Multiscale Terrain Representation

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CEGIS 2011
Objectives

- Generalize terrain for multi-scale mapping
- Create contours for multi-scale mapping
- Find a solution that will work for entire US (or most of it)
- Implement in ScaleMaster
Terrain Generalization: Study Areas

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Terrain Generalization: Projecting Rasters

Resampling Technique (optional)

The resampling algorithm to be used. The default is NEAREST.

- NEAREST—Nearest neighbor assignment
- BILINEAR—Bilinear interpolation
- CUBIC—Cubic convolution
- MAJORITY—Majority resampling

The NEAREST and MAJORITY options are used for categorical data, such as a landuse classification. The NEAREST option is the default since it is the quickest and also because it will not change the cell values. Do not use NEAREST or MAJORITY for continuous data, such as elevation surfaces. The BILINEAR option and the CUBIC option are most appropriate for continuous data. It is not recommended that BILINEAR or CUBIC be used with categorical data because the cell values may be altered.
Terrain Generalization: Projecting Rasters

Unprojected Raster

Projected, Nearest

Projected, Cubic

Projected, Bilinear

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Terrain Generalization: Repetitive Mean filtering

Optional clip to cut DEM to same size as a study area

10x repetitive mean focal statistics with a 5x5 window to gradually smooth a DEM

(Leonowicz, Jenny, Hurni, 2010)
Terrain Generalization: Aggregation

Aggregates a 10m DEM to a 30m DEM
Terrain Generalization: Repetitive Mean filtering

More repetitive mean focal statistics
Grand Canyon
Rugged Terrain
<table>
<thead>
<tr>
<th></th>
<th>10-L</th>
<th>10-1</th>
<th>10-5</th>
<th>10-10</th>
<th>10-15</th>
<th>30-L</th>
<th>30-1</th>
<th>30-5</th>
<th>30-10</th>
<th>30-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drumlin Field Flat Terrain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The diagram shows a grid with different sections labeled 10-L, 10-1, 10-5, 10-10, 10-15, 30-L, 30-1, 30-5, 30-10, and 30-15, with a section marked as Drumlin Field Flat Terrain.
Valley and Ridge Mixed Terrain
Yellowstone Mixed Terrain
## Terrain Generalization: Analyzing Hillshades

- Grand Canyon hillshades through smoothing repetition

<table>
<thead>
<tr>
<th></th>
<th>10-L</th>
<th>10-1</th>
<th>10-5</th>
<th>10-10</th>
<th>10-15</th>
<th>30-L</th>
<th>30-1</th>
<th>30-5</th>
<th>30-10</th>
<th>30-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>24K</td>
<td>-2</td>
<td>-3</td>
<td>-5</td>
<td>-7</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
</tr>
<tr>
<td>50K</td>
<td></td>
<td>-1</td>
<td>-3</td>
<td>-3</td>
<td>-5</td>
<td>-5</td>
<td>-7</td>
<td>-10</td>
<td>-10</td>
<td>-10</td>
</tr>
<tr>
<td>100K</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-3</td>
<td>-2</td>
<td>-2</td>
<td>-7</td>
<td>-5</td>
<td>-7</td>
<td></td>
</tr>
<tr>
<td>250K</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-3</td>
<td>-3</td>
<td>-3</td>
</tr>
<tr>
<td>500K</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>750K</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>1M</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Terrain Generalization: Recommendations

- 3 breaks
  - 24K – 250K
  - 250K – 750K
  - 750K – 1M

- Processing Steps
  - 10m DEM, smoothed once (LGDEM)
  - 10m DEM, smoothed 10 times (MDDEM)
  - 10m DEM aggregated, smoothed 10 times (SMDEM)
Close up Example of Decisions

24K

50K

250K

500K

1M
Close up Example – Unprojected, Default Hillshade

24K

50K

250K

500K

1M
Was it Successful?

1M correct

1M using 24K processing
Close up Example of Decisions

24K

50K

250K

500K

1M
Was it Successful?

1M correct

1M using 24K processing
Close up Example of Decisions

24K  50K  250K

500K  1M
Was it Successful?

1M correct

1M using 24K processing
Was it Successful?

1M correct

1M using 24K processing
Adjustment to Hillshading

- Sky Illumination Model hillshade (Kennelly, 2006)
  - Combine multiple hillshades with different azimuths
Contours: Study Areas

- 8 subbasins
  - ATL
  - CO
  - FL/GA
  - MO
  - STL
  - TX
  - UT
  - WV

- Terrain Classifications
  - Mountainous
  - Hilly
  - Flat

Draft Landscape Types
(Stanislawski, Buttenfield, Finn, Roth, 2009)
Contours: Intervals

<table>
<thead>
<tr>
<th>Map Scales</th>
<th>Predominant Terrain Type¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Mountains</td>
</tr>
<tr>
<td></td>
<td>Feet</td>
</tr>
<tr>
<td>1:1,000</td>
<td>5</td>
</tr>
<tr>
<td>1:2,000</td>
<td>5-10</td>
</tr>
<tr>
<td>1:5,000</td>
<td>10-20</td>
</tr>
<tr>
<td>1:10,000</td>
<td>20</td>
</tr>
<tr>
<td>1:20,000</td>
<td>20-40</td>
</tr>
<tr>
<td>1:25,000</td>
<td>20-50</td>
</tr>
<tr>
<td>1:50,000</td>
<td>50-100</td>
</tr>
<tr>
<td>1:100,000</td>
<td>100</td>
</tr>
<tr>
<td>1:200,000</td>
<td>200-250</td>
</tr>
<tr>
<td>1:250,000</td>
<td>200-400</td>
</tr>
<tr>
<td>1:500,000</td>
<td>400-500</td>
</tr>
<tr>
<td>1:1,000,000</td>
<td>500-800</td>
</tr>
</tbody>
</table>

¹Predominant terrain type should be representative of over 50% of the area on a given map. When an even distribution of all three terrain types or between high mountains and flat or undulating (with a relatively low area of low mountains), then consider using supplementary contour lines as well.

Imhof, 2007 and Frye, 2008

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Contours : Creation and Indexing

• Custom code to index contours (Frye)

• By setting definition queries, 4 variations on index/intermediate contours sets can be created from 1 shapefile

```vba
Dim k As String
k = Right(Str([CONTOUR]),2)
Dim p As Integer
p = 0
if k = "25" then 
  p = 1
elseif k = "50" then 
  p = 1
elseif k = "75" then 
  p = 1
elseif k = "00" then 
  p = 1
endif
```
Contours : Analyzing contours

- Looked at each subbasin to determine:
  - Contour density
  - Contour complexity
Contours: 250K, 25m intervals

Derived from md scale DEM

Derived from sm scale DEM

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<table>
<thead>
<tr>
<th>Location:</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>n</td>
</tr>
<tr>
<td>10</td>
<td>n</td>
</tr>
<tr>
<td>25</td>
<td>n</td>
</tr>
<tr>
<td>50</td>
<td>n</td>
</tr>
<tr>
<td>100</td>
<td>n</td>
</tr>
<tr>
<td>250</td>
<td>n</td>
</tr>
<tr>
<td>500</td>
<td>n</td>
</tr>
<tr>
<td>1000</td>
<td>n</td>
</tr>
</tbody>
</table>
## Contours : Recommendations

<table>
<thead>
<tr>
<th>Scale</th>
<th>Contour Smoothing</th>
<th>Mountainous Contour Interval</th>
<th>Hilly Contour Interval</th>
<th>Flat Contour Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>24K</td>
<td>LG DEM</td>
<td>25m</td>
<td>10m</td>
<td>5m</td>
</tr>
<tr>
<td>50K</td>
<td>LG DEM</td>
<td>25</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>100K</td>
<td>MED DEM</td>
<td>25</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>250K</td>
<td>SM DEM</td>
<td>100</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>500K</td>
<td>SM DEM</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>750K</td>
<td>XS DEM</td>
<td>250</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>1M</td>
<td>XS DEM</td>
<td>250</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

CO WV ATL MO STL TX FL/GA UT

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Contours: Mountainous Results

24K, 25m intervals

CO

WV

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Contours: Mountainous Results

50K, 25m intervals

CO

WV

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Contours: Mountainous Results

100K, 25m intervals

CO

WV

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Contours: Mountainous Results

250K, 100m intervals

CO

WV

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Contours : Mountainous Results

500K, 100m intervals

CO

WV

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Contours: Mountainous Results

750K, 250m intervals

CO       WV

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Contours : Mountainous Results

1M, 250m intervals

CO

WV

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Contours : Hilly Results

24K, 10m intervals

TX

MO

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Contours: Hilly Results

50K, 10m intervals

TX

MO

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Contours : Hilly Results

100K, 25m intervals

TX

MO

CEGIS June 2011
Contours: Hilly Results

250K, 25m intervals

TX  MO

CEGIS June 2011
Contours : Hilly Results

500K, 50m intervals

TX

MO

CEGIS June 2011
Contours: Hilly Results

750K, 100m intervals

TX

MO

CEGIS June 2011
Contours: Hilly Results

1M, 100m intervals

TX

MO

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Contours: Urban (Hilly) Results

24K, 10m intervals

ATL

STL

CEGIS June 2011
Contours: Urban (Hilly) Results

50K, 10m intervals

ATL

STL

CEGIS June 2011
Contours: Urban (Hilly) Results

100K, 25m intervals

ATL

STL

CEGIS June 2011
Contours: Urban (Hilly) Results

250K, 25m intervals

ATL

STL

CEGIS June 2011
Contours: Urban (Hilly) Results

500K, 50m intervals

ATL

STL

CEGIS June 2011
Contours : Urban (Hilly) Results

750K, 100m intervals

ATL

STL

CEGIS June 2011
Contours: Urban (Hilly) Results

1M, 100m intervals

ATL

STL

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Contours : Flat Results

24K, 5m intervals

FL/GA  UT

CEGIS June 2011
Contours: Flat Results

50K, 5m intervals

FL/GA

UT

CEGIS June 2011
Contours : Flat Results

100K, 5m intervals

FL/GA

UT

CEGIS June 2011
Contours : Flat Results

250K, 25m intervals

FL/GA

UT

CEGIS June 2011
Contours : Flat Results

500K, 50m intervals

FL/GA

UT

CEGIS June 2011
Contours : Flat Results

750K, 50m intervals

FL/GA

UT

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Contours : Flat Results

1M, 100m intervals

FL/GA

UT

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Putting it all together: ScaleMaster
Problems and other Concerns

- Resolution of landscape types analysis
  - General solution for flat landscapes

- Feet or meters
  - Encounter memory allocation errors when contouring subbasins in feet
Questions??


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Pat Kennelly on resampling methods for projecting rasters
babs buttenfield and Alex Tait on grid cell sizes
Steven Butzler for debugging

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