Lecture 4

Single View Metrology

Professor Silvio Savarese

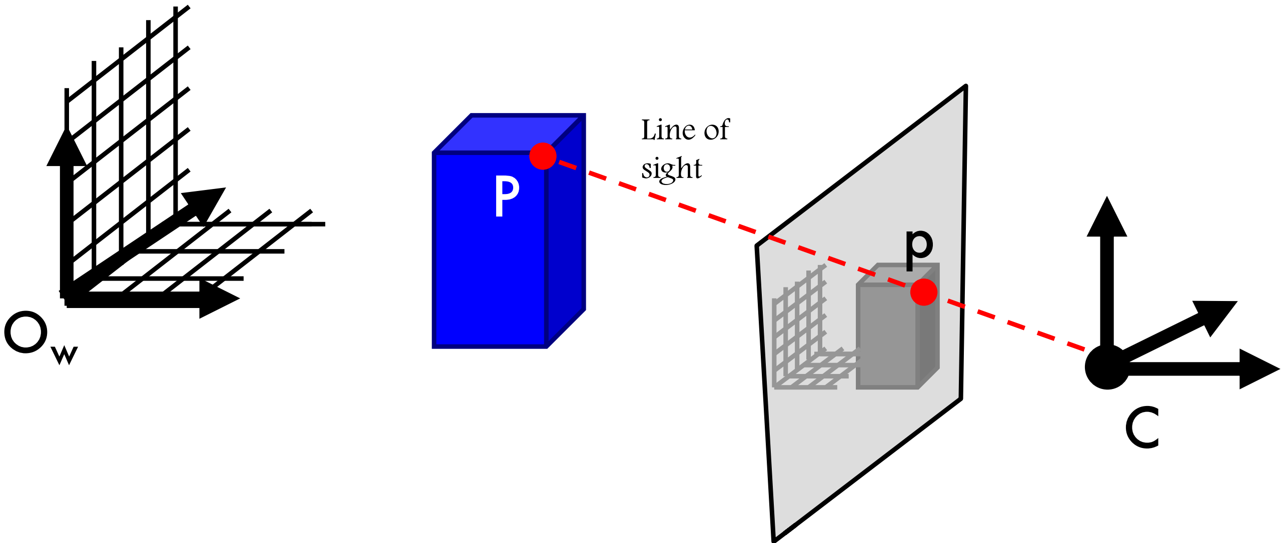
Computational Vision and Geometry Lab

Lecture 4
Single View Metrology

- Review calibration and 2D transformations
- Vanishing points and lines
- Estimating geometry from a single image
- Extensions

Reading:
[HZ] Chapter 2 “Projective Geometry and Transformation in 2D”
[HZ] Chapter 3 “Projective Geometry and Transformation in 3D”
[HZ] Chapter 8 “More Single View Geometry”
[Hoeim & Savarese] Chapter 2

Once the camera is calibrated...



$$M = K\begin{bmatrix} R & T \end{bmatrix}$$

-Internal parameters K are known

-R, T are known – but these can only relate C to the calibration rig

Can I estimate P from the measurement p from a single image?

No - in general ☹ (P can be anywhere along the line defined by C and p)

Recovering structure from a single view

http://www.robots.ox.ac.uk/~vgg/projects/SingleView/models/hut/hutme.wrl

Transformation in 2D

-Isometries

-Similarities

-Affinity

-Projective

Transformation in 2D

$det(R) = \pm 1$

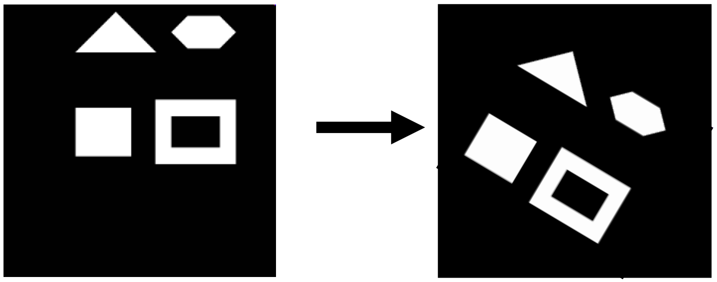
$R^T R = I$

Isometries:

[Euclideans]

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} R & t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = H_e \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$ [Eq. 4]

- Preserve distance (areas)
- 3 DOF → 1 rot, 2 translation
- Regulate motion of rigid object



Transformation in 2D

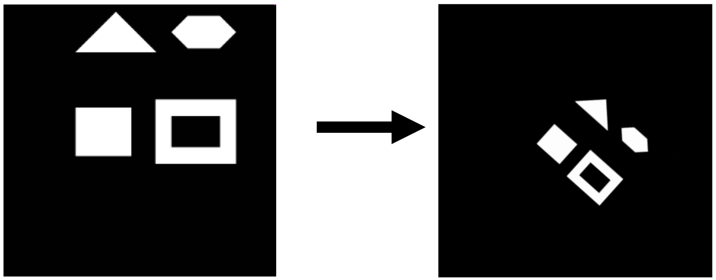
$$(sR^T)(sR) = s^2 I$$

Similarities:
$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} S\,R & t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = H_s \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

[Eq. 5]

$$S = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix}$$

- Preserve
    - ratio of lengths
    - angles
-4 DOF



Transformation in 2D

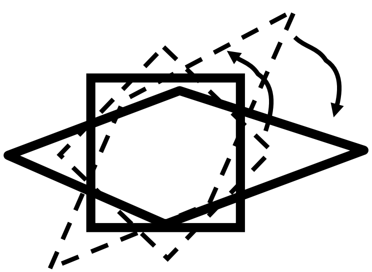
$A^T A \begin{bmatrix} & \emptyset \\ \emptyset & \end{bmatrix}$ non-zero

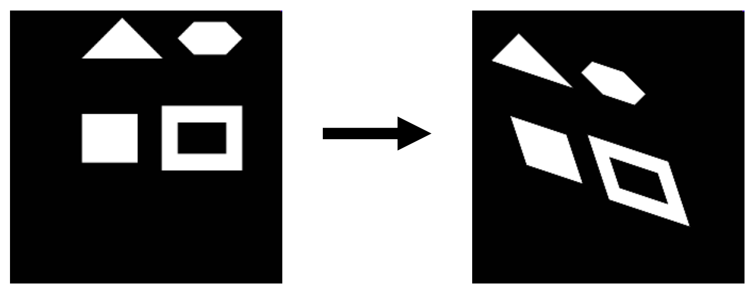
Affinities:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} A & t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = H_a \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad \text{[Eq. 6]}$$

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = R(\theta) \cdot R(-\phi) \cdot D \cdot R(\phi) \qquad D = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix}$$

[Eq. 7]





Transformation in 2D

Affinities:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} A & t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = H_a \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

[Eq. 6]

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = R(\theta) \cdot R(-\phi) \cdot D \cdot R(\phi) \qquad D = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix}$$

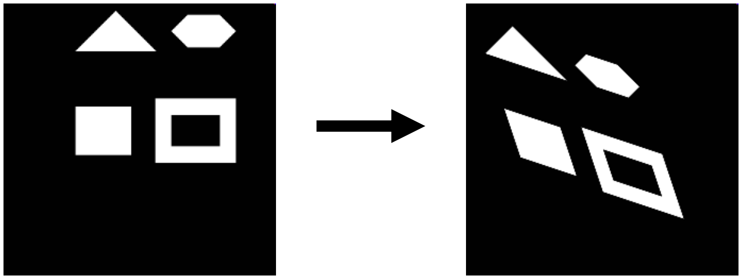
[Eq. 7]

$A = UDV^T = UV^TVDV^T = (UV^T)(V)(D)(V^T)$

-Preserve:

- Parallel lines
- Ratio of areas
- Ratio of lengths on collinear lines
- others…

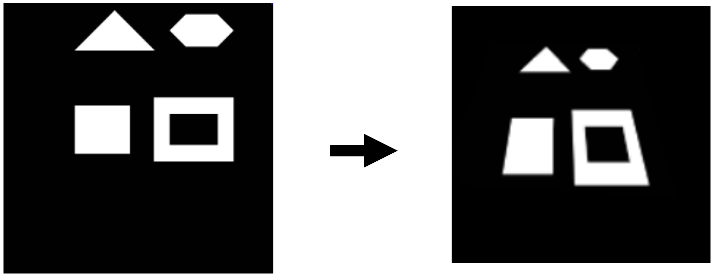
- 6 DOF



Transformation in 2D

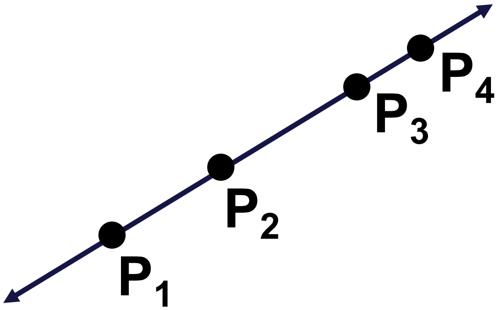
Projective:
$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} A & t \\ \boxed{v} & b \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = H_p \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$
[Eq. 8]

- 8 DOF → 9 elements of matrix minus the scaling factor (3,3)
- Preserve:
  - collinearity
  - cross ratio of 4 collinear points
  - and a few others…



The cross ratio

The cross-ratio of 4 collinear points is defined as



[Eq. 9]

$$\frac{\|\mathbf{P}_3 - \mathbf{P}_1\| \, \|\mathbf{P}_4 - \mathbf{P}_2\|}{\|\mathbf{P}_3 - \mathbf{P}_2\| \, \|\mathbf{P}_4 - \mathbf{P}_1\|}$$

$$\mathbf{P}_i = \begin{bmatrix} X_i \\ Y_i \\ Z_i \\ 1 \end{bmatrix}$$

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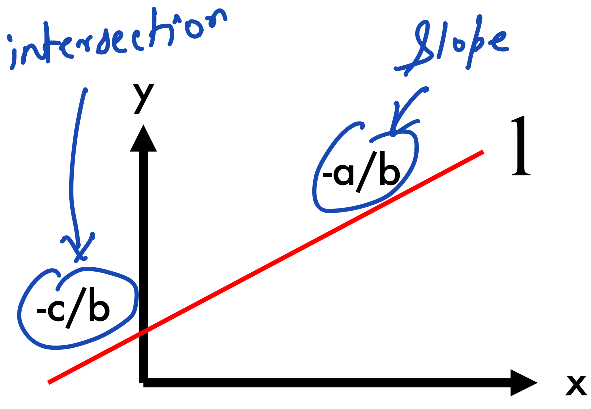
Lines in a 2D plane

$y = -\frac{a}{b}x - \frac{c}{b}$

$$ax + by + c = 0$$

$$l = \begin{bmatrix} a \\ b \\ c \end{bmatrix}$$



If $x = [\, x_1, x_2]^T \in l$

if x lies on the line, dot product = 0

$$\begin{bmatrix} x_1 \\ x_2 \\ 1 \end{bmatrix}^T \begin{bmatrix} a \\ b \\ c \end{bmatrix} = 0$$

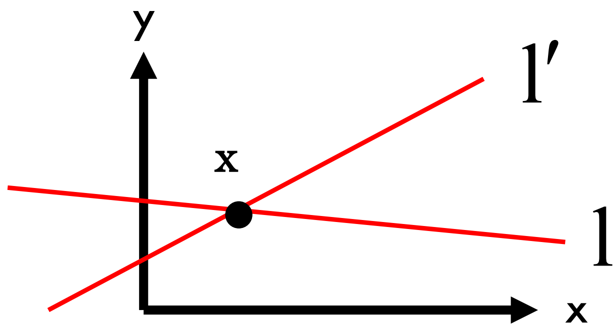
[Eq. 10]

Lines in a 2D plane

Intersecting lines

$l \times l'$

$$\mathrm{x} = \mathrm{l} \times \mathrm{l}' \quad \text{[Eq. 11]}$$



Proof

$$l \rightarrow \mathrm{l} \times \mathrm{l}' \perp \mathrm{l} \quad \rightarrow (\mathrm{l} \times \mathrm{l}') \cdot \mathrm{l} = 0 \quad \rightarrow \underline{x \in l} \quad \text{[Eq. 12]}$$

$$\mathrm{l} \times \mathrm{l}' \perp \mathrm{l}' \quad \rightarrow \underbrace{(\mathrm{l} \times \mathrm{l}')}_{\mathrm{x}} \cdot \mathrm{l}' = 0 \quad \rightarrow \underline{x \in l'} \quad \text{[Eq. 13]}$$

x belongs to both l & l'

$\rightarrow$ x is the intersection point

2D Points at infinity (ideal points)

$ax+by+c=0 \Rightarrow y = -\frac{a}{b}x - \frac{c}{b}$ slope

$$\mathrm{x} = \begin{bmatrix} \mathrm{x}_1 \\ \mathrm{x}_2 \\ \mathrm{x}_3 \end{bmatrix}, \mathrm{x}_3 \neq 0$$

$$l \times l' = \begin{vmatrix} i & j & k \\ a & b & c \\ a' & b' & c' \end{vmatrix} = \begin{bmatrix} bc' - cb' \\ ca' - ac' \\ ab' - a'b \end{bmatrix}$$

$ab' - a'b = 0$

$$x_\infty = \begin{bmatrix} x'_1 \\ x'_2 \\ 0 \end{bmatrix}$$

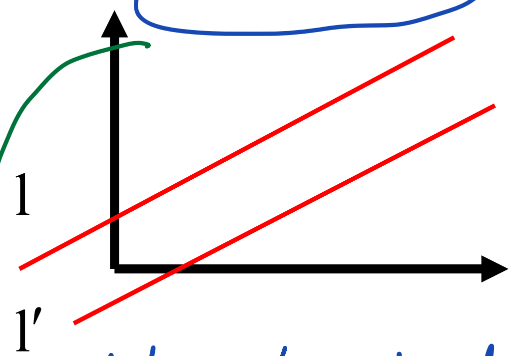
$$x_{euclidean} = \begin{bmatrix} x'_1/0 \\ x'_2/0 \end{bmatrix} = \begin{bmatrix} \infty \\ \infty \end{bmatrix}$$

same slope

$$-a/b = -a'/b'$$

Parallel lines

$$\mathrm{l} = \begin{bmatrix} \mathrm{a} \\ \mathrm{b} \\ \mathrm{c} \end{bmatrix} \qquad l' = \begin{bmatrix} a' \\ b' \\ c' \end{bmatrix}$$



Let's intersect two parallel lines:

intersection point for parallel lines is at ∞

$$\rightarrow l \times l' \propto \begin{bmatrix} b \\ -a \\ 0 \end{bmatrix} = x_\infty \quad \text{[Eq.13]}$$

= **ideal point!**

- In Euclidian coordinates this point is at infinity
- Agree with the general idea of two lines intersecting at infinity

2D Points at infinity (ideal points)

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}, x_3 \neq 0$$

$y = mx + c$

$c = y - mx$

$= y_2 - mx_2$

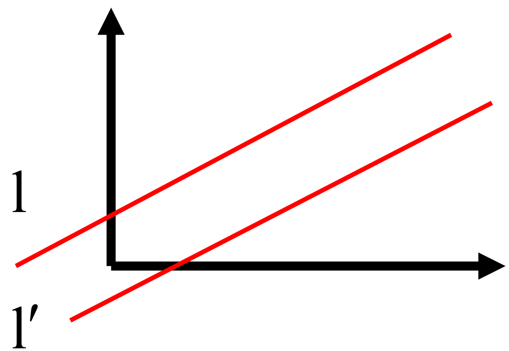
m

x_2, y_2

x_1, y_1

$m = \frac{y_2 - y_1}{x_2 - x_1}$

$$-a/b = -a'/b'$$



$$\mathbf{l} = \begin{bmatrix} a \\ b \\ c \end{bmatrix} \qquad l' = \begin{bmatrix} a' \\ b' \\ c' \end{bmatrix}$$

Note: the line l = [a b c]^T pass trough the ideal point x_∞

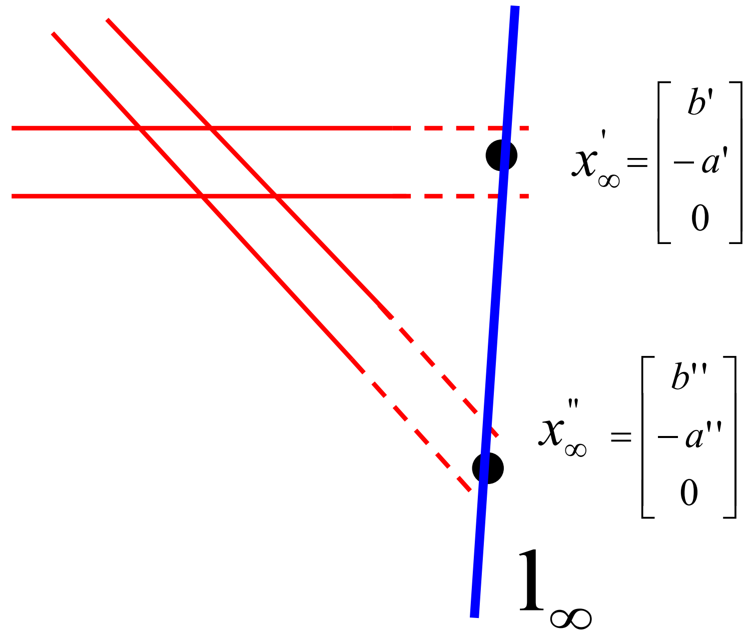
$$\mathbf{l}^T x_\infty = \begin{bmatrix} a & b & c \end{bmatrix} \begin{bmatrix} b \\ -a \\ 0 \end{bmatrix} = 0 \quad \text{[Eq. 15]}$$

So does the line l′ since a b′ = a′ b

Lines infinity $\mathbf{l}_\infty$

Set of ideal points lies on a line called the line at infinity.
How does it look like?

$$l_\infty \rightarrow \mathbf{l}_\infty = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$



Indeed: $\begin{bmatrix} x_1 \\ x_2 \\ 0 \end{bmatrix}^T \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = 0$

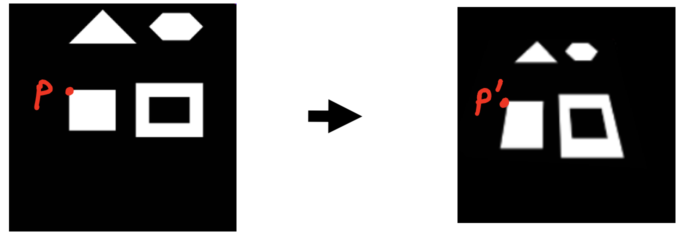
Point at infinity

line at infinity

A line at infinity can be thought of the set of "directions" of lines in the plane

Projective transformation of a point at infinity

$$H = \begin{bmatrix} \mathrm{A} & \mathrm{t} \\ \mathrm{v} & \mathrm{b} \end{bmatrix}$$



$$p' = H\ p$$

is it a point at infinity?

$$H\ p_\infty = ? = \begin{bmatrix} A & t \\ v & b \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} p'_x \\ p'_y \\ p'_z \end{bmatrix}$$

[Eq. 17]

...no!

→ Preserves ideal points

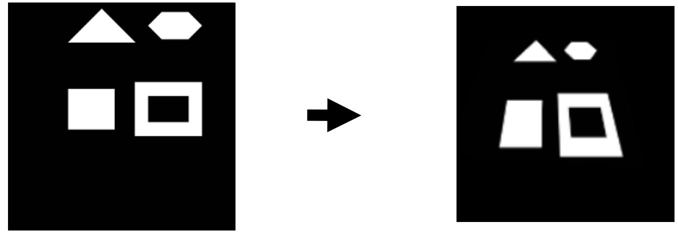
$$H_A\ p_\infty = ? = \begin{bmatrix} A & t \\ 0 & b \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} p'_x \\ p'_y \\ 0 \end{bmatrix}$$

[Eq. 18]

An affine transformation of a point at infinity is still a point at infinity

Projective transformation of a line (in 2D)

$$\mathrm{H} = \begin{bmatrix} \mathrm{A} & \mathrm{t} \\ \mathrm{v} & \mathrm{b} \end{bmatrix}$$



Applying projective transformation on a line

$$\mathrm{l}' = \mathrm{H}^{-\mathrm{T}}\ \mathrm{l}$$

[Eq. 19]

is it a line at infinity?

projective

$$\mathrm{H}^{-\mathrm{T}}\ \mathrm{l}_{\infty} = ? = \begin{bmatrix} \mathrm{A} & \mathrm{t} \\ \mathrm{v} & \mathrm{b} \end{bmatrix}^{-\mathrm{T}} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} \mathrm{t}_{\mathrm{x}} \\ \mathrm{t}_{\mathrm{y}} \\ \mathrm{b} \end{bmatrix}$$

[Eq. 20]

...no!

affine

$$\mathrm{H}_{\mathrm{A}}^{-\mathrm{T}}\ \mathrm{l}_{\infty} = ? \quad = \begin{bmatrix} A & t \\ 0 & 1 \end{bmatrix}^{-T} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} A^{-T} & 0 \\ -t^T A^{-T} & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

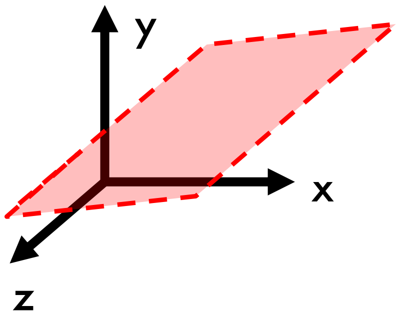
line at infinity

[Eq. 21]

Points and planes in 3D

$$\mathrm{x} = \begin{bmatrix} \mathrm{x}_1 \\ \mathrm{x}_2 \\ \mathrm{x}_3 \\ 1 \end{bmatrix}$$

$$\Pi = \begin{bmatrix} \mathrm{a} \\ \mathrm{b} \\ \mathrm{c} \\ \mathrm{d} \end{bmatrix}$$



$$x \in \Pi \leftrightarrow x^T \Pi = 0$$

[Eq. 22]

if x belongs to a plane

$$\mathrm{ax} + \mathrm{by} + \mathrm{cz} + \mathrm{d} = 0$$

[Eq. 23]

equation of a plane

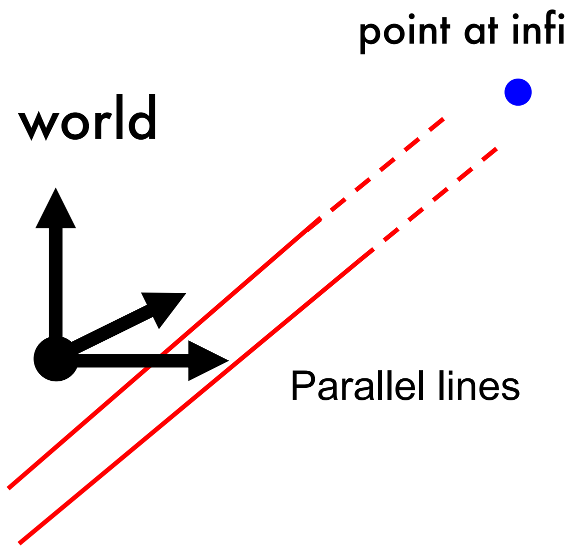
Lines in 3D

- Lines have 4 degrees of freedom - hard to represent in 3D-space
- Can be defined as intersection of 2 planes

$$\mathbf{d} = \text{direction of the line}$$
$$= [a, b, c]^T$$

Points at infinity in 3D

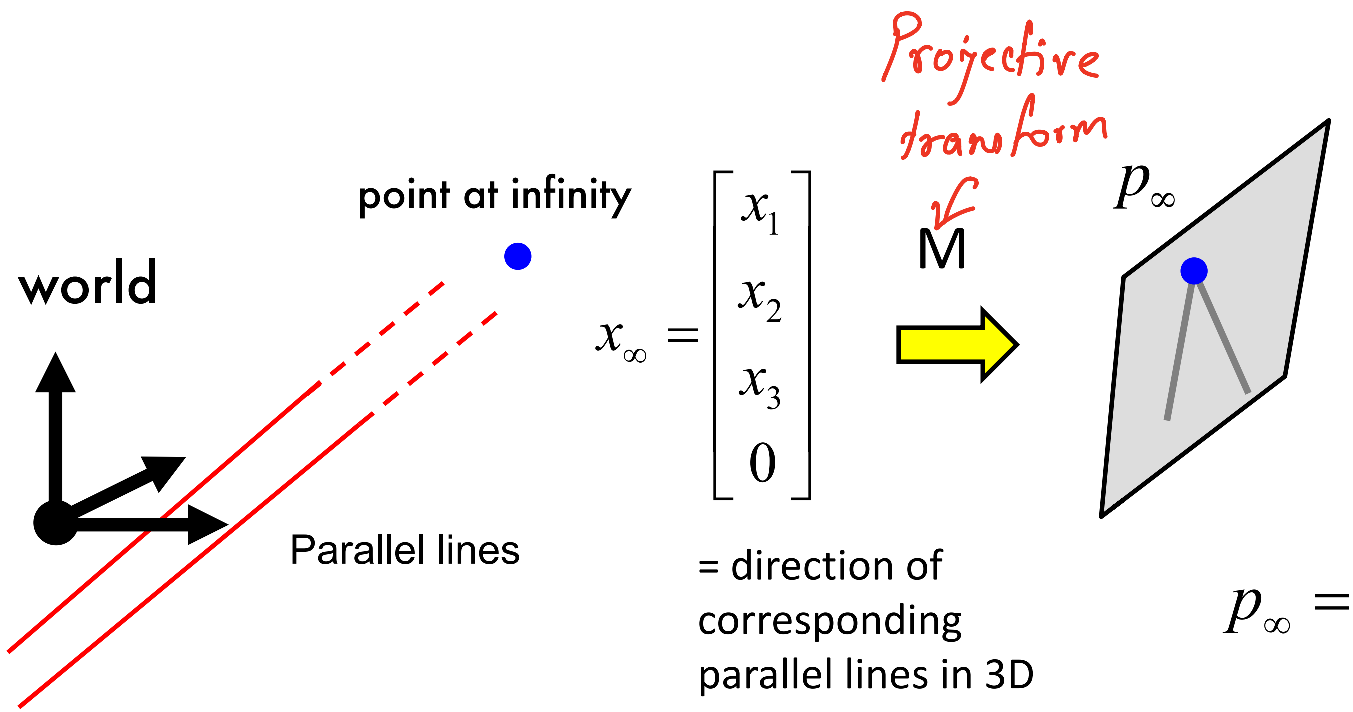
Points where parallel lines intersect in 3D



$$x_\infty = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ 0 \end{bmatrix}$$

Vanishing points

The projective projection of a point at infinity into the image plane defines a vanishing point.

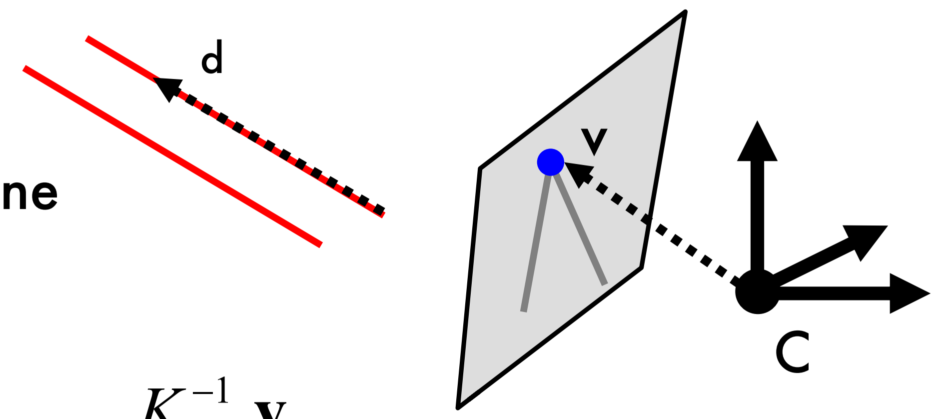


$$x_\infty = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ 0 \end{bmatrix}$$

= direction of corresponding parallel lines in 3D

$$p_\infty = \begin{bmatrix} p_1 \\ p_2 \\ p_3 \end{bmatrix}$$

Vanishing points and directions



d = direction of the line
= [a, b, c]^T

$$\mathbf{v} = K\,\mathbf{d}$$
[Eq. 24]

$$\mathbf{d} = \frac{K^{-1}\,\mathbf{v}}{\left\| K^{-1}\,\mathbf{v} \right\|}$$
[Eq. 25]

→ d is direction, hence normalize to form unit vector.

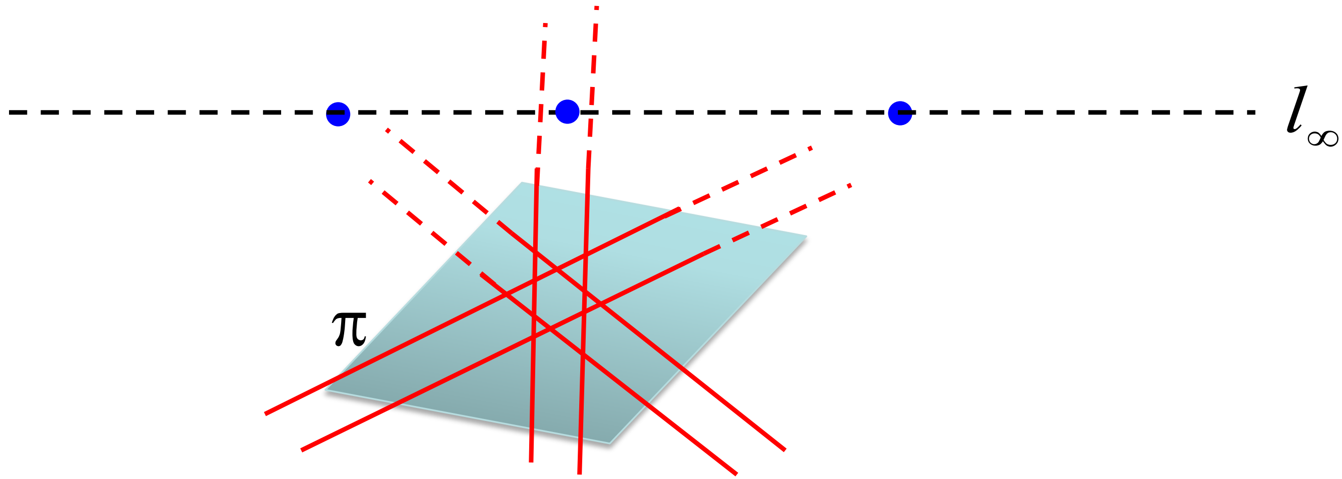
Proof:

3D point

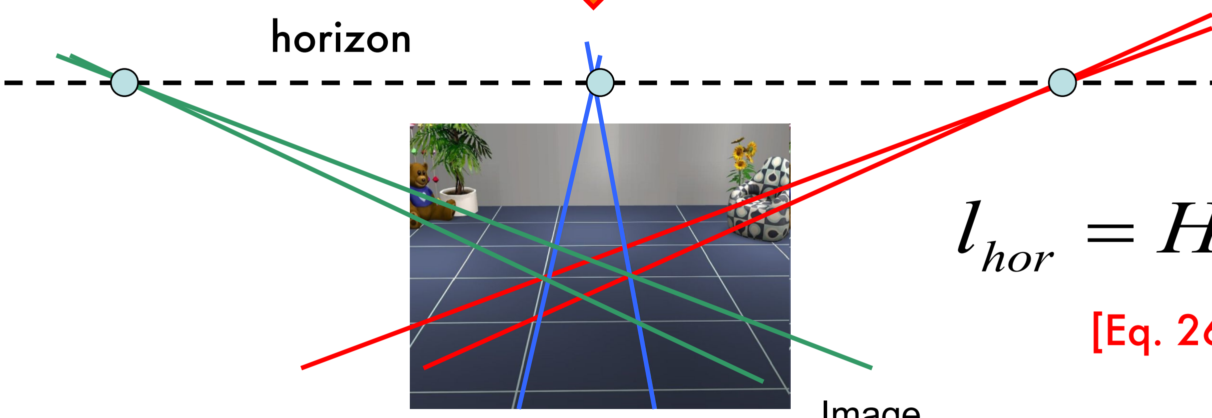
$$X_\infty = \begin{bmatrix} a \\ b \\ c \\ 0 \end{bmatrix} \xrightarrow{M} \mathbf{v} = \mathbf{M}\,\mathbf{X}_\infty = \mathbf{K}\begin{bmatrix}\mathbf{I} & \mathbf{0}\end{bmatrix}\begin{bmatrix} a \\ b \\ c \\ 0 \end{bmatrix} = \mathbf{K}\begin{bmatrix} a \\ b \\ c \end{bmatrix}$$

direction of line

Vanishing (horizon) line



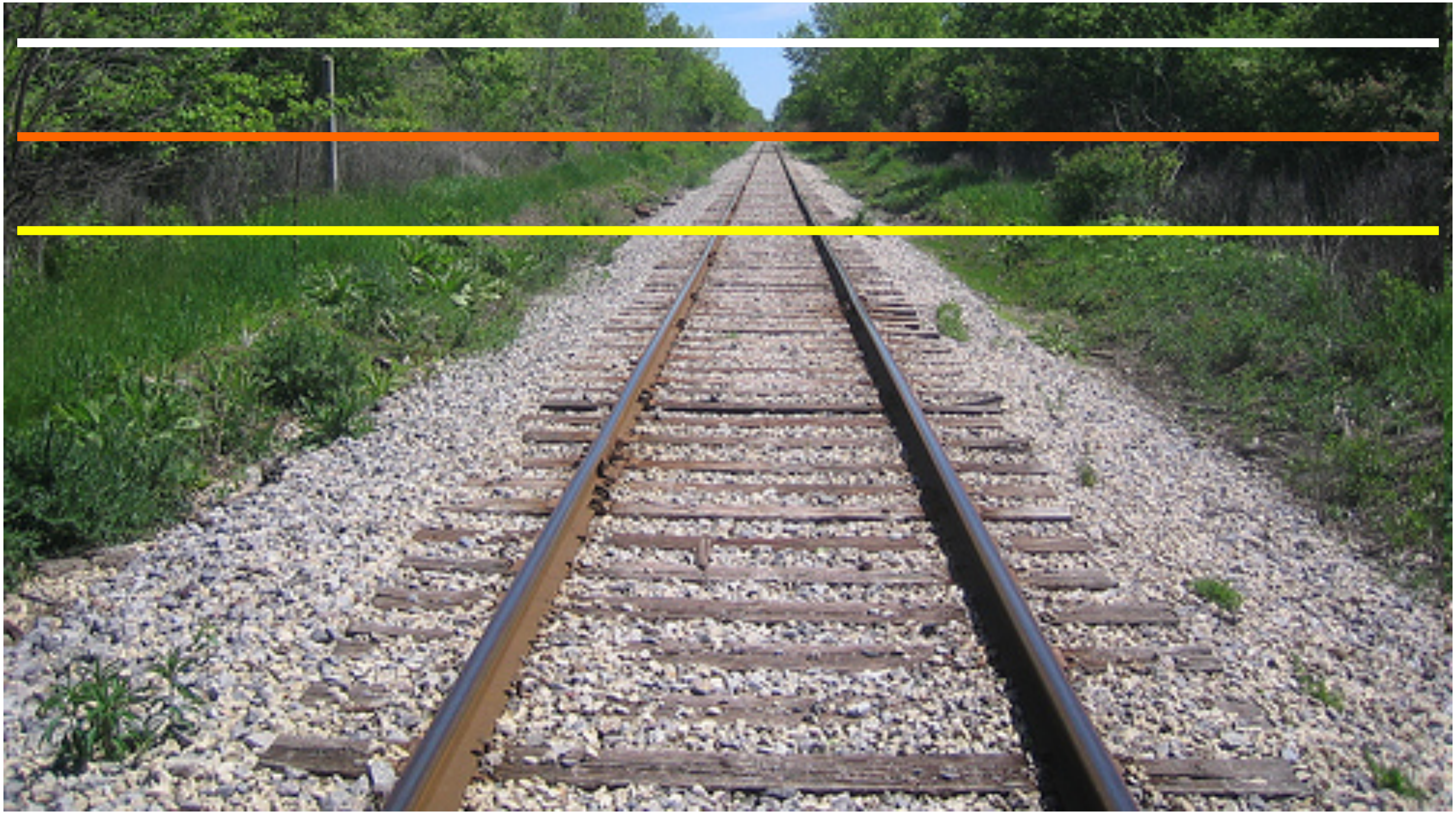
Projective transformation M



$$l_{hor} = H_P^{-T} \; l_\infty$$

[Eq. 26]

Example of horizon line

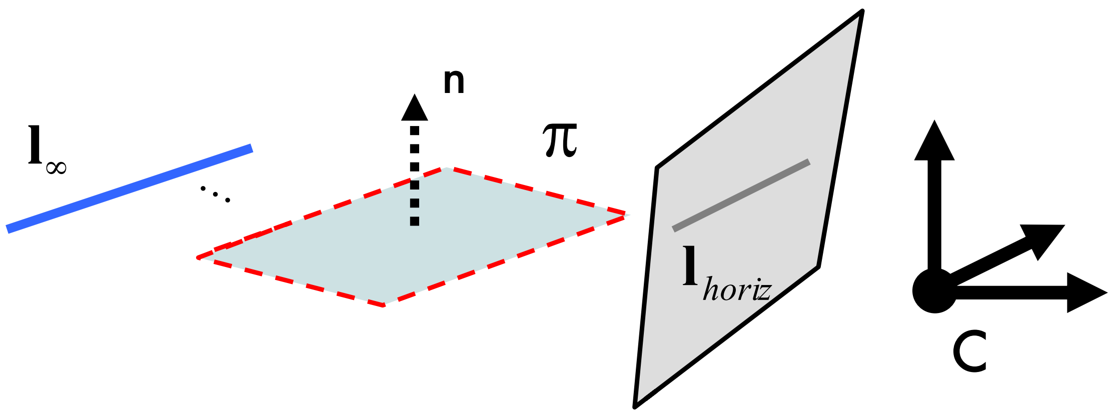


The orange line is the horizon!

Are these two lines parallel or not?

- Recognize the horizon line
- Measure if the 2 lines meet at the horizon
- if yes, these 2 lines are // in 3D

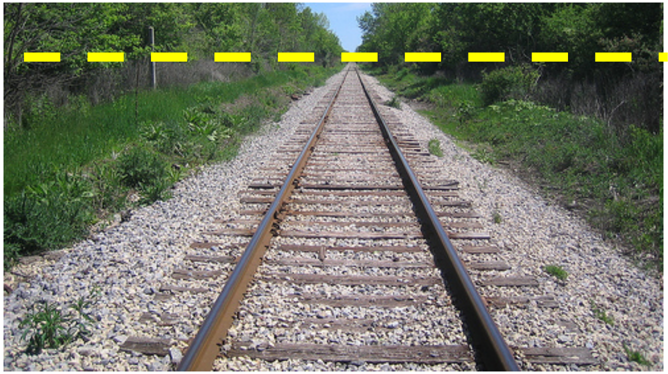
Vanishing points and planes



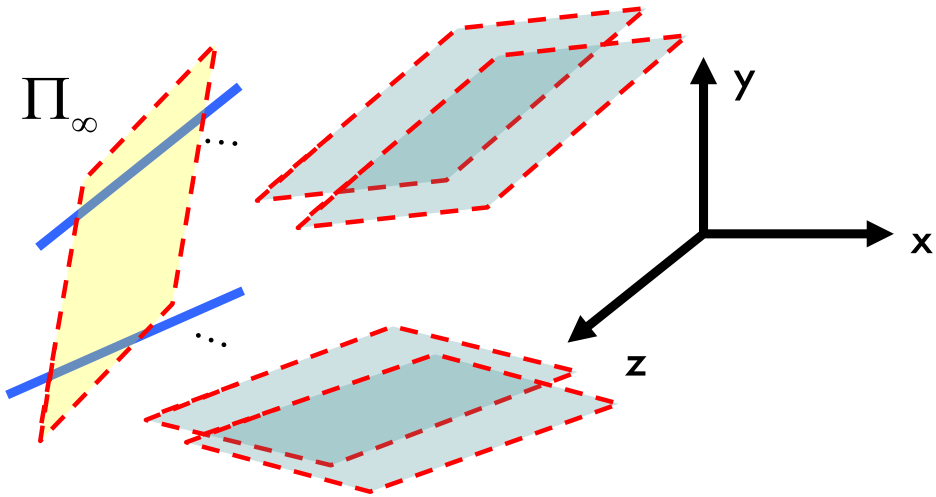
$$\mathbf{n} = K^T \mathbf{l}_{\mathrm{horiz}}$$

[Eq. 27]

See sec. 8.6.2 [HZ] for details



Planes at infinity



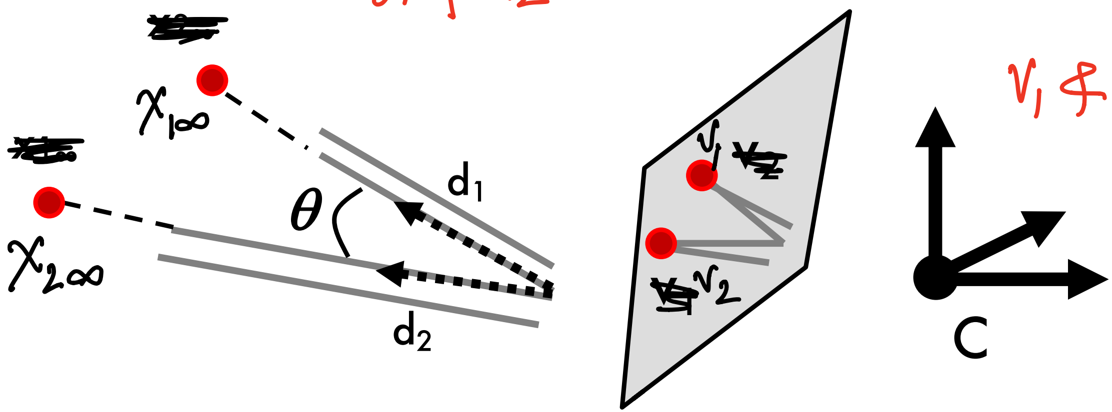
$$\Pi_\infty = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

plane at infinity

- Parallel planes intersect at infinity in a common line – **the line at infinity**
- A set of 2 or more lines at infinity defines the plane at infinity Π_∞

Angle between 2 vanishing points

d_1 & d_2 are directions



v_1 & v_2 are vanishing points

$$\cos\theta = \frac{v_1^T \omega\, v_2}{\sqrt{v_1^T \omega\, v_1}\sqrt{v_2^T \omega\, v_2}}$$ [Eq. 28]

$$\omega = (K\,K^T)^{-1}$$ [Eq. 30]

If $\theta = 90$ $\rightarrow$ $$\boxed{v_1^T \omega\, v_2 = 0}$$ [Eq. 29]

Scalar equation

Properties of ω

$$\boxed{\omega = (K K^T)^{-1}}$$

[Eq. 30]

$$M = K\begin{bmatrix} R & T \end{bmatrix}$$

1. $\omega = \begin{bmatrix} \omega_1 & \omega_2 & \omega_4 \\ \omega_2 & \omega_3 & \omega_5 \\ \omega_4 & \omega_5 & \omega_6 \end{bmatrix}$ symmetric and known up scale

2. $\omega_2 = 0$ zero-skew

3. $\omega_2 = 0$, $\omega_1 = \omega_3$ square pixel

Summary

$$\boxed{\mathbf{v} = K\,\mathbf{d}}$$

[Eq. 24]

$$\boxed{\mathbf{n} = \mathrm{K}^{\mathrm{T}}\mathbf{l}_{\mathrm{horiz}}}$$

[Eq. 27]

$$\cos\theta = \frac{\mathrm{v}_1^{\mathrm{T}}\boldsymbol{\omega}\,\mathrm{v}_2}{\sqrt{\mathrm{v}_1^{\mathrm{T}}\boldsymbol{\omega}\,\mathrm{v}_1}\sqrt{\mathrm{v}_2^{\mathrm{T}}\boldsymbol{\omega}\,\mathrm{v}_2}} \xrightarrow{\theta = 90} \boxed{\mathrm{v}_1^{\mathrm{T}}\boldsymbol{\omega}\,\mathrm{v}_2 = 0}$$

[Eq. 28]

[Eq. 29]

$$\boxed{\omega = (K\,K^T)^{-1}}$$

[Eq. 30]

Useful to:

- To calibrate the camera
- To estimate the geometry of the 3D world

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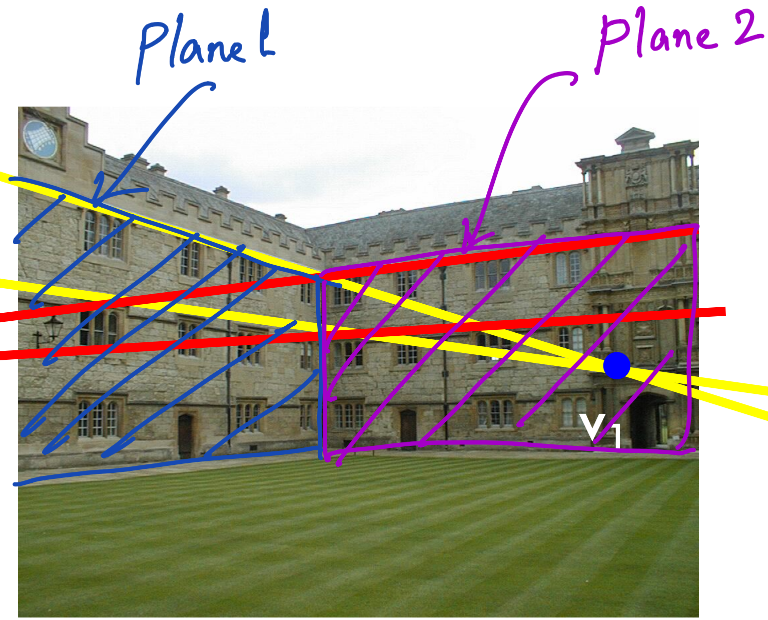
Single view calibration - example

[Eq. 28]

$$\cos\theta = \frac{\mathrm{v}_1^{\mathrm{T}} \boldsymbol{\omega}\, \mathrm{v}_2}{\sqrt{\mathrm{v}_1^{\mathrm{T}} \boldsymbol{\omega}\, \mathrm{v}_1}\sqrt{\mathrm{v}_2^{\mathrm{T}} \boldsymbol{\omega}\, \mathrm{v}_2}}$$

v_2



$$\theta = 90^o$$

[Eq. 29]

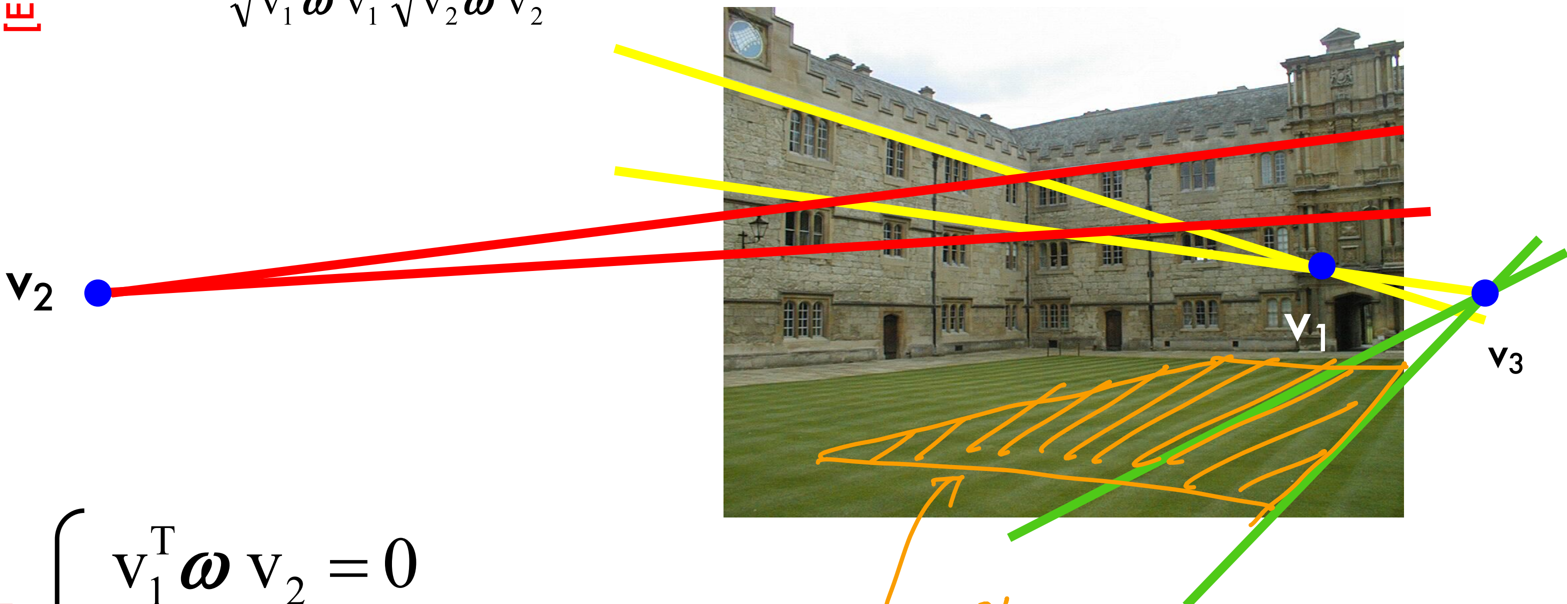
$$\begin{cases} \mathrm{v}_1^{\mathrm{T}} \boldsymbol{\omega}\, \mathrm{v}_2 = 0 \\ \omega = (K\, K^T)^{-1} \end{cases}$$

Do we have enough constraints to estimate K?
K has 5 degrees of freedom and Eq.29 is a scalar equation ☹

Single view calibration - example

[Eq. 28]

$$\cos\theta = \frac{v_1^T \boldsymbol{\omega}\, v_2}{\sqrt{v_1^T \boldsymbol{\omega}\, v_1}\sqrt{v_2^T \boldsymbol{\omega}\, v_2}}$$



[Eqs. 31]

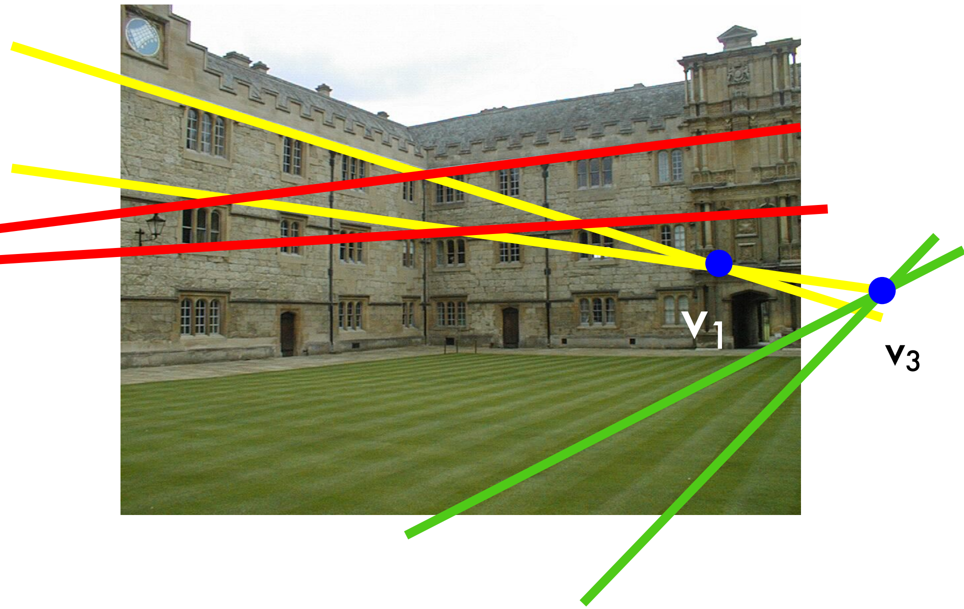
$$\begin{cases} v_1^T \boldsymbol{\omega}\, v_2 = 0 \\ v_1^T \boldsymbol{\omega}\, v_3 = 0 \\ v_2^T \boldsymbol{\omega}\, v_3 = 0 \end{cases}$$

3 Planes are orthogonal to each other

Single view calibration - example

$$\omega = \begin{bmatrix} \omega_1 & \omega_2 & \omega_4 \\ \omega_2 & \omega_3 & \omega_5 \\ \omega_4 & \omega_5 & \omega_6 \end{bmatrix}$$

v_2



$\boxed{\text{assume}}$

- Square pixels
- No skew

$\rightarrow$ $\omega_2 = 0$, $\omega_1 = \omega_3$

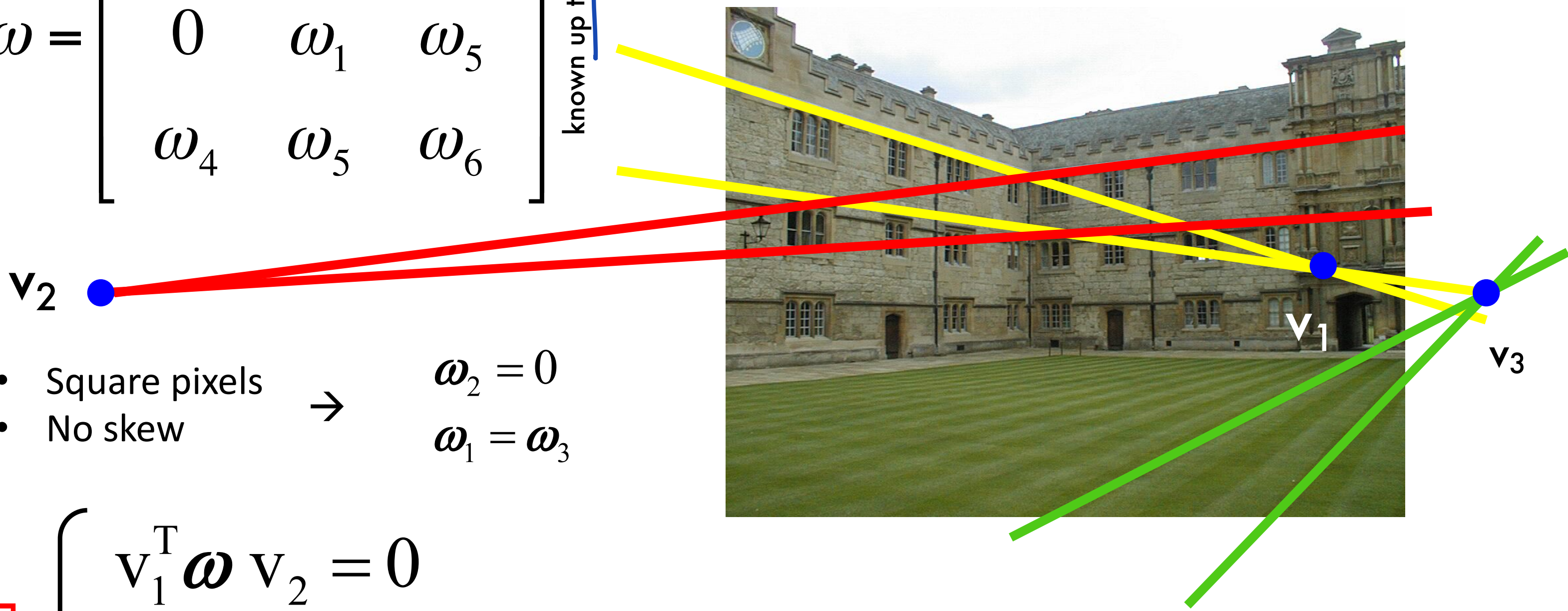
[Eqs. 31]

$$\left\{ \begin{array}{l} v_1^T \omega \, v_2 = 0 \\ v_1^T \omega \, v_3 = 0 \\ v_2^T \omega \, v_3 = 0 \end{array} \right\} 3 \text{ constraints}$$

Single view calibration - example

$$\omega = \begin{bmatrix} \omega_1 & 0 & \omega_4 \\ 0 & \omega_1 & \omega_5 \\ \omega_4 & \omega_5 & \omega_6 \end{bmatrix}$$

known up to scale



- Square pixels
- No skew

→ $\omega_2 = 0$, $\omega_1 = \omega_3$

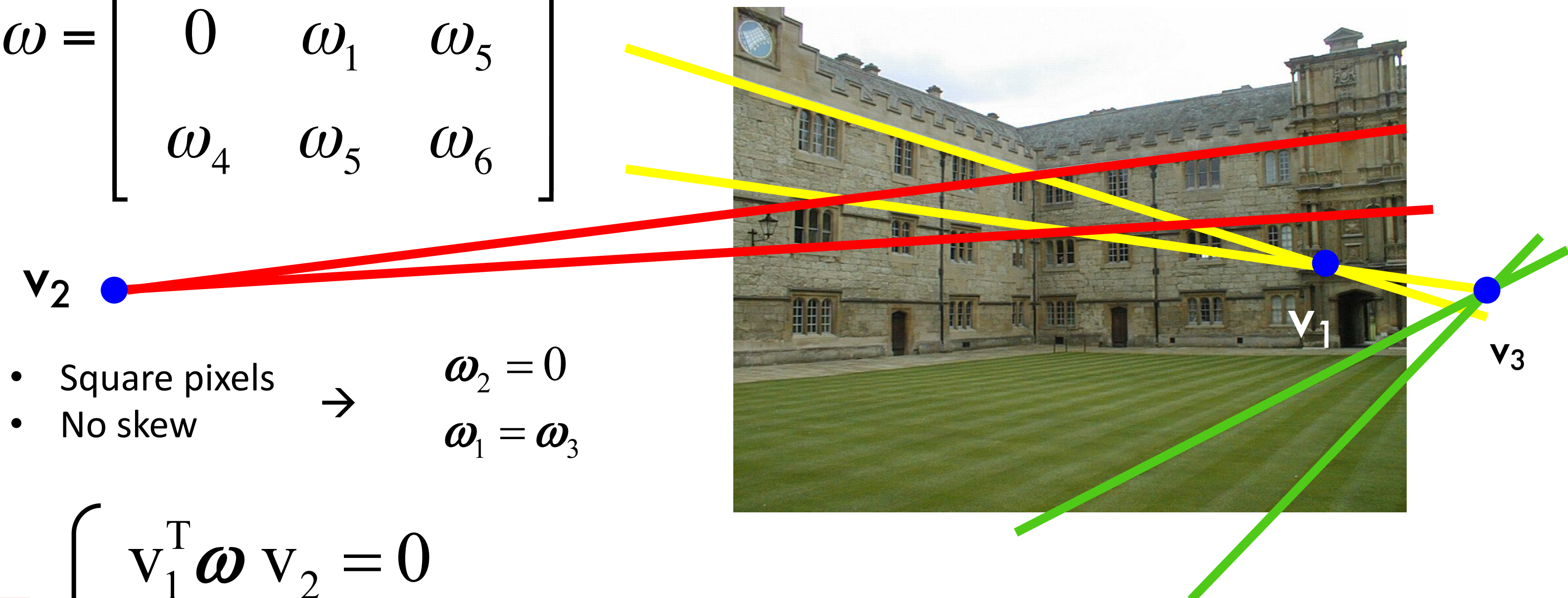
[Eqs. 31]

$$\begin{cases} v_1^T \omega \, v_2 = 0 \\ v_1^T \omega \, v_3 = 0 \\ v_2^T \omega \, v_3 = 0 \end{cases}$$

→ Compute ω !

Single view calibration - example

$$\omega = \begin{bmatrix} \omega_1 & 0 & \omega_4 \\ 0 & \omega_1 & \omega_5 \\ \omega_4 & \omega_5 & \omega_6 \end{bmatrix}$$



- Square pixels
- No skew

$\rightarrow$ $\omega_2 = 0$, $\omega_1 = \omega_3$

[Eqs. 31]

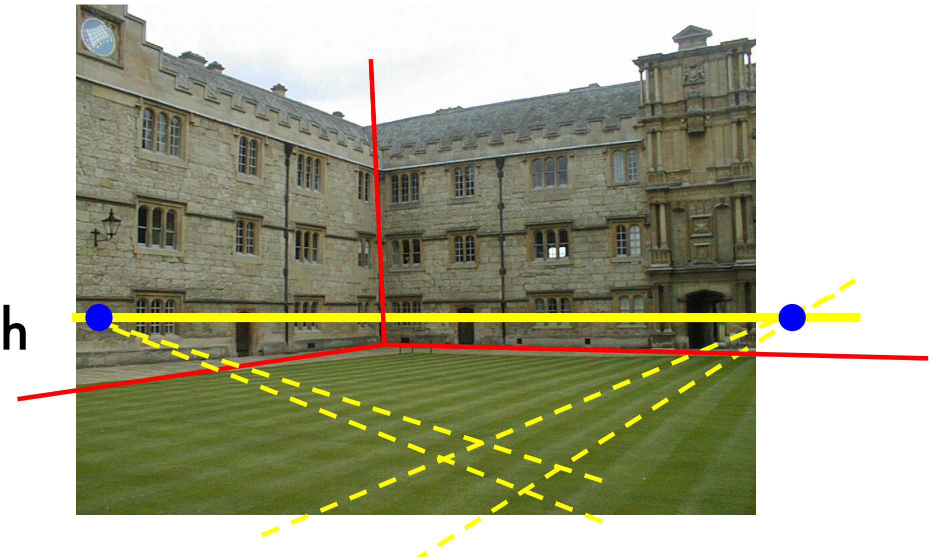
$$\begin{cases} \mathrm{v}_1^{\mathrm{T}} \boldsymbol{\omega}\, \mathrm{v}_2 = 0 \\ \mathrm{v}_1^{\mathrm{T}} \boldsymbol{\omega}\, \mathrm{v}_3 = 0 \\ \mathrm{v}_2^{\mathrm{T}} \boldsymbol{\omega}\, \mathrm{v}_3 = 0 \end{cases}$$

Once ω is calculated, we get K:

$$\omega = (K\, K^T)^{-1} \rightarrow \mathrm{K}$$

(Cholesky factorization; HZ pag 582)

Single view reconstruction - example

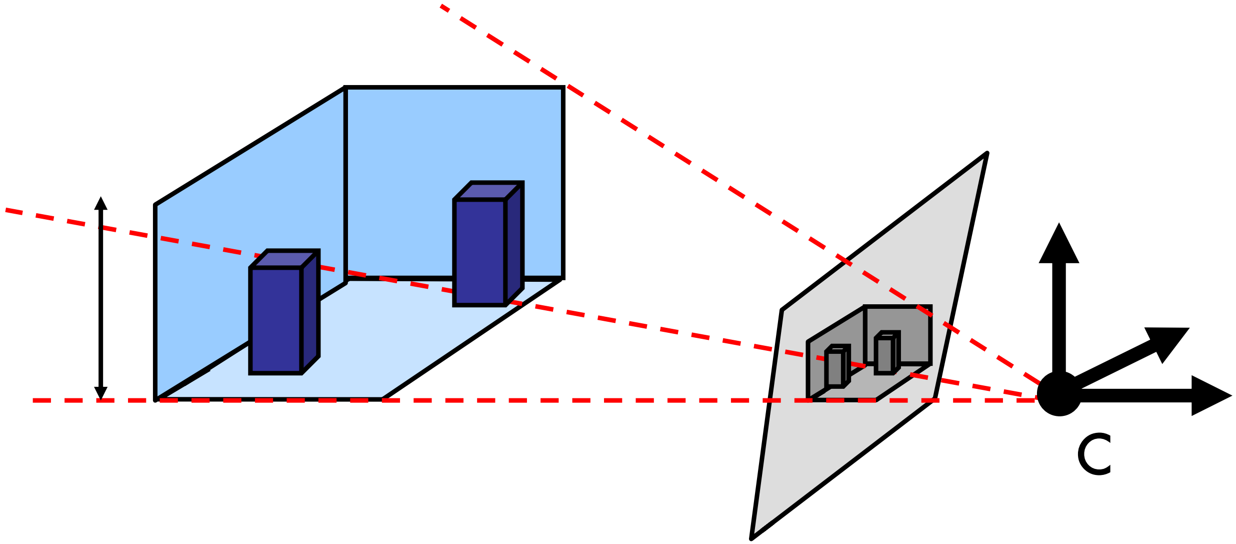


[Eq. 27]

$$\mathrm{K} \text{ known} \rightarrow \quad \mathbf{n} = \mathrm{K}^T \mathbf{l}_{\text{horiz}}$$ = Scene plane orientation in the camera reference system

Select orientation discontinuities

Single view reconstruction - example



Recover the structure within the camera reference system

Notice: the actual scale of the scene is NOT recovered

- Recognition helps reconstruction!
- Humans have learnt this

Lecture 4
Single View Metrology

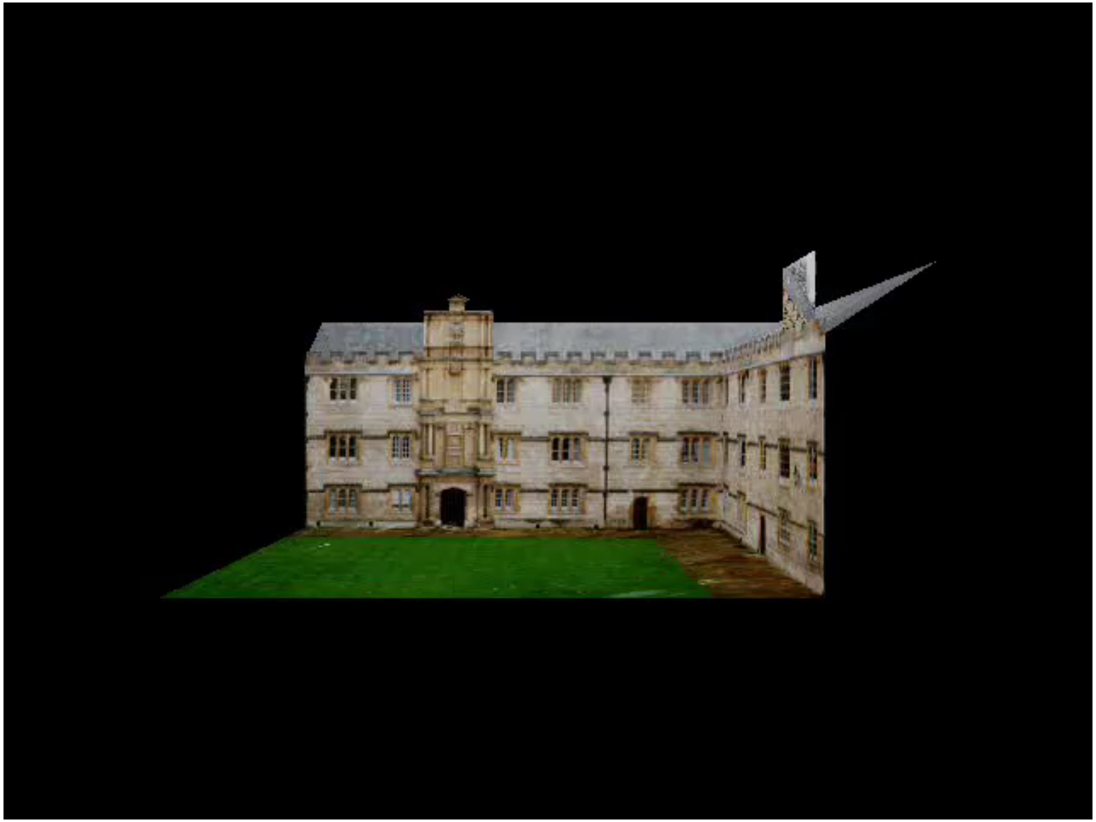
- Review calibration
- Vanishing points and lines
- Estimating geometry from a single image
- Extensions

Reading:
[HZ] Chapter 2 "Projective Geometry and Transformation in 3D"
[HZ] Chapter 3 "Projective Geometry and Transformation in 3D"
[HZ] Chapter 8 "More Single View Geometry"
[Hoeim & Savarese] Chapter 2

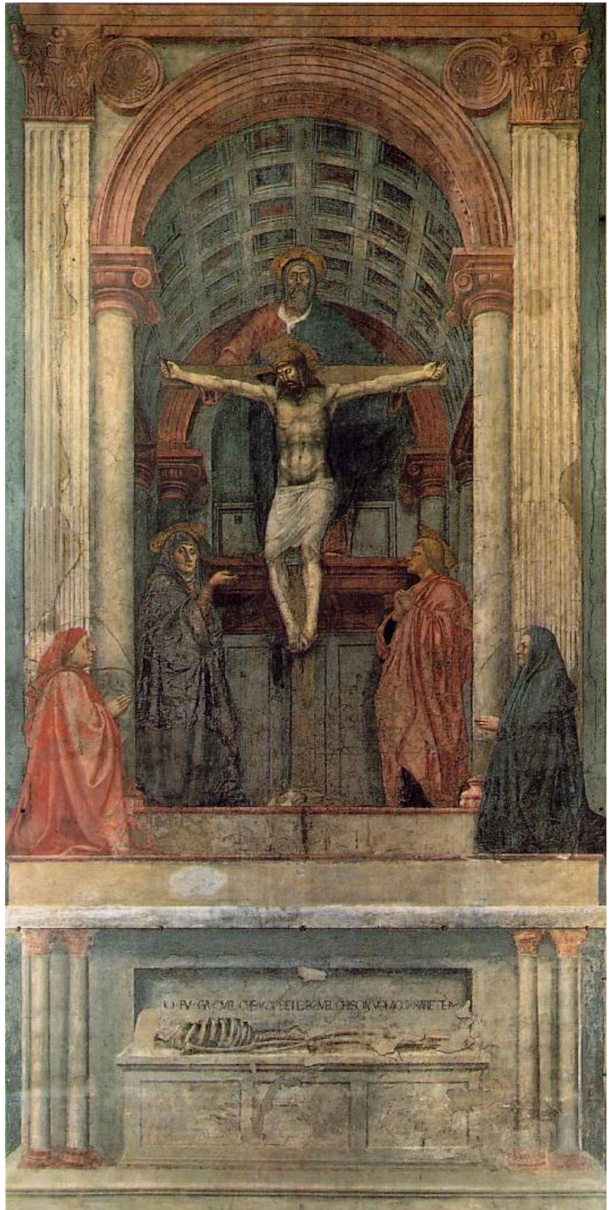
Criminisi & Zisserman, 99

http://www.robots.ox.ac.uk/~vgg/projects/SingleView/models/merton/merton.wrl

Criminisi & Zisserman, 99



http://www.robots.ox.ac.uk/~vgg/projects/SingleView/models/merton/merton.wrl

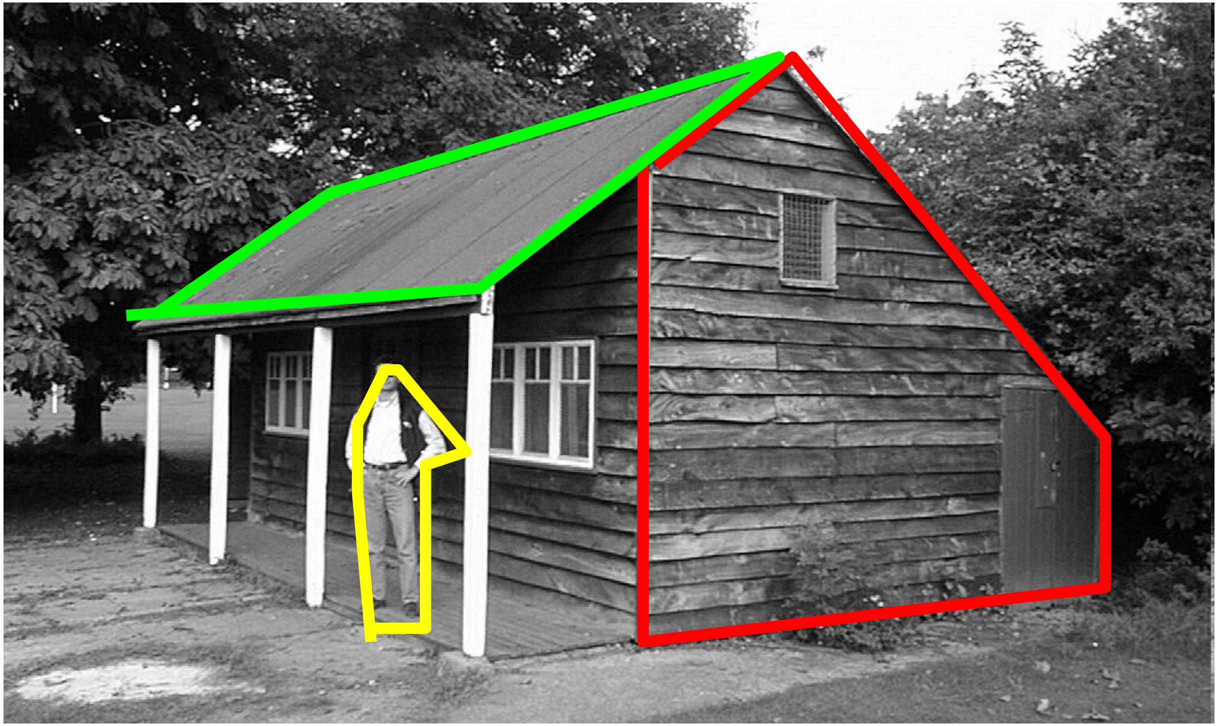


La Trinita' (1426)
Firenze, Santa Maria Novella; by Masaccio (1401-1428)

La Trinita' (1426)
Firenze, Santa Maria
Novella; by Masaccio
(1401-1428)

http://www.robots.ox.ac.uk/~vgg/projects/SingleView/models/hut/hutme.wrl

Single view reconstruction - drawbacks



Manually select:

- Vanishing points and lines;
- Planar surfaces;
- Occluding boundaries;
- Etc..

Automatic Photo Pop-up

Hoiem et al, 05

Automatic Photo Pop-up

Hoiem et al, 05...

Automatic Photo Pop-up

Hoiem et al, 05…

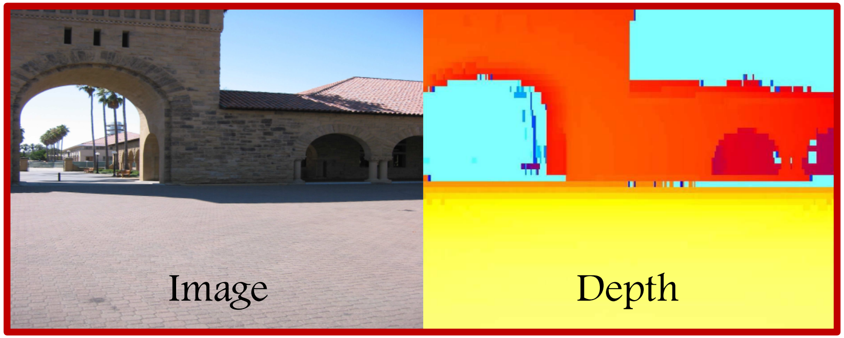
Software:

http://www.cs.uiuc.edu/homes/dhoiem/projects/software.html

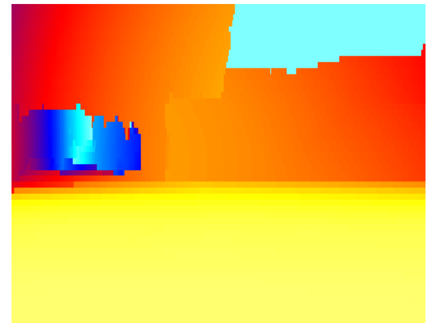
Make3D

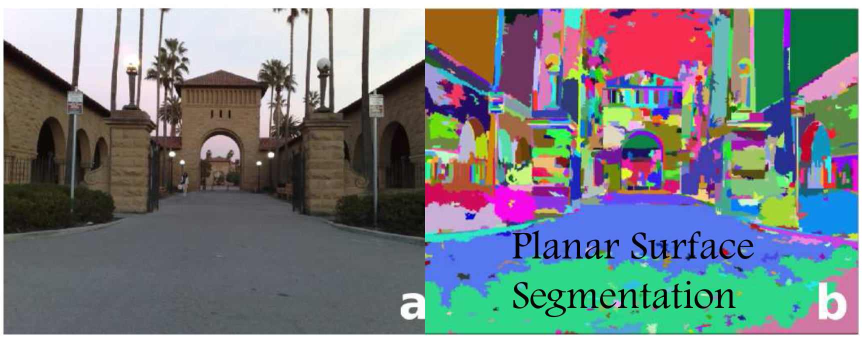
Saxena, Sun, Ng, 05…

Training



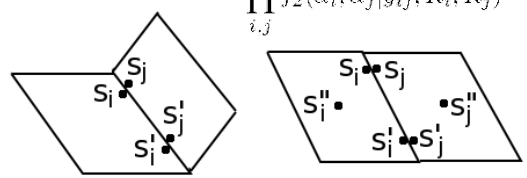
Prediction





Plane Parameter MRF

$$P(\alpha|X,\nu,y,R;\theta) = \frac{1}{Z}\prod_i f_1(\alpha_i|X_i,\nu_i,R_i;\theta) \prod_{i,j} f_2(\alpha_i,\alpha_j|y_{ij},R_i,R_j)$$



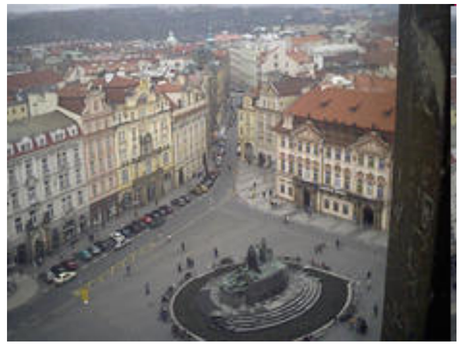
(a) Connectivity

(b) Co-Planarity

youtube

Make3D

Saxena, Sun, Ng, 05…

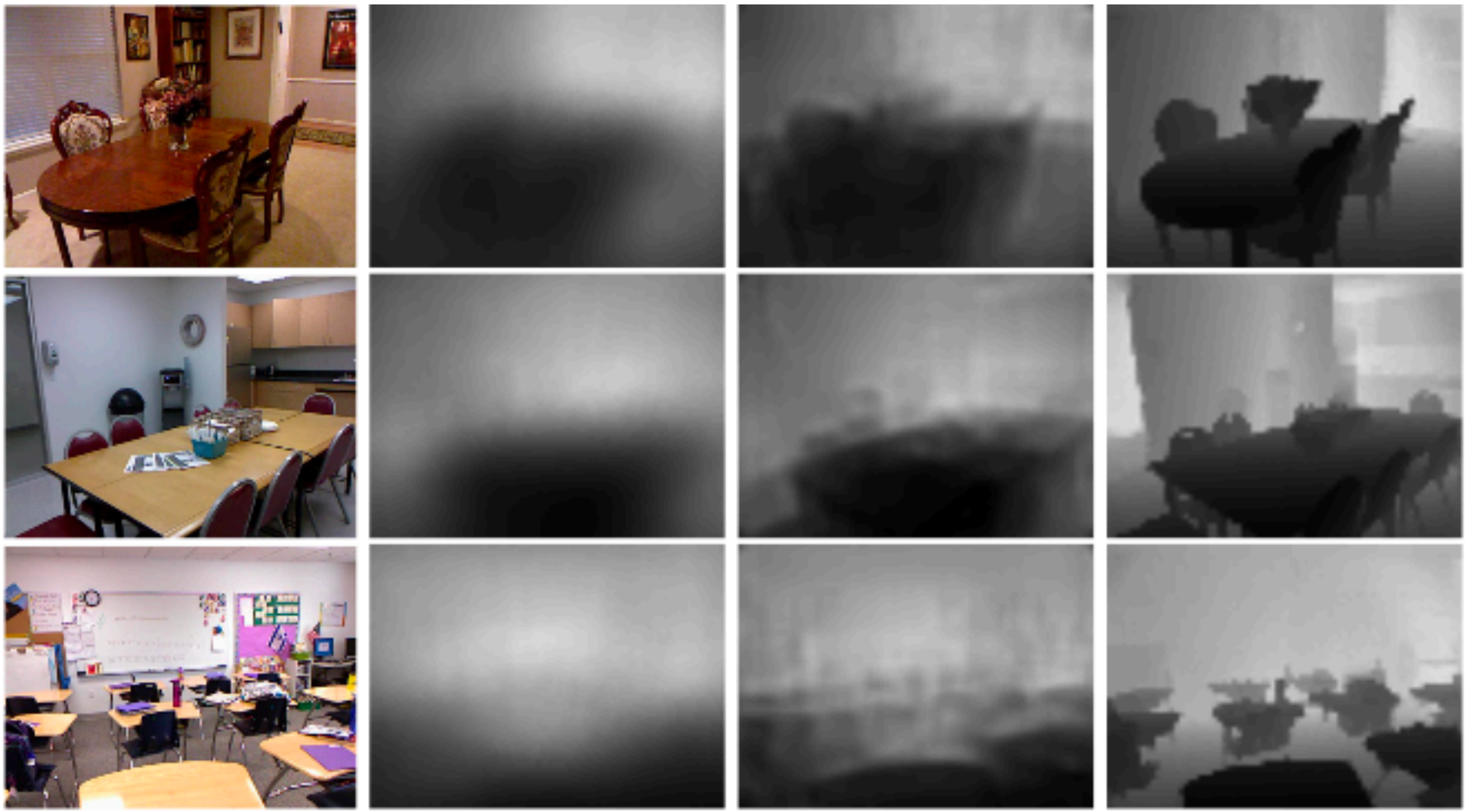

A software: **Make3D**
"Convert your image into 3d model"

http://make3d.stanford.edu/

http://make3d.cs.cornell.edu/

Depth map reconstruction using deep learning

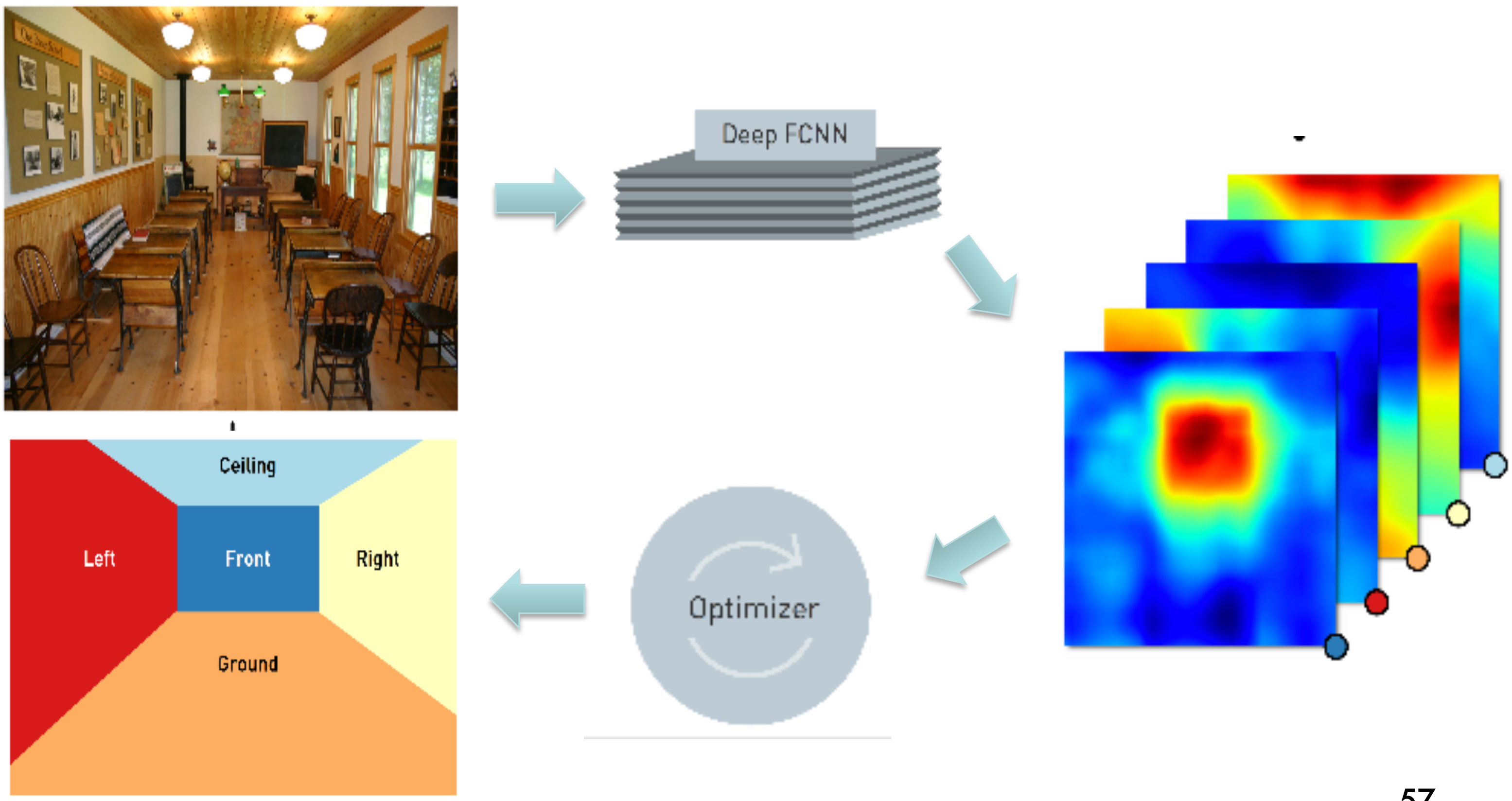
Eigen et al., 2014



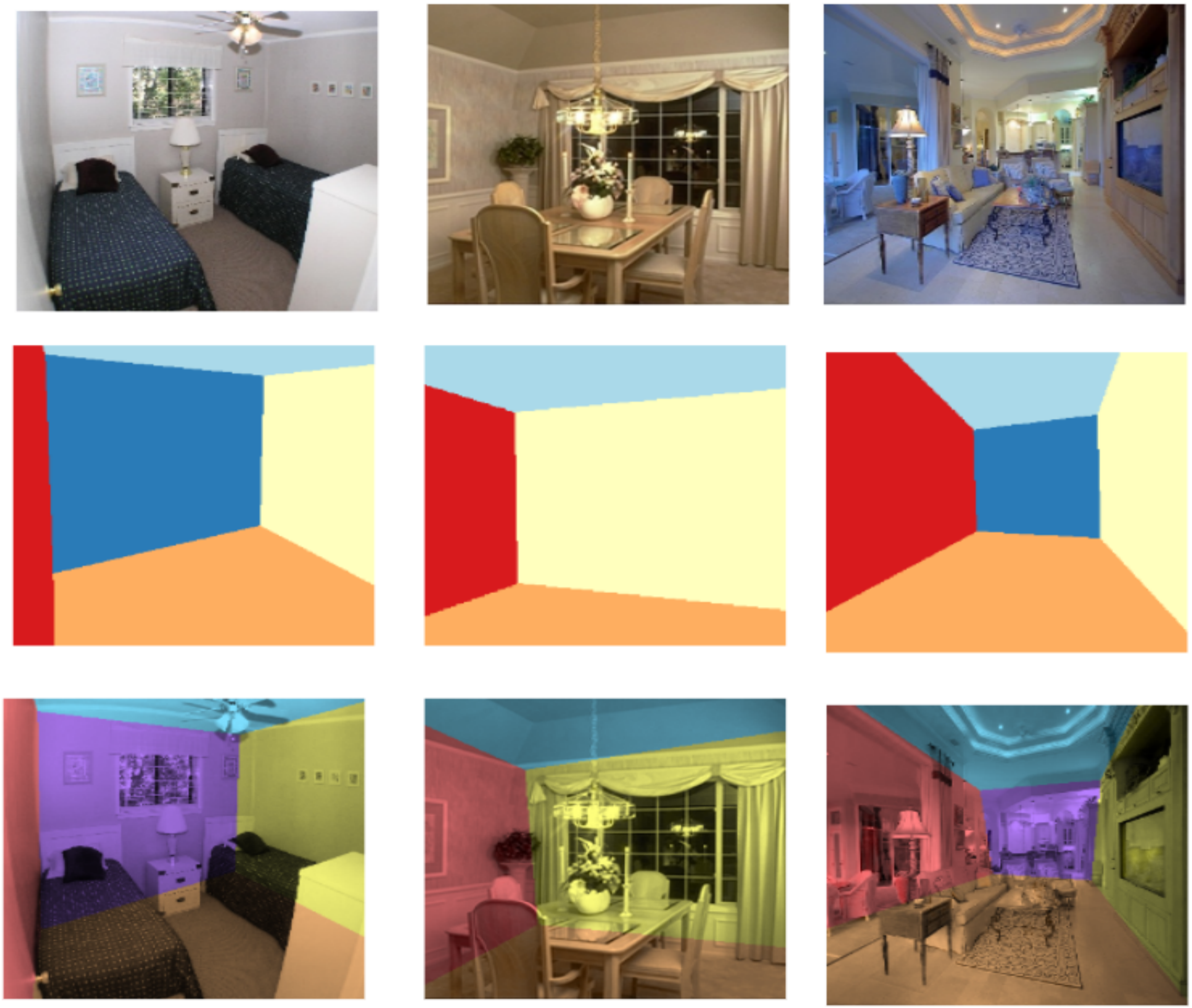
Depth Map Prediction from a Single Image using a Multi-Scale Deep Network,
Eigen, D., Puhrsch, C. and Fergus, R. Proc. Neural Information Processing Systems 2014,

3D Layout estimation

Dasgupta, et al. CVPR 2016

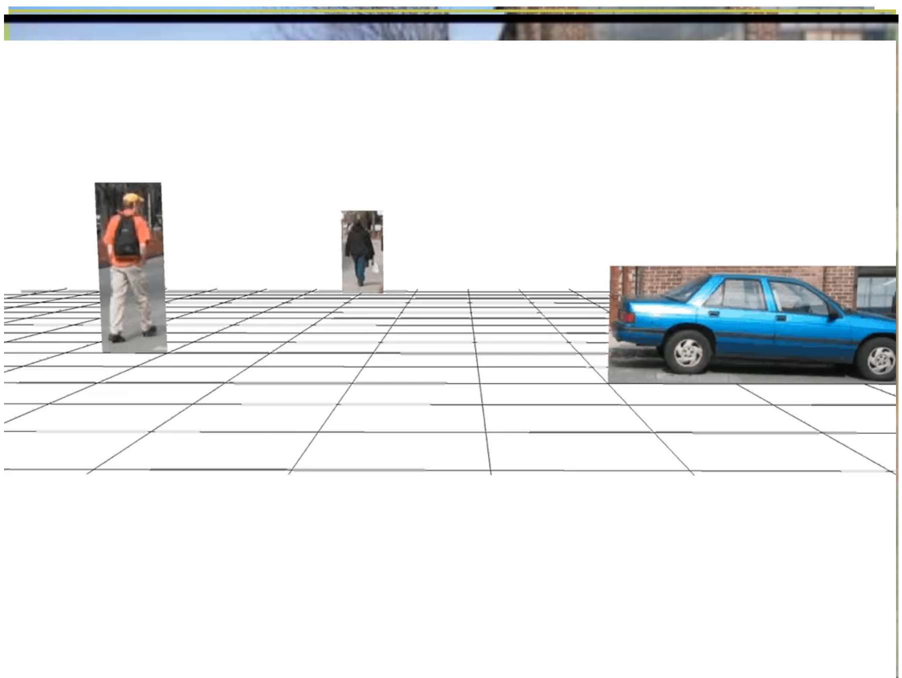


3D Layout estimation



Coherent object detection and scene layout estimation from a single image

Y. Bao, M. Sun, S. Savarese, CVPR 2010, BMVC 2010



Next lecture:

Multi-view geometry (epipolar geometry)

Appendix