Package ‘rayrender’

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Type Package

Title Build and Raytrace 3D Scenes

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Description Render scenes using pathtracing. Build 3D scenes out of spheres, cubes, planes, disks, triangles, cones, curves, line segments, cylinders, ellipsoids, and 3D models in the 'Wavefront' OBJ file format or the PLY Polygon File Format. Supports several material types, textures, multicore rendering, and tone-mapping. Based on the ``Ray Tracing in One Weekend'' book series. Peter Shirley (2018) <https://raytracing.github.io>.

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Depends R (>= 4.1.0)

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LinkingTo Rcpp, RcppThread, progress, spacefillr (>= 0.3.0), testthat

URL https://www.rayrender.net,
https://github.com/tylermorganwall/rayrender,
http://www.rayrender.net/

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Contents

`add_object` *Add Object*

Description

Add Object

Usage

```
add_object(scene, objects = NULL)
```

Arguments

`scene`	Tibble of pre-existing object locations and properties.
`objects`	A tibble row or collection of rows representing each object.

Value

Tibble of object locations and properties.

Examples

```
#Generate the ground and add some objects
scene = generate_ground(depth=-0.5,material = diffuse(checkercolor="blue")) %>%
  add_object(cube(x=0.7,
             material=diffuse(noise=5,noisecolor="purple",color="black",noisephase=45),
                 angle=c(0,-30,0))) %>%
  add_object(sphere(x=-0.7,radius=0.5,material=metal(color="gold")))
if(run_documentation()) {
render_scene(scene,parallel=TRUE)
}
```

`animate_objects` *Animate Objects*

Description

This function animates an object between two states. This animates objects separately from the transformations set in 'group_objects()' and in the object transformations themselves. This creates motion blur, controlled by the shutter open/close options in 'render_scene()'.

Usage

```
animate_objects(
  scene,
  start_time = 0,
  end_time = 1,
  start_pivot_point = c(0, 0, 0),
  start_position = c(0, 0, 0),
  start_angle = c(0, 0, 0),
  start_order_rotation = c(1, 2, 3),
  start_scale = c(1, 1, 1),
  start_axis_rotation = NA,
  end_pivot_point = c(0, 0, 0),
  end_position = c(0, 0, 0),
  end_angle = c(0, 0, 0),
  end_order_rotation = c(1, 2, 3),
  end_scale = c(1, 1, 1),
  end_axis_rotation = NA
)
```

Arguments

- `scene` Tibble of pre-existing object locations.
- `start_time` Default '0'. Start time of movement.
- `end_time` Default '1'. End time of movement.
- `start_pivot_point` Default 'c(0,0,0)'. The point about which to pivot, scale, and move the objects.
- `start_position` Default 'c(0,0,0)'. Vector indicating where to offset the objects.
- `start_angle` Default 'c(0,0,0)'. Angle of rotation around the x, y, and z axes, applied in the order specified in 'order_rotation'.
- `start_order_rotation` Default 'c(1,2,3)'. The order to apply the rotations, referring to "x", "y", and "z".
- `start_scale` Default 'c(1,1,1)'. Scaling factor for x, y, and z directions for all objects.
- `start_axis_rotation` Default 'NA'. Provide an axis of rotation and a single angle (via 'angle') of rotation
- `end_pivot_point` Default 'c(0,0,0)'. The point about which to pivot, scale, and move the group.
- `end_position` Default 'c(0,0,0)'. Vector indicating where to offset the objects.
- `end_angle` Default 'c(0,0,0)'. Angle of rotation around the x, y, and z axes, applied in the order specified in 'order_rotation'.
- `end_order_rotation` Default 'c(1,2,3)'. The order to apply the rotations, referring to "x", "y", and "z".
- `end_scale` Default 'c(1,1,1)'. Scaling factor for x, y, and z directions for all objects.
- `end_axis_rotation` Default 'NA'. Provide an axis of rotation and a single angle (via 'angle') of rotation around that axis.

Value

Tibble of animated object.

Examples

```
#Render a pig
if(run_documentation()) {
generate_studio() %>%
  add_object(pig(y=-1.2,scale=0.5,angle=c(0,-70,0)))%>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=16,sample_method = "sobol_blue")
}
if(run_documentation()) {
#Render a moving pig
generate_studio() %>%
  add_object(
```

```
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_position = c(-0.1,0,0), end_position = c(0.1,0.2,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=16,sample_method = "sobol_blue",clamp_value = 10)
}
if(run_documentation()) {

#Render a shrinking pig
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_scale = c(1,1,1), end_scale = c(0.5,0.5,0.5))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=16,sample_method = "sobol_blue",clamp_value = 10)
}
if(run_documentation()) {
#Render a spinning pig
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_angle = c(0,-30,0), end_angle = c(0,30,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=16,sample_method = "sobol_blue",clamp_value = 10)
}
if(run_documentation()) {

#Shorten the open shutter time frame
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_angle = c(0,-30,0), end_angle = c(0,30,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=16,sample_method = "sobol_blue",clamp_value = 10,
               shutteropen=0.4, shutterclose = 0.6)
}
if(run_documentation()) {
#Change the time frame when the shutter is open
generate_studio() %>%
  add_object(
    animate_objects(
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_angle = c(0,-30,0), end_angle = c(0,30,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=16,sample_method = "sobol_blue",clamp_value = 10,
```

```
                  shutteropen=0, shutterclose = 0.1)
}
if(run_documentation()) {
#Shorten the time span in which the movement occurs (which, in effect,
#increases the speed of the transition).
generate_studio() %>%
  add_object(
    animate_objects(start_time = 0, end_time=0.1,
      pig(y=-1.2,scale=0.5,angle=c(0,-70,0)),
      start_angle = c(0,-30,0), end_angle = c(0,30,0))
  ) %>%
  add_object(sphere(y=5,x=5,z=5,radius=2,material=light())) %>%
  render_scene(samples=16,sample_method = "sobol_blue",clamp_value = 10,
                  shutteropen=0, shutterclose = 0.1)
}
```

arrow *Arrow Object*

Description

Composite object (cone + segment)

Usage

```
arrow(
  start = c(0, 0, 0),
  end = c(0, 1, 0),
  radius_top = 0.2,
  radius_tail = 0.1,
  tail_proportion = 0.5,
  direction = NA,
  from_center = TRUE,
  material = diffuse(),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`start` Default ‘c(0, 0, 0)‘. Base of the arrow, specifying ‘x‘, ‘y‘, ‘z‘.

`end` Default ‘c(0, 1, 0)‘. Tip of the arrow, specifying ‘x‘, ‘y‘, ‘z‘.

`radius_top` Default ‘0.5‘. Radius of the top of the arrow.

`radius_tail` Default ‘0.2‘. Radius of the tail of the arrow.

`tail_proportion` Default ‘0.5‘. Proportion of the arrow that is the tail.

direction	Default 'NA'. Alternative to 'start' and 'end', specify the direction (via a length-3 vector) of the arrow. Arrow will be centered at 'start', and the length will be determined by the magnitude of the direction vector.
from_center	Default 'TRUE'. If orientation specified via 'direction', setting this argument to 'FALSE' will make 'start' specify the bottom of the cone, instead of the middle.
material	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
flipped	Default 'FALSE'. Whether to flip the normals.
scale	Default 'c(1, 1, 1)'. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Notes: this will change the stated start/end position of the cone. Emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cone in the scene.

Examples

```
#Draw a simple arrow from x = -1 to x = 1
if(run_documentation()) {
generate_studio() %>%
  add_object(arrow(start = c(-1,0,0), end = c(1,0,0), material=glossy(color="red"))) %>%
  add_object(sphere(y=5,material=light(intensity=20))) %>%
  render_scene(clamp_value=10,  samples=16)
}
if(run_documentation()) {
#Change the proportion of tail to top
generate_studio(depth=-2) %>%
  add_object(arrow(start = c(-1,-1,0), end = c(1,-1,0), tail_proportion = 0.5,
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(-1,0,0), end = c(1,0,0), tail_proportion = 0.75,
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(-1,1,0), end = c(1,1,0), tail_proportion = 0.9,
                   material=glossy(color="red"))) %>%
  add_object(sphere(y=5,z=5,x=2,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, fov=25,  samples=16)
}
if(run_documentation()) {
#Change the radius of the tail/top segments
generate_studio(depth=-1.5) %>%
  add_object(arrow(start = c(-1,-1,0), end = c(1,-1,0), tail_proportion = 0.75,
                   radius_top = 0.1, radius_tail=0.03,
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(-1,0,0), end = c(1,0,0), tail_proportion = 0.75,
                   radius_top = 0.2, radius_tail=0.1,
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(-1,1,0), end = c(1,1,0), tail_proportion = 0.75,
                   radius_top = 0.3, radius_tail=0.2,
                   material=glossy(color="red"))) %>%
```

```
  add_object(sphere(y=5,z=5,x=2,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, samples=16)
}
if(run_documentation()) {
#We can also specify arrows via a midpoint and direction:
generate_studio(depth=-1) %>%
  add_object(arrow(start = c(-1,-0.5,0), direction = c(0,0,1),
                   material=glossy(color="green"))) %>%
  add_object(arrow(start = c(1,-0.5,0), direction = c(0,0,-1),
                   material=glossy(color="red"))) %>%
  add_object(arrow(start = c(0,-0.5,1), direction = c(1,0,0),
                   material=glossy(color="yellow"))) %>%
  add_object(arrow(start = c(0,-0.5,-1), direction = c(-1,0,0),
                   material=glossy(color="purple"))) %>%
  add_object(sphere(y=5,z=5,x=2,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, samples=16,
               lookfrom=c(0,5,10), lookat=c(0,-0.5,0), fov=16)
}
if(run_documentation()) {
#Plot a 3D vector field for a gravitational well:

r = 1.5
theta_vals = seq(0,2*pi,length.out = 16)[-16]
phi_vals = seq(0,pi,length.out = 16)[-16][-1]
arrow_list = list()
counter = 1
for(theta in theta_vals) {
  for(phi in phi_vals) {
    rval = c(r*sin(phi)*cos(theta),r*cos(phi),r*sin(phi)*sin(theta))
    arrow_list[[counter]] = arrow(rval, direction = -1/2*rval/sqrt(sum(rval*rval))^3,
                              tail_proportion = 0.66, radius_top=0.03, radius_tail=0.01,
                                 material = diffuse(color="red"))
    counter = counter + 1
  }
}
vector_field = do.call(rbind,arrow_list)
sphere(material=diffuse(noise=1,color="blue",noisecolor="darkgreen")) %>%
  add_object(vector_field) %>%
  add_object(sphere(y=0,x=10,z=5,material=light(intensity=200))) %>%
  render_scene(fov=20, ambient=TRUE, samples=16,
               backgroundlow="black",backgroundhigh="white")
}
```

`bezier_curve` *Bezier Curve Object*

Description

Bezier curve, defined by 4 control points.

Usage

```
bezier_curve(
  p1 = c(0, 0, 0),
  p2 = c(-1, 0.33, 0),
  p3 = c(1, 0.66, 0),
  p4 = c(0, 1, 0),
  x = 0,
  y = 0,
  z = 0,
  width = 0.1,
  width_end = NA,
  u_min = 0,
  u_max = 1,
  type = "cylinder",
  normal = c(0, 0, -1),
  normal_end = NA,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

p1	Default ‘c(0,0,0)‘. First control point. Can also be a list of 4 length-3 numeric vectors or 4x3 matrix/data.frame specifying the x/y/z control points.
p2	Default ‘c(-1,0.33,0)‘. Second control point.
p3	Default ‘c(1,0.66,0)‘. Third control point.
p4	Default ‘c(0,1,0)‘. Fourth control point.
x	Default ‘0‘. x-coordinate offset for the curve.
y	Default ‘0‘. y-coordinate offset for the curve.
z	Default ‘0‘. z-coordinate offset for the curve.
width	Default ‘0.1‘. Curve width.
width_end	Default ‘NA‘. Width at end of path. Same as ‘width‘, unless specified.
u_min	Default ‘0‘. Minimum parametric coordinate for the curve.
u_max	Default ‘1‘. Maximum parametric coordinate for the curve.
type	Default ‘cylinder‘. Other options are ‘flat‘ and ‘ribbon‘.
normal	Default ‘c(0,0,-1)‘. Orientation surface normal for the start of ribbon curves.
normal_end	Default ‘NA‘. Orientation surface normal for the start of ribbon curves. If not specified, same as ‘normal‘.
material	Default diffuse.The material, called from one of the material functions diffuse, metal, or dielectric.

angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default ‘FALSE‘. Whether to flip the normals.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cube in the scene.

Examples

```
#Generate the default curve:
if(run_documentation()) {
generate_studio(depth=-0.2) %>%
  add_object(bezier_curve(material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,radius=0.3,
                    material=light(intensity=200, spotlight_focus = c(0,0.5,0)))) %>%
  render_scene(clamp_value = 10, lookat = c(0,0.5,0), fov=13,
               samples=16)
}

if(run_documentation()) {
#Change the control points to change the direction of the curve. Here, we place spheres
#at the control point locations.
generate_studio(depth=-0.2) %>%
  add_object(bezier_curve(material=diffuse(color="red"))) %>%
  add_object(sphere(radius=0.075,material=glossy(color="green"))) %>%
  add_object(sphere(radius=0.075,x=-1,y=0.33,material=glossy(color="green"))) %>%
  add_object(sphere(radius=0.075,x=1,y=0.66,material=glossy(color="green"))) %>%
  add_object(sphere(radius=0.075,y=1,material=glossy(color="green"))) %>%
  add_object(sphere(y=3,z=5,x=2,radius=0.3,
                    material=light(intensity=200, spotlight_focus = c(0,0.5,0)))) %>%
  render_scene(clamp_value = 10, lookat = c(0,0.5,0), fov=15,
               samples=16)
}
if(run_documentation()) {
#We can make the curve flat (always facing the camera) by setting the type to `flat`
generate_studio(depth=-0.2) %>%
  add_object(bezier_curve(type="flat", material=glossy(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,radius=0.3,
                    material=light(intensity=200, spotlight_focus = c(0,0.5,0)))) %>%
  render_scene(clamp_value = 10, lookat = c(0,0.5,0), fov=13,
               samples=16)
}
if(run_documentation()) {
#We can also plot a ribbon, which is further specified by a start and end orientation with
#two surface normals.
```

```
generate_studio(depth=-0.2) %>%
  add_object(bezier_curve(type="ribbon", width=0.2,
                  p1 = c(0,0,0), p2 = c(0,0.33,0), p3 = c(0,0.66,0), p4 = c(0.3,1,0),
                  normal_end = c(0,0,1),
                  material=glossy(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,radius=0.3,
                   material=light(intensity=200, spotlight_focus = c(0,0.5,0)))) %>%
  render_scene(clamp_value = 10, lookat = c(0,0.5,0), fov=13,
               samples=16)
}
if(run_documentation()) {
#Create a single curve and copy and rotate it around the y-axis to create a wavy fountain effect:
scene_curves = list()
for(i in 1:90) {
  scene_curves[[i]] = bezier_curve(p1 = c(0,0,0),p2 = c(0,5-sinpi(i*16/180),2),
                            p3 = c(0,5-0.5 * sinpi(i*16/180),4),p4 = c(0,0,6),
                            angle=c(0,i*4,0), type="cylinder",
                            width = 0.1, width_end =0.1,material=glossy(color="red"))
}
all_curves = do.call(rbind, scene_curves)
generate_ground(depth=0,material=diffuse(checkercolor="grey20")) %>%
  add_object(all_curves) %>%
  add_object(sphere(y=7,z=0,x=0,material=light(intensity=100))) %>%
  render_scene(lookfrom = c(12,20,50),samples=100,
               lookat=c(0,1,0), fov=15, clamp_value = 10)

}
```

---

cone *Cone Object*

Description

Cone Object

Usage

```
cone(
  start = c(0, 0, 0),
  end = c(0, 1, 0),
  radius = 0.5,
  direction = NA,
  from_center = TRUE,
  material = diffuse(),
  angle = c(0, 0, 0),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`start`	Default 'c(0, 0, 0)'. Base of the cone, specifying 'x', 'y', 'z'.
`end`	Default 'c(0, 1, 0)'. Tip of the cone, specifying 'x', 'y', 'z'.
`radius`	Default '1'. Radius of the bottom of the cone.
`direction`	Default 'NA'. Alternative to 'start' and 'end', specify the direction (via a length-3 vector) of the cone. Cone will be centered at 'start', and the length will be determined by the magnitude of the direction vector.
`from_center`	Default 'TRUE'. If orientation specified via 'direction', setting this argument to 'FALSE' will make 'start' specify the bottom of the cone, instead of the middle.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default 'c(0, 0, 0)'. Rotation angle. Note: This will change the 'start' and 'end' coordinates.
`flipped`	Default 'FALSE'. Whether to flip the normals.
`scale`	Default 'c(1, 1, 1)'. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Notes: this will change the stated start/end position of the cone. Emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cone in the scene.

Examples

```
#Generate a cone in a studio, pointing upwards:
if(run_documentation()) {
generate_studio() %>%
 add_object(cone(start=c(0,-1,0), end=c(0,1,0), radius=1,material=diffuse(color="red"))) %>%
 add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
 render_scene(samples=16,clamp_value=10)
}
if(run_documentation()) {
 #Change the radius, length, and direction
generate_studio() %>%
 add_object(cone(start=c(0,0,0), end=c(0,-1,0), radius=0.5,material=diffuse(color="red"))) %>%
 add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
 render_scene(samples=16,clamp_value=10)
}
if(run_documentation()) {
#Give custom start and end points (and customize the color/texture)
generate_studio() %>%
 add_object(cone(start=c(-1,0.5,-1), end=c(0,0,0), radius=0.5,material=diffuse(color="red"))) %>%
 add_object(cone(start=c(1,0.5,-1), end=c(0,0,0), radius=0.5,material=diffuse(color="green"))) %>%
 add_object(cone(start=c(0,1,-1), end=c(0,0,0), radius=0.5,material=diffuse(color="orange"))) %>%
 add_object(cone(start=c(-1,-0.5,0), end=c(1,-0.5,0), radius=0.25,
   material = diffuse(color="red",gradient_color="green"))) %>%
 add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
```

```
 render_scene(samples=16,clamp_value=10)
}
if(run_documentation()) {
#Specify cone via direction and location, instead of start and end positions
#Length is derived from the magnitude of the direction.
gold_mat = microfacet(roughness=0.1,eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661))
generate_studio() %>%
  add_object(cone(start = c(-1,0,0), direction = c(-0.5,0.5,0), material = gold_mat)) %>%
  add_object(cone(start = c(1,0,0), direction = c(0.5,0.5,0), material = gold_mat)) %>%
  add_object(cone(start = c(0,0,-1), direction = c(0,0.5,-0.5), material = gold_mat)) %>%
  add_object(cone(start = c(0,0,1), direction = c(0,0.5,0.5), material = gold_mat)) %>%
  add_object(sphere(y=5,material=light())) %>%
  add_object(sphere(y=3,x=-3,z=-3,material=light(color="red"))) %>%
  add_object(sphere(y=3,x=3,z=-3,material=light(color="green"))) %>%
  render_scene(lookfrom=c(0,4,10), clamp_value=10, samples=16)
}
if(run_documentation()) {
 #Render the position from the base, instead of the center of the cone:
 noise_mat = material = glossy(color="purple",noisecolor="blue", noise=5)
 generate_studio() %>%
  add_object(cone(start = c(0,-1,0), from_center = FALSE, radius=1, direction = c(0,2,0),
    material = noise_mat)) %>%
 add_object(cone(start = c(-1.5,-1,0), from_center = FALSE, radius=0.5, direction = c(0,1,0),
    material = noise_mat)) %>%
 add_object(cone(start = c(1.5,-1,0), from_center = FALSE, radius=0.5, direction = c(0,1,0),
    material = noise_mat)) %>%
 add_object(cone(start = c(0,-1,1.5), from_center = FALSE, radius=0.5, direction = c(0,1,0),
    material = noise_mat)) %>%
  add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
  render_scene(lookfrom=c(0,4,10), clamp_value=10,fov=25, samples=16)
}
```

`create_instances` *Create Instances of an Object*

Description

This creates multiple instances of the ‘ray_scene‘ passed, each with it’s own transformation applied (measured from the origin of the ray_scene). This means the scene only uses the memory of the object once and each copy only requires a 4x4 matrix in memory.

Usage

```
create_instances(
  ray_scene,
  x = 0,
  y = 0,
  z = 0,
  angle_x = 0,
```

```
  angle_y = 0,
  angle_z = 0,
  scale_x = 1,
  scale_y = 1,
  scale_z = 1,
  material = diffuse(),
  order_rotation = c(1, 2, 3)
)
```

Arguments

ray_scene	A ‘ray_scene‘ object to be copied at the specified transformed coordinates.
x	Default ‘0‘. A vector of x-coordinates to offset the instances. Note that this can also be a 3 column matrix or ‘data.frame()‘ parsable by ‘xyz.coords()‘: if so, the other axes will be ignored.
y	Default ‘0‘. A vector of y-coordinates to offset the instances.
z	Default ‘0‘. A vector of z-coordinates to offset the instances.
angle_x	Default ‘0‘. A vector of angles around the x axis to rotate the instances.
angle_y	Default ‘0‘. A vector of angles around the y axis to rotate the instances.
angle_z	Default ‘0‘. A vector of angles around the z axis to rotate the instances.
scale_x	Default ‘0‘. A vector of values around the scale the instances on the x-axis.
scale_y	Default ‘0‘. A vector of values around the scale the instances on the y-axis.
scale_z	Default ‘0‘. A vector of values around the scale the instances on the z-axis.
material	Default diffuse.The material, called from one of the material functions diffuse, metal, or dielectric.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z" axes.

Value

Single row of a tibble describing the instance in the scene.

Examples

```
if (run_documentation()) {
# Generate the base scene
base_scene = generate_ground(material = diffuse(checkercolor = "grey20")) %>%
  add_object(sphere(z = 100, radius = 10, material = light(intensity = 70)))

# Start with a single sphere with an R in it
sphere_scene = sphere(y = 0, material = glossy(color = "#2b6eff", reflectance = 0.05)) %>%
  add_object(obj_model(r_obj(simple_r = TRUE), z = 0.9, y = -0.2,
  scale_obj = 0.45, material = diffuse())) %>%
  group_objects(scale = 0.1)

# Render the scene
sphere_scene %>%
```

```
  add_object(base_scene) %>%
 render_scene(lookat = c(0, 1, 0), width = 800, sample_method = "sobol_blue", aperture = 0.2,
               height = 800, samples = 16, clamp_value = 20)
}

if (run_documentation()) {
# Create instances at different x positions, with random rotations applied
create_instances(sphere_scene,
                 x = seq(-1.5, 1.5, length.out = 10),
                 angle_x = 90 * (runif(10) - 0.5),
                 angle_y = 90 * (runif(10) - 0.5),
                 angle_z = 90 * (runif(10) - 0.5)) %>%
  add_object(base_scene) %>%
  render_scene(lookat = c(0, 1, 0), width = 800, sample_method = "sobol_blue",
               height = 800, samples = 16, clamp_value = 20)
}

if (run_documentation()) {
# Create instances at different x/z positions, with random scaling factors
create_instances(sphere_scene,
                 x = seq(-1.5, 1.5, length.out = 10),
                 y = seq(0, 1.5, length.out = 10),
                 scale_x = 0.5 + runif(10),
                 scale_y = 0.5 + runif(10),
                 scale_z = 0.5 + runif(10)) %>%
  add_object(base_scene) %>%
  render_scene(lookat = c(0, 1, 0), width = 800, sample_method = "sobol_blue",
               height = 800, samples = 16, clamp_value = 20)
}

if (run_documentation()) {
# Create instances of instances
create_instances(sphere_scene,
                 x = seq(-1.5, 1.5, length.out = 10),
                 angle_y = 90 * (runif(10) - 0.5)) %>%
  create_instances(y = seq(0, 2, length.out = 10)) %>%
  add_object(base_scene) %>%
  render_scene(lookat = c(0, 1, 0), width = 800, sample_method = "sobol_blue",
               height = 800, samples = 16, clamp_value = 20)
}

if (run_documentation()) {
# Create instances of instances of instances of instances
create_instances(sphere_scene,
                 x = seq(-1.5, 1.5, length.out = 10),
                 angle_y = 90 * (runif(10) - 0.5)) %>%
  create_instances(y = seq(0, 1, length.out = 5)) %>%
  create_instances(y = seq(0, 2, length.out = 20) * 10,
                   angle_y = seq(0, 360, length.out = 20)) %>%
  create_instances(x = c(-5, 0, 5),
                   scale_y = c(0.5, 1, 0.75)) %>%
  add_object(base_scene) %>%
  render_scene(lookat = c(0, 10, 0), lookfrom = c(0, 10, 50),
```

```
               width = 800, sample_method = "sobol_blue", fov = 30,
               height = 800, samples = 16, clamp_value = 20)
}

if (run_documentation()) {
# Generate a complex scene in a Cornell box and replicate it in a 3x3 grid
# Here, a single `data.frame` with all three coordinates is passed to the `x` argument.
tempfileplot = tempfile()
png(filename = tempfileplot, height = 1600, width = 1600)
plot(iris$Petal.Length, iris$Sepal.Width, col = iris$Species, pch = 18, cex = 12)
dev.off()
image_array = png::readPNG(tempfileplot)

# Note that if a instanced scene has importance sampled lights and there are many instances,
# it will be slow to render.
generate_cornell(importance_sample=FALSE) %>%
  add_object(ellipsoid(x = 555 / 2, y = 100, z = 555 / 2, a = 50, b = 100, c = 50,
             material = metal(color = "lightblue"))) %>%
  add_object(cube(x = 100, y = 130 / 2, z = 200, xwidth = 130,
                  ywidth = 130, zwidth = 130, angle = c(0, 10, 0),
                  material = diffuse(checkercolor = "purple", checkerperiod = 30))) %>%
  add_object(pig(x = 100, y = 190, z = 200, scale = 40, angle = c(0, 30, 0))) %>%
  add_object(sphere(x = 420, y = 555 / 8, z = 100, radius = 555 / 8,
                    material = dielectric(color = "orange"))) %>%
  add_object(yz_rect(x = 5, y = 300, z = 555 / 2, zwidth = 400, ywidth = 400,
                     material = diffuse(image_texture = image_array))) %>%
  add_object(yz_rect(x = 555 / 2, y = 300, z = 555 - 5, zwidth = 400, ywidth = 400,
                 material = diffuse(image_texture = image_array), angle = c(0, 90, 0))) %>%
  add_object(yz_rect(x = 555 - 5, y = 300, z = 555 / 2, zwidth = 400, ywidth = 400,
                material = diffuse(image_texture = image_array), angle = c(0, 180, 0))) %>%
  create_instances(x = expand.grid(x = seq(-1, 1, by = 1) * 570 - 555 / 2,
                                   y = seq(-1, 1, by = 1) * 570 - 555 / 2,
                                   z = 0)) %>%
  render_scene(lookfrom = c(0, 0, -800) * 3, fov = 40,
               samples = 16, sample_method = "sobol_blue",
               parallel = TRUE, width = 800, height = 800)
}
```

---

csg_box *CSG Box*

Description

CSG Box

Usage

```
csg_box(x = 0, y = 0, z = 0, width = c(1, 1, 1), corner_radius = 0)
```

Arguments

x	Default '0'. An x-coordinate on the box.
y	Default '0'. A y-coordinate on the box.
z	Default '0'. A z-coordinate on the box
width	Default 'c(1,1,1)'. Length-3 vector describing the x/y/z widths of the box
corner_radius	Default '0'. Radius if rounded box.

Value

List describing the box in the scene.

Examples

```
if(run_documentation()) {
#Generate a box
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_box(), material=glossy(color="#FF69B4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=5))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(7,3,7))
  }
if(run_documentation()) {
#Change the width
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_box(width = c(2,1,0.5)), material=glossy(color="#FF69B4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=5))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(7,3,7))
}
if(run_documentation()) {
#Subtract two boxes to make stairs
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_box(),
    csg_box(x=0.5,y=0.5,width=c(1,1,1.1)),operation="subtract"),
   material=glossy(color="#FF69B4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=5))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(7,3,7),fov=13)
  }
```

---

csg_capsule *CSG Capsule*

Description

CSG Capsule

Usage

```
csg_capsule(start = c(0, 0, 0), end = c(0, 1, 0), radius = 1)
```

Arguments

start	Default ‘c(0, 0, 0)‘. Start point of the capsule, specifying ‘x‘, ‘y‘, ‘z‘.
end	Default ‘c(0, 1, 0)‘. End point of the capsule, specifying ‘x‘, ‘y‘, ‘z‘.
radius	Default ‘1‘. Capsule radius.

Value

List describing the capsule in the scene.

Examples

```
if(run_documentation()) {
#Generate a basic capsule:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_capsule(radius=0.5),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20)
  }
if(run_documentation()) {
#Change the orientation by specifying a start and end
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(csg_capsule(start = c(-1,0.5,-2), end = c(1,0.5,-2),
  radius=0.5),material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(3,3,10))
 }
if(run_documentation()) {
#Show the effect of changing the radius
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(
    csg_combine(
    csg_capsule(start = c(-1,0.5,-2), end = c(1,0.5,-2), radius=0.5),
    csg_capsule(start = c(-0.5,1.5,-2), end = c(0.5,1.5,-2), radius=0.25)),
    material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(-3,3,10))
   }
if(run_documentation()) {
#Render a capsule in a Cornell box
generate_cornell() %>%
  add_object(csg_object(
   csg_capsule(start = c(555/2-100,555/2,555/2), end = c(555/2+100,555/2,555/2), radius=100),
    material=glossy(color="dodgerblue4"))) %>%
  render_scene(clamp_value=10, samples=16)
}
```

---

csg_combine *CSG Combine*

Description

Note: Subtract operations aren't commutative: the second object is subtracted from the first.

Usage

```
csg_combine(object1, object2, operation = "union", radius = 0.5)
```

Arguments

object1	First CSG object
object2	Second CSG object
operation	Default ‘union‘. Can be ‘union‘, ‘subtract‘, ‘intersection‘, ‘blend‘, ‘subtract-blend‘, or ‘mix‘.
radius	Default ‘0.5‘. Blending radius.

Value

List describing the combined csg object in the scene.

Examples

```
if(run_documentation()) {
#Combine two spheres:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="union"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(-3,5,10))
  }
if(run_documentation()) {
#Subtract one sphere from another:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="subtract"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(-3,5,10))
  }
if(run_documentation()) {
#Get the intersection of two spheres:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="intersection"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(-3,5,10))
```

```
  }
if(run_documentation()) {
#Get the blended union of two spheres:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="blend"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(-3,5,10))
  }
if(run_documentation()) {
#Get the blended subtraction of two spheres:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="subtractblend"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(-3,5,10))
  }
if(run_documentation()) {
#Change the blending radius:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="blend", radius=0.2),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(-3,5,10))
  }
if(run_documentation()) {
#Change the subtract blending radius:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(x=-0.4,z=-0.4),
     csg_sphere(x=0.4,z=0.4), operation="subtractblend", radius=0.2),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(-3,5,10))
  }
if(run_documentation()) {
#Get the mixture of various objects:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
     csg_sphere(),
     csg_box(), operation="mix"),
  material=glossy(color="dodgerblue4"))) %>%
  add_object(csg_object(csg_translate(csg_combine(
     csg_box(),
     csg_torus(), operation="mix"),z=-2.5),
  material=glossy(color="red"))) %>%
  add_object(csg_object(csg_translate(csg_combine(
```

```
    csg_pyramid(),
    csg_box(), operation="mix"),z=2.5),
  material=glossy(color="green"))) %>%
  add_object(sphere(y=10,x=-5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(-15,10,10))
}
```

csg_cone *CSG Cone*

Description

CSG Cone

Usage

```
csg_cone(start = c(0, 0, 0), end = c(0, 1, 0), radius = 0.5)
```

Arguments

start	Default ‘c(0, 0, 0)‘. Start point of the cone, specifing ‘x‘, ‘y‘, ‘z‘.
end	Default ‘c(0, 1, 0)‘. End point of the cone, specifing ‘x‘, ‘y‘, ‘z‘.
radius	Default ‘1‘. Radius of the bottom of the cone.

Value

List describing the box in the scene.

Examples

```
if(run_documentation()) {
#Generate a basic cone:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_cone(),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20)
  }
if(run_documentation()) {
#Change the orientation by specifying a start and end
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(csg_cone(start = c(-1,0.5,-2), end = c(1,0.5,-2),
  radius=0.5),material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(3,3,10))
 }
if(run_documentation()) {
#Show the effect of changing the radius
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(
    csg_combine(
```

```
    csg_cone(start = c(-1,0.5,-2), end = c(1,0.5,-2), radius=0.5),
    csg_cone(start = c(-0.5,1.5,-2), end = c(0.5,1.5,-2), radius=0.2)),
    material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(-3,3,10))
    }
if(run_documentation()) {
#Render a glass cone in a Cornell box
generate_cornell() %>%
  add_object(csg_object(
    csg_cone(start = c(555/2,0,555/2), end = c(555/2,555/2+100,555/2), radius=100),
    material=dielectric(attenuation=c(1,1,0.3)/100))) %>%
  render_scene(clamp_value=10, samples=16)
}
```

`csg_cylinder` *CSG Cylinder*

Description

CSG Cylinder

Usage

```
csg_cylinder(
  start = c(0, 0, 0),
  end = c(0, 1, 0),
  radius = 1,
  corner_radius = 0
)
```

Arguments

`start`	Default ‘c(0, 0, 0)‘. Start point of the cylinder, specifing ‘x‘, ‘y‘, ‘z‘.
`end`	Default ‘c(0, 1, 0)‘. End point of the cylinder, specifing ‘x‘, ‘y‘, ‘z‘.
`radius`	Default ‘1‘. Cylinder radius.
`corner_radius`	Default ‘0‘. Radius if rounded cylinder.

Value

List describing the cylinder in the scene.

Examples

```
if(run_documentation()) {
#Generate a basic cylinder:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_cylinder(radius=0.25),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20)
  }
if(run_documentation()) {
#Change the orientation by specifying a start and end
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(csg_cylinder(start = c(-1,0.5,-2), end = c(1,0.5,-2),
    radius=0.5),material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(3,3,10))
 }
if(run_documentation()) {
#Show the effect of changing the radius
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(
    csg_combine(
    csg_cylinder(start = c(-1,0.5,-2), end = c(1,0.5,-2), radius=0.5),
    csg_cylinder(start = c(-0.5,1.5,-2), end = c(0.5,1.5,-2), radius=0.25)),
    material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(-3,3,10))
    }
if(run_documentation()) {
#Render a red marble cylinder in a Cornell box
generate_cornell(light=FALSE) %>%
  add_object(csg_object(
    csg_cylinder(start = c(555/2,0,555/2), end = c(555/2,350,555/2), radius=100),
    material=glossy(color="darkred",noisecolor="white",noise=0.03))) %>%
    add_object(sphere(y=555,x=5,z=5, radius=5,
               material=light(intensity=10000,
                      spotlight_focus = c(555/2,555/2,555/2),spotlight_width = 45))) %>%
  render_scene(clamp_value=4)
}
```

---

csg_ellipsoid *CSG Ellipsoid*

Description

CSG Ellipsoid

Usage

```
csg_ellipsoid(x = 0, y = 0, z = 0, axes = c(0.5, 1, 0.5))
```

Arguments

x	Default '0'. x-coordinate on the ellipsoid.
y	Default '0'. y-coordinate on the ellipsoid.
z	Default '0'. z-coordinate on the ellipsoid.
axes	Default 'c(0.5,1,0.5)'. Ellipsoid principle axes.

Value

List describing the ellipsoid in the scene.

Examples

```
if(run_documentation()) {
#Generate a basic ellipsoid:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_ellipsoid(),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20)
  }
if(run_documentation()) {
#Three different ellipsoids:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_group(list(
   csg_ellipsoid(x=-1.2, axes = c(0.2,0.5,0.5)),
   csg_ellipsoid(x=0, axes = c(0.5,0.2,0.5)),
   csg_ellipsoid(x=1.2, axes = c(0.5,0.5,0.2)))),
   material=glossy(color="red"))) %>%
 render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(0,5,10))
 }
if(run_documentation()) {
#Generate a glass ellipsoid:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_ellipsoid(),material=dielectric(attenuation = c(1,1,0.3)))) %>%
  render_scene(clamp_value=10, samples=16,fov=20)
  }
if(run_documentation()) {
#Generate a glass ellipsoid in a Cornell box:
generate_cornell() %>%
  add_object(csg_object(csg_ellipsoid(x=555/2,y=555/2,z=555/2,axes=c(100,150,200)),
    material=dielectric(attenuation = c(1,0.3,1)/200))) %>%
  render_scene(clamp_value=10, samples=16)
}
```

---

csg_elongate *CSG Elongate*

Description

This operation elongates an existing CSG object in a direction.

Usage

```
csg_elongate(object, x = 0, y = 0, z = 0, elongate = c(0, 0, 0), robust = TRUE)
```

Arguments

object	CSG object.
x	Default ‘0‘. Center of x-elongation.
y	Default ‘0‘. Center of y-elongation.
z	Default ‘0‘. Center of z-elongation.
elongate	Default ‘c(0,0,0)‘ (no elongation). Elongation amount.
robust	Default ‘TRUE‘. ‘FALSE‘ switches to a faster (but less robust in 2D) method.

Value

List describing the triangle in the scene.

Examples

```
if(run_documentation()) {
#Elongate a sphere to create a capsule in 1D or a rounded rectangle in 2D:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_sphere(z=-3,x=-3),
                       material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_sphere(z=-3,x=3),x=3,z=-3, elongate = c(0.8,0,0)),
                       material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_sphere(z=2),z=2, elongate = c(0.8,0,0.8)),
                       material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10, samples=16,fov=40,lookfrom=c(0,10,10))
  }
if(run_documentation()) {
#Elongate a torus:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_torus(z=-3,x=-3),
                       material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_torus(z=-3,x=3),x=3,z=-3, elongate = c(0.8,0,0)),
                       material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_torus(z=2),z=2, elongate = c(0.8,0,0.8)),
                       material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10, samples=16,fov=40,lookfrom=c(0,10,10))
 }
if(run_documentation()) {
#Elongate a cylinder:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_cylinder(start=c(-3,0,-3), end = c(-3,1,-3)),
                       material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_cylinder(start=c(3,0,-3), end = c(3,1,-3)), x=3, z=-3,
                      elongate = c(0.8,0,0)),
                      material=glossy(color="red"))) %>%
```

```
 add_object(csg_object(csg_elongate(csg_cylinder(start=c(0,0,3), end = c(0,1,3)), z=3,
                       elongate = c(0.8,0,0.8)),
                       material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10, samples=16,fov=40,lookfrom=c(0,10,10))
 }
if(run_documentation()) {
#Elongate a pyramid:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_pyramid(z=-3,x=-3),
                        material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_pyramid(z=-3,x=3),x=3,z=-3, elongate = c(0.8,0,0)),
                        material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_pyramid(z=2),z=2, elongate = c(0.8,0,0.8)),
                        material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10, samples=16,fov=40,lookfrom=c(0,10,10))
}
if(run_documentation()) {
#Change the elongation point to start the elongation on the side of the pyramid:
generate_ground(material=diffuse(checkercolor="grey20",color="dodgerblue4")) %>%
 add_object(csg_object(csg_pyramid(z=-3,x=-3),
                        material=glossy(color="purple"))) %>%
 add_object(csg_object(csg_elongate(csg_pyramid(z=-3,x=3),x=2.75,z=-2.75, elongate = c(0.8,0,0)),
                        material=glossy(color="red"))) %>%
 add_object(csg_object(csg_elongate(csg_pyramid(z=2),z=2.25, elongate = c(0.8,0,0.8)),
                        material=glossy(color="white"))) %>%
 add_object(sphere(y=10,radius=3,material=light(intensity=8))) %>%
 render_scene(clamp_value=10, samples=16,fov=40,
              lookfrom=c(5,5,10),lookat=c(0,0,-1.5))
}
```

---

csg_group *CSG Group*

Description

CSG Group

Usage

```
csg_group(object_list)
```

Arguments

object_list	List of objects created with the csg_* functions. This will make all further operations be applied to this object as a group.

Value

List describing the group in the scene.

Examples

```
if(run_documentation()) {
#Group four spheres together and merge them with a box:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
  csg_group(list(csg_sphere(x=1,z=1, radius=0.5),csg_sphere(x=-1,z=1, radius=0.5),
                 csg_sphere(x=1,z=-1, radius=0.5),csg_sphere(x=-1,z=-1, radius=0.5))),
 csg_box(y=0.5, width=c(2,0.2,2)), operation="blend"), material=glossy(color="red"))) %>%
  add_object(sphere(y=10,x=-5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(5,5,10))
}
```

---

csg_object *Constructive Solid Geometry Object*

Description

This object takes an object constructed using the ‘csg_*‘ functions. The object is drawn using ray marching/sphere tracing.

Usage

```
csg_object(
  object,
  x = 0,
  y = 0,
  z = 0,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`object`	Object created with CSG interface.
`x`	Default ‘0‘. x-offset of the center of the object.
`y`	Default ‘0‘. y-offset of the center of the object.
`z`	Default ‘0‘. z-offset of the center of the object.
`material`	Default `diffuse`. The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".

flipped	Default ‘FALSE‘. Whether to flip the normals.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Details

Note: For dielectric objects, any other objects not included in the CSG object and nested inside will be ignored.

Value

Single row of a tibble describing the sphere in the scene.

Examples

```
if(run_documentation()) {
#We will combine these three objects:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_box(), material=glossy(color="red"))) %>%
  add_object(csg_object(csg_sphere(radius=0.707), material=glossy(color="green"))) %>%
 add_object(csg_object(csg_group(list(csg_cylinder(start=c(-1,0,0), end=c(1,0,0), radius=0.4),
                  csg_cylinder(start=c(0,-1,0), end=c(0,1,0), radius=0.4),
                  csg_cylinder(start=c(0,0,-1), end=c(0,0,1), radius=0.4))),
                  material=glossy(color="blue"))) %>%
  add_object(sphere(y=5,x=3,radius=1,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, fov=15,lookfrom=c(5,5,10),
               samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Standard CSG sphere + box - crossed cylinder combination:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_combine(
      csg_box(),
      csg_sphere(radius=0.707),
      operation="intersection"),
    csg_group(list(csg_cylinder(start=c(-1,0,0), end=c(1,0,0), radius=0.4),
                  csg_cylinder(start=c(0,-1,0), end=c(0,1,0), radius=0.4),
                  csg_cylinder(start=c(0,0,-1), end=c(0,0,1), radius=0.4))),
    operation="subtract"),
    material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=3,radius=1,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, fov=10,lookfrom=c(5,5,10),
               samples=16, sample_method="sobol_blue")
  }
if(run_documentation()) {
#Blend them all instead:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_combine(
      csg_box(),
```

```
      csg_sphere(radius=0.707),
      operation="blend"),
    csg_group(list(csg_cylinder(start=c(-1,0,0), end=c(1,0,0), radius=0.4),
                   csg_cylinder(start=c(0,-1,0), end=c(0,1,0), radius=0.4),
                   csg_cylinder(start=c(0,0,-1), end=c(0,0,1), radius=0.4))),
    operation="blend"),
    material=glossy(color="purple"))) %>%
  add_object(sphere(y=5,x=3,radius=1,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, fov=15,lookfrom=c(5,5,10),
               samples=16, sample_method="sobol_blue")
}
```

---

csg_onion *CSG Onion*

Description

Note: This operation has no overt effect on the external appearance of an object–it carves regions on the interior. Thus, you will only see an effect with a transparent material or when you carve into the object.

Usage

```
csg_onion(object, thickness = 0.1)
```

Arguments

object	CSG object.
thickness	Default ‘0.1‘. Onioning distance.

Value

List describing the triangle in the scene.

Examples

```
if(run_documentation()) {
#Cut and onion a sphere:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_onion(csg_sphere(z=2,x=2,radius=1), thickness = 0.2),
    csg_box(y=1,width=c(10,2,10)), operation = "subtract"),
    material=glossy(color="red"))) %>%
    add_object(csg_object(csg_combine(
      csg_onion(csg_sphere(radius=1), thickness = 0.4),
      csg_box(y=1,width=c(10,2,10)), operation = "subtract"),
      material=glossy(color="purple"))) %>%
    add_object(csg_object(csg_combine(
      csg_onion(csg_sphere(z=-2.5,x=-2.5,radius=1), thickness = 0.6),
```

```
      csg_box(y=1,width=c(10,2,10)), operation = "subtract"),
      material=glossy(color="green"))) %>%
 add_object(sphere(y=5,x=5,radius=2,material=light())) %>%
 render_scene(clamp_value=10, samples=16,lookat=c(0,-0.5,0),
              lookfrom=c(3,5,10),fov=35)
}
if(run_documentation()) {
#Multiple onion layers:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_onion(csg_onion(csg_onion(csg_sphere(radius=1), 0.4), 0.2),0.1),
    csg_box(y=1,width=c(10,2,10)), operation = "subtract"),
    material=glossy(color="purple"))) %>%
  add_object(sphere(y=5,x=5,radius=2,material=light())) %>%
  render_scene(clamp_value=10, samples=16,lookat=c(0,-0.5,0),
               lookfrom=c(3,5,10),fov=20)
  }
if(run_documentation()) {
#Onion with dielectric sphere to make a bubble:
generate_cornell() %>%
  add_object(csg_object(
    csg_onion(csg_sphere(x=555/2,y=555/2,z=555/2, radius=150), 5),
    material=dielectric(attenuation=c(1,1,0.3)/100))) %>%
  render_scene(clamp_value=10, samples=16)
  }
if(run_documentation()) {
#Multiple onion operations to make a bubble within a bubble:
generate_cornell() %>%
  add_object(csg_object(
    csg_onion(csg_onion(csg_sphere(x=555/2,y=555/2,z=555/2, radius=150), 10),5),
    material=dielectric(attenuation=c(1,1,0.3)/100))) %>%
  render_scene(clamp_value=10, samples=16)
}
```

---

csg_plane *CSG Plane*

Description

Note: This shape isn't closed, so there may be odd lighting issues if it's oriented the wrong way.

Usage

```
csg_plane(x = 0, y = 0, z = 0, normal = c(0, 1, 0), width_x = 4, width_z = 4)
```

Arguments

x	Default '0'. An x-coordinate on the plane.
y	Default '0'. A y-coordinate on the plane.

z	Default '0'. A z-coordinate on the plane.
normal	Default 'c(0,1,0)'. Surface normal of the plane.
width_x	Default '10'.
width_z	Default '10'.

Value

List describing the plane in the scene.

Examples

```
if(run_documentation()) {
#Generate a plane
csg_object(csg_plane(width_x=4, width_z=4), material=diffuse(checkercolor="purple")) %>%
  add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
  render_scene(clamp_value=10, samples=16)
 }
if(run_documentation()) {
#Combine the plane with a sphere
csg_object(csg_combine(
    csg_sphere(radius=0.5),
    csg_plane(width_x=4, width_z=4,y=-0.5),
    operation="blend"),material=diffuse(checkercolor="purple")) %>%
  add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
  render_scene(clamp_value=10, samples=16)
  }
if(run_documentation()) {
#Re-orient the plane using the normal and
csg_object(csg_combine(
    csg_sphere(radius=0.5),
    csg_plane(normal = c(1,1,0),width_x=4, width_z=4,y=-0.5),
    operation="blend"),material=diffuse(checkercolor="purple")) %>%
  add_object(sphere(y=5,x=5,material=light(intensity=40))) %>%
  render_scene(clamp_value=10, samples=16)
}
```

---

csg_pyramid *CSG Pyramid*

Description

Note: This primitive slows down immensely for large values of base and height. Try using csg_scale() with this object for large pyramids instead.

Usage

```
csg_pyramid(x = 0, y = 0, z = 0, height = 1, base = 1)
```

Arguments

x	Default '0'. x-coordinate on the pyramid.
y	Default '0'. y-coordinate on the pyramid.
z	Default '0'. z-coordinate on the pyramid.
height	Default '1'. Pyramid height.
base	Default '1'. Pyramid base width.

Value

List describing the box in the scene.

Examples

```
if(run_documentation()) {
#Generate a simple pyramid:
generate_ground() %>%
  add_object(csg_object(csg_pyramid(y=-0.99),
                        material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=20))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(-3,1,10),
               fov=15, lookat=c(0,-0.5,0))
}
if(run_documentation()) {
#Make a taller pyramid
generate_ground() %>%
  add_object(csg_object(csg_pyramid(y=-0.95, height=1.5),
                        material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=20))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(-3,1,10),
               fov=15, lookat=c(0,-0.5,0))
  }
if(run_documentation()) {
#Make a wider pyramid
generate_ground() %>%
  add_object(csg_object(csg_pyramid(y=-0.95, base=1.5),
                        material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=20))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(-3,1,10),
               fov=15, lookat=c(0,-0.5,0))
}
```

---

csg_rotate *CSG Rotate*

Description

CSG Rotate

Usage

```
csg_rotate(
  object,
  pivot_point = c(0, 0, 0),
  angles = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  up = c(0, 1, 0),
  axis_x = NULL,
  axis_z = NULL
)
```

Arguments

object	CSG object.
pivot_point	Default ‘c(0,0,0)‘. Pivot point for the rotation.
angles	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
up	Default ‘c(0,1,0). Alternative method for specifying rotation–change the new "up" vector.
axis_x	Default ‘NULL‘, computed automatically if not passed. Given the ‘up‘ vector as the y-axis, this is the x vector.
axis_z	Default ‘NULL‘, computed automatically if not passed. Given the ‘up‘ vector as the y-axis, this is the z vector.

Value

List describing the triangle in the scene.

Examples

```
if(run_documentation()) {
#Rotate a pyramid (translating it upwards because the object is scaled from the center):
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_pyramid(z=1,y=-0.99),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_rotate(csg_pyramid(z=-1.5,y=-0.99),
                        pivot_point = c(0,-0.99,-1.5),angle=c(0,45,0)),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=40))) %>%
  render_scene(lookfrom=c(-3,4,10), fov=15,
               lookat=c(0,-0.5,0),clamp_value=10)
  }
if(run_documentation()) {
#Rotate by specifying a new up vector:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_pyramid(z=1,y=-0.99),
```

```
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_rotate(csg_pyramid(z=-1.5,y=-0.49),
                        pivot_point = c(0,-0.49,-1.5), up =c(1,1,0)),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=40))) %>%
  render_scene(lookfrom=c(-3,4,10), fov=15,
               lookat=c(0,-0.5,0),clamp_value=10)
}
```

---

csg_round *CSG Round*

Description

CSG Round

Usage

```
csg_round(object, radius = 0.1)
```

Arguments

object	CSG object.
radius	Default '0.1'. Rounding distance.

Value

List describing the triangle in the scene.

Examples

```
if(run_documentation()) {
#Generate a rounded pyramid:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_pyramid(x=-1,y=-0.99,z=1),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_round(csg_pyramid(x=1,y=-0.89)),
                        material=glossy(color="blue"))) %>%
  add_object(csg_object(csg_round(csg_pyramid(x=0,z=-2,y=-0.5), radius=0.5),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,radius=1,material=light(intensity=50))) %>%
  render_scene(lookfrom=c(-3,4,10), fov=22,
               lookat=c(0,-0.5,0),clamp_value=10)
}
if(run_documentation()) {
#Round a blend of two objects
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_round(csg_combine(
    csg_pyramid(x=-0.5,y=-0.99,z=1.5),
```

```
    csg_pyramid(x=0.5,y=-0.99,z=2), operation="blend"), radius=0),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_round(csg_combine(
    csg_pyramid(x=-0.5,y=-0.79,z=-1.5),
    csg_pyramid(x=0.5,y=-0.79,z=-1), operation="blend"), radius=0.2),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,radius=1,material=light(intensity=50))) %>%
  render_scene(lookfrom=c(-3,5,10), fov=22,
               lookat=c(0,-0.5,0),clamp_value=10)
}
```

---

csg_rounded_cone *CSG Rounded Cone*

Description

CSG Rounded Cone

Usage

```
csg_rounded_cone(
  start = c(0, 0, 0),
  end = c(0, 1, 0),
  radius = 0.5,
  upper_radius = 0.2
)
```

Arguments

start	Default ‘c(0, 0, 0)‘. Start point of the cone, specifing ‘x‘, ‘y‘, ‘z‘.
end	Default ‘c(0, 1, 0)‘. End point of the cone, specifing ‘x‘, ‘y‘, ‘z‘.
radius	Default ‘0.5‘. Radius of the bottom of the cone.
upper_radius	Default ‘0.2‘. Radius from the top of the cone.

Value

List describing the box in the scene.

Examples

```
if(run_documentation()) {
#Generate a basic rounded cone:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_rounded_cone(),material=glossy(color="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20)
  }
if(run_documentation()) {
#Change the orientation by specifying a start and end
```

```
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(csg_rounded_cone(start = c(-1,0.5,-2), end = c(1,0.5,-2),
  radius=0.5),material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(3,3,10))
 }
if(run_documentation()) {
#Show the effect of changing the radius
generate_ground(material=diffuse(color="dodgerblue4",checkercolor="grey10")) %>%
  add_object(csg_object(
    csg_combine(
    csg_rounded_cone(start = c(-1,0.5,-2), end = c(1,0.5,-2), radius=0.5),
   csg_rounded_cone(start = c(-0.5,1.5,-2), end = c(0.5,1.5,-2), radius=0.2,upper_radius = 0.5)),
    material=glossy(checkercolor="red"))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,
               lookat=c(0,0.5,-2),lookfrom=c(-3,3,10))
}
if(run_documentation()) {
#Render a glass rounded cone in a Cornell box
generate_cornell() %>%
  add_object(csg_object(
   csg_rounded_cone(start = c(555/2,555/2-100,555/2), end = c(555/2,555/2+100,555/2), radius=100),
    material=dielectric(attenuation=c(1,1,0.3)/100))) %>%
  render_scene(clamp_value=10, samples=16)
}
```

`csg_scale` *CSG Scale*

Description

CSG Scale

Usage

```
csg_scale(object, scale = 1)
```

Arguments

`object`	CSG object.
`scale`	Default ‘1‘.

Value

List describing the triangle in the scene.

Examples

```
if(run_documentation()) {
#Scale a pyramid (translating it upwards because the object is scaled from the center):
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_pyramid(z=1,y=-0.99),
                        material=glossy(color="red"))) %>%
  add_object(csg_object(csg_scale(csg_pyramid(z=-1,y=-0.5),2),
                        material=glossy(color="green"))) %>%
  add_object(sphere(y=5,x=5,z=5,material=light(intensity=40))) %>%
  render_scene(lookfrom=c(-3,4,10), fov=20,
               lookat=c(0,-0.5,-0.5),clamp_value=10)
}
```

---

csg_sphere *CSG Sphere*

Description

CSG Sphere

Usage

```
csg_sphere(x = 0, y = 0, z = 0, radius = 1)
```

Arguments

x	Default ‘0‘. x-coordinate of the center of the sphere.
y	Default ‘0‘. y-coordinate of the center of the sphere.
z	Default ‘0‘. z-coordinate of the center of the sphere.
radius	Default ‘1‘. Radius of the sphere.

Value

List describing the sphere in the scene.

Examples

```
if(run_documentation()) {
#Generate a simple sphere:
generate_ground() %>%
  add_object(csg_object(csg_sphere(),
                        material=glossy(color="purple"))) %>%
  render_scene(clamp_value=10, samples=16)
}
if(run_documentation()) {
#Generate a bigger sphere in the cornell box.
generate_cornell() %>%
  add_object(csg_object(csg_sphere(x=555/2,y=555/2,z=555/2,radius=100),
```

```
                        material=glossy(checkercolor="purple", checkerperiod=100))) %>%
  render_scene(clamp_value=10, samples=16)
}
if(run_documentation()) {
#Combine two spheres of different sizes
generate_cornell() %>%
  add_object(csg_object(
    csg_combine(
      csg_sphere(x=555/2,y=555/2-50,z=555/2,radius=100),
      csg_sphere(x=555/2,y=555/2+50,z=555/2,radius=80)),
    material=glossy(color="purple"))) %>%
  render_scene(clamp_value=10, samples=16)
}
if(run_documentation()) {
#Subtract two spheres to create an indented region
generate_cornell() %>%
  add_object(csg_object(
    csg_combine(
      csg_sphere(x=555/2,y=555/2-50,z=555/2,radius=100),
      csg_sphere(x=555/2+30,y=555/2+20,z=555/2-90,radius=40),
      operation="subtract"),
    material=glossy(color="grey20"))) %>%
  render_scene(clamp_value=10, samples=16)
}
if(run_documentation()) {
#Use csg_combine(operation="blend") to melt the two together
generate_cornell() %>%
  add_object(csg_object(
    csg_combine(
      csg_sphere(x=555/2,y=555/2-50,z=555/2,radius=100),
      csg_sphere(x=555/2,y=555/2+50,z=555/2,radius=80),
      operation="blend", radius=20),
    material=glossy(color="purple"))) %>%
  render_scene(clamp_value=10, samples=16)
}
```

---

csg_torus *CSG Torus*

Description

CSG Torus

Usage

```
csg_torus(x = 0, y = 0, z = 0, radius = 1, minor_radius = 0.5)
```

Arguments

x	Default '0'. x-coordinate on the torus.
y	Default '0'. y-coordinate on the torus.
z	Default '0'. z-coordinate on the torus.
radius	Default '1'. Torus radius.
minor_radius	Default '0.5'. Cross section radius of the torus.

Value

List describing the torus in the scene.

Examples

```
if(run_documentation()) {
#Generate a torus:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_torus(), material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(0,5,10),fov=30)
}
if(run_documentation()) {
#Change the radius of the torus:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_torus(radius=2), material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(0,5,10),fov=30)
}
if(run_documentation()) {
#Change the minor radius of the torus:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_torus(radius=2, minor_radius=0.25),
                        material=glossy(color="dodgerblue4"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(0,5,10),fov=30)
  }
if(run_documentation()) {
#Generate a rotated torus in the Cornell Box
generate_cornell() %>%
  add_object(csg_object(csg_rotate(
    csg_torus(x=555/2,y=555/2,z=555/2,radius=100, minor_radius=50),
    pivot_point = c(555/2,555/2,555/2), up =c(0,1,-1)),
                        material=glossy(color="dodgerblue4"))) %>%
  render_scene(clamp_value=10, samples=16)
}
```

csg_translate *CSG Translate*

Description

CSG Translate

Usage

```
csg_translate(object, x = 0, y = 0, z = 0)
```

Arguments

object	CSG object.
x	Default ‘0‘. x translation.
y	Default ‘0‘. y translation.
z	Default ‘0‘. z translation.

Value

List describing the triangle in the scene.

Examples

```
if(run_documentation()) {
#Translate a simple object:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_torus(), material=glossy(color="dodgerblue4"))) %>%
  add_object(csg_object(csg_translate(csg_torus(),x=-2,y=1,z=-2),
                        material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(0,5,10),fov=30,
               lookat=c(-1,0.5,-1))
}
if(run_documentation()) {
#Translate a blended object:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_combine(
    csg_torus(),
   csg_torus(y=1, radius=0.8), operation="blend"), material=glossy(color="dodgerblue4"))) %>%
  add_object(csg_object(csg_translate(
    csg_combine(
      csg_torus(),
      csg_torus(y=1, radius=0.8), operation="blend"),
    x=-3,y=1,z=-3),
    material=glossy(color="red"))) %>%
  add_object(sphere(y=5,x=5,radius=3,material=light(intensity=10))) %>%
  render_scene(clamp_value=10, samples=16,lookfrom=c(0,5,10),fov=30,
```

```
                lookat=c(-1.5,0.5,-1.5))
}
```

`csg_triangle` *CSG Triangle*

Description

CSG Triangle

Usage

```
csg_triangle(v1 = c(0, 1, 0), v2 = c(1, 0, 0), v3 = c(-1, 0, 0))
```

Arguments

v1	Default ‘c(0,1,0)‘. First vertex.
v2	Default ‘c(1,0,0)‘. Second vertex.
v3	Default ‘c(-1,0,0)‘. Third vertex.

Value

List describing the triangle in the scene.

Examples

```
if(run_documentation()) {
#Generate a basic triangle:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
  add_object(csg_object(csg_triangle(),material=diffuse(color="red"))) %>%
  add_object(sphere(y=5,z=3,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, samples=16,fov=20)
  }
if(run_documentation()) {
#Change a vertex:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_triangle(v1 = c(1,1,0)),material=diffuse(color="green"))) %>%
  add_object(sphere(y=5,z=3,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, samples=16,fov=20)
  }
if(run_documentation()) {
#Change all three vertices:
generate_ground(material=diffuse(checkercolor="grey20")) %>%
 add_object(csg_object(csg_triangle(v1 = c(0.5,1,0), v2 = c(1,-0.5,0), v3 = c(-1,0.5,0)),
                       material=diffuse(color="blue"))) %>%
  add_object(sphere(y=5,z=3,material=light(intensity=30))) %>%
  render_scene(clamp_value=10, samples=16,fov=20,lookfrom=c(0,5,10))
}
```

cube — *Cube Object*

Description

Cube Object

Usage

```
cube(
  x = 0,
  y = 0,
  z = 0,
  width = 1,
  xwidth = 1,
  ywidth = 1,
  zwidth = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`x`	Default '0'. x-coordinate of the center of the cube
`y`	Default '0'. y-coordinate of the center of the cube
`z`	Default '0'. z-coordinate of the center of the cube
`width`	Default '1'. Cube width.
`xwidth`	Default '1'. x-width of the cube. Overrides 'width' argument for x-axis.
`ywidth`	Default '1'. y-width of the cube. Overrides 'width' argument for y-axis.
`zwidth`	Default '1'. z-width of the cube. Overrides 'width' argument for z-axis.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default 'c(0, 0, 0)'. Angle of rotation around the x, y, and z axes, applied in the order specified in 'order_rotation'.
`order_rotation`	Default 'c(1, 2, 3)'. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default 'FALSE'. Whether to flip the normals.
`scale`	Default 'c(1, 1, 1)'. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cube in the scene.

Examples

```
#Generate a cube in the cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(cube(x = 555/2, y = 100, z = 555/2,
                  xwidth = 200, ywidth = 200, zwidth = 200, angle = c(0, 30, 0))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
#Generate a gold cube in the cornell box
if(run_documentation()) {
generate_cornell() %>%
  add_object(cube(x = 555/2, y = 100, z = 555/2,
                  xwidth = 200, ywidth = 200, zwidth = 200, angle = c(0, 30, 0),
                  material = metal(color = "gold", fuzz = 0.2))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}

#Generate a rotated dielectric box in the cornell box
if(run_documentation()) {
generate_cornell() %>%
  add_object(cube(x = 555/2, y = 200, z = 555/2,
                  xwidth = 200, ywidth = 100, zwidth = 200, angle = c(-30, 30, -30),
                  material = dielectric())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

---

cylinder *Cylinder Object*

Description

Cylinder Object

Usage

```
cylinder(
  x = 0,
  y = 0,
  z = 0,
  radius = 1,
  length = 1,
  phi_min = 0,
```

```
    phi_max = 360,
    material = diffuse(),
    angle = c(0, 0, 0),
    order_rotation = c(1, 2, 3),
    flipped = FALSE,
    scale = c(1, 1, 1),
    capped = TRUE
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the cylinder
`y`	Default ‘0‘. y-coordinate of the center of the cylinder
`z`	Default ‘0‘. z-coordinate of the center of the cylinder
`radius`	Default ‘1‘. Radius of the cylinder.
`length`	Default ‘1‘. Length of the cylinder.
`phi_min`	Default ‘0‘. Minimum angle around the segment.
`phi_max`	Default ‘360‘. Maximum angle around the segment.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly.
`capped`	Default ‘TRUE‘. Whether to add caps to the segment. Turned off when using the ‘light()‘ material. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cylinder in the scene.

Examples

```
#Generate a cylinder in the cornell box. Add a cap to both ends.

if(run_documentation()) {
generate_cornell() %>%
  add_object(cylinder(x = 555/2, y = 250, z = 555/2,
                      length = 300, radius = 100, material = metal())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

```
#Rotate the cylinder
if(run_documentation()) {
generate_cornell() %>%
  add_object(cylinder(x = 555/2, y = 250, z = 555/2,
                      length = 300, radius = 100, angle = c(0, 0, 45),
                      material = diffuse())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}

# Only render a subtended arc of the cylinder, flipping the normals.
if(run_documentation()) {
generate_cornell(lightintensity=3) %>%
  add_object(cylinder(x = 555/2, y = 250, z = 555/2, capped = FALSE,
                length = 300, radius = 100, angle = c(45, 0, 0), phi_min = 0, phi_max = 180,
                      material = diffuse(), flipped = TRUE)) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

`dielectric` *Dielectric (glass) Material*

Description

Dielectric (glass) Material

Usage

```
dielectric(
  color = "white",
  refraction = 1.5,
  attenuation = c(0, 0, 0),
  attenuation_intensity = 1,
  priority = 0,
  importance_sample = FALSE,
  bump_texture = "",
  bump_intensity = 1
)
```

Arguments

`color`	Default 'white'. The color of the surface. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between '0' and '1'.
`refraction`	Default '1.5'. The index of refraction.
`attenuation`	Default 'c(0,0,0)'. The Beer-Lambert color-channel specific exponential attenuation through the material. Higher numbers will result in less of that color making it through the material. If a character string is provided (either as a

named R color or a hex string), this will be converted to a length-3 vector equal to one minus the RGB color vector, which should approximate the color being passed. Note: This assumes the object has a closed surface.

`attenuation_intensity`
: Default '1'. Changes the attenuation by a multiplicative factor. Values lower than one will make the dielectric more transparent, while values greater than one will make the glass more opaque.

`priority`
: Default '0'. When two dielectric materials overlap, the one with the lower priority value is used for intersection. NOTE: If the camera is placed inside a dielectric object, its priority value will not be taken into account when determining hits to other objects also inside the object.

`importance_sample`
: Default 'FALSE'. If 'TRUE', the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

`bump_texture`
: Default '""'. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.

`bump_intensity`
: Default '1'. Intensity of the bump map. High values may lead to unphysical results.

Value

Single row of a tibble describing the dielectric material.

Examples

```
#Generate a checkered ground
scene = generate_ground(depth=-0.5, material = diffuse(checkercolor="grey30",checkerperiod=2))
if(run_documentation()) {
render_scene(scene,parallel=TRUE, samples=16)
}

#Add a glass sphere
if(run_documentation()) {
scene %>%
  add_object(sphere(x=-0.5,radius=0.5,material=dielectric())) %>%
  render_scene(parallel=TRUE,samples=16)
}

#Add a rotated colored glass cube
if(run_documentation()) {
scene %>%
  add_object(sphere(x=-0.5,radius=0.5,material=dielectric())) %>%
 add_object(cube(x=0.5,xwidth=0.5,material=dielectric(color="darkgreen"),angle=c(0,-45,0))) %>%
  render_scene(parallel=TRUE,samples=16)
}
```

```
#Add an area light behind and at an angle and turn off the ambient lighting
if(run_documentation()) {
scene %>%
  add_object(sphere(x=-0.5,radius=0.5,material=dielectric())) %>%
 add_object(cube(x=0.5,xwidth=0.5,material=dielectric(color="darkgreen"),angle=c(0,-45,0))) %>%
  add_object(yz_rect(z=-3,y=1,x=0,zwidth=3,ywidth=1.5,
                     material=light(intensity=15),
                     angle=c(0,-90,45), order_rotation = c(3,2,1))) %>%
  render_scene(parallel=TRUE,aperture=0, ambient_light=FALSE,samples=16)
}

#Color glass using Beer-Lambert attenuation, which attenuates light on a per-channel
#basis as it travels through the material. This effect is what gives some types of glass
#a green glow at the edges. We will get this effect by setting a lower attenuation value
#for the `green` (second) channel in the dielectric `attenuation` argument.
if(run_documentation()) {
generate_ground(depth=-0.5,material=diffuse(checkercolor="grey30",checkerperiod=2)) %>%
  add_object(sphere(z=-5,x=-0.5,y=1,material=light(intensity=10))) %>%
  add_object(cube(y=0.3,ywidth=0.1,xwidth=2,zwidth=2,
                 material=dielectric(attenuation=c(1.2,0.2,1.2)),angle=c(45,110,0))) %>%
  render_scene(parallel=TRUE, samples = 16)
}

#If you have overlapping dielectrics, the `priority` value can help disambiguate what
#object wins. Here, I place a bubble inside a cube by setting a lower priority value and
#making the inner sphere have a index of refraction of 1. I also place spheres at the corners.
if(run_documentation()) {
generate_ground(depth=-0.51,material=diffuse(checkercolor="grey30",checkerperiod=2)) %>%
  add_object(cube(material = dielectric(priority=2, attenuation = c(10,3,10)))) %>%
  add_object(sphere(radius=0.49,material = dielectric(priority=1, refraction=1))) %>%
  add_object(sphere(radius=0.25,x=0.5,z=-0.5,y=0.5,
                    material = dielectric(priority=0,attenuation = c(10,3,10) ))) %>%
  add_object(sphere(radius=0.25,x=-0.5,z=0.5,y=0.5,
                    material = dielectric(priority=0,attenuation = c(10,3,10)))) %>%
  render_scene(parallel=TRUE, samples = 16,lookfrom=c(5,1,5))
}

# We can also use this as a basic Constructive Solid Geometry interface by setting
# the index of refraction equal to empty space, 1. This will subtract out those regions.
# Here I make a concave lens by subtracting two spheres from a cube.
if(run_documentation()) {
generate_ground(depth=-0.51,material=diffuse(checkercolor="grey30",checkerperiod=2,sigma=90)) %>%
  add_object(cube(material = dielectric(attenuation = c(3,3,1),priority=1))) %>%
  add_object(sphere(radius=1,x=1.01,
                    material = dielectric(priority=0,refraction=1))) %>%
  add_object(sphere(radius=1,x=-1.01,
                    material = dielectric(priority=0,refraction=1))) %>%
  add_object(sphere(y=10,x=3,material=light(intensit=150))) %>%
  render_scene(parallel=TRUE, samples = 16,lookfrom=c(5,3,5))
}
```

`diffuse` *Diffuse Material*

Description

Diffuse Material

Usage

```
diffuse(
  color = "#ffffff",
  checkercolor = NA,
  checkerperiod = 3,
  noise = 0,
  noisephase = 0,
  noiseintensity = 10,
  noisecolor = "#000000",
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA,
  gradient_point_end = NA,
  gradient_type = "hsv",
  image_texture = "",
  image_repeat = 1,
  alpha_texture = "",
  bump_texture = "",
  bump_intensity = 1,
  fog = FALSE,
  fogdensity = 0.01,
  sigma = NULL,
  importance_sample = FALSE
)
```

Arguments

`color`	Default ‘white‘. The color of the surface. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`checkercolor`	Default ‘NA‘. If not ‘NA‘, determines the secondary color of the checkered surface. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`checkerperiod`	Default ‘3‘. The period of the checker pattern. Increasing this value makes the checker pattern bigger, and decreasing it makes it smaller
`noise`	Default ‘0‘. If not ‘0‘, covers the surface in a turbulent marble pattern. This value will determine the amount of turbulence in the texture.
`noisephase`	Default ‘0‘. The phase of the noise. The noise will repeat at ‘360‘.

noiseintensity Default '10'. Intensity of the noise.

noisecolor Default '#000000'. The secondary color of the noise pattern. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

gradient_color Default 'NA'. If not 'NA', creates a secondary color for a linear gradient between the this color and color specified in 'color'. Direction is determined by 'gradient_transpose'.

gradient_transpose
Default 'FALSE'. If 'TRUE', this will use the 'v' coordinate texture instead of the 'u' coordinate texture to map the gradient.

gradient_point_start
Default 'NA'. If not 'NA', this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value 'color'.

gradient_point_end
Default 'NA'. If not 'NA', this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value 'gradient_color'.

gradient_type Default 'hsv'. Colorspace to calculate the gradient. Alternative 'rgb'.

image_texture Default '""'. A 3-layer RGB array or filename to be used as the texture on the surface of the object.

image_repeat Default '1'. Number of times to repeat the image across the surface. 'u' and 'v' repeat amount can be set independently if user passes in a length-2 vector.

alpha_texture Default '""'. A matrix or filename (specifying a greyscale image) to be used to specify the transparency.

bump_texture Default '""'. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.

bump_intensity Default '1'. Intensity of the bump map. High values may lead to unphysical results.

fog Default 'FALSE'. If 'TRUE', the object will be a volumetric scatterer.

fogdensity Default '0.01'. The density of the fog. Higher values will produce more opaque objects.

sigma Default 'NULL'. A number between 0 and Infinity specifying the roughness of the surface using the Oren-Nayar microfacet model. Higher numbers indicate a roughed surface, where sigma is the standard deviation of the microfacet orientation angle. When 0, this reverts to the default lambertian behavior.

importance_sample
Default 'FALSE'. If 'TRUE', the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

Value

Single row of a tibble describing the diffuse material.

Examples

```
#Generate the cornell box and add a single white sphere to the center
scene = generate_cornell() %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,material=diffuse()))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}

#Add a checkered rectangular cube below
scene = scene %>%
  add_object(cube(x=555/2,y=555/8,z=555/2,xwidth=555/2,ywidth=555/4,zwidth=555/2,
  material = diffuse(checkercolor="purple",checkerperiod=20)))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}

#Add a marbled sphere
scene = scene %>%
  add_object(sphere(x=555/2+555/4,y=555/2,z=555/2,radius=555/8,
  material = diffuse(noise=1/20)))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}

#Add an orange volumetric (fog) cube
scene = scene %>%
  add_object(cube(x=555/2-555/4,y=555/2,z=555/2,xwidth=555/4,ywidth=555/4,zwidth=555/4,
  material = diffuse(fog=TRUE, fogdensity=0.05,color="orange")))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}

#' #Add an line segment with a color gradient
scene = scene %>%
  add_object(segment(start = c(555,450,450),end=c(0,450,450),radius = 50,
                     material = diffuse(color="#1f7326", gradient_color = "#a60d0d")))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}
```

disk *Disk Object*

Description

Disk Object

Usage

```
disk(
  x = 0,
  y = 0,
  z = 0,
  radius = 1,
  inner_radius = 0,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`x`	Default ‘0‘. x-coordinate of the center of the disk
`y`	Default ‘0‘. y-coordinate of the center of the disk
`z`	Default ‘0‘. z-coordinate of the center of the disk
`radius`	Default ‘1‘. Radius of the disk.
`inner_radius`	Default ‘0‘. Inner radius of the disk.
`material`	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`angle`	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`flipped`	Default ‘FALSE‘. Whether to flip the normals.
`scale`	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the disk in the scene.

Examples

```
#Generate a disk in the cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(disk(x = 555/2, y = 50, z = 555/2, radius = 150,
                  material = diffuse(color = "orange"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
#Rotate the disk.
if(run_documentation()) {
generate_cornell() %>%
  add_object(disk(x = 555/2, y = 555/2, z = 555/2, radius = 150, angle = c(-45, 0, 0),
                  material = diffuse(color = "orange"))) %>%
  render_scene(lookfrom = c(278, 278, -800) , lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
#Pass a value for the inner radius.
if(run_documentation()) {
generate_cornell() %>%
  add_object(disk(x = 555/2, y = 555/2, z = 555/2,
                  radius = 150, inner_radius = 75, angle = c(-45, 0, 0),
                  material = diffuse(color = "orange"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

`ellipsoid` *Ellipsoid Object*

Description

Note: this is just a scaled sphere.

Usage

```
ellipsoid(
  x = 0,
  y = 0,
  z = 0,
  a = 1,
  b = 1,
  c = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

x	Default ‘0‘. x-coordinate of the center of the ellipsoid.
y	Default ‘0‘. y-coordinate of the center of the ellipsoid.
z	Default ‘0‘. z-coordinate of the center of the ellipsoid.
a	Default ‘1‘. Principal x-axis of the ellipsoid.
b	Default ‘1‘. Principal y-axis of the ellipsoid.
c	Default ‘1‘. Principal z-axis of the ellipsoid.
material	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default ‘FALSE‘. Whether to flip the normals.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the ellipsoid in the scene.

Examples

```
#Generate an ellipsoid in a Cornell box
if(run_documentation()) {
generate_cornell() %>%
  add_object(ellipsoid(x = 555/2, y = 555/2, z = 555/2,
                       a = 100, b = 50, c = 50)) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}

#Change the axes to make it taller rather than wide:
if(run_documentation()) {
generate_cornell() %>%
  add_object(ellipsoid(x = 555/2, y = 555/2, z = 555/2,
                       a = 100, b = 200, c = 100, material = metal())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}

#Rotate it and make it dielectric:
if(run_documentation()) {
generate_cornell() %>%
  add_object(ellipsoid(x = 555/2, y = 555/2, z = 555/2,
                       a = 100, b = 200, c = 100, angle = c(0, 0, 45),
```

```
                     material = dielectric())) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

---

extruded_path *Extruded Path Object*

Description

Note: Bump mapping with non-diffuse materials does not work correctly, and smoothed normals will be flat when using a bump map.

Usage

```
extruded_path(
  points,
  x = 0,
  y = 0,
  z = 0,
  polygon = NA,
  polygon_end = NA,
  breaks = NA,
  closed = FALSE,
  closed_smooth = TRUE,
  polygon_add_points = 0,
  twists = 0,
  texture_repeats = 1,
  straight = FALSE,
  precomputed_control_points = FALSE,
  width = 1,
  width_end = NA,
  width_ease = "spline",
  smooth_normals = FALSE,
  u_min = 0,
  u_max = 1,
  linear_step = FALSE,
  end_caps = c(TRUE, TRUE),
  material = diffuse(),
  material_caps = NA,
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

points	Either a list of length-3 numeric vectors or 3-column matrix/data.frame specifying the x/y/z points that the path should go through.
x	Default '0'. x-coordinate offset for the path.
y	Default '0'. y-coordinate offset for the path.
z	Default '0'. z-coordinate offset for the path.
polygon	Defaults to a circle. A polygon with no holes, specified by a data.frame() parsable by 'xy.coords()'. Vertices are taken as sequential rows. If the polygon isn't closed (the last vertex equal to the first), it will be closed automatically.
polygon_end	Defaults to 'polygon'. If specified, the number of vertices should equal the to the number of vertices of the polygon set in 'polygon'. Vertices are taken as sequential rows. If the polygon isn't closed (the last vertex equal to the first), it will be closed automatically.
breaks	Defaults to '20' times the number of control points in the bezier curve.
closed	Default 'FALSE'. If 'TRUE', the path will be closed by smoothly connecting the first and last points, also ensuring the final polygon is aligned to the first.
closed_smooth	Default 'TRUE'. If 'closed = TRUE', this will ensure C2 (second derivative) continuity between the ends. If 'closed = FALSE', the curve will only have C1 (first derivative) continuity between the ends.
polygon_add_points	Default '0'. Positive integer specifying the number of points to fill in between polygon vertices. Higher numbers can give smoother results (especially when combined with 'smooth_normals = TRUE'.
twists	Default '0'. Number of twists in the polygon from one end to another.
texture_repeats	Default '1'. Number of times to repeat the texture along the length of the path.
straight	Default 'FALSE'. If 'TRUE', straight lines will be used to connect the points instead of bezier curves.
precomputed_control_points	Default 'FALSE'. If 'TRUE', 'points' argument will expect a list of control points calculated with the internal rayrender function 'rayrender:::calculate_control_points()'.
width	Default '0.1'. Curve width. If 'width_ease == "spline"', 'width' is specified in a format that can be read by 'xy.coords()' (with 'y' as the width), and the 'x' coordinate is between '0' and '1', this can also specify the exact positions along the curve for the corresponding width values. If a numeric vector, specifies the different values of the width evenly along the curve. If not a single value, 'width_end' will be ignored.
width_end	Default 'NA'. Width at end of path. Same as 'width', unless specified. Ignored if multiple width values specified in 'width'.
width_ease	Default 'spline'. Ease function between width values. Other options: 'linear', 'quad', 'cubic', 'exp'.
smooth_normals	Default 'FALSE'. Whether to smooth the normals of the polygon to remove sharp angles.

u_min	Default ‘0‘. Minimum parametric coordinate for the path. If ‘closed = TRUE‘, values greater than one will refer to the beginning of the loop (but the path will be generated as two objects).
u_max	Default ‘1‘. Maximum parametric coordinate for the path. If ‘closed = TRUE‘, values greater than one will refer to the beginning of the loop (but the path will be generated as two objects).
linear_step	Default ‘FALSE‘. Whether the polygon intervals should be set at linear intervals, rather than intervals based on the underlying bezier curve parameterization.
end_caps	Default ‘c(TRUE, TRUE)‘. Specifies whether to add an end cap to the beginning and end of a path.
material	Default diffuse. The material, called from one of the material functions.
material_caps	Defaults to the same material set in ‘material‘. Note: emissive objects may not currently function correctly when scaled.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default ‘FALSE‘. Whether to flip the normals.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly.

Value

Single row of a tibble describing the cube in the scene.

Examples

```
if(run_documentation()) {
#Specify the points for the path to travel though and the ground material
points = list(c(0,0,1),c(-0.5,0,-1),c(0,1,-1),c(1,0.5,0),c(0.6,0.3,1))
ground_mat = material=diffuse(color="grey50",
                              checkercolor = "grey20",checkerperiod = 1.5)
}
if(run_documentation()) {
#Default path shape is a circle
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points, width=0.25,
                           material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,0.5),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Change the width evenly along the tube
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points, width=0.25,
                           width_end = 0.5,
                           material=diffuse(color="red"))) %>%
```

```
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,0.5),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Change the width along the full length of the tube
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points,
                           width=0.25*sinpi(0:72*20/180),
                           material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,0.5),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Specify the exact parametric x positions for the width values:
custom_width = data.frame(x=c(0,0.2,0.5,0.8,1), y=c(0.25,0.5,0,0.5,0.25))
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points,
                           width=custom_width,
                           material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,0.5),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Generate a star polygon
angles = seq(360,0,length.out=21)
xx = c(rep(c(1,0.75,0.5,0.75),5),1) * sinpi(angles/180)/4
yy = c(rep(c(1,0.75,0.5,0.75),5),1) * cospi(angles/180)/4
star_polygon = data.frame(x=xx,y=yy)

#Extrude a path using a star polygon
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points, width=0.5,
                           polygon = star_polygon,
                           material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,1),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Specify a circle polygon
angles = seq(360,0,length.out=21)
xx = sinpi(angles/180)/4
yy = cospi(angles/180)/4
circ_polygon = data.frame(x=xx,y=yy)

#Transform from the circle polygon to the star polygon and change the end cap material
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points, width=0.5,
                           polygon=circ_polygon, polygon_end = star_polygon,
                           material_cap  = diffuse(color="white"),
```

```
                           material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,0.5),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Add three and a half twists along the path, and make sure the breaks are evenly spaced
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points, width=0.5, twists = 3.5,
                           polygon=star_polygon, linear_step = TRUE, breaks=360,
                           material_cap  = diffuse(color="white"),
                           material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,0),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Smooth the normals for a less sharp appearance:
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points, width=0.5, twists = 3.5,
                           polygon=star_polygon,
                           linear_step = TRUE, breaks=360,
                           smooth_normals = TRUE,
                           material_cap  = diffuse(color="white"),
                           material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,0),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Only generate part of the curve, specified by the u_min and u_max arguments
generate_studio(depth=-0.4,material=ground_mat) %>%
  add_object(extruded_path(points = points, width=0.5, twists = 3.5,
                           u_min = 0.2, u_max = 0.8,
                           polygon=star_polygon, linear_step = TRUE, breaks=360,
                           material_cap  = diffuse(color="white"),
                           material=diffuse(color="red"))) %>%
  add_object(sphere(y=3,z=5,x=2,material=light(intensity=15))) %>%
  render_scene(lookat=c(0.3,0.5,0),fov=12, width=800,height=800, clamp_value = 10,
               aperture=0.025, samples=16, sample_method="sobol_blue")
}
if(run_documentation()) {
#Render a Mobius strip with 1.5 turns
points = list(c(0,0,0),c(0.5,0.5,0),c(0,1,0),c(-0.5,0.5,0))
square_polygon = matrix(c(-1, -0.1, 0,
                           1, -0.1, 0,
                           1,  0.1, 0,
                          -1,  0.1, 0)/10, ncol=3,byrow = T)

generate_studio(depth=-0.2,
               material=diffuse(color = "dodgerblue4", checkercolor = "#002a61",
                                checkerperiod = 1)) %>%
 add_object(extruded_path(points = points,  polygon=square_polygon, closed = TRUE,
```

```
                          linear_step = TRUE, twists = 1.5, breaks = 720,
                          material = diffuse(noisecolor = "black", noise = 10,
                                             noiseintensity = 10))) %>%
 add_object(sphere(y=20,x=0,z=21,material=light(intensity = 1000))) %>%
 render_scene(lookat=c(0,0.5,0), fov=10, samples=16, sample_method = "sobol_blue",
             width = 800, height=800)
}
if(run_documentation()) {
#Create a green glass tube with the dielectric priority interface
#and fill it with a purple neon tube light
generate_ground(depth=-0.4,material=diffuse(color="grey50",
                                          checkercolor = "grey20",checkerperiod = 1.5)) %>%
  add_object(extruded_path(points = points, width=0.7, linear_step = TRUE,
                           polygon = star_polygon, twists = 2, closed = TRUE,
                           polygon_end = star_polygon, breaks=500,
                           material=dielectric(priority = 1, refraction = 1.2,
                                               attenuation=c(1,0.3,1),
                                               attenuation_intensity=20))) %>%
  add_object(extruded_path(points = points, width=0.4, linear_step = TRUE,
                           polygon = star_polygon,twists = 2, closed = TRUE,
                           polygon_end = star_polygon, breaks=500,
                           material=dielectric(priority = 0,refraction = 1))) %>%
  add_object(extruded_path(points = points, width=0.05, closed = TRUE,
                           material=light(color="purple", intensity = 5,
                                          importance_sample = FALSE))) %>%
 add_object(sphere(y=10,z=-5,x=0,radius=5,material=light(color = "white",intensity = 5))) %>%
  render_scene(lookat=c(0,0.5,1),fov=10,
              width=800,height=800, clamp_value = 10,
              aperture=0.025, samples=16, sample_method="sobol_blue")
}
```

---

extruded_polygon *Extruded Polygon Object*

Description

Extruded Polygon Object

Usage

```
extruded_polygon(
  polygon = NULL,
  x = 0,
  y = 0,
  z = 0,
  plane = "xz",
  top = 1,
  bottom = 0,
  holes = NULL,
```

```
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  material = diffuse(),
  center = FALSE,
  flip_horizontal = FALSE,
  flip_vertical = FALSE,
  data_column_top = NULL,
  data_column_bottom = NULL,
  scale_data = 1,
  scale = c(1, 1, 1)
)
```

Arguments

- `polygon` ‘sf‘ object, "SpatialPolygon" ‘sp‘ object, or xy coordinates of polygon represented in a way that can be processed by ‘xy.coords()‘. If xy-coordinate based polygons are open, they will be closed by adding an edge from the last point to the first. If the ‘sf‘ object contains MULTIPOLYGONZ data, it will flattened.
- `x` Default ‘0‘. x-coordinate to offset the extruded model.
- `y` Default ‘0‘. y-coordinate to offset the extruded model.
- `z` Default ‘0‘. z-coordinate to offset the extruded model.
- `plane` Default ‘xz‘. The plane the polygon is drawn in. All possibile orientations are ‘xz‘, ‘zx‘, ‘xy‘, ‘yx‘, ‘yz‘, and ‘zy‘.
- `top` Default ‘1‘. Extruded top distance. If this equals ‘bottom‘, the polygon will not be extruded and just the one side will be rendered.
- `bottom` Default ‘0‘. Extruded bottom distance. If this equals ‘top‘, the polygon will not be extruded and just the one side will be rendered.
- `holes` Default ‘0‘. If passing in a polygon directly, this specifies which index represents the holes in the polygon. See the ‘earcut‘ function in the ‘decido‘ package for more information.
- `angle` Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
- `order_rotation` Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
- `material` Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
- `center` Default ‘FALSE‘. Whether to center the polygon at the origin.
- `flip_horizontal` Default ‘FALSE‘. Flip polygon horizontally in the plane defined by ‘plane‘.
- `flip_vertical` Default ‘FALSE‘. Flip polygon vertically in the plane defined by ‘plane‘.
- `data_column_top` Default ‘NULL‘. A string indicating the column in the ‘sf‘ object to use to specify the top of the extruded polygon.

data_column_bottom
: Default ‘NULL‘. A string indicating the column in the ‘sf‘ object to use to specify the bottom of the extruded polygon.

scale_data
: Default ‘1‘. If specifying ‘data_column_top‘ or ‘data_column_bottom‘, how much to scale that value when rendering.

scale
: Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Multiple row tibble describing the extruded polygon in the scene.

Examples

```
#Manually create a polygon object, here a star:

if(run_documentation()) {
angles = seq(0,360,by=36)
xx = rev(c(rep(c(1,0.5),5),1) * sinpi(angles/180))
yy = rev(c(rep(c(1,0.5),5),1) * cospi(angles/180))
star_polygon = data.frame(x=xx,y=yy)
}

if(run_documentation()) {
generate_ground(depth=0,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
  add_object(extruded_polygon(star_polygon,top=0.5,bottom=0,
                              material=diffuse(color="red",sigma=90))) %>%
  add_object(sphere(y=4,x=-3,z=-3,material=light(intensity=30))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,2,3),samples=16,lookat=c(0,0.5,0),fov=60)
}

#Now, let's add a hole to the center of the polygon. We'll make the polygon
#hollow by shrinking it, combining it with the normal size polygon,
#and specify with the `holes` argument that everything after `nrow(star_polygon)`
#in the following should be used to draw a hole:

if(run_documentation()) {
hollow_star = rbind(star_polygon,0.8*star_polygon)
}

if(run_documentation()) {
generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
 add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, holes = nrow(star_polygon) + 1,
                              material=diffuse(color="red",sigma=90))) %>%
  add_object(sphere(y=4,x=-3,z=-3,material=light(intensity=30))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,2,4),samples=16,lookat=c(0,0,0),fov=30)
}

# Render one in the y-x plane as well by changing the `plane` argument,
```

```
# as well as offset it slightly.
if(run_documentation()) {
generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
  add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, holes = nrow(star_polygon),
                              material=diffuse(color="red",sigma=90))) %>%
  add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, y=1.2, z=-1.2,
                              holes = nrow(star_polygon) + 1, plane = "yx",
                              material=diffuse(color="green",sigma=90))) %>%
  add_object(sphere(y=4,x=-3,material=light(intensity=30))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,2,4),samples=16,lookat=c(0,0.9,0),fov=40)
}

# Now add the zy plane:
if(run_documentation()) {
generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
 add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, holes = nrow(star_polygon) + 1,
                              material=diffuse(color="red",sigma=90))) %>%
  add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, y=1.2, z=-1.2,
                              holes = nrow(star_polygon) + 1, plane = "yx",
                              material=diffuse(color="green",sigma=90))) %>%
  add_object(extruded_polygon(hollow_star,top=0.25,bottom=0, y=1.2, x=1.2,
                              holes = nrow(star_polygon) + 1, plane = "zy",
                              material=diffuse(color="blue",sigma=90))) %>%
  add_object(sphere(y=4,x=-3,material=light(intensity=30))) %>%
  render_scene(parallel=TRUE,lookfrom = c(-4,2,4),samples=16,lookat=c(0,0.9,0),fov=40)
}

#We can also directly pass in sf polygons:
if(run_documentation()) {
if(length(find.package("spData",quiet=TRUE)) > 0) {
  us_states = spData::us_states
  texas = us_states[us_states$NAME == "Texas",]
  #Fix no sfc class in us_states geometry data
  class(texas$geometry) = c("list","sfc")
}
}

#This uses the raw coordinates, unless `center = TRUE`, which centers the bounding box
#of the polygon at the origin.
if(run_documentation()) {
generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
  add_object(extruded_polygon(texas, center = TRUE,
                              material=diffuse(color="#ff2222",sigma=90))) %>%
  add_object(sphere(y=30,x=-30,radius=10,
                    material=light(color="lightblue",intensity=40))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,10,-10),samples=16,fov=60)
}

#Here we use the raw coordinates, but offset the polygon manually.
if(run_documentation()) {
```

```
generate_ground(depth=-0.01,
                material = diffuse(color="grey50",checkercolor="grey20")) %>%
  add_object(extruded_polygon(us_states, x=-96,z=-40, top=2,
                              material=diffuse(color="#ff2222",sigma=90))) %>%
  add_object(sphere(y=30,x=-100,radius=10,
                    material=light(color="lightblue",intensity=200))) %>%
  add_object(sphere(y=30,x=100,radius=10,
                    material=light(color="orange",intensity=200))) %>%
  render_scene(parallel=TRUE,lookfrom = c(0,120,-120),samples=16,fov=20)
}

#We can also set the map the height of each polygon to a column in the sf object,
#scaling it down by the maximum population state.

if(run_documentation()) {
generate_ground(depth=0,
                material = diffuse(color="grey50",checkercolor="grey20",sigma=90)) %>%
  add_object(extruded_polygon(us_states, x=-96,z=-45, data_column_top = "total_pop_15",
                              scale_data = 1/max(us_states$total_pop_15)*5,
                              material=diffuse(color="#ff2222",sigma=90))) %>%
  add_object(sphere(y=30,x=-100,z=60,radius=10,
                    material=light(color="lightblue",intensity=250))) %>%
  add_object(sphere(y=30,x=100,z=-60,radius=10,
                    material=light(color="orange",intensity=250))) %>%
 render_scene(parallel=TRUE,lookfrom = c(-60,50,-40),lookat=c(0,-5,0),samples=16,fov=30)
}
```

---

generate_camera_motion *Generate Camera Movement*

Description

Takes a series of key frame camera positions and smoothly interpolates between them. Generates a data.frame that can be passed to ‘render_animation()‘.

Usage

```
generate_camera_motion(
  positions,
  lookats = NULL,
  apertures = 0,
  fovs = 40,
  focal_distances = NULL,
  ortho_dims = NULL,
  camera_ups = NULL,
  type = "cubic",
  frames = 30,
```

```
  closed = FALSE,
  aperture_linear = TRUE,
  fov_linear = TRUE,
  focal_linear = TRUE,
  ortho_linear = TRUE,
  constant_step = TRUE,
  curvature_adjust = "none",
  curvature_scale = 30,
  offset_lookat = 0,
  damp_motion = FALSE,
  damp_magnitude = 0.1,
  progress = TRUE
)
```

Arguments

`positions` A list or 3-column XYZ matrix of camera positions. These will serve as key frames for the camera position. Alternatively, this can also be the a dataframe of the keyframe output from an interactive rayrender session (‘ray_keyframes‘).

`lookats` Default ‘NULL‘, which sets the camera lookat to the origin ‘c(0,0,0)‘ for the animation. A list or 3-column XYZ matrix of ‘lookat‘ points. Must be the same number of points as ‘positions‘.

`apertures` Default ‘0‘. A numeric vector of aperture values.

`fovs` Default ‘40‘. A numeric vector of field of view values.

`focal_distances` Default ‘NULL‘, automatically the distance between positions and lookats. Numeric vector of focal distances.

`ortho_dims` Default ‘NULL‘, which results in ‘c(1,1)‘ orthographic dimensions. A list or 2-column matrix of orthographic dimensions.

`camera_ups` Default ‘NULL‘, which gives at up vector of ‘c(0,1,0)‘. Camera up orientation.

`type` Default ‘cubic‘. Type of transition between keyframes. Other options are ‘linear‘, ‘quad‘, ‘bezier‘, ‘exp‘, and ‘manual‘. ‘manual‘ just returns the values passed in, properly formatted to be passed to ‘render_animation()‘.

`frames` Default ‘30‘. Total number of frames.

`closed` Default ‘FALSE‘. Whether to close the camera curve so the first position matches the last. Set this to ‘TRUE‘ for perfect loops.

`aperture_linear` Default ‘TRUE‘. This linearly interpolates focal distances, rather than using a smooth Bezier curve or easing function.

`fov_linear` Default ‘TRUE‘. This linearly interpolates focal distances, rather than using a smooth Bezier curve or easing function.

`focal_linear` Default ‘TRUE‘. This linearly interpolates focal distances, rather than using a smooth Bezier curve or easing function.

`ortho_linear` Default ‘TRUE‘. This linearly interpolates orthographic dimensions, rather than using a smooth Bezier curve or easing function.

constant_step Default ‘TRUE‘. This will make the camera travel at a constant speed.

curvature_adjust
: Default ‘none‘. Other options are ‘position‘, ‘lookat‘, and ‘both‘. Whether to slow down the camera at areas of high curvature to prevent fast swings. Only used for curve ‘type = bezier‘. This does not preserve key frame positions. Note: This feature will likely result in the ‘lookat‘ and ‘position‘ diverging if they do not have similar curvatures at each point. This feature is best used when passing the same set of points to ‘positions‘ and ‘lookats‘ and providing an ‘offset_lookat‘ value, which ensures the curvature will be the same.

curvature_scale
: Default ‘30‘. Constant dividing factor for curvature. Higher values will subdivide the path more, potentially finding a smoother path, but increasing the calculation time. Only used for curve ‘type = bezier‘. Increasing this value after a certain point will not increase the quality of the path, but it is scene-dependent.

offset_lookat Default ‘0‘. Amount to offset the lookat position, either along the path (if ‘constant_step = TRUE‘) or towards the derivative of the Bezier curve.

damp_motion Default ‘FALSE‘. Whether to damp the motion of the camera, so that quick movements are damped and don’t result in shakey motion. This function tracks the current position, and linearly interpolates between that point and the next point using value ‘damp_magnitude‘. The equation for the position is ‘cam_current = cam_current * damp_magnitude + cam_next_point * (1 - damp_magnitude)‘.

damp_magnitude Default ‘0.1‘. Amount to damp the motion, a numeric value greater than ‘0‘ (no damping) and less than ‘1‘.

progress Default ‘TRUE‘. Whether to display a progress bar.

Value

Data frame of camera positions, orientations, apertures, focal distances, and field of views

Examples

```
#Create and animate flying through a scene on a simulated roller coaster
if(run_documentation()) {
set.seed(3)
elliplist = list()
ellip_colors = rainbow(8)
for(i in 1:1200) {
  elliplist[[i]] = ellipsoid(x=10*runif(1)-5,y=10*runif(1)-5,z=10*runif(1)-5,
                             angle = 360*runif(3), a=0.1,b=0.05,c=0.1,
                             material=glossy(color=sample(ellip_colors,1)))
}
ellip_scene = do.call(rbind, elliplist)

camera_pos = list(c(0,1,15),c(5,-5,5),c(-5,5,-5),c(0,1,-15))

#Plot the camera path and render from above using the path object:
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
```

```
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(0,20,0), width=800,height=800,samples=16,
               camera_up = c(0,0,1),
               fov=80)
}
if(run_documentation()) {
#Side view
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(20,0,0),width=800,height=800,samples=16,
                fov=80)
 }
if(run_documentation()) {
#View from the start
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(0,1.5,16),width=800,height=800,samples=16,
                fov=80)
 }
if(run_documentation()) {
#Generate Camera movement, setting the lookat position to be same as camera position, but offset
#slightly in front. We'll render 12 frames, but you'd likely want more in a real animation.

camera_motion =  generate_camera_motion(positions = camera_pos, lookats = camera_pos,
                                       offset_lookat = 1, fovs=80, frames=12,
                                       type="bezier")

#This returns a data frame of individual camera positions, interpolated by cubic bezier curves.
camera_motion

#Pass NA filename to plot to the device. We'll keep the path and offset it slightly to see
#where we're going. This results in a "roller coaster" effect.
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(obj_model(r_obj(simple_r = TRUE),x=10,y=-10,scale_obj=3, angle=c(0,-45,0),
                       material=dielectric(attenuation=c(1,1,0.3)))) %>%
  add_object(pig(x=-7,y=10,z=-5,scale=1,angle=c(0,-45,80),emotion="angry")) %>%
 add_object(pig(x=0,y=-0.25,z=-15,scale=1,angle=c(0,225,-22), order_rotation = c(3,2,1),
                emotion="angry", spider=TRUE)) %>%
  add_object(path(camera_pos, y=-0.2,material=diffuse(color="red"))) %>%
  render_animation(filename = NA, camera_motion = camera_motion, samples=16,
                   sample_method="sobol_blue",
                   clamp_value=10, width=400, height=400)

}
```

generate_cornell *Generate Cornell Box*

Description

Generate Cornell Box

Usage

```
generate_cornell(
  light = TRUE,
  lightintensity = 5,
  lightcolor = "white",
  lightwidth = 332,
  lightdepth = 343,
  light_position = c(555/2, 554, 555/2),
  sigma = 0,
  leftcolor = "#1f7326",
  rightcolor = "#a60d0d",
  roomcolor = "#bababa",
  importance_sample = TRUE
)
```

Arguments

`light`	Default ‘TRUE‘. Whether to include a light on the ceiling of the box.
`lightintensity`	Default ‘5‘. The intensity of the light.
`lightcolor`	Default ‘white‘. The color the of the light.
`lightwidth`	Default ‘332‘. Width (z) of the light.
`lightdepth`	Default ‘343‘. Depth (x) of the light.
`light_position`	Default ‘c(555/2,554,555/2)‘. Position of the light.
`sigma`	Default ‘0‘. Oren-Nayar microfacet angle.
`leftcolor`	Default ‘#1f7326‘ (green).
`rightcolor`	Default ‘#a60d0d‘ (red).
`roomcolor`	Default ‘#bababa‘ (light grey).
`importance_sample`	Default ‘TRUE‘. Importance sample the light in the room.

Value

Tibble containing the scene description of the Cornell box.

Examples

```
#Generate and render the default Cornell box.
if(run_documentation()) {
render_scene(generate_cornell(),
             samples=16,aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}
if(run_documentation()) {
#Make a much smaller light in the center of the room.
render_scene(generate_cornell(lightwidth=200,lightdepth=200),
             samples=16,aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}
if(run_documentation()) {
#Place a sphere in the middle of the box.
scene = generate_cornell(lightwidth=200,lightdepth=200) %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/4))
render_scene(scene, samples=16,aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}
if(run_documentation()) {
#Reduce "fireflies" by setting a clamp_value in render_scene()
render_scene(scene, samples=16,aperture=0, fov=40, ambient_light=FALSE,
             parallel=TRUE,clamp_value=3)
}
if(run_documentation()) {
# Change the color scheme of the cornell box
generate_cornell(leftcolor="purple", rightcolor="yellow") |>
  render_scene(samples=16,aperture=0, fov=40, ambient_light=FALSE,
               parallel=TRUE,clamp_value=3)
}
```

---

generate_ground *Generate Ground*

Description

Generates a large sphere that can be used as the ground for a scene.

Usage

```
generate_ground(
  depth = -1,
  spheresize = 1000,
  material = diffuse(color = "#ccff00")
)
```

Arguments

depth	Default '-1'. Depth of the surface.
spheresize	Default '1000'. Radius of the sphere representing the surface.

material
: Default diffuse with 'color= "#ccff00"'.The material, called from one of the material functions diffuse, metal, or dielectric.

color
: Default '#ccff00'. The color of the sphere. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

Value

Single row of a tibble describing the ground.

Examples

```
#Generate the ground and add some objects
scene = generate_ground(depth=-0.5,
                        material = diffuse(noise=1,noisecolor="blue",noisephase=10)) %>%
  add_object(cube(x=0.7,material=diffuse(color="red"),angle=c(0,-15,0))) %>%
  add_object(sphere(x=-0.7,radius=0.5,material=dielectric(color="white")))
if(run_documentation()) {
render_scene(scene, parallel=TRUE,lookfrom=c(0,2,10))
}

# Make the sphere representing the ground larger and make it a checkered surface.
scene = generate_ground(depth=-0.5, spheresize=10000,
                        material = diffuse(checkercolor="grey50")) %>%
  add_object(cube(x=0.7,material=diffuse(color="red"),angle=c(0,-15,0))) %>%
  add_object(sphere(x=-0.7,radius=0.5,material=dielectric(color="white")))
if(run_documentation()) {
render_scene(scene, parallel=TRUE,lookfrom=c(0,1,10))
}
```

---

generate_studio *Generate Studio*

Description

Generates a curved studio backdrop.

Usage

```
generate_studio(
  depth = -1,
  distance = -10,
  width = 100,
  height = 100,
  curvature = 8,
  material = diffuse()
)
```

Arguments

depth	Default '-1'. Depth of the ground in the scene.
distance	Default '-10'. Distance to the backdrop in the scene from the origin, on the z-axis.
width	Default '100'. Width of the backdrop.
height	Default '100'. height of the backdrop.
curvature	Default '2'. Radius of the curvature connecting the bottom plane to the vertical backdrop.
material	Default diffuse with 'color= "#ccff00"'.The material, called from one of the material functions diffuse, metal, or dielectric.

Value

Tibble representing the scene.

Examples

```
#Generate the ground and add some objects
scene = generate_studio(depth=-1, material = diffuse(color="white")) %>%
   add_object(obj_model(r_obj(),y=-0.5,x=0.5, scale=1.2,
                        material=glossy(color="darkred"),angle=c(0,-20,0))) %>%
   add_object(sphere(x=-0.5,radius=0.5,material=dielectric())) %>%
   add_object(sphere(y=3,x=-2,z=20,material=light(intensity=600)))
if(run_documentation()) {
render_scene(scene, parallel = TRUE, lookfrom = c(0,2,10), lookat=c(0,-0.25,0),
             fov = 14, clamp_value = 10, samples = 16)
}

#Zooming out to show the full default scene
if(run_documentation()) {
render_scene(scene, parallel=TRUE,lookfrom=c(0,200,400),clamp_value=10,samples=16)
}
```

---

get_saved_keyframes *Get Saved Keyframes*

Description

Get a dataframe of the saved keyframes (using the interactive renderer) to pass to 'generate_camera_motion()'

Usage

```
get_saved_keyframes()
```

Value

Data frame of keyframes

Examples

```
#This will return an empty data frame if no keyframes have been set.
get_saved_keyframes()
```

---

glossy *Glossy Material*

Description

Glossy Material

Usage

```
glossy(
  color = "white",
  gloss = 1,
  reflectance = 0.05,
  microfacet = "tbr",
  checkercolor = NA,
  checkerperiod = 3,
  noise = 0,
  noisephase = 0,
  noiseintensity = 10,
  noisecolor = "#000000",
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA_real_,
  gradient_point_end = NA_real_,
  gradient_type = "hsv",
  image_texture = "",
  image_repeat = 1,
  alpha_texture = "",
  bump_texture = "",
  bump_intensity = 1,
  roughness_texture = "",
  roughness_range = c(1e-04, 0.2),
  roughness_flip = FALSE,
  importance_sample = FALSE
)
```

Arguments

`color`	Default ‘white‘. The color of the surface. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
`gloss`	Default ‘0.8‘. Gloss of the surface, between ‘1‘ (completely glossy) and ‘0‘ (rough glossy). Can be either a single number, or two numbers indicating an anisotropic distribution of normals (as in ‘microfacet()‘).

reflectance
: Default '0.03'. The reflectivity of the surface. '1' is a full mirror, '0' is diffuse with a glossy highlight.

microfacet
: Default 'tbr'. Type of microfacet distribution. Alternative option 'beckmann'.

checkercolor
: Default 'NA'. If not 'NA', determines the secondary color of the checkered surface. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

checkerperiod
: Default '3'. The period of the checker pattern. Increasing this value makes the checker pattern bigger, and decreasing it makes it smaller

noise
: Default '0'. If not '0', covers the surface in a turbulent marble pattern. This value will determine the amount of turbulence in the texture.

noisephase
: Default '0'. The phase of the noise. The noise will repeat at '360'.

noiseintensity
: Default '10'. Intensity of the noise.

noisecolor
: Default '#000000'. The secondary color of the noise pattern. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

gradient_color
: Default 'NA'. If not 'NA', creates a secondary color for a linear gradient between the this color and color specified in 'color'. Direction is determined by 'gradient_transpose'.

gradient_transpose
: Default 'FALSE'. If 'TRUE', this will use the 'v' coordinate texture instead of the 'u' coordinate texture to map the gradient.

gradient_point_start
: Default 'NA'. If not 'NA', this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value 'color'.

gradient_point_end
: Default 'NA'. If not 'NA', this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value 'gradient_color'.

gradient_type
: Default 'hsv'. Colorspace to calculate the gradient. Alternative 'rgb'.

image_texture
: Default '""'. A 3-layer RGB array or filename to be used as the texture on the surface of the object.

image_repeat
: Default '1'. Number of times to repeat the image across the surface. 'u' and 'v' repeat amount can be set independently if user passes in a length-2 vector.

alpha_texture
: Default '""'. A matrix or filename (specifying a greyscale image) to be used to specify the transparency.

bump_texture
: Default '""'. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.

bump_intensity
: Default '1'. Intensity of the bump map. High values may lead to unphysical results.

roughness_texture
: Default '""'. A matrix, array, or filename (specifying a greyscale image) to be used to specify a roughness map for the surface.

roughness_range
: Default ‘ c(0.0001, 0.2)‘. This is a length-2 vector that specifies the range of roughness values that the ‘roughness_texture‘ can take.

roughness_flip
: Default ‘FALSE‘. Setting this to ‘TRUE‘ flips the roughness values specified in the ‘roughness_texture‘ so high values are now low values and vice versa.

importance_sample
: Default ‘FALSE‘. If ‘TRUE‘, the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

Value

Single row of a tibble describing the glossy material.

Examples

```
if(run_documentation()) {
#Generate a glossy sphere
generate_ground(material=diffuse(sigma=90)) %>%
  add_object(sphere(y=0.2,material=glossy(color="#2b6eff"))) %>%
  add_object(sphere(y=2.8,material=light())) %>%
  render_scene(parallel=TRUE,clamp_value=10,samples=16,sample_method="sobol_blue")
 }
if(run_documentation()) {
#Change the color of the underlying diffuse layer
generate_ground(material=diffuse(sigma=90)) %>%
  add_object(sphere(y=0.2,x=-2.1,material=glossy(color="#fc3d03"))) %>%
  add_object(sphere(y=0.2,material=glossy(color="#2b6eff"))) %>%
  add_object(sphere(y=0.2,x=2.1,material=glossy(color="#2fed4f"))) %>%
  add_object(sphere(y=8,z=-5,radius=3,material=light(intensity=20))) %>%
 render_scene(parallel=TRUE,clamp_value=10,samples=16,fov=40,sample_method="sobol_blue")
 }
if(run_documentation()) {
#Change the amount of gloss
generate_ground(material=diffuse(sigma=90)) %>%
  add_object(sphere(y=0.2,x=-2.1,material=glossy(gloss=1,color="#fc3d03"))) %>%
  add_object(sphere(y=0.2,material=glossy(gloss=0.5,color="#2b6eff"))) %>%
  add_object(sphere(y=0.2,x=2.1,material=glossy(gloss=0,color="#2fed4f"))) %>%
  add_object(sphere(y=8,z=-5,radius=3,material=light(intensity=20))) %>%
 render_scene(parallel=TRUE,clamp_value=10,samples=16,fov=40,sample_method="sobol_blue")
 }
if(run_documentation()) {
#Add gloss to a pattern
generate_ground(material=diffuse(sigma=90)) %>%
  add_object(sphere(y=0.2,x=-2.1,material=glossy(noise=2,noisecolor="black"))) %>%
  add_object(sphere(y=0.2,material=glossy(color="#ff365a",checkercolor="#2b6eff"))) %>%
 add_object(sphere(y=0.2,x=2.1,material=glossy(color="blue",gradient_color="#2fed4f"))) %>%
  add_object(sphere(y=8,z=-5,radius=3,material=light(intensity=20))) %>%
 render_scene(parallel=TRUE,clamp_value=10,samples=16,fov=40,sample_method="sobol_blue")
```

```
 }
if(run_documentation()) {
#Add an R and a fill light (this may look familiar)
generate_ground(material=diffuse()) %>%
  add_object(sphere(y=0.2,material=glossy(color="#2b6eff",reflectance=0.05))) %>%
  add_object(obj_model(r_obj(simple_r = TRUE),
                       z=1,y=-0.05,scale=0.45,material=diffuse())) %>%
  add_object(sphere(y=6,z=1,radius=4,material=light(intensity=3))) %>%
  add_object(sphere(z=15,material=light(intensity=50))) %>%
  render_scene(parallel=TRUE,clamp_value=10,samples=16,sample_method="sobol_blue")
}
```

`group_objects` *Group Objects*

Description

Group and transform objects together.

Usage

```
group_objects(
  scene,
  pivot_point = c(0, 0, 0),
  translate = c(0, 0, 0),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  scale = c(1, 1, 1),
  axis_rotation = NA
)
```

Arguments

`scene`	Tibble of pre-existing object locations and properties to group together.
`pivot_point`	Default ‘c(0,0,0)‘. The point about which to pivot, scale, and move the group.
`translate`	Default ‘c(0,0,0)‘. Vector indicating where to offset the group.
`angle`	Default ‘c(0,0,0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
`order_rotation`	Default ‘c(1,2,3)‘. The order to apply the rotations, referring to "x", "y", and "z".
`scale`	Default ‘c(1,1,1)‘. Scaling factor for x, y, and z directions for all objects in group.
`axis_rotation`	Default ‘NA‘. Provide an axis of rotation and a single angle (via ‘angle‘) of rotation around that axis.

Value

Tibble of grouped object locations and properties.

Examples

```
#Generate the ground and add some objects
if(run_documentation()) {
scene = generate_cornell() %>%
        add_object(cube(x=555/2,y=555/8,z=555/2,width=555/4)) %>%
        add_object(cube(x=555/2,y=555/4+555/16,z=555/2,width=555/8))
render_scene(scene,lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=16, fov=50, parallel=TRUE, clamp_value=5)
}
if(run_documentation()) {

#Group the entire room and rotate around its center, but keep the cubes in the same place.
scene2 = group_objects(generate_cornell(),
                       pivot_point=c(555/2,555/2,555/2),
                       angle=c(0,30,0)) %>%
         add_object(cube(x=555/2,y=555/8,z=555/2,width=555/4)) %>%
        add_object(cube(x=555/2,y=555/4+555/16,z=555/2,width=555/8))

render_scene(scene2,lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=16, fov=50, parallel=TRUE, clamp_value=5)
}
if(run_documentation()) {
#Now group the cubes instead of the Cornell box, and rotate/translate them together
twocubes = cube(x=555/2,y=555/8,z=555/2,width=555/4) %>%
           add_object(cube(x=555/2, y=555/4 + 555/16, z=555/2, width=555/8))
scene3 = generate_cornell() %>%
         add_object(group_objects(twocubes, translate = c(0,50,0),angle = c(0,45,0),
         pivot_point = c(555/2,0,555/2)))

render_scene(scene3,lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=16, fov=50, parallel=TRUE, clamp_value=5)
}
if(run_documentation()) {
#Flatten and stretch the cubes together on two axes
scene4 = generate_cornell() %>%
         add_object(group_objects(twocubes, translate = c(0,-40,0),
                                  angle = c(0,45,0), scale = c(2,0.5,1),
                                  pivot_point = c(555/2,0,555/2)))

render_scene(scene4,lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=16, fov=50, parallel=TRUE, clamp_value=5)
}
if(run_documentation()) {
#Add another layer of grouping, including the Cornell box
scene4 %>%
  group_objects(pivot_point = c(555/2,555/2,555/2),scale=c(1.5,0.5,0.3), angle=c(-20,0,20)) %>%
  render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), aperture=0,
             samples=509, fov=50, parallel=TRUE, clamp_value=5)
```

```
}
```

hair *Hair Material*

Description

Hair Material

Usage

```
hair(
  pigment = 1.3,
  red_pigment = 0,
  color = NA,
  sigma_a = NA,
  eta = 1.55,
  beta_m = 0.3,
  beta_n = 0.3,
  alpha = 2
)
```

Arguments

pigment	Default '1.3'. Concentration of the eumelanin pigment in the hair. Blonde hair has concentrations around 0.3, brown around 1.3, and black around 8.
red_pigment	Default '0'.Concentration of the pheomelanin pigment in the hair. Pheomelanin makes red hair red.
color	Default 'NA'. Approximate color. Overrides 'pigment'/'redness' arguments.
sigma_a	Default 'NA'. Attenuation. Overrides 'color' and 'pigment'/'redness' arguments.
eta	Default '1.55'. Index of refraction of the hair medium.
beta_m	Default '0.3'. Longitudinal roughness of the hair. Should be between 0 and 1. This roughness controls the size and shape of the hair highlight.
beta_n	Default '0.3'. Azimuthal roughness of the hair. Should be between 0 and 1.
alpha	Default '2'. Angle of scales on the hair surface, in degrees.

Value

Single row of a tibble describing the hair material.

Examples

```
#Create a hairball
if(run_documentation()) {
#Generate rendom points on a sphere
lengthval = 0.5
theta = acos(2*runif(10000)-1.0);
phi = 2*pi*(runif(10000))
bezier_list = list()

#Grow the hairs
for(i in 1:length(phi)) {
  pointval = c(sin(theta[i]) * sin(phi[i]),
               cos(theta[i]),
               sin(theta[i]) * cos(phi[i]))
  bezier_list[[i]] = bezier_curve(width=0.01, width_end=0.008,
                                  p1 = pointval,
                                  p2 = (1+(lengthval*0.33))*pointval,
                                  p3 = (1+(lengthval*0.66))*pointval,
                                  p4 = (1+(lengthval)) * pointval,
                                  material=hair(pigment = 0.3, red_pigment = 1.3,
                                                beta_m = 0.3, beta_n= 0.3),
                                  type="flat")
}
hairball = dplyr::bind_rows(bezier_list)

generate_ground(depth=-2,material=diffuse(color="grey20")) %>%
  add_object(sphere()) %>%
  add_object(hairball) %>%
 add_object(sphere(y=20,z=20,radius=5,material=light(color="white",intensity = 100))) %>%
  render_scene(samples=16, lookfrom=c(0,3,10),clamp_value = 10,
               fov=20, width=800, height=800)
}
if(run_documentation()) {

#Specify the color directly and increase hair roughness
for(i in 1:length(phi)) {
  pointval = c(sin(theta[i]) * sin(phi[i]),
               cos(theta[i]),
               sin(theta[i]) * cos(phi[i]))
  bezier_list[[i]] = bezier_curve(width=0.01, width_end=0.008,
                                  p1 = pointval,
                                  p2 = (1+(lengthval*0.33))*pointval,
                                  p3 = (1+(lengthval*0.66))*pointval,
                                  p4 = (1+(lengthval)) * pointval,
                                  material=hair(color="purple",
                                                beta_m = 0.5, beta_n= 0.5),
                                  type="flat")
}
hairball = dplyr::bind_rows(bezier_list)
generate_ground(depth=-2,material=diffuse(color="grey20")) %>%
  add_object(sphere()) %>%
  add_object(hairball) %>%
```

```
  add_object(sphere(y=20,z=20,radius=5,material=light(color="white",intensity = 100))) %>%
   render_scene(samples=16, lookfrom=c(0,3,10),clamp_value = 10,
                fov=20, width=800, height=800)
}
```

`lambertian` *Lambertian Material (deprecated)*

Description

Lambertian Material (deprecated)

Usage

```
lambertian(...)
```

Arguments

`...`	Arguments to pass to diffuse() function.

Value

Single row of a tibble describing the diffuse material.

Examples

```
#Deprecated lambertian material. Will display a warning.
if(run_documentation()) {
scene = generate_cornell() %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,material=lambertian()))
  render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}
```

`light` *Light Material*

Description

Light Material

Usage

```
light(
  color = "#ffffff",
  intensity = 10,
  importance_sample = TRUE,
  spotlight_focus = NA,
  spotlight_width = 30,
  spotlight_start_falloff = 15,
  invisible = FALSE,
  image_texture = "",
  image_repeat = 1,
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA,
  gradient_point_end = NA,
  gradient_type = "hsv"
)
```

Arguments

`color` Default ‘white‘. The color of the light Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.

`intensity` Default ‘10‘. If a positive value, this will turn this object into a light emitting the value specified in ‘color‘ (ignoring other properties). Higher values will produce a brighter light.

`importance_sample` Default ‘TRUE‘. Keeping this on for lights improves the convergence of the rendering algorithm, in most cases. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

`spotlight_focus` Default ‘NA‘, no spotlight. Otherwise, a length-3 numeric vector specifying the x/y/z coordinates that the spotlight should be focused on. Only works for spheres and rectangles.

`spotlight_width` Default ‘30‘. Angular width of the spotlight.

`spotlight_start_falloff` Default ‘15‘. Angle at which the light starts fading in intensity.

`invisible` Default ‘FALSE‘. If ‘TRUE‘, the light itself will be invisible.

`image_texture` Default ‘""‘. A 3-layer RGB array or filename to be used as the texture on the surface of the object.

`image_repeat` Default ‘1‘. Number of times to repeat the image across the surface. ‘u‘ and ‘v‘ repeat amount can be set independently if user passes in a length-2 vector.

`gradient_color` Default ‘NA‘. If not ‘NA‘, creates a secondary color for a linear gradient between the this color and color specified in ‘color‘. Direction is determined by ‘gradient_transpose‘.

`gradient_transpose`
: Default ‘FALSE‘. If ‘TRUE‘, this will use the ‘v‘ coordinate texture instead of the ‘u‘ coordinate texture to map the gradient.

`gradient_point_start`
: Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘color‘.

`gradient_point_end`
: Default ‘NA‘. If not ‘NA‘, this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value ‘gradient_color‘.

`gradient_type`
: Default ‘hsv‘. Colorspace to calculate the gradient. Alternative ‘rgb‘.

Value

Single row of a tibble describing the light material.

Examples

```
#Generate the cornell box without a light and add a single white sphere to the center
scene = generate_cornell(light=FALSE) %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,material=light()))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}

#Remove the light for direct camera rays, but keep the lighting
scene = generate_cornell(light=FALSE) %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,
             material=light(intensity=15,invisible=TRUE)))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}

#All gather around the orb
scene = generate_ground(material = diffuse(checkercolor="grey50")) %>%
  add_object(sphere(radius=0.5,material=light(intensity=5,color="red"))) %>%
  add_object(obj_model(r_obj(simple_r = TRUE), z=-3,x=-1.5,y=-1, angle=c(0,45,0))) %>%
  add_object(pig(scale=0.3, x=1.5,z=-2,y=-1.5,angle=c(0,-135,0)))
if(run_documentation()) {
render_scene(scene, samples=16, parallel=TRUE, clamp_value=10)
}
```

mesh3d_model *'mesh3d' model*

Description

Load an 'mesh3d' (or 'shapelist3d') object, as specified in the 'rgl' package.

Usage

```
mesh3d_model(
  mesh,
  x = 0,
  y = 0,
  z = 0,
  swap_yz = FALSE,
  reverse = FALSE,
  subdivision_levels = 1,
  verbose = FALSE,
  displacement_texture = "",
  displacement_intensity = 1,
  displacement_vector = FALSE,
  recalculate_normals = FALSE,
  override_material = FALSE,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`mesh` A 'mesh3d' or 'shapelist3d' object. Pulls the vertex, index, texture coordinates, normals, and material information. If the material references an image texture, the 'mesh$material$texture' argument should be set to the image filename. The 'mesh3d' format only supports one image texture per mesh. All quads will be triangulated.

`x` Default '0'. x-coordinate to offset the model.

`y` Default '0'. y-coordinate to offset the model.

`z` Default '0'. z-coordinate to offset the model.

`swap_yz` Default 'FALSE'. Swap the Y and Z coordinates.

`reverse` Default 'FALSE'. Reverse the orientation of the indices, flipping their normals.

`subdivision_levels` Default '1'. Number of Loop subdivisions to be applied to the mesh.

`verbose` Default 'FALSE'. If 'TRUE', prints information about the mesh to the console.

displacement_texture
: Default ‘""‘. File path to the displacement texture. This texture is used to displace the vertices of the mesh based on the texture’s pixel values.

displacement_intensity
: Default ‘1‘. Intensity of the displacement effect. Higher values result in greater displacement.

displacement_vector
: Default ‘FALSE‘. Whether to use vector displacement. If ‘TRUE‘, the displacement texture is interpreted as providing a 3D displacement vector. Otherwise, the texture is interpreted as providing a scalar displacement.

recalculate_normals
: Default ‘FALSE‘. Whether to recalculate vertex normals based on the connecting face orientations. This can be used to compute normals for meshes lacking them or to calculate new normals after a displacement map has been applied to the mesh.

override_material
: Default ‘FALSE‘. If ‘TRUE‘, overrides the material specified in the ‘mesh3d‘ object with the one specified in ‘material‘.

material
: Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.

angle
: Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.

order_rotation
: Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".

flipped
: Default ‘FALSE‘. Whether to flip the normals.

scale
: Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the mesh3d model in the scene.

Examples

```
#Load a mesh3d object (from the Rvcg) and render it:
if(run_documentation()) {
  library(Rvcg)
  data(humface)

  generate_studio() %>%
    add_object(mesh3d_model(humface,y=-0.3,x=0,z=0,
                          material=glossy(color="dodgerblue4"), scale = 1/70)) %>%
    add_object(sphere(y=5,x=5,z=5,material=light(intensity=50))) %>%
    render_scene(samples=16,width=800,height=800,
                 lookat = c(0,0.5,1), aperture=0.0)
}
```

metal *Metallic Material*

Description

Metallic Material

Usage

```
metal(
  color = "#ffffff",
  eta = 0,
  kappa = 0,
  fuzz = 0,
  checkercolor = NA,
  checkerperiod = 3,
  noise = 0,
  noisephase = 0,
  noiseintensity = 10,
  noisecolor = "#000000",
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA,
  gradient_point_end = NA,
  gradient_type = "hsv",
  image_texture = "",
  image_repeat = 1,
  alpha_texture = "",
  bump_texture = "",
  bump_intensity = 1,
  importance_sample = FALSE
)
```

Arguments

color	Default ‘white‘. The color of the sphere. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.
eta	Default ‘0‘. Wavelength dependent refractivity of the material (red, green, and blue channels). If single number, will be repeated across all three channels.
kappa	Default ‘0‘. Wavelength dependent absorption of the material (red, green, and blue channels). If single number, will be repeated across all three channels.
fuzz	Default ‘0‘. Deprecated–Use the microfacet material instead, as it is designed for rough metals. The roughness of the metallic surface. Maximum ‘1‘.
checkercolor	Default ‘NA‘. If not ‘NA‘, determines the secondary color of the checkered surface. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.

- `checkerperiod` Default '3'. The period of the checker pattern. Increasing this value makes the checker pattern bigger, and decreasing it makes it smaller
- `noise` Default '0'. If not '0', covers the surface in a turbulent marble pattern. This value will determine the amount of turbulence in the texture.
- `noisephase` Default '0'. The phase of the noise. The noise will repeat at '360'.
- `noiseintensity` Default '10'. Intensity of the noise.
- `noisecolor` Default '#000000'. The secondary color of the noise pattern. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.
- `gradient_color` Default 'NA'. If not 'NA', creates a secondary color for a linear gradient between the this color and color specified in 'color'. Direction is determined by 'gradient_transpose'.
- `gradient_transpose` Default 'FALSE'. If 'TRUE', this will use the 'v' coordinate texture instead of the 'u' coordinate texture to map the gradient.
- `gradient_point_start` Default 'NA'. If not 'NA', this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value 'color'.
- `gradient_point_end` Default 'NA'. If not 'NA', this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value 'gradient_color'.
- `gradient_type` Default 'hsv'. Colorspace to calculate the gradient. Alternative 'rgb'.
- `image_texture` Default '""'. A 3-layer RGB array or filename to be used as the texture on the surface of the object.
- `image_repeat` Default '1'. Number of times to repeat the image across the surface. 'u' and 'v' repeat amount can be set independently if user passes in a length-2 vector.
- `alpha_texture` Default '""'. A matrix or filename (specifying a greyscale image) to be used to specify the transparency.
- `bump_texture` Default '""'. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.
- `bump_intensity` Default '1'. Intensity of the bump map. High values may lead to unphysical results.
- `importance_sample` Default 'FALSE'. If 'TRUE', the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

Value

Single row of a tibble describing the metallic material.

Examples

```
# Generate the cornell box with a single chrome sphere in the center. For other metals,
# See the website refractiveindex.info for eta and k data, use wavelengths 5
# 80nm (R), 530nm (G), and 430nm (B).
scene = generate_cornell() %>%
  add_object(sphere(x=555/2,y=555/2,z=555/2,radius=555/8,
  material=metal(eta=c(3.2176,3.1029,2.1839), k = c(3.3018,3.33,3.0339))))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}
#Add an aluminum rotated shiny metal block
scene = scene %>%
  add_object(cube(x=380,y=150/2,z=200,xwidth=150,ywidth=150,zwidth=150,
 material = metal(eta = c(1.07,0.8946,0.523), k = c(6.7144,6.188,4.95)),angle=c(0,45,0)))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}
#Add a copper metal cube
scene = scene %>%
  add_object(cube(x=150,y=150/2,z=300,xwidth=150,ywidth=150,zwidth=150,
                  material = metal(eta = c(0.497,0.8231,1.338),
                                   k = c(2.898,2.476,2.298)),
                  angle=c(0,-30,0)))
if(run_documentation()) {
render_scene(scene, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}

#Finally, let's add a lead pipe
scene2 = scene %>%
  add_object(cylinder(x=450,y=200,z=400,length=400,radius=30,
                  material = metal(eta = c(1.44,1.78,1.9),
                                   k = c(3.18,3.36,3.43)),
                  angle=c(0,-30,0)))
if(run_documentation()) {
render_scene(scene2, lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, ambient_light=FALSE, parallel=TRUE)
}
```

---

microfacet *Microfacet Material*

Description

Microfacet Material

Usage

```
microfacet(
  color = "white",
  roughness = 1e-04,
  transmission = FALSE,
  eta = 0,
  kappa = 0,
  microfacet = "tbr",
  checkercolor = NA,
  checkerperiod = 3,
  noise = 0,
  noisephase = 0,
  noiseintensity = 10,
  noisecolor = "#000000",
  gradient_color = NA,
  gradient_transpose = FALSE,
  gradient_point_start = NA_real_,
  gradient_point_end = NA_real_,
  gradient_type = "hsv",
  image_texture = "",
  image_repeat = 1,
  alpha_texture = "",
  bump_texture = "",
  bump_intensity = 1,
  roughness_texture = "",
  roughness_range = c(1e-04, 0.2),
  roughness_flip = FALSE,
  importance_sample = FALSE
)
```

Arguments

`color` Default ‘white‘. The color of the surface. Can be either a hexadecimal code, R color string, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.

`roughness` Default ‘0.0001‘. Roughness of the surface, between ‘0‘ (smooth) and ‘1‘ (diffuse). Can be either a single number, or two numbers indicating an anisotropic distribution of normals. ‘0‘ is a smooth surface, while ‘1‘ is extremely rough. This can be used to create a wide-variety of materials (e.g. ‘0-0.01‘ is specular metal, ‘0.02‘-‘0.1‘ is brushed metal, ‘0.1‘-‘0.3‘ is a rough metallic surface , ‘0.3‘-‘0.5‘ is diffuse, and above that is a rough satin-like material). Two numbers will specify the x and y roughness separately (e.g. ‘roughness = c(0.01, 0.001)‘ gives an etched metal effect). If ‘0‘, this defaults to the ‘metal()‘ material for faster evaluation.

`transmission` Default ‘FALSE‘. If ‘TRUE‘, this material will be a rough dielectric instead of a rough metallic surface.

`eta` Default ‘0‘. Wavelength dependent refractivity of the material (red, green, and blue channels). If single number, will be repeated across all three channels. If 'transmission = TRUE', this is a single value representing the index of refraction of the material.

kappa
: Default '0'. Wavelength dependent absorption of the material (red, green, and blue channels). If single number, will be repeated across all three channels. If 'transmission = TRUE', this length-3 vector specifies the attenuation of the dielectric (analogous to the dielectric 'attenuation' argument).

microfacet
: Default 'tbr'. Type of microfacet distribution. Alternative option 'beckmann'.

checkercolor
: Default 'NA'. If not 'NA', determines the secondary color of the checkered surface. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

checkerperiod
: Default '3'. The period of the checker pattern. Increasing this value makes the checker pattern bigger, and decreasing it makes it smaller

noise
: Default '0'. If not '0', covers the surface in a turbulent marble pattern. This value will determine the amount of turbulence in the texture.

noisephase
: Default '0'. The phase of the noise. The noise will repeat at '360'.

noiseintensity
: Default '10'. Intensity of the noise.

noisecolor
: Default '#000000'. The secondary color of the noise pattern. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

gradient_color
: Default 'NA'. If not 'NA', creates a secondary color for a linear gradient between the this color and color specified in 'color'. Direction is determined by 'gradient_transpose'.

gradient_transpose
: Default 'FALSE'. If 'TRUE', this will use the 'v' coordinate texture instead of the 'u' coordinate texture to map the gradient.

gradient_point_start
: Default 'NA'. If not 'NA', this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value 'color'.

gradient_point_end
: Default 'NA'. If not 'NA', this changes the behavior from mapping texture coordinates to mapping to world space coordinates. This should be a length-3 vector specifying the x,y, and z points where the gradient begins with value 'gradient_color'.

gradient_type
: Default 'hsv'. Colorspace to calculate the gradient. Alternative 'rgb'.

image_texture
: Default '""'. A 3-layer RGB array or filename to be used as the texture on the surface of the object.

image_repeat
: Default '1'. Number of times to repeat the image across the surface. 'u' and 'v' repeat amount can be set independently if user passes in a length-2 vector.

alpha_texture
: Default '""'. A matrix or filename (specifying a greyscale image) to be used to specify the transparency.

bump_texture
: Default '""'. A matrix, array, or filename (specifying a greyscale image) to be used to specify a bump map for the surface.

`bump_intensity` Default ‘1‘. Intensity of the bump map. High values may lead to unphysical results.

`roughness_texture`
Default ‘""‘. A matrix, array, or filename (specifying a greyscale image) to be used to specify a roughness map for the surface.

`roughness_range`
Default ‘ c(0.0001, 0.2)‘. This is a length-2 vector that specifies the range of roughness values that the ‘roughness_texture‘ can take.

`roughness_flip` Default ‘FALSE‘. Setting this to ‘TRUE‘ flips the roughness values specified in the ‘roughness_texture‘ so high values are now low values and vice versa.

`importance_sample`
Default ‘FALSE‘. If ‘TRUE‘, the object will be sampled explicitly during the rendering process. If the object is particularly important in contributing to the light paths in the image (e.g. light sources, refracting glass ball with caustics, metal objects concentrating light), this will help with the convergence of the image.

Value

Single row of a tibble describing the microfacet material.

Examples

```
# Generate a golden egg, using eta and kappa taken from physical measurements
# See the website refractiveindex.info for eta and k data, use
# wavelengths 580nm (R), 530nm (G), and 430nm (B).
if(run_documentation()) {
generate_cornell() %>%
  add_object(ellipsoid(x=555/2,555/2,y=150, a=100,b=150,c=100,
             material=microfacet(roughness=0.1,
                         eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, parallel=TRUE,clamp_value=10)
 }
if(run_documentation()) {
#Make the roughness anisotropic (either horizontal or vertical), adding an extra light in front
#to show off the different microfacet orientations
generate_cornell() %>%
  add_object(sphere(x=555/2,z=50,y=75,radius=20,material=light())) %>%
  add_object(ellipsoid(x=555-150,555/2,y=150, a=100,b=150,c=100,
             material=microfacet(roughness=c(0.3,0.1),
                         eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 add_object(ellipsoid(x=150,555/2,y=150, a=100,b=150,c=100,
             material=microfacet(roughness=c(0.1,0.3),
                         eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40,  parallel=TRUE,clamp_value=10)
}
if(run_documentation()) {
#Render a rough silver R with a smaller golden egg in front
generate_cornell() %>%
```

```
  add_object(obj_model(r_obj(simple_r = TRUE),
                       x=555/2,z=350,y=0, scale_obj = 200, angle=c(0,200,0),
             material=microfacet(roughness=0.2,
                         eta=c(1.1583,0.9302,0.5996), kappa=c(6.9650,6.396,5.332)))) %>%
 add_object(ellipsoid(x=200,z=200,y=80, a=50,b=80,c=50,
             material=microfacet(roughness=0.1,
                        eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, parallel=TRUE,clamp_value=10)
 }
if(run_documentation()) {
#Increase the roughness
generate_cornell() %>%
  add_object(obj_model(r_obj(simple_r = TRUE),
                       x=555/2,z=350,y=0, scale_obj = 200, angle=c(0,200,0),
             material=microfacet(roughness=0.5,
                         eta=c(1.1583,0.9302,0.5996), kappa=c(6.9650,6.396,5.332)))) %>%
 add_object(ellipsoid(x=200,z=200,y=80, a=50,b=80,c=50,
             material=microfacet(roughness=0.3,
                        eta=c(0.216,0.42833,1.3184), kappa=c(3.239,2.4599,1.8661)))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, parallel=TRUE,clamp_value=10)
 }
if(run_documentation()) {
 #Use transmission for a rough dielectric
generate_cornell() %>%
  add_object(obj_model(r_obj(simple_r = TRUE),
                       x=555/2,z=350,y=0, scale_obj = 200, angle=c(0,200,0),
             material=microfacet(roughness=0.3, transmission=T, eta=1.6))) %>%
 add_object(ellipsoid(x=200,z=200,y=80, a=50,b=80,c=50,
             material=microfacet(roughness=0.3, transmission=T, eta=1.6))) %>%
 render_scene(lookfrom=c(278,278,-800),lookat = c(278,278,0), samples=16,
             aperture=0, fov=40, parallel=TRUE,clamp_value=10, min_variance=1e-6)
}
```

`obj_model` *'obj' File Object*

Description

Load an obj file via a filepath. Currently only supports the diffuse texture with the 'texture' argument. Note: light importance sampling currently not supported for this shape.

Usage

```
obj_model(
  filename,
  x = 0,
  y = 0,
  z = 0,
```

```
  scale_obj = 1,
  load_material = TRUE,
  load_textures = TRUE,
  load_normals = TRUE,
  vertex_colors = FALSE,
  calculate_consistent_normals = TRUE,
  subdivision_levels = 1,
  displacement_texture = "",
  displacement_intensity = 1,
  displacement_vector = FALSE,
  recalculate_normals = FALSE,
  importance_sample_lights = TRUE,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`filename`	Filename and path to the ‘obj‘ file. Can also be a ‘txt‘ file, if it’s in the correct ‘obj‘ internally.
`x`	Default ‘0‘. x-coordinate to offset the model.
`y`	Default ‘0‘. y-coordinate to offset the model.
`z`	Default ‘0‘. z-coordinate to offset the model.
`scale_obj`	Default ‘1‘. Amount to scale the model. Use this to scale the object up or down on all axes, as it is more robust to numerical precision errors than the generic scale option.
`load_material`	Default ‘TRUE‘. Whether to load the obj file material (MTL file). If material for faces aren’t specified, the default material will be used (specified by the user in ‘material‘).
`load_textures`	Default ‘TRUE‘. If ‘load_material = TRUE‘, whether to load textures in the MTL file (versus just using the colors specified for each material).
`load_normals`	Default ‘TRUE‘. Whether to load the vertex normals if they exist in the OBJ file.
`vertex_colors`	Default ‘FALSE‘. Set to ‘TRUE‘ if the OBJ file has vertex colors to apply them to the model.
`calculate_consistent_normals`	Default ‘TRUE‘. Whether to calculate consistent vertex normals to prevent energy loss at edges.
`subdivision_levels`	Default ‘1‘. Number of Loop subdivisions to be applied to the mesh.
`displacement_texture`	Default ‘""‘. File path to the displacement texture. This texture is used to displace the vertices of the mesh based on the texture’s pixel values.

displacement_intensity
: Default '1'. Intensity of the displacement effect. Higher values result in greater displacement.

displacement_vector
: Default 'FALSE'. Whether to use vector displacement. If 'TRUE', the displacement texture is interpreted as providing a 3D displacement vector. Otherwise, the texture is interpreted as providing a scalar displacement.

recalculate_normals
: Default 'FALSE'. Whether to recalculate vertex normals based on the connecting face orientations. This can be used to compute normals for meshes lacking them or to calculate new normals after a displacement map has been applied to the mesh.

importance_sample_lights
: Default 'TRUE'. Whether to importance sample lights specified in the OBJ material (objects with a non-zero Ke MTL material).

material
: Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.

angle
: Default 'c(0, 0, 0)'. Angle of rotation around the x, y, and z axes, applied in the order specified in 'order_rotation'.

order_rotation
: Default 'c(1, 2, 3)'. The order to apply the rotations, referring to "x", "y", and "z".

flipped
: Default 'FALSE'. Whether to flip the normals.

scale
: Default 'c(1, 1, 1)'. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the obj model in the scene.

Examples

```
#Load the included example R object file, by calling the r_obj() function. This
#returns the local file path to the `r.txt` obj file. The file extension is "txt"
#due to package constraints, but the file contents are identical and it does not
#affect the function.

if(run_documentation()) {
#Load the basic 3D R logo with the included materials
generate_ground(material = diffuse(checkercolor = "grey50")) %>%
  add_object(obj_model(y = 0.2, filename = rayrender::r_obj(),
                       scale_obj=3)) %>%
   add_object(sphere(z = 20, x = 20, y = 20, radius = 10,
                     material = light(intensity = 10))) %>%
  render_scene(parallel = TRUE, samples = 16, aperture = 0.05,
               sample_method="sobol_blue",
               fov = 20, lookfrom = c(0, 2, 10))
}
```

```
if(run_documentation()) {
# Smooth a mesh by setting the number of subdivision levels
generate_ground(material = diffuse(checkercolor = "grey50")) %>%
  add_object(obj_model(y = 0.2, filename = rayrender::r_obj(),
                       scale_obj=3, subdivision_levels = 3)) %>%
   add_object(sphere(z = 20, x = 20, y = 20, radius = 10,
                     material = light(intensity = 10))) %>%
  render_scene(parallel = TRUE, samples = 16, aperture = 0.05,
               sample_method="sobol_blue",
               fov = 20, lookfrom = c(0, 2, 10))
}

if(run_documentation()) {
#Override the materials for each object
generate_ground(material = diffuse(checkercolor = "grey50")) %>%
  add_object(obj_model(y = 1.4, filename = rayrender::r_obj(), load_material = FALSE,
                       scale_obj = 1.8, angle=c(10,0,0),
                       material = microfacet(color = "gold", roughness = 0.05))) %>%
 add_object(obj_model(x = 0.9, y = 0, filename = rayrender::r_obj(), load_material = FALSE,
                       scale_obj = 1.8, angle=c(0,-20,0),
                       material = diffuse(color = "dodgerblue"))) %>%
 add_object(obj_model(x = -0.9, y = 0, filename = rayrender::r_obj() , load_material = FALSE,
                       scale_obj = 1.8, angle=c(0,20,0),
                       material = dielectric(attenuation = c(1,0.3,1), priority = 1,
                                             attenuation_intensity = 20))) %>%
  add_object(sphere(z = 20, x = 20, y = 20, radius = 10,
                    material = light(intensity = 10))) %>%
  render_scene(parallel = TRUE, samples = 16, aperture = 0.05,
               sample_method="sobol_blue", lookat=c(0,0.5,0),
               fov = 22, lookfrom = c(0, 2, 10))

}
```

---

path *Path Object*

Description

Either a closed or open path made up of bezier curves that go through the specified points (with continuous first and second derivatives), or straight line segments.

Usage

```
path(
  points,
  x = 0,
  y = 0,
  z = 0,
  closed = FALSE,
  closed_smooth = TRUE,
```

```
  straight = FALSE,
  precomputed_control_points = FALSE,
  width = 0.1,
  width_end = NA,
  u_min = 0,
  u_max = 1,
  type = "cylinder",
  normal = c(0, 0, -1),
  normal_end = NA,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

points	Either a list of length-3 numeric vectors or 3-column matrix/data.frame specifying the x/y/z points that the path should go through.
x	Default ‘0‘. x-coordinate offset for the path.
y	Default ‘0‘. y-coordinate offset for the path.
z	Default ‘0‘. z-coordinate offset for the path.
closed	Default ‘FALSE‘. If ‘TRUE‘, the path will be closed by smoothly connecting the first and last points.
closed_smooth	Default ‘TRUE‘. If ‘closed = TRUE‘, this will ensure C2 (second derivative) continuity between the ends. If ‘closed = FALSE‘, the curve will only have C1 (first derivative) continuity between the ends.
straight	Default ‘FALSE‘. If ‘TRUE‘, straight lines will be used to connect the points instead of bezier curves.
precomputed_control_points	Default ‘FALSE‘. If ‘TRUE‘, ‘points‘ argument will expect a list of control points calculated with the internal rayrender function ‘rayrender:::calculate_control_points()‘.
width	Default ‘0.1‘. Curve width.
width_end	Default ‘NA‘. Width at end of path. Same as ‘width‘, unless specified.
u_min	Default ‘0‘. Minimum parametric coordinate for the path.
u_max	Default ‘1‘. Maximum parametric coordinate for the path.
type	Default ‘cylinder‘. Other options are ‘flat‘ and ‘ribbon‘.
normal	Default ‘c(0,0,-1)‘. Orientation surface normal for the start of ribbon curves.
normal_end	Default ‘NA‘. Orientation surface normal for the start of ribbon curves. If not specified, same as ‘normal‘.
material	Default diffuse.The material, called from one of the material functions diffuse, metal, or dielectric.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.

order_rotation Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".

flipped Default ‘FALSE‘. Whether to flip the normals.

scale Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the cube in the scene.

Examples

```
if(run_documentation()) {
#Generate a wavy line, showing the line goes through the specified points:
wave = list(c(-2,1,0),c(-1,-1,0),c(0,1,0),c(1,-1,0),c(2,1,0))
point_mat = glossy(color="green")
generate_studio(depth=-1.5) %>%
  add_object(path(points = wave,material=glossy(color="red"))) %>%
  add_object(sphere(x=-2,y=1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(x=-1,y=-1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(x=0,y=1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(x=1,y=-1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(x=2,y=1,radius=0.1,material=point_mat)) %>%
  add_object(sphere(z=5,x=5,y=5,radius=2,material=light(intensity=15))) %>%
  render_scene(samples=16, clamp_value=10,fov=30)
}
if(run_documentation()) {
#Here we use straight lines by setting `straight = TRUE`:
generate_studio(depth=-1.5) %>%
  add_object(path(points = wave,straight = TRUE, material=glossy(color="red"))) %>%
  add_object(sphere(z=5,x=5,y=5,radius=2,material=light(intensity=15))) %>%
  render_scene(samples=16, clamp_value=10,fov=30)
}
if(run_documentation()) {
#We can also pass a matrix of values, specifying the x/y/z coordinates. Here,
#we'll create a random curve:
set.seed(21)
random_mat = matrix(runif(3*9)*2-1, ncol=3)
generate_studio(depth=-1.5) %>%
  add_object(path(points=random_mat, material=glossy(color="red"))) %>%
  add_object(sphere(y=5,radius=1,material=light(intensity=30))) %>%
  render_scene(samples=16, clamp_value=10)
}
if(run_documentation()) {
#We can ensure the curve is closed by setting `closed = TRUE`
generate_studio(depth=-1.5) %>%
  add_object(path(points=random_mat, closed = TRUE, material=glossy(color="red"))) %>%
  add_object(sphere(y=5,radius=1,material=light(intensity=30))) %>%
  render_scene(samples=16, clamp_value=10)
}
if(run_documentation()) {
```

```
#Finally, let's render a pretzel to show how you can render just a subset of the curve:
pretzel = list(c(-0.8,-0.5,0.1),c(0,-0.2,-0.1),c(0,0.3,0.1),c(-0.5,0.5,0.1), c(-0.6,-0.5,-0.1),
               c(0,-0.8,-0.1),
          c(0.6,-0.5,-0.1),c(0.5,0.5,-0.1), c(0,0.3,-0.1),c(-0,-0.2,0.1), c(0.8,-0.5,0.1))

#Render the full pretzel:
generate_studio(depth = -1.1) %>%
  add_object(path(pretzel, width=0.17,  material = glossy(color="#db5b00"))) %>%
 add_object(sphere(y=5,x=2,z=4,material=light(intensity=20,spotlight_focus = c(0,0,0)))) %>%
  render_scene(samples=16, clamp_value=10)
}
if(run_documentation()) {
#Here, we'll render only the first third of the pretzel by setting `u_max = 0.33`
generate_studio(depth = -1.1) %>%
 add_object(path(pretzel, width=0.17, u_max=0.33, material = glossy(color="#db5b00"))) %>%
 add_object(sphere(y=5,x=2,z=4,material=light(intensity=20,spotlight_focus = c(0,0,0)))) %>%
  render_scene(samples=16, clamp_value=10)
}
if(run_documentation()) {
#Here's the last third, by setting `u_min = 0.66`
generate_studio(depth = -1.1) %>%
 add_object(path(pretzel, width=0.17, u_min=0.66, material = glossy(color="#db5b00"))) %>%
 add_object(sphere(y=5,x=2,z=4,material=light(intensity=20,spotlight_focus = c(0,0,0)))) %>%
  render_scene(samples=16, clamp_value=10)
}
if(run_documentation()) {
#Here's the full pretzel, decomposed into thirds using the u_min and u_max coordinates
generate_studio(depth = -1.1) %>%
  add_object(path(pretzel, width=0.17, u_max=0.33, x = -0.8, y =0.6,
                  material = glossy(color="#db5b00"))) %>%
  add_object(path(pretzel, width=0.17, u_min=0.66, x = 0.8, y =0.6,
                  material = glossy(color="#db5b00"))) %>%
  add_object(path(pretzel, width=0.17, u_min=0.33, u_max=0.66, x=0,
                  material = glossy(color="#db5b00"))) %>%
 add_object(sphere(y=5,x=2,z=4,material=light(intensity=20,spotlight_focus = c(0,0,0)))) %>%
  render_scene(samples=16, clamp_value=10, lookfrom=c(0,3,10))
}
```

pig *Pig Object*

Description

Pig Object

Usage

```
pig(
  x = 0,
  y = 0,
```

```
  z = 0,
  emotion = "neutral",
  spider = FALSE,
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  scale = c(1, 1, 1),
  diffuse_sigma = 0
)
```

Arguments

x	Default ‘0‘. x-coordinate of the center of the pig.
y	Default ‘0‘. y-coordinate of the center of the pig.
z	Default ‘0‘. z-coordinate of the center of the pig.
emotion	Default ‘neutral‘. Other options include ‘skeptical‘, ‘worried‘, and ‘angry‘.
spider	Default ‘FALSE‘. Spiderpig.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly.
diffuse_sigma	Default ‘0‘. Controls the Oren-Nayar sigma parameter for the pig’s diffuse material.

Value

Single row of a tibble describing the pig in the scene.

Examples

```
#Generate a pig in the cornell box.

if(run_documentation()) {
generate_cornell() %>%
  add_object(pig(x=555/2,z=555/2,y=120,
  scale=c(80,80,80), angle = c(0,135,0))) %>%
  render_scene(parallel=TRUE, samples=16,clamp_value=10)
}
if(run_documentation()) {
# Show the pig staring into a mirror, worried
generate_cornell() %>%
  add_object(pig(x=555/2-70,z=555/2+50,y=120,scale=c(80,80,80),
                 angle = c(0,-40,0), emotion = "worried")) %>%
  add_object(cube(x=450,z=450,y=250, ywidth=500, xwidth=200,
                  angle = c(0,45,0), material = metal())) %>%
  render_scene(parallel=TRUE, samples=16,clamp_value=10)
}
```

```
if(run_documentation()) {
# Render many small pigs facing random directions, with an evil pig overlord
set.seed(1)
lots_of_pigs = list()
for(i in 1:10) {
  lots_of_pigs[[i]] = pig(x=50 + 450 * runif(1), z = 50 + 450 * runif(1), y=50,
                    scale = c(30,30,30), angle = c(0,360*runif(1),0), emotion = "worried")
}

many_pigs_scene = do.call(rbind, lots_of_pigs) %>%
 add_object(generate_cornell(lightintensity=30, lightwidth=100)) %>%
 add_object(pig(z=500,x=555/2,y=350, emotion = "angry",
            scale=c(100,100,100),angle=c(-30,90,0), order_rotation=c(3,2,1)))

render_scene(many_pigs_scene,parallel=TRUE,clamp_value=10, samples=16)
}
if(run_documentation()) {
#Render spiderpig
generate_studio() %>%
  add_object(pig(y=-1,angle=c(0,-100,0), scale=1/2,spider=TRUE)) %>%
  add_object(sphere(y=5,z=5,x=5,material=light(intensity=100))) %>%
  render_scene(samples=16,lookfrom=c(0,2,10),clamp_value=10)
}
```

---

ply_model *'ply' File Object*

Description

Load an PLY file via a filepath. Note: light importance sampling currently not supported for this shape.

Usage

```
ply_model(
  filename,
  x = 0,
  y = 0,
  z = 0,
  scale_ply = 1,
  subdivision_levels = 1,
  recalculate_normals = FALSE,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

filename	Filename and path to the ‘ply‘ file. Can also be a ‘txt‘ file, if it’s in the correct ‘ply‘ internally.
x	Default ‘0‘. x-coordinate to offset the model.
y	Default ‘0‘. y-coordinate to offset the model.
z	Default ‘0‘. z-coordinate to offset the model.
scale_ply	Default ‘1‘. Amount to scale the model. Use this to scale the object up or down on all axes, as it is more robust to numerical precision errors than the generic scale option.
subdivision_levels	Default ‘1‘. Number of Loop subdivisions to be applied to the mesh.
recalculate_normals	Default ‘FALSE‘. Whether to recalculate vertex normals based on the connecting face orientations. This can be used to compute normals for meshes lacking them or to calculate new normals after a displacement map has been applied to the mesh.
material	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default ‘FALSE‘. Whether to flip the normals.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the obj model in the scene.

Examples

```
#See the documentation for `obj_model()`--no example PLY models are included with this package,
#but the process of loading a model is the same (without support for vertex colors).
```

---

raymesh_model *‘raymesh‘ model*

Description

Load an ‘raymesh‘ object, as specified in the ‘rayvertex‘ package.

Usage

```
raymesh_model(
  mesh,
  x = 0,
  y = 0,
  z = 0,
  flip_transmittance = TRUE,
  verbose = FALSE,
  importance_sample_lights = FALSE,
  calculate_consistent_normals = TRUE,
  subdivision_levels = 1,
  displacement_texture = "",
  displacement_intensity = 1,
  displacement_vector = FALSE,
  recalculate_normals = FALSE,
  override_material = TRUE,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1),
  validate_mesh = TRUE
)
```

Arguments

`mesh` A ‘raymesh‘ object. Pulls the vertex, index, texture coordinates, normals, and material information.

`x` Default ‘0‘. x-coordinate to offset the model.

`y` Default ‘0‘. y-coordinate to offset the model.

`z` Default ‘0‘. z-coordinate to offset the model.

`flip_transmittance` Default ‘TRUE‘. Flips ‘(1-t)‘ the transmittance values to match the way the colors would be interpreted in a rasterizer (where it specifies the transmitted color). Turn off to specify the attenuation values directly.

`verbose` Default ‘FALSE‘. If ‘TRUE‘, prints information about the mesh to the console.

`importance_sample_lights` Default ‘TRUE‘. Whether to importance sample lights specified in the OBJ material (objects with a non-zero Ke MTL material).

`calculate_consistent_normals` Default ‘TRUE‘. Whether to calculate consistent vertex normals to prevent energy loss at edges.

`subdivision_levels` Default ‘1‘. Number of Loop subdivisions to be applied to the mesh.

`displacement_texture` Default ‘""‘. File path to the displacement texture. This texture is used to displace the vertices of the mesh based on the texture’s pixel values.

displacement_intensity
: Default '1'. Intensity of the displacement effect. Higher values result in greater displacement.

displacement_vector
: Default 'FALSE'. Whether to use vector displacement. If 'TRUE', the displacement texture is interpreted as providing a 3D displacement vector. Otherwise, the texture is interpreted as providing a scalar displacement.

recalculate_normals
: Default 'FALSE'. Whether to recalculate vertex normals based on the connecting face orientations. This can be used to compute normals for meshes lacking them or to calculate new normals after a displacement map has been applied to the mesh.

override_material
: Default 'TRUE'. If 'TRUE', overrides the material specified in the 'raymesh' object with the one specified in 'material'.

material
: Default diffuse, but ignored unless 'override_material = TRUE'. The material, called from one of the material functions diffuse, metal, or dielectric.

angle
: Default 'c(0, 0, 0)'. Angle of rotation around the x, y, and z axes, applied in the order specified in 'order_rotation'.

order_rotation
: Default 'c(1, 2, 3)'. The order to apply the rotations, referring to "x", "y", and "z".

flipped
: Default 'FALSE'. Whether to flip the normals.

scale
: Default 'c(1, 1, 1)'. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

validate_mesh
: Default 'TRUE'. Validates the 'raymesh' object using 'rayvertex::validate_mesh()' before parsing to ensure correct parsing. Set to 'FALSE' to speed up scene construction if 'raymesh_model()' is taking a long time (Note: this does not affect rendering time).

Value

Single row of a tibble describing the raymesh model in the scene.

Examples

```
#Render a simple raymesh object
library(rayvertex)
if(run_documentation()) {
raymesh_model(sphere_mesh(position = c(-1, 0, 0),
              material = material_list(transmittance = "red"))) %>%
  add_object(generate_ground(material = diffuse(checkercolor="grey20"))) %>%
  render_scene(fov = 30, samples=16, sample_method="sobol_blue")
}

# We create a complex rayvertex mesh, using the `rayvertex::add_shape` function which
# creates a new `raymesh` object out of individual `raymesh` objects
rm_scene = sphere_mesh(position = c(-1, 0, 0),
```

```
            material = material_list(transmittance = "red")) %>%
    add_shape(sphere_mesh(position = c(1, 0, 0),
            material = material_list(transmittance = "green", ior = 1.5)))

# Pass the single raymesh object to `raymesh_model()`
# `raymesh_model()`
if(run_documentation()) {
raymesh_model(rm_scene) %>%
  add_object(generate_ground(material = diffuse(checkercolor="grey20"))) %>%
  render_scene(fov = 30, samples=16, sample_method="sobol_blue")
}

# Set `flip_transmittance = FALSE` argument to specify attenuation coefficients directly
# (as specified in the `dielectric()` material). We change the material's numerical attenuation
# constants using `rayvertex::change_material`
rm_scene_new= change_material(rm_scene, transmittance = c(1,2,0.3), id = 1) %>%
  change_material(transmittance = c(3,1,2), id = 2)
if(run_documentation()) {
raymesh_model(rm_scene_new, flip_transmittance = FALSE) %>%
  add_object(generate_ground(material = diffuse(checkercolor="grey20"))) %>%
  render_scene(fov = 30, samples=16, sample_method="sobol_blue")
}

# Override the material specified in the `raymesh` object and render the scene
if(run_documentation()) {
raymesh_model(rm_scene,
           material = dielectric(attenuation = "dodgerblue2", attenuation_intensity = 4),
  override_material = TRUE) %>%
  add_object(generate_ground(material = diffuse(checkercolor="grey20"))) %>%
  render_scene(fov = 30, samples=16, sample_method="sobol_blue")
}

# Adjusting the scale, position, and rotation parameters of the `raymesh` model
if(run_documentation()) {
raymesh_model(rm_scene,
              x = 0, y = 0.5, z = -1, angle = c(0, 0, 20)) %>%
  add_object(generate_ground(material = diffuse(checkercolor="grey20"))) %>%
  render_scene(fov = 30,lookat=c(0,0.5,0), samples=16, sample_method="sobol_blue")
}
```

`render_animation` *Render Animation*

Description

Takes the scene description and renders an image, either to the device or to a filename.

Usage

```
render_animation(
```

```
  scene,
  camera_motion,
  start_frame = 1,
  end_frame = NA,
  width = 400,
  height = 400,
  preview = interactive(),
  denoise = TRUE,
  camera_description_file = NA,
  camera_scale = 1,
  iso = 100,
  film_size = 22,
  samples = 100,
  min_variance = 0,
  min_adaptive_size = 8,
  sample_method = "sobol",
  ambient_occlusion = FALSE,
  keep_colors = FALSE,
  sample_dist = 10,
  max_depth = 50,
  roulette_active_depth = 10,
  ambient_light = FALSE,
  clamp_value = Inf,
  filename = NA,
  backgroundhigh = "#80b4ff",
  backgroundlow = "#ffffff",
  shutteropen = 0,
  shutterclose = 1,
  focal_distance = NULL,
  ortho_dimensions = c(1, 1),
  tonemap = "gamma",
  bloom = TRUE,
  parallel = TRUE,
  bvh_type = "sah",
  environment_light = NULL,
  rotate_env = 0,
  intensity_env = 1,
  debug_channel = "none",
  return_raw_array = FALSE,
  progress = interactive(),
  verbose = FALSE,
  transparent_background = FALSE,
  preview_light_direction = c(0, -1, 0),
  preview_exponent = 6,
  integrator_type = "rtiow"
)
```

Arguments

- `scene` Tibble of object locations and properties.
- `camera_motion` Data frame of camera motion vectors, calculated with ‘generate_camera_motion()‘.
- `start_frame` Default ‘1‘. Frame to start the animation.
- `end_frame` Default ‘NA‘. By default, this is set to ‘nrow(camera_motion)‘, the full number of frames.
- `width` Default ‘400‘. Width of the render, in pixels.
- `height` Default ‘400‘. Height of the render, in pixels.
- `preview` Default ‘interactive()‘. Whether to display a realtime progressive preview of the render. Press ESC to cancel the render.
- `denoise` Default ‘TRUE‘. Whether to de-noise the final image and preview images. Note, this requires the free Intel Open Image Denoise (OIDN) library be installed on your system. Pre-compiled binaries can be installed from ppenimagedenoise.org, as well as . Linking during rayrender installation is done by defining the environment variable OIDN_PATH (set it in the .Renviron file by calling ‘usethis::edit_r_environ()‘) to the top-level directory for OIDN (the directory containing the "lib", "bin", and "include" directories) and re-installing this package from source.
- `camera_description_file` Default ‘NA‘. Filename of a camera description file for rendering with a realistic camera. Several camera files are built-in: ‘"50mm"‘,‘"wide"‘,‘"fisheye"‘, and ‘"telephoto"‘.
- `camera_scale` Default ‘1‘. Amount to scale the camera up or down in size. Use this rather than scaling a scene.
- `iso` Default ‘100‘. Camera exposure.
- `film_size` Default ‘22‘, in ‘mm‘ (scene units in ‘m‘. Size of the film if using a realistic camera, otherwise ignored.
- `samples` Default ‘100‘. The maximum number of samples for each pixel. If this is a length-2 vector and the ‘sample_method‘ is ‘stratified‘, this will control the number of strata in each dimension. The total number of samples in this case will be the product of the two numbers.
- `min_variance` Default ‘0‘. Minimum acceptable variance for a block of pixels for the adaptive sampler. Smaller numbers give higher quality images, at the expense of longer rendering times. If this is set to zero, the adaptive sampler will be turned off and the renderer will use the maximum number of samples everywhere.
- `min_adaptive_size` Default ‘8‘. Width of the minimum block size in the adaptive sampler.
- `sample_method` Default ‘sobol‘. The type of sampling method used to generate random numbers. The other options are ‘random‘ (worst quality but simple), ‘stratified‘ (only implemented for completion), and ‘sobol_blue‘ (best option for sample counts below 256).
- `ambient_occlusion` Default ‘FALSE‘. If ‘TRUE‘, the animation will be rendered with the ambient occlusion renderer. This uses the background color specified in ‘background-high‘

keep_colors
: Default ‘FALSE‘. Whether to keep the diffuse material colors.

sample_dist
: Default ‘10‘. Sample distance if ‘debug_channel = "ao"‘.

max_depth
: Default ‘50‘. Maximum number of bounces a ray can make in a scene.

roulette_active_depth
: Default ‘10‘. Number of ray bounces until a ray can stop bouncing via Russian roulette.

ambient_light
: Default ‘FALSE‘, unless there are no emitting objects in the scene. If ‘TRUE‘, the background will be a gradient varying from ‘backgroundhigh‘ directly up (+y) to ‘backgroundlow‘ directly down (-y).

clamp_value
: Default ‘Inf‘. If a bright light or a reflective material is in the scene, occasionally there will be bright spots that will not go away even with a large number of samples. These can be removed (at the cost of slightly darkening the image) by setting this to a small number greater than 1.

filename
: Default ‘NULL‘. If present, the renderer will write to the filename instead of the current device.

backgroundhigh
: Default ‘#ffffff‘. The "high" color in the background gradient. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.

backgroundlow
: Default ‘#ffffff‘. The "low" color in the background gradient. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between ‘0‘ and ‘1‘.

shutteropen
: Default ‘0‘. Time at which the shutter is open. Only affects moving objects.

shutterclose
: Default ‘1‘. Time at which the shutter is open. Only affects moving objects.

focal_distance
: Default ‘NULL‘, automatically set to the ‘lookfrom-lookat‘ distance unless otherwise specified.

ortho_dimensions
: Default ‘c(1,1)‘. Width and height of the orthographic camera. Will only be used if ‘fov = 0‘.

tonemap
: Default ‘gamma‘. Choose the tone mapping function, Default ‘gamma‘ solely adjusts for gamma and clamps values greater than 1 to 1. ‘reinhold‘ scales values by their individual color channels ‘color/(1+color)‘ and then performs the gamma adjustment. ‘uncharted‘ uses the mapping developed for Uncharted 2 by John Hable. ‘hbd‘ uses an optimized formula by Jim Hejl and Richard Burgess-Dawson. Note: If set to anything other than ‘gamma‘, objects with material ‘light()‘ may not be anti-aliased. If ‘raw‘, the raw array of HDR values will be returned, rather than an image or a plot.

bloom
: Default ‘TRUE‘. Set to ‘FALSE‘ to get the raw, pathtraced image. Otherwise, this performs a convolution of the HDR image of the scene with a sharp, long-tailed exponential kernel, which does not visibly affect dimly pixels, but does result in emitters light slightly bleeding into adjacent pixels. This provides an antialiasing effect for lights, even when tonemapping the image. Pass in a matrix to specify the convolution kernel manually, or a positive number to control the intensity of the bloom (higher number = more bloom).

parallel
: Default ‘FALSE‘. If ‘TRUE‘, it will use all available cores to render the image (or the number specified in ‘options("cores")‘ if that option is not ‘NULL‘).

bvh_type
: Default ‘"sah"‘, "surface area heuristic". Method of building the bounding volume hierarchy structure used when rendering. Other option is "equal", which splits tree into groups of equal size.

environment_light
: Default ‘NULL‘. An image to be used for the background for rays that escape the scene. Supports both HDR (‘.hdr‘) and low-dynamic range (‘.png‘, ‘.jpg‘) images.

rotate_env
: Default ‘0‘. The number of degrees to rotate the environment map around the scene.

intensity_env
: Default ‘1‘. The amount to increase the intensity of the environment lighting. Useful if using a LDR (JPEG or PNG) image as an environment map.

debug_channel
: Default ‘none‘. If ‘depth‘, function will return a depth map of rays into the scene instead of an image. If ‘normals‘, function will return an image of scene normals, mapped from 0 to 1. If ‘uv‘, function will return an image of the uv coords. If ‘variance‘, function will return an image showing the number of samples needed to take for each block to converge. If ‘dpdu‘ or ‘dpdv‘, function will return an image showing the differential ‘u‘ and ‘u‘ coordinates. If ‘color‘, function will return the raw albedo values (with white for ‘metal‘ and ‘dielectric‘ materials). If ‘preview‘, an image rendered with ‘render_preview()‘ will be returned. Can set to ‘ao‘ to render an animation with the ambient occlusion renderer.

return_raw_array
: Default ‘FALSE‘. If ‘TRUE‘, function will return raw array with RGB intensity information.

progress
: Default ‘TRUE‘ if interactive session, ‘FALSE‘ otherwise.

verbose
: Default ‘FALSE‘. Prints information and timing information about scene construction and raytracing progress.

transparent_background
: Default ‘FALSE‘. If ‘TRUE‘, any initial camera rays that escape the scene will be marked as transparent in the final image. If for a pixel some rays escape and others hit a surface, those pixels will be partially transparent.

preview_light_direction
: Default ‘c(0,-1,0)‘. Vector specifying the orientation for the global light using for phong shading.

preview_exponent
: Default ‘6‘. Phong exponent.

integrator_type
: Default ‘"rtiow"‘ (the algorithm specified in the book "Raytracing in One Weekend", a basic form of path guiding). Other options include ‘"nee"‘ (Next Event Estimation, with direct light sampling) and ‘"basic"‘ (basic pathtracing, for high sample reference renders and debugging only).

Value

Raytraced plot to current device, or an image saved to a file.

Examples

```
#Create and animate flying through a scene on a simulated roller coaster
if(run_documentation()) {
set.seed(3)
elliplist = list()
ellip_colors = rainbow(8)
for(i in 1:1200) {
  elliplist[[i]] = ellipsoid(x=10*runif(1)-5,y=10*runif(1)-5,z=10*runif(1)-5,
                             angle = 360*runif(3), a=0.1,b=0.05,c=0.1,
                             material=glossy(color=sample(ellip_colors,1)))
}
ellip_scene = do.call(rbind, elliplist)

camera_pos = list(c(0,1,15),c(5,-5,5),c(-5,5,-5),c(0,1,-15))

#Plot the camera path and render from above using the path object:
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(0,20,0), width=800,height=800,samples=32,
               camera_up = c(0,0,1),
               fov=80)
}
if(run_documentation()) {
#Side view
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(20,0,0),width=800,height=800,samples=32,
                 fov=80)
 }
if(run_documentation()) {
#View from the start
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(path(camera_pos, material=diffuse(color="red"))) %>%
  render_scene(lookfrom=c(0,1.5,16),width=800,height=800,samples=32,
                 fov=80)
 }
if(run_documentation()) {
#Generate Camera movement, setting the lookat position to be same as camera position, but offset
#slightly in front. We'll render 12 frames, but you'd likely want more in a real animation.

camera_motion =  generate_camera_motion(positions = camera_pos, lookats = camera_pos,
                                        offset_lookat = 1, fovs=80, frames=12,
                                        type="bezier")

#This returns a data frame of individual camera positions, interpolated by cubic bezier curves.
camera_motion
```

```
#Pass NA filename to plot to the device. We'll keep the path and offset it slightly to see
#where we're going. This results in a "roller coaster" effect.
generate_ground(material=diffuse(checkercolor="grey20"),depth=-10) %>%
  add_object(ellip_scene) %>%
  add_object(sphere(y=50,radius=10,material=light(intensity=30))) %>%
  add_object(obj_model(r_obj(),x=10,y=-5,z=10,scale=7, angle=c(-45,-45,0),
                       material=dielectric(attenuation=c(1,1,0.3)))) %>%
  add_object(pig(x=-7,y=10,z=-5,scale=1,angle=c(0,-45,80),emotion="angry")) %>%
 add_object(pig(x=0,y=-0.25,z=-15,scale=1,angle=c(0,225,-22), order_rotation = c(3,2,1),
                 emotion="angry", spider=TRUE)) %>%
  add_object(path(camera_pos, y=-0.2,material=diffuse(color="red"))) %>%
  render_animation(filename = NA, camera_motion = camera_motion, samples=16,
                   sample_method="sobol_blue",
                   clamp_value=10, width=400, height=400)

}
```

---

render_ao *Render Ambient Occlusion*

Description

Takes the scene description and renders an image using ambient occlusion, either to the device or to a filename.

Usage

```
render_ao(
  scene,
  width = 400,
  height = 400,
  fov = 20,
  sample_dist = 10,
  keep_colors = FALSE,
  samples = 100,
  camera_description_file = NA,
  camera_scale = 1,
  iso = 100,
  film_size = 22,
  min_variance = 0,
  min_adaptive_size = 8,
  sample_method = "sobol",
  background_color = "white",
  lookfrom = c(0, 1, 10),
  lookat = c(0, 0, 0),
  camera_up = c(0, 1, 0),
  aperture = 0.1,
```

```
  clamp_value = Inf,
  filename = NULL,
  shutteropen = 0,
  shutterclose = 1,
  focal_distance = NULL,
  ortho_dimensions = c(1, 1),
  parallel = TRUE,
  bvh_type = "sah",
  progress = interactive(),
  verbose = FALSE
)
```

Arguments

`scene` Tibble of object locations and properties.

`width` Default '400'. Width of the render, in pixels.

`height` Default '400'. Height of the render, in pixels.

`fov` Default '20'. Field of view, in degrees. If this is '0', the camera will use an orthographic projection. The size of the plane used to create the orthographic projection is given in argument 'ortho_dimensions'. From '0' to '180', this uses a perspective projections. If this value is '360', a 360 degree environment image will be rendered.

`sample_dist` Default '10'. Ambient occlusion sampling distance.

`keep_colors` Default 'FALSE'. Whether to keep the diffuse material colors.

`samples` Default '100'. The maximum number of samples for each pixel. If this is a length-2 vector and the 'sample_method' is 'stratified', this will control the number of strata in each dimension. The total number of samples in this case will be the product of the two numbers.

`camera_description_file` Default 'NA'. Filename of a camera description file for rendering with a realistic camera. Several camera files are built-in: '"50mm"','"wide"','"fisheye"', and '"telephoto"'.

`camera_scale` Default '1'. Amount to scale the camera up or down in size. Use this rather than scaling a scene.

`iso` Default '100'. Camera exposure.

`film_size` Default '22', in 'mm' (scene units in 'm'. Size of the film if using a realistic camera, otherwise ignored.

`min_variance` Default '0.00005'. Minimum acceptable variance for a block of pixels for the adaptive sampler. Smaller numbers give higher quality images, at the expense of longer rendering times. If this is set to zero, the adaptive sampler will be turned off and the renderer will use the maximum number of samples everywhere.

`min_adaptive_size` Default '8'. Width of the minimum block size in the adaptive sampler.

`sample_method` Default 'sobol'. The type of sampling method used to generate random numbers. The other options are 'random' (worst quality but fastest), 'stratified' (only implemented for completion), 'sobol_blue' (best option for sample counts below

256), and ‘sobol‘ (slowest but best quality, better than ‘sobol_blue‘ for sample counts greater than 256).

background_color
: Default ‘"white"‘. Background color.

lookfrom
: Default ‘c(0,1,10)‘. Location of the camera.

lookat
: Default ‘c(0,0,0)‘. Location where the camera is pointed.

camera_up
: Default ‘c(0,1,0)‘. Vector indicating the "up" position of the camera.

aperture
: Default ‘0.1‘. Aperture of the camera. Smaller numbers will increase depth of field, causing less blurring in areas not in focus.

clamp_value
: Default ‘Inf‘. If a bright light or a reflective material is in the scene, occasionally there will be bright spots that will not go away even with a large number of samples. These can be removed (at the cost of slightly darkening the image) by setting this to a small number greater than 1.

filename
: Default ‘NULL‘. If present, the renderer will write to the filename instead of the current device.

shutteropen
: Default ‘0‘. Time at which the shutter is open. Only affects moving objects.

shutterclose
: Default ‘1‘. Time at which the shutter is open. Only affects moving objects.

focal_distance
: Default ‘NULL‘, automatically set to the ‘lookfrom-lookat‘ distance unless otherwise specified.

ortho_dimensions
: Default ‘c(1,1)‘. Width and height of the orthographic camera. Will only be used if ‘fov = 0‘.

parallel
: Default ‘FALSE‘. If ‘TRUE‘, it will use all available cores to render the image (or the number specified in ‘options("cores")‘ if that option is not ‘NULL‘).

bvh_type
: Default ‘"sah"‘, "surface area heuristic". Method of building the bounding volume hierarchy structure used when rendering. Other option is "equal", which splits tree into groups of equal size.

progress
: Default ‘TRUE‘ if interactive session, ‘FALSE‘ otherwise.

verbose
: Default ‘FALSE‘. Prints information and timing information about scene construction and raytracing progress.

Value

Raytraced plot to current device, or an image saved to a file. Invisibly returns the array (containing either debug data or the RGB)

Examples

```
#Generate and render a regular scene and an ambient occlusion version of that scene
if(run_documentation()) {
angles = seq(0,360,by=36)
xx = rev(c(rep(c(1,0.5),5),1) * sinpi(angles/180))
yy = rev(c(rep(c(1,0.5),5),1) * cospi(angles/180))
star_polygon = data.frame(x=xx,y=yy)
hollow_star = rbind(star_polygon,0.8*star_polygon)
```

```
generate_ground(material = diffuse(color="grey20", checkercolor = "grey50",sigma=90)) %>%
 add_object(sphere(material=metal())) %>%
 add_object(obj_model(r_obj(),y=-0.25,x=-1.8,scale=2,
                      angle=c(0,135,0),material = diffuse(sigma=90))) %>%
 add_object(pig(x=1.8,y=-1.2,scale=0.5,angle=c(0,90,0),diffuse_sigma = 90)) %>%
 add_object(extruded_polygon(hollow_star,top=-0.5,bottom=-1, z=-2,
                             hole = nrow(star_polygon),
                             material=diffuse(color="red",sigma=90))) %>%
 render_scene(parallel = TRUE,width=800,height=800,
             fov=70,clamp_value=10,samples=16, aperture=0.1,
             lookfrom=c(-0.9,1.2,-4.5),lookat=c(0,-1,0))
}
if(run_documentation()) {

#Render the scene with ambient occlusion
generate_ground(material = diffuse(color="grey20", checkercolor = "grey50",sigma=90)) %>%
 add_object(sphere(material=metal())) %>%
 add_object(obj_model(r_obj(),y=-0.25,x=-1.8,scale=2,
                      angle=c(0,135,0),material = diffuse(sigma=90))) %>%
 add_object(pig(x=1.8,y=-1.2,scale=0.5,angle=c(0,90,0),diffuse_sigma = 90)) %>%
 add_object(extruded_polygon(hollow_star,top=-0.5,bottom=-1, z=-2,
                             hole = nrow(star_polygon),
                             material=diffuse(color="red",sigma=90))) %>%
 render_ao(parallel = TRUE,width=800,height=800, sample_dist=10,
          fov=70,samples=16, aperture=0.1,
          lookfrom=c(-0.9,1.2,-4.5),lookat=c(0,-1,0))
 }
if(run_documentation()) {
#Decrease the ray occlusion search distance
generate_ground(material = diffuse(color="grey20", checkercolor = "grey50",sigma=90)) %>%
 add_object(sphere(material=metal())) %>%
 add_object(obj_model(r_obj(),y=-0.25,x=-1.8,scale=2,
                      angle=c(0,135,0),material = diffuse(sigma=90))) %>%
 add_object(pig(x=1.8,y=-1.2,scale=0.5,angle=c(0,90,0),diffuse_sigma = 90)) %>%
 add_object(extruded_polygon(hollow_star,top=-0.5,bottom=-1, z=-2,
                             hole = nrow(star_polygon),
                             material=diffuse(color="red",sigma=90))) %>%
 render_ao(parallel = TRUE,width=800,height=800, sample_dist=1,
          fov=70,samples=16, aperture=0.1,
          lookfrom=c(-0.9,1.2,-4.5),lookat=c(0,-1,0))
}
if(run_documentation()) {
#Turn on colors
generate_ground(material = diffuse(color="grey20", checkercolor = "grey50",sigma=90)) %>%
 add_object(sphere(material=metal())) %>%
 add_object(obj_model(r_obj(), y=-0.25,x=-1.8,scale=2,
                      angle=c(0,135,0),material = diffuse(sigma=90))) %>%
 add_object(pig(x=1.8,y=-1.2,scale=0.5,angle=c(0,90,0),diffuse_sigma = 90)) %>%
 add_object(extruded_polygon(hollow_star,top=-0.5,bottom=-1, z=-2,
                             hole = nrow(star_polygon),
                             material=diffuse(color="red",sigma=90))) %>%
 render_ao(parallel = TRUE,width=800,height=800, sample_dist=1,
```

```
          fov=70,samples=16, aperture=0.1, keep_colors = TRUE,
          lookfrom=c(-0.9,1.2,-4.5),lookat=c(0,-1,0))

}
```

---

render_preview *Render Preview*

Description

Takes the scene description and renders an image, either to the device or to a filename.

Usage

```
render_preview(..., light_direction = c(0, -1, 0), exponent = 6)
```

Arguments

...	All arguments that would be passed to 'render_scene()'.
light_direction	Default 'c(0,-1,0)'. Vector specifying the orientation for the global light using for phong shading.
exponent	Default '6'. Phong exponent.

Value

Raytraced plot to current device, or an image saved to a file.

Examples

```
if(run_documentation()) {
generate_ground(material=diffuse(color="darkgreen")) %>%
  add_object(sphere(material=diffuse(checkercolor="red"))) %>%
  render_preview()
  }
if(run_documentation()) {
#Change the light direction
generate_ground(material=diffuse(color="darkgreen")) %>%
  add_object(sphere(material=diffuse(checkercolor="red"))) %>%
  render_preview(light_direction = c(-1,-1,0))
}
if(run_documentation()) {
#Change the Phong exponent
generate_ground(material=diffuse(color="darkgreen")) %>%
  add_object(sphere(material=diffuse(checkercolor="red"))) %>%
  render_preview(light_direction = c(-1,-1,0), exponent=100)
}
```

render_scene *Render Scene*

Description

Takes the scene description and renders an image, either to the device or to a filename. The user can also interactively fly around the 3D scene if they have X11 support on their system or are on Windows.

Usage

```
render_scene(
  scene,
  width = 400,
  height = 400,
  fov = 20,
  samples = 100,
  camera_description_file = NA,
  preview = interactive(),
  interactive = TRUE,
  denoise = TRUE,
  camera_scale = 1,
  iso = 100,
  film_size = 22,
  min_variance = 0,
  min_adaptive_size = 8,
  sample_method = "sobol_blue",
  max_depth = NA,
  roulette_active_depth = 100,
  ambient_light = NULL,
  lookfrom = c(0, 1, 10),
  lookat = c(0, 0, 0),
  camera_up = c(0, 1, 0),
  aperture = 0.1,
  clamp_value = Inf,
  filename = NULL,
  backgroundhigh = "#80b4ff",
  backgroundlow = "#ffffff",
  shutteropen = 0,
  shutterclose = 1,
  focal_distance = NULL,
  ortho_dimensions = c(1, 1),
  tonemap = "gamma",
  bloom = TRUE,
  parallel = TRUE,
  bvh_type = "sah",
  environment_light = NULL,
```

```
  rotate_env = 0,
  intensity_env = 1,
  transparent_background = FALSE,
  debug_channel = "none",
  return_raw_array = FALSE,
  progress = interactive(),
  verbose = FALSE,
  print_debug_info = FALSE,
  new_page = TRUE,
  integrator_type = "rtiow"
)
```

Arguments

`scene` Tibble of object locations and properties.

`width` Default '400'. Width of the render, in pixels.

`height` Default '400'. Height of the render, in pixels.

`fov` Default '20'. Field of view, in degrees. If this is '0', the camera will use an orthographic projection. The size of the plane used to create the orthographic projection is given in argument 'ortho_dimensions'. From '0' to '180', this uses a perspective projections. If this value is '360', a 360 degree environment image will be rendered.

`samples` Default '100'. The maximum number of samples for each pixel. If this is a length-2 vector and the 'sample_method' is 'stratified', this will control the number of strata in each dimension. The total number of samples in this case will be the product of the two numbers.

`camera_description_file` Default 'NA'. Filename of a camera description file for rendering with a realistic camera. Several camera files are built-in: '"50mm"','"wide"','"fisheye"', and '"telephoto"'.

`preview` Default 'interactive()'. Whether to display a real-time progressive preview of the render. Press ESC to cancel the render.

`interactive` Default 'interactive()'. Whether the scene preview should be interactive. Camera movement orbits around the lookat point (unless the mode is switched to free flying), with the following control mapping: W = Forward, S = Backward, A = Left, D = Right, Q = Up, Z = Down, E = 2x Step Distance (max 128), C = 0.5x Step Distance, Up Key = Zoom In (decrease FOV), Down Key = Zoom Out (increase FOV), Left Key = Decrease Aperture, Right Key = Increase Aperture, 1 = Decrease Focal Distance, 2 = Increase Focal Distance, 3/4 = Rotate Environment Light, R = Reset Camera, TAB: Toggle Orbit Mode, Left Mouse Click: Change Look Direction, Right Mouse Click: Change Look At K: Save Keyframe (at the conclusion of the render, this will create the 'ray_keyframes' data.frame in the global environment, which can be passed to 'generate_camera_motion()' to tween between those saved positions. L: Reset Camera to Last Keyframe (if set) F: Toggle Fast Travel Mode

Initial step size is 1/20th of the distance from 'lookat' to 'lookfrom'.

Note: Clicking on the environment image will only redirect the view direction, not change the orbit point. Some options aren't available all cameras. When using a realistic camera, the aperture and field of view cannot be changed from their initial settings. Additionally, clicking to direct the camera at the background environment image while using a realistic camera will not always point to the exact position selected.

denoise
: Default 'TRUE'. Whether to de-noise the final image and preview images. Note, this requires the free Intel Open Image Denoise (OIDN) library be installed on your system. Pre-compiled binaries can be installed from ppenimagedenoise.org, as well as . Linking during rayrender installation is done by defining the environment variable OIDN_PATH (set it in the .Renviron file by calling 'usethis::edit_r_environ()') to the top-level directory for OIDN (the directory containing the "lib", "bin", and "include" directories) and re-installing this package from source.

camera_scale
: Default '1'. Amount to scale the camera up or down in size. Use this rather than scaling a scene.

iso
: Default '100'. Camera exposure.

film_size
: Default '22', in 'mm' (scene units in 'm'. Size of the film if using a realistic camera, otherwise ignored.

min_variance
: Default '0'. Minimum acceptable variance for a block of pixels for the adaptive sampler. Smaller numbers give higher quality images, at the expense of longer rendering times. If this is set to zero, the adaptive sampler will be turned off and the renderer will use the maximum number of samples everywhere.

min_adaptive_size
: Default '8'. Width of the minimum block size in the adaptive sampler.

sample_method
: Default 'sobol'. The type of sampling method used to generate random numbers. The other options are 'random' (worst quality but fastest), 'stratified' (only implemented for completion), 'sobol_blue' (best option for sample counts below 256), and 'sobol' (slowest but best quality, better than 'sobol_blue' for sample counts greater than 256). If 'samples > 256' and 'sobol_blue' is selected, the method will automatically switch to 'sample_method = "sobol"'.

max_depth
: Default 'NA', automatically sets to 50. Maximum number of bounces a ray can make in a scene. Alternatively, if a debugging option is chosen, this sets the bounce to query the debugging parameter (only for some options).

roulette_active_depth
: Default '100'. Number of ray bounces until a ray can stop bouncing via Russian roulette.

ambient_light
: Default 'FALSE', unless there are no emitting objects in the scene. If 'TRUE', the background will be a gradient varying from 'backgroundhigh' directly up (+y) to 'backgroundlow' directly down (-y).

lookfrom
: Default 'c(0,1,10)'. Location of the camera.

lookat
: Default 'c(0,0,0)'. Location where the camera is pointed.

camera_up
: Default 'c(0,1,0)'. Vector indicating the "up" position of the camera.

aperture
: Default '0.1'. Aperture of the camera. Smaller numbers will increase depth of field, causing less blurring in areas not in focus.

clamp_value Default 'Inf'. If a bright light or a reflective material is in the scene, occasionally there will be bright spots that will not go away even with a large number of samples. These can be removed (at the cost of slightly darkening the image) by setting this to a small number greater than 1.

filename Default 'NULL'. If present, the renderer will write to the filename instead of the current device.

backgroundhigh Default '#80b4ff'. The "high" color in the background gradient. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

backgroundlow Default '#ffffff'. The "low" color in the background gradient. Can be either a hexadecimal code, or a numeric rgb vector listing three intensities between '0' and '1'.

shutteropen Default '0'. Time at which the shutter is open. Only affects moving objects.

shutterclose Default '1'. Time at which the shutter is open. Only affects moving objects.

focal_distance Default 'NULL', automatically set to the 'lookfrom-lookat' distance unless otherwise specified.

ortho_dimensions
Default 'c(1,1)'. Width and height of the orthographic camera. Will only be used if 'fov = 0'.

tonemap Default 'gamma'. Choose the tone mapping function, Default 'gamma' solely adjusts for gamma and clamps values greater than 1 to 1. 'reinhold' scales values by their individual color channels 'color/(1+color)' and then performs the gamma adjustment. 'uncharted' uses the mapping developed for Uncharted 2 by John Hable. 'hbd' uses an optimized formula by Jim Hejl and Richard Burgess-Dawson. If 'raw', the raw array of HDR values will be returned, rather than an image or a plot.

bloom Default 'TRUE'. Set to 'FALSE' to get the raw, pathtraced image. Otherwise, this performs a convolution of the HDR image of the scene with a sharp, long-tailed exponential kernel, which does not visibly affect dimly pixels, but does result in emitters light slightly bleeding into adjacent pixels. This provides an antialiasing effect for lights, even when tonemapping the image. Pass in a matrix to specify the convolution kernel manually, or a positive number to control the intensity of the bloom (higher number = more bloom).

parallel Default 'TRUE'. If 'FALSE', it will use all available cores to render the image (or the number specified in 'options("cores")' or 'options("Ncpus")' if that option is not 'NULL').

bvh_type Default '"sah"', "surface area heuristic". Method of building the bounding volume hierarchy structure used when rendering. Other option is "equal", which splits tree into groups of equal size.

environment_light
Default 'NULL'. An image to be used for the background for rays that escape the scene. Supports both HDR ('.hdr') and low-dynamic range ('.png', '.jpg') images.

rotate_env Default '0'. The number of degrees to rotate the environment map around the scene.

intensity_env: Default ‘1‘. The amount to increase the intensity of the environment lighting. Useful if using a LDR (JPEG or PNG) image as an environment map.

transparent_background: Default ‘FALSE‘. If ‘TRUE‘, any initial camera rays that escape the scene will be marked as transparent in the final image. If for a pixel some rays escape and others hit a surface, those pixels will be partially transparent.

debug_channel: Default ‘none‘. If ‘depth‘, function will return a depth map of rays into the scene instead of an image. If ‘normals‘, function will return an image of scene normals, mapped from 0 to 1. If ‘uv‘, function will return an image of the uv coords. If ‘variance‘, function will return an image showing the number of samples needed to take for each block to converge. If ‘dpdu‘ or ‘dpdv‘, function will return an image showing the differential ‘u‘ and ‘u‘ coordinates. If ‘color‘, function will return the raw albedo values (with white for ‘metal‘ and ‘dielectric‘ materials).

return_raw_array: Default ‘FALSE‘. If ‘TRUE‘, function will return raw array with RGB intensity information.

progress: Default ‘interactive()‘ if interactive session, ‘FALSE‘ otherwise.

verbose: Default ‘FALSE‘. Prints information and timing information about scene construction and raytracing progress.

print_debug_info: Default ‘FALSE‘. This will print out additional information on the compilation environment with each render.

new_page: Default ‘TRUE‘. Whether to call ‘grid::grid.newpage()‘ when plotting the image (if no filename specified). Set to ‘FALSE‘ for faster plotting (does not affect render time).

integrator_type: Default ‘"rtiow"‘ (the algorithm specified in the book "Raytracing in One Weekend", a basic form of path guiding). Other options include ‘"nee"‘ (Next Event Estimation, with direct light sampling) and ‘"basic"‘ (basic pathtracing, for high sample reference renders and debugging only).

Value

A pathtraced image to the current device, or an image saved to a file. Invisibly returns the array (containing either debug data or the RGB).

Examples

```
# Generate a large checkered sphere as the ground
if (run_documentation()) {
  scene = generate_ground(depth = -0.5,
                         material = diffuse(color = "white", checkercolor = "darkgreen"))
  render_scene(scene, parallel = TRUE, samples = 16, sample_method = "sobol")
}
if (run_documentation()) {
  # Add a sphere to the center
  scene = scene %>%
```

```
   add_object(sphere(x = 0, y = 0, z = 0, radius = 0.5, material = diffuse(color = c(1, 0, 1))))
  render_scene(scene, fov = 20, parallel = TRUE, samples = 16)
}
if (run_documentation()) {
  # Add a marbled cube
  scene = scene %>%
    add_object(cube(x = 1.1, y = 0, z = 0, material = diffuse(noise = 3)))
  render_scene(scene, fov = 20, parallel = TRUE, samples = 16)
}
if (run_documentation()) {
  # Add a metallic gold sphere, using stratified sampling for a higher quality render
  # We also add a light, which turns off the default ambient lighting
  scene = scene %>%
    add_object(sphere(x = -1.1, y = 0, z = 0, radius = 0.5,
                      material = metal(color = "gold", fuzz = 0.1))) %>%
    add_object(sphere(y=10,z=13,radius=2,material=light(intensity=40)))
  render_scene(scene, fov = 20, parallel = TRUE, samples = 16)
}
if (run_documentation()) {
  # Lower the number of samples to render more quickly (here, we also use only one core).
  render_scene(scene, samples = 4, parallel = FALSE)
}
if (run_documentation()) {
  # Add a floating R plot using the iris dataset as a png onto a floating 2D rectangle
  tempfileplot = tempfile()
  png(filename = tempfileplot, height = 400, width = 800)
  plot(iris$Petal.Length, iris$Sepal.Width, col = iris$Species, pch = 18, cex = 4)
  dev.off()
  image_array = aperm(png::readPNG(tempfileplot), c(2, 1, 3))
  scene = scene %>%
    add_object(xy_rect(x = 0, y = 1.1, z = 0, xwidth = 2, angle = c(0, 0, 0),
                       material = diffuse(image_texture = image_array)))
  render_scene(scene, fov = 20, parallel = TRUE, samples = 16)
}
if (run_documentation()) {
  # Move the camera
 render_scene(scene, lookfrom = c(7, 1.5, 10), lookat = c(0, 0.5, 0), fov = 15, parallel = TRUE)
}
if (run_documentation()) {
  # Change the background gradient to a firey sky
  render_scene(scene, lookfrom = c(7, 1.5, 10), lookat = c(0, 0.5, 0), fov = 15,
               backgroundhigh = "orange", backgroundlow = "red", parallel = TRUE,
               ambient = TRUE,
               samples = 16)
}
if (run_documentation()) {
  # Increase the aperture to blur objects that are further from the focal plane.
  render_scene(scene, lookfrom = c(7, 1.5, 10), lookat = c(0, 0.5, 0), fov = 15,
               aperture = 1, parallel = TRUE, samples = 16)
}
if (run_documentation()) {
 # We can also capture a 360 environment image by setting `fov = 360` (can be used for VR)
  generate_cornell() %>%
```

```
  add_object(ellipsoid(x = 555 / 2, y = 100, z = 555 / 2, a = 50, b = 100, c = 50,
                       material = metal(color = "lightblue"))) %>%
 add_object(cube(x = 100, y = 130 / 2, z = 200, xwidth = 130, ywidth = 130, zwidth = 130,
                  material = diffuse(checkercolor = "purple",
                                     checkerperiod = 30), angle = c(0, 10, 0))) %>%
  add_object(pig(x = 100, y = 190, z = 200, scale = 40, angle = c(0, 30, 0))) %>%
  add_object(sphere(x = 420, y = 555 / 8, z = 100, radius = 555 / 8,
                    material = dielectric(color = "orange"))) %>%
  add_object(xz_rect(x = 555 / 2, z = 555 / 2, y = 1, xwidth = 555, zwidth = 555,
                     material = glossy(checkercolor = "white",
                                       checkerperiod = 10, color = "dodgerblue"))) %>%
  render_scene(lookfrom = c(278, 278, 30), lookat = c(278, 278, 500), clamp_value = 10,
               fov = 360,  samples = 16, width = 800, height = 800)
}
if (run_documentation()) {
 # Spin the camera around the scene, decreasing the number of samples to render faster. To make
 # an animation, specify the a filename in `render_scene` for each frame and use the `av` package
  # or ffmpeg to combine them all into a movie.
  t = 1:30
  xpos = 10 * sin(t * 12 * pi / 180 + pi / 2)
  zpos = 10 * cos(t * 12 * pi / 180 + pi / 2)
  # Save old par() settings
  old.par = par(no.readonly = TRUE)
  on.exit(par(old.par))
  par(mfrow = c(5, 6))
  for (i in 1:30) {
    render_scene(scene, samples = 16,
                 lookfrom = c(xpos[i], 1.5, zpos[i]), lookat = c(0, 0.5, 0), parallel = TRUE)
  }
}
```

---

run_documentation *Run Documentation*

Description

This function determines if the examples are being run in pkgdown. It is not meant to be called by the user.

Usage

```
run_documentation()
```

Value

Boolean value.

Examples

```
# See if the documentation should be run.
run_documentation()
```

r_obj	*R 3D Model*

Description

3D obj model of R logo (created from the R SVG logo with the ‘raybevel‘ package), to be used with ‘obj_model()‘

Usage

```
r_obj(simple_r = FALSE)
```

Arguments

simple_r	Default ‘FALSE‘. If ‘TRUE‘, this will return a 3D R (instead of the R logo).

Value

File location of the 3d_r_logo.obj file (saved with a .txt extension)

Examples

```
#Load and render the included example R object file.
if(run_documentation()) {
generate_ground(material = diffuse(noise = TRUE, noisecolor = "grey20")) %>%
  add_object(sphere(x = 2, y = 3, z = 2, radius = 1,
                    material = light(intensity = 10))) %>%
  add_object(obj_model(r_obj(), scale=2.5,  material = diffuse(color="red"))) %>%
  render_scene(parallel=TRUE, lookfrom = c(0, 1, 10), clamp_value = 5, samples = 200)
}
```

segment	*Segment Object*

Description

Similar to the cylinder object, but specified by start and end points.

Usage

```
segment(
  start = c(0, -1, 0),
  end = c(0, 1, 0),
  radius = 0.1,
  phi_min = 0,
  phi_max = 360,
```

```
  from_center = TRUE,
  direction = NA,
  material = diffuse(),
  capped = TRUE,
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

start	Default 'c(0, -1, 0)'. Start point of the cylinder segment, specifing 'x', 'y', 'z'.
end	Default 'c(0, 1, 0)'. End point of the cylinder segment, specifing 'x', 'y', 'z'.
radius	Default '1'. Radius of the segment.
phi_min	Default '0'. Minimum angle around the segment.
phi_max	Default '360'. Maximum angle around the segment.
from_center	Default 'TRUE'. If orientation specified via 'direction', setting this argument to 'FALSE' will make 'start' specify the bottom of the segment, instead of the middle.
direction	Default 'NA'. Alternative to 'start' and 'end', specify the direction (via a length-3 vector) of the segment. Segment will be centered at 'start', and the length will be determined by the magnitude of the direction vector.
material	Default diffuse.The material, called from one of the material functions diffuse, metal, or dielectric.
capped	Default 'TRUE'. Whether to add caps to the segment. Turned off when using the 'light()' material.
flipped	Default 'FALSE'. Whether to flip the normals.
scale	Default 'c(1, 1, 1)'. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Notes: this will change the stated start/end position of the segment. Emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the segment in the scene.

Examples

```
#Generate a segment in the cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(segment(start = c(100, 100, 100), end = c(455, 455, 455), radius = 50)) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}

# Draw a line graph representing a normal distribution, but with metal:
xvals = seq(-3, 3, length.out = 30)
```

```
yvals = dnorm(xvals)

scene_list = list()
for(i in 1:(length(xvals) - 1)) {
  scene_list[[i]] = segment(start = c(555/2 + xvals[i] * 80, yvals[i] * 800, 555/2),
                           end = c(555/2 + xvals[i + 1] * 80, yvals[i + 1] * 800, 555/2),
                            radius = 10,
                            material = metal())
}
scene_segments = do.call(rbind,scene_list)
if(run_documentation()) {
generate_cornell() %>%
  add_object(scene_segments) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}

#Draw the outline of a cube:

cube_outline = segment(start = c(100, 100, 100), end = c(100, 100, 455), radius = 10) %>%
  add_object(segment(start = c(100, 100, 100), end = c(100, 455, 100), radius = 10)) %>%
  add_object(segment(start = c(100, 100, 100), end = c(455, 100, 100), radius = 10)) %>%
  add_object(segment(start = c(100, 100, 455), end = c(100, 455, 455), radius = 10)) %>%
  add_object(segment(start = c(100, 100, 455), end = c(455, 100, 455), radius = 10)) %>%
  add_object(segment(start = c(100, 455, 455), end = c(100, 455, 100), radius = 10)) %>%
  add_object(segment(start = c(100, 455, 455), end = c(455, 455, 455), radius = 10)) %>%
  add_object(segment(start = c(455, 455, 100), end = c(455, 100, 100), radius = 10)) %>%
  add_object(segment(start = c(455, 455, 100), end = c(455, 455, 455), radius = 10)) %>%
  add_object(segment(start = c(455, 100, 100), end = c(455, 100, 455), radius = 10)) %>%
  add_object(segment(start = c(455, 100, 455), end = c(455, 455, 455), radius = 10)) %>%
  add_object(segment(start = c(100, 455, 100), end = c(455, 455, 100), radius = 10))

if(run_documentation()) {
generate_cornell() %>%
  add_object(cube_outline) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}

#Shrink and rotate the cube
if(run_documentation()) {
generate_cornell() %>%
  add_object(group_objects(cube_outline, pivot_point = c(555/2, 555/2, 555/2),
                           angle = c(45,45,45), scale = c(0.5,0.5,0.5))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

set_scene_material *Set Material for All Objects*

Description

Set Material for All Objects

Usage

```
set_scene_material(scene, material)
```

Arguments

scene	A ray_scene object.
material	A material specification created by diffuse(), metal(), dielectric(), etc.

Value

A modified ray_scene with the new material applied to all objects

Examples

```
# Create a scene with different materials
scene = generate_cornell() %>%
  add_object(sphere(x=555/2, y=555/2, z=555/2, radius=100))

# Set all objects to be metallic
scene = set_scene_material(scene, metal(color="gold"))

# Set all objects to be glass
scene = set_scene_material(scene, dielectric())
```

---

sphere *Sphere Object*

Description

Sphere Object

Usage

```
sphere(
  x = 0,
  y = 0,
  z = 0,
  radius = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

- `x` — Default ‘0‘. x-coordinate of the center of the sphere.
- `y` — Default ‘0‘. y-coordinate of the center of the sphere.
- `z` — Default ‘0‘. z-coordinate of the center of the sphere.
- `radius` — Default ‘1‘. Radius of the sphere.
- `material` — Default `diffuse`. The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
- `angle` — Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
- `order_rotation` — Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
- `flipped` — Default ‘FALSE‘. Whether to flip the normals.
- `scale` — Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the sphere in the scene.

Examples

```
#Generate a sphere in the cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(sphere(x = 555/2, y = 555/2, z = 555/2, radius = 100)) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, clamp_value = 5)
}

#Generate a gold sphere in the cornell box
if(run_documentation()) {
generate_cornell() %>%
  add_object(sphere(x = 555/2, y = 100, z = 555/2, radius = 100,
                    material = microfacet(color = "gold"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, clamp_value = 5)
}
```

---

text3d *Text Object*

Description

Text Object

Usage

```
text3d(
  label,
  x = 0,
  y = 0,
  z = 0,
  text_height = 1,
  orientation = "xy",
  material = diffuse(),
  font = "sans",
  font_style = "plain",
  font_color = "black",
  font_lineheight = 1,
  font_size = 100,
  background_color = "white",
  background_alpha = 0,
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

`label`	Text string.
`x`	Default '0'. x-coordinate of the center of the label.
`y`	Default '0'. y-coordinate of the center of the label.
`z`	Default '0'. z-coordinate of the center of the label.
`text_height`	Default '1'. Height of the text.
`orientation`	Default 'xy'. Orientation of the plane. Other options are 'yz' and 'xz'.
`material`	Default `diffuse`. The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
`font`	Default '"sans"'. A character string specifying the font family (e.g., '"Arial"', '"Times"', '"Helvetica"').
`font_style`	A character string specifying the font style, such as '"plain"', '"italic"', or '"bold"'. Default is '"plain"'.
`font_color`	Default '"black"'. The font color.
`font_lineheight`	Default '12'. The lineheight for strings with newlines.
`font_size`	Default '100'. The size of the font. Note that this does not control the size of the text, just the resolution as rendered in the texture.
`background_color`	Default '"white"'. The background color.
`background_alpha`	Default '0'. The background opacity. '1' is fully opaque.

angle Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.

order_rotation Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".

flipped Default ‘FALSE‘. Whether to flip the normals.

scale Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the text in the scene.

Examples

```
#Generate a label in the cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(text3d(label="Cornell Box", x=555/2,y=555/2,z=555/2,text_height=60,
                    material=diffuse(color="grey10"), angle=c(0,180,0))) %>%
  render_scene(samples=16)
}
if(run_documentation()) {
#Change the orientation
generate_cornell() %>%
  add_object(text3d(label="YZ Plane", x=550,y=555/2,z=555/2,text_height=150,
                    orientation = "yz",
                    material=diffuse(color="grey10"), angle=c(0,180,0))) %>%
 add_object(text3d(label="XY Plane", z=550,y=555/2,x=555/2,text_height=150,
                    orientation = "xy",
                    material=diffuse(color="grey10"), angle=c(0,180,0))) %>%
 add_object(text3d(label="XZ Plane", z=555/2,y=5,x=555/2,text_height=150,
                    orientation = "xz",
                    material=diffuse(color="grey10"))) %>%
  render_scene(samples=16)
}
if(run_documentation()) {
#Add an label in front of a sphere
generate_cornell() %>%
  add_object(text3d(label="Cornell Box", x=555/2,y=555/2,z=555/2,text_height=90,
                    material=diffuse(color="grey10"), angle=c(0,180,0))) %>%
  add_object(text3d(label="Sphere", x=555/2,y=100,z=100,text_height=60,
                    material=diffuse(color="white"), angle=c(0,180,0))) %>%
  add_object(sphere(y=100,radius=100,z=555/2,x=555/2,
                    material=glossy(color="purple"))) %>%
  add_object(sphere(y=555,radius=100,z=-1000,x=555/2,
                    material=light(intensity=100,
                                   spotlight_focus=c(555/2,100,100)))) %>%
  render_scene(samples=16)
}
```

```
if(run_documentation()) {
#A room full of bees
bee_list = list()
for(i in 1:100) {
bee_list[[i]] = text3d("B", x=20+runif(1)*525, y=20+runif(1)*525, z=20+runif(1)*525,
                       text_height = 50, angle=c(0,180,0))
}
bees = do.call(rbind,bee_list)
generate_cornell() %>%
  add_object(bees) %>%
  render_scene(samples=16)
}
if(run_documentation()) {
# If you have ragg installed, you can also use color emojis.
library(rayrender)
generate_cornell(light_position = c(555/2,554,10),
                 lightwidth = 10, lightdepth = 100,
                 lightintensity = 800) |>
  add_object(text3d(label="\U1F30A",font_size = 500,angle=c(0,180,0),
                    x=555/2,y=555/2,z=260,text_height=1000)) |>
  add_object(text3d(label="\U1F6A3", x=180,y=140,z=260-50,
                    text_height=400, font_size = 500,
                    material=diffuse(color="black"),
                    angle=c(0,0,30))) |>
  add_object(text3d(label="\U1F5FB", x=180,y=230,z=260+50,text_height=300,
                    font_size = 500,material=diffuse(color="black"),
                    angle=c(0,0,0))) |>
  render_scene(samples=16)



}
```

---

triangle *Triangle Object*

Description

Triangle Object

Usage

```
triangle(
  v1 = c(1, 0, 0),
  v2 = c(0, 1, 0),
  v3 = c(-1, 0, 0),
  n1 = rep(NA, 3),
  n2 = rep(NA, 3),
  n3 = rep(NA, 3),
  color1 = rep(NA, 3),
```

```
  color2 = rep(NA, 3),
  color3 = rep(NA, 3),
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  reversed = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

v1	Default ‘c(1, 0, 0)‘. Length-3 vector indicating the x, y, and z coordinate of the first triangle vertex.
v2	Default ‘c(0, 1, 0)‘. Length-3 vector indicating the x, y, and z coordinate of the second triangle vertex.
v3	Default ‘c(-1, 0, 0)‘. Length-3 vector indicating the x, y, and z coordinate of the third triangle vertex.
n1	Default ‘NA‘. Length-3 vector indicating the normal vector associated with the first triangle vertex.
n2	Default ‘NA‘. Length-3 vector indicating the normal vector associated with the second triangle vertex.
n3	Default ‘NA‘. Length-3 vector indicating the normal vector associated with the third triangle vertex.
color1	Default ‘NA‘. Length-3 vector or string indicating the color associated with the first triangle vertex. If NA but other vertices specified, color inherits from material.
color2	Default ‘NA‘. Length-3 vector or string indicating the color associated with the second triangle vertex. If NA but other vertices specified, color inherits from material.
color3	Default ‘NA‘. Length-3 vector or string indicating the color associated with the third triangle vertex. If NA but other vertices specified, color inherits from material.
material	Default `diffuse`.The material, called from one of the material functions `diffuse`, `metal`, or `dielectric`.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default ‘FALSE‘. Whether to flip the normals.
reversed	Default ‘FALSE‘. Similar to the ‘flipped‘ argument, but this reverses the handedness of the triangle so it will be oriented in the opposite direction.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the XZ plane in the scene.

Examples

```
#Generate a triangle in the Cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(triangle(v1 = c(100, 100, 100), v2 = c(555/2, 455, 455), v3 = c(455, 100, 100),
                      material = diffuse(color = "purple"))) %>%
   render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
                ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
#Pass individual colors to each vertex:
if(run_documentation()) {
generate_cornell() %>%
  add_object(triangle(v1 = c(100, 100, 100), v2 = c(555/2, 455, 455), v3 = c(455, 100, 100),
                      color1 = "green", color2 = "yellow", color3 = "red")) %>%
   render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
                ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

---

xy_rect *Rectangular XY Plane Object*

Description

Rectangular XY Plane Object

Usage

```
xy_rect(
  x = 0,
  y = 0,
  z = 0,
  xwidth = 1,
  ywidth = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

x	Default ‘0‘. x-coordinate of the center of the rectangle.
y	Default ‘0‘. x-coordinate of the center of the rectangle.

z	Default ‘0‘. z-coordinate of the center of the rectangle.
xwidth	Default ‘1‘. x-width of the rectangle.
ywidth	Default ‘1‘. y-width of the rectangle.
material	Default diffuse.The material, called from one of the material functions diffuse, metal, or dielectric.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default ‘FALSE‘. Whether to flip the normals.
scale	Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the XY plane in the scene.

Examples

```
#Generate a purple rectangle in the cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(xy_rect(x = 555/2, y = 100, z = 555/2, xwidth = 200, ywidth = 200,
             material = diffuse(color = "purple"))) %>%
  render_scene(lookfrom = c(278, 278, -800), lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}

#Generate a gold plane in the cornell box
if(run_documentation()) {
generate_cornell() %>%
  add_object(xy_rect(x = 555/2, y = 100, z = 555/2,
                     xwidth = 200, ywidth = 200, angle = c(0, 30, 0),
                     material = metal(color = "gold"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

---

xz_rect *Rectangular XZ Plane Object*

Description

Rectangular XZ Plane Object

Usage

```
xz_rect(
  x = 0,
  xwidth = 1,
  z = 0,
  zwidth = 1,
  y = 0,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

x	Default '0'. x-coordinate of the center of the rectangle.
xwidth	Default '1'. x-width of the rectangle.
z	Default '0'. z-coordinate of the center of the rectangle.
zwidth	Default '1'. z-width of the rectangle.
y	Default '0'. y-coordinate of the center of the rectangle.
material	Default diffuse.The material, called from one of the material functions diffuse, metal, or dielectric.
angle	Default 'c(0, 0, 0)'. Angle of rotation around the x, y, and z axes, applied in the order specified in 'order_rotation'.
order_rotation	Default 'c(1, 2, 3)'. The order to apply the rotations, referring to "x", "y", and "z".
flipped	Default 'FALSE'. Whether to flip the normals.
scale	Default 'c(1, 1, 1)'. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the XZ plane in the scene.

Examples

```
#Generate a purple rectangle in the cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(xz_rect(x = 555/2, y = 100, z = 555/2, xwidth = 200, zwidth = 200,
             material = diffuse(color = "purple"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

```
#Generate a gold plane in the cornell box
if(run_documentation()) {
generate_cornell() %>%
  add_object(xz_rect(x = 555/2, y = 100, z = 555/2,
             xwidth = 200, zwidth = 200, angle = c(0, 30, 0),
             material = metal(color = "gold"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

---

yz_rect *Rectangular YZ Plane Object*

Description

Rectangular YZ Plane Object

Usage

```
yz_rect(
  x = 0,
  y = 0,
  z = 0,
  ywidth = 1,
  zwidth = 1,
  material = diffuse(),
  angle = c(0, 0, 0),
  order_rotation = c(1, 2, 3),
  flipped = FALSE,
  scale = c(1, 1, 1)
)
```

Arguments

x	Default ‘0‘. x-coordinate of the center of the rectangle.
y	Default ‘0‘. y-coordinate of the center of the rectangle.
z	Default ‘0‘. z-coordinate of the center of the rectangle.
ywidth	Default ‘1‘. y-width of the rectangle.
zwidth	Default ‘1‘. z-width of the rectangle.
material	Default diffuse.The material, called from one of the material functions diffuse, metal, or dielectric.
angle	Default ‘c(0, 0, 0)‘. Angle of rotation around the x, y, and z axes, applied in the order specified in ‘order_rotation‘.
order_rotation	Default ‘c(1, 2, 3)‘. The order to apply the rotations, referring to "x", "y", and "z".

`flipped` Default ‘FALSE‘. Whether to flip the normals.

`scale` Default ‘c(1, 1, 1)‘. Scale transformation in the x, y, and z directions. If this is a single value, number, the object will be scaled uniformly. Note: emissive objects may not currently function correctly when scaled.

Value

Single row of a tibble describing the YZ plane in the scene.

Examples

```
#Generate a purple rectangle in the cornell box.
if(run_documentation()) {
generate_cornell() %>%
  add_object(yz_rect(x = 100, y = 100, z = 555/2, ywidth = 200, zwidth = 200,
                     material = diffuse(color = "purple"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
#Generate a gold plane in the cornell box
if(run_documentation()) {
generate_cornell() %>%
  add_object(yz_rect(x = 100, y = 100, z = 555/2,
                     ywidth = 200, zwidth = 200, angle = c(0, 30, 0),
                     material = metal(color = "gold"))) %>%
  render_scene(lookfrom = c(278, 278, -800) ,lookat = c(278, 278, 0), fov = 40,
               ambient_light = FALSE, samples = 16, parallel = TRUE, clamp_value = 5)
}
```

Index