Projection Taxonomy

COMP 557

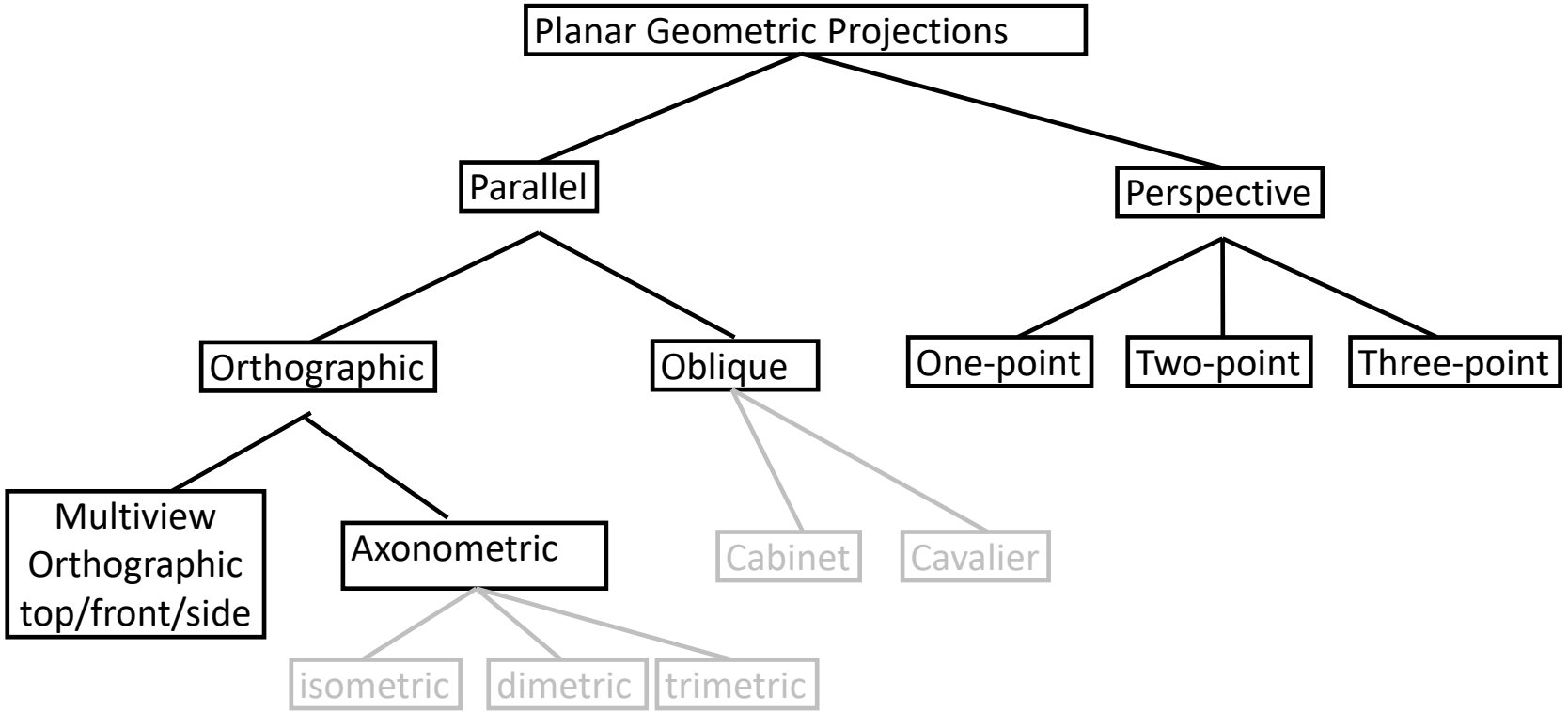
Paul Kry

Recall: Ray Generation vs. Projection

- Viewing in ray tracing
  - start with ***planar*** image point
  - compute ray that projects to that point
  - do this using geometry
- Viewing by projection
  - start with 3D point
  - compute image point that it projects to
  - do this using transforms
- In this case, both provide planar projection

Taxonomy of Classical Projections

- Emphasis on cube-like objects
  - traditional in mechanical and architectural drawing

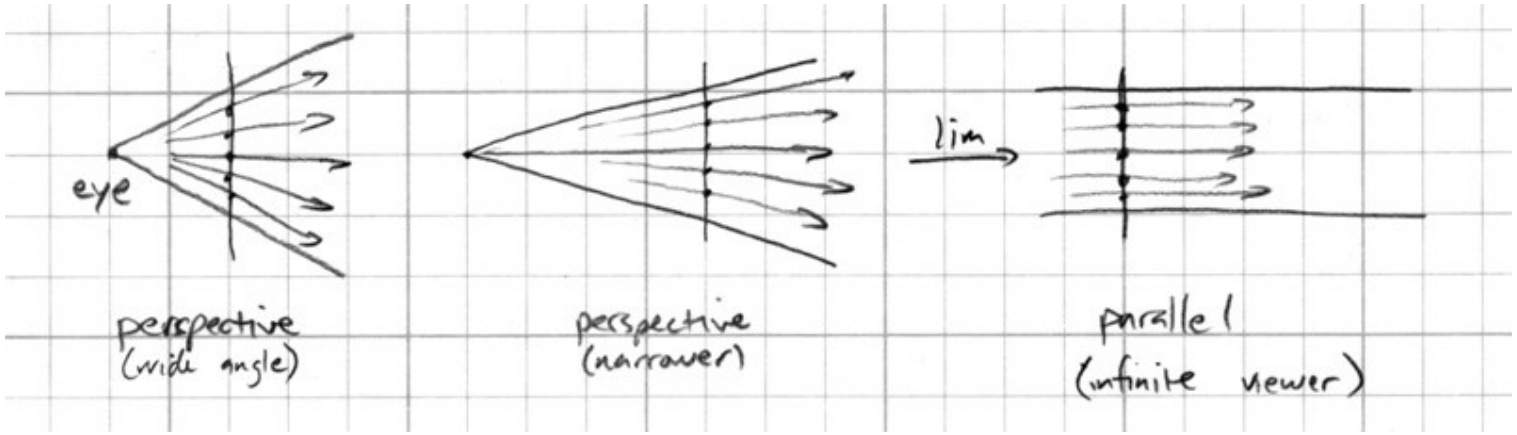


[after Carlbom & Paciorek 78]

Based on slides by Steve Marschner

Parallel Projection

- Viewing rays are parallel rather than diverging
  - like a perspective camera that's far away



Based on slides by Steve Marschner

Multiview Orthographic

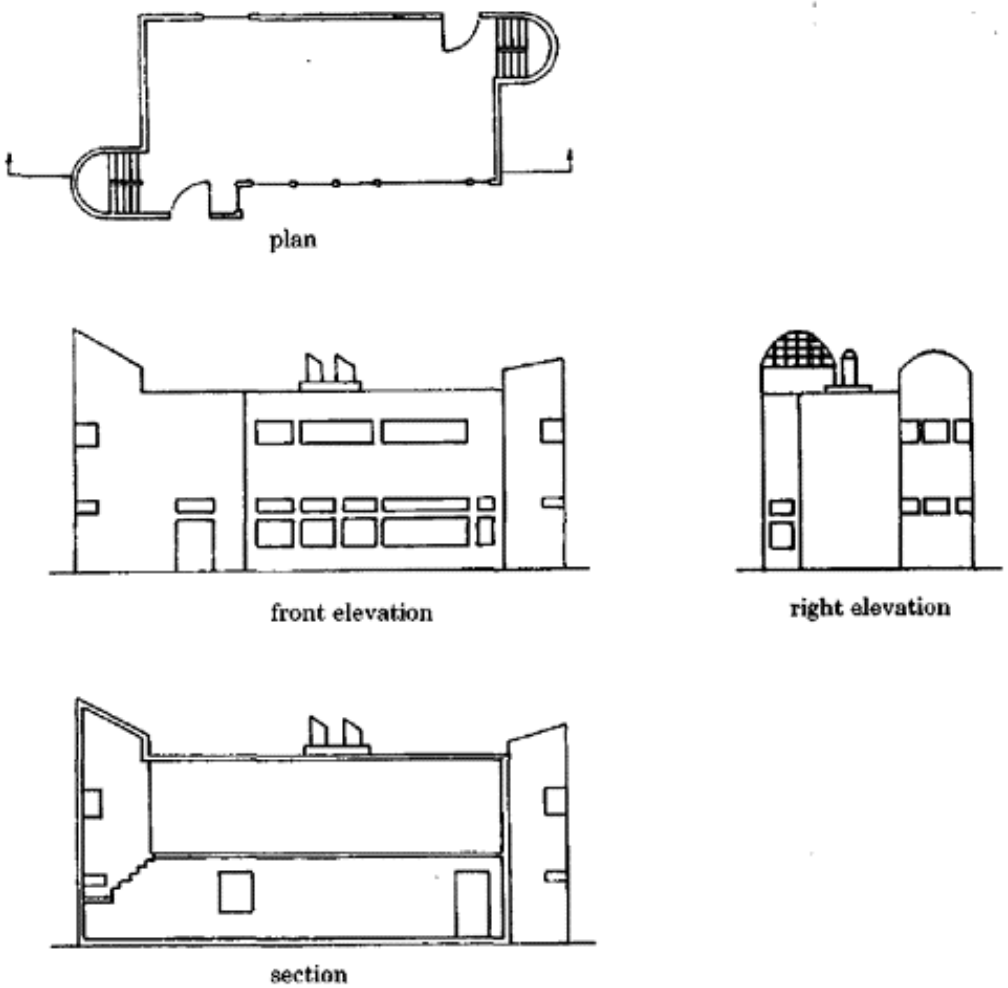


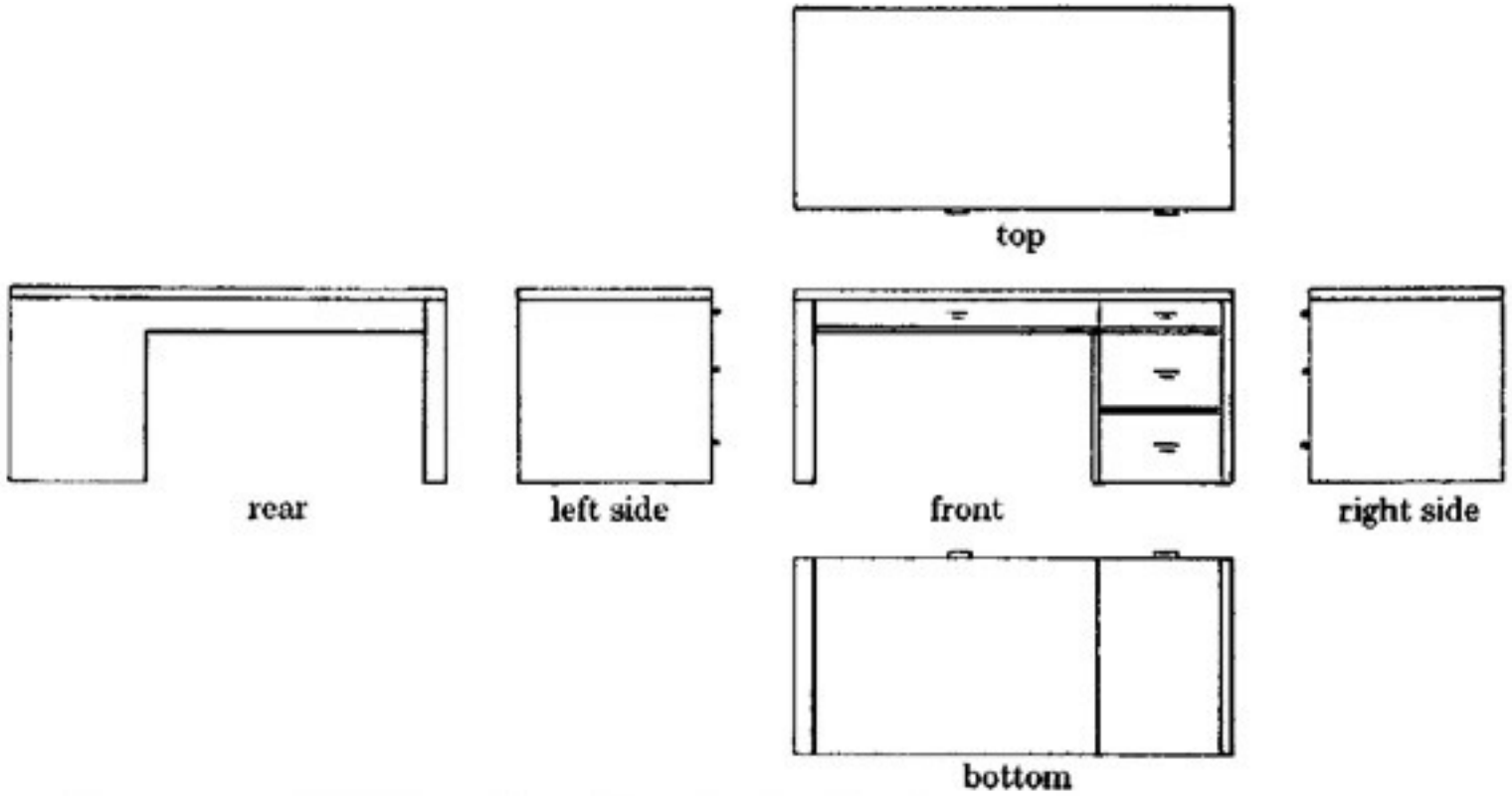
FIGURE 2-1. Multiview orthographic projection: plan, elevations, and section of a building.

[Carlbom & Paciorek 78]

Based on slides by Steve Marschner

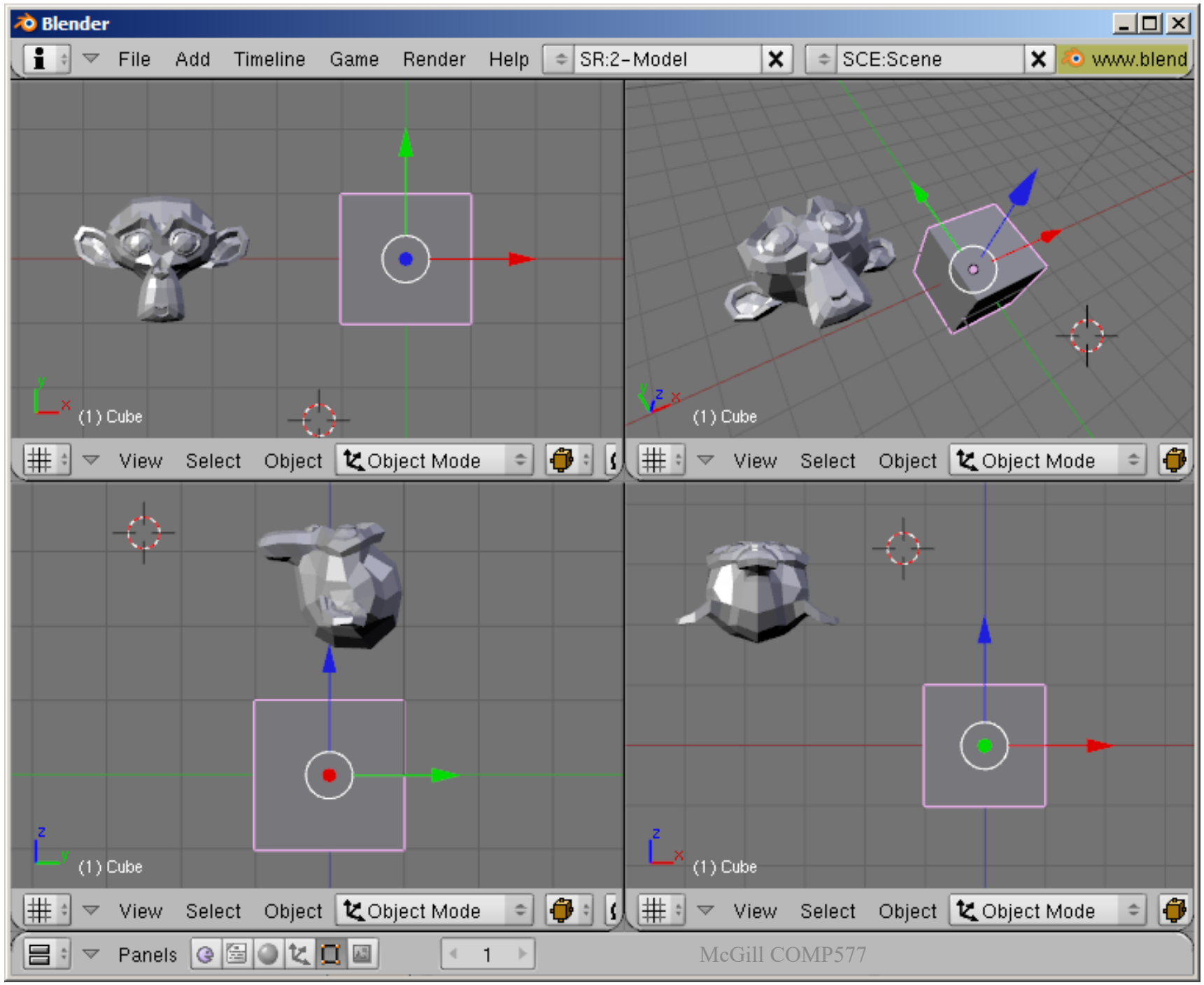
Multiview Orthographic

- Projection plane parallel to a coordinate plane
- Projection direction perpendicular to projection plane



[Carlbom & Paciorek 78]

Based on slides by Steve Marschner


Blender
File
Add
Timeline
Game
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SCE:Scene
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View
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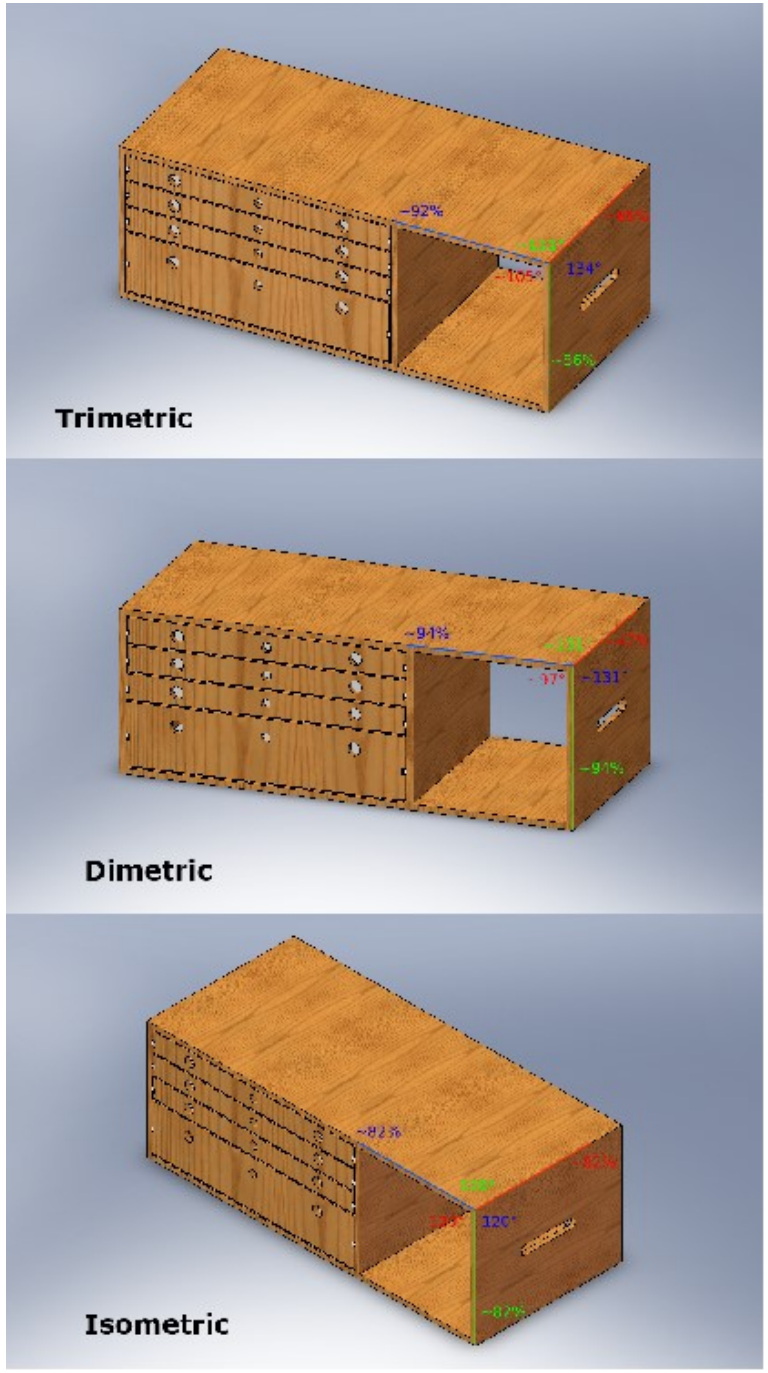
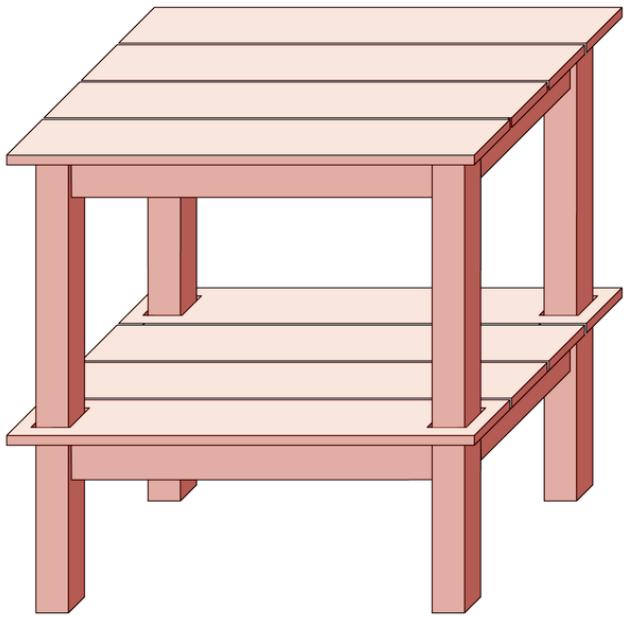
1

Off-axis parallel

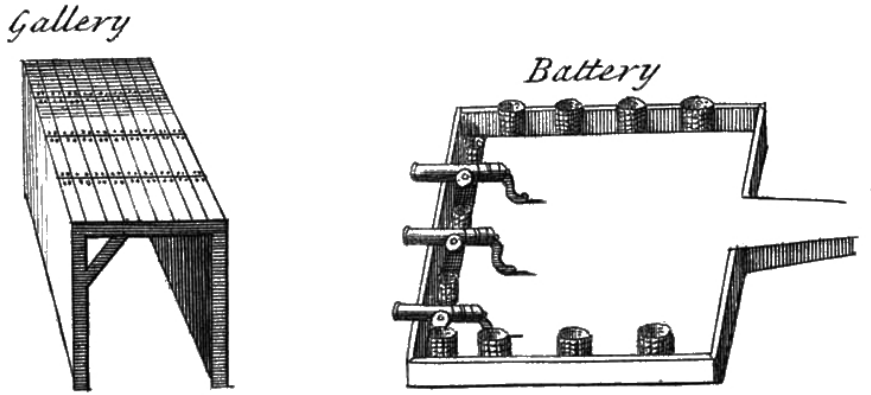


axonometric: projection plane perpendicular to projection direction but not parallel to coordinate planes

Oblique Parallel Projection



Cabinet, ½ length in z

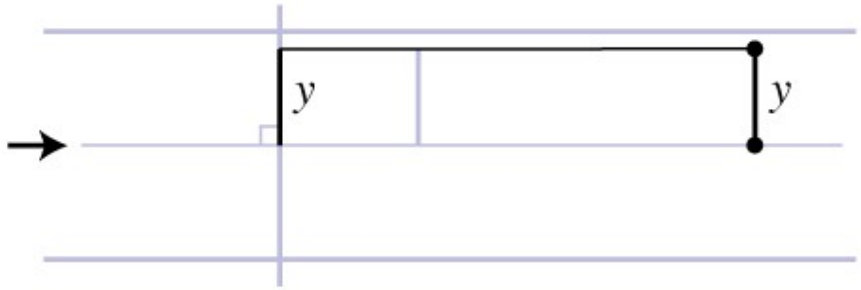


Cavalier... same length in all dimensions

oblique: projection plane parallel to a coordinate plane but not perpendicular to projection direction.

Orthographic Projection

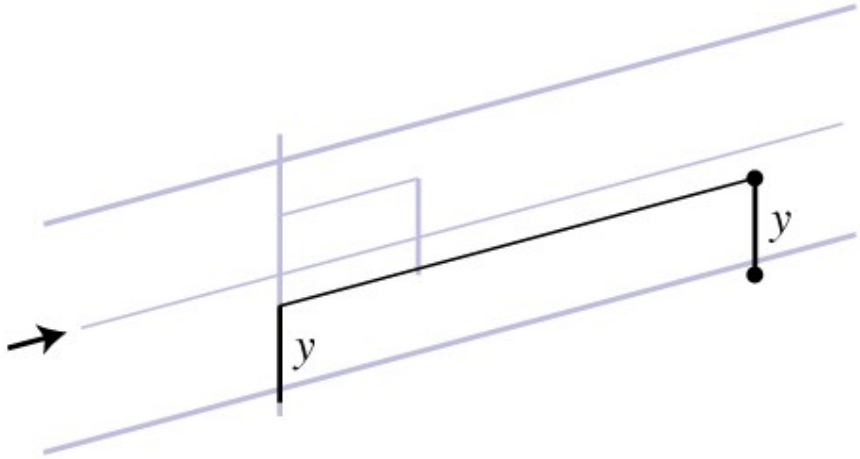
- In graphics, we associate axonometric with orthographic
  - projection plane perpendicular to projection direction
  - image height determines size of objects in image



Based on slides by Steve Marschner

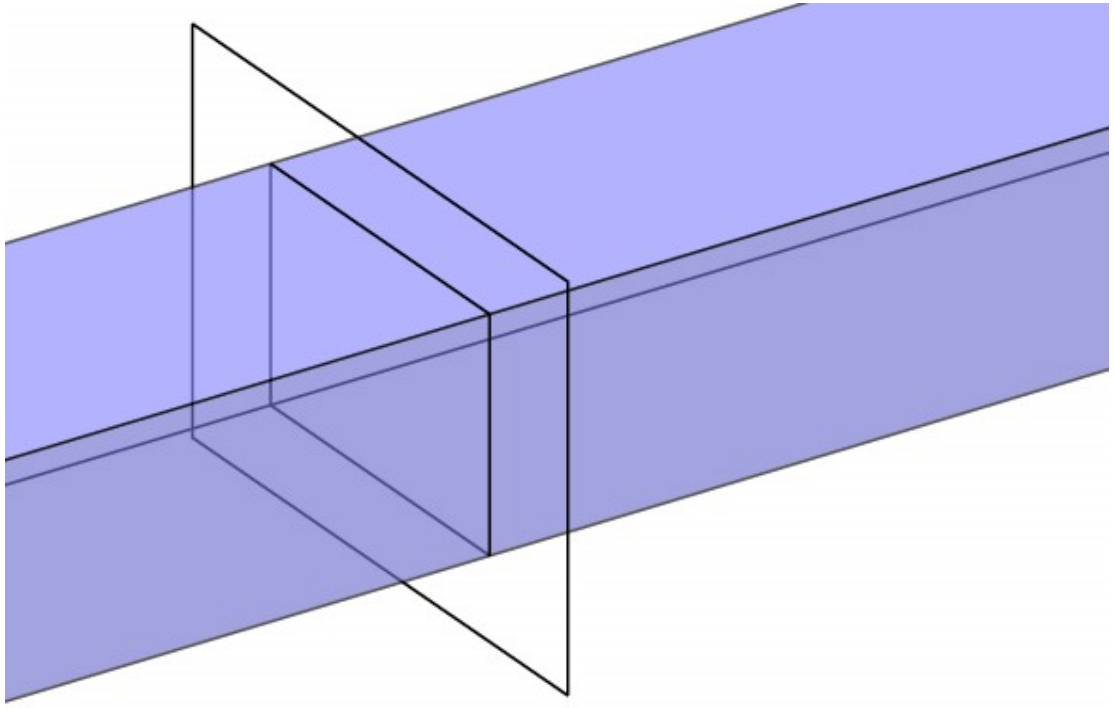
Oblique projection

- View direction no longer coincides with projection plane normal (one more parameter)
  - objects at different distances still same size
  - objects are shifted in the image depending on their depth



Based on slides by Steve Marschner

Orthographic View Volume

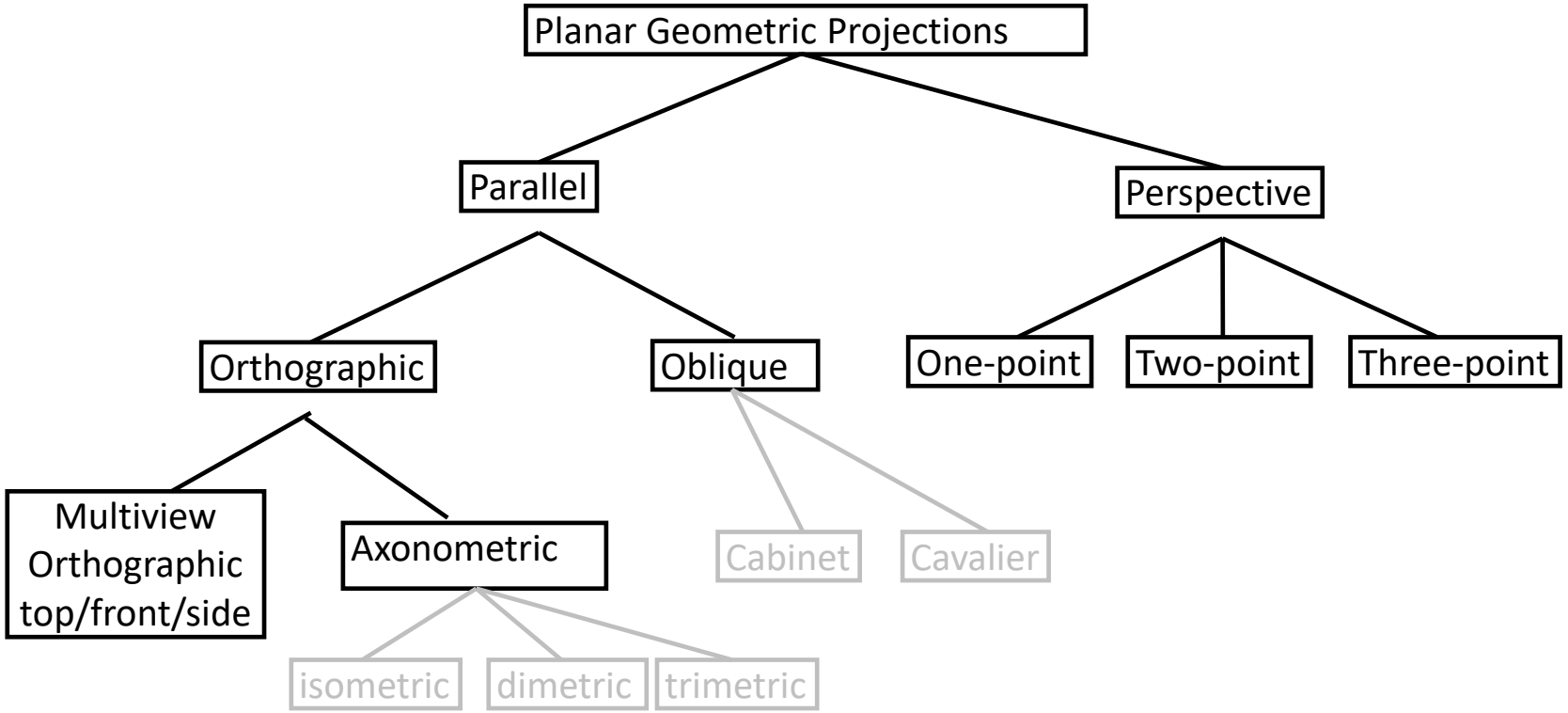


Recall: view volume is specified by left right top and bottom

Parallel projections in video games?

Taxonomy of Classical Projections

- Emphasis on cube-like objects
  - traditional in mechanical and architectural drawing



[after Carlbom & Paciorek 78]

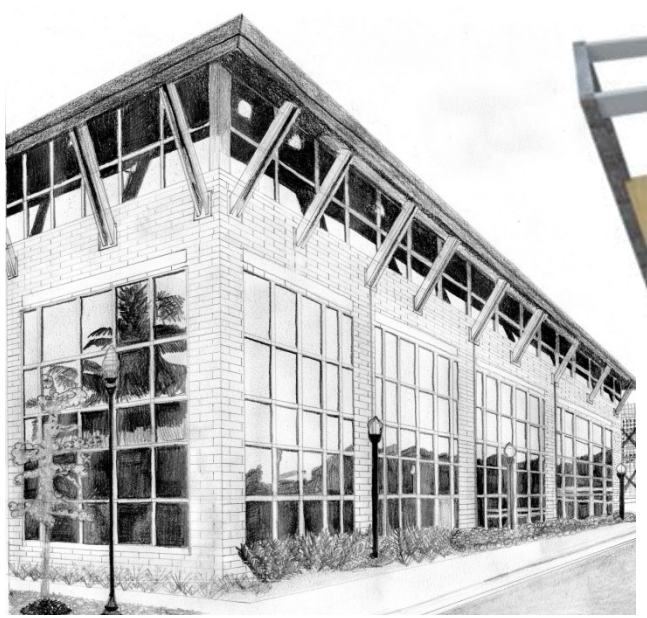
Based on slides by Steve Marschner

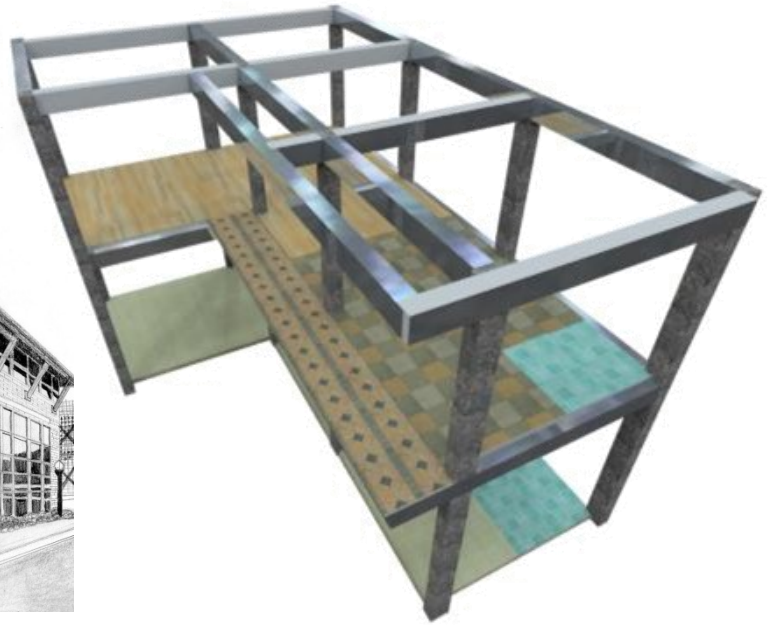
Perspective

one-point: projection plane parallel to a coordinate plane (to two coordinate axes)

two-point: projection plane parallel to one coordinate axis

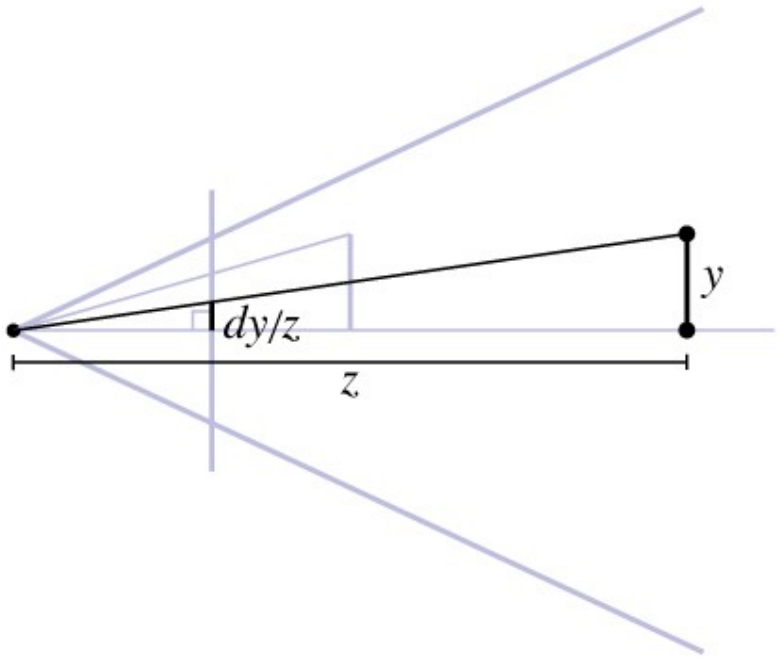
three-point: projection plane not parallel to a coordinate axis





Perspective projection (normal)

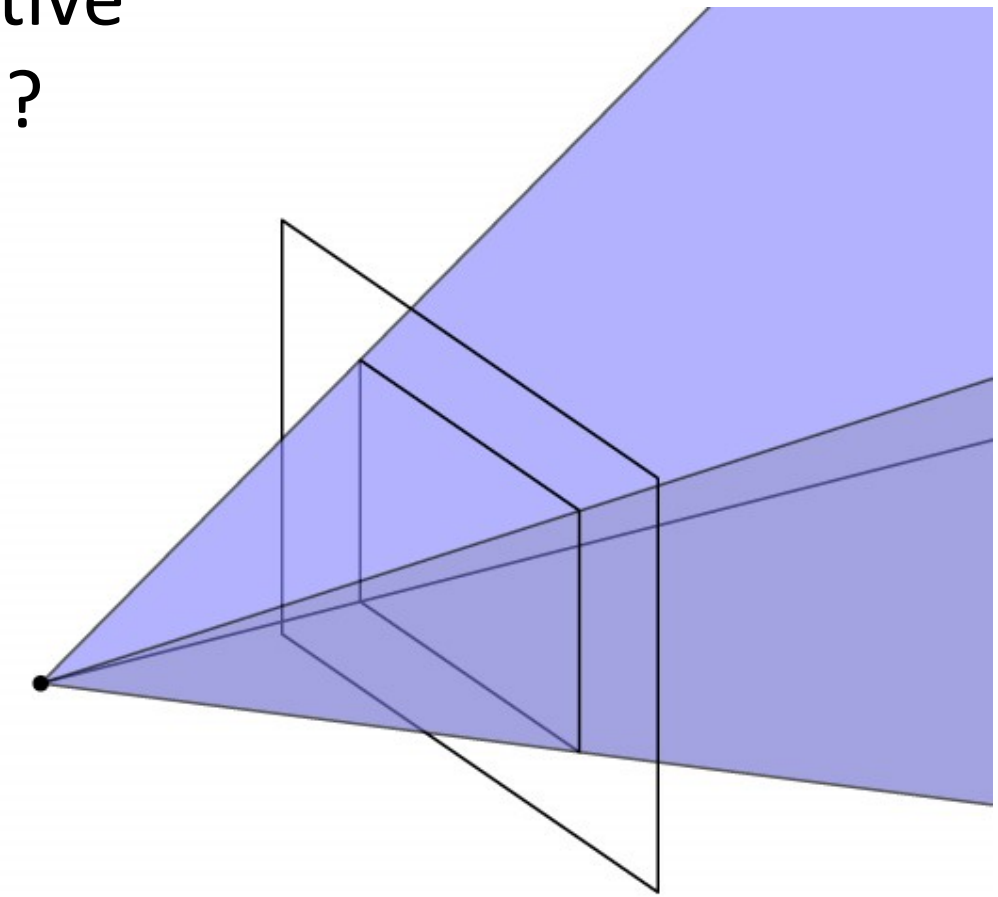
- Perspective is projection by lines through a point; "normal" = plane perpendicular to view direction
  - magnification determined by:
    - image height
    - object depth
    - image plane distance
  - FOV = 2 atan(h / (2d))
  - $y' = d\,y / z$
  - "normal" case corresponds to common types of cameras



Based on slides by Steve Marschner

View volume: perspective

- Recall: how is perspective view volume specified?

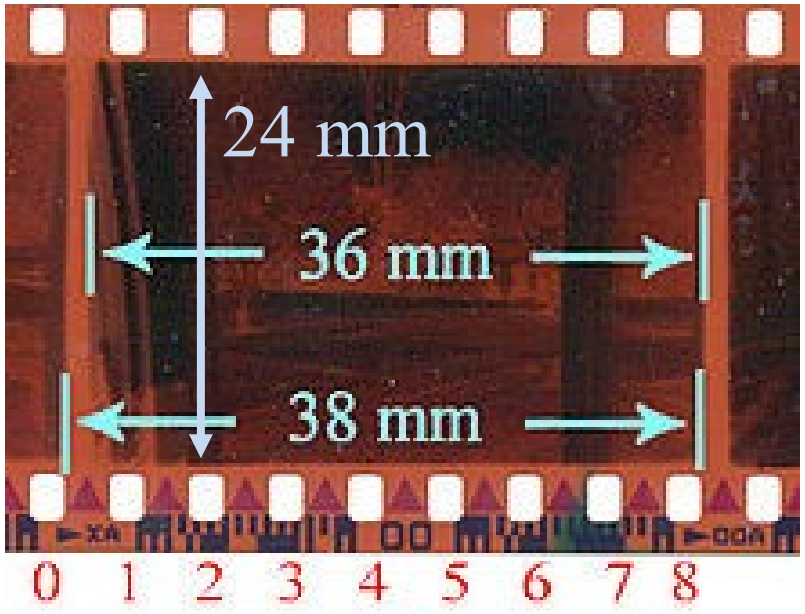


Based on slides by Steve Marschner

Field of view (or f.o.v.)

- The angle between the rays corresponding to opposite edges of a perspective image
  - Easy to compute only for “normal” perspective
    - Normal, meaning non-shifted, i.e., the ray from the center of projection of the middle of the image is perpendicular to the image plane.
  - Must decide to measure vertical, horizontal, or diagonal
- In cameras, determined by focal length
  - Confusing because it depends on film image size

Field of view (or f.o.v.)



- Photography, full frame digital or 35mm film: 36 x 24 mm image
  - 18mm = — super-wide angle
  - 28mm = — wide angle
  - 50mm = — “normal”
  - 100mm = — narrow angle (“telephoto”)

  - What is the *vertical field of view* in degrees?
    - This angle and the aspect ratio are needed choosing good values for the l, r, t, b of the windowing transformation.
  - Given n and f, how would you compute l, r, t, b for creating a projection and windowing transformation for these cases?

Field of view

- Determines “strength” of perspective effects

close viewpoint
wide angle
prominent foreshortening

far viewpoint
narrow angle
little foreshortening

[Ansel Adams]

Based on slides by Steve Marschner

18mm

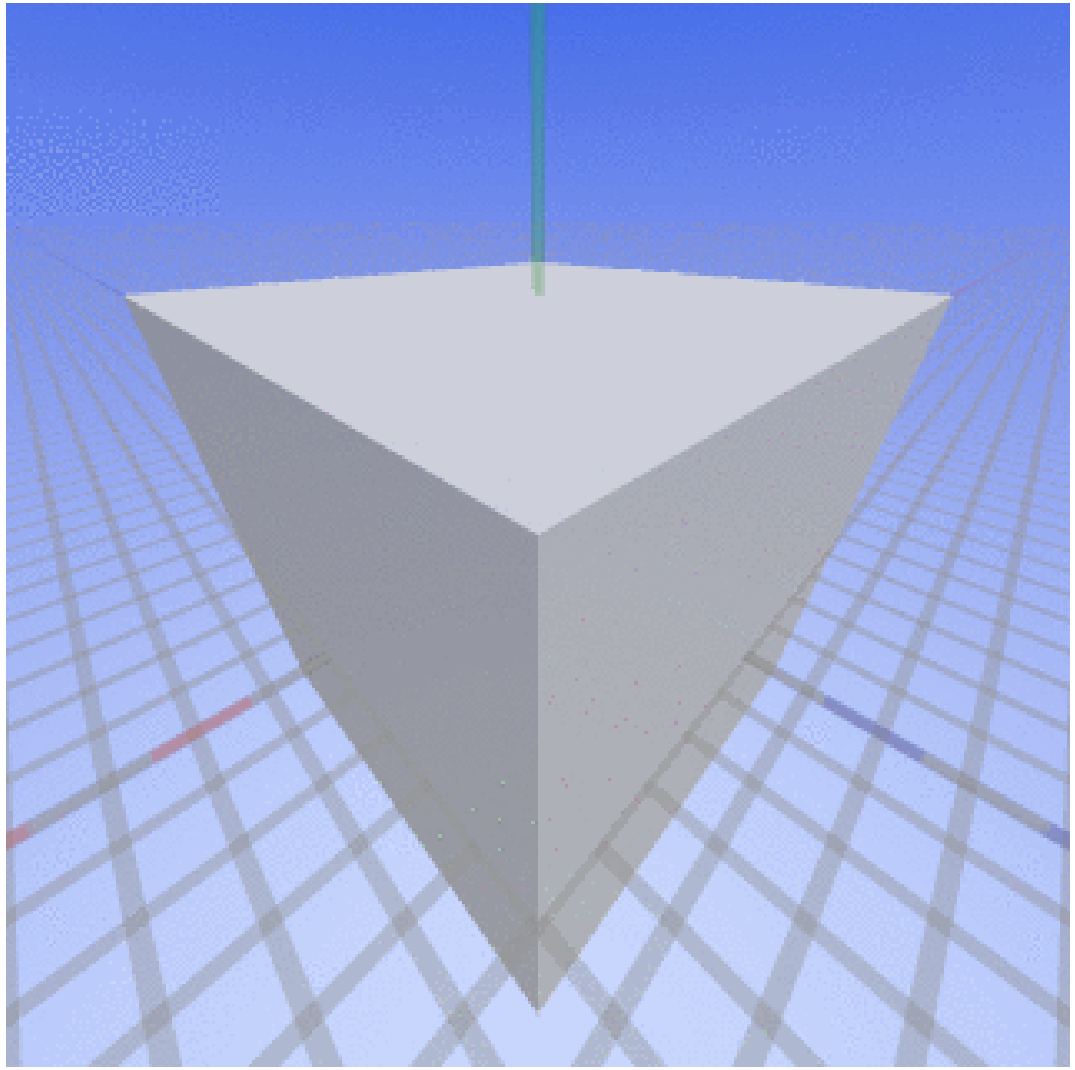
Choice of field of view

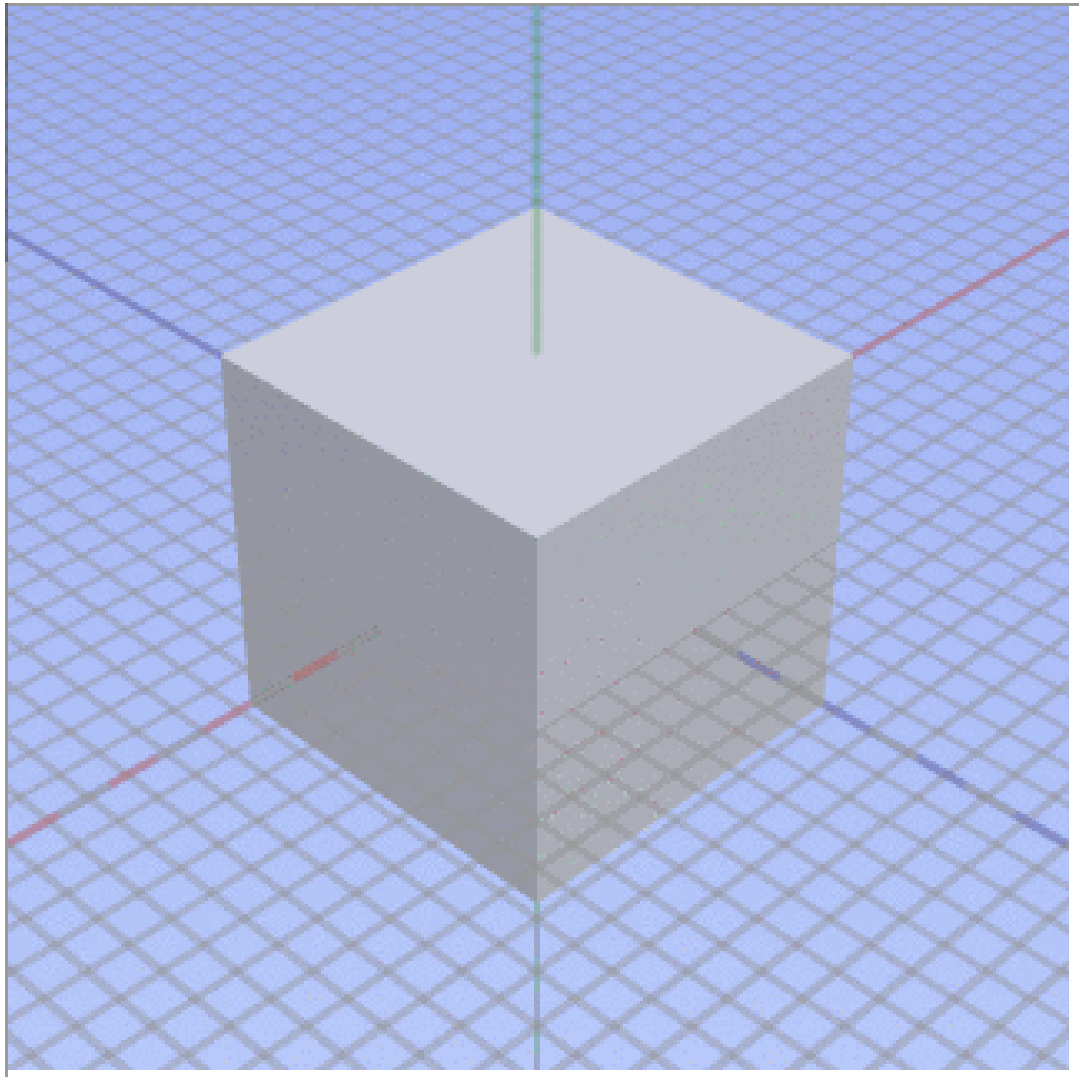
- In photography, wide angle lenses are specialty tools
  - “hard to work with”
  - easy to create weird-looking perspective effects
- In graphics, you can type in whatever f.o.v. you want
  - Don’t be one of those people that type in big numbers unless you really mean it!

[Ken Perlin]

Based on slides by Steve Marschner

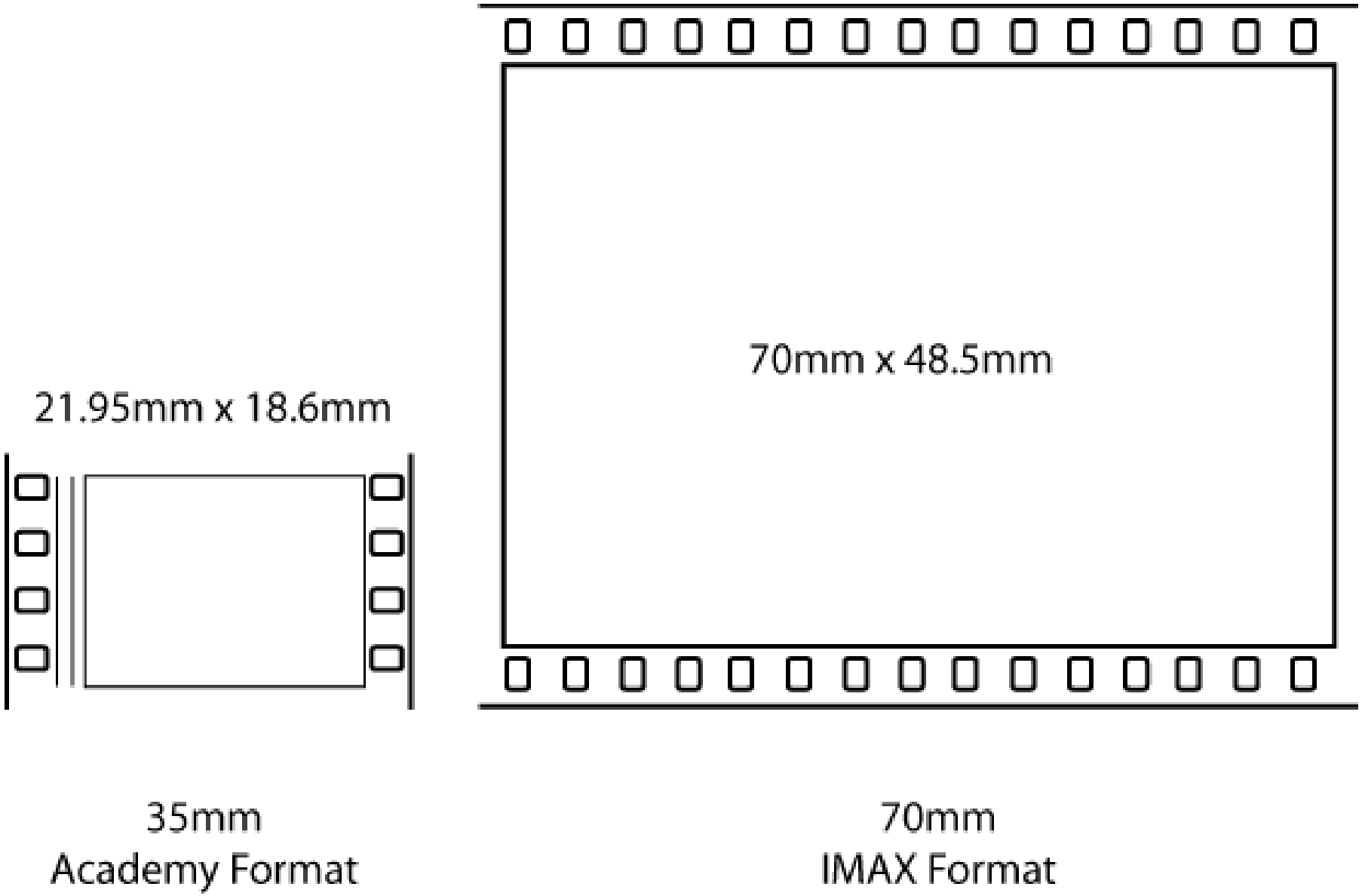
Perspective Distortions



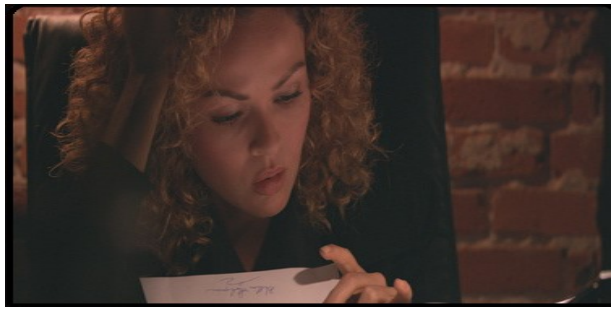


Based on slides by Steve Marschner

Brief aside...


21.95mm x 18.6mm
70mm x 48.5mm
35mm
Academy Format
70mm
IMAX Format

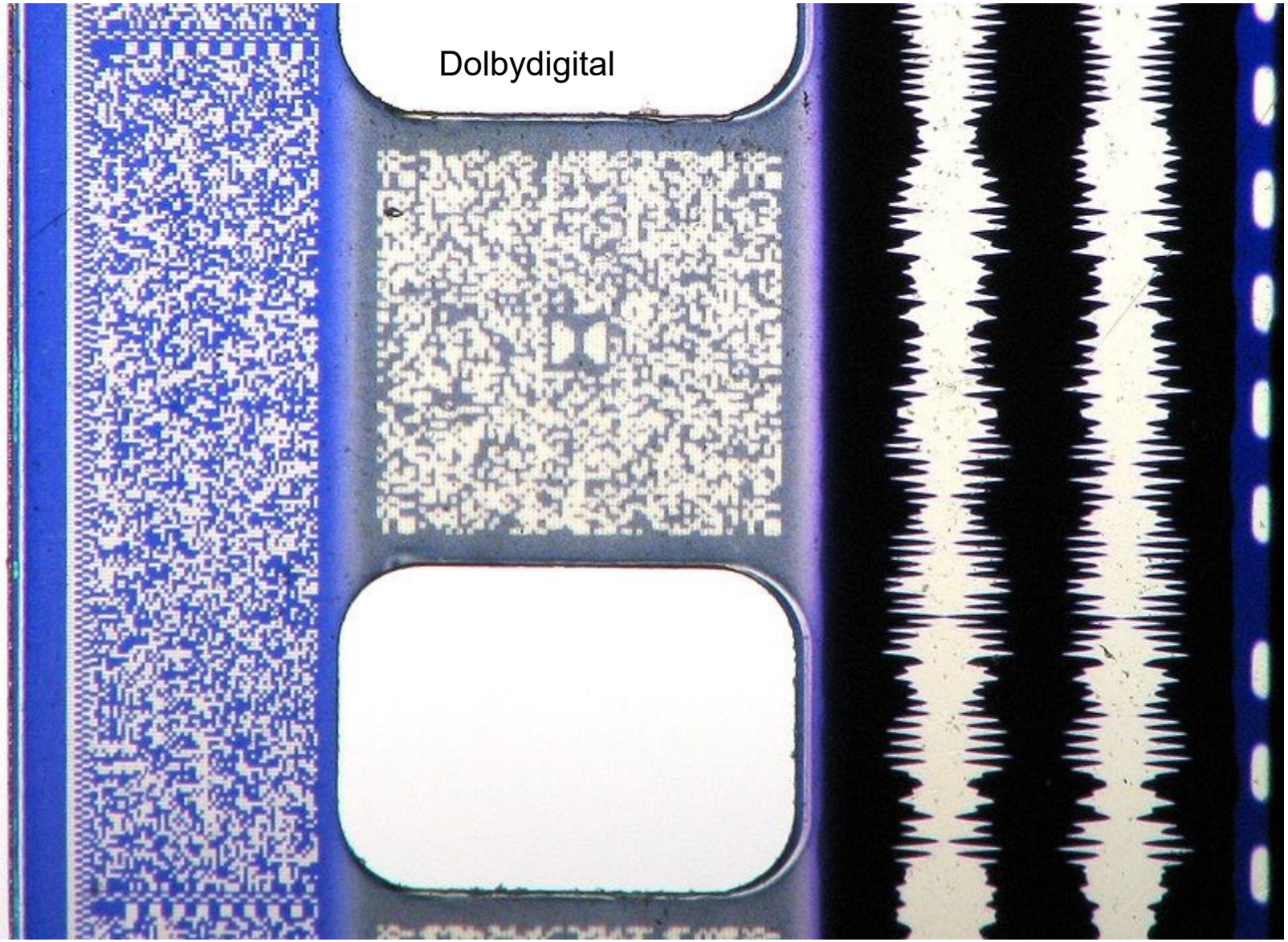
Widescreen
anamorphic
e.g., CinemaScope



SDDS
(sony dynamic digital sound)

Analog optical

DTS
time code



ANAMORPHIC VINTAGE OVAL BOKEH FILTER+ FLARE/STREAK

GET A VINTAGE LOOK TO YOUR VIDEOS

1.33 or 4:3

Standard aspect ratio
and
standard-definition video

1.66:1

Aspect ratio used for
most European theatrical
showings

1.78:1 or 16:9

Standard aspect ratio for
high-definition video

1.85:1

Aspect ratio used for most
U.S. theatrical showings
since the 1960s

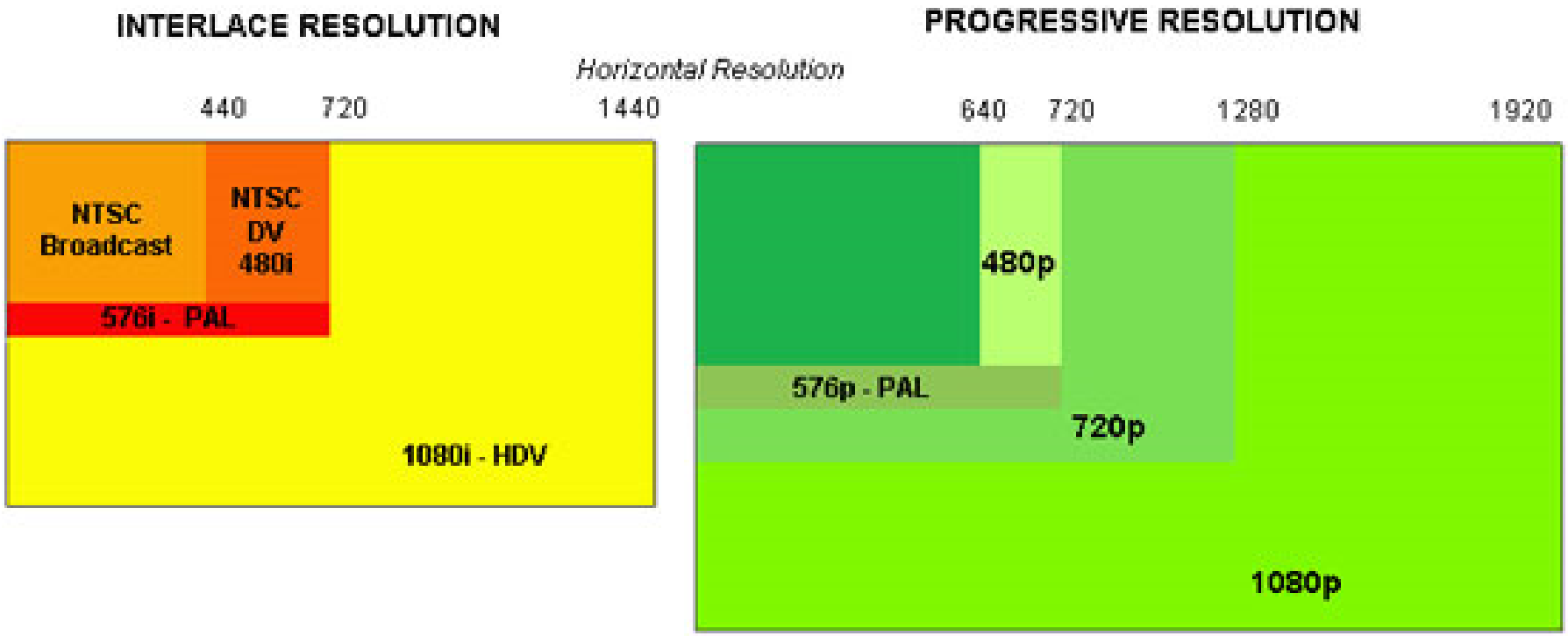
2.40:1

Aspect ratio of current anamorphic
(wide-screen) showings

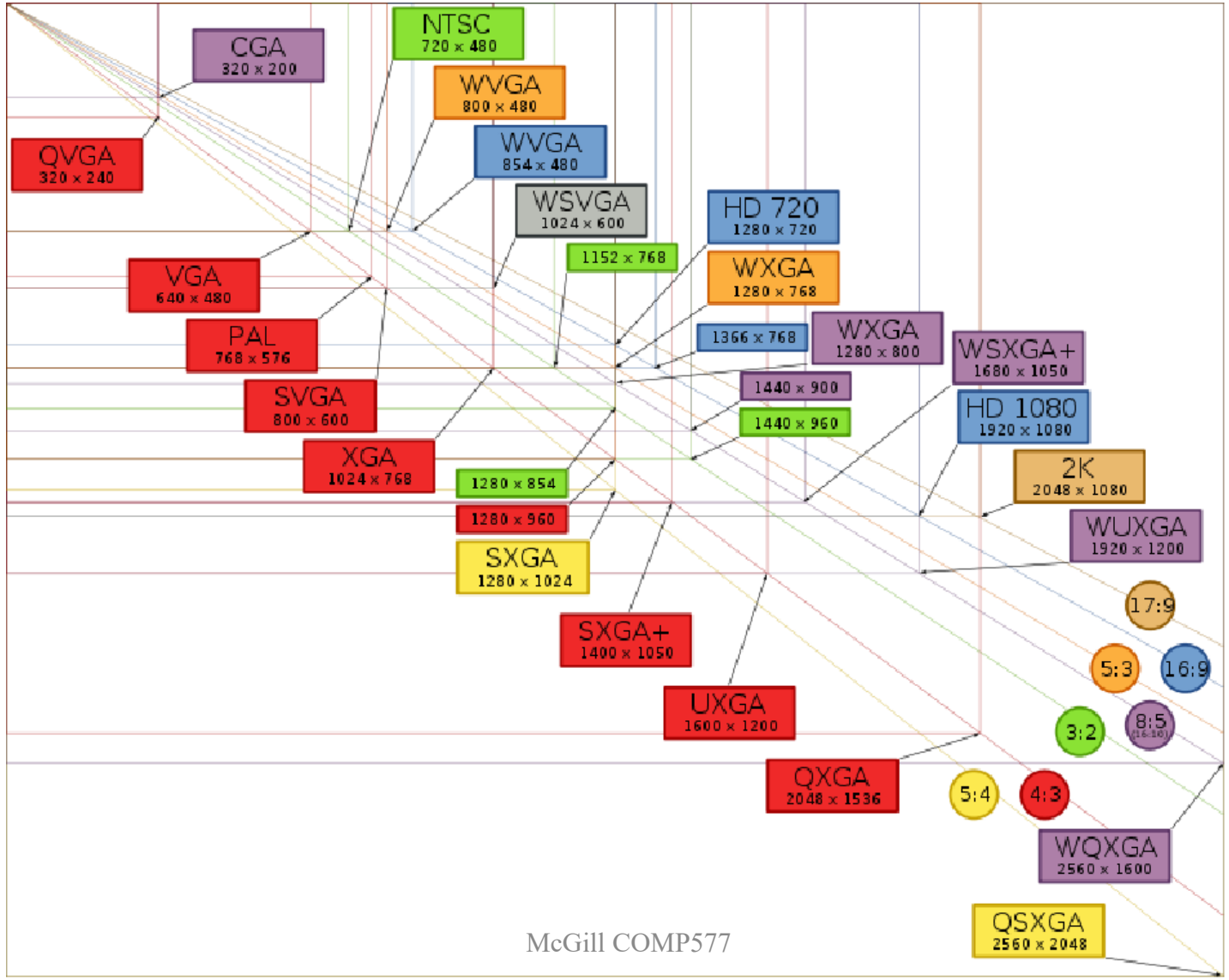
2.75:1

Aspect ratio of Ultra-Panavision 70

Common Resolutions



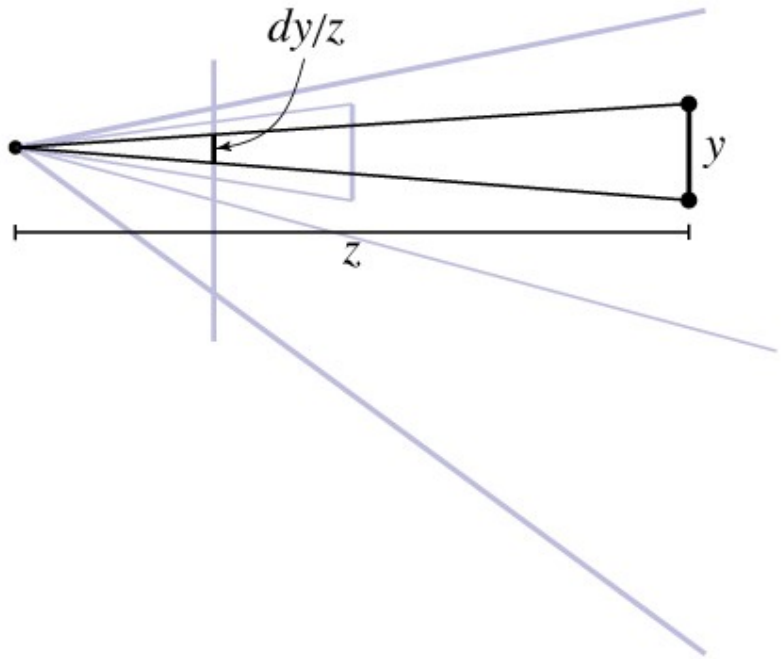
Resolutions and Aspect Ratios
Square Pixels?



Back to projections…

Shifted perspective projection

- Perspective but with projection plane not perpendicular to view direction
  - additional parameter: projection plane normal
  - exactly equivalent to cropping out an *off-center* rectangle from a larger "normal" perspective
  - corresponds to *view camera* in photography



Why shifted perspective?

- Control convergence of parallel lines
- Standard example: architecture
  - buildings are taller than you, so you look up
  - top of building is farther away, so it looks smaller
- Solution: make projection plane parallel to facade
  - top of building is the same distance *from the projection plane*
- Same perspective effects can be achieved using post-processing
  - (though not the focus effects)
  - choice of *which* rays vs. arrangement of rays in image

[Philip Greenspun]

camera tilted up: converging vertical lines

[Philip Greenspun]

lens shifted up: parallel vertical lines

Specifying perspective projections

- Many ways to do this
  - common: from, at, up, v.f.o.v. (but not for shifted)
- One way:
  - viewpoint, view direction, up
    - establishes location and orientation of viewer
    - view direction is the direction of the center ray
  - image width, image height, projection distance
    - establishes size and location of image rectangle
  - image plane normal
    - can be different from view direction to get shifted perspective
- Can likewise accomplish this with glFrustum

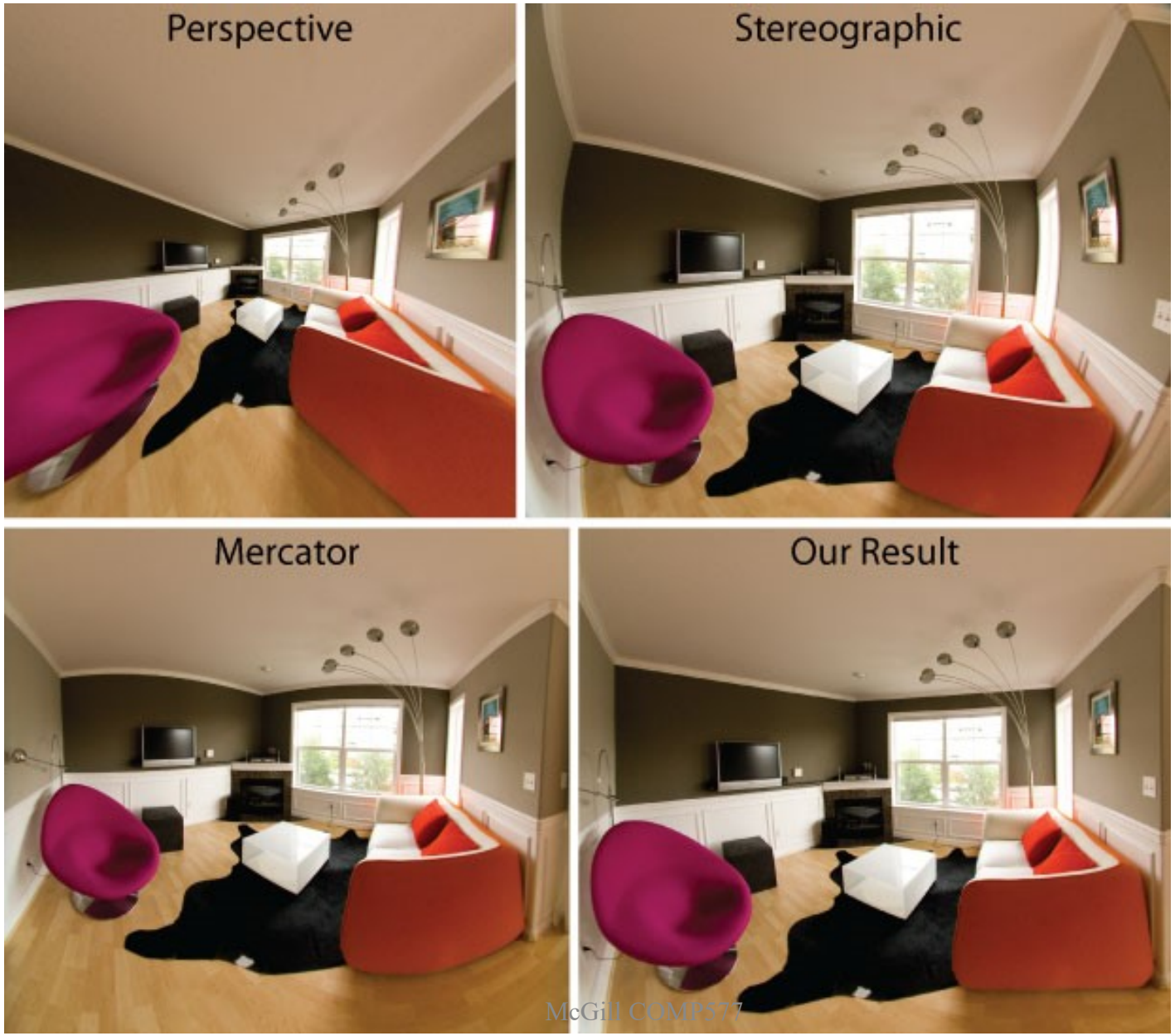
Non-planar Projections…

- Not in the scope of this course

Non-planar Projections... (panoramas, environment maps, etc.)

YAMAHA

Optimizing Content-Preserving Projections for Wide-Angle Images
Robert Carroll, Maneesh Agrawala, Aseem Agarwala, SIGGRAPH 2009



Perspective

Mercator

Stereographic

Our Result

RYAN: Render Your Animation Nonlinearly Projected,
P. Coleman & K. Singh
NPAR 04