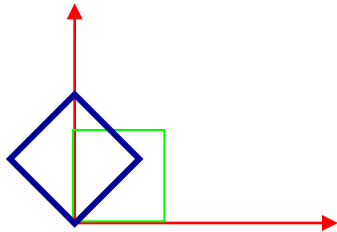
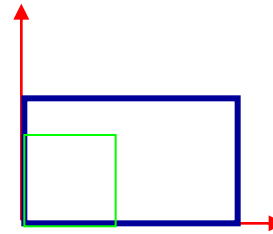


Georeferencing & Spatial Adjustment

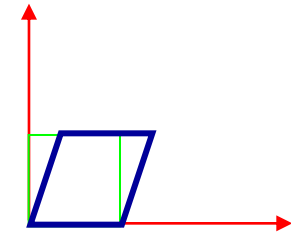
Aligning Raster and Vector Data to a GIS



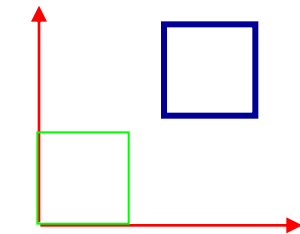
Rotation



Differential Scaling



Skew



Translation

Distortion

The Problem



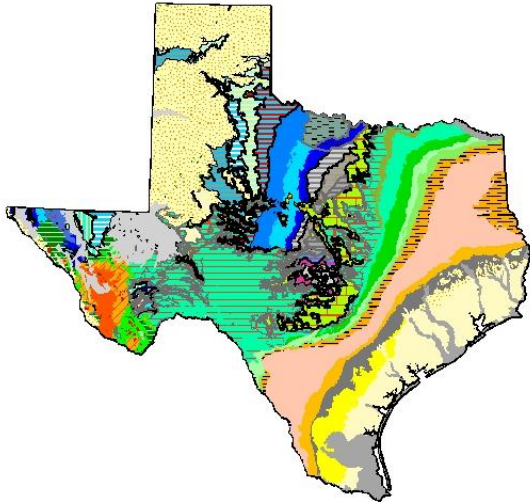
⌘ How are geographically unregistered data, either raster or vector, made to align with data that exist in geographical coordinates?

OR

⌘ How are arbitrary coordinates transformed into geographical coordinates?

For Example:

- ⌘ Align raster image to vector map of state outline



Raster- no geographic coordinates



Shapefile stored in geographic coordinates

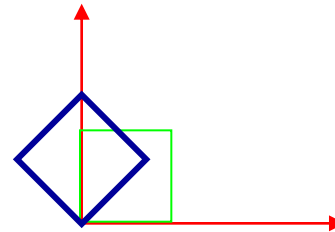
Nature of the problem:

⌘ Data source registration may differ by:

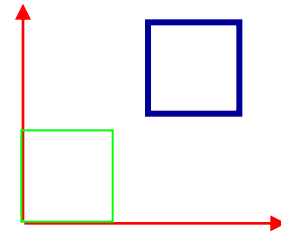
☑ Rotation

☑ Translation

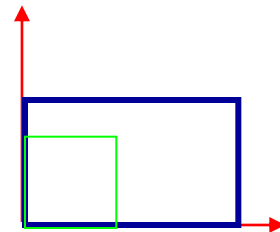
☑ Distortion



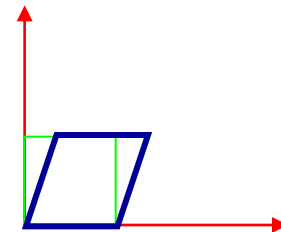
Rotation



Translation



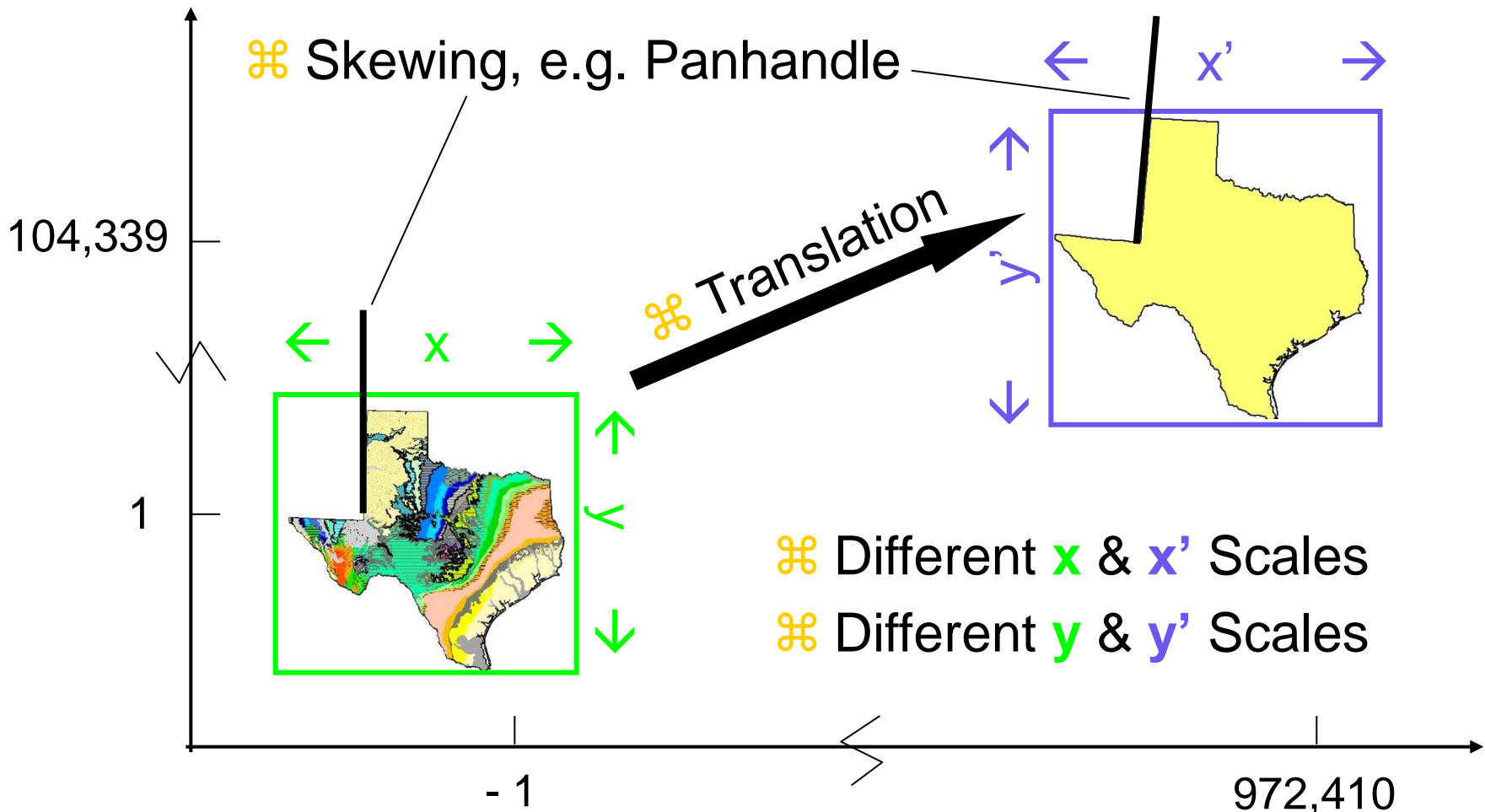
Differential Scaling



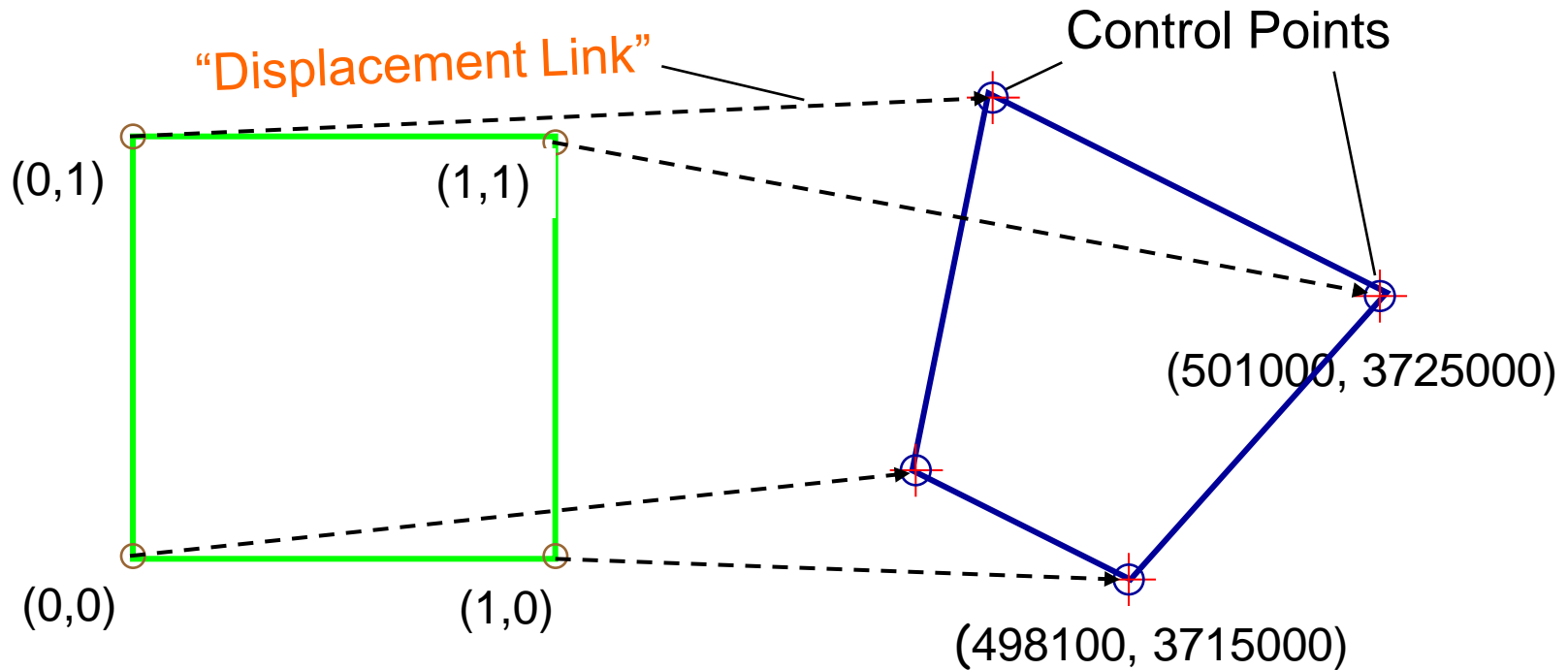
Skew

Distortion

Texas Example:



General problem is then:



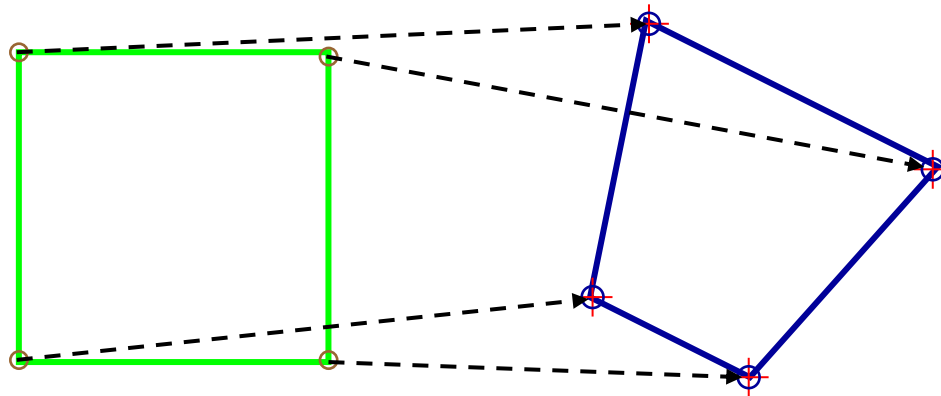
Source $(x, y; \text{unspec.})$ \longrightarrow **Destination** $(x', y'; \text{UTM})$
("Warp")

How Solved?

⌘ Geometric Transformations

1. First-order ("*Affine*") transformation

- ☒ Accomplishes translation, distortion and rotation
- ☒ Straight lines are mapped onto straight lines, e.g. square \rightarrow parallelogram



Geometric Transformations

⌘ Affine transformation:

$$X_1' = Ax_1 + By_1 + C$$

$$Y_1' = Dx_1 + Ey_1 + F$$

Where:

x_1, y_1 = coords. of pt. in source layer

X_1', Y_1' = coords. of same pt. in destination layer

A, B, C ... F = unknown constants giving best fit of all points
(minimize Root Mean Square [RMS] error)

Geometric Transformations

⌘ Affine transformation constants:

$$X_1' = Ax_1 + By_1 + C$$

$$Y_1' = Dx_1 + Ey_1 + F$$

A, E = scale factors

B, D = rotation terms

C, F = translation terms

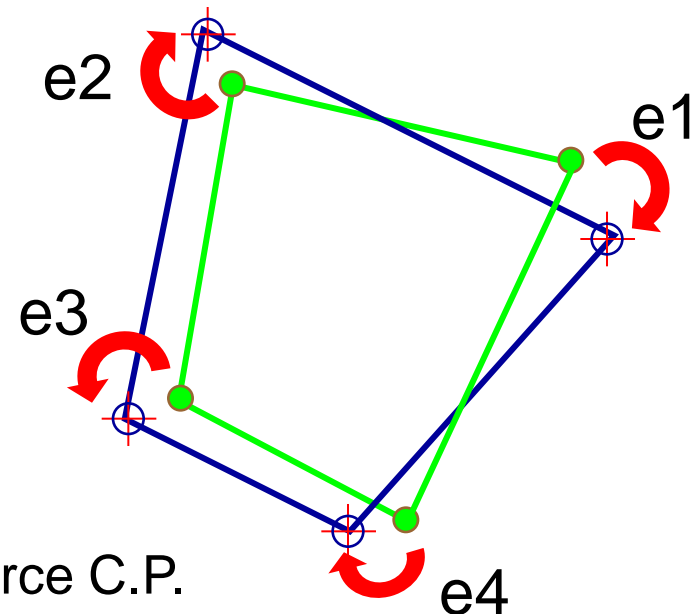
⌘ With six unknowns, need *minimum of three points* (yielding 6 equations).

Affine Transformations

⌘ "Goodness of Fit" given by RMS error:

RMS error =

$$\left[\frac{e1^2 + e2^2 + e3^2 + e4^2}{4} \right]^{1/2}$$



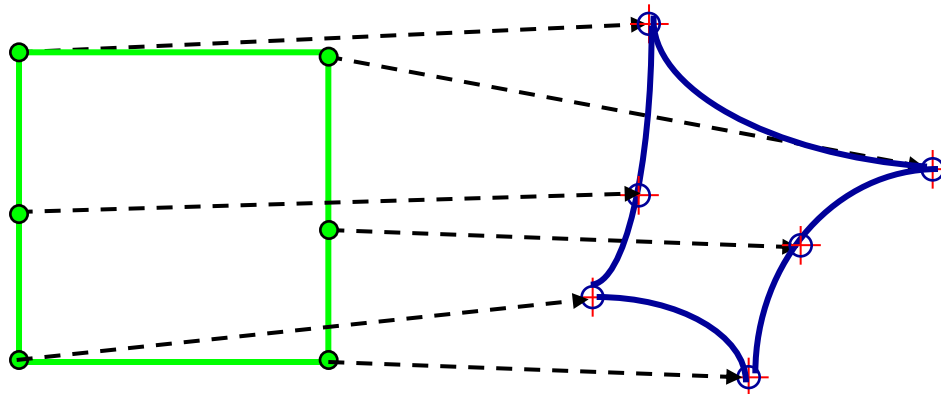
● Source C.P.
⊕ Destination C.P.

e2  Residual Error

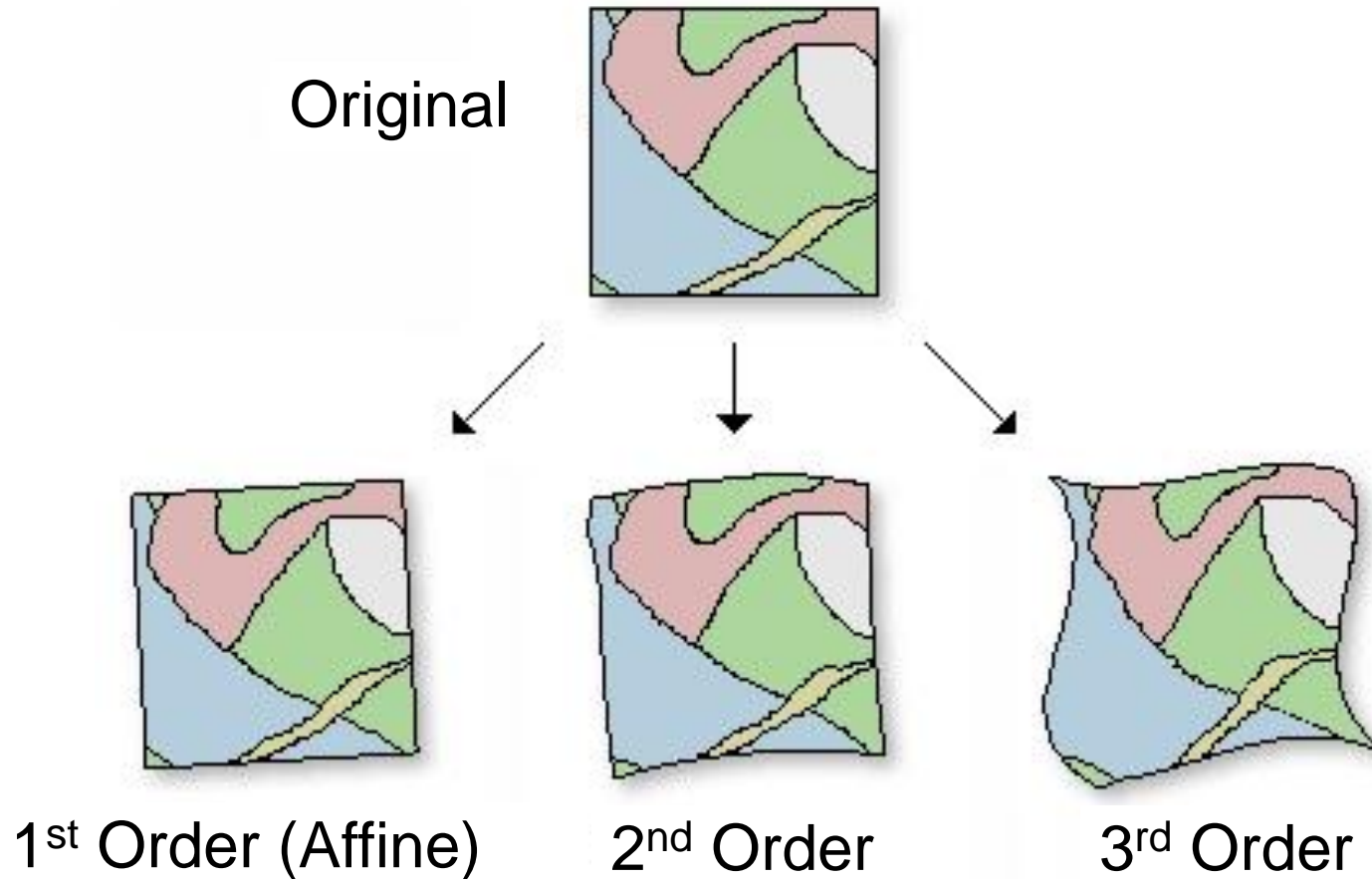
Geometric Transformations

2. Second- or Third-order Transformations

- ☒ Fit with more constants (12 or 20)
- ☒ *Allow straight lines to map to curves*
- ☒ More displacement links (6 or 10 minimum) required



Transformation Characteristics



Other Transformation Types

⌘ Spline - For local fits only

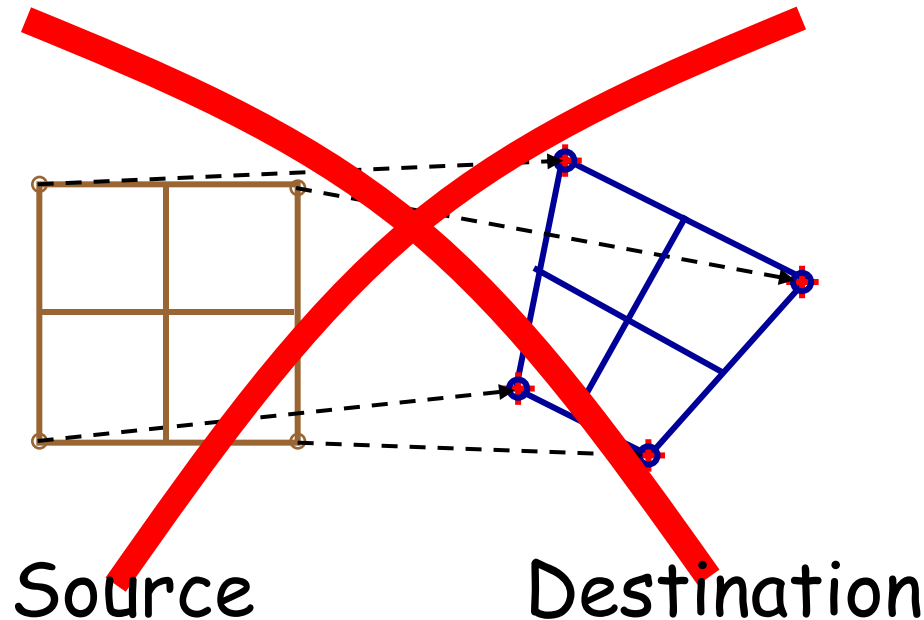
☑ Source control pts. match reference pts. exactly at expense of global fit. 3 pts. required

⌘ Adjust - For global and local fitting

☑ Relies on polynomial fitting adjusted to a TIN. 3 pts. required.

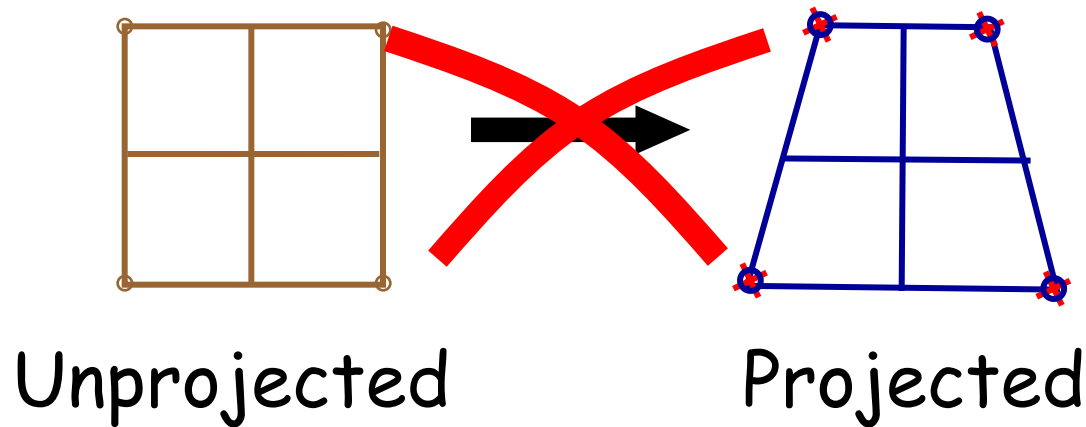
Geometric Transformation of Raster Data

- ⌘ The Problem: Square cells must remain square after transformation. How?



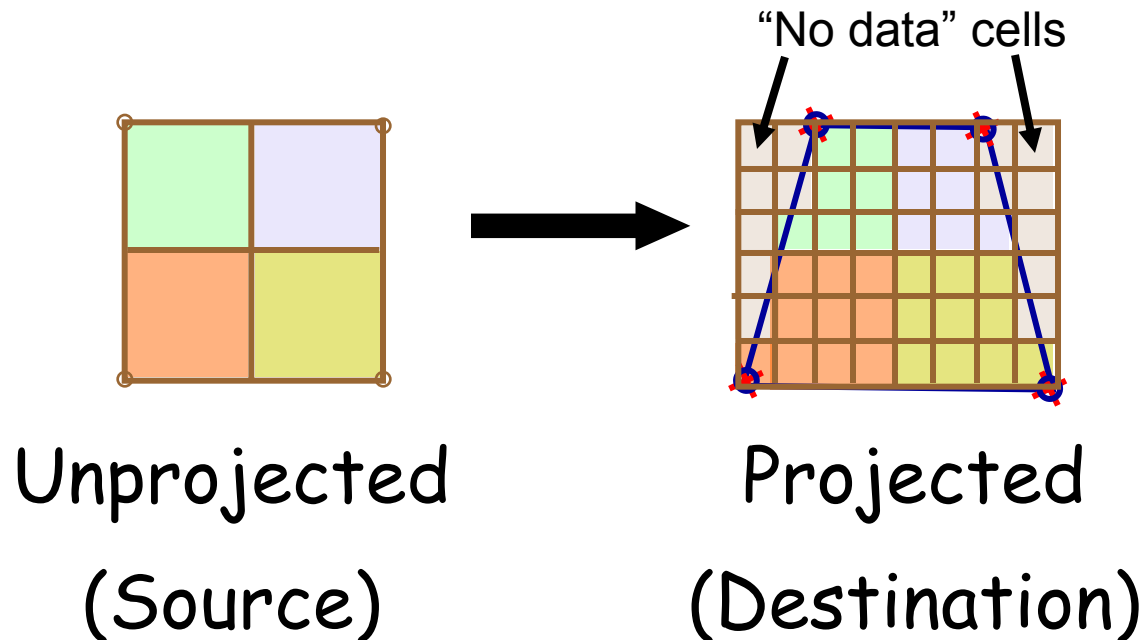
Geometric Transformation of Raster Data

⌘ Related Problem: Square cells must remain square after projection. How?



Geometric Transformation of Raster Data

- ⌘ **Solution:** "Resampling" - Create and fill a *new matrix* of empty destination cells with values from source raster. Tag remaining cells as "no data".



Resampling Techniques

1. **Nearest Neighbor** - use value of source cell that is nearest transformed destination cell
 - ⌘ Fastest technique; *use for categorical (nominal or ordinal) or thematic data*
2. **Bilinear interpolation** - combine 4 nearest source cells to compute value for destination cell
3. **Cubic Convolution** - same, but combine 16 nearest cells
 - ☒ Methods 2 and 3 are weighted average techniques - *use for continuous data (slope, elevation, rainfall, temp. rainfall, etc.)*

Implications of Resampling

- ⌘ Cell size and number of rows and columns will change on projection and/or georeferencing
- ⌘ Minimize problems by georeferencing to a desired projection, not to unprojected vector data
- ⌘ Raster datasets must be in same projection and coordinate system for analysis.

Where are new coordinates stored?

- ⌘ "Update Georeferencing" writes transformation to a "world" (.jpw, etc.) file of same name as raster



- ⌘ "Rectify..." creates a new, georeferenced, raster dataset in GRID, JPEG, TIF or IMAGINE format

Georeferencing in ArcMap

⌘ Georeferencing Toolbar

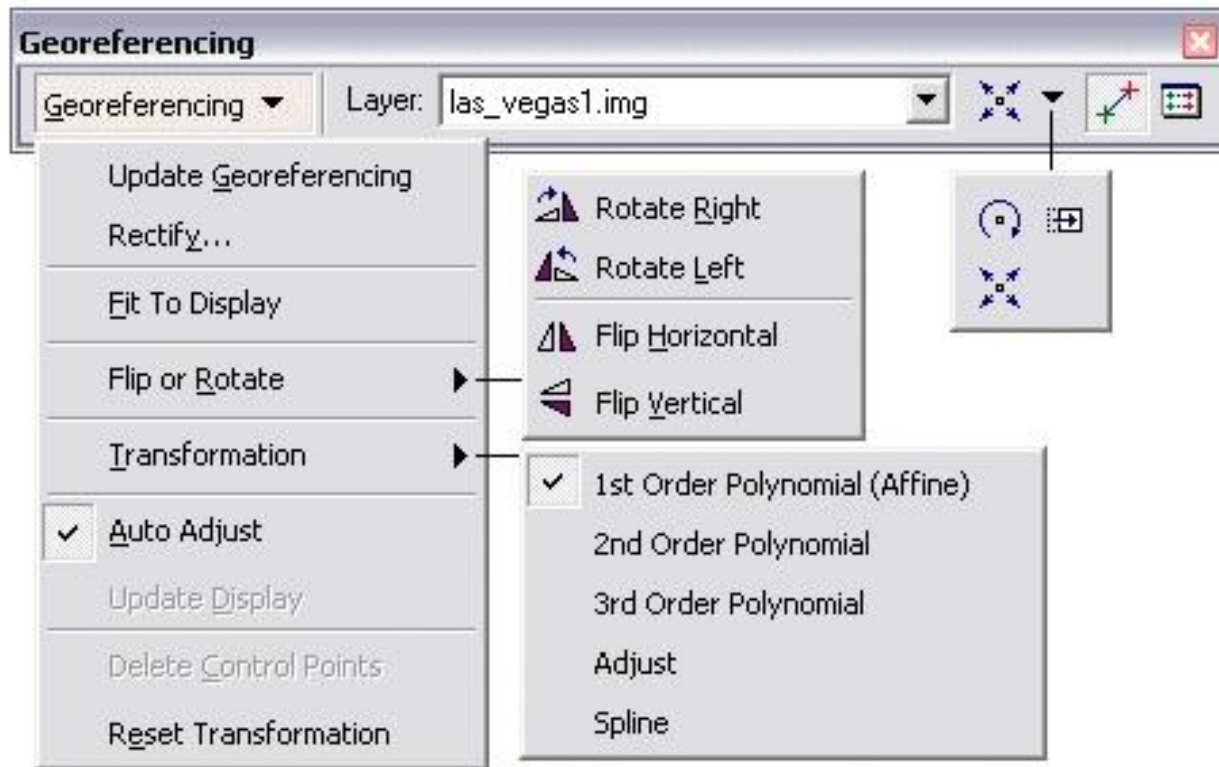


Image from ArcGIS georeferencing help file

Procedure

⌘ See "Using Arc Map" or Help File on Georeferencing

☑ Remember:

☑ Align to data that has GCS and PCS of interest.

☑ Finish by "Update Georeferencing" or "Rectify..." to ensure coordinates are saved with file

Georeferencing Vector Files

- ⌘ Take C.A.D. (e.g. .DXF, .AI, .CDR) drawings into a GIS
- ⌘ Conceptually simpler, in practice more difficult? No.
 - ⏏ Two equally useful techniques:
 - ⊗ By writing or making reference to a 2 line text ("world" .wld) file
 - ⊗ By entering transformation coordinates in the drawing Layer Properties

Vector World File format

⌘ World text file format is as follows:

Line 1:

<x,y location of pt. 1 in CAD drawing> <space>
<x,y location of pt. 1 in geographic space>

Line 2:

<x,y location of pt. 2 in CAD drawing> <space>
<x,y location of pt. 2 in geographic space>

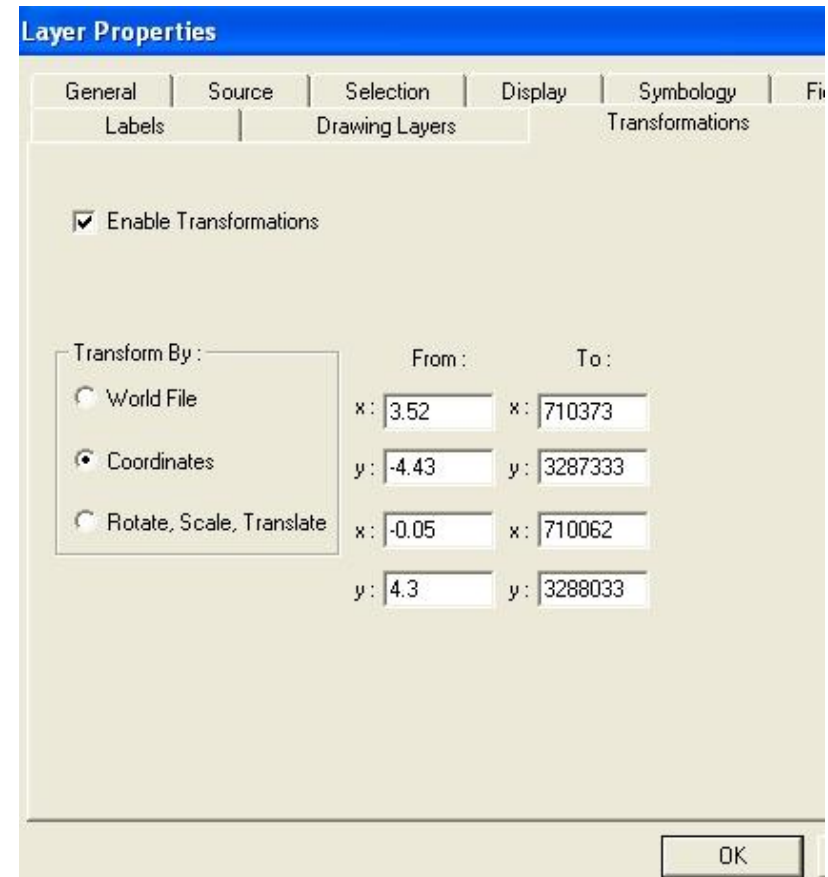
E.g. 3.52,4.43 710373,3287333

-0.05,4.3 710062,3288033

⌘ See Help on World Files and CAD transformations

Transform by Coordinates

- ⌘ Enter same information interactively
- ⌘ Use georeferencing tools to create 2 link points, then "Update Georeferencing"
 - 📁 See Help file on "Transforming CAD datasets"



"Spatial Adjustment" of Vector Data

⌘ Via special editing toolbar permits:

☑ Transformations ("Warping")

☑ Affine

☑ Similarity

☑ Projective

☑ "Rubber Sheeting"

☑ "Edge Matching"

☑ Attribute transfer

"Georeferencing" vs. "Spatial Adjustment"

⌘ Georeferencing - raster and vector data

- ☑ Best fit of all source control points to all destination control points - transformation ("*Warping*") of data for overall best fit
- ☑ Alignment of data to map coordinates
- ☑ R.M.S. error given

⌘ "Spatial Adjustment" - **vector data**

- ☑ More versatile; can "Warp", also "Rubbersheet" and "Edgematch"
- ☑ Adjustment by latter two is piece-wise fitting; point by point matching but no overall warping.