Homework 1

Prepare a web page containing answers to the following questions, and email the URL to me by 1 Mar, 2008. Please use the term "homework" in the subject line of your email, and give me the names of all participants. You may work in groups of up to three.

Written items

Prepare an answer to each of these.

1. **An absorbing medium:** assume that the world is filled with an isotropic absorbing medium. A good, simple model of such a medium is obtained by considering a line along which radiance travels. If the radiance along the line is N at x, it will be $N - (\alpha dx)N$ at $x + dx$.

   - Write an expression for the radiance transferred from one surface patch of small area (dA) to another of small area in the presence of this medium.
   - Now *qualitatively* describe the distribution of light in a room filled with this medium for three cases:
     - α is a very small positive number;
     - α is a medium sized positive number;
     - α is a large positive number.

     What the terms "small", "medium-sized" and "large" mean has to do with the different qualitative regimes; give a reasonable estimate for a small, medium-sized and large number referred to 103 Transportation. You can model the room as a cube, and the light as a single small patch in the center of the ceiling. **Hint:** Keep in mind that if α is large and positive, very little light will actually reach the walls of the room directly from the light source.

2. Identify common surfaces that are neither Lambertian nor specular, using the underside of a CD as a working example. There are a variety of important biological examples, which are often blue in colour. Typically, the colour of these surfaces comes from mechanisms that do not have to do with differential reflection of wavelengths (interference and

diffraction are more common). Typically, surfaces that use these mechanisms have deeper hues that surfaces that are coloured by differential reflection, and often the colour is dependent on viewing angle - why?

3. *Volume colour* is a phenomenon associated with translucent materials that are coloured — one attractive example is a glass of wine. The colouring comes from different absorption coefficients at different wavelengths. Explain (1) why a small glass of sufficiently deeply coloured liquid (if you like wine, a good Cahors, or Gigondas might work) looks black (2) why a big glass of lightly coloured liquid (if you like wine, a Beaujolais might work) also looks black. Experimental work is optional.

4. If one looks across a large bay in the daytime, it is often hard to distinguish the mountains on the opposite side; near sunset, they are clearly visible. This phenomenon has to do with scattering of light by air — a large volume of air is actually a source. Explain what is happening. We have modelled air as a vacuum, and asserted that no energy is lost along a straight line in a vacuum. Use your explanation to give an estimate of the kind of scales over which that model is acceptable.

Practical exercises

You must do at least one of these exercises:

1. Sit down with a friend and a packet of coloured papers, and compare the colour names that you use. You will need a large packet of papers — one can very often get collections of coloured swatches for paint, or for the Pantone colour system very cheaply or for free (try a paint shop). The best names to try are basic colour names — the terms red, pink, orange, yellow, green, blue, purple, brown, white, gray and black, which (with a small number of other terms) have remarkable canonical properties that apply widely across different languages [1, 2, 3]. You will find it surprisingly easy to disagree on which colours should be called blue and which green, for example. Now choose a set of at least 15 colour names that you agree with your co-workers. You should:

    - Estimate how reliably a patch can be named, and how this changes from patch to patch, using your naming system. You should compare how different people name the same patch.

- Estimate how reliably individuals can name patches (i.e will you use the same name for a patch on different days? in different lighting conditions?)

You need a decent number of coloured papers to see this variation.

2. Spectra for illuminants and for surfaces are available on the web (for example `http://www-cvrl.ucsd.edu/index.htm`, `http://www.it.lut.fi/research/color/lutcs_database.html`). Fit a finite-dimensional linear model to a set of illuminants and surface reflectances using principal components analysis, render the resulting models, and compare your rendering with an exact rendering. Where do you get the most significant errors? why?

3. Estimate the variations in appearance obtainable by printing a coloured image on a colour inkjet printer using different papers and compare the result. It is particularly informative to (a) ensure that the driver knows what paper the printer will be printing on, and compare the variations in colours (which are ideally imperceptible) and (b) deceive the driver about what paper it is printing on (i.e. print on plain paper and tell the driver it is printing on photographic paper). Can you explain the variations you see? Why is photographic paper glossy? Is this variation the same from image to image? (it is particularly instructive to compare photographs with bar charts) What happens if you use a system for accurate colour reproduction (Macintoshes have a thing called colorsync; there's something of the sort on PC's too)?

4. Give a brief account of the evidence of how good human colour constancy is; what's missing? (don't be surprised if you can find very few papers — there are very few).

5. An area source can be approximated as a grid of point sources. The weakness of this approximation is that the penumbra contains quantization errors, which can be quite offensive to the eye.
   (a) Explain.
   (b) Render this effect for a square source and a single occluder, casting a shadow onto an infinite plane. For a fixed geometry, you should find that as the number of point sources goes up, the quantization error goes down.

(c) This approximation has the unpleasant property that it is possible to produce arbitrarily large quantization errors with any finite grid, by changing the geometry. This is because there are configurations of source and occluder that produce very large penumbrae. Use a square source and a single occluder casting a shadow onto an infinite plane, to explain this effect.

6. Make a world of black objects and another of white objects (paper, glue and spraypaint are useful here) and prepare figures illustrating the effects of interreflections. Can you come up with a criterion that reliably tells, *from an image* which is which? (if you can, you can probably publish it; the problem looks easy, but isn't — use your data to explain why).

Bibliography

[1] B. Berlin and P. Kay. *Basic Color Terms: Their Universality and Evolution*. University of California Press, 1969.

[2] C.L. Hardin and L. Maffi. *Color Categories in thought and lanuage*. Cambridge University Press, 1997.

[3] S.E. Palmer. *Vision Science : Photons to Phenomenology*. MIT Press, 1999.