Intro to Computer Vision

- What is Computer Vision? Objectives?
- Relation to other fields
- Challenges
- Three processing levels: low/mid/high
- The role of various visual cues
- Applications

Image Formation and Representation

- Image formation: geometry + light
- Pinhole camera model
- Effect of aperture size (blurring, diffraction)
- Lens, properties of thin lens, thin lens equation
- Focal length, focal plane, image plane, focus/defocus (circle of confusion)
- Depth of field, relation to aperture size
- Field of view, relation to focal length
- Lens flaws (chromatic aberration, radial distortion)
- Human eye (focusing, rods, cones)
- Digital cameras (CCD/CMOS) – similarities/differences with cameras
- Image digitization (sampling, quantization) and representation
- Color images (how is color represented – primary colors), effect of lighting
- Image file formats

Image Filtering

- Point/Area processing methods
- Examples of point processing methods
- Area processing methods using masks
- Linear vs non-linear mask processing methods
• Correlation (and normalized correlation) - applications
• Convolution; similarities/differences with correlation
• How to choose the mask weights?
• Smoothing (averaging, Gaussian),
  o Effect of mask size, mask size for Gaussian
  o Gaussian filter properties
    ▪ Convolution with self → another Gaussian ($\sigma\sqrt{2}$ width)
    ▪ Separability (2D convolution using 1D masks) – Grad Students: proof
• Sharpening
  o Using derivatives for sharpening
  o What is the gradient and what are its properties?
  o Build sharpening masks by discrete gradient approximations

Edge Detection
• What is an edge? What causes intensity changes? Effect of illumination changes
• Edge descriptors (direction, position, strength)
• Edge models (step, ramp, ridge, roof)
• Mains steps in edge detection (smoothing, enhancement, thresholding, localization)
• Edge detection using derivatives (first → min./max, second → zero-crossings)
• Build edge masks by discrete gradient approximations (Robert, Sobel, Prewitt)
• Isotropic property of gradient magnitude
• Practical issues
  o Noise suppression-localization tradeoff
  o Thresholding
  o Edge thinning and linking
• Criteria for optimal edge detection
• Canny edge detector, steps of Canny edge detector
• Laplacian edge detector, properties, comparison with gradient magnitude
• Laplacian of Gaussian (LoG) edge detector, Difference of Gaussians (DoG) edge detector – when is it a good approximation of LoG?
• Anisotropic filtering – main idea
• Scale space methods (effect of $\sigma$, multiple scales, “interesting” scales, coarse-to-fine tracking)
Math Review

- Vectors
  - Dot (inner) / Outer products
  - Orthogonal/Orthonormal vectors
  - Linear dependence/independence
  - Vector basis
  - Vector expansion given a vector basis

- Matrices
  - Transpose, Symmetric, Determinants, Inverse, Pseudo-inverse, Trace, Rank
  - Orthogonal/Orthonormal
  - Eigenvalues/Eigenvectors, Matrix determinant/trace using eigenvalues
  - Diagonalization (and conditions), Decomposition
  - Ax=b (determined, under-determined, over-determined)
  - Conditions for solution existence of Ax=b

- Singular Value Decomposition
  - What is it? How is it computed? What is it useful for?
  - Solve Ax=b using SVD

- 2D/3D Geometric Transformations
  - Translation, scale, rotation, shear using matrices
  - Homogeneous coordinates
  - Composition of transformations
  - Rigid, similarity, affine transformations
  - Change of coordinate systems

Interest Points Detection

- What is an interest point? Why are they useful? Applications
- Invariance to geometric/photometric transformations (detector + descriptor)
- What features to use? (variation in at least two directions)
- Characteristics of good features (repeatability, saliency, compactness, locality)
- Main steps in corner detection
- Corner detection methods (contour, intensity, parametric)
- Moravec detector (steps, weaknesses)
Harris detector

- How does it improve the Moravec detector? – Grad student: proof
- Auto-correlation matrix: what information does it encode?
- Steps of Harris detector
- Strengths (good repeatability, rotation invariance)
- Weaknesses (not invariant to scale, partial invariant to photometric changes)