Ray Tracing

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Rendering

- Two basic Methods of rendering
  - Rasterization
  - Ray Tracing

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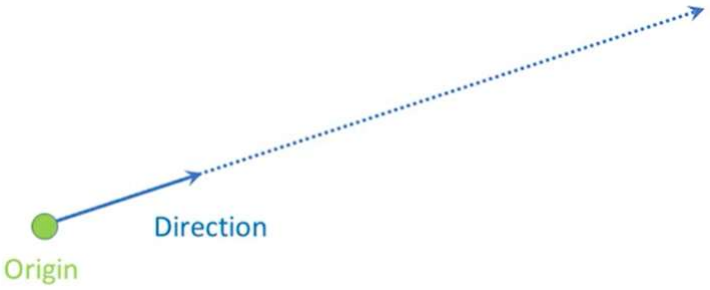
What is a Ray?



Courtesy NVIDIA

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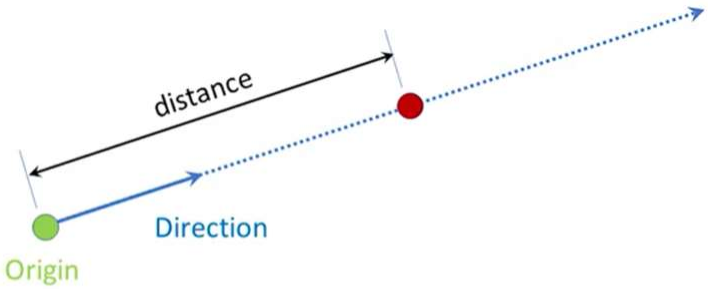
Ray Casting



Point(distance) = Origin + distance*Direction

Courtesy NVIDIA

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What is Ray Tracing

- Ray tracing is a rendering technique for generating an image by tracing the path of light as pixels in an image plane and simulating the effects of its encounters with virtual objects.
- The technique is capable of producing a high degree of visual realism, more so than typical scanline rendering methods, but at a greater computational cost.
- "Ray Tracing is the technology of the future and it always will be" an old joke

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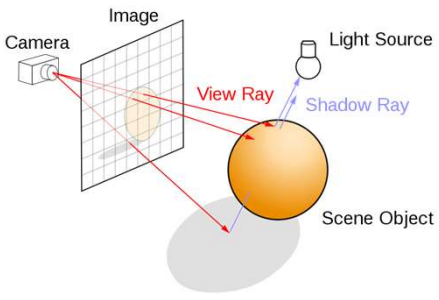
What is Ray Tracing

- Generating an image by tracing the path of light through pixels in an image plane
- Simulating the effects of light's encounters with virtual objects.



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Shading vs Ray Tracing

- Shaders give light a direction to create a dynamic and realistic effect.
- Ray tracing gives light weight as well as direction, it calculates how the light should react when hitting a material and where it should go after that.

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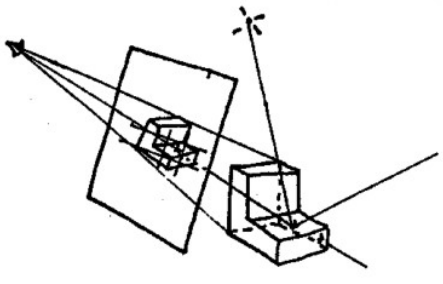
Ray Tracing History

Ray Tracing in Computer Graphics

Appel 1968 - Ray casting

1. Generate an image by sending one ray per pixel

2. Check for shadows by sending a ray to the light



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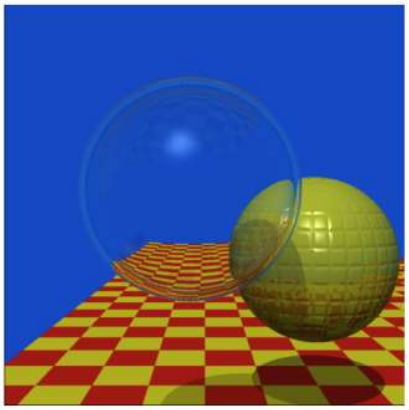
Ray Tracing History

Ray Tracing in Computer Graphics

"An improved Illumination model for shaded display," T. Whitted, CACM 1980

Resolution:
512 x 512
Time:
VAX 11/780 (1979)
74 min.
PC (2006)
6 sec.



Spheres and Checkerboard, T. Whitted, 1979

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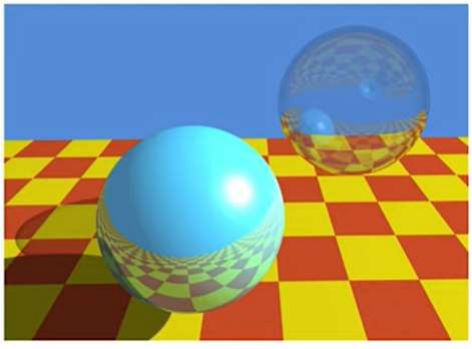
1980: Classical Ray Tracing

For each pixel

- Send ray from eye into scene
- Send a ray from the intersection to each light: shadows
- Spawn a new color ray for each reflection & refraction

highly polished surface



Generated using OptiX sample "optixWhitted"

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Ray Tracing History

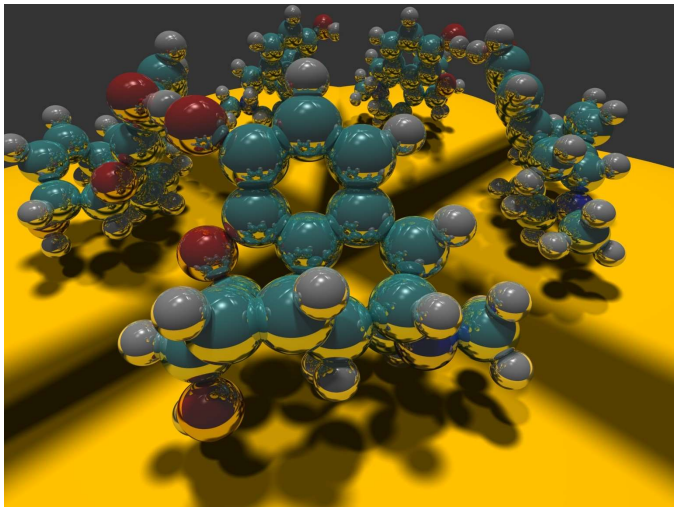

Image courtesy Paul Heckbert 1983

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Real-Time Ray Tracing

- Ray tracing is typically not used in games
  - Too expensive but possible
  - GPUs are very good at tasks that are easily parallelizable
- NVIDIA Optix system
- Typically all GPU power is used

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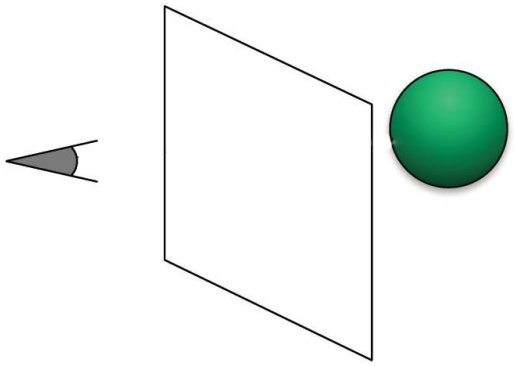
Basic Ray Tracing Algorithm



Create a 'virtual window' into the scene

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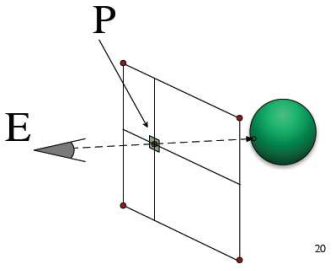
Defining the Rays

- Ray equation

$$\mathbf{R}(t) = \mathbf{E} + t(\mathbf{P} - \mathbf{E})$$

$$t \in [0, +\infty)$$

- Through eye at $t = 0$
- At pixel center at $t = 1$



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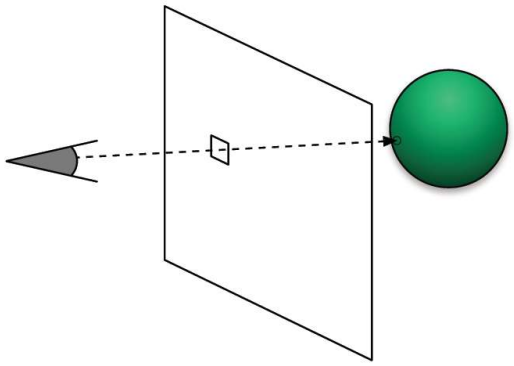
Basic Ray Tracing Algorithm



Shoot ray from eye through pixel, see what it hits

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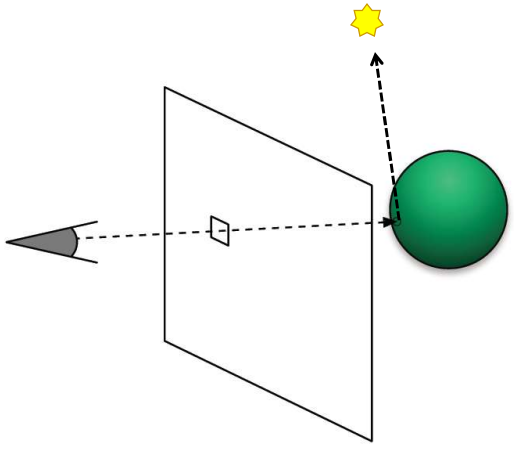
Basic Ray Tracing Algorithm



Shoot ray toward light to see if point is in shadow

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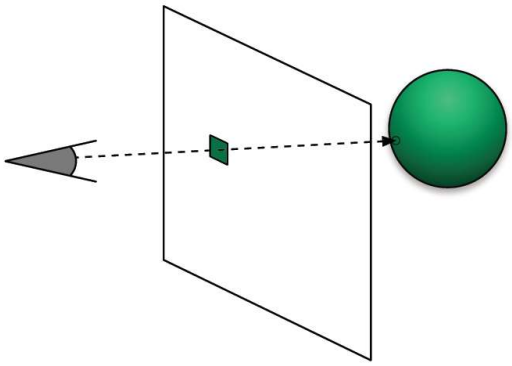
Basic Ray Tracing Algorithm



Record pixel color

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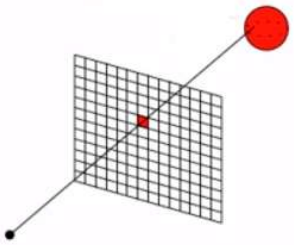
Basic Ray Tracing Algorithm

For photo-realistic rendering, usually ray tracing algorithms are used: for every pixel

- Compute ray from viewpoint through pixel center
- Determine intersection point with first object hit by ray
- Calculate shading for the pixel (possibly with recursion)



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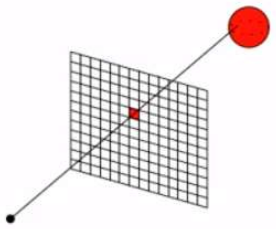
Basic Ray Tracing Algorithm

FOR each pixel DO

- find 1st object hit by ray and surface normal $\vec{n}$
- set pixel color to value computed from hit point, light, and $\vec{n}$



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Pseudocode

```
Image Raytrace (Eye eye, Scene scene, int width, int height)
{
  Image image = new Image (width, height) ;
  for (int i = 0 ; i < height ; i++)
        for (int j = 0 ; j < width ; j++)
        {
              Ray ray = RayThruPixel (eye, i, j) ;
              Intersection hit = Intersect (ray, scene) ;
              image[i][j] = FindColor (hit) ;
         }
  return image ;
}
```

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Ray Tracing Transformed Objects

- Rendering duplicated objects in the scene.
- Keep one instance of the geometry data and transform it.

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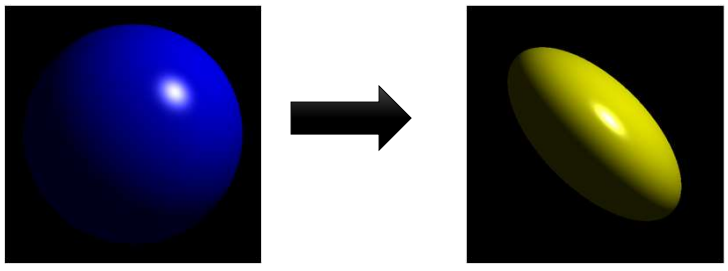
Ray Tracing Transformed Objects

- Triangle: Still a triangle after transformation
- Sphere: becomes ellipsoid



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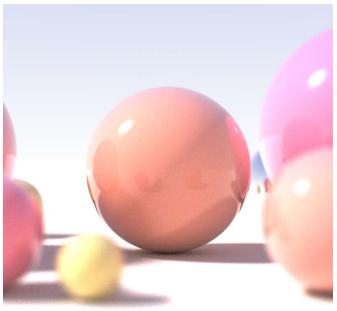
Example



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Rasterization vs Ray Tracing

Rasterization loop:

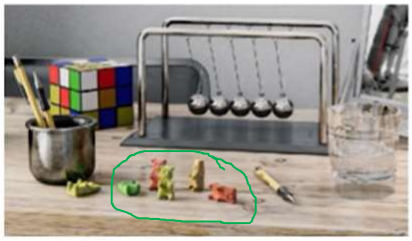
For each object

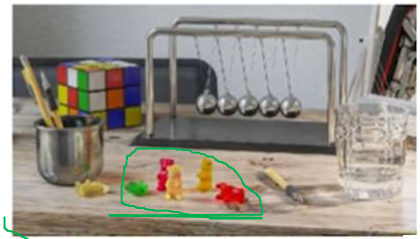
For each pixel—closer?

Ray tracing loop:

For each pixel

For each object—closest?





Courtesy NVIDIA

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Hybrid Technique

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