Perspective

CS 4620 Lecture 3

History of projection

- Ancient times: Greeks wrote about laws of perspective
- Renaissance: perspective is adopted by artists

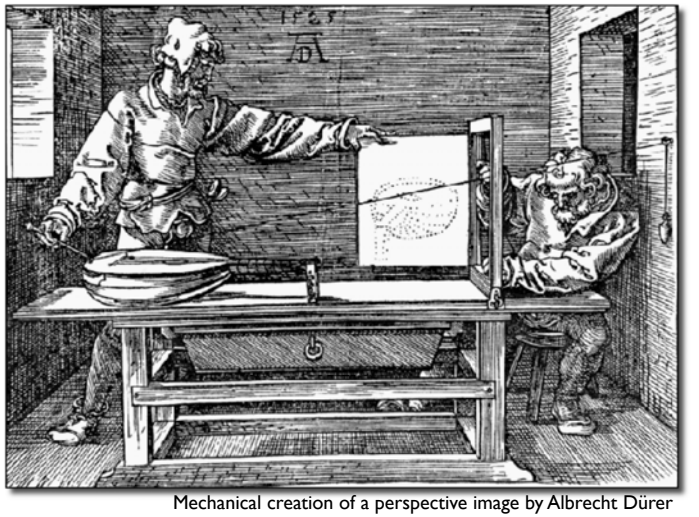
Duccio c. 1308

History of projection

- Later Renaissance: perspective formalized precisely

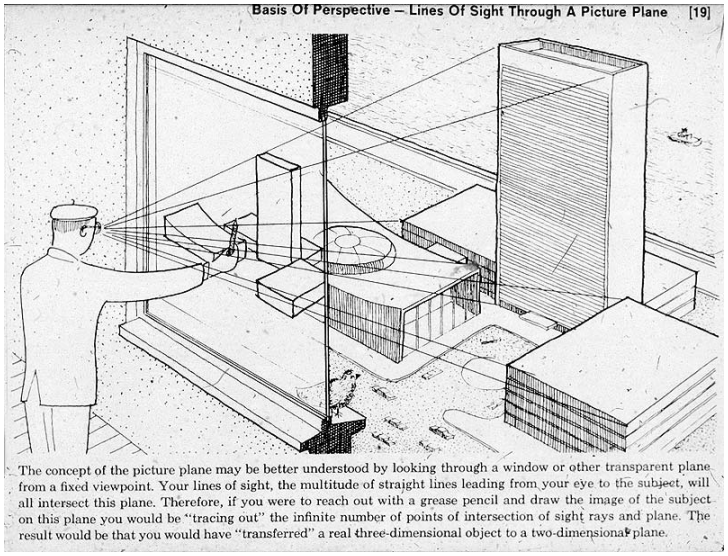
da Vinci c. 1498

Plane projection in drawing



Mechanical creation of a perspective image by Albrecht Dürer

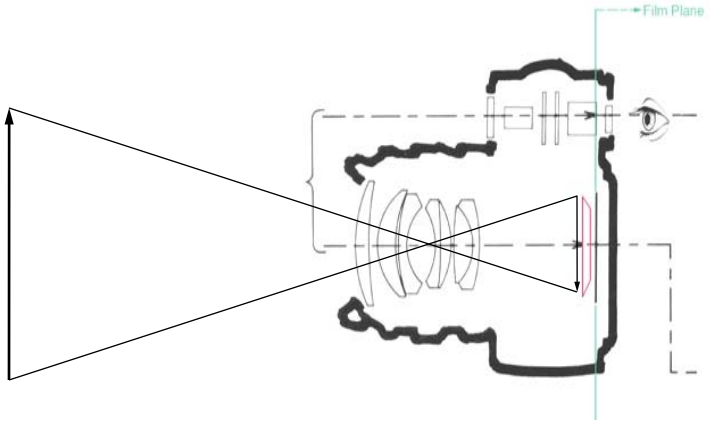
Plane projection in drawing



[CS 417 Spring 2002]

Plane projection in photography

- This is another model for what we are doing
  - applies more directly in realistic rendering



[Source unknown]

Plane projection in photography

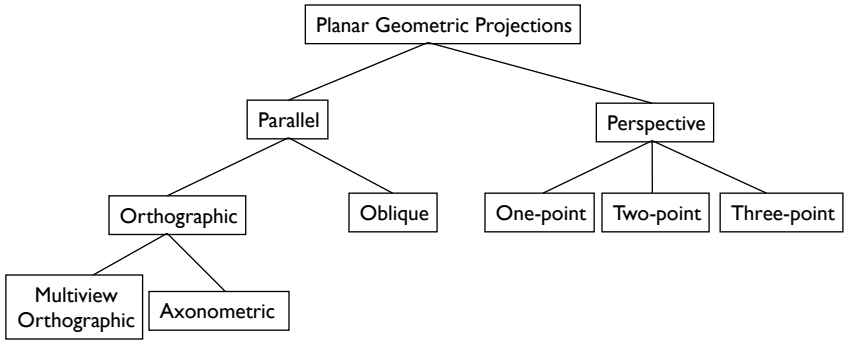
[Richard Zakia]

Ray generation vs. projection

- Viewing in ray tracing
  - start with 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
- Inverse processes
  - ray casting computes the 3D preimage of projection

Classical projections

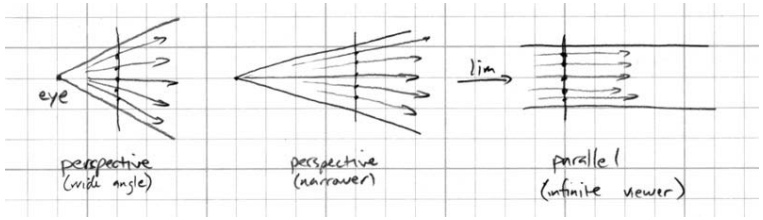
- Emphasis on cube-like objects
  - traditional in mechanical and architectural drawing



[after Carlbom & Paciorek 78]

Parallel projection

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



Multiview orthographic

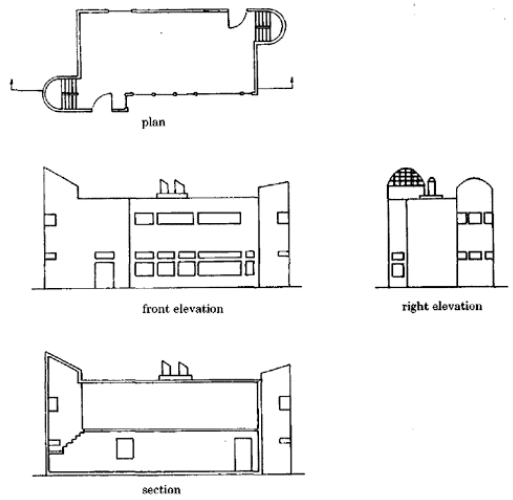
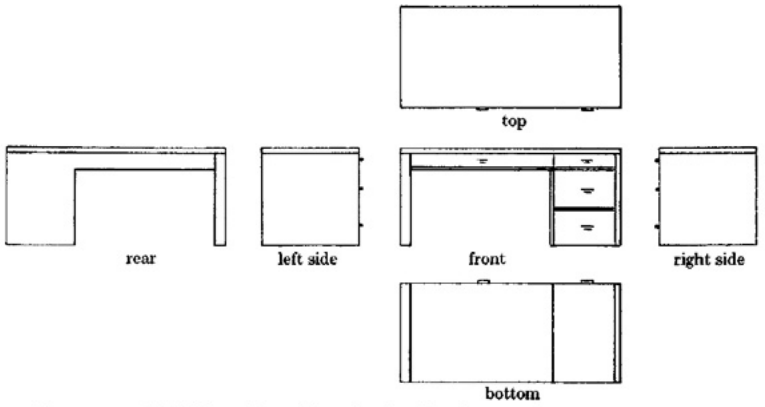


FIGURE 2-1. Multiview orthographic projection: plan, elevations, and section of a building.

[Carlbom & Paciorek 78]

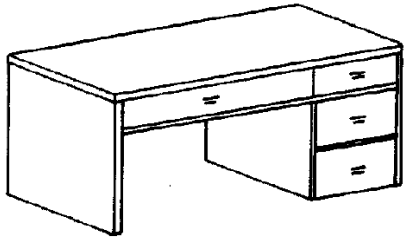
Multiview orthographic

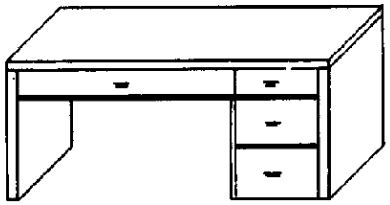


[Carlbom & Paciorek 78]

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

Off-axis parallel





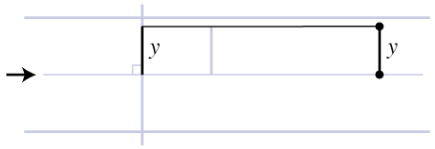
[Carlbom & Paciorek 78]

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

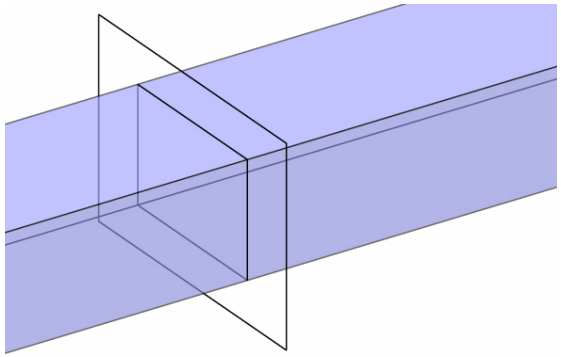
oblique: projection plane parallel to a coordinate plane but not perpendicular to projection direction.

"Orthographic" projection

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

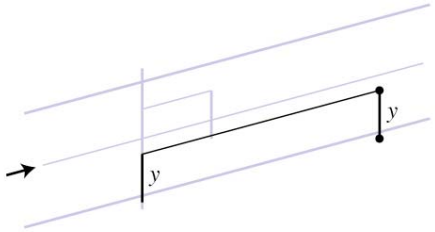


View volume: orthographic



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

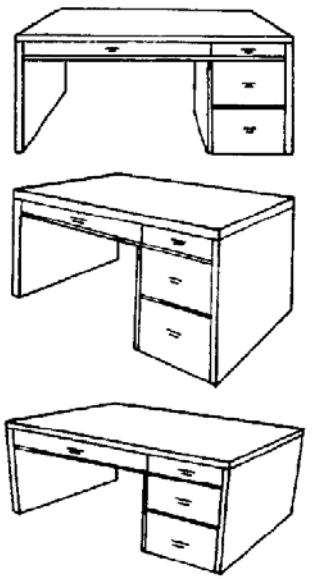


Perspective

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

two-point: projection plane parallel to one coordinate axis

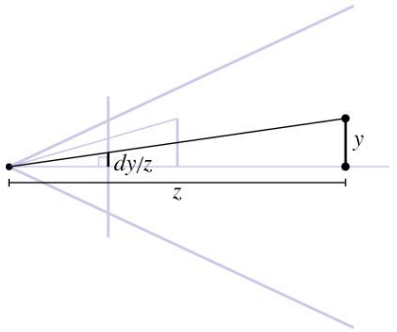
three-point: projection plane not parallel to a coordinate axis



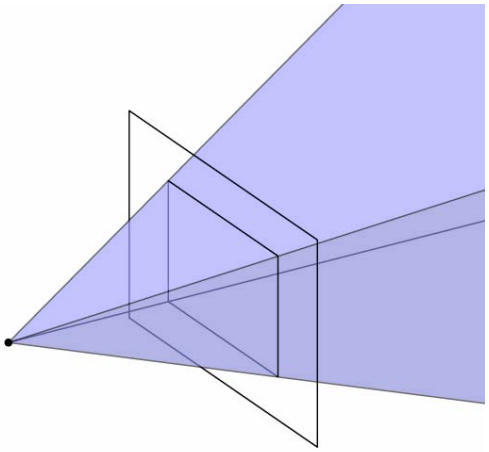
[Carlbom & Paciorek 78]

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
  - f.o.v. $\alpha = 2\,\mathrm{atan}(h/(2d))$
  - $y' = d\,y\,/\,z$
  - "normal" case corresponds to common types of cameras



View volume: perspective



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
  - have to decide to measure vert., horiz., or diag.
- In cameras, determined by focal length
  - confusing because of many image sizes
  - for 35mm format (36mm by 24mm image)
    - 18mm = 67° v.f.o.v. — super-wide angle
    - 28mm = 46° v.f.o.v. — wide angle
    - 50mm = 27° v.f.o.v. — "normal"
    - 100mm = 14° v.f.o.v. — narrow angle ("telephoto")

Field of view

- Determines "strength" of perspective effects

close viewpoint
wide angle
prominent foreshortening

far viewpoint
narrow angle
little foreshortening

[Ansel Adams]

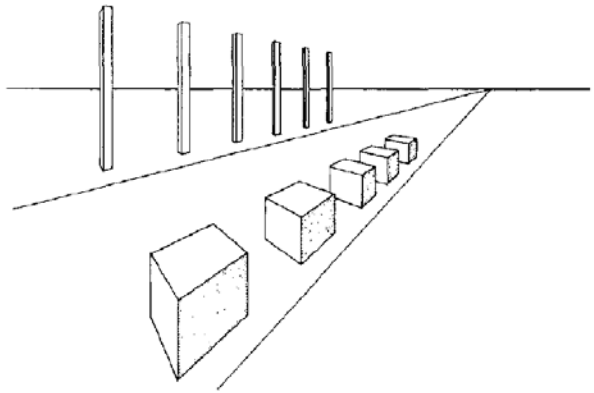
Choice of field of view

- 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
  - and people often type in big numbers!

[Ken Perlin]

Perspective distortions

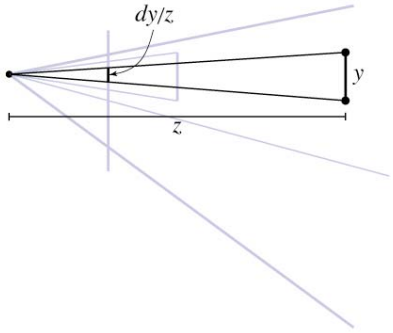
- Lengths, length ratios



[Carlbom & Paciorek 78]

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

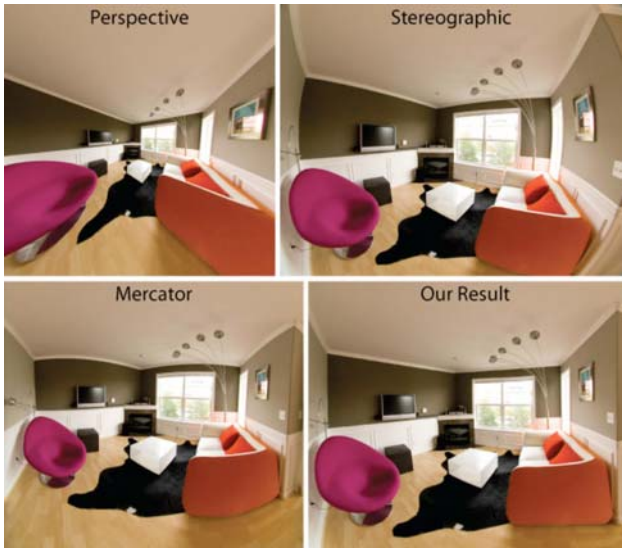
[Philip Greenspun]

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 (used in ray tracer):
  - 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

Many other projections possible



Optimizing Content-Preserving Projections for Wide-Angle Images

[Carroll et al., SIGGRAPH 2009]

