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12 Lectures on Selected Topics in Image Processing

Imaging Transforms in Digital Computers

Fast Transform Methods for Image Resampling

Image Recovery from Sparse Data

Adaptive Filters for Target Location and Image Restoration

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12 Lectures on Selected Topics in Digital Image Processing

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Part 1. Imaging transforms in digital computers (4 hours).

Lect. 1. Convolution integral and digital filters

Principles of discrete representation of continuous transforms. Overall point spread function (PSF) and frequency response (FrR) of convolutional digital filtering. Continuous PSF and FrR of convolutional digital filtering.

Lect. 2. Fourier integral and Discrete Fourier Transforms

Discrete Fourier Transforms: canonical DFT, Shifted DFT and its derivatives, DCT, Scaled DFT, Affine DFT, Rotated DFT. Point spread function and resolving power of discrete Fourier analysis. Boundary effect free fast convolution in DCT domain.

Part 2. Fast transform methods for image resampling (6 hours)

Lect. 3. Perfect resampling filter and fast algorithms

Image resampling task. Convolutional resampling algorithms. Signal/image fractional shift as a basic resampling procedure. Point spread function and frequency response of the perfect continuous resampling (PCRS) filter. Point spread function and frequency response of the perfect discrete resampling (PDRS) filter

Lect. 4. Implementations and applications of PDRS filters.

PDRS filtering through signal DFT or DCT zero padding. Zero padding in other transform domains. Fractional shift DPRS filter implementations through FFT and Fast DCT. Fast image magnification and rotation. Fast Radon and Inverse Radon Transforms. Signal re-scaling using Scaled DFT. Image re-scaling and rotation using RotDFT. Local adaptive methods for image re-sampling.

Lect. 5. Precise numerical integration and differentiation

Commonly used methods for numerical integration and differentiation. Integration and differentiation as convolutions. Frequency responses of perfect integration and differentiation. Implementation of perfect integration and differentiation in DFT and DCT domain. Comparison of methods of numerical integration and differentiation. Examples of applications.

Part. 3. Discrete sampling theorem and signal reconstruction from non-uniform sampled or sparse data (4 hours)

Lect. 6. Discrete sampling theorem.

Discrete signals as band limited ones. Discrete sampling theorem. Separable and non-separable image 2D and multidimensional band-limitation. Conditions of signal recoverability from sparse data. Discrete sampling theorem and Whittaker-Kotelnikov-Shannon's sampling theorem. Exact image recovery from sparse data: examples.

Lect. 7. Algorithms for reconstruction of signals from sparse samples and applications

Direct matrix inversion and iterative Papoulis-Gershberg algorithms. Image restoration from level lines. Restoration of turbulent videos with “super-resolution”. Image reconstruction from projections with “super-resolution”

Part 4. Optimal linear filters for target location and tracking (4 hours)

Lect. 8. Target location as a parameter estimation task.

White Gaussian Signal Independent Noise (WGSIN)-observation model. Correlator as the Optimal Target Location (OTL) filter for the WGSIN-model. OTL filter for non-white noise model. OTL-filters as maximum signal-to-noise filters. OTL-filters for target location in color and multi-component images.

Lect. 9. Accuracy and reliability of target location

Two types of localization errors: normal and anomalous ones. WGSIN-model: localization accuracy and signal shape. Localization accuracy in non-white noise. Fundamental threshold in target location reliability. Target localization reliability in the presence of foreign non-overlapping objects.

Lect. 10. Target location in clutter

Target location in cluttered images: formulation of the task. Optimal Adaptive Target Location (OATL) filters for target location in cluttered images. OATL-filters and image “edges”. OATL-filters and target “goodness” measure. Target location in blurred images. Local adaptive OATL-filters.

Part 5. Local adaptive filters for image restoration and enhancement (4 hours)

Lect. 11. Local adaptive transform domain scalar filters

Local criteria of image processing quality. Mean Squared Error (MSE) – optimal transform domain scalar filtering (OTDSF) for image denoising, deblurring and enhancement. OTDSF and wavelet shrinkage methods: a comparison and interpretation. OTDSF for multi-component images and video. OTDSF and image data fusion.

Lect. 12. Local adaptive nonlinear filters.

Nonlinear filters and classification principles. Rank filters. Pixel attributes and neighborhood building operations. Iterative nature of nonlinear filters. Typical estimation operations. Examples of rank filters for image denoising, enhancement and segmentation.

Recommended reading

1. L. Yaroslavsky, Digital Holography and Digital Image Processing, Kluwer Academic Publishers, Boston, 2004
2. J. Astola and L. Yaroslavsky, Eds., Advances in Signal Transforms: Theory and Applications, Hindawi Publ. Corp. N.Y. 2007