

VOLUMETRIC PRINCIPLE COMPONENT ANALYSIS FOR 3D SEISMIC FACIES ANALYSIS – PROGRAM pca3d

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Overview

Principal component analysis (PCA) is widely used to reduce the redundancy and excess dimensionality of the input attribute data. Such reduction is based on the assumption that most of the signals are preserved in the first few principle components (eigenvectors) and the last eigenvectors are mainly noise or redundant data that are already captured in the first few eigenvectors. While many workers use PCA to reduce redundant attributes into "meta attributes" to simplify the computation, in AASPI, we use PCA as the first iteration of the SOM and GTM algorithms, but a standalone module for volumetrically PCA analysis was not provided in previous releases. **pca3d** is developed for users who want to analyze data before feeding them into more complicated "black-box" algorithms, and for users who want to identify the most representative features in multiple seismic attributes. The first principal component (or first eigenvector) is a vector in *N*-dimensional attribute space that least-squares fits the data. If we then project the data onto this vector and subtract it, the second principal component (eigenvector) is the vector in (*N*-1)-dimensional space that least-squares fits the data residual that was not represented by the first eigenvector. This process continues for all *N*-dimensions resulting in *N* principal components.

Theory

Given a suite of N attributes, the covariance matrix is defined as

$$C_{mn} = \frac{1}{J} \sum_{j=1}^{J} (a_{jm}(t_j, x_j, y_j) - \mu_m) (a_{jn}(t_j, x_j, y_j) - \mu_n),$$

where a_{jm} and a_{jn} are the m^{th} and n^{th} attributes, J is the total number of data vectors, and where

$$\mu_n = \frac{1}{J} \sum_{j=1}^J a_{jn}(t_j, x_j, y_j),$$

is the mean of the n^{th} attribute. If we compute the eigenvalues, λ_{i} , and eigenvectors, \mathbf{v}_{i} , of the real, symmetric covariance matrix, \mathbf{C} , the i^{th} principal component at data vector j is defined as

$$v_{ji} = \sum_{n=1}^{N} a_{jn}(t_j, x_j, y_j) v_{ni},$$

where v_{ni} indicates the n^{th} attribute component of the i^{th} eigenvector.

🗙 aaspi_util GUI - Post Stack Utilities (Release Da	te: November 10, 2015)			_		×
Eile Volumetric Attributes Spectral A	Attributes Formation Attributes	Volumetric Classification	Image Processing			<u>H</u> elp
Analytic Tools Display Tools Other Uti	ilities Set AASPI Default Paramet	pca3d				
SEGY to AASPI format conversion SEGY to AASPI - Convert Poststack seiso	AASPI to SEGY format conversion (single file) nic volumes from SEGY to AASPI fo	kmeans <u>3d 78</u> som3 <u>3D principal com</u> gtm3d psvm3d define_training_data	Prestack Utilities			
SEGY Header Utility :	SEGY Header Utility					
2D SEG-Y Line rather than 3D Survey ?						
SEGY format input file name (*.segy,*.sgy,*.SEGY,*.SGY):			Browse	View EBCDIC	Heade	r]

This Program pca3d is launched from the Volumetric Classification in the main aaspi_util GUI

Computing pca3d module

Setting the parameters defining principle components is the first step of the analysis. Use the browser on the first eight lines to choose the input seismic data file (*Arrow 1*). It is not mandatory to take in eight inputs. The number of inputs can vary from two–to–eight. The input attributes that one considers for facies analysis will vary according to the specific applications. For identifying the depositional facies variation the volumetric attributes such as dip magnitude, coherency, GLCM attributes, spectral magnitude and coherent energy can be considered as input. For characterizing geo-mechanical variation in shale plays one should consider different volumes that helps in identifying the rock physics such as inversion volumes, lambda-rho, mu-rho, intercept or gradient AVO volumes, etc. Specify the number of input attributes in the field labeled "Number of attributes to use" (*Arrow 2*). This value will be updated automatically when a file is selected. Do not forget to give a "Unique Project Name". A z-score algorithm is used to normalize the input files. Then specify the number of desired

Volumetric Classification: Program pca3d

principle components to output (*Arrow 3*). The number of principle components cannot go beyond the number of input attributes.

🗙 aaspi_pca3d GUI (Release Date: November 10, 2015)			□ ×
Eile Elot_Training_Iterations Eca_Plot_Projections			Help
3D Principal Component Analysis Seismic Facies Classification			
Input atribute 1(* H): mes/zhao7520/waka3d/gtm3d_test/coherent_energy_waka3d_small_pass2.	Browse		
Input atribute 2(*.H): ouhomes/zhao7520/waka3d/gtm3d_test/glcm_homogeneity_waka3d_small.	Browse		
Input atribute 3(* H): homes/zhao7520/waka3d/gtm3d_test/k_curvedness_waka3d_small_long_w.	Browse	-<	1
Input atribute 4(* H): //ouhomes/zhao7520/waka3d/gtm3d_test/peak_freq_cwt_waka3d_small.H	Browse		
Input atribute 5(* H): //ouhomes/zhao7520/waka3d/gtm3d_test/peak_mag_cwt_waka3d_small.H	Browse		
Input atribute 6(*.H):	Browse		
Input atribute 7(*.H):	Browse		
Input atribute 8(* H):	Browse		
*Unique Project Name: waka3d Suffix: GUI_test			
Verbose Output?			
Parameters defining principal components Operation window	Parallelization pa	rameters	1
Number of input attribute volumes			
Number of desired principal components : 5			
Reset			
		~	
(c) 2008-2015 AASPI - The University of Oklahoma		Ex	ecute pca3d

Then, the user needs to define the operation window in the *Operation Window* tab shown below. A user can either use a fixed time window, or a window defined by two horizons.

Parameters defining principal comp	onents	Operation window		Para	llelization paramete	rs	
Start Time in s:	1.7	1					
Start Time in s:	2.1	2					
Use horizons as limits?	USE TIME Click to	change to Use Ho	rizon 🖊	_ 3			
Input upper horizon filename:			Brow	vse 🦯 🗖	4		
(Choose Horizon Type Below:)		5 🛛	View	horizon file	Convert DOS to Uni	к <mark>ст</mark> е	5
Input lower horizon filename:			Brow	vse	7		
(Choose Horizon Type Below:)		, 8 <mark>-</mark>	View	horizon file	Convert DOS to Uni) (
Choose horizon type:	gridded (e.g. Earth	Vision)	10			N	
Number of header lines to skip:	0	— <u>(</u> 1	1				
Total number of columns:	5	— <u> </u>	2				
Column number of line_no:	1		3				
Column number of cdp_no:	2		4				
Column number of time or depth picks:	5		5				
znull value (indicates missing pick):	-999999	1	6		4		
Vertical axis of picked surface?	Positive Down	<u>17</u>	Verti Picke	ical Units of ed Horizons:	ms 🚽 🧲	18	
(c) 2008-2015 AASPI - The University	y of Oklahoma					Execute	pca3d

Horizon definition

The horizon definition panel will look the same for almost all AASPI GUIs:

- 1. Start time (upper boundary) of the analysis window.
- 2. End time (lower boundary) of the analysis window.
- **3.** Toggle that allows one to do the analysis between the top and bottom time slices described in 1 and 2 above, or alternatively between two imported horizons. If *USE HORIZON* is selected, all horizon related options will be enabled. If the horizons extend beyond the window limits defined in 1 and 2, the analysis window will be clipped.
- 4. Browse button to select the name of the upper (shallower) horizon.
- 5. Button that displays the horizon contents (see Figure 1).
- 6. Button to convert horizons from Windows to Linux format. If the files are generated from Windows based software (e.g. Petrel), they will have the annoying carriage return (^M) at the end of each line (Shown in Figure 1). Use these two buttons to delete those carriage returns. Note: This function depends on your Linux environment. If you do not have the program **dos2unix** it may not work. In these situations, the files may have been automatically converted to Linux and thus be properly read in.
- 7. Browse button to select the name of the lower (deeper) horizon.
- 8. Button that displays the horizon contents (see Figure 1).
- 9. Button to convert horizons from Windows to Linux format. (see 6 above).
- 10. Toggle that selects the horizon format. Currently gridded (e.g. EarthVision in Petrel) and interpolated (ASCII free format, e.g. SeisX) formats are supported. The gridded horizon are nodes of B-splines used in mapping and have no direct correlation to the seismic data survey. For example, gridded horizons may be computed simply from well tops. The x and y locations are aligned along north and east axes. In contrast interpolated horizons are defined by *line_no, cdp_no (crossline_no)* and *time* triplets for each trace location. Examples of both formats are shown in Figure 1. If interpolated is selected, the user needs to manually define each column in the file.
- **11.** Number of header lines to skip in the *interpolated* horizon files.
- **12.** Total number of columns in the *interpolated* horizon files.
- **13.** Enter the column number containing the *line_no (inline_no)* of the interpolated data triplet.
- **14.** Enter the column number containing the *cdp_no* (*crossline_no*) of the interpolated data triplet.
- **15.** Enter the column number containing the *time* or *depth* value of the interpolated data triplet.
- 16. Znull value (indicate missing picks) in the horizon files.
- **17.** Toggle to choose between positive down and negative down for the horizon files (e.g. Petrel uses negative down).
- **18.** Choose the vertical units used to define the horizon files (either *s*, ms, *kft*, *ft*, *km*, or *m*).

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X horizon file content	x	X	horizon fi	le content	And A REPORT OF THE REPORT OF	
Type: scattered data "M # Vype: scattered data "M # Version. 6-M # Description: No description "M # Findi 1. xrM # Findi 1. xrM # Findi 1. xrM # Findi 1. xrM # Findi 2. yrM # Findi 2. yrM # Findi 2. yrM # Findi 5. rowrM # Findi 5. rowrM # Contart. Incla Rectangular M # Units: meters "M # Information from grid "M # Grid size: 41 x 210.37 M # Grid size: 41 x 20.07 M # Z. findi "The Netwallable "M # Jintory: No history"M # Wortcal, faults: Not, available "M # Wartcal, faults: Not, available "M # Bastyris Notoon 4393712.500000 1851.7143408.490 c "M # Bastyris Notoon 4393735.00000 1851.7143729 500 c "M # Bastyris Notoon 4393735.00000 1851.71279 500 c "M # Bastyris Notoon 4393735.0			$\begin{array}{c} \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & 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Qlos	se					ose

Figure 1. (left) A gridded horizon file (EarthVision format). (right) An interpolated horizon file with five columns (ASCII free format).

After defining the parallelization parameters, select *Execute pca3d*.

Parameters defining principal co	omponents Operation window	Parallelization parameters	
Use MPI: 🔽			
Processors per node: 20	Determine Maximum Processors on localhost		
Node list (separated by blanks)	localhost		
Build an LSF Script?	Do Not Run Under LSF		
Build a PBS Script?	Do Not Run Under PBS		
Maximum LSF run time (hrs):	10		
Available batch processors:	0		
	Determine Optimum Number of Batch Processors		
LSF Batch Queue:			
			
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The generated principle component files are named as: pc_\${unique project name}_\${suffix}__j.H

, where j is the principle component order.

Visualization of the result

To view the resulted principle components, a user can either use **aaspi_plot** to display each component individually, or use **aaspi_crossplot** to crossplot two components. One can also use crossplot tools in commercial interpretation packages. The figure below is a crossplot of first two principle components using the horizon probe in Petrel, along a horizon in a turbidite system in Canterbury basin, New Zealand. We interpret the white arrows as multistoried channels, black arrows as sinuous channel complexes, blue arrows as a sand filled channel, and red arrows as slope fans.



References

Zhao, T., V. Jayaram, A. Roy, and K. J. Marfurt, 2015, A comparison of classification techniques for seismic facies recognition: Interpretation, **3**, SAE29-SAE58.