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This depiction of Neptune by the 18th century French artist Francois Boucher is the frontispiece from the 1774 edition of Jean Baptiste Nicolas Denis d'Apres de Manneville, *Le Neptune Oriental* which gives sailing directions from France to the East Indies. Courtesy of the Osher Map Library of the University of Southern Maine.

cartographic techniques

Using Remote Sensing Imagery to Texturize Layer Tinted Relief

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Combining layer tinting or "painting" with relief shading has proven to be a very effective method for portraying the landscape. Ad-

ditionally, the "painted relief" is important in providing a backdrop for maps designed for land management and resource planning at the Bureau of Land Management's Oregon State Office. Figure 1 illustrates a typical "painted relief" image (color image can be viewed at <http://www.or.blm.gov/gis>). This article introduces a technique that gives cartographers a new capability of adding visual texture to maps, by combining layer tinted relief with a modified Digital Elevation Model (DEM) using SPOT or Thematic Mapper imagery or Digital Ortho-photography. This texturizing method has greatly enhanced the "painted" relief maps in communicating detailed land-

cover features. The result is not only more informative, but also very visually exciting because of the tactile appearance. This technique has been particularly useful in showing patterns of recent forest management activities in the Northwest. Figure 2 illustrates the same area as Figure 1, but with landscape patterns texturizing the surface. The techniques described here specifically uses ESRI Arc/Info software, but the general methodology could be applied using other mapping software.

A step by step flow through the process of "texturizing" painted relief with land-cover patterns derived from SPOT satellite imagery using Arc/Grid and Arc Macro

Language programming is covered in this paper. The inputs needed for the processes presented here are a SPOT satellite image and a digital elevation model that cover the same area.

Extract Land Cover Textures and Patterns from Imagery

The first step in texturizing "Painted Relief" is to derive fundamental land-cover patterns from satellite imagery. In this example, SPOT panchromatic imagery is used as shown in Figure 3. One simple way to capture land-cover patterns is to perform a binary classification of the image based on the mean image value. The result is a map with two classes, a dark class which consists of all pixels where the value is less than the mean, and a light class where all the pixel values are greater than the mean. In this densely forested area, as shown in Figure 4, light values are usually indicative of recent forest harvest activities. Dark values are forested areas. More sophisticated schemes should probably be used in order to be more truly reflective of human activity, but for the purposes here, this will suffice.

Lower Elevation values in Disturbed Areas

To begin this step, a Digital Elevation Model (DEM) of the study area is needed. The procedure here is to lower elevation values in the DEM according to the lighter classes, which represent forest harvest activities. The depth of this subtraction should be about the average tree height, which in this area is about 20 meters. This depth value should be less if you need the land cover patterns to be less obvious, and more if you want extreme exaggeration. Subtracting the patterned area from the Digital Elevation Model can be performed in ArcGrid using the CON function as shown here:

```
Pattern_elv = CON(Two_class_
image
eq 1,DEM - 20,DEM)
```

Where:

Pattern_elv is the output image;
Two_class_image is the reclassified SPOT image and DEM is the Digital Elevation Model of the study area.

The function lowers all areas of the DEM by 20 meters where the two-class image was equal to 1; all other areas remain the same. Although probably not apparent in a graphic of the gray-scale image of the Pattern_elv, (so they are not presented here), this process creates depressions in the DEM which will emphasize and emulate the clearings created by forest harvest activities.

Create a Gray-scale Relief Image

Create a gray scale relief image using Pattern_elv, which was created in the previous step. Use the ArcGrid HILLSHADE function to do this. The syntax is show below:

```
Hill_img =
HILLSHADE(Pattern_
elv,345,65,#,1.2)
```

The Hill_img, shown in Figure 5, displays the simulated illumination of the sun at an azimuth of 345 degrees and a solar altitude of 65 degrees, taking shadows into account and exaggerating the vertical 120 percent. Notice how the areas of disturbance now appear to have dimension. In some mapping applications only a gray-scale or monochromatic image is sought. When that is the case, then the areas of disturbance should be lightened at this point and the process will be completed. To lighten areas of disturbance use the ArcGrid CON function with this syntax:

```
Finalhill = con(Two_class_im-
age eq 1,hill_img + (255 - hill_
```

```
img) * .2),hill_img)
```

Where: Finalhill is the output map; Two_class_image is the reclassified SPOT image; and hill_img is the hillshade image created in the preceding step.

This function will lighten all areas of surface disturbance by 20 percent of the difference between the existing value and white (255). The results of this process are shown in Figure 6.

Lighten Areas of Disturbance on GIS Theme Category image

If just painted relief is desired, a GIS theme is needed to direct the colorization of the relief image. In this example, the DEM was categorized into 500 foot categories using the ArcGrid RECLASS function and an elevation category lookup table. The colors are assigned to each class via an ASCII color lookup table. The image is displayed in ArcInfo grid with the GRID-PAINT command. The syntax for these processes is as follows:

```
Elev_cat = RECLASS(DEM *
3.28089,elev.lut)
GRIDPAINT elev_cat value
identity nowrap color.lut
```

Where:

Elev_cat is the output of the RECLASS function; DEM is the elevation data for the study area; 3.28089 is a meters to feet conversion factor; elev.lut is a reclass table which converts 500 foot ranges of feet to a unique class number. Color.lut is an ASCII lookup table that relates elevation category number to red green and blue values to create colors.

The result of this process is shown in Figure 7. Keep in mind that other themes such as vegetation, soils, surface ownership, etc., could be used instead of elevation

categories.

The next step is to lighten areas of disturbance on the GIS theme image according to the two class binary image. Because of the use of color, both the output image and its color map must reflect this lightening process. To perform this process, an Arc Macro Language (AML) program was written and used. This AML, ADD_HIGHLIGHT.AML calls the ArcGrid CON function:

```
Cat_cut = CON(two_class_image eq 1,elev_cat + 100,elev_cat)
```

Where:

Cat_cut is the output; two_class_image is the two class SPOT image, and Elev_cat is the elevation category map.

The AML process creates new unique class numbers by adding 100 to every elevation class whenever the two-class image was equal to 1. This creates a numerical offset so the original color and its lightened color can be tracked in the image. To create the colors for the new categories, the program reads the color lookup table for the elevation category map, adds that information to the INFO database system, then calculates a new color

for value + 100. That creates a new color value that is 50 percent lighter than the original value. The program writes out a new color lookup table for the output image. The output of this process is shown in Figure 8.

Build Final Texturized Painted Relief Image

The final texturized painted relief image, shown in Figure 2, is created by combining the "Elevation categories with patterns image" shown in Figure 8 with the "Textured relief image" shown in Figure 5. As in the previous step, this process is fairly complex so an AML was written to perform the process. The NEWRELIEF.AML uses the ArcGrid COMBINE function to create a unique class for every combination of classes in the two input images. The AML loads the color maps from each input image into the INFO system, and finds the average of the color values of the inputs for each unique class. A new ASCII color lookup table is written to a disc file. This file and the output image can be used with the ArcGrid GRIDPAINT command to display the new image to the screen or hardcopy device.

Conclusions

The above example explains how satellite imagery can be used to enhance and improve painted relief images for cartographic purposes. The process can be extended to include as many themes as needed to create a beautiful and striking map product. The AML programs used here, plus other related AMLs and information on painted relief can be downloaded from the Bureau of Land Management, Oregon State Office website at www.or.blm.gov/gis.

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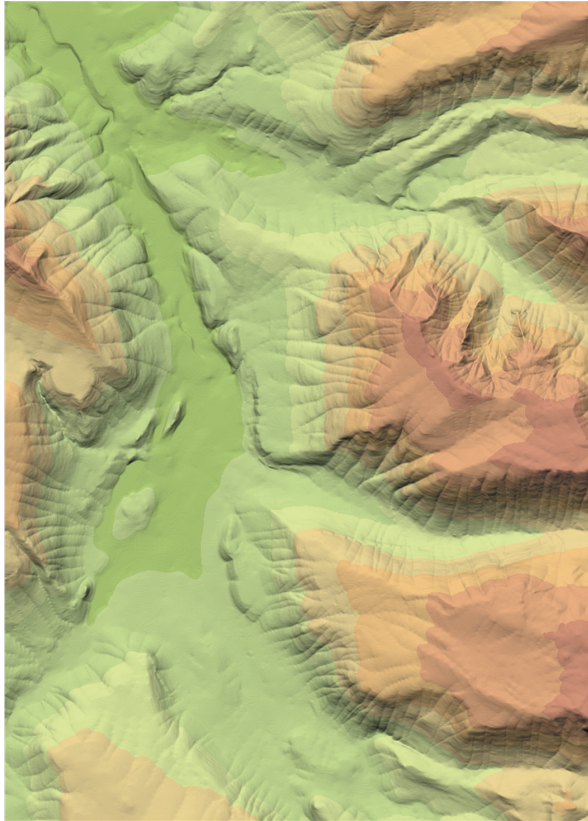


Figure 1. Typical "Painted" Relief.

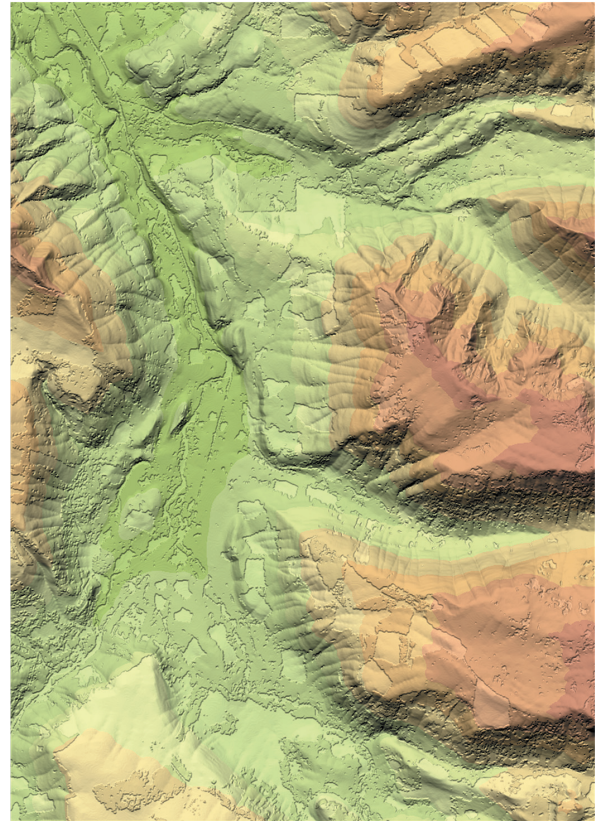


Figure 2. "Texturized Painted" Relief.

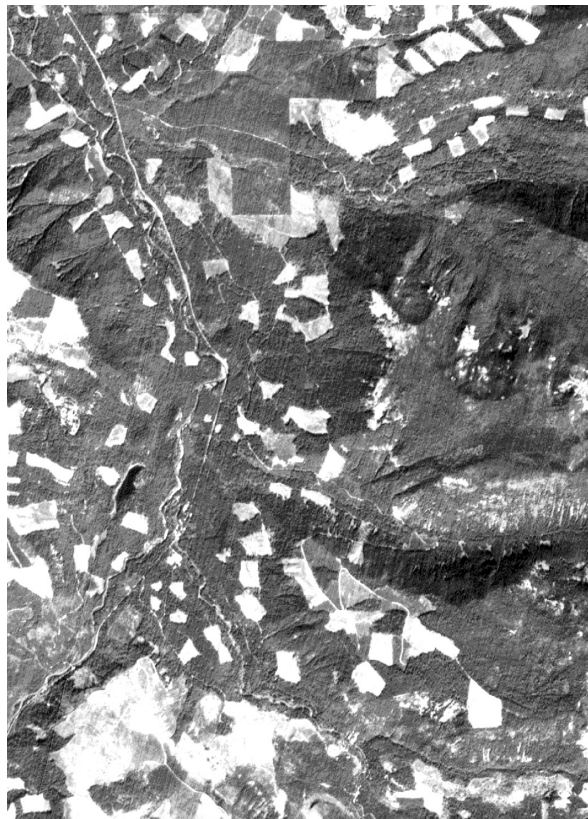


Figure 3. Panchromatic Spot Image.



Figure 4. Two Class Classification.



Figure 5. Textured Relief Image.

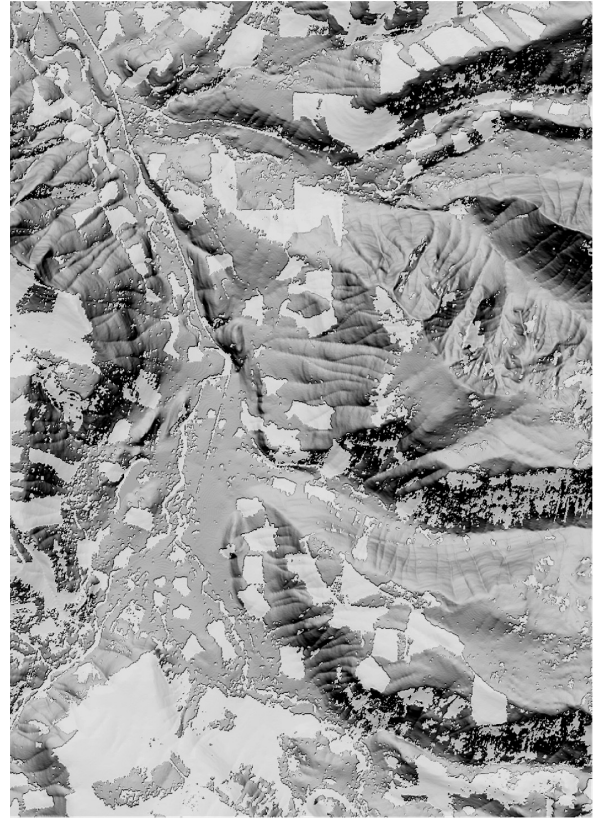


Figure 6. Textured Image with "lightened" areas.

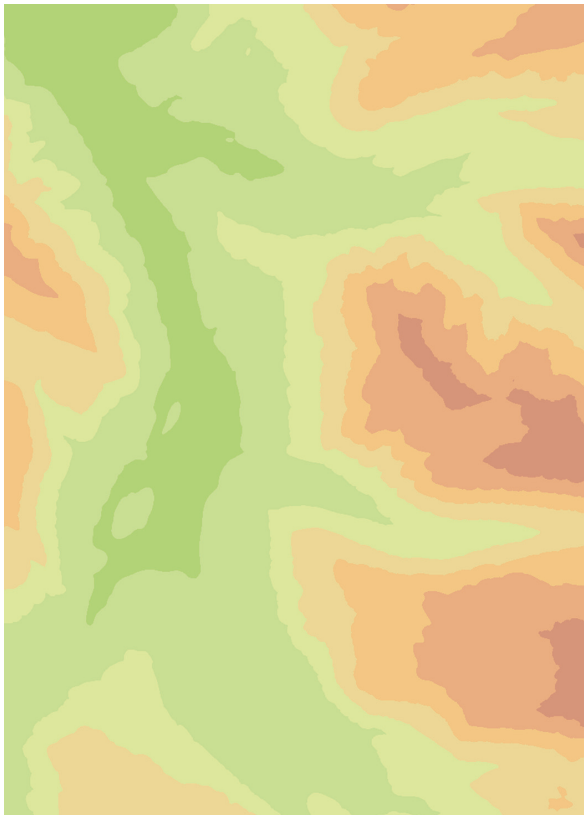


Figure 7. Elevation Category Image.

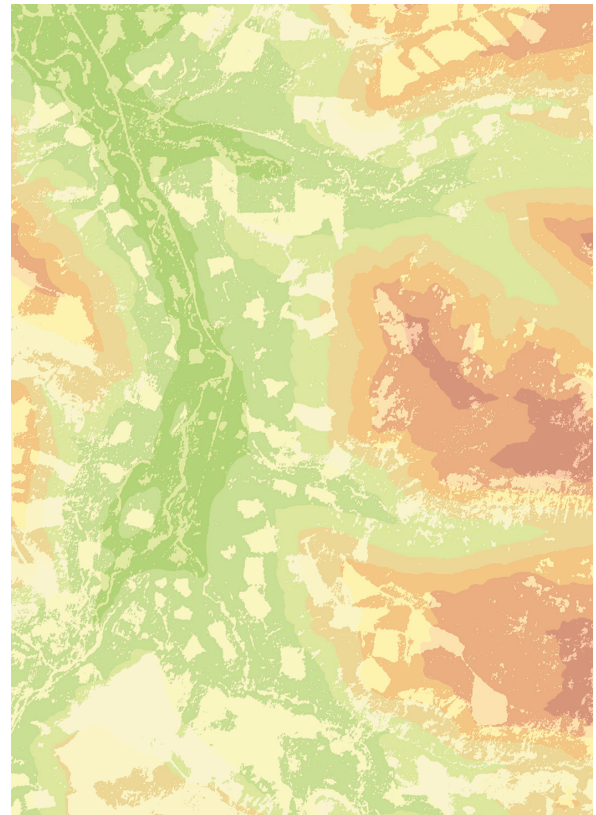


Figure 8. Elevation Categories with patterns.