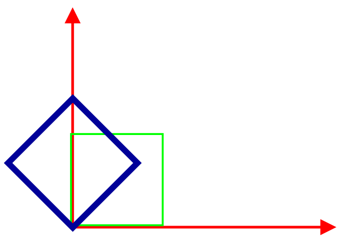
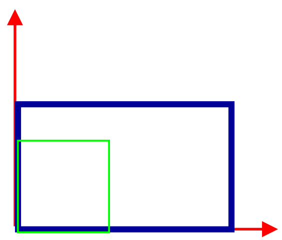
Georeferencing & Spatial Adjustment

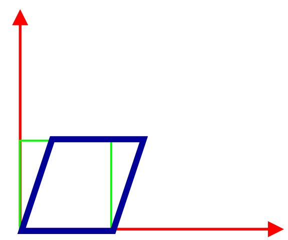
Aligning Raster and Vector Data to the Real World



Rotation

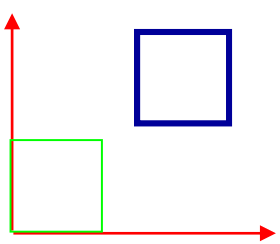


Differential Scaling



Skew

Distortion



Translation

The Problem

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

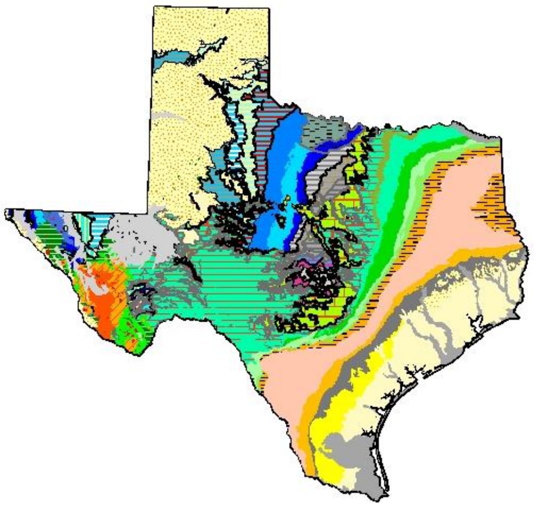
OR

- How are arbitrary coordinates transformed into geographical coordinates?

For Example:

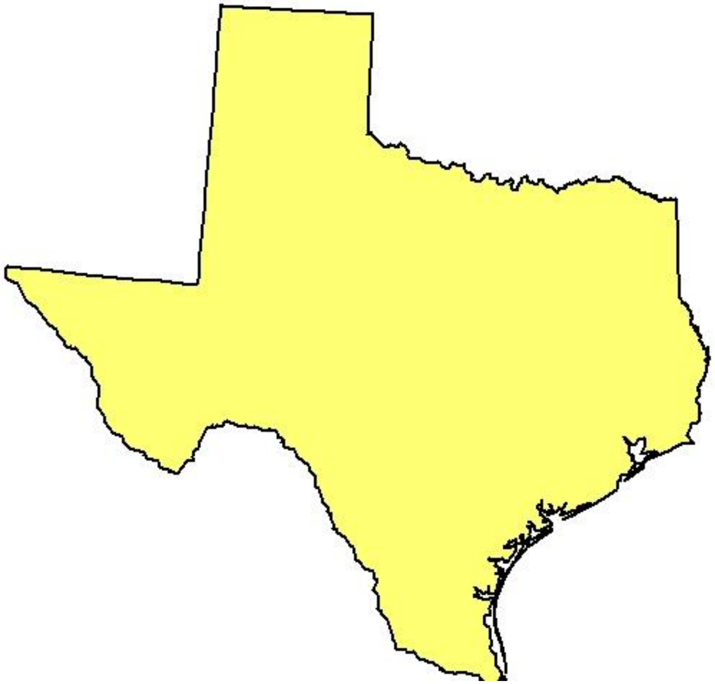
- Align raster image to vector map of state outline

"Source location"



Raster- no geographic coordinates

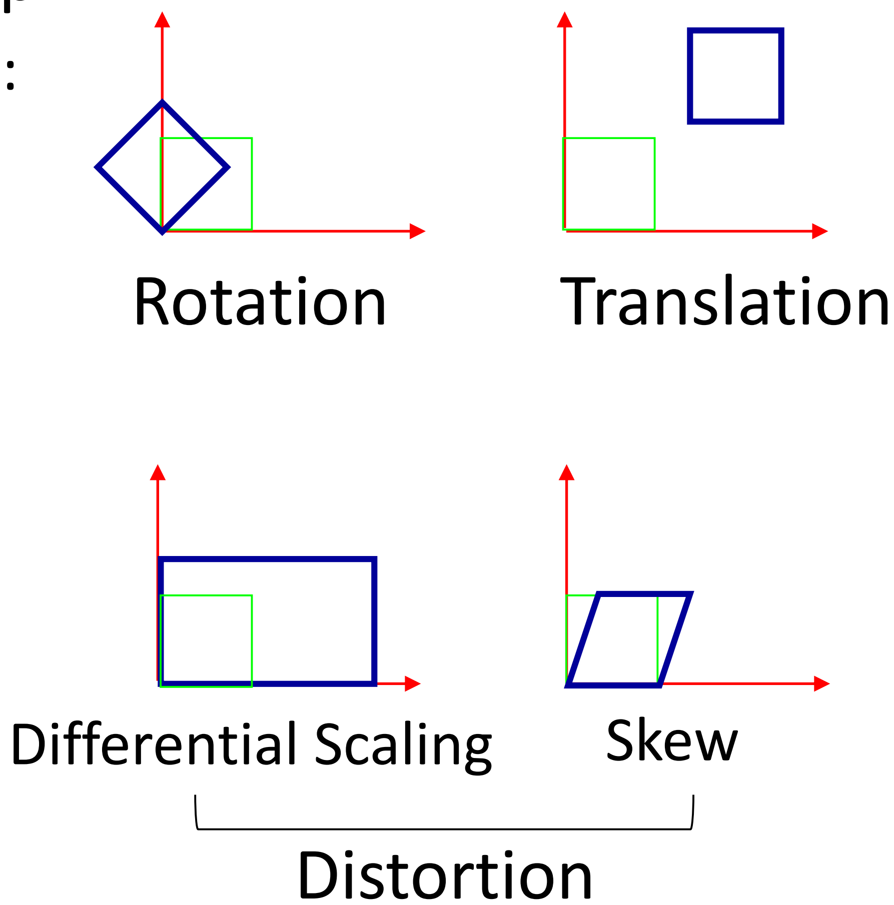
"Destination location"

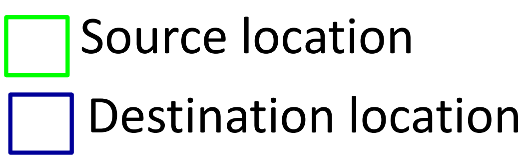


Shapefile – projected, stored in State Plane coordinates

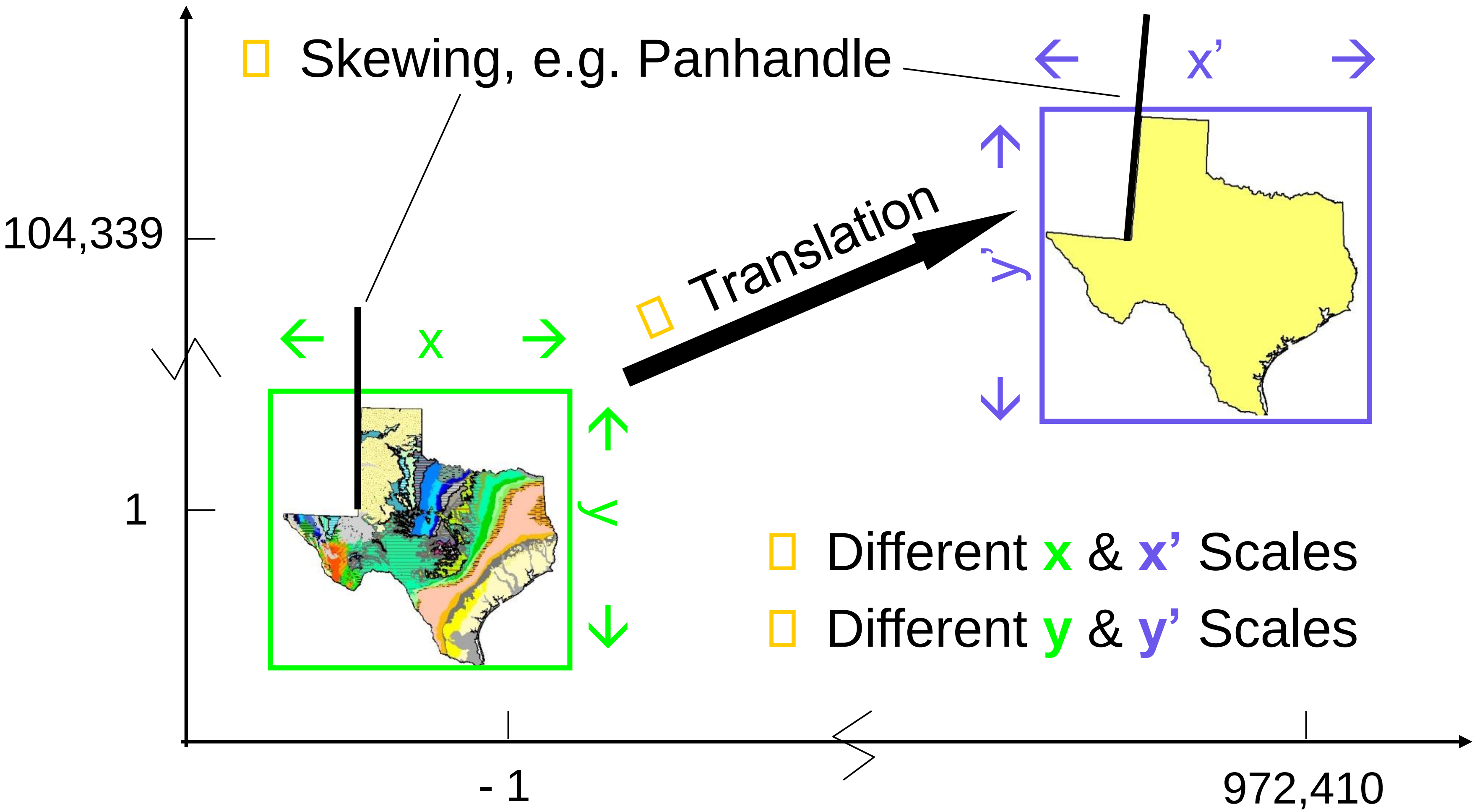
Nature Of The Problem:

- Data source and final map registration may differ by:
  - Rotation
  - Translation
  - Distortion

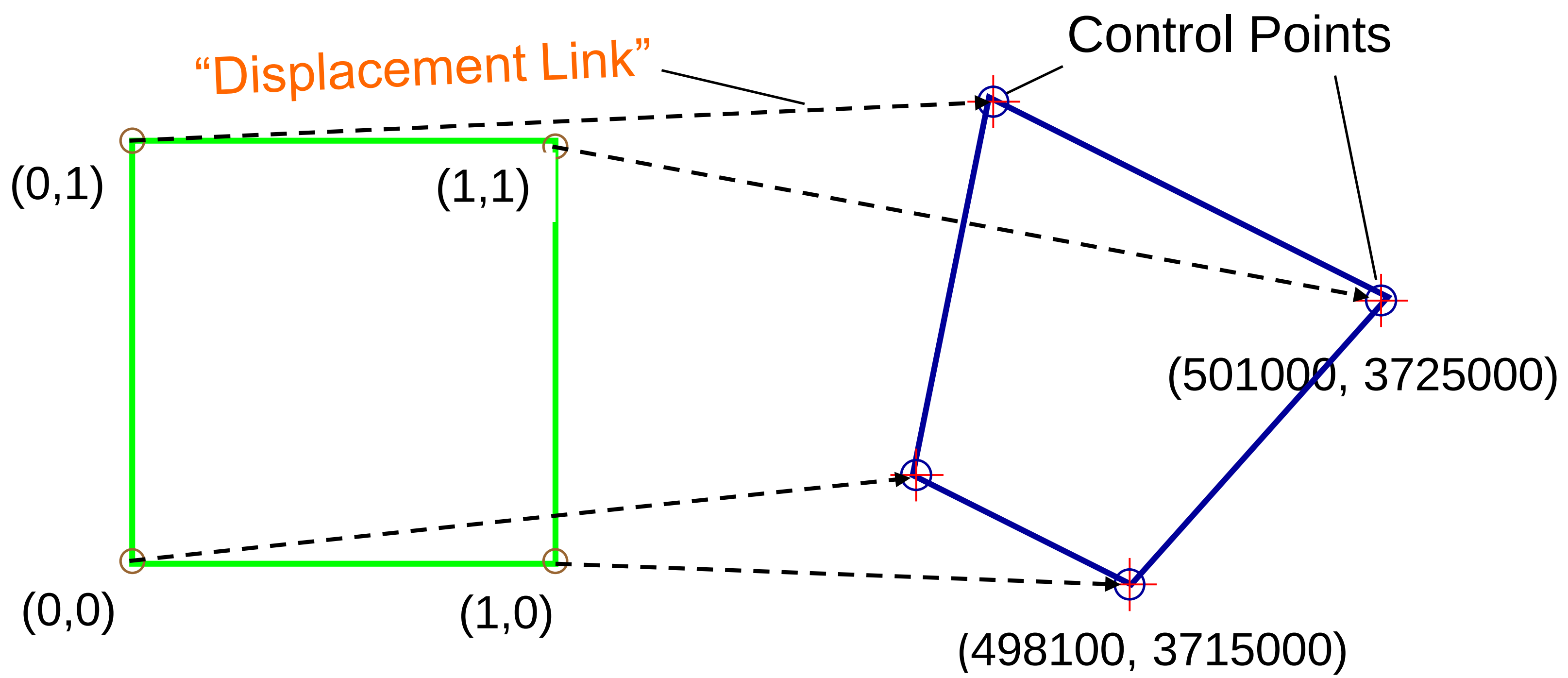




Texas Example:



General Problem Is Then:

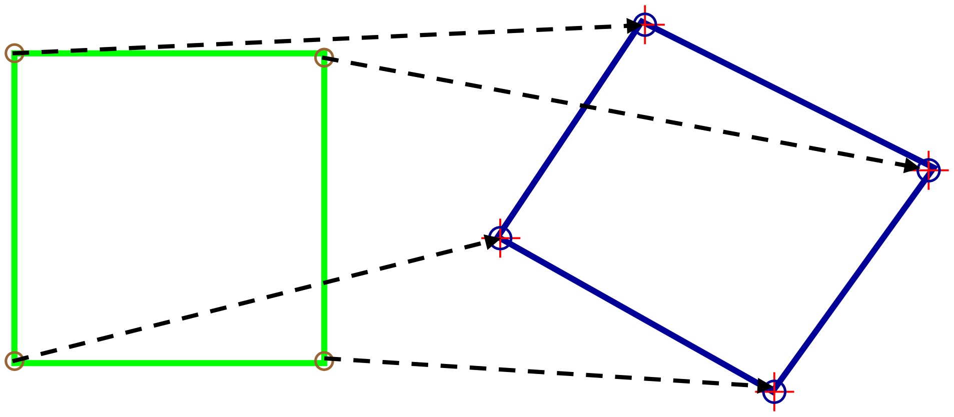


Source (x, y; unspec.) ➡ ***Destination*** (x', y'; UTM)

("Warp")

How Solved?

- Geometric Transformations
  1. First-order ("*Affine*") transformation
     - Accomplishes translation, distortion and rotation
     - **Straight lines are mapped onto straight lines, parallel lines remain parallel, e.g. square to rectangle**



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)

Affine Transformation

- 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

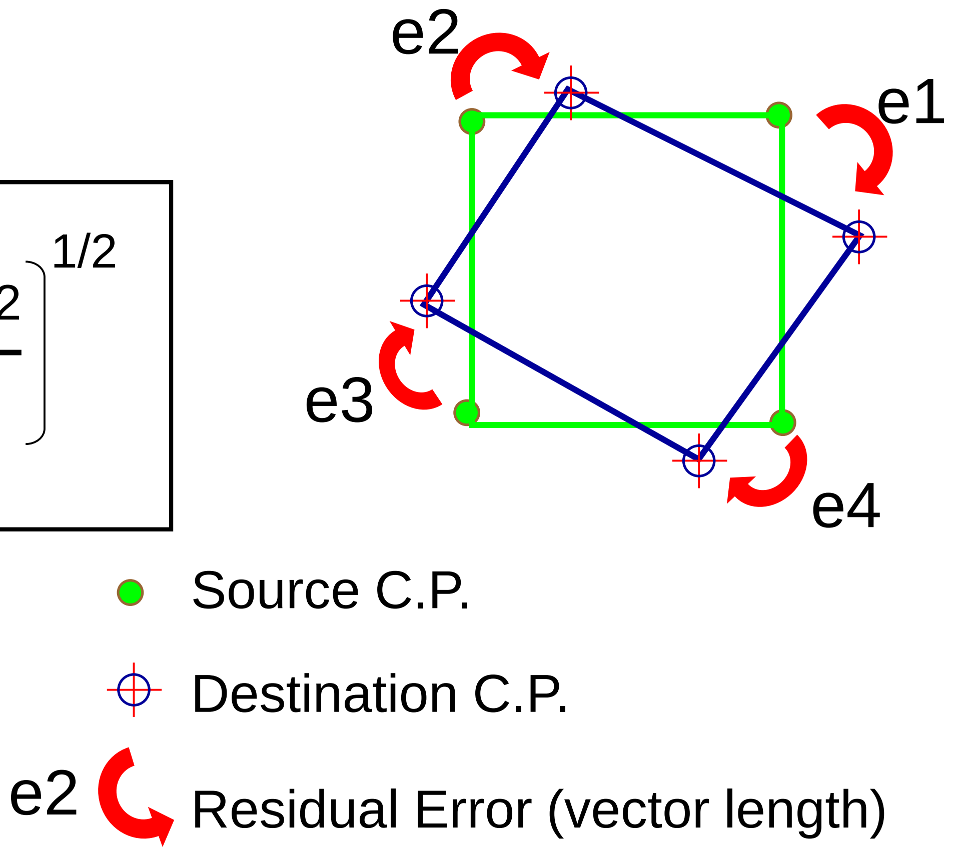
- With six unknowns, need *minimum of three points* (yielding 6 equations).

Affine Transformation

- "Goodness of Fit" given by RMS error:

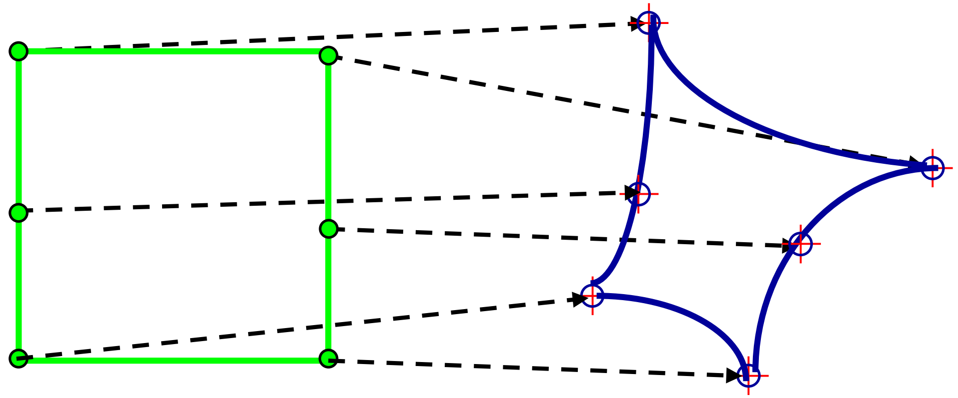
RMS error =

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



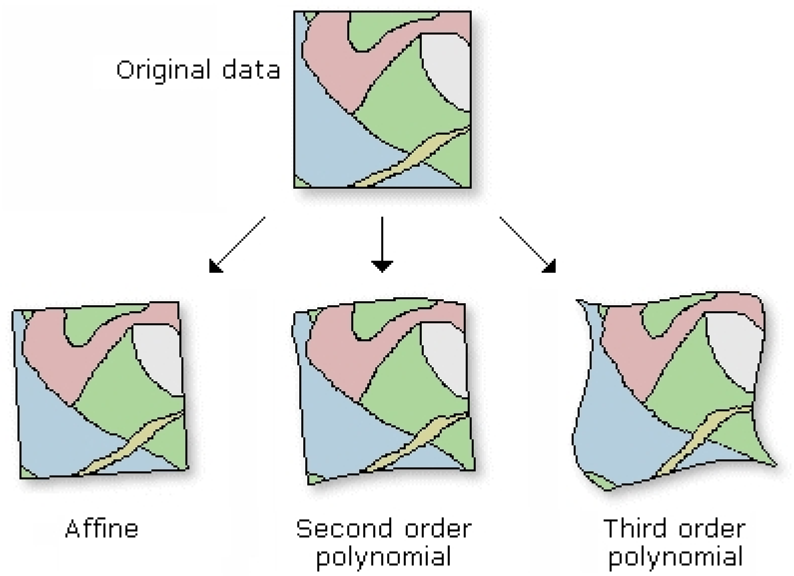
Geometric Transformations

- 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

Original



1st Order (Affine) 2nd Order 3rd Order

Image from ESRI Help file

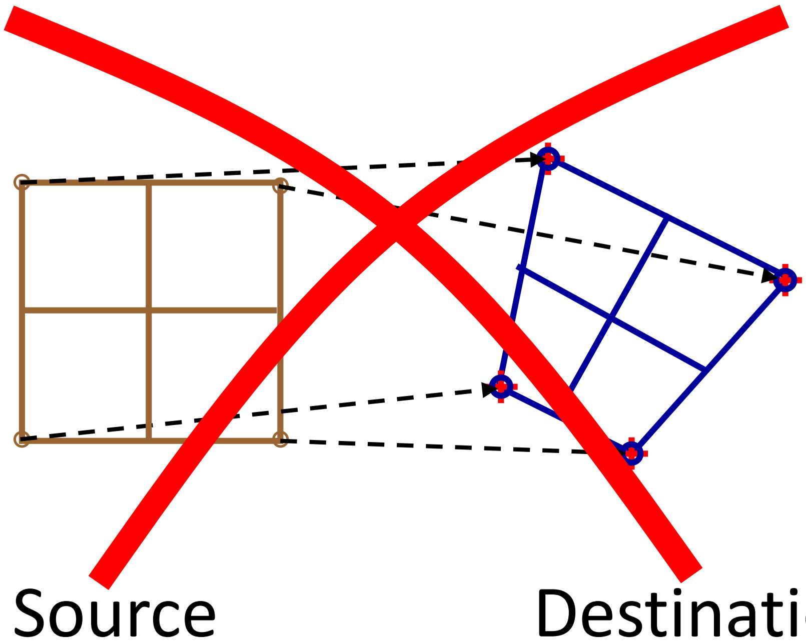
Other Transformation Types

- Spline – For local fits only
  - Source control pts. match reference pts. ***exactly*** at expense of global fit. 10 pts. required
- Adjust – For global and local fitting
  - Relies on polynomial fitting adjusted to a TIN. 3 pts. required
- Projective – For imagery or scanned maps that differ from source primarily by the map projection
  - Minimum of 4 pts required, RMS given.

Image from ESRI Help file

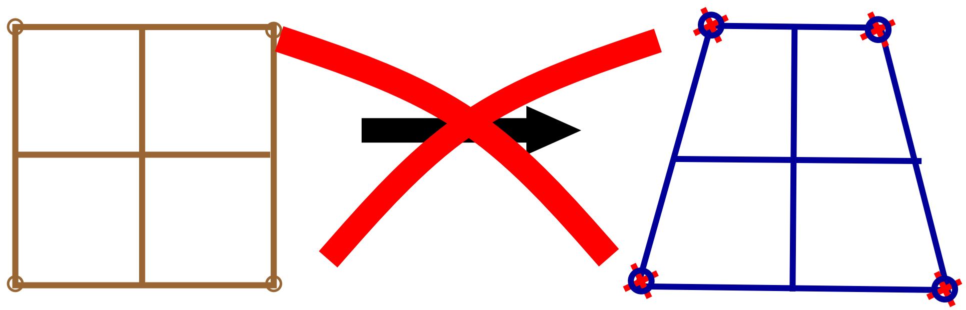
Geometric Transformation of Raster Data

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



Geometric Transformation of Raster Data – Raster Projection

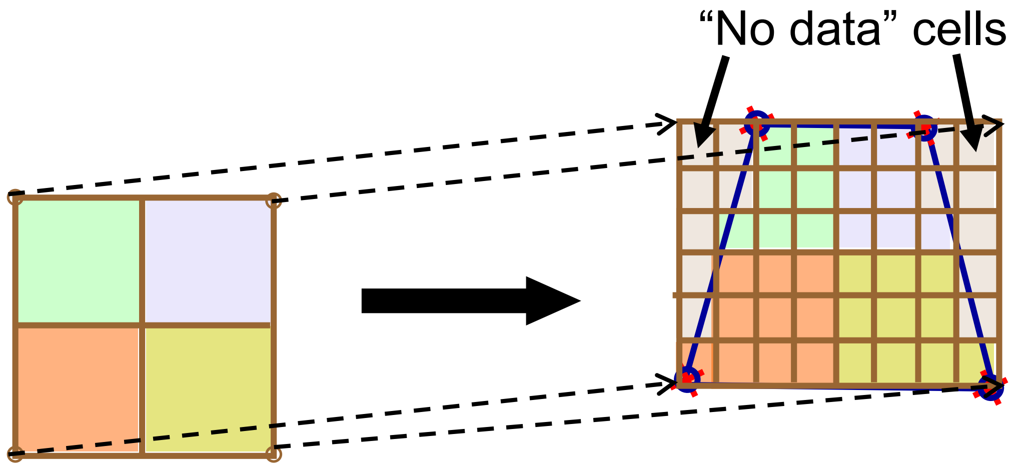
- Related Problem: Square cells must remain square after projection. How?



Unprojected   Projected

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" (null).



Unprojected

(Source)

Projected

(Destination)

Creating New Cells: 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 with a reference layer that closely matches projection of the layer being georeferenced
- Raster datasets must be in same projection and coordinate system for analysis.

Where Are New Coordinates Stored?

- "Update Georeferencing" writes transformation parameters to a new, small, separate file of same name as raster but with a different extension (e.g. .jpw, .aux, .xml), depending on original file type

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

Georeferencing in ArcMap

- Georeferencing Toolbar

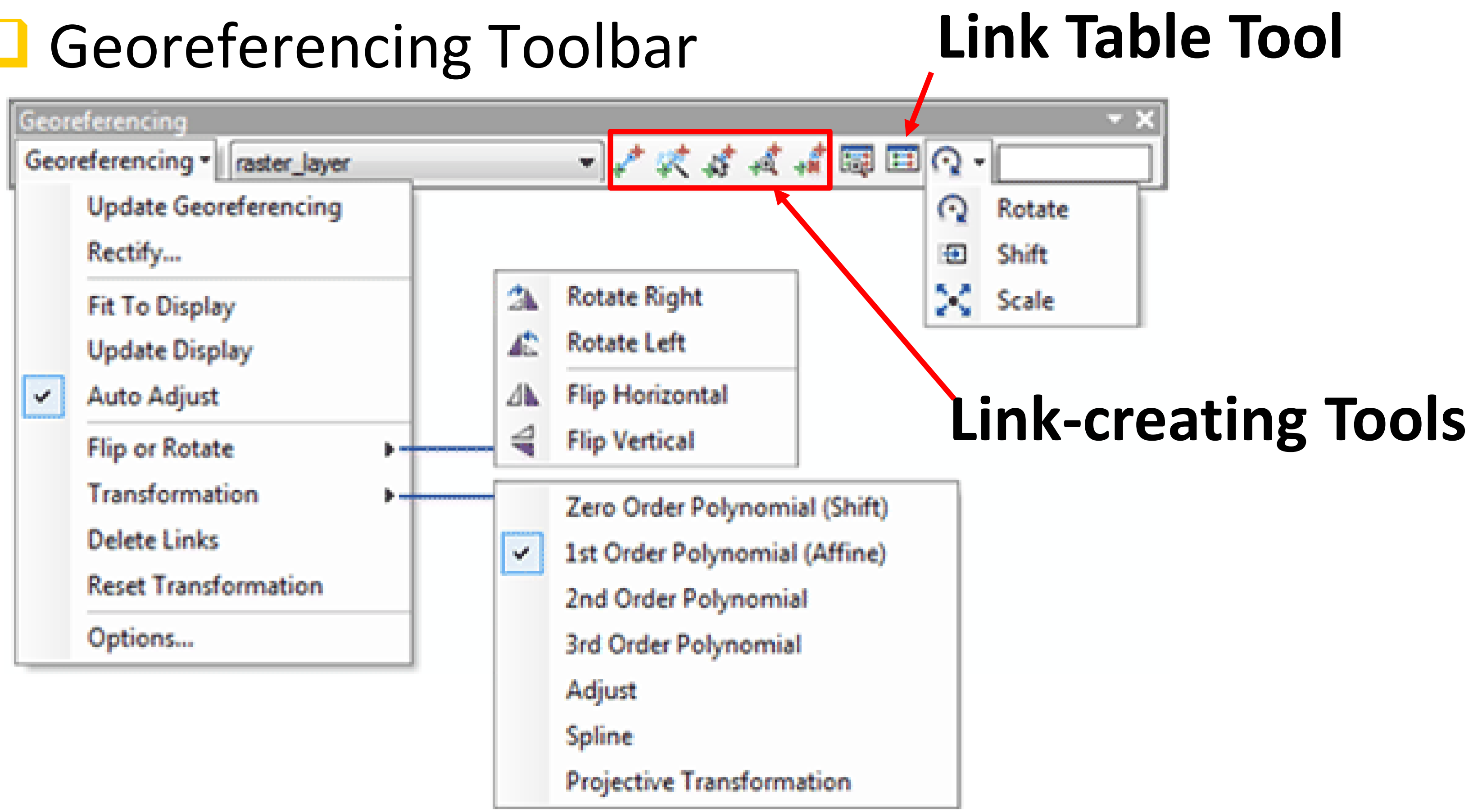


Image from ArcGIS georeferencing help file

Procedure

- See 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.
  - Three 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
    - By importing vector layers into a Geodatabase and using the Spatial Adjustment (see below) toolbar!

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:

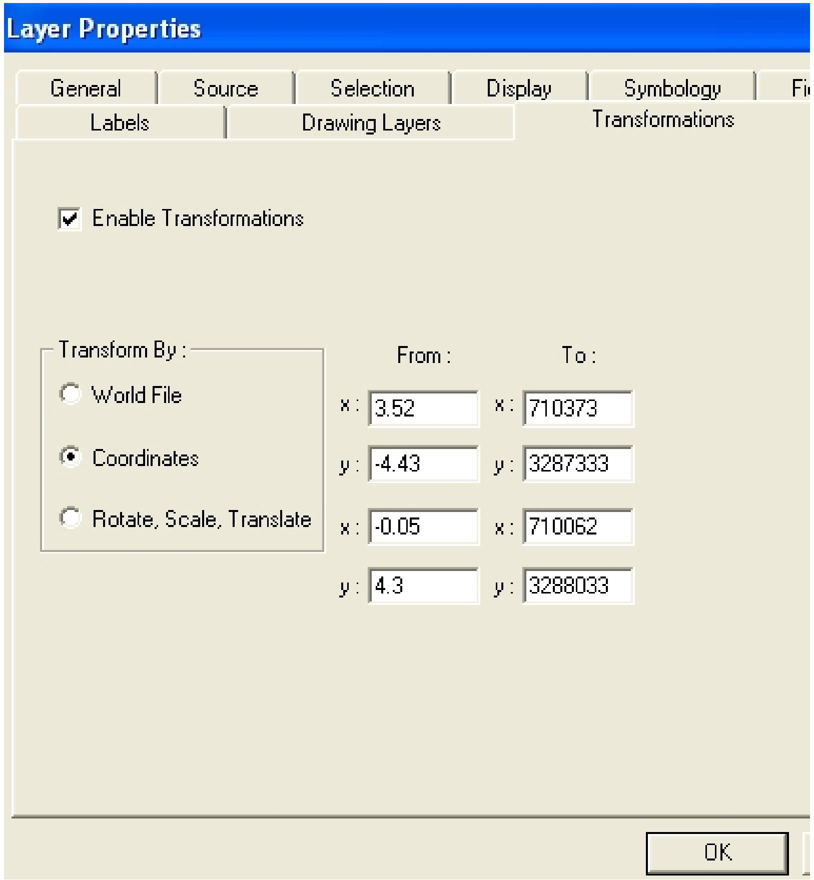
<x,y location of pt. 2 in CAD drawing> <space>
<x,y location of pt. 2 in geographic space>

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.

Georeferencing Demo

- Practice georeferencing scanned geologic map for Lab 4 & 5
- Download:

  Geo-327g_386g>Georeferencing_Demo>*2019WMA*

  to begin