CRT – Intermediary Presentation

Hamza Haiken

24 June 2015

Introduction

CRT

- Stands for Cathode Ray Tracer
- Available on GitHub: https://github.com/Tenchi2xh/CRT

1 Introduction

2 Ray Tracing

3 CRT Language

4 Interface

5 Demonstration

6 Conclusion

Goal

- Artistic conception tool
- Realistic 3D images via ray tracing
- Physical light simulation
- Custom language

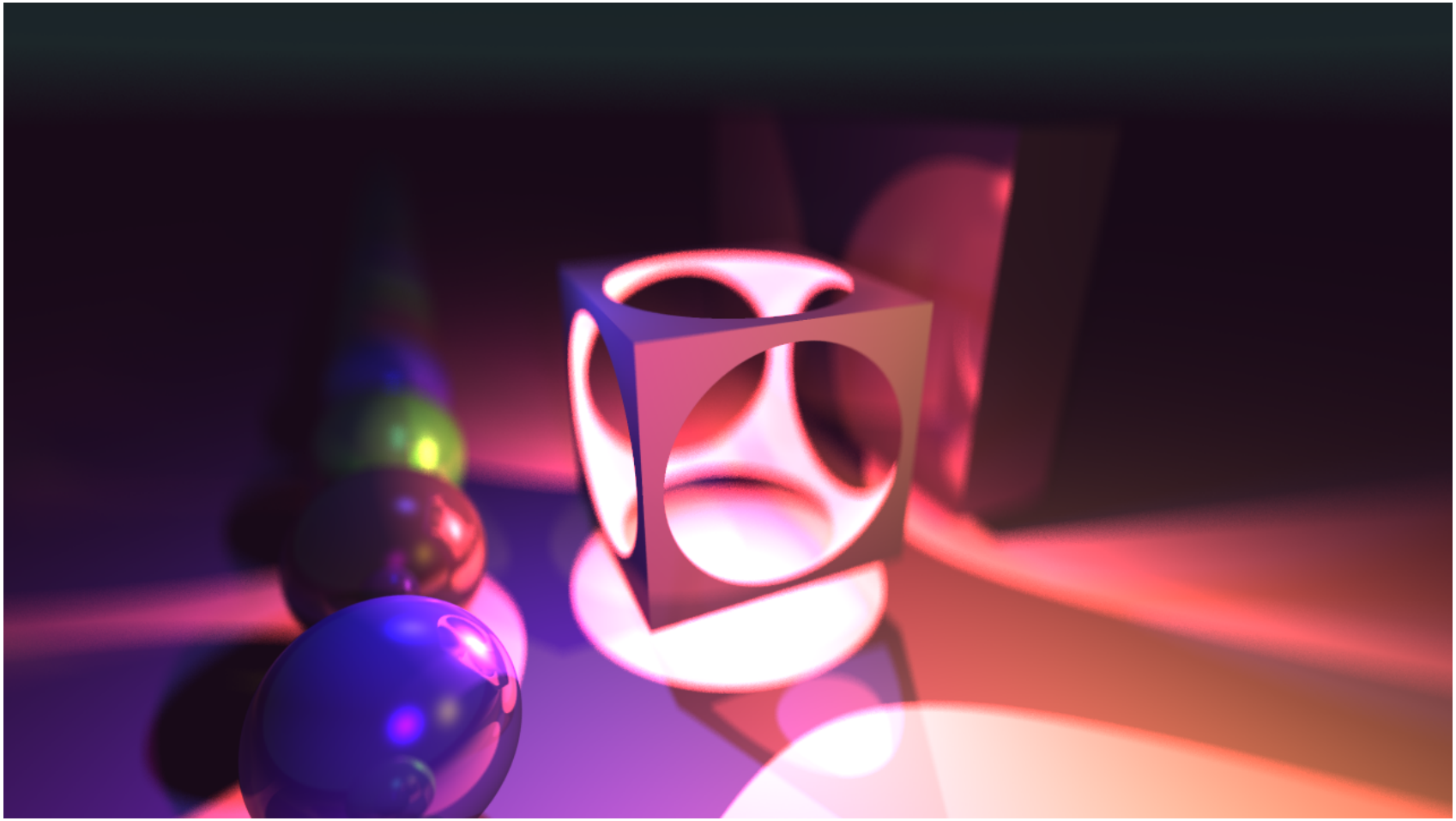


Figure 1: Example of a rendered 3D image

Ray Tracing

Classical method

- Live 3D uses rasterisation
- World is approximated using triangles
- Project triangles on screen
- Fill the gaps with color
- Many *hacks* to produce real-life effects
- Fast

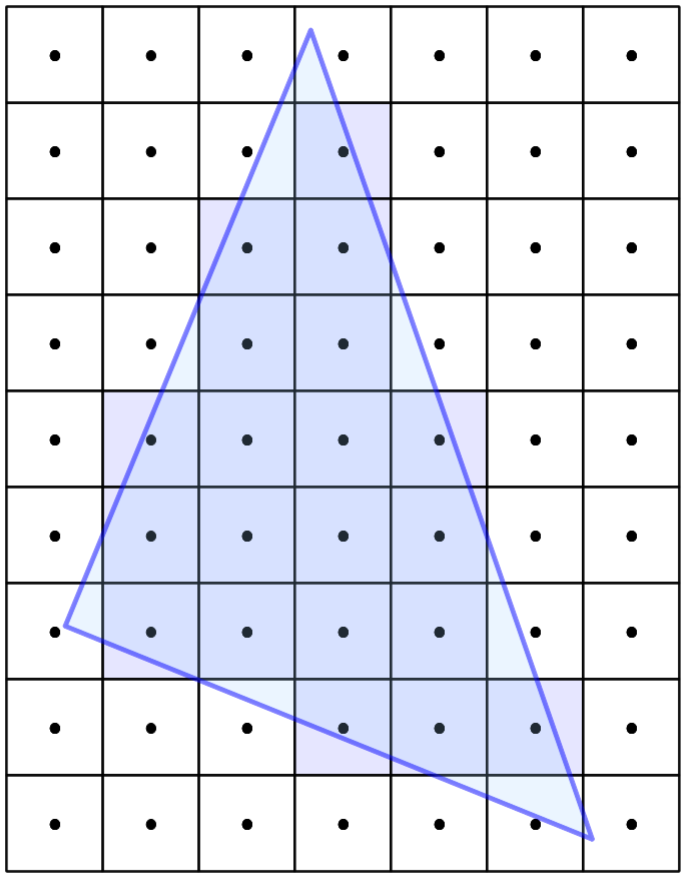


Figure 2: Rasterisation

Principle

- Simulate light's path and interactions with environment
- Objects absorb color from rays hitting them, makes colors
- Tracing forward like in nature is too costly
- Backward-tracing requires only one ray per pixel
- Rays are traced from the camera and look for light sources
- Rays can bounce off surfaces
- Effects are naturally derived from physics

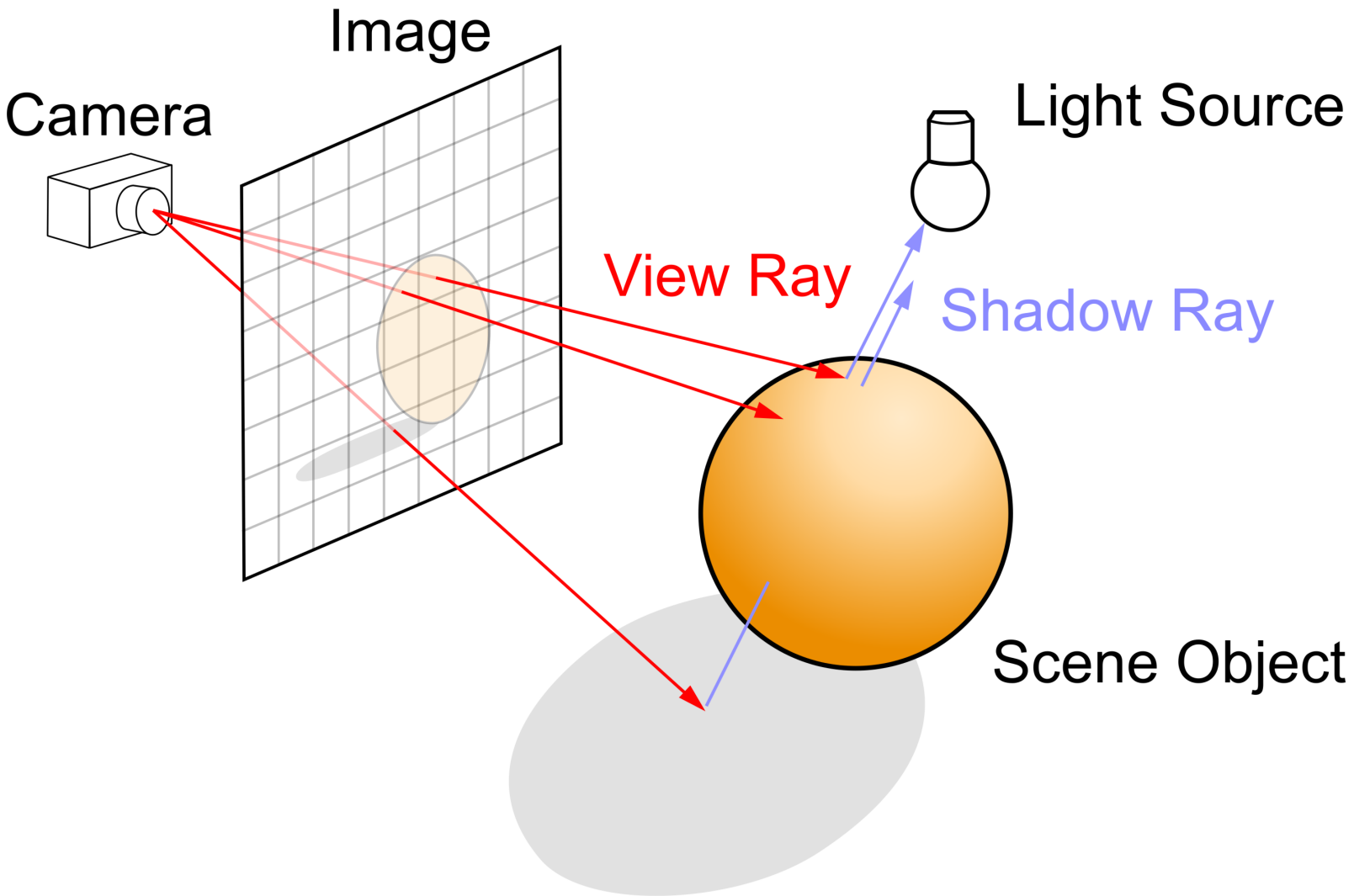


Figure 3: Backward-tracing

Modelization

- Top-level `Scene` object
- Contains `Entities` and `Lights`
- CSG is recursive

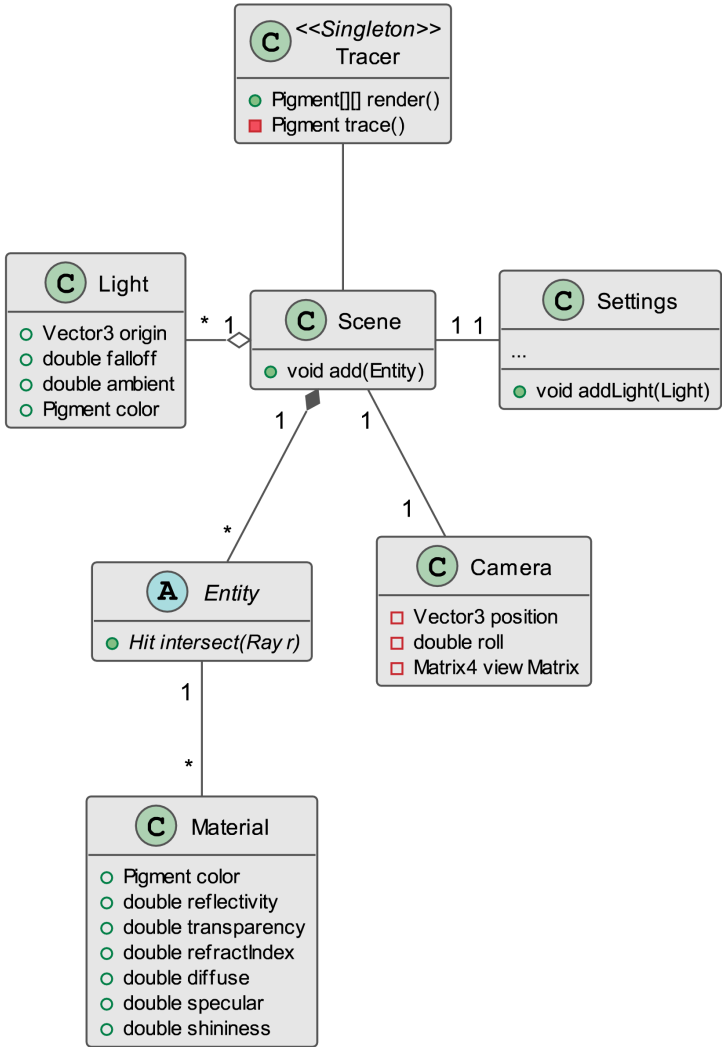


Figure 4: Rendering model

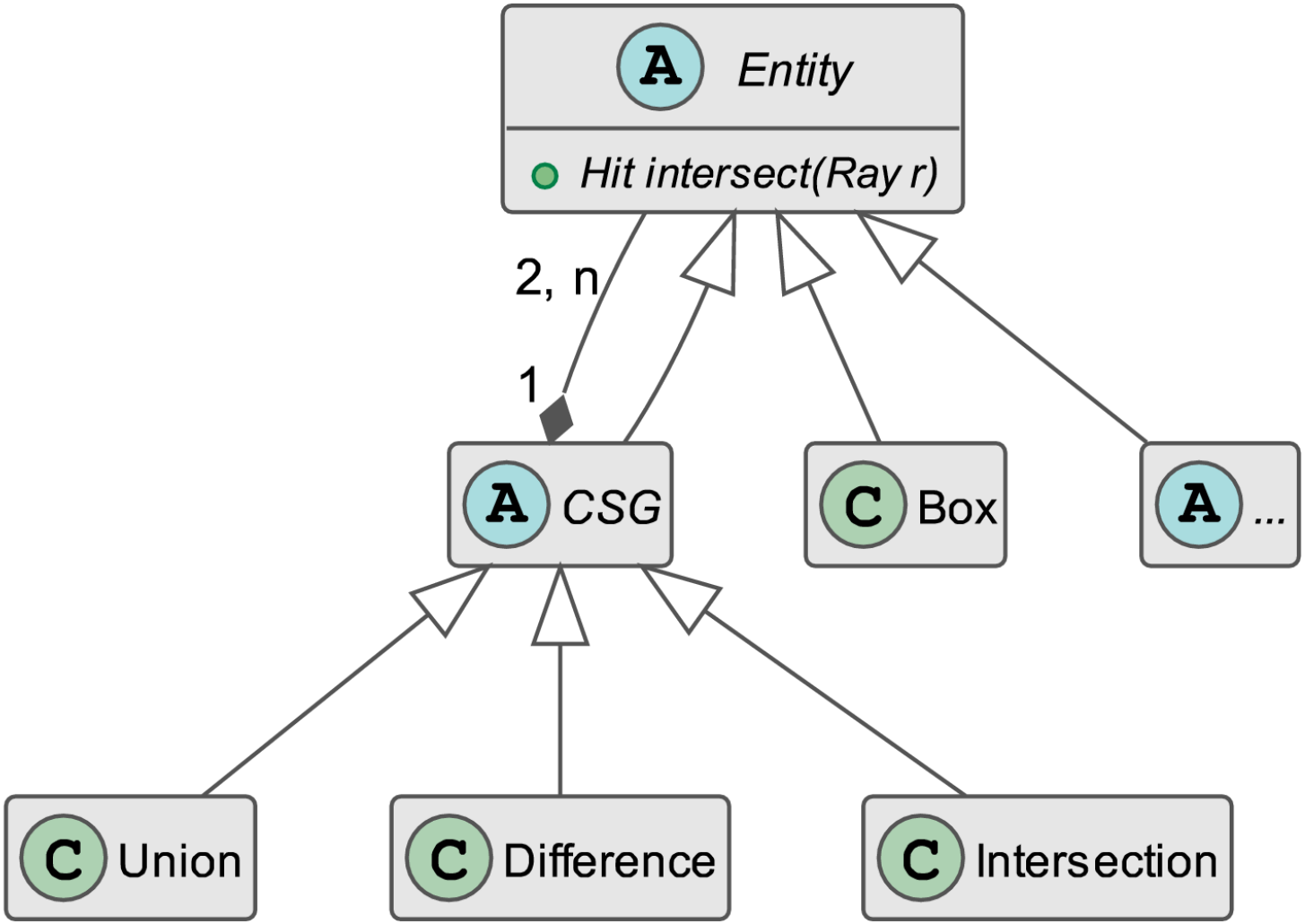


Figure 5: Entity model

Generating rays

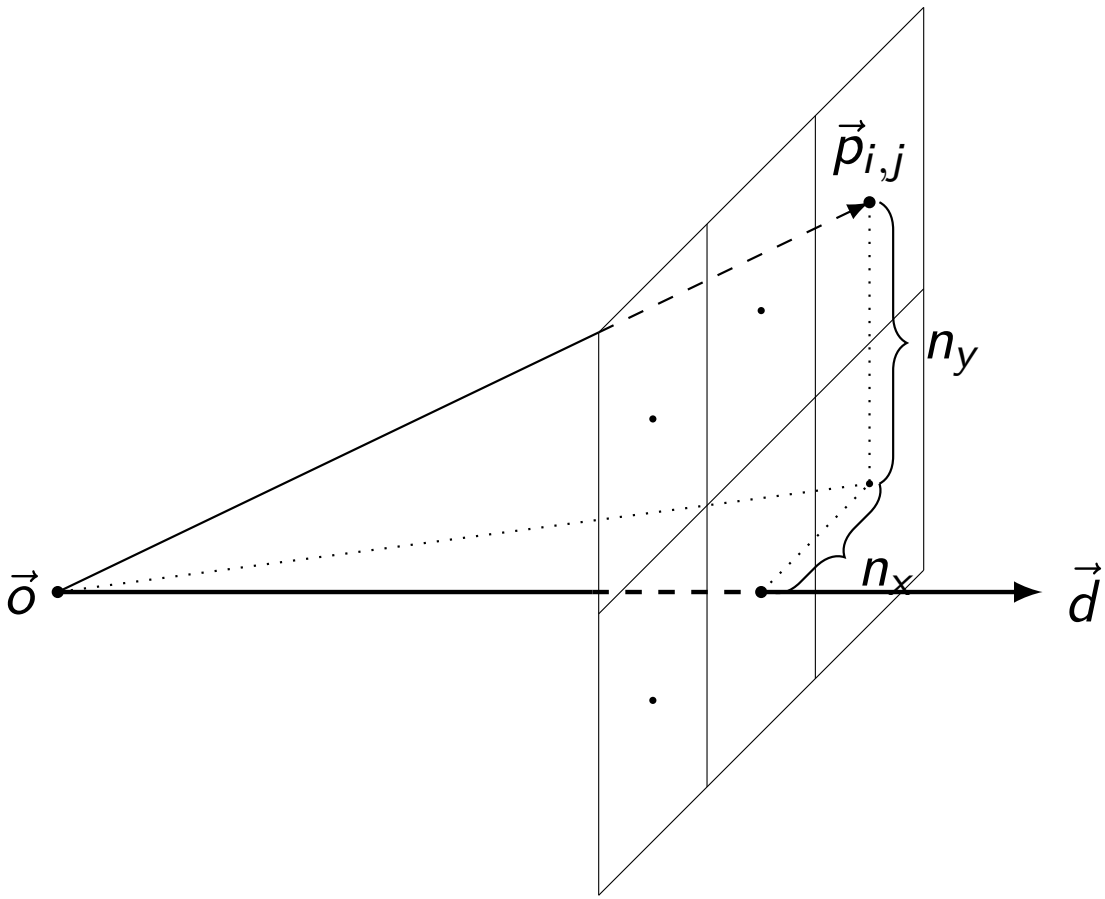


Figure 6: Primary ray generation

Shading

- Color of point depends on how ray touches surface:
  - Angle of incidence
  - Angle of the light source
  - Distance / number of bounces

- Inverse square law: $I \propto \frac{1}{t^2}$
- Ambient lighting hack: $\vec{c}_{\mathrm{a}} = I_{\mathrm{a}} \vec{l}_{\mathrm{c}}$
- Diffuse light, approximation using angle with normal: $\vec{c}_{\mathrm{d}} = \left[\vec{l}_{\mathrm{c}} I(\vec{l}_{\mathrm{d}} \cdot \vec{n})\right] \cdot (\vec{m}_{\mathrm{c}} m_{\mathrm{d}})$
- Specular light, using reflected rays: $\vec{c}_{\mathrm{s}} = (\vec{l'} \cdot \vec{r})^{m_{\mathrm{sh}}} m_{\mathrm{s}} I(\vec{l}_{\mathrm{c}} \cdot \vec{m}_{\mathrm{c}})$
- Final composite color for a pixel: $\vec{c}_{\mathrm{a}} + \vec{c}_{\mathrm{d}} + \vec{c}_{\mathrm{s}}$

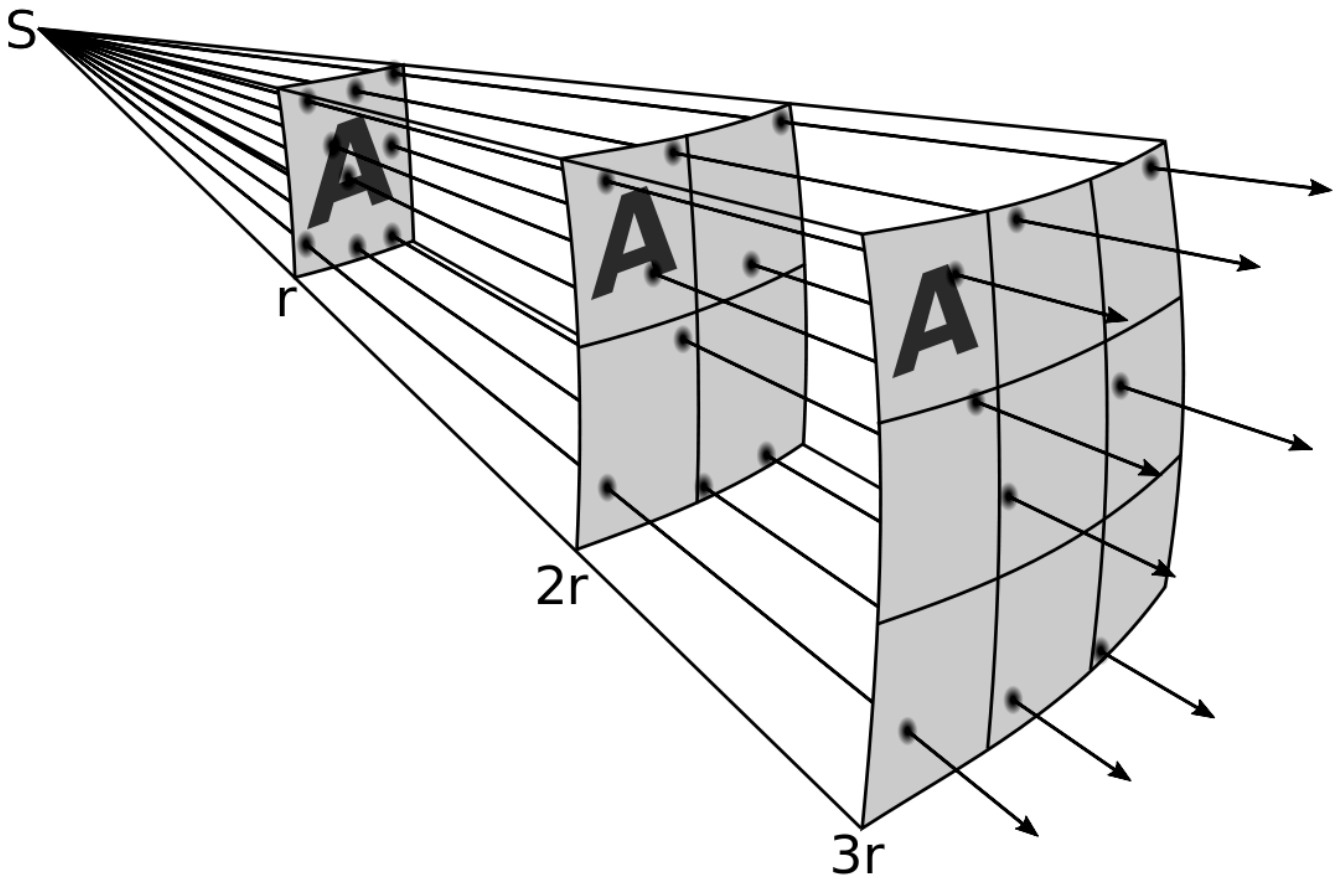
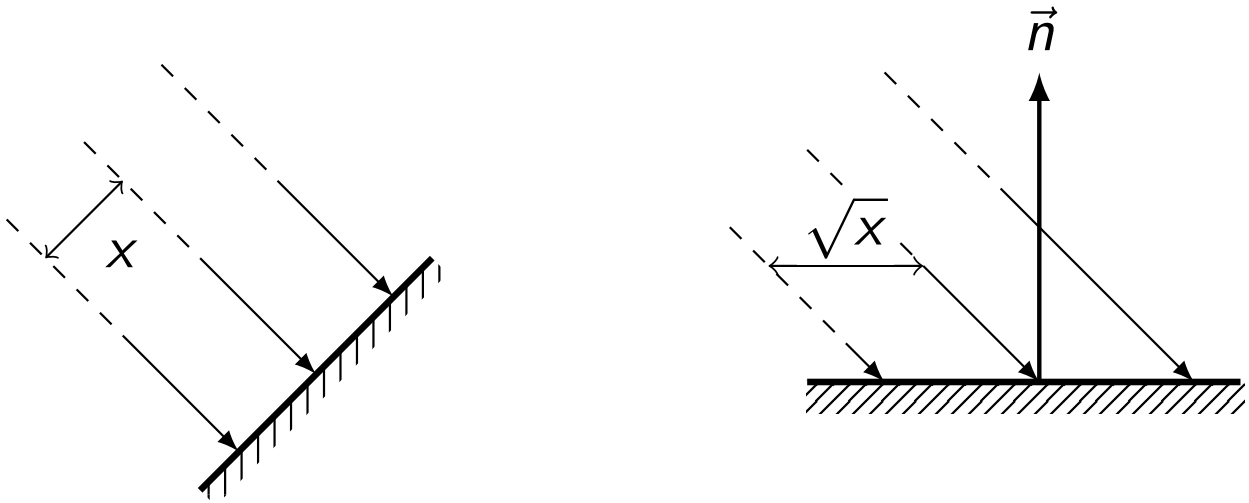
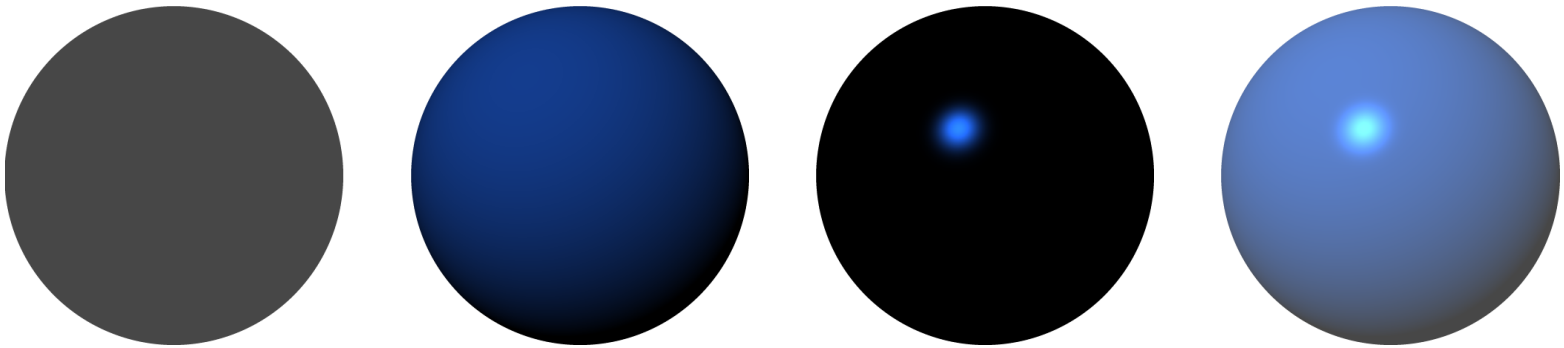


Figure 7: Demonstration of the inverse square law



(a) Rays parallel with normal (b) Rays at 45° with normal

Figure 8: Impact of normal angle for diffuse light



(a) Ambient (b) Diffuse (c) Specular (d) Combined

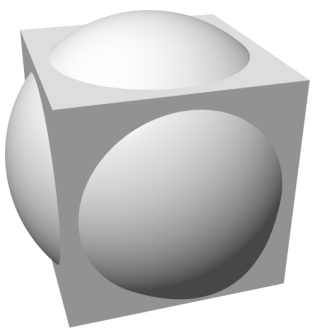
Figure 9: Phong shading model — light components are computed in steps.

Primitives

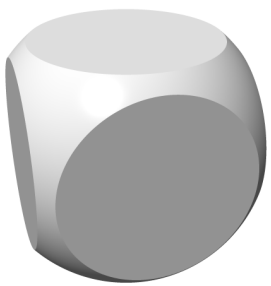
- For each type of volume, compute its intersection with a ray
- Requires solving vector equations

CSG

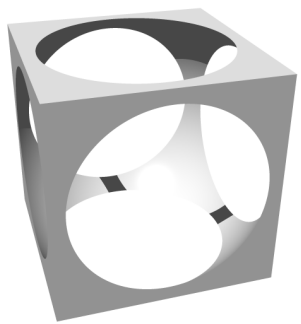
- Primitives are too simple for artistic creativity
- Constructive Solid Geometry combines objects in 3 ways:
  - Union
  - Intersection
  - Difference



(a) Union



(b) Intersection



(c) Difference

Figure 10: All three CSG types

- Recursive implementation
- Compare distances, see what object gets hit first
- Continue to the end of the objects
- Return appropriate normals and distances

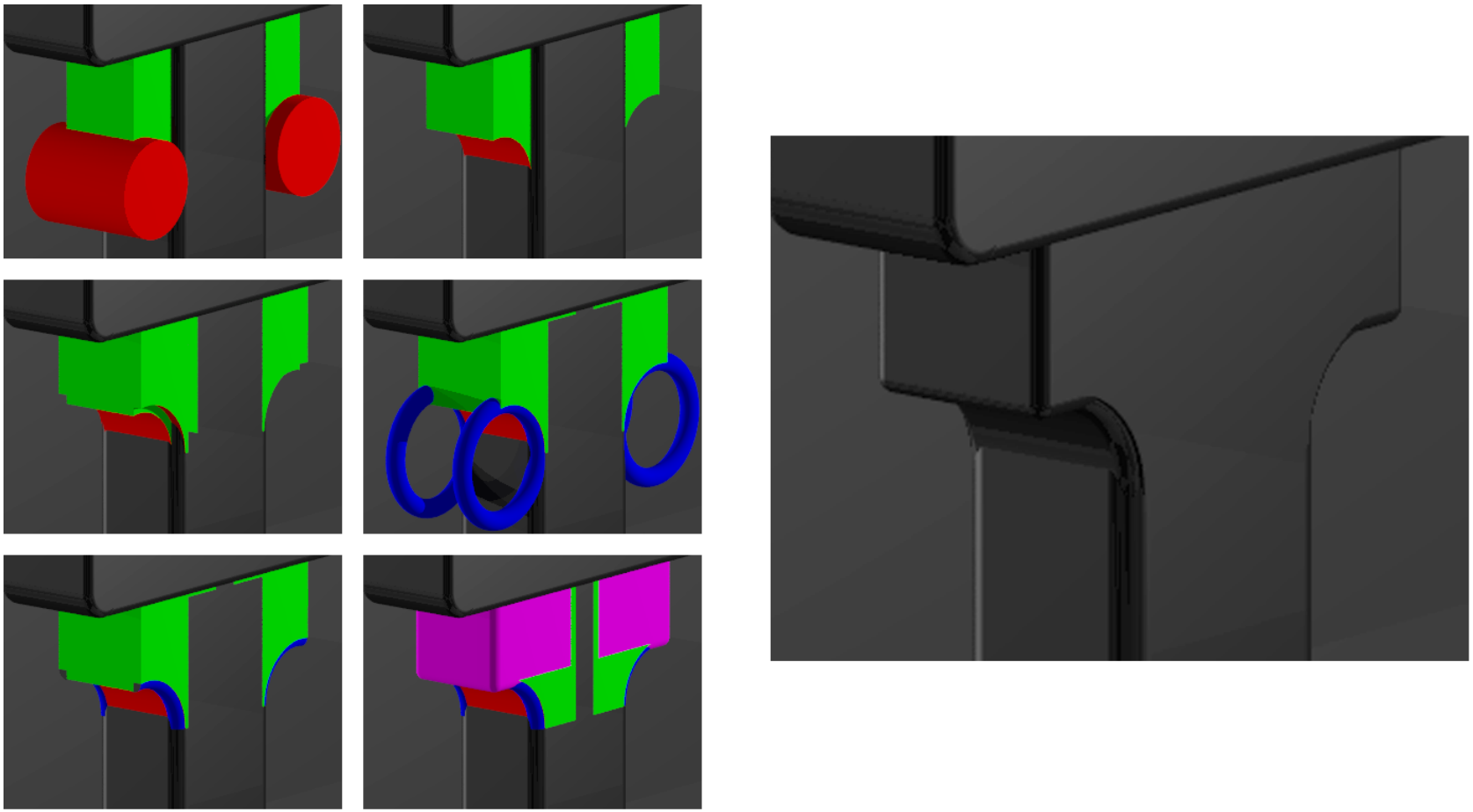


Figure 11: Concrete example of CSG use

Also implemented

Other notable features:

Depth of field

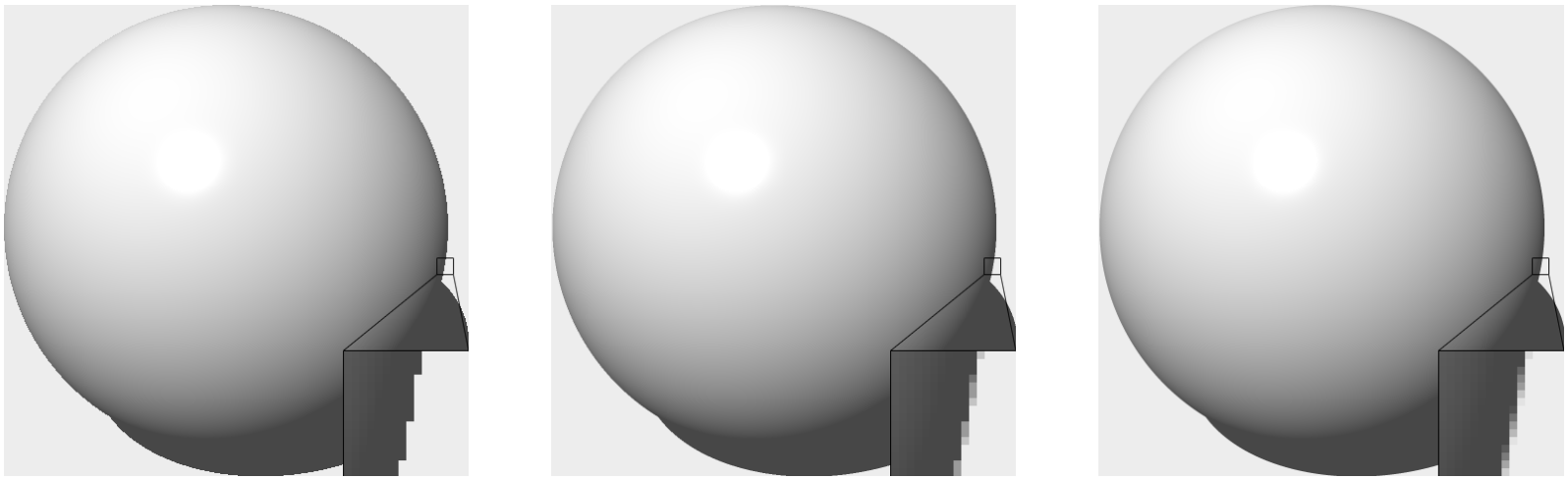
Shifting the ray's origin with a random offest

Supersampling

Split each pixel into subpixel coordinates, trace multiple rays

Backgrounds

Spherical mapping of 360° panoramas



(a) No supersampling (b) 2×2 SSAA (c) 4×4 SSAA

Figure 12: Different supersampling values

CRT Language

Goal

- Simple language
- Control every aspect of the rendering
- Define user variables, references
- Simple loops and conditions
- Macros

Aspect

```
1  --Entities-----------------------------------------------
2  sphere1 = Sphere {
3      center -> vec3(0, 0.5, 0)
4      radius -> 0.5
5  }
6
7  --Constants----------------------------------------------
8  n = 18
9  max = (3 * n) / 4 + 5
10
11 --Macros-------------------------------------------------
12 myMacro = Macro (arg1) {
13     i = 0
14     -- Draw sphere1 "max" times on the x axis
15     while (i < max) {
16         sphere1 <translate vec3(i*1.0, 0.0, 0.0)>
17         i = i - 1
18     }
19 }
```

Listing 1: Sample CRT script

ANTLR

- Provides easy syntax for grammar
- Generates all the lexer and parser code
- Also generates base classes for *visitors* and *listeners*

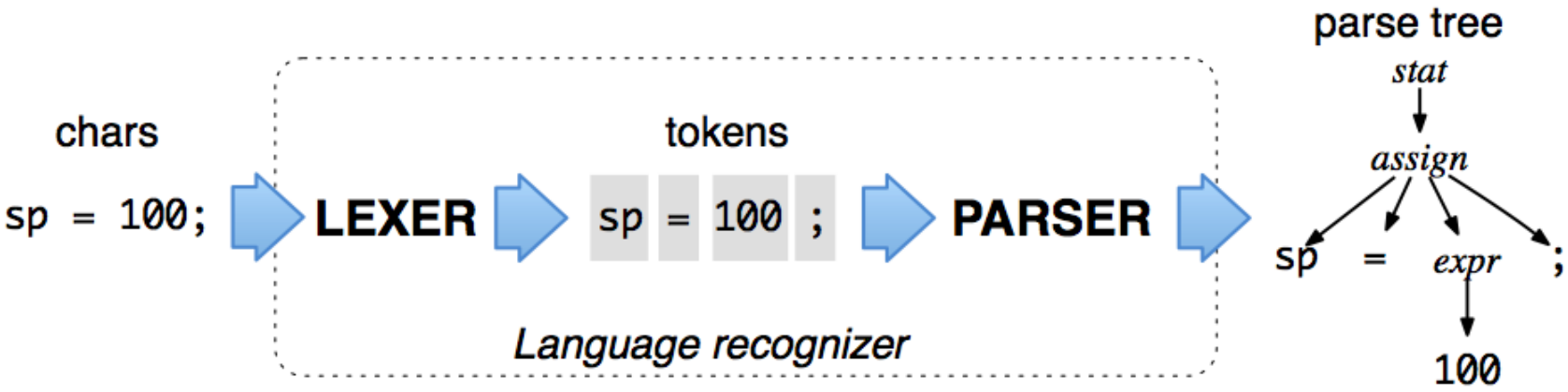


Figure 13: ANTLR4 langage recognition process

Grammar

- Non-ambiguous design (context-free)
- Left-recursion for simplicity
- Labelling of alternatives generates a visitor method for each

Compiling

- Top-down process
- Many tests on types, can't use polymorphism
- Accent on exceptions and error handling
- Recursive variable solving
- Nested scopes resolution

Interface

Implemented features

Text editor

Docking frames

Netbeans API

Live view

Demonstration

Conclusion

What remains ?

- Animations
- Drag-and-drop
- Code generation
- User interface