Class Information

• Instructor
  – Professor Kok-Meng Lee
  – MARC 474
  – Office hours: Tues/Thurs 1:00-2:00 pm
  – kokmeng.lee@me.gatech.edu
  – (404)-894-7402

• Class Website
  – http://kmlee.gatech.edu/me6406
  – http://t-square.gatech.edu
  – Notes, Homework submissions, links, etc
Prerequisites

• Graduate Standing

• MATLAB proficiency
  – Required for homework submission
  – Image Processing Toolbox
  – Available in computer labs
    • MRDC 2104, 2105
    • Library commons
Recommended Texts


Evaluation Policy

• 4 Homeworks (20% each)
  – Electronic submission to T-square
  – Individual submission
• 2 In-class Midterms (10% each)
Course Description

• Design of **algorithms** for **vision systems** for manufacturing, farming, construction and the service **industries**. **Image processing**, **optics**, **illumination** and **feature representation**.
What is Machine Vision?

• The process of acquiring one or more images, using an optical sensing device, and subsequent processing and analysis so that decisions can be made.

• Machine vision encompasses computer science, optics, mechanical engineering, and industrial automation.
What is Machine Vision?

- **Machine Vision**
  - Context of industrial applications
  - Integration with sensing & control theory
  - Illumination regulation

- **Computer Vision**
  - Field in general

- **Image Processing**
  - Operation that produces images from images
What is Machine Vision?

• Human (Biological) vs Machine Vision
  – **Qualitative vs Quantitative**
  – People can rely on inference systems and assumptions for comprehension
  – Computers do not 'see' in the same way that human beings are able to
  – Examine individual pixels of images, processing them and attempting to develop conclusions in a **consistent** manner
  – Spectral limitations of human vision (only visible spectrum)
  – Passive vs Active (we rely on external illumination to see)
Human Perception

A & B are of different gray shades?
A Machine Vision System

Sensor → Image Acquisition → Pre-processing & Enhancement

Feature Extraction → Image Analysis → Decision Making
Image Acquisition (Hardware)

Video Camera (TV-based) → Frame Grabber → Video Buffer

RS-170 standard (30 fps)

Decision → Computer Program (processing) → Computer Memory (RAM)

“Smart Cameras”

External Controller
Image Formation

- Image sensor
  - CCD, CID, CMOS, vidicon tube (visible spectrum)
  - X-ray, MRI, sonar, thermal, etc
- Sensor arrangement
  - single/array/area
- Optics
  - Pin-hole camera
  - Thin lens equation
- Illumination & lighting
- Surface texture & reflectance
  - Objects
  - Background
Illumination Surfaces

• Diffuse
  – Appear equally bright from all viewing directions
  – Absorbs no light
  – Paper & matte paints

• Specular
  – Incident angle = reflected angle
  – mirrors

• Retroreflective
  – Returns most of incident radiation in the direction close to where it originated
  – 3M’s ‘Scotchlite©’
Retroreflective Characteristics

• 3M Scotchlite

Relative reflectance compared to flat white surface.
Retroreflective illumination

- Object-Diffuse
- Background-Retroreflective
Retroreflective illumination

- Object-Retroreflective
- Background-Diffuse
Sensor Device Arrangement

- Single pixel
- Line of pixels
- 2-Dimension area of pixels
Sensor Device Arrangement

• Image acquisition using single, line sensor configurations
Image Sensors

- Charge-Coupled Device (CCD)
- Complementary metal–oxide–semiconductor (CMOS) or Active pixel sensor (APS)
- Charge Injection Device (CID)
  - Similar to CCD except in the way the electric charge is transferred before it is recorded
- Vidicon tube
  - Cathode ray tube technology
CCD Architecture

- Full-frame transfer
  - Row-by-row
  - Pixel-by-pixel
  - Simultaneous acquisition and reading
- Frame-transfer
  - Duplicate array so that image can be read slowly from the storage region while a new image is exposing in active area
- Interline transfer
  - 1 pixel transfer from image to storage
  - Imaging area is reduced 50%
• Pinhole camera
  – The most basic/elementary imaging device
  – Projection of image without lens
• Hole size
  – Smaller: better focus, darker image
  – Larger: blurred image, brighter image
• Issues:
  – Low-light accumulation capability
  – Light diffraction
    • Bending of light as it passes an aperture
The Optical Lens

- Optical lens allow creation of a brighter image by converging light
Thin Lens Equation

- \( f_o = f_i \) ideal lens,

By similar triangles,

\[
\frac{d_o}{d_i} = \frac{z_o}{f_o} = \frac{f_i}{z_i}
\]

\[ z_i z_o = f_i f_o = f^2 \]

\[ Z = z_o + f_o \]

\[ z = z_i + f_i \]

\[ (Z - f_o)(z - f_i) = f_i f_o \]

\[
\frac{1}{Z} + \frac{1}{z} = \frac{1}{f} \]

Ideal thin lens equation
Lens Imaging

- Points at other distances are imaged as little circles (red)

By ideal lens equation: \( \frac{1}{z'} + \frac{1}{-z} = \frac{1}{f} \) & similar triangles, \( \bar{d}' = \frac{|\bar{z}' - z'|}{z'} \cdot d \)

Blur circle definition

\[
\bar{d}' = \frac{d}{z} \left( \frac{f}{z + f} \right) \left( \frac{f}{\bar{z} + f} \right) |\bar{z} - z|
\]

Blur size decreases with focal length

\( f=0, \text{ blur is a point} \)

To attain a ‘clear’ image, diameter of blur circle is less than resolution of imaging device