Irradiance & radiance caching (2)

Jaroslav Křivánek
Charles University, Prague
Jaroslav.Krivanek@mff.cuni.cz

SEVENTH FRAMEWORK PROGRAMME
MARIE CURIE ACTIONS

Last Lecture

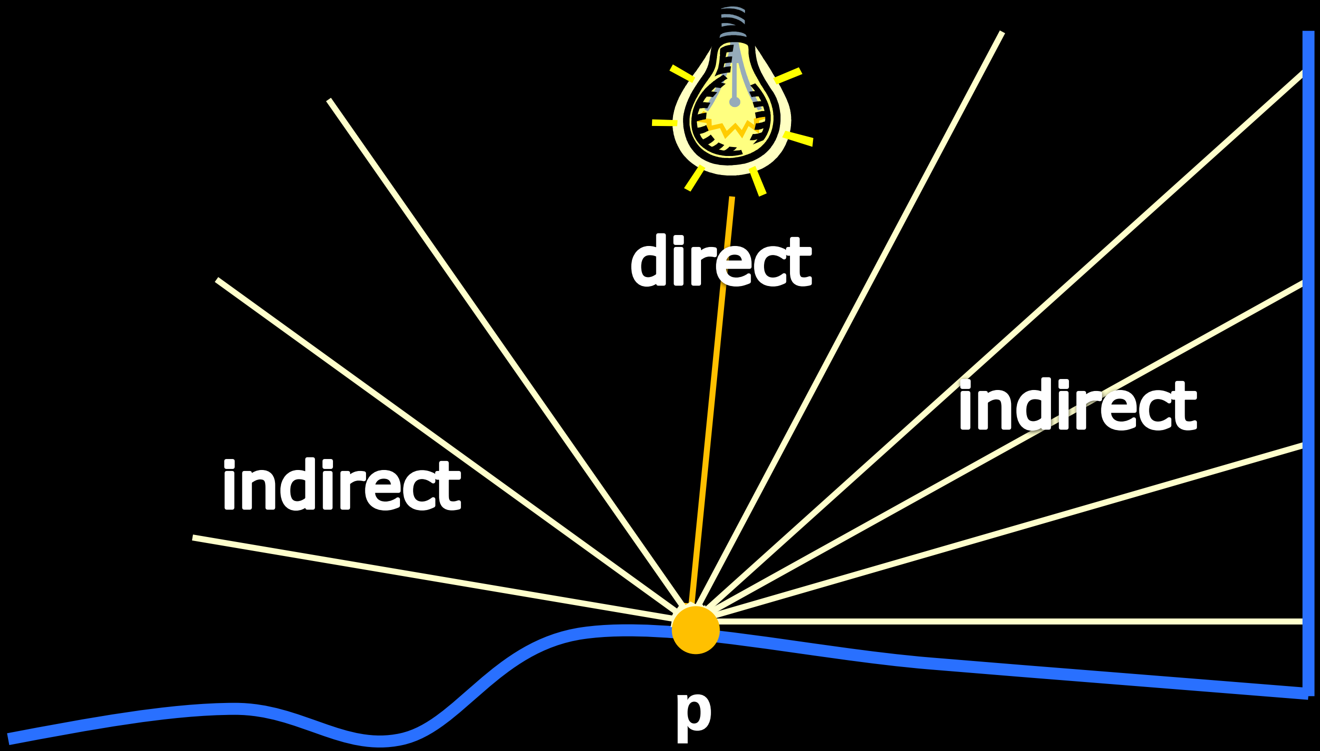
Diffuse inter-reflection

- May go unnoticed, but looks odd if missing

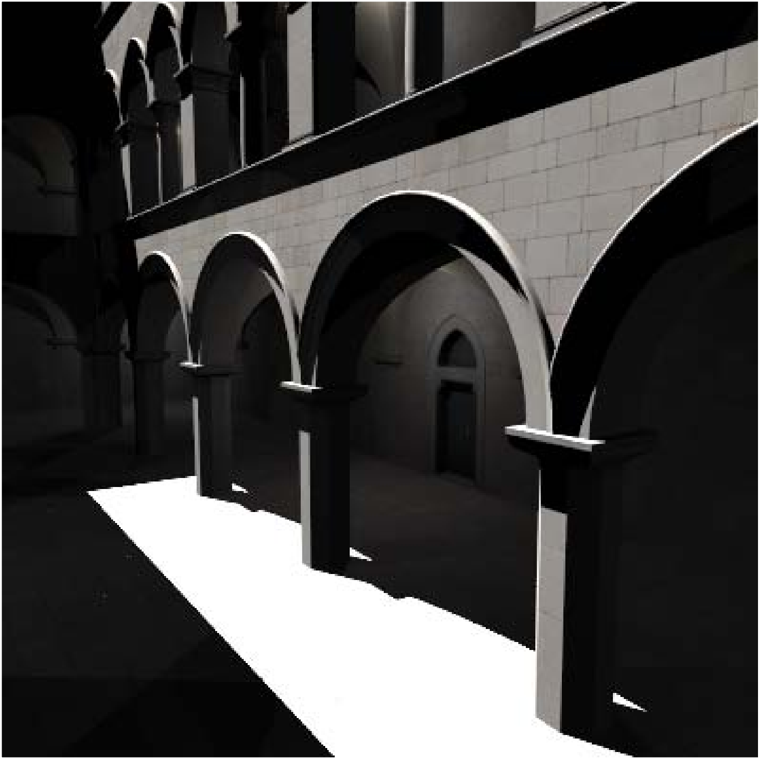
Slide credit: Michael Bunnell

Where does the light come from?

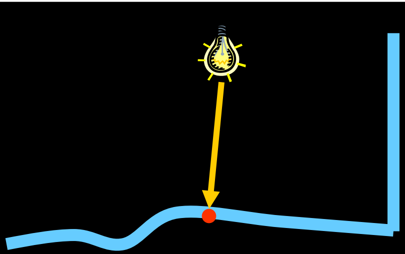
- From light sources (*direct illumination*)
- From scene surfaces (*indirect illumination*)



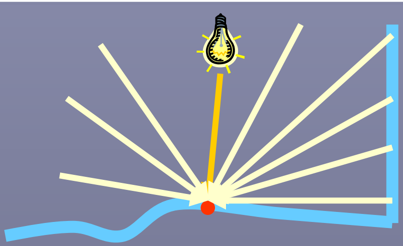
Direct and global illumination



Direct-only



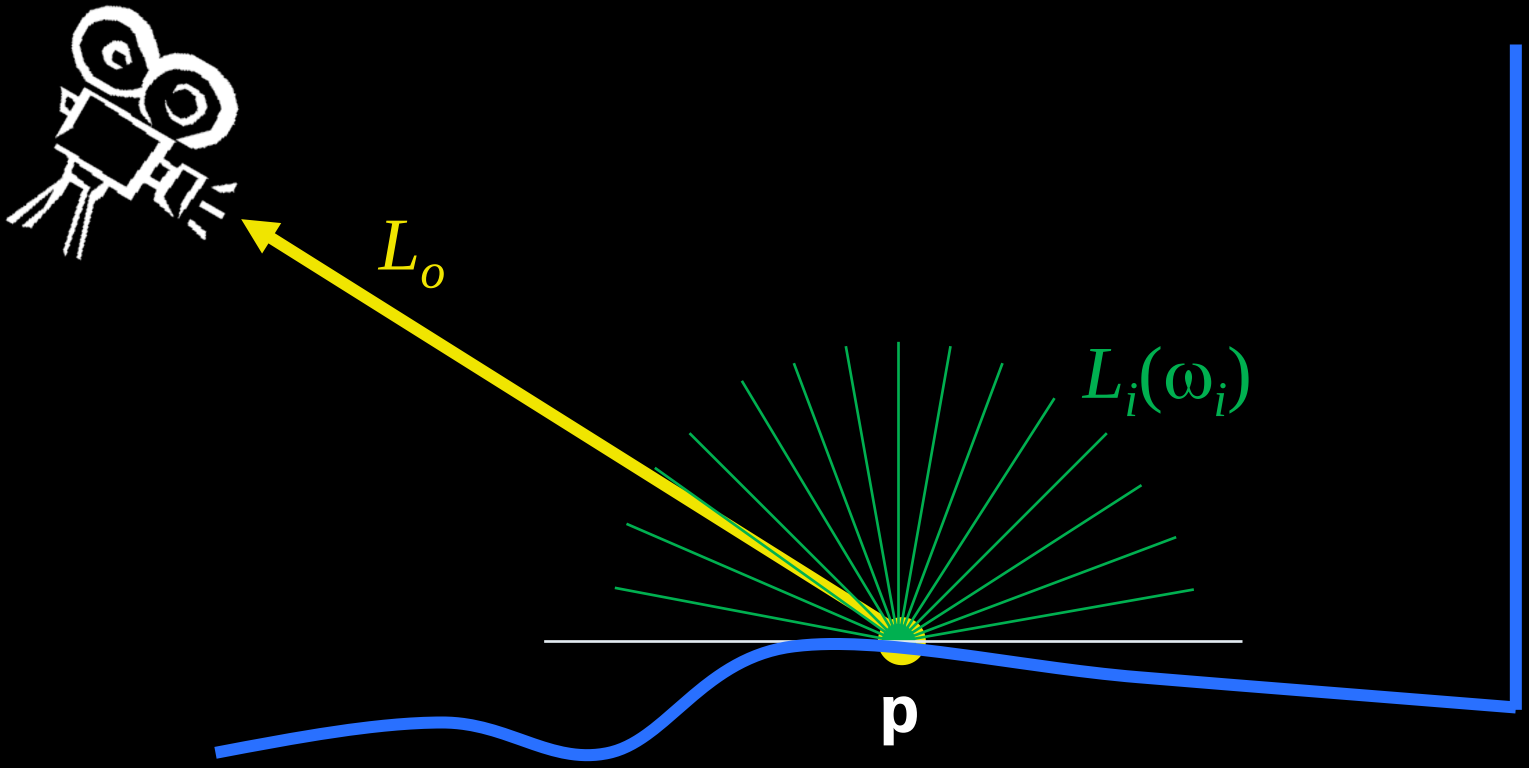
global =
direct +
indirect



Illumination integral

- Total amount of light reflected to ω_o:

$$L_o = \int L_i(\omega_i)\ \mathrm{BRDF}\,(\omega_i)\ \cos\theta_i\ d\omega_i$$



Observation

- Spatial coherence
  - Diffuse indirect illumination changes slowly over surfaces

Indirect irradiance – changes slowly

Sparse irradiance computation

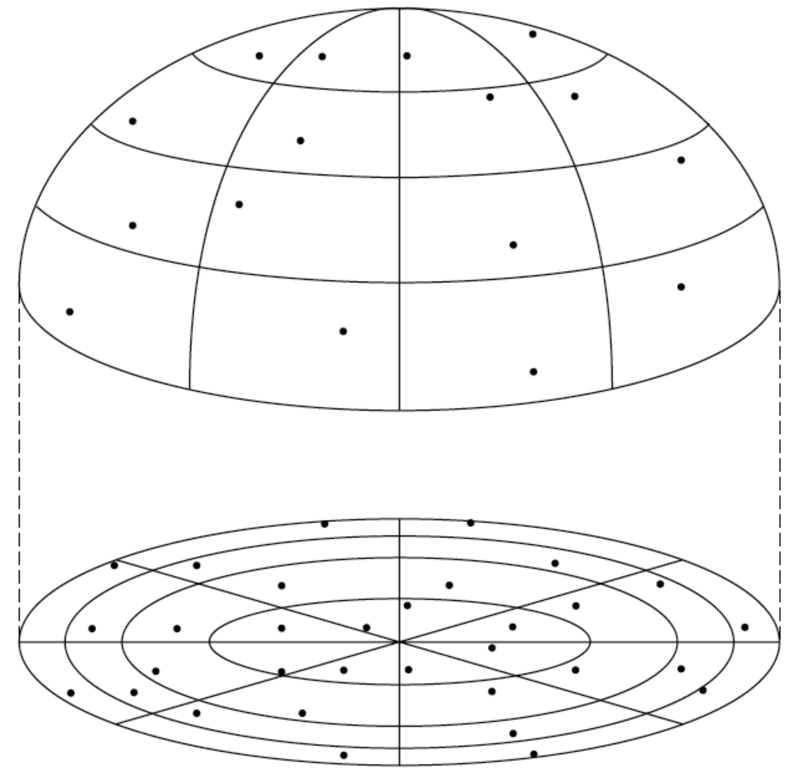
Irradiance caching pseudocode

```
GetIrradiance(p):
    Color E = InterpolateFromCache(p);
    if( E == invalid )
        E = SampleHemisphere(p);
        InsertIntoCache(E, p);
    return E;
```

Indirect irradiance calculation

```
E = SampleHemisphere(p);
```

- *Stratified Monte Carlo* hemisphere sampling
  - Subdivide hemisphere into cells
  - Choose a random direction in each cell and trace ray



Irradiance caching pseudocode

```
GetIrradiance(p):
  Color E = InterpolateFromCache(p);
  if( E == invalid )
    E = SampleHemisphere(p);
    InsertIntoCache(E, p);
  return E;
```

Irradiance interpolation

`E = InterpolateFromCache(p)`

- Weighted average: $$E(\mathbf{p}) = \frac{\sum_{i \in S(\mathbf{p})} E_i(\mathbf{p}) w_i(\mathbf{p})}{\sum_{i \in S(\mathbf{p})} w_i(\mathbf{p})},$$

- Records used for interpolation:

$$S(\mathbf{p}) = \{i;\ w_i(\mathbf{p}) > 0\}$$

Irradiance caching pseudocode

```
GetIrradiance(p):
  Color E = InterpolateFromCache(p);
  if( E == invalid )
    E = SampleHemisphere(p);
    InsertIntoCache(E, p);
  return E;
```

Irradiance cache record

```
InsertIntoCache(E, p);
```

Vector3 position;	Position in space
Vector3 normal;	Normal at P
float R;	Validity radius
Color E;	Stored irradiance
Color dEdP[3];	Gradient w.r.t. translation
Color dEdN[3];	Gradient wrt rotation

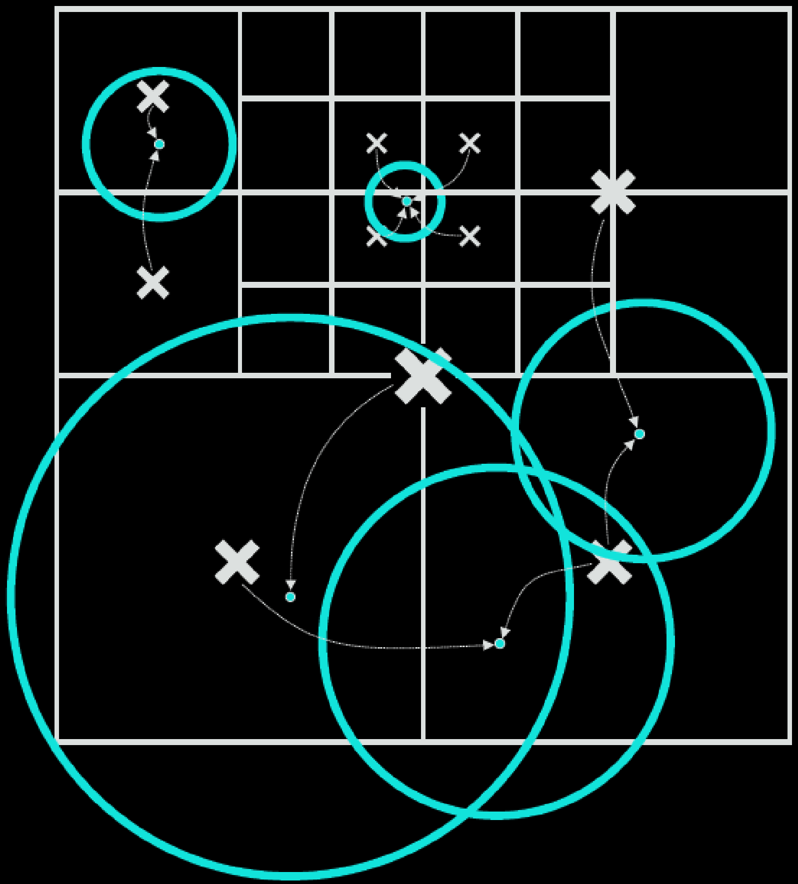
Irradiance cache data structure

`InsertIntoCache(E, p);`

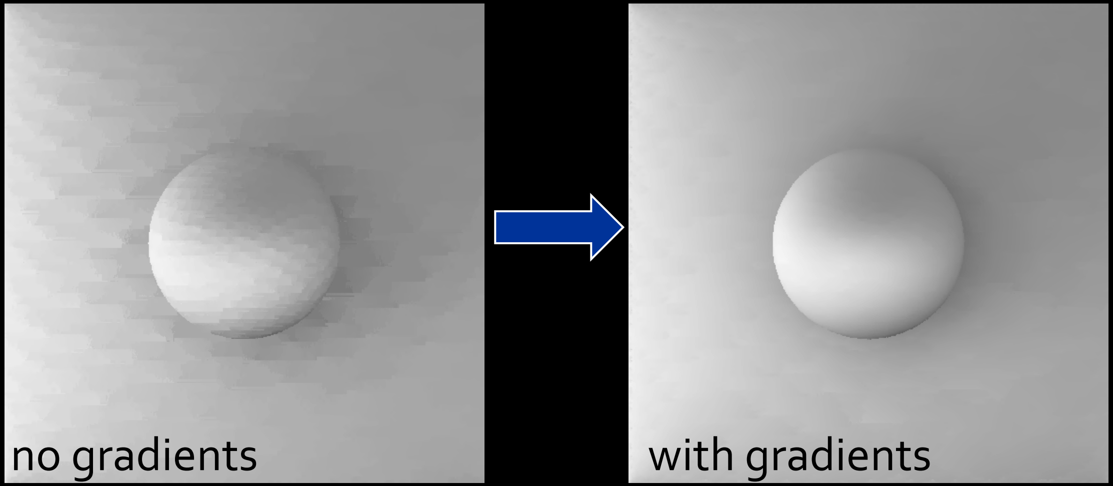
- Requirements
  - Fast incremental updates (records stored on the fly)
  - Fast query for all records (spheres) overlapping a given point **p**

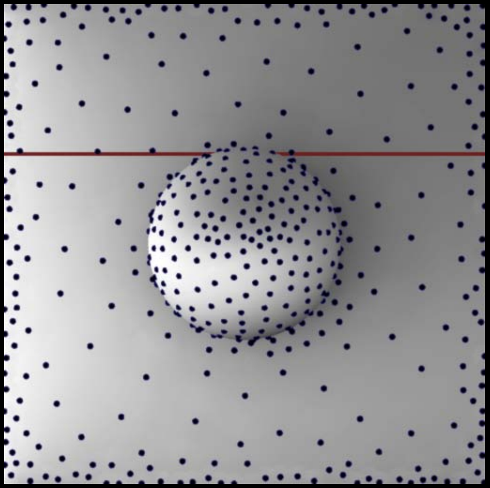
Data structure: Octree

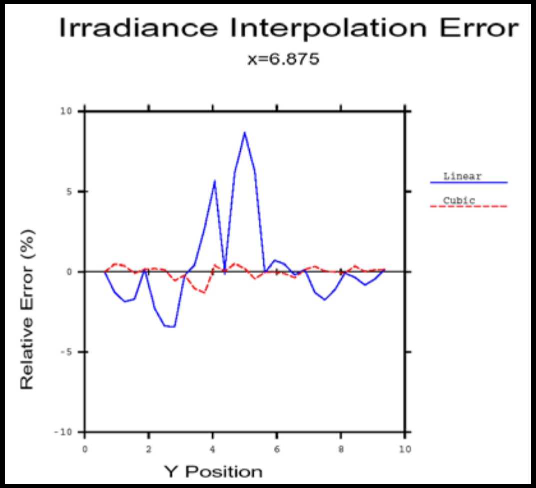
```
InsertIntoCache(E, p);
```



Irradiance gradients







Rotation gradient

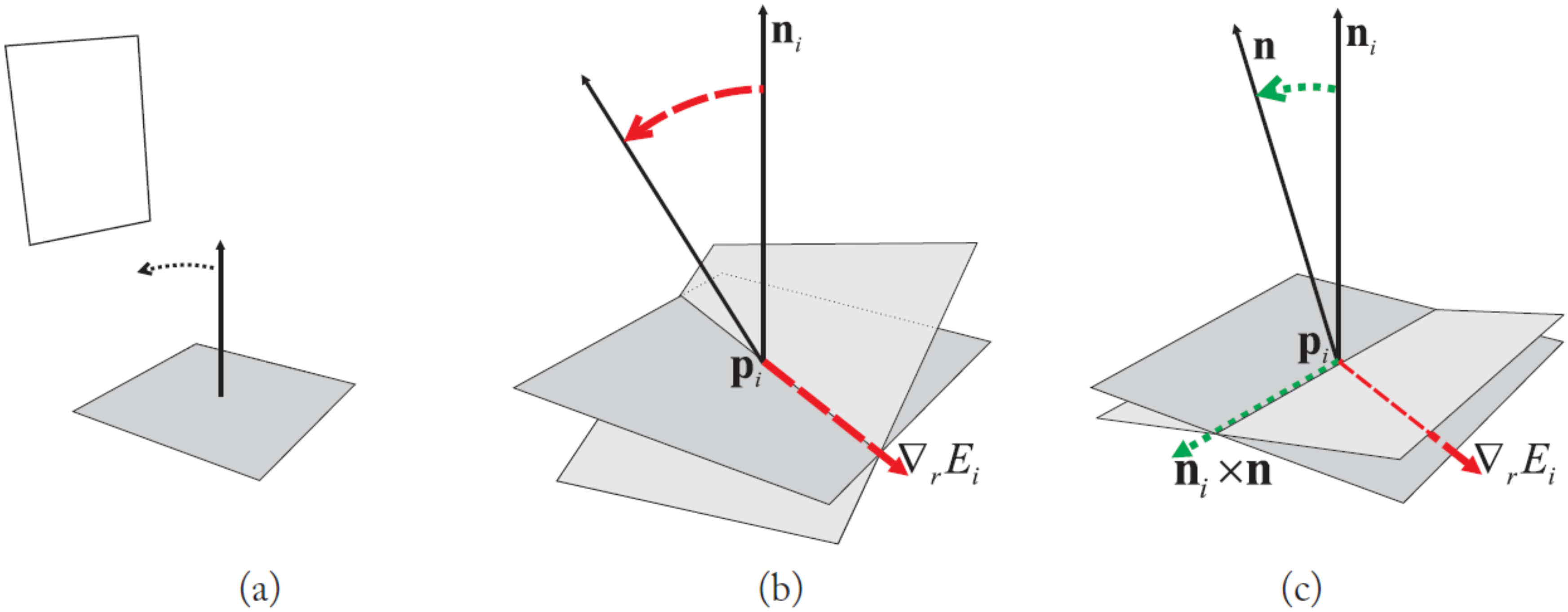
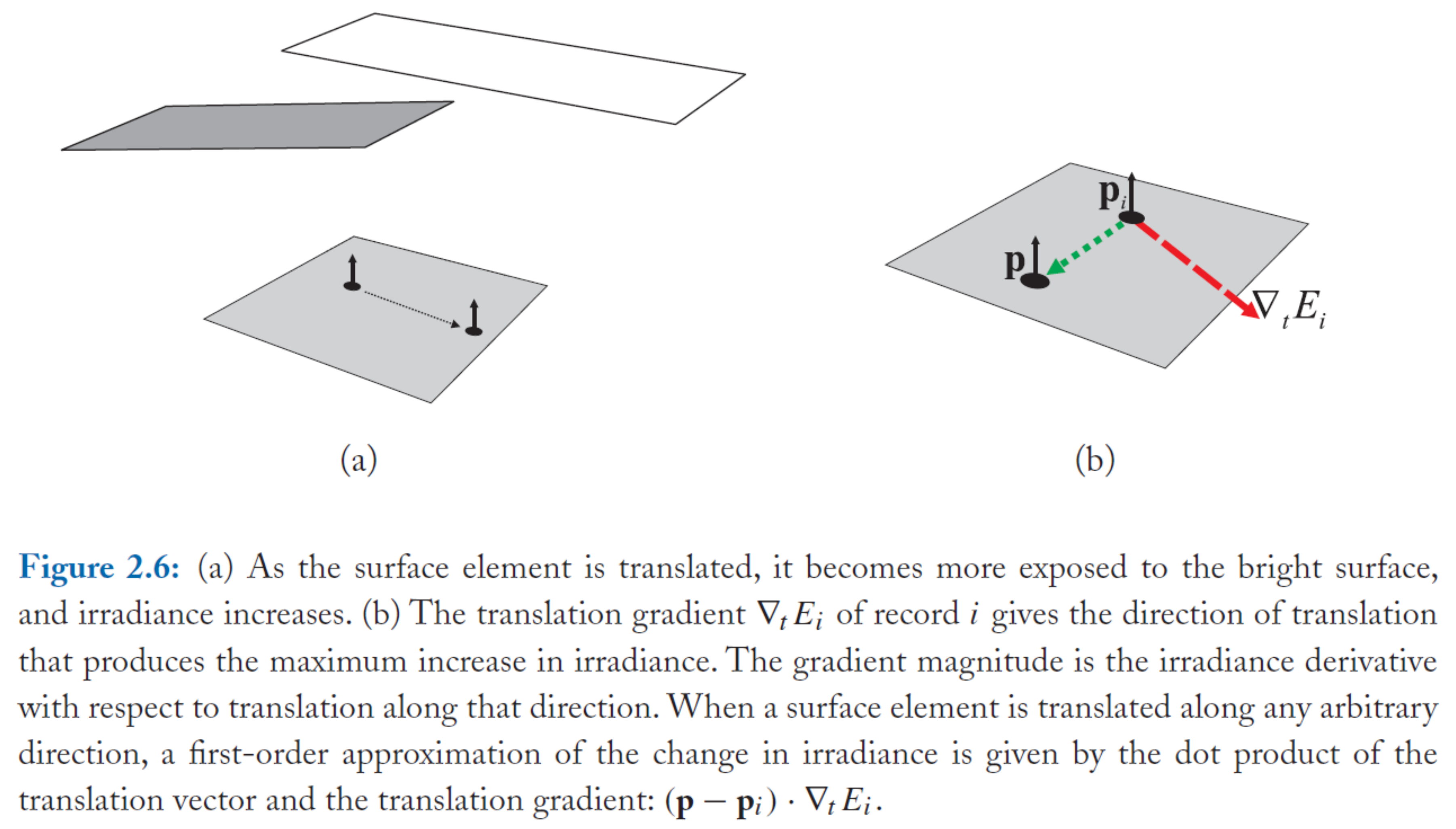


Figure 2.4: (a) As the surface element is rotated towards the bright surface, irradiance increases. (b) The rotation gradient $\nabla_r E_i$ of cache record i gives the axis of rotation that produces maximum increase in irradiance. The gradient magnitude is the irradiance derivative with rotation around that axis. (c) When the surface element is rotated around any arbitrary axis (in our example determined by the change in surface normal as $\mathbf{n}_i \times \mathbf{n}$) the irradiance derivative is given by the dot product of the axis of rotation and the rotation gradient: $(\mathbf{n}_i \times \mathbf{n}) \cdot \nabla_r E_i$.

Translation gradient



(a) (b)

Figure 2.6: (a) As the surface element is translated, it becomes more exposed to the bright surface, and irradiance increases. (b) The translation gradient $\nabla_t E_i$ of record i gives the direction of translation that produces the maximum increase in irradiance. The gradient magnitude is the irradiance derivative with respect to translation along that direction. When a surface element is translated along any arbitrary direction, a first-order approximation of the change in irradiance is given by the dot product of the translation vector and the translation gradient: $(\mathbf{p} - \mathbf{p}_i) \cdot \nabla_t E_i$.

Irradiance caching examples

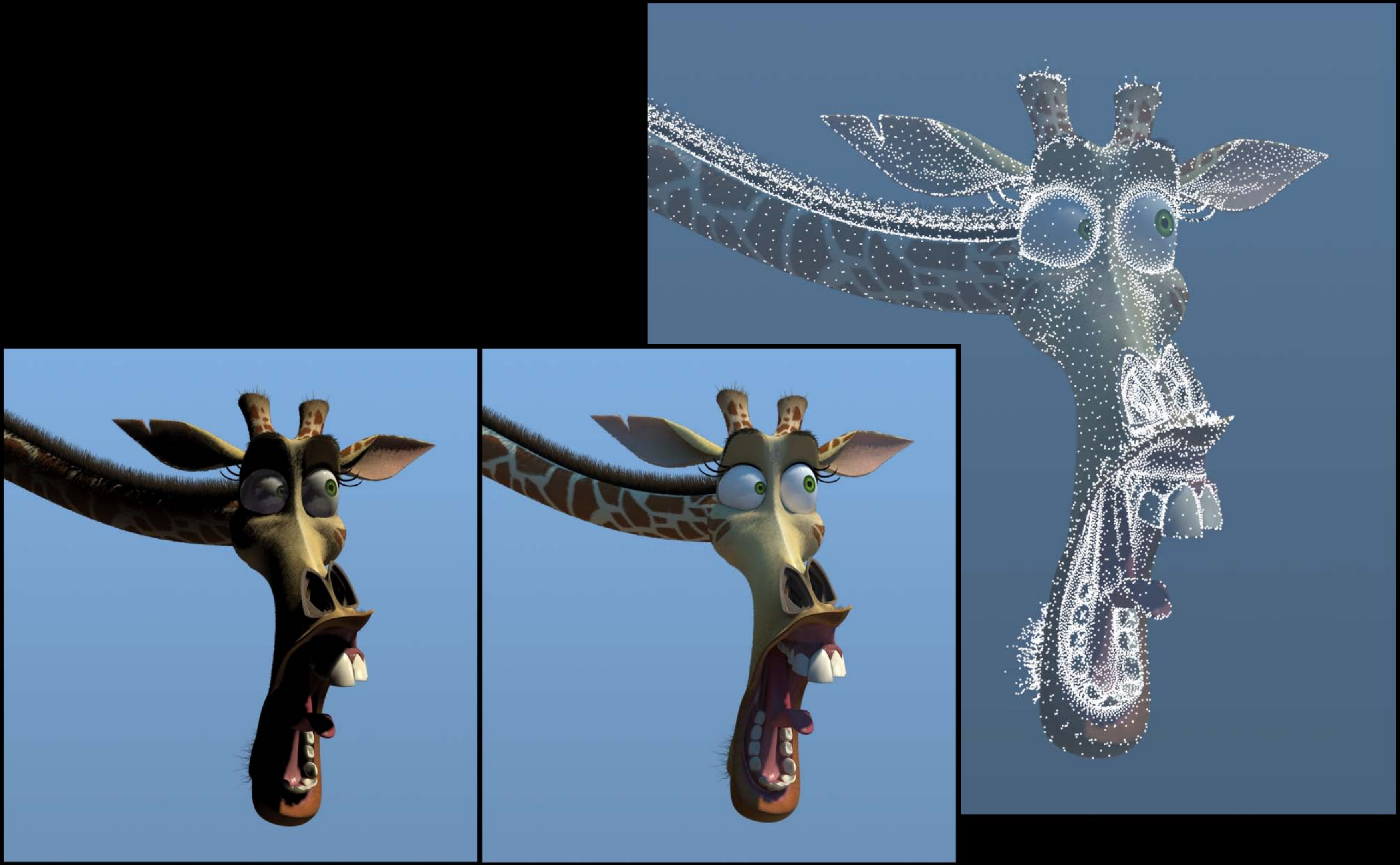


Image credit: Eric Tabellion, PDI DreamWorks

Irradiance caching examples

Image credit: Eric Tabellion, PDI DreamWorks

Ambient occlusion

X

=

Conclusion

- Fast indirect illumination of diffuse surfaces
  - Sprase sampling & fast interpolation

- Consistent but not unbiased

Unbiased vs. consistent estimator

- Unbiased estimator
  - No systematic error, only variance
- Consistent estimator
  - Has systematic error
  - Converges to the correct result
  - E.g. irradiance caching

Limitations of irradiance caching

- Only diffuse component of indirect illumination
- How about glossy surfaces?

Frank Gehry: Walt Disney Concert Hall, Los Angeles, CA

- Radiance caching - today

Limitations of irradiance caching

- Ray tracing too slow for huge scenes (film)
- Point-based global illumination – next lecture

Digression before Radiance caching:

Function Approximation & Spherical Harmonics