## CS4620/5620: Lecture 6

## Perspective

## Announcements

- HW I out
-Due in two weeks (Mon 9/I7)
-Due right before class
- Turn it in online AND in class (preferably)


## Transforming normal vectors

- Transforming surface normals
- differences of points (and therefore tangents) transform OK
- normals do not --> use inverse transpose matrix

have: $\mathbf{t} \cdot \mathbf{n}=\mathbf{t}^{T} \mathbf{n}=0$
want: $M \mathbf{t} \cdot X \mathbf{n}=\mathbf{t}^{T} M^{T} X \mathbf{n}=0$
so set $X=\left(M^{T}\right)^{-1}$
then: $M \mathbf{t} \cdot X \mathbf{n}=\mathbf{t}^{T} M^{T}\left(M^{T}\right)^{-1} \mathbf{n}=\mathbf{t}^{T} \mathbf{n}=0$


## History of projection

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


Duccio c. I308


## History of projection

- Later Renaissance: perspective formalized precisely

da Vinci c. 1498


## Plane projection in drawing like ray tracing



Durer, I525

## Plane projection in drawing: hardware pipeline rendering



## Plane projection in photography

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



## Ray generation vs. projection

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


## Classical projections

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



## Classical projections

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



## Parallel projection

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



## Multiview orthographic


front elevation

right elevation


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

## 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



## 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. $\alpha=2 \operatorname{atan}(h /(2 d))$
$-y^{\prime}=d y / z$
-"normal" case corresponds to common types of cameras


## View volume

## orthographic vs. 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 35 mm format ( 36 mm by 24 mm image)
- $18 \mathrm{~mm}=67^{\circ}$ v.f.o.v. - super-wide angle
- $28 \mathrm{~mm}=46^{\circ}$ v.f.o.v. - wide angle
- $50 \mathrm{~mm}=27^{\circ}$ v.f.o.v. - "normal"
- $100 \mathrm{~mm}=14^{\circ}$ v.f.o.v. - narrow angle ("telephoto")


## 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



## 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

