karansher / **computer-graphics-ray-casting** Public

forked from alecjacobson/computer-graphics-ray-casting

Computer Graphics Assignment about Ray Casting

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master

This branch is up to date with alecjacobson/computer-graphics-ray-casting:master.

**psarahdactyl** Update README.tex.md ... on May 11, 2020 29

View code

# Computer Graphics – Ray Casting

> **To get started:** Clone this repository and its submodule using
>
> ```
> git clone --recursive http://github.com/alecjacobson/computer-graphics-ray-casting.git
> ```
>
> **Do not fork:** Clicking "Fork" will create a *public* repository. If you'd like to use GitHub while you work on your assignment, then mirror this repo as a new *private* repository: https://stackoverflow.com/questions/10065526/github-how-to-make-a-fork-of-public-repository-private

## Background

### Read Sections 4.1-4.4 of *Fundamentals of Computer Graphics (4th Edition)*.

*We will cover basic shading, shadows and reflection in the next assignment.*

## Scene Objects

This assignment will introduce a few *primitives* for 3D geometry: spheres, planes and triangles. We'll get a first glimpse that more complex shapes can be created as a collection of these primitives.

The core interaction that we need to start visualizing these shapes is ray-object intersection. A ray emanating from a point $\mathbf{e} \in \mathbb{R}^3$ (e.g., a camera's "eye") in a direction $\mathbf{d} \in \mathbb{R}^3$ can be *parameterized* by a single number $t \in [0, \infty)$. Changing the value of $t$ picks a different point along the ray. Remember, a ray is a 1D object so we only need this one "knob" or parameter to move along it. The parametric function for a ray written in vector notation is:

$$\mathbf{r}(t) = \mathbf{e} + t\mathbf{d}.$$

For each object in our scene we need to find out:

1. is there some value $t$ such that the ray $\mathbf{r}(t)$ lies on the surface of the object?
2. if so, what is that value of $t$ (and thus what is the position of intersection $\mathbf{r}(t) \in \mathbb{R}^3$
3. and what is the surface's unit normal vector at the point of intersection.

For each object, we should carefully consider how *many* ray-object intersections are possible for a given ray (always one? sometimes two? ever zero?) and in the presence of multiple answers choose the closest one.

> **Question:** Why keep the closest hit?
>
> **Hint:** 🤦🏻

In this assignment, we'll use simple representations for primitives. For example, for a plane we'll store a point on the plane and the normal anywhere on the plane.

> **Question:** How many numbers are needed to uniquely determine a plane?
>
> **Hint:** A point position (3) + normal vector (3) is too many. Consider how many numbers are needed to specify a line in 2D.

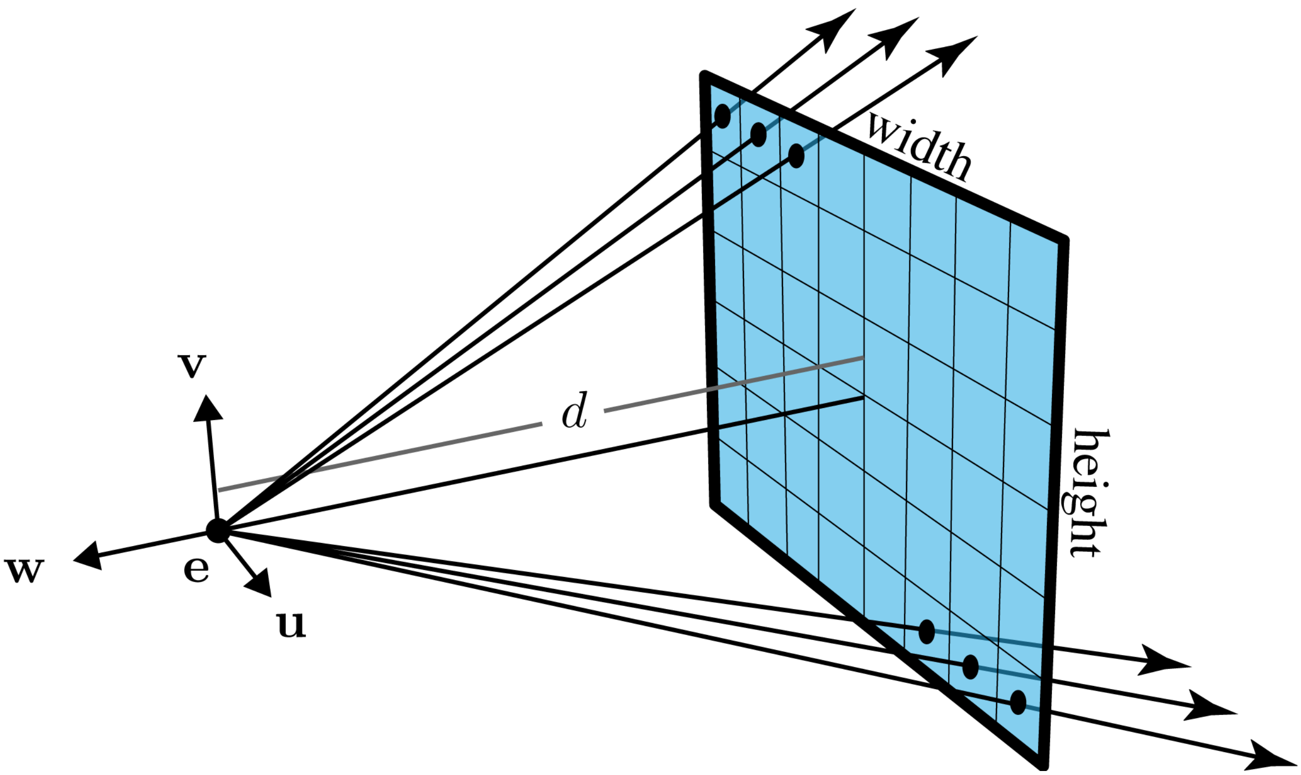
## Camera

README.md

In this assignment we will pretend that our "camera" or "eye" looking into the scene is shrunk to a single 3D point $\mathbf{e} \in \mathbb{R}^3$ in space. The image rectangle (e.g., 640 pixels by 360 pixels) is placed so the image center is directly *in front* of the "eye" point at a certain "focal length" $d$. The image of pixels is scaled to match the given `width` and `height` defined by the `camera`. Camera is equipped with a direction that moves left-right across the image $\mathbf{u}$, up-down $\mathbf{v}$, and from the "eye" to the image $-\mathbf{w}$. Keep in mind that the `width` and `height` are measure in the units of the *scene*, not in the number of pixels. For example, we can fit a 1024x1024 image into a camera with width $= 1$ and height $= 1$.

**Note:** The textbook puts the pixel coordinate origin in the bottom-left, and uses $i$ as a column index and $j$ as a row index. In this assignment; the origin is in the *top-left*, $i$ is a *row* index, and $j$ is a *column* index.

> **Question:** Given that $\mathbf{u}$ points right and $\mathbf{v}$ points up, why does *minus* $\mathbf{w}$ point into the scene?
>
> **Hint:** ☝️




## Triangle Soup

Triangles are the simplest 2D polygon. On the computer we can represent a triangle efficiently by storing its 3 corner positions. To store a triangle floating in 3D, each corner position is stored as 3D position.

A simple, yet effective and popular way to approximate a complex shape is to store list of (many and small) triangles covering the shape's surface. If we place no assumptions on these triangles (i.e., they don't have to be connected together or non-intersecting), then we call this collection a "triangle soup".

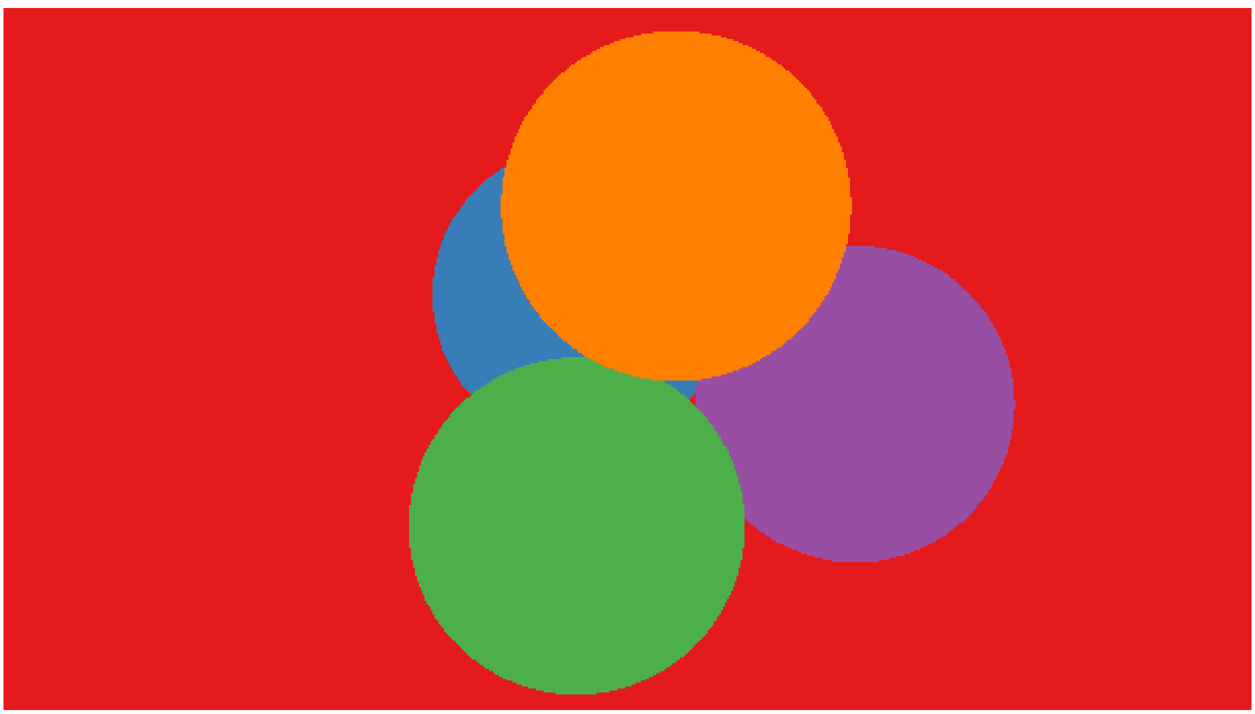
When considering the intersection of a ray and a triangle soup, we simply need to find the *first* triangle in the soup that the ray intersects first.

## False color images

Our scene does not yet have light so the only accurate rendering would be a pitch black image. Since this is rather boring, we'll create false or pseudo renderings of the information we computed during ray-casting.

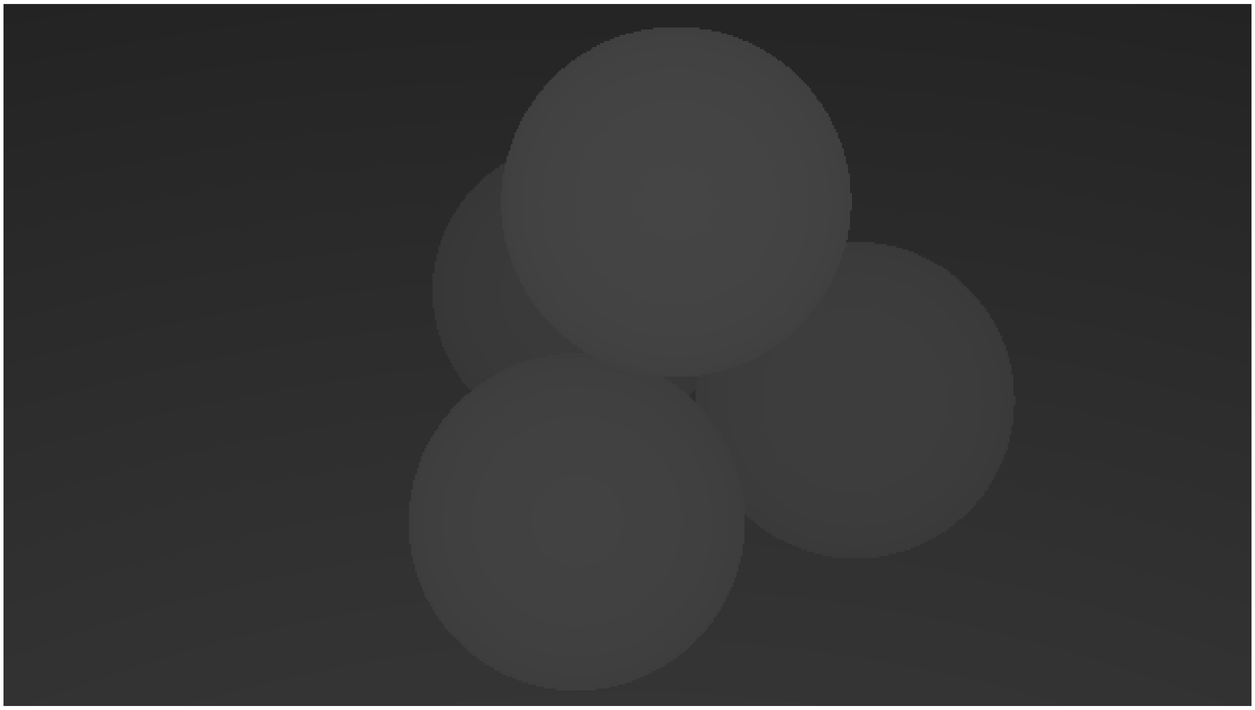
### Object ID image

The simplest image we'll make is just assigning each object to a color. If a pixel's closest hit comes from the $i$-th object then we paint it with the $i$-th rgb color in our `color_map` .



### Depth images

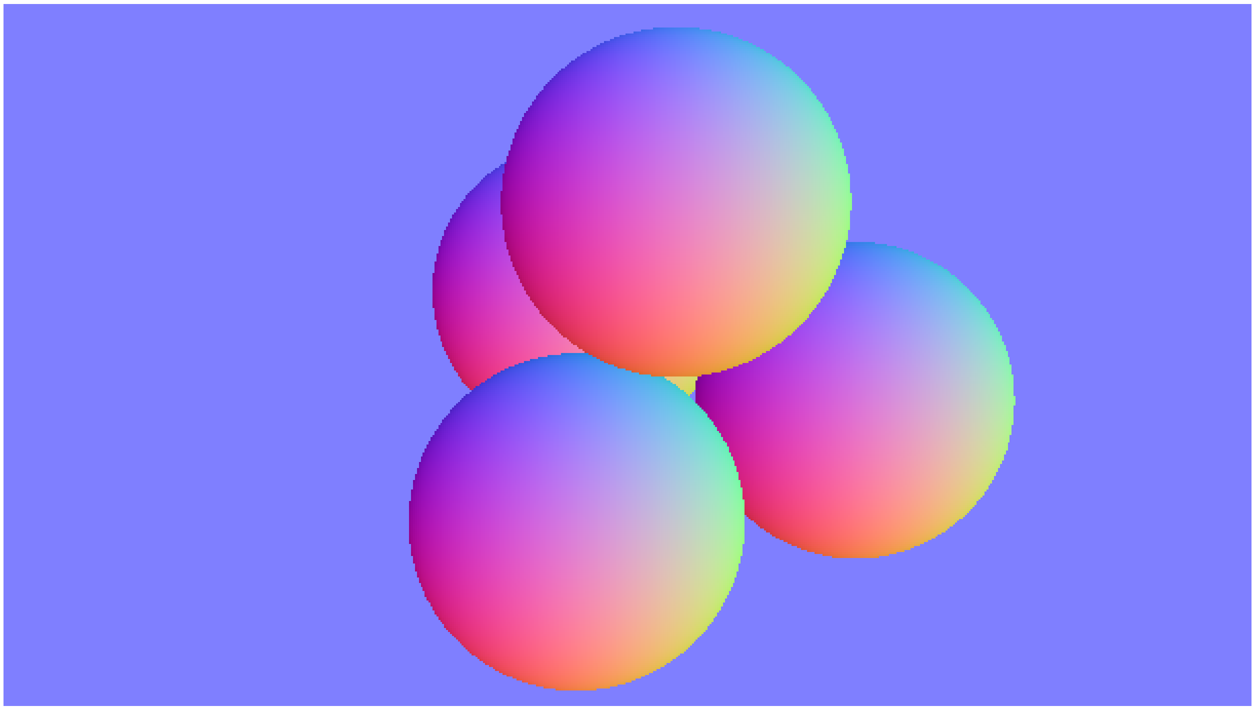
The object ID image gives us very little sense of 3D. The simplest image to encode the 3D geometry of a scene is a depth image. Since the range of depth is generally $[d, \infty)$ where $d$ is the distance from the camera's eye to the camera plane, we must map this to the range $[0, 1]$ to create a grayscale image. In this assignment we use a simple non-linear mapping based on reasonable default values.



### Normal images

The depth image technically captures all geometric information visible by casting rays from the camera, but interesting surfaces will appear dull because small details will have nearly the same depth. During ray-object intersection we compute or return the surface normal vector $\mathbf{n} \in \mathbf{R}^3$ at the point of intersection. Since the normal vector is unit length, each coordinate value is between $[-1, 1]$. We can map the normal vector to an rgb value in a linear way (e.g., $r = \frac{1}{2}x + \frac{1}{2}$).

Although all of these images appear cartoonish and garish, together they reveal that ray-casting can probe important pixel-wise information in the 3D scene.



## Tasks

In this assignment you will implement core routines for casting rays into a 3D and collect "hit" information where they intersect 3D objects.

## Whitelist

This assignment uses the Eigen for numerical linear algebra. This library is used in both professional and academic numerical computing. We will use its `Eigen::Vector3d` as a double-precision 3D vector class to store $x, y, z$ data for 3D points and 3D vectors. You can add ( `+` ) vectors and points together, multiply them against scalars ( $*$ ) and compute vector dot products ( `a.dot(b)` ). In addition, `#include <Eigen/Geometry>` has useful geometric functions such as 3D vector cross product ( `a.cross(b)` ).

### `src/write_ppm.cpp`

See computer-graphics-raster-images.

### `src/viewing_ray.cpp`

Construct a viewing ray given a camera and subscripts to a pixel.

### `src/first_hit.cpp`

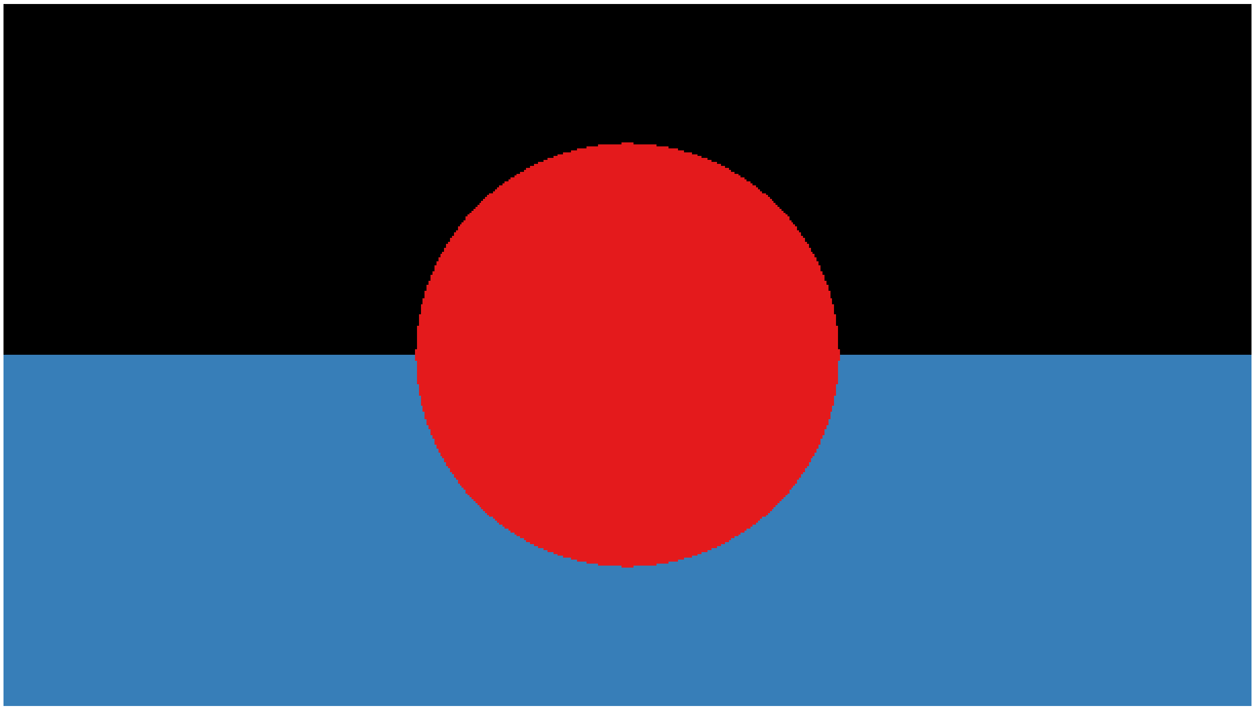
Find the first (visible) hit given a ray and a collection of scene objects

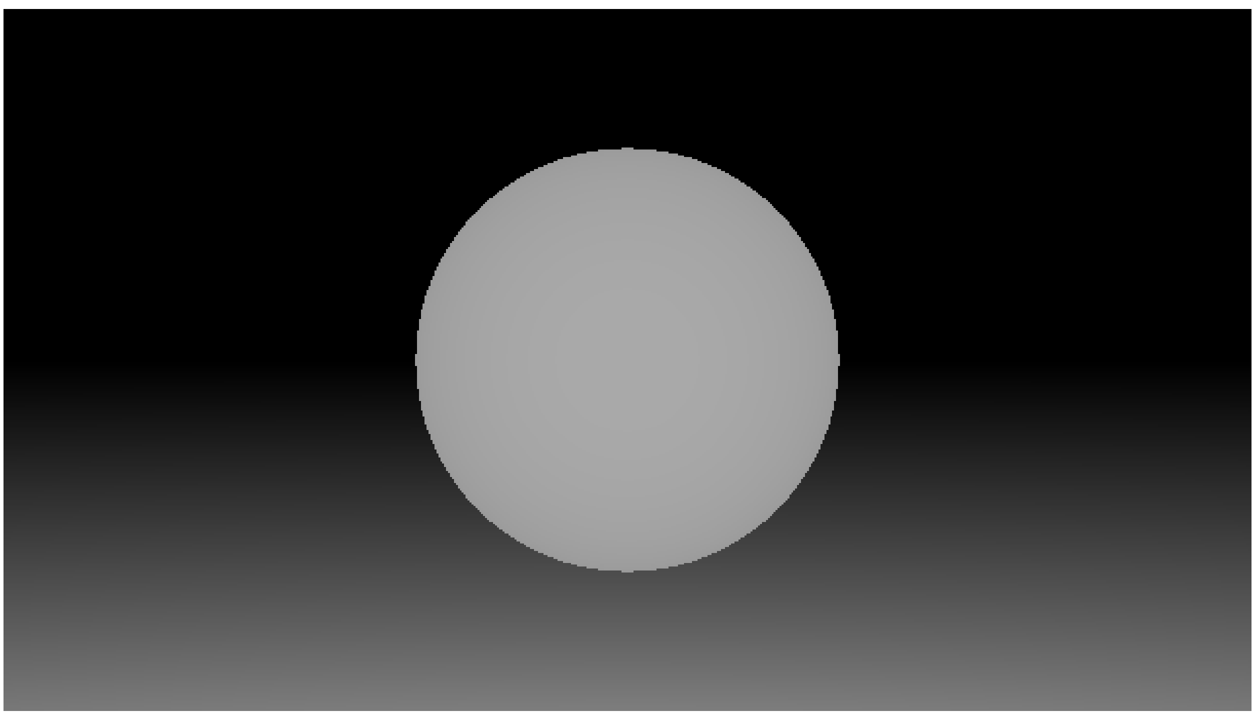
### `Sphere::intersect_ray` in `src/Sphere.cpp`

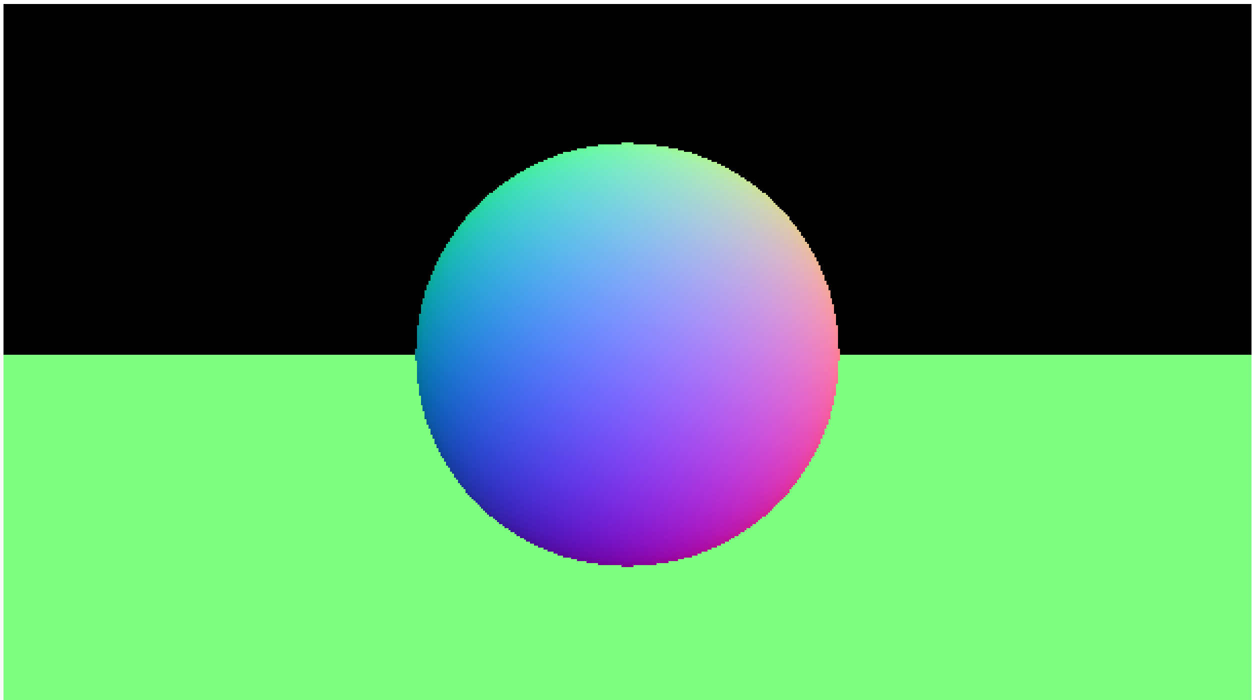
Intersect a sphere with a ray.

### `Plane::intersect_ray` in `src/Plane.cpp`

Intersect a plane with a ray.

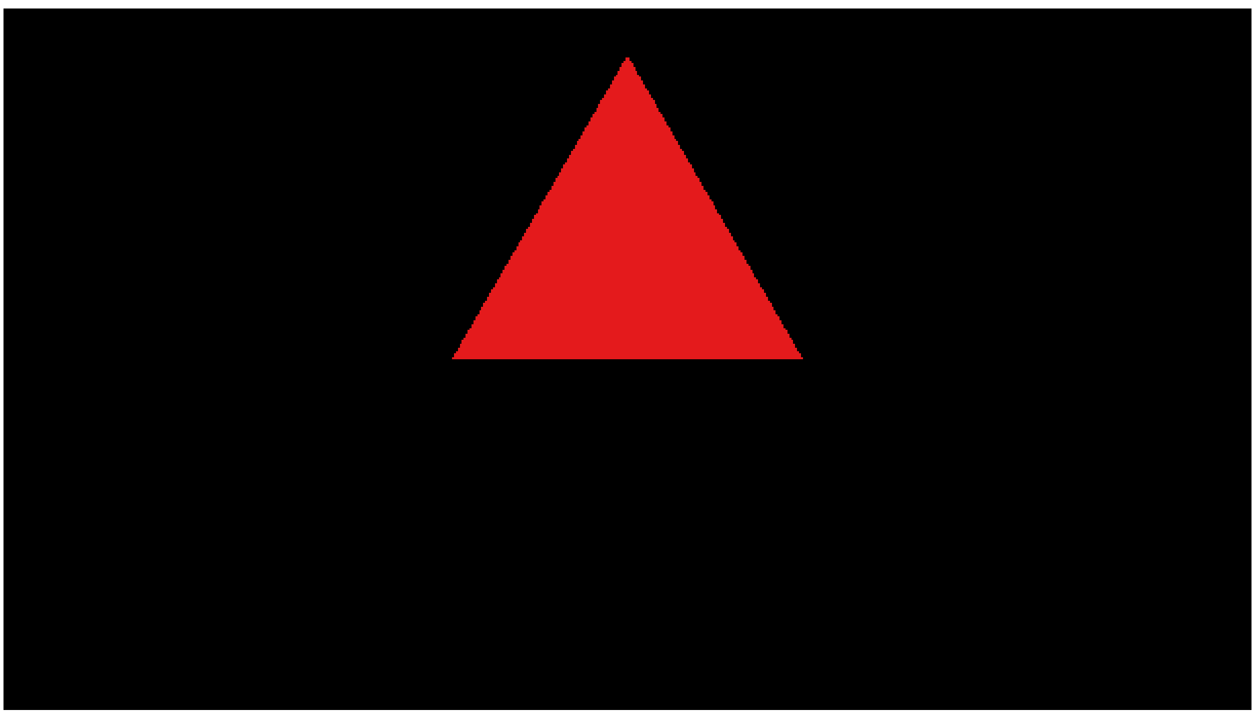






### `Triangle::intersect_ray` in `src/Triangle.cpp`

Intersect a triangle with a ray.



### `TriangleSoup::intersect_ray` in `src/TriangleSoup.cpp`

Intersect a triangle soup with a ray.

> **Pro Tip:** Mac OS X users can quickly preview the output images using
>
> ```
> ./raycasting && qlmanage -p {id,depth,normal}.ppm
> ```
>
> Flicking the left and right arrows will toggle through the results

> **Pro Tip:** After you're confident that your program is working *correctly*, you can dramatic improve the performance simply by enabling compiler optimization:
>
> ```
> mkdir build-release
> cd build-release
> cmake ../ -DCMAKE_BUILD_TYPE=Release
> make
> ```

### Releases

No releases published

### Packages

No packages published

### Languages

- **C++** 97.6%
- **CSS** 2.0%
- **Other** 0.4%