GIST 8118 Module 5A
Image pre-processing

Geometric Transformations

Outline

- Lecture
  - Pre processing
  - Geometric
- Lab
  - Tutorial geometric correction

Pre Processing of images

- Corrections are made to allow for
  - distortions
  - errors
  - noise
- created during
  - scanning
  - transmission
  - recording
  - storage

Data Errors

- Internal errors are
  - systematic sensor errors
  - may be predicted
  - E.g. sensor recording high or low
  - generally corrected before you receive data
- External errors are
  - platform instability
  - atmospheric conditions
    - E.g. Lots of pollution (haze)
  - cannot be predicted
  - methods to correct
- Two types of errors
  - Radiometric (covered in 5B)
  - Geometric

GEOMETRIC CORRECTION

Image Rectification

- All remote sensing images are subject to some form of geometric distortions, variety of factors:
  - the perspective of the sensor optics,
  - the motion of the scanning system,
  - the motion and (in)stability of the platform,
  - the platform altitude, attitude, and velocity,
  - the terrain relief, and
  - the curvature and rotation of the Earth.

Geometry Errors

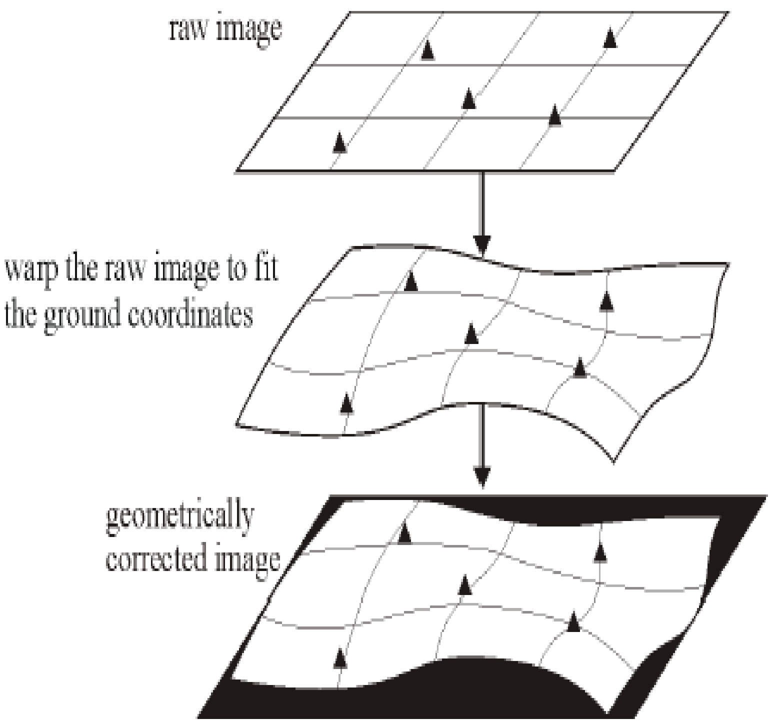
- Systematic errors
  - can be calculated and corrected using software without operator input
    - eg sensor geometry errors
- Non-systematic errors
  - are removed using <u>Geometric rectification</u>
    - e.g. sensor attitude / altitude

Geometric rectification

- an operator identifies known *control points*
  - on the source image using map coordinates
    - image to map
  - another image's coordinates
    - image to image
- process is often known as *warping*

Two step process

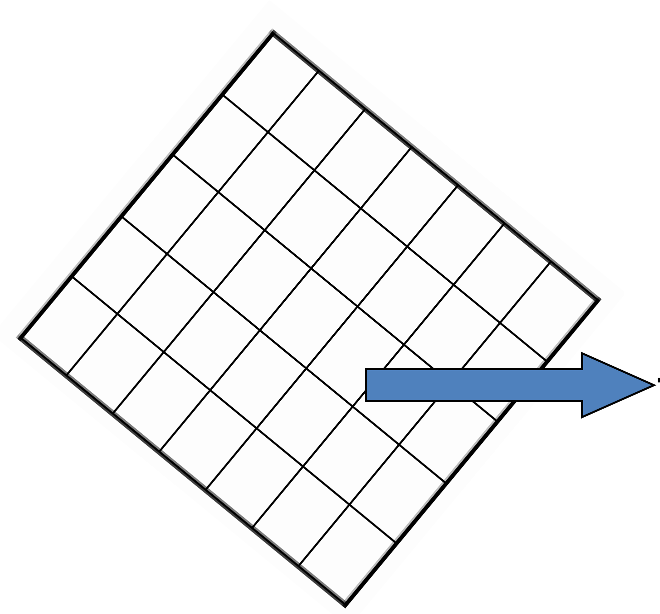
Figure 8.2: The process of geometric correction



- Step 1: transformation of pixel coordinates
  - Determine transformation equation for pixel line location to georeferenced location
- Step 2: resampling
  - Determine the pixel value (DN) for each pixel in the corrected image

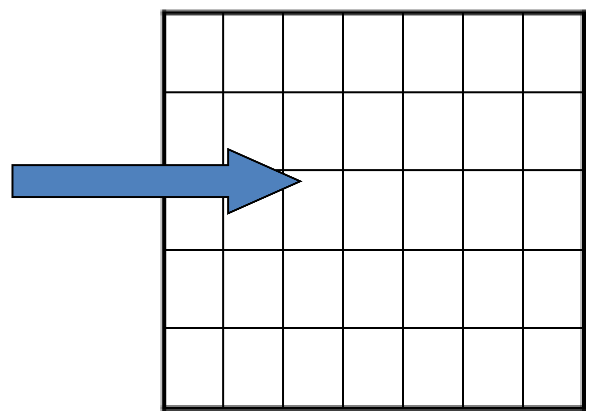
http://www.pcigeomatics.com/cgi-bin/pcihlp/GCPWORKS%7CTheory

Step 1: Transformation of Pixel Coordinates



Mathematical transformation

Example:
Polynomial
or
Thin Plate Spline
or
Many others



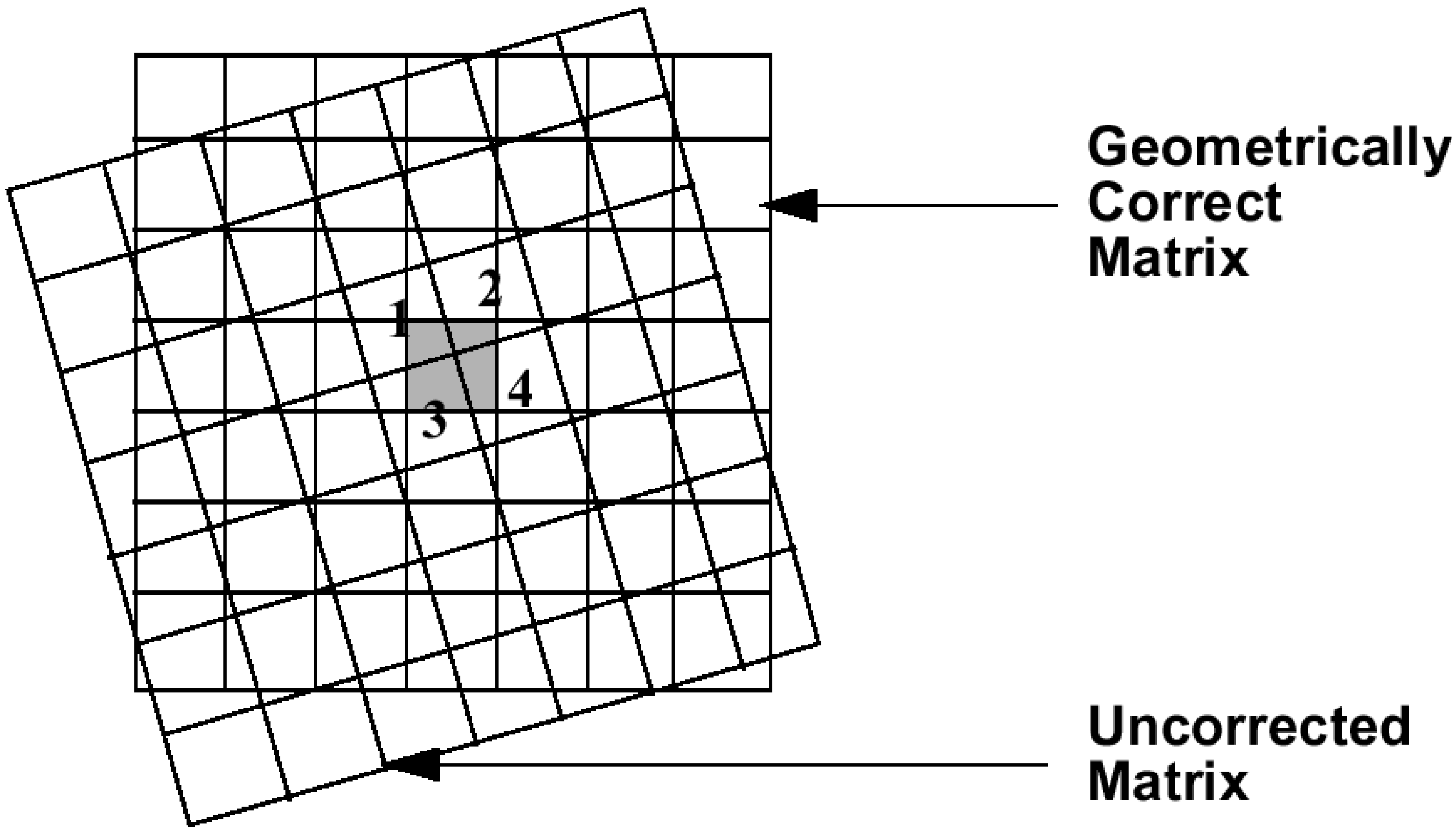
Raw image

Pixel / Line locations

e.g. Landsat WRS

Corrected image
UTM NAD83 ZONE 10 coordinates

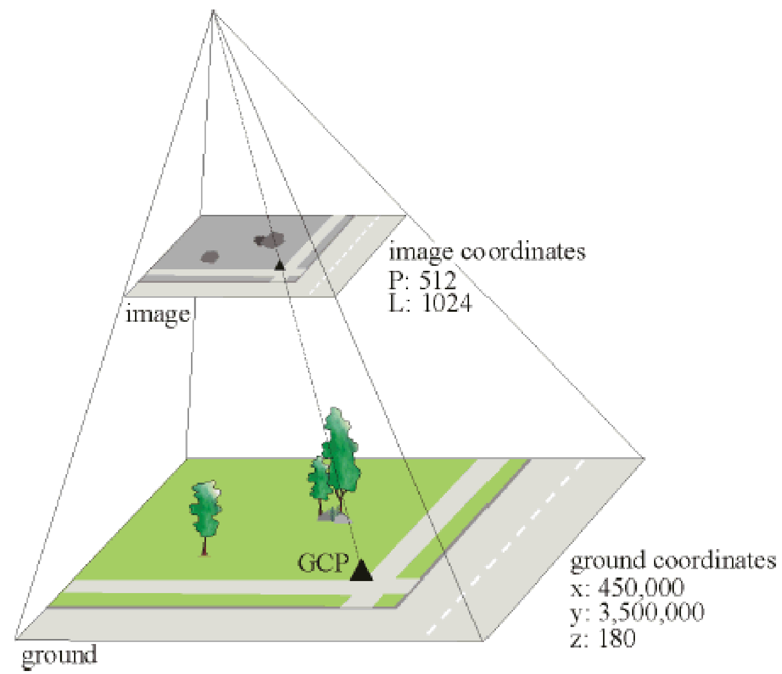
Transformed GRID

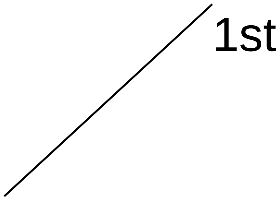


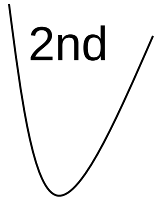
Mathematical Transformation

- Require
  - ground control points (GCP)
  - Pair of recognizable locations
  - One must have real world coordinate locations

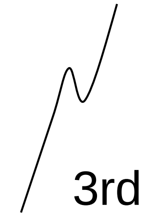
Figure 5.1: The relationship between the ground coordinate system and the image coordinate system







Polynomial



- Polynomial equations fitted to GCP with least squares
  - also known as least square linear regression,
  - a line is fitted through a bunch of points
- 1st , 2nd, 3rd order transformations can be selected
- Depends on number of GCP and desired accuracy
- Website to view different polynomial equations
  - http://zonalandeducation.com/mmts/functionInstitute/polynomialFunctions/graphs/polynomialFunctionGraphs.html
- Good for images with high relief (mountains)

Transformation

- Want:
  - the best fit
    - between the image coordinates and the geo coordinates
- Find this by:
  - least-squares criteria
    - sum of the differences squared between each calculated geo coordinate and the actual geo coordinate for each control point
- Residual error
  - RMS

Finding a Transformation Equation

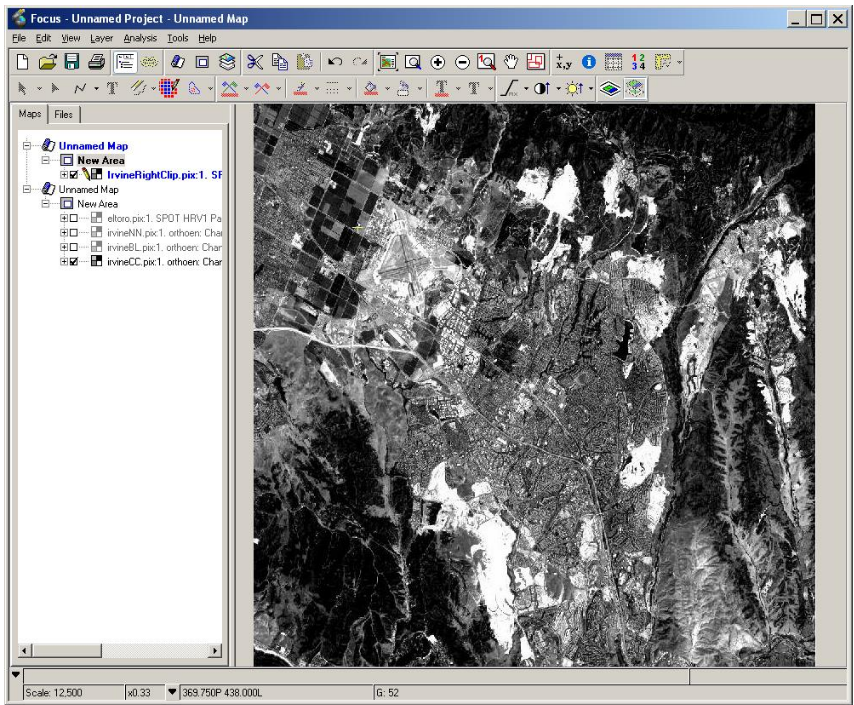
- GCP = two sets of coordinates
  - x1,y1 = image and a x, y = geo coordinates
- Need a minimum of 3 GCPs
- Using the equations (1^{st} order)
  - $X1= a1X + a2Y + a3$ $\qquad$ $Y1= b1X + b2Y + b3$
  - find the coefficients of these equations (a1,a2,a3,b1,b2,b3) and the transformation is found.
    - a1 = x scale $\qquad$ a2 = rotation
    - a3 = translate $\qquad$ b1 = rotation
    - b2 = y scale $\qquad$ b3 = translate

Thin Plate Spine

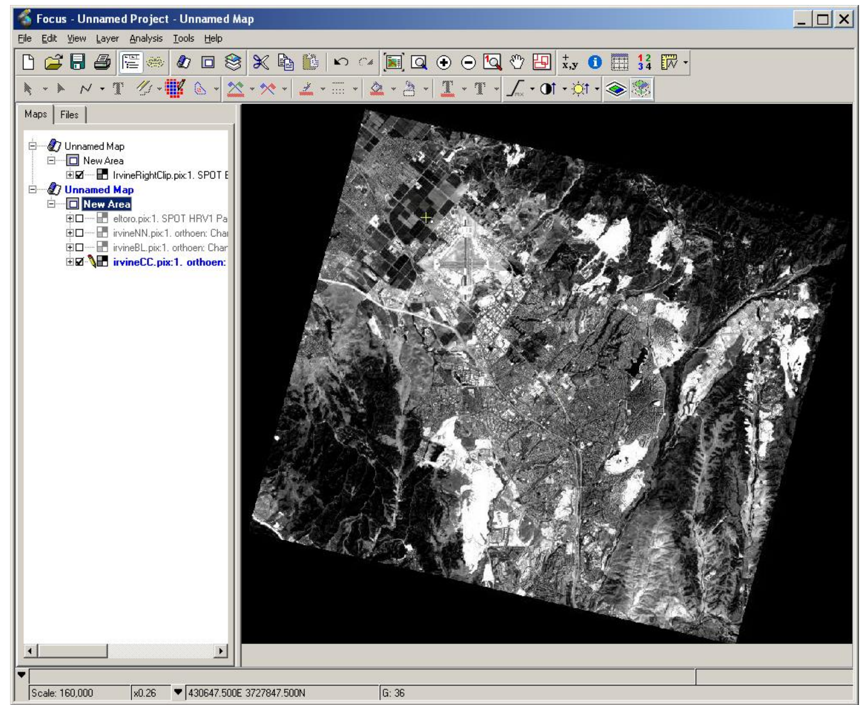
- All GCPs are used simultaneously to derive the transformation
- Derived functions have minimum curvature between control points
- Good for flat areas
- Not good in images with high relief

After Correction GRIDS are *different*

Original (clipped to look square) Pixel/Line space



Corrected (black outline – *no data* in original) UTM space



Step 2 - Resampling

- Determine pixel values (DN) for new image
- for each new image row,col the equations are used to find the uncorrected image row,col
  - only the values calculated using the transformation will not be integers
    - Will not fit exactly at a row/col location
- decide what DN should be put into the new image using one of three interpolation methods
  - Nearest neighbour interpolation
  - Bilinear interpolation
  - Cubic convolution interpolation

Resample DN

- Find location in uv space for xy space (centre of pixel)
- Not exact match
  - (uv space not exactly centre)
- Need to determine the DN to enter in xy space

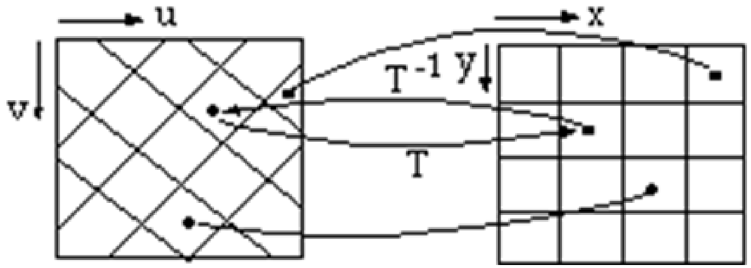


Image source
http://www.cnr.berkeley.edu/~gong/textbook/chapter4/html/sect44.htm

Resampling Example

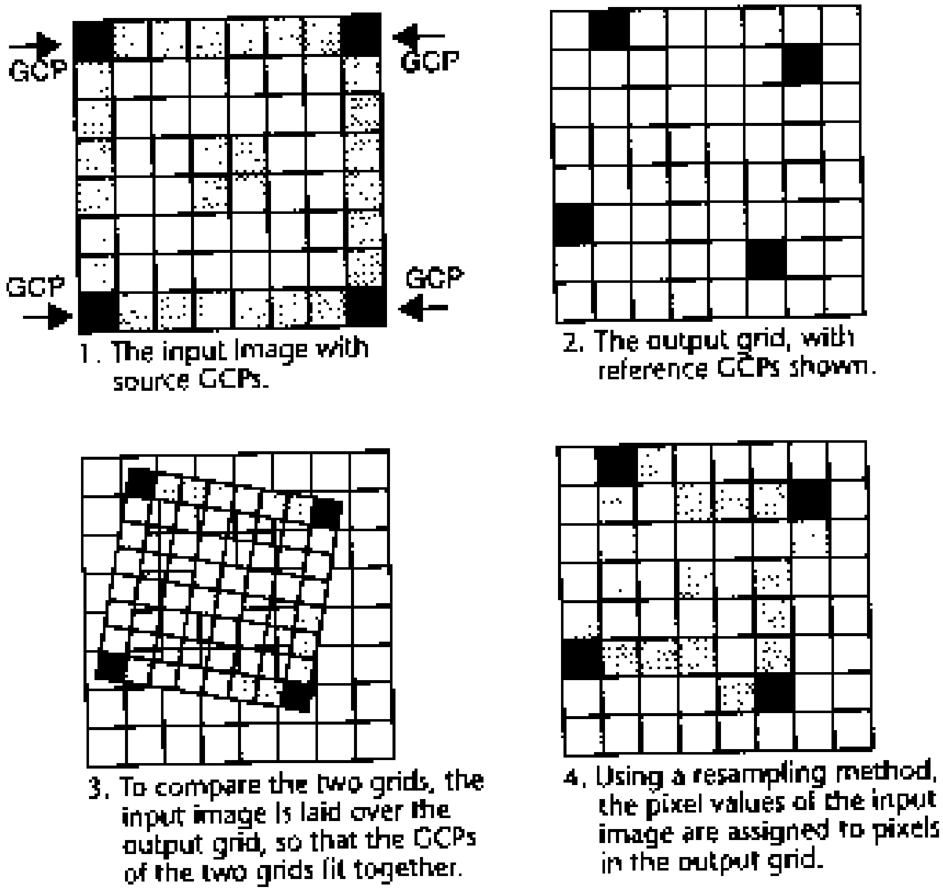
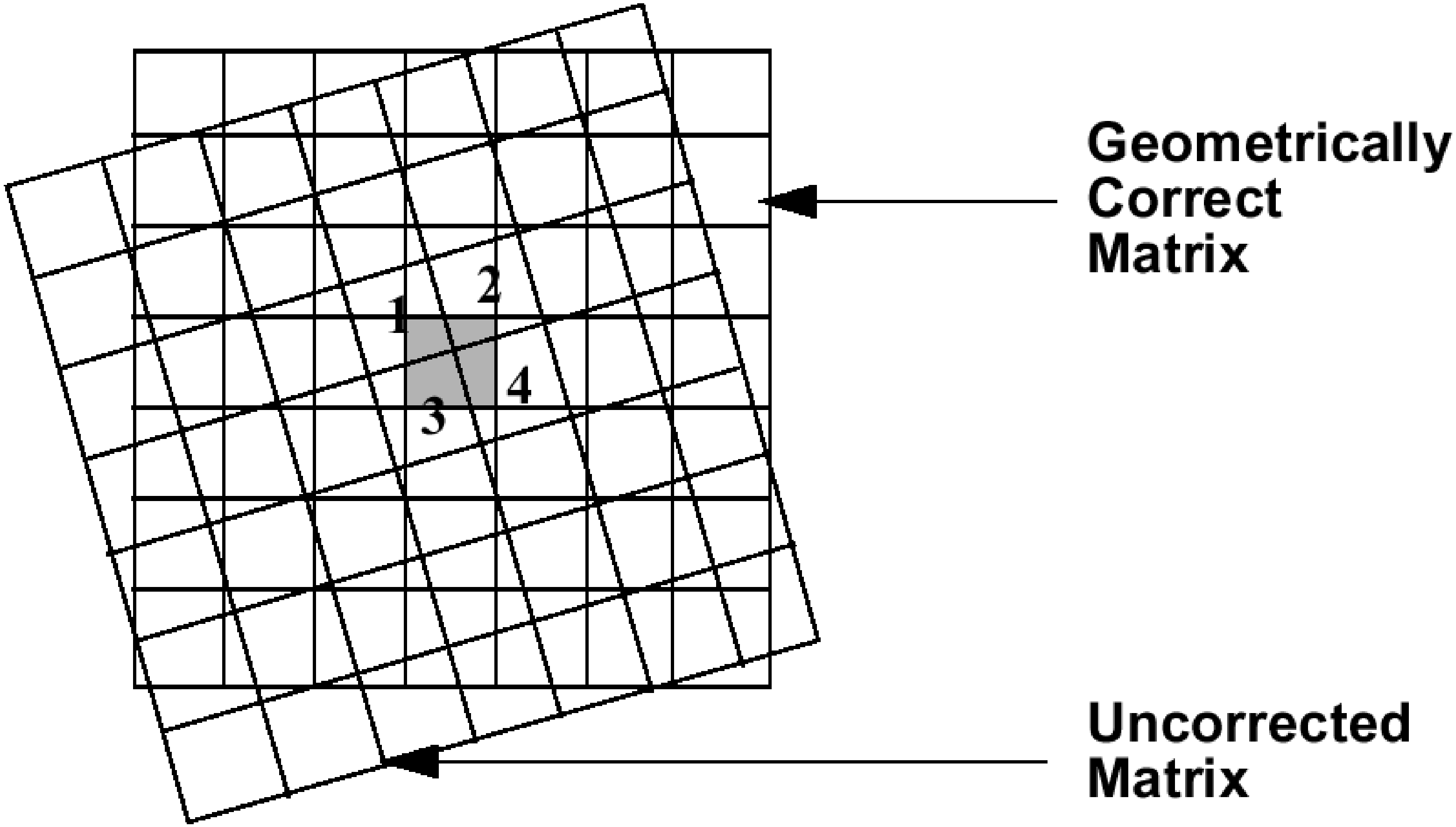


Figure 14: Resampling

Determine the new DN



Nearest neighbour interpolation

- Just take closest pixel DN
- Advantages
  – no change in pixel DN
    - good if you classify
  – Fast
  – Can use on GIS data
    - Ie classified rasters
- Problems
  – May lose or duplicate pixels
  – Not smooth - can get a staircase effect

Bilinear interpolation

- Use the four nearest pixels DN around the calculated location
- Average their values weighted by their distance from the calculated value Bilinear interpolation
- Advantage:
  - Smoother output
  - Accurate representation
- Disadvantage:
  - is slower than nearest neighbour
  - modifies image DN to new values

Bilinear calculation

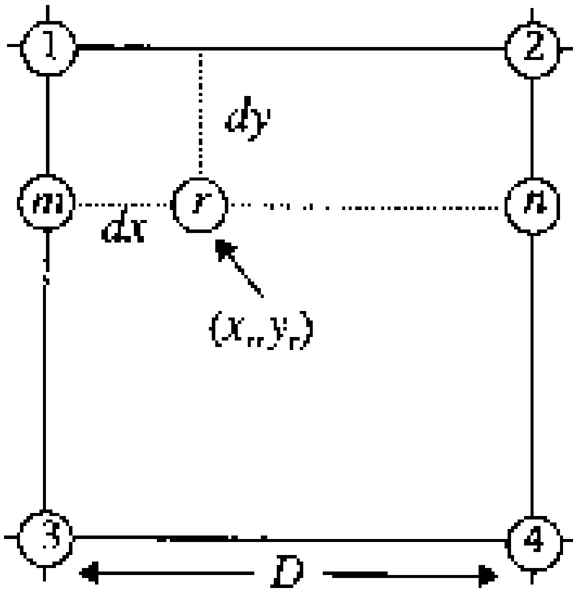
$$BV_{wt} = \sum_{k=1}^{4}(Z_k / D_k^2) / \sum_{k=1}^{4}(1/D_k^2)$$

where :

$\mathrm{BV_{wt}}$ = weighted average of new brightness

D = distance from point todata point

Z = the surrounding data point values



r is the location of the retransformed coordinate

Figure 16: Bilinear Interpolation

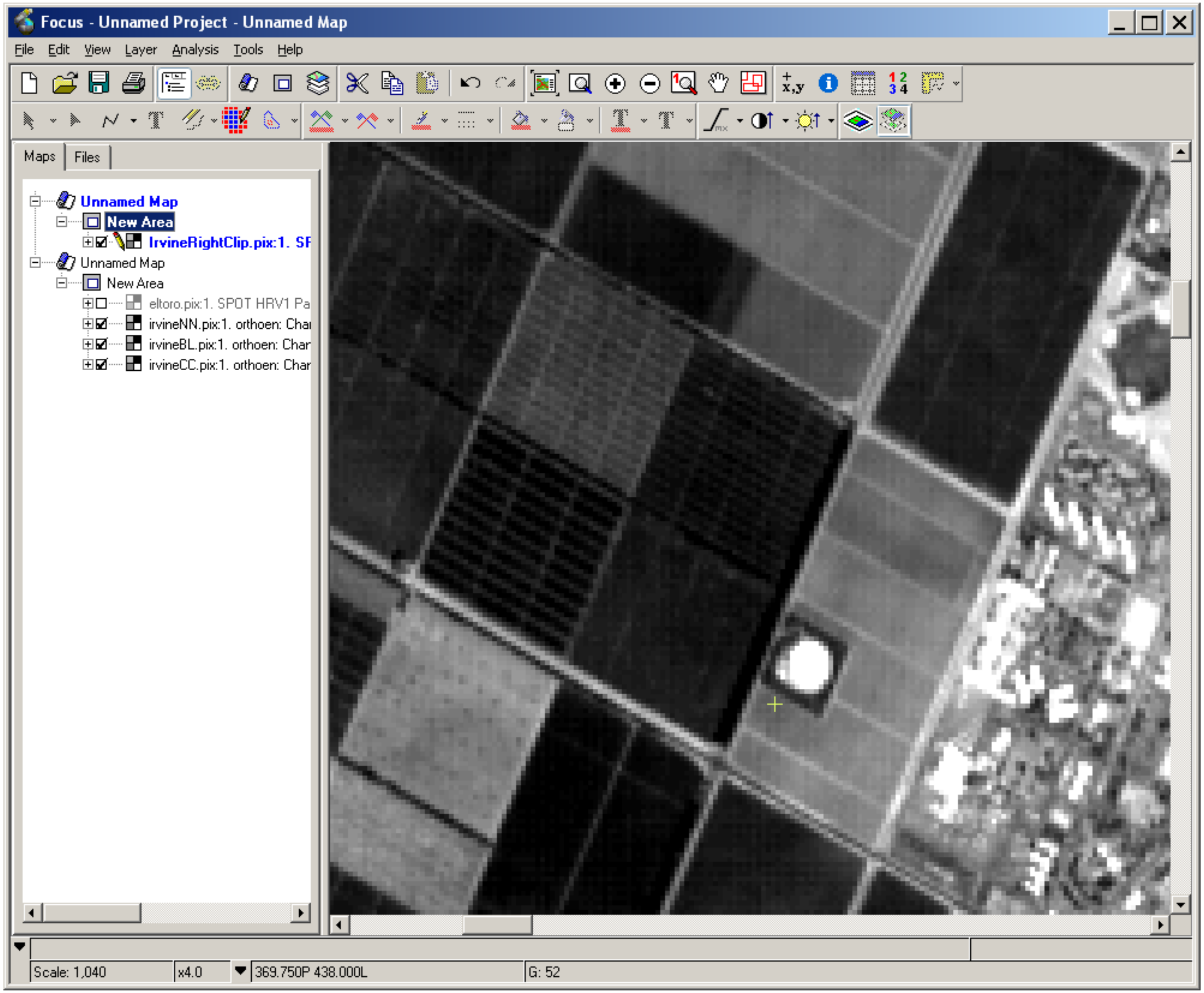
Cubic convolution interpolation

- Uses the 16 nearest pixel DN around the calculated value
- Use a cubic equation to find 4 new pixel values, then another cubic equation to find the required pixel value
- Cube function used to weight the input values pixels further away have exponentially less weight
- Advantage
    - accurate matching of input/output pixel values
    - Useful if a major grid size change is needed
- Disadvantage
    - Slow
    - Alters DN values

Compare three methods

Method	Technique	Advantages	Disadvantages
Nearest Neighbour	Transfer grey level of nearest pixel	Simple and grey levels unaltered	Image blocky; pixels may be offset by up to half a pixel
Bi-Linear Interpolation	Transfer proximity weighted average of 4 nearest pixels	Smoother and more accurate image than NN	Grey values are altered; some blurring and slower than NN
Cubic Convolution	Transfer evaluated weight of 16 nearest pixels	Very smooth image and most accurate	Grey values are altered and slower method

Original


Focus - Unnamed Project - Unnamed Map
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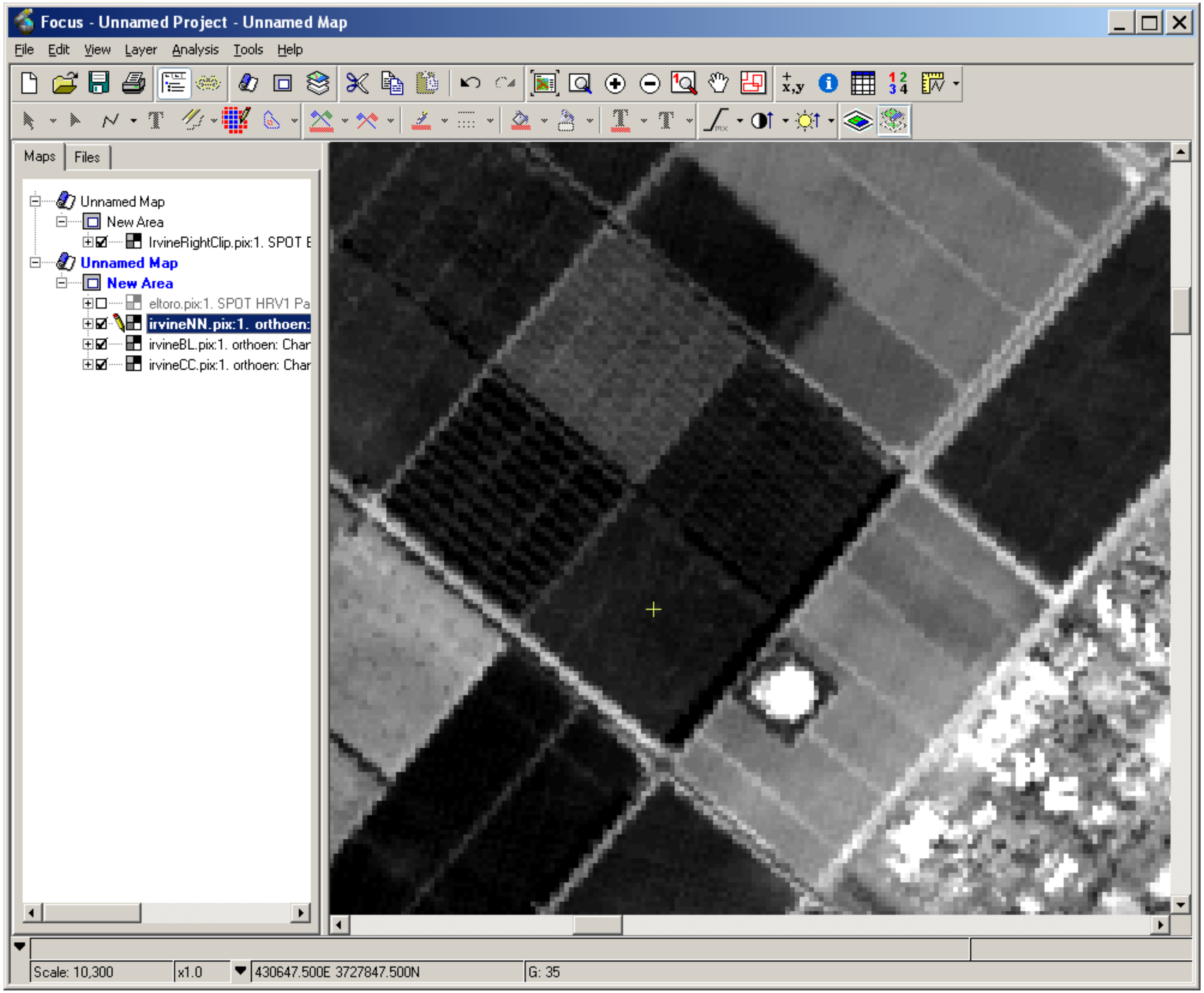
NN



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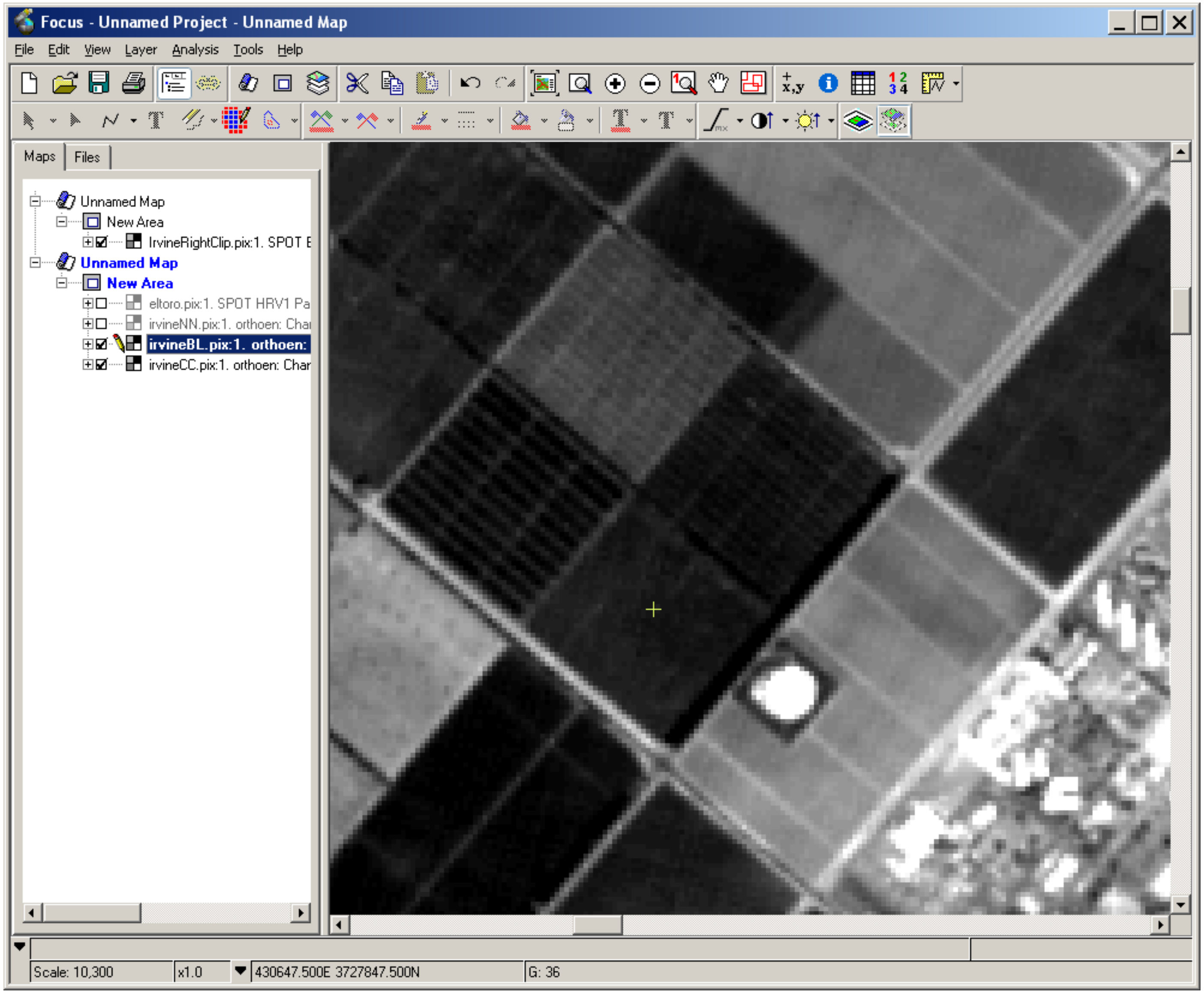
Bi-Linear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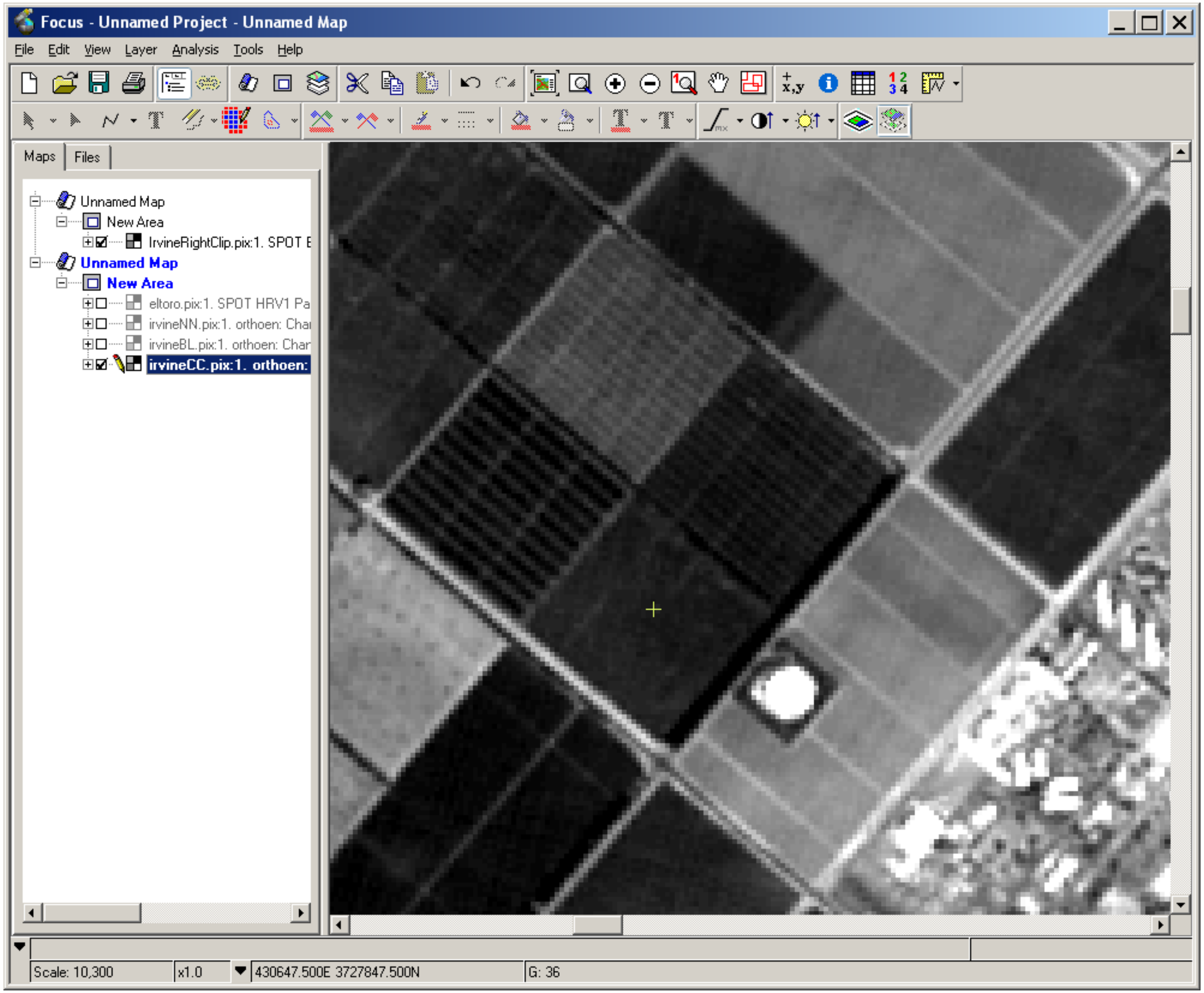
Cubic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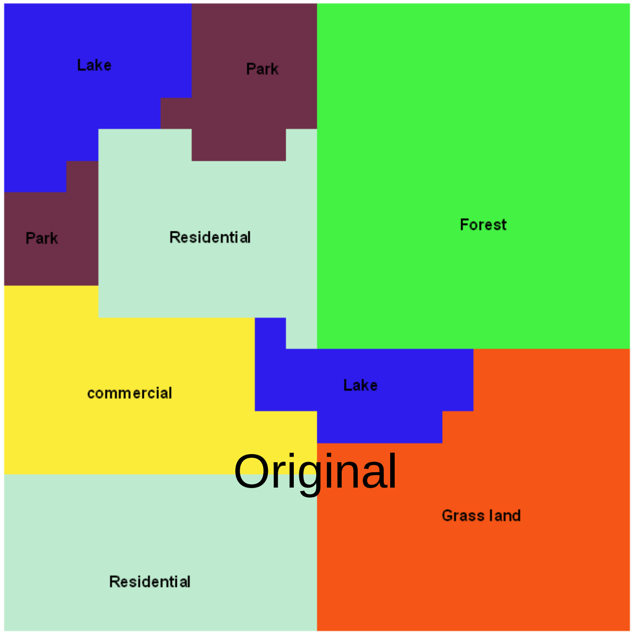
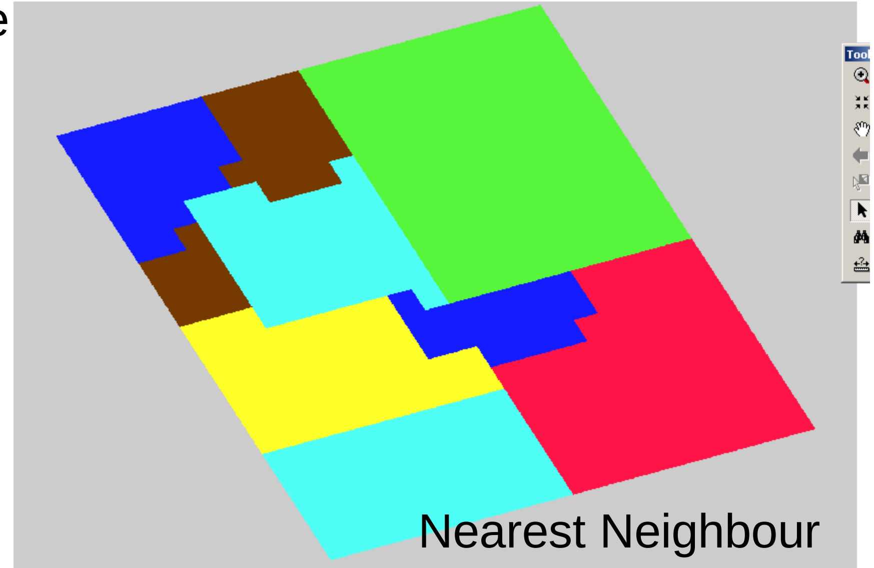
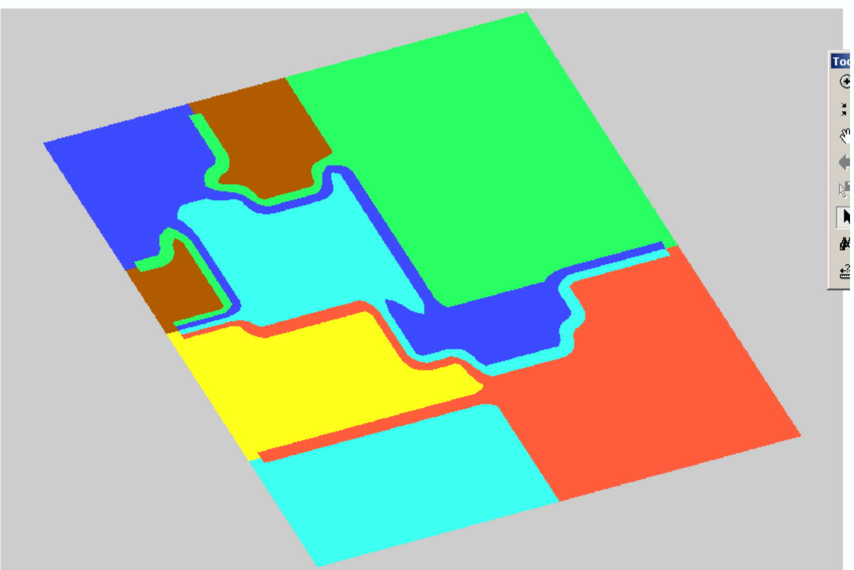
Scale: 10,300
x1.0
430647.500E 3727847.500N
G: 36

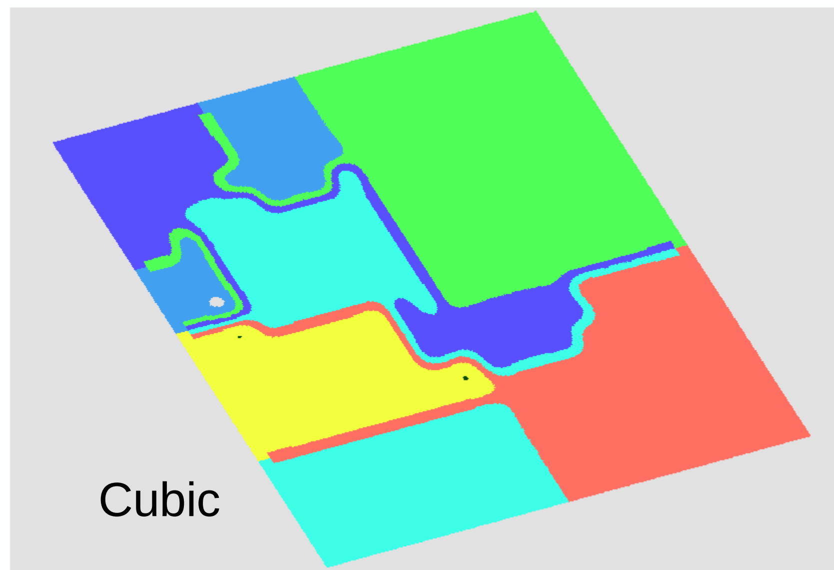
Resample with classified data







Bi-Linear



- End of lecture
- On to practical Exercises.