

ECS 174: Computer Vision, Final exam study-guide

1. Linear filters

Image formation

- Light to discrete pixel arrays
- Images in Matlab

Image noise (as motivation for linear filtering)

- Types of noise

Correlation/convolution filtering with linear filters

- 1D and 2D examples
- Definition of correlation
- Implementation detail: handling boundaries
- Smoothing filters
 - Averaging/box filter
 - Gaussian filter
 - Impact of filter width in smoothing
 - Properties
- Definition of convolution
- Examples: predicting linear filter outputs
- Properties of convolution
- Separability

Median filter, an example of a non-linear smoothing filter

2. Edge detection and image gradients

Computing image gradients with convolution

- Partial derivatives in x and y via finite differences
- Other popular finite difference derivative masks
- Properties of the gradient: direction, magnitude
- Impact of noise, counteracting with smoothing
 - Smoothing and differentiating with derivative of Gaussian filters
 - Laplacian of Gaussian filter for edges
 - Impact of smoothing scale on edges found
- Compare: mask properties for smoothing vs. derivatives
- Application with image gradients: seam carving

- Energy function definition
- Greedy solution
- Optimal solution with dynamic programming

3. Edges, contours, and binary image analysis

Edge detection

- Basic pipeline: smooth, enhance, localize
- Thresholding a gradient image for edges
- Canny edge detector
 - Non-maximum suppression
 - Hysteresis
- Low-level edges vs. perceived contours

Chamfer matching: comparing shapes from edges

- Definition of the Chamfer distance
- Computing Chamfer efficiently with the distance transform
 - Definition of the distance transform
 - Efficiently computing the distance transform
 - Using distance transform to get Chamfer distances against template
- Properties of Chamfer matching

Binary image analysis

- Thresholding to create a binary image
- Morphological operators
 - Dilation
 - Erosion

4. Texture

What is texture? What is it useful for?

Psychophysics of texture, “Textons” as primitive units of texture Texture representation

- Detect local patterns
- Describe their statistics
 - Example with gradients
- Compute distances in texture descriptor space
- Scale of a texture pattern

- Filter banks
 - Example application
 - Name that filter bank response
- Applications of texture representations

Non-parametric texture synthesis

- Markov chains, Markov random fields
- Text synthesis example
- Analogy for texture generation in images
- Image quilting extension
 - Minimum error boundary computation

5. Segmentation and grouping

Grouping problems in vision

Inspiration from human perception, Gestalt properties

Bottom-up segmentation via clustering

- Mode finding and mean shift
 - k-means:
 - Algorithm definition
 - Pros and cons
 - Examples of feature spaces: color, intensity,...
 - Texton histograms; clustering for feature space quantization
 - Mean-shift:
 - Algorithm sketch
 - Pros and cons
- Graph-based:
 - Images as graphs
 - Measuring affinity between nodes
 - Minimum cut
 - Normalized cuts; objective definition, pros and cons

Segmentation by cutting graphs

Graph definition

- Visualizing affinity matrices

Min cut and Normalized cut

- Objectives
- Pros and cons

6. Fitting

Hough Transform for lines

- Image space vs. parameter space and concept of voting
- Complete Hough Transform algorithm for lines
- Examples: interpreting Hough space, strengths and weaknesses
- Extensions to the basic approach: esp., using gradient direction
- Computational complexity

Hough Transform for circles

- Parameterization
- Variants depending on (un)known gradient direction, radius

Voting/Hough recap

- Strengths and weaknesses of the approach

Generalized Hough Transform

- Offline training for arbitrary shape model
- Detection of shapes in novel images
- Applicability beyond shape fitting

7. Fitting with deformable contours

Motivation for deformable contours:

- Beyond explicit models, need to fit unpredictable shapes
- Want to express loose shape priors
- Non-rigid, deformable objects; video
- Compare/contrast with Hough

Defining the energy functions

- External term to match image data: definition, example
- Internal term to enforce generic priors (smoothness, low curvature): definition, example
- Role of the weights in the energy function

Minimizing the energy function

- Greedy search
- Dynamic programming Viterbi algorithm (for a chain)

Summary of pros and cons

8. Alignment and fitting

- Feature-based alignment
 - Definition of alignment, place in fitting
 - 2D transformations
 - Parametric transformations

- Representing with matrices, homogeneous coordinates
- Affine fit
 - Fitting with least squares given correspondences
 - What are the correspondences?
 - Number of correspondences needed?
 - Recognition by alignment
 - Problem: outliers
- RANSAC
 - Algorithm definition
 - RANSAC for line fitting (example)
 - Pros and cons
- Homography and image reprojection
 - Perspective projection intuition
 - Connection to image mosaics
 - Solving for homographies
 - Number of correspondences needed?
 - Applying with 2d image warping (forward, inverse)
 - Using homographies to manipulate images: rectification, stitching

9. Local invariant feature detection and description

Overview of main components:

1. Detection: find the interest points
2. Description: extract a descriptor for each one
3. Matching: determine correspondence

Desirable properties: repeatability during detection, distinctiveness during description

Detection

Rotation invariant interest point detection

- Harris corner detection: review of measure, main steps, properties

Scale invariant interest point detection

- Intuition behind automatic scale selection
- Laplacian of Gaussian filter: 1d, 2d
- Characteristic scale selection
- Interest point detection across an image
- Laplacian approximated as DoG in practice

Description

Desired invariance properties: geometric and photometric transformations

Simplest solution: SSD on patch intensity

SIFT descriptor

- Definition
- Rotation invariance

Matching

- Generating candidate matches
- Eliminating ambiguous matches
- Robust alignment pipeline using detection, description, and matching.
- Applications

10. Indexing local features and applications to visual search

- Visual words: Quantizing local descriptor space
 - Connection to textons
 - Issues in visual vocabulary formation
- Bag of words representation and matching
 - Comparing bags of words
 - Tf-idf weighting
 - Scoring retrieval results with precision recall
 - Pros and cons

11. Instance recognition

- Motivation: visual search
- Visual words
 - Feature space quantization (recap)
 - Indexing with inverted file
 - Issues in visual vocabulary formation
 - Bag of words representation and comparisons
 - Vocabulary trees for large vocabularies
 - Pros and cons of visual words
- Spatial verification strategies, using affine transformation
 - RANSAC
 - Example applications, evaluating retrieval results with precision recall
 - Generalized Hough transform
 - Tradeoffs between RANSAC, GHT
- More text retrieval influence
 - Tf-idf weighting
 - Query expansion

12. Generic category recognition

Introduction to the problem: applications, challenges, state-of-the-art

Basic pipeline of category recognition techniques

Supervised classification

- Definition
- Example with skin color detection

13. Window-based models for generic object detection

Basic pipeline for generic category recognition with a window-based representation

- Representation choice: pixels, gradients, colors
- Discriminative classifier choice
- Sliding windows to generate candidates
- Classifier to score candidates

Boosting classification algorithm

- Intuition
- Weights on training samples
- Training process
- Pros and cons

Viola-Jones face detector: a prime example of window-based object detection

- Overview
- Feature definition: rectangular features, integral images
- Selecting discriminative features among all candidates with Adaboost
- Attentional cascade of classifiers
- Summary of detector pipeline
- Example results

Strengths and weaknesses of window-based detection paradigm

14. Discriminative classifiers for image recognition

- Nearest neighbors and k-nearest neighbors
 - Definition of algorithm
 - Example for scene/location recognition, global "Gist" descriptor
 - Pros and cons
- Support vector machines (SVM)
 - Large margin motivation
 - Definition of algorithm for linear case, solution

- Non-linear SVMs and the kernel trick
- Multi-class classification via binary SVMs
- Example for gender classification
- Pros and cons

15. Deep learning

- Linear perceptron
- Simple backpropagation example
- Multi-layer neural network
 - Neural network properties
 - Detection (testing) process
- Convolutional neural network
 - Convolution, Non-linearity, spatial pooling, feature maps