Exam questions
Image Processing 2020

2D Fourier transform and its properties:

1. Fourier series. Explain the main principles of periodic function approximation. Explain 3 forms of Fourier series approximation (it can be interpreted as an inverse transform).
2. Fourier series. Explain the direct and inverse Fourier series computation. Explain why for the continuous time periodic functions do we have discrete Fourier coefficients? You can use an example of periodic square signal to explain the properties of Fourier series coefficients.
3. Fourier transform in continuous time and frequency. Explain the transition from periodic functions to aperiodic ones. Explain what is the main difference between the Fourier series and Fourier transform coefficients.
4. Fourier transform in continuous time and frequency. Explain Fourier transform as a projection onto complex exponent basis functions. Explain the corresponding properties of real and imaginary parts linking them with the properties of cosine and sine functions.
5. Fourier transform in continuous time and frequency. Explain properties of Fourier transform under time and frequency shifts.
6. Fourier transform in continuous time and frequency. Explain properties of Fourier transform under time reversal. Explain the effects observed on slide 47, Theme 7 block 2 under phase flipping in the Fourier domain. Provide mathematical justification. Explain signal scaling in the time/spatial domain and its counterpart in the Fourier domain.
7. Signal sampling in the time/spatial domain. Explain discrete time Fourier transform. Explain the properties of spectra of discritized signals. Explain the conditions of lossless data sampling allowing signal reconstructions and provide the definition of Nyquist sampling theorem.
8. Signal sampling in the time/spatial domain. Explain the principles of ideal signal reconstruction. Explain an ideal low pass filer based reconstruction.
9. Explain the transition from the discrete time continuous frequency Fourier transform to discrete time discrete frequency Fourier transform or simply discrete Fourier transform based on sampling in frequency domain. Explain the properties of sampled signals in the time domain.
10. Discrete Fourier transform (DFT). Explain DFT in matrix form. Explain the properties of DFT matrices and the interpretation of transform as a projection on the complex basis vectors.
11. Discrete Fourier transform (DFT). Explain the circulant convolution and its main differences to the linear convolution. Explain how to compute linear convolution via DFT.

Frequency domain filtering:

1. Explain the main principle of Fourier domain filtering. Complexity and advantages over direct convolution computation. Explain the construction of filters under the “zero-phase” conditions. The reasons of such a construction and properties of corresponding “zero-phase” filters.
2. Explain the algorithm of Fourier domain filtering. Explain each step of this algorithm and properties of images in Fourier domain. You can use as an example slide No 13, Theme 8. Explain the observed Fourier domain effects for the examples shown on slides No 14 and 15.
3. What is the application of image smoothing? Explain image smoothing in Fourier domain. What is an ideal low pass filter in Fourier domain and its representation in spatial domain. Why we do no use ideal low pass filers in practice? Explain all reasons for that.
4. Image smoothing in Fourier domain. Explain Butterworth and Gaussian filters. What is their main difference to the ideal low pass filter and why we do prefer them in practice? Explain whether one can implement the ideal low pass filter in the spatial domain. Explain what is the Fourier presentation of Gaussian low pass filter in the spatial domain.
5. Image sharpening. Explain what is the ideal high pass filer. How can one obtain the ideal high pass filter based on the ideal low pass filter. What are the main drawbacks of ideal high pass filter? How they are solved in practice. Exemplify two filters free of these drawbacks.
6. The Laplacian in Fourier domain. Explain the properties. Link the derivatives in the spatial domain to Fourier domain equivalent filters. Explain the correspondence between the spatial and Fourier domain filtering. Explain the essence of approximation of derivatives in the spatial domain (you can use examples from the previous semester).
7. What is image sharpening based on unsharpen mask? How can it be implemented in the spatial and Fourier domains? Explain two ways of implementation of unsharpen filters based on low pass filters and Laplacians (you can also refer to the materials from the previous semester).
8. Explain homomorphic filtering. Explain its applications.
9. Explain image selective filters: bandreject and bandpass filters, notch filters. Explain the domain of their applications. Explain the details of their implementation given some specific periodic patterns in the spatial domain. How can these filters be used to remove them in the spatial domain? Explain all details.

Multiresolution transformations:

1. Laplacian and Gaussian pyramids. Main properties and applications. Explain how to compute the direct and inverse pyramid and ensure perfect image reconstruction.

2. Image interpolation. Explain image interpolation in Fourier domain. Explain the role of low-pass filtering. Explain why we do not use ideal low pass filters in practice. Explain inheritability of interpolation: why it is possible.
3. Image decimation. Explain image decimation in Fourier domain. Explain main mechanism preventing image recovery after decimation. Explain the role of pre-filtering in image decimation.
4. Wavelet transform. Explain the main principle of 1D and 2D wavelet transform. Explain the properties of wavelet coefficients. Explain the differences between wavelet transform and Laplacian-Gaussian pyramids.
5. Gabor filters. Explain the main principles and applications. Provide Fourier domain interpretation of Gabor decomposition. Explain the main difference between Gabor decomposition and wavelet decomposition.