

# Computer Graphics, Autumn 2019

## Assignment 1

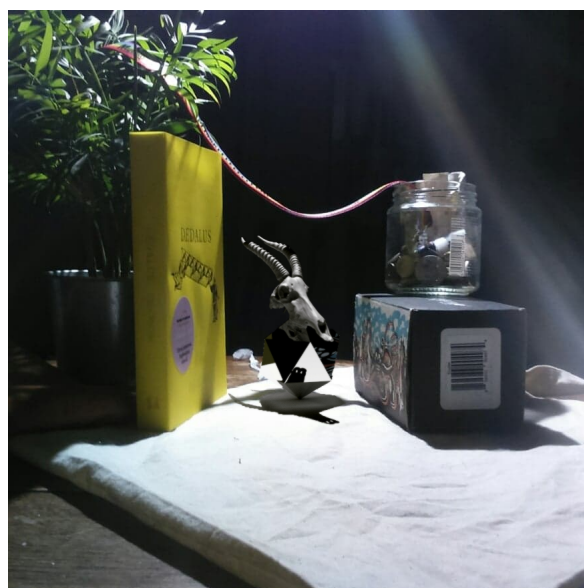
### Reel or Real?

Alexandros Keros, Kartic Subr

**Due: 07/10/19 (5pm)**



(a) Real-world photograph



(b) Composited image

Figure 1: Augmented reality by rendering a virtual object into a real scene.

“Reel to Real” Studios is conducting interviews on campus and would like to test your skill in producing a high-quality augmented reality still image. Impress them, and they might want to hire you. You are required to combine a photograph of the real world with an image obtained using a photorealistic renderer to produce a realistic augmented reality still image. The main requirement is that your rendered image represents lighting, reflections and shadows that are consistent with the viewer’s expectation of the real scene. The final output is a single photorealistic image that contains a 3D computer generated, or *rendered*, object (or multiple objects) overlaid convincingly, or *composited*, on a photograph. You may capture the photograph (e.g. using the camera on your phone) or use a stock royalty-free photograph off the internet.

## Tools

You are required to use the *Physically Based Renderer PBRT* to generate the synthetic objects/scene. In order to obtain consistent shadows, you might need to develop an approximate model of the real environment which will be input to the renderer. For this, you may use tools such as Blender. Then, you will need to use an image manipulation software (e.g. Gimp, Adobe Photoshop, etc.) to segment and composite the virtual image on the photograph. A list of tools is provided below.

- The book <https://www.pbrt.org/>
- The code <https://github.com/mmp/pbrt-v3>
- *Artec3D* online .ply library: <https://www.artec3d.com/3d-models/ply>
- *Blender 3D creation suite*: <https://www.blender.org/>
- *Blender exporter for PBRT* Blender add-on:  
<https://osr.jstudios.ovh/InstallBlenderExporterOnly>
- *Luminance HDR* tonemapping software: <http://qtpfsgui.sourceforge.net/>
- *Gimp* image manipulation program: <https://www.gimp.org/>

## What To Submit

Please submit a report explaining the steps taken to achieve your final image. A submission of only the final output without explanations and intermediate steps will only receive half the credit. The report should be in .pdf format, and explain your work, step by step, with screenshots and inline images. Figures should be numbered, annotated, referenced and clearly visible. Please outline the concept of your synthetic scene, and enumerate the steps taken to produce the final image. Finally, include a qualitative assessment of your result at each step. In addition to the report, your submitted zip file should contain the following images:

1. A composited image. Ensure that shadows, reflections, objects occlusions and colors are consistent and natural.
2. Intermediate images, including:
  - The initial, real-world photograph
  - Photos of textures (perceived surfaces of real world objects) that are necessary to produce a believable result. Textures might appear on reflections, in the background of synthetic objects that cast shadows on them, or might influence shadows and ways light interacts with surfaces of synthetic objects.

- If a 3D modeling program is used, such as *Blender*, screenshots illustrating the modelled scene that will later produce the synthetic objects.
- Renderings, as generated by *PBRT*, as well as color-corrected (tonemapped) versions.

3. The *PBRT* input file(s) used to render the synthetic image.

All necessary files, appropriately named, should be compressed into a `.zip` file and submitted via the *Learn* platform (<https://learn.ed.ac.uk>) as the first assignment for the course.

## Marking Scheme

A total of 100 points are assigned for this project, which will then be halved. i.e. its final contribution to your grade will be at most 50%, depending on the marks on your following two assignments. See the course website for clarification. The marking scheme is described below. Numbers in parentheses indicate points of the specific task. Each student is expected to design a unique scene and object(s). **Do not copy the example shown in this document.** Provide evidence of having achieved each of the following milestones, in your report.

- *PBRT*
  - Installation (5)
  - Generating a test image (10)
- Approximate model of a scene, necessary to produce photorealistic synthetic objects
  - Accurate model of the real-world lighting as in the original photograph (10)
  - ‘Proxy’ model(s) of real-world object(s) that affect rendered objects (10)
  - Textures on real objects that appear on rendered object(s) (20)
- Rendering synthetic object
  - Choose a synthetic object model from a 3D model library (`.ply` files) (5)
  - Render of synthetic scene with above parameters (5)
- Compositing / Merging of synthetic objects on the real-world image
  - Photometric consistency, i.e. light intensity, direction, color, shadows (10)
  - Seamless positional compositing – no mismatched edges (5)
  - Shadows of rendered object on real scene (5)
  - Shadows of real objects on rendered elements (5)
  - Reflections of textured objects on rendered objects (reflective material) (5)
  - Multiple rendered objects (5)

# Tips/How-To

Based on the example composited image of Figure 1b, what follows is an outline of its generation process, which will hopefully provide some tips and tricks on how to approach this problem.

## 1. Planning the scene

- (a) We captured a real world image (Figure 1a) exhibiting interesting visual properties, such as rough, difficult to render, textures (ground plane, box and book designs), complex objects (glass jar filled with coins) and distinct hard shadows cast from real-world objects. We planned to position the rendered objects in the middle of the image, while ensuring that interesting visual properties will be present, such as shadows cast from real-world objects onto the rendered ones, shadows of rendered objects will be clearly visible, and reflections of real-world objects will appear onto the rendered elements.
- (b) We identified the textures that will influence the appearance of the rendered objects. Here, the surfaces of the book and the box are separately photographed so that they can be used as textures on artificial proxy objects while modelling the synthetic scene.
- (c) We selected upon the rendered objects and their materials to be used for the new scene, making sure that they exhibit interesting visual properties, such as complex shadows and reflections. We decided upon a mirror icosahedron underneath an antelope skull, which is retrieved from an online 3D model library (<https://www.artec3d.com/3d-models/damaliscus-korrigum>).

## 2. Modelling the scene 6 Two approaches exist for modelling the desired scene

- One is to directly use *PBRT* and, by using built-in shapes and triangular meshes, define the scene to be rendered.
- An alternative approach is to use a 3D modeling software that interfaces with *PBRT* (see *Tools To Use* section). Blender, which is freely available, alongside its respective *PBRT* exporter (see *Tools To Use* section) were used for this example scene.

We modelled the scene in Blender (Figure 2), making sure that materials are appropriately defined, and desirable textures appropriately mapped. Next, we exported the appropriate *PBRT* input file.

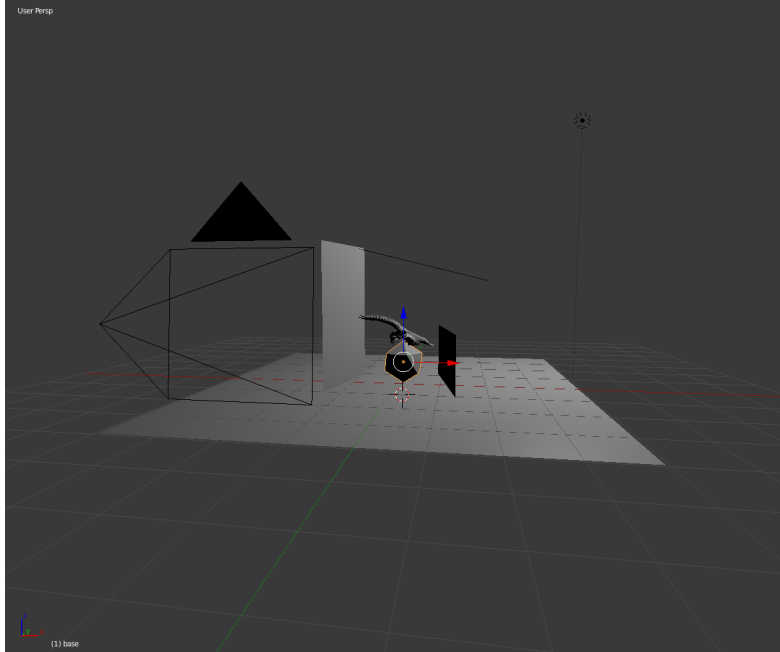


Figure 2: Blender model of the scene

### 3. Rendering the scene

We used the files produced by *Blender-to-PBRT exporter* to render the synthetic scene. Note that the exported does not define a light source, so the *PBRT* input file should be appropriately edited in order to get the desirable results (Figure 3).

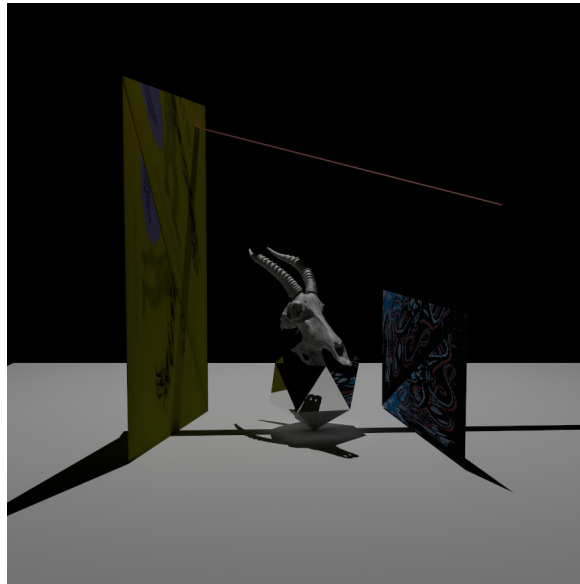


Figure 3: Rendered scene

### 4. Compositing the scene

- (a) We adjusted the color histogram and intensity of the produced *high dynamic range (HDR)* rendering (*tonemapping*) with the freely available *Luminance HDR* software (see *Tools To Use* section) to match as closely as possible the real-world scene.
- (b) We used *Gimp* image editing software (see *Tools To Use* section) to composite the virtual objects with the real-world photograph by further adjusting color values, where necessary, and making sure that objects with shadows produce a believable result.

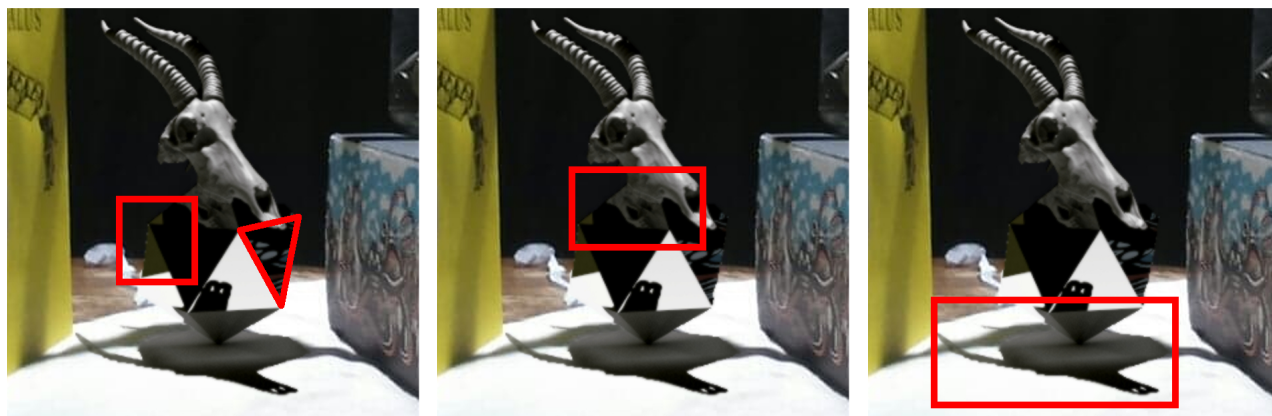


Figure 4: Zoomed area of final composited image (Figure 1b)

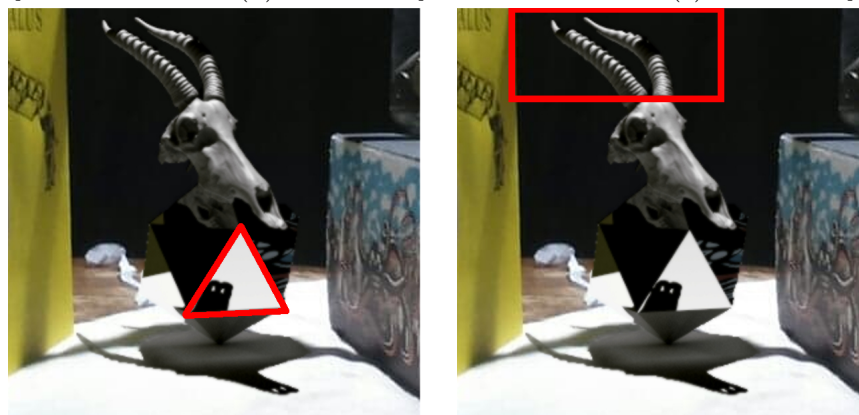
Lets breakdown the interesting visual features of the final composited image of Figure 4:

- Reflections of real objects are visible on the reflective surfaces of the rendered objects (Figure 5a). This is achieved by modeling the necessary real-world objects by appropriate shapes (here, we used planes) and attaching textures (book cover, box design).
- Synthetic objects coexist in a photorealistic way, visible from the reflection of the underside of the skull on the face of the mirrored icosahedron (Figure 5b).
- Shadows of synthetic objects are reproduced and blend in the real world scene (Figure 5c) due to modeling the overhanging ribbon. Since they have been rendered in a photorealistic way, a complex instance of an idol of the shadow of the skull is visible on a face of the icosahedron (Figure 5d).

- Shadows of real world objects are seen to be cast onto the synthetic objects, such as the horns of the skull (Figure 5e).



(a) Real objects' reflections (b) Virtual object's reflection (c) Virtual objects' shadows



(d) Reflection of virtual object's shadow

(e) Shadows of real objects on virtual objects

Figure 5: Collection of interesting photorealistic effects of the interaction of synthetic and virtual objects