The exercises will take place in room G40 in Mühlenpförtstrasse 23. Your y-account is sufficient to login and access all tools. Ctrl+Alt+T gives you a terminal and g++ is your GNU C++ compiler. This project offers a CMake configuration to generate and executable.

Throughout the course you will implement your own minimal raytracer. In each exercise you will extend your raytracer a little further. To make the task easier, you are provided with a basic raytracing framework so that you just have to fill in the missing core parts. You may use your own computer to solve the exercises, but your final program must run on the machines in the CIP pool.

Each week you must complete the assignments and hand in your commented source code for the practical tasks, as well as your solutions to the theoretical tasks (with drawings/formulas). Please use different colors in your drawings and also make sure that formulas are recognizable in your source code. Your group must present the completed assignments on each Friday, 9:45.
To keep presentation time short, keep (a copy of) the original scene to generate the result shown below.

By the end of this exercise your group will have the basic framework needed for the Raytracing Challenge. You can now start implementing your own extensions and create your demo scene for the Raytracing Challenge.

7.1 Bilinear Interpolation (20 Points)
You may have noticed that textures can become pixelated, especially near the camera, where one texel covers multiple pixels on the screen. To alleviate this, we will implement bilinear filtering. This allows us to linearly interpolate between texels and thus get a smoother result.
Take a look at Texture::color(float u, float v) in common/texture.cpp and implement bilinear filtering. Note that just using CImg linearAt methods is not a valid solution for this example; you have to implement the filtering yourself. If everything is implemented correctly, you should get smooth textures.

7.2 Material Shader (5 + 5 + 15 + 10 + 15 Points)
You have already implemented various individual shaders. We now want to create a new shader that combines various techniques you have learned before and uses image maps for additional artistic freedom.

Diffuse Map Implement diffuse mapping in the MaterialShader. The idea is basically the same as in lambertian shading, but instead of having one albedo value over the whole surface one samples the diffuse map to obtain the surface color. To get the texture coordinates of the intersection point use Ray::surface.

Specular Map A specular map is a grayscale image that represents the specularity at each point on the object. White means glossy and black means diffuse. Implement the specularity term you already know from the phong shader and use the specular map to scale the result.
**Alpha Map** An alpha map describes the local opacity of the object. White means opaque and black means transparent. Implement alpha mapping in the MaterialShader. Remember that you only have to propagate those rays, where the object is not fully opaque. Also keep in mind that the reflection map does also propagate rays, so you cannot just change the ray passed to the function, but have to create a copy of it. The color modulation should be a linear interpolation of the current color and the propagated ray based on the local opacity value and the global scaling.

**Normal Map** In order to add additional detail to otherwise boring and flat objects we want to add normal maps. In a normal map each pixel color describes the normal at the corresponding position. Note that you do not have negative colors, instead normal values are mapped to color channels in such a way that each component \([0, 1]\) in color space corresponds to \([-1, 1]\) in normal space. Additionally you will have to transform your normal into tangent space. Don’t worry, most of that is already done for you. The result should finally be linearly interpolated between the original surface normal and the normal from the normal map based on the normalCoefficient.

**Reflection Map** A reflection map is a grayscale image that represents the reflective property of the surface. White means a perfect mirror, whereas black means no reflection. You already know how to implement a mirror shader, and the value in the reflection map is simply a linear interpolation factor between the color of the mirrored ray and the color of the surface. Remember that you have to use the normal map when calculating the reflected ray.

### 7.3 Supersampling (20 + 10 Points)

**a)** Until now, we have used exactly one ray per pixel, with the pixel being a rectangular area \(p = a \times a\) and the ray going through center. However, as you may have already noticed this leads to aliasing artifacts (stair stepping at edges, etc.) for large ray distances. To counteract this effect, we use multiple rays per pixel and calculate the average. Subdivide the pixel into \(n = s \times s\) equally sized regions, all of which are sampled once. The final pixel color is the average over all samples. Take a look at the SimpleRenderer and create your own SuperRenderer class in renderer/superrenderer.cpp, which allows setting \(s\) and which renders a super sampled image.

**b)** Create a scene in which the differences between normal sampling and super sampling becomes very obvious (aliasing artifacts). Render both images for comparison.

![Figure 1](image-url)  
**Figure 1:** Result without and with \(4 \times 4\) uniform super-sampling; for this scene there is very little impact on image quality.

### 7.4 A little help for the Raytracing Challenge

The goal of the Raytracing Challenge is to give you a chance to express your artistic and technical knowledge. Implement some advanced rendering techniques and create a scene that is able to show them off. The
website now contains some ideas for extensions. You should aim to implement techniques that total 100 Points. You are not restricted to the suggestions on the website; these are just to help you estimate the number of points based on the difficulty of the task.

Each group members’ contribution should be stated clearly.

Prepare a short (5 - 6 minutes) presentation about your work. Hand the presentation and source code (link to the repository + commit hash) in at cgg@cg.cs.tu-bs.de till Monday, January 29.

*Check the internet for free models that you can use. For example:*

http://www.turbosquid.com
http://www.blendswap.com
https://3dwarehouse.sketchup.com