Final Exam
Signal and Image Processing
SS 2020

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Part	**A**	**B**	**C**	**Total**
Score	**/ 30**	**/ 30**	**/30**	**/ 90**

Part A: General Question [30 P]

1. **Filter design [8P]**

   a). There are many types of IIR filters, name **two** of them. Moreover, assuming that we want to design an IIR filter which has the least ripples in the pass-band and we do not care about the ripples in the stop-band, which type of IIR filters can we choose?

   [/ 5]

   b). For designing a zero phase FIR filter $h[n]$, what property should its frequency response function $H(\omega)$ have?

   [/ 3]

2. **Multitaper and constrained optimization [8P]**
   In power spectral density estimation, the multitaper algorithm is one of the most famous non-parametric methods.
   a). Name one special property that holds between each pair of tapers.

   [/ 3]

b). Constrained optimization is adopted for estimating the tapers, i.e., windows. Explain why do we use constrained optimization in the algorithm of multitaper?

[/ 5]

3. **Discrete Cosine Transform [14P]**

a). We usually apply DCT in image or audio signal compression instead of DFT. Name two reasons.

[/ 4]

b). Given a gray scaled image, if we want to encode this image into binary code using standard JPEG format, what are the procedures?

[/ 6]

c). We know DCT is an invertible transformation while standard JPEG format is still a lossy (irreversible) compression technique. Please point out where does the loss come from?

[/ 4]

Part B: Time-frequency analysis [30 P]

Short time Fourier transform (STFT) and discrete wavelet transform (DWT) are two of the most common time-frequency analysis methods.

a). Name one difference between STFT and DWT.

[/ 4]

b). Is it possible to have a fine frequency domain resolution and a narrow time window simultaneously? Justify your answer.

[/ 4]

c). Given a mother wavelet $h_{m=0,k=0}[n]$ as shown below, **sketch** the derived wavelets under following three cases. (Note: m and k represent scaling factor and shifting respectively.)

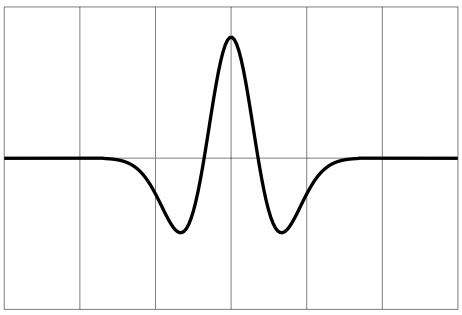

Figure 1: Mother wavelet $h_{m=0,k=0}[n]$

[/ 12]

- Case 1: $h_{m=1,k=0}[n]$

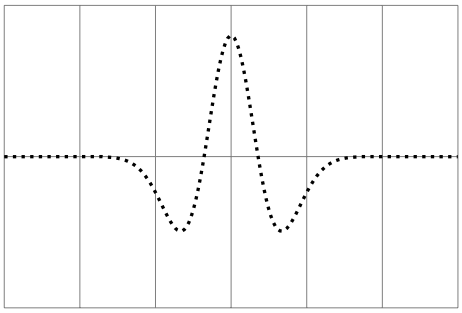

Figure 2: Dotted line: Mother wavelet $h_{m=0,k=0}[n]$

- Case 2: $h_{m=0,k=1}[n]$

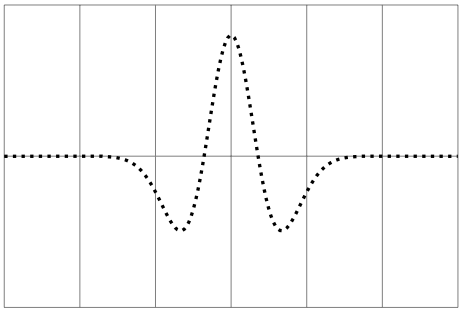

Figure 3: Dotted line: Mother wavelet $h_{m=0,k=0}[n]$

- Case 3: $h_{m=1,k=1}[n]$

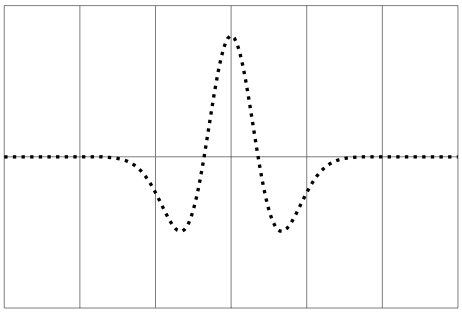

Figure 4: Dotted line: Mother wavelet $h_{m=0,k=0}[n]$

d). The basis functions of DWT are always orthogonal to each other, sometimes even orthonormal. Explain what is the difference between orthogonal and orthonormal basis?

[/ 5]

f). In most different transformation methods, the basis function is always required to possess the orthogonality. Explain the reason.

[/ 5]

Part C: Data compression [30 P]

To transmit messages between computers, we usually need to encode them into binary or hexadecimal code. To increase the efficiency of data transmission, many data compression techniques have been proposed, and one of the most famous algorithms is Huffman coding. Assume that we are going to transmit a sentence as written below:

In Ulm, um Ulm, und um Ulm herum wachsen viele Ulmen.

1. **ASCII-encoding**: With the standard ASCII, each character is encoded into 8 digits of binary code, e.g., 'A' = 0x41 = 0100 0001 . Please compute how many digits of binary code will be needed to encode the whole sentence. **(incl. space key ' ' but excl. ',' and '.')**

[/ 6]

2. **Huffman-encoding**: The distribution of each character is listed below. Please compute the probability of each character and encode all presented characters **(incl. space key ' ' but excl. ',' and '.')** using Huffman's method. Also please compute how many digits will be needed to encode this sentence.

(' ', 10)	('u', 8)	('m', 7)	('l', 5)	('e', 5)	('n', 4)	('i', 2)	('h', 2)
('d', 1)	('w', 1)	('a', 1)	('c', 1)	('s', 1)	('v', 1)	('r', 1)	

[/ 24]