Introduction to Visual Computing

*Duration: 3h. Lecture notes are authorized. Answers should be **justified** briefly.*

1 Color modifications (4 points)

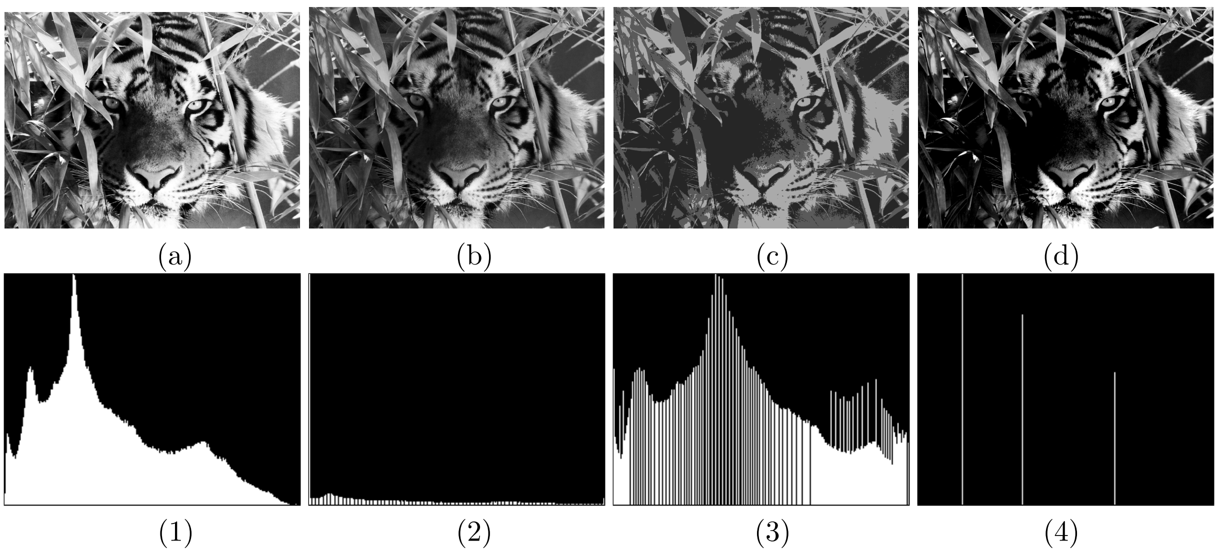

Figure 1: Histograms: (1) Original image; (2) Linear stretch; (3) Equalization; (4) Color quantization.

1. The figure (4) below is showing 4 images of a tiger that have been modified according to various transformations: (1) no modification; (2) histogram linear stretching to reduce the color range; (3) histogram equalization; (4) Color quantization to reduce the number of colors. The associated image histograms after modifications are shown in the figure (second row). However, the order of the corresponding image (a)-(d) in the first row has been modified. Can you associate the images (a), (b), (c) and (d) with their histogram (1),(2),(3) or (4) ? Please justify your answer.
2. Why is the histogram (3) no flat and not continuous ?
3. How could we obtain histogram (4) in the figure ?

2 Image Formation (6 points)

We are interested by the deformation of a circle in a perspective projection. As shown in Figure 2, assume that a circle of radius R, in a plane parallel to the image plane, is projected in the image plane.

1. Given the focal distance f show that its projection is still a circle and give the radius r of the projected circle (hint: check distances in a planar section of the projection as in the lecture notes).

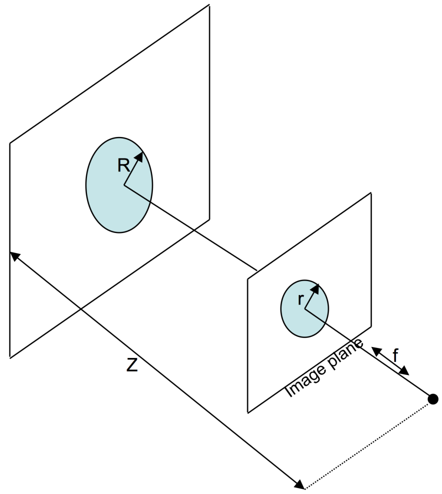

Figure 2: Projection of a circle.

2. If the focal distance focal goes to infinity what becomes then the radius of the projected circle ?
3. If we move the circle of radius R in the plane parallel to the image plane do we still see a circle with which radius ?
4. In which situation the circle projection would not be a circle ?

3 Histogram Matching (5 points)

Histogram matching is an image transformation where the histogram of an input image is transformed so that it fits the histogram of a reference image. In its simplest form, the reference image is assumed to have uniform distribution of intensities and the transformation is then a histogram equalization. As for the histogram equalization, the cumulative distributions of intensities, $F_i(I)$ and $F_r(I)$, are considered by the histogram matching algorithm which tries to equal them (illustrated by the arrow in figure 3).

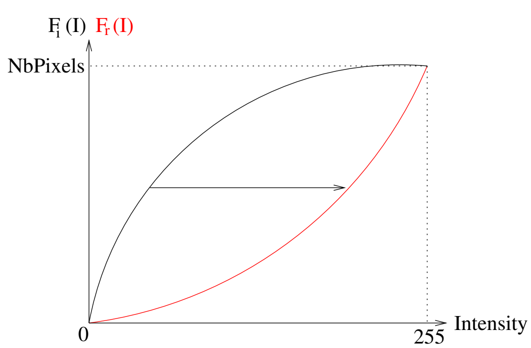

Figure 3: Histogram matching, F_i is the cumulative distribution function of intensities I for the input image and F_r (in red) the cumulative distribution of the reference image.

1. Explain shortly the purpose of histogram equalization and the associated algorithm.

2. Derive an equivalent algorithm for histogram matching, i.e. for an input intensity I_i what is the transformed intensity I_r (the 2 images have the same number of pixels):
   (a) Assume first that the inverse function F_r^{-1} is given.
   (b) Complete the algorithm with a solution to estimate $F_r^{-1}(n)$
3. How could we extend this algorithm to transform color images instead of intensity images ?

4 Color Spaces (5 points)

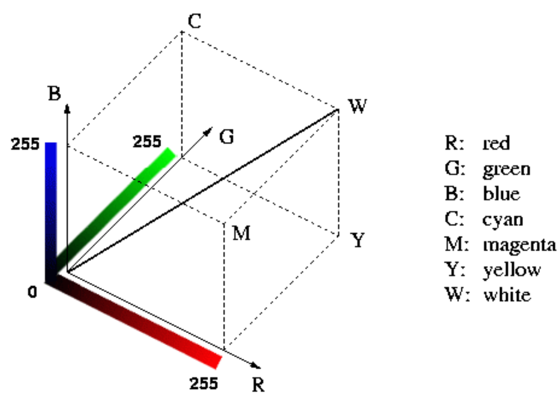

Figure 4: The RGB space

1. In Figure 2, what represent points on the diagonal OW of the cube RGB ?
2. A screen emits lights and uses in general the RGB space for that purpose. On the other hand, printers use a different principle. Inks absorb colors and the observed color on a printed document is the color component that is reflected by the ink and not absorbed. For instance, we can observe the cyan color when the red component of the white light is being absorbed, thus only the cyan component is reflected. The space CMY (for Cyan Magenta and Yellow) is well adapted to printers since it is complementary to the RGB space. Hence, the black color can be obtained by adding cyan, magenta and yellow with equal quantities.
   (a) The RGB space is assumed to be additive and the CMY space to be subtractive, why such terminology ?
   (b) How can we obtain the red color in the CMY space ?
3. To convert an RGB image to a greyscale image on a screen, the correspondence $N = 0.3R + 0.59G + 0.11B$, where N is the greyscale, is used. In your opinion, why color components in the above formula are differently weighted ? Another solution consists in projecting any color point onto the neutral axis (the diagonal OW in Figure 2) and to consider for N the coordinates' value of the corresponding point on this axis (the coordinates are then all equal). Give the corresponding formula for N given the R, G and B components (looking in 2D first, e.g. R and G only, might help).