Computer Graphics

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April 6, 2021

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Raster Images

Raster and Vector Images

Raster Images

- A raster image is a 2D array that stores the pixel value for each pixel
- Device independent representation of visual content
- Usually not displayed in their native resolution
- Fotos and computer generated images

Vector Graphics

- Description of how to compose an image using curves, simple shapes and shades
- Device and resolution independent
- Need to be rasterized prior to displaying
- Diagramms, fonts, and technical drawings

Especially in image processing a resolution and device independent language to communicate operations on images is required.

Definition

An image is a function

$$I : D \rightarrow V, \tag{1}$$

where $D \subseteq \mathbb{R}^2$ is the image domain and V is the set of possible pixel values (color). For example

- Grayscale: $V = \mathbb{R}^+$
- Color: $V = (\mathbb{R}^+)^3$

Raster images are a sampled representation of such an abstract image, where the pixel value is the local average of the color of I.

Definition
The rectangular domain of an image with height n_y and width n_x is given by
$$R = [-0.5, n_x - 0.5] \times [-0.5, n_y - 0.5]. \qquad (2)$$

Pixels are centered at positions (i, j), $i = 0, 1, \ldots, n_x - 1$ and $j = 0, 1, \ldots, n_y - 1$.

Range

- Observable intensities do not have a natural upper bound
- The intensities of displays are bound
- By convention all possible pixel values are chosen to lie in $[0, 1]$ for each color channel to mimic the restriction of our displays
- This restriction might lead to clipping

Encoding

- Reduction of quantization artifacts and banding requires a large number of bits to store pixel values
- Memory and bandwidth limitations require a low bit number
- Application specific compromise is required

Pixel Value Encoding

Typical pixel formats are

- 1-bit grayscale (scan of text)
- 8-bit fixed range RGB color (24 bits per pixel) (consumer photographs)
- 8-10-bit fixed range RGB color (computer displays)
- 12-14-bit fixed range RGB color (raw camera images)
- 16-bit fixed range RGB color (professional photography)
- 16-bit fixed range grayscale (medical images)
- 16-bit floating point numbers (real time rendering)
- 32-bit floating point numbers (software rendering)

Fixed Range Encoding
In a fixed range encoding the integer values (e.g. $0, 1, \ldots, 255$) are interpreted as equidistantly spaced values in the interval $[0, 1]$ $(0, 1/255, \ldots, 255/255)$. Standard encoding of the pixel values of an image.

Floating Point numbers
Floating point numbers are usually used during image generation prior to mapping the pixel values into the interval $[0, 1]$.

If we send pixel values 0.1, 0.2 and 0.3 straight to our monitor we will not get 0.1, 0.2 and 0.3 of the maximum intensity I_{max}, since most monitors are non-linear devices. To approximate these non-linearities one can use

$$I = I_{max}a^{\gamma}, \tag{3}$$

where I is the displayed intensity, a is the pixel value and γ is a device specific constant.

Example
Consider the values of an 8-bit grayscale image. The intensities are then given by $I_{max}(0/255)^{\gamma}$, $I_{max}(1/255)^{\gamma}$, ..., $I_{max}(255/255)^{\gamma}$.

Raster images can be stored in a vast number of formats. These formats can be categorized roughly into the following categories:

- Uncompressed formats (.bmp)
- Lossless compressed formats (.png)
- Lossy formats (.jpg)