A Fortran90 implementation of symmetric nonstationary phaseshift extrapolator

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ABSTRACT

Symmetric nonstationary phase-shift (SNPS) for 2D (SNPS2D) is a 2D prestack shot-gather depth-imaging Fortran90 and C++ code based upon the symmetric nonstationary phase-shift theory. A brief introduction to the theoretical fundamentals, the program structure and an example (Marmousi) are presented.

INTRODUCTION

The symmetric nonstationary phase-shift extrapolator (Ferguson, 1999) is a natural combination of two wavefield extrapolators: phaseshift-plus-interpolation (PSPI, Gazdag and Squazzero, 1985) and nonstationary-phaseshift (NSPS, Margrave and Ferguson, 1999). In their most accurate forms, PSPI is a nonstationary combination which performs wavefield extrapolation and an inverse spatial Fourier transform simultaneously, while NSPS is a nonstationary convolution which performs wavefield extrapolation and a forward spatial Fourier transform simultaneously (See Margrave, 1998 for a definition of the terms nonstationary convolution and nonstationary combination). Margrave and Ferguson (1999b) demonstrated that the error caused by PSPI and NSPS tend to oppose one another. A natural combination of the two lead to a symmetric wavefield extrapolator of higher accuracy. SNPS is an implementation of this algorithm in C++ and Fortran 90 for the case of isotropic media.

PROGRAM STRUCTURE

The software contains the following components:

C++ Data I/O wrapper functions.

The related files and their content are

segy.h

is a C++ header file which contains the definition of the SEGY file header and trace header structures, trace data and shot gather data classes and related member functions. This file was modified from header file segy.h in Seismic Unix by the Center of Wave Phenomena (CWP) in Colorado School of Mines (CSM).

segy.cpp

contains the bodies of the member functions of the classes defined in segy.h. With these member functions, SEGY data I/O becomes very convenient. However, only IBM 32bit floating-point format has been implemented. It is not difficult to modify the code to accommodate other SEGY formats.

pwsnmig.cpp

is the C++ main program, which serves as an interface between C++ data I/O and the migration kernel written in f90. It reads necessary input files and output migrated shot gathers in standard 32-bit IBM floating point SEGY format.

ebctoasc.h

contains the conversion definition between the EBCDIC header and ASCII headers. It enables the user to write comment or record specific processing details to the segy reel header.

Migration kernel functions

The related files and their contents are:

pwsn.f90

is the migration kernel function. It accepts the input from the C++ main program and returns band-limited depth image matrix.

ips.f90

does an isotropic phaseshift.

tips.f90

does transverse isotropic phaseshift. It is not yet implemented.

subroutines.f90

contains utility functions used by pwsn.f90.

The above migration kernel functions are F90 translation of the Matlab functions described in Ferguson, 1999.

Other utilities

FFTW

SNPS2D uses a free Fourier transform package, *Fastest Fourier Transform in the West* (FFTW) developed at MIT by Matteo Frigo and Steven G. Johnson. For more information, visit http://www.fftw.org. This package needs to be installed before SNPS can be compiled and the path of the library needs to be added to the library search path when compiling.

fftw_f77.i

contains parameter statements for various constants that can be passed to Fourier transform routines.

INSTALLATION

There are three steps to install the software

1) Copy the files from the CREWES 2000 CD to the installation directory.
2) Install FFTW Fourier transform package. The currently used version is fftw-2.1.3. Newer versions of FFTW can be downloaded from http://www.fftw.org. Only a single precision installation is necessary for SNPS2D. The installation procedure

can be found in the FFTW user's guide (Frigo and Johnson, 1999), which comes along with the software.

3) Install SNPS2D. First untar file snps.tar and then change the variable FFTWDIR in the makefile to the absolute path of the library file libsfftw.a (for single precision). Give command 'make snps2d' under the installation directory to generate the executable. For multi-workstation psuedo-parallel computing, the code needs to be compiled on each workstation.

PROGRAM I/O AND SELECTION OF PARAMETERS

An input parameter file is required to run SNPS. The input parameter files contains key words and their values. A key word tells the program what the number in the next line is. This file contains the following components,

1) File name of input shot gather data (key word: insegy or INSEGY). Shot number, field file ID, number of traces per shot, number of samples, sampling rate, offset should be correctly filled in the SEGY headers. Its format should be IBM 32-bit floating point. The coordinate or each shot location should concur with the velocity model. Zero traces used to accommodate migrated energy should have been padded.
2) File name of output shot gather data (key word: outsegy or OUTSEGY). Header words are properly duplicated from the input data. Each shot has equal number of traces as the input shot gather, but has samples equal to the number of imaging steps in the velocity model. Its format is IBM 32-bit floating point.
3) Source wavelet (key word: insource or INSOURCE). It has the same number of traces and samples as that of an input shot gather. The impulse should be put at the right shot location.
4) Model file name (key word: model or MODEL). The model is in binary format. It has a 3200 bytes file header, 3 4-byte integers, which define the model size, 4 4-bytes real number, which defines the spatial properties of the model, and the model data in IBM 32-bit floating point format. The format is also shown in table 1. A model with the format in table 1 is easy to generate by users.

Bytes	Type	Description
1-3200	Character	Similar to EBCDIC headers. Need conversion to view in ascii format (header)
3201-3204	Int*4	Number of rows in a model layer (nrow)
3205-3208	Int*4	Number of columns in a model layer (ncol)
3209-3212	Int*4	Number of layers in model. 1 for isotropic, 7 for TI media (mediaflag).
3213-3216	Real*4	Imaging step (dz)
3217-3220	Real*4	Horizontal interval (dx)
3221-3224	Real*4	Start of X coordinate (startx)
3225-3228	Real*4	Start of Y coordinate (starty)
Next (nrow*ncol)*4 bytes	Real*4	Model layer 1, organized columnwise. For isotropic case, this is P wave velocity.
. . .	Real*4	Next 6 layers contains TI parameters. Not yet implemented.

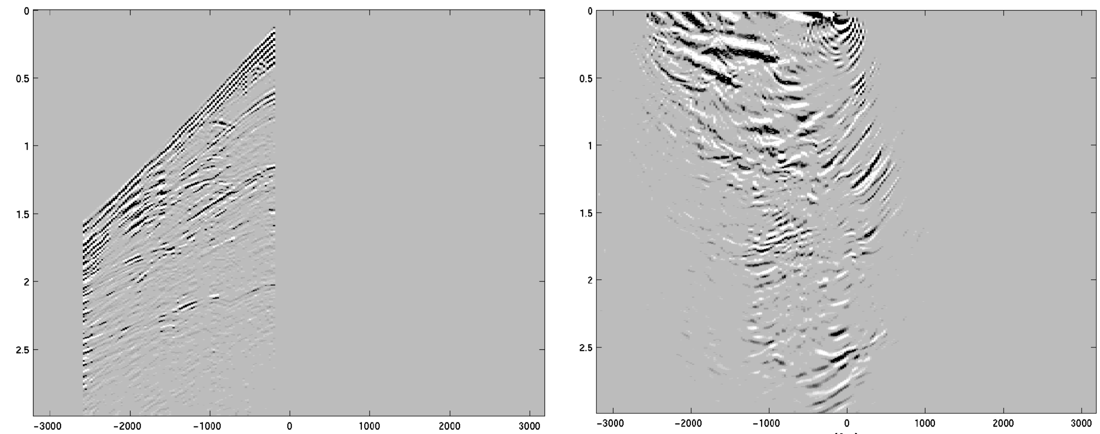
Table 1. Structure of model file.

5) Program mode (key word: verbose or VERBOSE). 0 for nonverbose mode, 1 gives program execution details.
6) Minimum and maximum frequency in Hz (key words: minfreq, maxfreq or MINFREQ, MAXFREQ).
7) Lower end frequency taper in Hz (key word: frqtprl or FRQTPRL).
8) Higher end frequency taper in Hz (key word: frqtprh or FRQTPRH).
9) Velocity model layer identifier (key word: key or KEY). For isotropic cases, it defaults to 1. For TI case, it points to the model layer where P wave velocity is stored.
10) Velocity field smoothing threshold value (key word: threshold or THRESHOLD). Velocity values within $v \pm \frac{1}{2} threshold$ are approximated by *v*. Reducing this threshold value increase accuracy and decrease the speed. For depth model as complex as the Marmousi, a 200 m threshold value should be good enough.
11) Length of median filter used to smooth the velocity field (key word: lmedian or LMEDIAN).
12) Starting shot number (key word: nshotstart or NSHOTSTART). It gives the start shot number in the shot gather files.
13) Number of shots to migrate (key word: nshots or NSHOTS). Combined with parameter nshotstart, this enables psuedo-parallel processing by distributing different segments of the shot gather file to multiple computing nodes.
14) File name of the ASCII file, which has the comment to be written into the reel header of the output SEGY file (key word: ebcdic or EBCDIC). The file length should be exactly 3200 bytes. Contents beyond byte 3200 are truncated. A recommended format is a 40 (rows) x 80 (columns) character matrix.

An example of this parameter file (.par) can also be found in the CD.

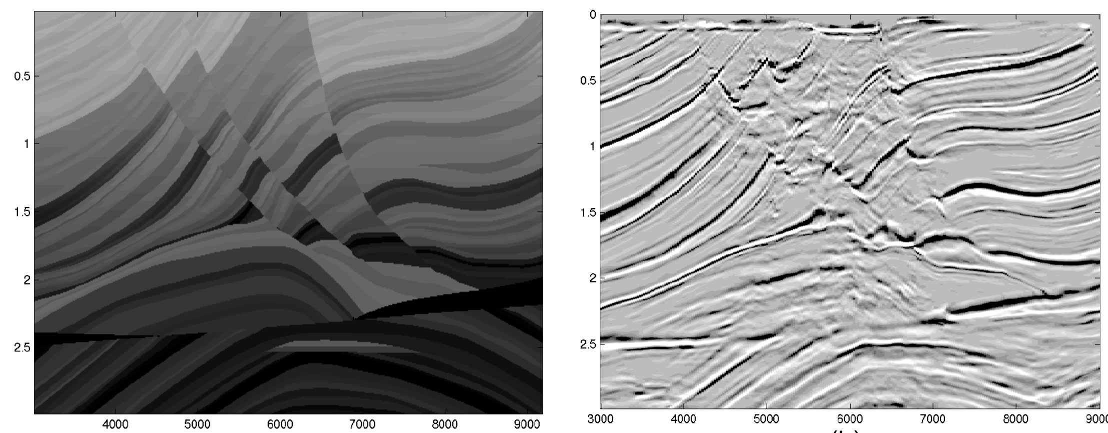
A WORKING EXAMPLE

Marmousi synthetic data was migrated with SNPS2D. The 240-shot 2D line was broken into several segments for multi-CPU processing. The running time is roughly equivalent to 50 hours on a single-CPU Sun Ultra-10 with 500 Mb memory. Each shot gather was expanded to 256 traces to accommodate the migrated energy. Each trace has 512 samples at a sample rate of 4 ms. Trace padding and geometry related processing was done in ProMax. The model has a horizontal interval of 25 m and an image step of 4m, which was generated by Fourier domain interpolation from the original 4m x 4 m grid model. The program is about 5 times faster than the previous Matlab release of Ferguson, 1999. No processing was done before the migration. Post-migration top mute functions were designed at an interval of 10 common image gathers (CIP). Each CIP gather was then stacked to produce a subsurface image. Figure 1 shows shot gather 120 before and after migration and Figure 2 shows the P wave velocity model and the final migration. Top mute functions were picked at an interval of 10 CIP gathers (250 m).



(a) (b)

Figure 1.Marmousi shot gather 120 before and after SNPS migration.



(a) (b)

Figure 2. Marmousi model (a) and SNPS2D migration image(b).

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