THE HUMAN VISUAL SYSTEM

- The eye, the **retina**
- Elements of **photometry**. **Polarization**
- **Weber's** ratio and law
- Naka-Rushton model, **JND** calculation
- **Ambient** light effects
- **CSF**: Contrast sensitivity function
- Perception of **colors**
- **Perception**: Simultaneous contrast, Mach bands, saccadic movements
- Shape from **shading**
- **3-D** perception

IMAGE ACQUISITION

- **Photodiode**: structure and basic circuit, eq. circuit. Active matrix connection
- Matrix **sensors**:
    - CCD structure and architectures. Dark current, transfer efficiency, blooming
    - CMOS sensors. Fixed-pattern noise
- **Color**: Bayer, Fuji, quantum dots
- **Datasheets**: examples
- **HDR** imaging:
    - piecewise-linear sensors
    - 3-sensor devices. Data fusion: sensors calibration; data weighting
    - Sequential approach; ghosts
- **Plenoptic** imaging:
    - pinhole model, microlenses, refocusing, depth image
    - Dual-pixel sensors
- **EM** imaging
- **X-ray** imaging
- **ToF** imaging
- **Multi**- and hyper-spectral imaging

DISPLAYS AND PROJECTORS

- **LC basics:**
    - Properties of liquid crystals. TN, IPS, transflective LCD
    - Colors
    - LED backlight
- **Advanced displays:**
    - Dual-layer LCD structure, Space-variant LED-LCD system
    - Quantum dots-based solutions
    - OLED displays (with touch screen)

- o MicroLEDs
- **HDR displays:**
  - o Dolby vision system. ITU recs. BT.2100 and BT.2390, perceptual quantizer
  - o HDR10 system
- **Special displays:** E-ink. Electrowetting
- **Projectors**: LCD, LCoS, DMD. Wobulation. Light sources
- **Stereo** and autostereo displays/projectors

DATA-DOMAIN PROCESSING
- **Basic notions:**
  - o Sampling, causality, aliasing (Moiré)
- **Tone mapping:**
  - o Gamma correction
  - o ITU Recs. BT 709 and 1886
  - o Functions for gray-level mapping
- **Histogram-based enhancement:**
  - o Histogram equalization and specification
  - o Useful color spaces: RGB, YCbCr, HVS
  - o Hist.Eq. of colour images in the HSV space
  - o Adaptive HE (CLAHE). Exact HE. 2D-HE (concept)
  - o Enhancement based on local image statistics
- **Local operators for image enhancement:**
  - o 2-D convolution. Padding. Lowpass filters.
  - o iterative filters, equivalent impulse response.
  - o Median filter, 1-D and 2-D cases; root signal
  - o Linear highpass filters, 1st and 2nd derivatives. Unsharp masking
  - o Gradient operators: Roberts, Sobel. Sobel-based UM
  - o Rational filter. DL_BUM filter
  - o Retinex-based filter: illumination estimation, mapping, reflectance mapping, dead zone

TRANSFORM-DOMAIN PROCESSING
- **Basic notions:**
  - o DFT 2-D: basic notions; quadrant swapping. Separability.
  - o Fundamental 2-D signals
  - o DFT of simple images. DFT-domain convolution; zero padding
  - o DFT-domain correlation. 2-D DFT properties.
  - o 2-D DCT: definition, properties, comparison with DFT.
  - o DFT-domain LP and HP filters
- **Fourier-domain image enhancement:**

- Linear filters: Ideal, Butterworth, Gaussian, DoG, Laplacian. UM
- Filter design: symmetries, windowing, freq. sampling. Separable filters
- Separable filter approximation using eigendecomposition
- McClellan Transform
- Alpha-rooting and Homomorphic filters

GEOMETRIC TRANSFORMATIONS AND INTERPOLATION
- **Geometric transformations:**
  - Bilinear and affine transformations
  - Applications: image morphing, face detection
- **1-D interpolation:**
  - R0, R1, R3 interpolation functions
  - Keys interpolator
  - 1-D interpolation by factors L and L/M using upsampling and filtering
- **2-D interpolation:**
  - 2-D separable interpolation
  - Edge-directed interpolation
  - Kriging
  - Demosaicking

IMAGE RESTORATION
- **Detail-preserving noise attenuation:**
  - Statistical properties of noise and noise generation
  - Filters: order-statistics, adaptive, rational, bilateral, BM3D
  - Noise estimation
- **Recovering from LSI degradations:**
  - Models for LSI degradation functions: defocus, atm. turbulence, motion
  - Filters: Inverse, Wiener, CLS restoration filters
  - Measuring signal fidelity: MSE and SSIM

MORPHOLOGIC IMAGE PROCESSING
- **Basic notions:**
  - Formal definitions
  - Erosion, dilation, opening, closing
- **Operators and applications:**
  - Boundary extraction
  - Hole filling
  - Extraction of connected components
  - Geodesic dilation, erosion

- o Opening and closing by reconstruction
- o Skeletonization

IMAGE SEGMENTATION
- **Methods based on image discontinuities:**
  - o Matched filtering for points and thin lines
  - o Edge detection: Sobel, LoG, Canny
  - o Edge linking: Hough transform
- **Methods based on local uniformity:**
  - o Thresholding: quality parameters; optimal thresholding; Otsu method
  - o Region growing, split and merge, watersheds
  - o Video segmentation

IMAGE COMPRESSION
- **Basic notions and tools:**
  - o Lossless and lossy coding
  - o Efficient codes, redundancy, relevance and perceptibility
  - o Run-length coding; Huffman coding
  - o Block-transform coding, quantization matrix
- **Image codecs:**
  - o JPEG baseline coder, also for color
  - o Wavelet coding concept (Jpeg2000)
  - o Lossless predictive coding
  - o Lossy predictive coding, HEVC concept
  - o Standard and popular codes