

Exercises for Advanced Graphics - second part

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1 Cameras and optics

1. You need to choose a lens for a computer vision camera, which will be used for a particular application. Your camera has a sensor size of 6.4×4.8 mm (width \times height) and it will be monitoring an object of the height of 200 mm from the distance of 1 meter. What should be the focal length of the lens so that the object is projected to the full height of the sensor. Derive the formula using the thin lens equation

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}. \quad (1)$$

Note that you can find many lens calculators on-line but some of them may not give the exact result. They often round the result to the nearest focal length of a stock lens.

2 Light and colour

1. A display emits light specified by three primaries with spectral emission functions given by $r(\lambda)$, $g(\lambda)$ and $b(\lambda)$, where λ is the wavelength. The pixel colour is controlled by adjusting three scalar intensity values, R , G and B , each controlling one primary colour. Therefore, the spectrum of emitted light is given by

$$f(\lambda) = R r(\lambda) + G g(\lambda) + B b(\lambda). \quad (2)$$

Given colour matching functions $x(\lambda)$, $y(\lambda)$ and $z(\lambda)$ of the XYZ colour space, derive a color transformation matrix M , converting a column

vector of $[RGB]'$ intensities into a column vector of $[XYZ]'$ trichromatic colour values, so that:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = M \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix}, \quad (3)$$

2. Two printed colour patches result in a metameric match for a standard observer. What can be said about:
 - (a) The CIE XYZ trichromatic values for both patches;
 - (b) Their spectral reflectance;
 - (c) Their perceived colour when seen under different illumination than one producing the metameric match.

3. Digital cameras often have a white balancing option to correct colours in captured images. Why is this option needed? What perceptual phenomenon does the white balance operation compensate for?

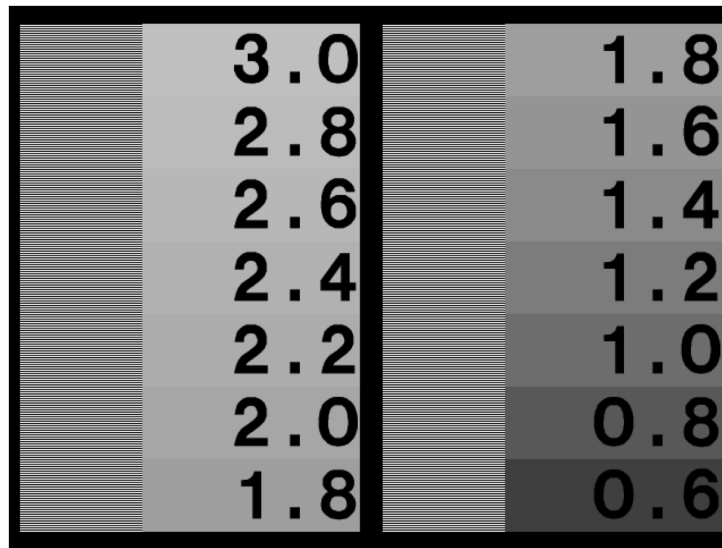


Figure 1: A chart that can be used to visually estimate the *gamma* of a display. Note that you may see aliasing artefacts in the lines unless the figure is enlarged to a sufficiently large resolution.

4. A gamma of a display can be found by matching the brightness of alternating white and black lines with the brightness of a uniform gray-level, such as in the gamma chart shown in the Figure 1. Derive a formula for computing the exponent “gamma” given luma (pixel value) of the gray level that matches brightness of the white and black lines.

Assume that the display black level is 0 and the formula for transforming luma into luminance is $L = V^\gamma$, where L is luminance, V is luma and γ is the “gamma” exponent.

3 Models of early stages of visual perception

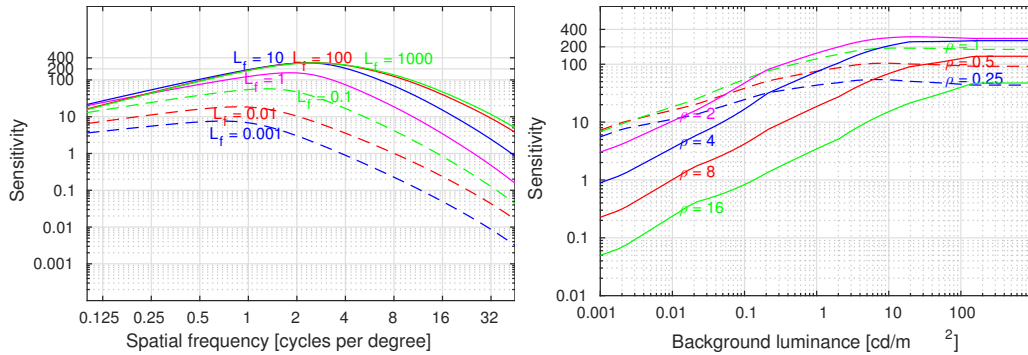


Figure 2: The contrast sensitivity function (CSF), as a function of spatial frequency (left) and background luminance (right).

1. The angular resolution of an image is 32 pixels per visual degree. If you want to draw in that image a sinusoid of the frequency 8 cycles per visual degree, what should be its frequency in cycles per pixel?
2. Given the CSF function in Figure 2, read the data from the plot and answer the questions:
 - a) What spatial frequency is the easiest to detect at a uniform field of 0.01 cd/m^2 ?
 - b) What is the smallest detectable difference in luminance (in cd/m^2) for 8 cycles per visual degree pattern shown at the background of 1 cd/m^2 ?

- c) What is the highest spatial frequency of a just noticeable sinusoidal pattern of a relative contrast ($\Delta L/L$) of 0.01 (1%) at 100 cd/m^2 ?

Note that the values read from the plot do not need to be exact.

4 High dynamic range and post-processing for graphics

The following set of exercises need to be completed either in Matlab or in GNU Octave. To make your work easier, you should use a set of helper functions, which you can download from <https://goo.gl/r3UXRd>. The ZIP file also contains an example HDR image “memorial”, stored both in Radiance *.hdr* format and as Octave *.mat* file. Use `hdrread` function in Matlab and `load` function in Octave to load the image. Use `imview` function to view (LDR) images.

1. Convert an HDR image to the sRGB color space and display it. The image is likely to come out too bright or too dark. What operation do you need to perform before applying the sRGB non-linearity to get a well exposed image?

You can use `lin2srgb` function for the color space conversion.

2. Compute the dynamic range of a display used
 - a) in a dark room with ambient light illumination $E_{amb} = 0 \text{ lux}$.
 - b) in sunlight, under ambient light $E_{amb} = 10\,000 \text{ lux}$

The parameters of the display are as follows: $\gamma = 2.2$, $L_{peak} = 500 \text{ cd/m}^2$, $L_{black} = 0.5 \text{ cd/m}^2$. You can use `gog_fw_display_model` function for this task.

If you want to improve legibility of a display in sunlight, which display parameters do you need to alter?

3. Create reflectance-illumination decomposition TMO that
 - a) uses Gaussian filter
 - b) uses Bilateral filter (function `bilateral_fast`)

Both filters need to operate on an image in the logarithmic domain. You can perform all processing on a gray-scale (luminance only) image, or perform the same operation on each color channel. Employ a simple contrast compression for the tone mapping of the base layer:

$$\log(L'_{base}) = c \cdot \log(L_{base}), \quad (4)$$

where L_{base} is the base (illumination) layer before tone-mapping, and L'_{base} is the layer after tone-mapping.

5 Applications of computational photography

1. Compare the camera noise model with the threshold vs. intensity (t.v.i.) function of the human visual system. Note that you need to compare standard deviation rather than variance of the camera noise to have units comparable to the detection thresholds ΔL of the t.v.i. Are cameras more sensitive than the visual system for low or for high light intensities?
2. Discuss how to generate from a light field a 2D image that is sharp at every pixel (has very shallow depth-of-field).