EE C145B / BioE C165 Spring 2004: Expectations for Midterm Exam

1. Know how to identify linear and space-invariant systems.
2. Know what an impulse response, PSF, kernel and transfer function are.
3. Know how to perform 1D and 2D discrete convolution.
4. Know that convolution in 1D and 2D can be implemented as matrix operations.
5. Know how to form a 1D convolution matrix given a kernel.
6. Know how to calculate 1D DFTs by hand.
7. Know the frequency values on the axis on which the DFT is defined.
8. Be able to calculate the index of spectral peaks in a DFT.
9. Know how to draw the sinusoids each DFT coefficient represents.
10. Know that the 1D sinc function contains equal amounts of all frequencies up to a cutoff.
11. Know that the 2D jinc function contains equal amounts of all frequencies up to a cutoff.
12. Know how to apply the properties of the FT, especially the duality property and the convolution property.
13. Know that the magnitude of the FT is translation invariant.
14. Understand the separability property of the FT.
15. Know how a lens may be used to perform analog filtering in 2D.
16. Be able to explain the difference between image enhancement and restoration.
17. Know how 2D DFTs may be calculated using a 1D DFT engine.
18. Understand image sampling in 2D.
19. Understand the relationship between the continuous space FT, the discrete space FT, and the DFT.
20. Be able to locate the index of a given frequency in the DFT of an image.
21. Be able to work out where aliased frequency components will appear.

22. Understand the implications in the frequency domain of sampling a space signal.

23. Understand the implications (with respect to periodicity) of sampling the FT of a sampled space signal.

24. Understand the ramifications of the periodicity of the DFT and DSFT.

25. Understand the purpose of windowing and its pros and cons.

26. Know how to make a separable 2D window out of 1D windows.

27. Know that the maximum sampling rate of an image containing square pixels occurs on the diagonal, and that the minimum occurs on the axes. Know how to explain why this is.

28. Know how to construct discrete 2D low-pass Gaussian filters.

29. Know how to convert these to high-pass filters.

30. Be able to explain quantitatively the effects of various filters on the appearance of an image.

31. Understand the effects of filters based on derivatives on graylevel-constant and graylevel-ramp image regions. Be able to explain the effects of these filters on lines and isolated features.

32. Know how to apply thresholds to an image.

33. Know how and when to apply the median filter and other order statistics based filters.

34. Be able to construct a histogram of an image.

35. Be able to construct the cumulative histogram of an image.

36. Know the purpose of histogram equalization, and when this procedure should be applied.

37. Be able to explain and execute the steps necessary to equalize and specify an image histogram.

38. Be able to identify linear models.

39. Be able to formulate the sum of squared residuals (SSR) for a linear model.

40. Be able to find and solve the system of equations that results from taking the derivatives of the SSR.

41. Know what is meant by a singular matrix.

42. Be able to apply the pseudoinverse to solve a system of overdetermined equations.

43. Know the conditions under which this pseudoinverse exists.

44. Understand the concepts of the range and the nullspace of a matrix.

45. Know that for every matrix there exists a decomposition $\mathbf{F} = \mathbf{U}\mathbf{S}\mathbf{V}^T$ where the columns of $\mathbf{U}$ for which the corresponding singular values are non-zero span the range of $\mathbf{F}$. Know that the columns of $\mathbf{V}$ for which the corresponding singular values are zero span the nullspace of $\mathbf{F}$. Know that $\mathbf{S}$ has the singular values of $\mathbf{F}$ along its diagonal in order of decreasing magnitude. Know the dimensions of these matrices.

46. Know that the columns of $\mathbf{U}$ are orthonormal (unitary matrix).

47. Know that the columns of $\mathbf{V}$ are orthonormal (unitary matrix).

48. Know how to modify $\mathbf{S}$ to get the pseudoinverse of $\mathbf{F}$. Know that this pseudoinverse is the same as that derived by minimizing the sum of squared residuals for an overdetermined problem.

49. Be able to use the SVD to solve any system of linear equations.

50. Know how to interpret and when to manipulate the singular value spectrum.

51. Know two reasons why it is better to calculate the pseudoinverse via the SVD than by the direct formula.

52. Know how to use the SVD to approximate a matrix and compress images.

53. Understand how we can compare matrices using the sum of squared differences.

54. Be able to explain the difference between emission and transmission tomography in terms of: contrast mechanism and source of illumination.

55. Be able to calculate photon attenuation through different successive media.

56. Understand how we calculate a projection measurement in x-ray tomography.

57. Understand how we linearize this problem.

58. Understand the geometry of the Radon transform in 2D.

59. Be able to explain what a sinogram is, and be able to qualitatively draw a sinogram of a distribution.

60. Be able to show that each point in a distribution becomes a sinusoid in sinogram space.

61. Understand and know how to apply and explain the properties of the Radon transform.

62. Be able to derive and interpret the projection slice theorem (either in vector or scalar form, whichever you prefer).

63. Know the steps needed to invert the 2D Radon transform using the projection theorem. Know two reasons why this is not a good idea in practice.

64. Understand what the backprojection operator does and be able to qualitatively draw a backprojection image given some projections.

65. Be able to derive the equation from which the backprojection-based reconstruction methods follow by means of the inverse FT, the projection slice theorem, and changes in integral limits.

66. Be able to explain where the ramp filter function comes from.

67. Be able to draw the ramp filter.

68. Be able to explain why this filter isn't realizable and explain why it performs poorly in the presence of noise.

69. Know the advantages and disadvantages of the modified ramp filters. Be able to qualitatively draw a modified ramp filter.

70. Understand the problem associated with implementing space-domain filtering of projections using the inverse FT of the ideal ramp filter (Hilbert transform of the derivative).

71. Know the steps involved in reconstructing images from projections using the four algorithms that involve backprojections and filtering (BCFP, BPFP, FFBP and SFBP).

72. Know how many angular and radial samples are needed to adequately sample a 2D distribution in Radon transform space.

73. Be able to derive these criteria.

74. Be able to form the discrete Radon transform projection matrix and know how to automatically determine the geometric weighting factors automatically.

75. Understand how to use the pseudoinverse to reconstruct tomographic images.

76. Know that the transpose of the projection matrix is the discrete backprojection operator.

77. Be able to explain the relationships between the pseudoinverse solution and the SFBP algorithm.

78. Understand the significance of the matrix $\mathbf{F}^T\mathbf{F}$ being block Toeplitz.