

MODULATING A POLYCHROMATIC IMAGE BY ONE PLOTTED AGAINST SATURATION – PROGRAM hsplot

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Overview

There are two main reasons to modulate one attribute by another. The first is when the two attributes form components of a 2D vector such as dip magnitude and dip azimuth, envelope and instantaneous phase, or spectral peak magnitude and spectral peak phase. The second is when we wish to modulate one attribute by another that measures the confidence in the first. For example, we may wish to map the acoustic impedance by a volume that measures the error misfit between the synthetics and the original data.

The AASPI software allows two ways to do this. Program **hlplot** modulates an attribute plotted against a polychromatic color bar by a second against lightness. Program **hsplot** modulates an attribute plotted against a polychromatic color bar by a second against saturation. Program **hlsplot** allows two levels of modulation. Program **corender** provides an interactive means to modulate one attribute by one or two others.

Computation Flow Chart

Program **hsplot** reads in two attribute volumes and outputs a composite volume, a color legend, a histogram, and a suite of multiplexed colorbars that can be used to load the composite volume into the more common interpretation workstations software products.



Output file naming convention

Output file description	File name syntax
Composite attribute	<pre>saturation_axis_title_vs_hue_axis_title_unique_project_name.H</pre>
Color legend (2D colorbar)	hsplot_color_legend_ <i>saturation_axis_title_</i> vs_ <i>hue_axis_title_unique_project_name</i> .H
2D histogram	hsplot_histogram_ <i>saturation_axis_title_</i> vs_ <i>hue_axis_title_unique_project_name</i> .H
Multiplexed 1D	
colorbars	hs_colorbar.alut, hs_colorbar.CLM, colorbar.geomodeling,
Program log	
information	hsplot_ <i>unique_project_name</i> .log
Program	
error/completion	hsplot_ <i>unique_project_name</i> .err
information	

Program **nonparallelism** will always generate the following output files:

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.

Invoking the hsplot GUI

To invoke program **hsplot**, on the **aaspi_util** GUI select *Display Tools* and then select **hsplot** on the drop-down menu:

🗙 aaspi_util GUI - Post Stack Utilities (Release Date: 20 April 2	 020) — 🗆 X
Eile Geometric Attributes Spectral Attributes	Single Trace Attributes Formation Attributes Volumetric Classification Image Processing Help
Attribute Correlation Tools Display Tools Machin	e Learning Toolbox Well Log Utilities Other Utilities Set AASPI Default Parameters
SEGY to AASPI format conversion (mult hlplot	wer n AASPI QC Plotting AASPI Workflows Prestack Utilities
SEGY to AASPI - Convert Po	SEGY to AASPI format
SEGY Header Ut	inst Hue by a second attribute plotted against Saturation
2D SEG-Y Line rather than generate_roses	
SEGY format input file nam graph_plot (*.segy,*.sgy,*.SEGY,*.SG `\7.	Browse View EBCDIC Header
AASPI binary file datapath: ./	

Program **hsplot** plots one attribute against hue (H) and a second attribute against saturation (S). You should have a GUI that looks like this:

🗙 aaspi_hsplot GUI (Release Date: 31 May 2020) — 🗆	×
<u> </u>	<u>H</u> elp
hsplot - bins two input attributes against a 2D hue vs. saturation color table. The output composite data volume ranges in value from 0 to max_color-1 which maps one-to-one against the corresponding color table. IESX, Landmark, Voxelgeo, geomodeling, Kingdom, and SEP format color tables are generated which can be loaded into commercial workstation software applications.	
Input attribute plotted against the hue axis	
Input attribute file name (*.H): mes6/marf2925/projects/GSB_AAPG/dip_azimuth_GSB_AAPG_0_broadband.H_Browse	
Title on hue axis:	
Common hue 1D colorbars:	
Custom hue colorbar (ascii-format):	
Attribute value to be plotted against min. bu	
Attribute value to be plotted against max_h e: 180	
- Input attribute plotted against the saturation axis	
Input attribute file name (*.H):	
Title on saturation axis: magnitude Re-scan saturation attribute	
Attribute value to be plotted against min_saturation:	
Attribute value to be mapped against max saturation: 10 9	
Min saturation value (0.0 => gray):	
Max saturation value (1.0 => pure colors):	
Fixed lightness value (0.0 => black, 1.0 => white):	
Maximum number of colors (256 for Petrel, Geoviz, Geomodeling, Seisworks) (230 for Kingdom Suite):	
2D color bar size: (H*L<= max_color) nhue: 15 saturation: 15 ncolor: 225	
Plot title: magnitude_vs_azimuth	
Composite Output File (*.H): magnitude_vs_azimuth_GSB_AAPG.H	
Colorbars to Generate	
M AASPI (lalut) GeoFrame (liesx) Landmark (landmark .cl2) VoxelGeo (lcolor) Geomodeling (geomodeling)	
SeisWare (.xml) Transform (.cmp) Kingdom (.CLM) GeoProbe (.gpc)	
(c) 2008-2020 AASPI for Linux - authors at Univ. Oklahoma, Univ. Alabama, Univ. Texas Permian Basin, Univ. Alaska, and SISMO	plot

In this example I browse and select (1) the file *dip_azimuth_GSB_AAPG_0_broadband.H* as the file to be plotted against Hue. The current GUI is somewhat more clever than previous releases and will trigger off the substring "dip_azimuth" in the file name such that (2) the string *azimuth* appears for the *Title on Hue Axis*. (3) The string *cyclical (-180 +180)* color bar will appear as the appropriate color bar, and (4) the *Attribute value to be plotted against min_hue* (in this case, -180.0 degrees) and the *Attribute value to be plotted against max_hue* (+180.0 degrees) are read from the values of *min_amplitude* and *max_amplitude* from the input file entered after arrow 1. All of these default values can be altered, though for azimuth attributes these values are almost always the optimum values. If you mistype the range of minimum and maximum values, or if for some reason they are not in your *.H input file, you can always (5) *Rescan Hue Attr* to recompute the largest possible range in the data.

Other color bars useful in plotting AASPI attributes are found on the drop-down menu:

Common hue 1D colorbars:	, Cyclical (-180 to +180)	
Custom hue colorbar (ascii-format):	Temperature (hot to cold)	
Attribute value to be plotted against min busy	Temperature (cold to hot)	
Attribute value to be plotted against min_ride.	Cyclical (0 to 360)	
Attribute value to be plotted against max_hue:	Cyclical (-180 to +180)	
	Shape Colorbar (blue to red)	

The saturation section is similar. The current GUI is again, somewhat more intelligent than our first releases, such that when (6) I click the *Browse* button, only the files that most commonly couple with those after arrow 1 will appear. Since I have previously entered a file name beginning with "dip azimuth", the GUI will present a list of those beginning with "dip magnitude". In this case I choose *dip_magnitude_GSB_AAPG_0.H* as the file to be plotted against Saturation. The (7) Title on Saturation Axis defaults to be "magnitude", the (8) Attribute value to be plotted against min saturation defaults at "0" and the (9) Attribute value to be plotted against max saturation defaults at "90" where the latter two values were stored as "min_amplitude" and "max amplitude" in the input *. If file. However, our previous dip magnitude images showed a maximum dip magnitude of about 10 degrees, so (9) in the Attribute value to be plotted against max_saturation box, I typed in 10. The Minimum and Maximum saturation values (10) and (11) respectively, allow you to define the saturation values to plot the attribute against, with a maximum saturation of 1.0, representing full saturation (or pure colors), and a minimum saturation of 0.0, representing gray. Leave the (12) Maximum number of colors to be 256 since most workstation software will not allow you to import files with more than 256 colors. If this is the case, (13) keep the number of Hue and Saturation bins at 17 and 15. If desired, (16) modify the name for your output file magnitude_vs_azimuth_GSB_AAPG.H. Finally, if you intend to convert the output to SEGY format and load them into commercial workstation software, place a checkmark in front of the software that you use. Finally, click *Execute*. The following images will appear when the job completes:



The first image is a 2D color bar. On the right of the 2D color bar is the 1D color bar that you will load into your interpretation workstation. Note that it has been multiplexed (or wrapped) horizontally with color zero at the bottom left and color 224 in the upper right. Gray corresponds to low dip magnitude, and the fully saturation colors correspond to high dip magnitude, with dirty colors in between. Note that an azimuth of 0[°] (North) appears as blue, while azimuths of both -180[°] and +180[°] (South) appear as yellow. The GUI recognizes this to be a cyclic 2D color bar or color wheel and also provides the following image:



The color wheel is plotted using the **aaspi_plot** utility which is designed to display seismic amplitude and attribute data. I've annotated the image in PowerPoint to give a more explicit definition of the color wheel:



Flat (horizontal) events with a dip magnitude of 0° are plotted against white. Events with a dip magnitude of 50 and dip azimuth of 0° (North) appear as blue, 60° as magenta, 120° as red, 180° (South) as yellow, 240° as green, 300° as cyan, and 360° as blue. Less strongly dipping events appear as pastel colors.

We also have a histogram of how many voxels in the volume are plotted against each color. In this example we can see the data have a regional trend towards the east.





The final image will be an animation of time slices of the output data mapped to the 2D color bar. Strong dips are displayed as pure colors and weak dips as gray. In this example we see the strong dip adjacent to the fault blocks and the regional dip to east (in a magenta-red color).



Generating images with more colors than supported by your commercial workstation software

If you want to plot an image with greater color depth, you can. The only restriction is that you probably will not be able to import the resulting color table into your commercial workstation software. In this example, I set the limits to be those of my Dell display device which supports 32-bit color (256 values for R, G, B, and alpha):

Maximum number of colors	65536	Warning
(230 for Kingdom Suite): 2D color bar size: (H*L<= max_color)	nhue: 256 * nsaturation: 256 = ncolor: 65536	Color Map Size too large to load in most workstations > 256
Plot title: Composite Output File (*.H):	magnitude_vs_azimuth magnitude_vs_azimuth_GSB_AAPG.H	QK

A warning appears. I check OK and obtain the following (more continuous) colorbar and image with greater color depth:





Importing and modulating a custom colorbar with saturation

Although the dropdown menu described above for the more common continuous, fully saturated color bars constructed along the hue axis works well for the AASPI attributes, different companies and different software packages may have their own colorbars. For example, it is common in impedance inversion to use color bars that do not follow a smooth curve in RGB or HLS space, but rather "jump around" to enhance discrete changes. In this case, you need to export the corresponding RGB color bar. At present, our format looks like this (which is equivalent to the color *.CLM format used by Kingdom Suite):

0	0
255	0
255	0
255	255
0	255
0	255
	0 255 255 255 0 0

Or alternatively with an unused alpha value as 4th column (the *.alut format used by Petrel):

255,	0,	0,	255
255,	255,	0,	255
0,	255,	0,	255
0,	255,	255,	255
0,	0,	255,	255
255,	0,	255,	255

In both files, *test.CLM* and *test.alut*, there are 6 rows containing RGB triplets whose values range between 0 and 255. The values can be separated by spaces, commas, or tabs and do not need to be in strictly aligned columns. If you construct these files by hand, be aware that there can be *no blank lines* at the end of the file, which would add additional undefined RGB triplets! You may recognize these colors as being fully saturated values of red, yellow, green, cyan, blue, and magenta. Be sure the add the first line indicating the number of custom colors. Reexamining the GUI

🗙 aaspi_hsplot GUI (Release Date: 31 May 2020)		- 0	×
Eile			<u>H</u> elp
nsplot - bins two input attributes against a 2D i data volume ranges in value from 0 to max colo able. IESX, Landmark, Voxelgeo, geomodeling, generated which can be loaded into commercial	ue vs. saturation color table. The output composite r-1 which maps one-to-one against the corresponding color Kingdom, and SEP format color tables are workstation software applications.		
nput attribute plotted against the hue axis —			
Input attribute file name (*.H):	mes6/marf2925/projects/GSB_AAPG/dip_azimuth_GSB_AAPG_0_broadband.H Browse		
Title on hue axis:	azimuth Re-scan hue attribute		
Common hue 1D colorbars:	Cyclical (-180 to +180)		1
Custom hue colorbar (ascii-format):	/ouhomes6/marf2925/projects/GSB_AAPG/test.alut Browse for custom hue	colorbar file	
Attribute value to be plotted against min_hue:	-180		
Attribute value to be plotted against max_hue:	180		
nput attribute plotted against the saturation a	ds		
Input attribute file name (*.H):	s6/marf2925/projects/GSB AAPG/dip magnitude GSB AAPG 0 broadband.H Browse		
Title on saturation axis:	magnitude Re-scan saturation	n attribute	
Attribute value to be plotted against min_satur	ation: 0		
Attribute value to be mapped against max satu (use a negative number for k2, e_neg,	ration: 10		
Min saturation value (0.0 => gray):	0		
Max saturation value (1.0 => pure colors):	1		
Fixed lightness value (0.0 $=>$ black, 1.0 $=>$ wh	ite): 1		
Maximum number of colors (256 for Petrel, Geoviz, Geomodeling, Seiswork (230 for Kingdom Suite):	s) 256 20		
2D color bar size: (H*L<= max_color)	nhue: 6 Isaturation: 15 = ncolor: 90		
Plot title:	magnitude_vs_azimuth		
Composite Output File (*.H):	magnitude_vs_azimuth_GSB_AAPG.H		
Colorbars to Generate			
🔽 AASPI (.alut) 🛛 🗖 GeoFrame (.iesx) 🗖 I	andmark (.landmark .cl2) 🗖 VoxelGeo (.color) 🗖 Geomodeling (.geomodeling)		
🗖 SeisWare (.xml) 🗧 Transform (.cmp) 🗖 🛙	Cingdom (.CLM) 🗖 GeoProbe (.gpc)		
(c) 2008-2020 AASPI for Linux - authors at Unit	7. Okianoma, Univ. Alabama, Univ. Lexas Permian Basin, Univ. Alaska, and SISMO	Execute	nsplot

click (18) *Browse for custom hue colorbar file* and select from your suite of *.CLM or *.alut format files the one you wish to use (in this case, test.rgb). The *.alut and *CLM endings are optional, but helps minimize searching for the proper file from a potentially long list in your directory. After selection, three options are disabled – the drop down colorbar choices, the level of lightness (defined implicitly in your *.rgb file from the range of values) and the number of hues (defined explicitly in your *.rgb file). The value of lightness is changed to 1 and will multiply (preserve) the implicit values of lightness in the *.alut or *.CLM file.



The resulting colorbar and colorwheel look like this



where the first color (red) is mapped to the minimum value of the attribute plotted against hue in the GUI. Unused colors are set to white. The resulting time slice in the composite data volume looks like this:



This first 6-color example showed fully saturated colors. Any RGB color triplets will work. Partially saturated colors will simply be multiplied by the saturation value of the second attribute. Here is another 6-color example that proves the point (but it is NOT one I would use to plot these data):





Loading and displaying multiattribute plots in Petrel

Schlumberger has been gracious enough to provide OU with licenses for education and research, hence the example on how to load a composite attribute volume into Petrel. Loading such

volumes in Voxelgeo, Kingdom Suite, Landmark, Geoprobe, IESX, and Geomodeling are similar. Unfortunately, a few packages (e.g. Geographix) do not allow loading an ascii color bar from a file.

The first step is to convert the AASPI-format file dip_mag_vs_dip_azim.H to a SEGY-format file dip_mag_vs_dip_azim.segy using the AASPI to SEGY format conversion (single file) tab in **aaspi_util**. Then, depending on how your disk drives are mounted and shared, you will need to copy this data from your Linux system to your PC where you run Petrel. Once the data have been converted and copied, launch Petrel, open your project, and add the new SEGY file into the project by highlighting the survey name and clicking the *Import File (on selection)* icon:



The following window should pop up:

Import file						? 🗙
Look in:	🚞 segy		*	G 🦻	•111 🥙	
A 2 Documents Desktop My Documents	d_mig_boonsvill dip_azim_coh_t dip_mag_vs_dip energy_ratio_si hiplot_18_14_h hisplot3d_16_4 shape_vs_curv shape_vs_curv	le.segy boonsville.segy b_azim_boonsville.segy imilarity_boonsville_0.segy i4.alut _4_h3.alut .alut edness_boonsville.segy edness_pastel_boonsville.seg	у			
My Computer	File name: Files of type: iption:	SEG-Y Import with preset par	ameter	s (^{x, x})	v	Open Cancel
This SEG-Y import The SEG-Y trace I	allows loading para header positions car	meters to be set before the file: h be set and the file can be sca	s are lo anned.	aded.		~

First, choose to load (1) SEG-Y import with present parameters (*.*), since the header values for the AASPI volumes may be different from your default settings. (The Petrel loading utility is fairly clever, but let's just do this for clarity). Proceed to (2) select *dip_mag_vs_dip_azim_boonsville.segy* as the file to be loaded.

Click Open and the following panel is displayed (see next page):

	S-Y Import	X
		🕜 Vintage Set default vintage 🔽 New
	○ 2D ⊙ 3D	
	Ignore SEGY coordinates	Ignore traces with null (0,0) coordinates
	Byte Trace headers: position	Header format
	X coordinate 73 💌	4 byte (32-bit) integer 💉 Scan
	Y coordinate	4 byte (32-bit) integer 🕑 Start trace
	Line detection method Trace he	ader fields 🗸 👔
	Inline number	4 byte (32-bit) integer
	Crossline numb	A hute (22 hit) integer
		4 byte (32-bit) integer
	CDP number 21 🕑	4 byte (32-bit) integer 💽
	Shotpoint number 🛛 17 💽	4 byte (32-bit) integer 💉
	Sample format	floating point
	Samples per trace 800	Sample interval 2
	Time/depth first sample	Coordinate scale 1
	Use trace weighting factors	Skip header sanity checks
	SEGY headers from first file	
3	C18 Trace header location C19 line number in C20 xline (cdp) number in C21 coord scale factor in C22 shot x coord in	Is: 1 bytes 13-16 1 bytes 21-24 1 bytes 71-72 copied from input data 1 bytes 73-76 copied from input x-coordinat
	C23 shot y coord in C24 group x coord in C25 group y coord in C26	bytes 77-80 copied from input y-coordinat bytes 81-84 copied from input data bytes 85-88 copied from input data
	<	
		🗸 OK 📉 🗶 Cancel

First, select (1) *3D* since you will wish to load a 3D seismic volume. Then (2) select *Trace header fields* as the *Line detection method*. Next, scroll down under *SEGY headers from first file* and note that the (3) *Inline number* is in bytes 13-16 and the *Crossline number* in bytes 21-24. The value of 21 is the 1977 SEG-Y standard for CDP number and is usually set as the default crossline number for interpretation systems. However, most interpretation systems were started before the 2003 SEG-Y standard for 3D seismic data was adopted, such that finding the inline number takes some detective work. For all the AASPI volumes, the inline number will be in bytes 13-16. Enter (4) the value of 13 for the *Inline number* byte location. Click OK and the data begins to load. The file will then be under your *Input* tab:



Double click the last file in the list *dip_mag_vs_dip_azim_boonsville* to open the *Settings* pop-up window:

Settings for 'dip_mag_vs_dip_azim_boonsville'
📝 Style 📵 Info 🚹 Statistics 📮 Colors
Operations SEG-Y settings Geometry Opacity
Realize Amplitude
Source amplitude range: ~0.0000 to ~255.0000
Set from source as shown above
2 V Set from source symmetrical
3 Zero centric Min: 0.0000 Max: 255.0000
Histogram
× 300 A 1300 20 5 3000 3000 4000
8
6
4
2
Lower clipping: 0.0000% Upper clipping: 0.0000%
🔲 Filter Bins: 4096 Original quality: Floating point 32 bit 👔
6 Realization quality: Integer 8 bit 💽 Show
Uutput file <project folder="" pdb=""></project>
Vintage
✓ Use default ⇒
Realized volume size: Max 23.0 MB
🗸 Apply 🛛 🗸 Cancel

Under the *Operations* tab, you will note that (1) the histogram is neither Gaussian (like seismic amplitude) nor log-normal (like RMS amplitude and envelope). Rather, what you see is the histogram of the dual attribute data multiplexed into a single composite attribute histogram. Next, select (2) *User defined* and unselect (3) *Zero centric*. The composite attributes will range from 0 to 255. In order to map accurately against the 2D color bar, explicitly set (4) *Min* to be 0.0 and (5) *Max* to be 255.0. Since the data range between 0 and 255, choose the (6) *Realization quality* to be *Integer 8 bit*. Finally, click Realize and close the window to exit when you are done.



Your Input tab should have the Realized data below it:

Choosing the plot, the time slice at t=-1100 ms (for those of you not familiar with Petrel, it has the time and depth axes as Positive Up) should give you the following display:



Petrel assigns the default Seismic color bar. Therefore, you will need to import the 2D color bar generated by the program **hlplot**. To do so, first copy the file *hsplot_18_14_360.alut* from your Linux workstation. Rename it to be something that makes sense, such as *dip_azim_2D.alut*. Then highlight your *Templates* tab and click the import icon:



The following window opens:

Import file						? 🗙
Look in:	🚞 segy		*	G 💋	ب 🔝 	
2 My Recent Documents	<pre>dip_azim_2D.al hlplot_18_14_h hlsplot3d_16_4 shape_vs_curv</pre>	ut 14.alut 5_4_h3.alut 7.alut				
Desktop						
My Documents						
Si Mu Computer						
	File name:				*	Open
1	Files of type:	Color tables (alut file) (*.alut)			*	Cancel
My Network		Open as read-only				
File example/desc	ription:					
140 255 000,000,000,255 001,001,001,255 002,002,002,255 003,003,003,255						<
<						

First, (1) select *Files of type* to be *Color tables (alut file) (*.alut)*. Then (2) select the file *dip_azim_2D.alut* and click *Open*.

The following pop-up window appears:



Petrel will want to Trim your color and opacity control points. <u>It is extremely important that you</u> <u>unselect this default option or your color mapping will not work!</u> Once unselected, click OK.

The new color bar will appear at the bottom of your *Seismic color tables* in the *Templates* tab:



Return to the Input tab and double-click the realized data volume dip_mag_vs_dip_azim_boonsville (Realized) to open the Setting tab:

Settings for 'dip_	mag_vs_dip_azim_boonsville [Reali 🔀					
Colors 🔯	Operations Geometry Opacity					
💜 Style	🕄 Info 🚹 Statistics					
🔟 Name:	dip_mag_vs_dip_azim_boonsville [Realized]					
Color:	· · · ·					
Туре:	3D seismic 🚳					
1 Template:	📑 🗘 dip_azim_2D 🛛 👻 🚰					
Domain:	t↓ Elevation time 💌					
Vintage:	🔿 🛐 Seismic Time 16					
Date:	11/ 3/2009 💌					
S Comments 3 History						
	<u>^</u>					

Under the *Info* tab, (1) select your new color bar, *dip_azim_2D*. Click Apply and your seismic attribute time slice may look like the following:



The problem here is that Petrel is interpolating colors. Go back to the *Settings* tab and under the *Style* tab, click (1) *None* as the *Interpolation Method*. You will encounter this problem when using any discontinuous color bar. In addition to multiattribute images, these may occur with discrete classifications (e.g. if you import classes from Stratimagic) or discrete color tables from facies inversion (e.g. green for shale, yellow for sandstone, blue for limestone).

🏶 Settings for 'dip_mag_vs_dip_azim_boonsville [Reali 🔀						
Colors 🔯 Operations Geometry Opacity						
Style 🚺 Info 📊 Statistics						
🎲 'Base map' annotation						
Settings are inherited from parent folder.						
Intersection S Volume visualization						
Interpolative Source Bilinear Smooth						
Vertical: 3 Vertic						
Visualization Enable zone and segment filters for intersections Enable bump mapping Enable transparency for intersections						
Max resolution 💿 Full 🔿 Medium 🔿 Low						
Performance Enable compressed textures Fast scene movement						
Decimation while dragging: 2 🗸						
Time to wait for data 500 ms						
🖌 Apply 🖌 OK 🖌 Cancel						

The new image looks like this:



Later, using program **similarity3d**, you will generate various coherence images. You will wish to set your transparency for energy-ratio similarity to be transparent for coherent regions, and black for incoherent regions:



Co-rendering the energy ratio similarity image with the composite dip magnitude vs. dip azimuth image results in the following:



Careful examination indicates that the color-encoded dip magnitude vs. dip azimuth images shows the reflectors dipping into the circular karst collapse features.

References

Marfurt, K. J., 2015, Techniques and best practices in multiattribute display: Interpretation, **3**, 1-24.