Geometric Transformation Based on Ground Control Points

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Introduction

- Several methods to transform satellite image to projected map for analysis
- Using ground control points (GCPs) one way
- Empirical or nonparametric: do not need orbital data, etc.

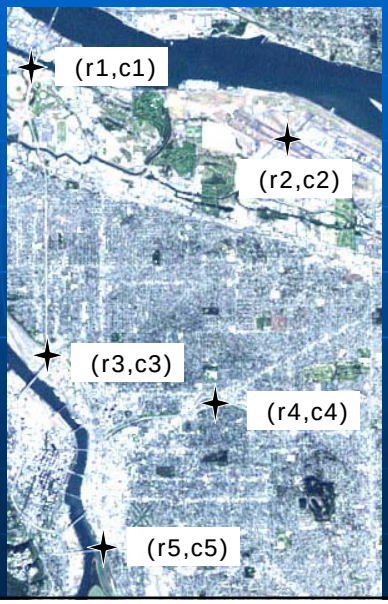
Limitations

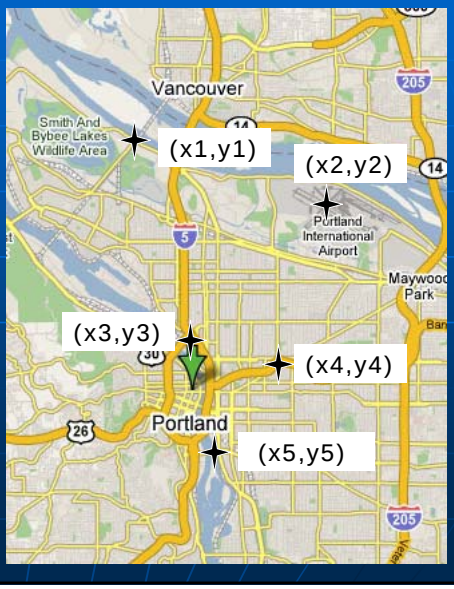
- “Easy” but labor intensive
- Must have “enough” GCPs for statistically reasonable transformation
- Limited GCPs in “boring” topographies: desert, ocean
- Map must “match” scale & area covered
- Transformation can be complicated by heterogenous terrain

Requirements

- Suitable vector map with sufficient GCPs
- Mapping software (GIS) to display & transform image
- Good hand-eye coordination
- Digitizing tablet or on-screen marking

Basic Set-up





Least Squares Regression

Regress or plot (r,c) values versus (x,y) values

Generic equations:

x = f (c,r); y = f (c,r); c = f (x,y); r = f (x,y)

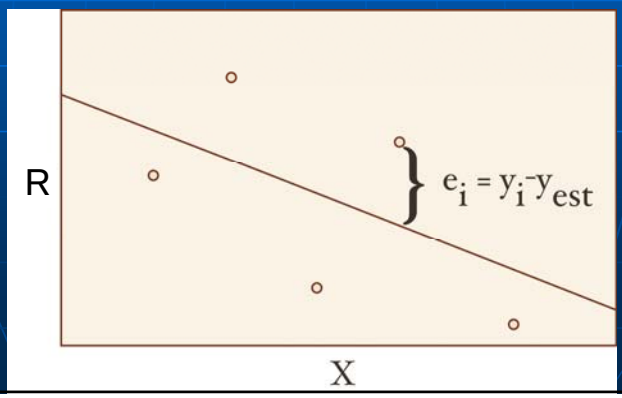
Want to minimize sum of square of residuals i.e. difference in real values versus estimated values

Software solves all 4 equations simultaneously

Least Squares Regression

Simplest is linear regression:

$X = a_o + a_1 R$



Least Squares Regression

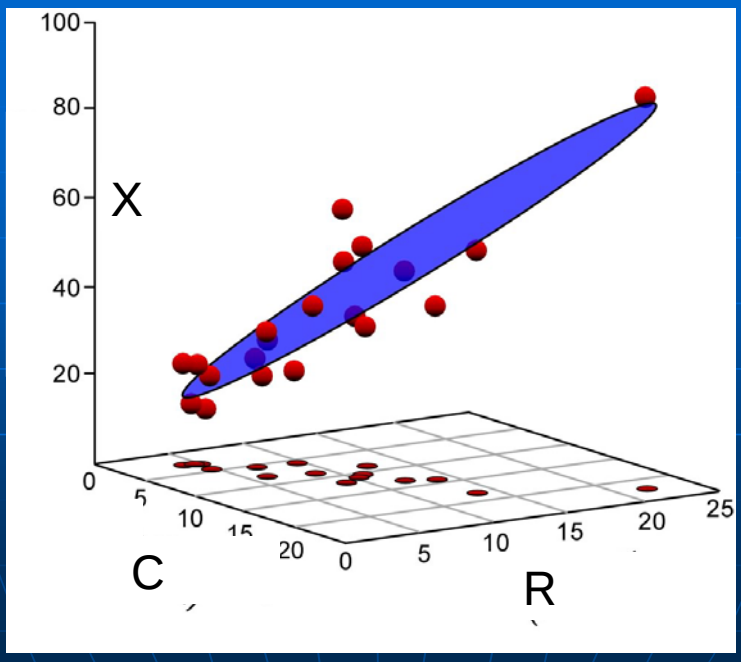
Most common geometric transformation is bivariate, affine or first-order least squares function:

$X = a_0 + a_1 R + a_2 C$

$Y = b_o + b_1 R + b_2 C$

$R = d_o + d_1 X + d_2 Y$

$C = f_0 + f_1 X + f_2 Y$



Least Squares Regression

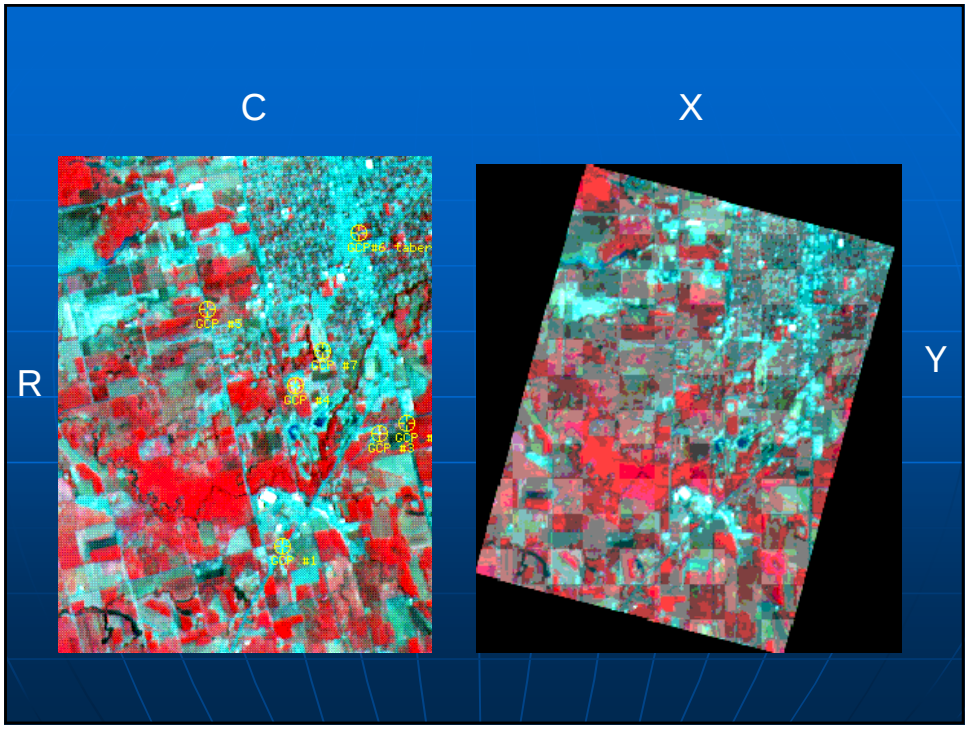
- First-order usually OK for modest resolution on relatively flat area
- Can accomplish scaling, rotation, shearing & reflection
- May need higher-order functions for oblique angles and/or rough terrain

GCPs

- Best are pinpoint, permanent features
- Need 10-15 for first-order fit, and image area up to 1024 x 1024 pixels
- Need more for relief or wide areas that induce distortion from nadir
- Need to be spread out to cover all of area
- Keep some in reserve to validate transformation

Geometric Transformation

- Once equations known:
  - Calculate X,Y coordinates of 4 corners to form bounding rectangle of transformed image
  - Then calculate X,Y coordinate of the center of each pixel
  - To get pixel values image has to be re-sampled (later)

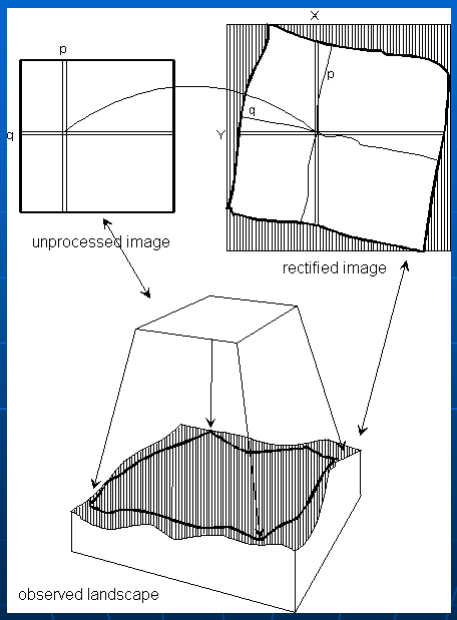


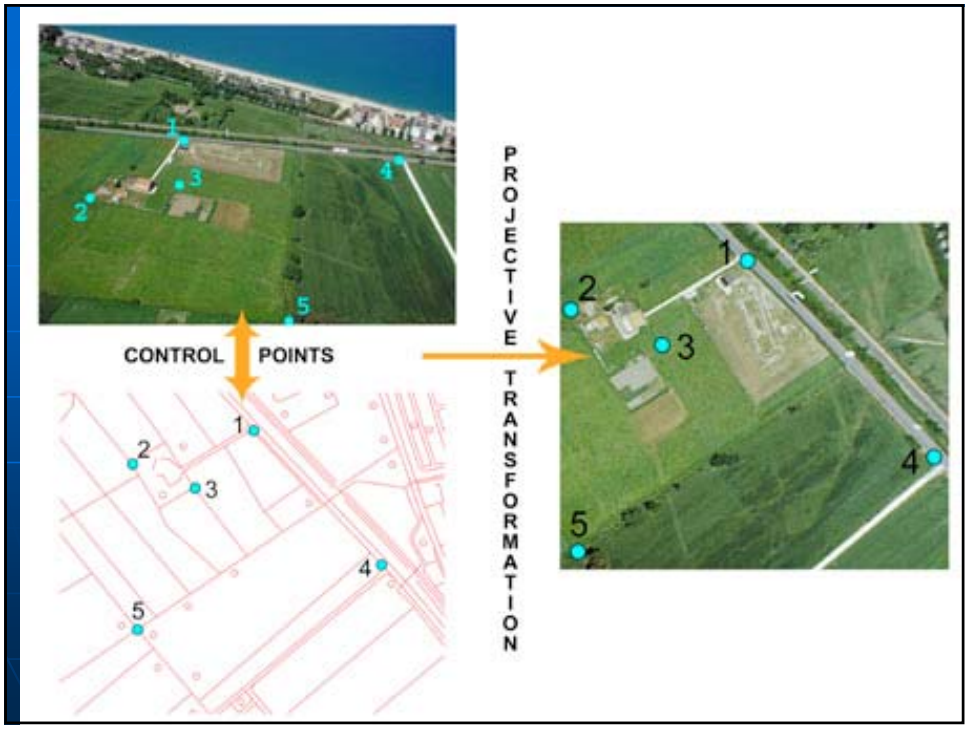
Root-Mean-Square Error

GCP	R	C	X	Y	Residual
1	134	230	3098	12	- 18.9
2	1304	304	4449	23	20.9
3	120	3245	2345	213	302.3
4	534	645	1235	324	15.5
5	756	1287	3456	250	- 12.3

RMSE

- Check each GCP for outlier
- Can try different models to minimize total RMSE
- Use other GCPs to validate transformation





Questions ?