Image representation
- Digital image representation
- Sampling
- Quantization
- Sub-sampling
- Pixel interpolation

Digital image representation
Distinguishing images: audio spectrograms, 2D function (time, frequency) —> not image
x, y —> spatial coordinates (same units)
exceptionL white-noise time series f(t) —> chop up into 2D table (is a image)

Sampling and Quantization

Sampling:
Nyquist theorem —> The sampling rate should be at least twice the maximum frequency responses

Cameras: bayer filter

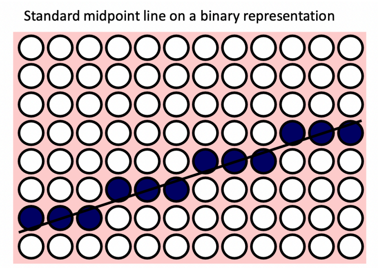
Eyes: Retinal cone mosaic

Scanline: convert the continuous 2D signal in a digital image by sampling per scanline

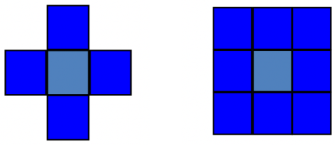
Image resolution
Low resolution: image —> blocky (aliasing)

Image sampling methods
- Uniform: same sampling frequency everywhere
- Adaptive: higher sampling frequency in areas with greater detail

Sampling effects: double resolution does not solve the problem, can be alleviate using more grey-level



Relationship between pixels
- 4-neighborhood: each neighbor shares a single edge with the pixel
- 8-neighborhood: each neighbor shares an edge or a corner with the pixel



Quantization
Intensity resolution: more bits —> better intensity resolution, but more storage space (trade-off)
Fewer bit: a wider range of intensities mapped into a single grey level

Dithering and half-toning
Problem: coarse quantization —> false contours
作用: provide more apparent colors (large regions of high-frequency color changes —> blend into uniform color)

Dithering and half toning
Dithering: adding small amount of random noise (regular, correlated random)
- Dithering decreases the SNR yet improves the perceived quality of the output

Juxtaposing pixels of two colors —> third color is present

Half toning: uses dots of various size to represent intensity

Quantization
- Uniform
- Logarithmic: higher intensity resolution in darker areas

(Human eye is logarithmic)

Gamma transformation

$f = f^{\gamma}$, $\gamma < 1$ emphasize dark region, $\gamma > 1$ emphasize bright region.

Non-uniform quantization
Suitable: when probability density of a signal is not uniform
- Allows to take into account the characteristic of HVS

LUT (Look-up table): (e.g. false color image)

Digital image quality factors
- Spatial resolution: spatial sampling
- Intensity resolution: the number of quantization levels allocated for each pixel

Sub-sampling
- Zooming: over sampling
- Shrinking: under sampling

Sub-sampled images are of low quality: it is equivalent to reducing the spatial sampling rate into a certain factors, which will reduce the spatial resolution. It will leads to blocky issues.

Pixel Interpolation
- Forward mapping: map the input grid to non-integer located positions in output image (problem: redundant conversions)
- Backward interpolation: estimate integer output grid —> inverse map integer output grid (only converts data required for generating output pixels)

Nearest neighbor interpolation (NN)
NN interpolation: pixels are generated by copying the nearest available pixel
Bilinear interpolation:
- Interpolate linear on each horizontal edge
- Interpolate linear in the vertical direction using obtained results

Practice

c) This question is about **image sampling and quantization**.

[5 marks]

i) What is the sampling rate for a lossless digitization (Nyquist theorem)? If the effective sampling rate is below Nyquist sampling rate, what problem appears due to this?

(3 marks)

ii) What problem could be caused by using **too few** quantization levels? What problem could be caused by using **too many** quantization levels?

(2 marks)

(1) The sampling rate for a lossless digitization is at least twice the maximum frequency of the signal. The aliasing will happen, the image will appear blocky.
(2) Too few quantization levels cause discontinuity in the image, too large quantization will increase the space for storing the image and will increase the transmission latency/cost/bandwidth.

b) This question is about **image representation**.

[9 marks]

i) Depending on the neighbourhood definition of a pixel, explain two ways to define the neighbourhoods of a pixel P located at (x, y). Also, specify the corresponding neighbours' coordinates.

(4 marks)

ii) How would you generate a new pixel by using the **Nearest-Neighbour (NN) interpolation** algorithm in image processing? When would you use the NN interpolation algorithm, and what problem do you think it can cause?

(3 marks)

iii) What do you mean by **non-uniform** quantization, and why is it useful for image encoding?

(2 marks)

(1) 4-neighborhood: the pixel only shares the single edge with its neighbors, 8-neighborhood: the pixel shares the corner or the edge with its neighbors. For 4-neighborhood: (x, y-1), (x-1, y), (x+1, y), (x, y+1). For 8-neighborhood: (x-1, y-1), (x, y-1), (x, y-1), (x-1, y), (x+1, y), (x-1, y+1), (x, y+1), (x+1, y+1)
(2) Make the value of the new pixel equals to the nearest available pixel that has a value. The NN interpolation can be used when minimum computation load is required. The NN interpolation will lead to different extent of blurring and blocky issues, since the pixels neighboring each other has the same value and will be cluttered as blocks
(3) Non-uniform quantization means using different size of quantization level when quantizing. Since the image usually distributed not uniformly, it is better to assign more intensity resolution to pixels that appear more frequent