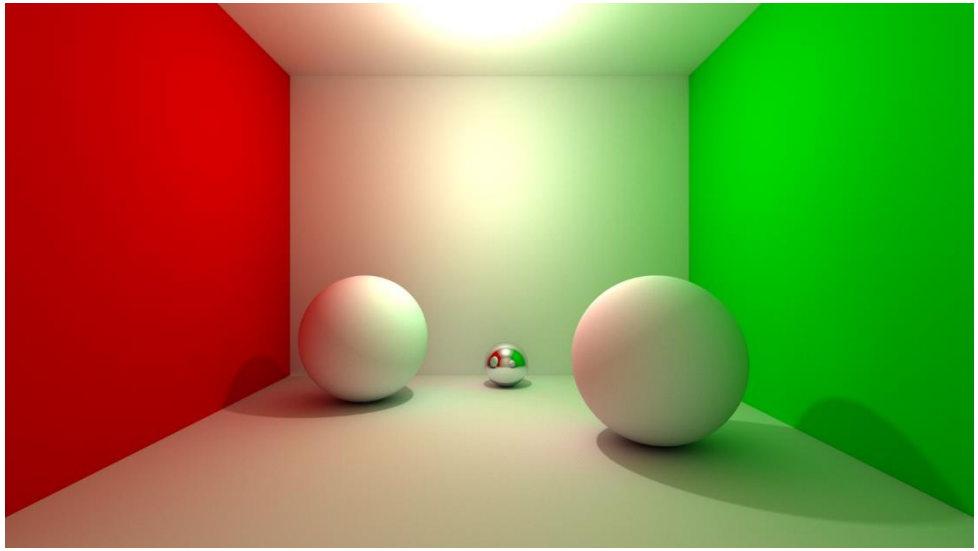
Computer Graphics

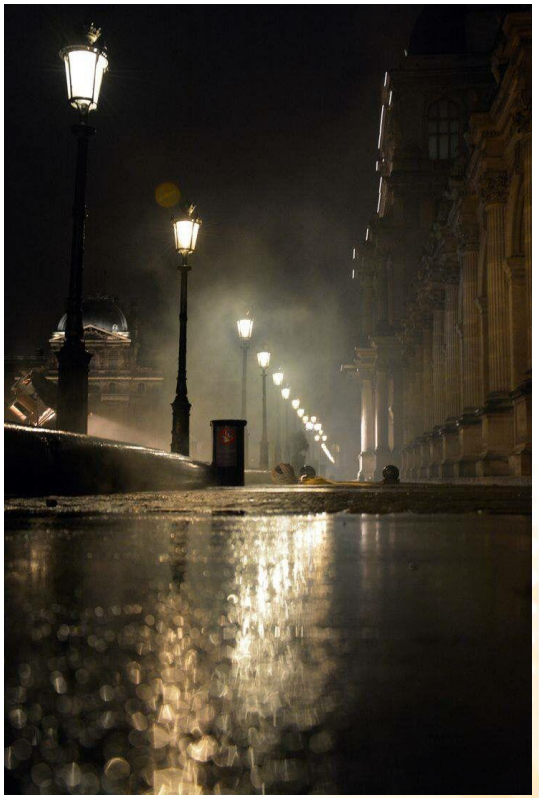
Lecture 08 – Global Illumination

Edirlei Soares de Lima
<edirlei.lima@universidadeeuropeia.pt>

Global Illumination

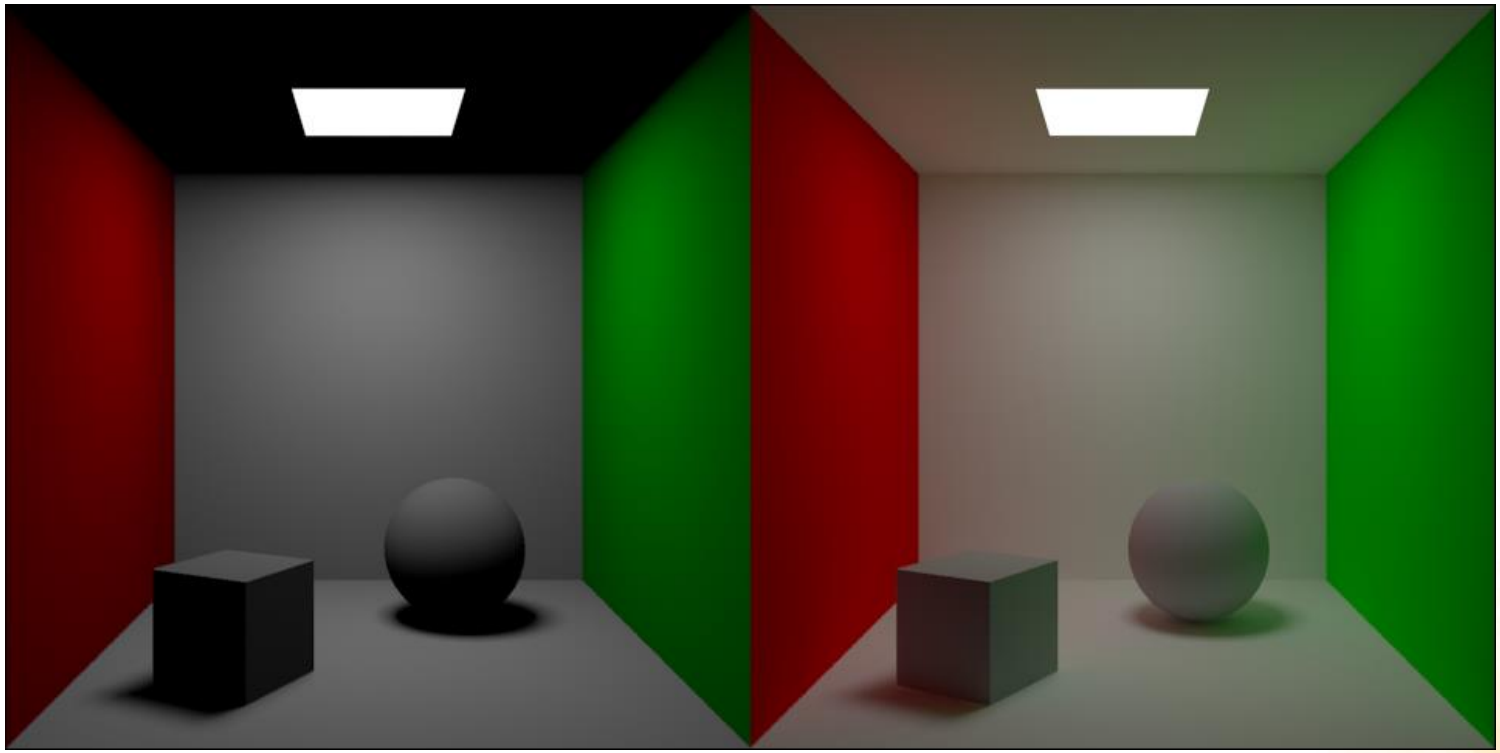
- Many surfaces in the real world receive most or all of their incident light from other reflective surfaces. This is often called indirect lighting or mutual illumination.





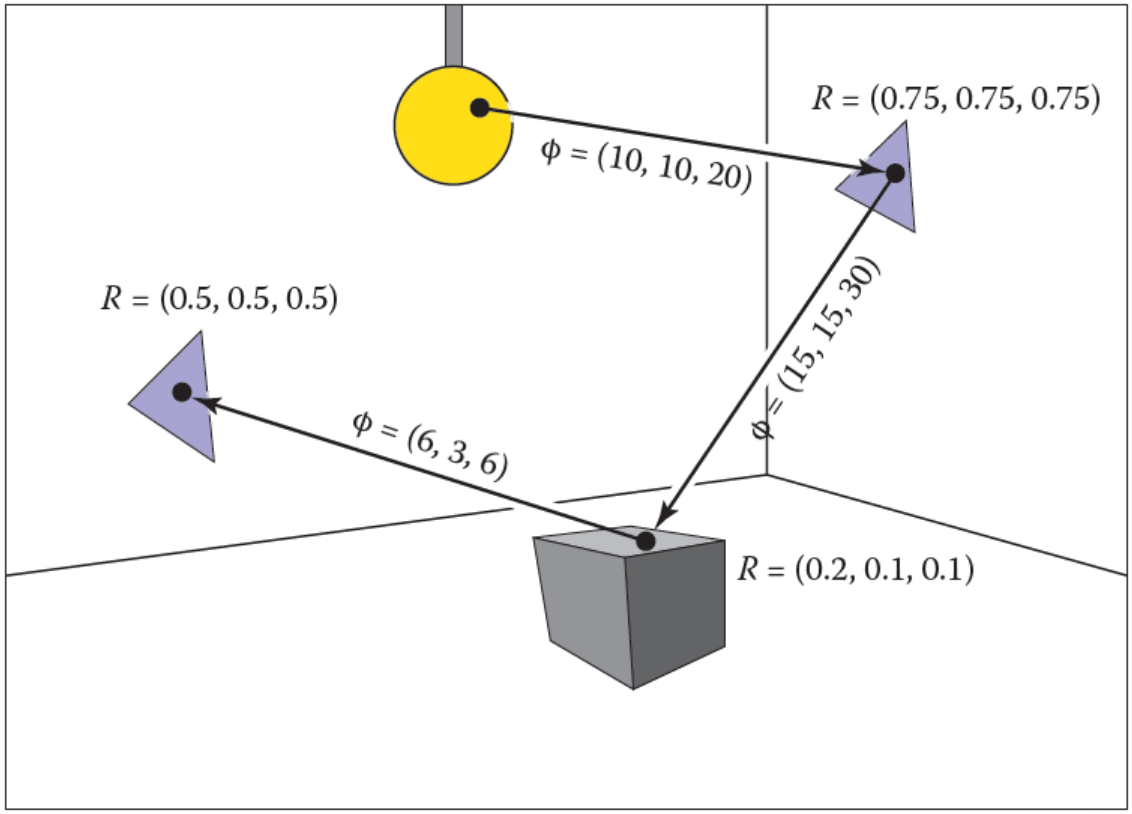
Global Illumination

- Although accounting for the interreflection of light between surfaces is straightforward, it is potentially costly because all surfaces may reflect any given surface.



Global Illumination

- Particle tracing process:



Global Illumination in Games

- Traditionally, video games have been limited to direct lighting.
  - The calculations required for indirect lighting were too slow so they could only be used in non-realtime situations (such as CG animated films).

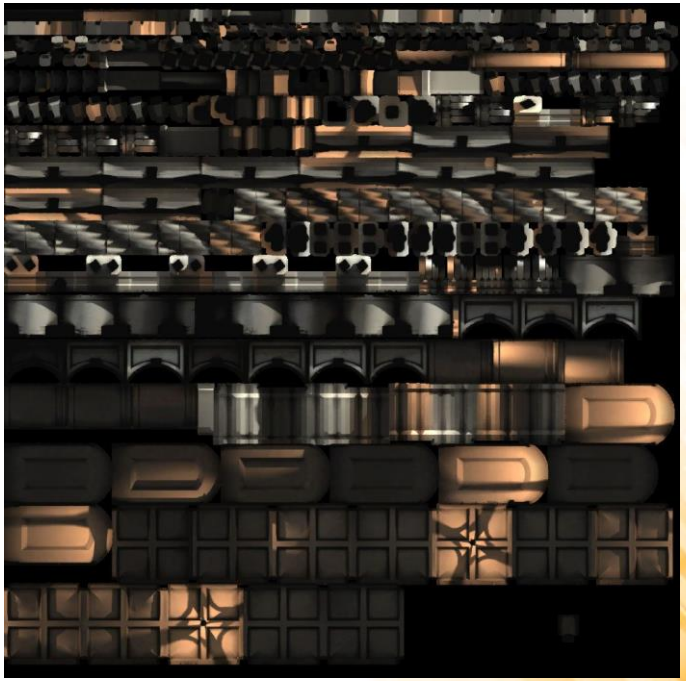
- A solution to this limitation is to calculate indirect light in a pre-processing phase (only for static objects and surfaces): pre-calculated global illumination.

  - Lightmapping!

Lightmapping

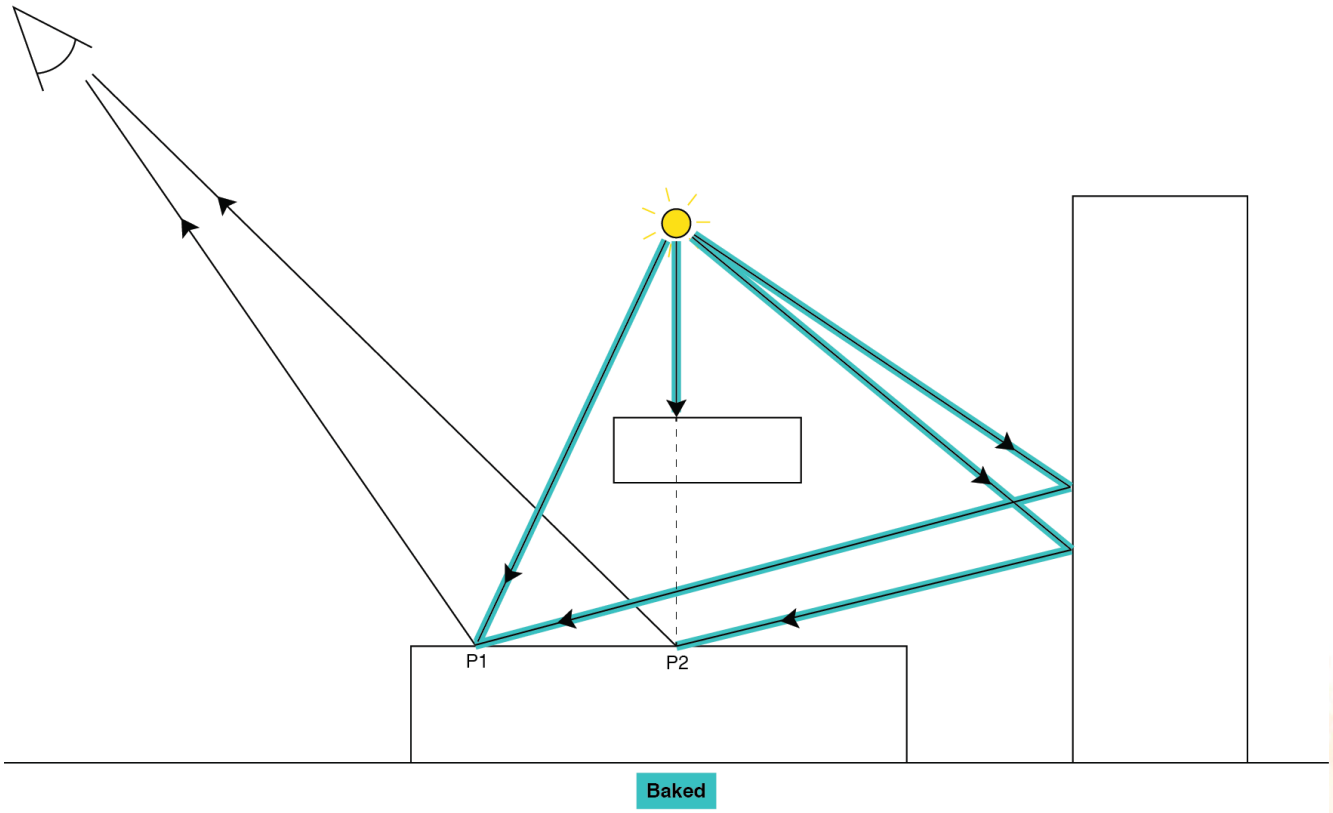
- Lightmapping is a technique used to store lighting information into textures.
  - Lightmaps allows global illumination at a relatively low computational cost.

- Instead of lighting the entire scene in real time, it pre-calculates all lighting information offline, render it into textures, and them use the textures in real-time.



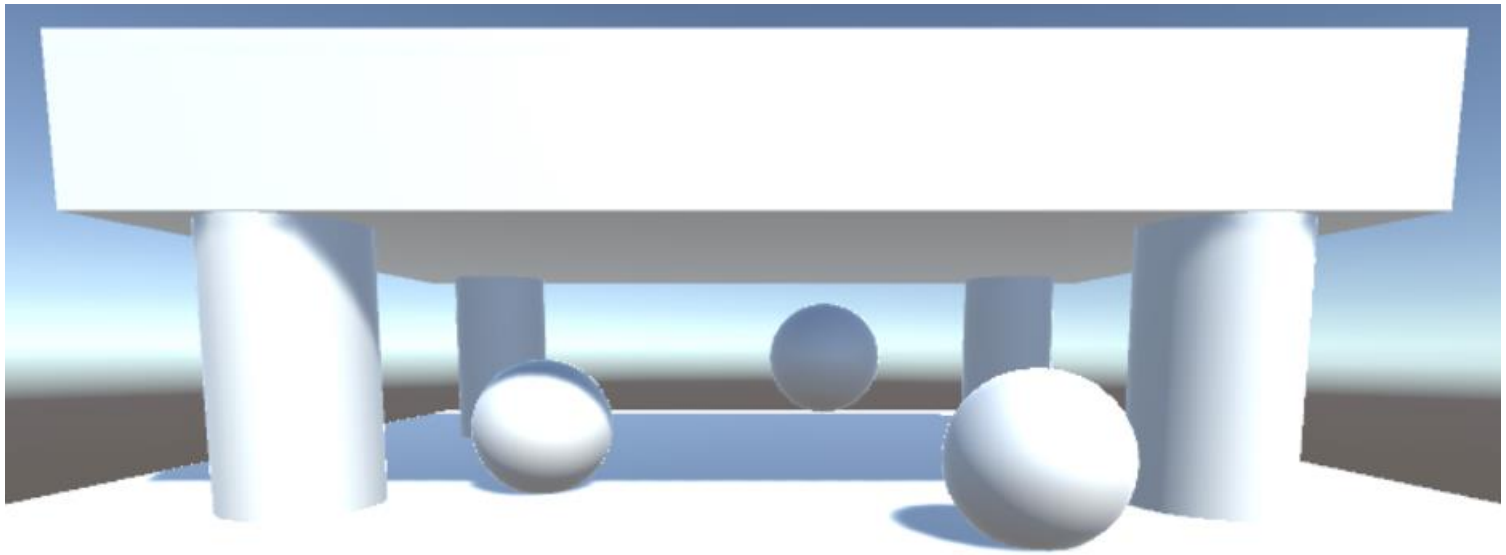
Lightmapping in Unity

- To create a lightmap, Unity computes the entire light path offline:



Lightmapping in Unity

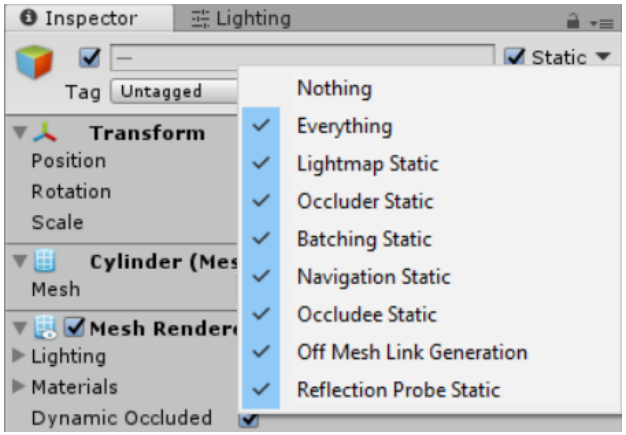
- Test scene:



Lightmapping in Unity

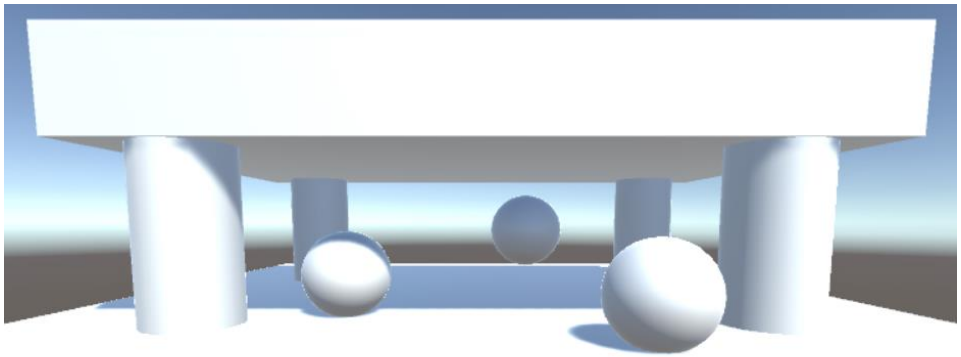
- Baked Light configuration:

- Static Geometry
  - The objects of the scene must be static:

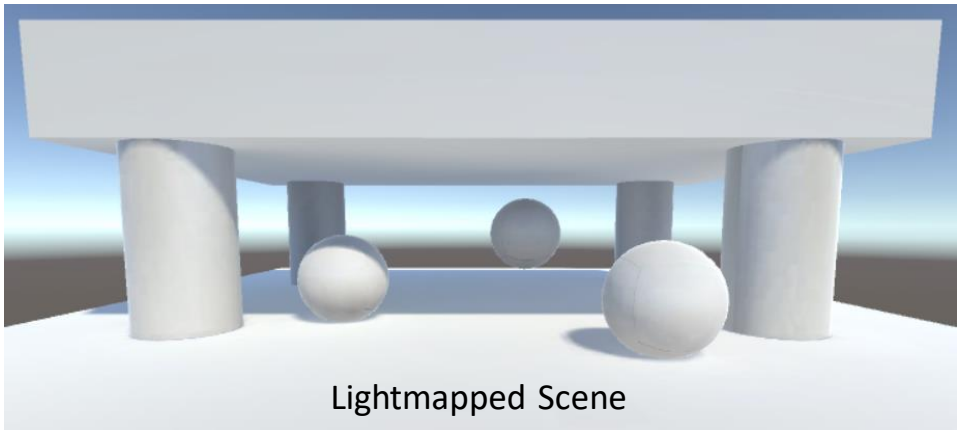


Lightmapping in Unity

- Real-Time Lightning vs. Lightmapped Scene:
  - There is no specular lighting in the lightmapped scene!



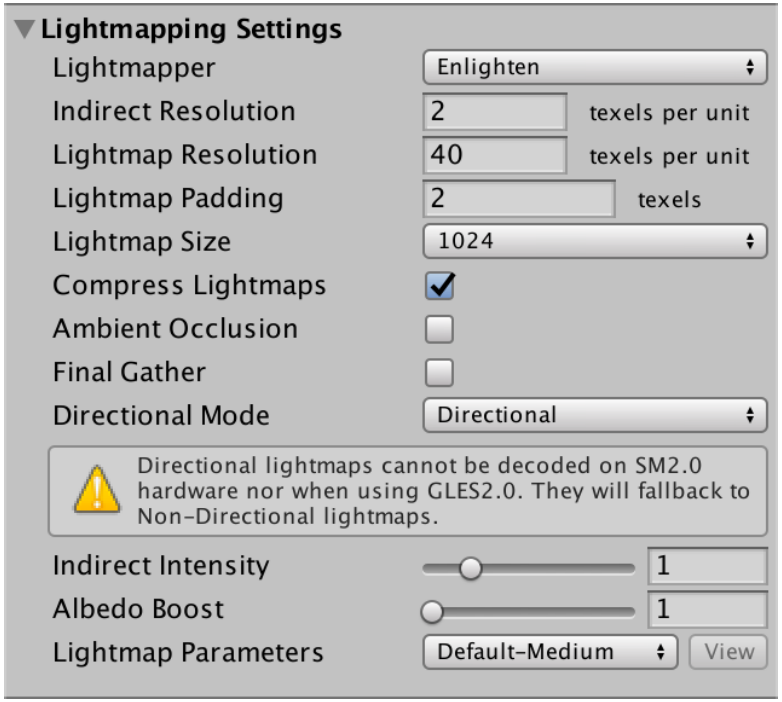
Real-Time Lightning

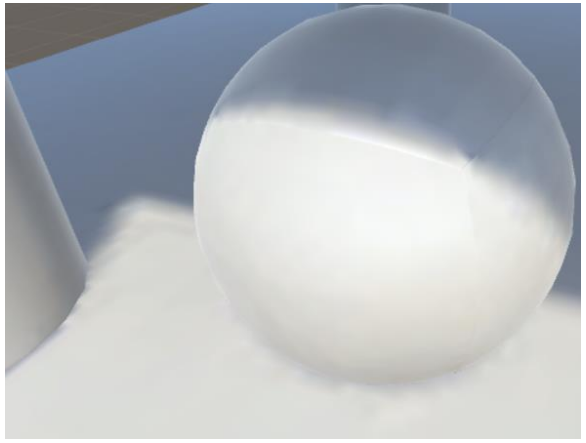


Lightmapped Scene

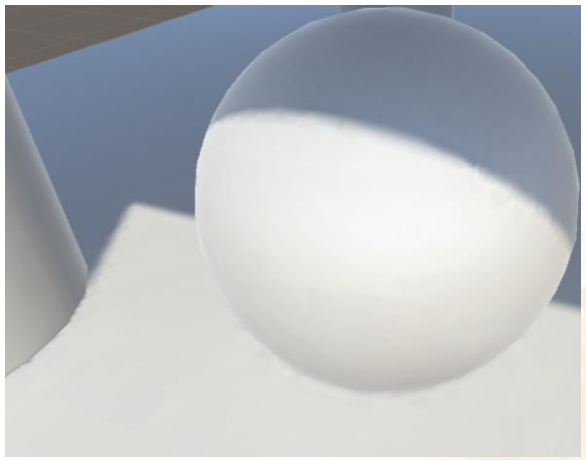
Lightmapping in Unity

- Lightmapping Settings





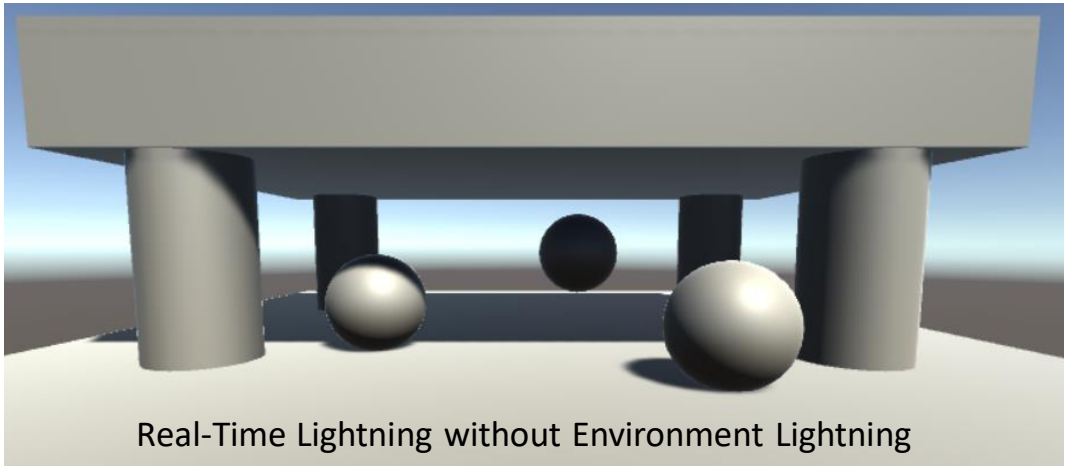
Default resolution



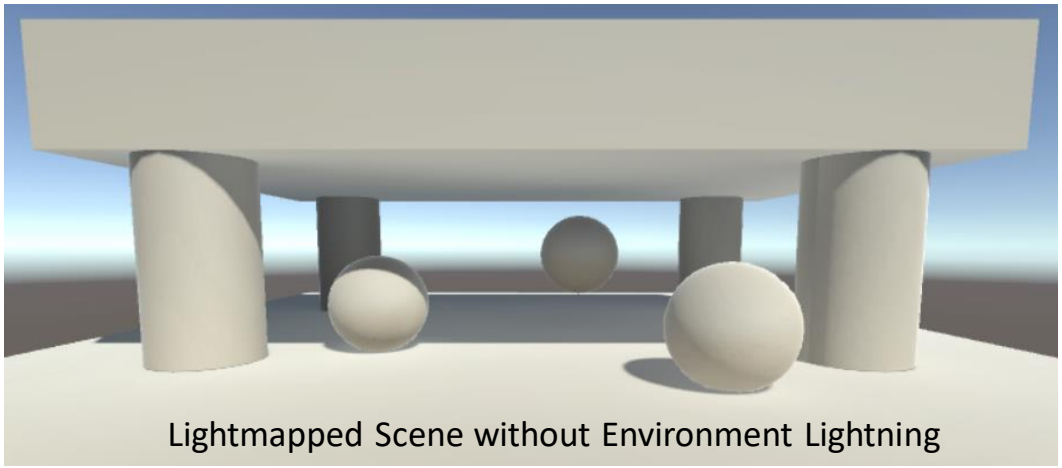
Higher resolution

Indirect Light

- With lightmapping we have indirect lighting.



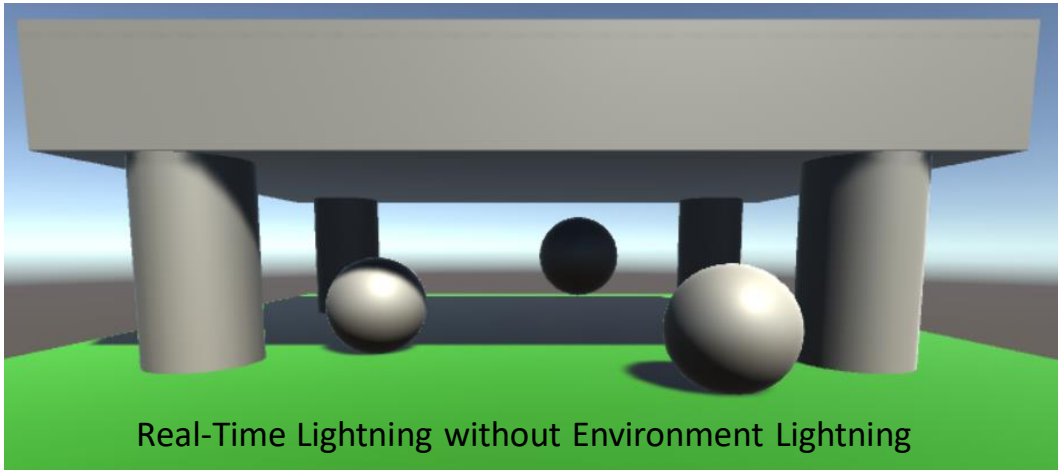
Real-Time Lightning without Environment Lightning



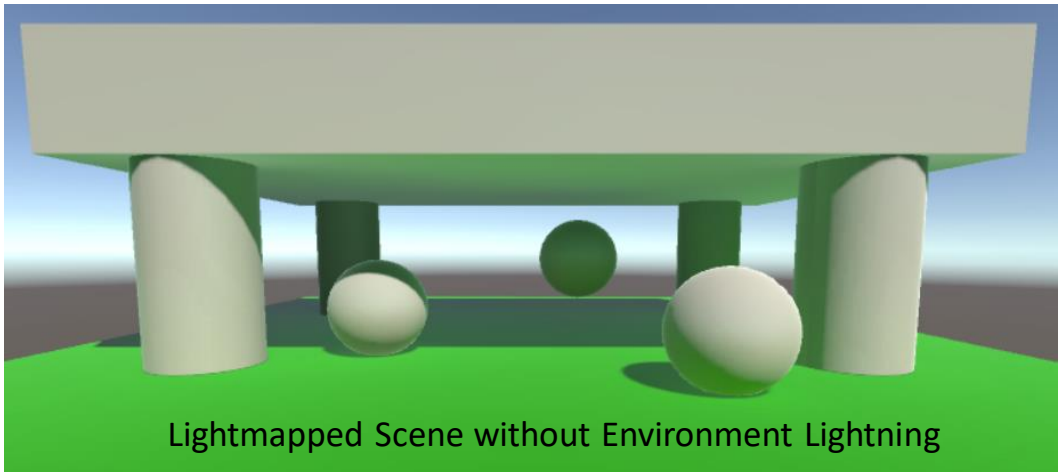
Lightmapped Scene without Environment Lightning

Indirect Light

- With lightmapping we have indirect lighting.



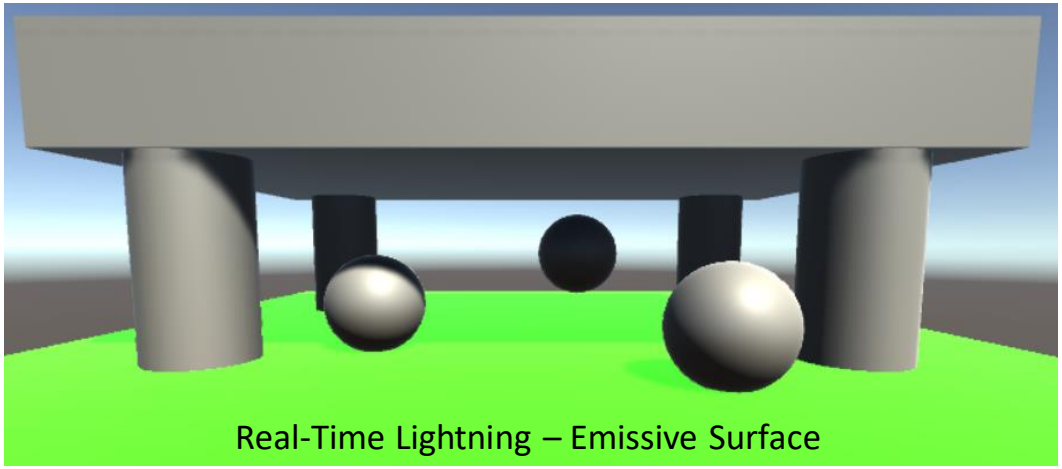
Real-Time Lightning without Environment Lightning



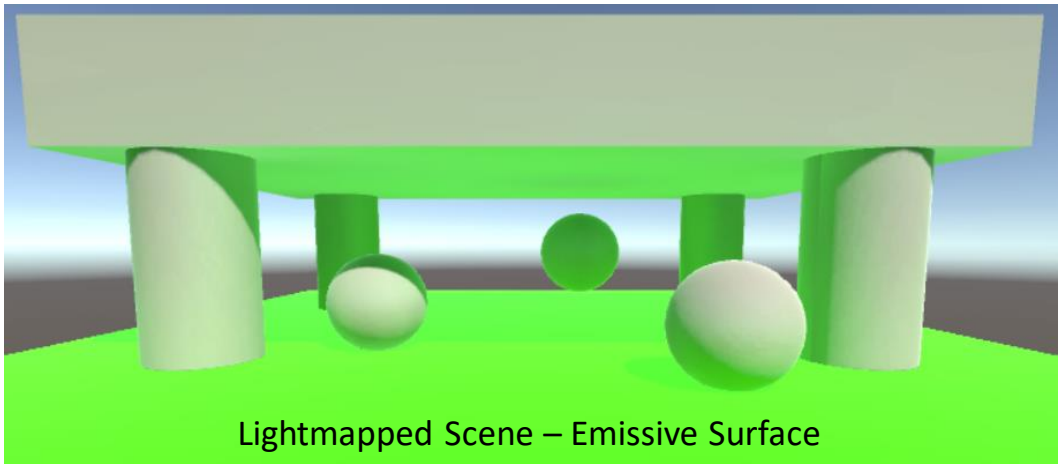
Lightmapped Scene without Environment Lightning

Indirect Light

- With lightmapping we have indirect lighting.



Real-Time Lightning – Emissive Surface

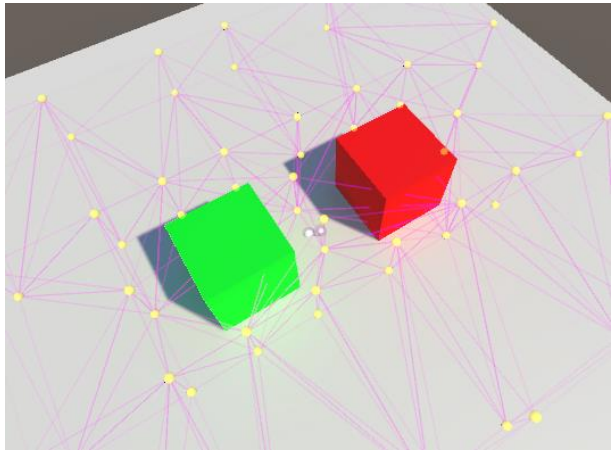


Lightmapped Scene – Emissive Surface

Light Probes

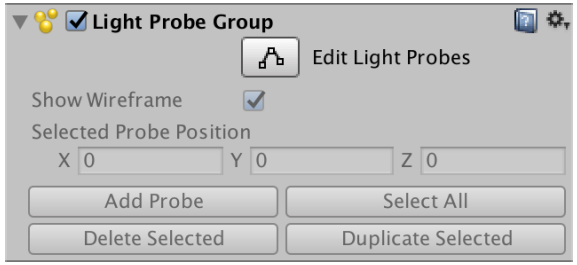
- Lightmaps only work for static objects. In order to apply the baked lighting to dynamic objects we can use light probes.

- A light probe is a point in space that stores information about the lighting at that location.
  - While lightmaps store information about light hitting the surfaces, light probes store information about light passing through a empty space.

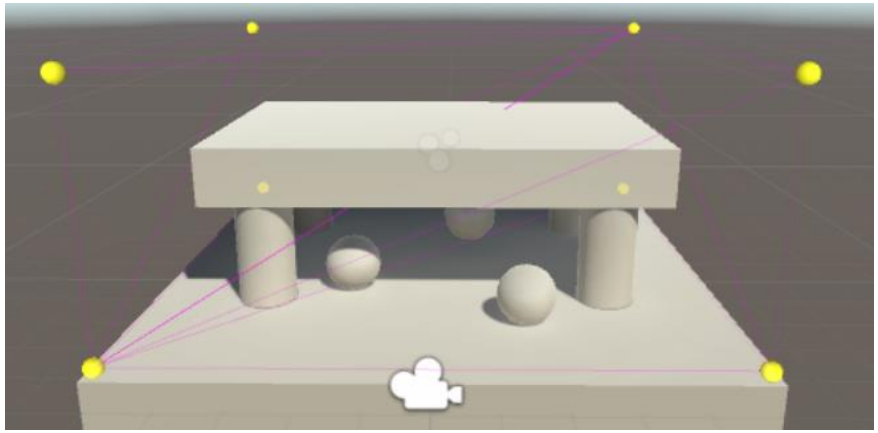


Placing Light Probes

- Add a new group of light probes:
  - **GameObject -> Light -> Light Probe Group**

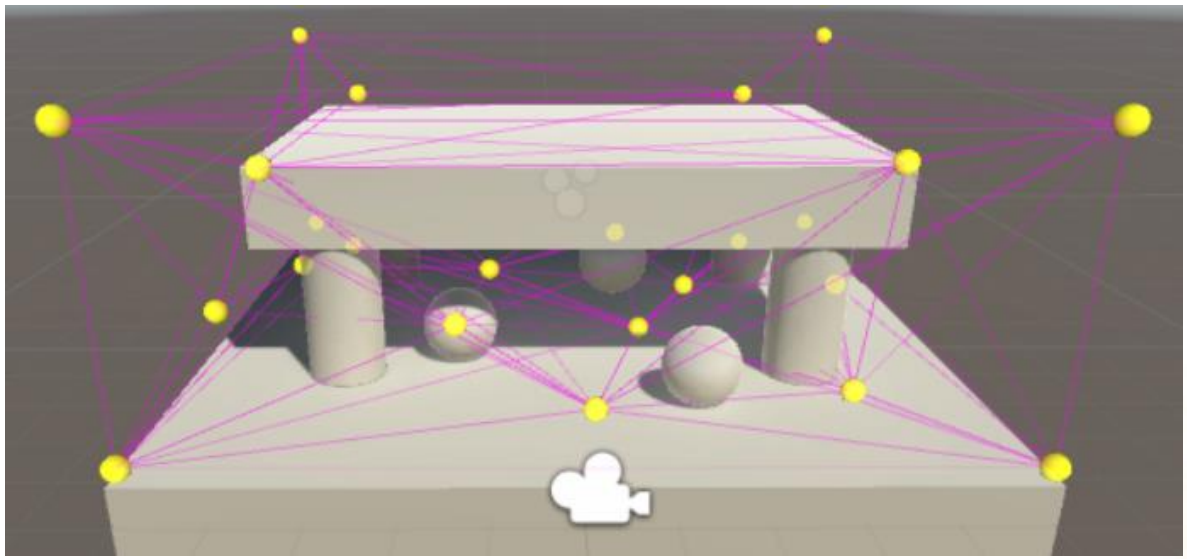


- Unlike lightmaps, the resolution of the light probe information is entirely defined by how closely packed the probes are positioned.
  - Usually you begins by involving the area that will contain dynamic objects with the probes:



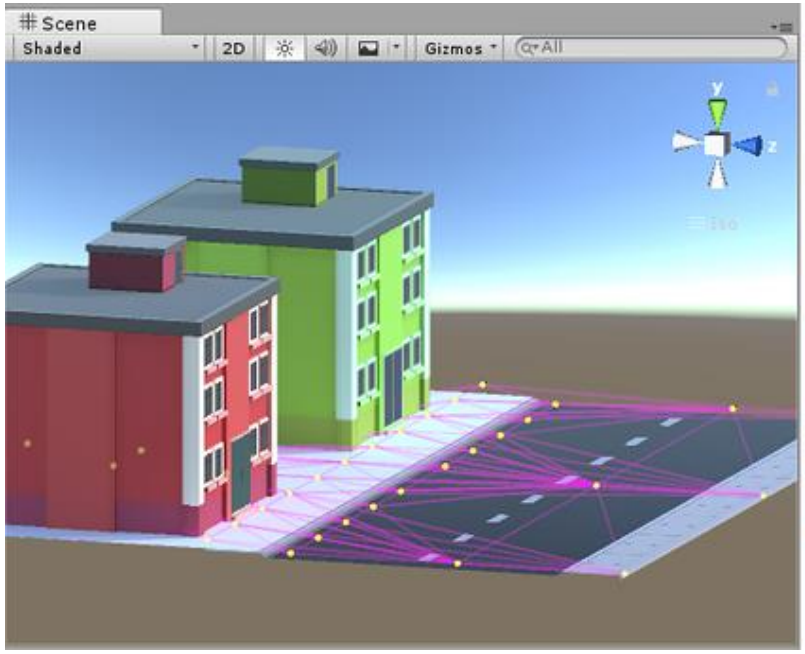
Placing Light Probes

- Then add more probes depending on how the lighting conditions change.
  - Place as few light probes as possible. It is essential that you do not place them inside static geometry.
  - Place then in a more condensed pattern around areas that have complex or contrasting light.

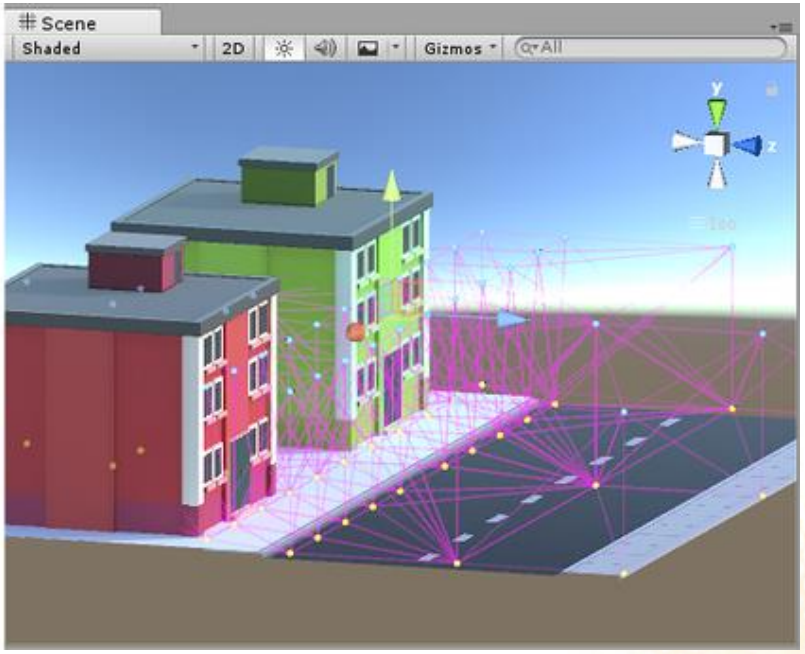


Placing Light Probes

- Even if the gameplay takes place on a 2D plane (for example, cars driving around on a road surface), the light probes must form a 3D volume.



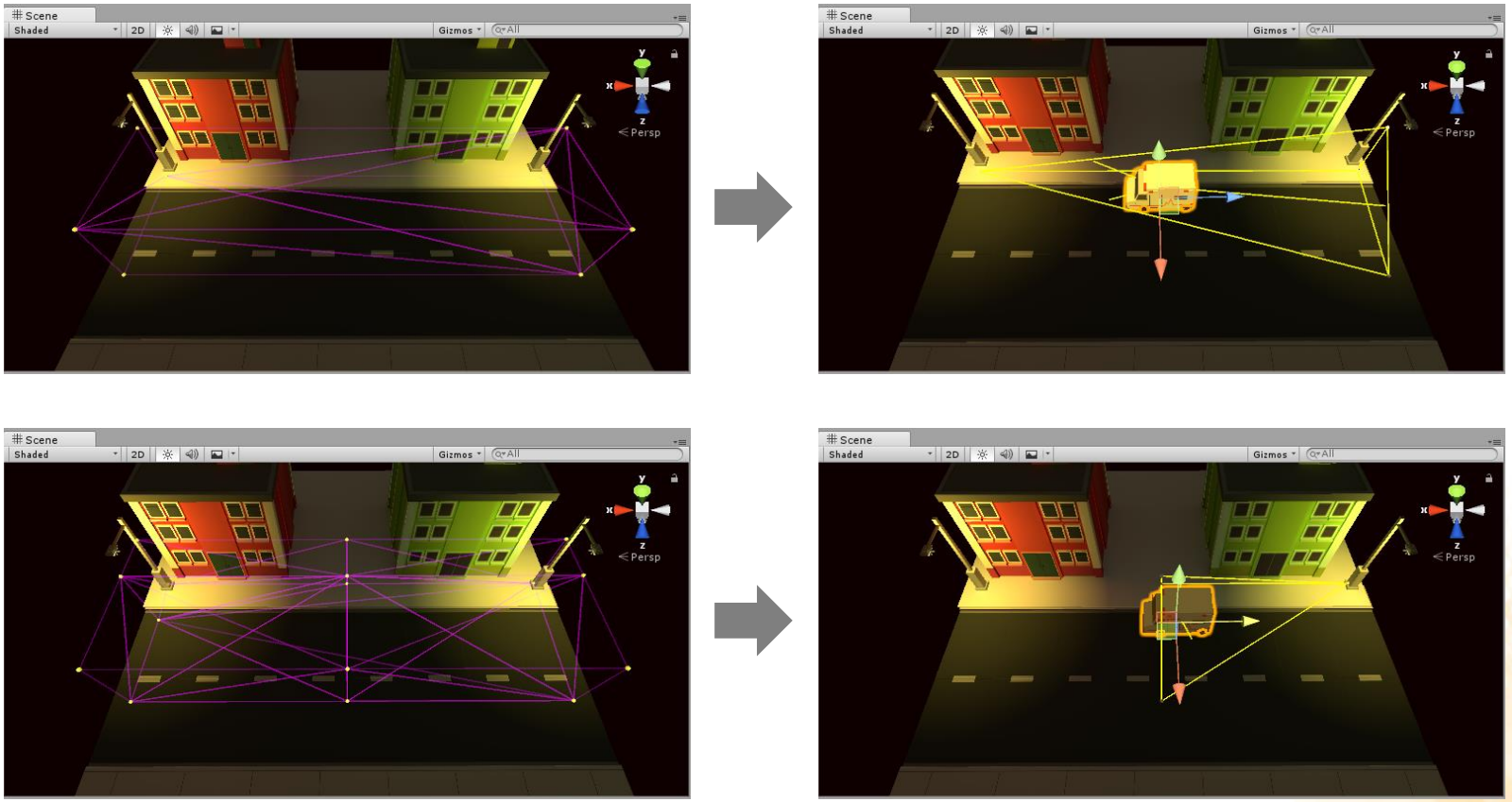
Bad choice of light probe positions



Good choice of light probe positions

Placing Light Probes

- Light probe positions must take into account that the lighting will be interpolated between sets of probes.

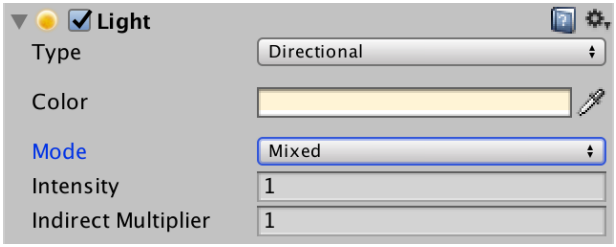


Mixed Lighting

- Lightmaps allow us to compute light offline.
  - Limitations: no specular lighting, no real-time shadows, and we need light probes to influence dynamic objects.
- Indirect light is the one thing that baked lighting has that real-time lighting lacks, because it requires a lightmap.
- Mixed lights allow indirect light to be combine it with real-time lighting.
  - Of course this means that shading becomes more expensive.

Mixed Lighting

- To use mixed lighting, the light's mode has to be set to Mixed.
  - The lightmap will only store indirect light information.
  - Dynamic objects use the light probes to compute indirect light.

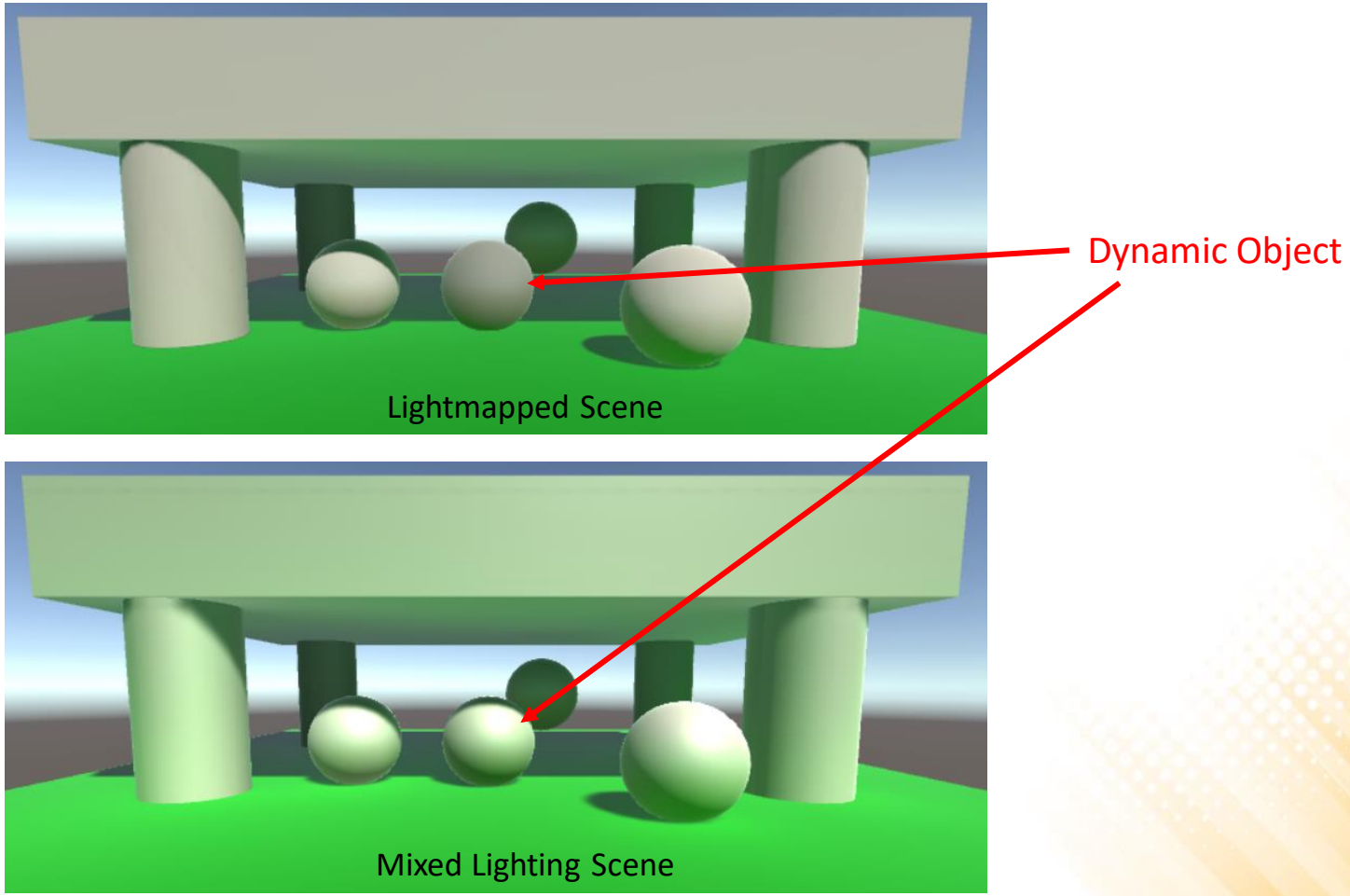


Full Lightmap

Only indirect light

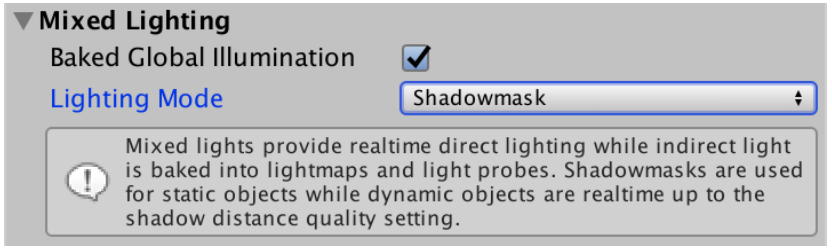
Mixed Lighting

- With lightmapping we have indirect lighting.

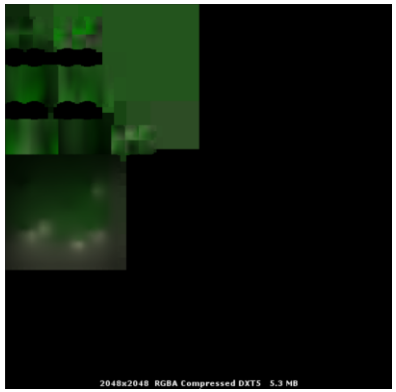


Mixed Lighting

- Mixed lighting is as much expensive as real-time lighting (it adds lightmaps for indirect light).
  - We can improve this by including shadows into lightmaps: Shadowmask Mode.



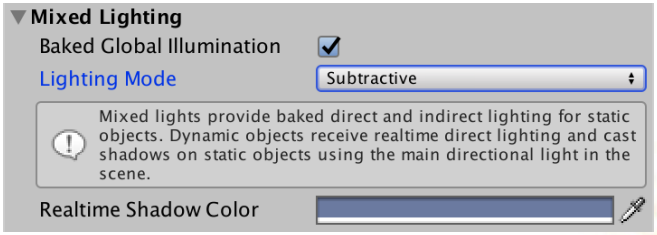
- In this mode, both the indirect lighting and the shadow attenuation for mixed lights are stored in lightmaps.



Mixed Lighting

- Mixed lighting with shadowmask is not as cheap as fully baked lighting.
  - Subtractive Mode provides the fast and lowest-quality results: it renders shadows of dynamic object in real time for only one light, and composites them with baked direct and indirect lighting.

- Only recommended for platforms that are unable to use any of the other modes.



- Limitations:
  - No specular lighting;
  - Dynamic shadows only for one Directional Light

Realtime Global Illumination

- Lightmapping works very well for static geometry, but it cannot deal with dynamic lights (like the sun traveling across the sky).

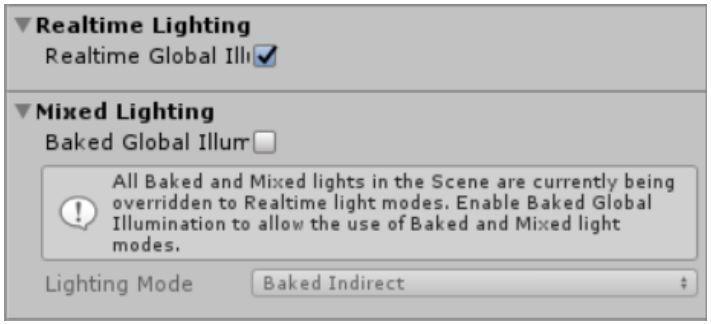
- To support real-time global illumination, Unity uses the Enlighten system (developed by SiliconStudio).
  - It still requires a precomputation phase similar to the lightmapping process, and it is still limited to static objects.
  - It precomputes all possible light bounces in the scene and encodes this information for use at runtime.

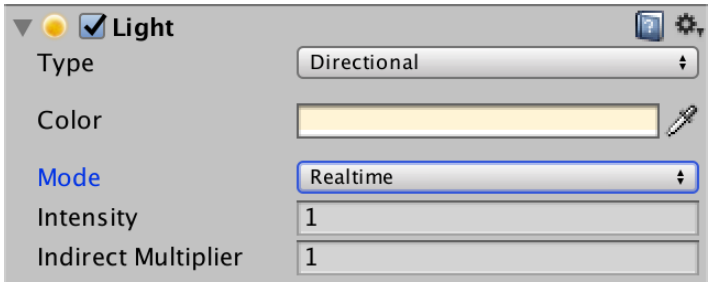
Realtime Global Illumination

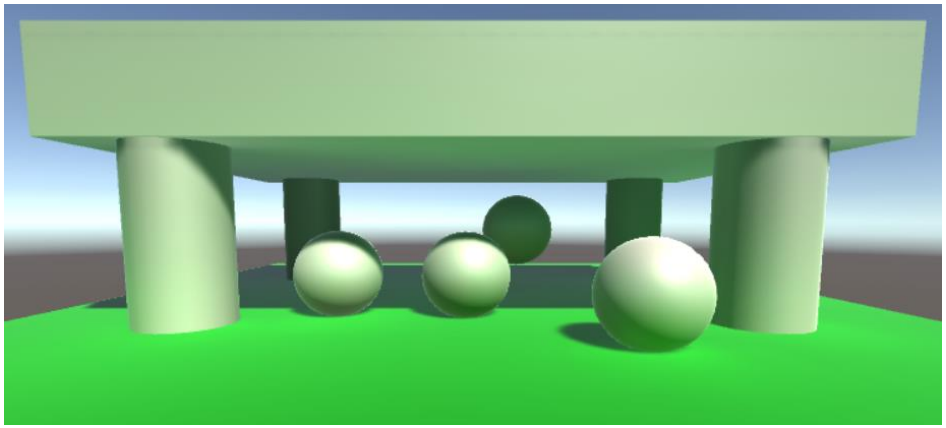
- Enlighten System:

Realtime Global Illumination

- Realtime global illumination can be enabled independent of baked lighting. In addition, the Light Mode must be set to Realtime.

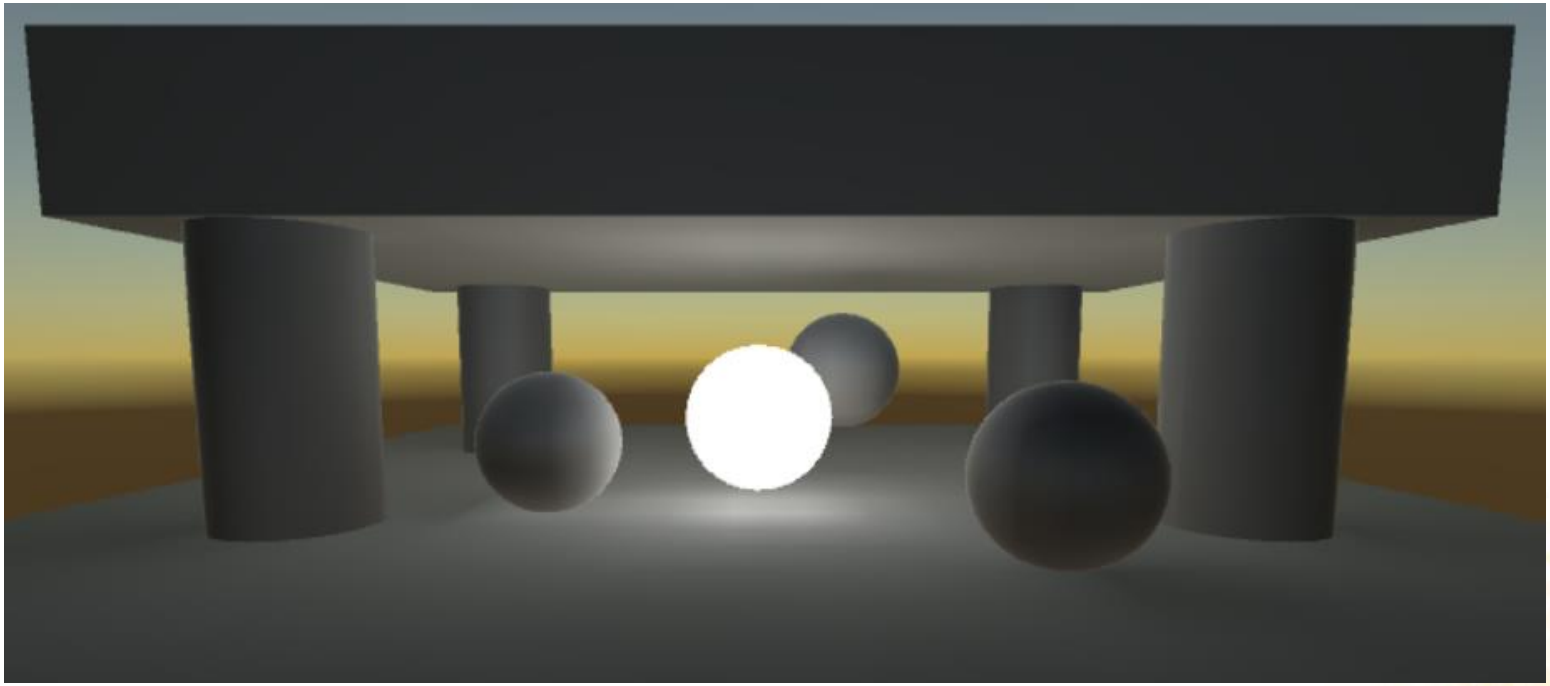






Realtime Global Illumination

- Realtime Global Illumination can also be used for static objects that emit light. This makes it possible to vary their emission with matching realtime indirect light.



Realtime Global Illumination

- Precomputed Realtime Global Illumination also has the limitation that only static objects can be included in the precomputation (moving objects cannot bounce light onto other objects).
  - However, they can still pick up bounce light from static objects using Light Probes.

Moving ambulance without indirect light

Moving ambulance with indirect light from light probes

Exercise 1

1) Add lights and configure global illumination for the morgue room scene.

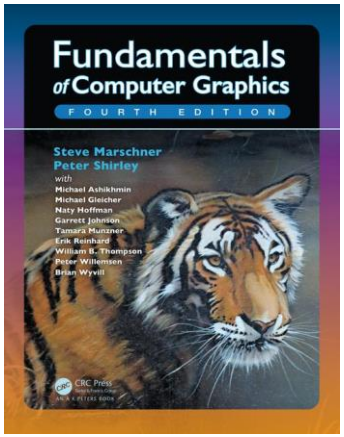
   – The scene must have:
     - Emissive ceiling lights;
     - Indirect lighting;
     - Shadows;

https://assetstore.unity.com/packages/3d/environments/morgue-room-pbr-65817

   – Base Scene: http://www.inf.puc-rio.br/~elima/cg/morgue_room.html

Further Reading

- Marschner, S., et al. (2015). **Fundamentals of Computer Graphics** (4th ed.). A K Peters/CRC Press. ISBN: 978-1482229394.
  - **Chapter 33: Global Illumination**



- **Web:**
  - http://catlikecoding.com/unity/tutorials/rendering/part-16/
  - http://catlikecoding.com/unity/tutorials/rendering/part-17/
  - http://catlikecoding.com/unity/tutorials/rendering/part-18/