COMPUTER SCIENCE TRIPOS Part II – 2019/2020 – Paper 10

1 Advanced Graphics and Image Processing (rkm38)

Answer ALL questions below.

Perception and tone mapping

(*a*) When working with high dynamic range (HDR) images, we often operate on logarithms of pixel values.

(*i*) Explain the main advantage of operating on logarithmic values when performing image processing on HDR images. [4 marks]

(*ii*) Show how the logarithmic transform can be derived from Weber's law. [7 marks]

(*iii*) How can you change the brightness of an HDR image represented by logarithmic values (without converting the image to linear values)? Write down the formula for brightness change in which $l(x, y, c)$ represents log_{10} of red ($c = 1$), green ($c = 2$) or blue ($c = 3$) linear colour values at location (x, y). [7 marks]

(*iv*) How can you change the contrast of an HDR image represented by logarithmic values (without converting the image to linear values)? Write down the formula for contrast change using the same notation as in the previous part. Explain how to choose the parameter to compress the contrast. [7 marks]

Answer: (i) The logarithms of linear colour values are more perceptually uniform than linear values. Because many existing image processing algorithms assume perceptual uniformity of the colour space, HDR pixel values must be converted to the logarithms of those before performing such image processing operations;
(ii) We want our perceptually encoded values to change by 1 unit when the luminance changes by the detection threshold. This means that the derivative of our encoding function is: $\frac{\partial R}{\partial L} = \frac{1}{\Delta L}$, where ΔL is the detection threshold. From Weber's law we get: $\Delta L = k\,L$. By integrating our unknown function R and assuming tha the detection thresholds are predicted by the Weber law, we get: $R = \frac{1}{k}\ln(L) + C$, where C is an arbitrary constant.
(iii) The brightness can be changed: $l_{new}(x, y, c) = l(x, y, c) + b$, where b is the logarithm of the brightness adjustment factor;
(iv) The contrast can be changed: $l_{new}(x, y, c) = c\cdot(l(x, y, c) - \log_{10}(L_{white})) + \log_{10}(L_{white})$, where c is the contrast change factor. c is less than 1 for contrast compression;

Light fields

(*b*) Planar light fields are used to represent light rays passing through a rectangular portion of a plane.

(*i*) A light field is typically represented as a 4-dimensional function. What are the dimensions? What are the two common ways of parametrising the light field? [4 marks]

(*ii*) Explain what kind of artifacts can be seen when rendering from a sparsely sampled light field (with a small number of views). [4 marks]

(*iii*) Under what assumptions can a light field represent the plenoptic function? [4 marks]

(*iv*) When rendering a light field, we typically project rays on a plane. What would the advantage be if we had an approximate geometry of the scene and could project a light field on it. [6 marks]

(*v*) Light fields can be captured with an array of cameras or using a camera with a micro-lens array. Describe the advantages and disadvantages of both approaches. [7 marks]

Answer: (i) The first two dimensions represent the position on a plane and the second two dimensions represent the angle of the ray. The angle can be represented as two angles (or a tangent of those), or as a position on another parallel plane.

(ii) When a light field is sparse and when rendering with a large aperture, the defocus blur may show ghosting instead of a typical camera blur. Ghosting will be also visible when rendering with a small aperture and intermediate views are interpolated.

(iii) The radiance must not change along the ray direction until it intersects an object. This happens when the light travels through homogenous media and there is no scattering of the light.

(iv) If we can project on a proxy geometry, we can obtain a result with a large depth of focus even given a small number of captured views. This is because the rays from multiple views would converge at approximately the correct distance, forming a sharp image.

(v) Camera array offers a large baseline and therefore a larger light field can be captured. It also offers a high resolution of each view. But a large baseline makes it difficult to render intermediate views without reconstructing depth. A camera with a lens-let array offers very small baseline and low effective spatial resolution. But a small baseline allows to produce better results of refocusing and makes it easier to interpolate the views. Lens-ley array camera has also a smaller form factor.
