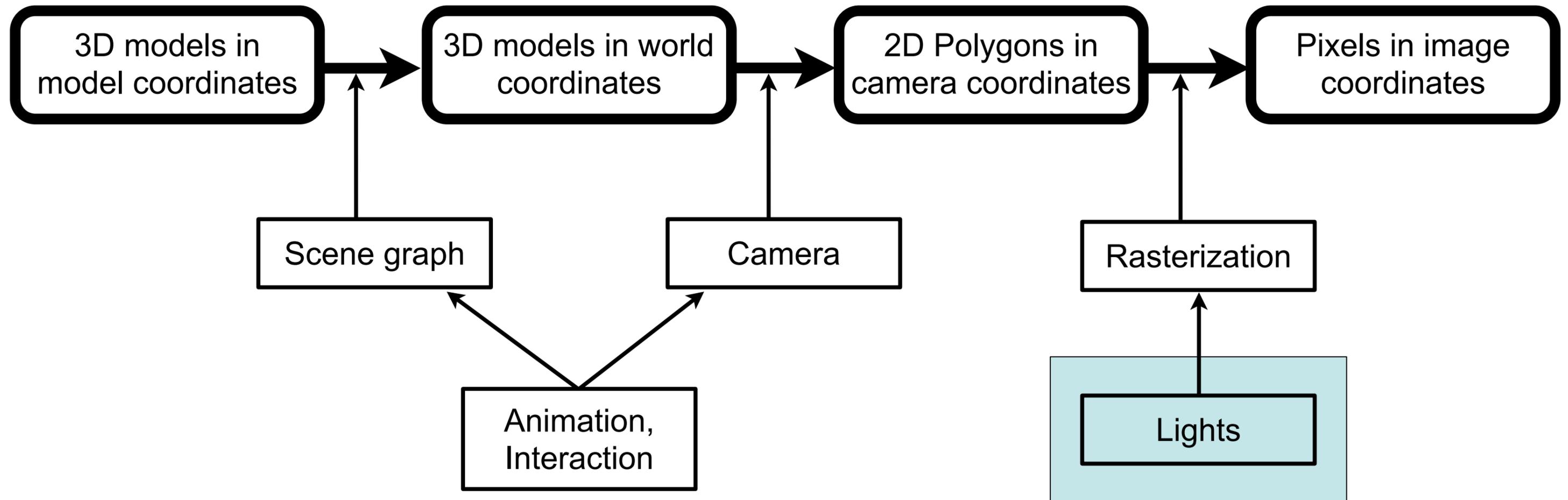


# Computer Graphics 1

Chapter 5 (June 9th, 2011, 2-4pm):

Light and shadows in 3D computer graphics

# The 3D rendering pipeline (our version for this class)



# Chapter 5 - Light and shadows in 3D computer graphics

- Types of light in nature and in CG
- Shadows
- Using lights in CG

# Light in nature (physics refresher)

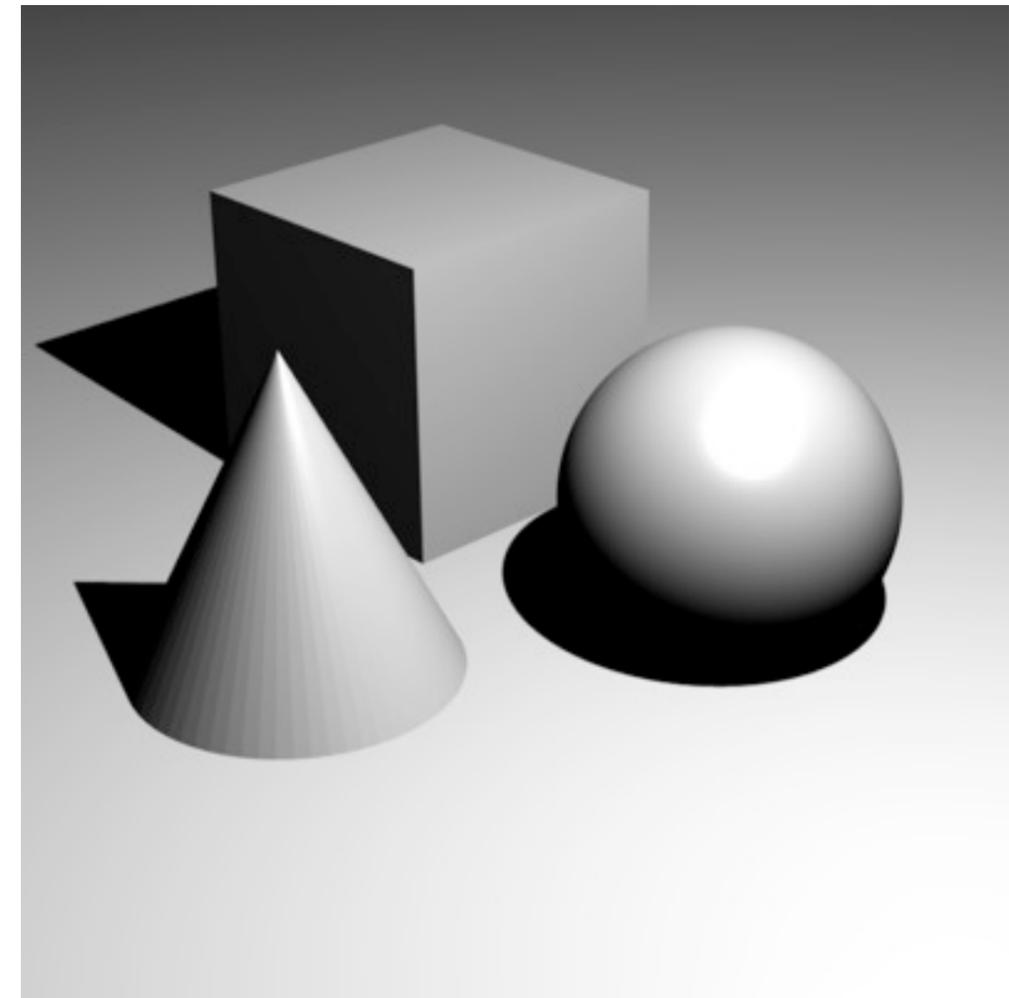
- Can be described as a electromagnetic wave
- Can also be described as a stream of photons
- Intensity drops with distance from the source
  - how?
  - \_\_\_\_\_
- Monochromatic (1 color) light has 1 frequency
- White light is a mixture of many frequencies
- Can be simulated for the human eye by adding Red, Green and Blue
- The human eye can discriminate a dynamic range of  $1:2^{30}$  with adaptation or  $1:2^{16}$  without [Seetzen et al., „High dynamic range display systems“, ACM Siggraph 2004]
- Film, digital cameras, and computer screens can only deal with less!



<http://www.lebjournal.com/newz/wp-content/candle-light-photography.jpg>

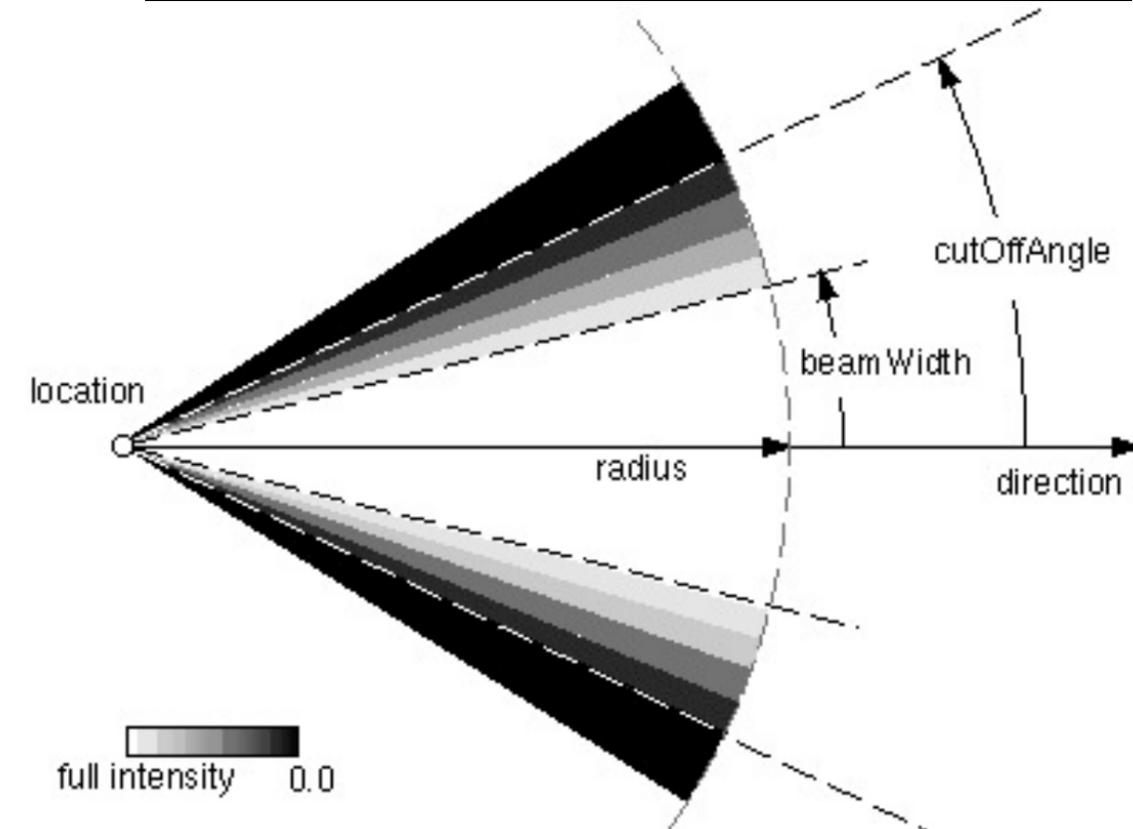
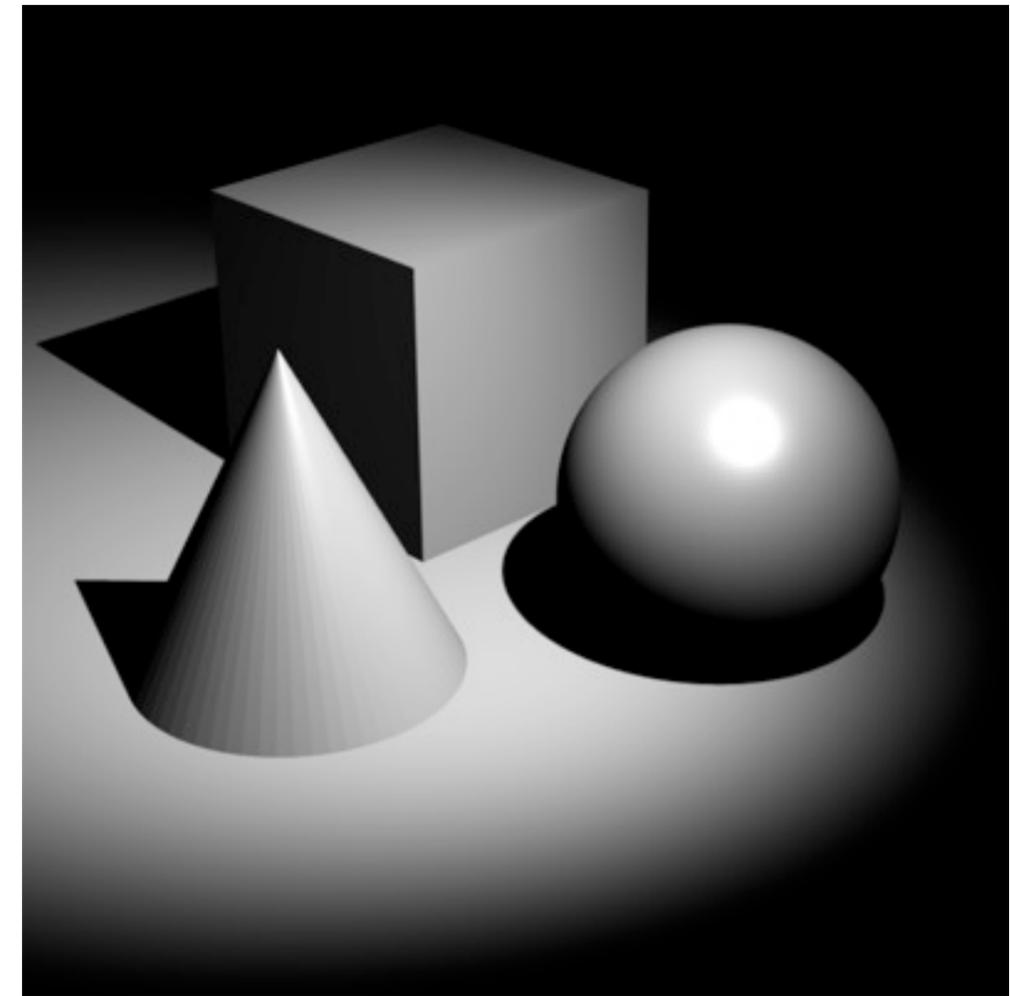
# Point light sources

- have just a position in space
- emit light equally in all directions
- Intensity falloff with distance  $d$  is:  
 $I = I_0 / (ad^2 + bd)$ 
  - this means that the falloff is less harsh than in nature. Why??
- Light source itself is invisible in the image
  - since points are infinitely small
- Shadows have sharp edges
- Shadows get bigger with distance from object



# Spot lights

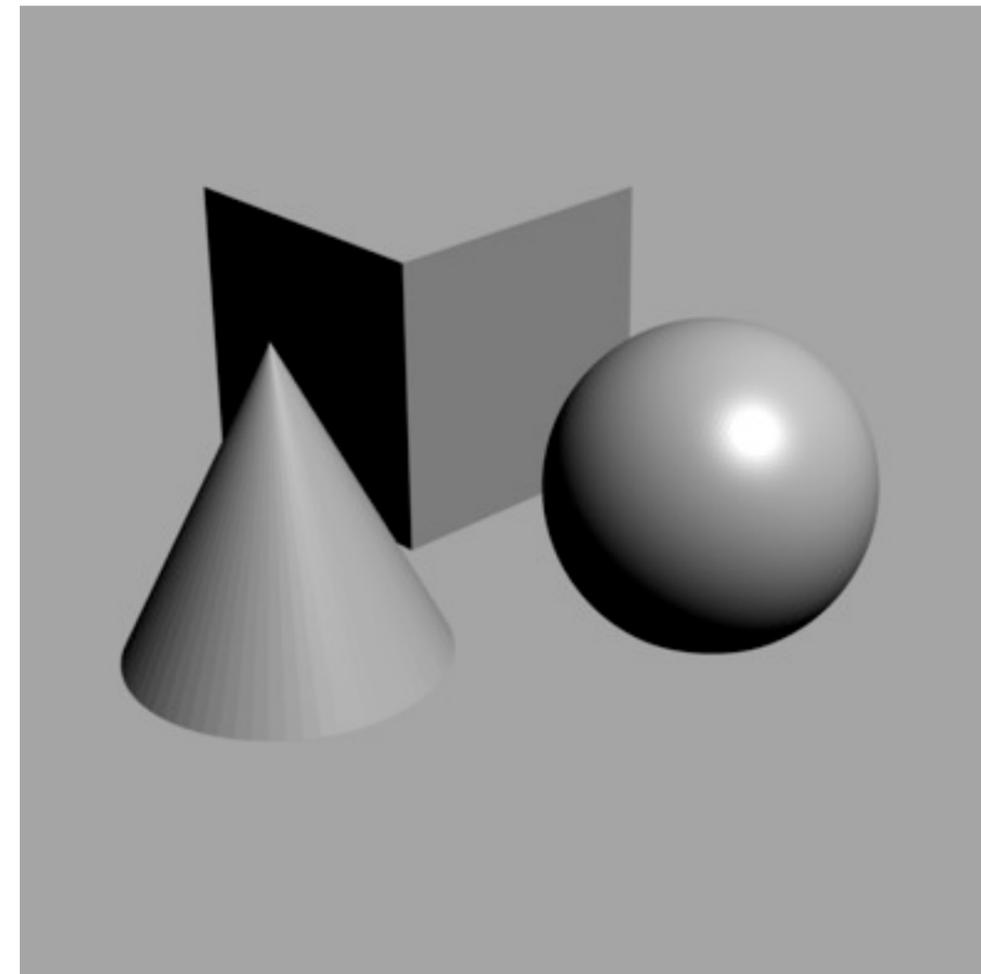
- have a position and orientation in space
- have an opening angle and a parameter controlling the softness of the beam's borders
- Intensity falloff with distance  $d$  is:  
$$I = I_0 / (ad^2 + bd)$$
  - this means that the falloff is less harsh than in nature. Why??
- Intensity falloff with angle depends on exact model
- light source itself invisible
- object shadows have sharp edges
- transition to surrounding shadow is soft.



<http://www.web3d.org/x3d/specifications/vrml/ISO-IEC-14772-VRML97/Images/spotlight.gif>

# Distant light source (a.k.a. the sun)

- size of the earth (radius) = 6.370 Km
- distance from earth to sun = 150.000.000 Km
- distance to the sun is practically equal for all points on earth
  - hence light falloff with distance is not noticeable for sunlight
  
- distant light source in 3DCG has only a direction and a fixed intensity
- good and neutral first step for lighting a scene!
- shadows should have sharp edges

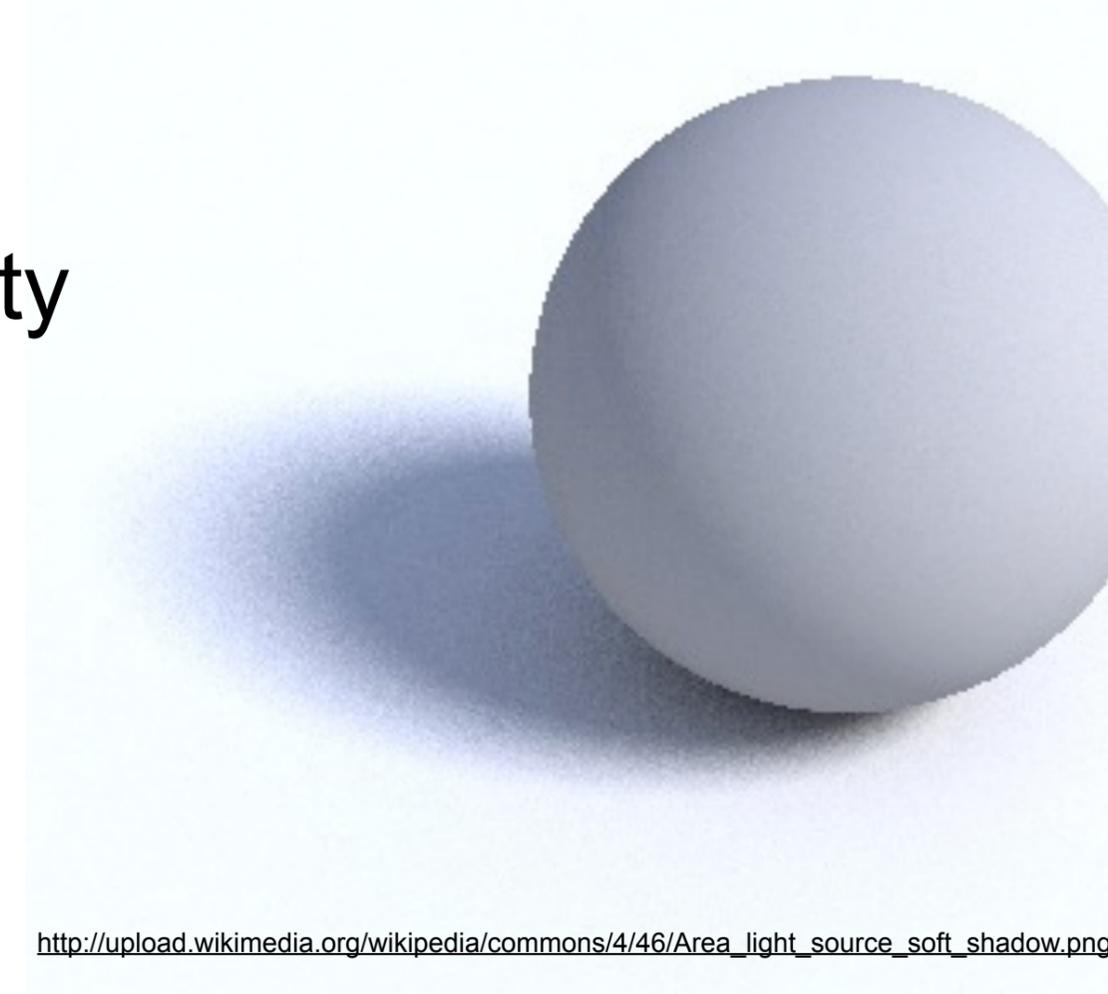


# Ambient light

- Equivalent in nature:
    - light emitted from the entire sky
    - indirect light reflected from objects in the scene
  - intensity is equal from all directions
  - creates low contrast images by itself
- 
- [http://de.wikibooks.org/wiki/Datei:Blender3D\\_li\\_ambient\\_light\\_occl.jpg](http://de.wikibooks.org/wiki/Datei:Blender3D_li_ambient_light_occl.jpg)
- ambient light is a good way to light up harsh shadows
  - combination with one distant light can already create a decent daylight simulation (sun + sky)

# Area light sources

- described by object geometry and light intensity
- entire area emits light
- all natural light sources are of this kind
  - even a light bulb has a surface  $> 0$
- shadows have soft edges
- light falloff with distance
- computationally difficult, take very long to render correctly
- can be simulated by many point light sources
- need global illumination techniques for correct rendering (see later)



# Chapter 5 - Light and shadows in 3D computer graphics

- Types of light in nature and in CG
- Shadows
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# Shadows in nature

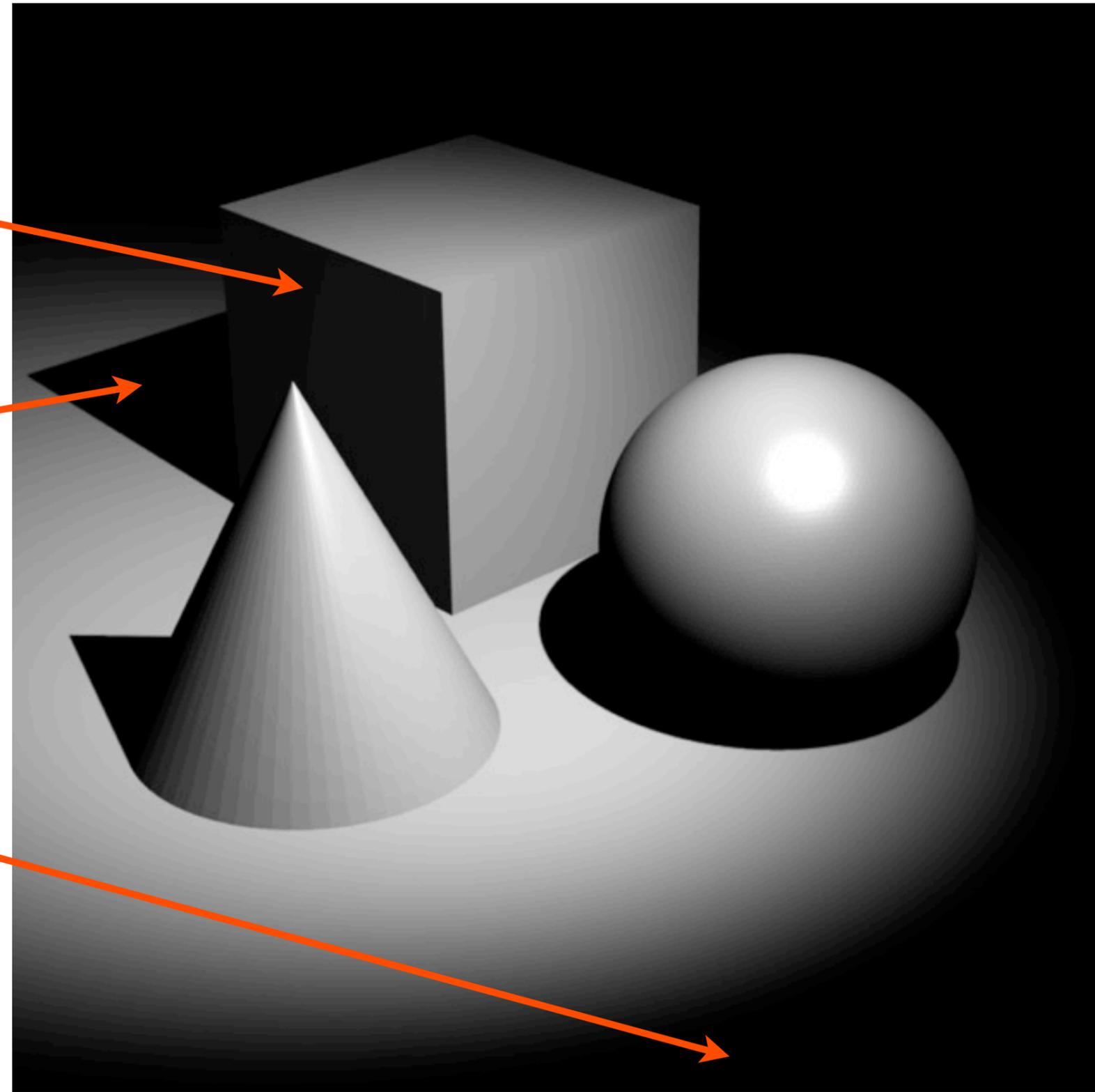
- Very important for spatial vision
- Artistically used in all art forms
  - drawing, painting
  - photography
  - cinematography
- Practically never really black
- Types of shadows in this image?



<http://www.heise.de/imagine/VzI2PeXewMuSsFADy2UvZXFzFUk/gallery/shadow-lines.jpg>

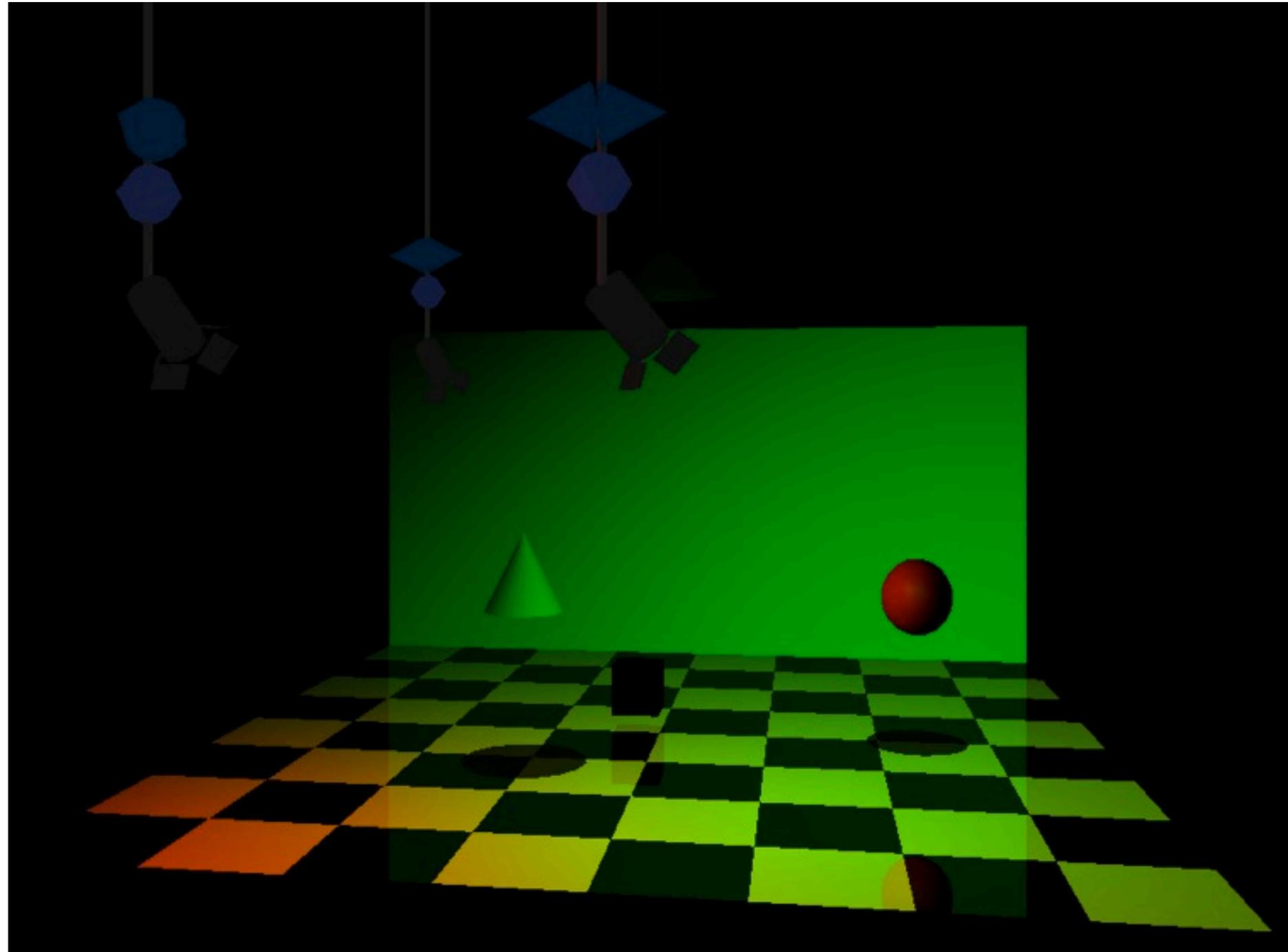
# Types of shadow

- Object shadow
  - the shadow side of objects
  - exists in free space
- Cast shadow / drop shadow
  - the shadow cast onto another object (or the ground)
  - need another object or ground plane
- Shadow as the absence of light
  - no light source reaches this place



# Cheating a shadow (and a reflection!)

- Try to guess how this simple VRML world creates shadows and reflections in real time!

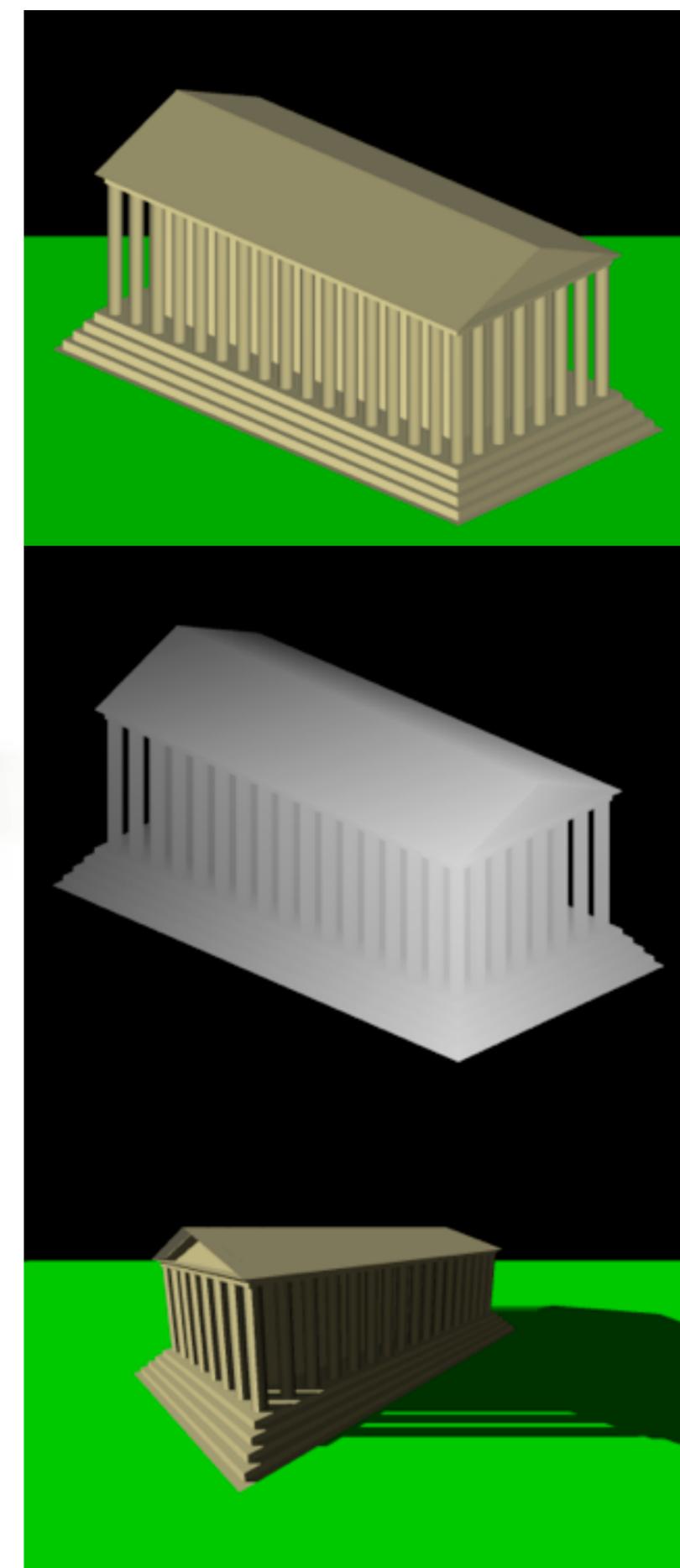


# shadow maps

- From the position of a light source, record a depth buffer
  - for each pixel in buffer, we know how far from the light it is
- For each rendered pixel in the camera image, check distance of its surface point to the light
  - if closer than shadow buffer: in this light
  - If further away: in the shadow of this light
- If scene or lights change, shadow map must be recalculated



[http://ecx.images-amazon.com/images/I/41YwkCd19DL\\_SL500\\_AA300.jpg](http://ecx.images-amazon.com/images/I/41YwkCd19DL_SL500_AA300.jpg)



[http://de.wikipedia.org/wiki/Shadow\\_Mapping](http://de.wikipedia.org/wiki/Shadow_Mapping)

# Chapter 5 - Light and shadows in 3D computer graphics

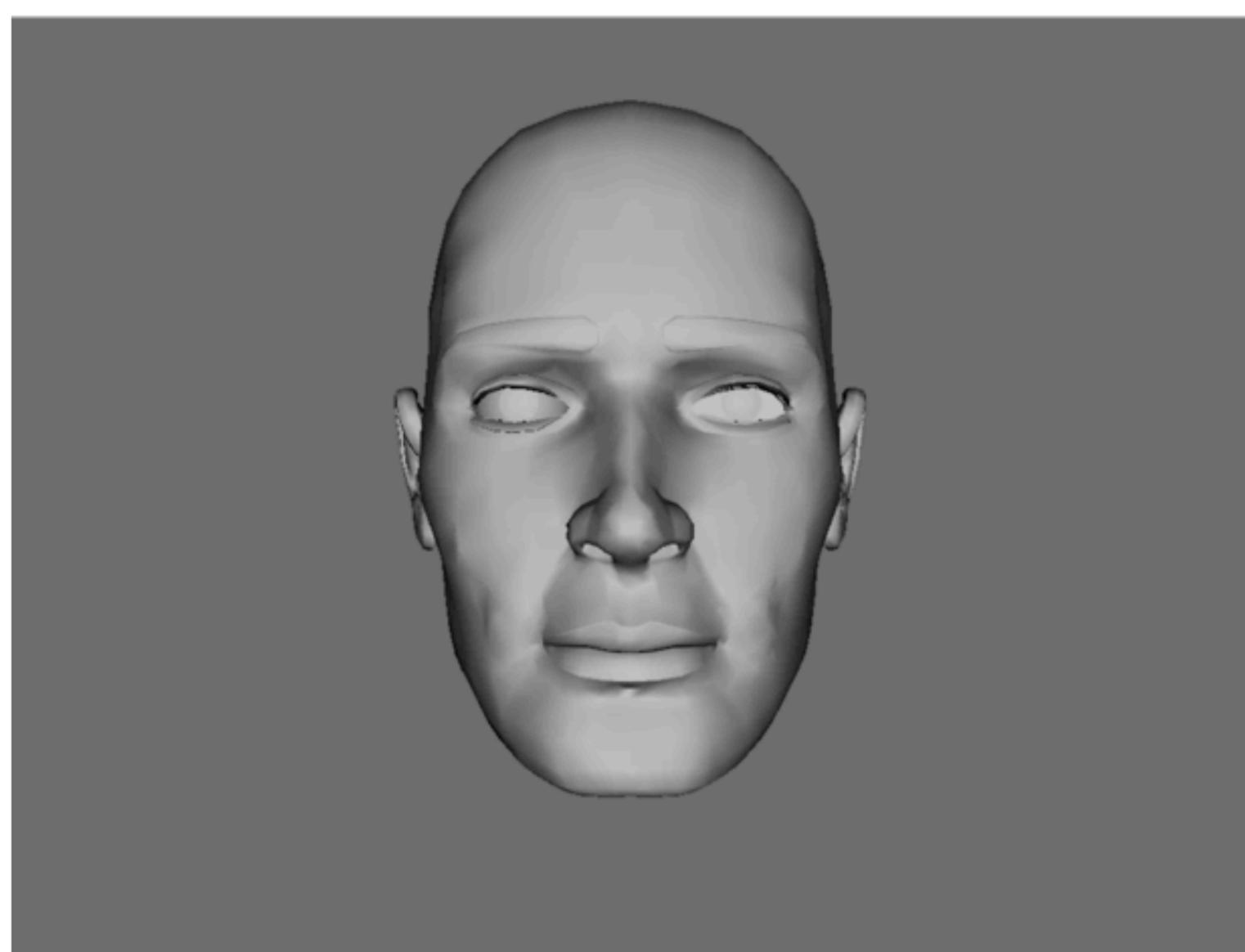
- Types of light in nature and in CG
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# Using Lights

- A few recipes to get started with lighting
- Really good lighting design is an art in itself
  - 3D animated movies hire full time light designers

# Headlight

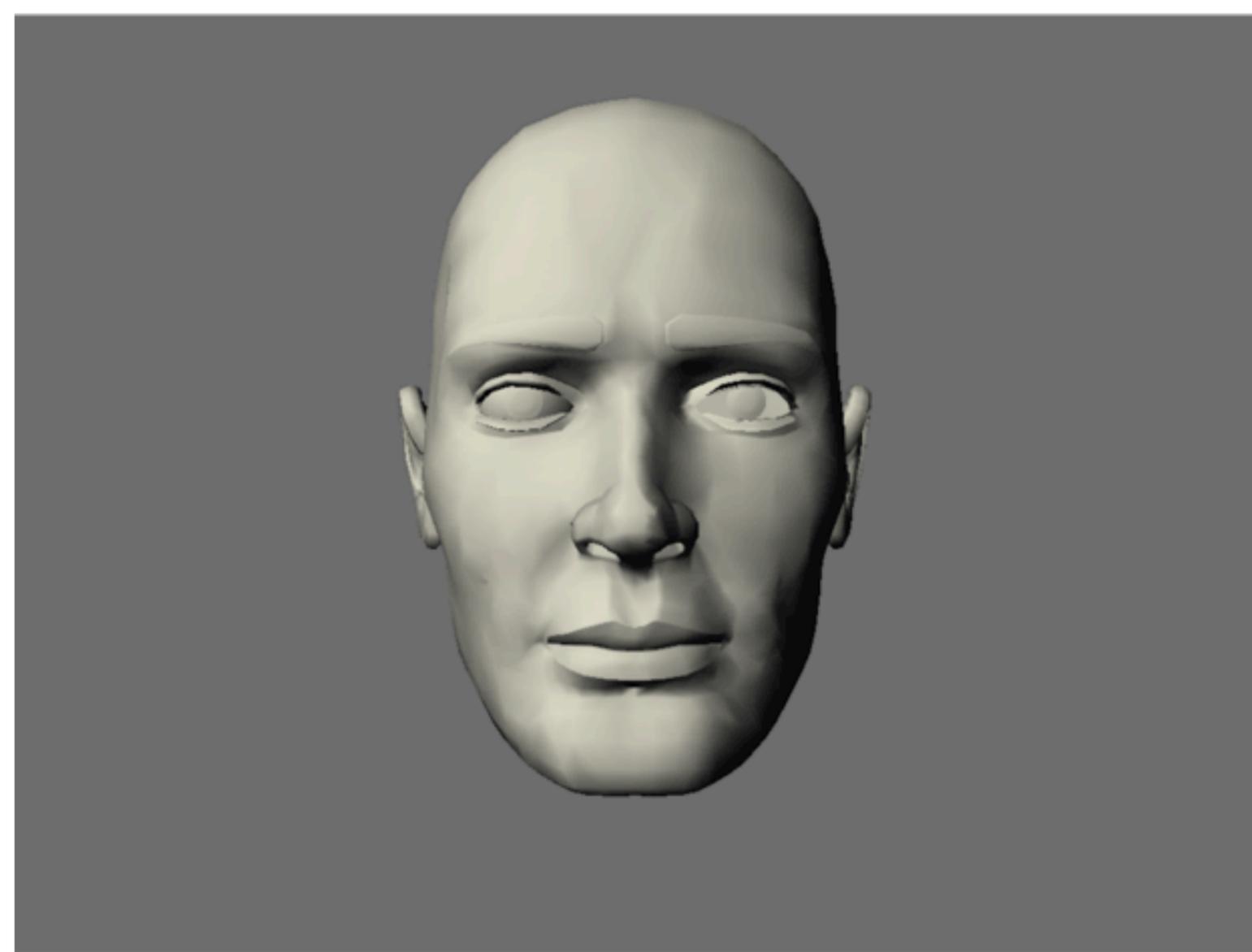
- Default light setup in VRML
- Light source in camera position
- Scene can be viewed from arbitrary directions
- Creates no visible drop shadows
  - why? or does it?
- Creates rather „flat“ images
- Unnatural „flashlight“ look
- Good in combination with other setups for lighting up the scene



<http://www.online-superpreis.de/images/produkte/476-stirnlampearcas9er400.jpg>

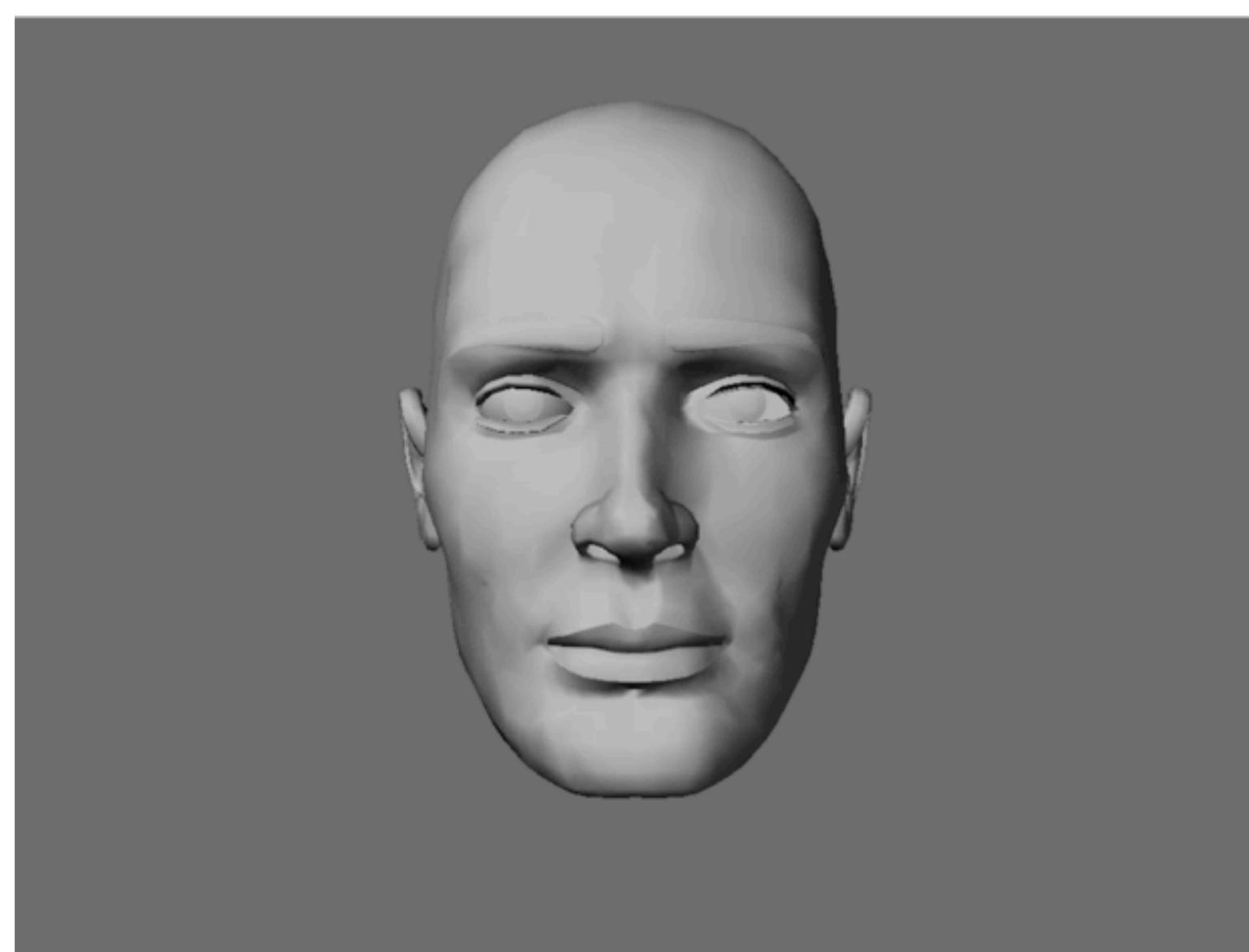
# Daylight simulation

- Sun
  - distant light source
  - warm color tint
- Sky
  - ambient light
  - cool color tint
  - can be simulated by directional light from opposite side
- creates a natural look
- can simulate daytimes (how??)
- can simulate sunny/cloudy weather (how??)



# Simple portrait light setup

- Borrows ideas from daylight
  - 1 main light source
  - direction: traditionally from top left
  - creates overall basic brightness
- One or several brighteners
  - from opposite sides
  - to light up shadows
  - sum of their brightness less than half of main light (why?)
- Basic setup for scenes viewed from just 1 direction



# Sided light

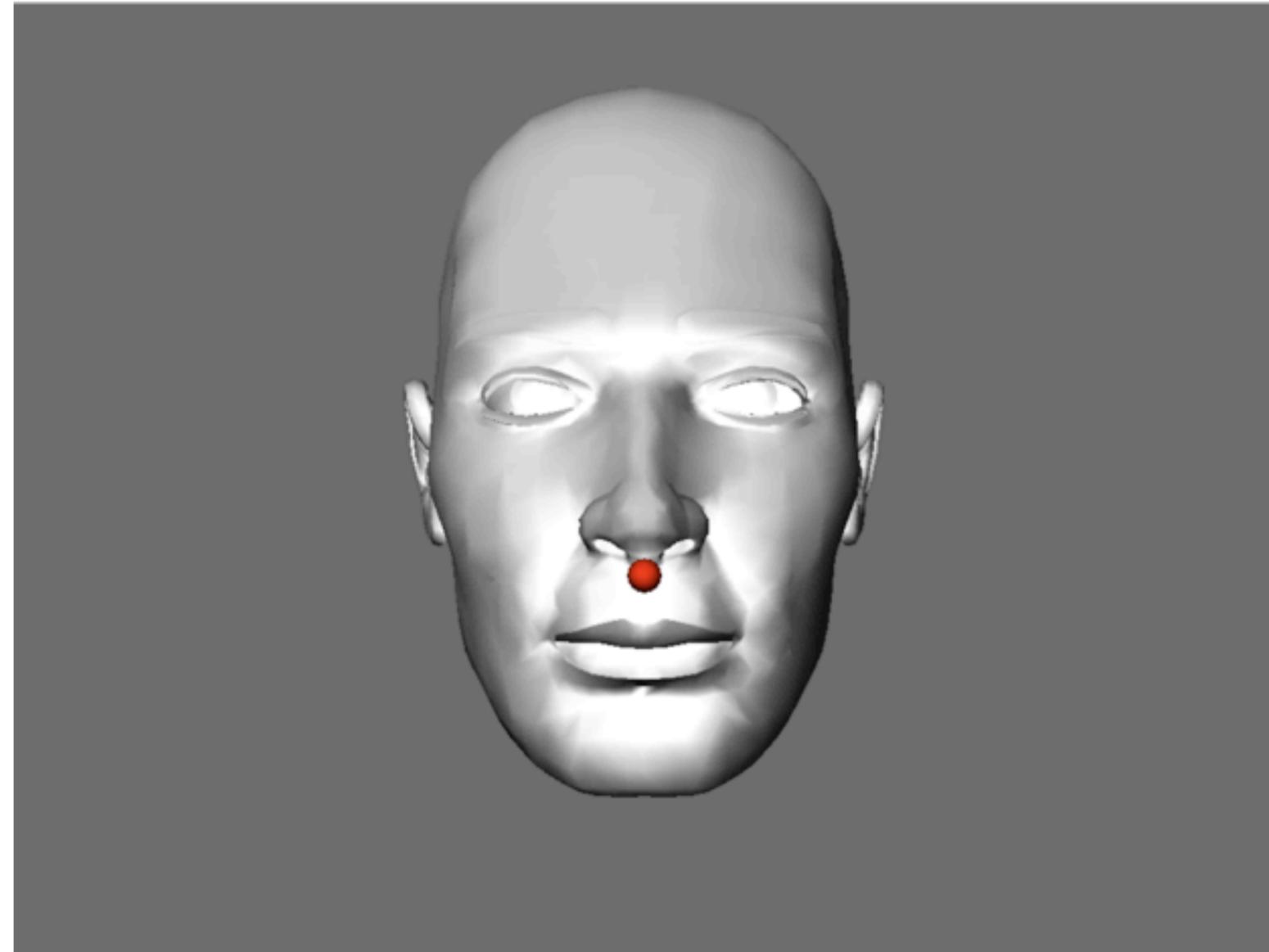
- Effect light known from movies
  - use only in addition to others
- Enhances object contours
- Placement behind the subject
  - not straight behind, but off-axis
  - positioning is difficult in real world
  - easier in graphics, but still:
  - highly position-dependent



- Can be used to clearly separate an object from the background.
- will highlight its silhouette.

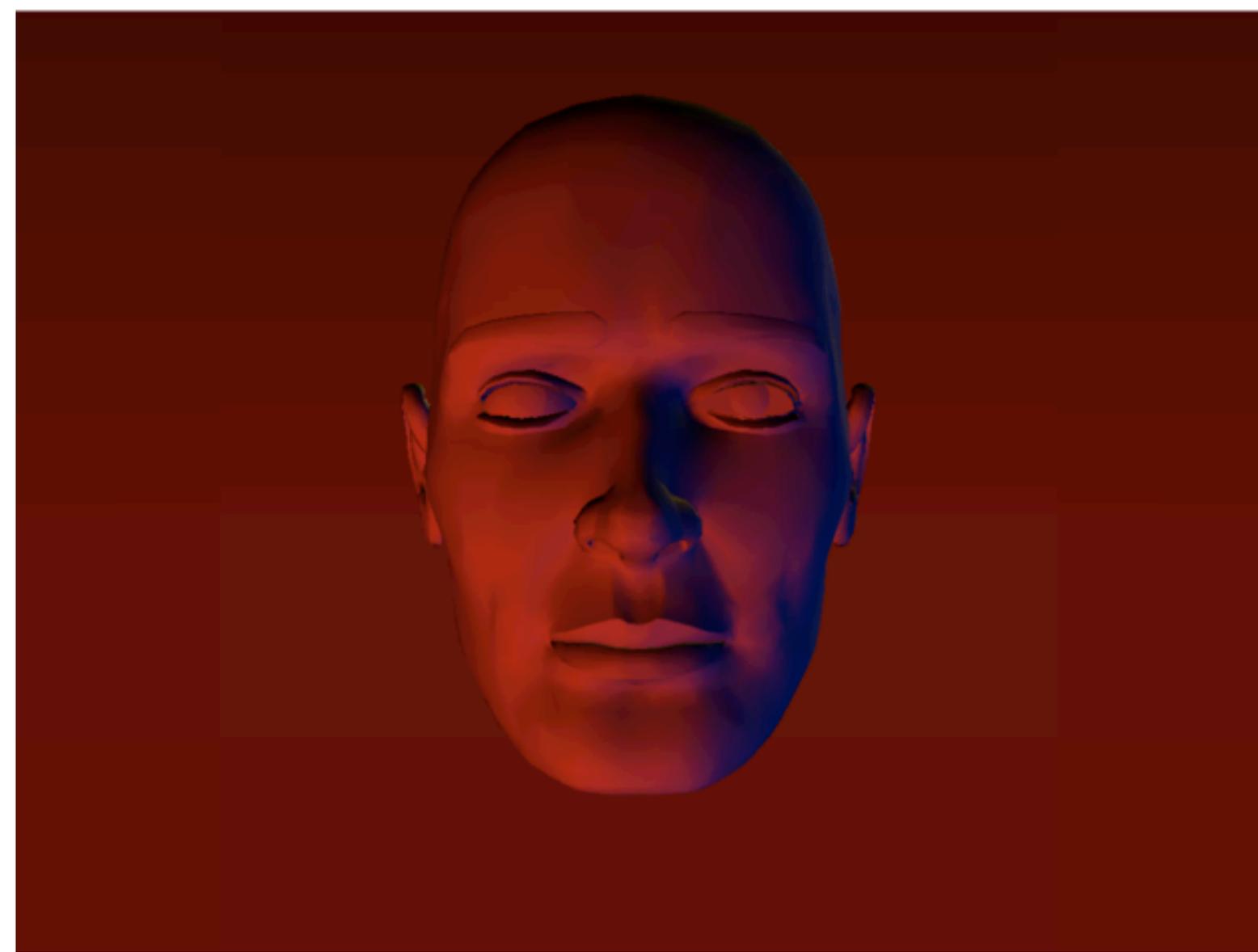
# Cheating with light

- Light sources in computer graphics are invisible
  - only their effects on objects are visible!
- Can be positioned anywhere in a scene to light up dark areas
- Example on this slide is exaggerated!



# Dramatic lighting

- Combination of unnatural lights
  - coming from below
  - strong colors
  - mostly low key
- Unlit shadows can create mystery
- Can be supported by unnatural camera
  - from below
  - wide angle and close up



# High Key, Low Key

- High Key: all colors in image are bright
  - start with very even lighting
  - frontal light will remove shadows
  - danger of saturated white
  - communicates light and cleanliness
- Low Key: all colors are very dark
  - often uses sided light
  - objects can be reduced to their contours
  - communicates e.g., mystery

