Ray generation vs. projection

- Viewing in ray tracing
  - start with image point
  - compute 3D point that projects to that point using ray
  - do this using geometry
- Viewing by projection
  - start with 3D point
  - compute image point that it projects to
  - do this using transforms
- Inverse processes

Classical projections

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

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Parallel projection

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

Multiview orthographic

- projection plane parallel to a coordinate plane
- projection direction perpendicular to projection plane
**Off-axis parallel**

- **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**

- 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

**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

**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
  - \( f.o.v. \ alpha = 2 \ atan(hi/(2d)) \)
  - \( y' = dy/z \)
  - “normal” case corresponds to common types of cameras
**View volume: perspective**

- 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 (or f.o.v.)**

- **Field of view**
  - Determines “strength” of perspective effects

  - close viewpoint: wide angle, prominent foreshortening
  - far viewpoint: narrow angle, little foreshortening

**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!

**Perspective distortions**

- Lengths
- Length Ratios

**Shifted perspective projection**

- Perspective but with projection plane not perpendicular to view direction
  - additional parameter: projection plane normal
  - 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

Specifying perspective projections

- Many ways to do this
  - common: from, at, up, v.o.f. (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