Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2010-2011 (2 hours)

EEE6081 Visual Information Engineering 6

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. The poly-phase decomposition of a wavelet transform is shown in the following equation.

$$\begin{bmatrix} y_0 \\ y_1 \end{bmatrix} = \begin{bmatrix} h & h \\ h & -h \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \end{bmatrix}$$

$[x_0, x_1]$ and $[y_0, y_1]$ represent the poly-phase components of the input and output signals, x and y, respectively. Subscripts, 0 and 1, corresponds to the even and odd indexed poly-phase components, respectively.

a. If this is an orthogonal transform, find the value of h. **(2)**

b. Verify the orthogonality of the transform **(2)**

c. Explain the characteristics of the output poly-phase components, y_0 and y_1. **(3)**

d. Write down the forward wavelet transform matrix corresponding to the first level of decomposition for an input signal that contains 4 elements. **(3)**

e. What is the corresponding inverse transform matrix of the forward wavelet transform matrix in question 1.d? **(2)**

f. What is the transform matrix corresponding to the second level of decomposition to obtain the full tree wavelet packet decomposition using the forward wavelet transform matrix in question 1.d? **(3)**

g. Explain how you use this wavelet transform to obtain the 2-level full tree wavelet packet decomposition of an image containing 128 x 128 pixels. **(5)**

2. The lifting steps of a wavelet transform are as follows:

$$\begin{aligned} y_i^1 &= y_i - \left(\sqrt{2}-1\right)x_i \\ x_i^f &= x_i + \frac{1}{\sqrt{2}}y_i^1 \\ y_i^f &= y_i^1 - \left(\sqrt{2}-1\right)x_i^f \end{aligned}$$

Use this lifting realisation to answer the following questions.

a. State 3 advantages of using lifting-based wavelet transform design and implementation as compared to the filter-bank-based approach. **(3)**

b. Derive the low pass and high pass filters in the analysis wavelet filter-bank corresponding to the shown lifting steps. **(3)**

c. If p_i is the original input signal, how do you obtain x_i and y_i from p_i? **(2)**

d. Write down the lifting steps for the corresponding inverse transform **(3)**

e. How do you obtain the reversible transform that maps integer inputs to integer outputs using the above lifting steps? **(2)**

f. In the shown lifting steps, the lifting templates use a single neighbour of a signal element to be predicted or updated. Extend the above lifting scheme to obtain a lifting scheme that uses both neighbours of a signal element to be predicted or updated. **(3)**

g. Explain how the 3-dimensional dyadic wavelet decomposition of video sequences is obtained. **(4)**

3.

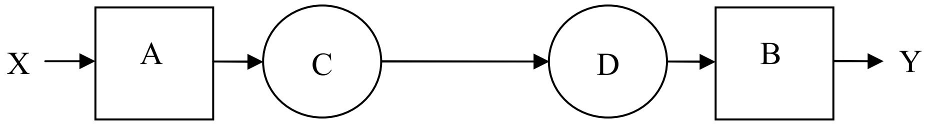

Figure 1

Figure 1 shows a block diagram of a system for creating an approximated version (Y) of a one-dimensional signal (X). A and B represent low pass filters. C and D represent down-sampling and interpolating (i.e., inserting zero –valued samples) by a factor of 2, respectively.

a. Explain briefly, using a diagram, how to design a pyramid-based multi-resolution **signal** representation scheme using the signal approximation scheme shown in Figure 1. **(3)**

b. Draw a block diagram of the inverse transform. **(3)**

c. What would be the choices for A, B, C and D, if the signal representation scheme in Q3.a was extended to a pyramid-based multi-resolution **image** representation scheme. **(2)**

d. Compute the sampling redundancy factor for a 3 level decomposition of the 2-dimensional pyramid transform you designed. **(2)**

e. Explain briefly an advantage of using the discrete wavelet transform for multi-resolution representation as opposed to using the pyramid-based multi-resolution representation. **(2)**

f.

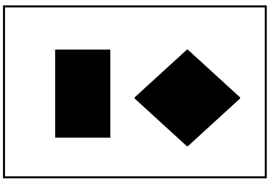

Figure 2

In the image in Figure 2, black and white represent the grey scale values 255 and 0, respectively. Sketch the sub bands of 1-level decomposition of this image using the 2-dimensional pyramid. **(3)**

g. Consider the sub bands produced from a 3 level 2-dimensional pyramid-based multi-resolution representation for embedding a watermark.

State, giving reasons, which sub bands and coefficients you would choose to embed the watermark ensuring both high imperceptibility and high robustness to compression at the same time. **(5)**

4. **a.** Explain briefly the purpose of the discrete wavelet transform in scalable image coding. **(5)**

b. Explain, using diagrams, how motion is estimated for motion compensated temporal prediction in video coding. Also, state how the accuracy of the motion estimation has been improved in the latest video coding standards, such as, H.264 and MPEG-4. **(5)**

In video coding, a frame can be encoded either as an intra frame (I) or as a forward predicted frame (P) or as a bi-directionally predicted frame (B). Four methods of frame organisation depending on these encoding types are listed below.

Method 1: All frames are encoded as intra frames (I I I I I I I ....)

Method 2: Forward motion predicted differential coding (I P P P P P P ...)

Method 3: Group of pictures with all I, P and B modes (I B P B P B)

Method 4: Group of pictures with I and hierarchical B modes (I B B B B B)

Consider these 4 scenarios to answer the questions 4.c – 4.f.

c. What are the advantages and disadvantages of Method 3 compared to Method 1? **(3)**

d. State why Method 2 is the least robust method and suggest a way to improve the robustness of method 2. **(2)**

e. Show graphically the coding/decoding path of frames shown in Method 4. **(2)**

f. Compare the decoding delay and the complexity of Method 3 and Method 4. **(3)**

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