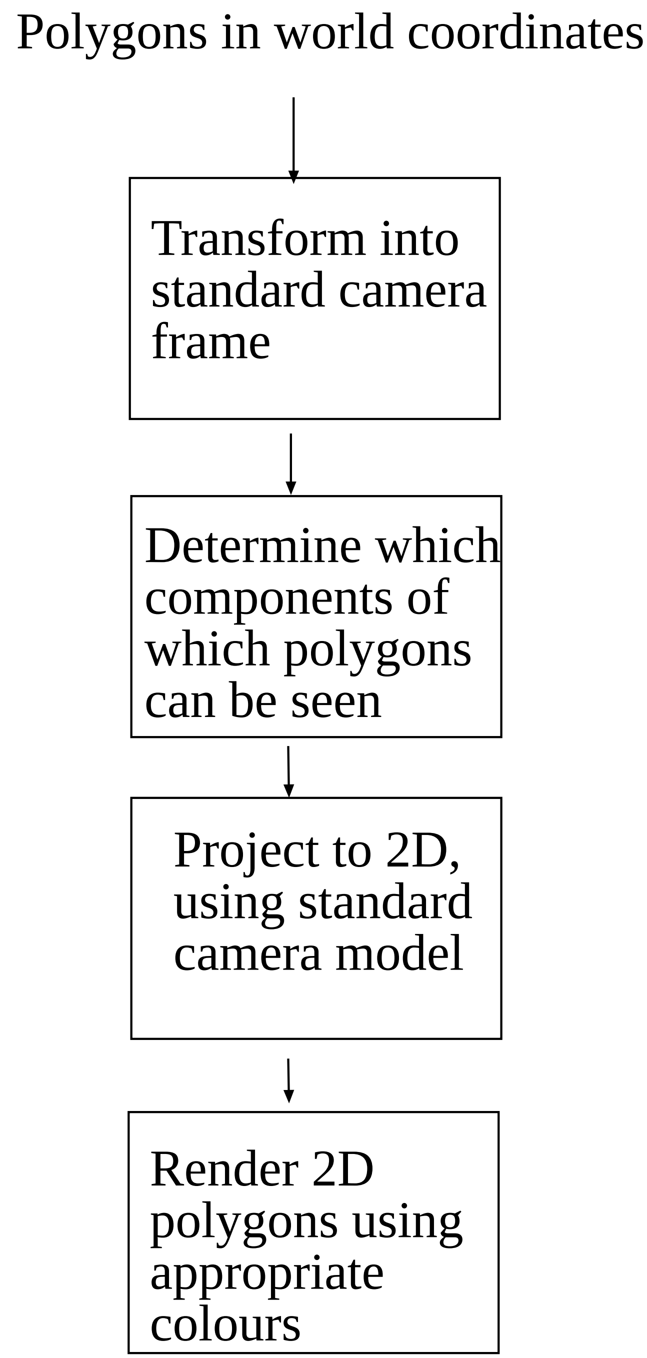
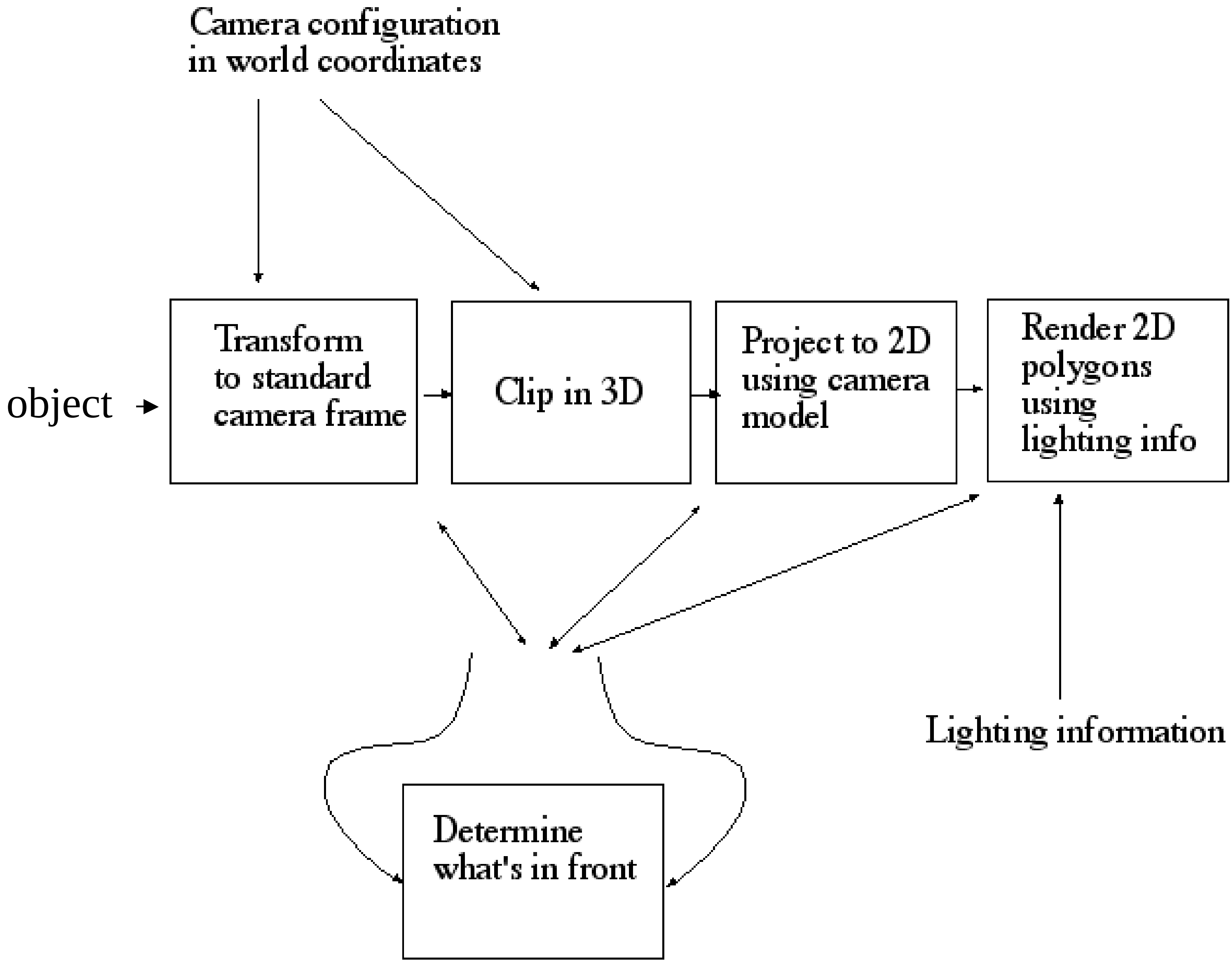
3D Graphics Concepts

- Modeling: For now, objects will be collections of polygons in 3D. Complex shapes will be many small polygons.
- Issues:
  - Which polygons can be seen? (some polygons hide others, and some are outside the relevant volume of space and need to be clipped).
  - Where do they go in the 2D image? (key abstraction is a virtual camera)
  - How bright should they be? (for example, to make it look as if we are looking at a real surface)

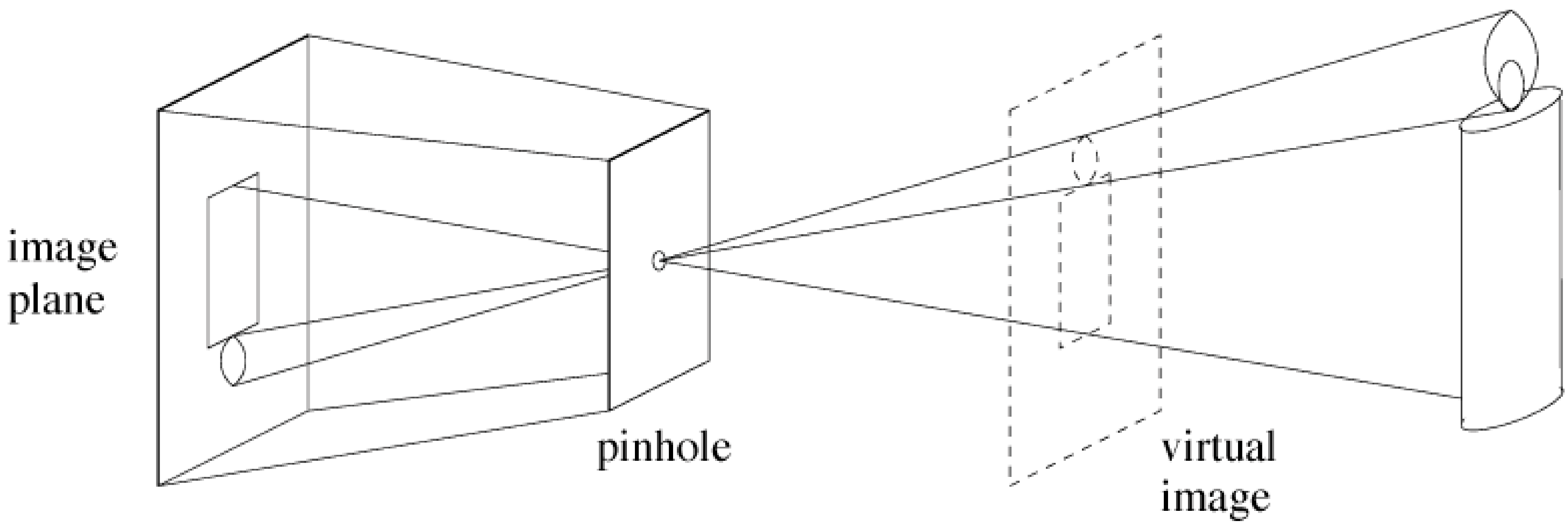




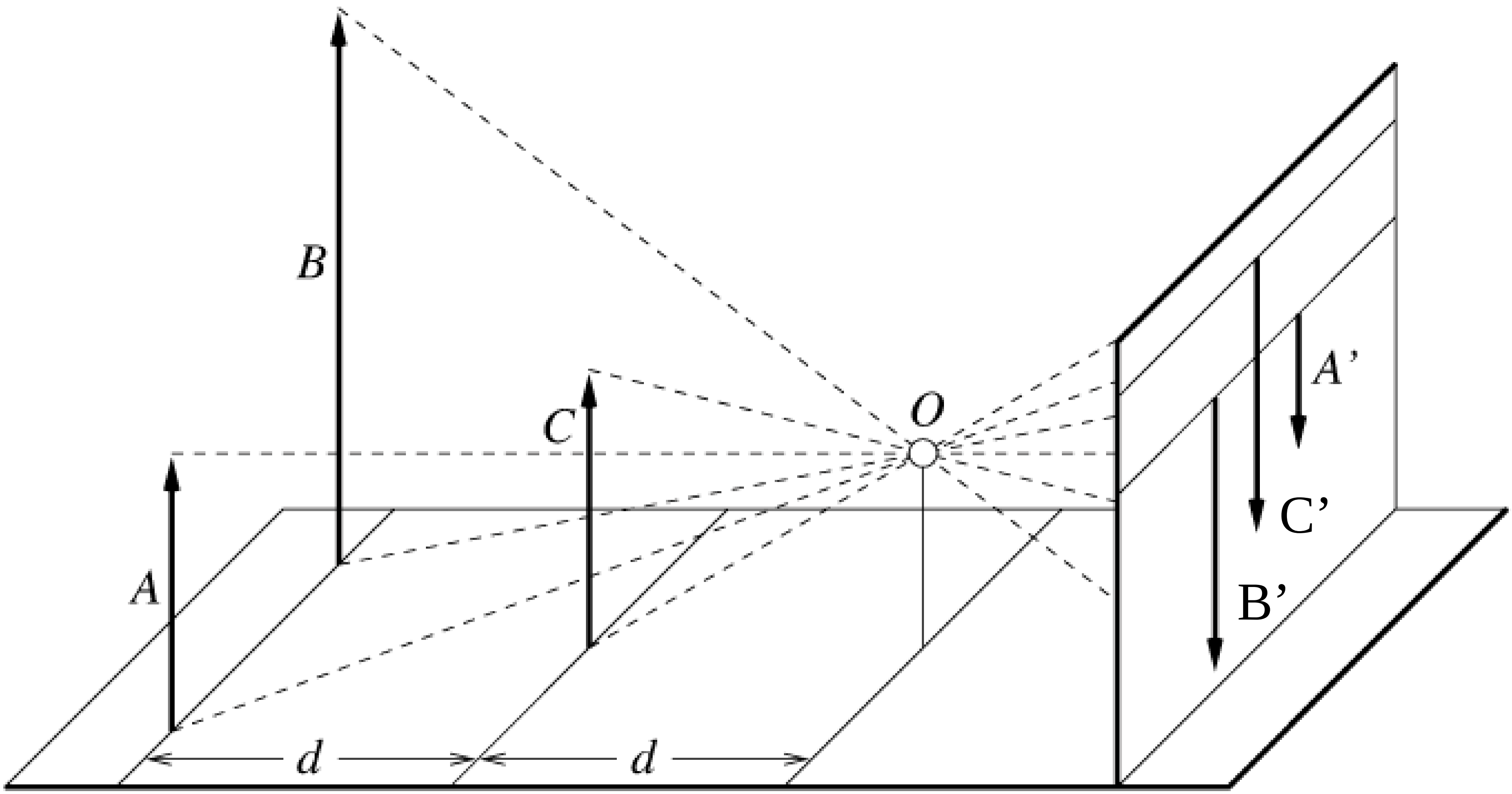
Camera configuration
in world coordinates
object
Transform
to standard
camera frame
Clip in 3D
Project to 2D
using camera
model
Render 2D
polygons
using
lighting info
Determine
what's in front
Lighting information

Pinhole cameras

- Abstract camera model--box with a small hole in it
- Pinhole cameras work for deriving algorithms--a real

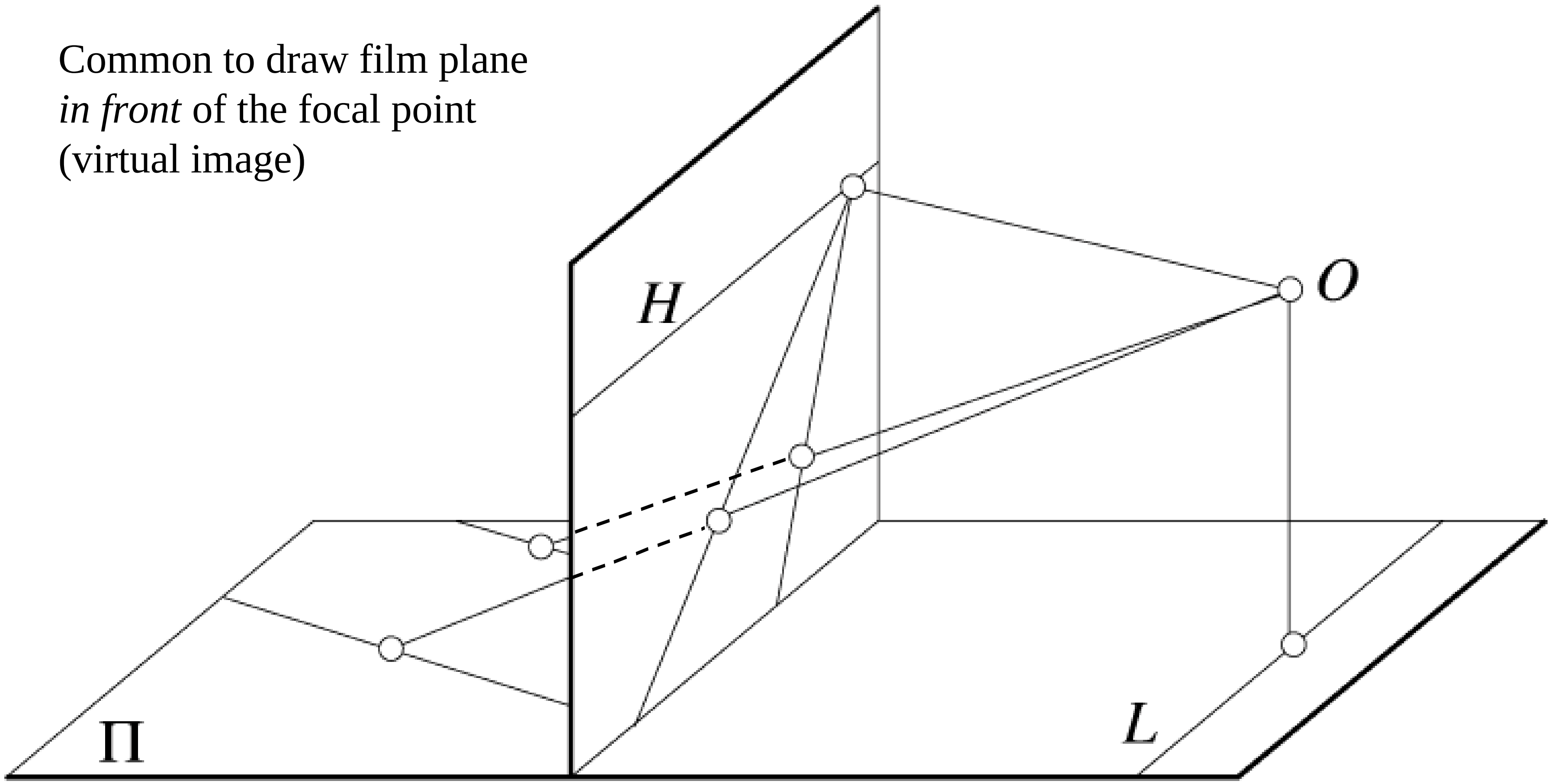


Distant objects are smaller



Parallel lines meet*

Common to draw film plane
in front of the focal point
(virtual image)



*Exceptions?

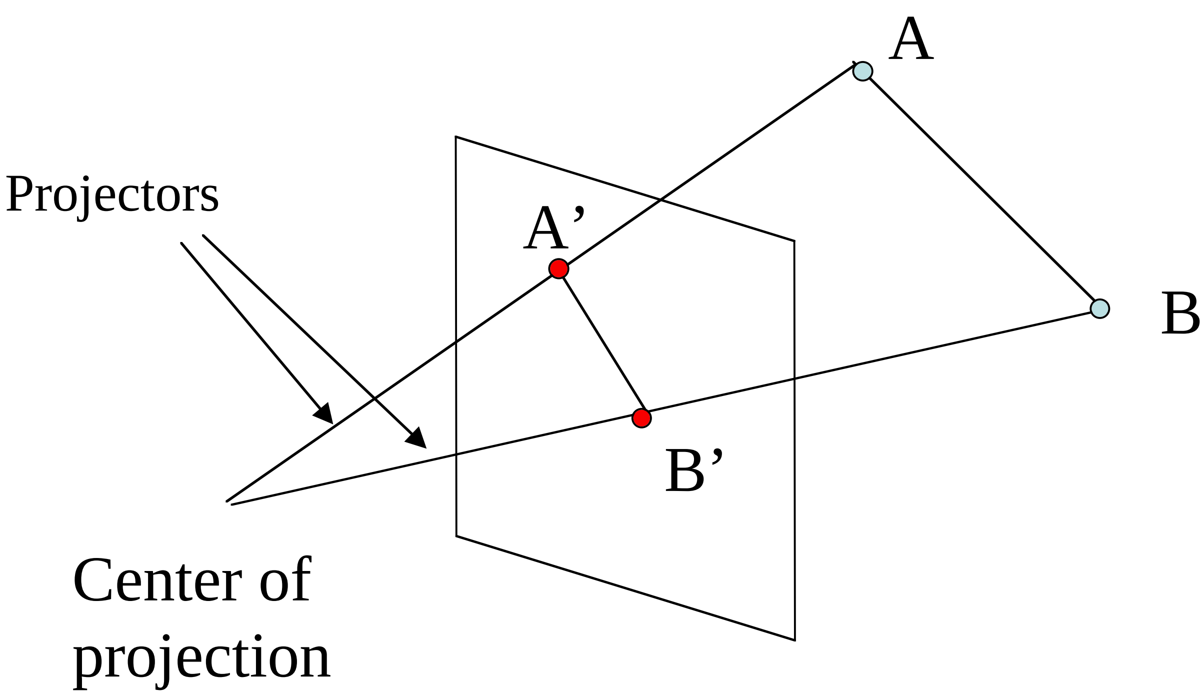
Vanishing points

- Each set of parallel lines (=direction) meets at a different point
  - The *vanishing point* for this direction
- Sets of parallel lines on the same plane lead to *collinear* vanishing points.
  - The line is called the *horizon* for that plane
  - Standard horizon is the horizon of the ground plane.
- One way to spot fake images

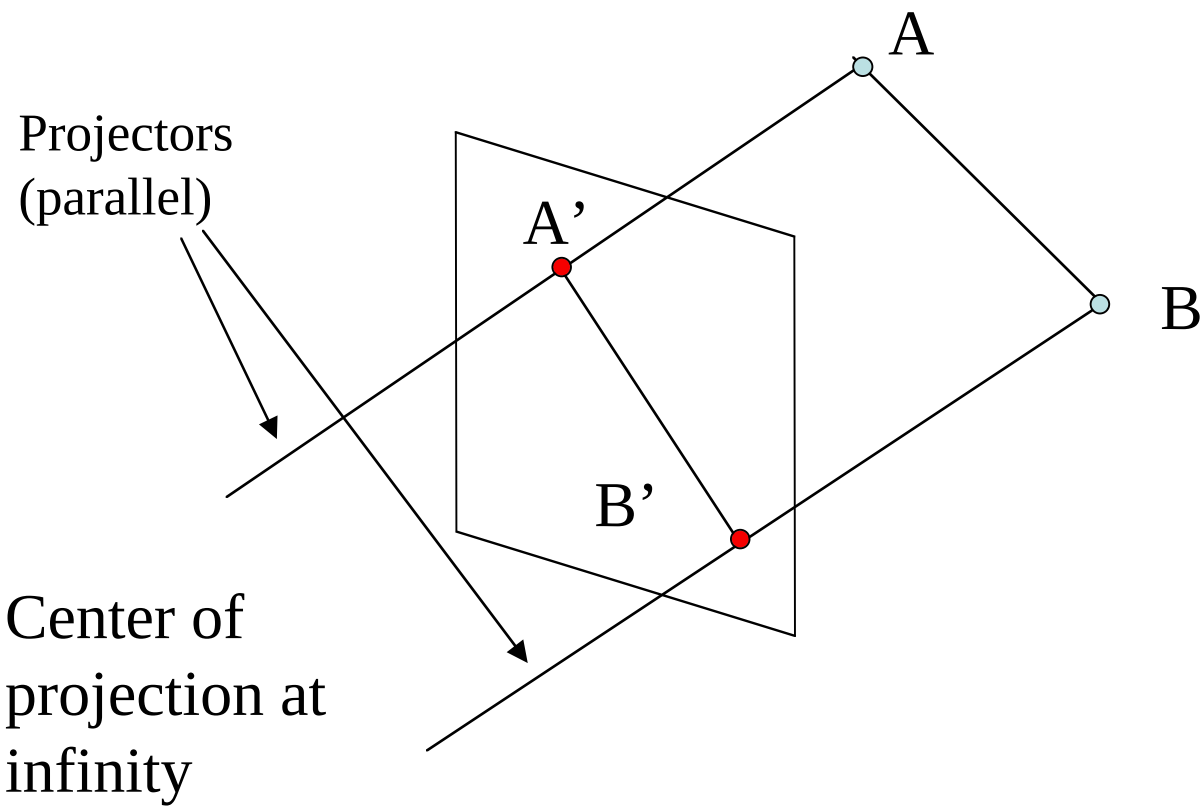
Projections

- Mathematical definition of a projection: PP=P
- (Doing it a second time has no effect).
- Generally rank deficient (non-invertable)-- exception is P=I
- Transformation looses information (e.g., depth)
- Given a 2D image, there are many 3D worlds that could have lead to it.

Projections (§6.2)



Parallel Projection



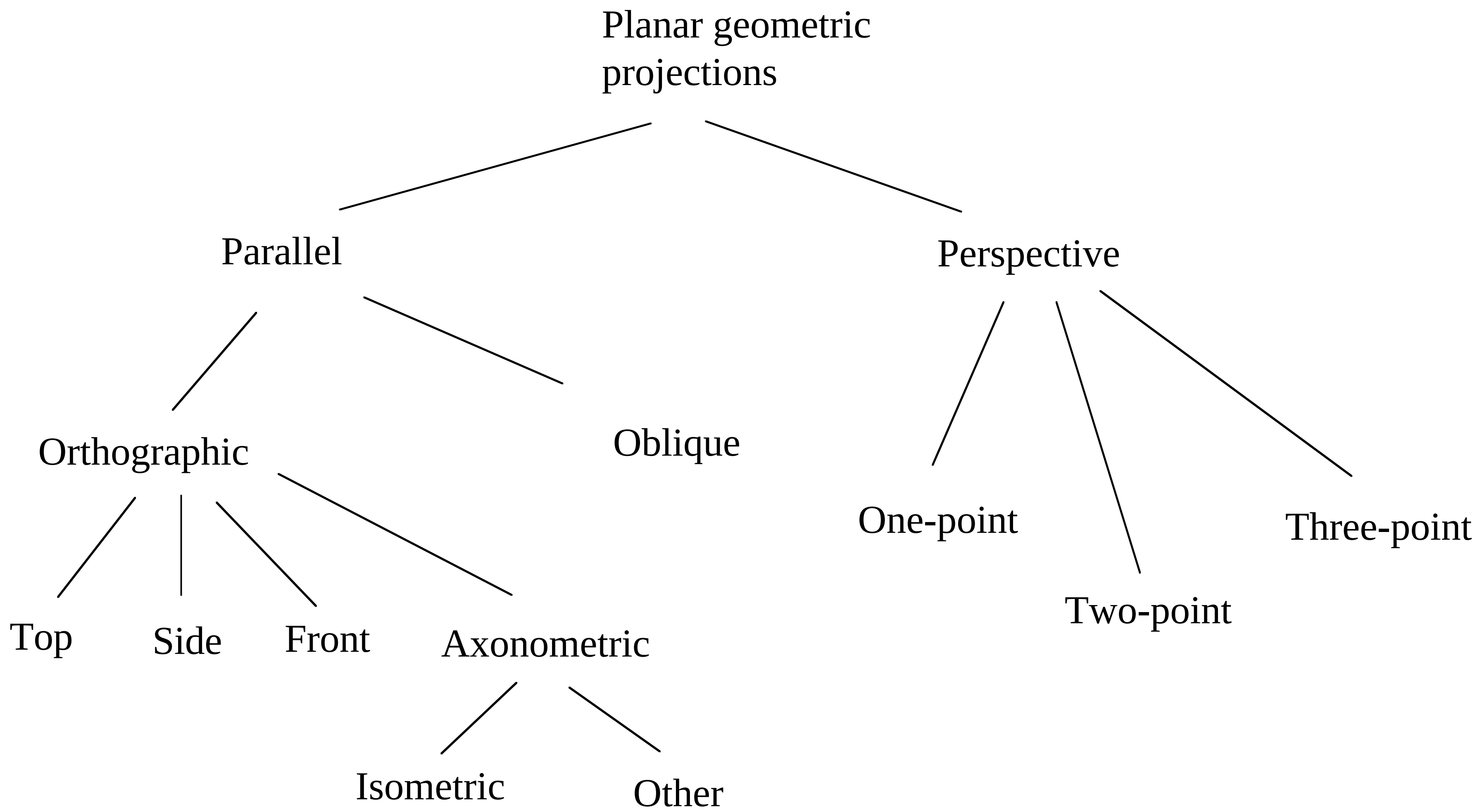
Parallel Projection

Parallel lines remain parallel, some 3D measurements can be made using 2D picture

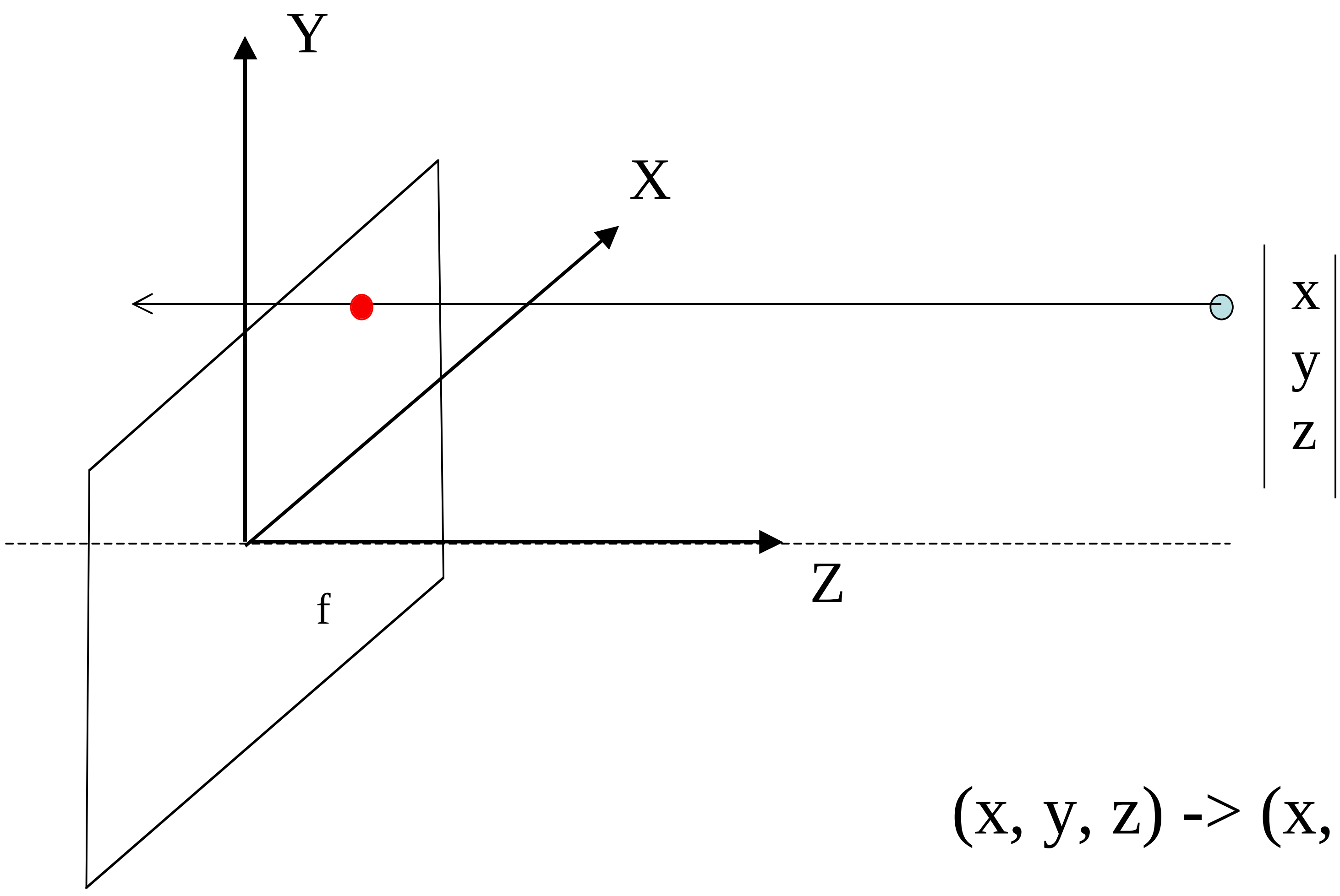
Does not give realistic 3D view because eye is more like perspective projection.

If projection plane is perpendicular to projectors the projection is orthographic (e.g., top view, side view, front view)

Projection Taxonomy (Figure 6.10)



Orthographic example (onto z=0)



(x, y, z) -> (x, y, 0)

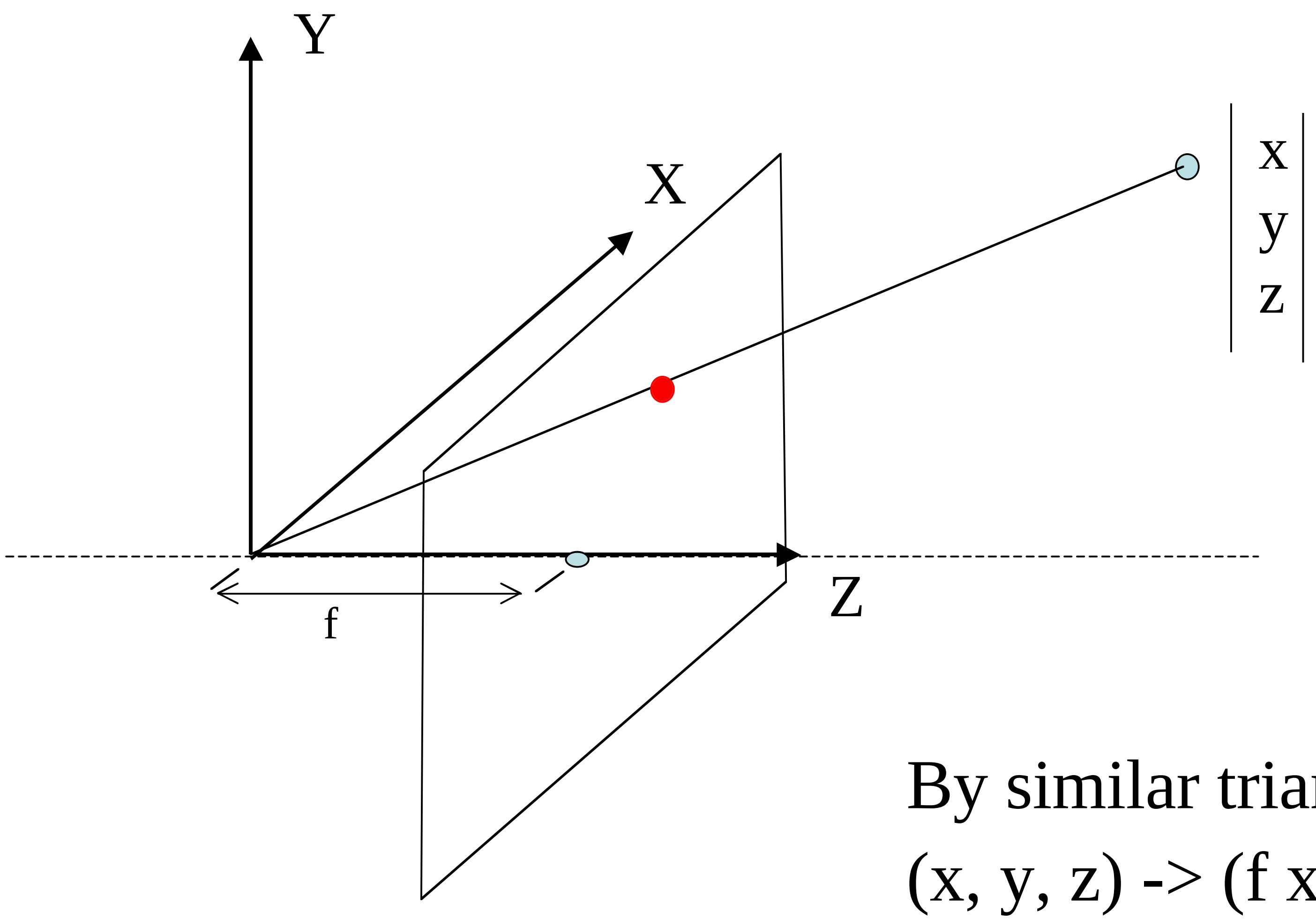
The camera matrix

$$\begin{pmatrix} x \\ y \\ 0 \\ w \end{pmatrix} = \begin{bmatrix} & & & \\ & & ? & \\ & & & \\ & & & \end{bmatrix} \begin{pmatrix} x \\ y \\ z \\ w \end{pmatrix}$$

The camera matrix

$$\begin{pmatrix} x \\ y \\ 0 \\ w \end{pmatrix} = \begin{bmatrix} 1 & & & \\ & 1 & & \\ & & 0 & \\ & & & 1 \end{bmatrix} \begin{pmatrix} x \\ y \\ z \\ w \end{pmatrix}$$

Perspective example (onto z=f)



By similar triangles,

(x, y, z) -> (f x/z, f y/z, f)

The equation of projection

- In homogeneous coordinates

$$(x,\ y,\ z,\ 1) \Rightarrow (f\frac{x}{z},\ f\frac{y}{z},\ f,\ 1)$$

- Equivalently

$$(x,\ y,\ z,\ 1) \Rightarrow (x,\ y,\ z,\ \frac{z}{f})$$

- (Now H.C. are being used to store foreshortening)

The camera matrix

$$\begin{pmatrix} x \\ y \\ z \\ \dfrac{z}{f} \end{pmatrix} = \begin{bmatrix} & & \\ & ? & \\ & & \end{bmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$$

The camera matrix

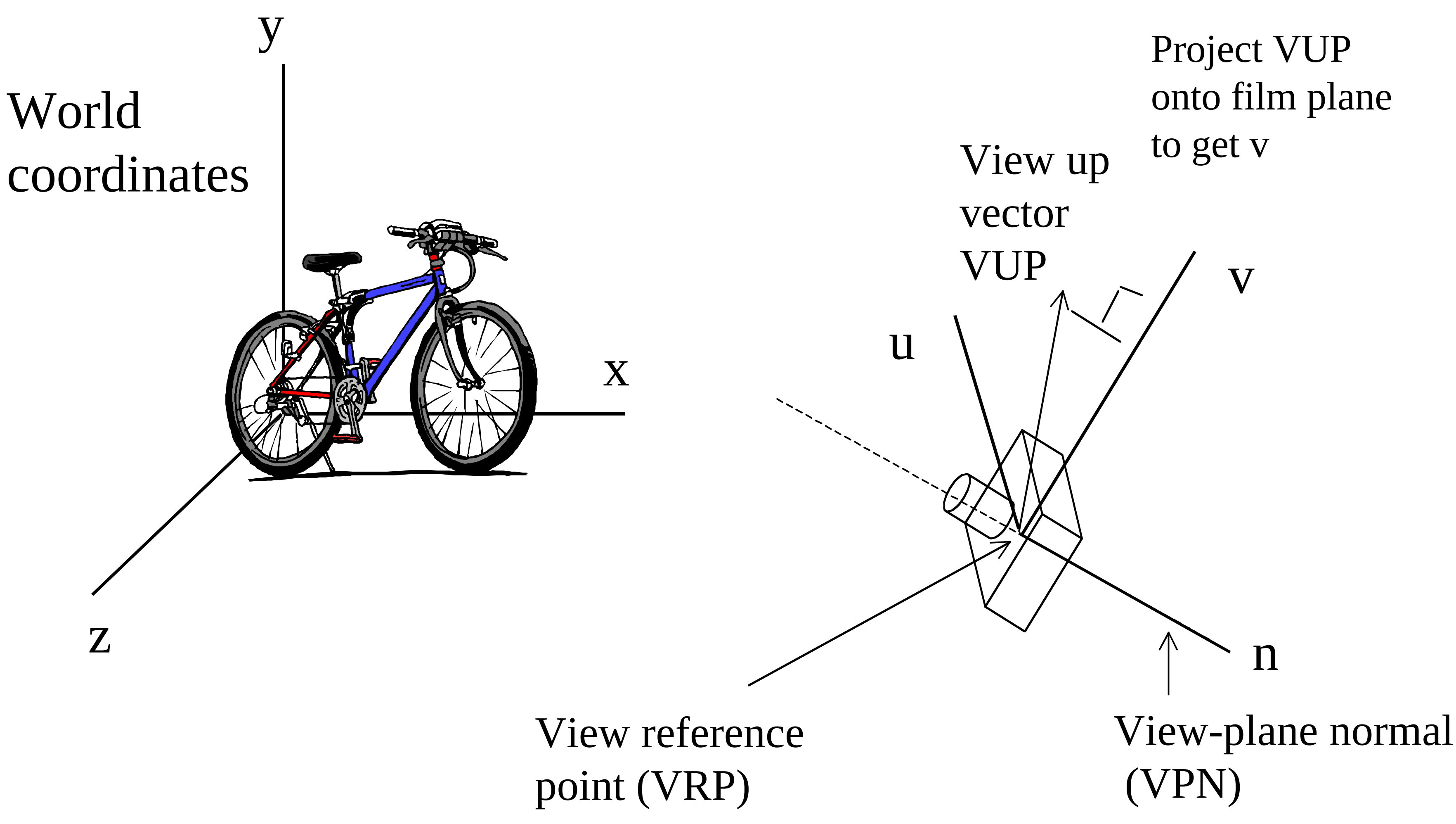
$$\begin{pmatrix} x \\ y \\ z \\ \frac{z}{f} \end{pmatrix} = \begin{bmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & \frac{1}{f} & 0 \end{bmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$$

Specifying a camera

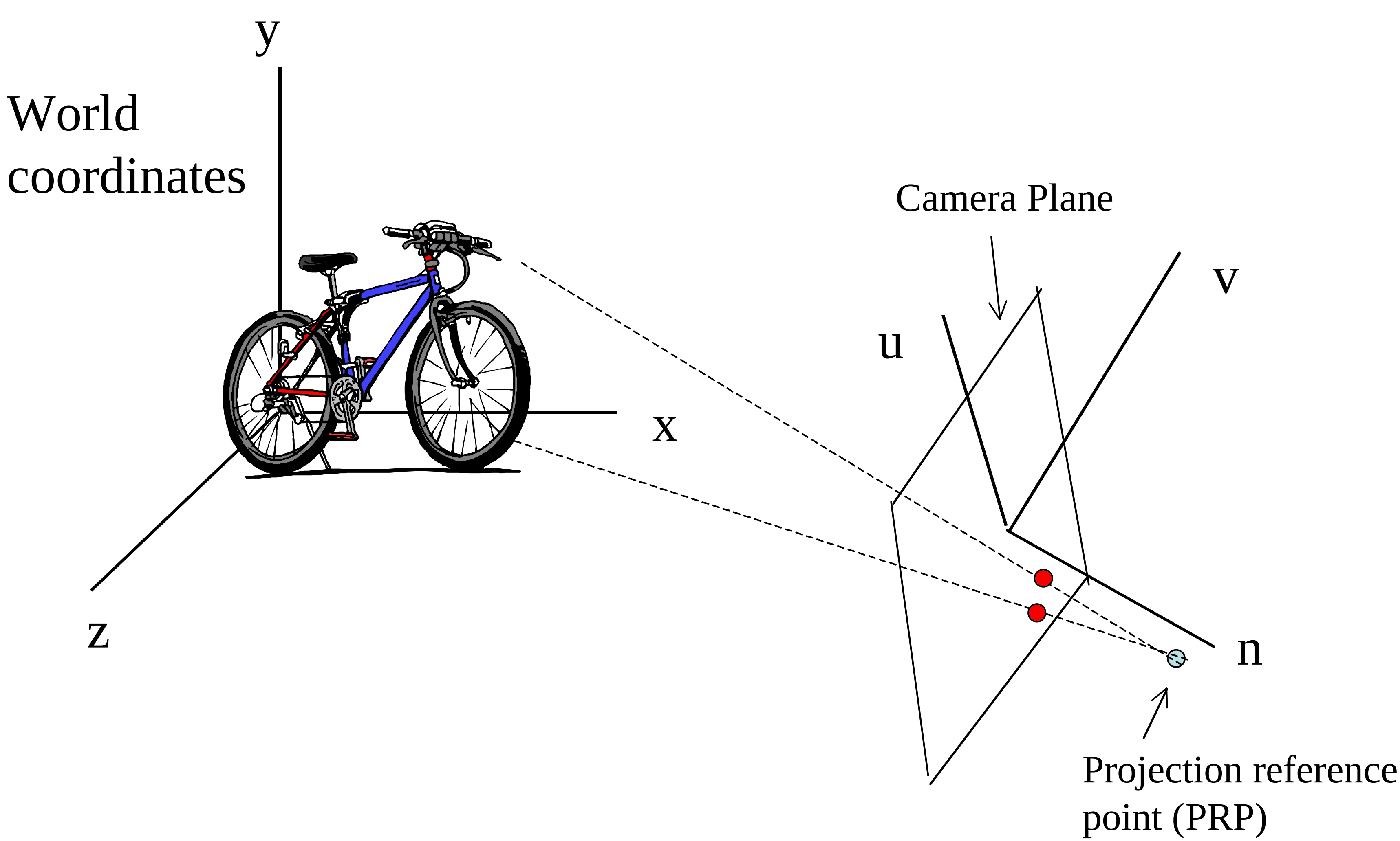
- Camera
  - Tell rendering system where camera is in world coordinates
  - Need to specify focal point and film plane.
  - Convenient to construct a coordinate system for the camera with origin on film plane

- Clipping volume
  - we render only a window in the film plane
  - Things beyond any of four sides don’t get rendered
  - Things that are too far away don’t get rendered
  - Things that are too near don’t get rendered.

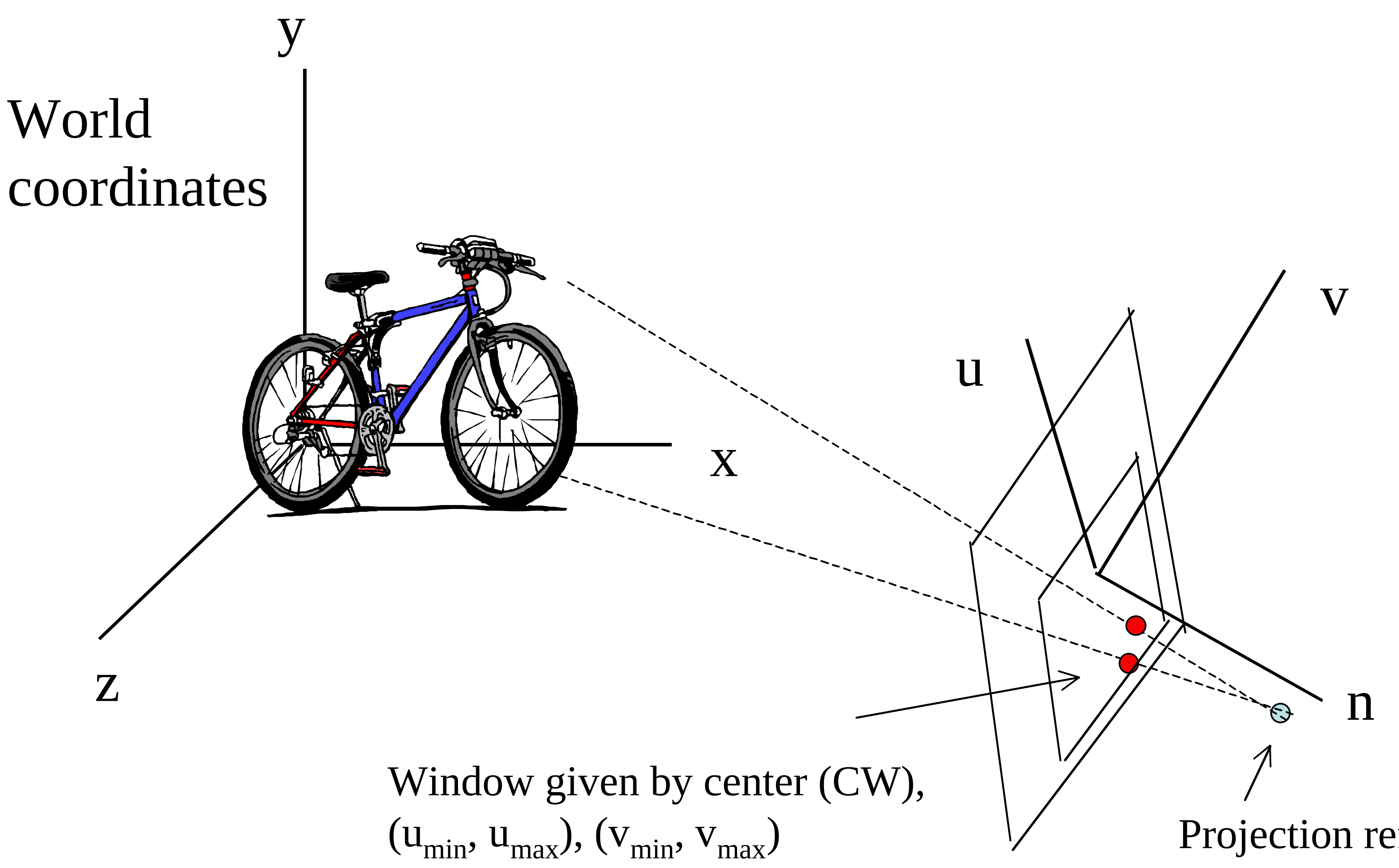
Specifying a camera



Specifying a camera



Specifying a camera



Window given by center (CW), (u_{min}, u_{max}), (v_{min}, v_{max})

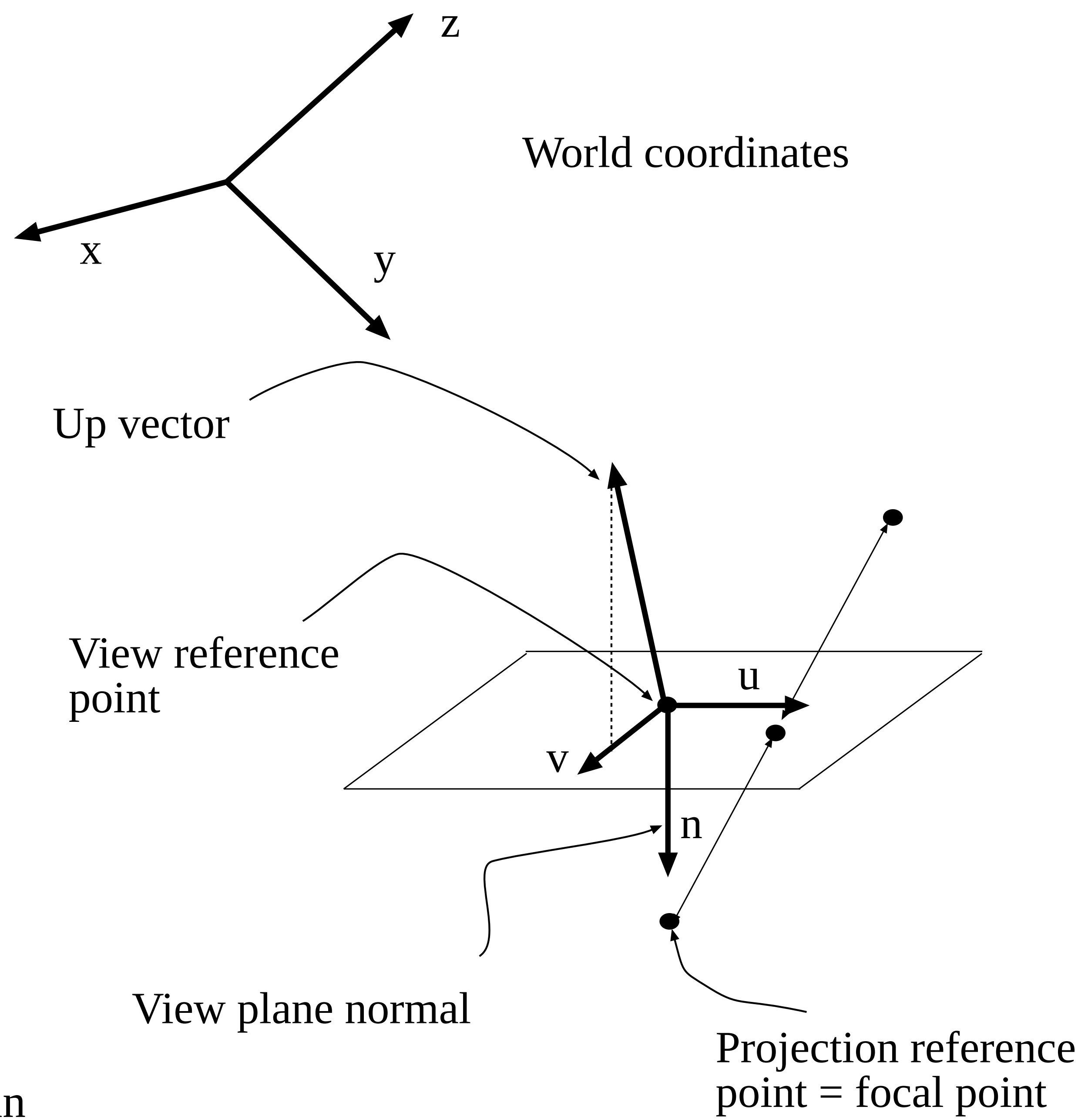
Projection reference point (PRP)

View reference point
and view plane normal
specify film plane.

Up vector gives an “up”
direction in the film plane.
vector v is projection of
up vector into film plane
(= $\mathbf{n} \times \mathrm{VUP} \times \mathbf{n}$).

u is chosen so that (u, v, n)
is a right handed coordinate
system; i.e. it is possible to
rotate (x->u, y->v, z->n)
(and we’ll do this shortly).

VRP, VPN, VUP must be in
world coords; PRP could be in
world coords or in camera coords



U, V can be used to specify a window in the film plane; only this section of film ends up on the screen.

This window defines four planes; points outside these planes are not rendered.

Hither and yon clipping planes, which are always given in terms of camera coordinates, and always parallel to the film plane, give a volume - known as the view frustum.

Orthographic case: - view frustum is cuboid (i.e. all angles right angles, but edges not necessarily of equal length).