CSE 534: Multimedia Systems

Effect of JPEG Compression on Image Segmentation Techniques

Subhranil Banerjee - 50096800

May 19, 2014

1. Introduction:

a) Advances in general multimedia communication research :

Remarkable progress in telecommunications technology has had, and will continue to have, an enormous impact on telecommunications manufacturing and service industries. In particular, digital technology that integrates transmission, switching, processing, and retrieval of information provides opportunities to merge various service modes into an integrated whole. This digitalization, merging the communications and computation functions, has been made possible by dramatic advances in device and material technology, including integrated circuits and optical fibers. As the role of digital processing increases, systems and services become more intelligent and labor-saving on the one hand, and more software-intensive on the other.

Satellites and optical fibers, among other technologies, contribute significantly to the globalization of telecommunications services. Standardization and interoperability of systems have become global issues, as have compatibility of regulatory measures that ensure free trade in telecommunication products and service.

Because telecommunications are now indispensable to socioeconomic activities, reliability and security of telecommunications services have emerged as central issues. In our information age, information retrieval is gaining in importance, while concerns are surfacing about the integrity and authenticity of the information to be provided, as well as the protection of privacy. These diverse issues are important to the future of telecommunications industries.

b) Literature Review :

The following research papers were considered for the development of this project.

- *Fast Two-Step Histogram-Based Image Segmentation : Damir Krstinic, Ana Kuzmanic Skelin, Ivan Slapnicar.*

The authors have proposed a novel image segmentation technique based on the non-parametric clustering procedure in the discretized color space. The discrete probability density function is estimated in two steps. Multi-dimensional color histogram is created, which is afterwards used to acquire final density estimate using the variable kernel density estimation technique. Segmentation is obtained by mapping revealed range domain

clusters to the spatial image domain. The proposed method is highly efficient, running in time linear to the number of the image pixels with low constant factors. The output of the algorithm can be accommodated for a particular application to simplify the integration with other image processing techniques. Quantitative evaluation on a standard test dataset proves that the quality of the segmentations provided by the proposed method is comparable to the quality of the segmentations generated by other widely adopted low-level segmentation techniques, while running times are several times faster. This concept has been implemented in the project using built-in library functions.

- *Image Thresholding by Histogram Segmentation Using Discriminant Analysis : Agus Zainal Arifin and Akira Asano.*

The paper presents a technique for image thresholding using the optimal histogram segmentation by the cluster organization based on the similarity between adjacent clusters. Contrary to the previous one, this method is not based on the minimization of a function, the problem of selecting the threshold at the local minima is avoided. This approach overcomes the local minima that affect most of the conventional methods by maximizing the between-class and minimizing within-class objects. Agglomerative clustering is used in this method so as to merge two adjacent clusters in the histogram. The distance measurement using discriminant analysis is adapted from the criterion function defined by Otsu. It directly approaches the feasibility of evaluating the goodness of every pair and automatically grouping the closest pair. The most similar pair is selected, which is the most homogeneous one. In addition, this pair should be the closest pair in the sense of means distance. All steps are repeated iteratively until achieving two clusters. I have implemented a bi-modal version of this technique in the project.

- *Segmentation of Natural Images by Texture and Boundary Compression : Hossein Mobahi,, Shankar R. Rao, Allen Y. Yang, Shankar S. Sastry, Yi Ma*

This paper targets the fact that a homogeneously textured region of a natural image can be well modeled by a Gaussian distribution and the region boundary can be effectively coded by an adaptive chain code. The authors have presented an algorithm for segmentation of natural images that harnesses the principle of minimum description length (MDL). The optimal segmentation of an image is the one that gives the shortest coding length for encoding all textures and boundaries in the image, and is obtained via an agglomerative

clustering process applied to a hierarchy of decreasing window sizes as multi-scale texture features. The optimal segmentation also provides an accurate estimate of the overall coding length and hence the true entropy of the image. It has been proved to achieve state-of-the-art segmentation results compared to other existing methods. I have attempted to implement a miniature prototype of this concept in this project.

- *Analysis of Impact of Lossy Image Compression of Image Quality: From Image Application Aspects :Zhai, L. , Tang, X. M. and Zhang, G*

This paper aims to provide a comprehensive analysis of the impacts of JPEG2000 compression on remote sensing image applications. Image classification and image matching quality assessment, which indicate the radiometric and geometric quality of the compressed images, were selected to test the compression impacts. Nine remote sensing images with different terrain types, land cover and image resolution were employed as original images for compression. The images were compressed by JPEG2000 at various compression ratios. In image classification quality assessment, the classification result from the original image was regarded as the ground truth. The results from original images and compressed images were then compared. I have used some of the heuristics from this paper and extended them to JPEG Compression in this project.

c) Motivation and Reason :

One of the characteristics of image data is the large volume, which has brought about considerable problems for image data transmission and storage in the realm of the internet, web browsing, multimedia, communication, medical imaging and remote sensing, etc. To overcome this problem, image compression plays an essential role in minimizing the data size and organizing it into a scalable stream. To further simplify the representation of an image into something that is more meaningful and easier to analyze, we use the process of segmentation. Segmentation involves a wide range of algorithms which partition a digital image into multiple segments, more precisely, by assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Since segmentation usually forms the lower level for multiple applications , with an application specific decision for the regions of interest, I have attempted to simulate a generic implementation for the same.

d) Project Overview:

The input images are first are first quantized and then compressed using Run length encoding and Huffman encoding. The decoded images are passed into each of the segmentation algorithms. The effect of varying the quantization matrix on the various clusters/objects is observed.

2. Proposed Approach:

a) Design:

The project execution comprises two major stages and was hence implemented accordingly.

i) *Compression*: This phase broadly comprises of the following steps:

- The representation of the colors in the image is converted from RGB to Y'CbCr, consisting of one luma component (Y'), representing brightness, and two chroma components (Cb and Cr), representing colour.
- The image is split into blocks of 8×8 pixels, and for each block, the Y component undergoes Discrete Cosine Transform (DCT).
- The amplitudes of the frequency components are quantized using the default JPEG Quantization Matrix. A scaling factor is used with the matrix for subsequent tests.
- The resulting data for all 8×8 blocks is further compressed with a two step entropy coding, run-length encoding followed by a variant of Huffman encoding.

The decoding performs the reverse of all the above mentioned steps.

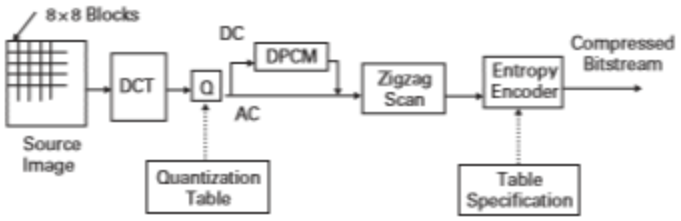

Fig 1 : DCT-based sequential baseline encoder of JPEG

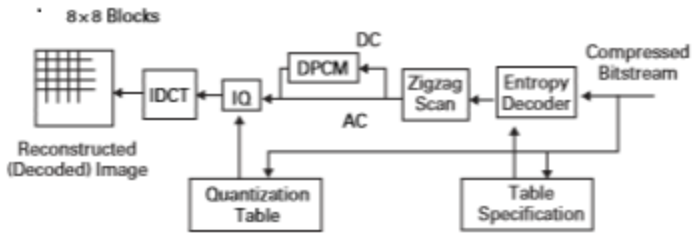

Fig 2 : DCT-based sequential baseline decoder of JPEG

ii) *Segmentation*: The project consists of working implementation of the following techniques and based on a user input, the corresponding function gets called. The compressed image is passed as input to each of them.

- Thresholding : It is based on a clip-level (or a threshold value) to turn a gray-scale image into a binary image. In this project, this has been implemented using Otsu's method.
- K-means clustering: Implemented using the iterative Lloyd's algorithm, it attempts to partition the grayscale image into K clusters based on the intensity values.
- Histogram Based : In this technique, a histogram is computed from all of the pixels in the image, and the peaks and valleys in the histogram are used to locate the clusters in the image. The intensity values are used as the measure. "Method of Two Peaks" is used by finding two local maximum points in the histogram and defining a threshold separating them.
- Edge Detection : Based on the fact that there is often a sharp adjustment in intensity at the region boundaries. This has been implemented using the *edge()* in MATLAB and altering the approximation to be used eg, Prewitt, Roberts or the Laplacian of Gaussian (LoG) Filter.

b) Hardware/software/resources used:

The entire project was coded in MATLAB and all tests were performed on my personal laptop with 4GB RAM and an Intel Core-i5 processor.

3. Outcome and Deviations:

a) Experimental results:

The amount of compression was altered by accordingly setting the scaling factor to the quantization matrix. There were three sets of tests run . For each of them, the compressed image was passed into each of the four segmentation algorithms and the output clusters/segments were recorded.

Set #1: The standard JPEG quantization tables.
Set #2: Half values of the standard JPEG quantization tables.
Set #3: Four times the values of the standard JPEG quantization tables.

Set	Compression Ratio	PSNR
1	0.0110261440277100	37.9055733133045
2	0.0192395448684692	44.4990694766606
3	0.00815105438232422	34.038749895778860

The following represent a handful of the segmentation outputs. A comparison is being done between the best case(Set#2) and the worst case(Set#3).

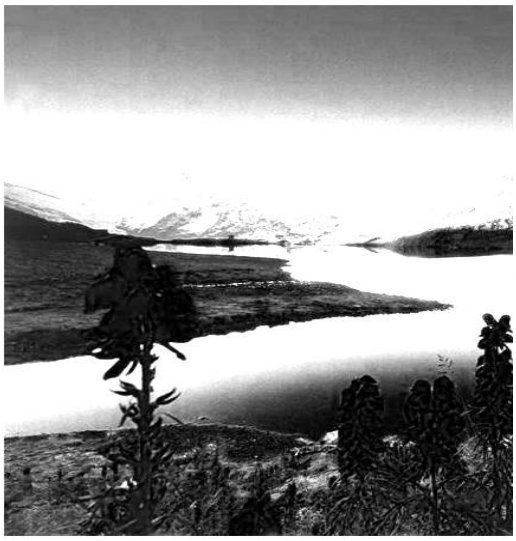

Fig 3: Compressed Image (Set#2)

Fig 4 : Compressed Image (Set#3)

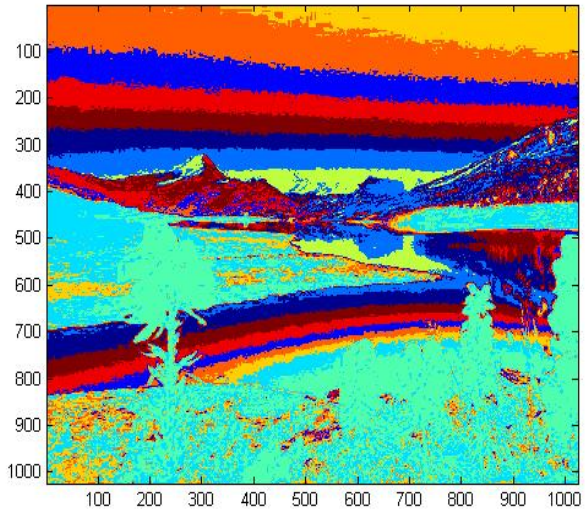

Fig 5 : K-means (Set#2, k=10)

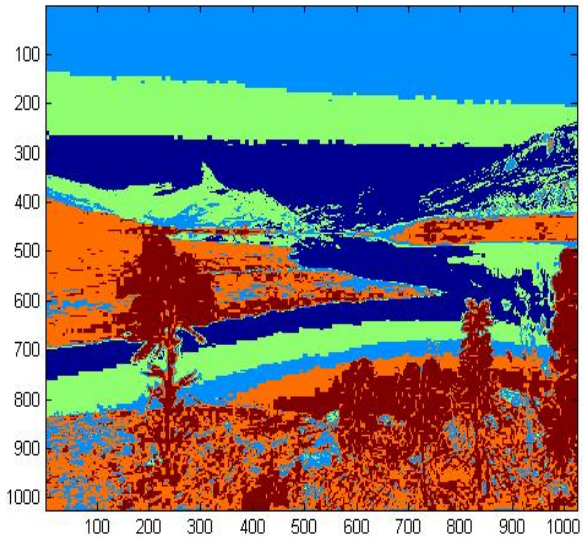

Fig 6 : K-means (Set#3, k=5)

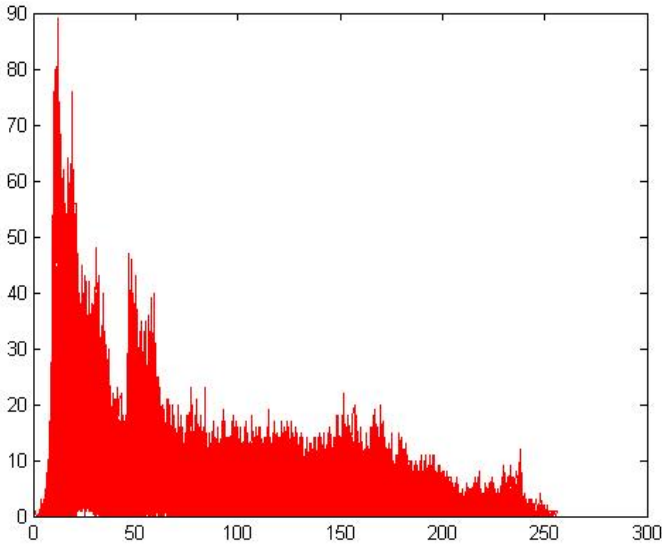

Fig 7 : Histogram (Set#2)

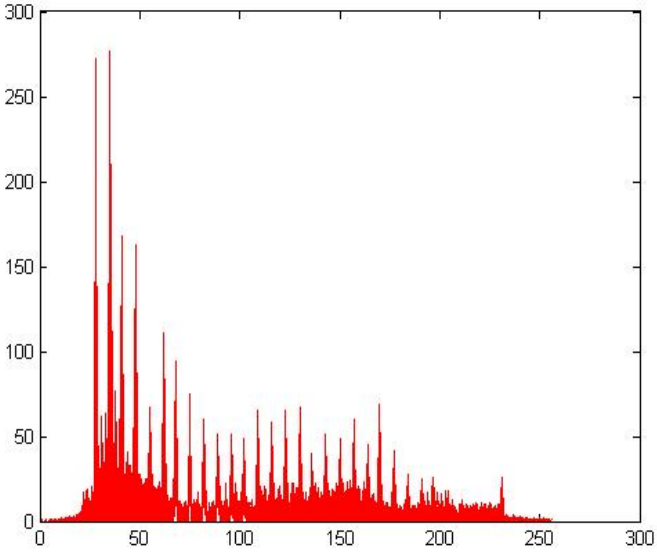

Fig8 : Histogram (Set#3)

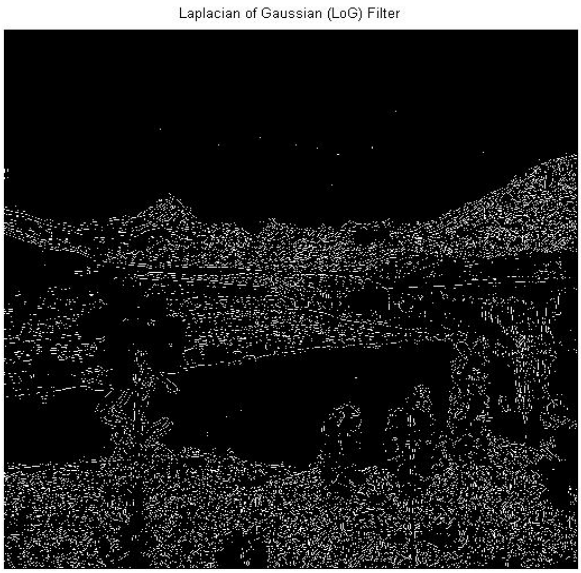

Fig 9 : Laplacian of Gaussian (Set#2)

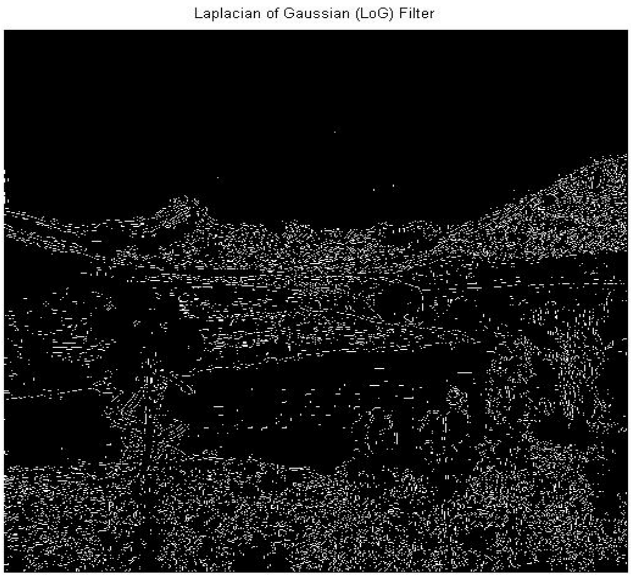

Fig 10 : Laplacian of Gaussian (Set#3)

b) Analysis/Lessons learnt:

- A decrease in the values (set #2) of the quantization matrix leads to a less lossy compression. It is manifested in a better image quality, higher PSNR values and a higher compression ratio. The opposite happens in case of an increase in quantization values(#set 3).
- Since all other steps are symmetrical, the only lossy component of this encoding/decoding process is the quantization and the output quality can heavily depend on it.
- The nature of histogram changes from set#2 to set#3 with the latter having a larger number of local maxima. This can be the result of higher noise level.
- For the other cases, there is no considerable differences in the outputs for the two test sets. All the algorithms perform well in all cases and we might have to test with much higher noise levels to get any significant differences in the segment outputs.
- There were also instances of empty clusters during the execution of the k-means algorithm , especially with higher values of k.

4. Summary:

a) Project Summary :

The project involved implementing a set of segmentation techniques and then observing the effects of compression on their performance and outputs. JPEG compression was implemented via Run length encoding and huffman encoding with the quantization matrix being varied to generate different compression levels and output quality. For each case , the segmentation outputs were plotted and a comparative analysis was done.

b) Course Summary :

The course titled “Multimedia Systems” was a great learning experience , within and beyond the classroom. The course material covered a wide array of topics and the homework assignments were a great platform for hands-on experience on the various aspects of multimedia communication.

- The first assignment gave us a good understanding of the various speech encoding/decoding techniques.
- The second assignment, involving JPEG image compression , formed the basis for my project.
- The quizzes and especially the final examination were a very good learning experience with the brain-racking problems that needed us to think out-of-the-box and go beyond our text books.

5. Acknowledgement :

I would like to thank Dr. Chang Wen Chen for making this course such a great learning experience and for inculcating interest in the subject.

6. References:

[1] Fast Two-Step Histogram-Based Image Segmentation : Damir Krstinic, Ana Kuzmanic Skelin, Ivan Slapnicar.
[2] Image Thresholding by Histogram Segmentation Using Discriminant Analysis : Agus Zainal Arifin and Akira Asano.
[3] Segmentation of Natural Images by Texture and Boundary Compression : Hossein Mobahi,, Shankar R. Rao, Allen Y. Yang, Shankar S. Sastry, Yi Ma
[4] Analysis of Impact of Lossy Image Compression of Image Quality: From Image Application Aspects :Zhai, L. , Tang, X. M. and Zhang, G
[5] Efficient Graph-Based Image Segmentation : Pedro F. Felzenszwalb, Daniel P. Huttenlocher
[6] Zhai, L. , Tang, X. M. and Zhang, G. -Evaluating the Impact of Iris Image Compression on Segmentation and Recognition Accuracy

[7] Luc Vincent : Recent Advances in Document Image Segmentation, Compression, and Encoding.
[8]http://en.wikipedia.org/wiki/Image_segmentation
[9] http://en.wikipedia.org/wiki/K-means_clustering
[10] Multimedia Networking - From Theory to Practice (2009) : JENQ-NENG HWANG