EE368B – Image and Video Compression

Homework Set #3

due Friday, November 3, 2000, 9 a.m.

Introduction

In this homework assignment you are asked to investigate the rate distortion performance of a transform image coder using the DCT for 8×8 blocks of an image.

Proceed according to the following steps:

1 Blockwise 8×8 DCT

There are four types of DCT, the most prevalent one being DCT-II, which is the one used in this homework. It is a separable orthonormal transform, so the DCT transform of a signal block of size $M \times M$ can be expressed by $y = AxA^T$, and the inverse DCT transform is $x = A^T yA$, where x is the $M \times M$ signal block, and A is the $M \times M$ transform matrix containing elements

$$a_{ik} = \alpha_i cos\left(\frac{(2k+1)i\pi}{2M}\right) \quad \text{for} \quad i,k = 0,1,...M-1$$

with

$$\begin{aligned} \alpha_0 &= \sqrt{\frac{1}{M}} \\ \alpha_i &= \sqrt{\frac{2}{M}} \quad \forall i > 0. \end{aligned}$$

Implement a DCT of blocksize 8×8 for still images and the inverse DCT of blocksize 8×8. Print out the values of the matrix A. Hint: we do not care about fast algorithms here, simply use a matrix multiplication in Matlab.

2 Uniform Quantizer

Implement quantization of the coefficients by a uniform mid-tread quantizer without threshold characteristic. Use the same step-size for all coefficients. Plot a graph of the quantizer function.

3 Distortion and Bit-Rate Estimation

The *Peak Signal to Noise Ratio* (PSNR) will be used to measure the quality of the reconstructed images. It is defined for 8-bit images as follows:

$$\text{PSNR} = 10 \log_{10} \left(\frac{255^2}{D} \right) \quad [\text{dB}]$$

The average distortion D will be the mean squared error between the original and the reconstructed images.

To estimate the bit-rate required to encode the coefficients, assume that we use the ideal code word length of a variable length code that encodes each coefficient individually, but uses a special code for each of the 64 coefficients in a block. With other words: we assume that we use a different VLC for coefficient 1, coefficient 2, etc. within each block, but coefficient i uses the same VLC in each block.

Carry out all measurements using the three images *boats, harbour,* and *peppers* from the class Web site, with the same set of VLCs applied across all three images. Vary the quantizer step-size over the range $2^0, 2^1, 2^2, ..., 2^9$ to measure a rate-PSNR curve that shows what PSNR we expect over a range of bit-rates.

Hint:

- Different VLCs should be used for different quantizer step-sizes.
- Ideal code word length can be fractional.
- Use the Parseval Theorem to determine the block distortion.
- To speed up your measurements you can use the function 'dct2'.

4 Judging Image Quality (Bonus Exercise)

The part is not mandatory, but it is fun, and you can earn bonus points. We want you to actually look at the encoded images and judge their impairment using the CCIR 5-point scale, formally known as *Double Stimulus Impairment Scale* (DSIS). In this subject testing method, observers are shown multiple reference-image-and-degraded-image pairs. The reference image is always first. Scoring is on an overall impression scale of impairment:

5 - imperceptible

4 - perceptible but not annoying

3 - slightly annoying

2 - annoying

1 - very annoying

Please supply a table and a graph showing PSNR vs. impairment and bit-rate vs. impairment for at least one image by varying quantization step-size. The PSNR and bit-rate values should be calculated for the individual images. Please use the quantizer dependent VLC codes from Problem 3.