ArcGIS bump map model

rajinder nagi, ESRI
aileen buckley, ESRI
jeff nighbert, OR BLM
Jeff nighbert

I 💘

[Image of a person]
rajinder nagi
background

- a method of adding texture to a hillshade to as to give an impression of a vegetated surface; “texturizing”
- Jeff Nighbert introduced the technique to ArcInfo users at the 2003 ESRI User Conference
background

- required the use of map algebra
  and the ArcMacro Language (AML)

```/* set your analysis window and your cell size */
/* regular pattern */
pattmap = focalmax(con(($$ROWMAP mod int(normal() * 0 + 10) eq 0) and ($$COLMAP mod int(normal() * 0 + 10) eq 0),255),rectangle,5,5)
/* random pattern */
Bump_patt = focalmax(con(($$ROWMAP mod int(normal() * 1 + 10) eq 0) and ($$COLMAP mod int(normal() * 1 + 10) eq 0),255,0),rectangle,5,5)
/* noise pattern */
Bump_noise = focalmax(con(($$ROWMAP mod int(normal() * 10 + 10) eq 0) and ($$COLMAP mod int(normal() * 10 + 10) eq 0),255,0),rectangle,5,5)
/* mape spheres pattern */
spheres_pat = eucdistance(con(($$ROWMAP mod int(normal() * 1 + 20) eq 0) and ($$COLMAP mod int(normal() * 1 + 20) eq 0),255),#,#,10,#) - 10) * (40 / 10)
/* make spheres part 2 give them height */
spheres = sqrt(pow(10,2) - pow(spheres_pat,2))
/* make cones */
Cones_pat = abs((eucdistance(con(($$ROWMAP mod int(normal() * 1 + 20) eq 0) and ($$COLMAP mod int(normal() * 1 + 20) eq 0),255),#,#,10,#) - 10) * (40 / 10))
/* make cubes */
Cubes_pat = focalmax(con(($$ROWMAP mod int(normal() * 1 + 20) eq 0) and ($$COLMAP mod int(normal() * 1 + 20) eq 0),255,0),rectangle,10,10) * 10
/* make aspen height map */
[aspen] = aspen_distribution_map_from_dogs
aspen_pat = eucdistance(con(($$ROWMAP mod int(normal() * 1 + 20) eq 0) and ($$COLMAP mod int(normal() * 1 + 20) eq 0) and [aspen] > 0,255),#,#,10,#)
/* now give them height */
esri_aspen = sqrt(pow(10,2) - pow([aspen],2))
aspen_bump = hillshade(con(isnull([esri_aspen]),[dem_1],[dem_1] + [esri_aspen]),345,65)```
background

- Using the map algebra statements, the technique could be replicated in ArcGIS using Spatial Analyst or a Map Algebra geoprocessing tool.
ArcInfo AML

- **problem**: none of these solutions made bump mapping easy for cartographers
  - the map algebra statements were difficult to parse so that they could be understood
  - even minute syntax errors resulted in a lack of desired results

Cones_pat = abs(eucdistance(con((rowmap mod int(normal() * 1 + 20) eq 0) and (colmap mod int(normal() * 1 + 20) eq 0),255),#,10,#) - 10) * (40 / 10)
ArcGIS bump map tool
ArcGIS bump map model

Part 1 of the Bump Map Tool creates the vegetation pattern as a surface that represents each vegetation type with “bumps” that are defined by height, radius, density (spacing) and type (cones for coniferous vegetation or domes for deciduous vegetation).

These vegetation pattern rasters can be used to symbolize the final map. Each raster can be given a color that relates to the type of vegetation it represents. These rasters are written into the Current Workspace. If you want to change the location where these are written to, double click the Vegetation Pattern oval below and change the location by replacing %workspace% with the path to the folder.

“Bump mapping” is a technique used by cartographers to add texture to a hillshaded surface. This technique is most often used to give the illusion of a vegetated surface. Jeff Nguyen introduced the technique to ArcInfo users at the 2007 ESRI User Conference. This bump map model creates a raster that represents the combination of multiple “bumped” surfaces, each relating to a different type of vegetation. It also allows users to specify the parameters for each type of vegetation including cones (coniferous vegetation) or domes (deciduous vegetation), vegetation radius, height and density (spacing). The model is built using two scripts that were written with the Python scripting language so they can be easily modified. With this model, you can easily and quickly create more realistic hillshades surfaces for vegetated areas.
demo
trees in Crater Lake National Park
first challenge

cell size selection is very important while creating the patterns. Cell size was originally user dependant.
cell size

- In this example:
  - radius: 20 m
  - cell size: 10 m
- 5 pixels to draw 40 m domes
  - resulted in bad output
  - size of output: 9.42 MB
  - processing time: 7 sec
cell size

- in this example:
  - radius: 20 m
  - cell size: 5
- 9 pixels to draw 40 m domes
  - they still have rough edges
  - size of output: 37.67 MB
  - processing time: 24 sec
Cell size

- In this example:
  - Radius: 20 m
  - Cell size: 1
  - 41 pixels to draw 40 m domes
    - Very smooth edges
    - Size of output: 941.75 MB
    - Processing time: 10 min 10 sec

- The smaller the cell size, the smoother the bump
- A cell size that is too small will likely increase the output raster size tremendously
- It took us some time to find out optimal cell size...
cell size

- the magic number is 11!
- in this example:
  - radius: 20 m
  - cell size: 3.63i
- 11 pixels to draw 40 m domes
  - smooth edges
  - size of output: 71 MB
  - processing time: 45 sec

- the ArcGIS bump map tool automatically figures out the optimal cell size based on the smallest vegetation radius
- however, the user can still create smoother output (if she or he wishes) by modifying one line in Python code
second challenge

stripes in the hillshade

a problem that relates to resampling the rasters
the resampling method was originally set automatically
stripes in the hillshade

- the DEM and vegetation pattern rasters can have different resolutions
- while adding the vegetation pattern raster to the DEM, the cell size is set to “Min of Inputs” (the minimum cell size)
- this could result in resampled rasters
- in this example:
  - DEM cell size : 10
  - vegetation pattern cell size : 3.63
- in this case, the DEM will be resampled to 3.63 m
- the hillshaded result is shown at the right
stripes in the hillshade

- **problem**: DEM has stripes
- **cause**: ArcGIS uses Nearest Neighbor as the default resampling method – as the cell size decreases there are too many cells with the same value found in the 3x3 processing kernel
- **solution**: force the rasters to be resampled using the bilinear interpolation method
- **how**: resample the DEM before adding it to the vegetation pattern and set the method explicitly
no stripes in the hillshade

- the cell size is derived from the radius of the bumps
- if required, which is most often, the Bump Map Tool resamples the DEM using the Bilinear Interpolation method before adding the bumps to the DEM
- this produces more aesthetically pleasing results, as shown at the right
- the user does not have to worry about setting the cell size or doing the resampling.
- if your DEM is much coarser than the cell size that is determined by the radius value you input, this resampling step can take a bit of time, and
- it is applied to each of the vegetation pattern outputs as well as the DEM, because ultimately they all have to be added together!
stripes in the hillshade (using Minimum of Inputs)

no stripes in the hillshade (using Bilinear Interpolation)
results with bilinear interpolation resampling
third challenge

stripes in the vegetation pattern

again elated to the resampling method

but we already figured out how to solve this!
stripes in the vegetation pattern

- what if we have more than one vegetation pattern, each with different resolutions?
  - in this example:
    - veg pattern 1: cell size - 1.8 m
    - veg pattern 2: cell size - 2.7 m
    - veg pattern 3: cell size - 0.9 m
    - DEM: cell size - 10 m
  - we need to resample the DEM to the smallest cell size, and
  - we have to resample vegetation patterns 1 & 2 to the cell size of vegetation pattern 3 (which has the smallest cell size - 0.9 m)
stripes in the vegetation pattern

- this will allow us to add all the rasters together
- **problem**: the dreaded nearest neighbor resampling method
- **solution**: resample each vegetation pattern raster, so that the cell size is set explicitly
no stripes in the vegetation pattern

- the results are more aesthetically pleasing
- this resampling may take some time (in this particular example, it took 3 hrs)
- you can overcome this time issue either by using a higher resolution DEM or resampling the DEM before running the script
- the cell size would be the smallest diameter divided by 11
- the ArcGIS bump map tool will automatically figure out the smallest cell size in the vegetation patterns (if there are more than one) and use that value to resample any lower resolution vegetation patterns and a lower resolution DEM
stripes in the vegetation patterns (using Minimum of Inputs)

no stripes in the vegetation patterns (using Bilinear Interpolation)
**Example – Crater Lake**

- Profile vertical exaggeration rule in Raisz's *General Cartography*, 2nd ed. 1948, on pg. 111
- Vertical exaggeration should be 2 times the square root of the scale in inches per mile
- So a profile from a 1:63,360 scale map should have a v.e. of 2, and so on
- Raisz does not say how he came up with this rule
- We tried 3x v.e. as well as 2x v.e.

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Cones or Domes</th>
<th>Density</th>
<th>Radius</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>sedge</td>
<td>domes</td>
<td>10m</td>
<td>(8’ diam / 2 w/ 2x v.e.) = 8 (4m)</td>
<td>(8’ ht * 2x v.e.) = 16 (5m)</td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td>cones</td>
<td>5m</td>
<td>(15’ diam / 2 w/ 2x v.e.) = 15 (5m)</td>
<td>(80’ ht * 2x v.e.) = 160 (50m)</td>
</tr>
<tr>
<td>Other conifers</td>
<td>cones</td>
<td>15m</td>
<td>(20’ diam / 2 w/ 2x v.e.) = 20 (7m)</td>
<td>(50’ ht * 2x v.e.) = 100 (17m)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Cones or Domes</th>
<th>Density</th>
<th>Radius</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>sedge</td>
<td>domes</td>
<td>10m</td>
<td>(8’ diam / 2 w/ 3x v.e.) = 12 (4m)</td>
<td>(8’ ht * 3x v.e.) = 24 (8m)</td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td>cones</td>
<td>5m</td>
<td>(15’ diam / 2 w/ 3x v.e.) = 22.5 (7m)</td>
<td>(80’ ht * 3x v.e.) = 240 (80m)</td>
</tr>
<tr>
<td>Other conifers</td>
<td>cones</td>
<td>15m</td>
<td>(20’ diam / 2 w/ 3x v.e.) = 30 (10m)</td>
<td>(50’ ht * 3x v.e.) = 150 (15m)</td>
</tr>
</tbody>
</table>
“flatten the rasters”
beta version ready for you to test!

mappingcenter.esri.com