process real data. It can be used as a standalone package or as plug-in to Seismic Unix. The main features of Cxtools are that it provides GUI tools to estimate velocity models, and a parallel tool to perform PKTM on a PC cluster. It also provides tools for dealing with large datasets and geometry setting. The GUI tools significantly reduce the time and cost of required precisely estimating the velocity model. The parallel version of PSTM greatly reduces the time for migrating 3D datasets. While developing Cxtools, we were able tofocus on implementing the processing theory and interactive functions because we could use the subroutines of Seismic Unix for I/O. EAP and several of EAP's sponsors have installed Cxtools. In EAP we have efficiently applied it to several marine and land (2D and 3D) multi-component datasets and obtained improved results (Dai et al., 2004; Fabio et al., 2005) at low cost.



(a)



(b)

Fig 4. Snapshots of the GUI tools for updating the velocity model for prestack time migration. The left-most panel shows the hyperbolic velocity spectrum obtained from an Inverse NMO CIP gather. The blue line indicates the picked velocity. The second panel shows γ_e and γ_0. The blue line shows both values of γ_e and the red line shows γ_0. The third panel shows the anisotropy. The right-most panel shows the CIP gather in (a) and the inverse NMO CIP in (b).

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