4422/5323 Computer Vision

Unit 0: Introduction

Outline

- Motivation
- Definition
- Allied areas
- Varied aspects of computer vision
- What this course will emphasize

Motivation: Vision as an information source

A source of information about the surrounding world

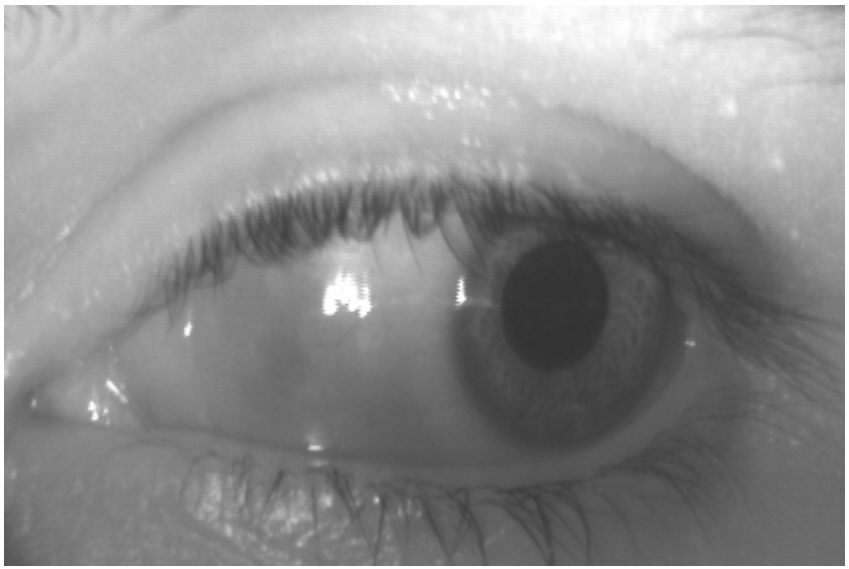
- Object identity
- Object location
- Object dynamics

Supports intelligent interaction with the environment

- Navigation
- Manipulation
- Decision making

Information derived without physical contact

- Optical data is acquired at a distance.
- Enables unobtrusive sensing.



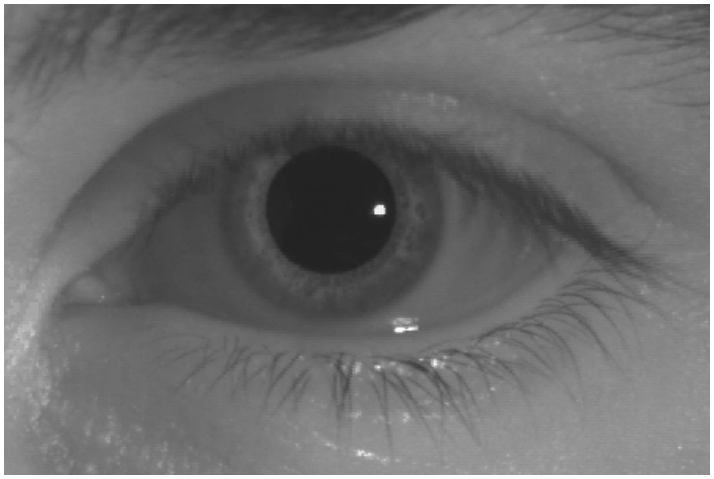
Motivation: Benefits of artificial vision systems

Theoretical

- Provides a rigorous paradigm for the study of visual processing.
- Provides a concrete example of a complex information processing task.

Practical

- Ameliorates need for people to perform tedious and/or dangerous tasks.
- Supports enhanced human performance.



“human eye”

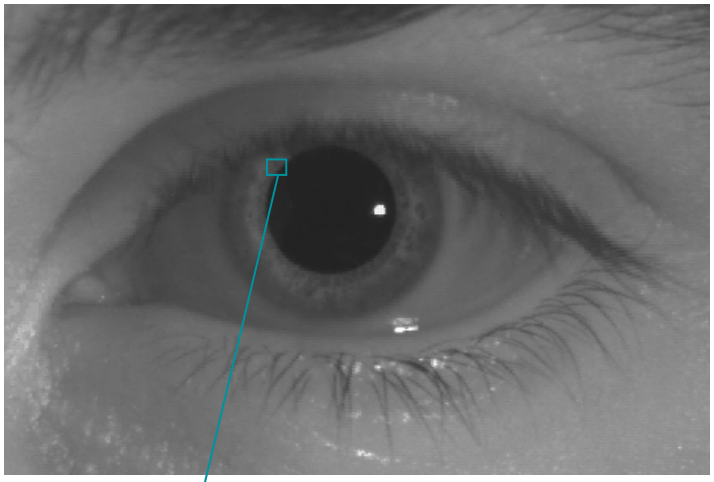
Motivation: Challenges of computer vision

Desired information is not explicit in the sensed data

- Image data is a complex function of
  - scene geometry
  - scene surface microstructure
  - scene illumination
- Biological systems provide an existence proof
  - but appear to be complex
  - are only partially understood, even after great research effort

Status

- Significant progress has been made for circumscribed scenarios.
- Much work to be done to support flexible, real-world operation.



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“human eye”

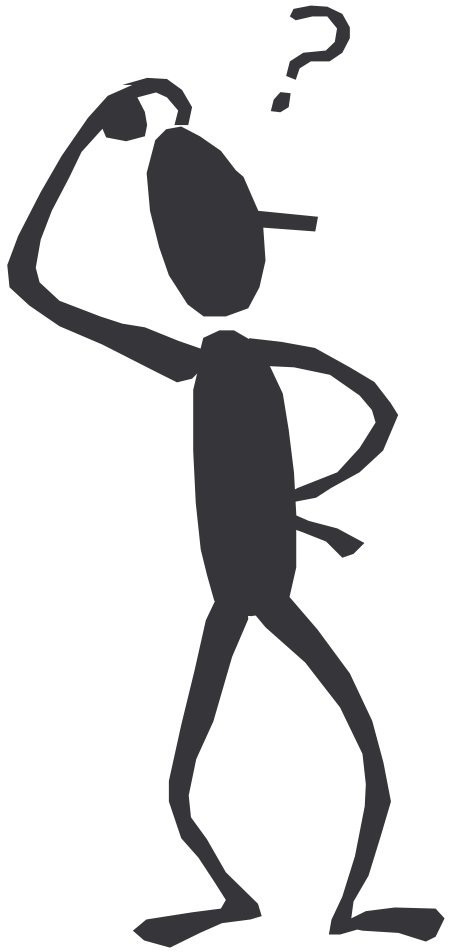
Definition: What is computer vision?

Problems of computer vision

- Computing properties of the world from one or more images
- Properties of interest:
  - geometric (shape, position),
  - photometric (surface reflectance)
  - dynamic (velocity)

Tools of computer vision

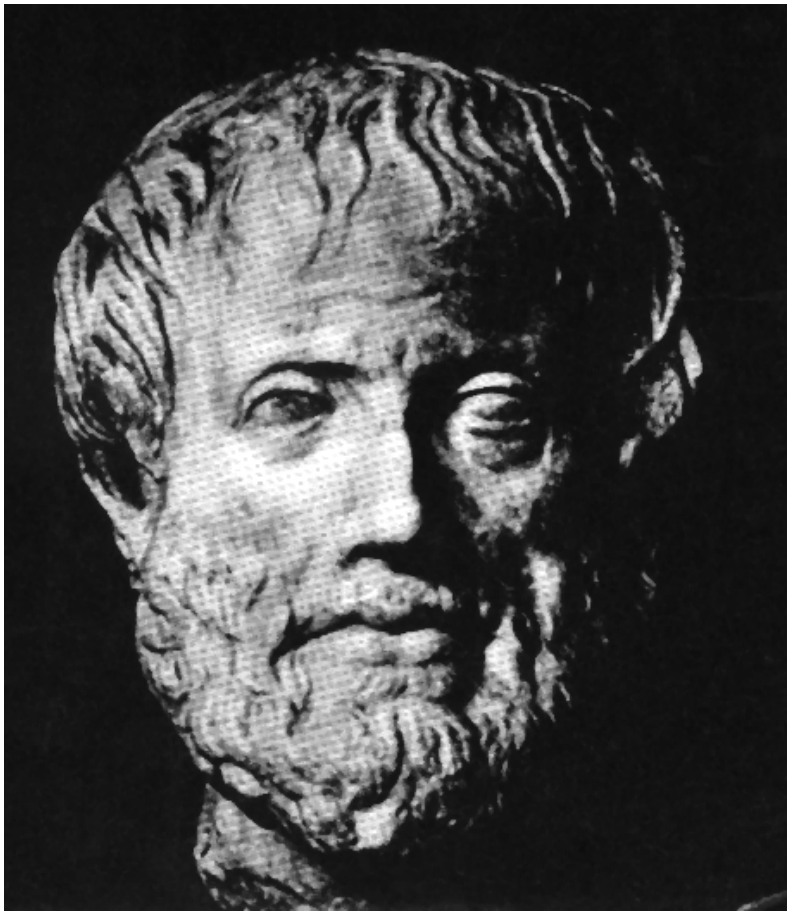
- Computers to interpret images
- Specific hardware and software to acquire, store, process and communicate (transmit) images.
- Algorithms for computing the desired information from available input.



Definition: What is computer vision?

Vision

- to know what is where by looking
- Aristotle's definition



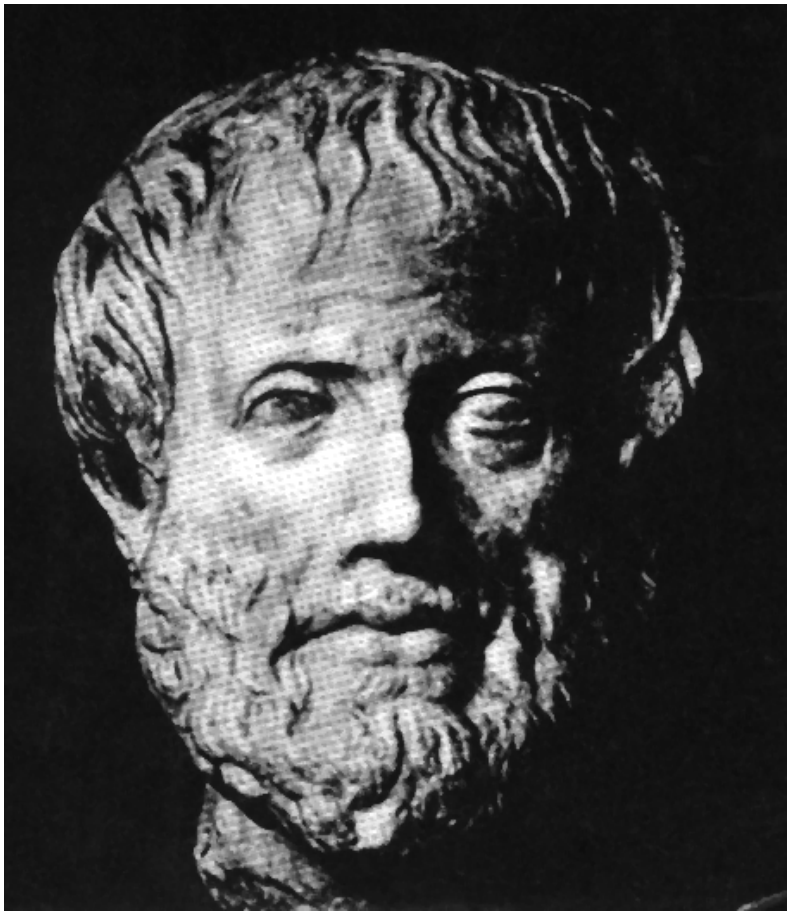
Definition: What is computer vision?

Vision

- to know what is where by looking
- Aristotle's definition

Computer vision

- the study of recovering useful properties of the world (what, where)
- from one or more images (by looking)
- with an algorithmic level of specification



Allied areas of investigation: Interrelationships

- **Image processing**
- **Photogrammetry**
- **Pattern recognition**
- **Computer graphics**

Allied areas: Image processing

Subject

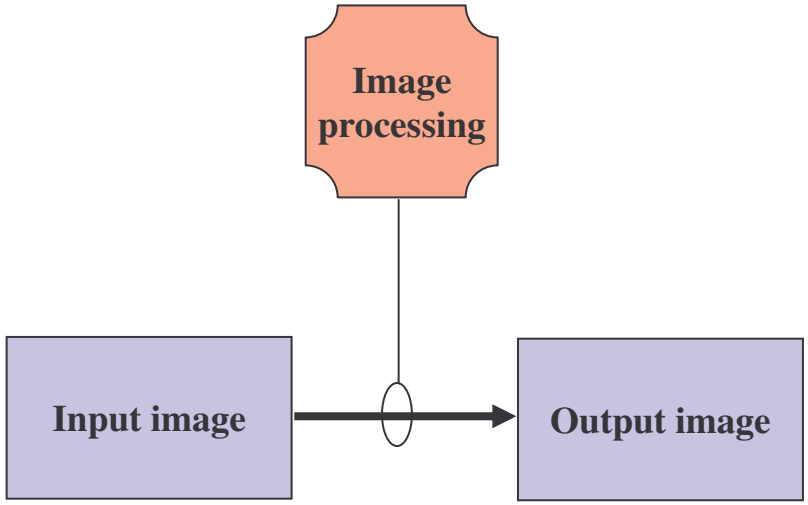
- Generation of new images from existing images.
- Images altered in some desired fashion.

Examples

- noise suppression
- feature enhancement
- video stabilization

Relationship to computer vision

- Often serves to provide components to computer vision.
- Preprocessing of sensed data.



Allied areas: Photogrammetry

Subject

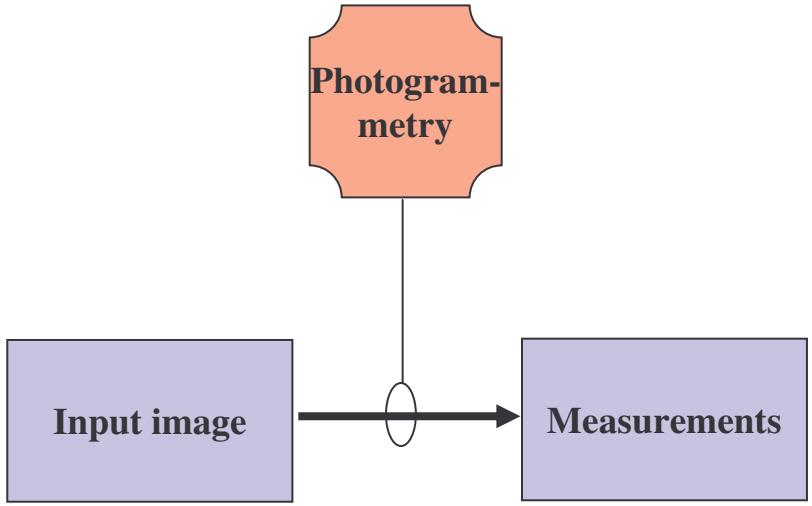
- reliably accurate measurements
- from noncontact imaging

Examples

- aerial cartography
- surveying

Relationship to computer vision

- Typically seeks higher levels of precision than computer vision.
- Not all computer vision is concerned with quantitative measurements.



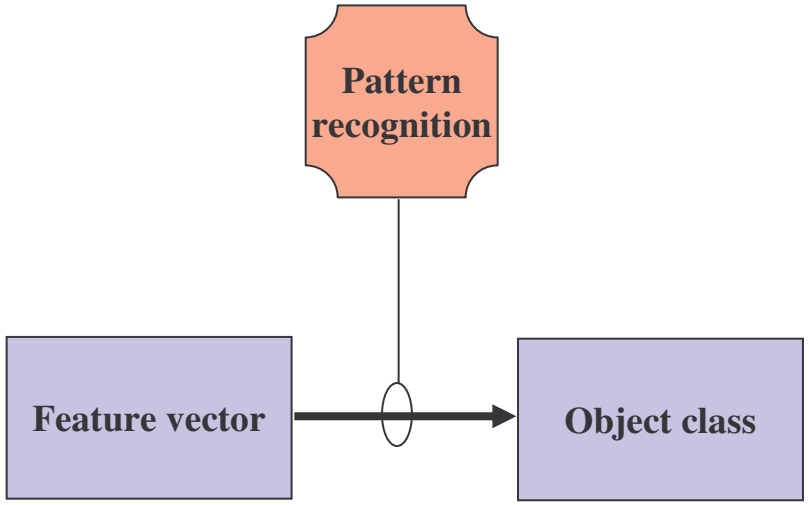
Allied areas: Pattern recognition

Subject

- Classification of patterns
- Pattern represented by a set of numbers representing characteristics of an object (e.g., height, weight)

Examples

- Classification of chemical composition from spectral measurements.
- Classification of disease from symptoms.
- Classification of targets from visual features.



Relationship to computer vision

- Techniques of pattern recognition can usefully be applied to the output of a computer vision system.
- Capable of assigning imaged objects to classes based on vision processing.

Allied areas: Computer graphics

Subject

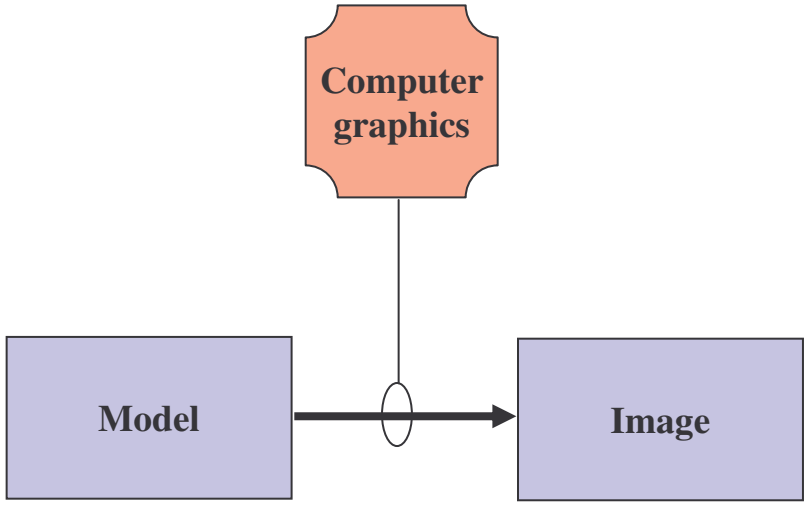
- Generation of images from models or other computational specification.

Examples

- Photorealistic rendering
- Computer animation
- Abstract design

Relationship to computer vision

- Akin to an inverse
- Potential to combine forces, e.g., image based rendering (IBR)



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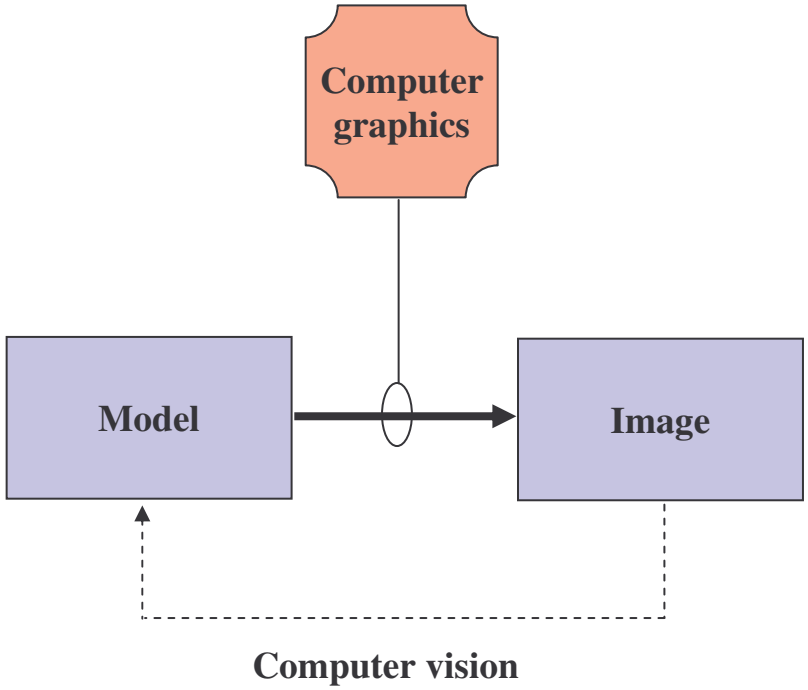

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Varied aspects of computer vision

- **Research areas**
  - topics addressed by a significant number of publications
  - a visible indicator of research

- **Application areas**
  - domains where computer vision is used to solve real-world problems
  - possibly in conjunction with other technologies

Varied aspects: Research

- **Image feature detection**
- **Colour analysis**
- **Texture analysis**
- **Camera calibration**
- **Shape representation**
- **Shape recovery from single image cues (shape-from-X)**
- **Stereopsis**
- **Motion analysis**
- **Object recognition and localization**
- **Active vision**
- **High-performance and real-time architectures**

Research areas: Feature detection

Goal

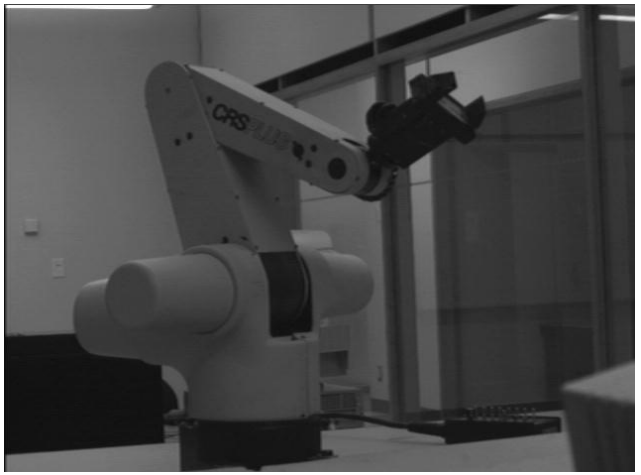
- Detect presence and position of specific structures in images
- Examples: edge detection, corner detection, shape detection (lines, circles)

Challenges

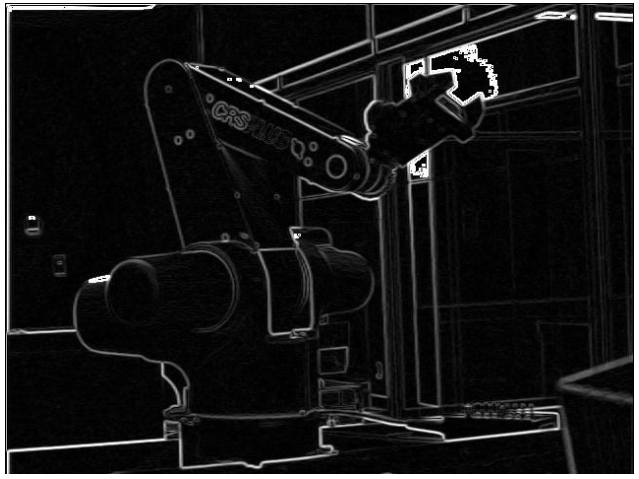
- Operation with clutter and other high noise situations
- Trade-offs in specificity vs. generality
- Trade-offs in sensitivity in identification vs. precision in localization

Approaches

- Template matching
- Tuned filtering



Source image



Edges detected

Research areas: Stereopsis

Goal

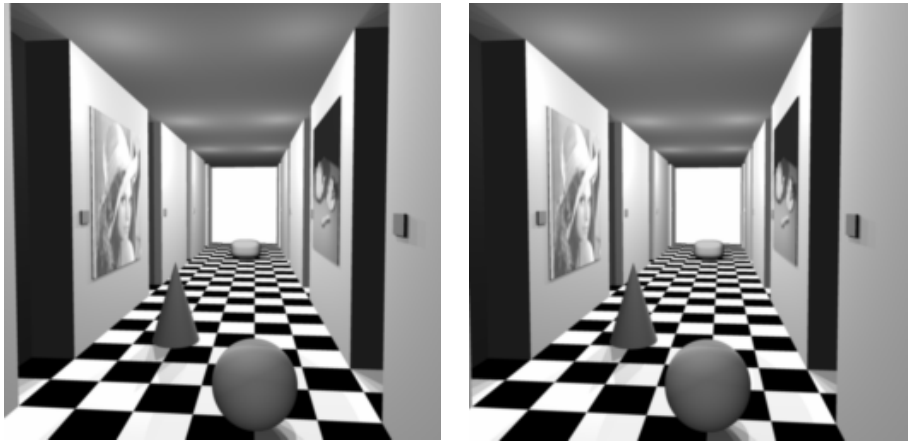
- given 2 (or more) images of a scene
- recover 3D scene geometry

Challenges

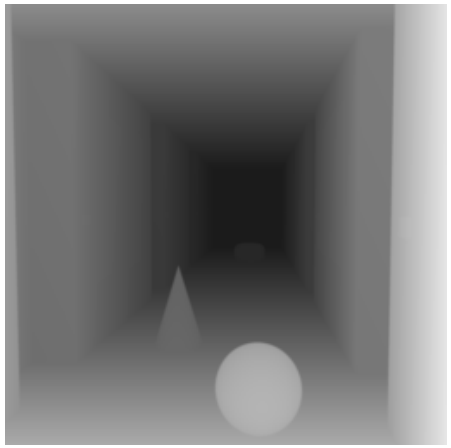
- attaining accurate camera calibration (or developing methods that due without)
- establishing correspondence between disparate views
- unambiguous interpretation of estimated correspondences

Approaches

- analysis based on extraction of discrete image features (e.g., edges)
- analysis based on continuous image regions



Stereo pair



Range map

Research areas: Motion analysis

Goals

- from a temporal sequence of images
- recover (dynamic) properties of the scene

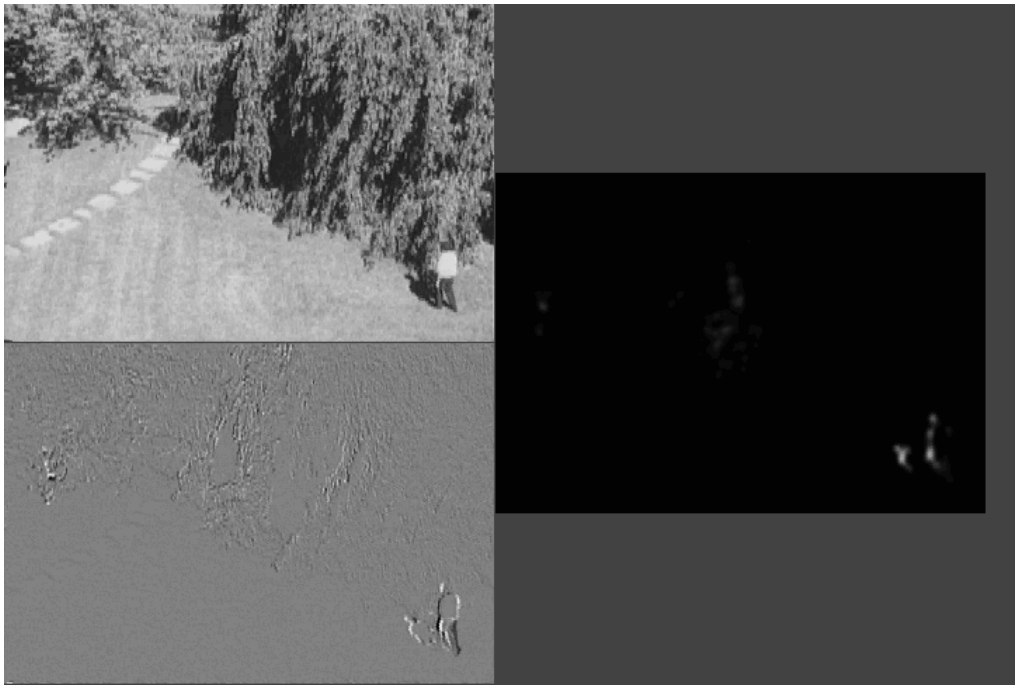
Challenges

- establishing relationship between image locations across time
- unambiguous interpretation of established relationships
- robustness to appearance change, large displacements and occlusion effects

Approaches

- correlational analysis of image templates
- analysis of spatial and temporal gradients
- spatiotemporal filtering
- regression-based model fitting

Source video



Change images

Detected coherently moving object

Research areas: Object recognition and localization

Goals

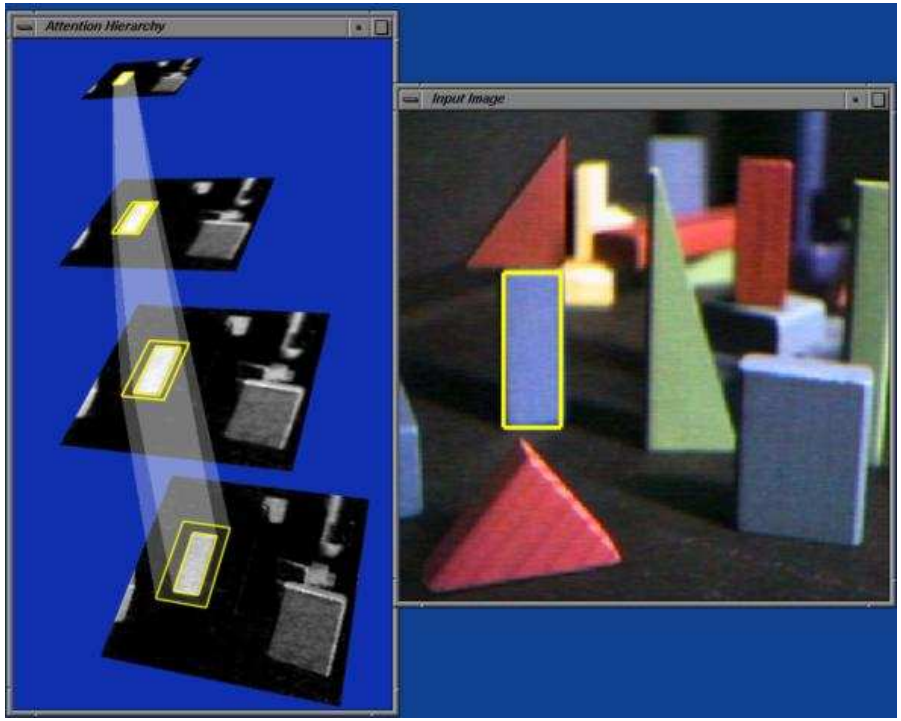
- identification of objects in scene
- and their positions

Challenges

- reliable extraction of object features
- grouping features of a common object (prior to recognition)
- indexing into large databases
- accurate verification of hypotheses

Approaches

- alignment of image features to stored models
- extraction of geometric and photometric invariants as indexing keys



Recognized model projected on source image

Varied aspects: Applications

- **Industrial inspection**
- **Surveillance and monitoring**
- **Person recognition (automated fingerprint, face, iris,…)**
- **Human computer interface**
- **Autonomous vehicles**
- **Hand-eye robotics**
- **Medical image analysis**
- **Image databases**
- **Virtual and augmented reality**

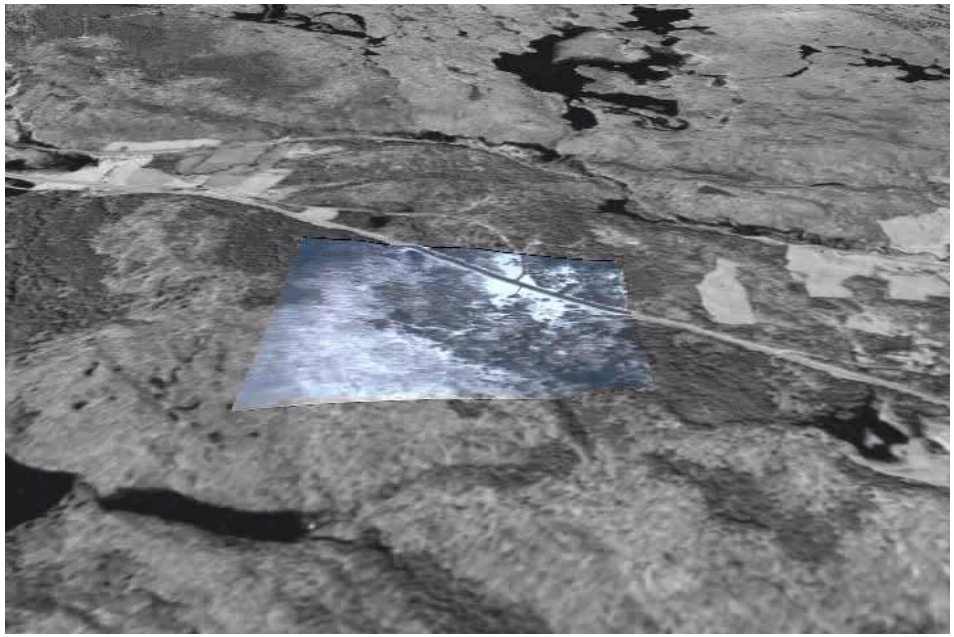
Application areas: Aerial surveillance

Real-world needs

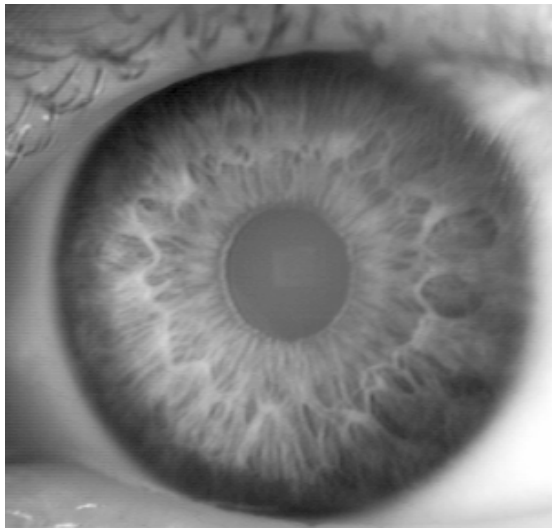
- acquisition of information about ground activities
- from well positioned mobile platform

State of the art example

- video geolocation
- alignment of video to calibrated reference imagery to attain geodetic coordinates



Application areas: Personal identification



Real-world needs

- secure access control to sensitive areas and materials
- reliable personal verification and identification

State of the art example

- biometric-based identification
- automated iris recognition

Application areas: Human computer interface

Real-world needs

- More natural interfaces between humans and computers (and other artifacts)
- Increased speed and ease of interaction

State of the art example

- Automated hand gesture recognition.
- Vision-based detection, localization and tracking

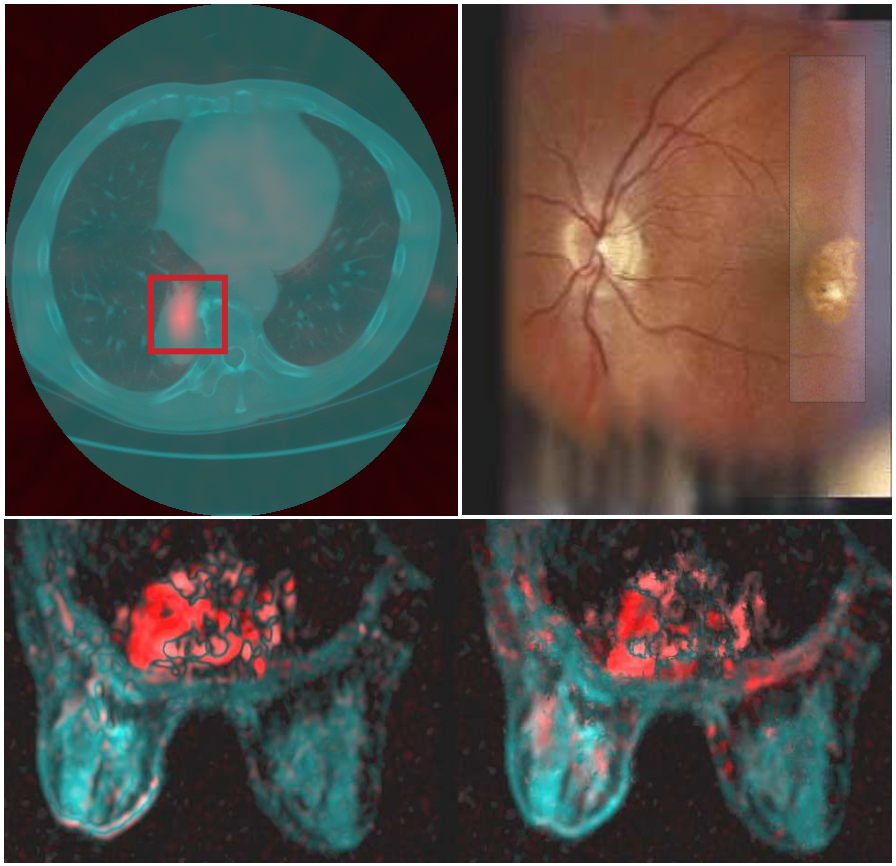
Application areas: Medical

Real-world needs

- aides to physicians in diagnosis of disease
- tools for increasing accuracy and throughput

State of the art examples

- shape-based lesion detection
- alignment of real-time retinal imagery with previous reference
- change detection for cancer detection



Emphasis of this course

- **Concentrate on**
  - Fundamental analyses of visual information processing
  - Algorithms that exploit these analyses

- **Topics**
  - Overview of computer vision
  - Image formation
  - Image representation
  - Feature detection
  - Stereopsis
  - Motion analysis
  - Example applications

Summary

- **Motivation**
- **Definition**
- **Allied areas**
- **Varied aspects of computer vision**
- **What this course will emphasize**