Slide 1

What is computer vision ?

Computer vision (image understanding) is a discipline that studies how to *reconstruct*, *interpret* and *understand* a 3D scene from its *2D images* in terms of the *properties* of the structures present in the scene.

Slide 2

What is computer vision (cont'd) ?

The ultimate goal of computer vision is to model, replicate, and more importantly exceed human vision using computer software and hardware at different levels. It needs knowledge in computer science, electrical engineering, mathematics, physiology, biology, and cognitive science.

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Limitations of Human Vision

- limited memory-cannot remember a quickly flashed image
- limited to visible spectrum
- illusion

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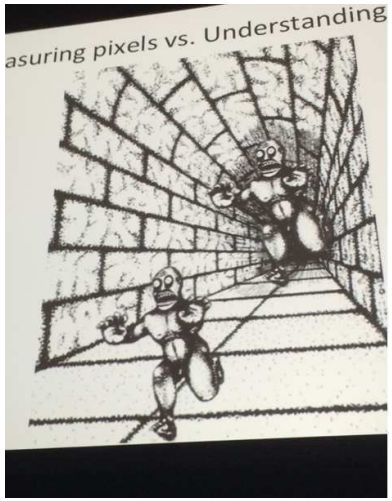
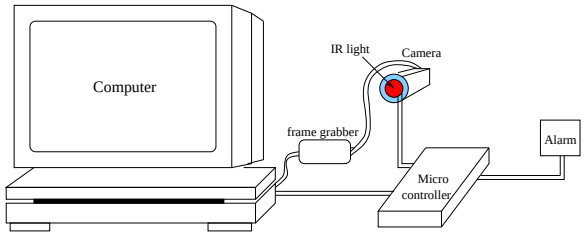


Slide 5

Typical hardware components of a computer vision system



We focus on *computer vision algorithms* and their software implementation.

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Computer Vision Hierarchy

- Low-level vision: process image for feature extraction (edge, corner, or optical flow).
- Middle-level vision: object recognition, motion analysis, and 3D reconstruction using features obtained from the low-level vision.
- High-level vision: interpretation of the evolving information provided by the middle level vision as well as directing what middle and low level vision tasks should be performed. Interpretation may include conceptual description of a scene like activity, intention and behavior.
- we focus mainly on middle level and some low level.

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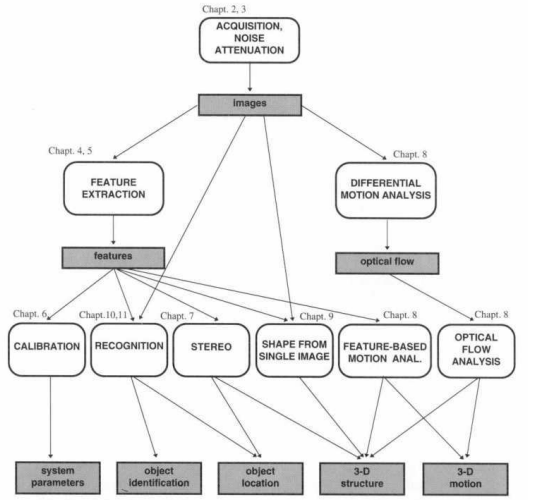
Computer Vision Hierarchy (cont'd)



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Why Is Computer Vision Difficult ?

- The problem is *ill-posed inverse* problem.
- Noisy image data or data with uncertainties.

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Related Fields

Computer vision overlaps significantly with the following fields: image processing, and pattern recognition.

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Computer Vision v.s. Image Processing

Image processing studies *image-to-image transformation*. The input and output of image processing are both images. Typical image processing operations include

- image compression
- image restoration
- image enhancement

Most computer vision algorithms usually assumes a significant amount of image processing has taken place to improve image quality.

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Computer Vision v.s. Pattern Recognition

Pattern recognition (also called machine learning) studies various mathematical techniques (such as statistical techniques, neural network, support vector machine, etc..) to classify different patterns. The input data for pattern recognition can be any data. Pattern recognition techniques are widely used in computer vision. Many vision problems can be formulated as classification problem.

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Computer Vision v.s. Image Processing (cont'd)

Computer vision is the construction of *explicit, meaningful descriptions* of physical objects from their images. The output of computer vision are a description or an interpretation or some quantitative measurements of the structures in the 3D scene. Image processing and pattern recognition are among many techniques computer vision employs to achieve its goals.

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Example Applications

- Robotics
- Medicine
- Security
- Transportation
- Industrial automation
- Image/video databases
- Human Computer Interface

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Robotics Applications

- Localization-determine robot location automatically (e.g. Vision-based GPS)
- Obstacles avoidance
- Navigation and visual servoing
- Assembly (peg-in-hole, welding, painting)
- Manipulation (e.g. PUMA robot manipulator)
- Human Robot Interaction (HRI): Intelligent robotics to interact with and serve people

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Figure 1: NASA rover for for planetary surface exploration

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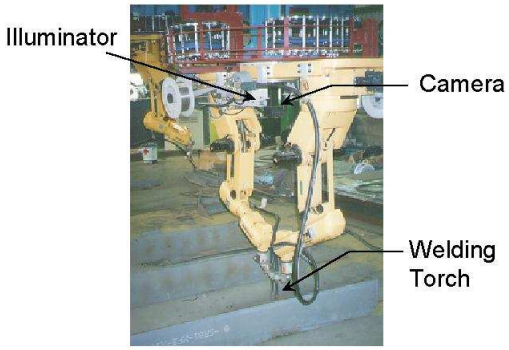

Figure 2: A vision-guided welding machine

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Figure 3: Real time visual servoing for robot grasping

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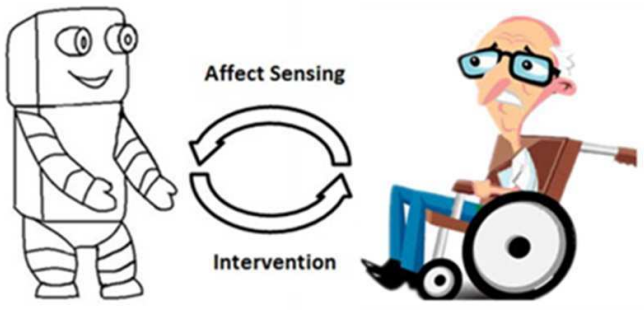

Figure 4: HRI: companion robot

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Industrial Automation

- Industrial inspection (defect detection and mensuration)
- Assembly
- Barcode and package label reading (e.g. iPhone scanner)
- Object sorting
- Document understanding (e.g. OCR)

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Geometric Tolerancing

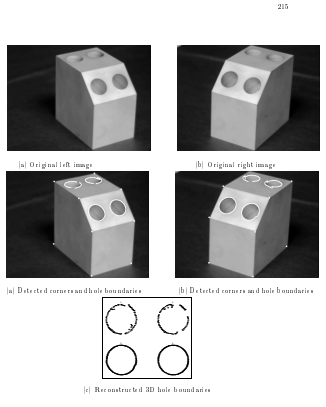

Figure 11.3: Results of feature extraction and 3D reconstruction for part 3

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Medicine (Medical Imaging)

- Classification and detection (e.g. lesion or cells classification and tumor detection)
- 2D/3D segmentation
- 3D human organ reconstruction (MRI or ultrasound)
- Vision-guided robotics surgery

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Medical Imaging

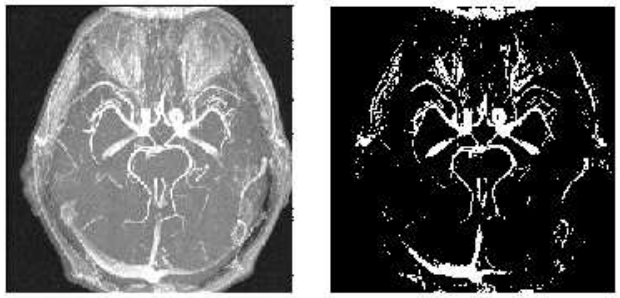

Figure 1.4: Magnetic resonance image (left) where brightness relates to material movement, and binary image (right) resulting from changing all pixels with value 208 or more to 255 and those below 208 to 0.

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Medical Imaging (cont'd)

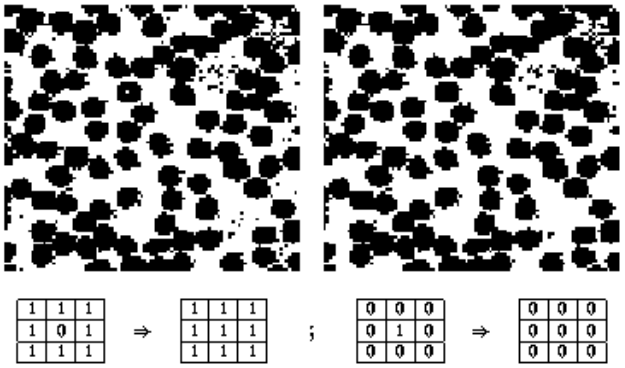

Figure 1.7: (Top left) Binary microscope image of red blood cells; (top right) cleaner image resulting from removal of tiny dark regions inside light regions or visa versa; (bottom) templates showing how pixel neighborhoods can be cleaned.

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Security

- Biometrics (iris, finger print, face recognition)
- Surveillance-detecting certain suspicious activities or behaviors

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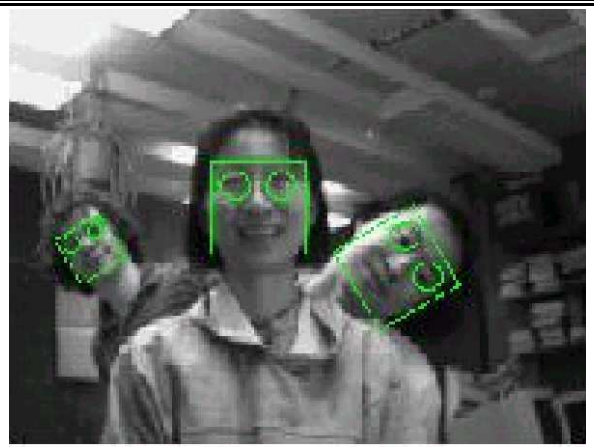
Security: Face Detection and Recognition



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Transportation

- Autonomous vehicle
- Safety, e.g., driver vigilance monitoring

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Image/Video Database Search/Retrieval

It is mainly used for image retrieval based on image content.

Figure 1.2: Image query by example: query image(left) and two most similar images produced by an image database system (from the MS thesis of Aditya Vailaya).

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Human Computer Interface

- Gaze estimation
- Face expression recognition
- Head and hand gesture recognition

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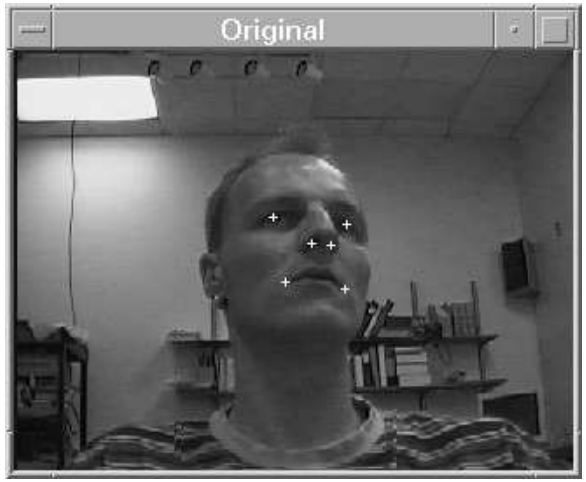
Head Pose and Gaze



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Computer Vision Literature

1. Journals
   - IEEE transactions on Pattern Recognition and Machine Intelligence (PAMI)
   - International Journal of Computer Vision
   - Computer vision and image understanding
   - Image vision and computing
   - Machine vision and application
   - Pattern recognition
2. Conferences
   - International conference on computer vision (ICCV)
   - IEEE conference on computer vision and pattern recognition (CVPR)
   - International conference on image processing (ICIP)

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- International conference on pattern recognition (ICPR)
- IEEE conference on robotics and automation

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Computer Vision Resources

Computer Vision Information Pages http://www.visionbib.com

- Publications
- Vision groups
- Software
- Conferences
- Image databases
- Vendors and companies

Additional links for computer vision may be found

http://www.cns.nyu.edu/∼eero/vision-links.html

http://www.cs.berkeley.edu/∼daf/book.html

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Image Processing Resources

- computer vision newsgroup:
  http://www.vislist.com/
- image processing newsgroup:
  sci.image.processing
- Fundamentals of Image Processing
  http://www.ph.tn.tudelft.nl/Courses/FIP/noframes/fip.html
- An Image Processing Tutorial
  http://www.cs.washington.edu/research/metip/tutor/tutor.html

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Topics

- Image Acquisition and Formation
- Perspective Projection Geometry
- Camera Calibration and Pose Estimation
- 3D Reconstruction (from a single and multiple images)
- Motion Estimation and Tracking
  Optical flow estimation
  Object tracking with Kalman filtering
  Structure from motion
- Feature Extraction (Edge, point, line, curve)
- Object recognition

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Background Needed

- Pattern recognition and machine learning
- Numerical analysis
- Statistics
- Linear and non-linear optimization and regression
- Programming skills
- Computational geometry
- Projective geometry
- Digital signal processing
- Physics

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Outcomes

- understand the fundamental computer vision theories
- have the ability to design and implement certain computer vision techniques
- have the capability of applying computer vision technologies to applications of interest.

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References to Computer Vision Terminologies

1. Dictionary of Computer Vision and Image Processing, Robert Fisher, Ken Dawson-Howe, Andrew Fitzgibbon, Craig Robertson, Emanuele Trucco, Wiley, 2005.

2. R. M. Haralick and L. G. Shapiro, "Glossary of Computer Vision Terms," *Pattern Recognition* 24:69-93, 1991.

3. R. M. Haralick, "Glossary and index to Remotely Sensed Image Pattern Recognition Concepts," *Pattern Recognition* 5:391-403, 1973.