Rendering Mirage

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CS482 Fall 2018 Midterm Presentation

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- Background
- Previous Works
- Our Ideas

Introduction

Mirage

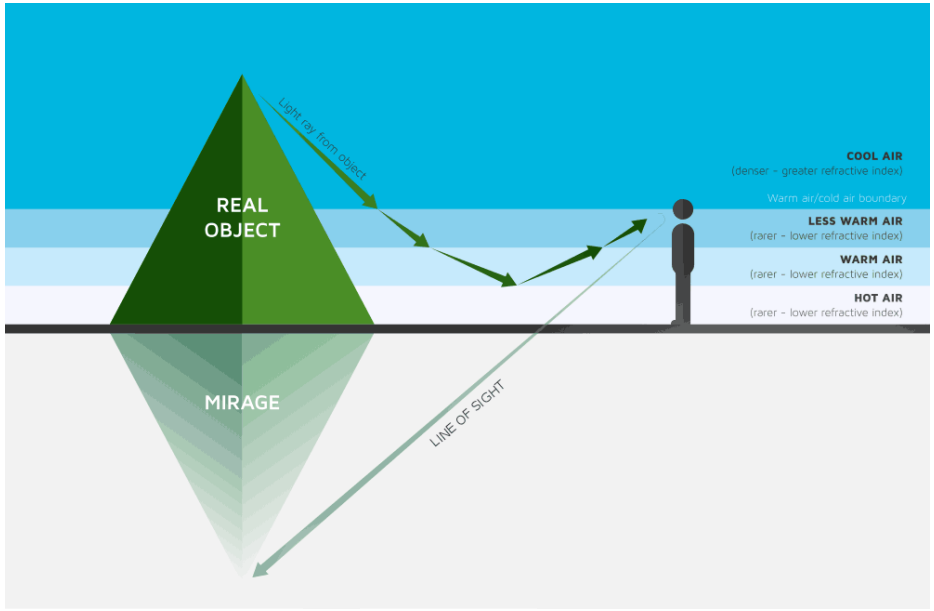
inferior mirage

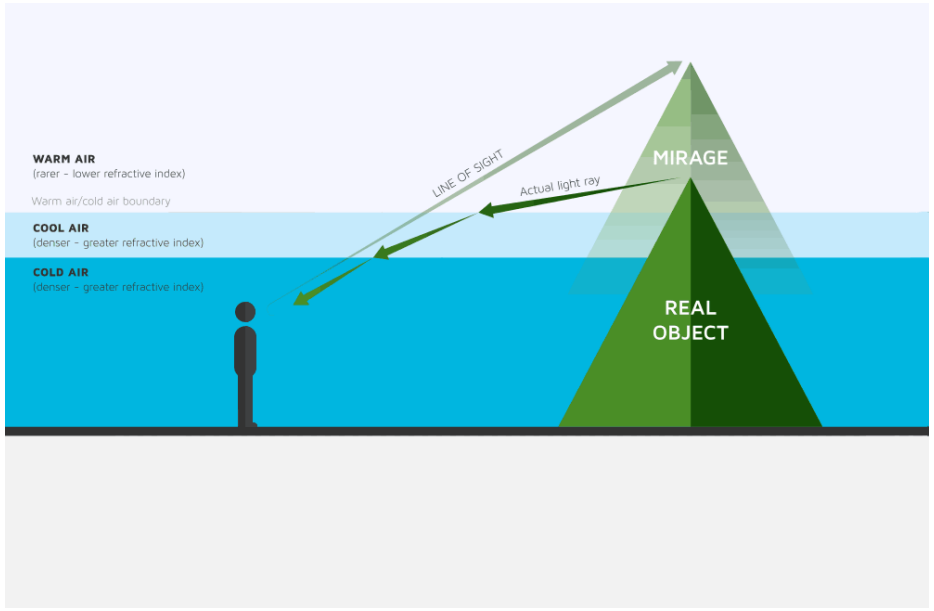
By Conjecture Corporation

superior mirage

By Shawn Stockman-Malone

Mirage





inferior mirage

superior mirage

Both by Ludovica Lorenzelli

Our Goal

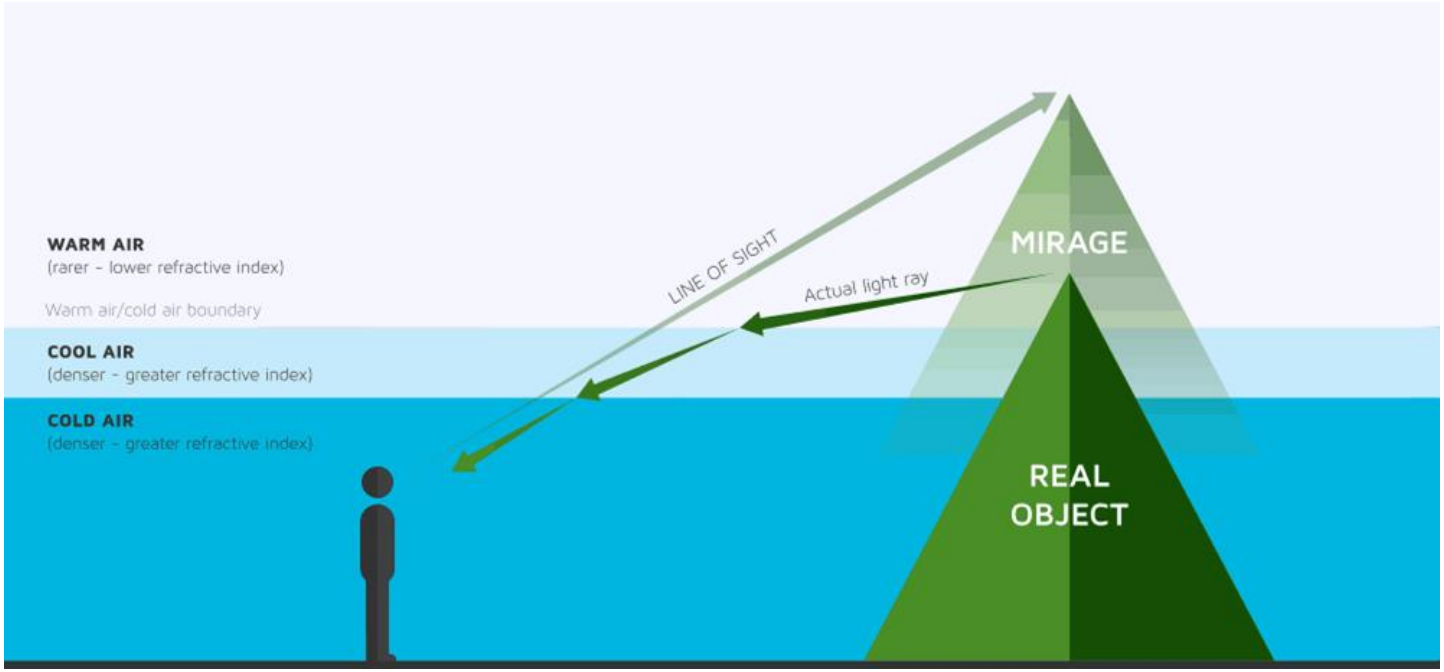
We want to render realistic, artistic mirages.

By Shawn Stockman-Malone

From [ABW14]

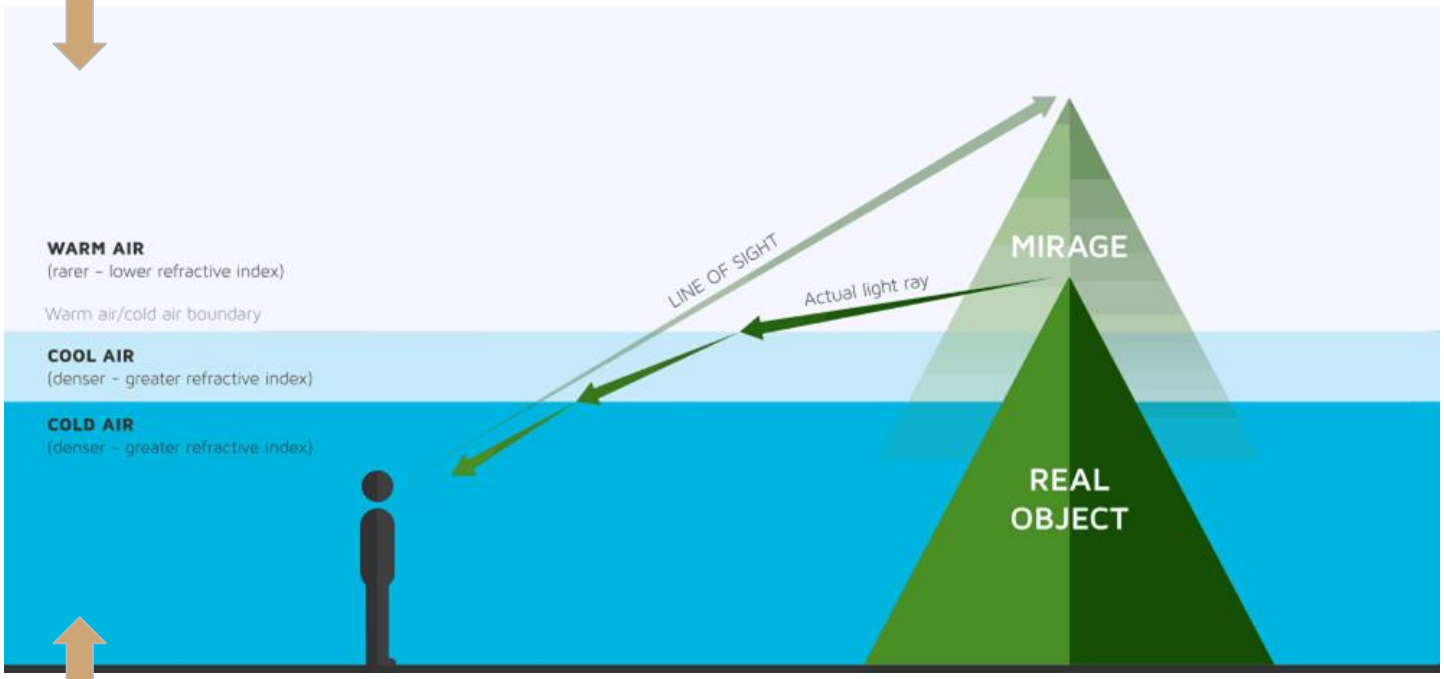
Background

Mirage Image: The Physics



Mirage Image: The Physics

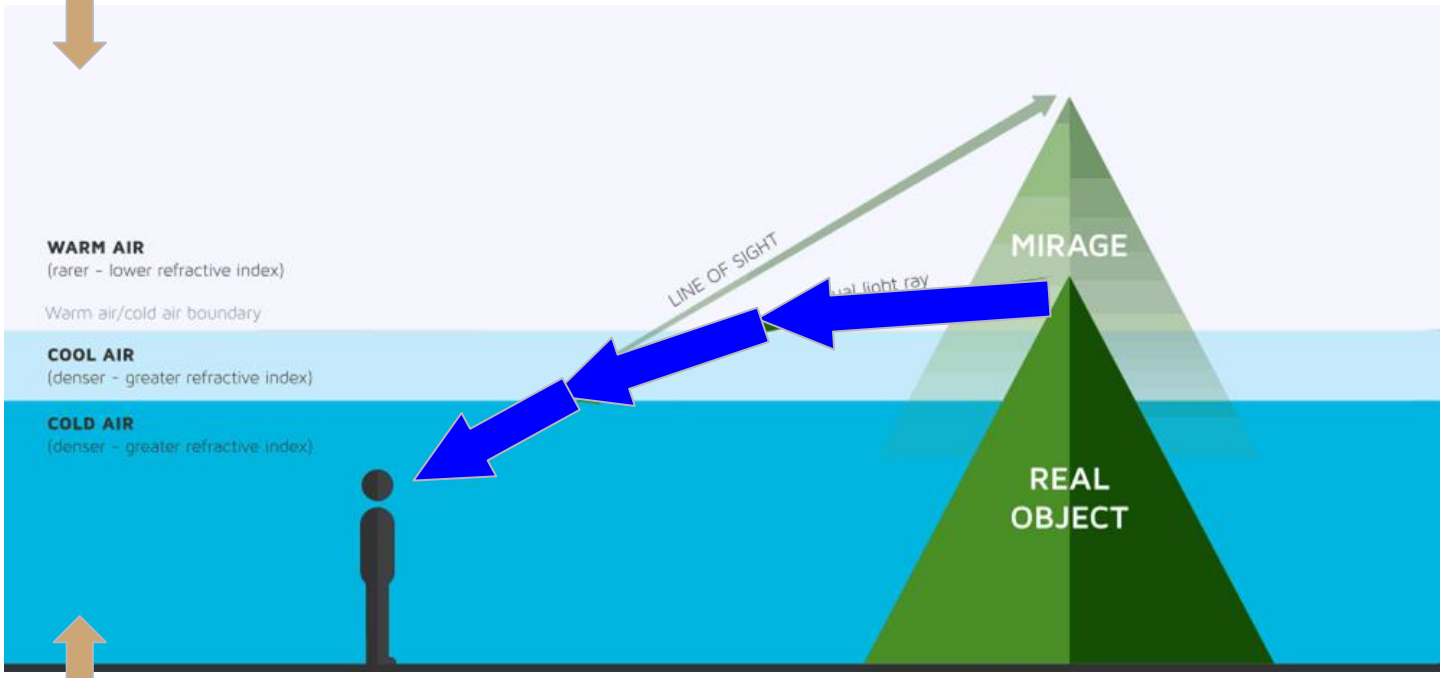
High $T \rightarrow$ Low $\rho \rightarrow$ High $v \rightarrow$ Low n



Low $T \rightarrow$ High $\rho \rightarrow$ Low $v \rightarrow$ High n

Mirage Image: The Physics

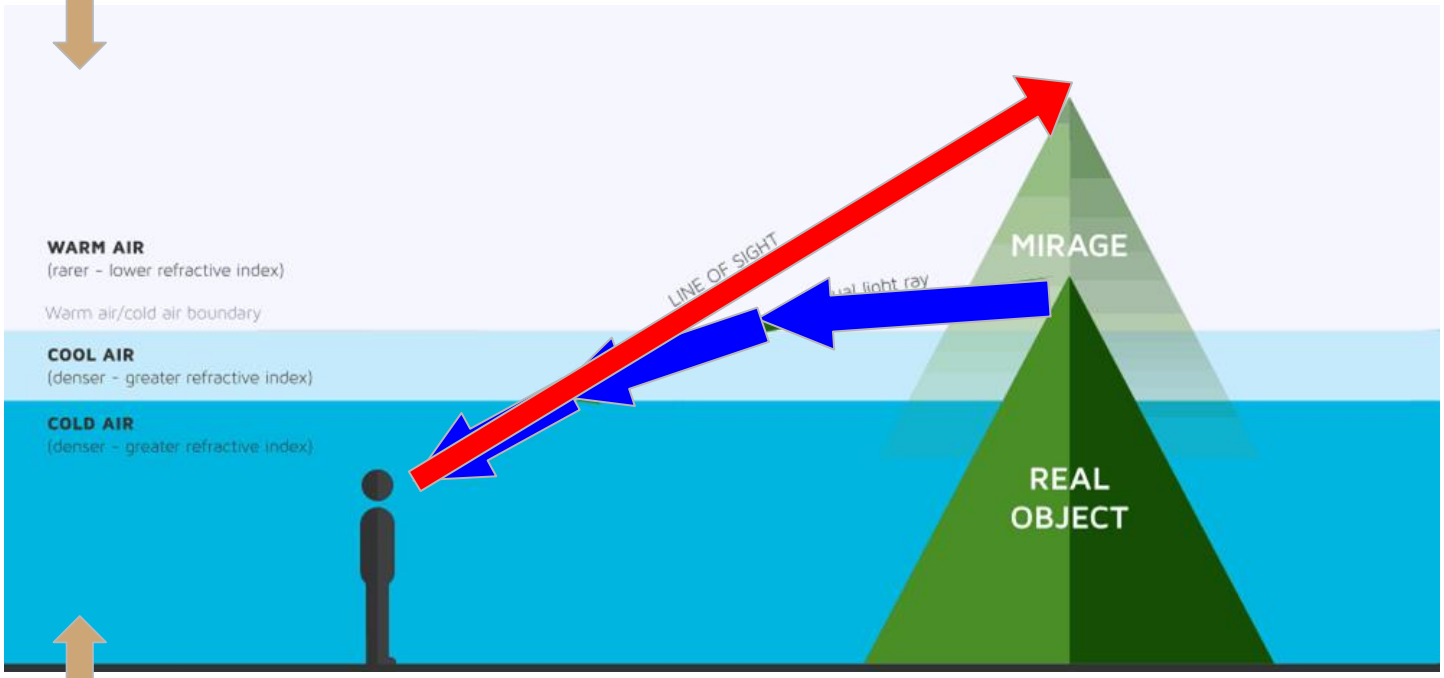
High $T \rightarrow$ Low $\rho \rightarrow$ High $v \rightarrow$ Low n



Low $T \rightarrow$ High $\rho \rightarrow$ Low $v \rightarrow$ High n

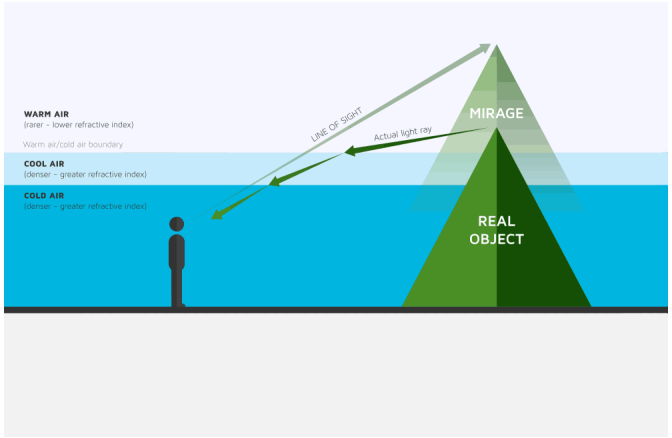
Mirage Image: The Physics

High $T \rightarrow$ Low $\rho \rightarrow$ High $v \rightarrow$ Low n

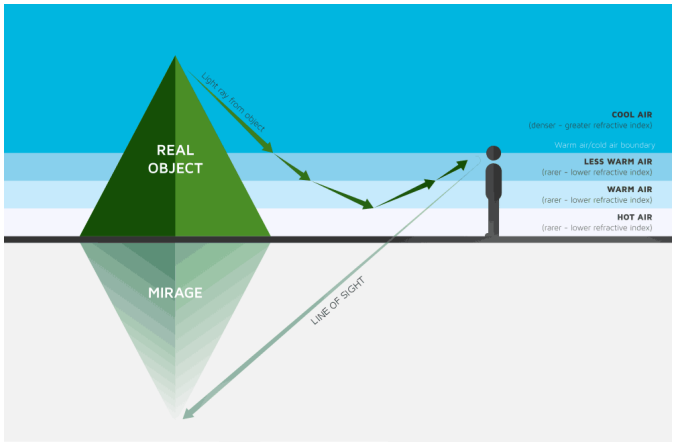


Low $T \rightarrow$ High $\rho \rightarrow$ Low $v \rightarrow$ High n

Mirage Image: The Physics



superior mirage



inferior mirage

Previous Works

Previous Works

- Modeling refractive index of atmosphere
- Rendering through refractive index model
- Artistic editing by user

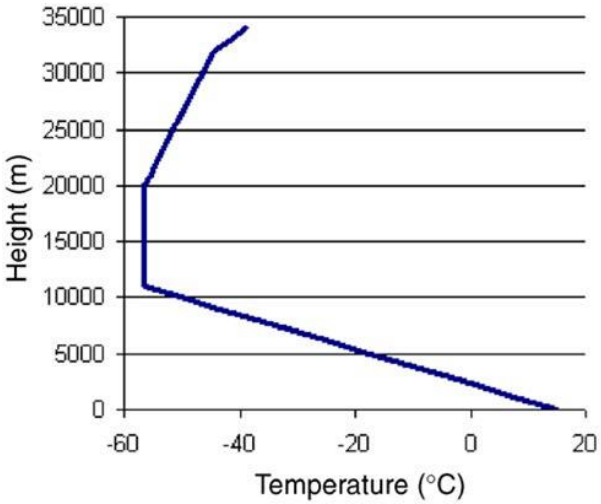
Refractive Index Modeling Of Atmosphere

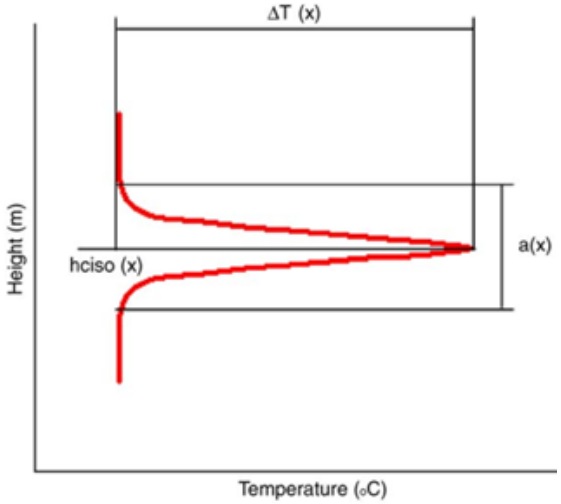
- Simulation of atmospheric phenomena [GSM*06]
- **Atmospheric Profile Manager (APM)**
- Simplified model of temperature, refractive index similar to real atmosphere

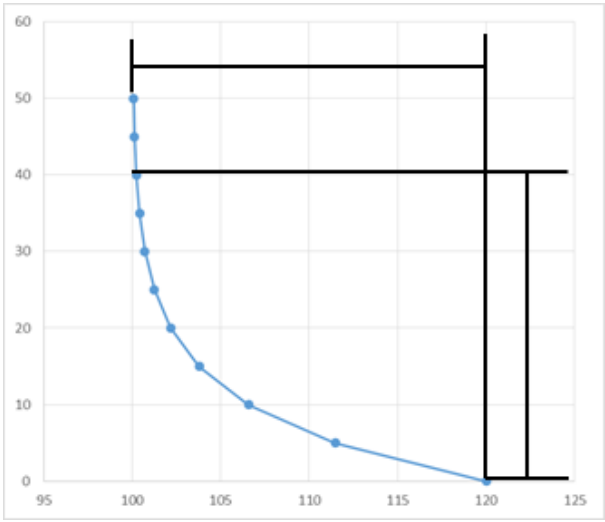
Refractive Index Modeling Of Atmosphere

Standardized

De-standardization







Background

Inversion Layer

Hot Spot

From [GSM*06]

From [GSM*06]

From slides of [Choi 17]

Rendering Through Refractive Index Model

- Refractive radiative transfer equation [ABW14]
- Applies Hamiltonian optics to the rendering equation

$$\frac{d\boldsymbol{v}}{ds} = \nabla_{\boldsymbol{x}} n,$$

$$\frac{d\boldsymbol{x}}{ds} = \frac{\boldsymbol{v}}{n}.$$

Image from [ABW14]

Artistic Editing

- Interactive reflection editing [ROT*09]
- User controllable reflection, defying physics
- Intuitive UI

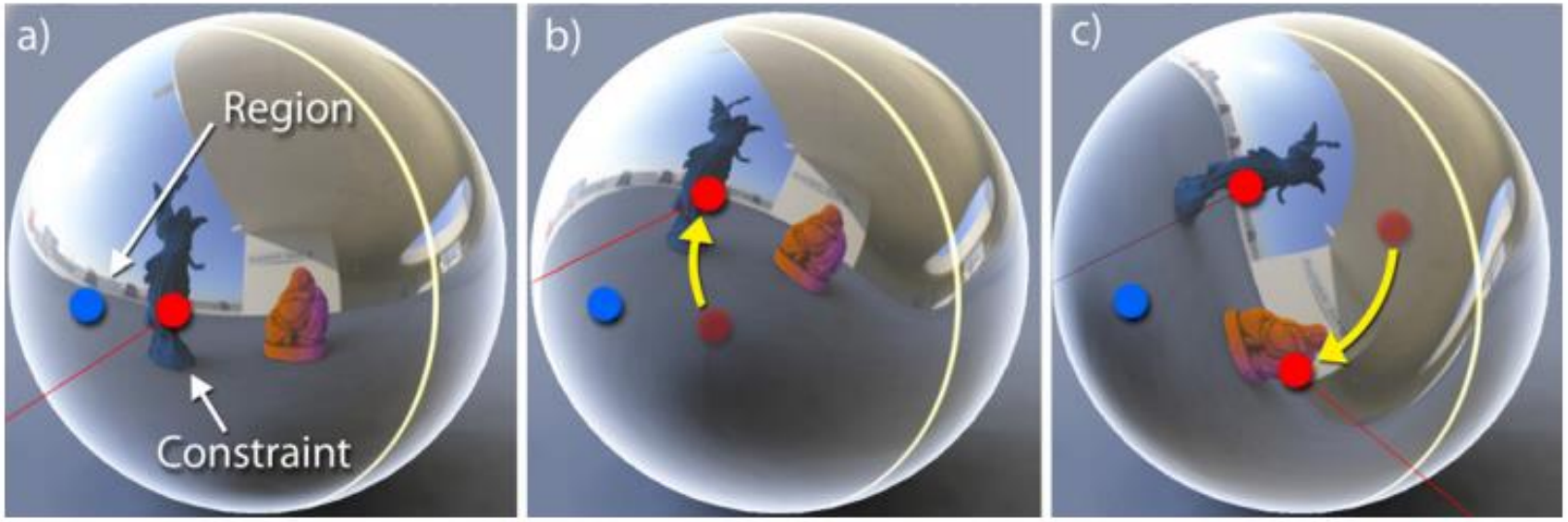
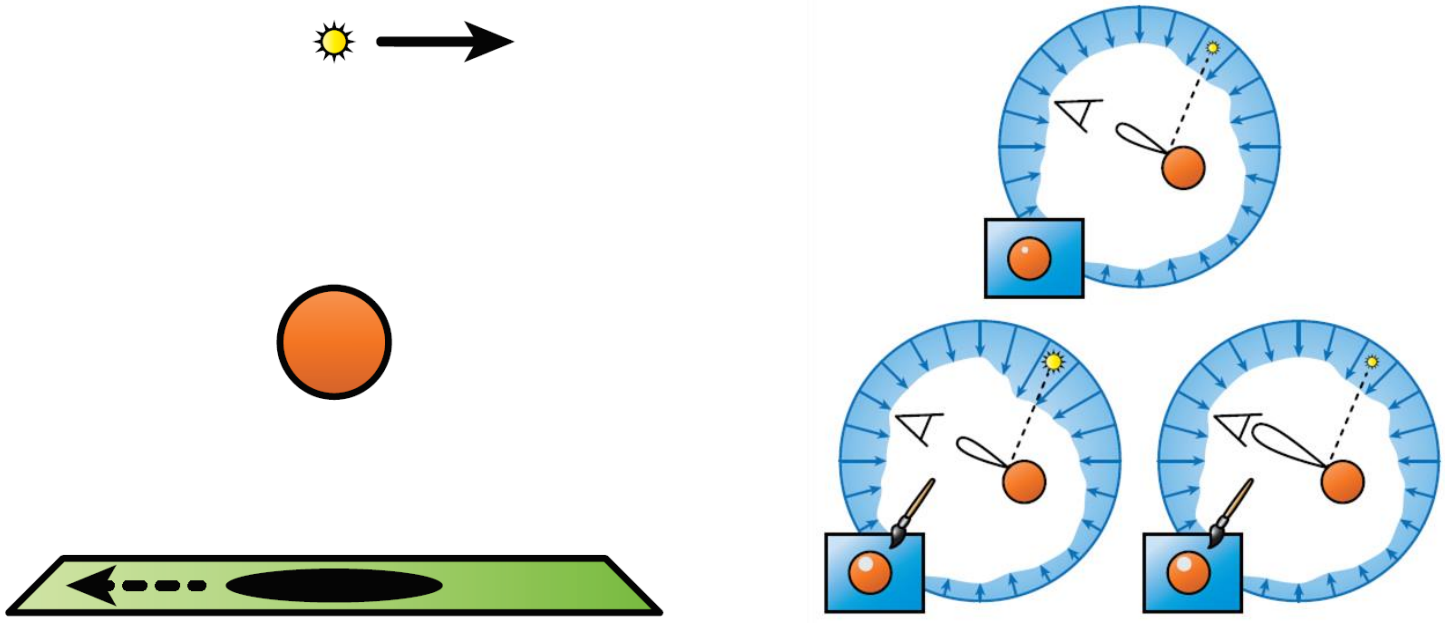


Image from [ROT*09]

Artistic Editing

- State of the art in artistic editing of appearance, lighting and material [SPN*14]
- User controlled lighting, BRDF, etc.
- Goal based interaction; user defines goal, system solves.



Images from [ABW14]

Previous Approaches To Mirage Rendering

- Visual simulation of heat shimmering and mirage [ZHF*07]
- Build refractive index from object heat map, renders with ray marching

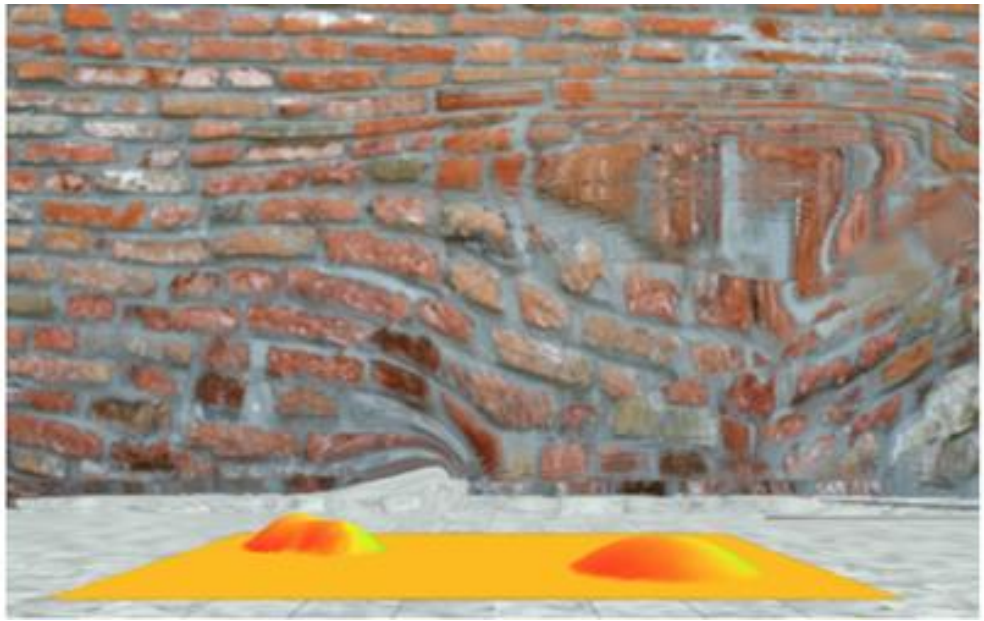
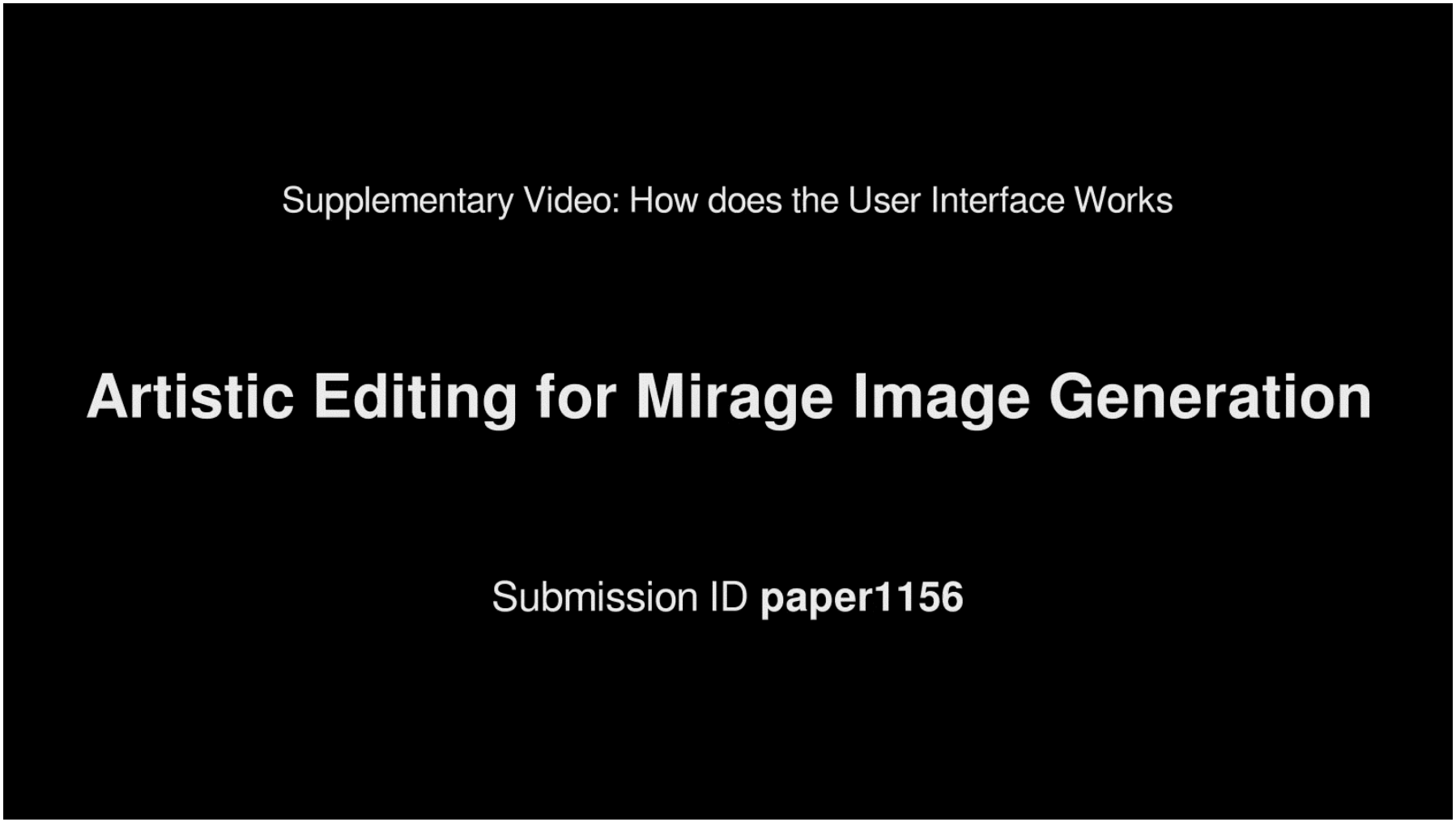


Image from [ZHF*07]

Artistic Editing For Mirage Image

Artistic Editing For Mirage Image [Choi 2017]

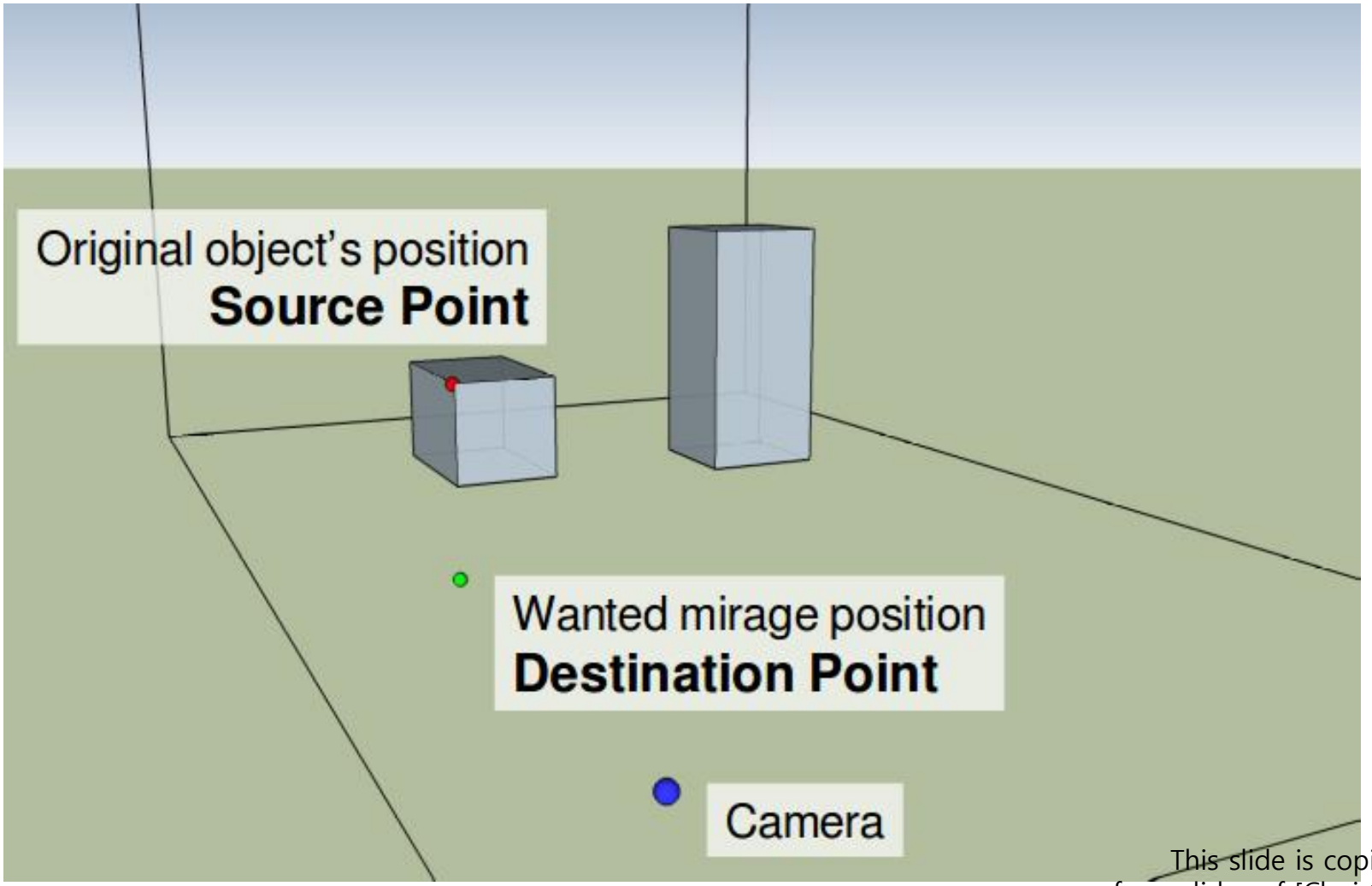


Overview

- **Source-to-Destination Point Pair**
  - The user specifies constraints, defined as a set of **original position (source)** + **mirage image position (destination)**
- Perform **physically correct** light path calculation
- Use **parametric optimization** to calculate
  - With an appropriate refractive index distribution model for the optimization

This slide is copied from slides of [Choi 17]

Source-to-Destination Point Pair



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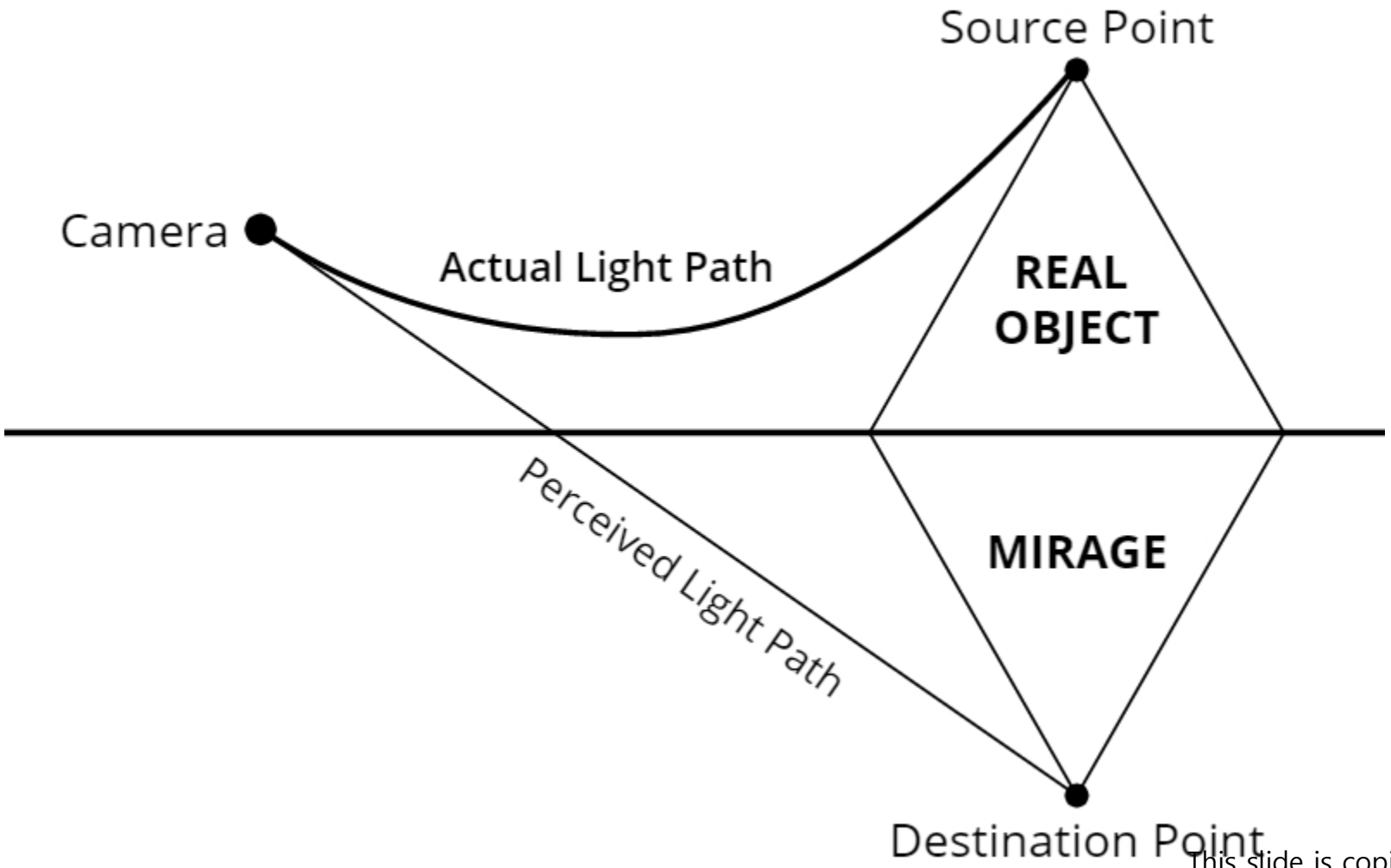
Source-to-Destination Point Pair



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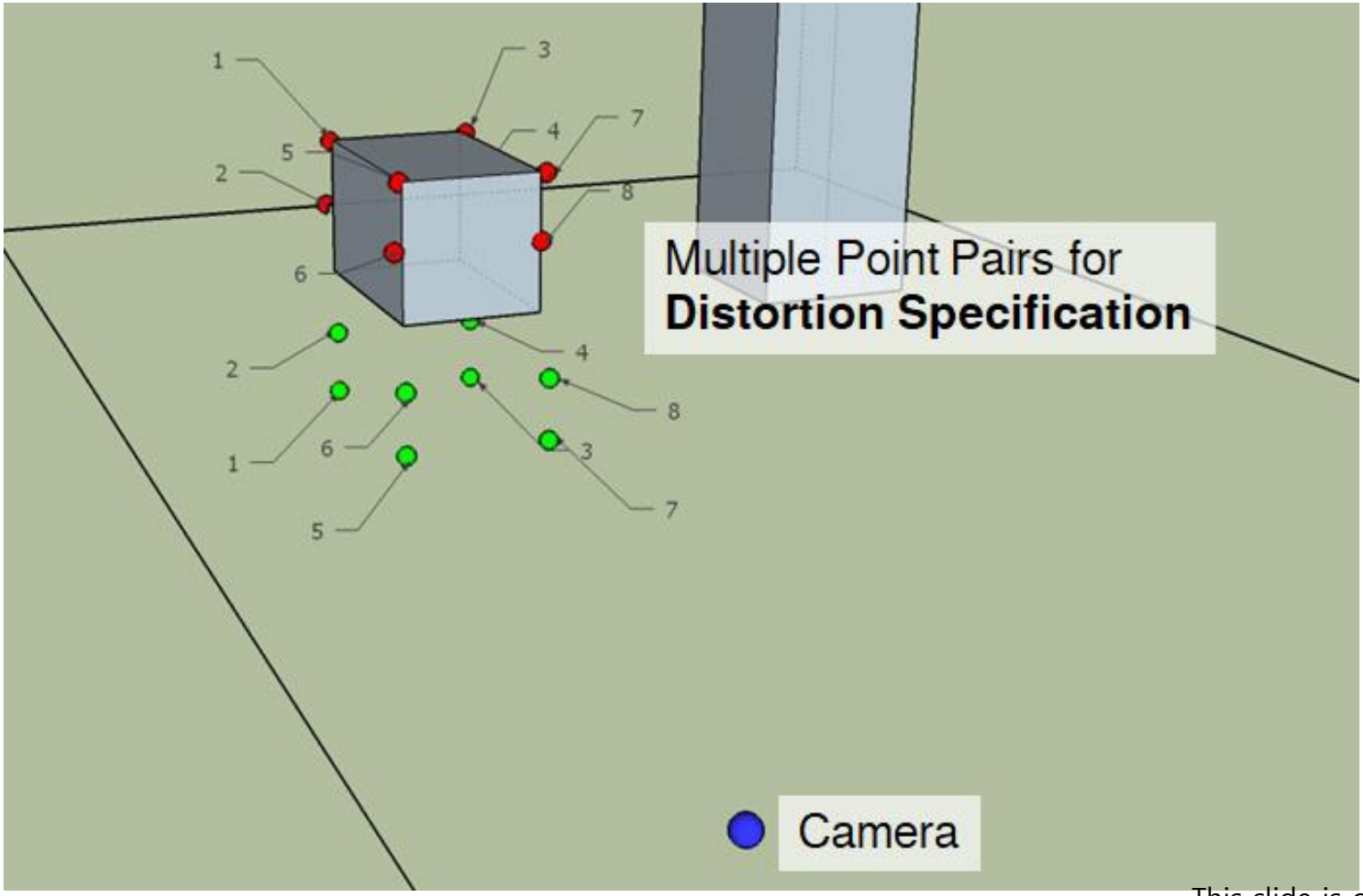
Source-to-Destination Point Pair



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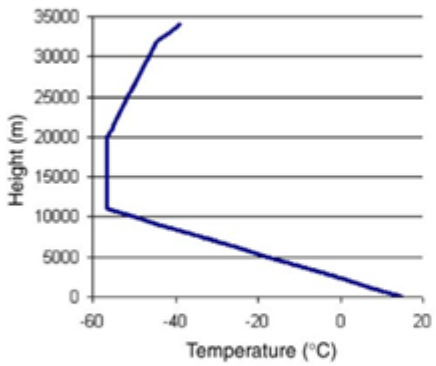
Refractive Index Distribution Model

Adapt **APM**[GSM*06] as a spatial encoding

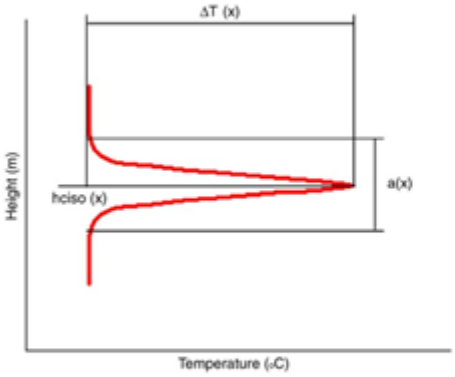
Standard

US Atmosphere Model

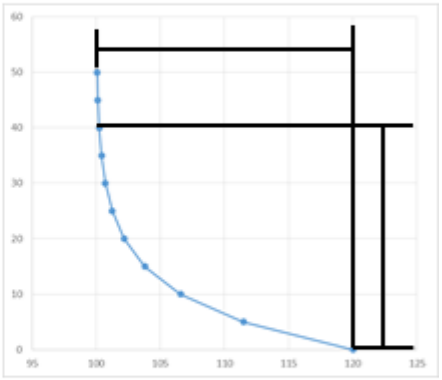


De-standardization

Inversion Layer



Hot Spot



Images from [GSM*06]

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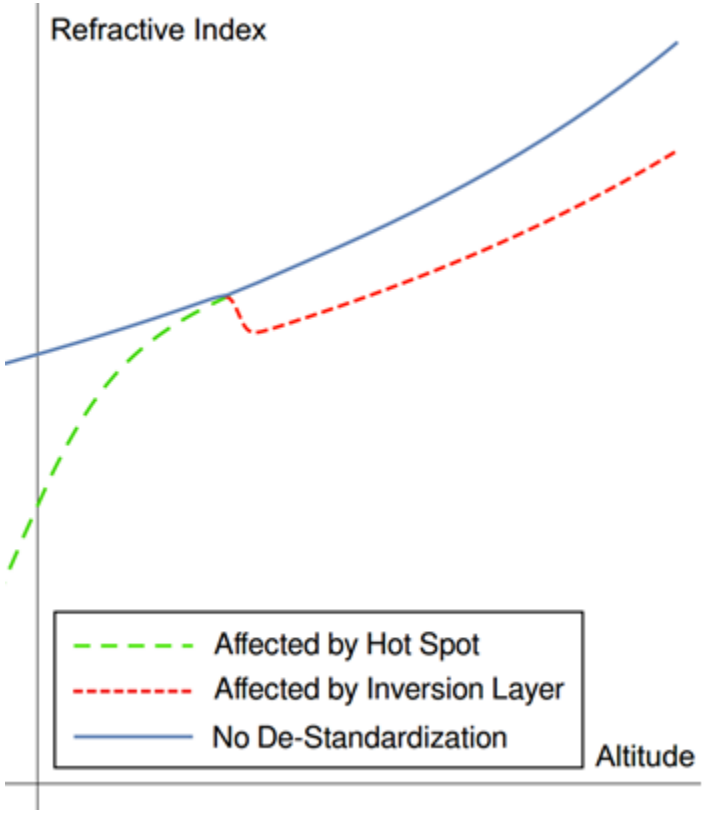
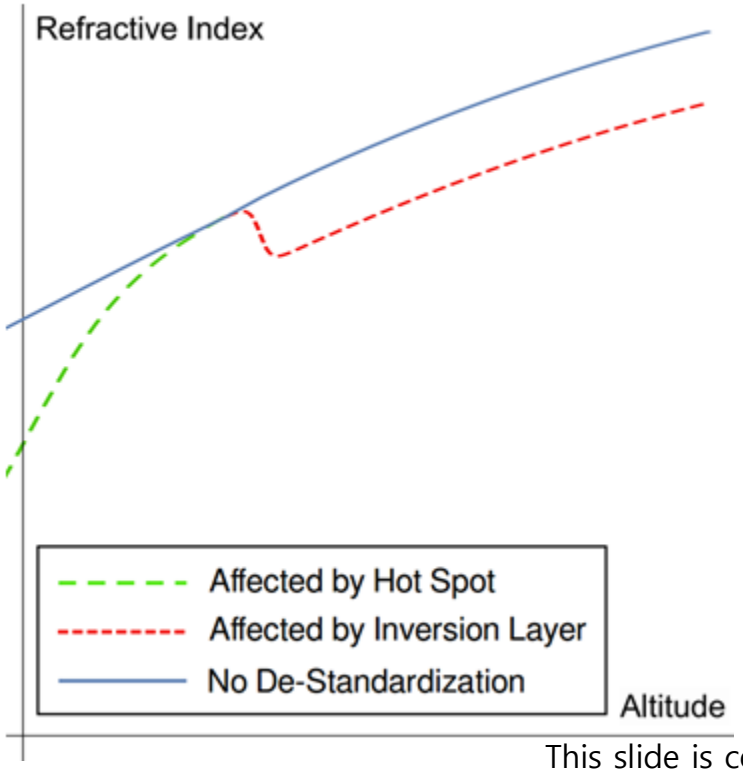
Refractive Index Distribution Model

Plot of **APM** vs. **New Formulation**





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Refractive Index Distribution Model

New formulation suggested for the refractive index distribution: **Logistic Approximation**

$$
\begin{aligned}
n(h) = & \frac{k_s}{|n_{bg}| + |n_{inv}| + |n_{hotspot}|} && \text{Normalize \& Scale} \\
& \cdot \Big(f_{logistic}(n_{bg}, a_{bg}, 0, h) && \text{Background} \\
& + f_{logistic}(n_{inv}, -a_{inv}, h_{ciso}, h) && \text{Inversion Layer} \\
& + f_{logistic}(n_{hotspot}, a_{hotspot}, 0, h) \Big) && \text{Hot Spot} \\
& + 1, && \text{Baseline}
\end{aligned}
$$

$$
f_{logistic}(L, k, x_0, x) := \frac{L}{1 + e^{(x_0 - x)/k}}.
$$

$$
\boldsymbol{k} = \begin{bmatrix} n_{bg} & n_{inv} & n_{hotspot} & h_{ciso} & a_{bg} & a_{inv} & a_{hotspot} & k_s \end{bmatrix}^T
$$

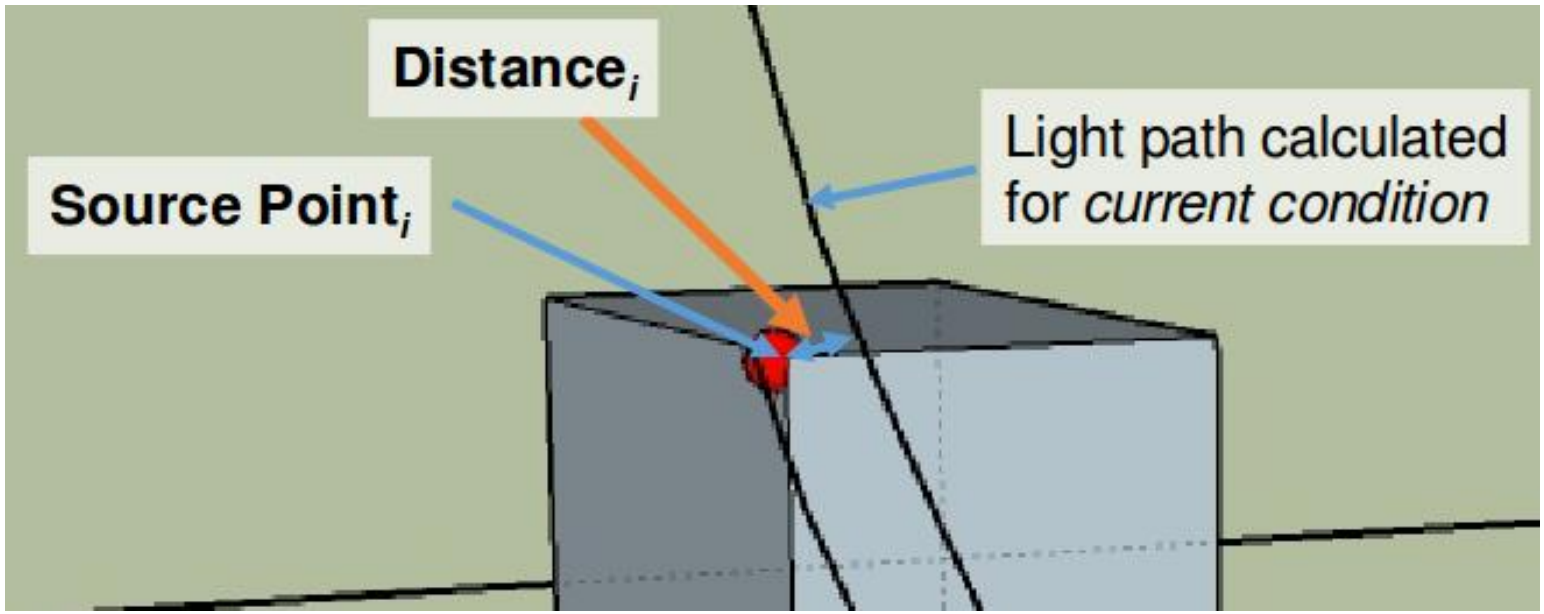
Spatial Encoding and Optimization

- Let the m-dimensional spatial encoding of **n(x)** be **L**

- And let the parameter vector for **L** be $\boldsymbol{k} \in \mathbb{R}^m$

Spatial Encoding and Optimization

- **Distance Function**
  - Define distance per **point pair**, as the **shortest distance** between the Source Point and the light path



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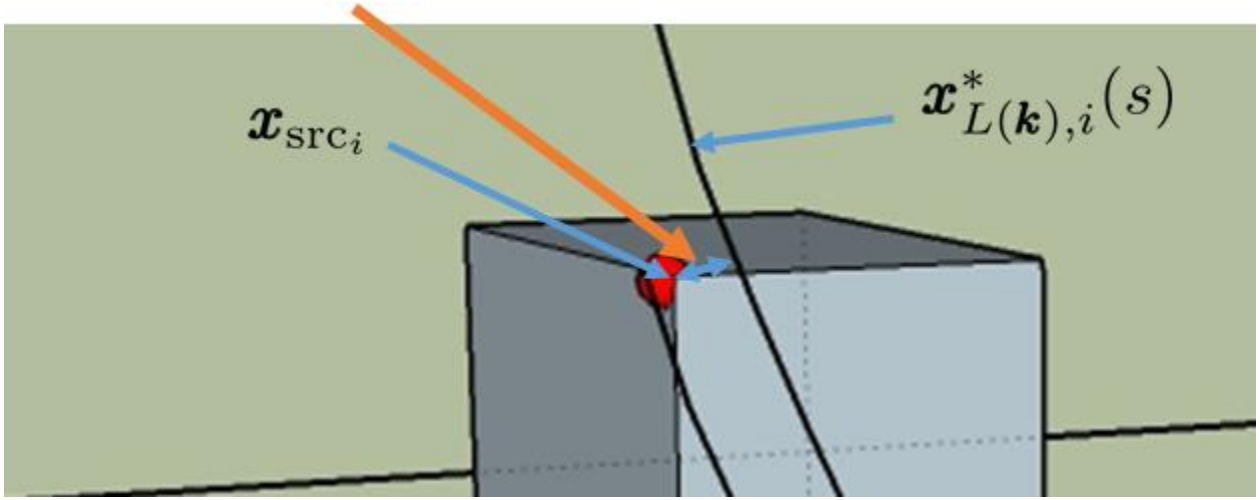
Spatial Encoding and Optimization

- **Distance Function**
  - For i-th pair, spatial encoding **L**, and parameter vector **k**

$$\mathrm{dist}_{L,i}(\boldsymbol{k}) := \inf\{\|\boldsymbol{x}^*_{L(\boldsymbol{k}),i}(s) - \boldsymbol{x}_{\mathrm{src}_i}\| : s \in [s_0, s_{\max}]\}$$



This slide is copied from slides of [Choi 17]

Spatial Encoding and Optimization

- **Cost Function**
  - For i-th pair, spatial encoding **L**, and parameter vector **k**

$$\mathrm{cost}(\boldsymbol{k}) := \sum_i \mathrm{dist}_{L,i}(\boldsymbol{k})$$

  - solve by **Regression**

$$\underset{\boldsymbol{k}}{\mathrm{argmin}}\ \mathrm{cost}(\boldsymbol{k})$$

This slide is copied from slides of [Choi 17]

Rendering method

- **Ray-marching algorithm**

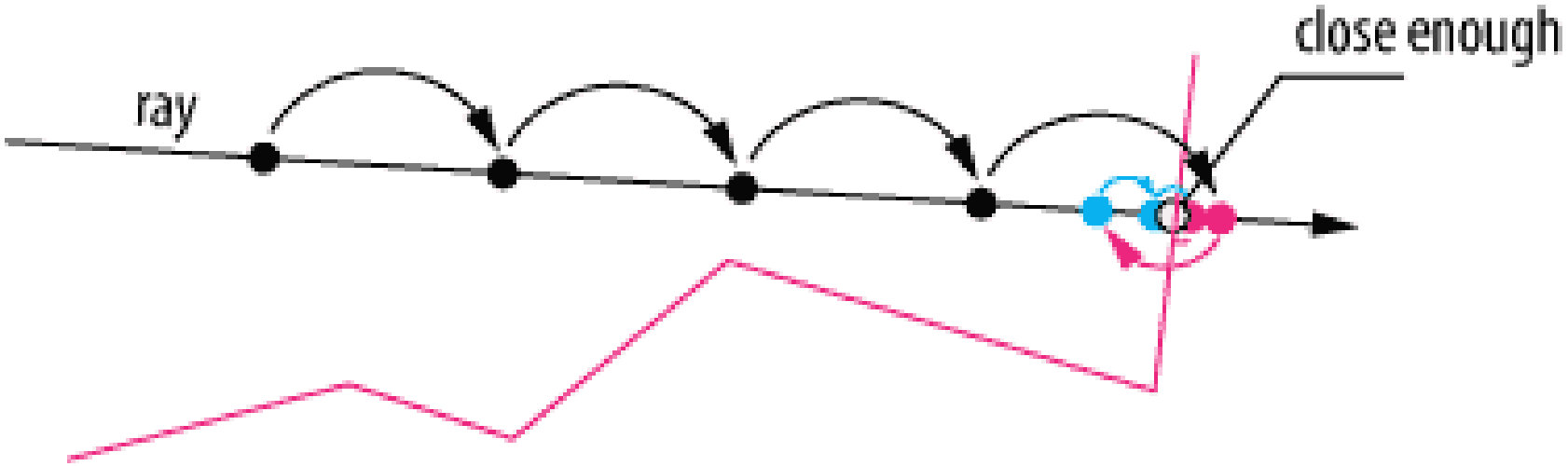


Image from https://computergraphics.stackexchange.com/questions/161/what-is-ray-marching-is-sphere-tracing-the-same-thing

Rendering method

- **Ray-marching algorithm**

$$\frac{d\boldsymbol{v}}{ds} = \nabla_{\boldsymbol{x}} n,$$
$$\frac{d\boldsymbol{x}}{ds} = \frac{\boldsymbol{v}}{n}.$$

[ABW14]

```
for (float s = 0; s < maxStep; s += stepDelta)
{
    dx1 = stepDelta * v / n(x);
    dv1 = stepDelta * gradN(x);
    dx2 = stepDelta * (v + dv1 / 2.0) / n(x + dx1 / 2.0);
    dv2 = stepDelta * gradN(x + dx1 / 2.0);
    dx3 = stepDelta * (v + dv2 / 2.0) / n(x + dx2 / 2.0);
    dv3 = stepDelta * gradN(x + dx2 / 2.0);
    dx4 = stepDelta * (v + dv3) / n(x + dx3);
    dv4 = stepDelta * gradN(x + dx3);
    dx = (dx1 + 2.0 * dx2 + 2.0 * dx3 + dx4) / 6.0;
    dv = (dv1 + 2.0 * dv2 + 2.0 * dv3 + dv4) / 6.0;
    x += dx;
    v += dv;
    /* do something here */
    vec4 projPos = (ProjectionMatrix * ViewMatrix * vec4(x, 1));
    vec3 projPosN = projPos.xyz/projPos.w;
    vec2 depthTexCoordThere = (projPosN.xy + vec2(1.0)) / 2.0;
    if (projPosN.z > texture2D(depthTex, depthTexCoordThere).r)
    {
        color = texture2D(colorTex, depthTexCoordThere).rgb;
        isIntersection = true;
    }
}
```

https://github.com/yoonlab/refractive-index-editor/blob/master/shaders/composite.frag

Limitations

- This system is focused on creating static scenes
  - This formulation does not consider **the spatial location** of the hot spot and the inversion layer
  - When you **move the camera**, you'll see a **different scene** than you intended
- No illumination model
- Poor, unintuitive UI

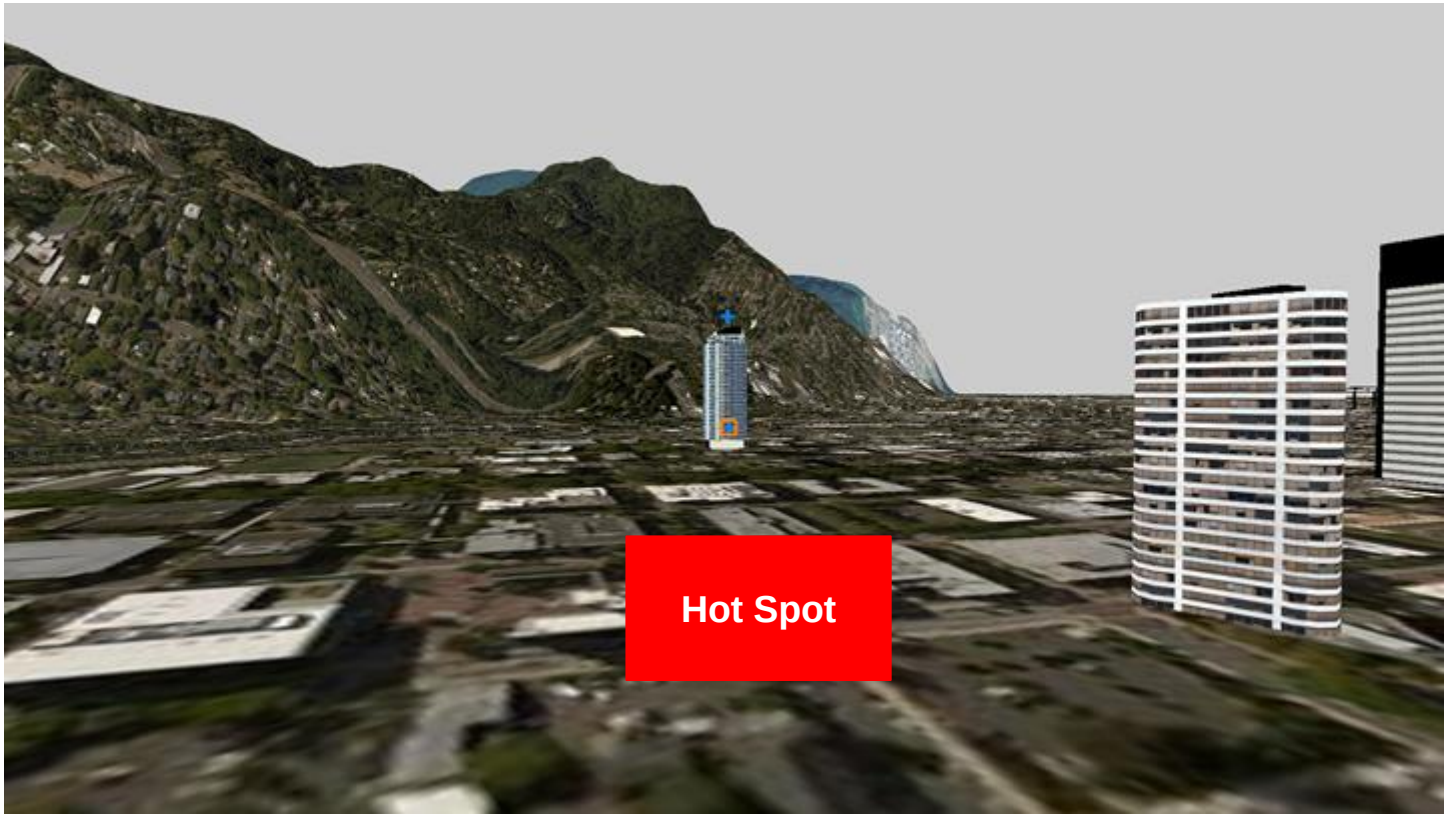
⇒ **Unrealistic mirage scenes**

Our Ideas

Areal Hot Spot

- Hot spot is no longer depends on only height
- Hot spot has xy-position and size, defined by user
- Optimize additional parameters using the existing optimizer
- By changing the formula to **take into account the area of the hot spot**, we can see a **more realistic scene** even if we **move the camera**

Areal Hot Spot



Atmospheric Noise

- Temperature variance is not smooth in real
- Air turbulences result in noises in real image
- We can add some noises to the scene for more realistic image
  - Temperature noise to model
  - Geometric noise to ray

Local Illumination Model: Phong Illumination

- Phong Illumination
- Complex global illumination is overkill in large outdoor scene with bright sunlight
- Phong illumination is simple and plausible enough

Texture Filtering

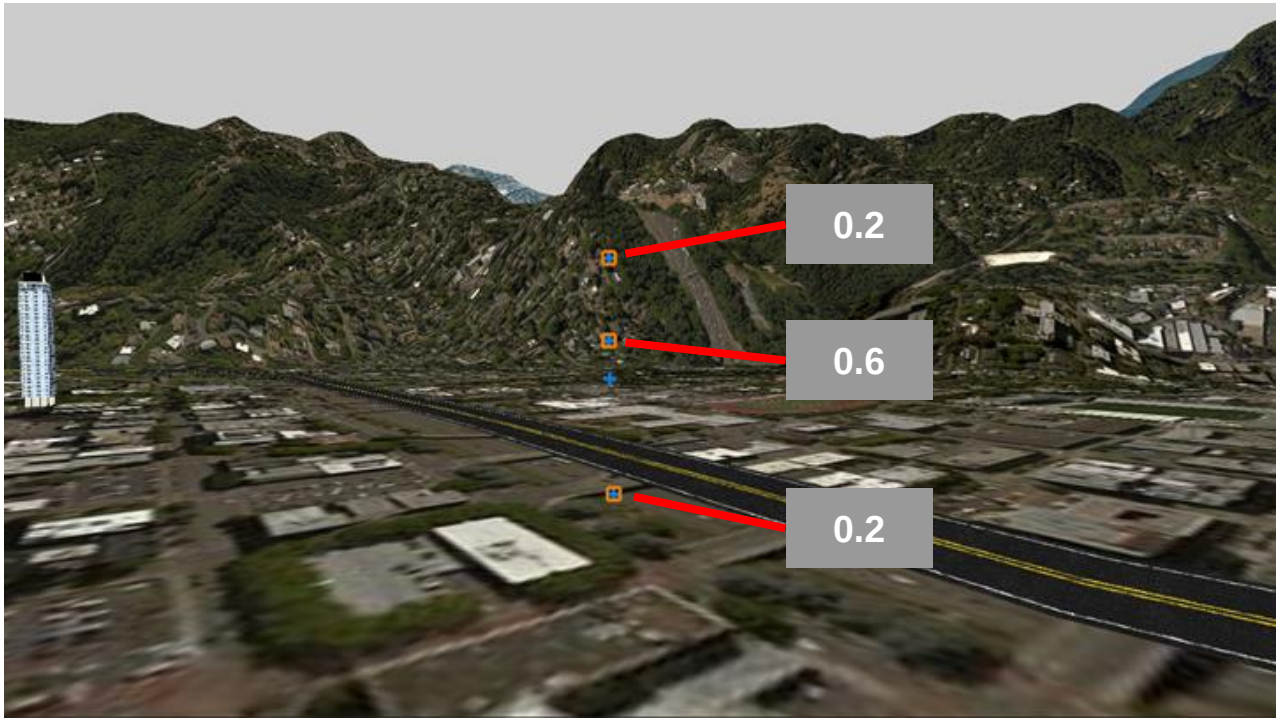
- Mip-mapping
- Anisotropic filtering
- Ray differential

Better UI

- Point positioning
- Camera positioning
- More interactive point addition and rendering; user should be able to see result of point addition more frequently
- Point importance

Better UI: Point Importance

- User defines optimization rate (intensity) for each point
- Optimizer has larger margins for less important points



Members & Roles

- Seo Hansol : Setting up the environment, Presentation, Coding

- Lim Mingi : Presentation, Coding

Q & A