Image Compression Using SOFM

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Why Image Compression?

- Application of data compression on digital images.
- Computer images are extremely data intensive and hence require large amounts of memory for storage.
  - E.g. size of 1 fingerprint picture = 10 MB

    FBI has to store hundreds of millions of pictures.
- Objective is to reduce redundancy of the image data
- Image compression can be lossy or lossless.
- Fields of Need:
  - Uploading your pictures on some Social Online Community like Orkut.
  - Medical images' compression – Requires lossless compression.

Techniques

- Lossy Compression
  - Transform Coding: Fourier Transform such as DCT or Wavelet.
  - Fractal Compression: Compression using Fractals.
    - Fractal: A shape that is recursively constructed or self-similar.

- Lossless Compression
  - Entropy Coding: Assigns codes to different colors such that

    Code length of color $\propto$ - log (P (color))

  - Run-length Encoding: Runs of data stored as data value & count.

E.g.

WWWWWWWWBWWWWWWWWBBBWWWWWWWWWWWWWBWWWWWWW

represented as : 8W1B8W3B14W1B7W

42 characters represented in 15 characters.

Evaluation of Image Compression techniques

- Two classes: Quantitative and Qualitative
- Quantitative:
  - Bit-Ratio: Measured as the average number of bits per pixel for the original image divided by the same for encoded image.
- Qualitative:
  - Time Complexity of the algorithm.
  - Distortion: Measured by Mean Square Error (MSE).
  - PSNR: Peak Signal/Noise Ratio
    - Measure of quality of reconstruction of image.
    - Proportional to negative of logarithm of MSE.

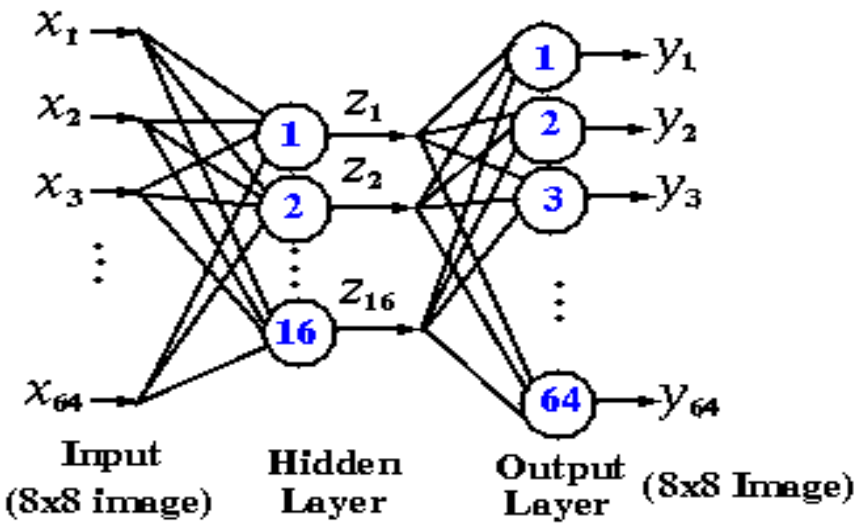
Perception of Visual Information

- “A picture is worth a thousand words.”
  - This axiom expresses the essential difference between our ability to perceive linguistic information and visual information.
- Visual information is perceived by massively parallel interconnected networks.
- So, a serial processing system is inferior to parallel processing system in case of Image Processing.
- Neural Networks - computational units, operates in parallel and highly interconnected fashion.
- And thus an intuition, that neural networks are well suited for image processing due to their such architecture.

Some NN techniques

Using Back Propagation

- Input layer : Original image
- Hidden layer : Quantized image
- Output layer : De-quantized image



Some NN techniques

Using Hebbian Learning

- Addresses the issue how the principal components can be directly extracted from input image.
- One input layer and one output layer.
- Hebbian learning rule comes from Hebb's postulation.
- Hebb's Postulation: if two neurons were very active at the same time, the strength of the connection between the two neurons will grow.
- This method is a good alteration of PCA (Principal Component Analysis).

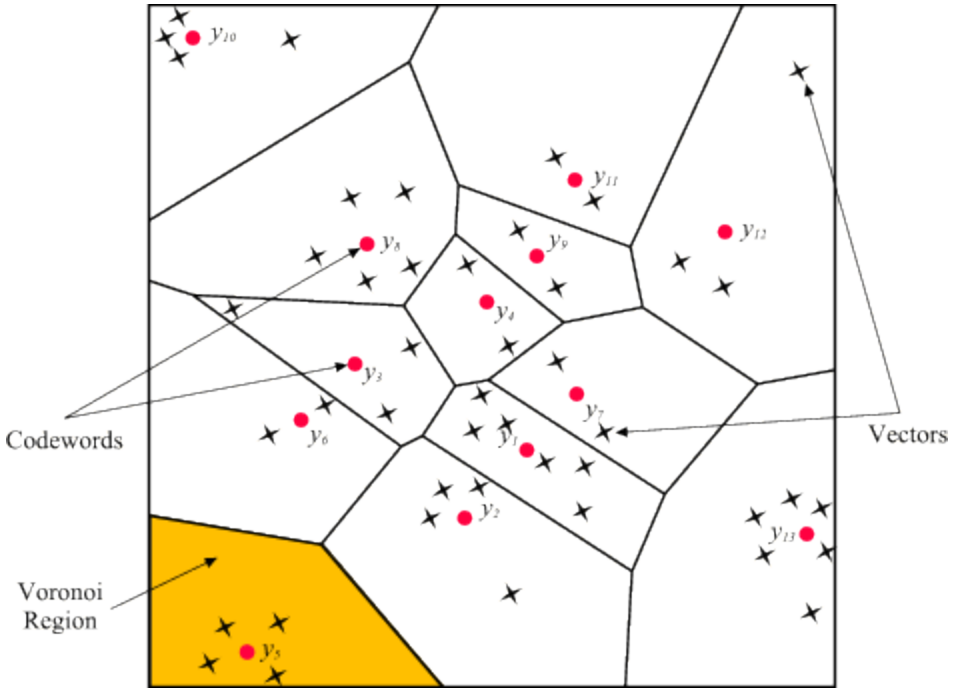
Vector Quantization

- A vector quantizer maps k-dimensional vectors in the vector space R^k into a finite set of vectors $Y = \{y_i: i = 1, 2, ..., N\}$.
- Each vector is y_i called a code vector or a codeword.
- Set of all the codewords is called a codebook.
- Associated with each codeword, y_i, is a nearest neighbor region called Voronoi region, and it is defined by:

$$V_i = \left\{ x \in R^k : \|x - y_i\| \leq \|x - y_j\|, \text{for all } j \neq i \right\}$$

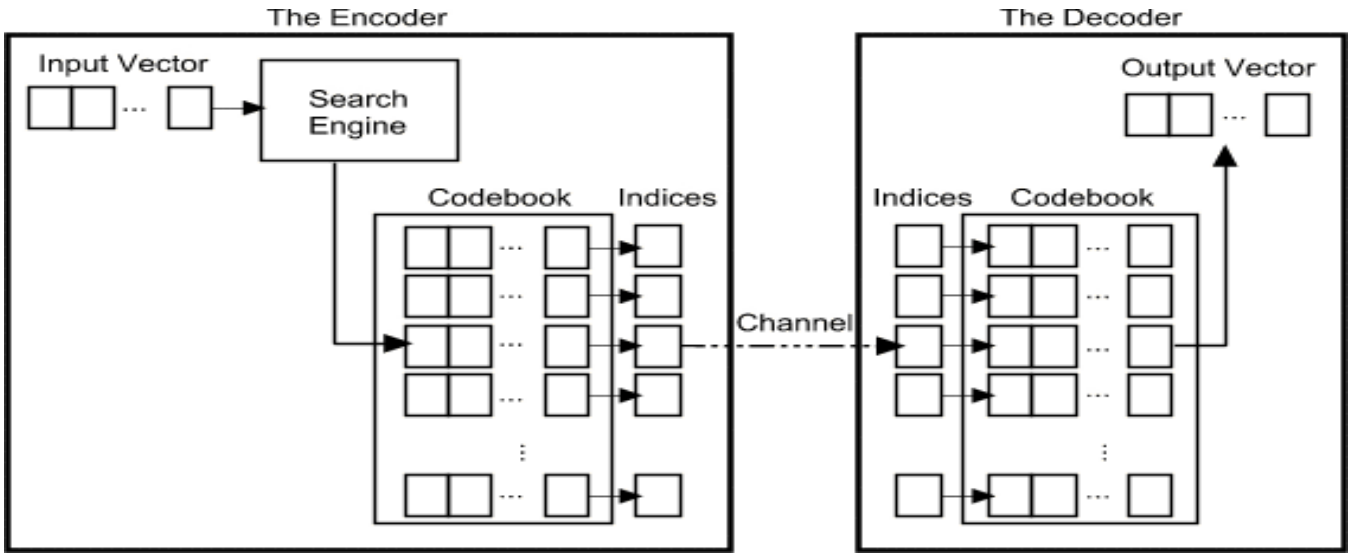
Vector Quantization (Example)

- Input vectors : x
- Codewords : red circles
- Voronoi regions are separated with boundary lines.



How does VQ work in Image Compression?

- 2 Operations : Encoder and Decoder
- Encoder takes an input vector and outputs the index of the codeword that offer lowest distortion.
- This index is sent to decoder through a channel.
- Decoder replaces index with associated codeword.



Global Compression Scheme

- For high compression ratio lossy compression methods are required.
- Relative and Huffman coding further compresses image with no loss.
- Quantization process is carried out using 1-D Self organizing feature map.

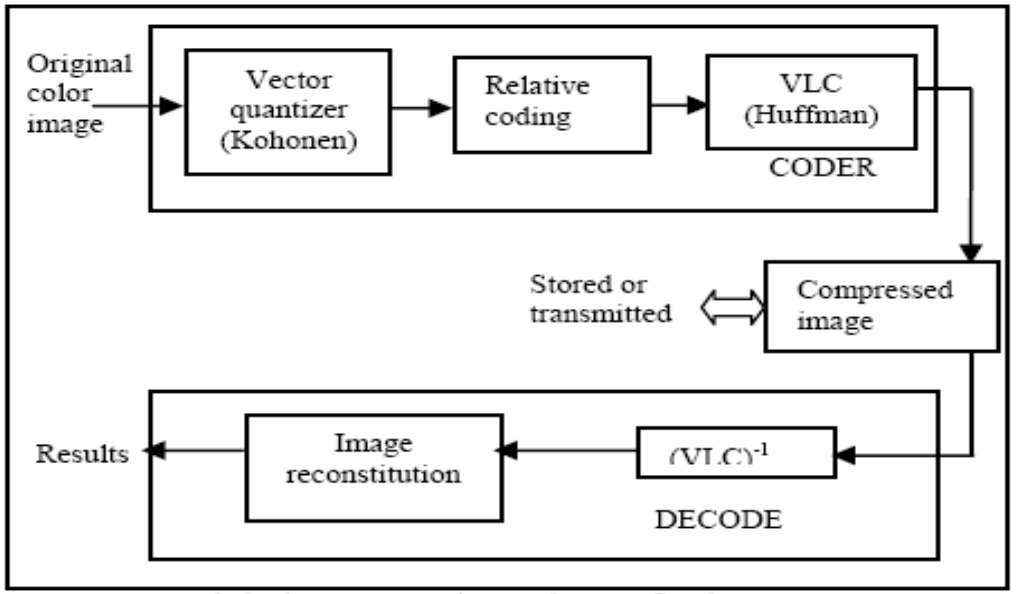


Figure 1. Global compression scheme for lossy compression

SOFM Algorithm

- SOFM is based on competitive learning.
- Neurons are placed at the nodes of a lattice.
- Neurons become selectively tuned to various input patterns.
- Output neurons compete among themselves to be activated.
- Only one (or 1 neuron per group) wins.
- The location of the winning neurons tends to become ordered in such a way that a meaningful coordinate system for different input feature is created.
- 4 basic steps :
  - Initialization
  - Sampling
  - Similarity Matching
  - Updating

SOFM Algorithm

- **Initialization:** Choose random values for the initial weight vector $c_j(0)$. $c_j(0)$ must be different for j=1,2,3…k.
- **Sampling:** Draw a sample *c* from the input distribution with a certain probability.
- **Similarity Matching:**
  - The best-matching criterion is equivalent to the minimum Euclidean distance between vectors.
  - Mapping *q(c)* identifies the neuron that best matches the input vector *c*:

$$q(c) = \arg\min_j \left\| c - \bar{c}_j(n) \right\| \quad j = 1,2,\ldots,K$$

- **Updating:**

$$\bar{c}_j(n+1) = \begin{cases} \bar{c}_j(n) + \eta(n)[c - \bar{c}_j(n)] & j \in A_{q(c)}(n) \\ \bar{c}_j(n) & otherwise \end{cases}$$

- **Continuation:** Continue until noticeable changes are observed

Lossless Compression Techniques

- **Relative Coding:**
  - Used where data to be compressed consists of a similar strings of numbers.
  - If most part of image is smooth, relative coding will lead to smaller code.
- **Huffman Coding:**
  - Minimum length coding
  - Given statistical distribution of the histogram, it generates a code close to minimum bound.
  - Reduces file by 10% to 50%

Results

- Test Image : Standard Lena Image (256 x 256).

Technique	Dimension N	PSNR (dB)	Bit Ratio
Back Propagation	64	25.06	4
Hebbian Learning	64	25.67	4
SOFM	64	27.93	4

Conclusion

- Amongst the 3 NN Techniques, SOFM seems to work best.
- Perform slightly better than another standard method (LBG) of generating codebooks.
- Not much work going on in this field.
- Neural Networks also give good results when applied in association with Wavelet Transformation.

References

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