Introduction to Computer Vision
What is Computer Vision?

• A process that produces from images of the external world a description that is useful to the viewer and not cluttered with irrelevant information (Marr)

• Construction of explicit, meaningful descriptions of physical objects from images (Ballard and Brown)

• To make useful decisions about real physical objects and scenes based on sensed images (Shapiro and Stockman)
Related Field – Image Processing

• Image Processing
  – Image in, image out
  – Usually low level techniques (eg, compression, edge detection)
  – Quantitative measurements

• Computer Vision
  – Extracting symbolic descriptions
  – Higher level techniques (eg, object recognition)
  – Semantic (quantitative or qualitative) output

• Image processing techniques are often used in computer vision

• The definitions are not firm - there is overlap between the fields

Example of median filtering, from Digital Image Processing, by Gonzalez and Woods
Related fields - continued

• **Pattern recognition**
  – Recognition of patterns (classification)
  – Inputs often represented as feature vectors
  – Techniques useful for 2D and constrained 3D image recognition problems, but usually too limited for general 3D problems

• **Photogrammetry**
  – Concerned with accurately measuring properties from images
  – An older field - historically focused on remote sensing (e.g., images from airplanes or satellites)
  – Computer vision concerned with more than just measuring
  – However, many techniques are the same or similar
Related field - Computer Graphics

• Computer vision is the inverse of computer graphics

3D Models of objects, locations
  Lighting information
  Camera parameters

• The forward process is unique, the inverse process is not!

http://www.matthewdoucette.com/renderedgraphics

http://www.balletwest.org/blog/2009/02/08/a-post-from-allison-debona/
Although easy for people, vision is difficult for computers

- Objects can be highly variable in shape
  - E.g., trees, cars, animals, ...
- Loss of information in sensing process
  - 3D objects projected onto 2D images
- Missing data
  - Occlusions and hidden surfaces
  - Shadows and noise obscure signal
- Confounding effects
  - Observed color may be due to object albedo or scene lighting
Approach to Solution

• Apply assumptions and *a priori* knowledge to recover the most likely description

• Use knowledge of object shape and the lighting that is present (if available)

• Use information from multiple images (stereo, motion sequences)

• Guess based on cues
  - Shading, texture, geometry
  - Knowledge about typical real world objects
Optical Illusions

- Human visual system is good at picking out structure from noisy, incomplete, and missing data

- We make and use assumptions about the real world to do this

- Optical illusions occur when these assumptions are incorrect

Subjective contours

dragon.uml.edu/psych/kaniza.html
Optical Illusions
Optical Illusions
Optical Illusions

• Perception of shape depends on context
Optical Illusions

- Perception of shape depends on context
Optical Illusions

• The influence of 3D interpretation
Optical Illusions

• The influence of shading

A raised cone?  A crater depression?
Optical Illusions

• Color perception

Which square is darker, A or B?
A difficult image interpretation problem
Example Application Areas

• Industrial inspection
  – Find known objects in the scene
  – Measure dimensions, verify features

• Optical character recognition
  – Processing scanned text pages
  – Detect and identify characters

儘眼望遠極，
侓程無窮哩。
壹物明域現，
以過吾後脊！
Example Application Areas

- Medical modeling
  - Surgical planning and navigation

- Robotic vehicle navigation
  - Estimate motion and position of vehicle
  - Detect and model obstacles
  - Find safe path through environment

Modeling bones from biplanar X-ray images (Hoff, King)
Convoy Active Safety Technology (CAST)

A Kit-Based, Platform-Independent and Cost-Effective Convoy Automation System

The AutoMate™ sensor and actuator kit enables CAST to be an agile, versatile and survivable sustainment system of multi-vehicle convoys which are ready, reliable and secure. With the need for a low-cost multi-vehicle autonomous convoy capability, our goal is to design, demonstrate and deploy a system that is capable of both lateral and longitudinal control of various tactical wheeled vehicles relative to a lead vehicle in order to improve convoy safety, security, survivability and sustainment. Our system has been shown to significantly reduce crew fatigue, eliminate rear-end collisions, enhance operator situational awareness and enable a more effective response to attack.

Proven Features

- Five-Vehicle Convoys
- Integrated FMTV & M915
- POV Incursion Handling
- Dynamic Obstacle Detection
- Governed Column Intervals
- Limited Visibility Operation
- Night-Vision Driving Ready
- Split and Rejoin Handling
- 50 mph on Paved Roads
- 35 mph on Dirt Roads
- Single Button Operation

CAST Performance

- 25% More Targets Identified and 10m Further Away
- 85% Improvement in Emergency Brake Response
- 87% Reduction in Governed Interval Distance Error

System Capabilities

- Vehicle Following
- Obstacle Avoidance
- Road Following
- Interval Maintenance
- Obstacle Avoidance
Example Application Areas

• Scene modeling
  – Find and identify objects (ships, buildings, roads)
  – Create models of scenes from multiple images

http://www.ai.sri.com/project/BADD

Paul Debevec and Jitendra Malik
Example Application Areas

- Target recognition
  - Find enemy vehicles (which are trying not to be found!)

- Human Interfaces
  - Detect faces and identify people
  - Recognize gestures, activities

FLIR image from sdvision.kaist.ac.kr/

SAR image from web.mit.edu/6.003/courseware/
Example Application Areas

- Augmented reality
  - Augment the real world with virtual objects

- Robotics
  - Recognize objects
  - Estimate motion and position

http://www.robocup.org/

John Steinbis, CSM MS thesis
Software

• MATLAB
  – Commercial package (but only $49-99 for students)
  – Interpreted language – easy to prototype
  – Image processing and computer vision toolbox

• OpenCV
  – Free
  – C/C++; good for real time applications

• Many applications have simple image editing functions
  – Photoshop
  – GIMP
  – iPhoto
  – ImageJ
Good Resources

• Some key journals
  – IEEE Trans. Pattern Analysis & Machine Intelligence
  – Int’l Journal of Computer Vision

• Some key conferences
  – Computer Vision and Pattern Recognition (CVPR)
  – Int’l Conference on Computer Vision (ICCV)

• Some good websites

• Getting papers
  – CSM library e-journal collection
  – CiteSeerx - http://citeseerx.ist.psu.edu/
  – Google Scholar