COMS 30115

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Last time

- BRDFs
    - a more realistic way to parametrise ray-surface interaction
- Approximations
    - Bump and Environment mapping

Today

- Shadows
  - Last element of raytracer lab
- Cameras
- Optimisations
  - ideas
- Summarise raytracing

The Book

- Shadows URL
- Cameras URL
- Optimisations
  - Jacco Bikker Flipcode
  - Gavan Woolery, Gamasutra, Why I still Think Raytracing is the Future
  - Accelerated Structures, Scratchapixel
  - Robin Marcus, Realtime rendering blog - 4 part article about realtime raytracing

Shadows

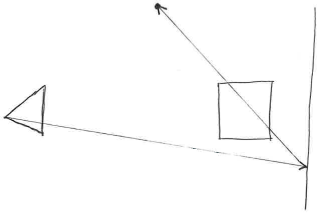
Shadows

1

[1] X-Files Universe

Direct Shadows

- Find intersection camera ray and surface



Direct Shadows

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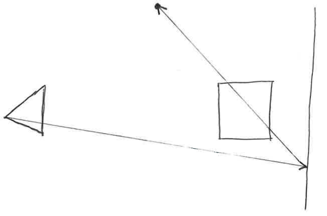
- Shoot ray from surface towards light



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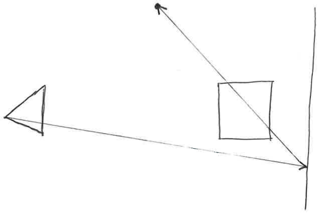

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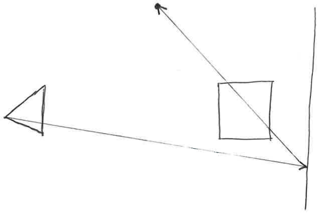

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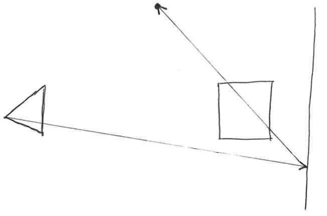

Direct Shadows

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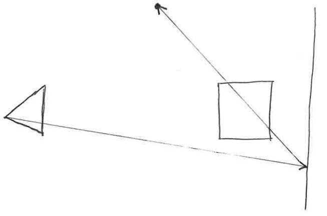
- Shade accordingly
- *Remember that ordering is not important*



Shadow Acne

- Self-intersection
- If our primitive is a triangle we do not have self-shadows
- Numerical error
- *you will see this in the lab*
- shadow bias

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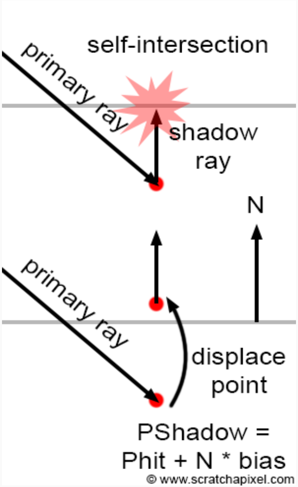

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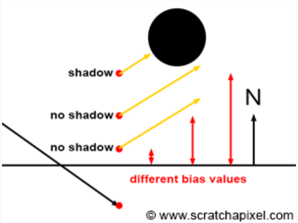
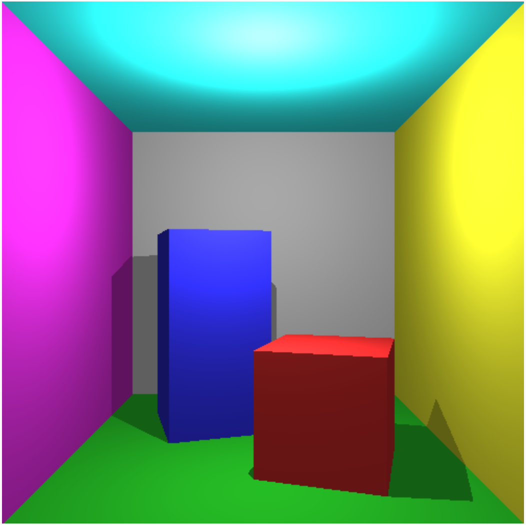
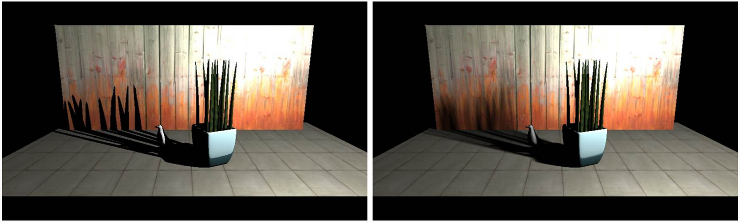


Lab 1



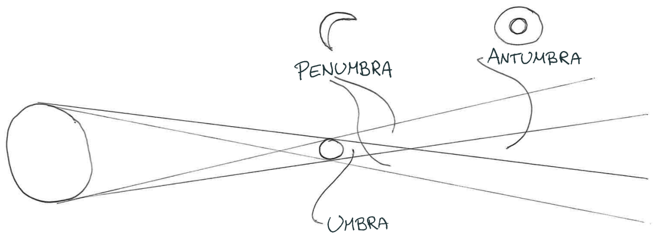
Soft Shadows



[2]

[2] Image URL

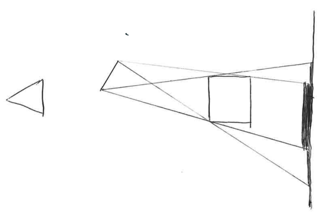
Soft Shadows



[2] Image URL

Soft Shadows

- Zero dimensional things aren't really that common
- Most light-sources have spatial extent
- umbra - hard shadow
- penumbra - partial shadow
- antumbra - cross over



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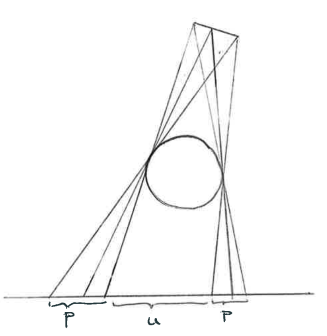

Soft Shadows

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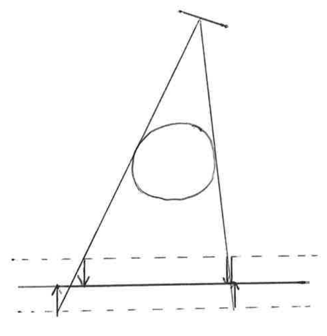
- Apprixomate using several point/spot lights
- Approximate with several intersection planes



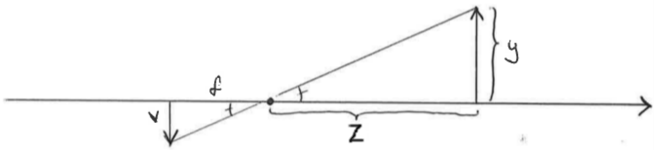
Summary

- Shadows adds a lot of realism
- Expensive to compute as you will need more rays
- If you use hard shadows compensate with a lot of ambient light

Cameras

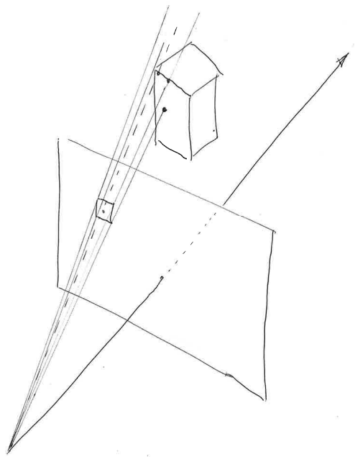
Image

Pinhole Cameras



- Raytraced images often looks too "clean"
- infinite depth-of-field

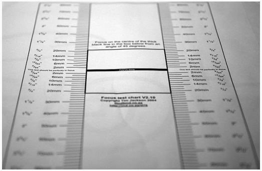
Anti-Aliasing



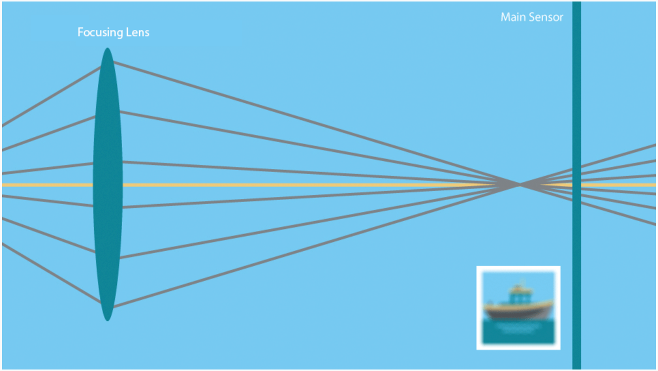
- shoot several rays per pixel and blend colours together

Depth-of-Field

- Film needs to be bombarded with sufficient energy to generate a colour
- Opening for rays bigger than a one photon wide pinhole: Aperture
- Same as glossy reflection, each ray hitting the eye comes from different parts of the world

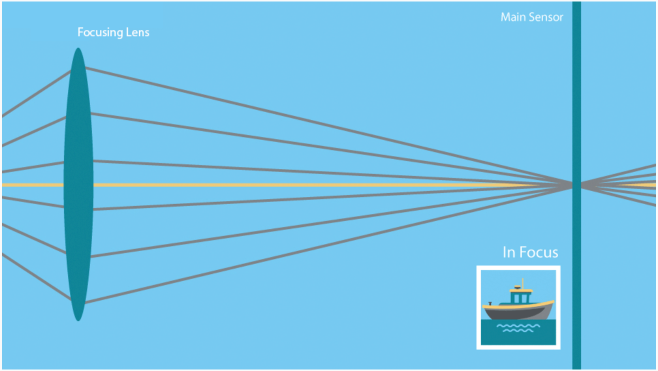


Depth-of-Field[3]



[3] https://www.bhphotovideo.com/explora/photography/tips-and-solutions/how-focus-works

Depth-of-Field[3]



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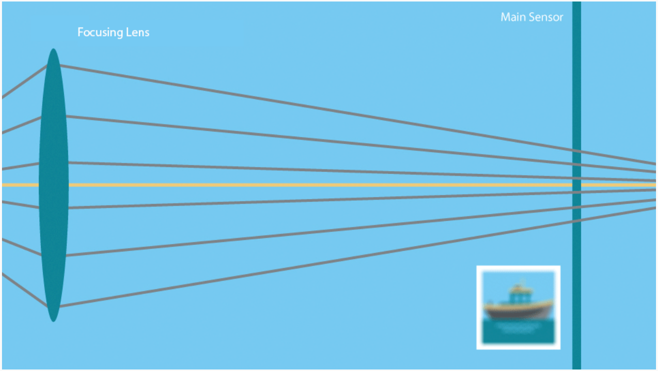

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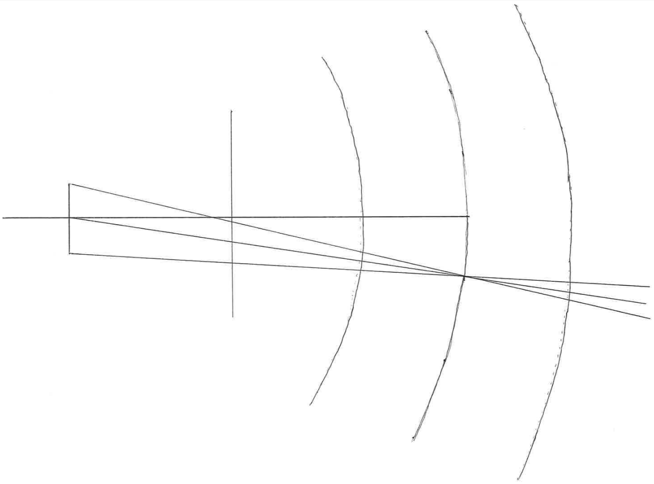
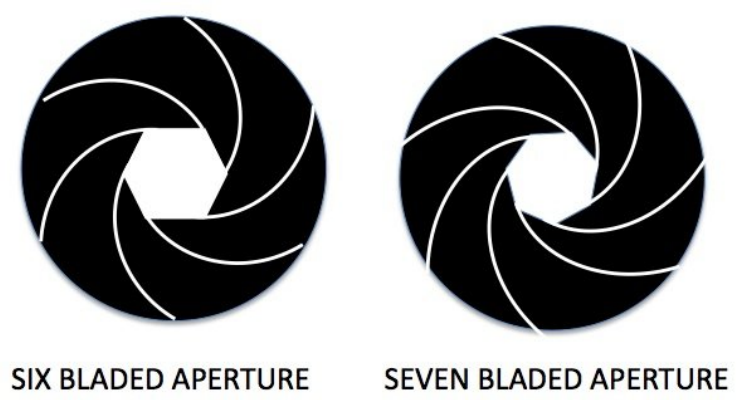
Depth-of-Field

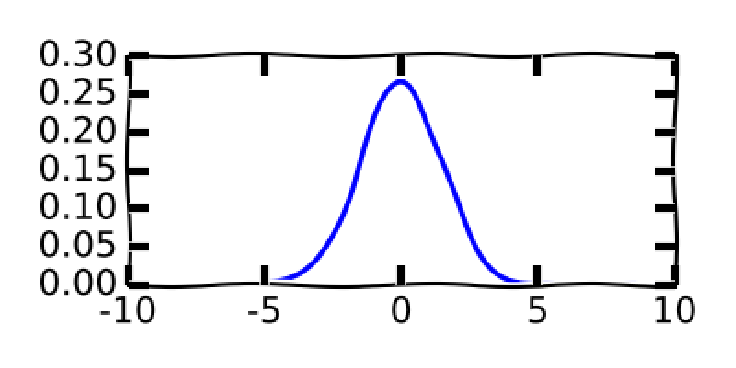


- Which rays to trace, how many?
- Different geometry aperture creates different images

Aperture



Random is your friend[4]



- *We (humans) are really good at picking up regularities, avoid them for increased fidelity*

[4] http://www-alg.ist.hokudai.ac.jp/~jan/randsphere.pdf

Lens Flare[5]

- A real camera has a lens
- Transition between two media causes refraction
- Light bounces inside lens
- Refraction calculations inside lens

[5] URL

Summary

- We have seen quite a few things now
  - reflection, refraction
  - shadows
  - depth-of-field
  - reflection models
  - material properties
  - etc.

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- We have seen quite a few things now
  - reflection, refraction
  - shadows
  - depth-of-field
  - reflection models
  - material properties
  - etc.
- All follows the same principle
  - *basic physics*
  - *If light can be assumed to be a ray, then we just have to follow it along its path!*

Optimisation

So far

Ek In the first part of the course we will look at raytracing

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UoB Damn this is slow, I can't even move the camera, or wait, did it move?

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Ek Well thats ray-tracing, try to reduce the screen-size to 10×10 so that we can see something

So far

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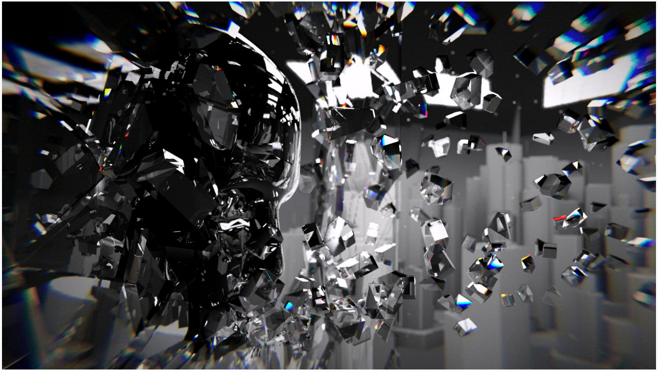
UoB Damn this is slow, I can't even move the camera, or wait, did it move?

Ek Well thats ray-tracing, try to reduce the screen-size to 10×10 so that we can see something

UoB Really useful this unit is, the graphics is both ugly and slow

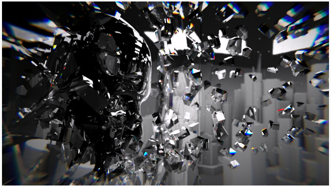
Smash of Fairlight



WTF

5 Faces

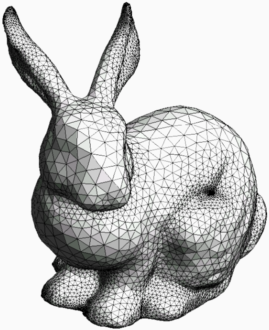
- Refraction
- Secondary rays in several levels (lots)
- Depth of Field
- Implicit surfaces
- Real-Time

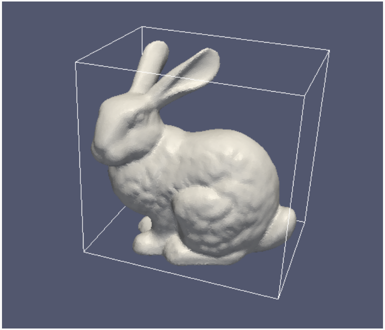


Optimisation

- Structure our data to do less calculations
  - Bounding Boxes, Tree's, etc.
- Optimise your code
- Reduce visual quality/correctness for speed

Data Structures

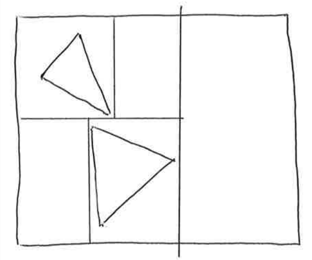




Bounding Boxes

- Intersections are expensive to compute
- Create simpler geometry that surrounds object
- The tighter the bounding volume the better but that usually requires more vertices

KD-Trees



- Do we need to check all object everywhere in space?
- Create a KD-Tree that splits up space
- Find large areas with single object

Cramer's Rule

$$\begin{pmatrix} t \\ u \\ v \end{pmatrix} = \frac{1}{\det(-\mathbf{d}, -\mathbf{e}_1, -\mathbf{e}_2)} \begin{pmatrix} \det(-\mathbf{s}, -\mathbf{e}_1, -\mathbf{e}_2) \\ \det(-\mathbf{d}, -\mathbf{s}, -\mathbf{e}_2) \\ \det(-\mathbf{d}, -\mathbf{e}_1, -\mathbf{s}) \end{pmatrix}$$

$$= \left\{\det(\mathbf{a}, \mathbf{b}, \mathbf{c}) = -(\mathbf{a} \times \mathbf{c})^{\mathrm{T}}\mathbf{b} = -(\mathbf{c} \times \mathbf{b})^{\mathrm{T}}\mathbf{a}\right\}$$

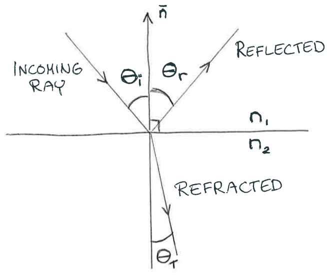
$$= \frac{1}{\mathbf{p}^{\mathrm{T}}\mathbf{e}_1} = \begin{pmatrix} \mathbf{q}^{\mathrm{T}}\mathbf{e}_2 \\ \mathbf{p}^{\mathrm{T}}\mathbf{s} \\ \mathbf{q}^{\mathrm{T}}\mathbf{d} \end{pmatrix}$$

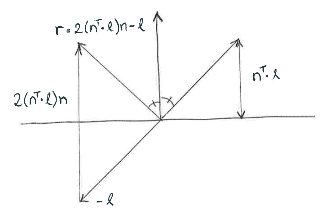
$$\mathbf{p} = \mathbf{d} \times \mathbf{e}_2$$

$$\mathbf{q} = \mathbf{s} \times \mathbf{e}_1$$

- Computing an inverse is more work $\mathbf{A}^{\mathrm{T}}\mathbf{A} = \mathbf{I}$

Refraction Rays





Refraction

$$\mathbf{t} = \left(\frac{n_i}{n_t} \cos(\theta_i) - \sqrt{1 - \left(\frac{n_i}{n_t}\right)^2 cos^2(\theta_i)} \right) \mathbf{n} - \frac{n_i}{n_t} \mathbf{i}$$

Refraction Rays

```
float b = Ni/Nt; float b2 = b*b;
float ni =N.x*I.x+N.y*I.y+N.z*I.z; //3m+2a
float ni2 = ni*ni;                 //1m
float D2 = 1.0f - b2*ni2;          //1m+1a
a = b*ni-sqrtf(D2);                //1m+1a+1sqrt
T.x = a*N.x-b*I.x;
T.y = a*N.y-b*I.y;
T.z = a*N.z-b*I.z;                 //6m+3a
```

Total: 12 multiplications, 6 additions, 1 square-root

[6] http://hugi.scene.org/online/hugi23/torefrac.htm Code on the course website

Refraction Rays

Code Optimisation

- What can we pre-compute?
- Something that does not have a massive range
- Something that has few indexing variables

[6] http://hugi.scene.org/online/hugi23/torefrac.htm Code on the course website

Refraction Rays

a is just a function of **ni** it can be pre-computed and tabled (**ni** is bounded)

```
float scalefac = 16384;
float *aLUT;

float ni=N.x*I.x+N.y*I.y+N.z*I.z; //3m+2a
float a=aLUT[(int)(ni*scalefac)]; //1m+1lu

T.x = a*N.x-b*I.x;
T.y = a*N.y-b*I.y;
T.z = a*N.z-b*I.z;                  //6m+3a
```

Total: 10 multiplications, 5 additions, 1 look-up

[6] http://hugi.scene.org/online/hugi23/torefrac.htm Code on the course website

Refraction Rays

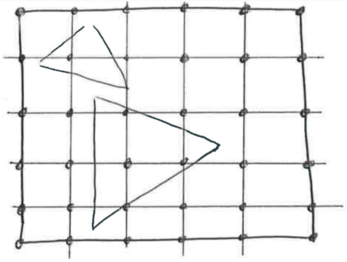
Do we need the vector to be normalised, if not we can table $\mathbf{g} = \frac{\mathbf{a}}{\mathbf{b}}$

```
float scalefac = 16384;
float *gLUT; //(a/b)

float ni=N.x*I.x+N.y*I.y+N.z*I.z; //3m+2a
float g=gLUT[(int)(ni*scalefac)]; //1m+1lu

T.x = g*N.x-I.x;
T.y = g*N.y-I.y;
T.z = g*N.z-I.z;                  //3m+3a
```

- Total: 7 multiplications, 5 additions, 1 look-up
- *This version is about twice as fast as the first*[6]

[6] http://hugi.scene.org/online/hugi23/torefrac.htm Code on the course website

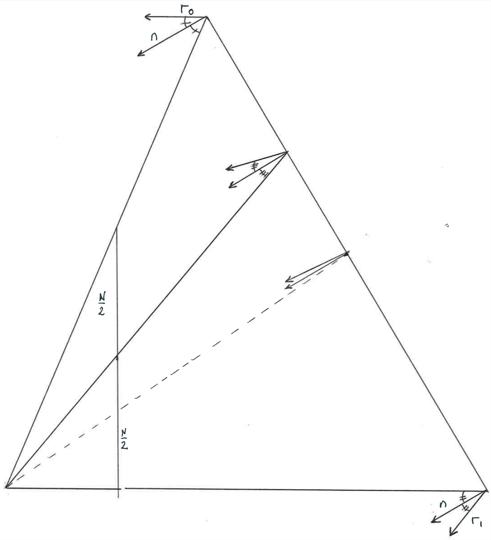
Reduce Visual Quality



Interpolation

- Light calculations are expensive
- Interpolation is cheap
- Compute lighting in few places and interpolate

Reduce Visual Quality



Summary

Summary

- Calculate number of operations
  - is there a less general way to do this
  - are there special cases, then code all of them
- Use heuristics
  - what is the most general case I'll see
- What shows and what doesnt?
- Profile your code

Raytracing

- Know your two weapons
  - Inner product

$$\mathbf{x}^{\mathrm{T}}\mathbf{y} = ||\mathbf{x}||||\mathbf{y}||\cos(\theta)$$

  - Outer product

$$\begin{aligned} \mathbf{x} \times \mathbf{y} =& \mathbf{z} \\ & \mathbf{z} \perp \mathbf{x} \\ & \mathbf{z} \perp \mathbf{y} \end{aligned}$$

  - Think how things work physically
    - how can we "mimick" this behaviour?
  - *Thats rendering for you*

Next Time

Next Time

Lecture Monday 13th of February

- We start with Real-time Graphics
- Rasterisation
- Will start with material for Lab 2

Lab Continue with Lab 1 and try to finish up to 50%

END

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