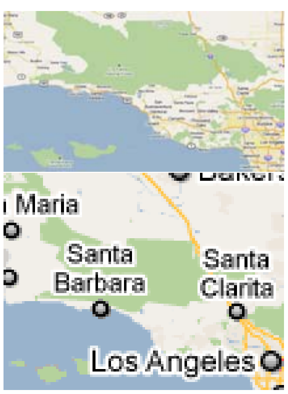
Analytical and Computer Cartography

Lecture 11: Generalization and Structure-to-Structure Transformations

Generalization Transformations

- Conversion of data collected at higher resolutions to lower resolution
- Change (reduction) in extent due to scale change (e.g. zoom)
- Less data *and* less detail
- Simplicity -> clarity
- Can be lossless or lossy

Less detail and fewer features

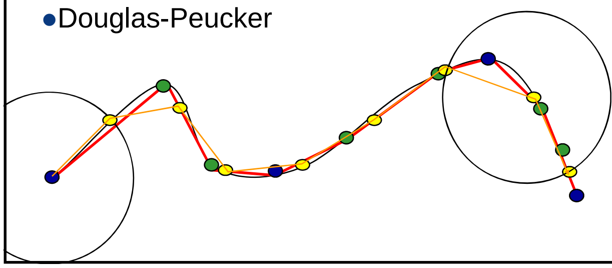


Generalization: Line to line transformations

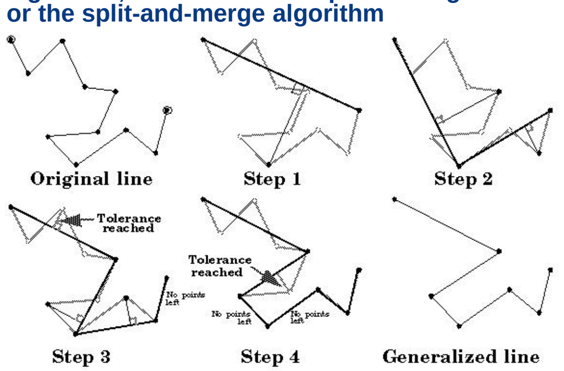
- Problem of "line character"
- Algorithmic resampling i.e. reduce # of points in finite sample
- Algorithmic reconstruction
- Enhancement

Algorithms (Reviewed by McMaster)

- N-th Point retention
- Equidistant Resampling
- Douglas-Peucker



Douglas-Peucker aka Ramer–Douglas–Peucker algorithm, the iterative end-point fit algorithm or the split-and-merge algorithm



Pseudocode

```
function DouglasPeucker(PointList[], epsilon)
//Find the point with the maximum distance
dmax = 0
index = 0
for i = 2 to (length(PointList) - 1)
    d = OrthogonalDistance(PointList[i], Line(PointList[1], PointList[end]))
        if d > dmax index = i dmax = d end
    end
    //If max distance is greater than epsilon, recursively simplify
    if dmax >= epsilon
     //Recursive call
    recResults1[] = DouglasPeucker(PointList[1...index], epsilon)
    recResults2[] = DouglasPeucker(PointList[index...end], epsilon)
    // Build the result list
    ResultList[ ] = {recResults1[1...end-1] recResults2[1...end]}
    else
    ResultList[] = {PointList[1], PointList[end]}
    end
    //Return the result
    return ResultList[]
    end
```

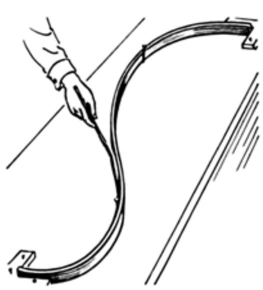
Douglas-Peucker for Michigan Counties

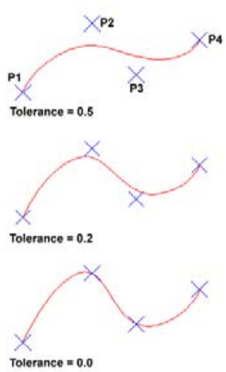
Example (Using Animation) Courtesy of Brad Allen and Waldo Tobler.

Enhancement: adding detail back!

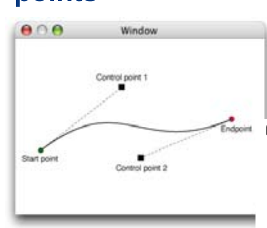
- Lines
  - Splines
  - Bezier Curves
  - Polynomial Functions
  - Trigonometric Functions (Fourier-based)
  - Fractals
- Surfaces
  - Fractal
  - Fourier
  - Manual

Splines

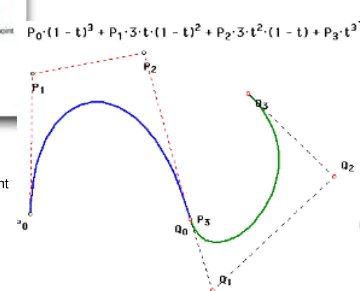




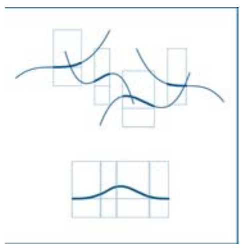
Bezier curves: Match points and guide points

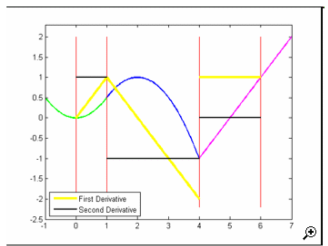


Continuous derivative at switching point

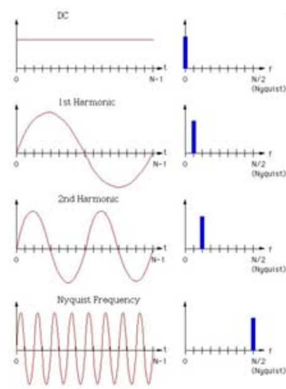


Polynomial curves





Fourier Series



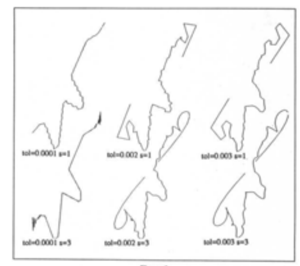
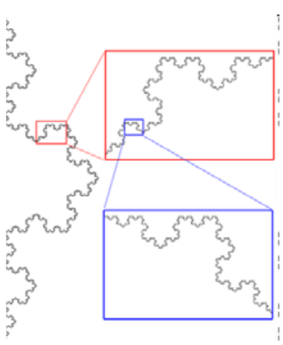


Figure 1

Fractals: Fractional Geometry



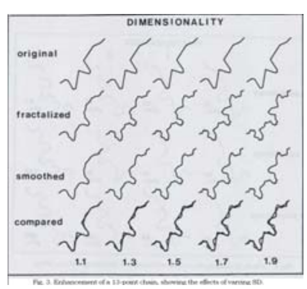
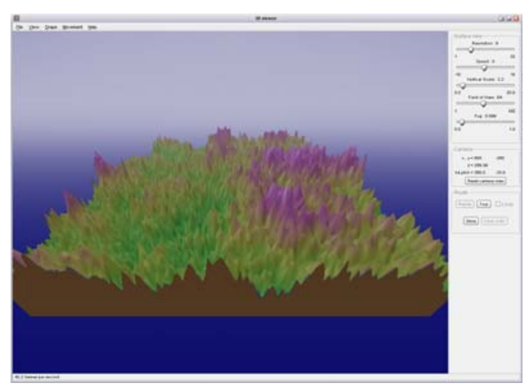


Fig. 3. Enhancement of a 13-point chain, showing the effects of varying SD.

Surfaces: Fractal 2.75



Fourier surfaces

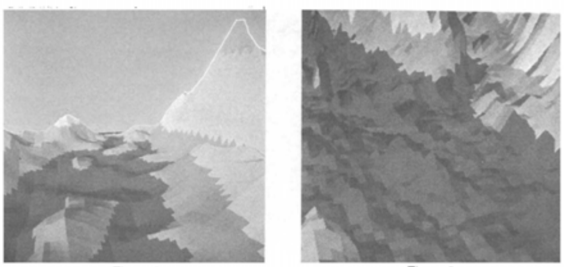
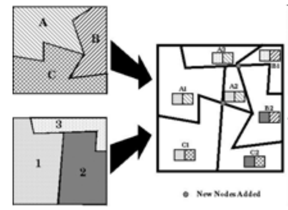


Figure 7 Figure 8

180 The American Cartographer

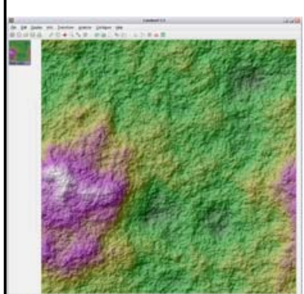
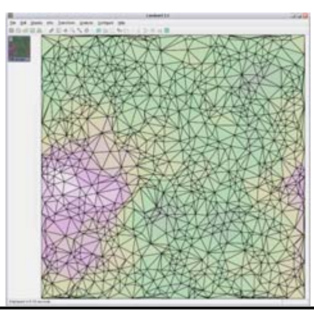
Algorithms for Areas: Overlay



- 1. Intersections
- 2. Chain splitting
- 3. Polygon reassembly
- 4. Labeling and attribution

Volume-to-Volume

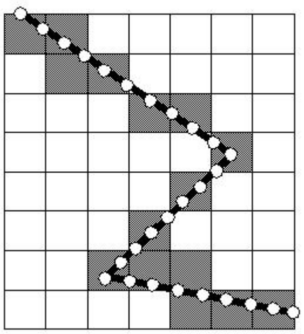
- Common conversion between two major data structures, vector (TIN) and grid.
- Often via points and interpolation
- Problem of VIPs

Vector to Raster and Back Again

- Efficient V->R-> V has eliminated vector-raster debate, BUT is a major source of error
- Major consumer of processing power
- **Vector to Raster**
  - Easy compared to inverse, a form of resampling
  - Grid must relate to coordinates (extent, bounds, resolution, orientation)
  - Rasters can be square, rectangular, hexagonal.
  - Resample at minimum r/2
  - Both structures may be tiled
  - Problem: What value goes into the cell?
  - Separate arrays for dimensions and binary data?
  - Index entries & look up tables

Bressenham's Algorithm

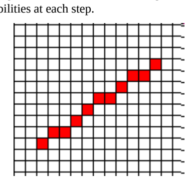


Consider drawing a line on a raster grid where we restrict the allowable slopes of the line to the range $0 \leq m \leq 1$

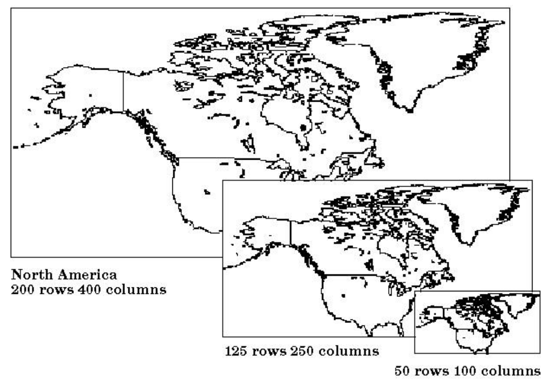
If we further restrict the line-drawing routine so that it always increments *x* as it plots, it becomes clear that, having plotted a point at *(x,y)*, the routine has a severely limited range of options as to where it may put the *next* point on the line:

- It may plot the point *(x+1,y)*, or:
- It may plot the point *(x+1,y+1)*.

So, working in the *first positive octant* of the plane, line drawing becomes a matter of deciding between two possibilities at each step.

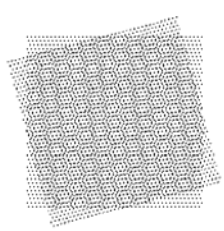


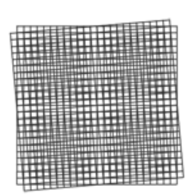
Resampling Problems



Issues in Resampling

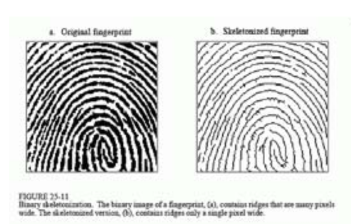
- Drop out
- Broken lines
- Fat lines
- Jaggies
- Moire patterns

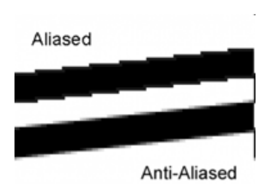




Algorithm (e.g. rasterize)

- Convert form of vectors (e.g. to slope intercept)
- Thin fat lines
- Compute implicit inclusion (anti-alias)

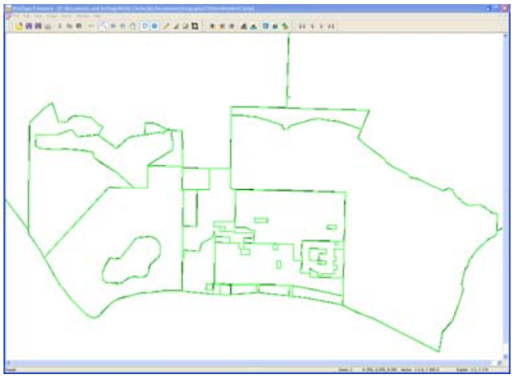




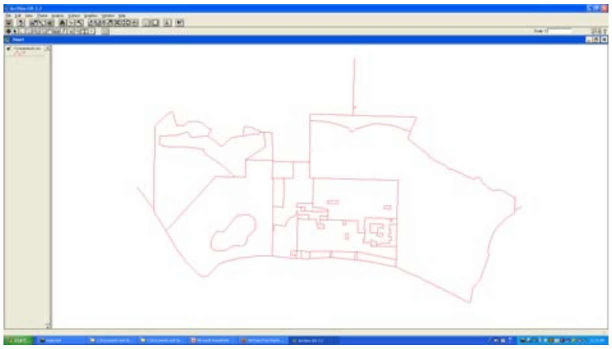
Raster to Vector

- Much harder, more error prone.
- May involve cartographer intervention (e.g. Laserscan)
- Importance of allignment
- Can do points, lines, area

WinTopo



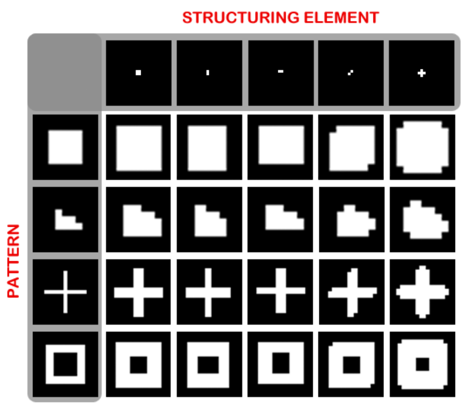
DXF file created



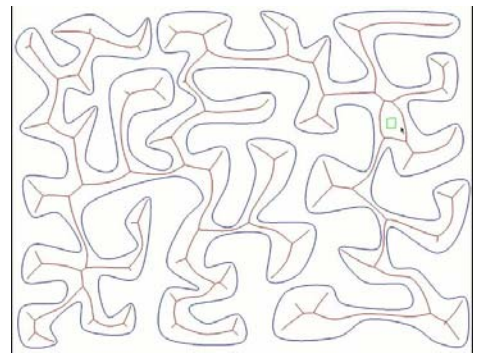
Algorithms

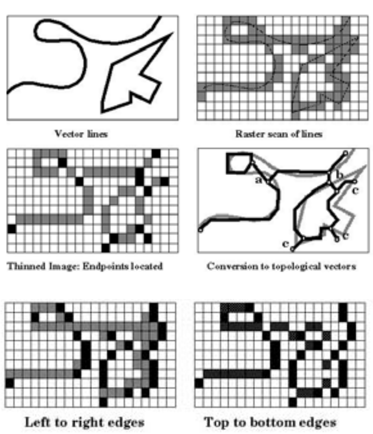
- Skeletonization and Thinning
  - Peeling/Erosion
  - Dilation
  - Medial Axis
- Feature Extraction
- Topological Reconstruction
- User assisted update

For example, dilation



For example: Medial Axis Transformation





Data Structure Transformations

- Scale transformations are lossy
- (re)storage produces error
- Algorithmic error, systematic and random
- Types are:
  - scale
  - structural (data structure)
  - dimensional
  - vector-to-raster

Data structure transformations

	Entity by Entity	Topological	TIN	Grid
Entity by Entity	Scaling Dimensional	Structural	Structural	Vector to raster
Topological	Structural	Scaling Dimensional	Structural	Vector to raster
TIN	Structural	Structural	Scaling Dimensional	Structural
Grid	Raster to vector	Raster to vector	Structural	Scaling Dimensional

The Role of Error

- Kate Beard: Source error, use error, process error
- Morrison: Method-produced error
- Error is inherent, can it be predicted, controlled or minimized?
- $XT = X'$
- $X' T^{-1} = X + E$

Map error

- positional
- attribute
- systematic
- random
- known
- uncertain

Avoiding error

- Errors can be attributed to poor choice of transformations
- Incompatible sequences of T's (non-invertible)
- "Hidden" Error = use error, not process error
- Blunders and misinterpretations: Design!

Summary

- Generalization a major issue in computer cartography
- Lossy vs Lossless
- Multiple representations vs continuous transformation
- Selection often hard, resampling easier e.g. n-th point
- Possible to create scale effects analytically e.g. by dilation, erosion, MAT
- Can invert scale loss using simulation, e.g. fractals
- Data structure transformations necessary: R -> V (hard) vs. V -> R (easy)
- Nature of error is complex, e.g. method error