

# GEOG 358: Introduction to Geographic Information Systems

Digitizing &  
georeferencing



- Vector data
- Aerial and satellite imagery
- Paper maps
- Field survey
- There's a lot of data out there but it was all created by someone!



# Existing data

- Vector and raster

The screenshot shows the USGS National Boundary Dataset page. The browser address bar is [apps.nationalmap.gov/datasets/](https://apps.nationalmap.gov/datasets/). The page features the USGS logo and a navigation menu with categories like Apps, Academic, Epicurean, Lifestyle, Media, and To Read. The main content area is titled "Boundaries - National Boundary Dataset" and includes a map thumbnail, a description of the data, and metadata such as refresh period, formats, and ScienceBase tags. Below this, the "Elevation Products (3DEP)" section is visible, also featuring a map thumbnail and metadata.

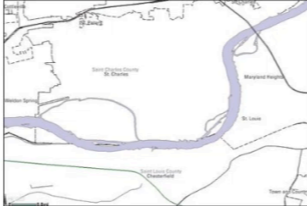

**USGS**  
science for a changing world

**Extents:** 1 x 1 degree, 1 x 2 degree, 1 x 3 degree, 1 x 4 degree, 15 x 15 minute, 2 x 1 degree, 3.75 x 3.75 minute, 30 x 30 minute, 30 x 60 minute, 7.5 x 15 minute, 7.5 x 7.5 minute

## Data

### Boundaries - National Boundary Dataset

Boundaries data or governmental units represent major civil areas including states, counties, Federal, and Native American lands, and incorporated places such as cities and towns. These data are useful for understanding the extent of jurisdictional or administrative areas for a wide range of applications, including managing resources, responding to natural disasters, or recreational activities such as hiking and backpacking.



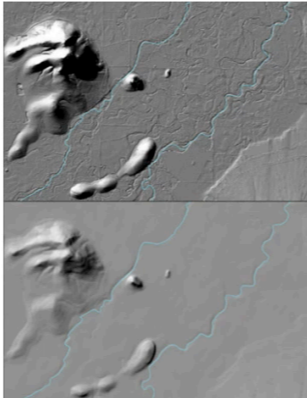
[More Info](#)  
**Refresh Period:** Monthly

**ScienceBase Tag:** [National Boundary Dataset \(NBD\)](#)  
**Extents:** National, State

[Data Gov](#)  
**Formats:** Shapefile, FileGDB, All  
**ScienceBase:** [4f70b219e4b058caae3f8e19](#)

### Elevation Products (3DEP)

The National Elevation Dataset (NED) is the primary elevation data product produced and distributed by the USGS. The NED provides seamless raster elevation data of the conterminous United States, Alaska, Hawaii, and the island territories. The NED is derived from diverse source data sets that are processed to a specification with a consistent resolution, coordinate system, elevation units, and horizontal and vertical datums. The NED is the logical result of the maturation of the long-standing USGS elevation program, which for many years concentrated on production of topographic map quadrangle-based digital elevation models. The NED serves as the elevation layer of The National Map, and provides basic elevation information for earth science studies and mapping applications in the United States.



[More Info](#)  
**Refresh Period:** Continuous

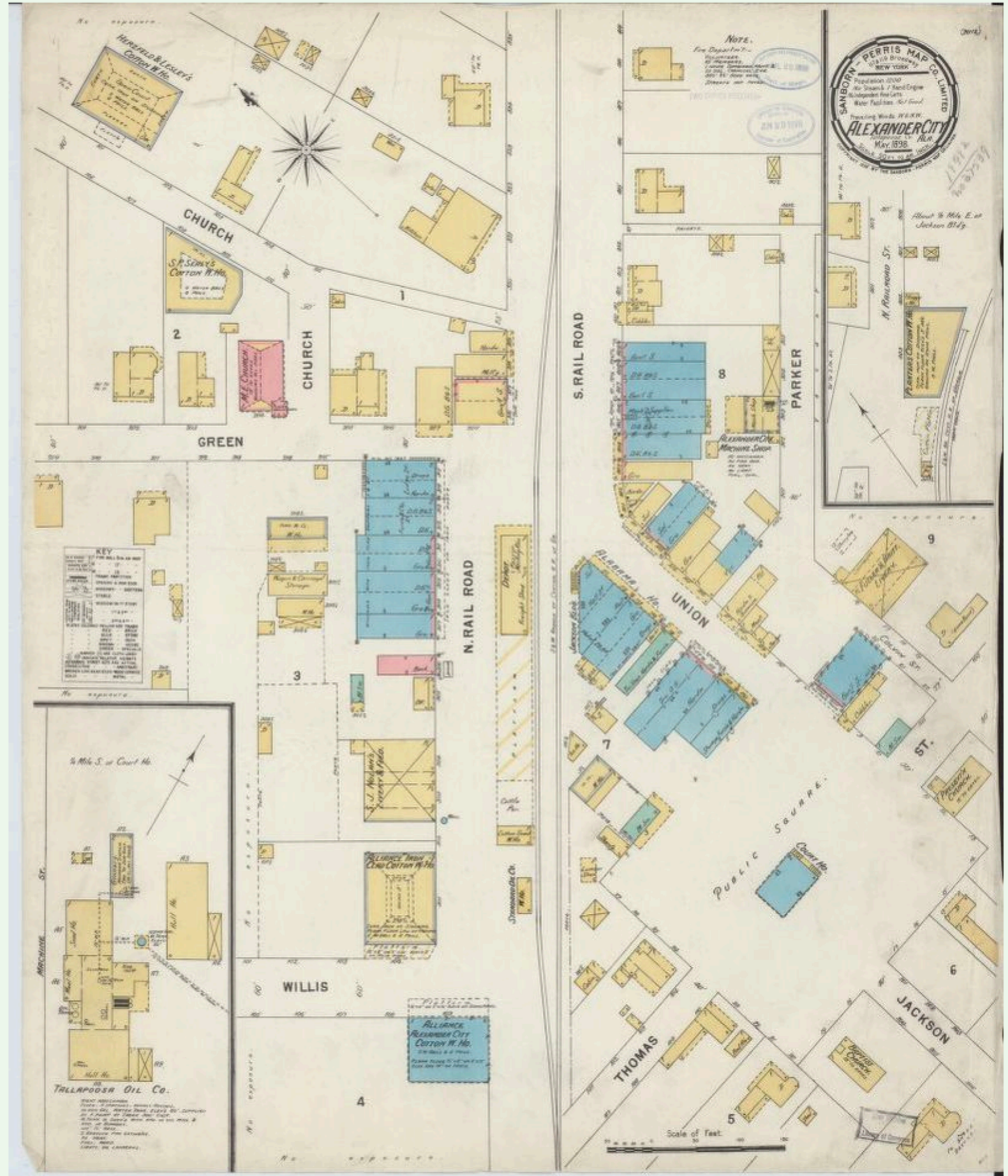
**ScienceBase Tag:** [National Elevation Dataset \(NED\)](#)  
**Extents:** 1 x 1 degree, 10000 x 10000 meter, 15 x 15 minute, Varies

**Formats:** GeoTIFF, GeoTIFF, IMG, Shapefile, FileGDB, All  
**ScienceBase:** [3dep\\_prodserv.html](#)

DOI Privacy Policy | Legal | Accessibility | Site Map | Contact USGS | U.S. Department of the Interior | DOI Inspector General | White House | E-gov | Open Government | No Fear Act | FOIA

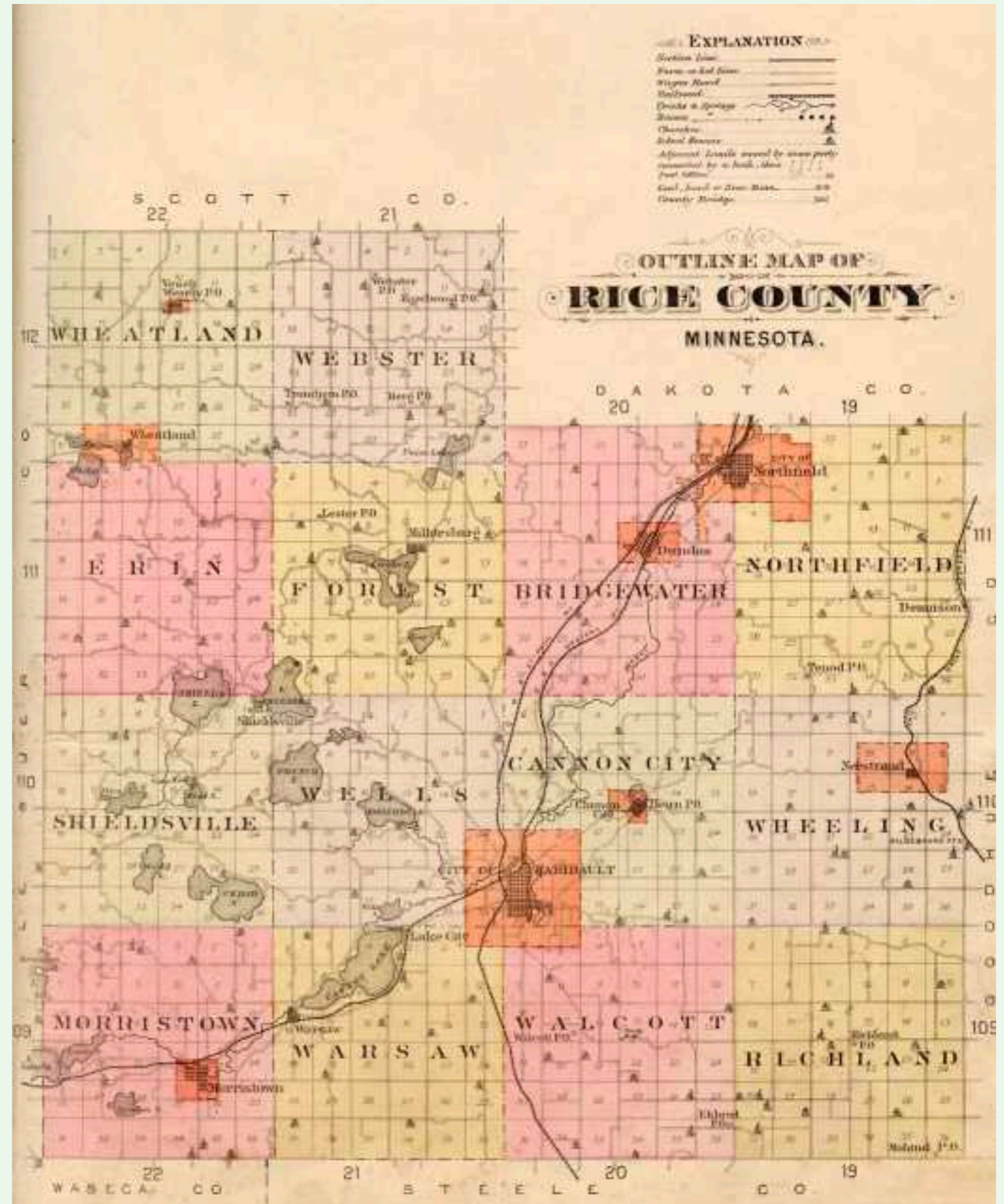
# Paper maps

- Insurance maps
- Plat maps
- Historic documents



# Paper maps

- Insurance maps
- Plat maps
- Historic documents



# Historic documents

RESIDENCE: \_\_\_\_\_  
 POST OFFICE: Ecoutechka

Roll No. \_\_\_\_\_ CARD NO. 8

Dawes' Roll No.	NAME.
24	1 Brain, Alexander
25	√2 " Lucy
26	√3 " Anna E
27	√4 " Allen M
28	√5 " Ambrose
6	
7	
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18	

6-1014

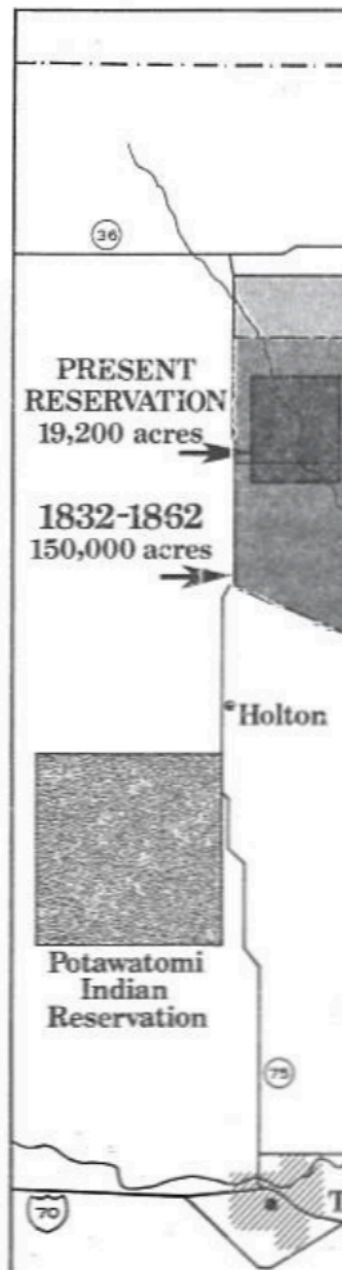


Figure 1. Map of diminishin p. 72. Original cartography

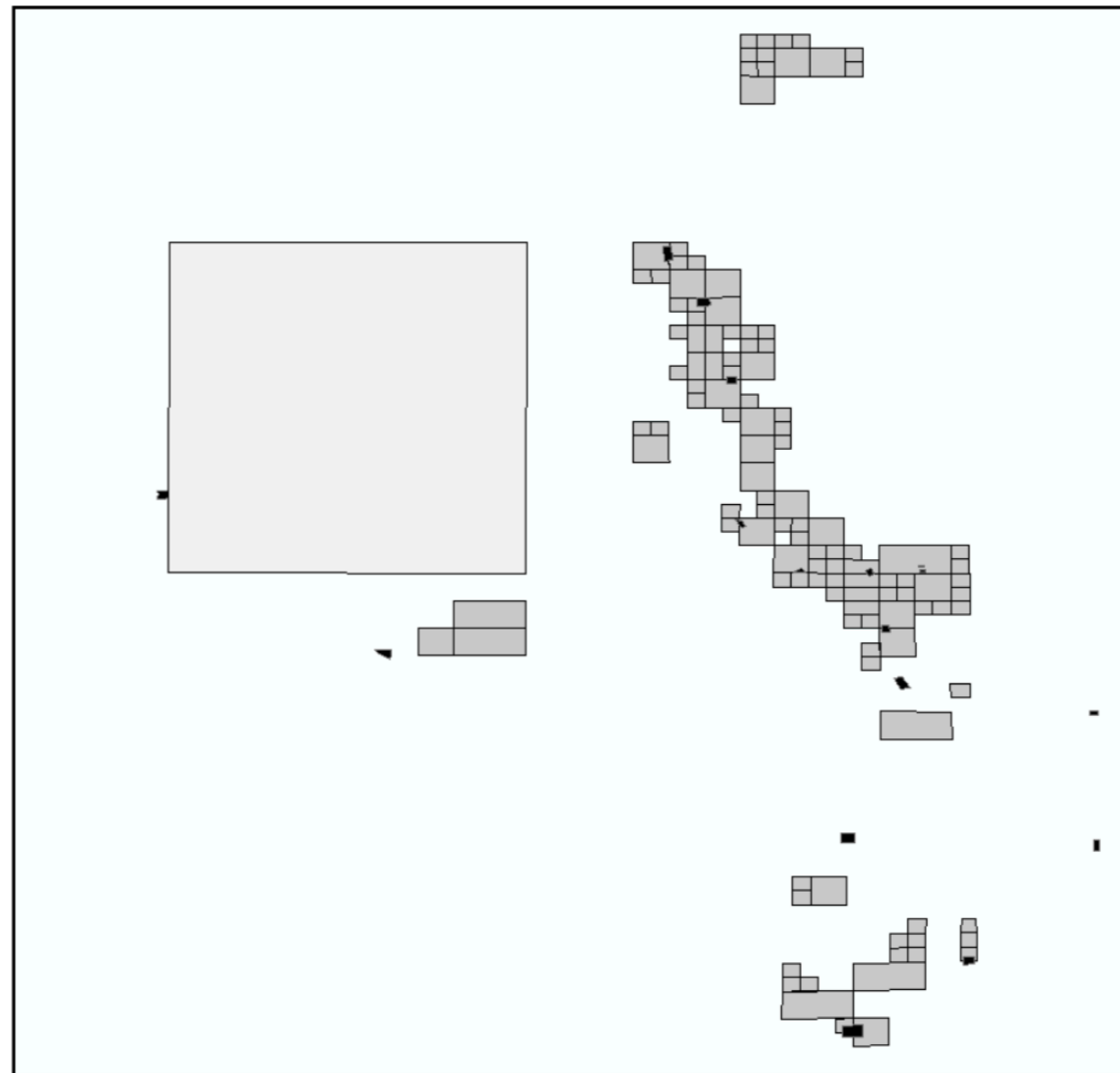


Figure 3. Lands allotted as a result of the Treaty of 1862. The large square on the left (light gray) is the land allotted in common, while the smaller parcels on the right (mid-gray) are the allotments in severalty. The small black polygons are cultivated fields as mapped in the original land surveys. (Map by authors in ArcGIS.)

Egbert, S., & Smith, P. (2017). "Great Frauds and Grievous Wrongs": Mapping the Loss of Kickapoo Allotment Lands. In *Native American Symposium, Representations and Realities*; Southeastern Oklahoma State University: Durant, OK, USA.



# Historic documents





# Historic remote sensing



Partial Clearing 2005



Post Backwater Excavation 2007



Prior to Completion of Planting 2009



Planting Completed 2010



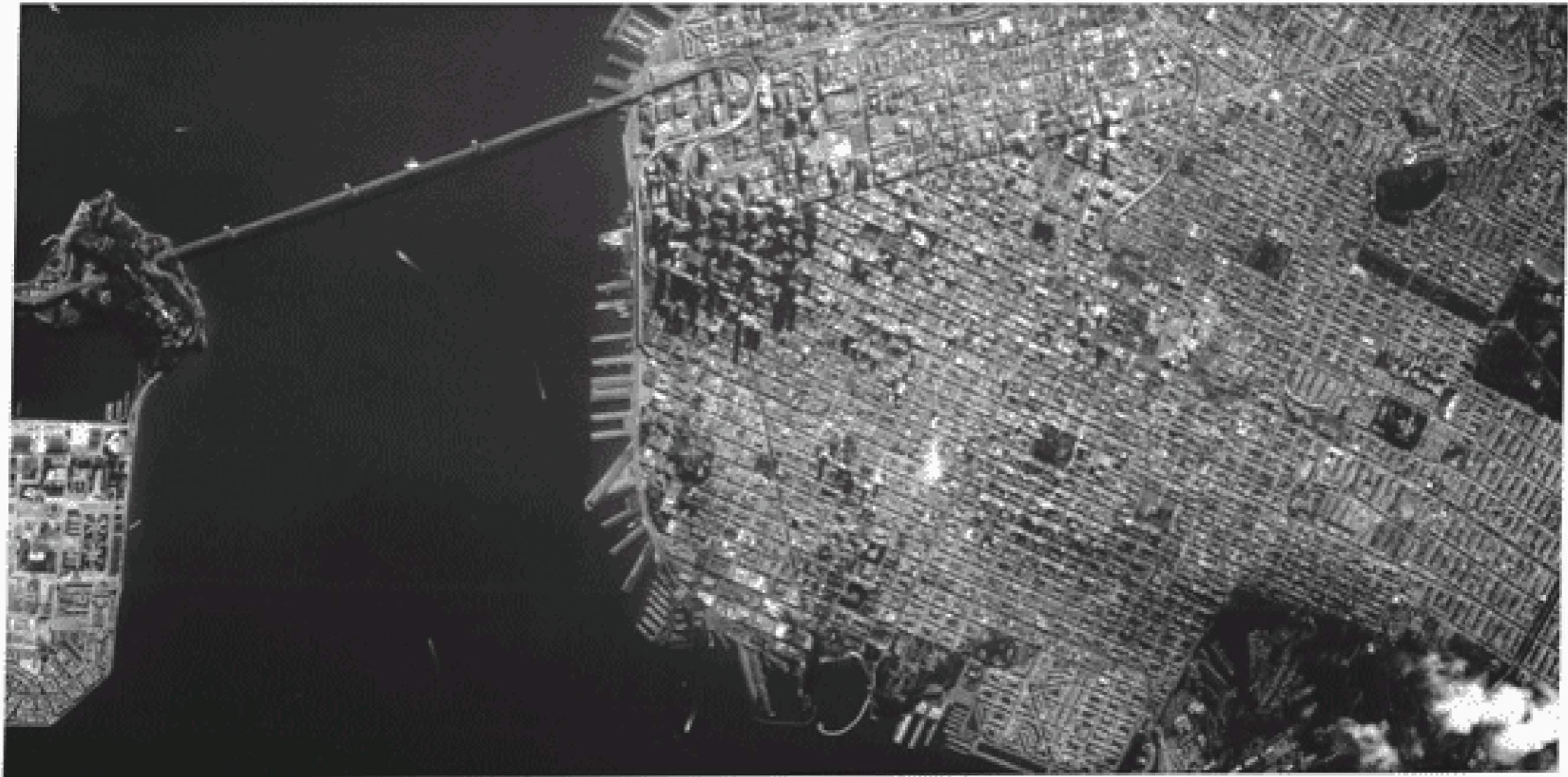
Plant Growth 2012



Project Completed 2013

**Figure 3.** Project Timeline Using Available NAIP Imagery

# Historic remote sensing



# Field Survey



# Digitizing

- Creating digital geographical features
  - Convert analogue features to digital features
    - Paper maps
  - Identify and record features
    - From images or recorded field data
- Two approaches
  - Digitizing tablets
  - On-screen digitization

# Digitizing with a tablet

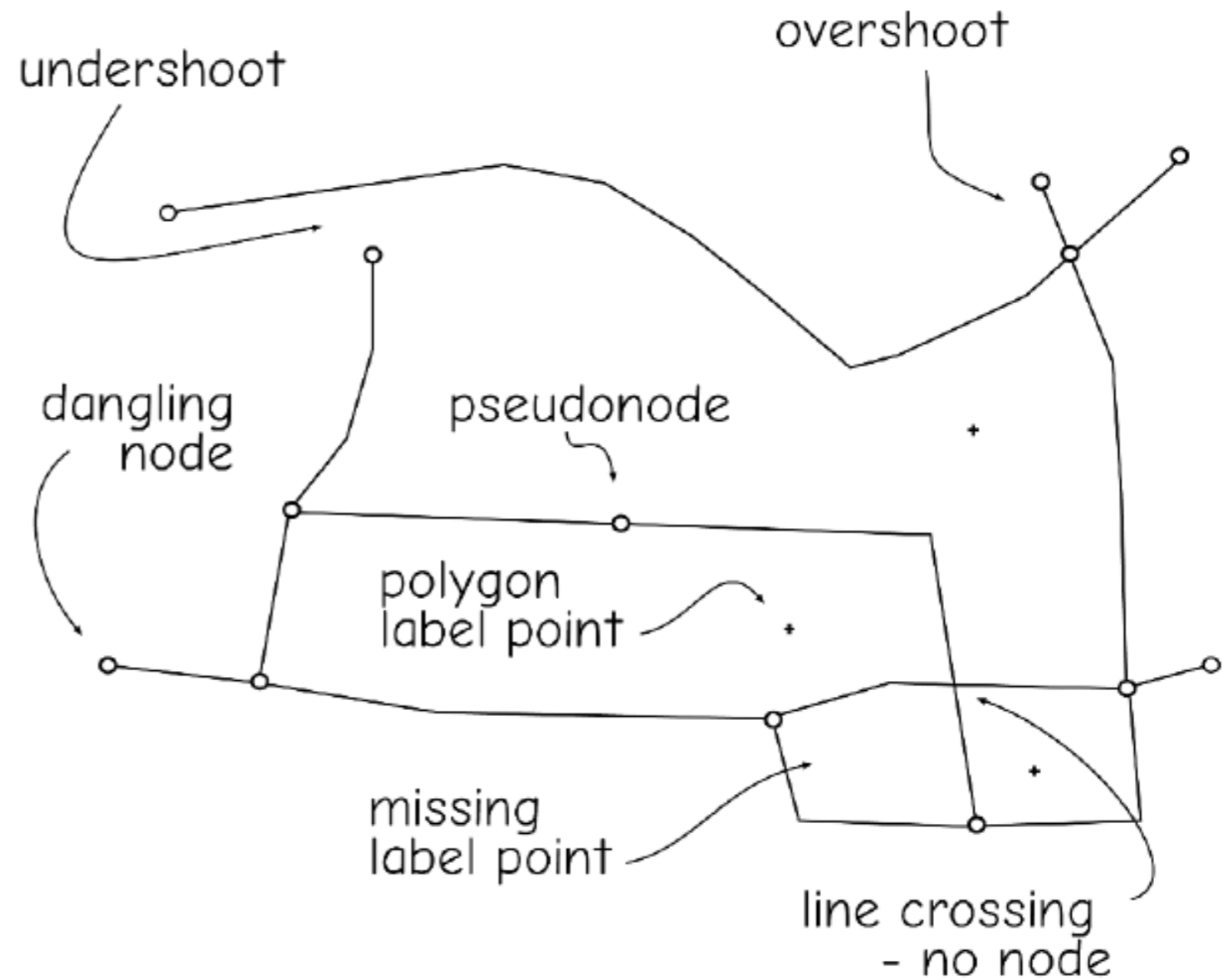


# Digitizing onscreen



# Common Errors in Manual Digitizing

**Figure 4-15:** Common digitizing errors.



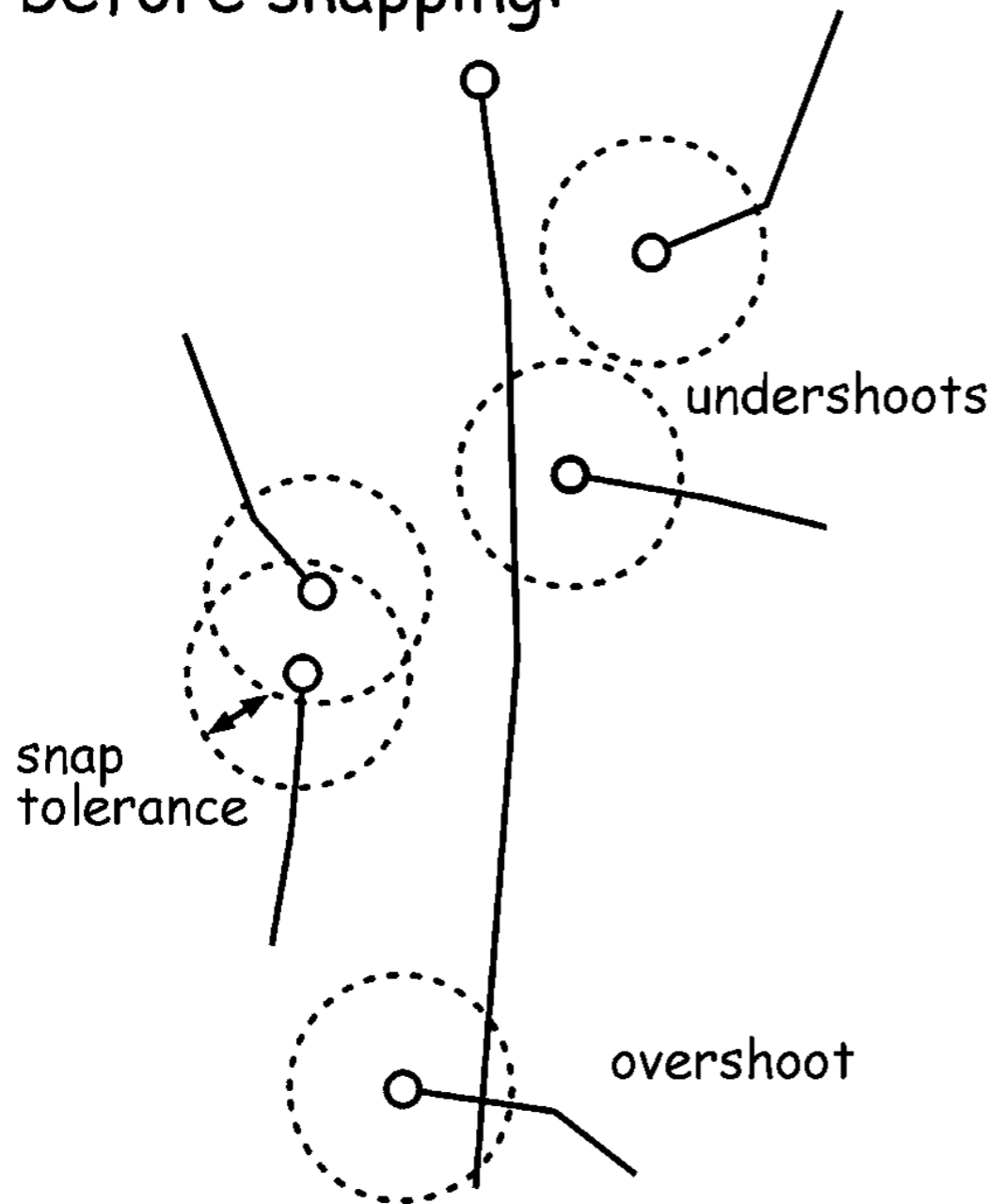
# Editing—Removing Errors

- Some errors could be automatically detected - topography
  - Missing intersections
  - Pseudo nodes
  - Dangle lines (lines shorter than a specified dangle distance)
- Interactive editing
  - Line and point locations are adjusted on computer screen
- Snapping function helps reduce some errors
  - Points which fall within a specified distance (snap distance) of each other are snapped together
  - During digitizing or in editing

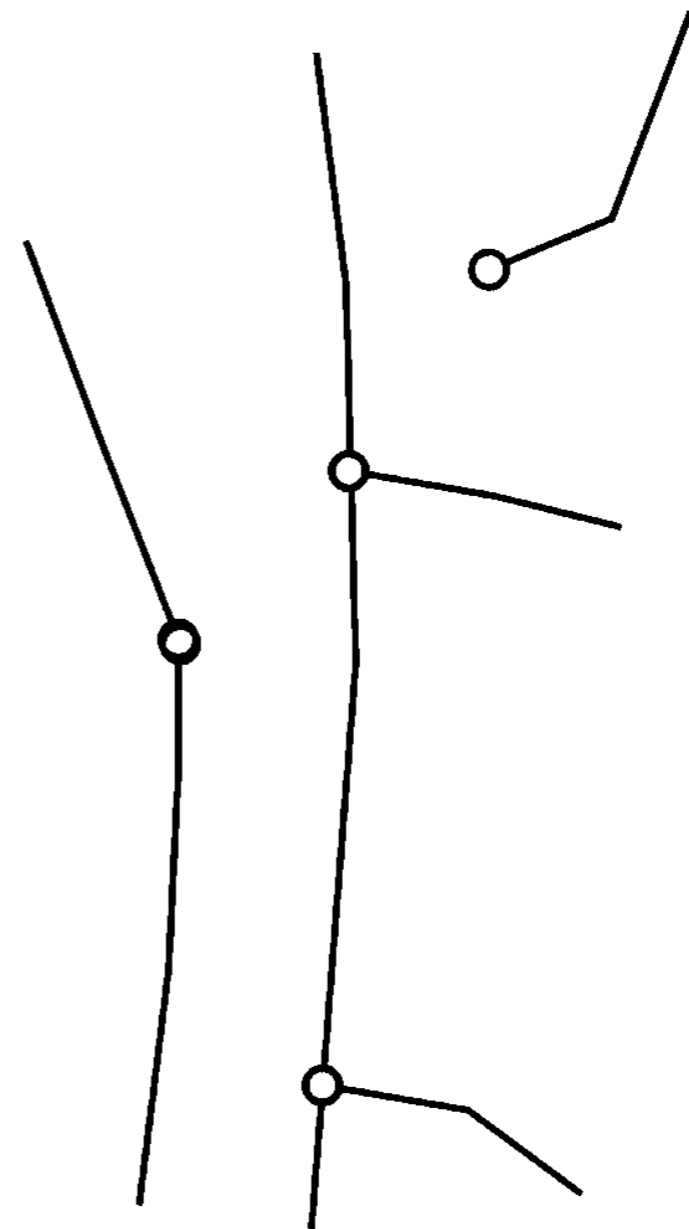


# Snapping


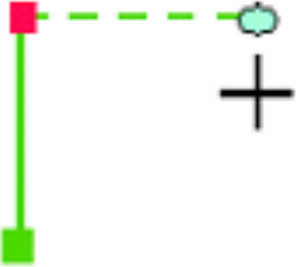

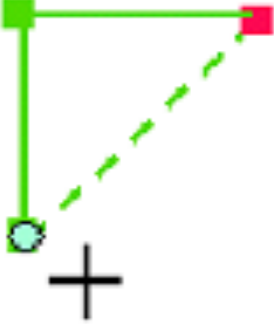

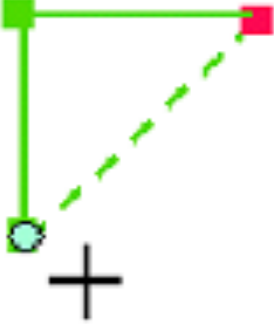
before snapping:



after snapping:

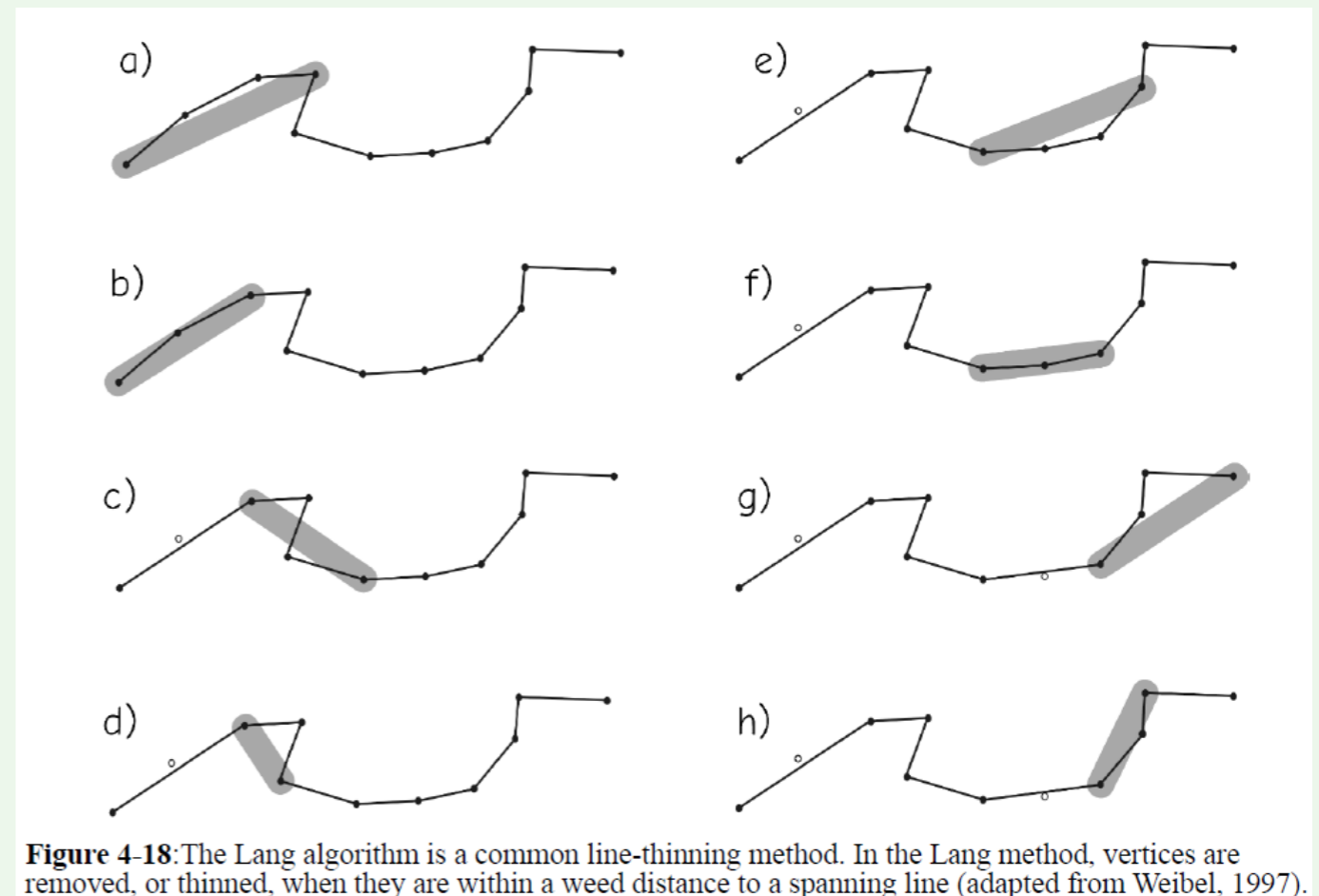
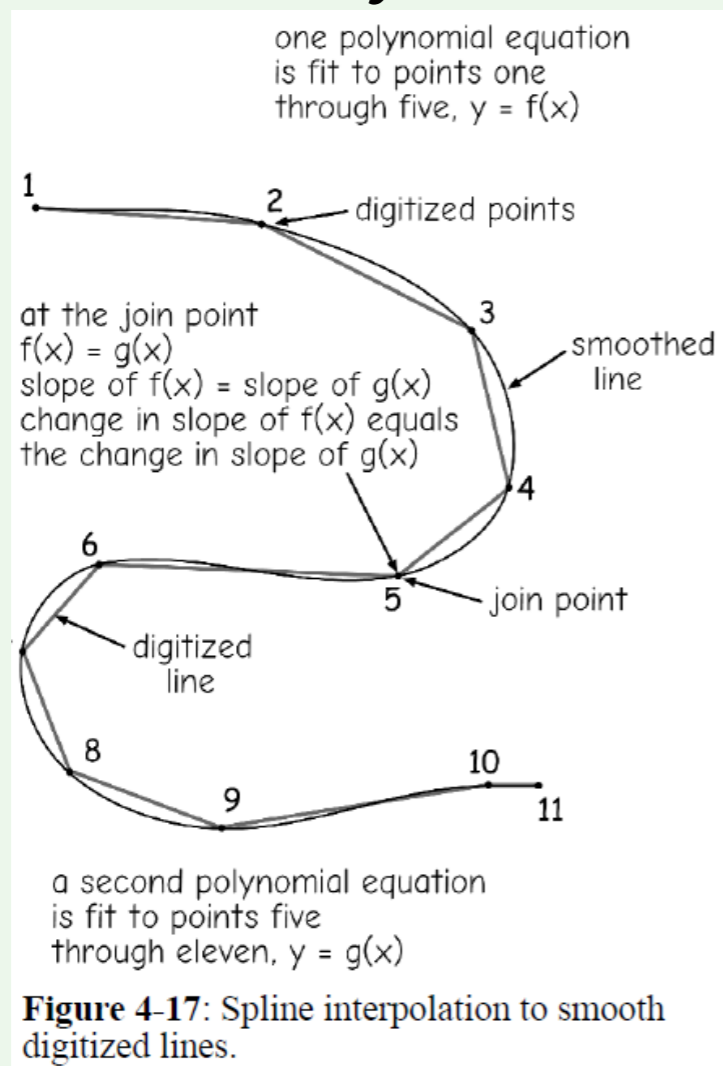


# Layer and Sketch Snapping Properties

Layer snapping properties		Sketch snapping properties	
Vertex	Snaps to each vertex of the features in that layer. 	Perpendicular to sketch	Lets you create a segment that will be perpendicular to the previous. 
Edge	Snaps to the entire outline (both segments and vertices) of each feature in that layer. 	Edit sketch vertices	Snaps to the vertices of the sketch. 
Endpoint	Snaps to the first vertex and the last vertex in a line feature. 	Edit sketch edges	Snaps to the entire outline (both segments and vertices) of the sketch. 

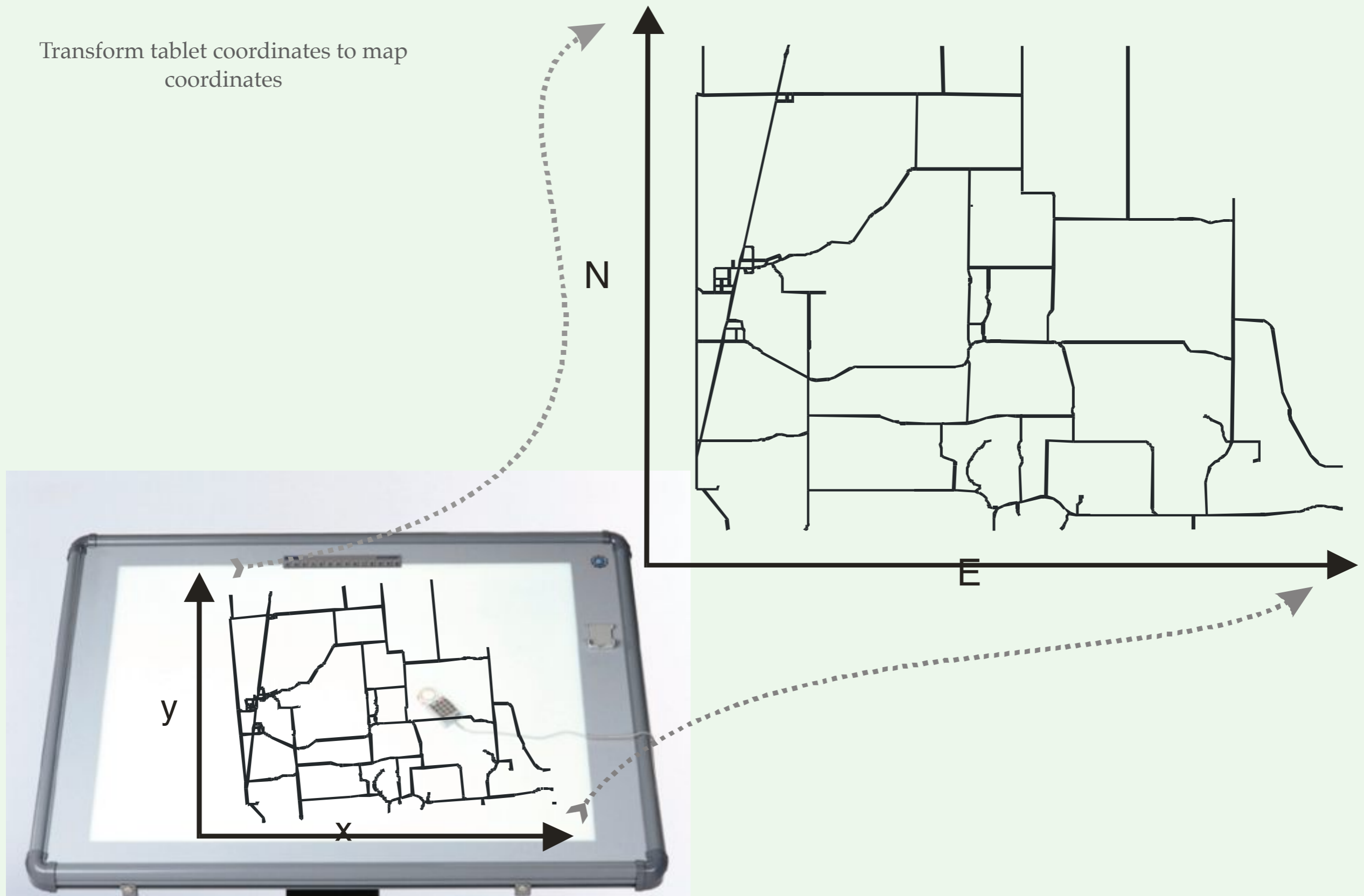
# Line Density and Thin

- Density
  - Too few vertices
  - A spline is a set of polynomial functions that join smoothly
- Thin or generalize
  - Too many vertices

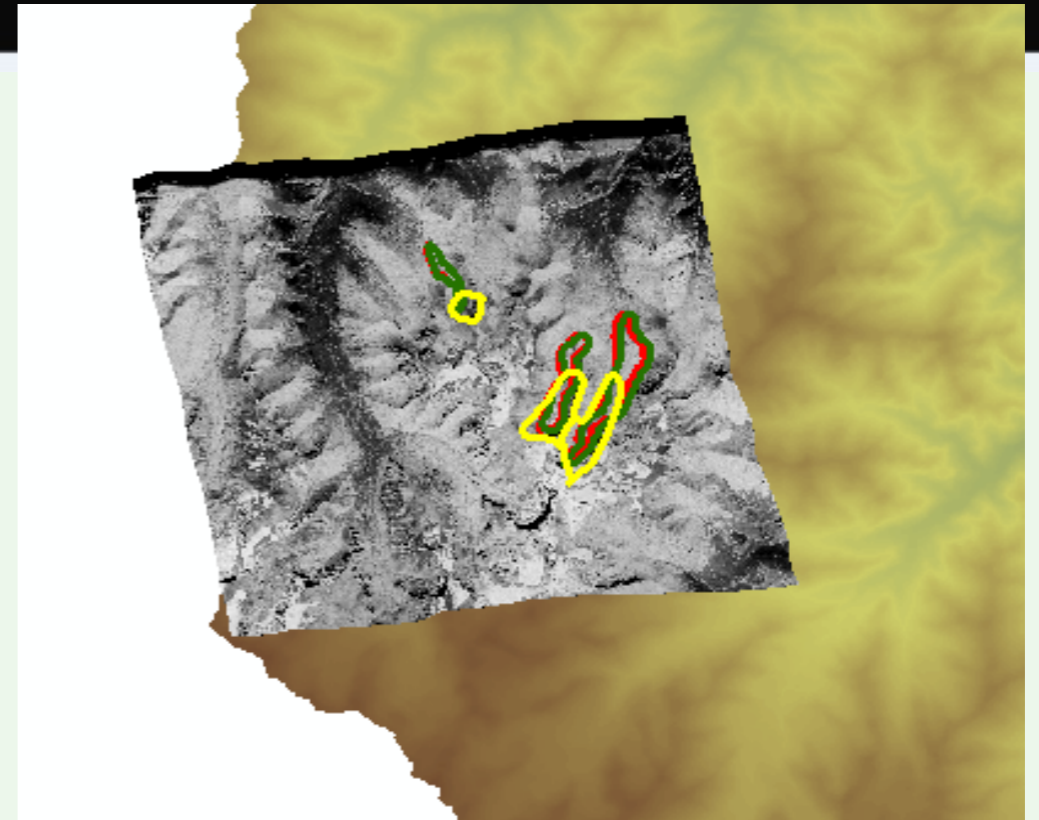


# Coordinate Transformation

Transform tablet coordinates to map coordinates



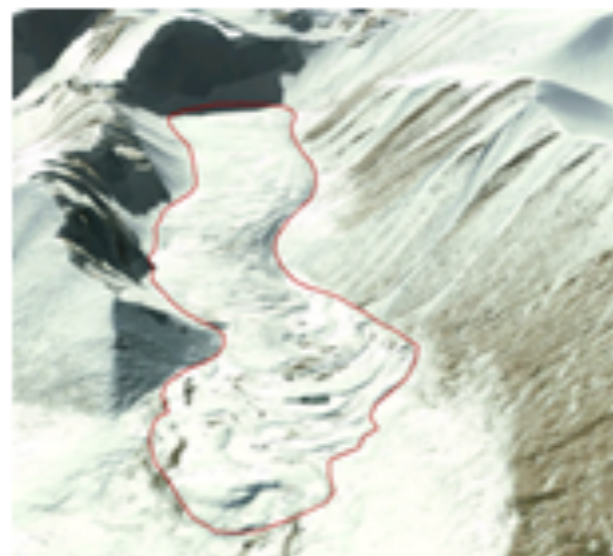
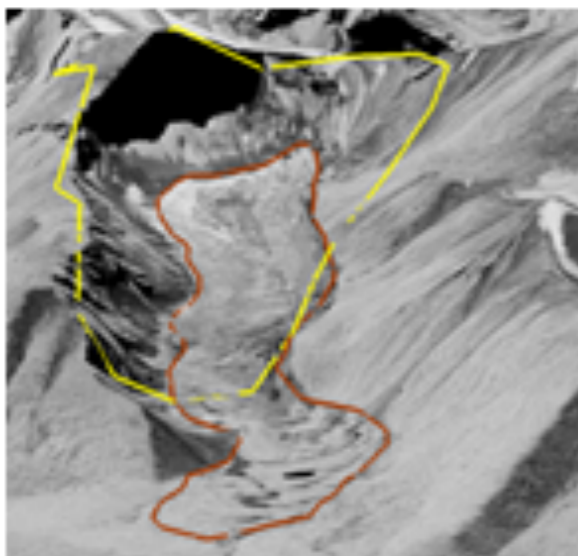
# Coordinate Transformation



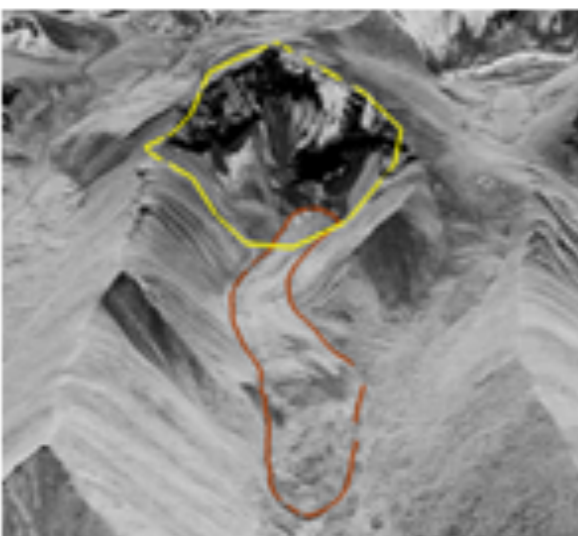
Corona Image

Google Earth™ Image

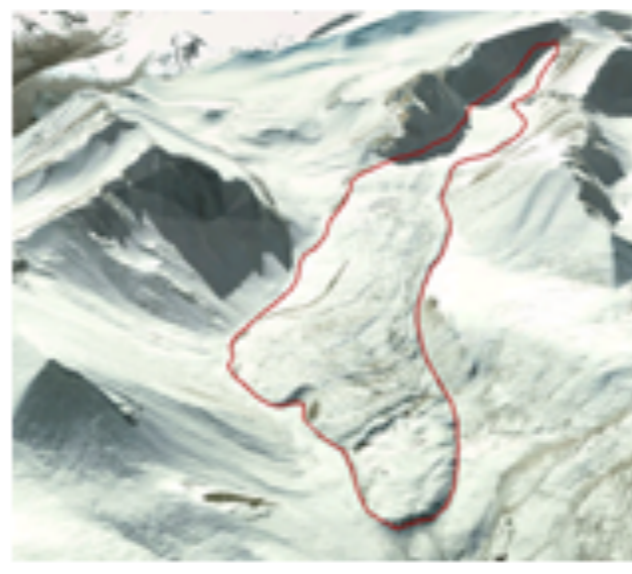
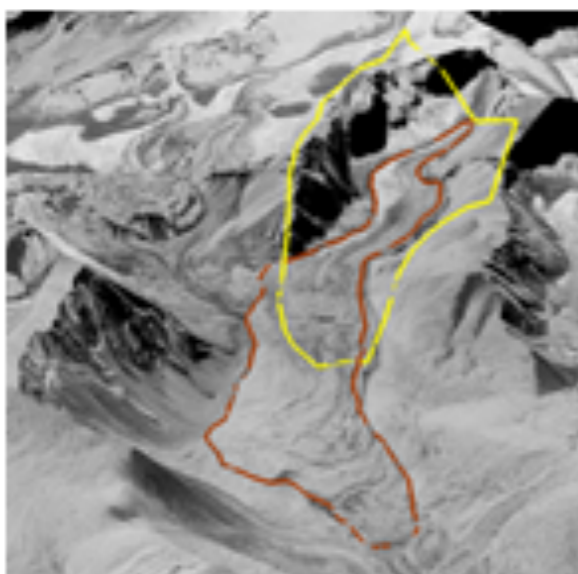
A



B



C



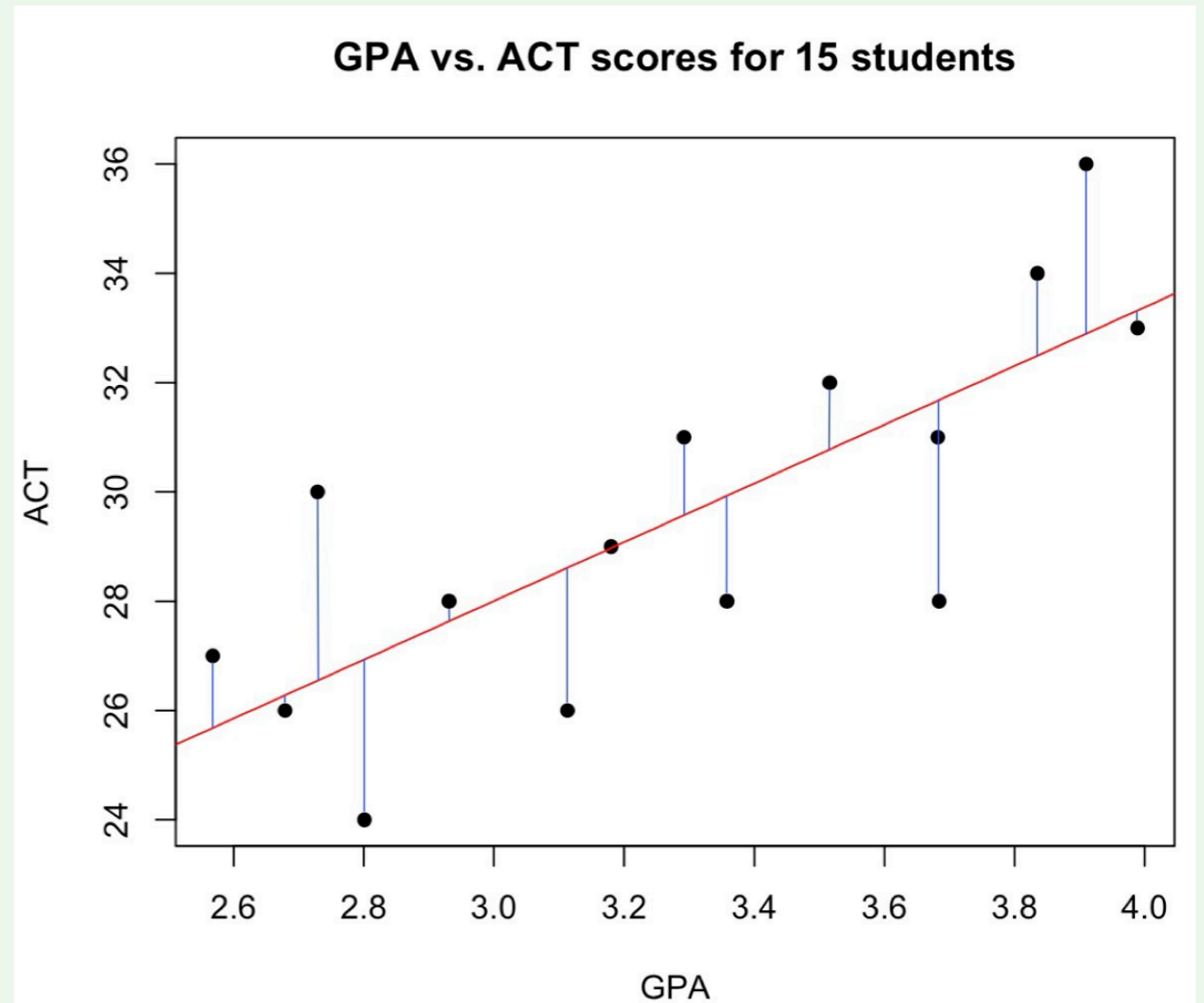
# Coordinate Transformation

# Coordinate Transformation

- Convert tablet or image coordinates to map coordinate systems
- When do you need it?
  - Digitizing maps on a tablet (inches)
  - Digitizing scanned images on screen (pixels)
- Transformation is typically done before digitizing starts
  - Transform the source (usually images) then digitize
- Also called image registration, rectification, or georeferencing when transform images

# Coordinate Transformation

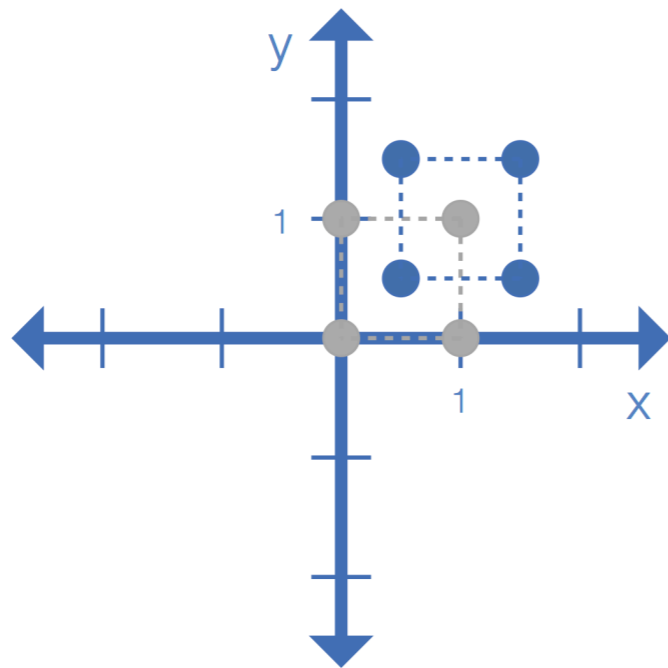
- The relationship between the coordinate systems is established using data fitting techniques
  - Similar to the least square method for linear regression on two variables
- Model parameters are obtained through a mathematical model and a set of points (control points) with known coordinates in both systems
- Should not be used to transform map projections or datums





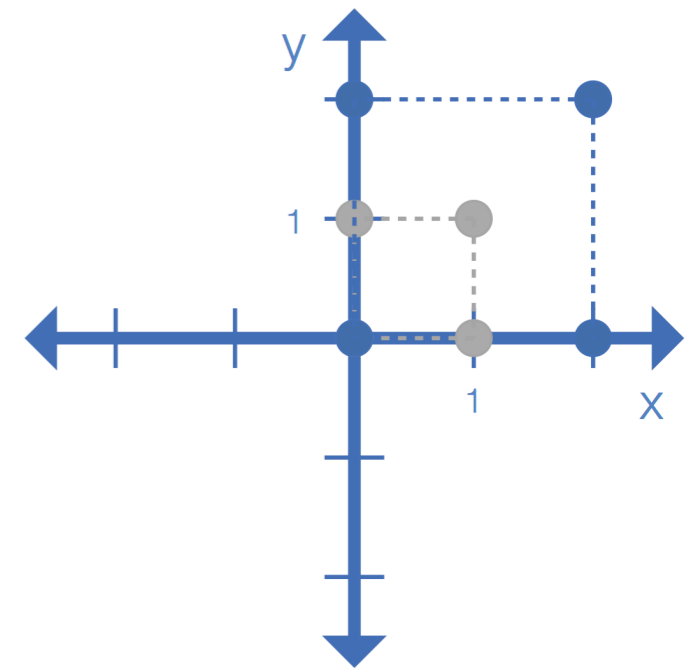
## Translate

$$\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$



## Scale

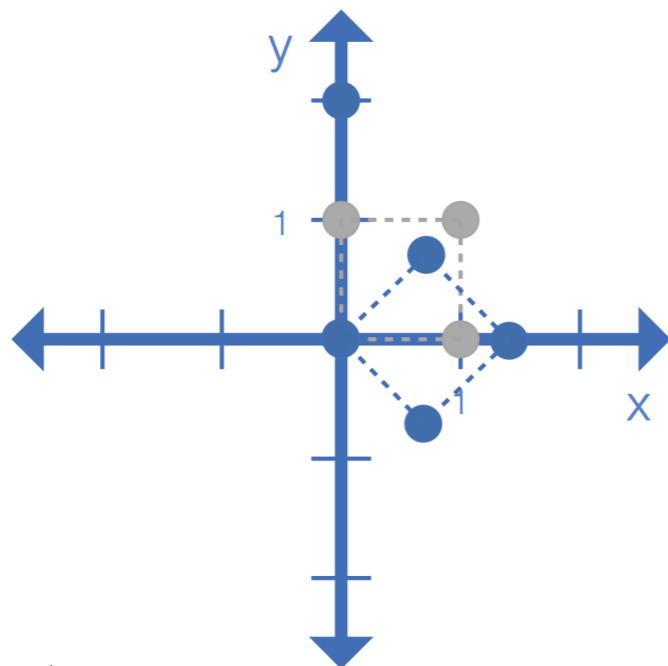
$$\begin{bmatrix} 2 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



## Rotate

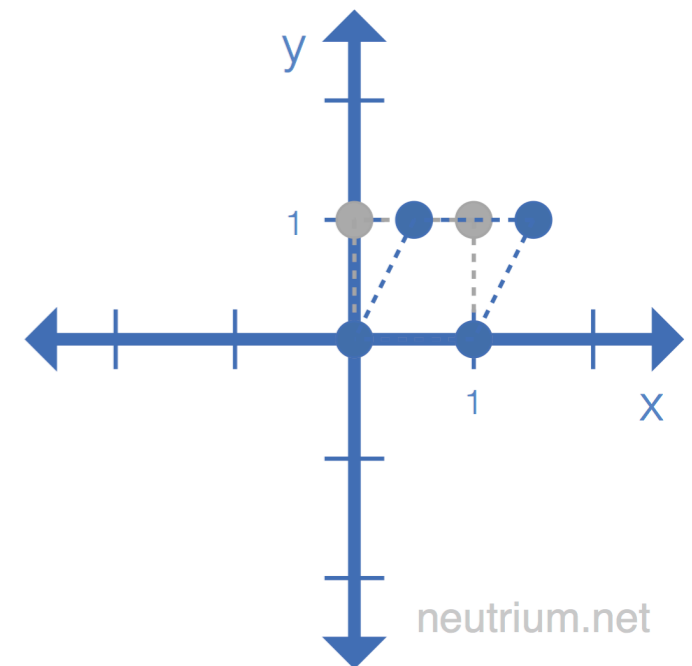
$$\begin{bmatrix} c & s & 0 \\ -s & c & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$c = s = \sin(45^\circ)$$



## Shear

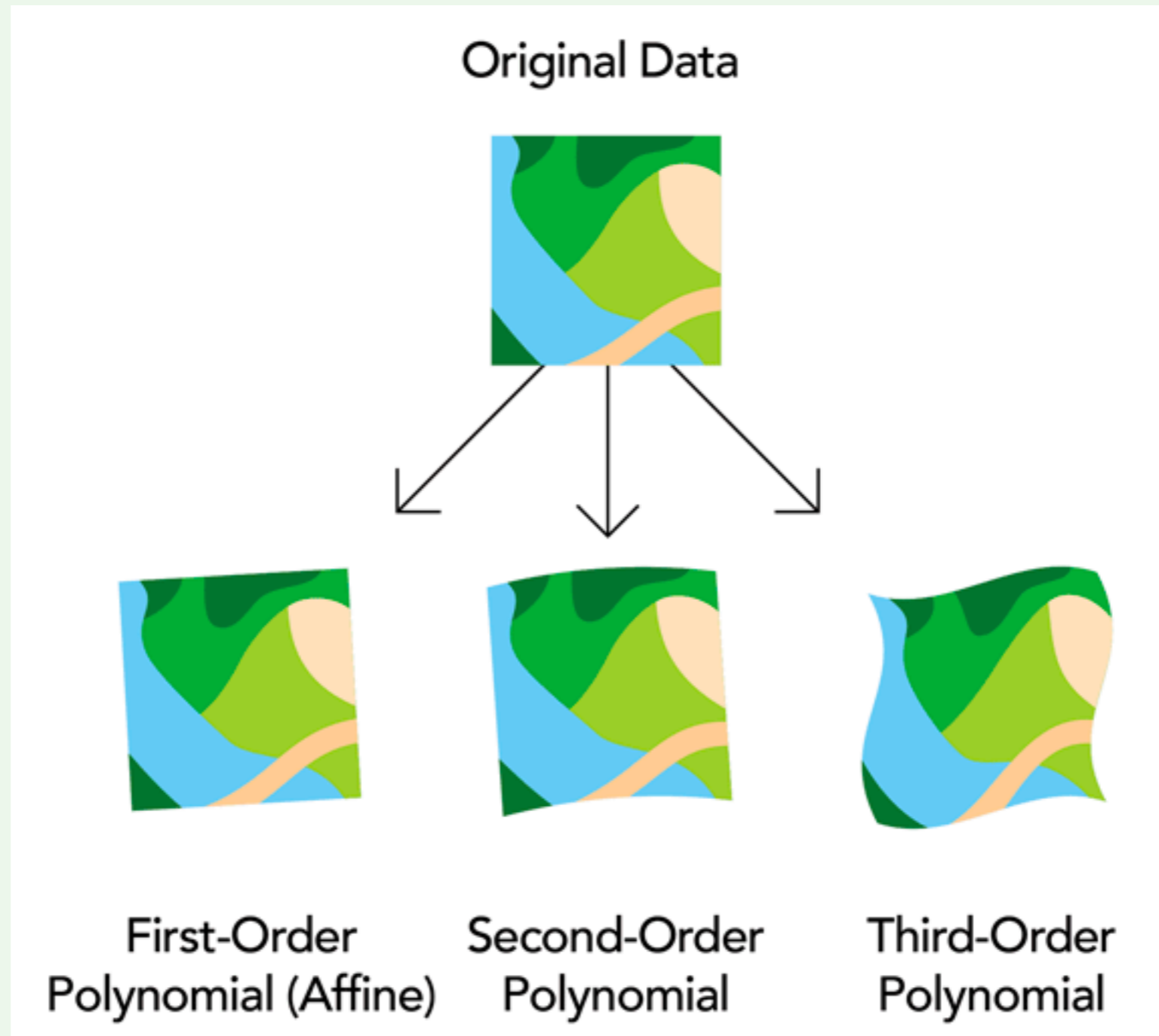
$$\begin{bmatrix} 1 & 0.5 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$



neutrium.net

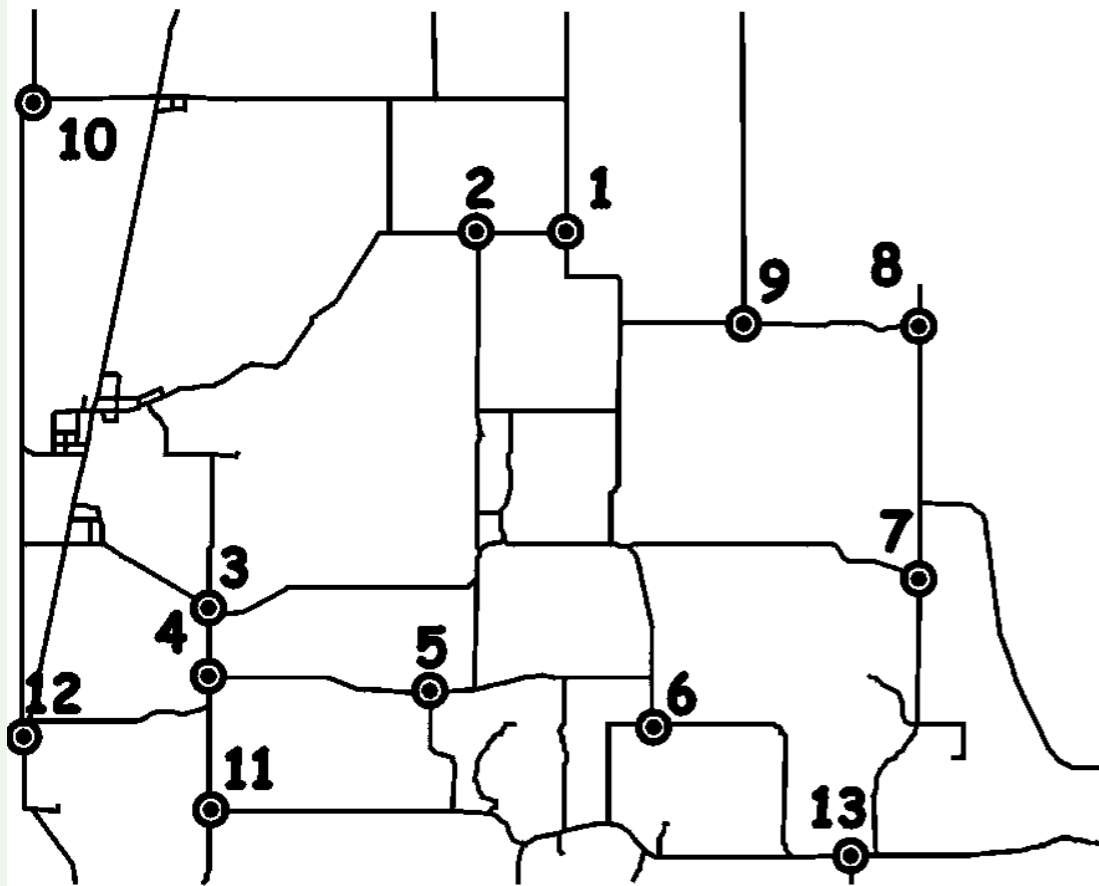
- Affine method is commonly used to transform digitized maps (paper maps or images) to a map coordinate system.
- Coefficients are obtained by control points through the least-square process.
- Rotation, shift (translation) in x and y, skew, scale in x and y
- A minimum number of 3 control points are needed to solve for the 6 unknown parameters
  - $E = a_0 + a_1x + a_2y$
  - $N = b_0 + b_1x + b_2y$

# Coordinate transformations



# Control Points

## Control Points



## Digitizer Coordinates

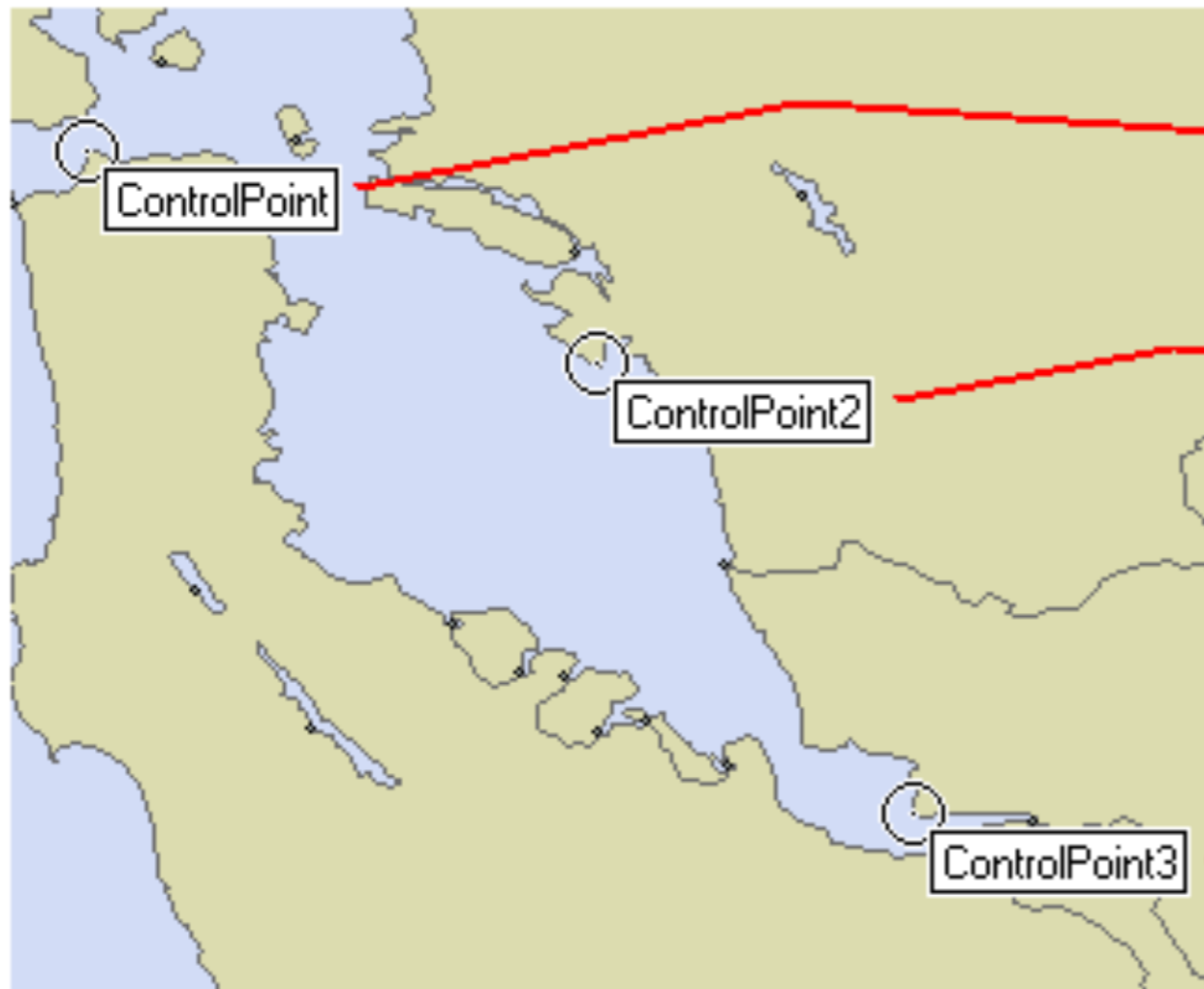
ID	x	y
1.0	103.0	-100.1
2.0	0.8	-69.1
3.0	-20.0	-69.0
4.0	-60.0	-47.0
5.0	-102.0	-47.2
6.0	-101.7	10.8
7.0	-86.0	75.8
8.0	-40.0	45.7
9.0	11.0	36.8
10.0	63.0	34.0
11.0	63.0	17.7
12.0	63.0	64.3
13.0	106.0	47.7

## Projection Coordinates (UTM)

E	N
500,083.4	5,003,683.5
504,092.3	5,002,499.5
504,907.5	5,002,499.5
506,493.3	5,001,673.5
508,101.3	5,001,651.0
508,090.1	4,999,384.0
507,475.9	4,996,849.0
505,689.2	4,998,022.0
503,679.2	4,998,368.0
501,657.9	4,998,479.5
501,669.1	4,999,116.0
501,680.3	4,997,296.0
500,005.3	4,997,943.5

# Control Points

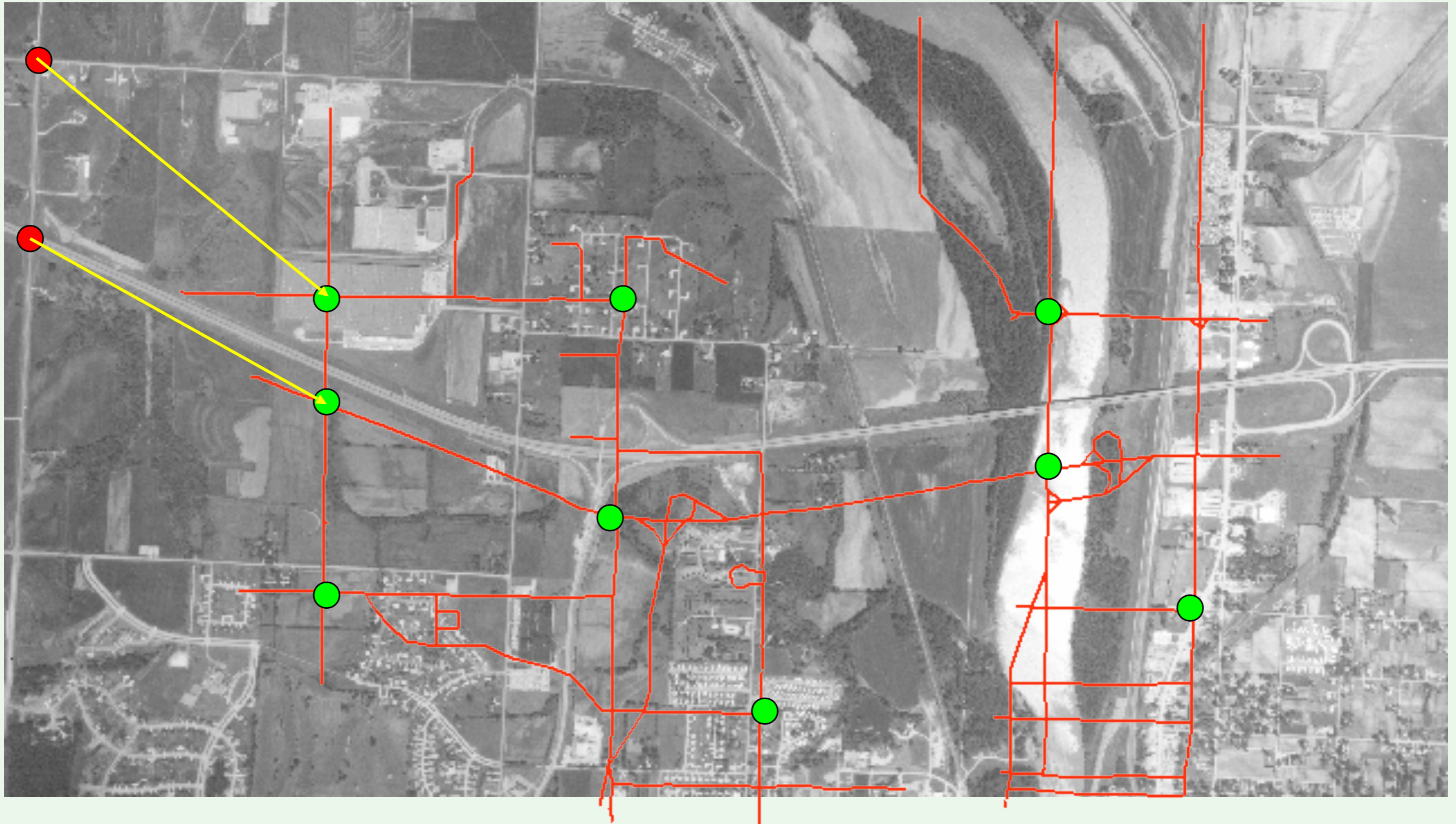
Reference



Target



# Collect Control Points from Existing Digital Data



# Transformation Errors

- There is always some lack-of-fit in the process
- Reasons
  - Pointing error
  - Blunders
  - Math model
- How to evaluate (quantify) the error?



# Root Mean Square Error (RMSE)

- Each control point has an actual and estimated x and y in map coordinates system
- Error (residual) for a control point
  - $X_a$ —actual;  $X_e$ --estimated

$$Error = \sqrt{(Xa - Xe)^2 + (Ya - Ye)^2} = e_i$$

- RMSE--average error of the transformation

$$\sqrt{\frac{\sum e_i^2}{N}}$$

- Possible reasons having a high RMSE
  - inaccurate control points
  - inappropriate math model

# Georeferencing--an Iteration Process

Model Fit 1:

1	518,687.6	5,015,347.0	513,734.1	5,007,087.4	3.07
2	516,907.3	5,013,549.1	511,355.8	5,004,707.2	8.13
3	516,952.2	5,017,965.3	511,438.3	5,010,573.9	4.38

Model Fit 2:

1	518,687.6	5,015,347.0	513,734.1	5,007,087.4	2.56
2	516,907.3	5,013,549.1	511,355.8	5,004,707.2	7.22
3	516,952.2	5,017,965.3	511,438.3	5,010,573.9	3.21

Model Fit 3:

1	518,687.6	5,015,347.0	513,734.1	5,007,087.4	2.48
2	516,907.3	5,013,549.1	511,355.8	5,004,707.2	5.63
3	516,952.2	5,017,965.3	511,438.3	5,010,573.9	3.84
4	518,699.6	5,014,396.8	513,739.3	5,005,831.0	6.62
5	518,099.6	5,013,576.2	512,938.9	5,004,733.6	2.71
6	518,992.6	5,017,306.0	514,144.0	5,009,699.3	8.40
7	519,150.0	5,013,556.6	514,331.9	5,004,709.3	6.55
8	519,259.8	5,013,600.0	514,482.8	5,004,764.0	1.52
9	516,916.8	5,016,528.9	511,378.9	5,008,669.6	3.30
10	516,659.6	5,018,093.8	511,043.8	5,010,744.1	5.27
11	519,474.3	5,018,046.9	514,807.0	5,010,675.2	11.78
12	519,549.2	5,014,375.9	514,873.0	5,005,798.0	3.54
13	518,089.4	5,014,478.2	512,938.6	5,005,931.0	9.34
14	518,087.4	5,014,755.2	512,936.0	5,006,299.0	8.30
15	518,079.1	5,016,483.3	512,921.1	5,008,596.5	5.67
16	516,947.5	5,017,736.1	511,424.5	5,010,277.6	6.73
17	517,015.8	5,014,443.1	511,495.1	5,005,894.9	3.30
18	517,785.1	5,017,492.6	512,542.4	5,009,954.0	8.86
19	519,435.7	5,017,340.7	514,736.0	5,009,735.7	4.13
20	518,710.3	5,016,544.2	513,778.7	5,008,679.7	9.55
21	518,984.0	5,016,548.6	514,127.8	5,008,678.2	9.53
22	516,717.8	5,014,546.4	511,106.4	5,006,028.8	9.01

$$E = 1.33118637 * x + 0.0056629 * y - 205490.3$$

$$N = -0.003516 * x + 1.3297296 * y - 1160143$$

RMSE = 6.78

Examine points, no more blunders found.

E = 1:  
+ 0:  
- 2:

N = -  
+  
-

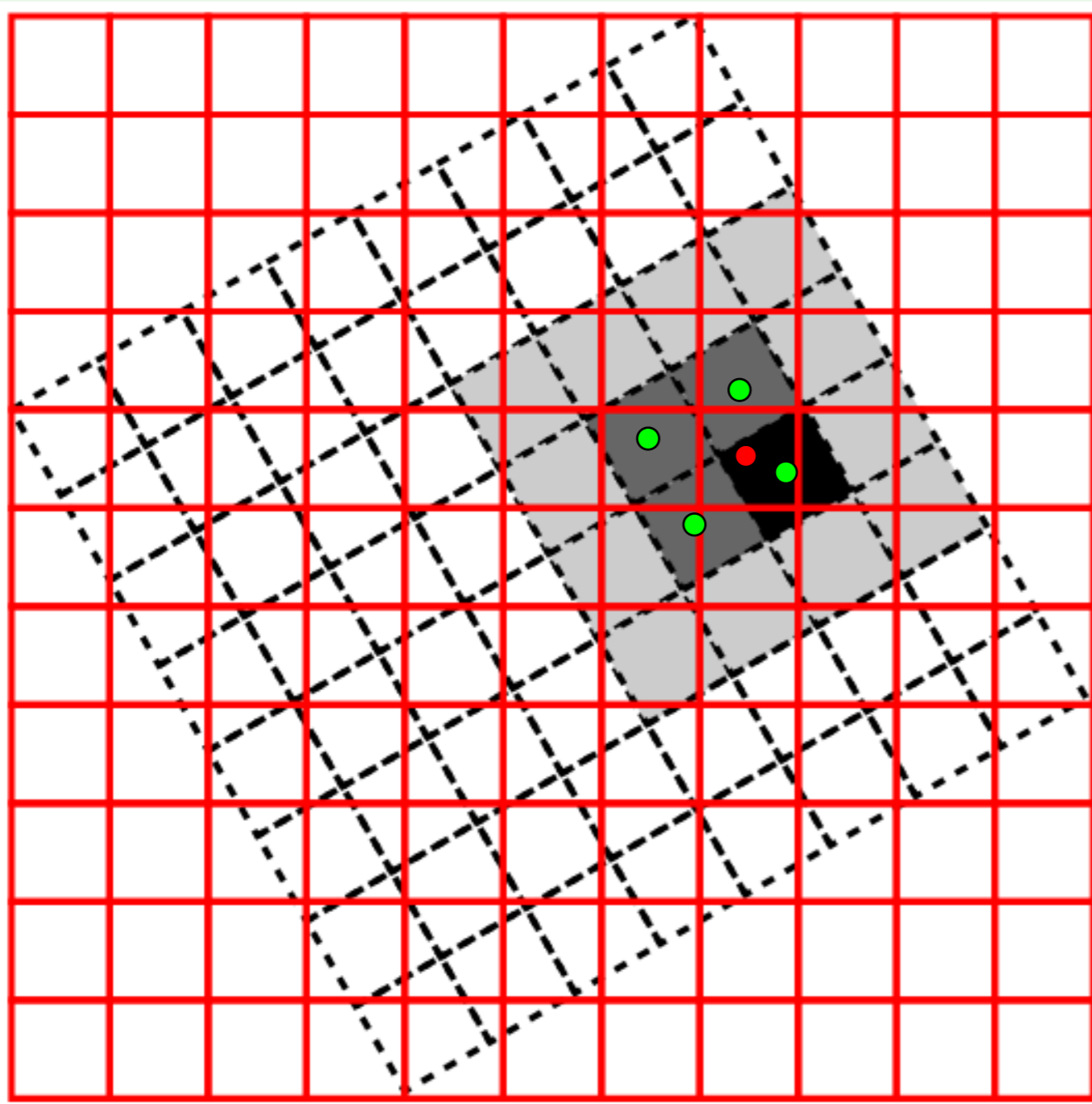
RMSI




Exam  
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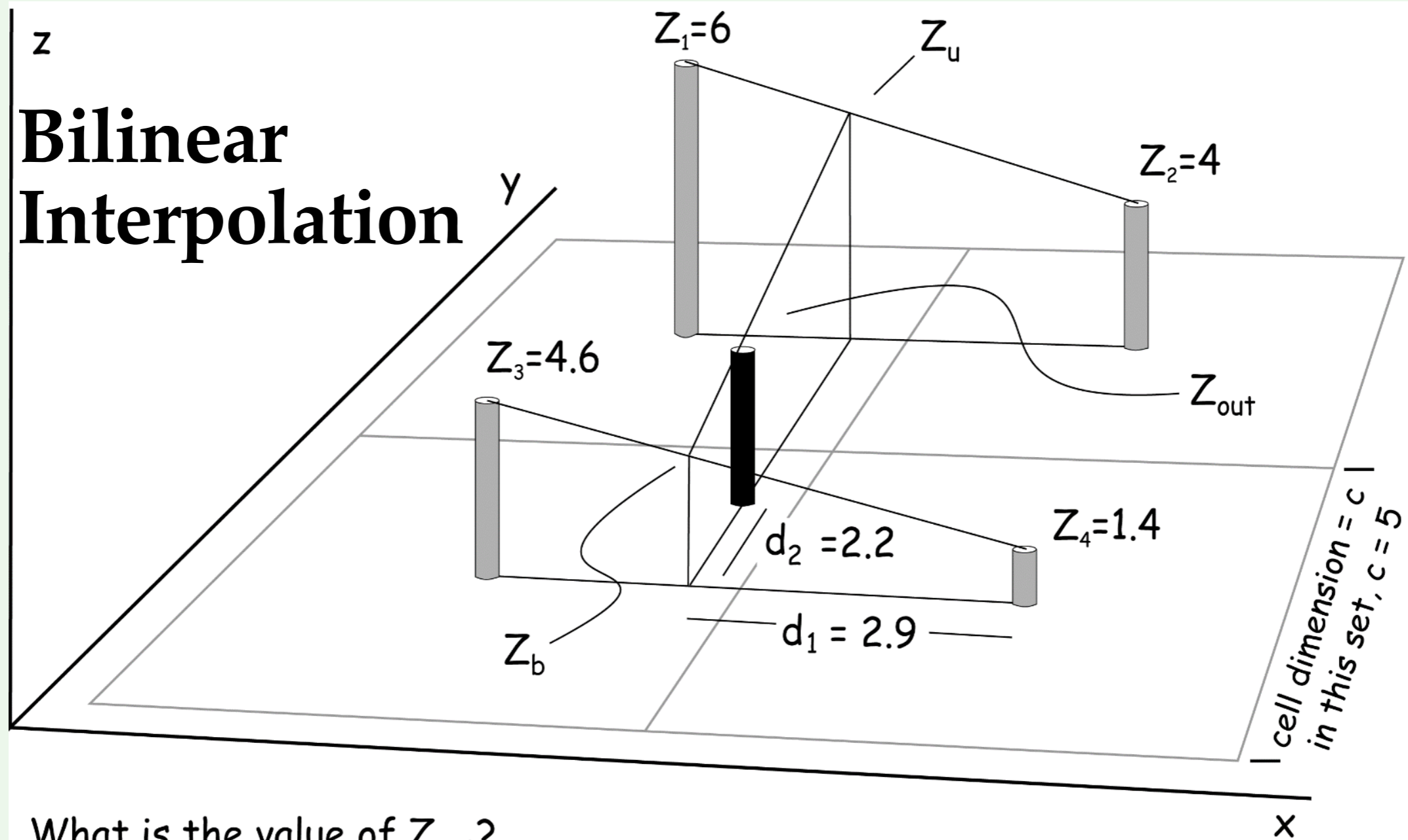
# Resampling (Creating a new image)



-  nearest neighbor assigns an output cell value from the nearest corresponding input cell
-  bilinear interpolation uses the nearest cell and next three closest cells in a weighted average
-  cubic-convolution includes the cells used for bilinear interpolation and the next 12 closest cells to compute a weighted average for each output cell

z

# Bilinear Interpolation



What is the value of  $Z_{out}$ ?

$$Z_b = Z_4 + \frac{(Z_3 - Z_4) * d_1}{c}$$

$$Z_b = 1.4 + \frac{(4.6 - 1.4) * 2.9}{5} = 3.26$$

$$Z_u = Z_2 + \frac{(Z_1 - Z_2) * d_1}{c}$$

$$Z_u = 4 + \frac{(6 - 4) * 2.9}{5} = 5.16$$

$$Z_{out} = Z_b + \frac{(Z_u - Z_b) * d_2}{c}$$

$$Z_{out} = 3.26 + \frac{(5.16 - 3.26) * 2.2}{5} = 4.1$$

# Upscaling

