



# Image Formation II

## Chapter 1 (Forsyth&Ponce)

Guido Gerig  
CS 6320 Spring 2013

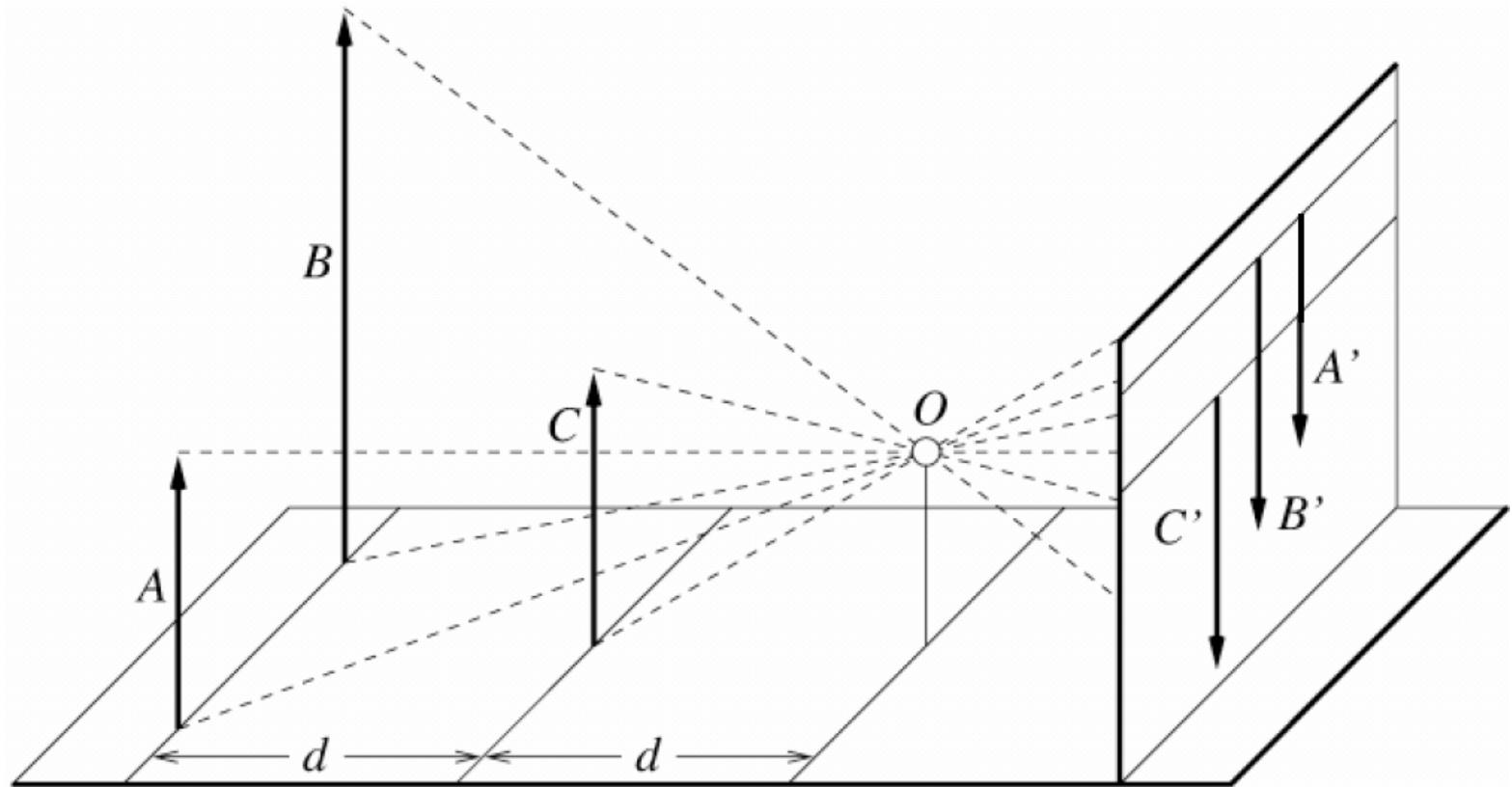
### Acknowledgements:

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



# Recall, perspective effects...

- Far away objects appear smaller



# Perspective effects





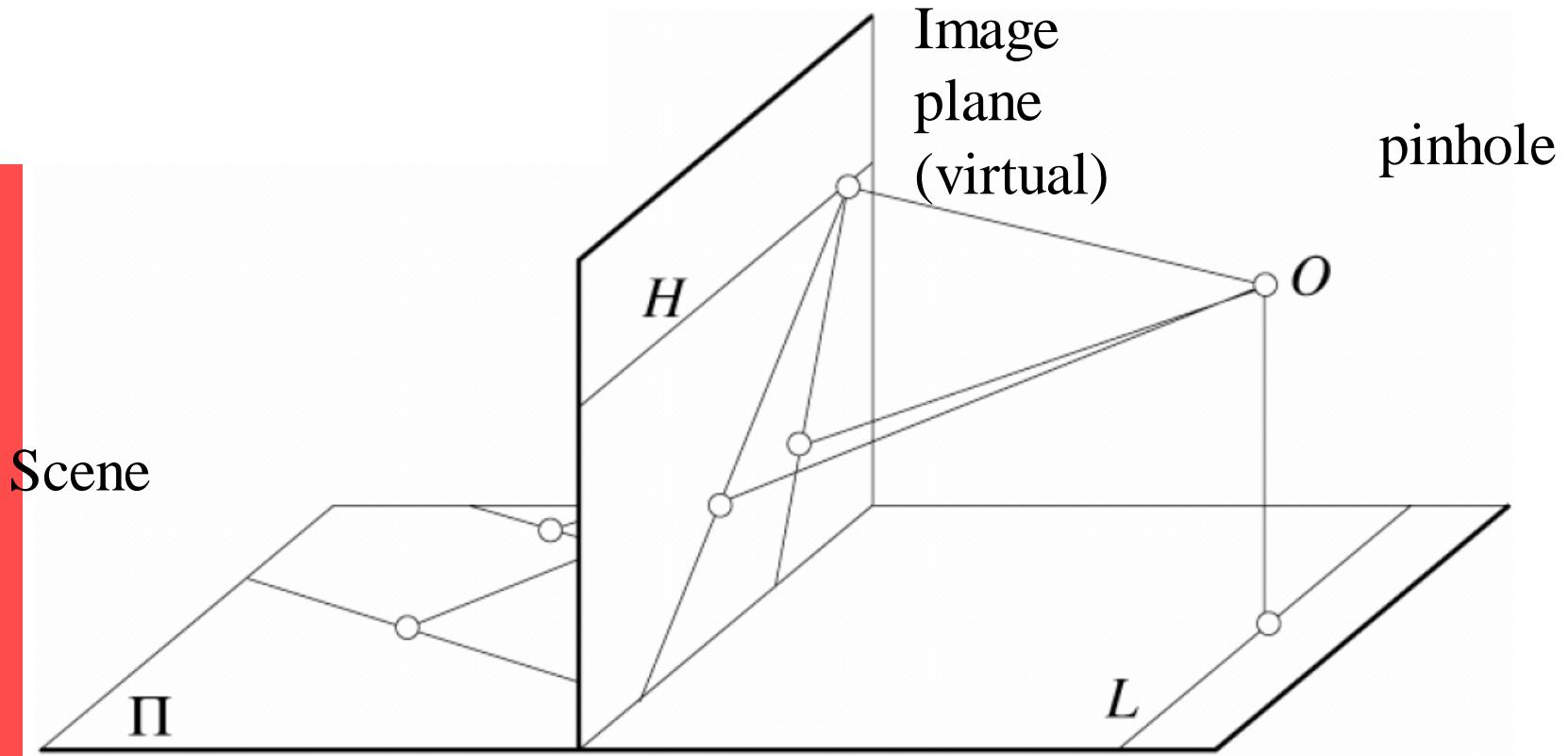
# Perspective effects





# Perspective effects

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





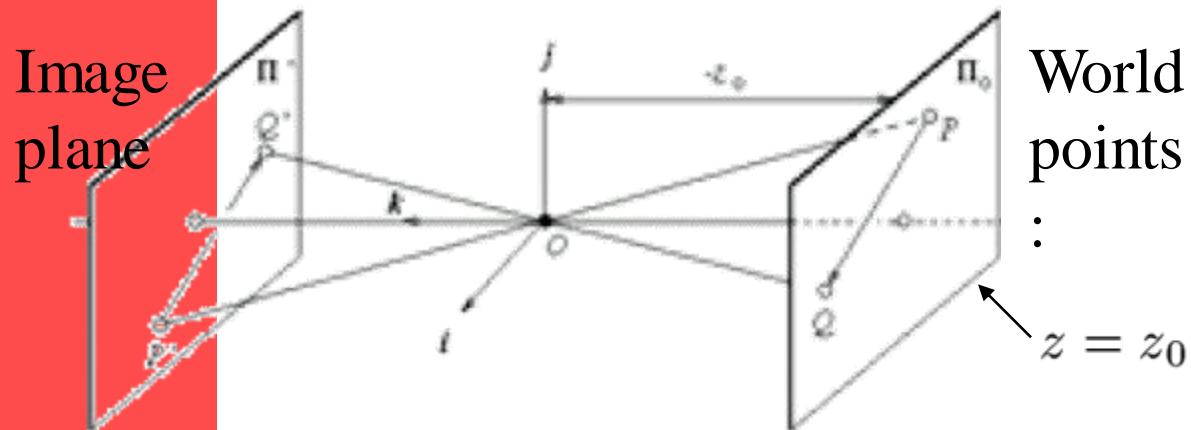
# Projection properties

- 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  $\ll$  average distance to camera



World  
points

:

$z = z_0$

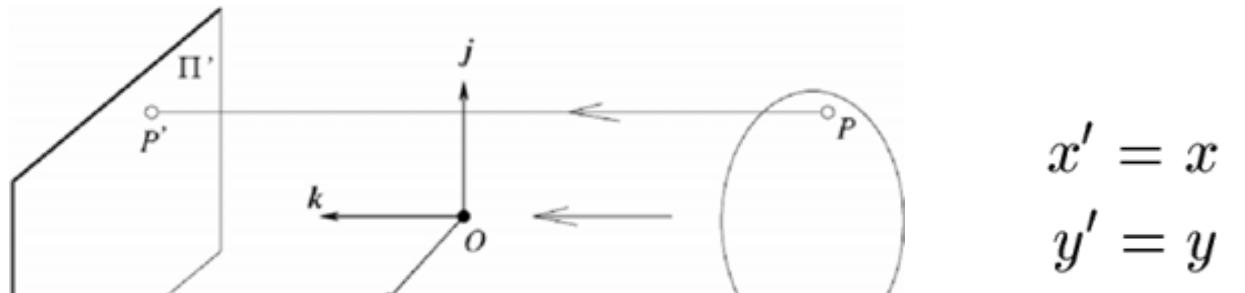
$$x' = f \frac{x}{z} \approx \frac{f}{z_0} x$$

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

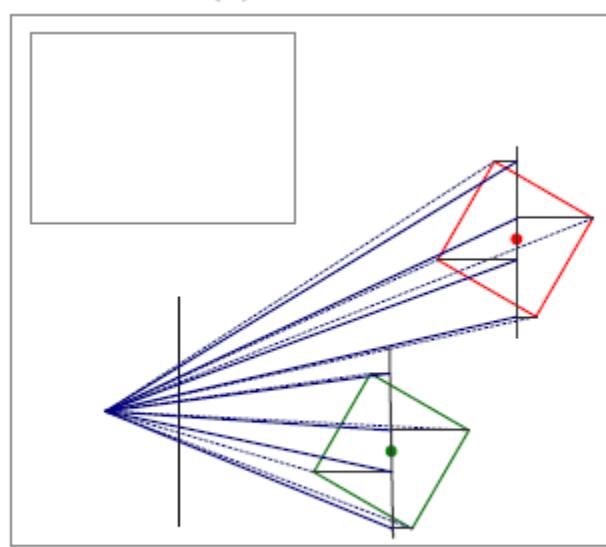
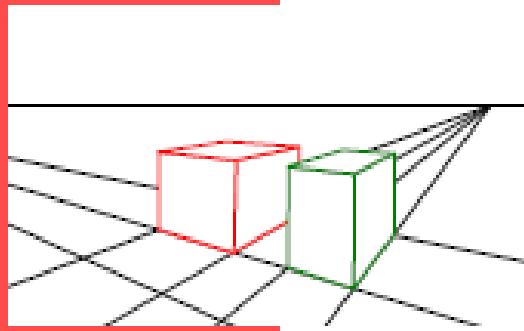


# Orthographic projection

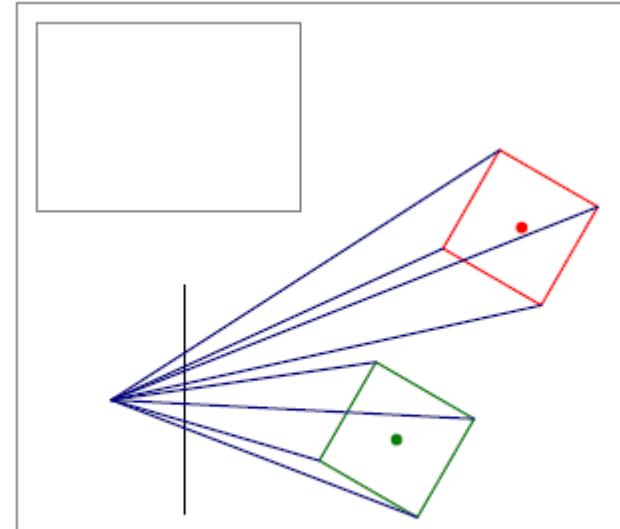
- Given camera at **constant** distance from scene
- World points projected along rays parallel to optical access



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



(c) scaled orthography



(e) perspective

$$x = [sI_{2 \times 2} | 0] p.$$

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

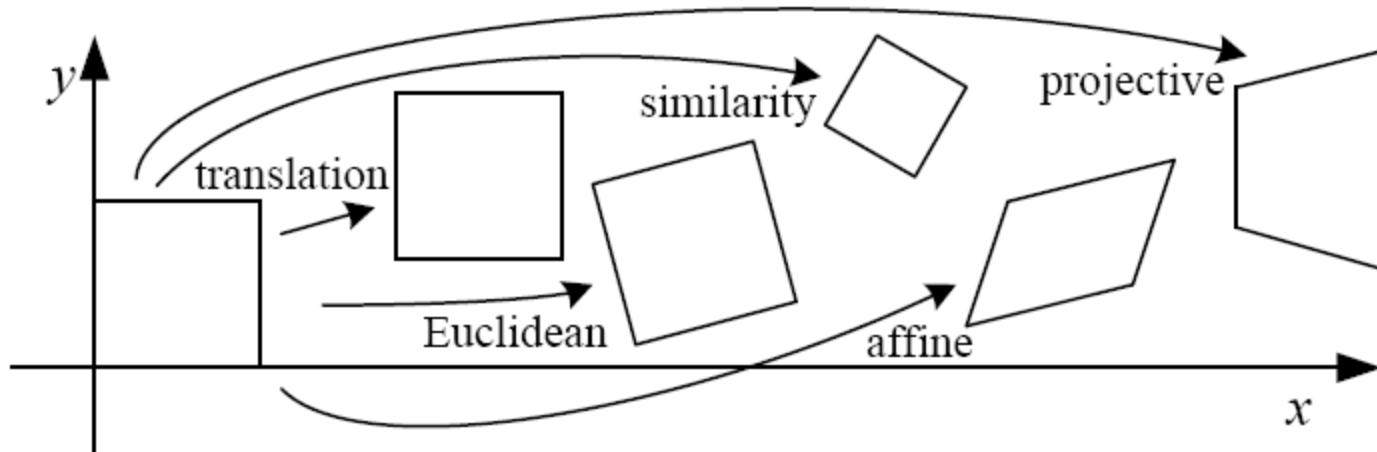


Figure 2.4: *Basic set of 2D planar transformations*



# 2D

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



# 3D

Name	Matrix	# D.O.F.	Preserves:	Icon
translation	$\begin{bmatrix} \mathbf{I} & \mathbf{t} \end{bmatrix}_{3\times 4}$	3	orientation + ⋯	
rigid (Euclidean)	$\begin{bmatrix} \mathbf{R} & \mathbf{t} \end{bmatrix}_{3\times 4}$	6	lengths + ⋯	
similarity	$\begin{bmatrix} s\mathbf{R} & \mathbf{t} \end{bmatrix}_{3\times 4}$	7	angles + ⋯	
affine	$\begin{bmatrix} \mathbf{A} \end{bmatrix}_{3\times 4}$	12	parallelism + ⋯	
projective	$\begin{bmatrix} \tilde{\mathbf{H}} \end{bmatrix}_{4\times 4}$	15	straight lines	



# Other types of projection

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



# 360 degree field of view...

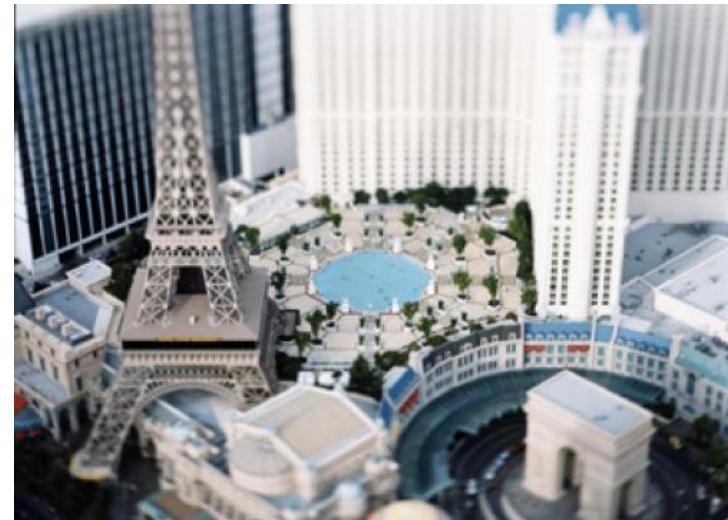
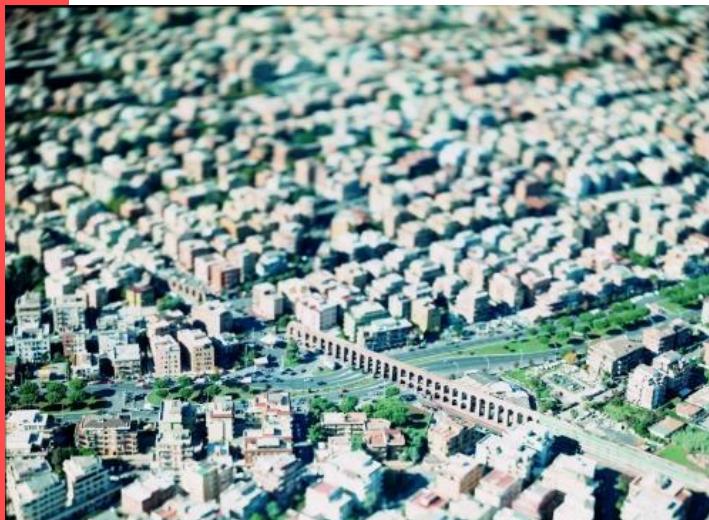


- Basic approach
  - Take a photo of a parabolic mirror with an orthographic lens (Nayar)
  - Or buy one a lens from a variety of omnicam manufacturers...
    - See <http://www.cis.upenn.edu/~kostas/omni.html>

# Tilt-shift



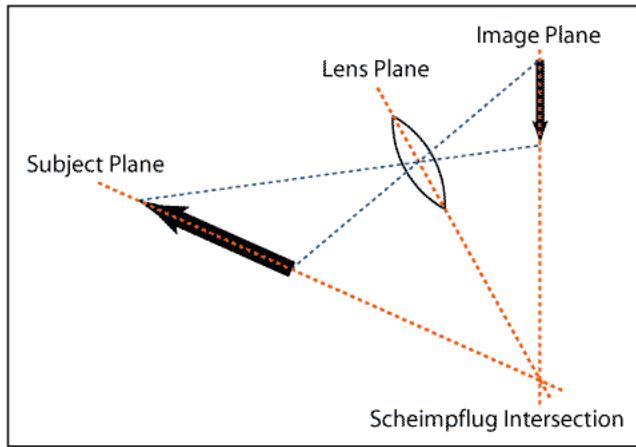
[http://www.northlight-images.co.uk/article\\_pages/tilt\\_and\\_shift\\_ts-e.html](http://www.northlight-images.co.uk/article_pages/tilt_and_shift_ts-e.html)



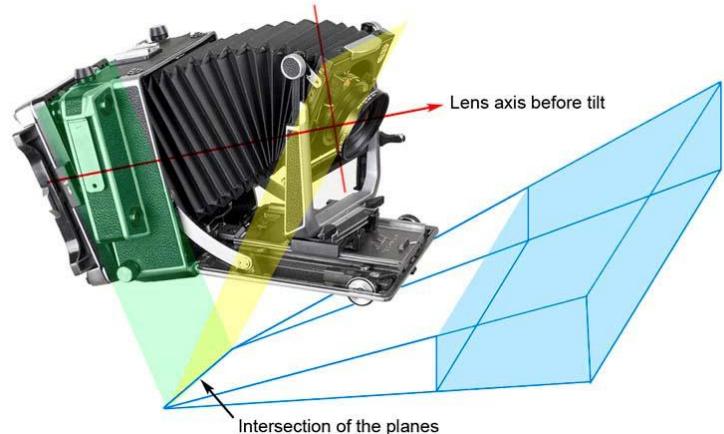
Tilt-shift images from [Olivo Barbieri](#)  
and Photoshop [imitations](#)



# tilt, shift



wikipedia



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



[http://en.wikipedia.org/wiki/Tilt-shift\\_photography](http://en.wikipedia.org/wiki/Tilt-shift_photography)



# Tilt-shift perspective correction



*Three photos of the 1858 Robert M. Bashford House Madison, Dane County, Wisconsin, placed on the National Register of Historic Places in 1973.*

*In the first photo, the camera has been leveled, but no shift lens was used. The top of the house isn't in the picture at all.*

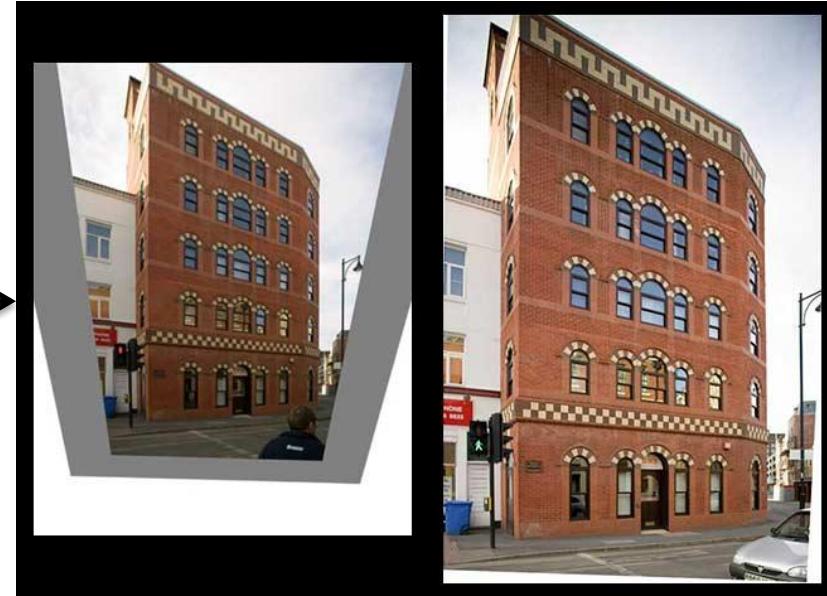
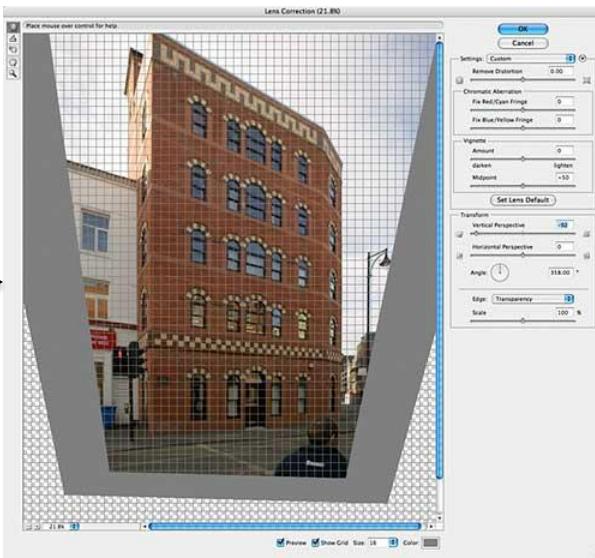
*The second shows what results when the same camera without a shift lens is tilted to get the whole house. The house looks like it is falling over backwards.*

*The third view, from the same angle, but this time with a shift, or PC, lens gives the results wanted.*

normal lens

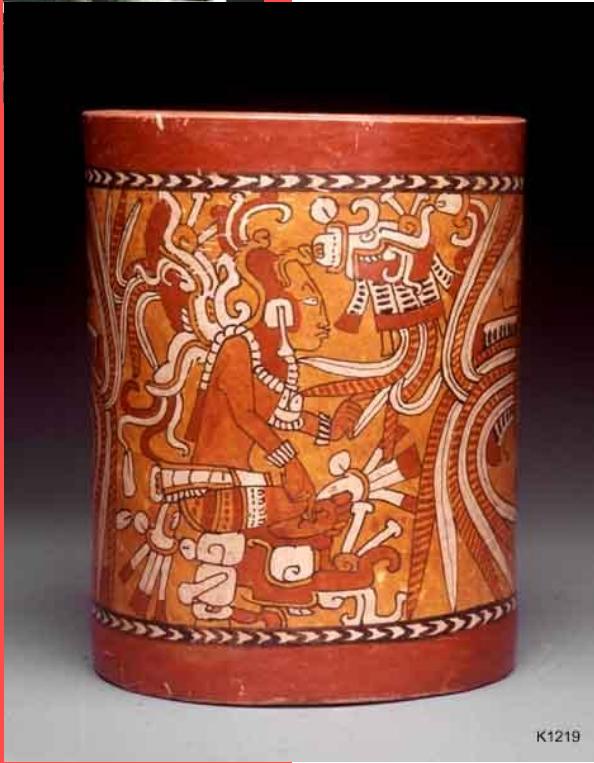


tilt-shift lens





# Rotating sensor (or object)



Rollout Photographs © Justin Kerr  
<http://research.famsi.org/kerrmaya.html>

Also known as “cyclographs”, “peripheral images”