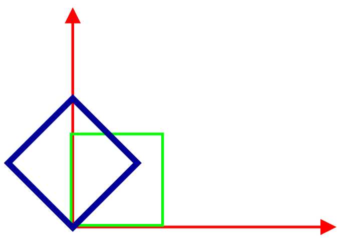
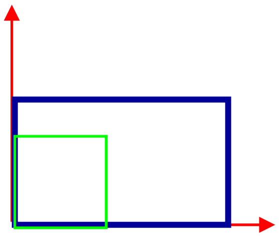
Georeferencing & Spatial Adjustment

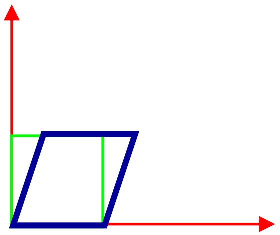
Aligning Raster and Vector Data to a GIS



Rotation

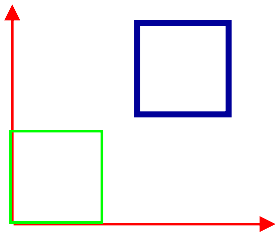


Differential Scaling



Skew

Distortion



Translation

The Problem

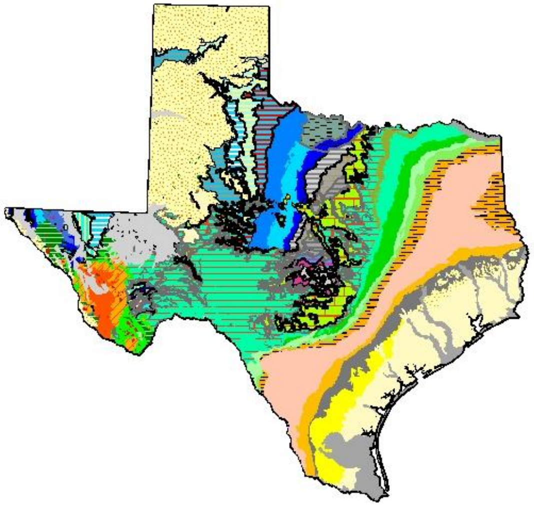
- How are geographically unregistered data, either raster or vector, made to align with data that exist in geographical coordinates?

OR

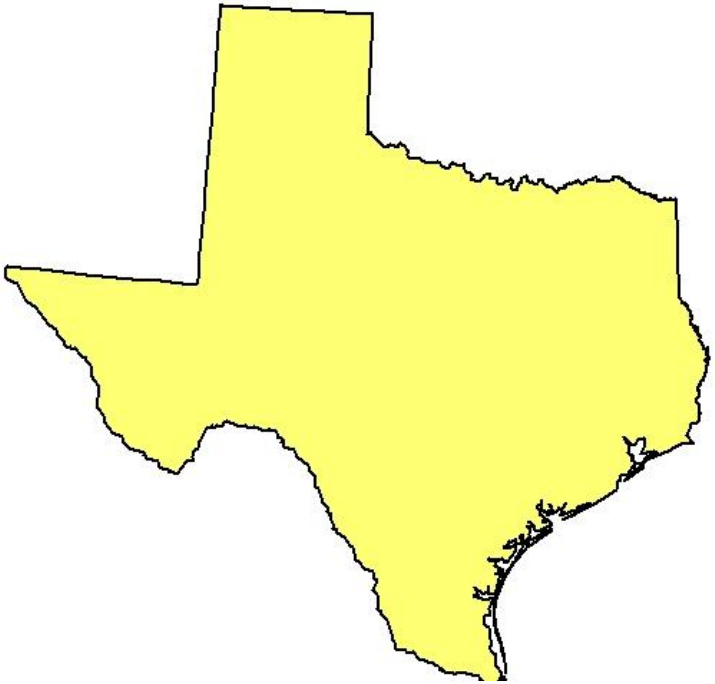
- How are arbitrary coordinates transformed into geographical coordinates?

For Example:

- Align raster image to vector map of state outline



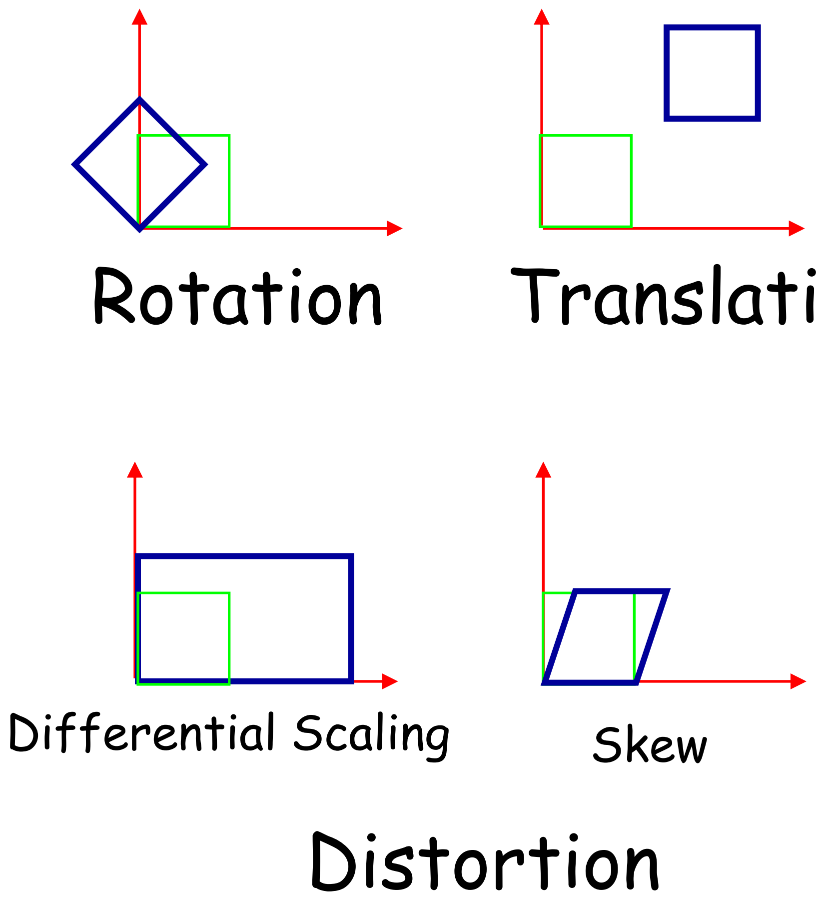
Raster- no geographic coordinates



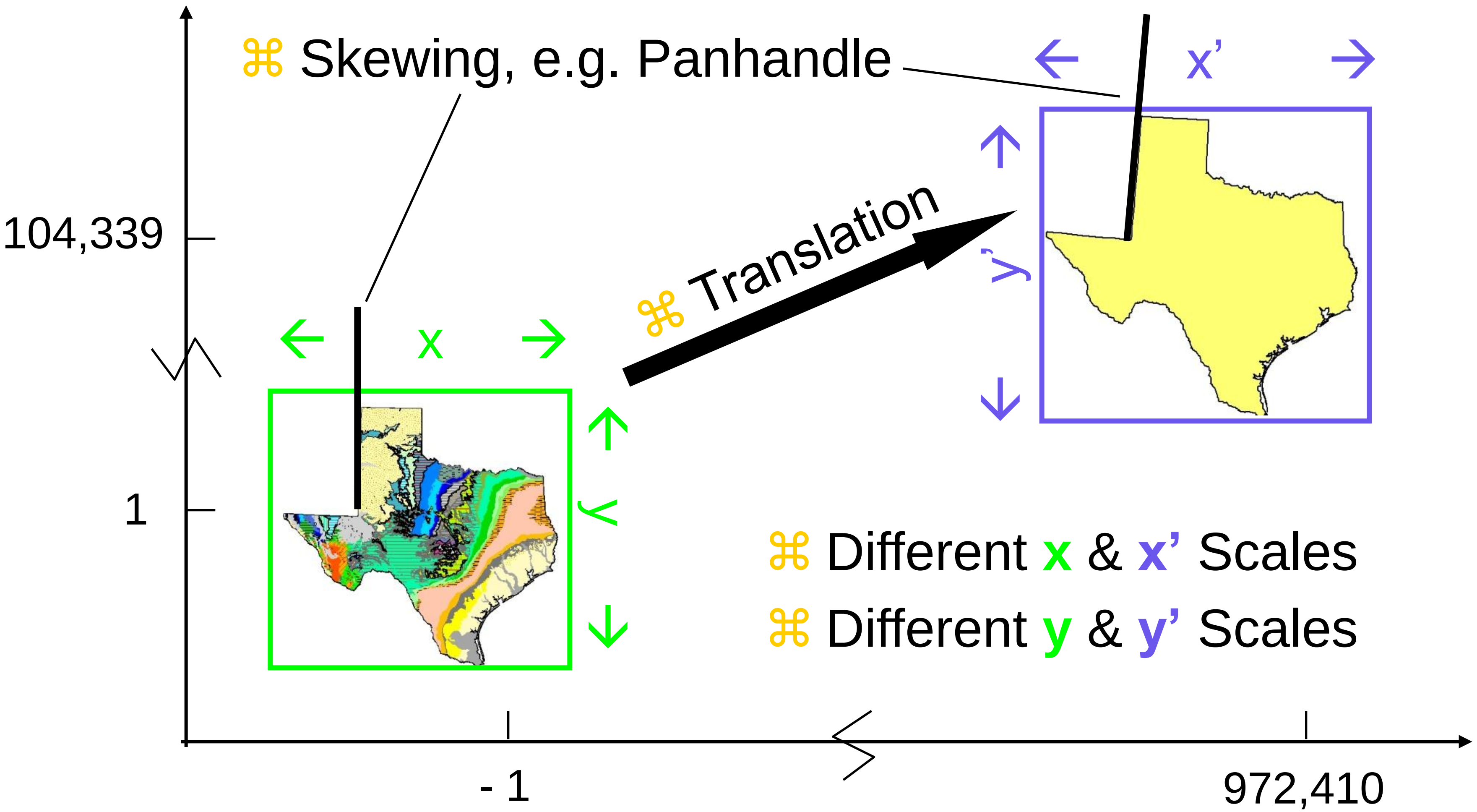
Shapefile stored in geographic coordinates

Nature of the problem:

- Data source registration may differ by:
  - Rotation
  - Translation
  - Distortion

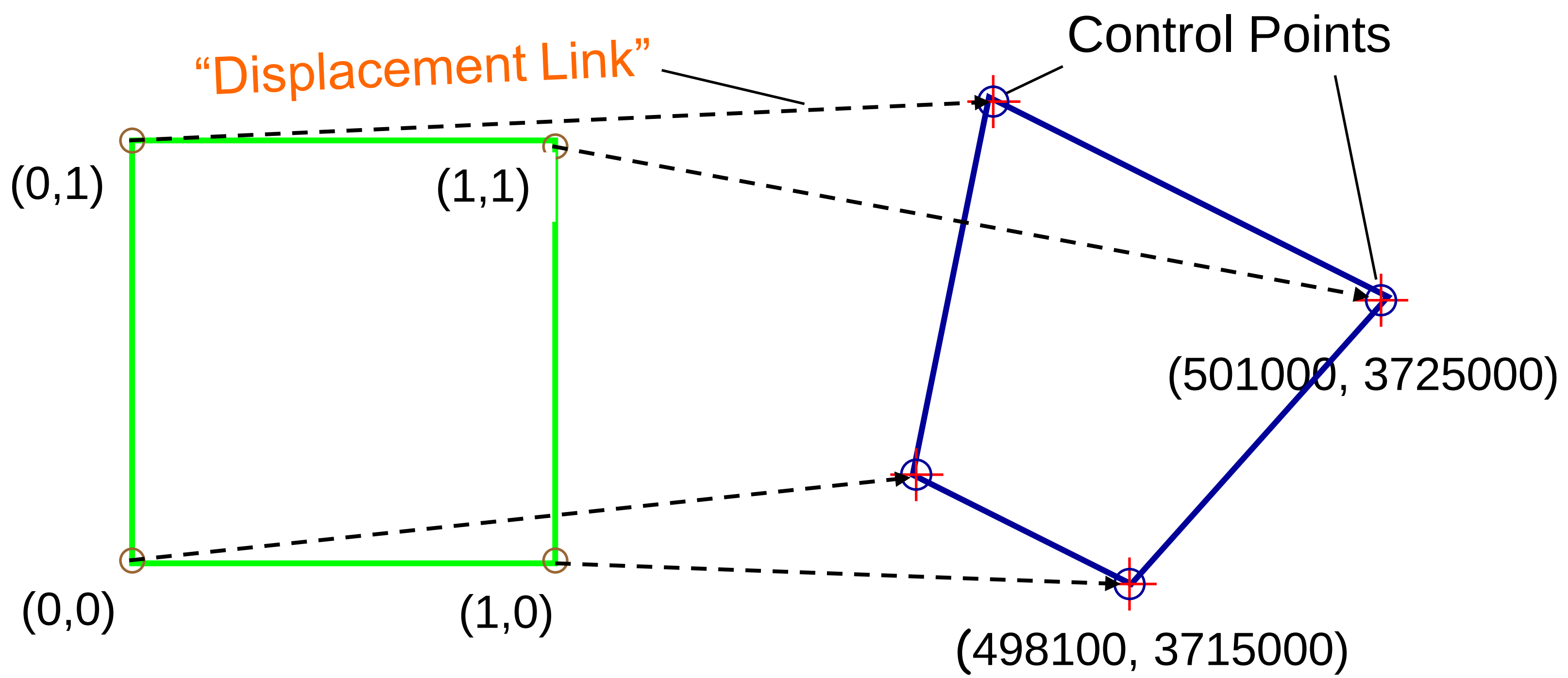


Texas Example:



- ⌘ Different **x** & **x'** Scales
- ⌘ Different **y** & **y'** Scales

General problem is then:

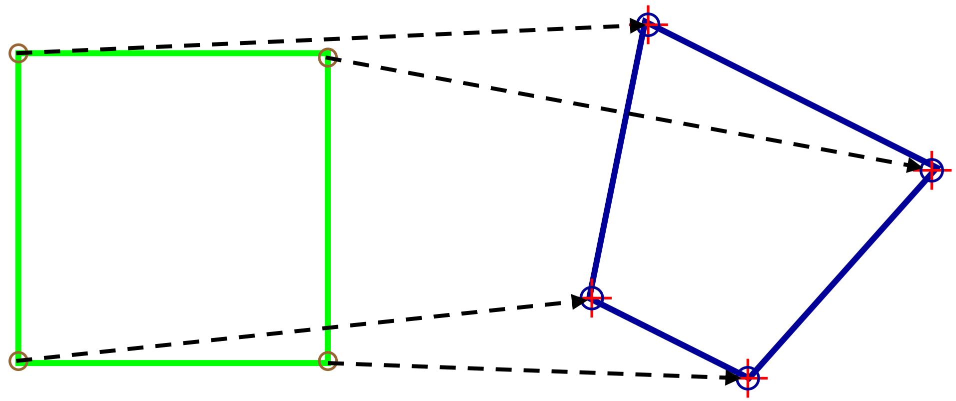


Source (x, y; unspec.) ➡ **Destination** (x', y'; UTM)

("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 → 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

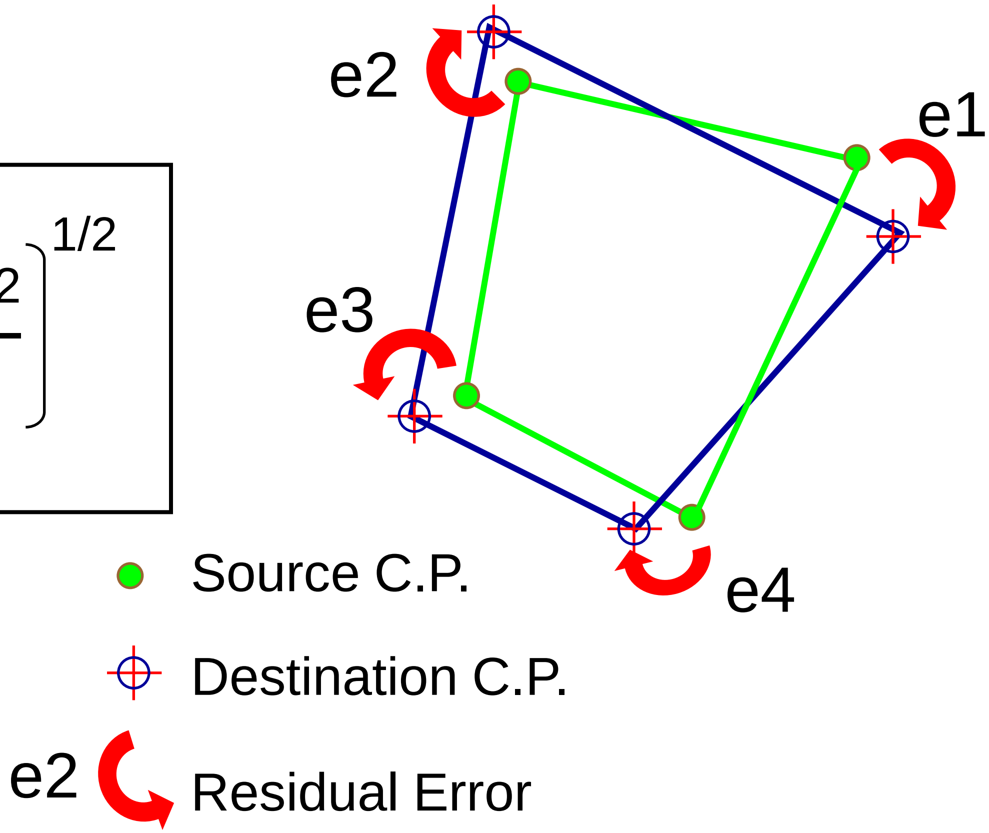
- With six unknowns, need *minimum of three points* (yielding 6 equations).

Affine Transformations

- "Goodness of Fit" given by RMS error:

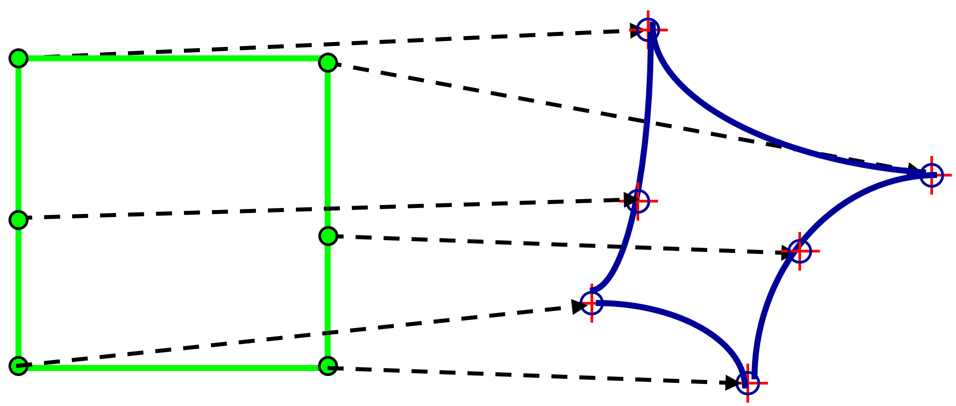
RMS error =

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



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



M. Helper
9-22-09

Transformation Characteristics

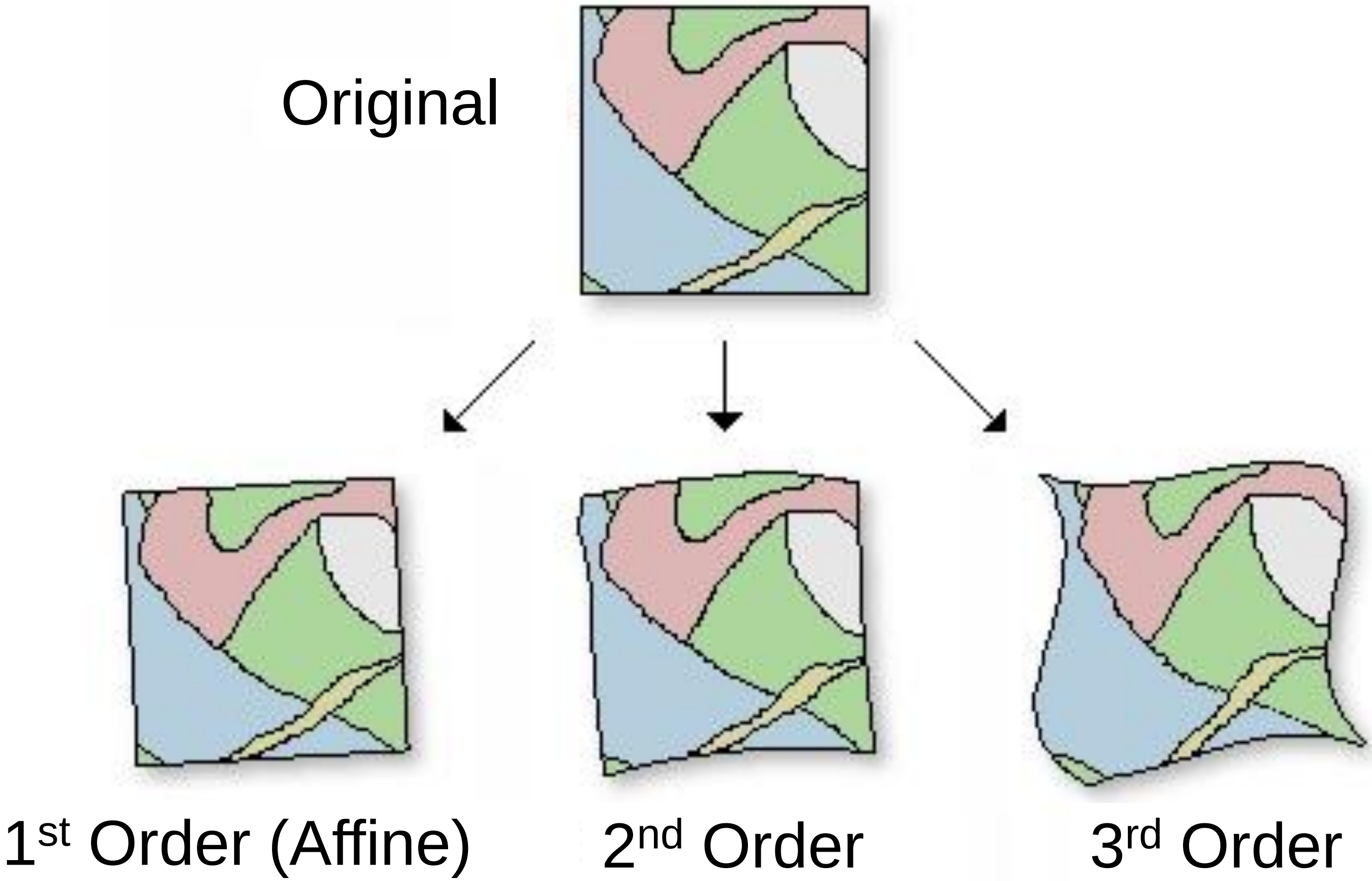


Image from ESRI Help file

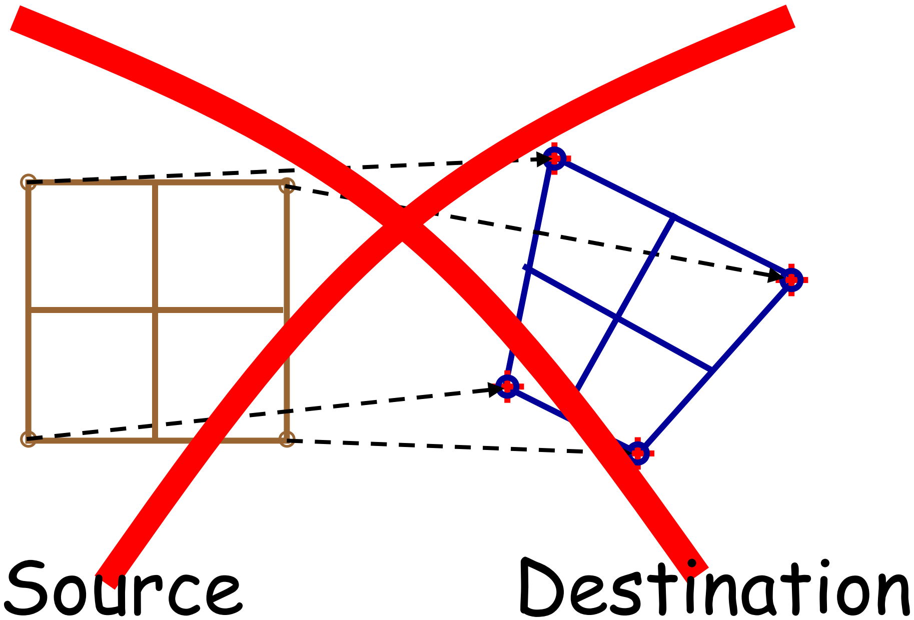
Other Transformation Types

- 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.

Image from ESRI Help file

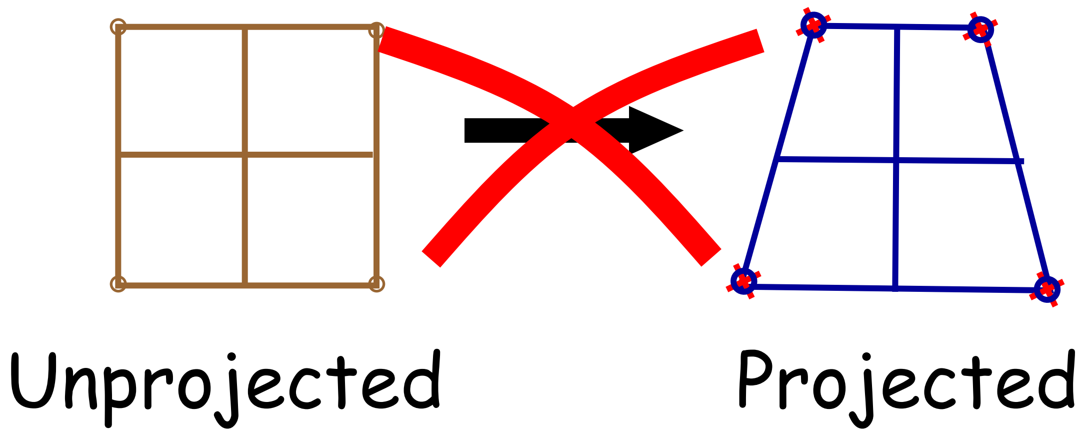
Geometric Transformation of Raster Data

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



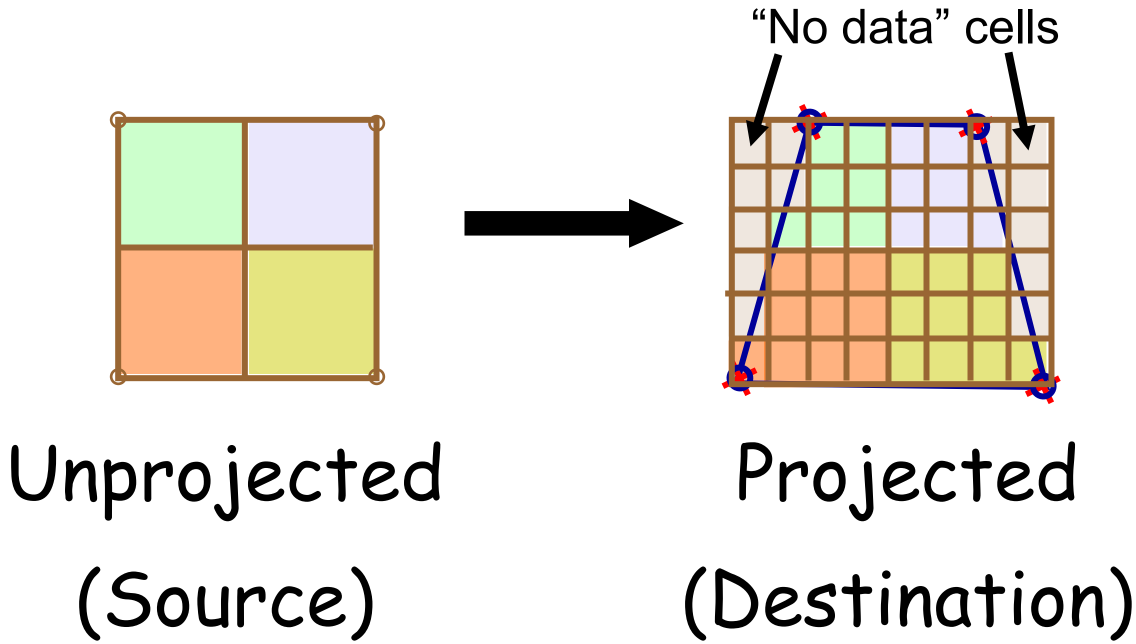
Geometric Transformation of Raster Data

- 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 an .aux file of same name as raster

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

Georeferencing in ArcMap

- Georeferencing Toolbar

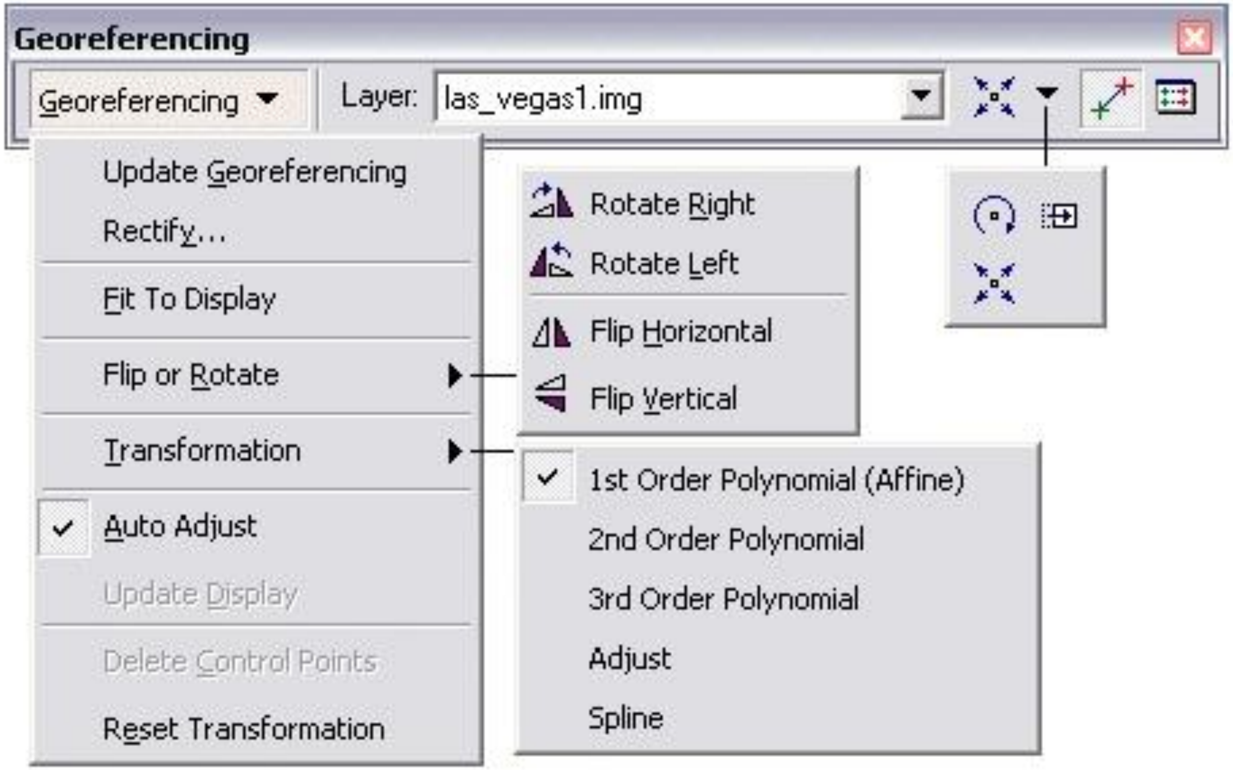


Image from ArcGIS georeferencing help file

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 technique:
    - 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>

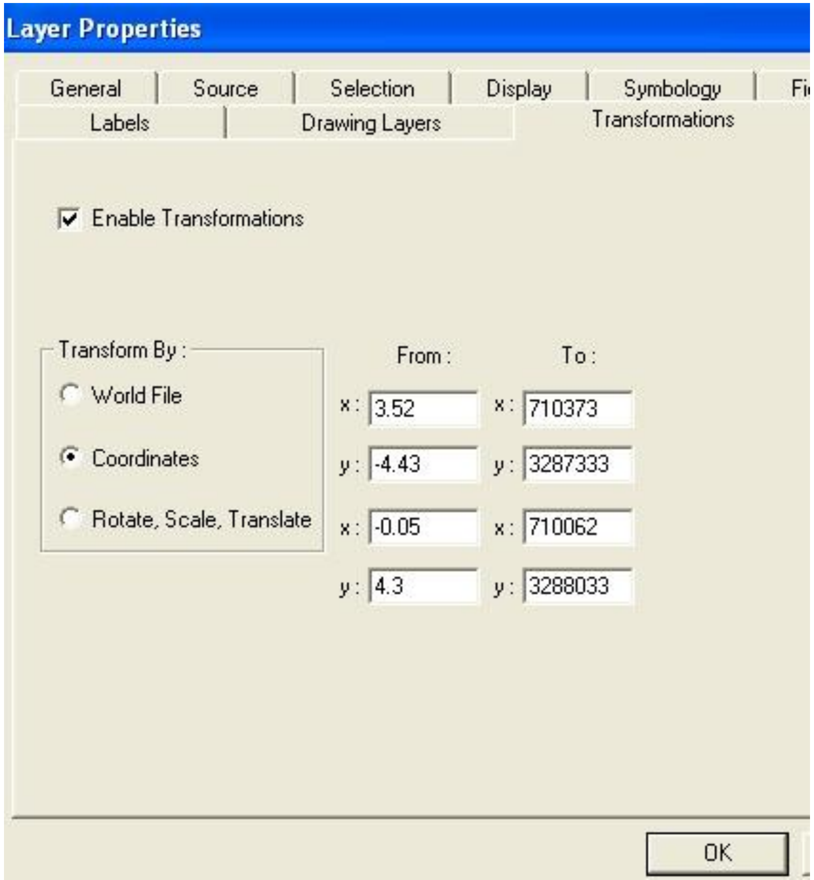
E.g. 3.52,4.43 710373,3287333

-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.