## 3D WINDOW-BASED STATISTICS – PROGRAM stat3d

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#### Overview

Program **stat3d** computes the mean, median, standard deviation, inverse of the coefficient of variation, and user-defined percentiles within structurally-oriented windows. These values can be used as an attribute by themselves, or provided as input to subsequent analysis, such as to programs **disorder** and **kuwahara3d**.

#### **Computation flow chart**

To compute statistical attributes along structural dip, the inline and crossline dip components of the seismic amplitude data need to be computed first, via program **dip3d**. Other attributes are also precomputed.

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## **Output file naming convention**

Program **stat3d** always generates the two output files:

Output file description	File name syntax
Program log information	stat3d_unique_project_name_suffix.log
Program error/completion	
information	stat3d_unique_project_name_suffix.err

where the values in red are defined by the program GUI. The errors we anticipated will be written to the \*.err file and be displayed in a pop-up window upon program termination. These errors, much of the input information, a description of intermediate variables, and any software traceback errors will be contained in the \*.log file.

It desired, program <b>stat3d</b> will also generate the following output files	If desired,	, program stat3d	will also generate	the following	output files:
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Output file description	File name syntax			
Mean value in the window	mean_attribute_name_unique_project_name_suffix.H			
Standard deviation in the window	sigma_attribute_name_unique_project_name_suffix.H			
Inverse coefficient of variation	Inv_coeff_variation_attribute_name_unique_project_name_suffix.H			

k <sup>th</sup>	percentile	in	the	nk attribute name unique project name nH
win	dow			
who	a tha intaga		June k	ranges from 1 to 00 and the pEO output volume is the median filtered

where the integer value *k* ranges from 1 to 99 and the p50 output volume is the median filtered data which will be called p50\_<u>attribute\_name\_unique\_project\_name\_p</u>.H .

## **AASPI Implementation**

You will find program **stat3d** under the AASPI *Image Processing* tab:

🗙 aaspi_util GUI - Post Stack Uti	lities (Release Date: 31 October 202	1)							-		×
	ations Spectral Attributes	Geometric Attributes Fo	ormation Attributes	Volumetric	Classification	Data Conditi	ioning	Image Processing			Help
Attribute Correlation Tools	Display Tools Machine Le	arning Toolbox Surface	Utilities Well Log	Utilities Oth	ner Utilities Set	t AASPI Defau	ult Para	stat3d			
SEGY to AASPI format conversion	AASPI to SEGY format conversion (multiple files)	AASPI to SEGY format conversion (single file)	AASPI QC	2 Plotting	AASPI W	orkflows	Comput AA	te mean, median, percentile nicer_single_attribute fault_enhancement	es, and sta	ndard	deviation
SEGY to AASPI - Convert P	oststack seismic volumes fro	m SEGY to AASPI format	:					fault_connectivity			
2D SEG-Y Line rather than	a 3D survey ?						-				

By clicking the program **stat3d**, the following GUI appears:

X aaspi_stat3d GUI (Rele	ase Date: 31 October 2024)		-	
<u>F</u> ile				
stat3d - computes sin	nple statistics within a user-	defined 3D window along structural dip		
Input data (*.H):	marf2925/projects/kora3d/e	nergy_ratio_similarity_kora3d_class_broadban	d.H Browse	
Inline dip (*.H):	/ouhomes6/marf2925/proje	ects/kora3d/inline_dip_kora3d_0_broadband.H	Browse	
Crossline dip(*.H):	/ouhomes6/marf2925/proje	ects/kora3d/crossline_dip_kora3d_0_broadband	J.H Browse	
Unique project name:	kora3d			
Suffix:	class			
Attribute name:	energy_ratio_coherence			
Primary parameter	s Parallelization parame	ters		
Compute mean (mu)	17	<b>u</b>		
Compute standard d	eviation (sigma)?	<b>T</b>		
Compute the inverse (n	of the coefficient of variation of variation of the coefficient of variation of the coefficient of the coeff	v r		
Number of percentile	es (n_pvals):	3		
Lowest percentile (p	low):	10		
Highest percentile (p	high):	90		
Window length:		50		
Window width:		50		
Window height:		0.008		
Use rectangular_win	dow?:	Г		
Save stat3d parame	ters for AASPI iterative Kuw	ahara filter workflow		
Save parameters	and return to Workflow GUI	1		
1		1		

The input parameters are self-explanatory. (1) Enter the name of the *Input data* (i.e., attribute) you wish to filter. In this example, I've chosen energy-ratio coherence. Then because the filtering is structure-oriented, enter the (2) inline and (3) crossline dip components for this survey. As with almost all AASPI programs, enter a (4) Unique project name and (5) Suffix. The output names will start with the type of statistic defined under (7) which include the mean, standard deviation, inverse of the coefficient of variation, and three or more percentile volumes (in this example, p10, p50 (the median), and p90). The (6) Attribute name, (4) Unique project name, and (5) Suffix will be concatenated with the filter name to generate the various output volume names. In this example, the median filtered volume will be called p5 energy ratio coherence kora3d class.H. Next, enter the (9) Number of percentiles desired and the range of the (10) Lowest percentile, pLow, and the (11) Highest percentile, pHigh. The final parameters defined the size of the Kuwahara window used. In this example the voxels are  $12.5 \text{ m} \times 25 \text{ m} \times 0.004 \text{ s}$ . In this example, I've chosen a larger window to generate more robust statistics of 50 m  $\times$  50 m  $\times$  0.008 s. All windows have vertical sides with tops and bottoms that are aligned with structure. In this example, I've chosen an oblique (13) rectangular prism rather than an oblique ellipsoidal analysis window.

# **Theory: Basic Statistics**

Let's assume we have J voxels that fall within a 2D or 3D analysis window along structural dip. There are several linear and nonlinear filters that can be applied.

#### The mean

The mean filter is the best-known and simplest random-noise suppression filter and forms the basis of most seismic stacking algorithms. On maps, the mean filter is a low-pass filter that typically is implemented as a running-window-average filter. The output-data value is the average of all the samples that fall within a centered analysis window. The window size is usually an odd number, such as three by three or five by five, and may be either rectangular or elliptical.

The mean filter is the simplest, where the mean  $\mu$  of J samples  $d_i$  is defined as:

$$\mu = \frac{1}{J} \sum_{j=1}^{J} d_j \,. \tag{1}$$

The mean filter is a smoothing filter and may not only smooth across faults but smooth in erroneous spikes into the output.

#### The standard deviation

The standard deviation is given by

$$\sigma = \left[\frac{1}{J}\sum_{j=1}^{J} \left(d_j - \mu\right)^2\right]$$
(2)

#### The inverse of the coefficient of variation

The coefficient of variation scales the standard deviation  $\sigma$  by it's mean  $\mu$ , giving  $V = \frac{\sigma}{\mu}$ . This metric can be

unstable if the mean  $\mu$  is close to zero. A more robust measure is the inverse of the coefficient of variation

$$V^{-1} = \frac{\mu}{\sigma} \,. \tag{3}$$

## The median

The median is one of the most widely used nonlinear techniques in signal and image processing and also is used routinely to filter VSP data. The median filter replaces each sample in a window of a seismic trace by the median of the samples that fall within the analysis window; in so doing it rejects outliers. The window size typically is an odd number (e.g.,  $3 \times 3 \times 3$ , or  $5 \times 5 \times 5$ ). The first step of the median filter is to sort the data vector, **d**, into a new vector **u** where  $u_k \le u_{k+1}$ :

$$\mathbf{u} = \text{sort} \{ d_1, d_2, \dots, d_i, \dots, d_{J-1}, d_J \}.$$

Then the median, *m*, is defined as:

$$m = u_{(J+1)/2}$$
.

The median filter is an edge-preserving filter and will preserve changes in dips across faults. It also rejects erroneous spikes in the input data.

## Percentiles

The pth percentile is simply the value  $u_k$  in equation 2 where

$$k = \operatorname{NINT}\left[\frac{p}{100}(J-1)\right] + 1.$$

(5)

(6)

(4)

### **Resulting statistics volumes from program stat3d**

Let's start by displaying a vertical slice through the original coherence volume, followed by the p10, p50 (median!), p90, mean, standard deviation, and inverse coefficient of variation











In the last two examples, the values of the standard deviation and the inverse of the coefficient of variation have scaled between their 0 and 95<sup>th</sup> percentile.

#### References

Qi, J. T. Lin, T. Zhao, F. Li, and K. J. Marfurt, 2016, Semisupervised multiattribute seismic facies analysis: Interpretation, **4**, SB91-SB106.