What’s color quantization?

- A process uses a limited number of colors to represent an image.
- The set of limited color is called a color palette.

Applications:

- displaying images with low-end display units
- playing video clips with low-end display units
- compressing images & video clips

Common research topics:

- How to make the output appear as the original by reducing/eliminating artifacts such as false contour, color-shift etc.
- How to do it quickly and to avoid flickering when dealing with video sequences.

- How to reorder the palette such that the image can be compressed more efficiently when the image is stored in some specific formats.
Color quantization methods

- Basically, there are 2 issues in color quantization:
  - Define a palette based on the colors of the image
  - For each pixel, replace its color with a color in the palette (generally by nearest-neighbor search)

The nearest-neighbor rule is generally used in the 2nd part.

A CQ algorithm generally implies an algorithm for determining a palette from a given set of image colors.

2 categories of CQ methods:
- Fixed quantization
  - A predefined set of display colors and a fixed mapping from image colors to display colors are used.
  - e.g. uniform quantization
  - How? Advantages? Disadvantages?
  - Potential artifacts: color-shift, false contour etc.

- Adaptive quantization
  - An image-dependent set of display colors and a corresponding mapping from image colors to display colors are used.
  - e.g. Popularity algorithm, Median-Cut algorithm, LBG algorithm
  - How? Advantages? Disadvantages?
  - Better quality but much more time-consuming for getting the palette

A block diagram of a simple vector quantizer is shown.
Popularity algorithm

Idea:
- The palette can be constructed by finding the densest regions of the image color distribution.

Approach:
- Get the image color distribution of the image.
- Select the n colors of the image with the highest frequencies and uses these colors for the palette.
- Performs poorly on images with a wide range of colors.

Median-Cut algorithm

Idea:
- Each of the colors in the palette should represent an approximately equal number of pixels in the original image.

Approach:
- RGB space is iteratively divided into rectangular boxes until sufficient boxes are obtained.
- The centroids of the boxes form the palette.

Details of each step:
- Divide the box containing the largest number of pixels into 2, each containing an equal number of pixels.
- The partition plane is perpendicular to the coordinate axis with the largest variance of the image pixels in the box, passes through the median point of the color distribution projected along this axis.

LBG algorithm

Idea:
- Try to optimize the palette in MSE sense.

Approach:
- RGB space is iteratively divided into clusters until sufficient clusters are obtained.
- The centroids of the clusters form the palette.
**LBG algorithm**

- Treat the RGB space as a 3D vector space and each pixel is a vector in the space (c.w. Vector quantization)
- Very time-consuming
- Generally used to optimize the palette after using other fast algorithms

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**LBG algorithm**

- An initial palette is required.
- Procedures:
  1. Color-quantize all pixels with the palette using the nearest neighbor rule.
  2. If the overall distortion is low enough, quit. Otherwise, for each palette color,
     - determine the subset of pixels that were mapped into it
     - replace it by another color that reduces the overall distortion for that subset of pixels & go to step 1

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**Example of vector quantization. The number of scalers in the vector is 2, and the number of reconstruction levels is 9.**

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**Palette generation (1)**

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**Palette generation (2)**

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**Palette generation (3)**
Which CQ technique is better?

- **Subjective criteria**
  - Any color-shift? False contour? Others?
  - Capable of providing sufficient details in a gradually changed color region?
- **Objective criteria**
  - Mean square error etc.

**Demonstration**
- Micro-browser for Palm Organizer
- Palm-based remote monitoring system
Appendix

**Median-Cut algorithm**

- Class 0 is of max. var.
- Divide cluster 0 further

- Col. 3 is of max. var.
- Sort according to col. 3
- Find the median of col. 3

**Fixed quantization**

**Popularity algorithm**

**Median-Cut algorithm**