Ray-Tracing

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Figure 1: Reflection test: (left) with environment map. (right) with environment map and ray-traced interreflections.

[Pixar: Ray Tracing for the Movie 'Cars'
http://graphics.pixar.com/library/RayTracingCars/paper.pdf]

raytracing
+ inter-reflections
+ (better) shadows
+ refraction effects

Compare:
Physics light → surface A → surface B → ey

Raytracing eye → surface B → surface A → ligh

Ray-tracing Overview

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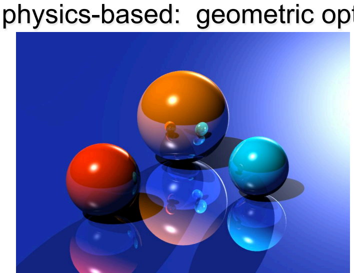
- flexible and simple* algorithm
- well suited to transparent and specular objects
- global illumination*
- partly physics-based: geometric optics



[http://www.futuretech.blinkenlights.nl/c-ray.html]

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```
raytrace( ray ) {
   find closest intersection
   cast shadow ray(s), compute colour_local
   colour_reflect = raytrace( reflected_ray )
   colour_refract = raytrace( refracted_ray )
   colour = k1*colour_local +
               k2*colour_reflect +
               k3*colour_refract
   return( colour )
}
```

R

= transmitted ray T

combining (1) reflected colour (2) transmitted color (3) local colour

- "raycasting" : only cast first ray from eye

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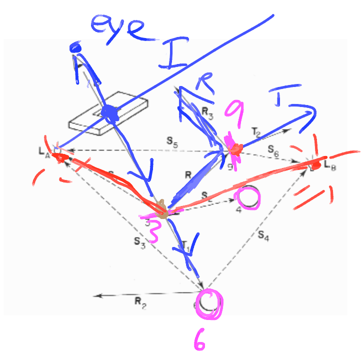

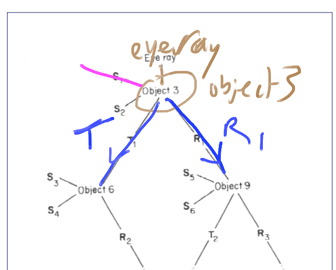

Fig. 12. The ray tree in schematic form.

Figure from Andrew S. Glassner, "An Overview of Ray Tracing" in An Introduction to Ray Tracing, Andrew Glassner, ed., Academic Press Limited, 1989.

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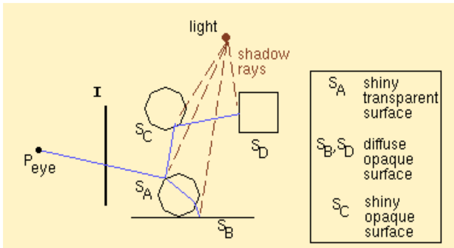

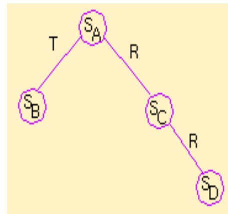

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Ray Termination Criteria:

- diffuse surface
- ray exits scene
- maximal depth
- ray contribution below threshold

Generation of Rays

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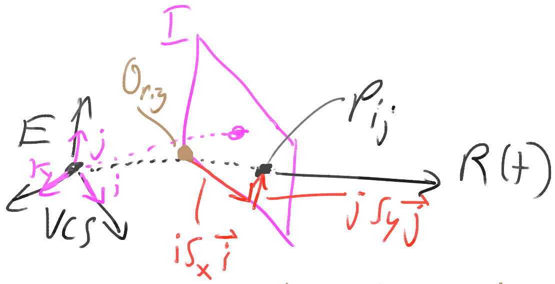

$$R(t) = E + t(\underline{P_{ij} - E})$$
$$= E + t\,\vec{V}_{ij}$$

where $P_{ij} = \text{Orig} + i\,\underbrace{s_x \vec{i}} + j\,s_y \vec{j}$

$$s_x = \frac{\text{right} - \text{left}}{\text{width in pixels}}$$

$$s_y = \frac{\text{top} - \text{bot}}{\text{height in pixels}}$$

Generation of Rays

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Ray Intersections

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Ray-Sphere Intersections

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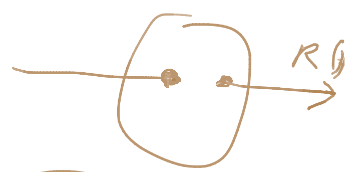

Ray : $R(t) = E + t\vec{V}$

$x(t) = e_x + t v_x$

$y(t) = e_y + t v_y$

$z(t) = e_z + t v_z$

Sphere : $F(x,y,z) = (x-x_c)^2 + (y-y_c)^2 + (z-z_c)^2 - r^2 = 0$

$\Rightarrow$ quadratic in t

0 solutions : miss sphere

1 solution : touch the sphere

2 solutions : two intersections   take first one

smallest value of t

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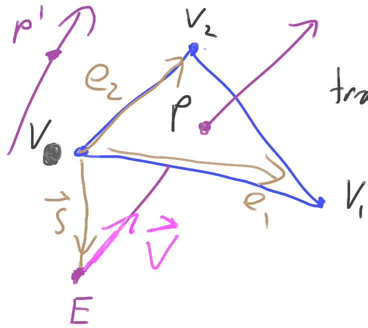
Ray-Triangle Intersections



$\alpha+\beta+\gamma=1$

$P(\alpha,\beta,\gamma) = \alpha V_0 + \beta V_1 + \gamma V_2 \quad 0 \le \alpha,\beta,\gamma \le 1$

triangle: $P(\beta,\gamma) = (1-\beta-\gamma)V_0 + \beta V_1 + \gamma V_2$

line: $P(t) = E + t\vec{V}$

$E + t\vec{V} = (1-\beta-\gamma)V_0 + \beta V_1 + \gamma V_2$

$\underbrace{E - V_0}_{\vec{S}} = -t\vec{V} + \beta\underbrace{(V_1 - V_0)}_{e_1} + \gamma\underbrace{(V_2 - V_0)}_{e_2}$

solve using determinants, etc. $\Rightarrow$

$\begin{bmatrix} \vec{S} \end{bmatrix} = \begin{bmatrix} -\vec{V} & \vec{e_1} & \vec{e_2} \end{bmatrix} \begin{bmatrix} t \\ \beta \\ \gamma \end{bmatrix}$ check $0 \le \beta,\gamma \le 1$

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Ray Intersections

Other Primitives:

- Implicit functions:
  - *Spheres at arbitrary positions*
    - Same thing
  - *Conic sections (hyperboloids, ellipsoids, paraboloids, cones, cylinders)*
    - Same thing (all are quadratic functions!)
  - *Higher order functions (e.g. tori and other quartic functions)*
    - root-finding more difficult
    - resort to numerical methods

Ray-Tracing – Geometric Transformations

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Transformations:

- Transform all rays into object coordinates
  - *Transform camera point and ray direction by inverse of model/view matrix*
- Shading has to be done in world coordinates (where light sources are given)
  - *Transform object space intersection point to world coordinates*
  - *Thus have to keep both world and object-space ray*