Geographic Information Systems 2018/19
Week 4, Topic 2

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In this session...

Digital Elevation Model (DEM)

Example representation

Encoding & compression

Quadtree

Other raster types

Digital Elevation Model (DEM)

Array of uniformly spaced cells containing elevation data

Primary source for terrain mapping and analysis

Many different sources (free and paid-for). We use SRTM as it’s free and suitable for most purposes.

SRTM

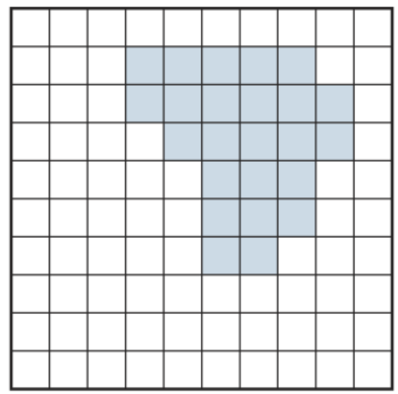
- The Shuttle Radar Topography Mission (SRTM) is an international research effort, spearheaded by the U.S. National Geospatial-Intelligence Agency (NGA) and the U.S. National Aeronautics and Space Administration (NASA), that obtained digital elevation models on a near-global scale from 56°S to 60°N, to generate the most complete high-resolution digital topographic database of Earth prior to the release of the ASTER GDEM in 2009. SRTM consisted of a specially modified radar system that flew on board the Space Shuttle Endeavour during the 11-day STS-99 mission in February 2000.
- Available as 3 arc-second (approx 90m) and 1-arc second (approx 30m) resolutions

Raster structure

Simple raster structure (top)

Feature coding of cells (bottom)

In both cases this is **cell-by-cell** encoding. This works fine if neighbouring cells are not equal.



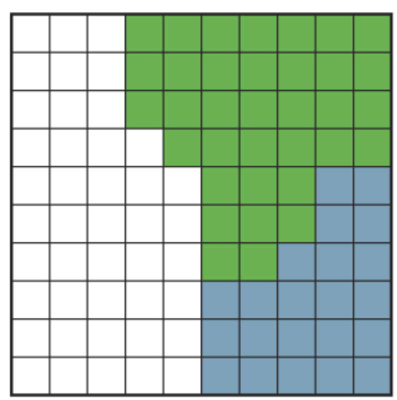
(a) Entity model

0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	1	0	0
0	0	0	1	1	1	1	1	1	0
0	0	0	0	1	1	1	1	1	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

(b) Cell values

10,10,1
0,0,0,0,0,0,0,0,0,0
0,0,0,1,1,1,1,1,0,0
0,0,0,1,1,1,1,1,1,0
0,0,0,0,1,1,1,1,1,0
0,0,0,0,0,1,1,1,0,0
0,0,0,0,0,1,1,1,0,0
0,0,0,0,0,1,1,0,0,0
0,0,0,0,0,0,0,0,0,0
0,0,0,0,0,0,0,0,0,0
0,0,0,0,0,0,0,0,0,0

(c) File structure



(a) Entity model

1	1	1	2	2	2	2	2	2	2
1	1	1	2	2	2	2	2	2	2
1	1	1	2	2	2	2	2	2	2
1	1	1	1	2	2	2	2	2	2
1	1	1	1	1	2	2	2	3	3
1	1	1	1	1	2	2	2	3	3
1	1	1	1	1	2	2	3	3	3
1	1	1	1	1	3	3	3	3	3
1	1	1	1	1	3	3	3	3	3
1	1	1	1	1	3	3	3	3	3

(b) Cell values

10,10,3
1,1,1,2,2,2,2,2,2,2
1,1,1,2,2,2,2,2,2,2
1,1,1,2,2,2,2,2,2,2
1,1,1,1,2,2,2,2,2,2
1,1,1,1,1,2,2,2,3,3
1,1,1,1,1,2,2,2,3,3
1,1,1,1,1,2,2,3,3,3
1,1,1,1,1,3,3,3,3,3
1,1,1,1,1,3,3,3,3,3
1,1,1,1,1,3,3,3,3,3

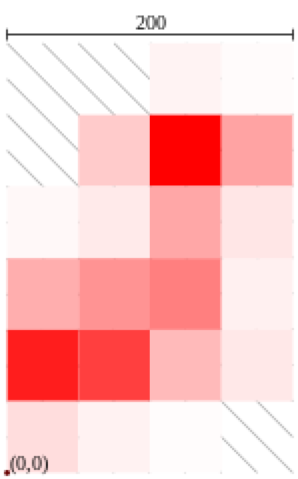
(c) File structure

Representation

Tiff / GeoTiff

- See earlier
- May have header and/or world file

ASCII Grid



	25	75	125	175
275	NA	NA	5	2
225	NA	20	100	36
175	3	8	35	10
125	32	42	50	6
75	88	75	27	9
25	13	5	1	NA

```
ncols         4
nrows         6
xllcorner     0.0
yllcorner     0.0
cellsize      50.0
NODATA_value  -9999
-9999 -9999 5 2
-9999 20 100 36
3 8 35 10
32 42 50 6
88 75 27 9
13 5 1 -9999
```

ASCII Grid from SRTM

```
ncols         6001
nrows         6001
xllcorner     -10.000416206603
yllcorner     49.999583793397
cellsize      0.00083333333333333
NODATA_value  -9999
```

```
-9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 - ■ ■ ■
-9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999
-9999 27 50 73 78 83 89 95 98 101 107 113 126 140 153 166 171 177 171 164 158 152 152 151 153 156 157 158 157 156 156
157 157 158 153 148 142 136 130 123 117 111 104 96 86 76 66 56 46 36 30 24 22 19 17 14 14 13 15 18 18 19 16 12 8 4 3 2 1
-9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999
-9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 1 2 4 7
10 13 11 9 6 3 3 2 2 2 3 5 4 3 5 7 8 9 11 13 14 16 15 14 14 15 15 16 17 19 19 18 18 17 17 18 15 12 8 4 4 4 8 13 16 20 21 23 23
23 23 24 24 25 24 22 21 20 19 18 13 8 5 1 1 0 0 0 1 3 3 4 3 1 2 3 6 10 12 15 16 17 17 17 17 17 17 17 16 14 14 14 13 12 12 11 11
10 10 11 13 16 18 21 22 23 23 23 22 21 19 17 18 19 20 21 21 20 20 21 22 23 24 26 29 32 34 37 37 36 39 43 46 49 50 51 51 50
48 46 44 41 39 37 34 31 30 28 28 27 26 24 23 22 25 29 30 31 31 32 35 39 41 44 45 46 46 47 47 48 48 49 49 49 50 51 50 49 48
47 47 48 49 50 50 50 52 55 58 62 64 67 68 69 69 69 67 64 60 55 55 56 56 55 54 52 50 48 45 41 40 39 38 37 37 36 34 32 32 32
34 37 40 44 47 50 58 66 75 84 94 105 112 119 123 127 122 117 114 111 107 103 104 106 112 118 122 127 131 136 141 146
148 151 150 149 145 141 138 135 139 143 151 159 170 182 192 202 212 222 232 243 253 264 272 281 283 286 286 287 290
293 298 303 307 312 317 323 330 337 343 349 350 352 355 358 363 368 375 382 392 402 414 426 437 448 454 460 463 467

471 475 479 484 485 486 481 476 476 476 476 475 463 451 425 398 377 355 348 340 338 336 338 340 351 363 384     ■ ■ ■
```

Encoding and compression

Image Compression Reduces File size

GIS data is abundant. With satellites acquiring images each day, raster data is the spatial model of choice. But which format will you use? Deploying efficient raster image compression techniques means reducing storage space. This is the primary benefit of compressing your data.

Run Length Encoding – Grouping Rows of Data

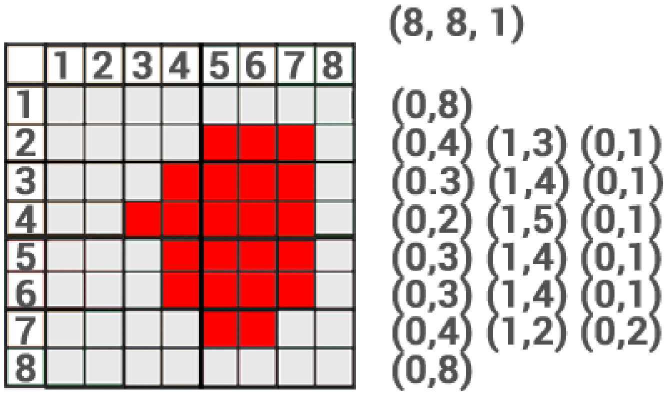
Run length encoding stores cells on a row-by-row basis. Instead of recording each individual cell’s values, run length encoding groups cell values by row.

Take this line of data:

AAAAAABBBBCCCCCCCCC

It can be rendered as:

6A4B9C



This image encoding method reduces data volumes because each line is recorded more efficiently. Even though the same information is being held, values that are the same are stored as a string.

In the example, the first row is blank and is stored as (0,8). This means there are 8 cells and they are all zeros. In the second row, there are 4 consecutive zeros so it gets a value of (0,4). After this, we have three consecutive cells with the value 1 so it gets a value of (1,3). This continues until it reaches the bottom-right cell.

Encoding

Block Coding – Grouping Blocks of Data

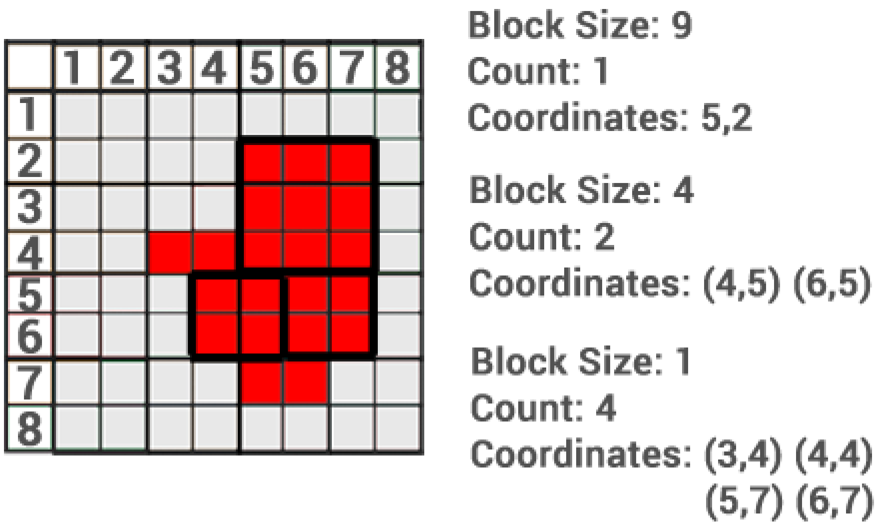
The block coding raster storage technique assigns areas that are blocks to reduce redundancy.

The block coding raster image compression method subdivides an entire raster image into hierarchical blocks. It’s an extension of the run length encoding technique, but extends it to two dimensions.

In the example:

Instead of storing 64 grid cells, all it takes is just 7 blocks. Using block coding, it requires one 3×3 block, two 2×2 blocks and four 1×1 cell blocks to encode this raster image.

In this block coding example, the top-left corner is used as a reference for each block.



Encoding

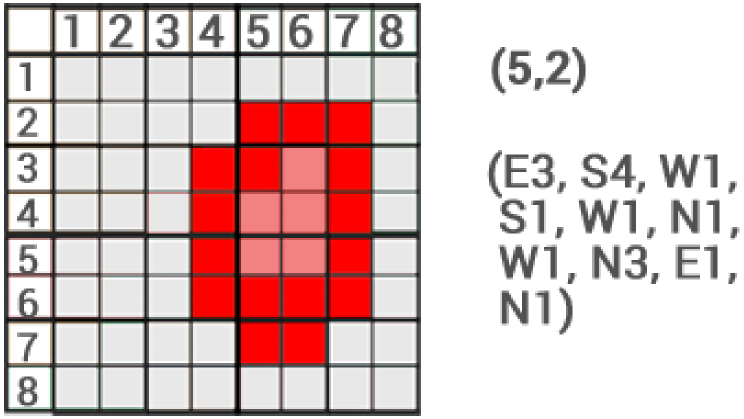
Chain Coding – Defining the Exterior Boundary

Chain coding defines the outer boundary using relative positions from a start point. The sequence of the exterior is stored where the endpoint finishes at the start point.

During the encoding, the direction is stored as an integer. However, in this example we use cardinal directions for simplicity. For example, the value 0 is north and 1 is east.

In the example, we start at position (5,2). From here we define the border using cardinal directions and number of movements. We move east 3 positions until we hit the edge. At this location, we move south 4 positions. This process continues until the end point hits the start point.

Note: Only for the purpose of this exercise, we used north, east, south and west as alphabetical values. When encoded, it is a numerical value.



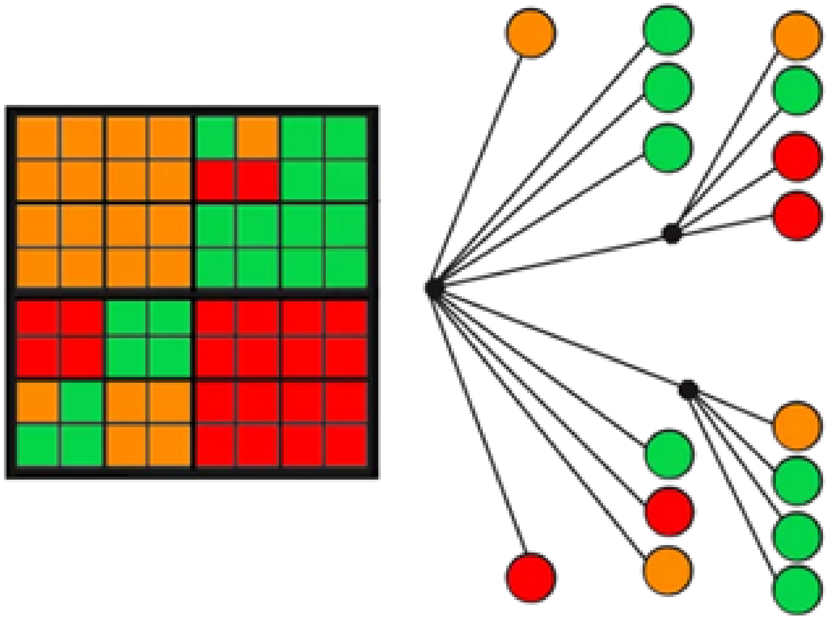
Quadtrees

Quadtree Encoding – Subdividing Data Into Quarters

Quadtrees are raster data structures based on the successive reduction of homogeneous cells. It recursively subdivides a raster image into quarters. The subdivision process continues until each cell is classed.

It reduces raster storage requirements. It also is dependent on the complexity of the feature and the resolution of the smallest grid cell.

In the example, the top-left and bottom-right 8×8 grids do not need to be subdivided further because they are homogeneous. The top-right 8×8 grid is subdivided into three 4×4 grid. The remaining 4×4 grid is separated into 4 individual classes.



Other raster types

LiDAR

A surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3-D representations of the target. The name lidar, now used as an acronym of light detection and ranging. Lidar sometimes is called 3D laser scanning, a special combination of a 3D scanning and laser scanning. It has terrestrial, airborne, and mobile applications.

Photogrammetry

Photogrammetry is the science of making measurements from photographs, especially for recovering the exact positions of surface points.

Photogrammetric analysis may be applied to one photograph, or may use high-speed photography and remote sensing to detect, measure and record complex 2-D and 3-D motion fields by feeding measurements and imagery analysis into computational models in an attempt to successively estimate, with increasing accuracy, the actual, 3-D relative motions.

From its beginning with the stereoplotters used to plot contour lines on topographic maps, it now has a very wide range of uses.

An **orthophoto**, orthophotograph or orthoimage is an aerial photograph or image geometrically corrected ("orthorectified") such that the scale is uniform: the photo has the same lack of distortion as a map. Unlike an uncorrected aerial photograph, an orthophotograph can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief, lens distortion, and camera tilt.

Common analysis methods used with DEM

From a DEM we can get…

- Slope
  - A value representing slope in degrees for each cell
  - Range 0-90
  - Calculation based on heights of 8 nearest neighbours
- Aspect
  - A value representing direction the cell is facing with respect to the compass
  - Range 0-359
  - Calculation based on heights of 8 nearest neighbours
- Contour generation
  - Extract contour lines on a best fit basis
- Filter queries based on criteria
  - Uses map algebra
  - e.g. show me only slope between 20^0 and 45^0
  - Usually produces a binary raster

Coming next...

Data display and cartography

- Cartographic representations
- Types of quantitative maps
- Map design
- Typography
- Map production