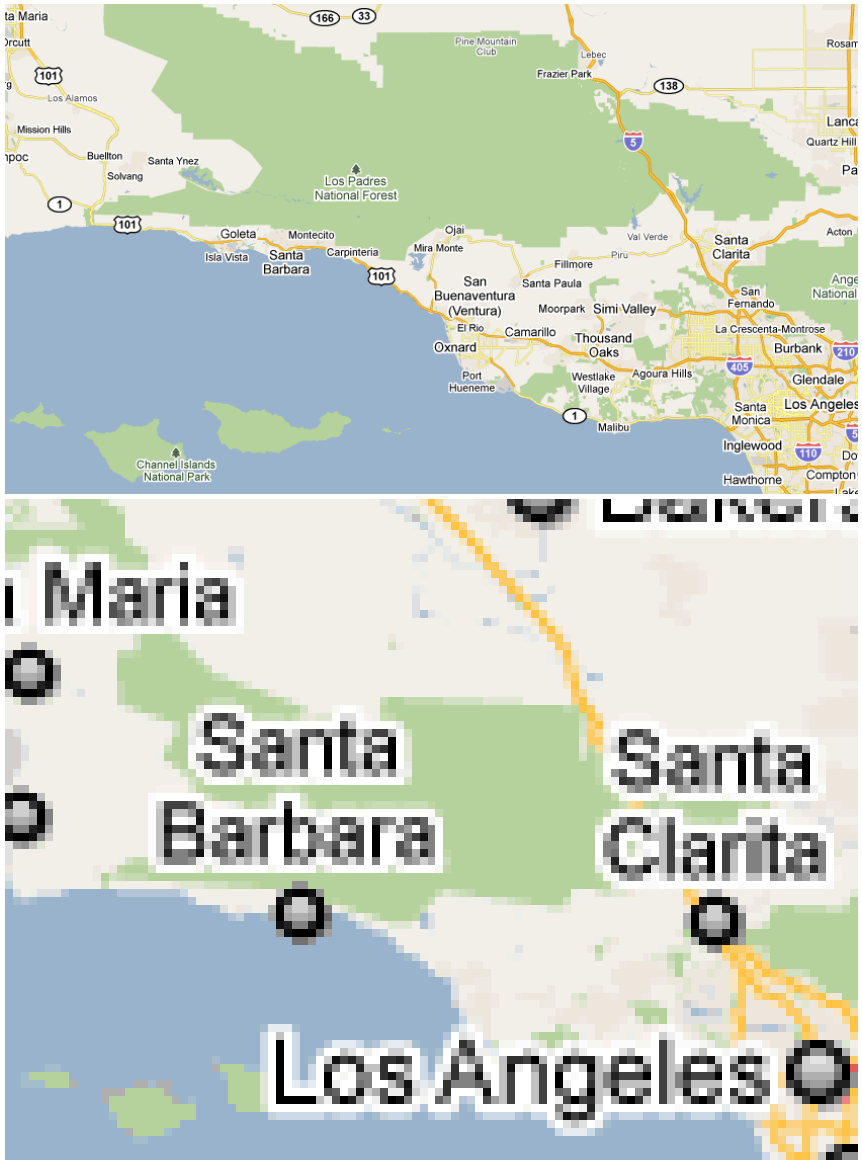
Analytical and Computer Cartography Winter 2017

# 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

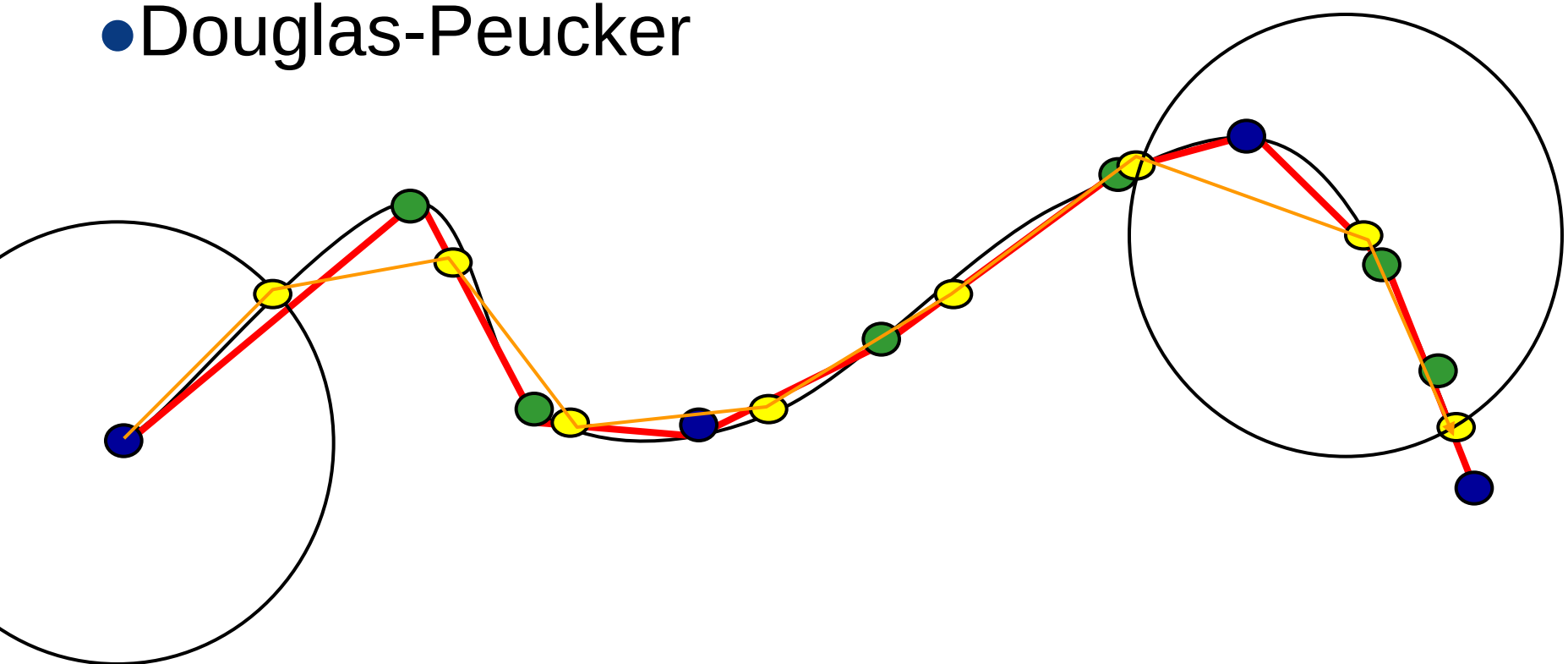
- Problem of "line character"
- Algorithmic resampling i.e. reduce # of points in finite sample
- Algorithmic reconstruction
- Enhancement

artificial

natural

# Algorithms (Reviewed by McMaster)

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

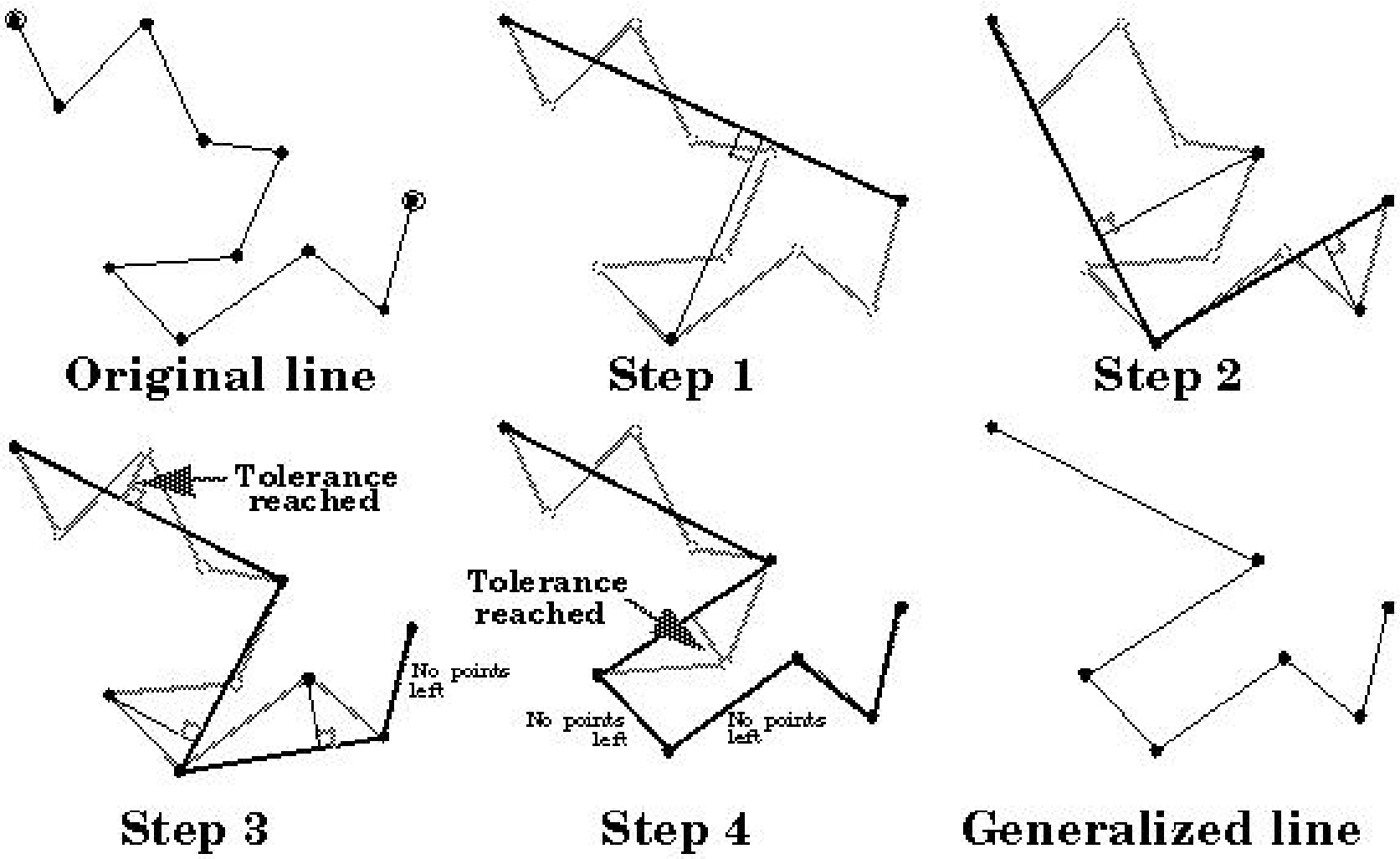


North America $n = 2$

North America $n = 15$

North America $n = 45$

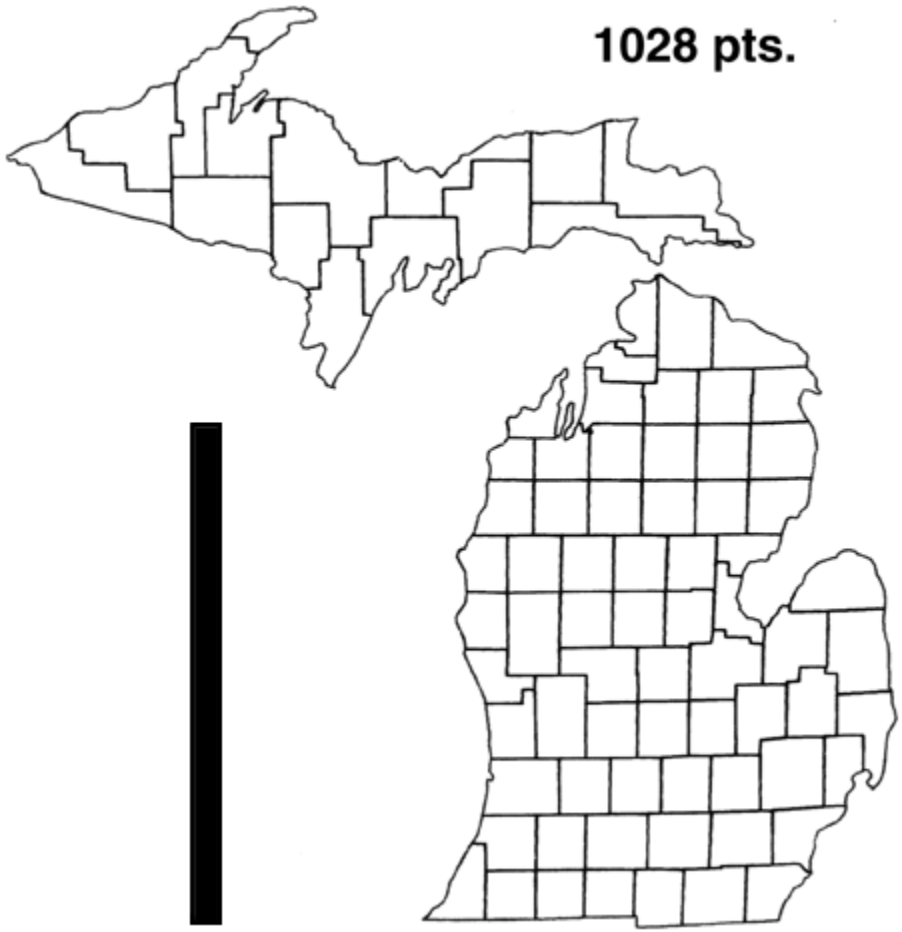
# Douglas-Peucker aka Ramer–Douglas–Peucker algorithm, the iterative end-point fit algorithm or the split-and-merge algorithm



# 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

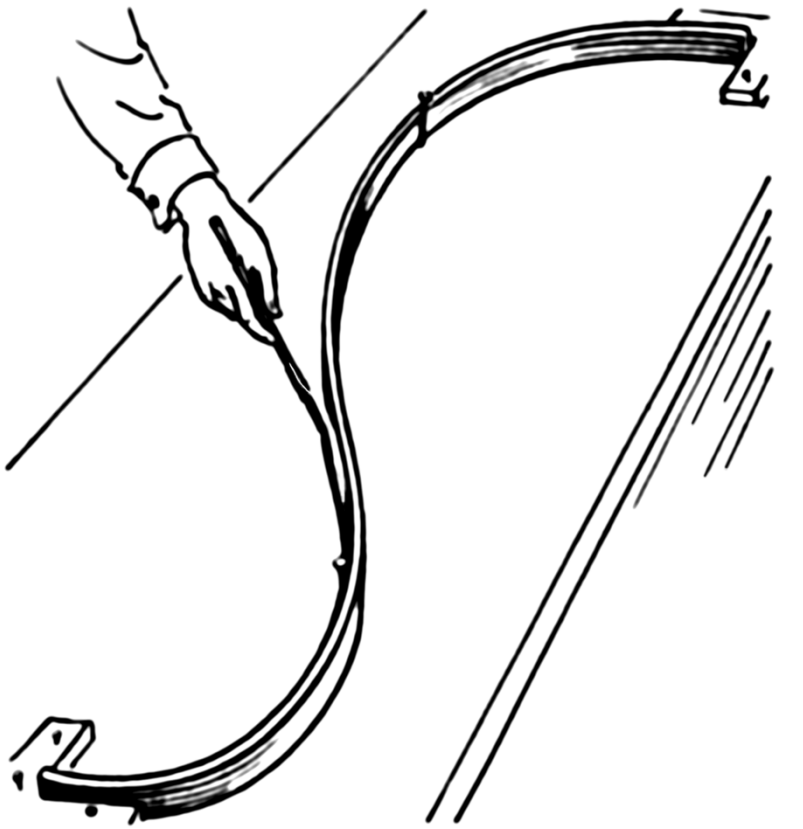


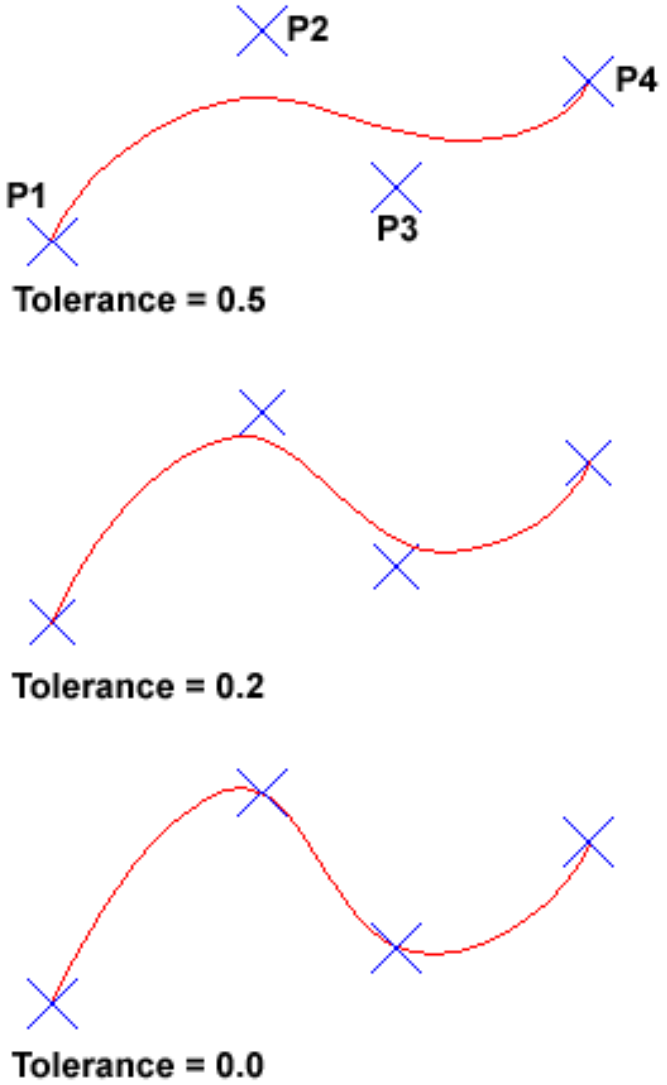

Example (Using Animation) Courtesy of Brad Allen and Waldo Tobler.

# Enhancement: adding detail back!

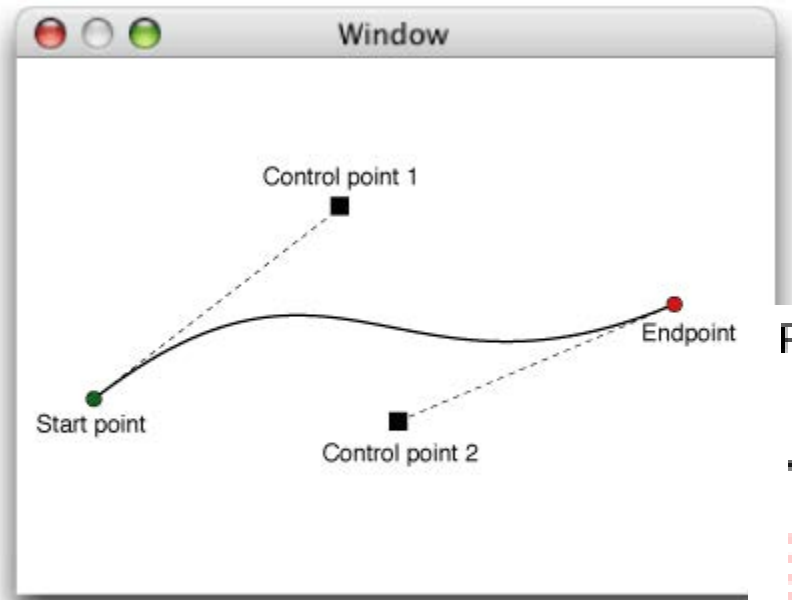
- Lines
  - Splines
  - Bezier Curves
  - Polynomial Functions
  - Trigonometric Functions (Fourier-based)
  - Fractals
- Surfaces
  - Fractal
  - Fourier
  - Manual

# Splines

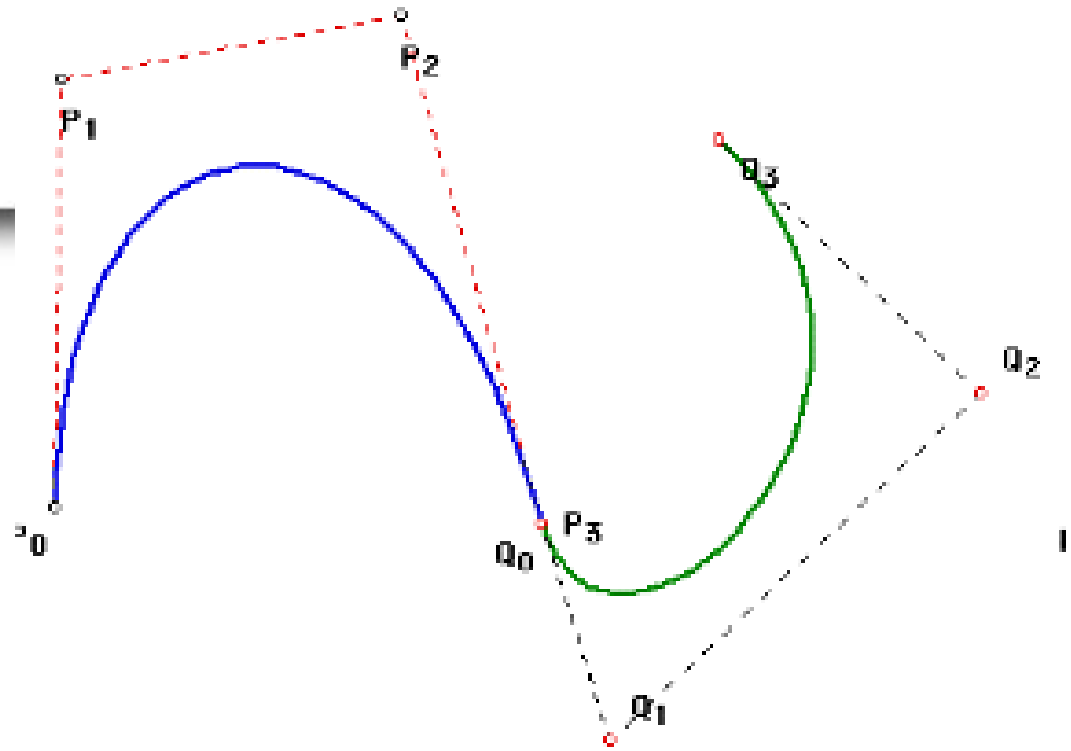




# Bezier curves: Match points and guide points

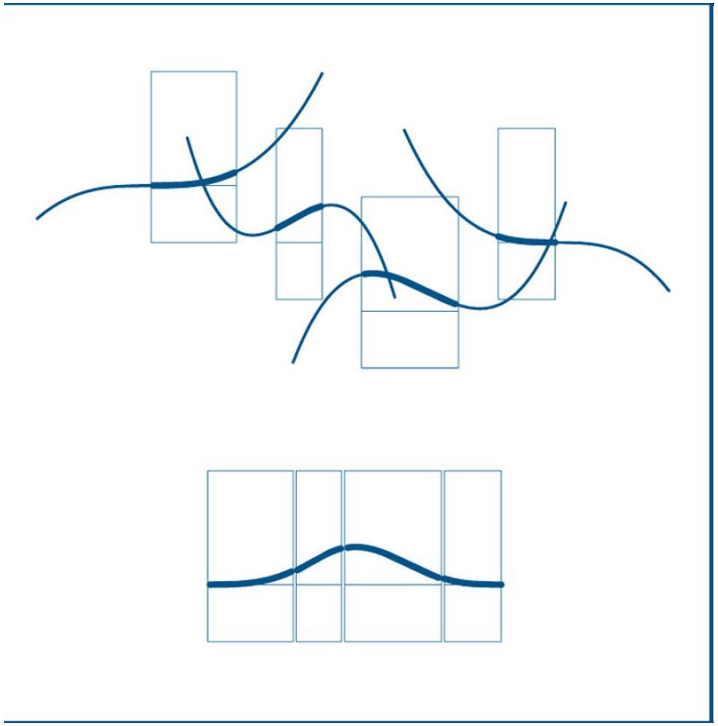


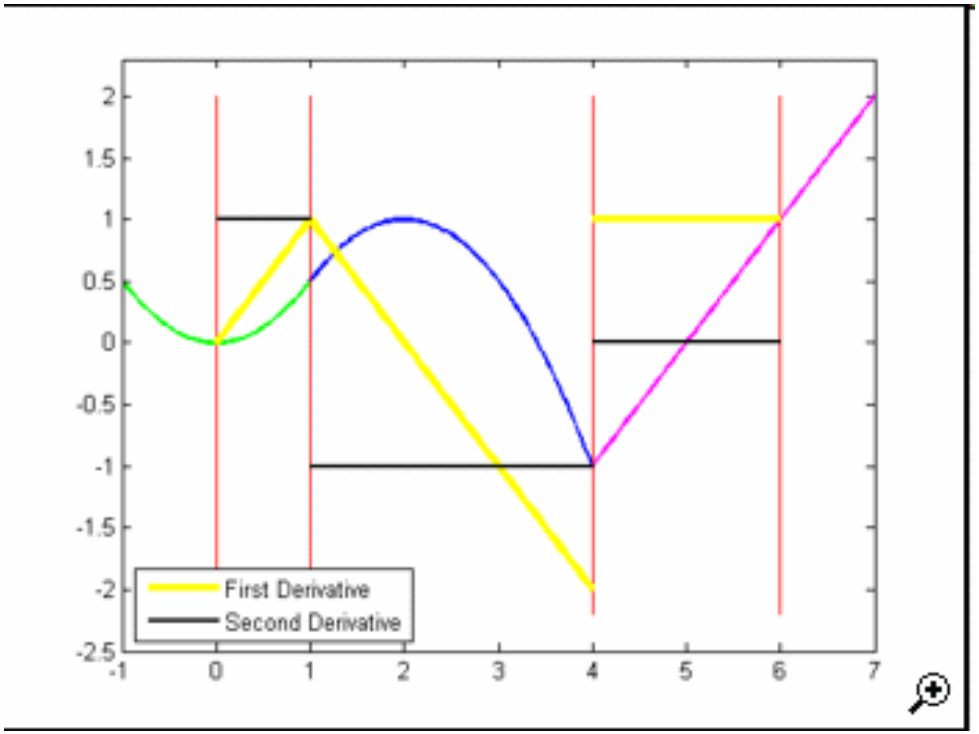

$$P_0 \cdot (1-t)^3 + P_1 \cdot 3 \cdot t \cdot (1-t)^2 + P_2 \cdot 3 \cdot t^2 \cdot (1-t) + P_3 \cdot t^3$$



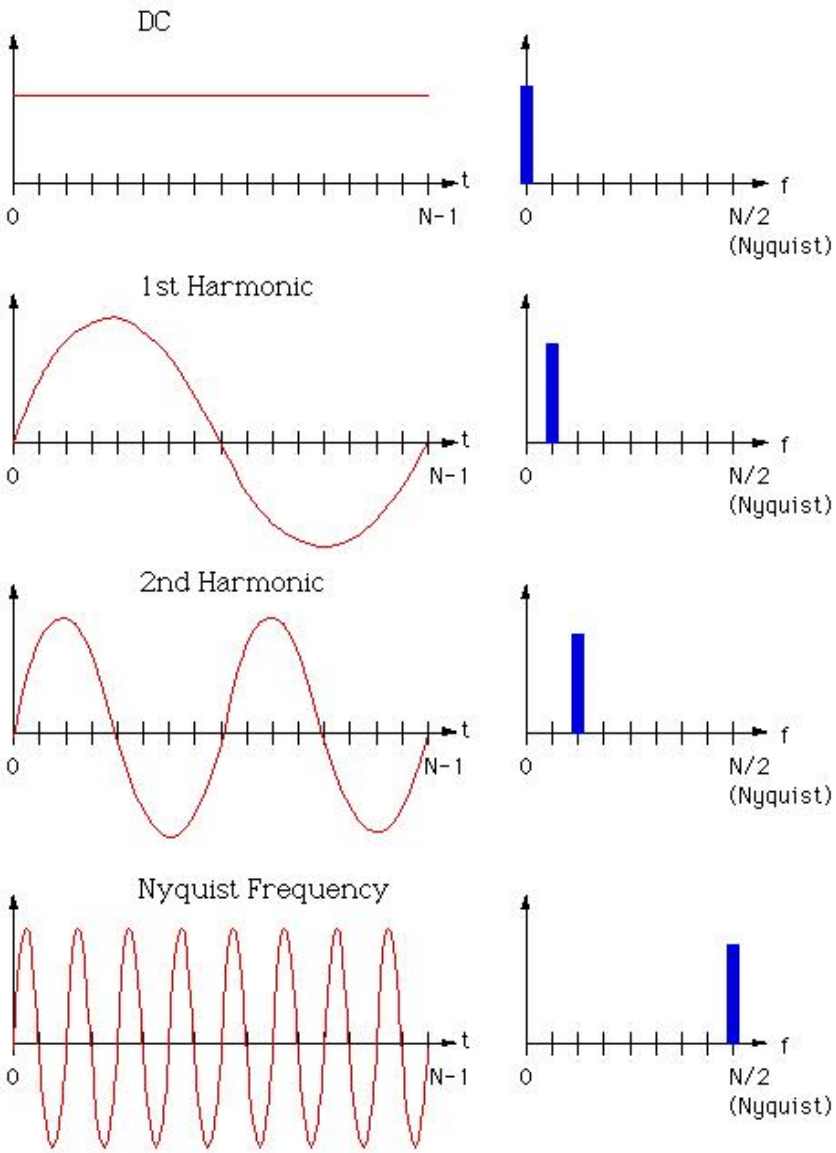

Continuous derivative at switching point

# Polynomial curves





# Fourier Series



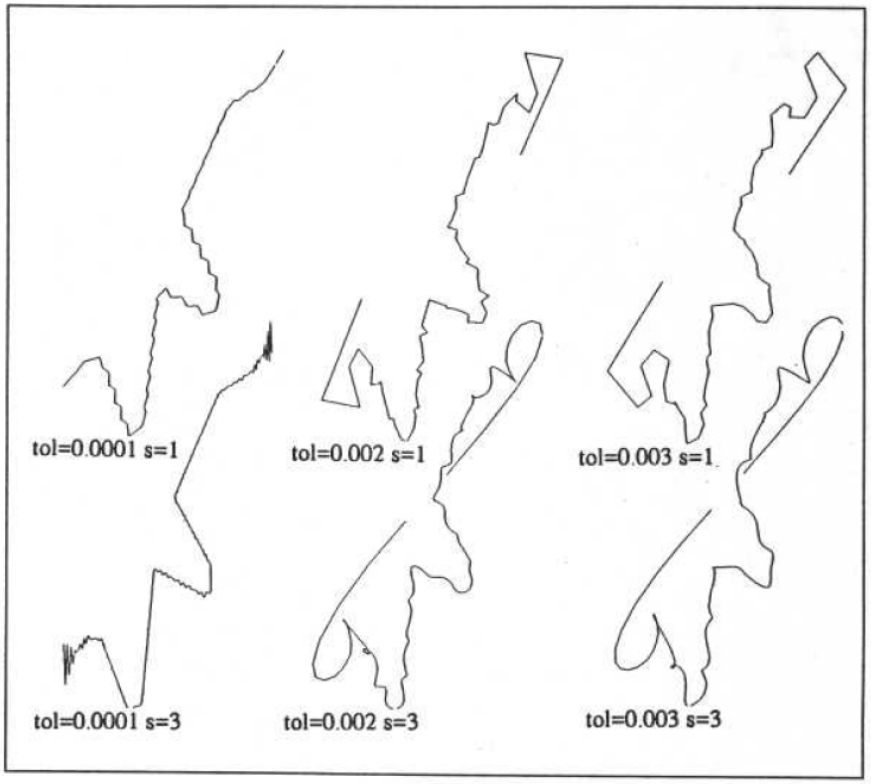
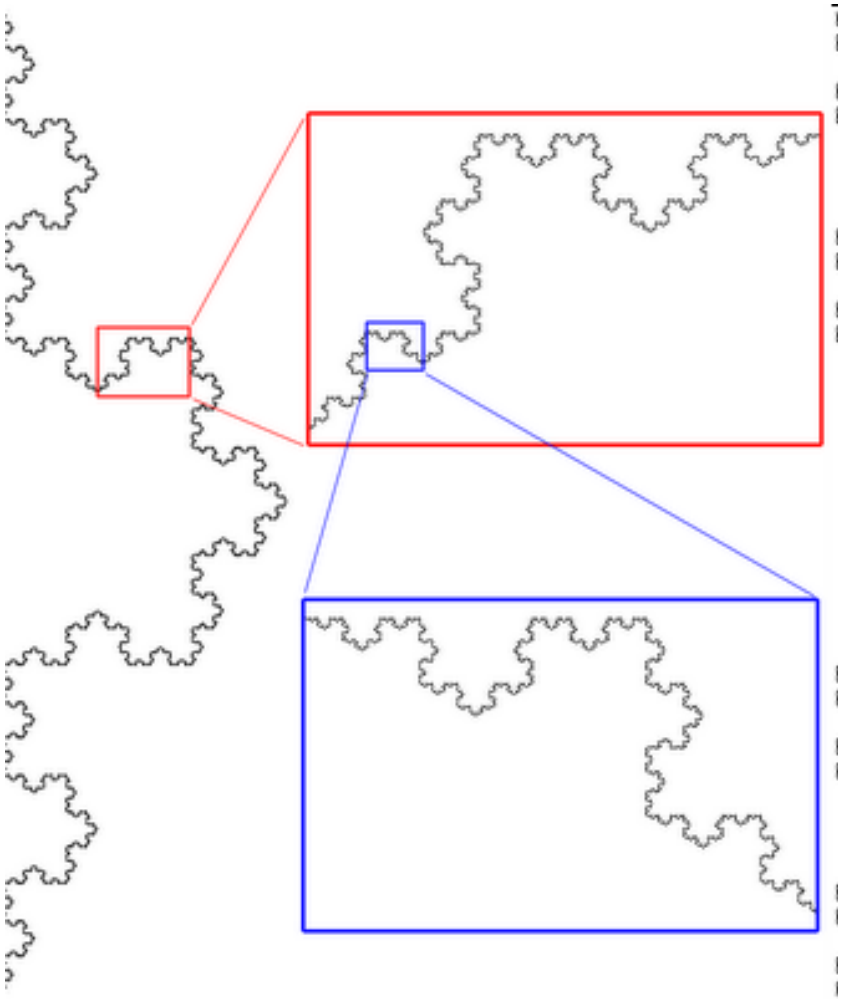




**Figure 1**

# Fractals: Fractional Geometry



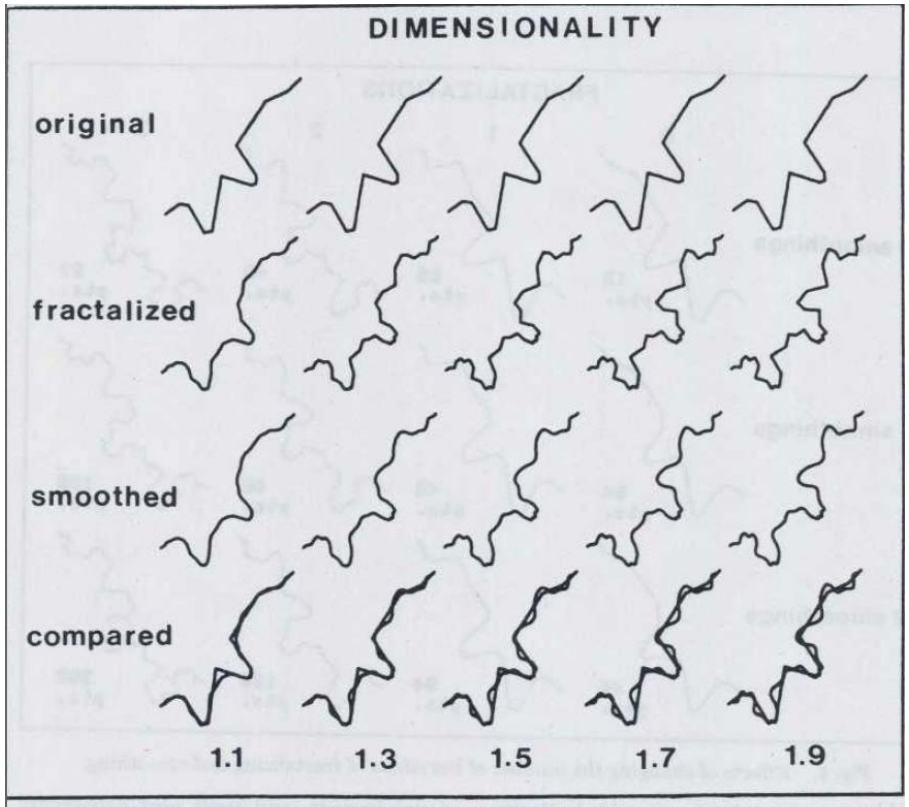
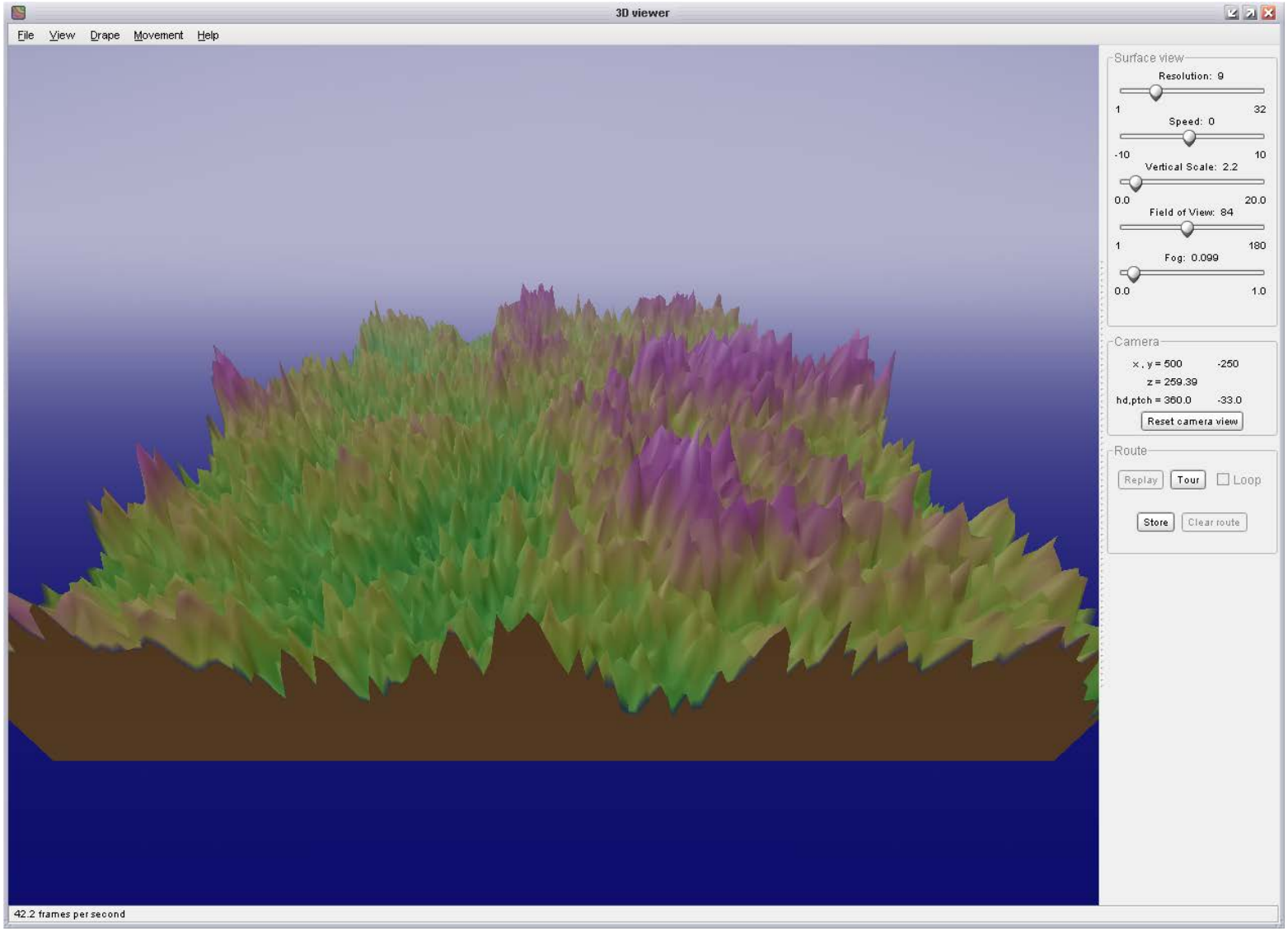



Fig. 3. Enhancement of a 13-point chain, showing the effects of varying SD.

# Surfaces: Fractal 2.75



# Fourier surfaces

**Figure 7**

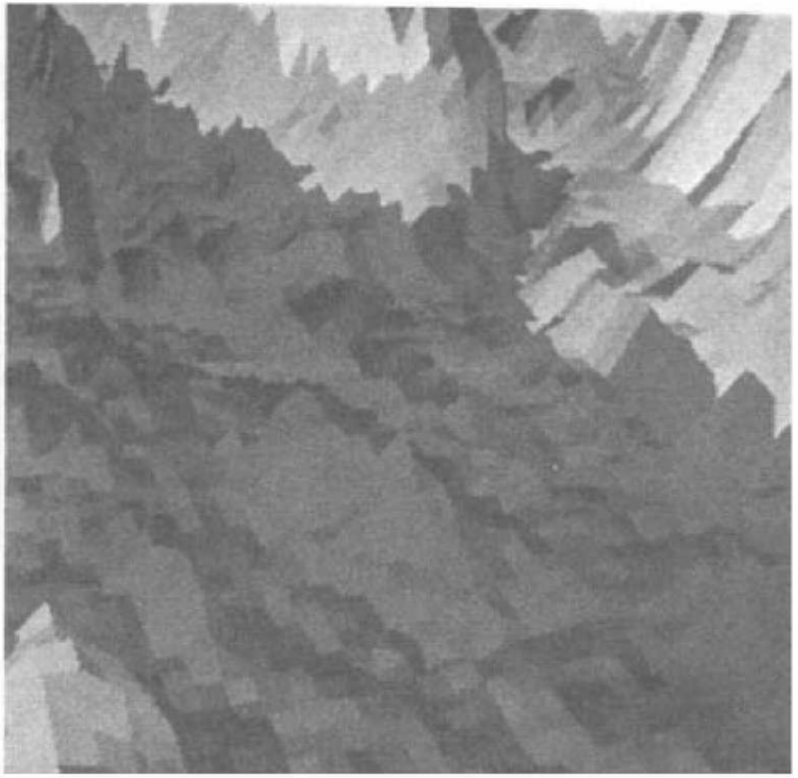
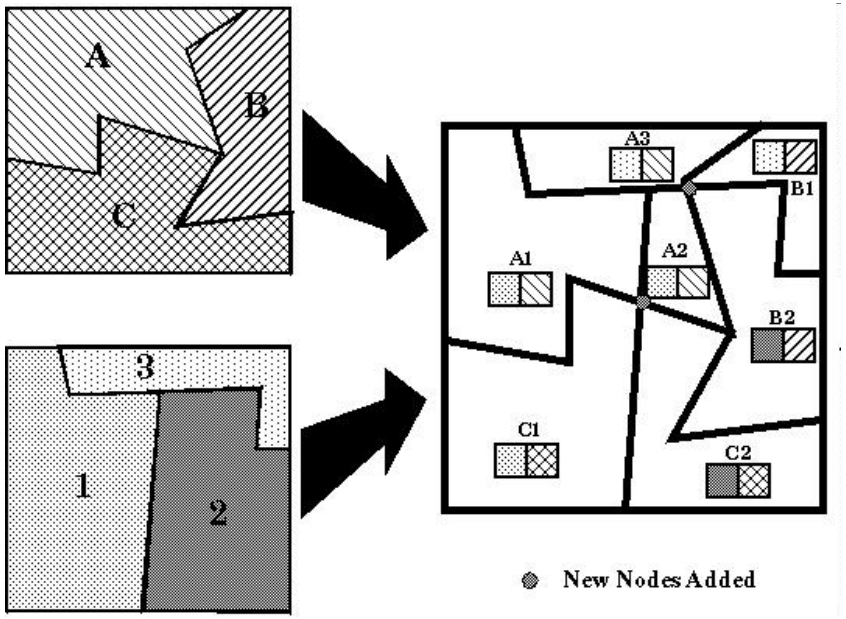


**Figure 8**

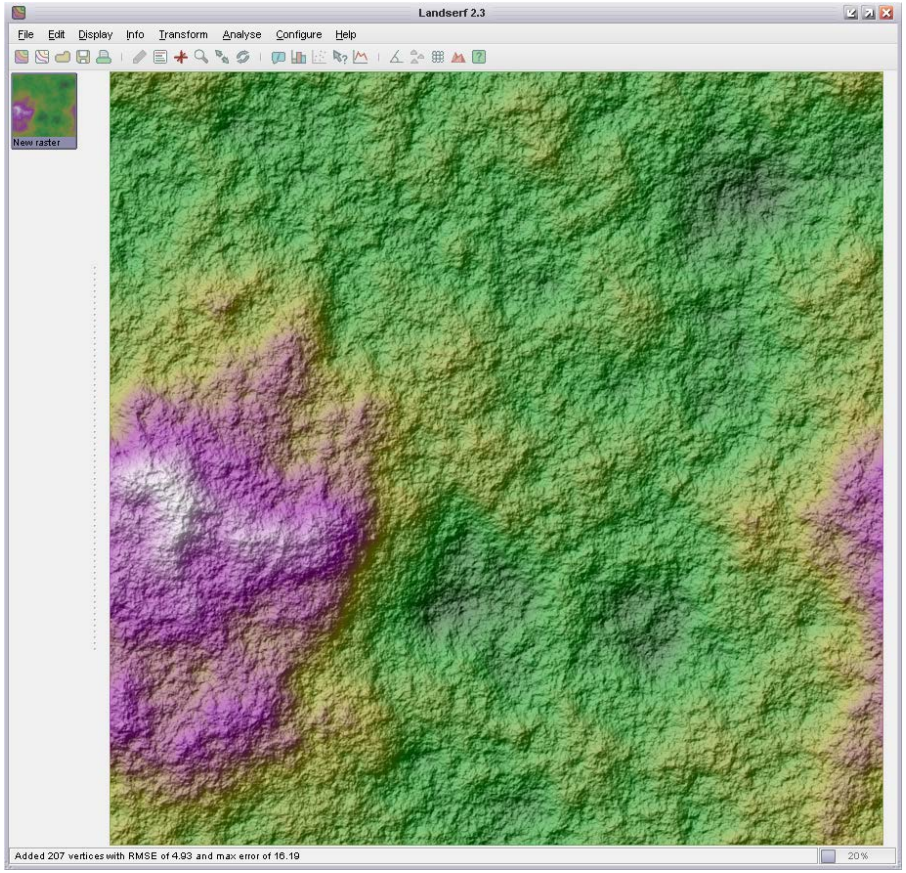
# Algorithms for Areas: Overlay

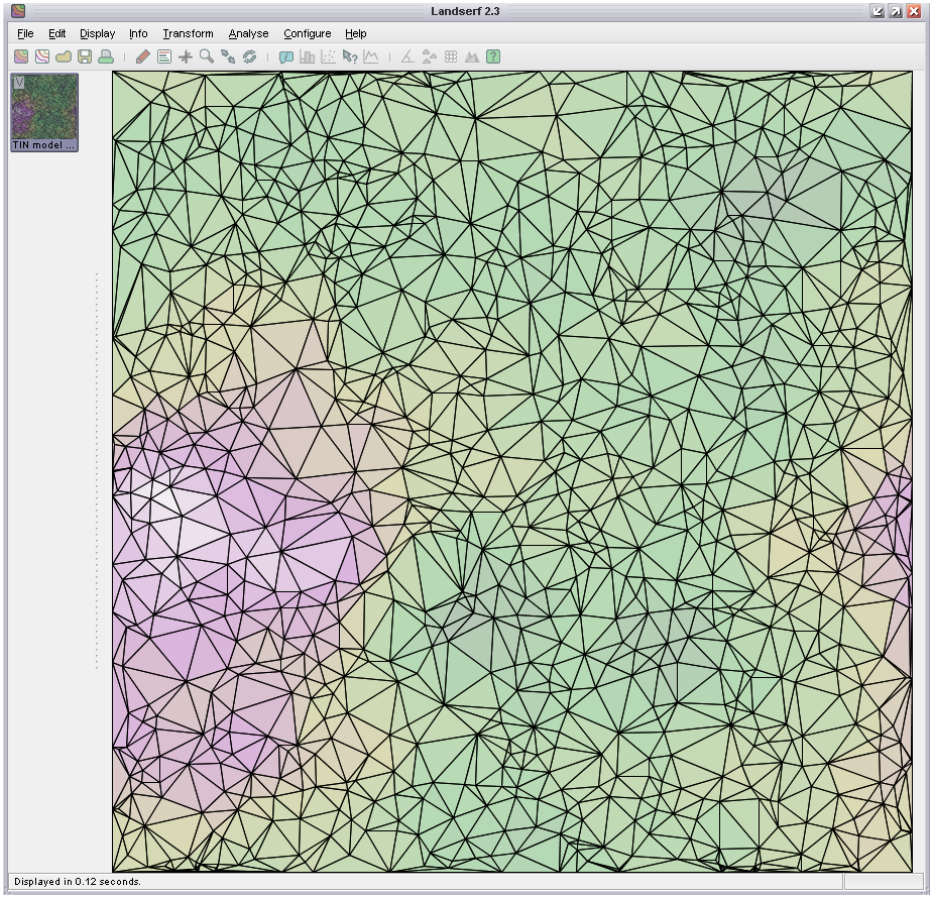



- 1. Intersections
- 2. Chain splitting
- 3. Polygon reassembly
- 4. Labeling and attribution

# Volume-to-Volume

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

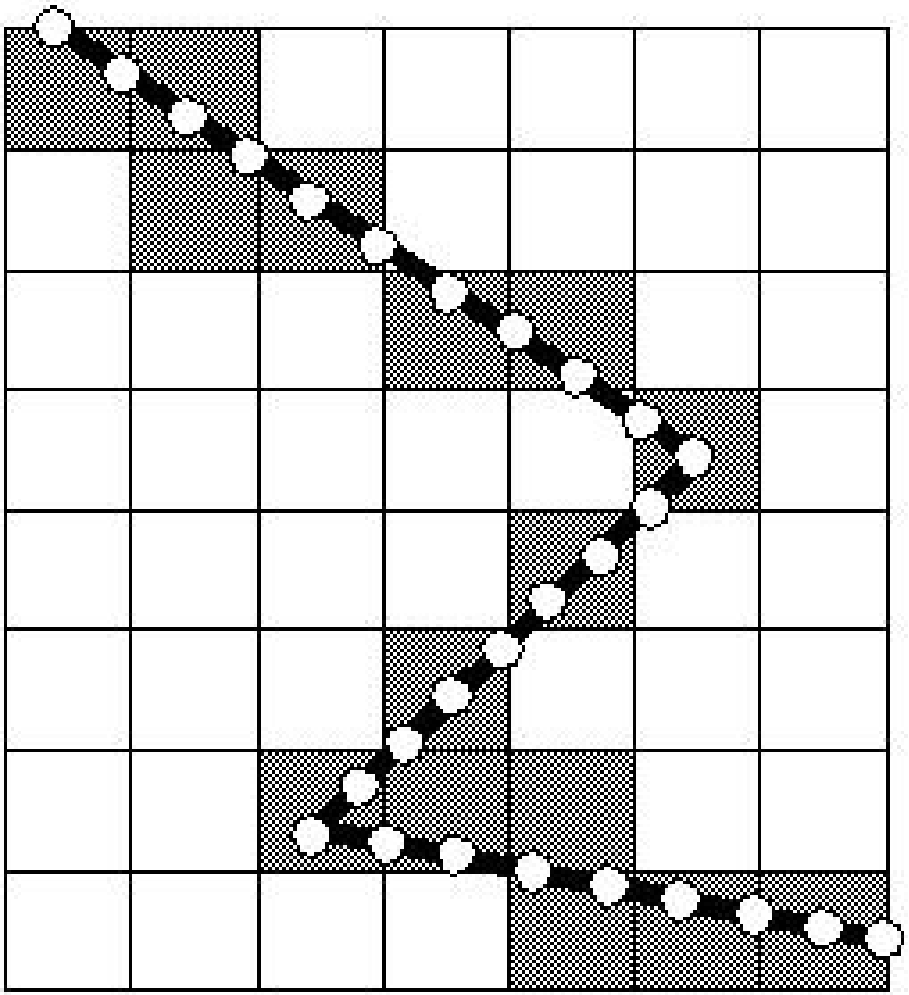


# Vector to Raster and Back Again

- 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



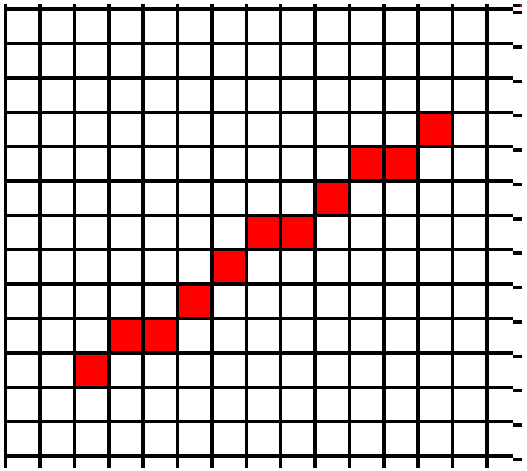
Consider drawing a line on a raster grid where we restrict the allowable slopes of the line to the range $0 \leq m \leq 1$

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:

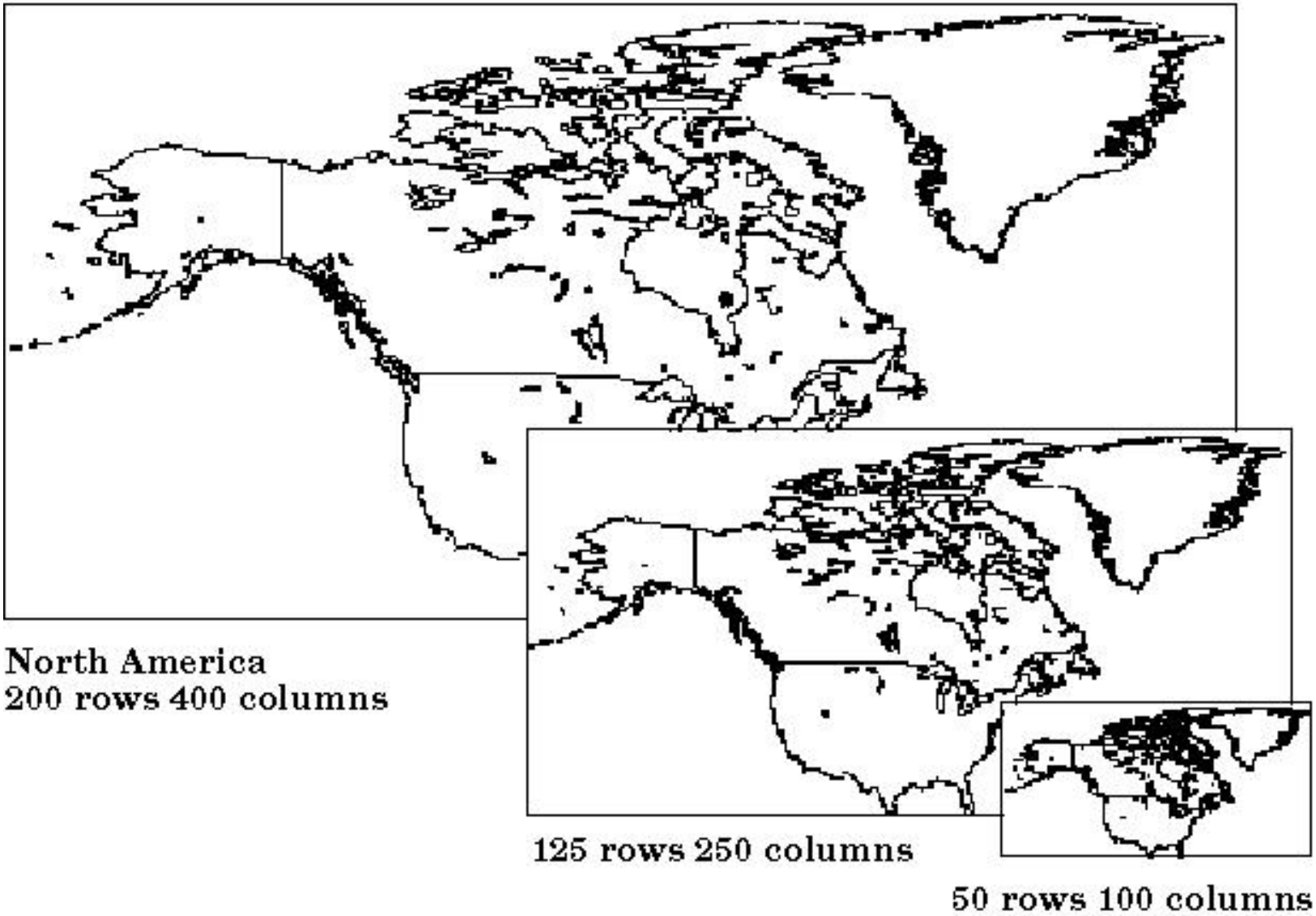
•It may plot the point *(x+1,y)*, or:

•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.

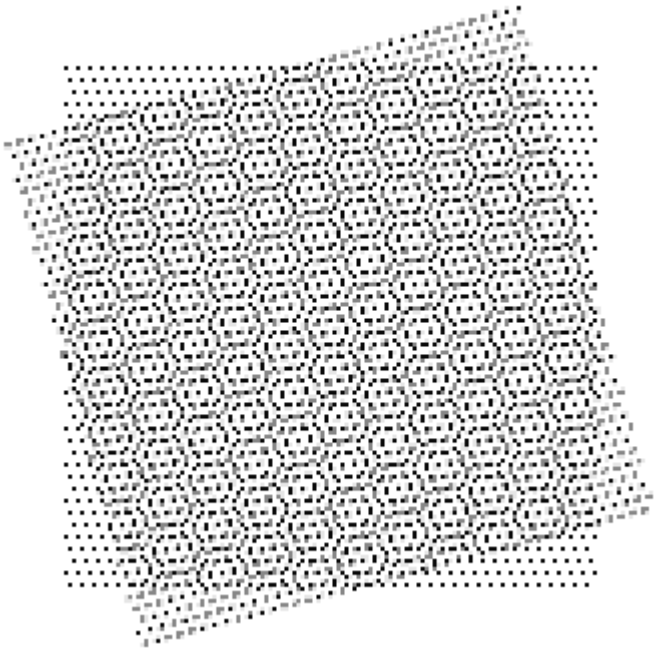


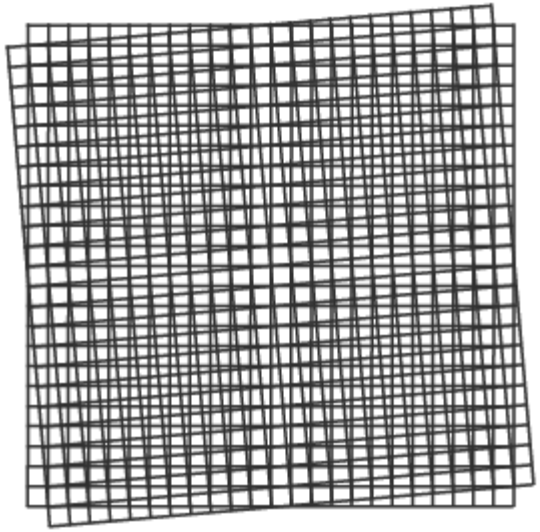
# Resampling Problems



# 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)

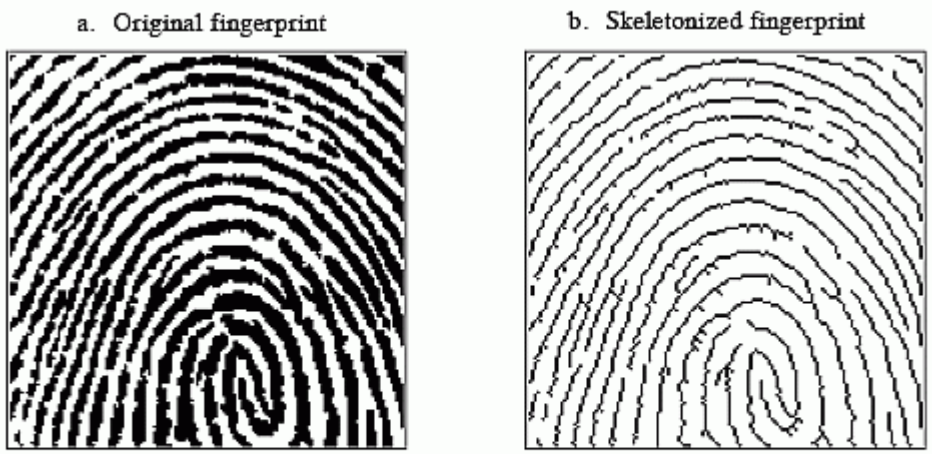
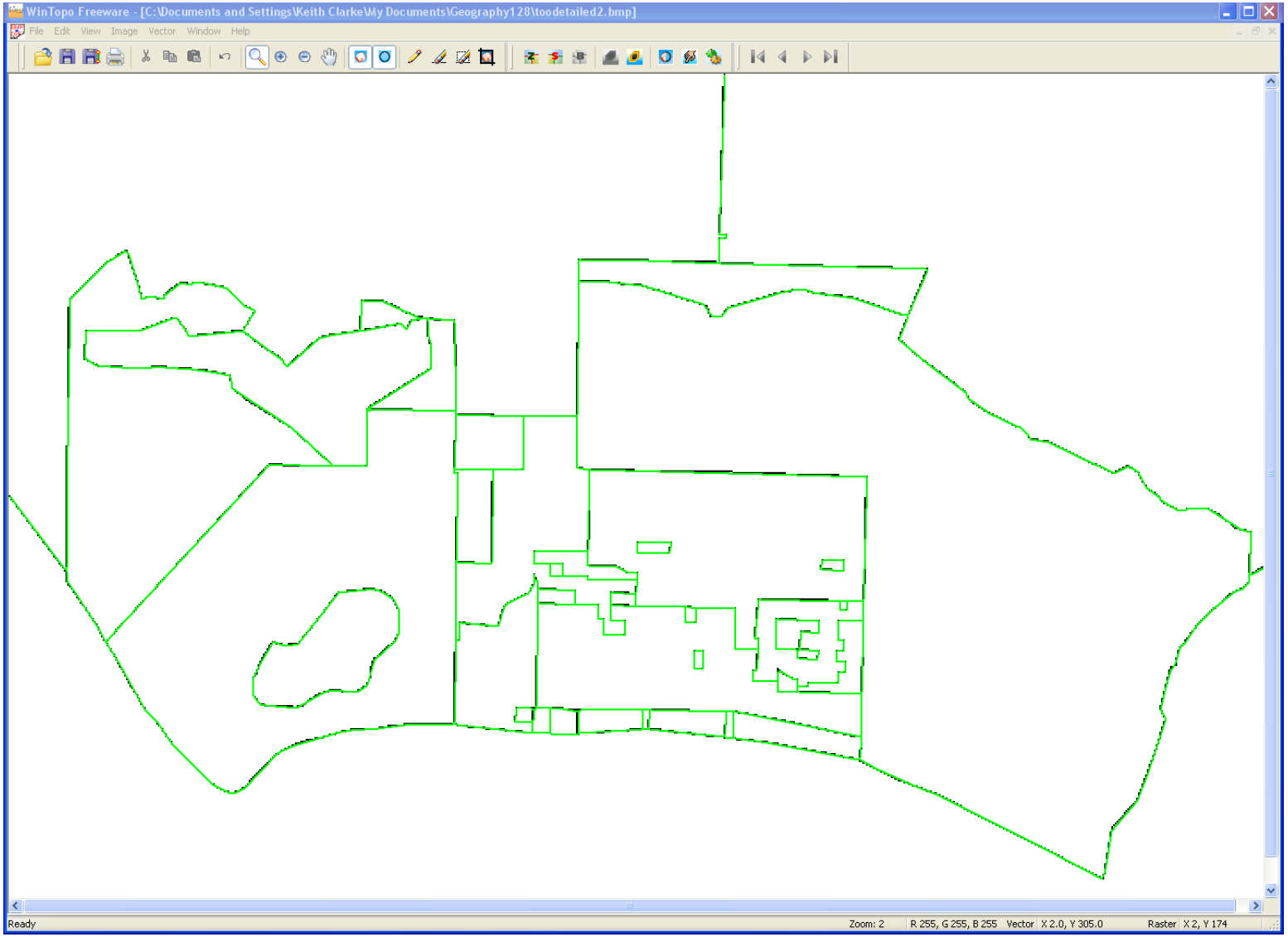



FIGURE 25-11
Binary skeletonization. The binary image of a fingerprint, (a), contains ridges that are many pixels wide. The skeletonized version, (b), contains ridges only a single pixel wide.

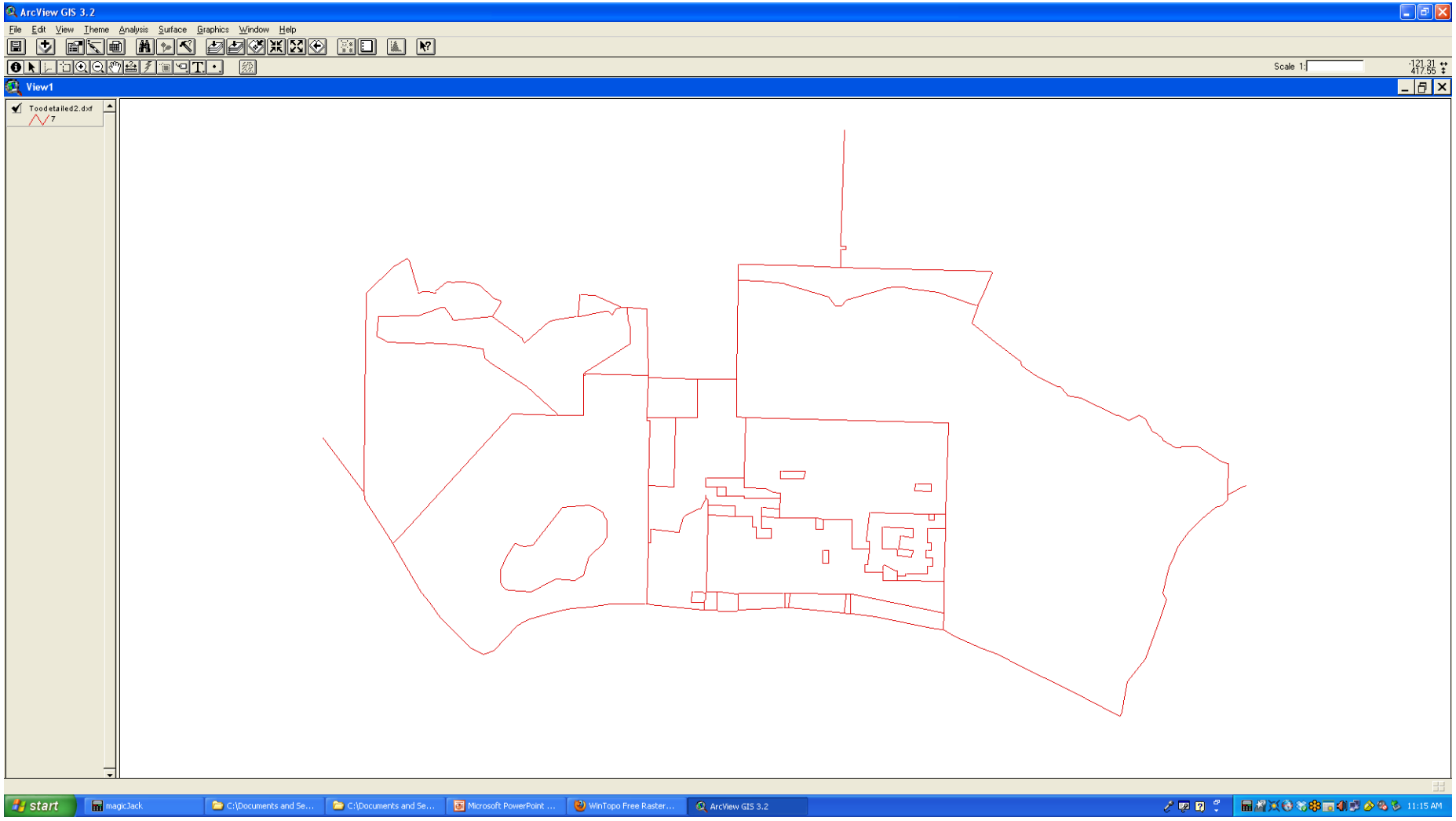
# Raster to Vector

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

# WinTopo

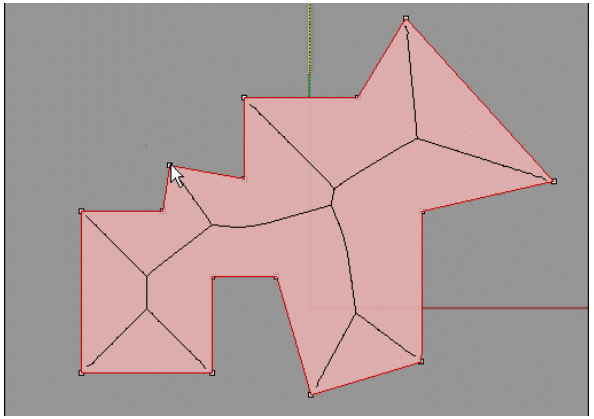

WinTopo Freeware - [C:\Documents and Settings\Keith Clarke\My Documents\Geography128\toodetailed2.bmp]
File Edit View Image Vector Window Help
Ready
Zoom: 2
R 255, G 255, B 255
Vector X 2.0, Y 305.0
Raster X 2, Y 174

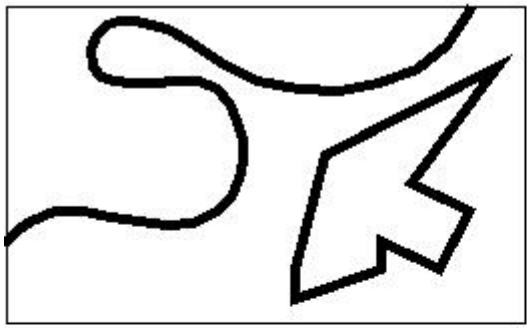
# DXF file created



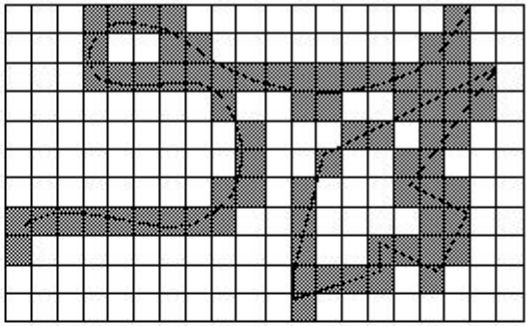
# Algorithms

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

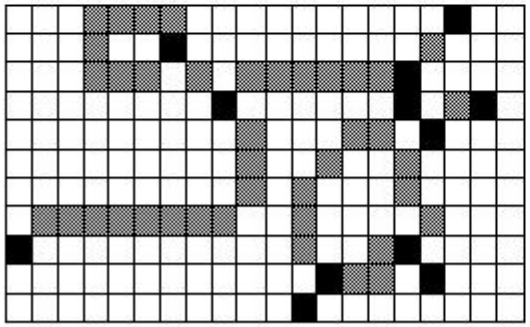




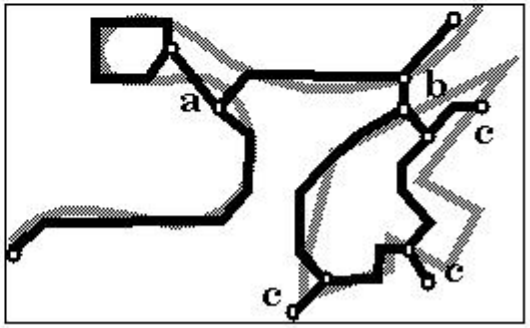
Vector lines



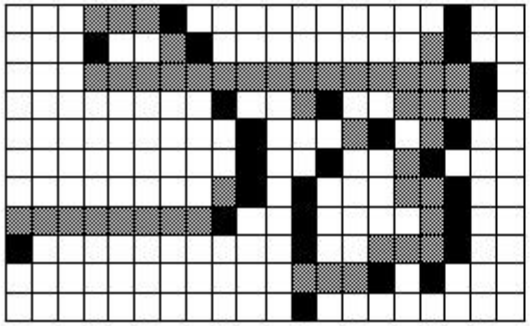
Raster scan of lines



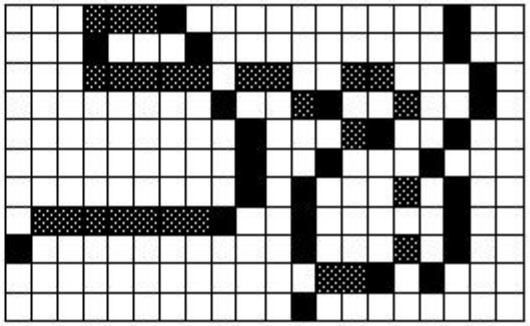
Thinned Image: Endpoints located




Conversion to topological vectors



Left to right edges



Top to bottom edges

# Data Structure Transformations

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

# JPG using lossy wavelet compression 100% to 1%

# 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?
- $XT = X'$
- $X' T^{-1} = X + E$

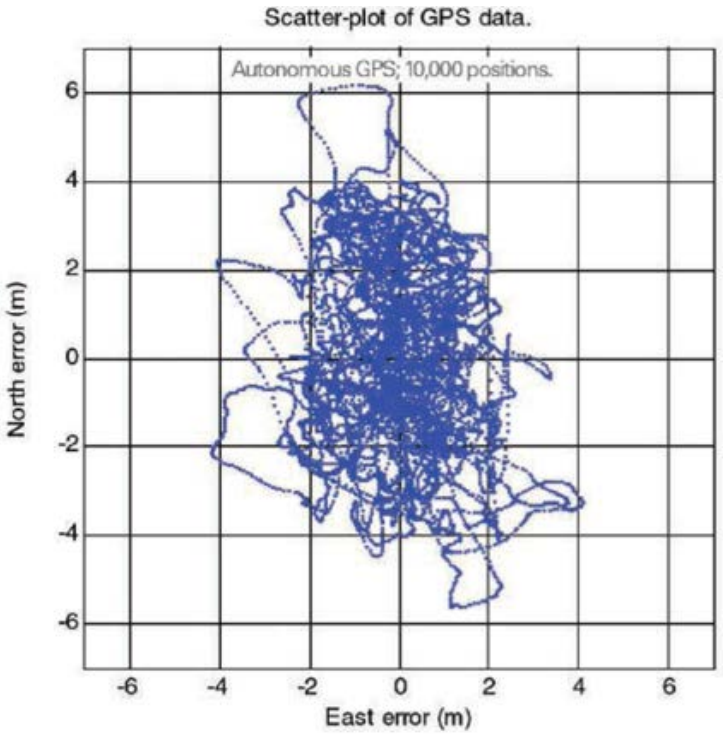
# Traditional View of Error

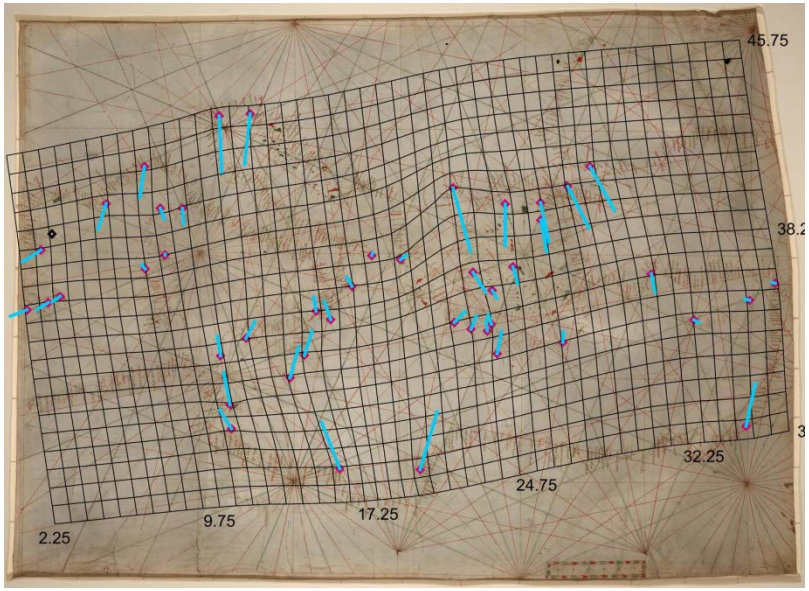
- Measurement error is random and Gaussian
- Many errors are also systematic
- Type 1 and Type 2: Omission and Commission
- Omission: Something real on the ground was missed
- Commission: Something NOT on the ground was captured

| | **Feature Present** | **Feature Absent** |
|---|---|---|
| Mapped | True Positive | False positive |
| Not mapped | False negative | True negative |

# Map error

- positional
- attribute
- systematic
- random
- blunder (e.g. 8 vs. 5)
- known
- uncertain



# Avoiding error

- Errors can be attributed to poor choice of transformations
- Chain of transformations: Which contributes most error?
- Worst case vs average
- Incompatible sequences of T's (non-invertible)
- "Hidden" Error = use error, not process error
- Blunders and misinterpretations: Design!
- Errors on maps can have major consequences!

# Summary

- Line-to-line algorithms resampling vs. modeling
- Also applies to surfaces
- Generalization algorithms examined, can they be inverted?
- Saw examples of data structure transformations
- Resampling and generalization can cause map errors
- Showed issues surrounding raster to vector conversion
- Data structure transformations can be lossy
- Errors on maps can be caused by sequences of transformation
- Errors on maps can be blunders, random or systematic