CSC I6716
Spring 2011

Midterm Review

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Course Outline

- Complete syllabus on the web pages (14 meets)
- Rough Outline (3D Computer Vision):
  
  **Part 1. Vision Basics** (Total 4)
  1. Introduction (1)
  2. Image Formation and Processing (1) (hw 1, matlab)
  3-4. Features and Feature Extraction (2) (hw 2)

  **Part 2. 3D Vision** (Total 7)
  5. Camera Models (1)
  6. Camera Calibration (2) (hw 3)
  7. Stereo Vision (2) (project assignments)
  8. Visual Motion (2) (hw 4)

  **Part 3. Exam and Projects** (Total 3)
  9. Project topics and exam review/discussion (1)
  10. Midterm exam (1)
  11. Student Project presentations (1)
What makes (3D) Computer Vision interesting?

- Image Modeling/Analysis/Interpretation
  - Interpretation is an Artificial Intelligence Problem
  - Sources of Knowledge in Vision
  - Levels of Abstraction
  - Interpretation often goes from 2D images to 3D structures
    - since we live in a 3D world

- Image Rendering/Synthesis/Composition
  - Image Rendering is a Computer Graphics problem
  - Rendering is from 3D model to 2D images

Related Fields

- Image Processing: image to image
- Computer Vision: Image to model
- Computer Graphics: model to image

- Pattern Recognition: image to class
  - image data mining/ video mining
  - Artificial Intelligence: machine smarts

- Photogrammetry: camera geometry, 3D reconstruction
- Medical Imaging: CAT, MRI, 3D reconstruction (2nd meaning)
- Video Coding: encoding/decoding, compression, transmission

Physics: basics
Mathematics: basics
Neuroscience: wetware to concept

Computer Science: programming tools and skills?

All three are interrelated!
3D Computer Vision
and Video Computing

Applications

- Visual Inspection (*)
- Robotics (*)
- Intelligent Image Tools
- Image Compression (MPEG 1/2/4/7)
- Document Analysis (OCR)
- Image Libraries (DL)
- Virtual Environment Construction (*)
- Environment (*)
- Media and Entertainment
- Medicine
- Astronomy
- Law Enforcement (*)
  - surveillance, security
- Traffic and Transportation (*)
- Tele-Conferencing and e-Learning (*)

2. Image Formations

- Light and Optics
  - Pinhole camera model
  - Perspective projection
  - Thin lens model
  - Fundamental equation
  - Distortion: spherical & chromatic aberration, radial distortion (*option)
- Sensing Light
- Conversion to Digital Images
- Sampling Theorem
- Other Sensors: frequency, type, ....
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3&4. Feature Extraction

- Image Enhancement
  - Brightness mapping
  - Contrast stretching/enhancement
  - Histogram modification
  - Noise Reduction
  - ........

- Mathematical Techniques
  - Convolution
  - Gaussian Filtering

- Edge and Line Detection and Extraction
- Region Segmentation
- Contour Extraction
- Corner Detection

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Edgels

- Define a local edge or edgel to be a rapid change in the image function over a small area
  - implies that edgels should be detectable over a local neighborhood
- Edgels are NOT contours, boundaries, or lines
  - edgels may lend support to the existence of those structures
  - these structures are typically constructed from edgels
- Edgels have properties
  - Orientation
  - Magnitude
  - Length (typically a unit length)
First order edge detectors (lecture - required)
- Mathematics
- 1x2, Roberts, Sobel, Prewitt
Canny edge detector (after-class reading)
Second order edge detector (after-class reading)
- (Laplacian, LOG / DOG
Hough Transform – detect by voting
- Lines
- Circles
- Other shapes

Noise Smoothing
- Suppress as much noise as possible while retaining ‘true’ edges
- In the absence of other information, assume ‘white’ noise with a Gaussian distribution

Edge Enhancement
- Design a filter that responds to edges; filter output high are edge pixels and low elsewhere

Edge Localization
- Determine which edge pixels should be discarded as noise and which should be retained
  - thin wide edges to 1-pixel width (nonmaximum suppression)
  - establish minimum value to declare a local maximum from edge filter to be an edge (thresholding)
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5. Camera Models

- Geometric Projection of a Camera
  - Pinhole camera model
  - Perspective projection
  - Weak-Perspective Projection

- Camera Parameters
  - Intrinsic Parameters: define mapping from 3D to 2D
  - Extrinsic parameters: define viewpoint and viewing direction
    - Basic Vector and Matrix Operations, Rotation

- Camera Models Revisited
  - Linear Version of the Projection Transformation Equation
    - Perspective Camera Model
    - Weak-Perspective Camera Model
    - Affine Camera Model
    - Camera Model for Planes

- Summary

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6. Camera Calibration

- Calibration: Find the intrinsic and extrinsic parameters
  - Problem and assumptions
  - Direct parameter estimation approach
  - Projection matrix approach

- Direct Parameter Estimation Approach
  - Basic equations (from Lecture 5)
  - Estimating the Image center using vanishing points- Orthocenter Theorem
  - SVD (Singular Value Decomposition) and Homogeneous System
  - Focal length, Aspect ratio, and extrinsic parameters
  - Discussion: Why not do all the parameters together?

- Projection Matrix Approach
  - Estimating the projection matrix M
  - Computing the camera parameters from M
  - Discussion

- Comparison and Summary
7. Stereo Vision

- **Problem**
  - Infer 3D structure of a scene from two or more images taken from different viewpoints

- **Two primary Sub-problems**
  - Correspondence problem (stereo match) -> disparity map
    - Similarity instead of identity
    - Occlusion problem: some parts of the scene are visible in one eye only
  - Reconstruction problem -> 3D
    - What we need to know about the cameras’ parameters
    - Often a stereo calibration problems

- **Lectures on Stereo Vision**
  - Stereo Geometry – Epipolar Geometry (*)
  - Correspondence Problem (*) – Two classes of approaches
  - 3D Reconstruction Problems – Three approaches

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- **Epipolar Geometry**
  - Where to search correspondences
  - Epipolar plane, epipolar lines and epipoles
  - **Essential matrix and fundamental matrix**

- **Correspondence Problem**
  - Correlation-based approach
  - Feature-based approach

- **3D Reconstruction Problem**
  - Both intrinsic and extrinsic parameters are known
  - Only intrinsic parameters
  - No prior knowledge of the cameras (optional)
### 8. Motion

- **Problems and Applications**
  - The importance of visual motion
  - Problem Statement

- **The Motion Field of Rigid Motion**
  - Basics – Notations and Equations
  - Three Important Special Cases: Translation, Rotation and Moving Plane
  - Motion Parallax

- **Optical Flow**
  - Optical flow equation and the aperture problem
  - Estimating optical flow
  - 3D motion & structure from optical flow

- **Feature-based Approach**
  - Two-frame algorithm
  - Multi-frame algorithm
  - Structure from motion – Factorization method (* option)

- **Advanced Topics**
  - Spatio-Temporal Image and Epipolar Plane Image
  - Video Mosaicing and Panorama Generation
  - Motion-based Segmentation and Layered Representation

### Types of questions

- Multiple choices (30)

- Short questions, proofs, and simple analysis (70%)

### Exam Time:
- May 10, 90 minutes (7:30 pm – 9:00 pm)