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K - Means Documentation & Log

- **Algorithm Used:** K-Means
- **Picture Used:** Tiger Picture
- **Framework:** CRISP-DM
- **Original Notebook**: Notebook

1. Business Understanding

- **Objective**:
  Using K-Means clustering, for compressing a tiger image (from 48.77 KB initial file size), reducing its file size while maintaining good visual quality.
- **Reason for Choosing K-Means**:
  - K-Means clustering **decreases color complexity** by providing clusters of similar colors.
  - This method can yield a **reduced range of color** so that it can be easier to compress.

2. Data Understanding

- **Data Source**:
  - The input image is a **JPEG** file (**tiger.jpg**) with dimensions fit for demonstration (not overly large).
  - JPEG is already a **lossy** format, therefore repeatedly saving as JPEG sometimes increase file size unless I am careful in manage parameters (quality, resolution, etc.).
- **Initial Observations**:
  - The original file size is **48.77 KB**.
  - The image has **continuous transitions of colours** and details making it hard for color quantization to compress them properly without seeing visual artifacts.

3. Data Preparation

1. **Read and Normalize Image**
   - I read the image using **skimage.io.imread** and converted pixel values from **[0, 255]** to **[0, 1].**
   - This is done to make sure all operations that happens afterwards (distance calculations in K-Means) goes well.
2. **Reshaping**
   - I converted the 3D image array **(height, width, 3)** into a 2D array **(height*width, 3)** to treat each pixel as a data point in the K-Means algorithm.

4. Modeling

4.1 Initial K-Means Approach

- **Original Random Initialization**:
    - Implemented **K-Means++** initialization in place of the default random centroid selection to enhance convergence and get better cluster centers.
- **Elbow Method (Sampling)**:
    - Proposed a **sampling approach** for the elbow method (use of only a portion of the pixels) to find a good range of **K** values without running K-Means multiple times on the whole image.
    - This generated **less runtime** with still a **good estimation** for the appropriate number of clusters.
- **Choosing K**:
    - Based on the elbow plot, I selected **K=8** as a compromise to preserve color fidelity while allowing for potential compression.

4.2 An Enhanced Method for More Compression

Having confirmed K=8 using the elbow method, I **expanded** upon the compression method with the following:

1. **Downsampling (75%)**
    - I resized the image to 75% of the original dimensions, thus reducing the total number of pixels.
    - This basically resizes a larger resolution down to a smaller one **compressing file size** while not compromising too much detail, particularly if the initial resolution was high.
2. **K-Means Color Quantization**
    - I then applied **K-Means** (with K=8) on the **downsampled** data to **limit the color palette even more**.
3. **Gaussian Blur**
    - A gentle blur will smooth out the **sharp edges** created from K-Means, making the image more flexible to **JPEG compression**.
4. **JPEG Quality (60)**
    - Finally, I saved the image with a **decent JPEG quality** of 60. By this **visual clarity** and **file size can be** balanced.

5. Evaluation

- **Visual Inspection**:
    1. The final compressed image preserves the appearance and color balance of the tiger.
    2. Some **banding** or minor artifacts may be visible upon close inspection, but overall fidelity is good.
- **File Size Comparison**:
    1. **Original**: 48.77 KB

2. **Compressed**: 19.38 KB
3. I achieved a **significant reduction** in size (more than 50% smaller) while maintaining **good** image clarity.

- **Analysis of Changes**:
  1. **Downsampling** reduced the resolution, with each pixel cluster represent a larger area.
  2. The color space was simplified by using **K=8** color clusters.
  3. **Gaussian Blur** diminished sharp edges and helped JPEG compression.
  4. **JPEG Quality** at 60 bypassed excessive artifacts while reducing the file size.

6. Overview of Changes & Practical Impact

1. **K-Means++ Initialization**
   - **From**: Random centroid selection.
   - **To**: K-Means++ for improved placement of initial cluster.
   - **Impact**: Faster convergence and usually reduced final distortion in the compressed image.
2. **Elbow Method with Sampling**
   - **Added**: A sampling strategy for fast identification of good range of K.
   - **Impact**: Significant decrease in computation time without losing out much accuracy in finding the best K value.
3. **Downsampling & Blur**
   - **From**: Full-resolution K-Means.
   - **To**: 75% resolution + a light Gaussian blur.
   - **Effect**: Fewer pixel count but smoother transitions thus creating a more compressible image.
4. **JPEG Quality**
   - **Chosen**: Quality=60.
   - **Impact**: Finally, achieved a **size of 19.38 KB** (Lowered from 48.77 KB) while retaining decent level of clarity.