Image Formation II
Chapter 1 (Forsyth&Ponce)

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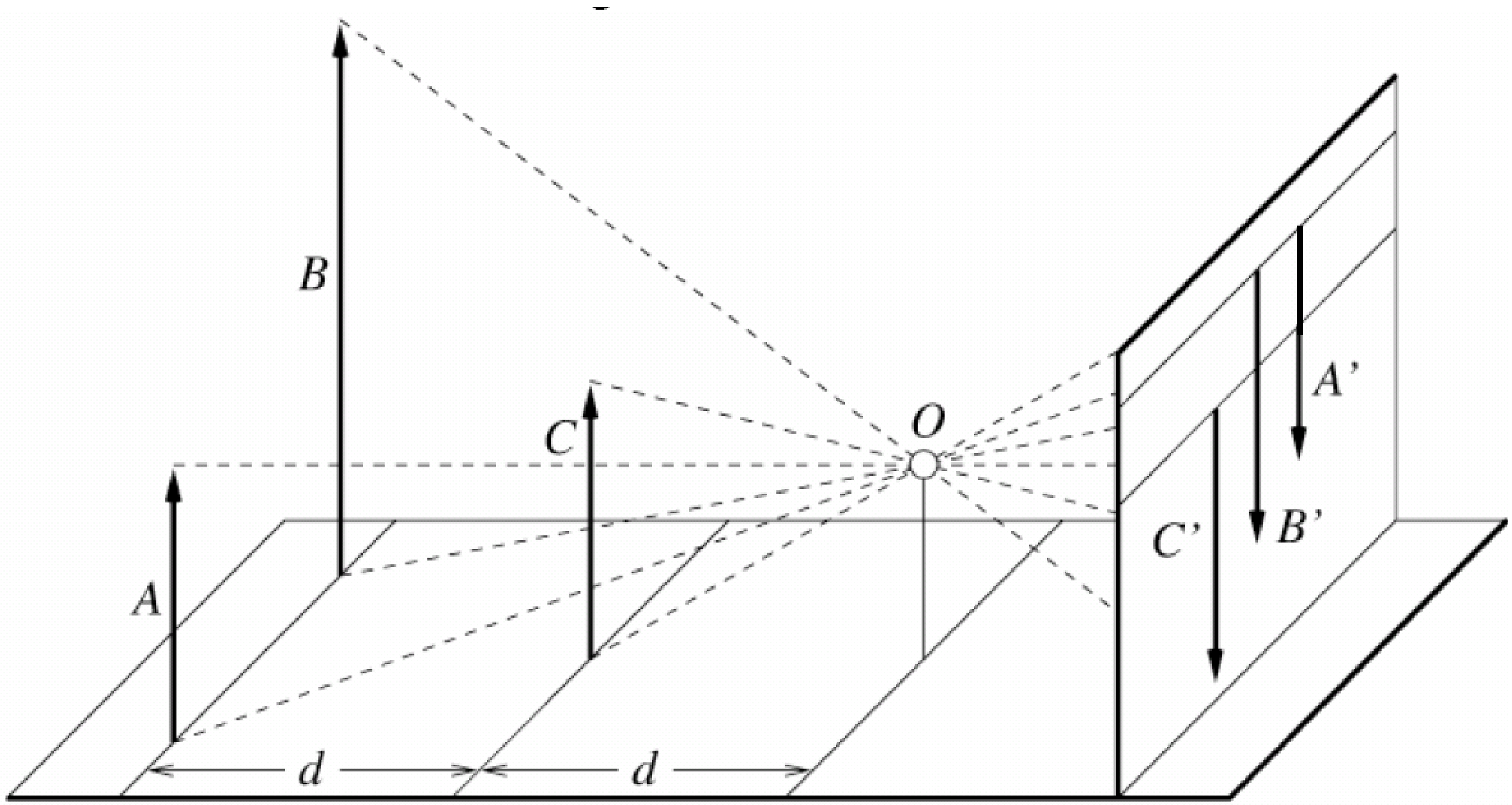
Acknowledgements:

- Slides used/modified from Prof. Trevor Darrell (trevor@eecs.berkeley.edu) (http://www.eecs.berkeley.edu/~trevor/CS280.html)

Recall, perspective effects…

- Far away objects appear smaller



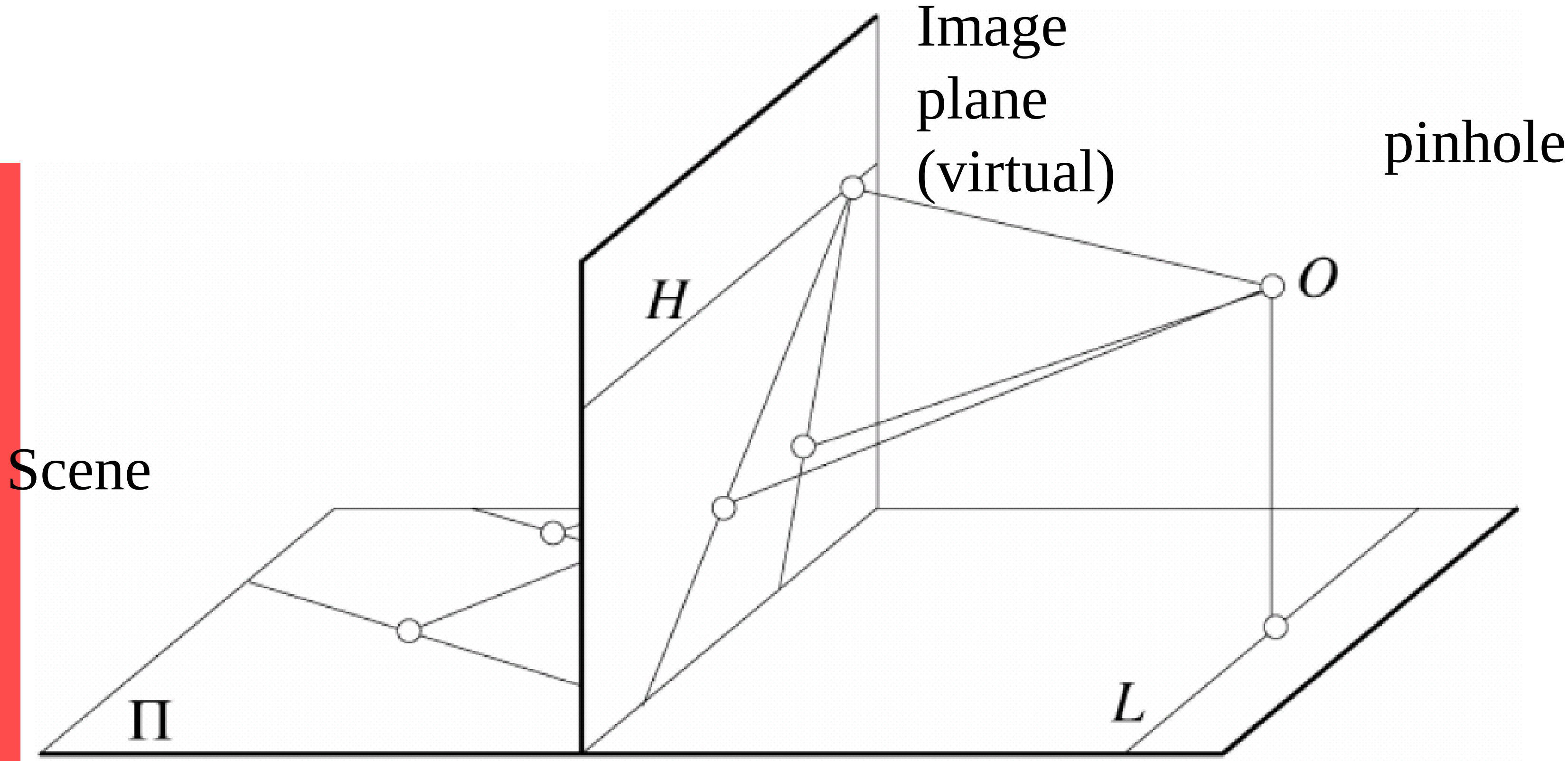
Forsyth and Ponce

Perspective effects

Perspective effects

Perspective effects

- Parallel lines in the scene intersect in the image
- Converge in image on horizon line

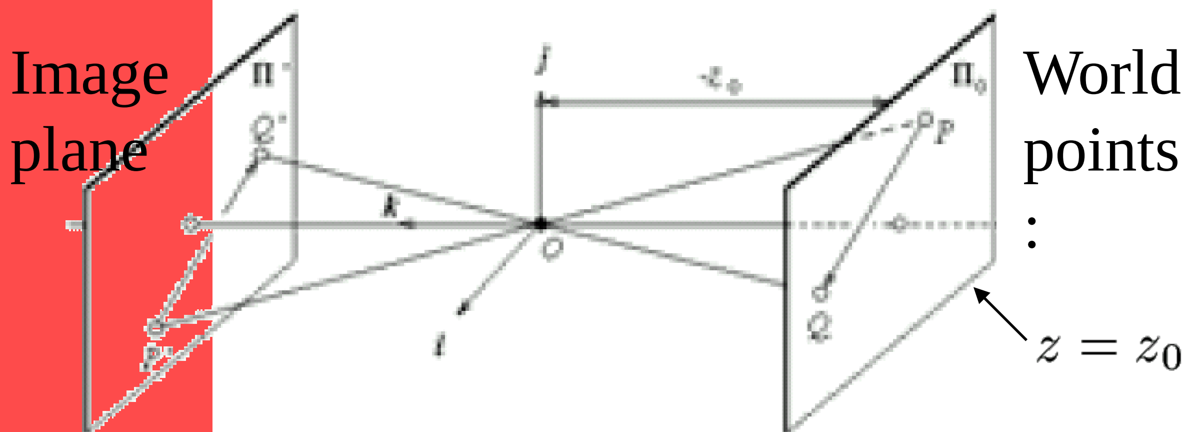


Projection properties

- Many-to-one: any points along same ray map to same point in image
- Points → ?
  - **points**
- Lines → ?
  - **lines** (collinearity preserved)
- Distances and angles are / are not **?** preserved
  - **are not**
- Degenerate cases:
  - Line through focal point projects to a point.
  - Plane through focal point projects to line
  - Plane perpendicular to image plane projects to part of the image.

Weak perspective

- Approximation: treat magnification as constant
- Assumes scene depth << average distance to camera

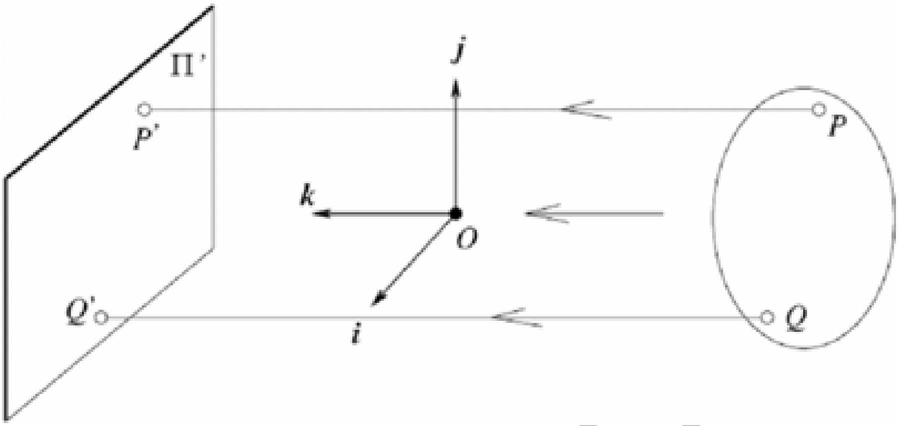


$$x' = f\frac{x}{z} \approx \frac{f}{z_0}x$$

$$y' = f\frac{y}{z} \approx \frac{f}{z_0}y$$

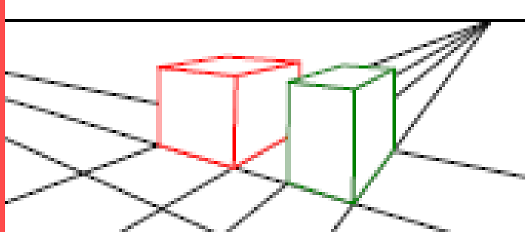
Orthographic projection

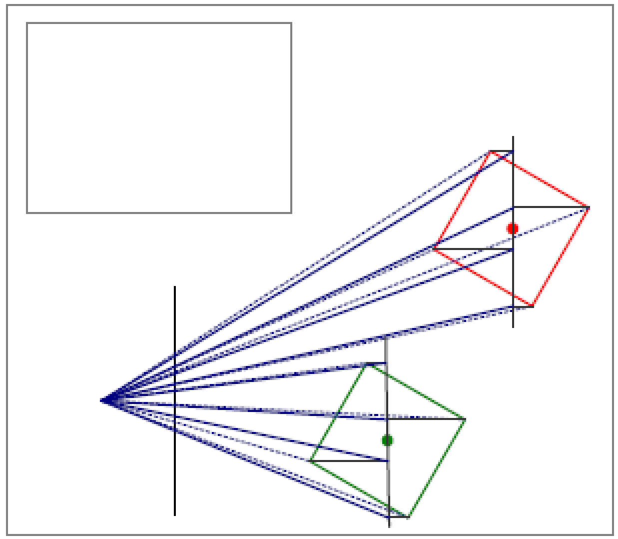
- Given camera at **constant** distance from scene
- World points projected along rays parallel to optical access



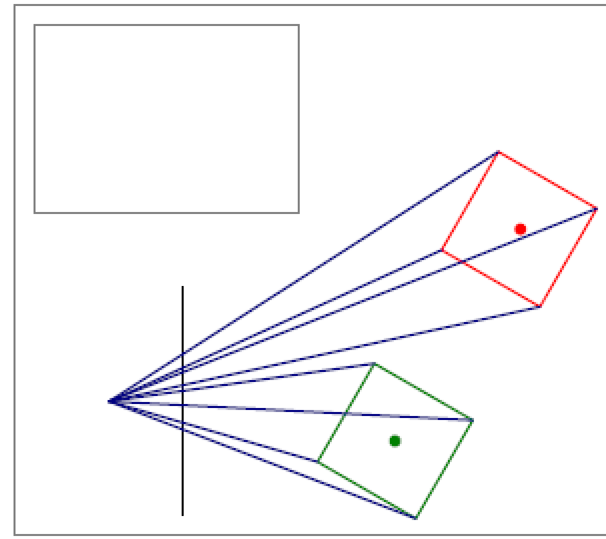
$$x' = x$$
$$y' = y$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \Rightarrow (x, y)$$





(c) scaled orthography



(e) perspective

$$\boldsymbol{x} = [s\boldsymbol{I}_{2\times2}|0]\,\boldsymbol{p}.$$

$$\boldsymbol{x} = \mathcal{P}_z(\boldsymbol{p}) = \begin{bmatrix} x/z \\ y/z \\ 1 \end{bmatrix}.$$

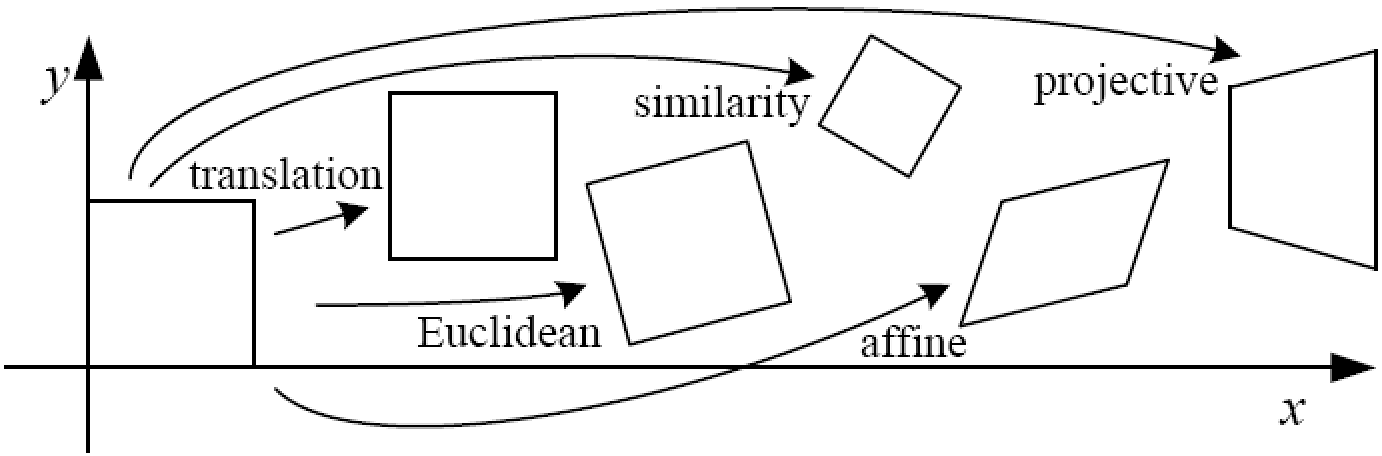
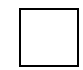
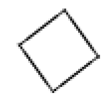
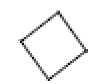
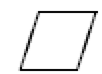
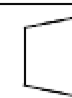


Figure 2.4: *Basic set of 2D planar transformations*

2D

Name	Matrix	# D.O.F.	Preserves:	Icon
translation	$\begin{bmatrix} \boldsymbol{I} & \vert & \boldsymbol{t} \end{bmatrix}_{2\times 3}$	2	orientation $+\cdots$	
rigid (Euclidean)	$\begin{bmatrix} \boldsymbol{R} & \vert & \boldsymbol{t} \end{bmatrix}_{2\times 3}$	3	lengths $+\cdots$	
similarity	$\begin{bmatrix} s\boldsymbol{R} & \vert & \boldsymbol{t} \end{bmatrix}_{2\times 3}$	4	angles $+\cdots$	
affine	$\begin{bmatrix} \boldsymbol{A} \end{bmatrix}_{2\times 3}$	6	parallelism $+\cdots$	
projective	$\begin{bmatrix} \tilde{\boldsymbol{H}} \end{bmatrix}_{3\times 3}$	8	straight lines	

3D

Name	Matrix	# D.O.F.	Preserves:	Icon
translation	$\left[\begin{array}{c\|c} \boldsymbol{I} & \boldsymbol{t} \end{array}\right]_{3\times 4}$	3	orientation $+\cdots$	
rigid (Euclidean)	$\left[\begin{array}{c\|c} \boldsymbol{R} & \boldsymbol{t} \end{array}\right]_{3\times 4}$	6	lengths $+\cdots$	
similarity	$\left[\begin{array}{c\|c} s\boldsymbol{R} & \boldsymbol{t} \end{array}\right]_{3\times 4}$	7	angles $+\cdots$	
affine	$\left[\begin{array}{c} \boldsymbol{A} \end{array}\right]_{3\times 4}$	12	parallelism $+\cdots$	
projective	$\left[\begin{array}{c} \tilde{\boldsymbol{H}} \end{array}\right]_{4\times 4}$	15	straight lines	

Other types of projection

- Lots of intriguing variants...
- (I’ll just mention a few fun ones)

S. Seitz

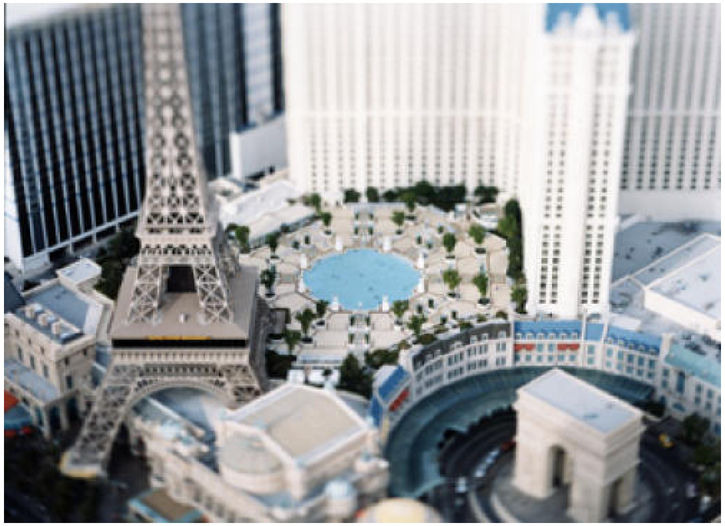
360 degree field of view…

- Basic approach
  - Take a photo of a parabolic mirror with an orthographic lens (Nayar)
  - Or buy one a lens from a variety of omnicam manufacturers…
    - See http://www.cis.upenn.edu/~kostas/omni.html

S. Seitz

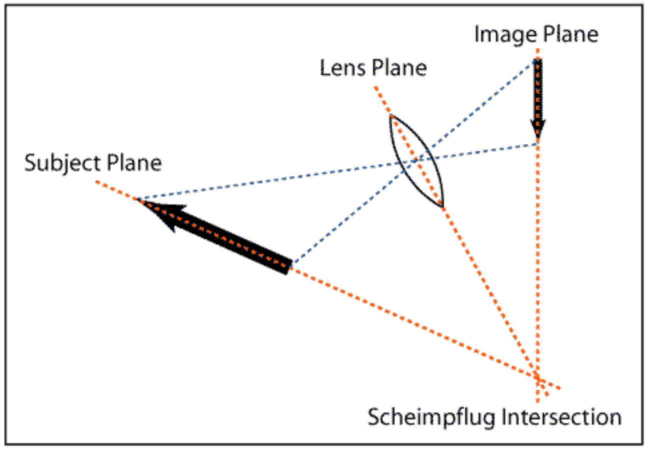
Tilt-shift

http://www.northlight-images.co.uk/article_pages/tilt_and_shift_ts-e.html

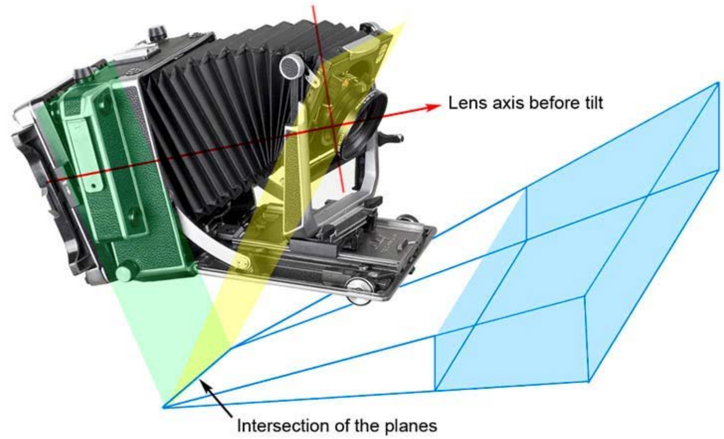


Titlt-shift images from Olivo Barbieri
and Photoshop imitations

tilt, shift



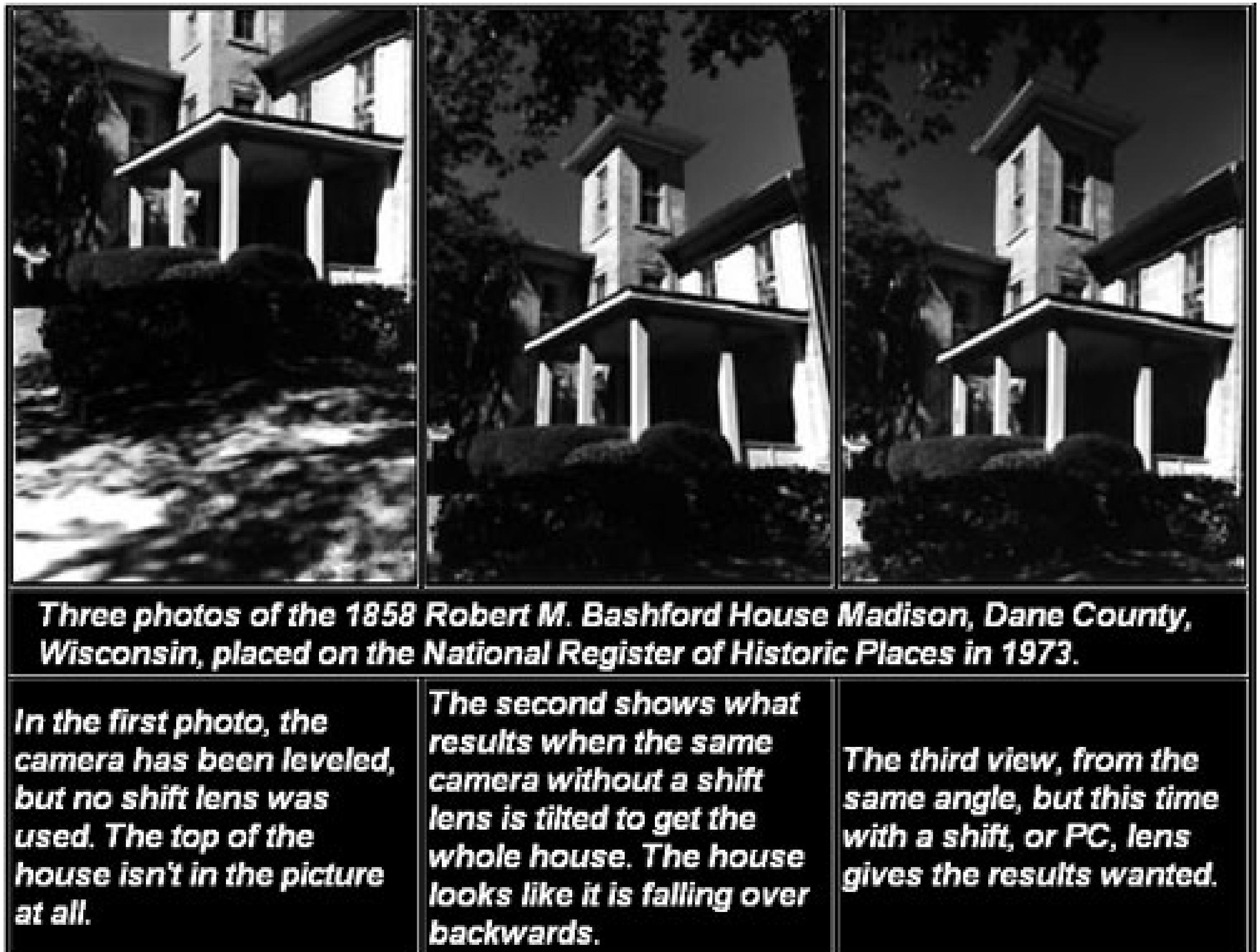
wikipedia



http://www.luminous-landscape.com/tutorials/focusing-ts.shtml

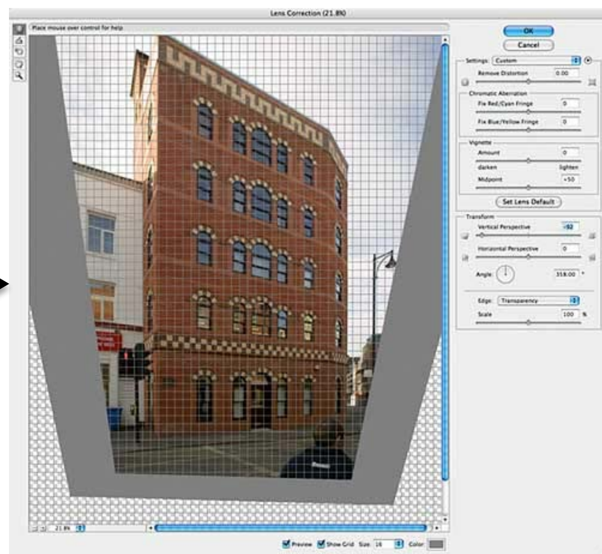
http://en.wikipedia.org/wiki/Tilt-shift_photography

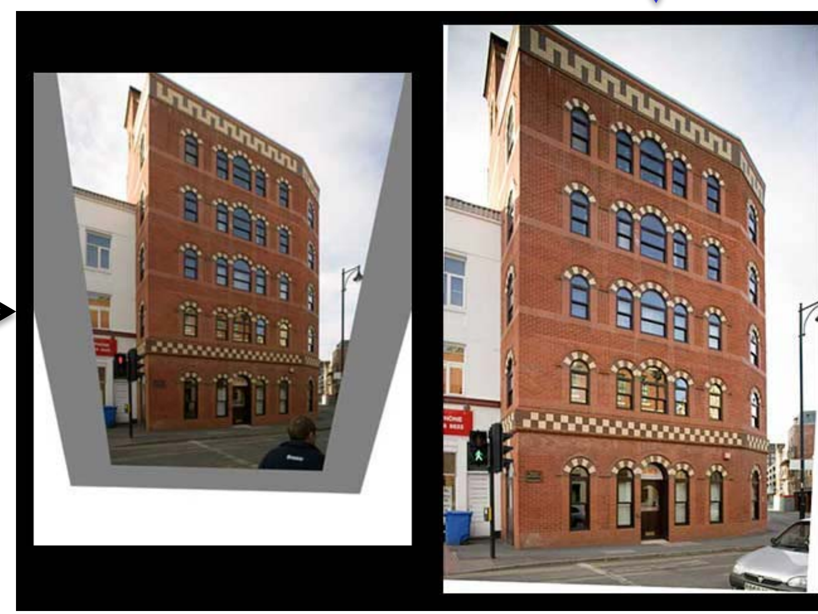
Tilt-shift perspective correction



http://en.wikipedia.org/wiki/Tilt-shift_photography normal lens

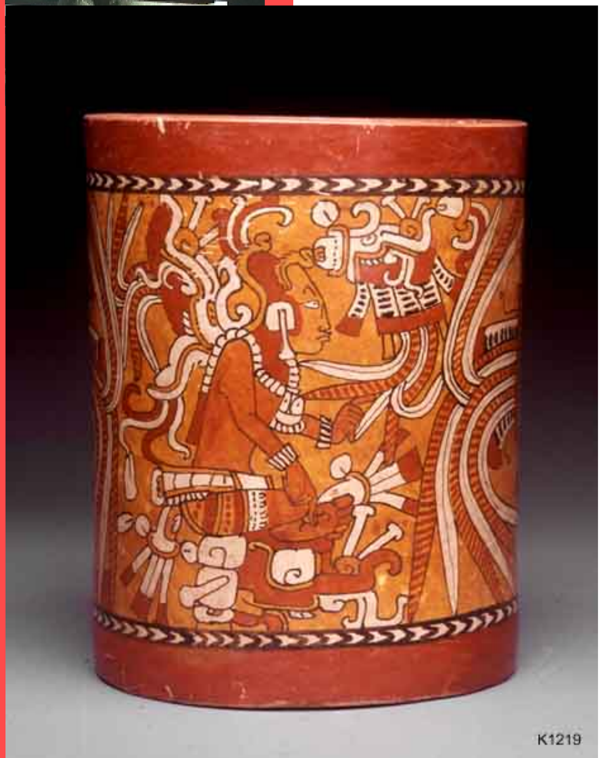
tilt-shift lens





http://www.northlight-images.co.uk/article_pages/tilt_and_shift_ts-e.html

Rotating sensor (or object)



Rollout Photographs © Justin Kerr

http://research.famsi.org/kerrmaya.html

Also known as “cyclographs”, “peripheral images”