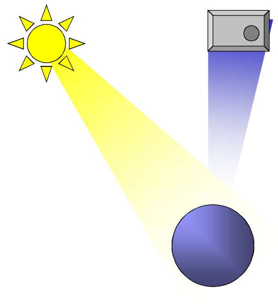
## Object rendering
## Overview

Scene
- Object
- Camera
- Light

Objects
- Geometry
- Colour
- Microstructure

## Rendering: setting up the scene

- Given
  - Object surfaces
  - Light sources
  - Camera
- Compute
  - Colour of each pixel on the screen
  - This is colour that bounces off the surface point and goes in the direction of the camera (viewer)



## Object

- Geometry
  - Structure √
  - Surface orientation (normal vectors)
- Colour
- Microstructure
  - Shiny
  - Matt
  - Textured
- Transparency

## Light

- Location
  - w.r.t object
  - w.r.t. camera
- Sources
  - Ambient
  - Directional: diffuse
  - Directional: point source
  - Divergence
- Colour

## Camera

- Position w.r.t. object
- Direction of view
- Angle of view
- Tilt (up-vector)

Camera viewing

- Magnification (zoom)
- Projection (parallel / perspective)

Projection

## Relationships between the entities

Light × Camera

| Light \ Camera | Position | View | Proj. |
|---|---|---|---|
| Position | X | X | |
| Direction | | X | |
| Colour | | | |

Light × Object

| Light \ Object | Orient. | Microstr | Colour |
|---|---|---|---|
| Position | X | | X |
| Direction | X | X | X |
| Colour | | | X |

Object × Camera

| Object \ Camera | Position | View | Proj. |
|---|---|---|---|
| Orient | X | X | X |
| Microstr | | | |
| Colour | | | |

## Topics for the next lectures

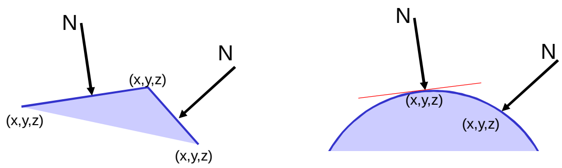
- Surface orientation – normal vectors
- Lighting
- Surface shading algorithms
- Colour and colour representations
- Viewing and projections

## Normal vectors

- What they are
- How to compute them

## Normal vectors

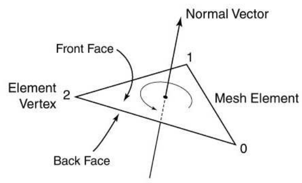
- Normal vector = vector perpendicular to the face

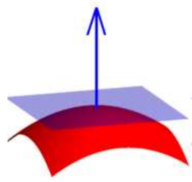


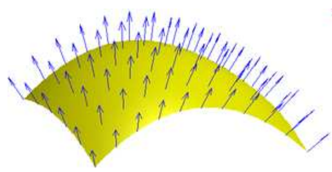

Flat surface patch

Curved surfaces

## Normal vectors





Flat surface patch

Curved surfaces

## Surface normal vectors - uses

- Surface visibility (→ hidden surface removal)
- Surface shading
- Surface texture

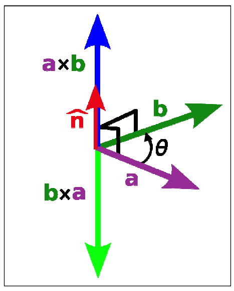
## Normal vectors

- Computing normal vectors
  - A cross-product of two vectors is a vector perpendicular (orthogonal, normal) to both input vectors

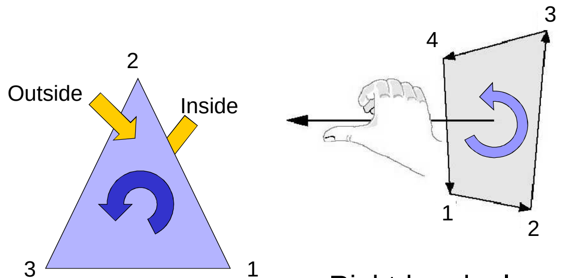
    if $n = a \times b$, $n \perp a$ and $n \perp b$
- Cross product is NOT commutative:

  $a \times b \neq b \times a$

  although both cross-products are orthogonal to a and b



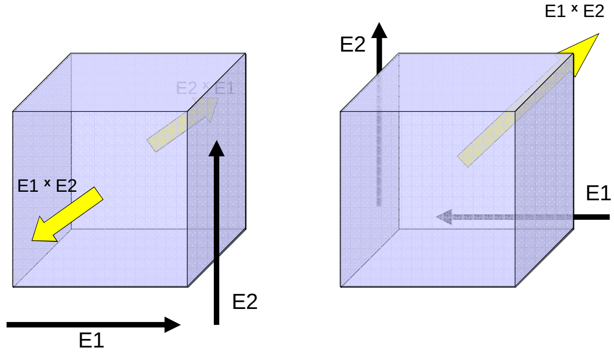
## “In-s and Out-s” of triangles



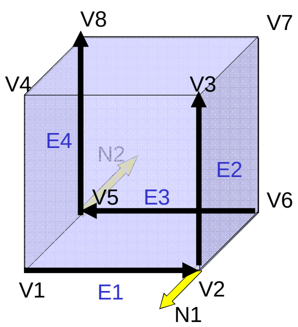

Right-hand rule

Unit 2

## Normal vectors




## Normal vectors




Front face

E1=V2 – V1

E2=V3 – V2

N1=E1 × E2

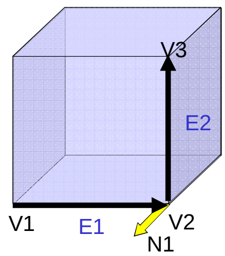
Back face

E3=V5 – V6

E4=V8 – V5

N2=E3 × E4

## Computing cross product




Front face

E1=V2 – V1

E2=V3 – V2

N1=E1 × E2

## Computing cross-product

E1=V2 – V1

E2=V3 – V2

N1=E1 × E2 =

Unit vectors

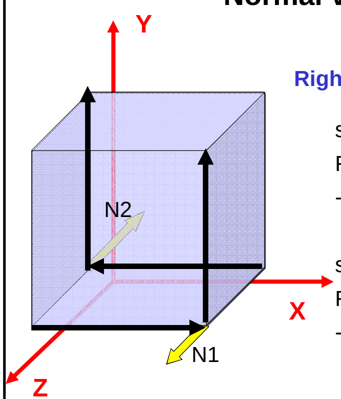
$$\begin{vmatrix} 1_x & 1_y & 1_z \\ x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ x_3 - x_2 & y_3 - y_2 & z_3 - z_2 \end{vmatrix} =$$

$1_x\,(y_2 - y_1)(z_3 - z_2) - (y_3 - y_2)(z_2 - z_1) +$

$1_y\,(x_3 - x_2)(z_2 - z_1) - (x_2 - x_1)(z_3 - z_2) +$

$1_z\,(x_2 - x_1)(y_3 - y_2) - (x_3 - x_2)(y_2 - y_1)$

## Normal vectors




**Right-handed** coordinate system

sign($N1_Z$) = sign(Z)
Facing towards the viewer:
- front face

sign($N2_Z$) = - sign(Z)
Facing away from the viewer
- back face

## Surface visibility from surface normal

E1=V2 – V1

E2=V3 – V2

N1=E1 × E2 =

Unit vectors

$$\begin{vmatrix} 1_x & 1_y & 1_z \\ x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ x_3 - x_2 & y_3 - y_2 & z_3 - z_2 \end{vmatrix} =$$

$1_x\,(y_2 - y_1)(z_3 - z_2) - (y_3 - y_2)(z_2 - z_1)$ +

$1_y\,(x_3 - x_2)(z_2 - z_1) - (x_2 - x_1)(z_3 - z_2)$ +

$1_z\,(x_2 - x_1)(y_3 - y_2) - (x_3 - x_2)(y_2 - y_1)$ ← $N_z$

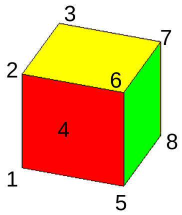
## Surface visibility from surface normal

- In right-handed coordinate system an outer (visible) surface will have positive value of z-coordinate of the normal vector: $N_z>0$
- Render only the visible surfaces facing the viewer

## Example

Vertices

| | | | |
|---|---|---|---|
| V1 | 0 | 0 | 0 |
| V2 | 0 | 1 | 0 |
| V3 | 0 | 1 | 1 |
| V4 | 0 | 0 | 1 |
| V5 | 1 | 0 | 0 |
| V6 | 1 | 1 | 0 |
| V7 | 1 | 1 | 1 |
| V8 | 1 | 0 | 1 |




| Faces | | | | | | sign $N_z$ |
|---|---|---|---|---|---|---|
| F1 | 1 | 5 | 6 | 2 | 1 | + |
| F2 | 2 | 6 | 7 | 3 | 2 | + |
| F3 | 3 | 7 | 8 | 4 | 3 | - |
| F4 | 4 | 8 | 5 | 1 | 4 | - |
| F5 | 1 | 2 | 3 | 4 | 1 | - |
| F6 | 8 | 7 | 6 | 5 | 8 | + |

## Homework

- In the cube defined by vertices and faces in the previous slide, demonstrate that face F2 is visible and face F4 is not visible in the left-handed coordinate system.

## Next lecture

Illumination and shading

## Credits

http://www.absoluteastronomy.com/topics/Surface_normal

http://commons.wikimedia.org/wiki/File:Crossproduct.png