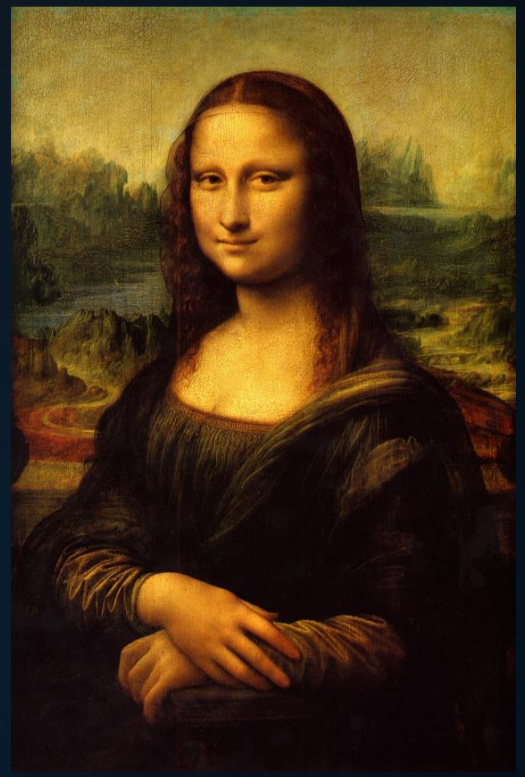
INFOGR – Computer Graphics

J. Bikker - April-July 2015 - Lecture 9: “Shading Models”

Welcome!

Today’s Agenda:

- Introduction
- Light Sources
- Materials
- Sensors
- Shading



Introduction

The Quest for (Photo-)Realism

- Objective in modern games
- Important improvements when using ray tracing (more in the next lecture, *‘ground truth’*)

The core algorithms of ray tracing and rasterization model light transport (with or without visibility):

$$L(p \to r) = L_e(p \to r) + \sum_{i=1}^{N_L} L(q_i \to p)\, f_r\,(q_i \to p \to r)\, G(q_i \leftrightarrow p)$$

Other factors:

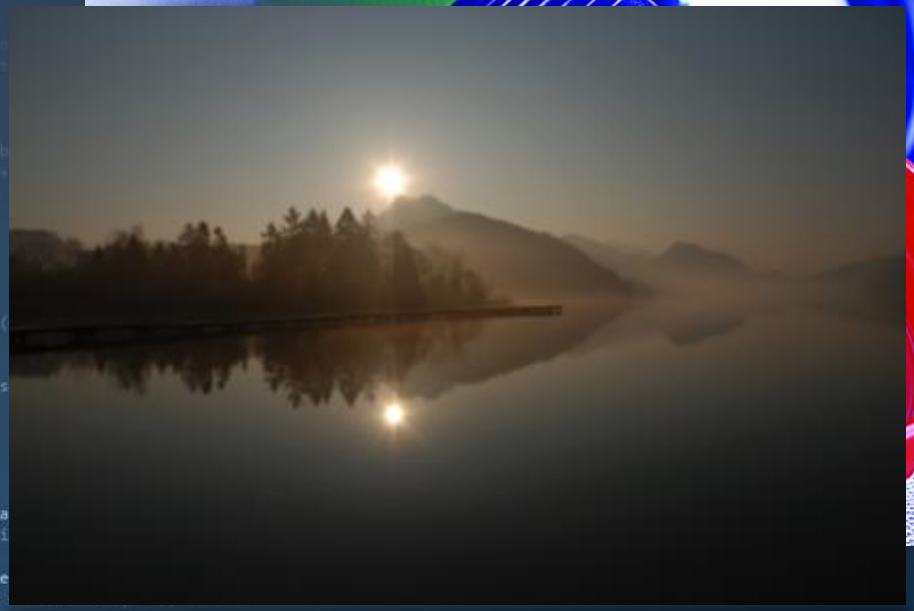
- Material interactions
- Light models
- Sensor models

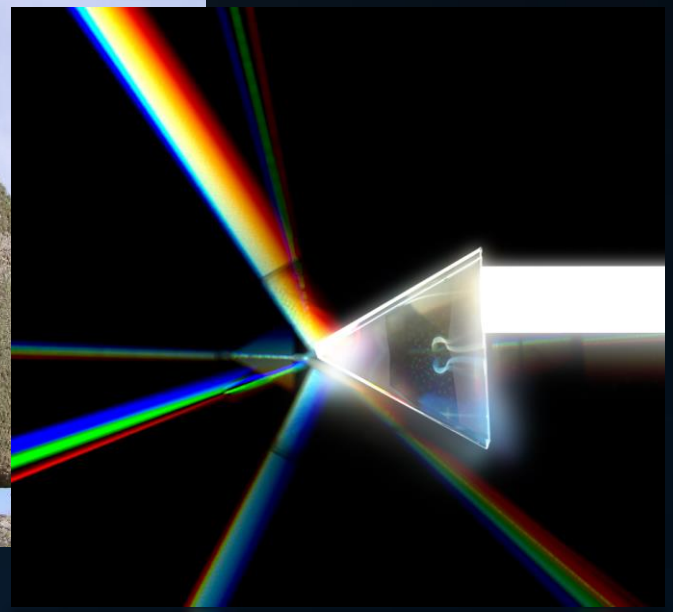
Introduction

Material interactions

Introduction

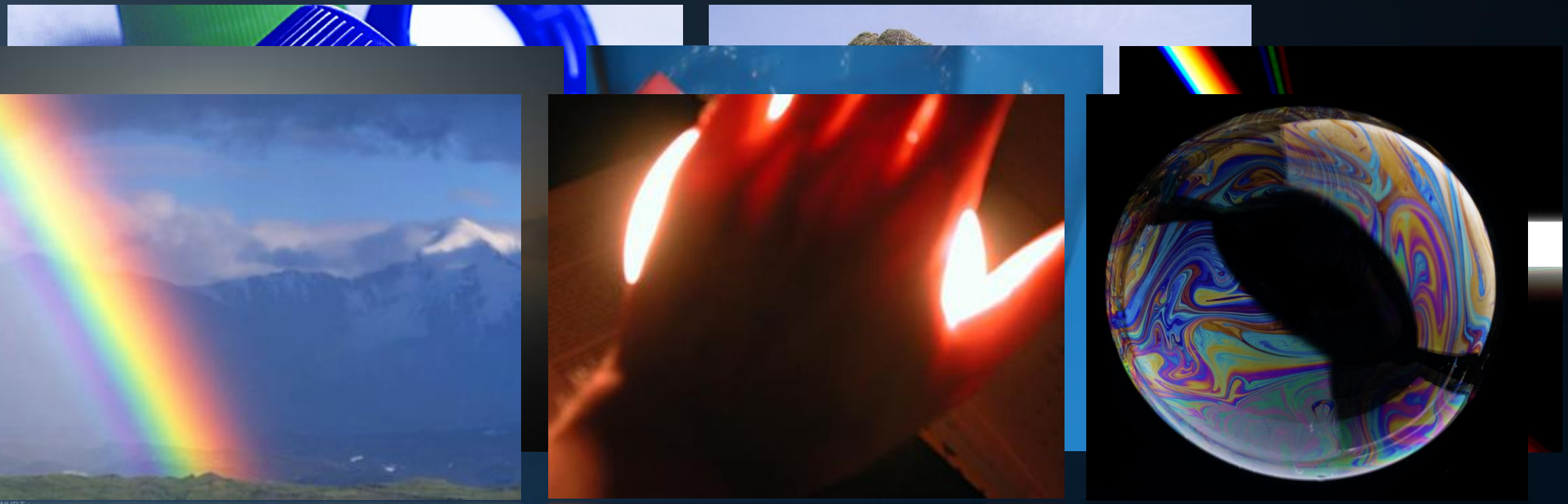
Material interactions





Introduction

Material interactions



Introduction

Light models

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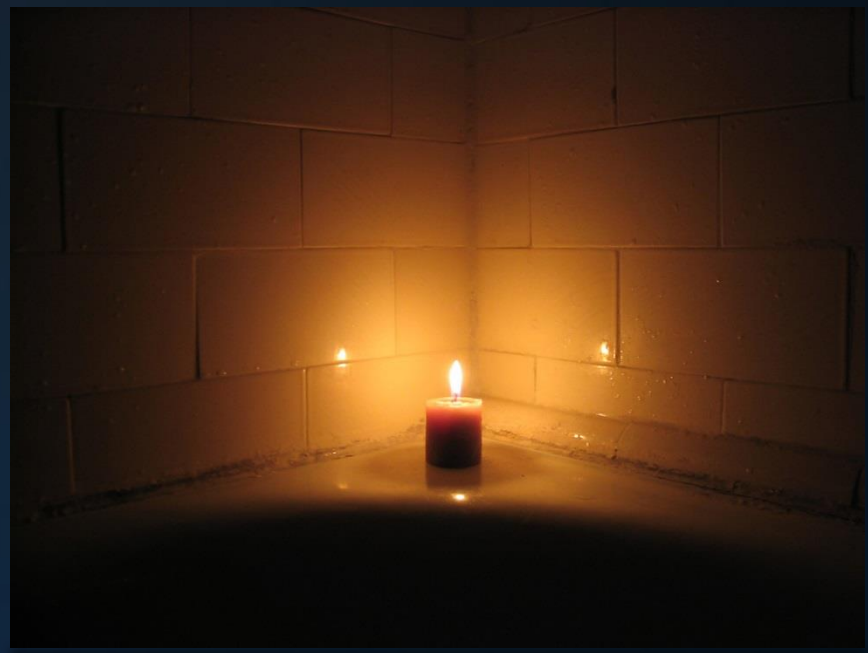

Introduction

Light models

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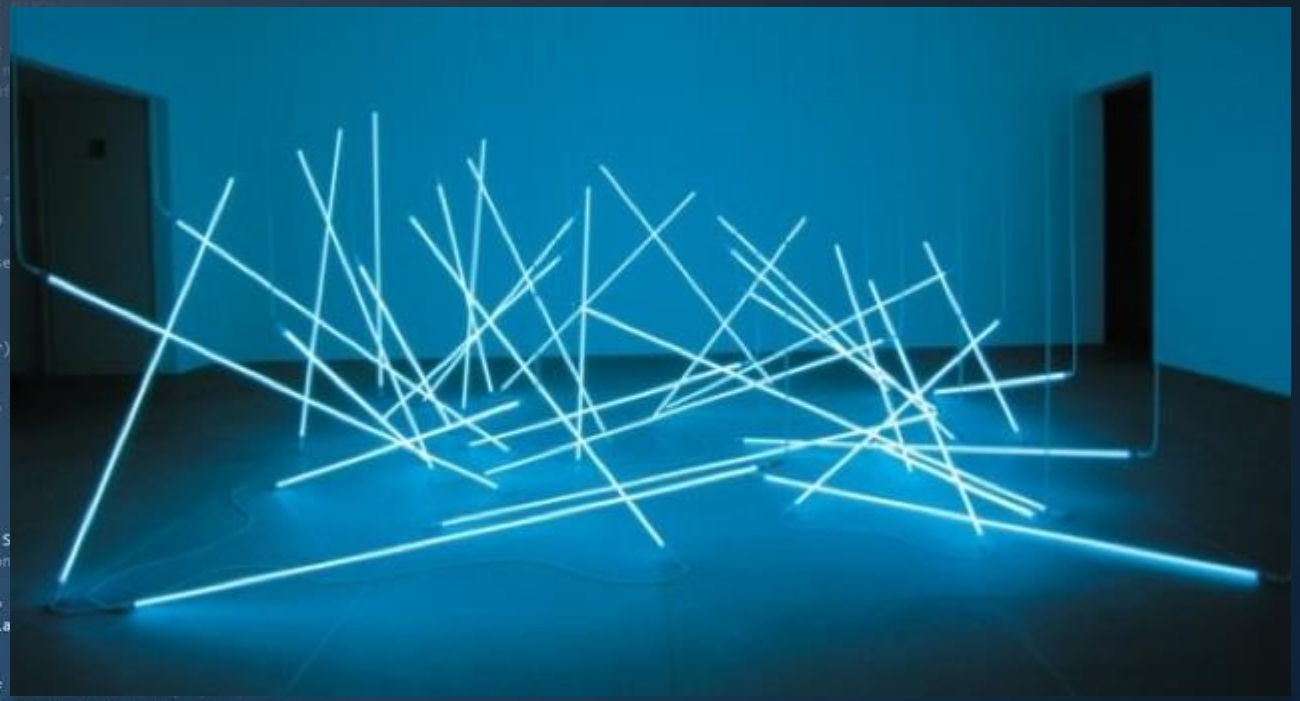

Introduction

Light models

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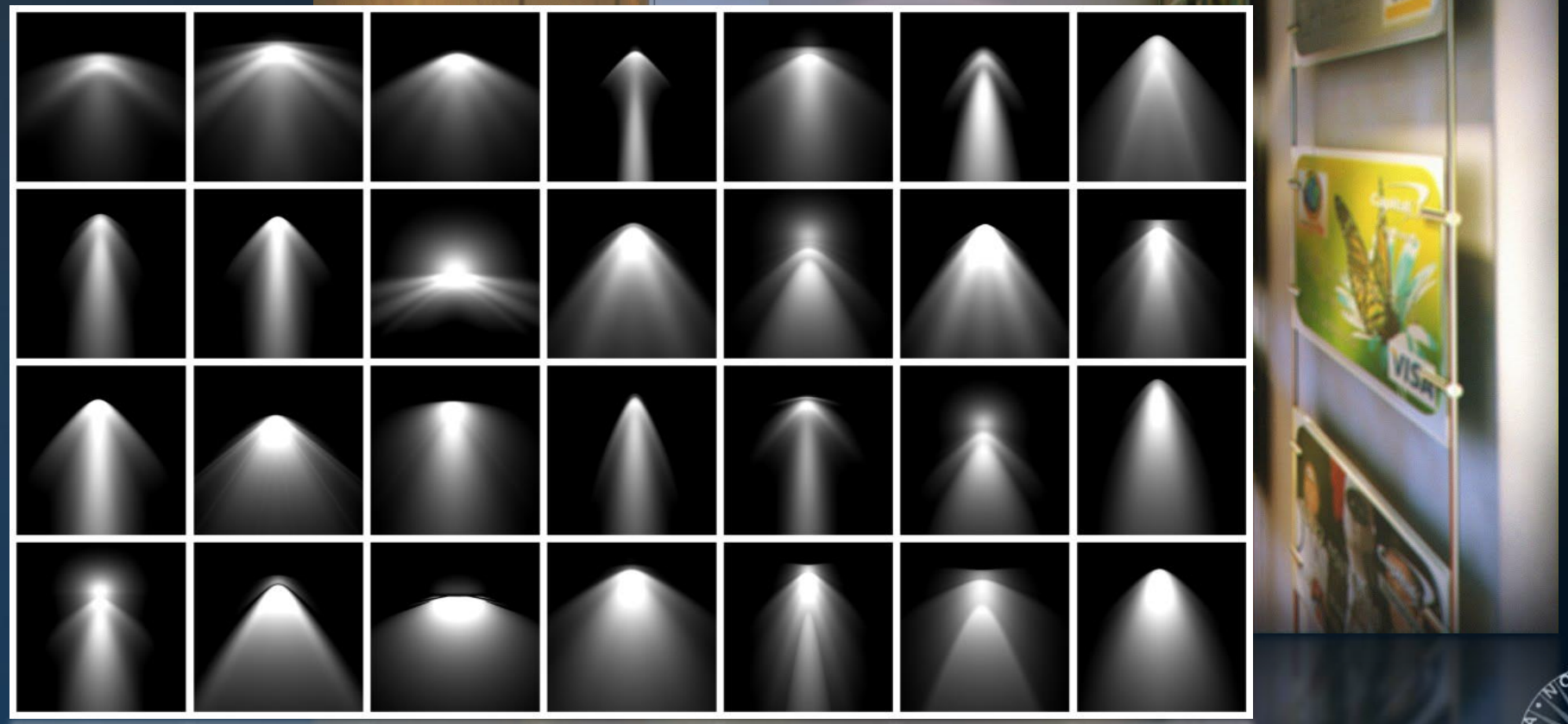
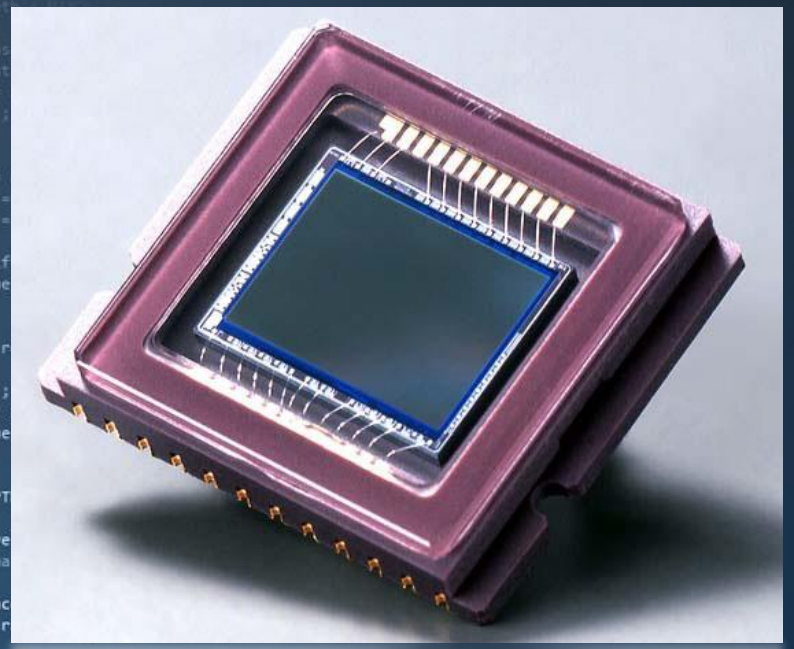


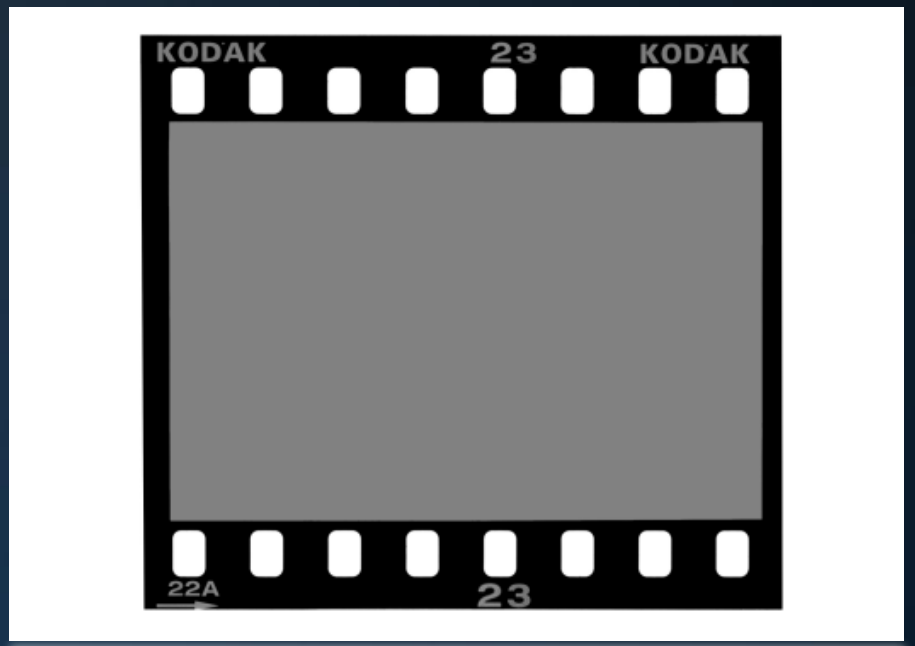
Introduction

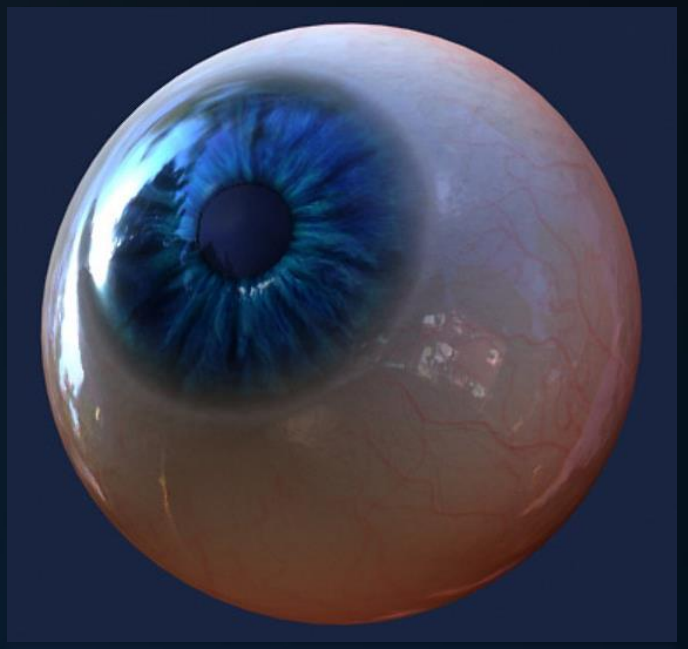
Light models

Introduction

Sensor models





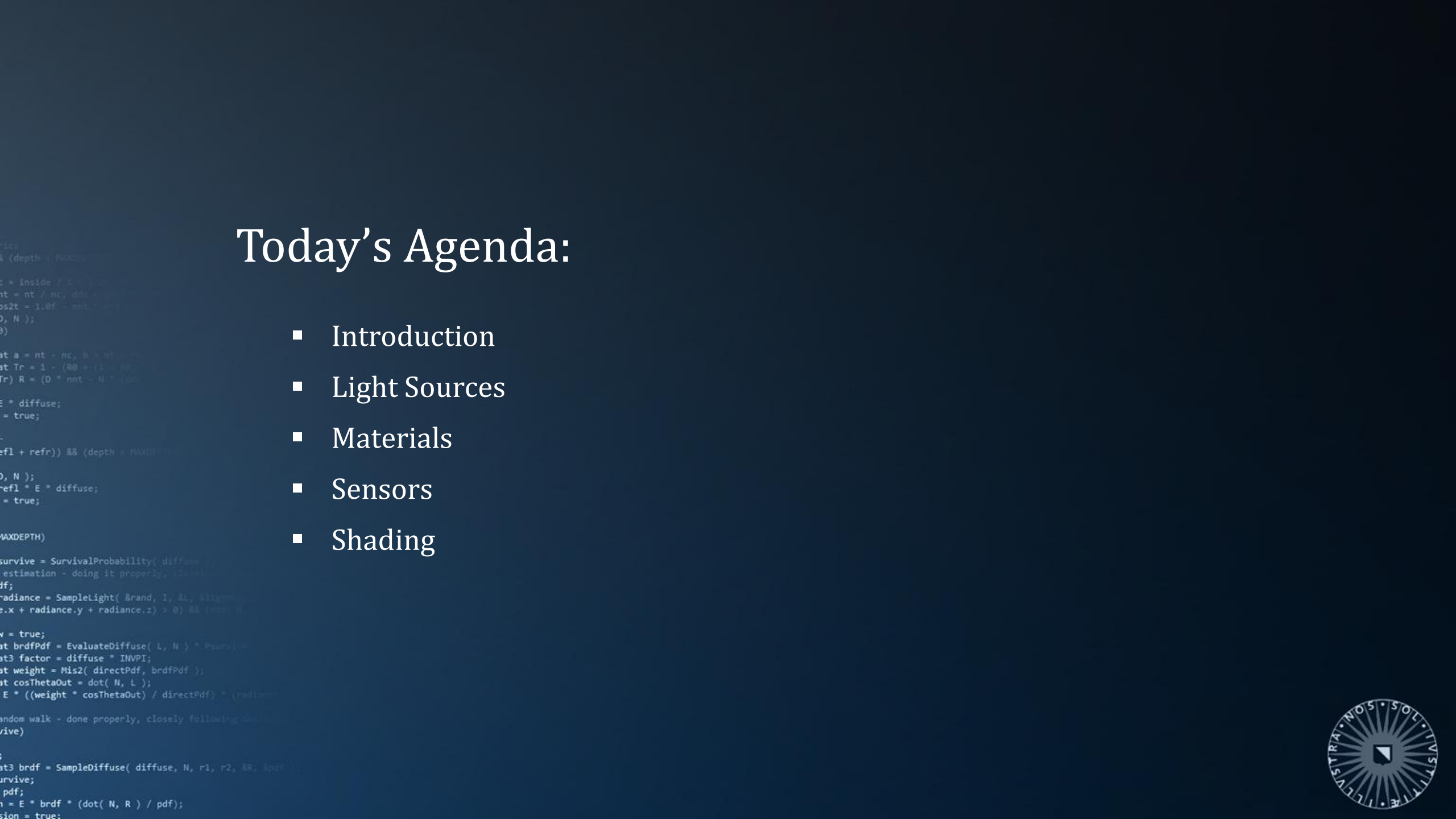


Introduction

1. Light is emitted by a light source
2. Light interacts with the scene — Absorption, Scattering
3. Light is absorbed by a sensor

Today’s Agenda:

- Introduction
- Light Sources
- Materials
- Sensors
- Shading



Light Sources

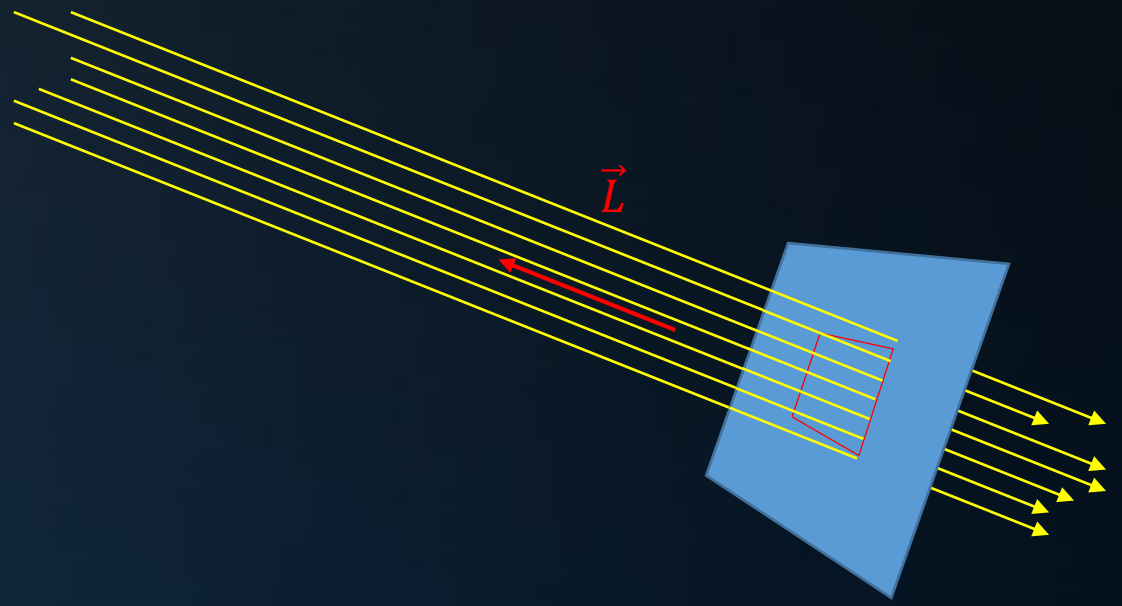
Directional lights

Directional light, such as the light from the sun:

Specified by a normalized, reversed vector $\vec{L}$.

Power is specified as energy travelling through a unit surface area, perpendicular to $\vec{L}$.

This quantity is called *irradiance*;
units: $W\ m^{-2}s^{-1}$.
The symbol for irradiance is E.



For practical purposes, we will express the energy as RGB vectors. Note that R,G,B can exceed 1, unlike e.g. colors in a painting.

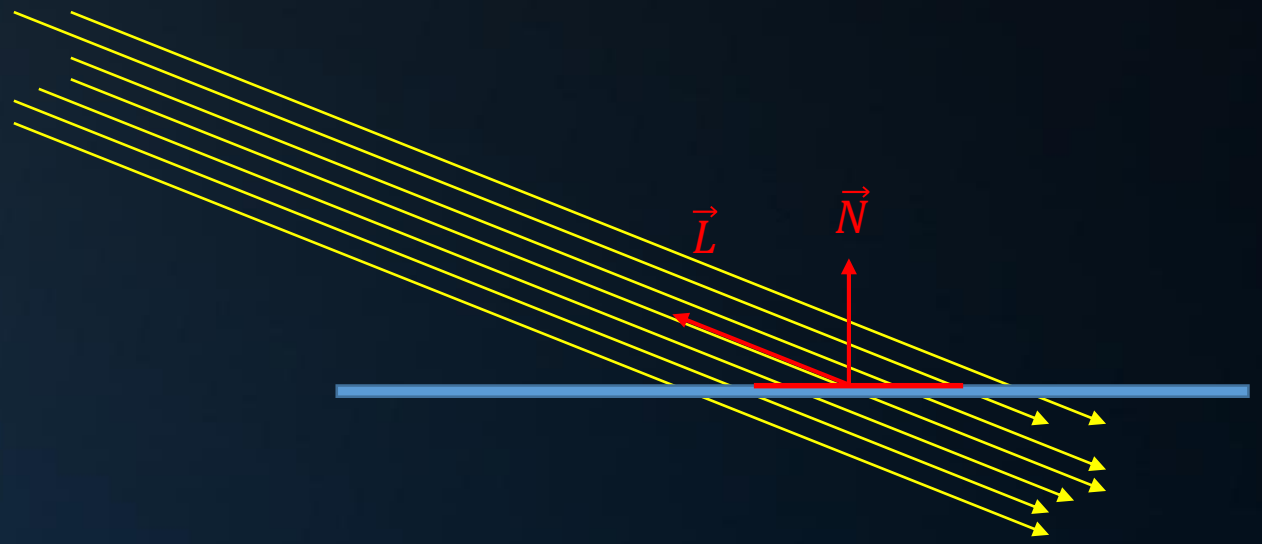
Light Sources

Directional lights

When illuminating a surface, we need to know how much light arrives at a unit area on the surface, i.e. how much light passes through a unit surface area perpendicular to $\vec{N}$.

For this, we multiply by the cosine of the angle between $\vec{N}$ and $\vec{L}$, i.e. $\vec{N} \cdot \vec{L}$.

Note that the cosine is clamped to 0, to prevent negative contributions from light arriving from the backside of the surface.



$$E = E_L \overline{cos}\theta_i$$
$$E = E_L \max(\vec{N} \cdot \vec{L}, 0)$$

Light Sources

Irradiance

The unit surface may receive light from many directions. For multiple lights, irradiance is additive, and represents the energy arriving over the hemisphere:

$$E = \sum_{k=1}^{n} E_{L_k} \overline{cos}\ \theta_{i_k}$$

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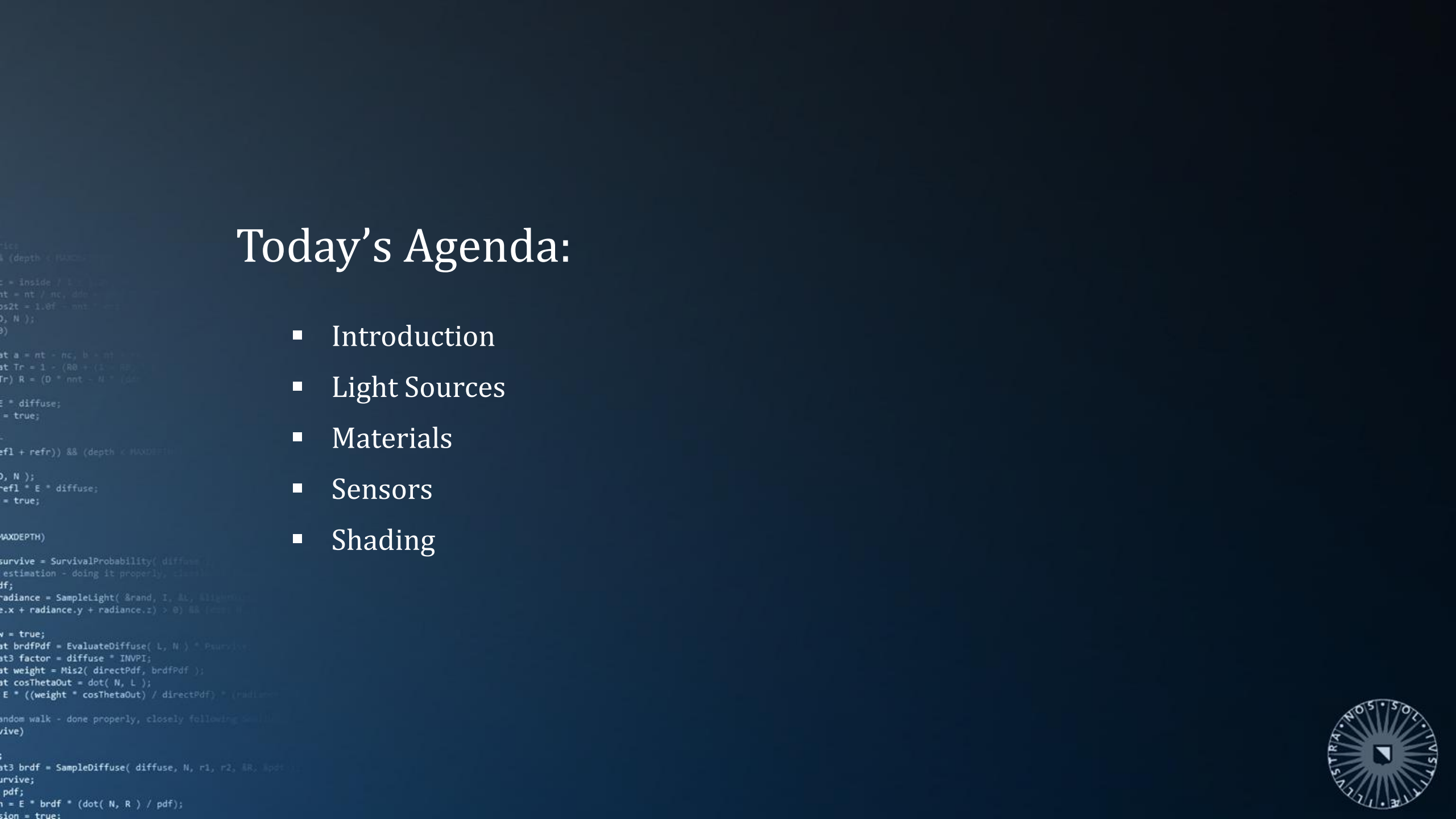


Materials

Material properties:

- Texture + detail texture
- Shader
- Normal map
- Specular map
- Color
- …

Used to simulate the interaction of light with a material.

Interaction:

- Absorption
- Scattering

Materials

Absorption:

Happens on ‘optical discontinuities’.

Light energy is converted in other forms of energy (typically heat), and disappears from our simulation.

Materials typically absorb light with a certain wavelength, altering the color of the scattered light. This is how we perceive material color.

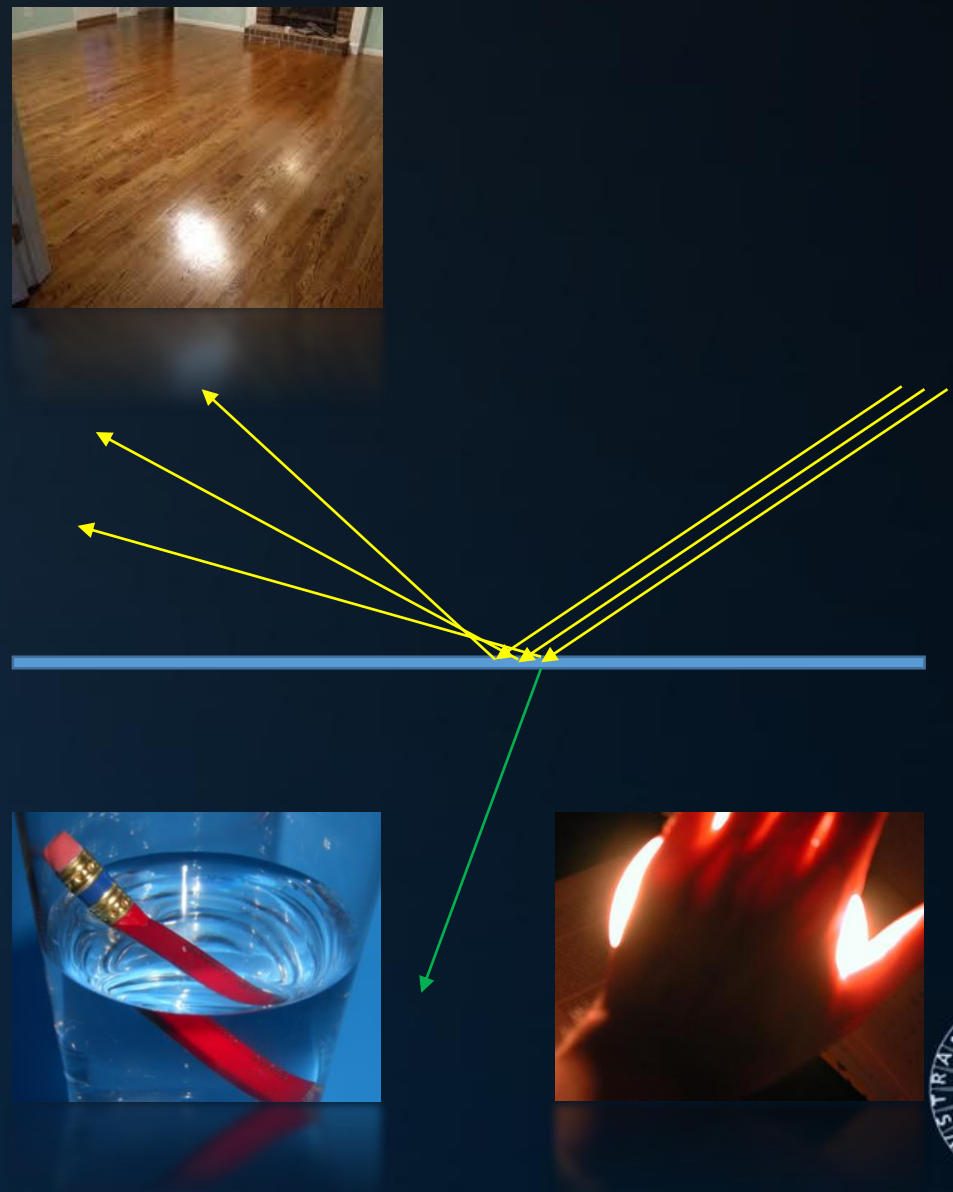
Materials

Scattering

Happens on ‘optical discontinuities’.

Scattering causes light to change direction. Note that the amount of energy does not change due to scattering.

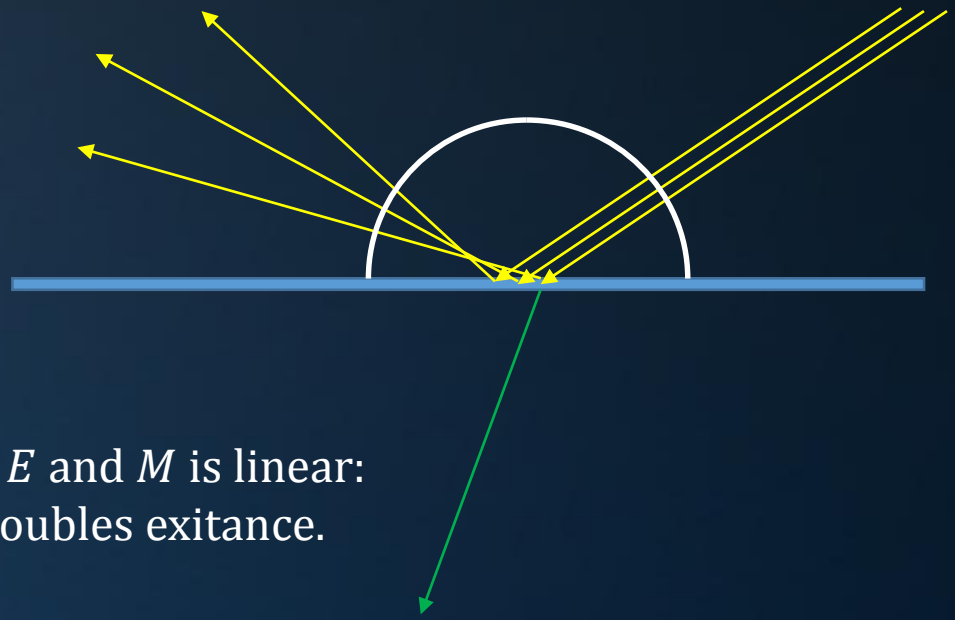
Light leaving the hemisphere can never exceed light entering the hemisphere, unless the material is emissive.



Materials

Light / surface interaction

In: irradiance (E), from all directions over the hemisphere.
Out: exitance (M), in all directions over the hemisphere.



The relation between E and M is linear:
doubling irradiance doubles exitance.

$\frac{M}{E}$ must be in the range 0..1.

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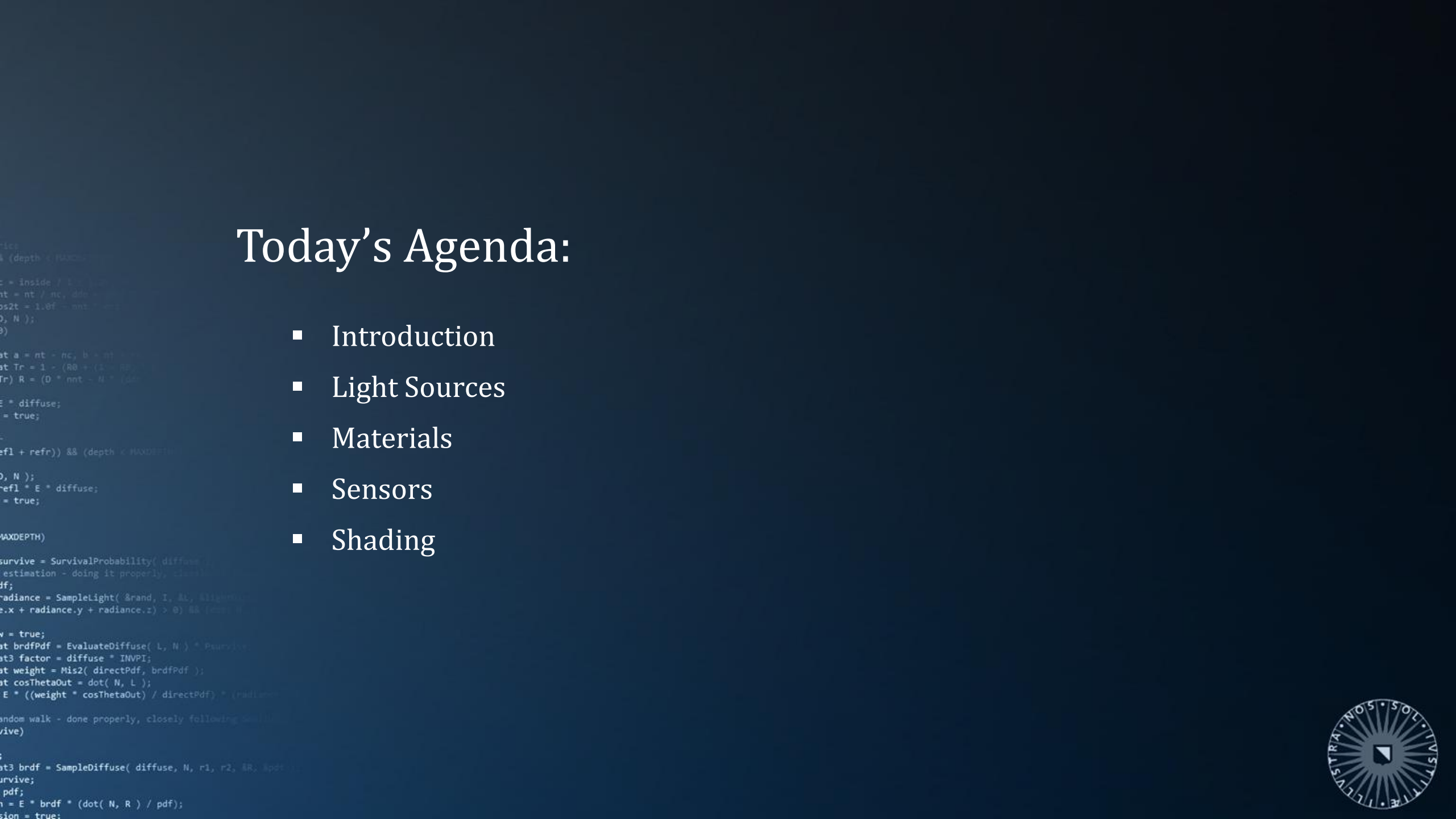
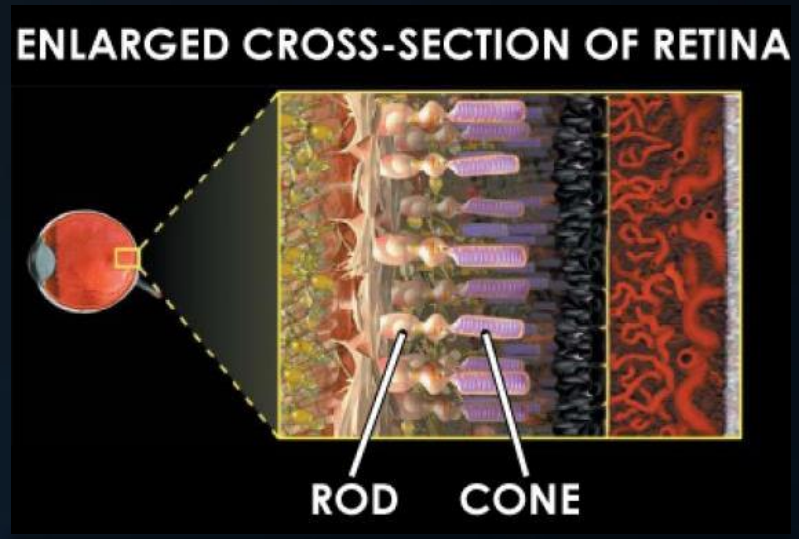


Sensors

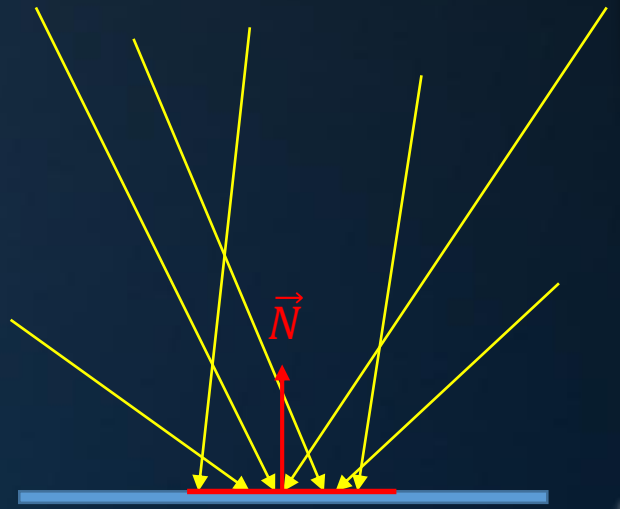
Sensors typically consists of many small sensors:

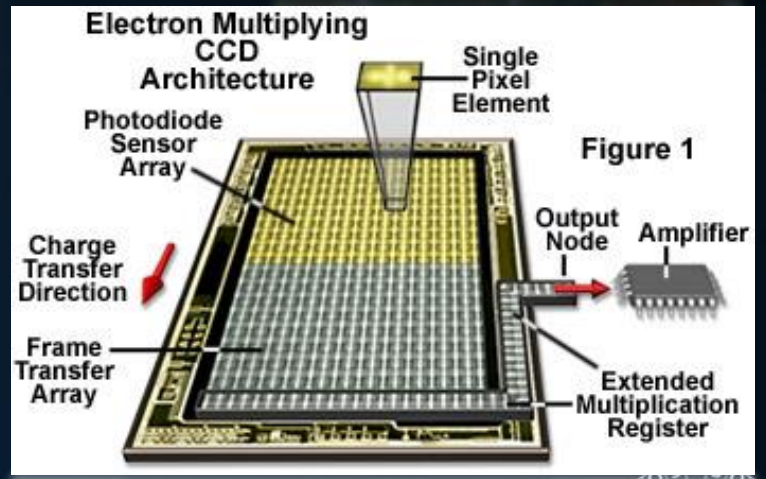
- Rods and cones in the eye
- Dye particles in the film
- Pixel elements in a CCD
- A ray in a ray tracer
- A fragment in a rasterizer



Note that we cannot use irradiance to generate an image:

irradiance is a measure for light arriving from all directions.

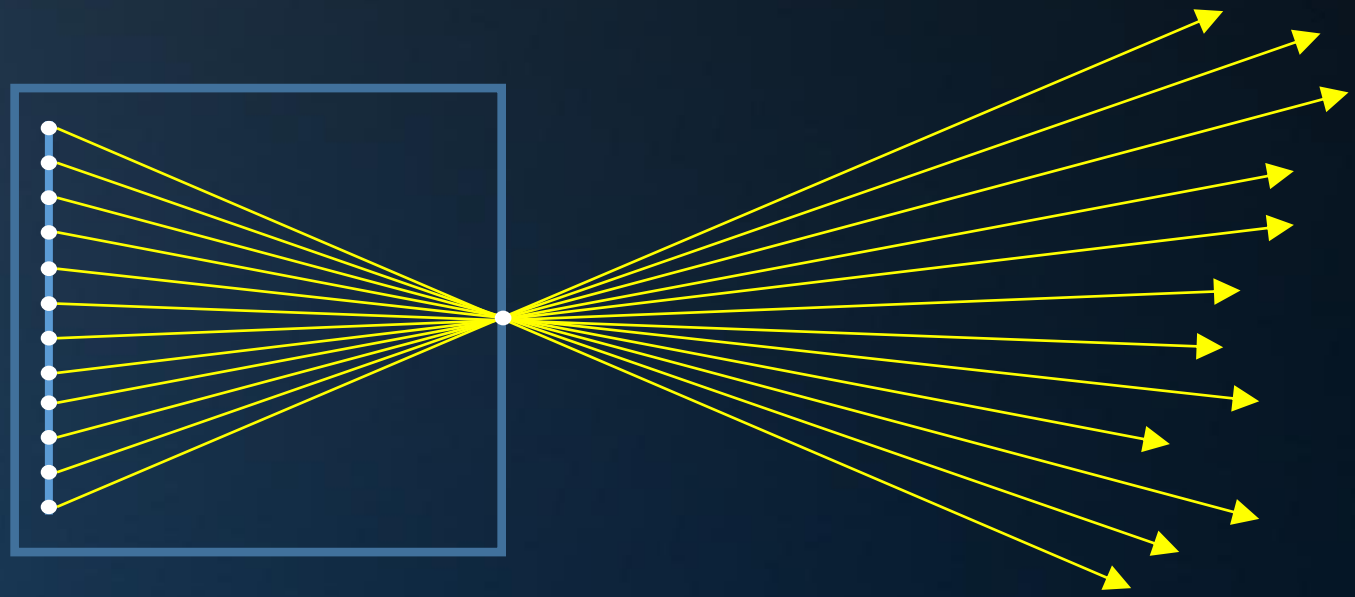




Sensors

Pinhole camera

To capture light from a specific direction, we use a camera with a small opening (the aperture), so that each sensor can ‘see’ a small set of incoming directions.



Sensors

Radiance

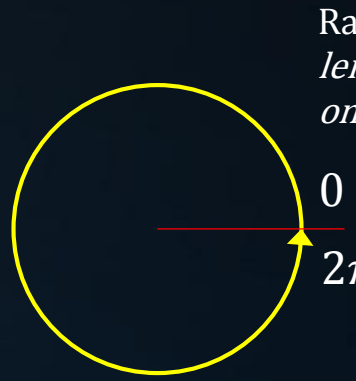
Using a pinhole camera, the sensors become directionally specific:

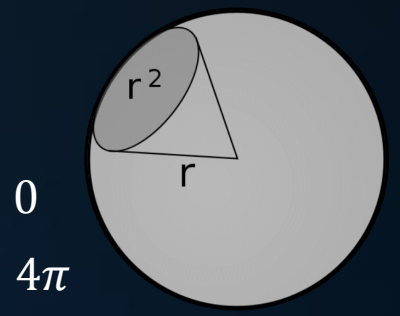
they average light over a small area, and a small set of incoming directions.

This is referred to as *radiance* :

The density of light flow per area per incoming direction.

Units: $W\ m^{-2}sr^{-1}s^{-1}$.
Symbol: L

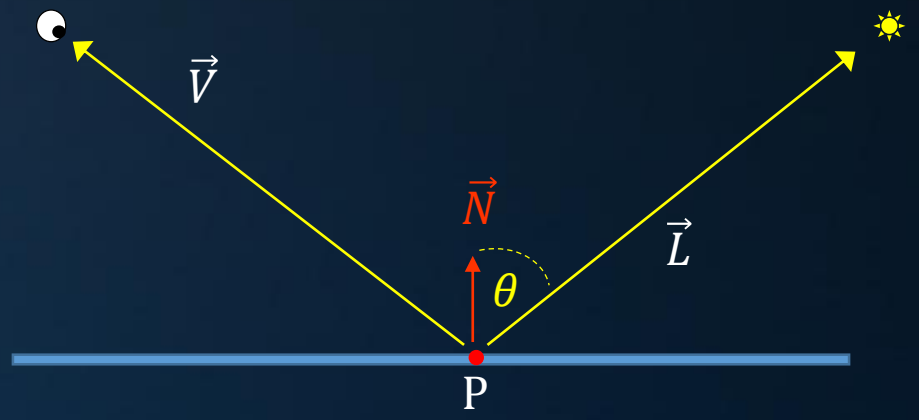




Sensors

Summing it up:

- Light arrives from all light sources on point P;
- The energy flow per unit area, perpendicular to $\vec{L}$ is projected on a surface perpendicular to $\vec{N}$. This is *irradiance,* or: E.
- Exitant light M is scattered over all directions on the hemisphere.
- Light scattered towards the eye arrives at a sensor.
- The sensor detects radiance: light from a specific set of directions.



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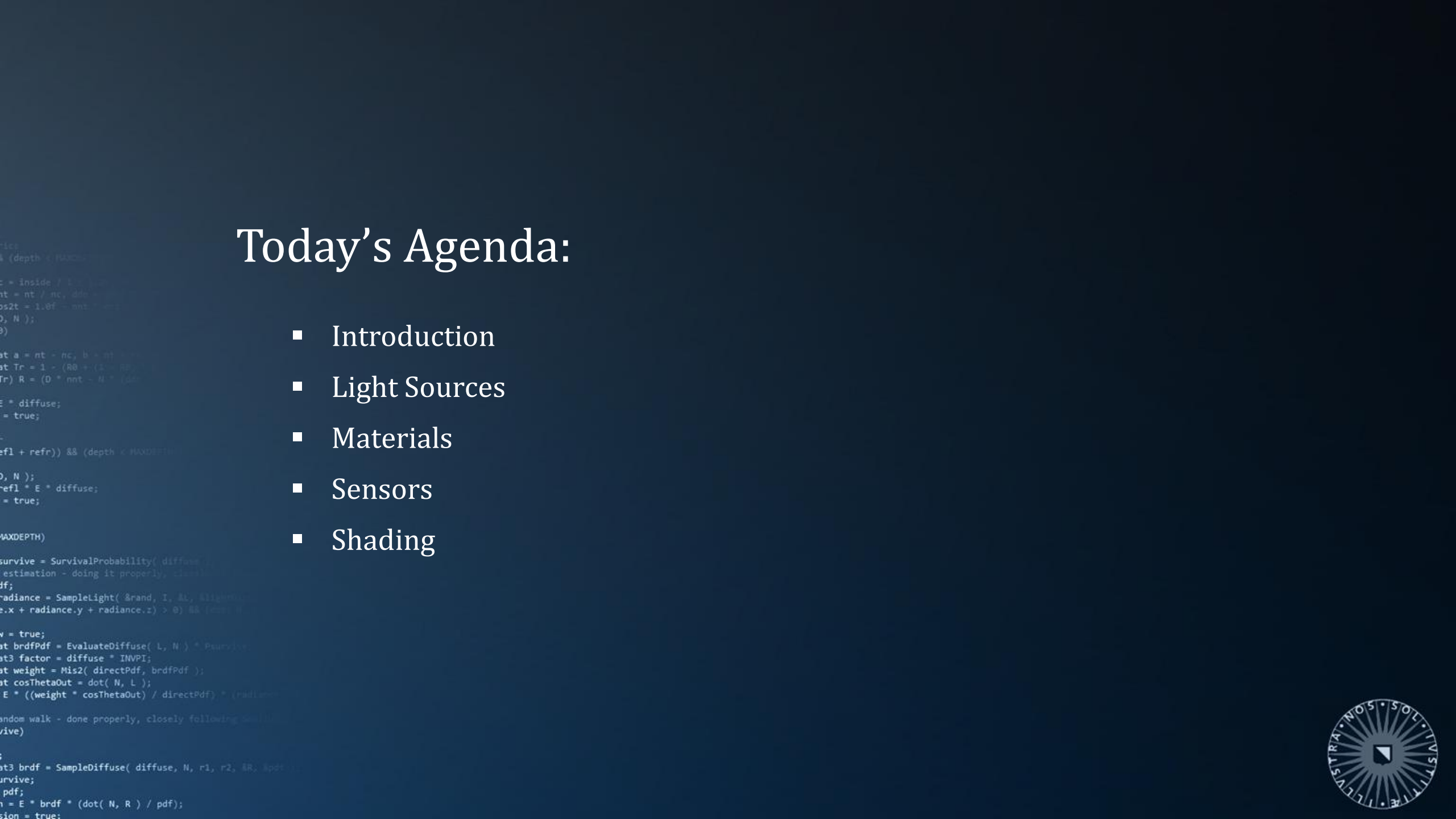
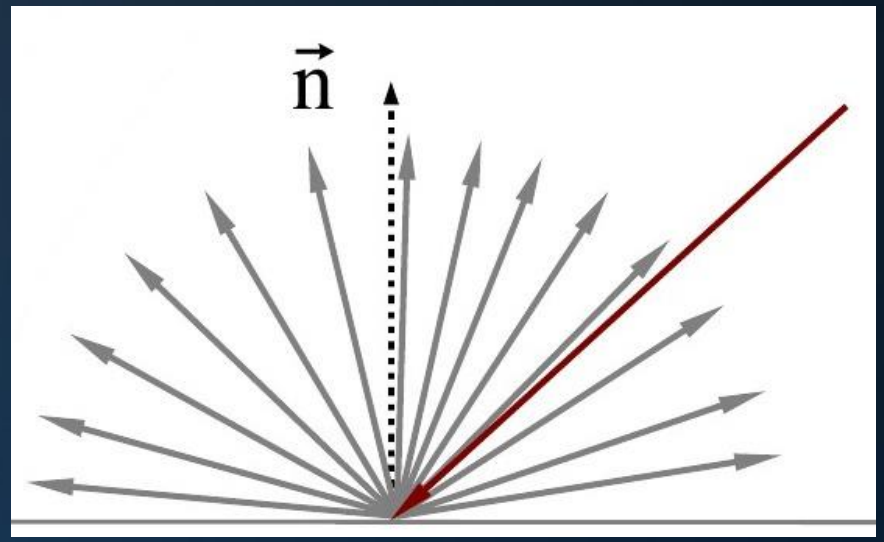


Shading

Definition

Shading: the process of using an equation to compute the outgoing radiance L_o along the view ray $\vec{V}$, based on material properties and light sources.



Diffuse or *Lambert* BRDF, also called “N dot L shading”

Shading

Lambert shading model

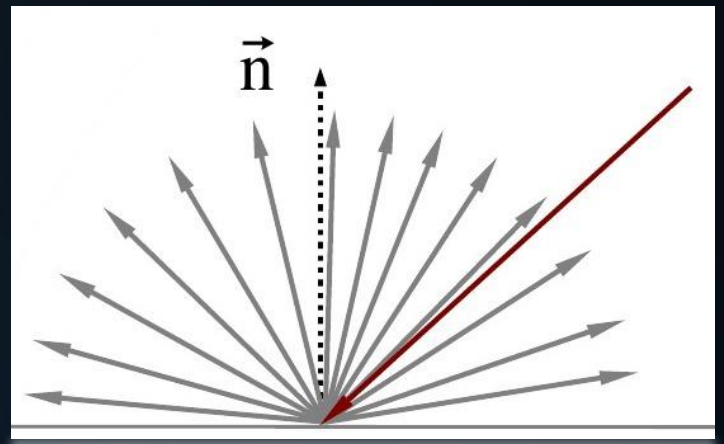
The diffuse shading model is:

$$M_{diff} = \frac{c_{diff}}{\pi} E_{L_i} \overline{cos}\theta_i$$

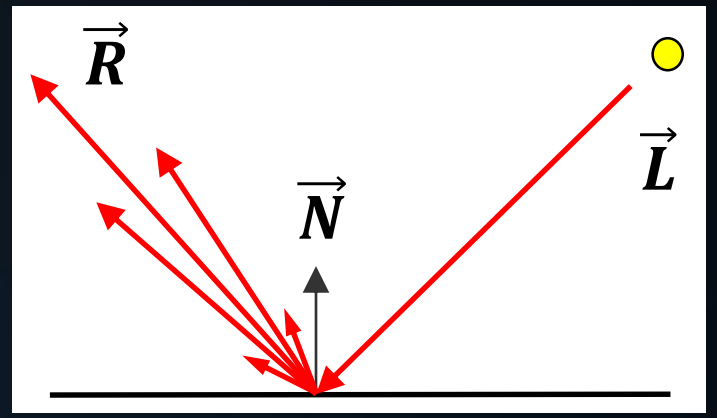
This takes into account:

- Projection of the directional light on the normal;
- Absorption due to material color c_{diff}.

Distance attenuation is represented in E_{L_i}
(for directional lights, this is not applicable)



Shading



Phong shading model

The Phong shading model combines a diffuse reflection with a glossy one, and adds an ambient factor.

$$M_{phong} = c_{ambient} + c_{diff}(\vec{N} \cdot \vec{L})L_{diff} + c_{spec}(\vec{V} \cdot \vec{R})^S L_{spec}$$

The Phong shading model is an ‘empirical model’, and has many problems:

- It doesn’t guarantee that $M \leq E$;
- It doesn’t take irradiance as input;
- It requires many (unnatural) parameters;
- That ambient factor…

Shading

BRDF – Bidirectional Reflectance Distribution Function

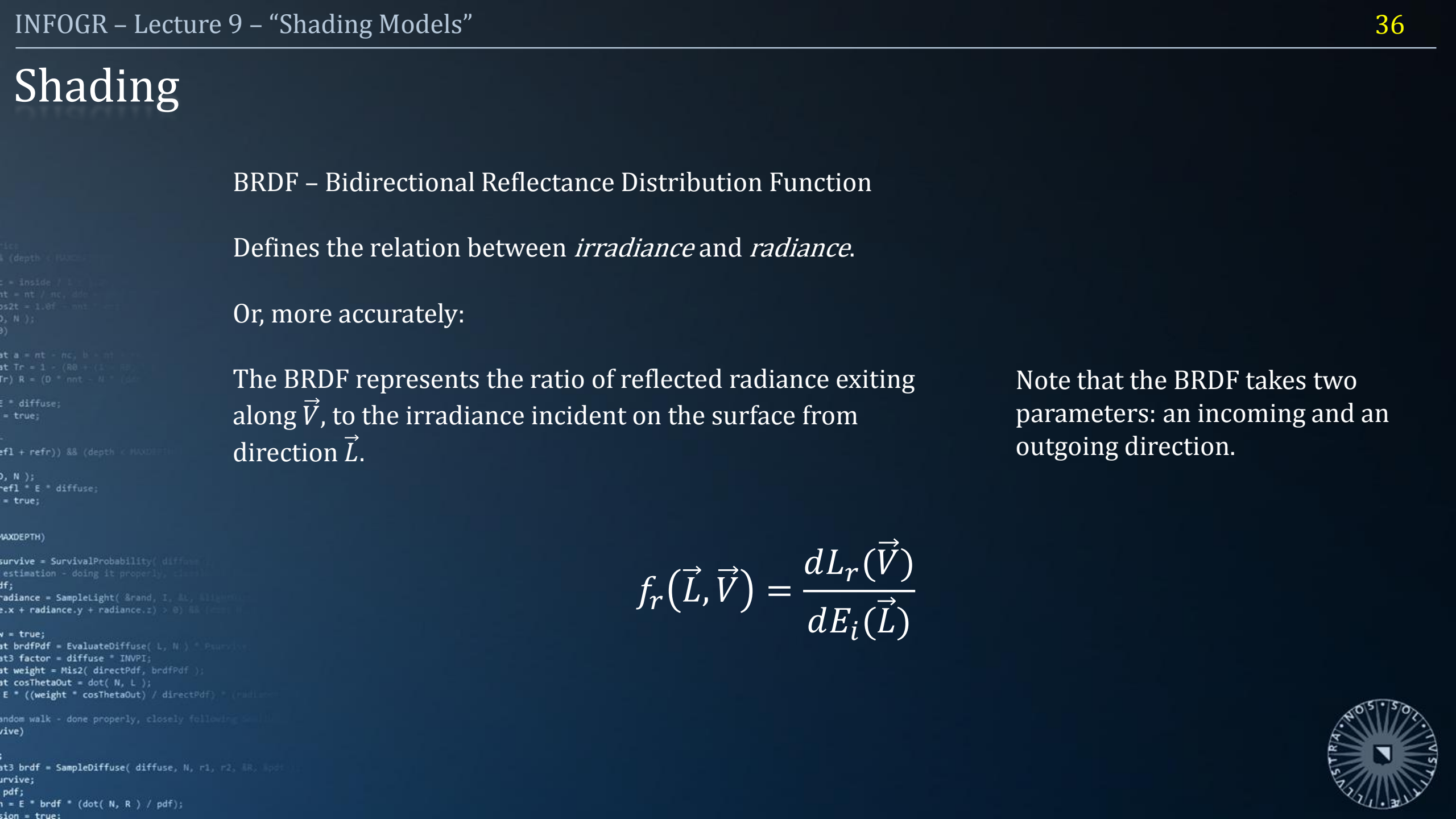
Defines the relation between *irradiance* and *radiance*.

Or, more accurately:

The BRDF represents the ratio of reflected radiance exiting along $\vec{V}$, to the irradiance incident on the surface from direction $\vec{L}$.

Note that the BRDF takes two parameters: an incoming and an outgoing direction.

$$f_r(\vec{L}, \vec{V}) = \frac{dL_r(\vec{V})}{dE_i(\vec{L})}$$



Shading

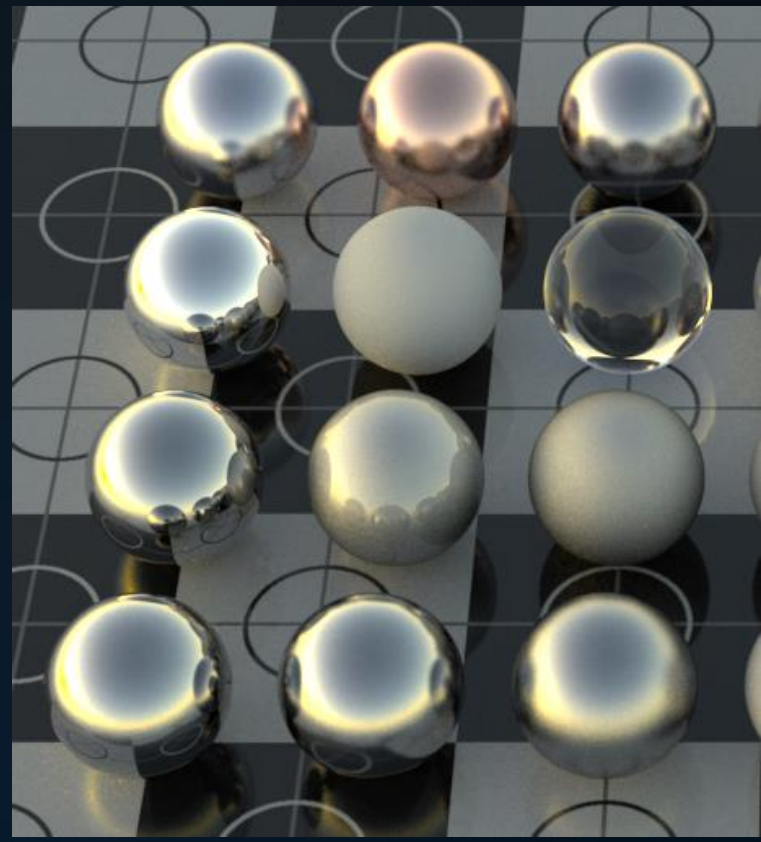
BRDF – Bidirectional Reflectance Distribution Function

BRDFs formalize the interaction of light / surface interaction, and allow us to do so in a physically correct way.

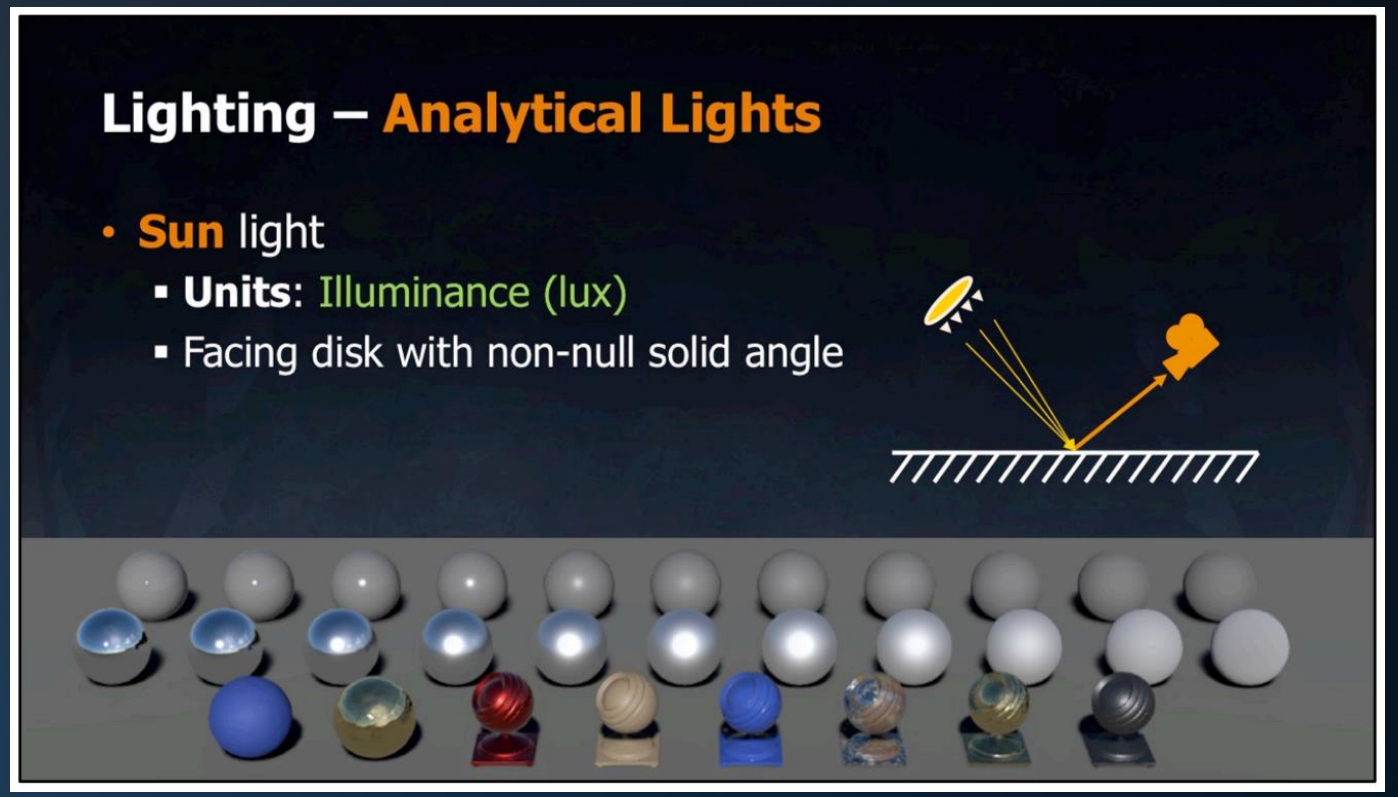
Games are switching to physically based models rapidly:

- To increase realism;
- To reduce the number of parameters in shaders;
- To have uniform shaders for varying lighting conditions.

More on this in Advanced Graphics!



Shading



“Moving Frostbite to PBR”
http://www.frostbite.com/wp-content/uploads/2014/11/s2014_pbs_frostbite_slides.pdf

Shading

“Lighting Killzone : Shadow Fall”
http://www.guerrilla-games.com/presentations/Drobot_Lighting_of_Killzone_Shadow_Fall.pdf

Shading

“Physically Based Shading in Unity”
http://aras-p.info/texts/files/201403-GDC_UnityPhysicallyBasedShading_notes.pdf

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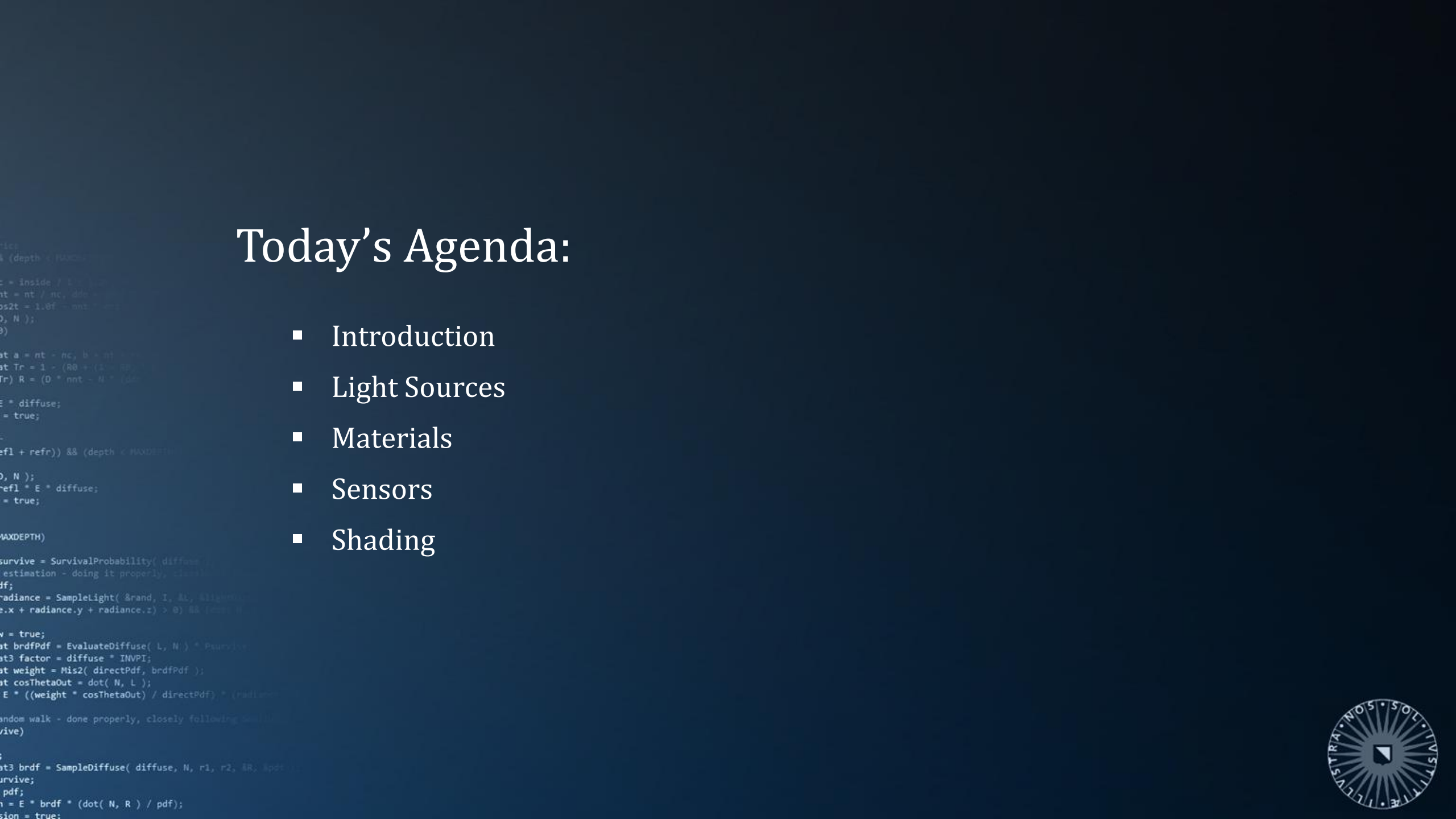

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J. Bikker - April-July 2015 - Lecture 9: “Shading Models”

END of “Shading Models”

next lecture: “Ground Truth”