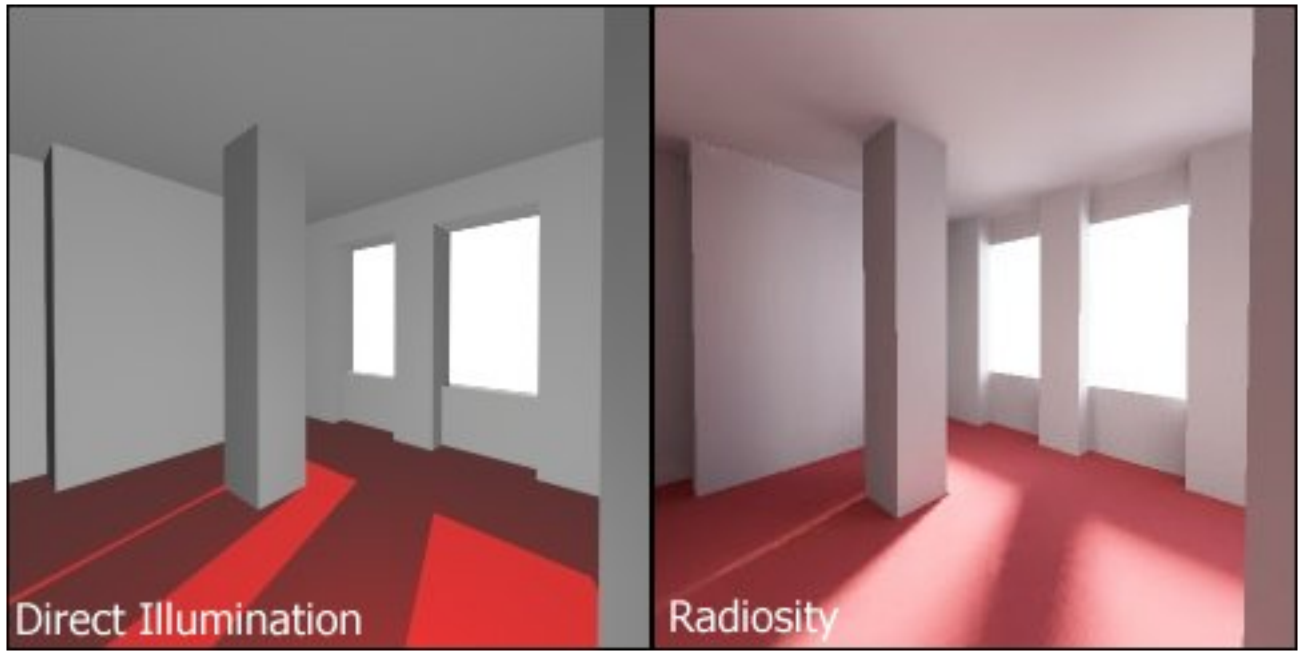
Radiosity

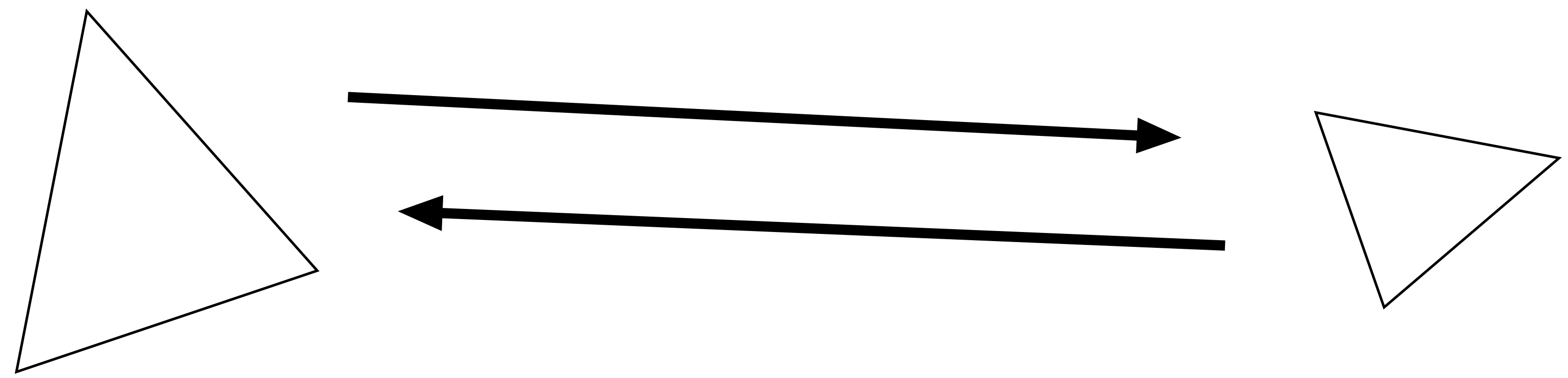
A method for high-quality rendering of scenes with diffuse reflections and soft shadows.



(image from Wikipedia)

Radiosity

Problem: Ray-tracing can not accurately model how diffuse light is reflected from object to object!



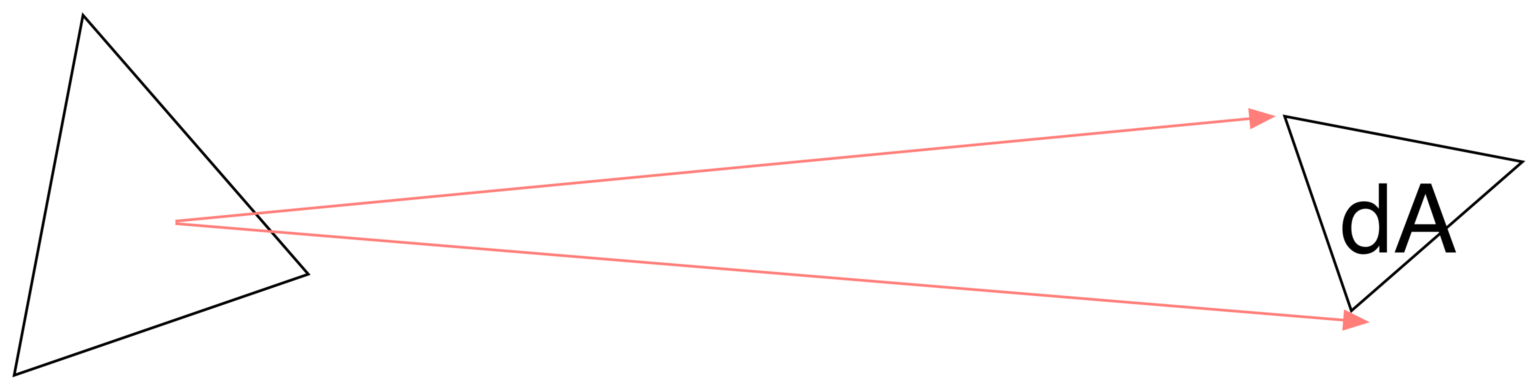
ALL diffusely reflecting objects are turned into light sources!

But – how bright?

Radiosity

Radiosity models the amount of energy that is emitted in different directions.

Ideal diffuse reflector => same intensity => energy proportional to the area



The size of a surface element as seen from some other point varies with the angle.

The model

A surface emits energy that is a sum of reflected and emitted energy:

Energy * area = emitted + reflected

$$B_k * dA_k = E_k * dA_k + R_k * \int B_j * F_{kj} * dA_k$$

Emitted light (true light sources only) — E_k

Reflectivity — R_k

Outgoing energy from the surface element j — B_j

Form factor between j and k — F_{kj}

Simplified to discrete patches

$$B_k = E_k + R_k * \sum B_j * F_{jk}$$

=> Equation system!

1) Solve equation system!

2) We must interpolate between patches (e.g. Gouraud shading)

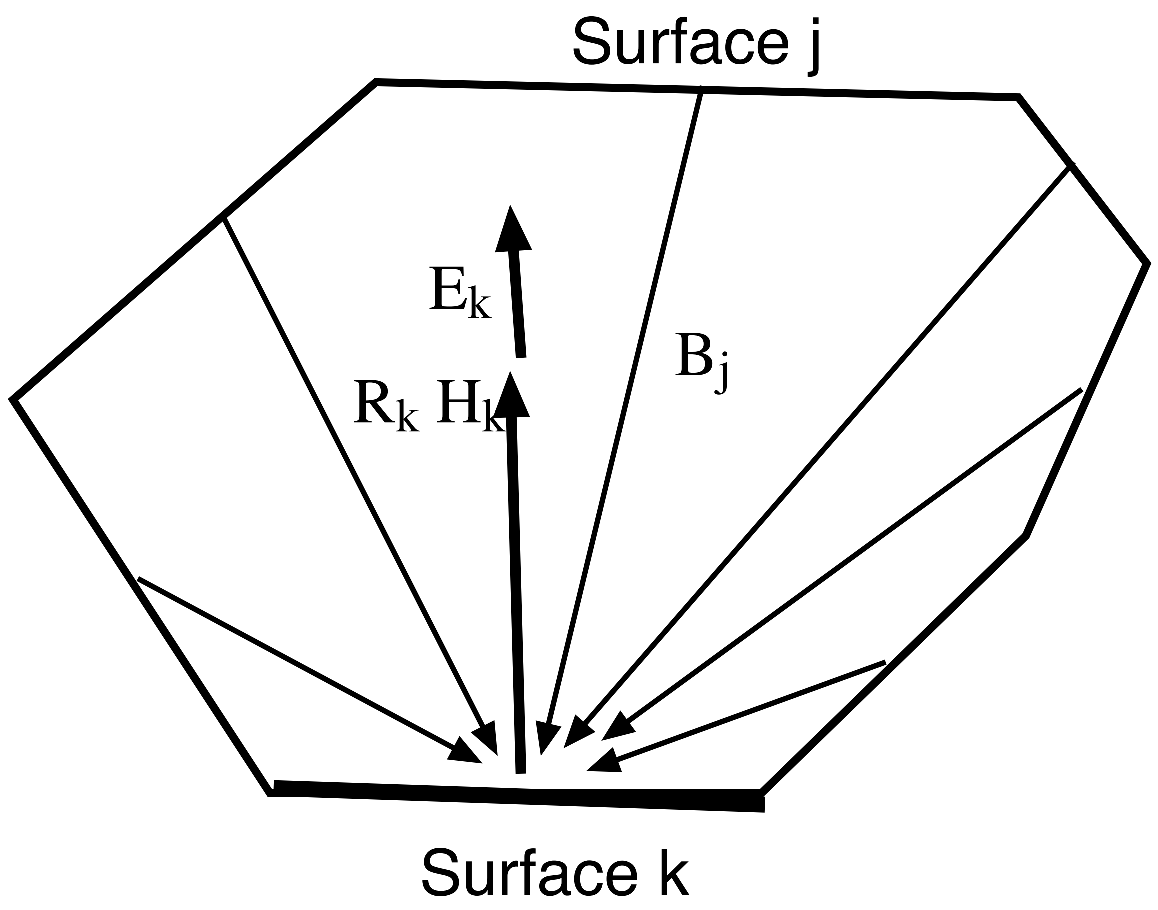
3) The form factors F_{jk} must be calculated

Radiosity equation

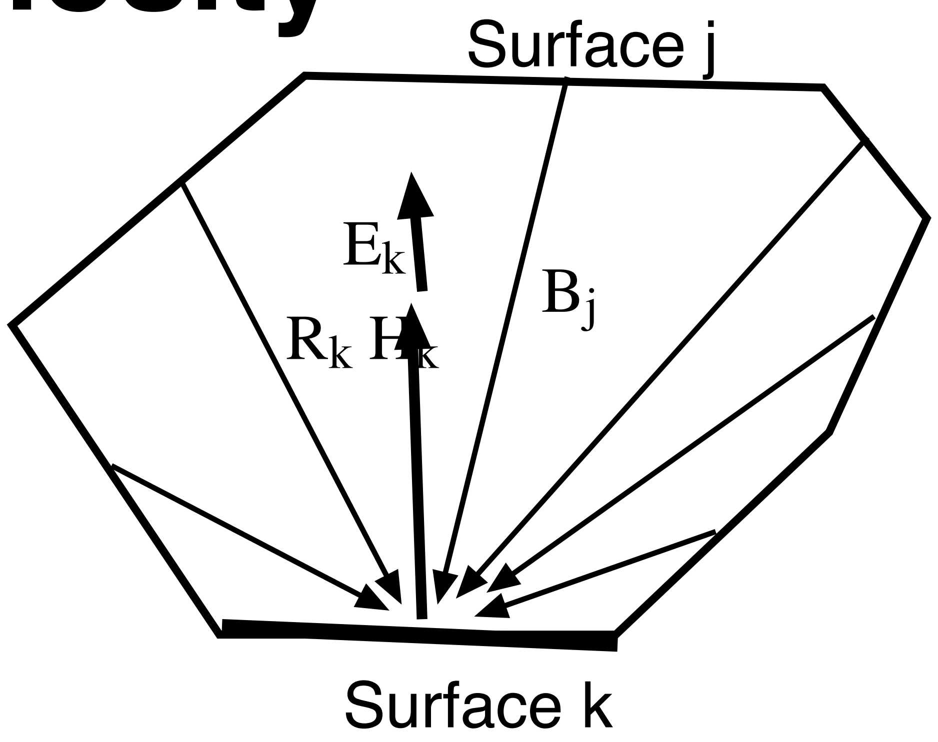
$H_k = \Sigma_j B_j F_{jk}$
$B_k = E_k + R_k H_k$

$B_k = E_k + R_k \Sigma_j B_j F_{jk}$

F_{jk} – Form Factor



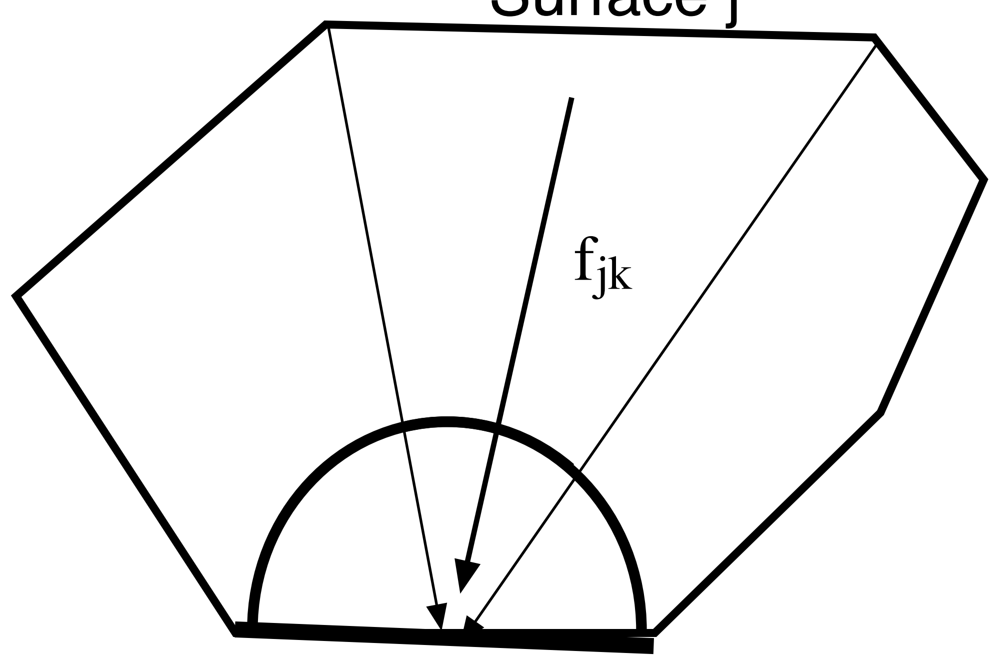
Solving radiosity



$B_k = E_k + R_k \Sigma_j B_j F_{jk}$

- One equation for each surface
- Solve this system of equations
- Result: radiosity of each surface
- Radiosity = light energy ≈ light intensity
- Solve for R, G, B – get color for each surface
- Render using gouraud shading: nice result guaranteed!
- Problem: calculate Form Factors
- Problem: huge equation system

Calculating form factors



How much energy comes from surface j to k?

f_{jk} = energy on k from j / total energy from j

Depends on how of j's "view" that is occupied by k, determined by distance, angle, occlusions.

Note! It is what j "see", not what k "see"!

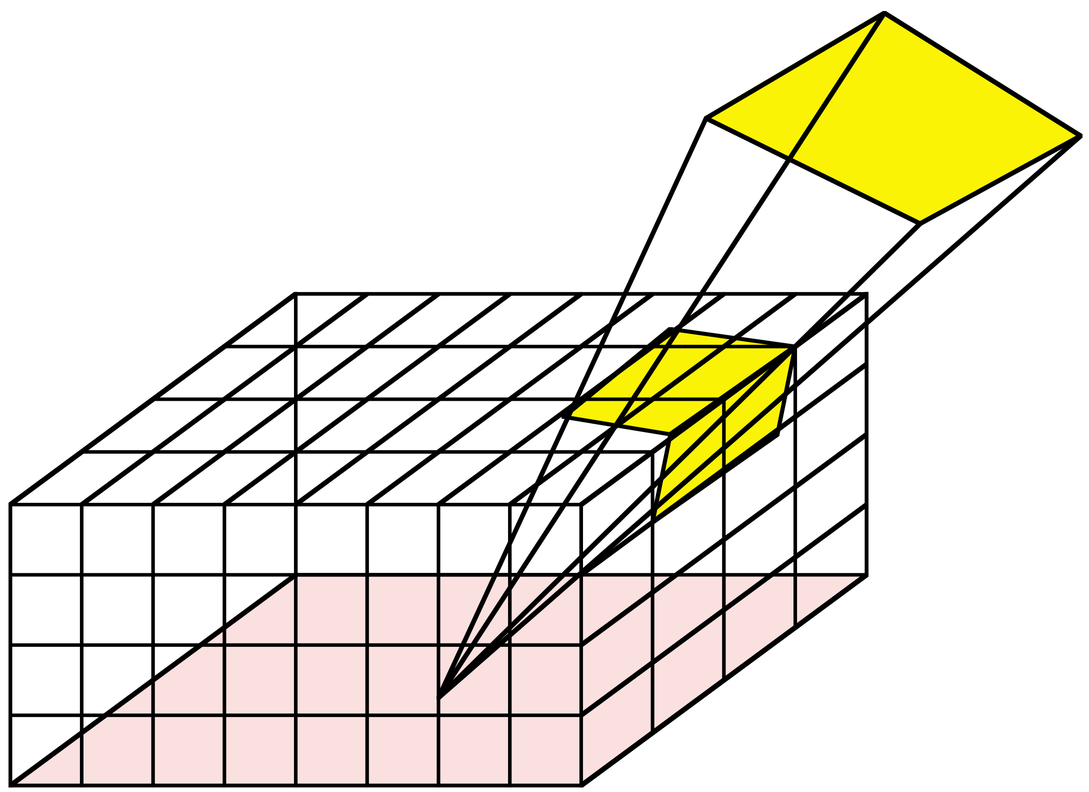
Calculating F_{jk}

Major problem of radiosity! F_{jk} calculations take most of the processing time!

F_{jk} = (Energy directly from j to k) / (Total energy from j)

This is calculated from the positions, angles and sizes of the two surfaces. All surfaces must be subdivided in parts. More parts give higher realism!

Hemicube for form factor calculation



Approximates f_{jk} by calculating projections

Progressive refinement radiosity

Step-wise refinement

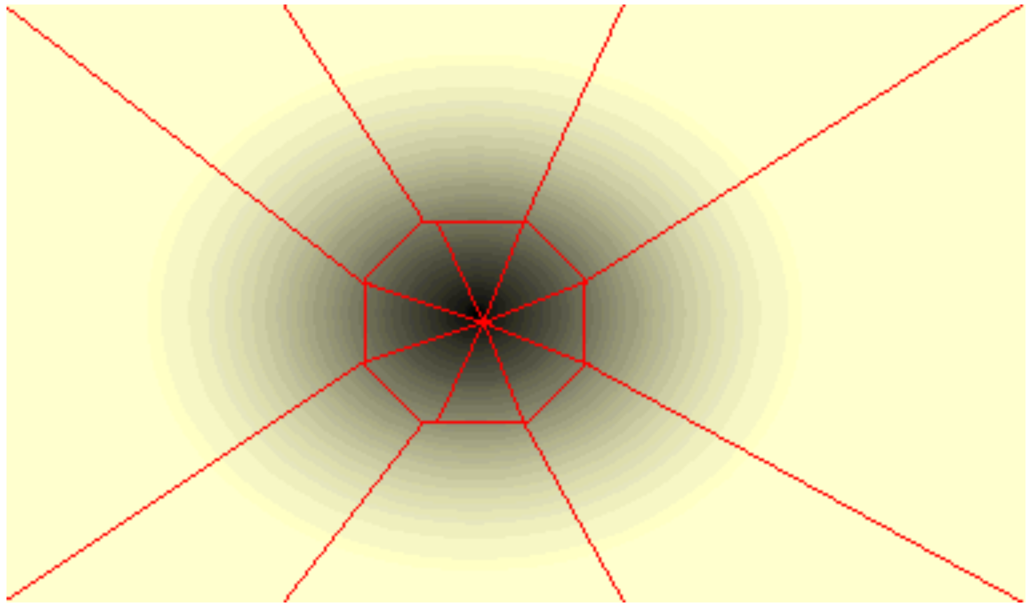
A method for solving the equation system in real time

Make one step of emission at a time.

Exact solution takes an infinite number of iterations, but a good approximation is found after a few steps.

Preview can be shown instantly!

Surface subdivision



Surfaces should be sufficiently small

Smaller surfaces where lighting varies

Better form factor approximations

Weaknesses with radiosity

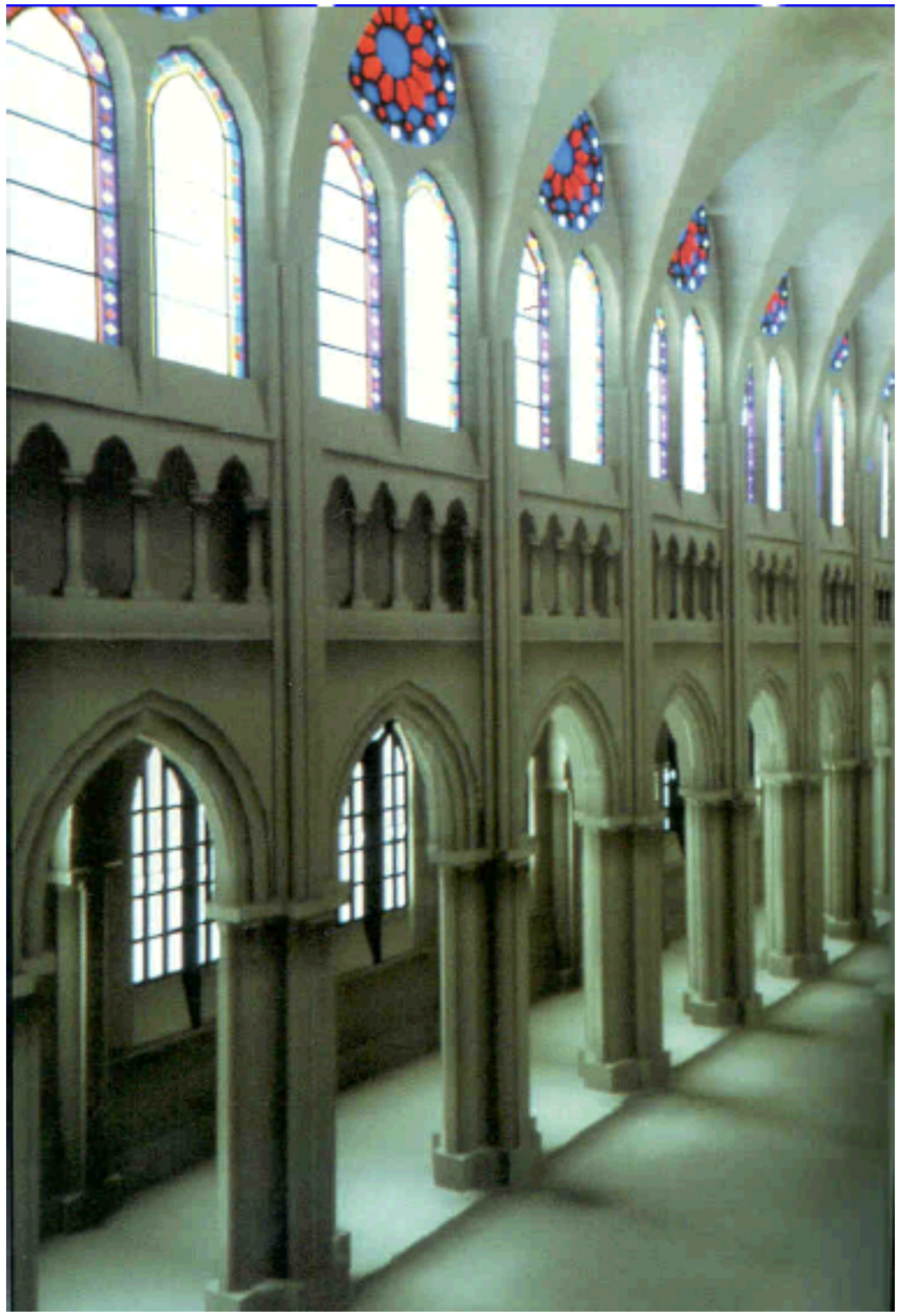
- Hemicube sampling error
- Insufficient subdivision
- No specular reflections

Example

(Unknown model)

Example

I *think* this is the ”Sibenik Cathedral” model.



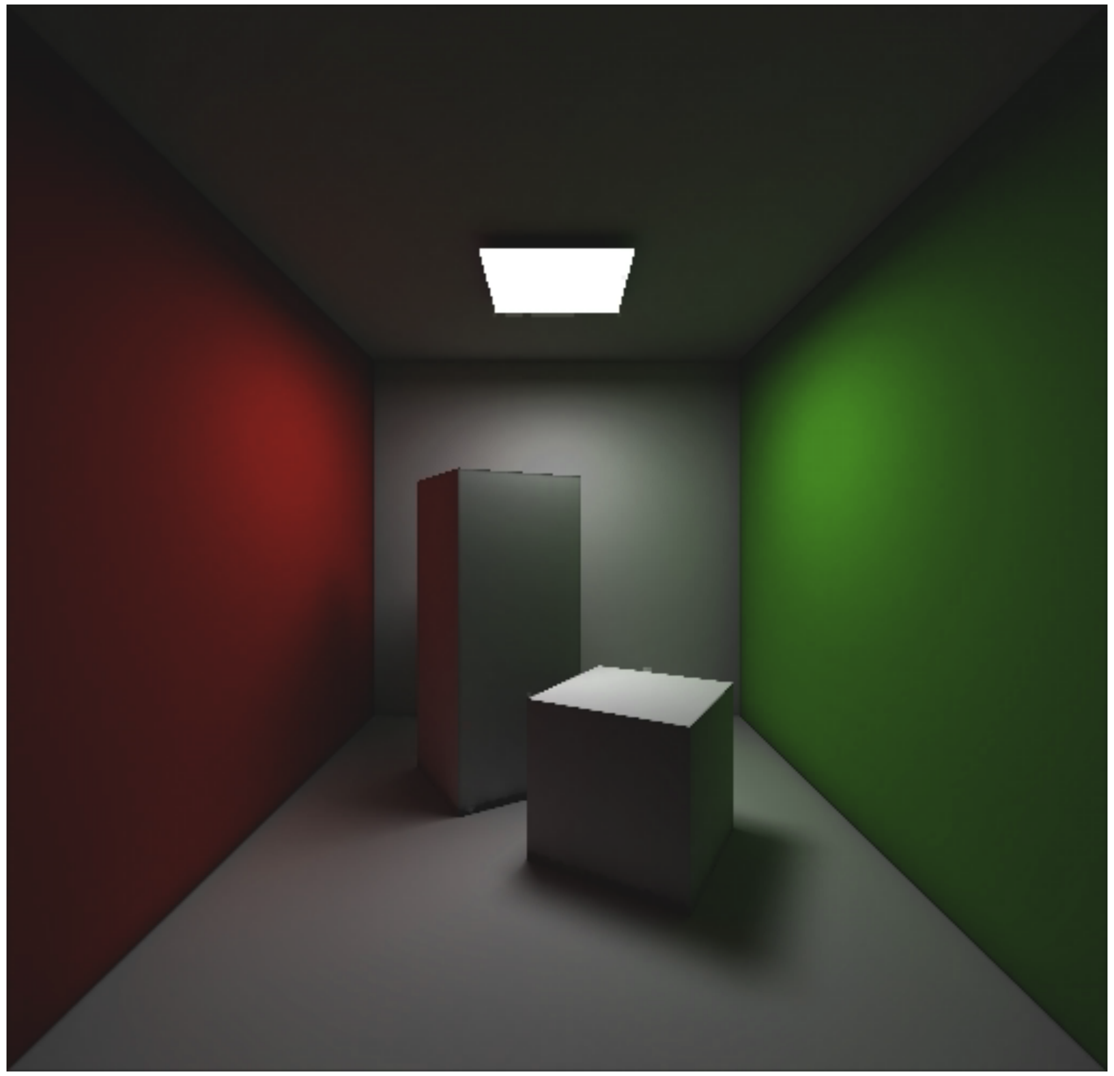
Example

(Power Plant model, available on-line for non-commercial use)

Example

TSBK03 project on progressive refinement

(Variant of Cornell Box, standard scene for illumination)



Other global illumination models

Very important problem, much research!

- **Photon mapping**
- **Approximation by proximity measurements**
- **Hybrid models**
- **Many variants and parallel implementations**

Photon mapping

"Backwards ray-tracing"

Applies ”backwards” light (from light sources) to measure how light is scattered over a scene

Gives a good measure of indirect light

Photon Mapping

Follow rays from light source with ray-tracing methods

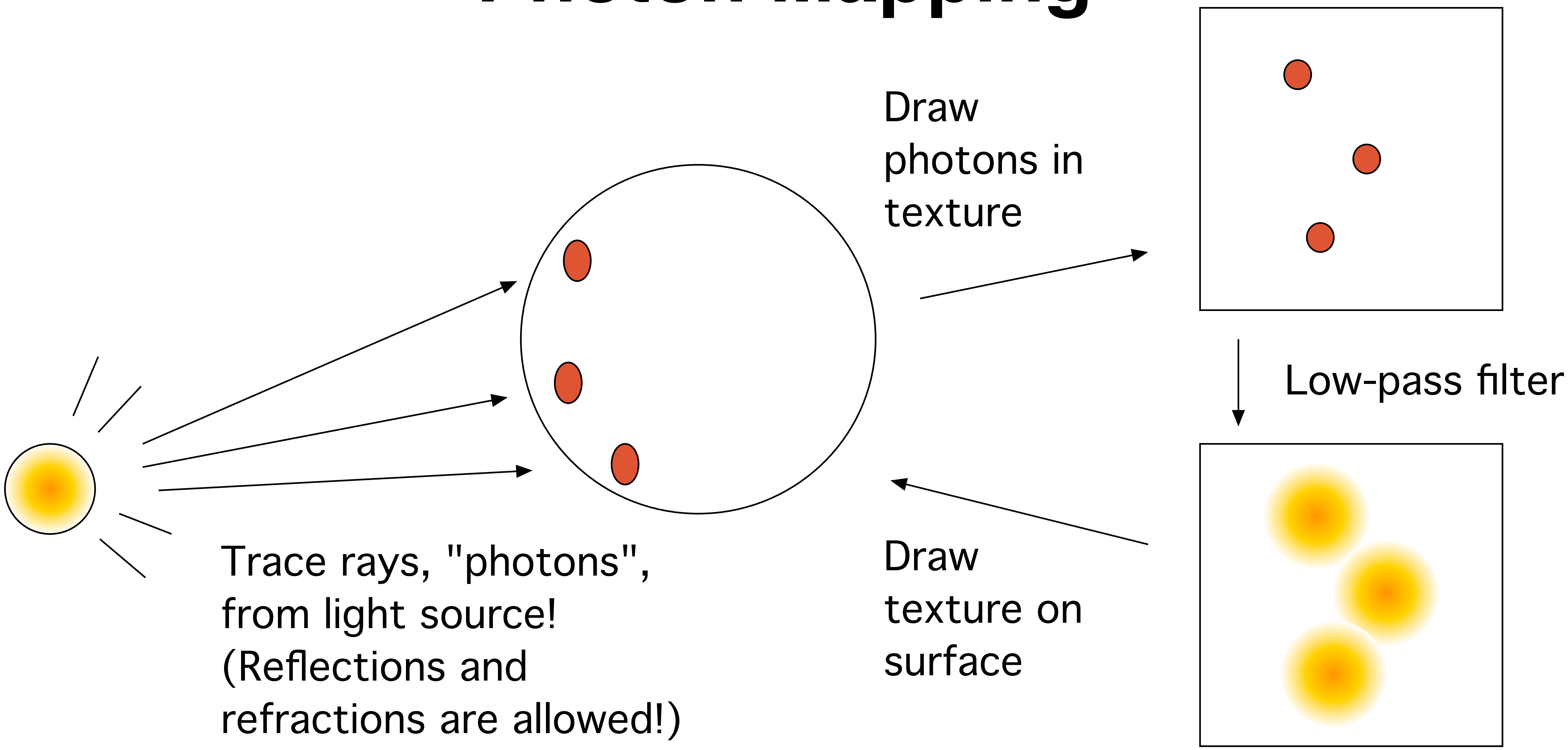
Accumulate light in ”photon maps”

Saves information about every photon - allows specular surfaces!

Low-pass filter

Then render scene using these maps as surfaces. Handles both diffuse and specular reflections!

Photon Mapping

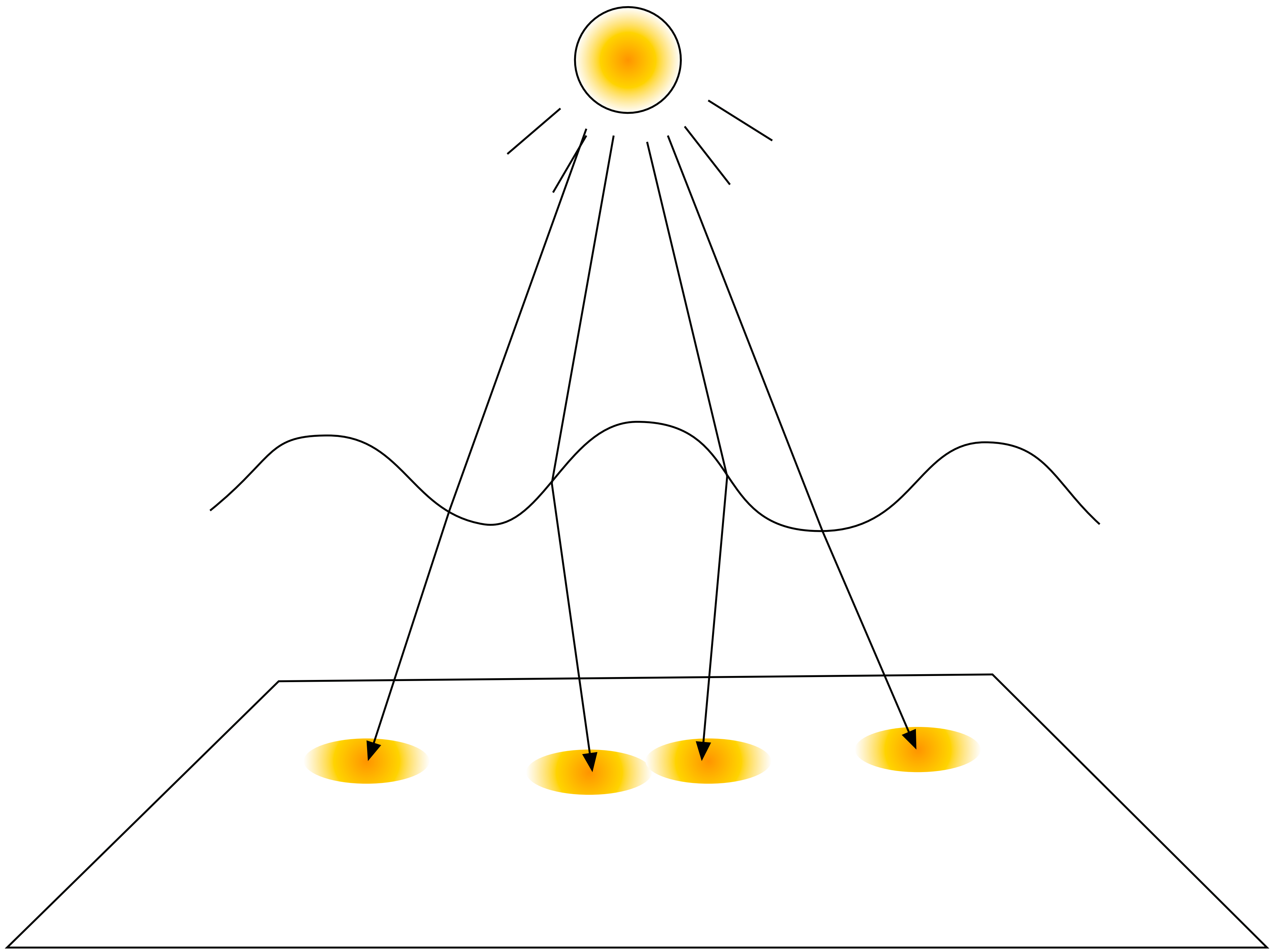


Caustics

Nice case for photon mapping

Bottom of lake only surface to illuminate

(Harder if the lake bottom is not flat or if there are several objects to illuminate.)

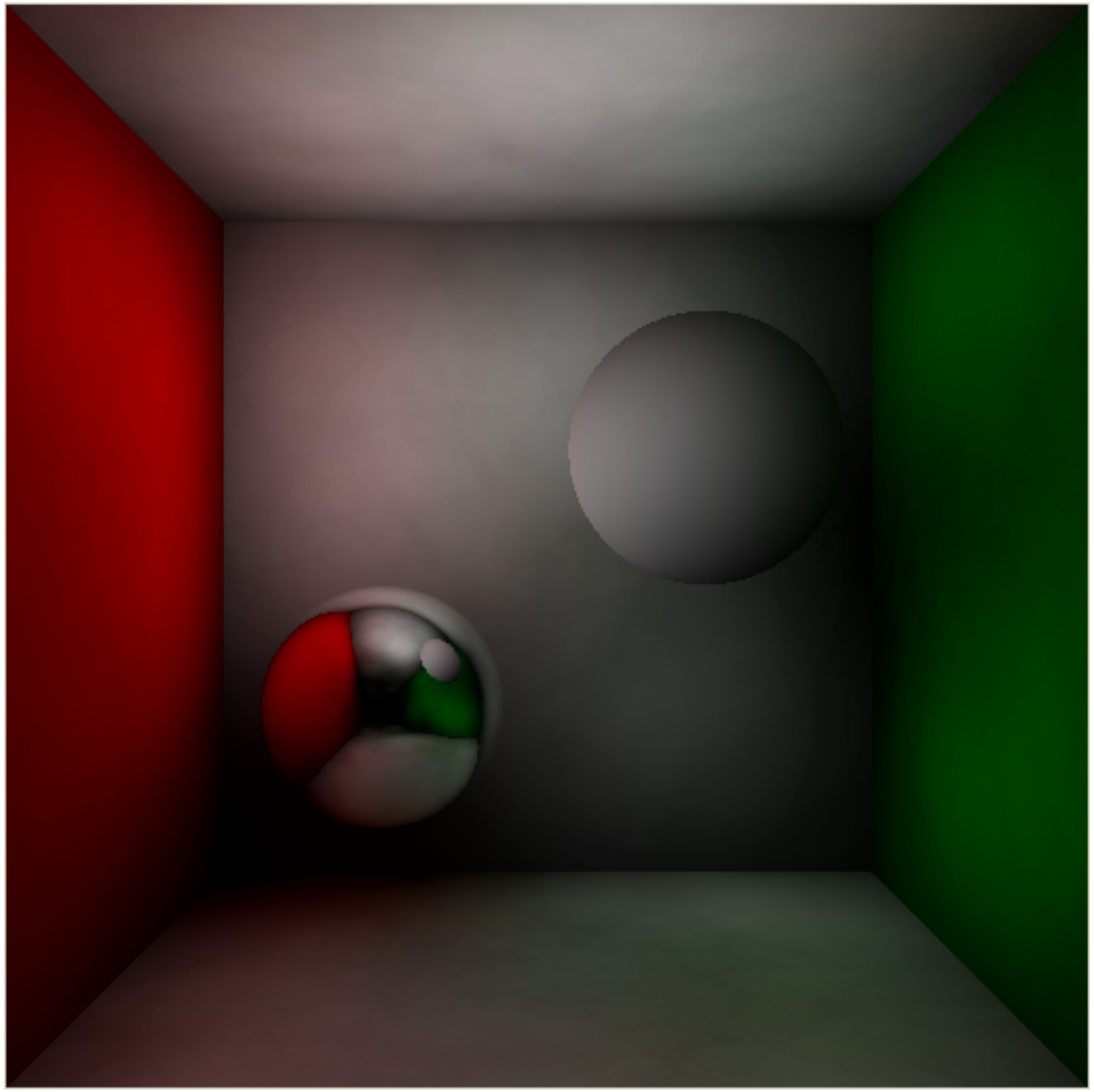


Photon Mapping Example

(The Schindler demo)

Typical features:

Reflections, caustics and diffuse shadows



Summary

Ray-tracing:

Good for shiny surfaces, transparency etc.
"Hard" images.

Radiosity:

Good for realistic images of diffuse surfaces.
Can not handle specular reflections!

Advanced methods (like Photon Mapping)