

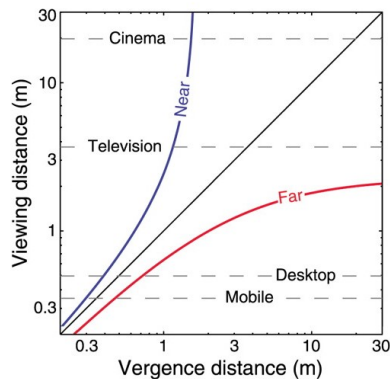
COMPUTER SCIENCE TRIPOS Part II – 2020/2021 – Paper 10

1 Advanced Graphics and Image Processing (rkm38)

Answer ALL questions below.

Stereo rendering

- (a) The data from Shibata et al. [JoV 2011] (shown below) indicates that the comfort of stereo-viewing is affected by the viewing distance.



- (i) What is the main cause of discomfort caused by stereo-displays?

[4 marks]

Answer: The discomfort is believed to be caused by the conflict between two ocular depth cues: vergence and accommodation. The vergence causes our eye to rotate to fuse objects that can be shown in front or behind the screen, while accommodation makes the lens in the eye always focus on the screen plane. The conflicting feedback from both mechanisms is believed to be the cause of discomfort.

- (ii) How can the discomfort be prevented when rendering in stereo on a given display device.

[4 marks]

Answer: The discomfort is often avoided by compressing the range of disparities or depth in rendered images so that they lie within the zone of viewing comfort, near the screen plane. This is conceptually similar to tone mapping, but instead of luminance range, we are compressing the range of depths.

- (iii) If you are to show the same 3D content on a small and a large 3D display, seen from the same distance, is the discomfort going to be larger for one of the displays? Justify your answer.

[7 marks]

Answer: The zone of stereo-comfort depends on the distance between the viewer and the display. The closer the viewer is to the display, the smaller is the comfort zone given in meters. This poses a problem for large stereo-displays seen from short distances. This is because the same content that is shown on a larger display also spans the larger range of depths, which can exceed the comfort zone.

Colour

- (b) (i) Two colours shown on two different displays are metamers. The first

colour on the first display has the colour value $C_{PQ:2020}$ represented in the PQ-encoded rec.2020 RGB colour space. $C_{PQ:2020}$ is a 3×1 column vector. Write the formula for the value of the colour on the second display in the gamma-encoded rec.709 colour space using the information below.

You are given colour transformation matrices $M_{2020 \rightarrow XYZ}$ and $M_{709 \rightarrow XYZ}$, the function for transforming from linear to PQ-encoded values $e_{PQ}(\cdot)$ and the function for transforming from the PQ-encoded values to linear values $d_{PQ}(\cdot)$. Use the regular gamma of 2.2 for the second display. All those functions and matrices are sufficient to find the answer but not all of them are required. [10 marks]

Answer:

The colour value on the second display in the gamma-encoded rec.709 colour space is:

$$C_{G:709} = (M_{709 \rightarrow XYZ}^{-1} M_{2020 \rightarrow XYZ} d_{PQ}(C_{PQ:2020}))^{1/2.2} \quad (1)$$

- (ii) For the same configuration as in the question above, write the formula for the gamma-encoded rec.709 pixel colour on the second display that has half of the luminance of the colour shown on the first display but the same chromaticity (the same CIE x and y chromatic values). [10 marks]

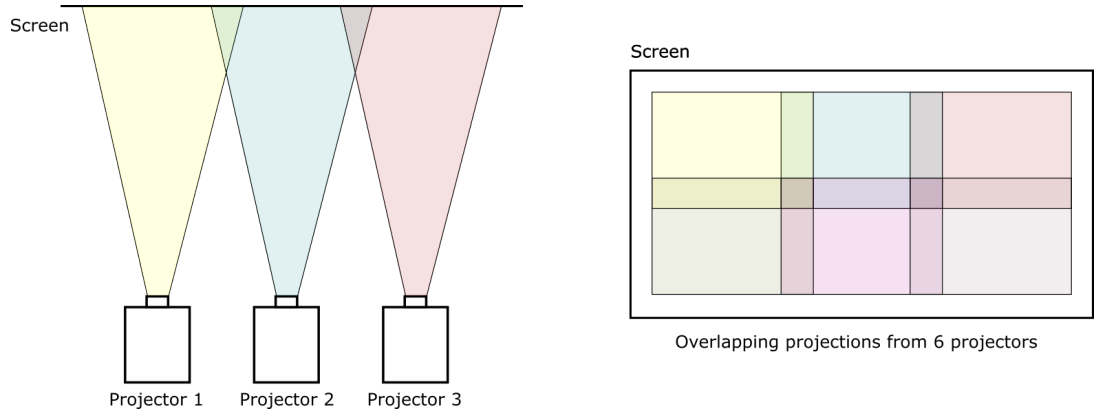
Answer:

Multiplying linear trichromatic colour values by a constant (0.5) will reduce luminance but will not change the chromatic coordinates.

$$C_{G:709} = (0.5 M_{709 \rightarrow XYZ}^{-1} M_{2020 \rightarrow XYZ} d_{PQ}(C_{PQ:2020}))^{1/2.2} \quad (2)$$

Colour

- (c) You are constructing a large-format projection display, where the image is formed by a tiled grid of individual projectors. To ensure a smooth transition between images formed by neighbouring projectors, there is a small overlap in projected images as shown in the figure below. Let us assume that you are projecting on a white screen and that all projectors are perfectly calibrated and driven by gamma-encoded rec.709 RGB values (with gamma 2.2). How do you need to modify the gamma-encoded pixel values for the parts of the image where the projections overlap. Write down the formula for the cases in which 2 or 4 projectors overlap. [15 marks]



Answer:

The colour mixture needs to be modelled in the linear color space. Therefore, if multiple projectors are displaying gamma-encoded colours C'_1 and C'_2 , ..., at a certain image location, the resulting colour in the linear space is:

$$C = C'^{2.2} = \sum_k C_k'^{2.2} \quad (3)$$

where the sum is over the number of overlapping projectors and the primed values denote gamma-encoding. For the overlapping pixels, we can drive all the projectors with the same pixel value C'_p :

$$C = C'^{2.2} = \sum_k C_p'^{2.2} = k C_p'^{2.2} \quad (4)$$

If we want to show the gamma-encoded pixel value C' in the overlapping region, we can set the pixel values on all the projectors to:

$$C'_p = \left(\frac{1}{k}\right)^{\frac{1}{2.2}} C' \quad (5)$$

where k is the number of overlapping projectors.
