Introduction to Computer Vision

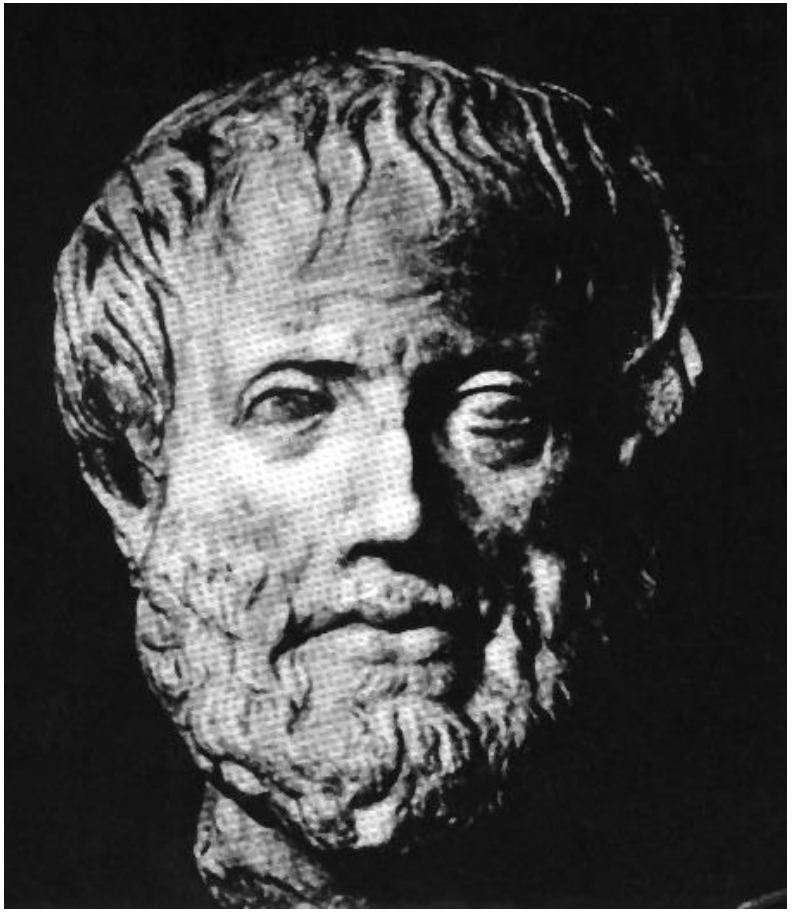
Vision: an information source

1. **A source of information about the surrounding world**
   - Object identity
   - Object location
   - Object dynamics

2. **Supports intelligent interaction with the environment**
   - Navigation
   - Manipulation
   - Decision making
3. **Information derived without physical contact**
   - Optical data is acquired at a distance.
   - Enables unobtrusive（不誇張的）sensing.

Vision

- What does it mean
  - to see?
  - **“to know what is where by looking”.**



---Aristotle’s definition

- Vision allows humans to perceive and understand the world surrounding us.

- How to discover from images what is present in the world, where things are, what actions are taking place.

Definition: What is computer vision?

- **Computer vision** aims to duplicate the effect of human vision by electronically perceiving and understanding an image.
  - The study of recovering useful properties of the world (what, where)
  - from one or more images (by looking)
  - with an algorithmic level of specification

- Deals with the development of the **theoretical** and **algorithmic** basis by which useful information about the 3D world can be automatically extracted and analyzed from a **single** or **multiple** of 2D images of the world.

Computer Vision, Also Known As ...

- Image Analysis
- Scene Analysis
- Image Understanding

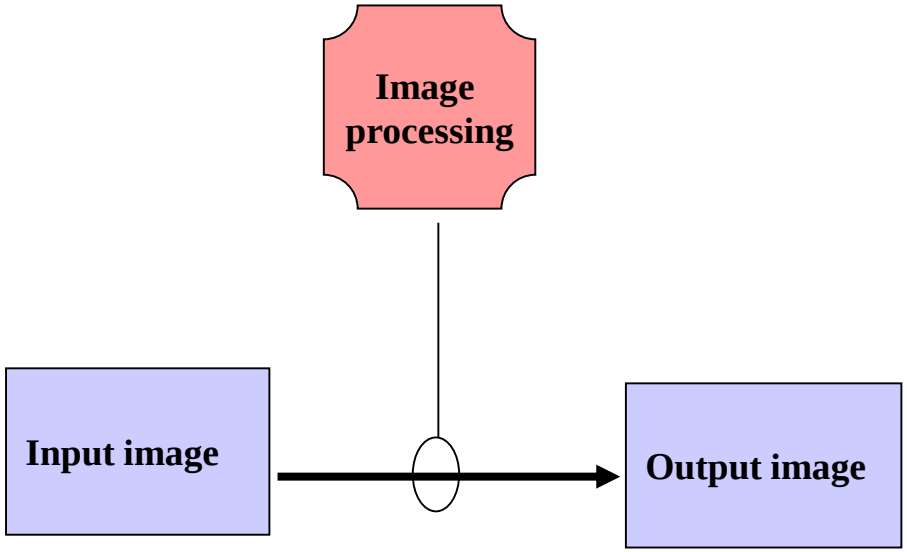
- **Problems the computer vision solves**
  - Computing properties of the world from one or more images
  - Properties of interest:
    - geometric (shape, position),
    - photometric (surface reflectance)
    - dynamic (velocity)

Some Related Disciplines

- Image processing
- Pattern recognition
- Computer graphics
- Robotics
- Artificial Intelligence

Image processing

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



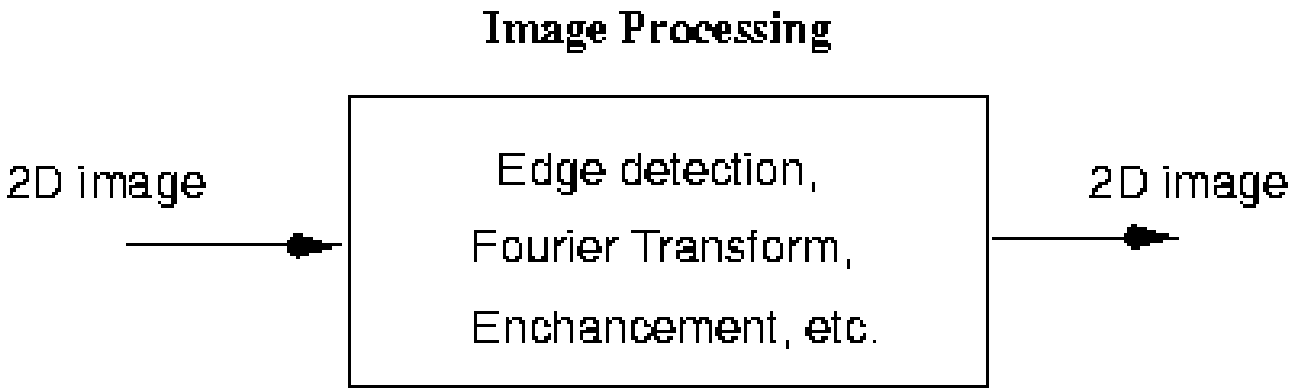


Image Enhancement

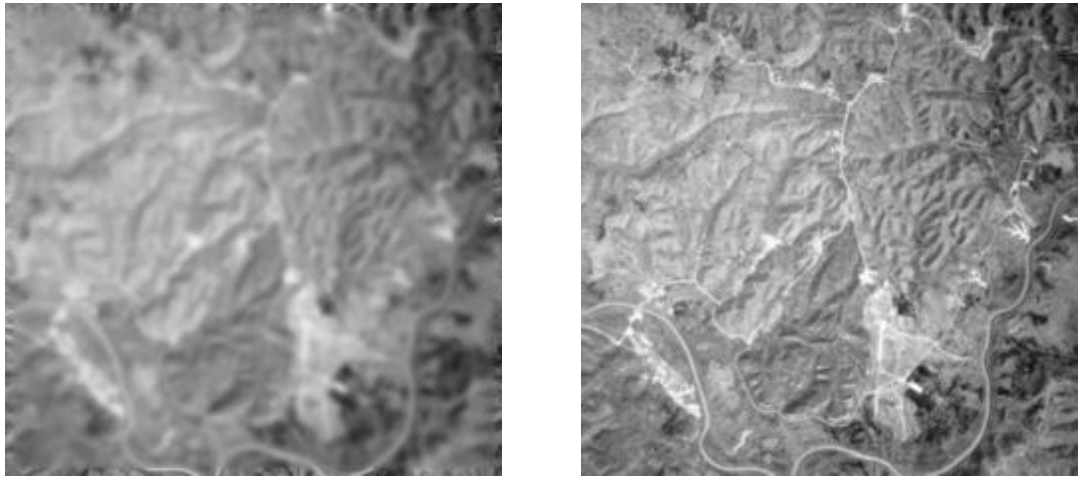
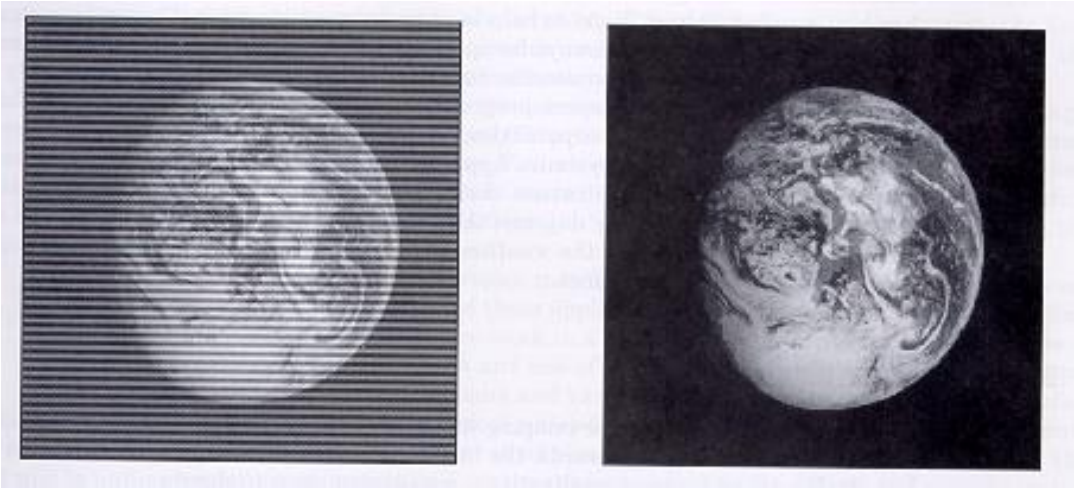
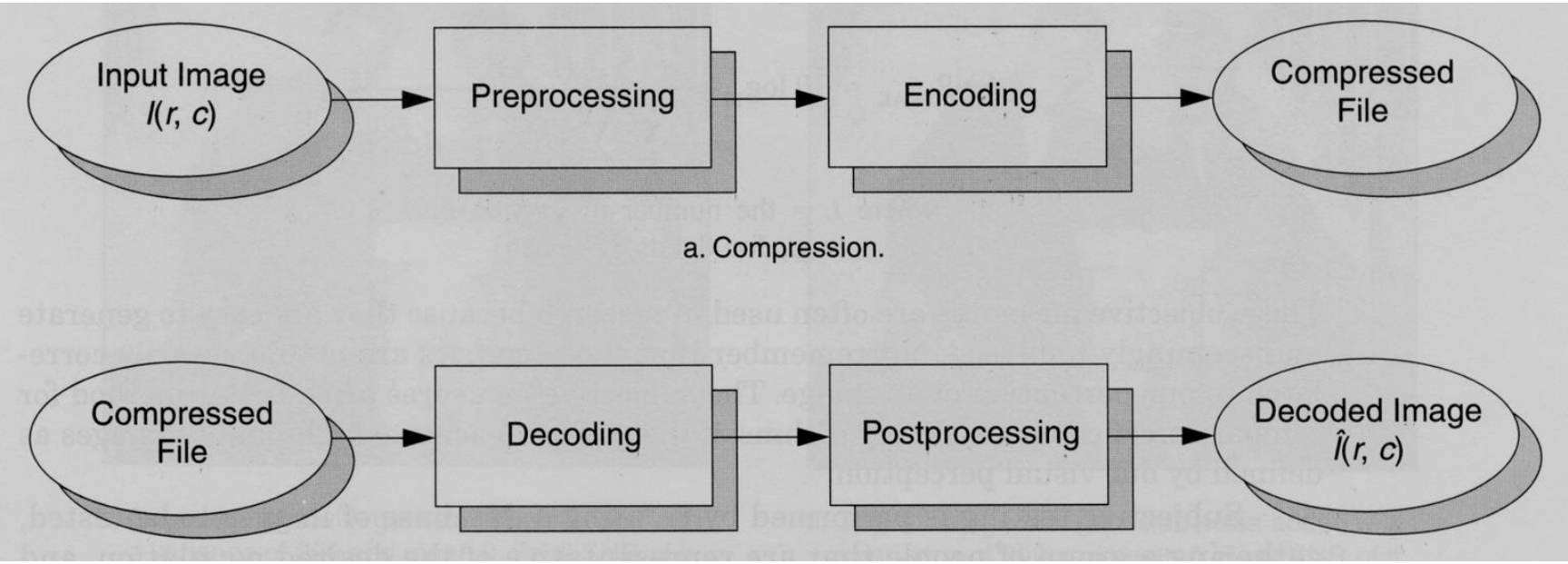


Image Restoration (e.g., correcting out-focus images)



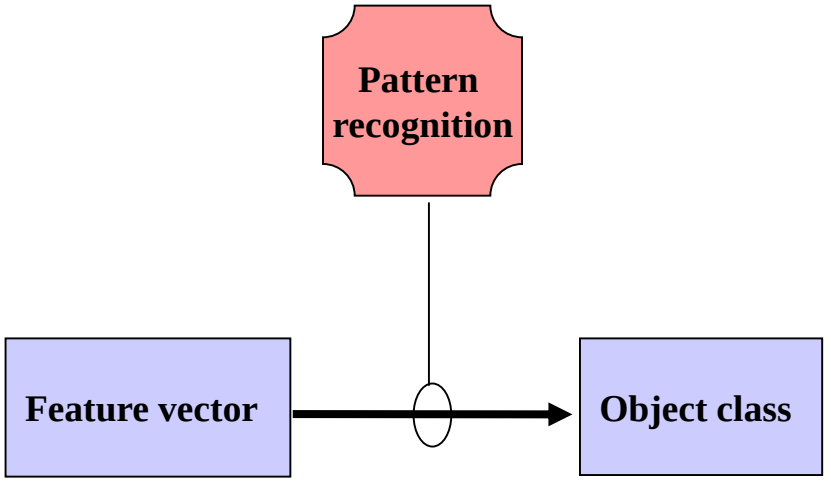
- Image Compression



- **Examples**
  - noise suppression
  - feature enhancement
  - video stabilization
- **Relationship to computer vision**
  - Often serves to provide components to computer vision.
  - Preprocessing of sensed data.

Pattern recognition

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

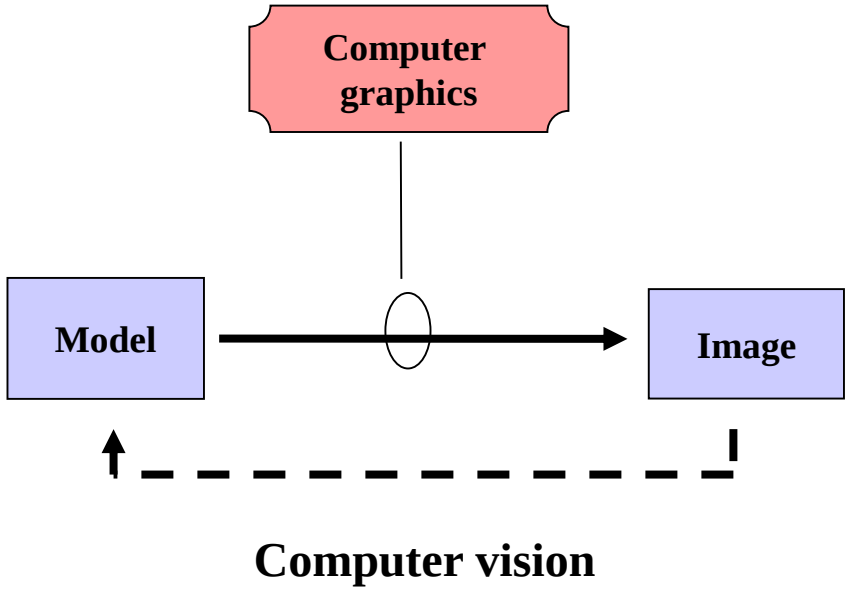


- Has a very long history (research work in this field started in the 60s).
- Concerned with the recognition and classification of 2D objects mainly from 2D images.
- Many classic approaches only worked under very constrained views (not suitable for 3D objects).
- It has triggered much of the research which led to today's field of computer vision.
- Many pattern recognition principles are used extensively in computer vision.

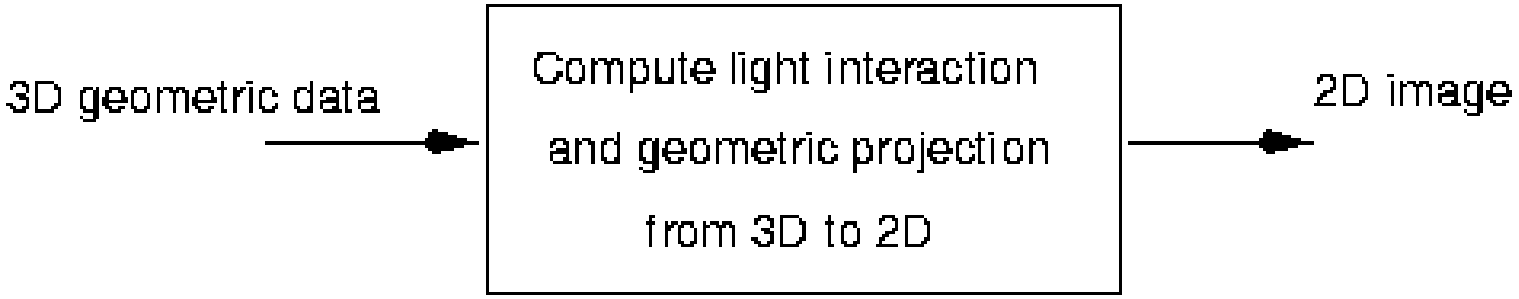
- **Examples**
  - Classification of chemical composition from spectral measurements.
  - Classification of disease from symptoms.
  - Classification of targets from visual features.
- **Relationship to computer vision**
  - Techniques of pattern recognition can usefully be applied to the output of a computer vision system. Capable of assigning imaged objects to classes based on vision processing.

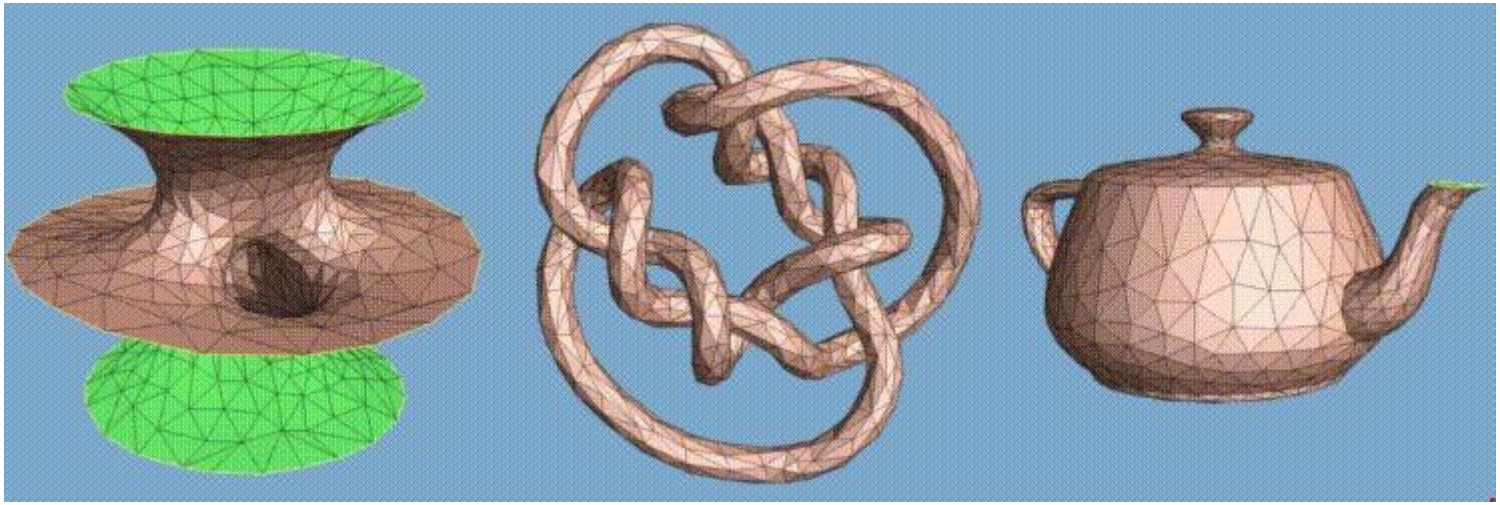
Computer graphics

- **Subject**
  - Generation of images from models or other computational specification.
  - Models to Images



Computer Graphics





- **Examples**
  - Photorealistic rendering (真實感渲染)
  - Computer animation
  - Abstract design
- **Relationship to computer vision**
  - Akin to an inverse
  - Potential to combine forces, e.g., image based rendering (IBR)

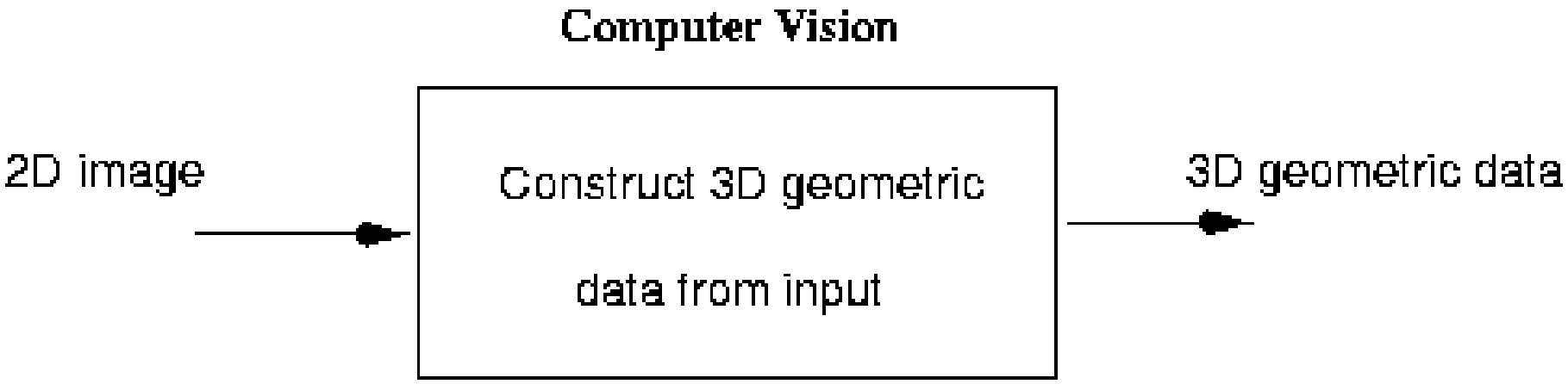
Robotic Vision

- Application of computer vision in robotics.
- Some important applications include :
  - Autonomous robot navigation
  - Inspection and assembly

Artificial Intelligence

- Concerned with designing systems that are intelligent and with studying computational aspects of intelligence.
- It is used to analyze scenes by computing a **symbolic representation** of the scene contents after the images have been processed to obtain features.
- Many techniques from artificial intelligence play an important role in many aspects of computer vision.
- Computer vision is considered a **sub-field** of artificial intelligence.

Computer Vision



Images to Models

- Giving computers the ability to see is not an easy task - we live in **a three dimensional (3D) world**, and when computers try to analyze objects in 3D space, available visual sensors (e.g., TV cameras) usually give **two dimensional (2D) images**, and this projection to a lower number of dimensions incurs an enormous loss of information.

Why is Computer Vision Difficult?

- It is a **many-to-one** mapping
  - A variety of surfaces with different ***material*** and ***geometrical*** properties, possibly under different ***lighting*** conditions, could lead to identical images
  - Inverse mapping has non unique solution (a lot of information is **lost** in the transformation from the 3D world to the 2D image)

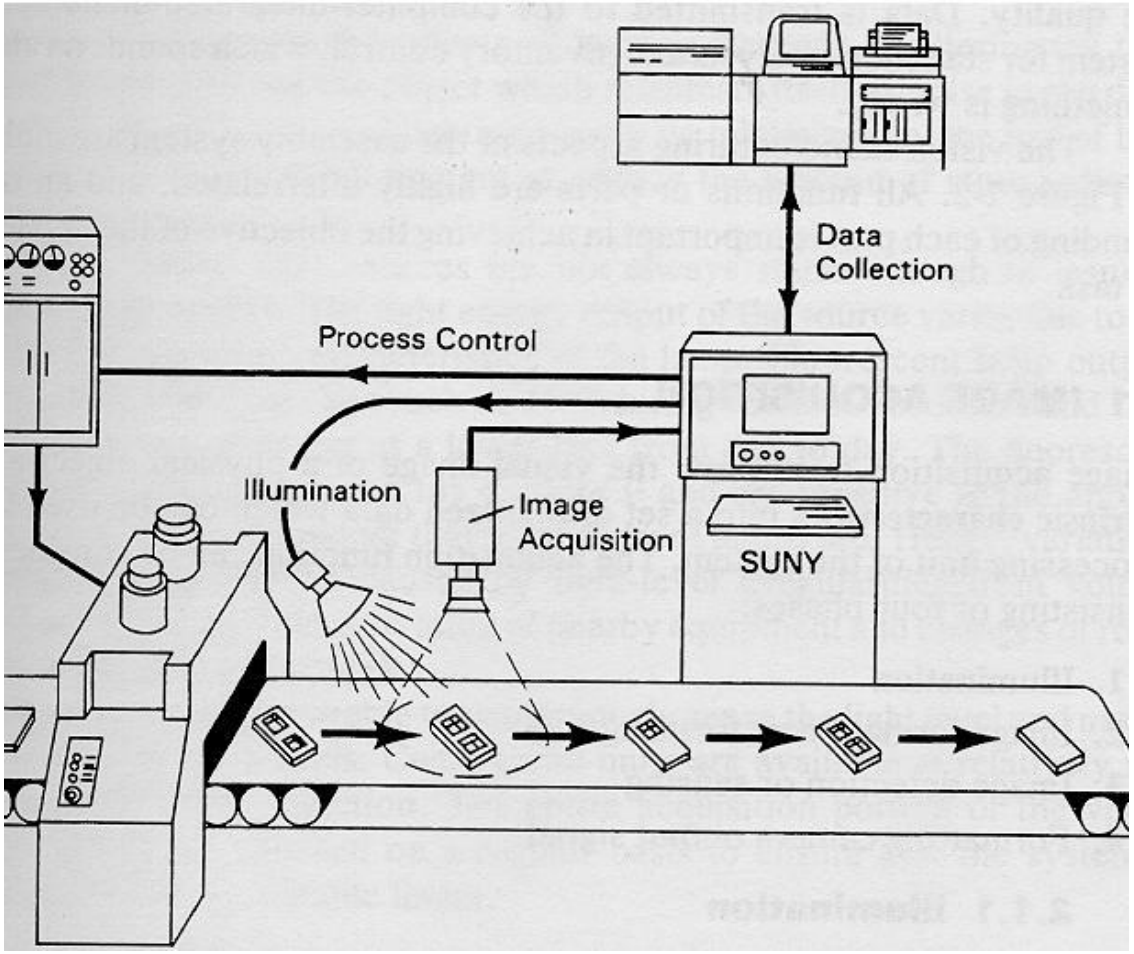
- It is **computationally intensive**
- We **do not understand** the recognition problem

Practical Considerations

- **Impose constraints** to recover the scene
  - Gather more data (images)
  - Make assumptions about the world
- **Computability** and **robustness**
  - Is the solution computable using reasonable resources?
  - Is the solution robust?

- Industrial computer vision systems work **very well**
  - Make strong assumptions about ***lighting conditions***
  - Make strong assumptions about the ***position*** of objects
  - Make strong assumptions about the ***type*** of objects

An Industrial Computer Vision System



- In order to simplify the task of computer vision understanding, three levels are usually distinguished
  - *Low level image processing*
  - *Intermediate-level image processing*
  - *High level image understanding.*

Low level digital image processing

- Low level computer vision techniques overlap almost completely with digital image processing, which has been practiced for decades.
- Low level methods usually use very little knowledge about the content of images.

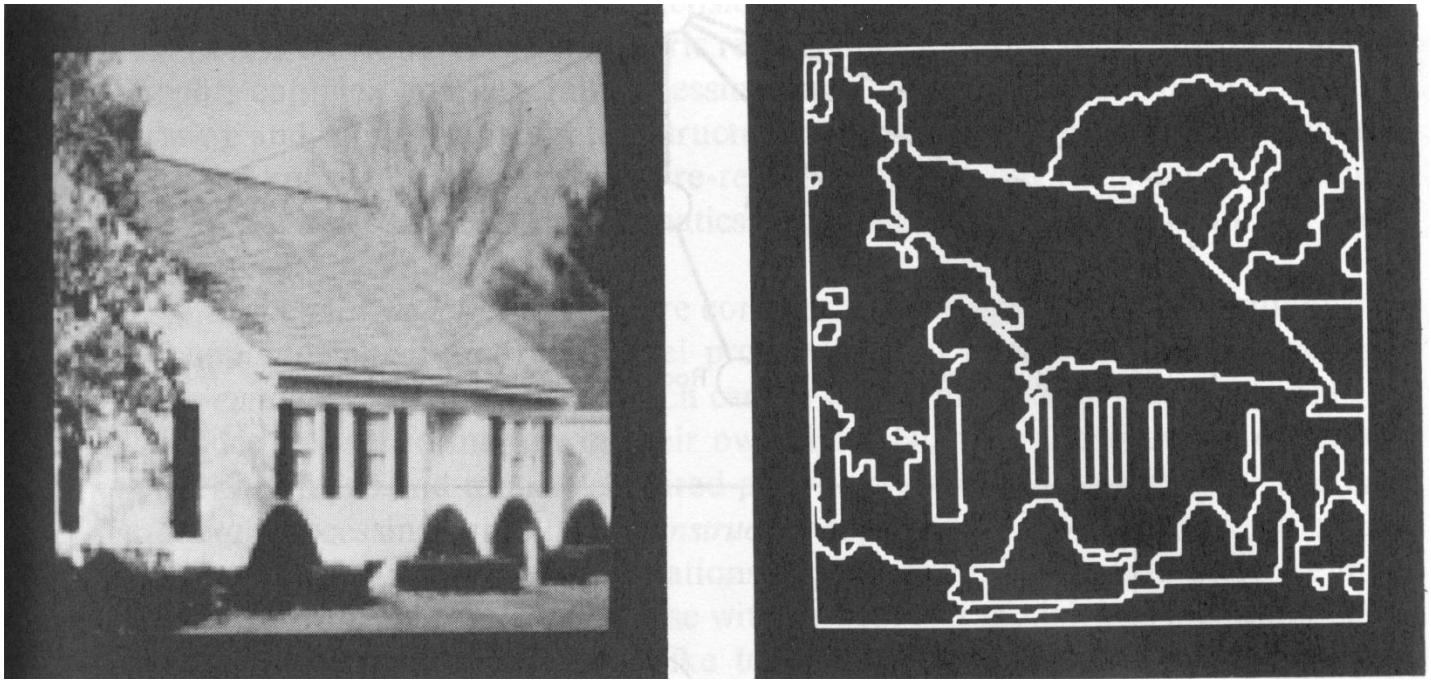
- Standard procedures are applied to improve image quality
- Procedures are required to have no intelligent capabilities.

The following sequence of processing steps is commonly recognized:

- **Image Acquisition**:
  - An image is captured by a sensor (such as a TV camera) and digitized;
- **Preprocessing**:
  - Computer suppresses noise (image pre-processing) and maybe enhances some object features which are relevant to understanding the image.

Intermediate-level processing

- Extract and characterize components in the image
- Some intelligent capabilities are required.



- **Image segmentation**:
  - Edge detection
  - Computer tries to separate objects from the image background.
- **Object description and classification** in a totally segmented image

High-level image understanding

- High level processing is based on knowledge, goals, and plans of how to achieve those goals.
- Artificial intelligence (AI) methods are used in many cases.
- High level computer vision tries to imitate human cognition and the ability to make decisions according to the information contained in the image.

Recognition Cues

- Scene interpretation, even of complex, cluttered scenes is a straightforward task for humans.

- How are we able to discern reality and an image of reality?
  What clues are present in the image?
  What knowledge do we use to process this image?

The role of color

- What is this object?
  Does color play a role in recognition?
  Might this be easier to recognize from a different view?

The role of texture

- Characteristic *image texture* can help us readily recognize objects.

The role of shape

The role of grouping

Mathematics in Computer Vision

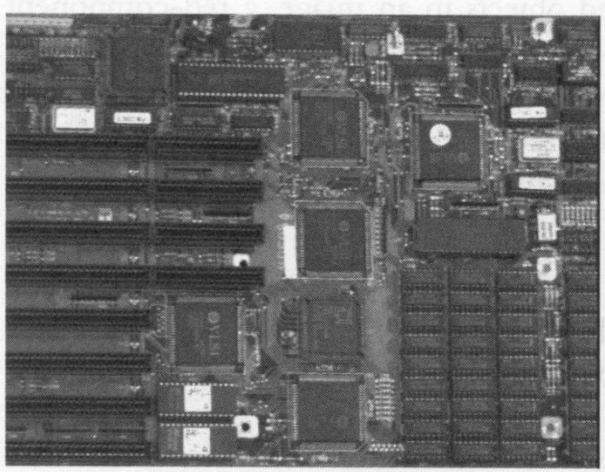
- In the early days of computer vision, vision systems employed simple heuristic (啟發式) methods.
- Today, the domain is heavily inclined towards theoretically, well-founded methods involving non-trivial mathematics.
  - **Calculus**
  - **Linear Algebra**
  - **Probabilities and Statistics**
  - **Signal Processing**
  - **Projective Geometry**
  - **Computational Geometry**
  - **Optimization Theory**
  - **Control Theory**

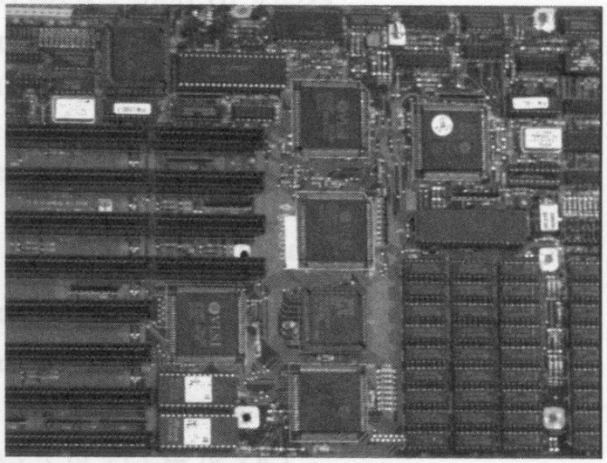
Computer Vision Applications

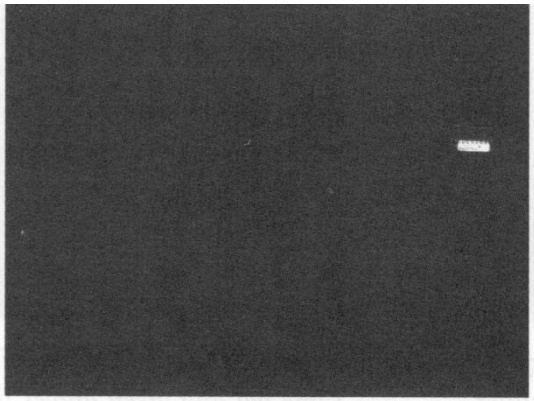
- Industrial inspection
- Surveillance, monitoring and security
- Person recognition (automated fingerprint, face, iris,…)
- Human computer interface (Gesture recognition)

- Autonomous vehicles
- Hand-eye robotics
- Medical image analysis
- Image databases
- Space applications
- Virtual reality

Visual Inspection





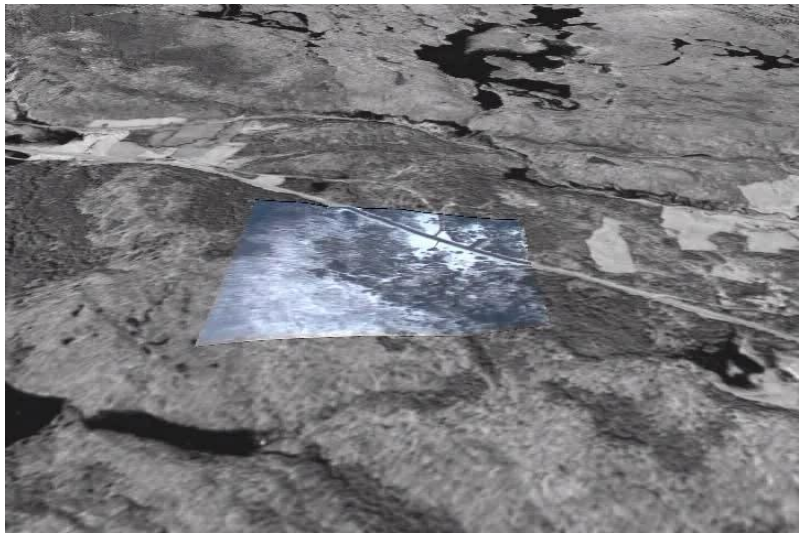


Industrial robots

Vision-guided robots position nut runners on wheels

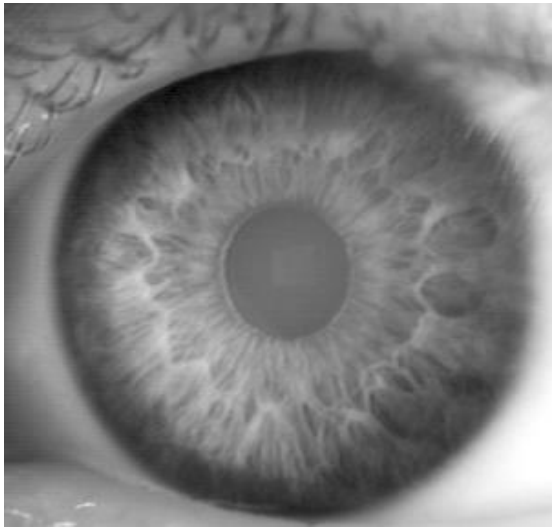
Aerial surveillance

- **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

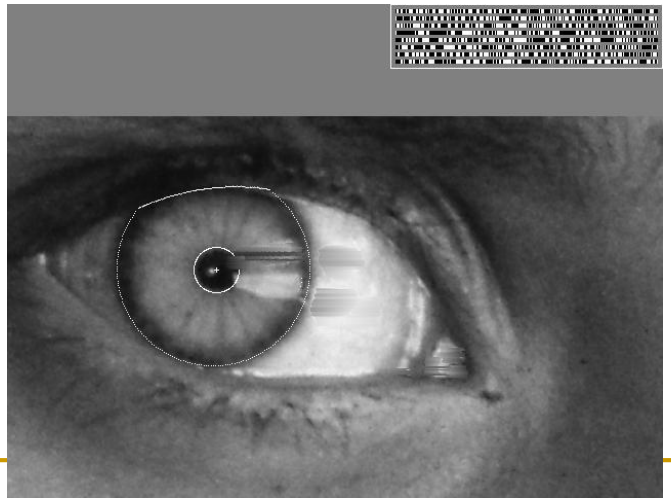


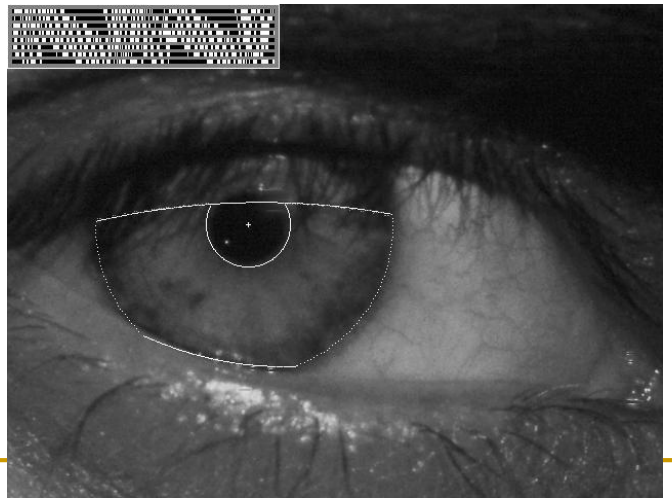
Personal identification

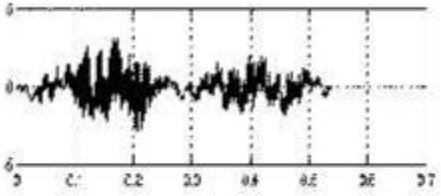
- **Real-world needs**
  - secure access control to sensitive areas and materials reliable personal verification and identification
- **State of the art example**
  - biometric-based identification
  - automated iris recognition



"*How the Afghan Girl was Identified by Her Iris Patterns*" Read the story wikipedia

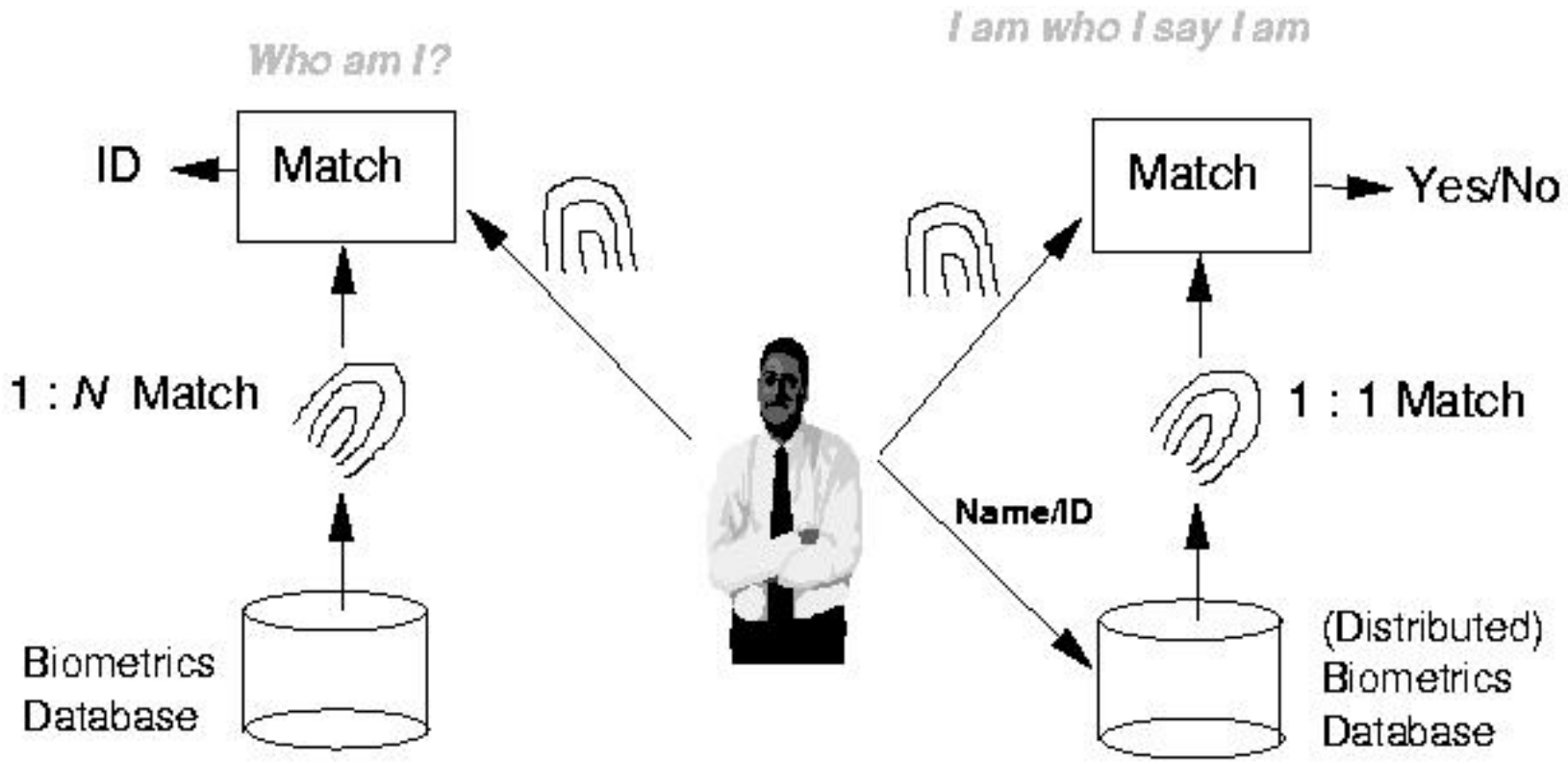




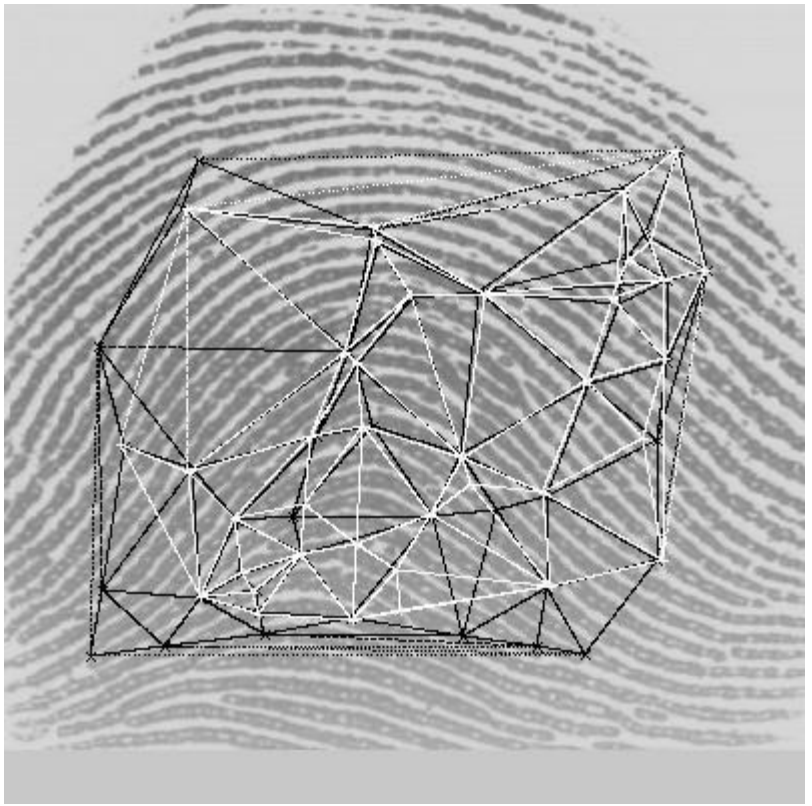



John Smith

- Fingerprint Verification / Identification



- Fingerprint Identification Research

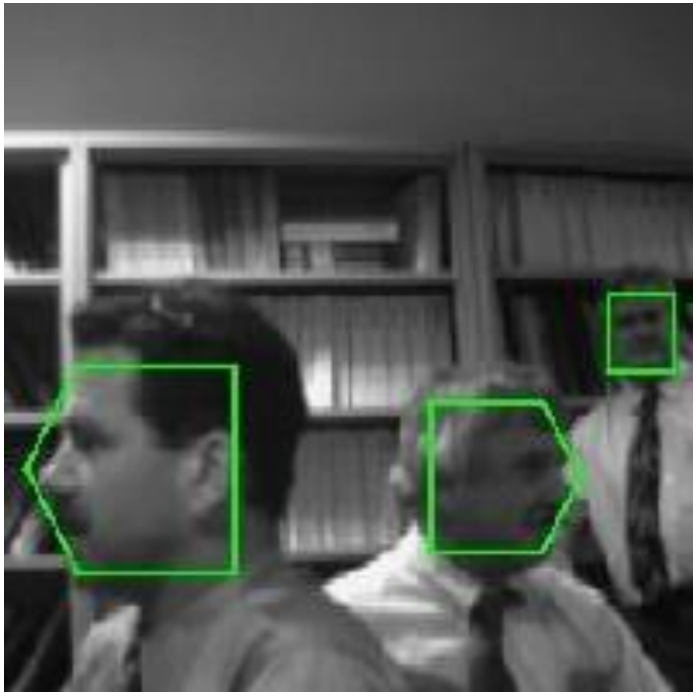


Login without a password…

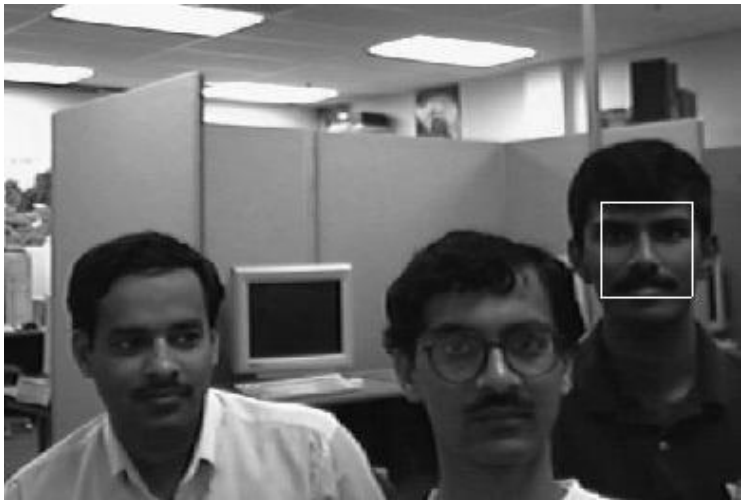
Fingerprint scanners on many new laptops, other devices

Face recognition systems now beginning to appear more widely
http://www.sensiblevision.com/

Face Detection

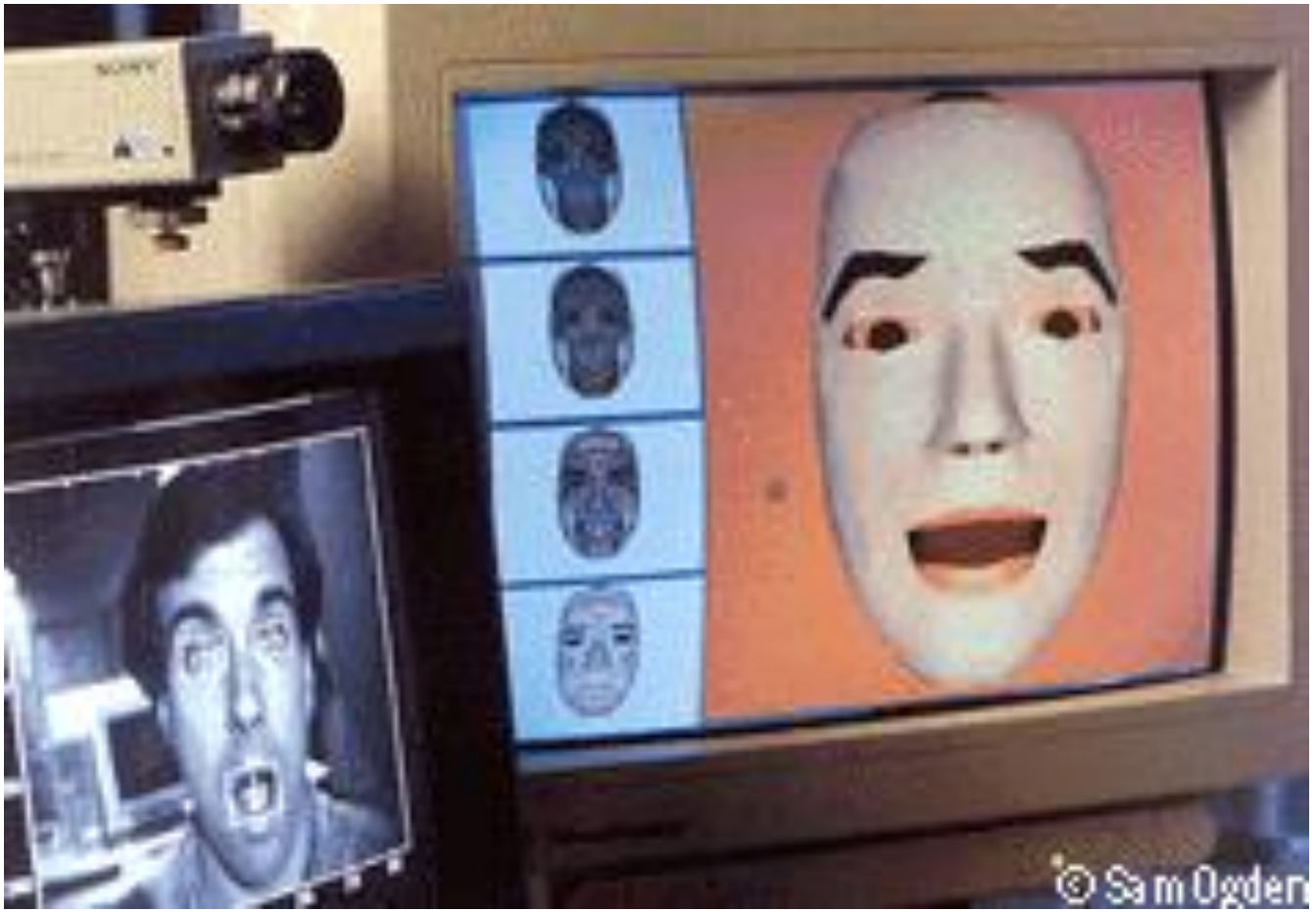


- Face Detection/Recognition Research

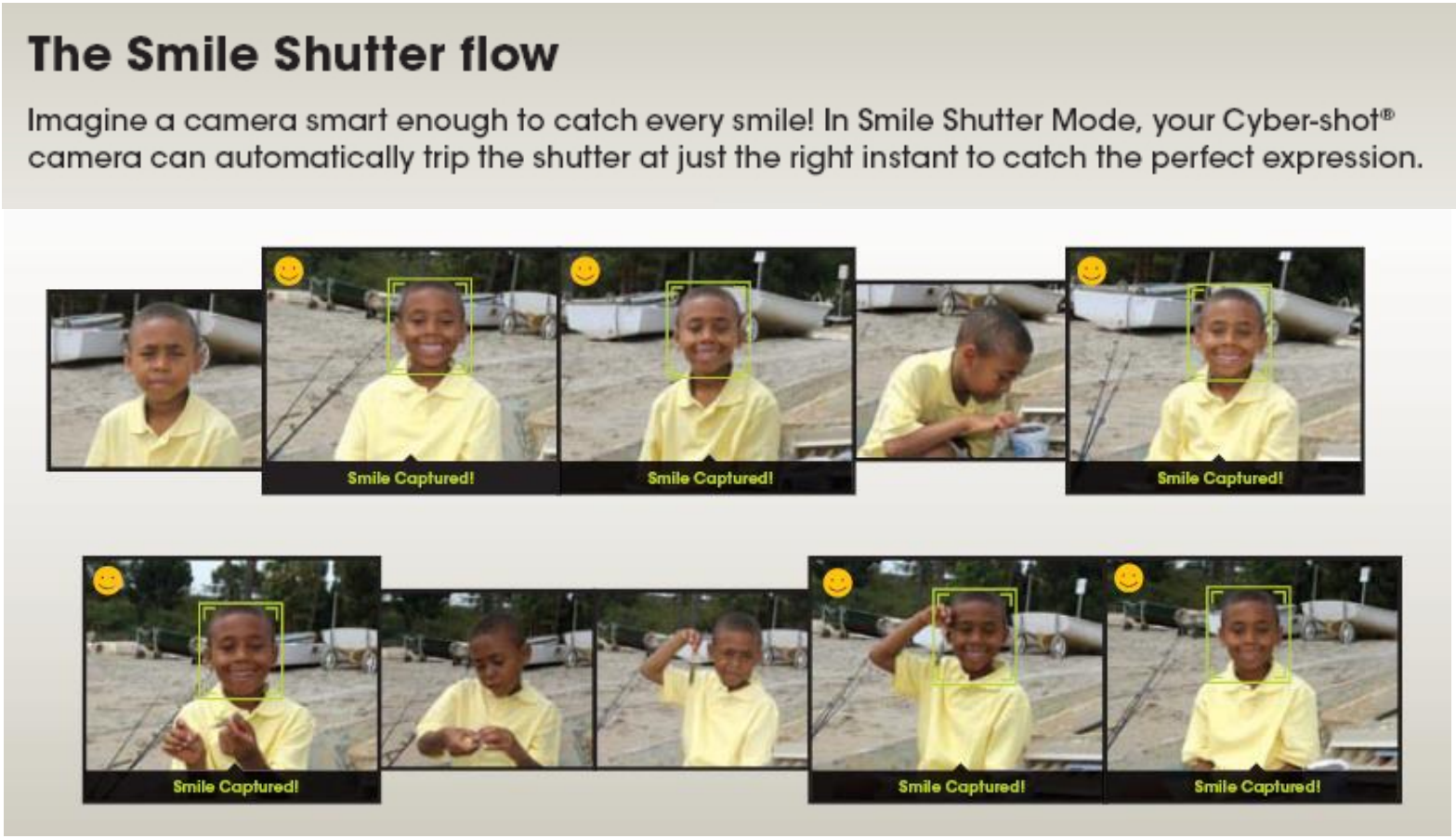


- Many new digital cameras now detect faces
  - Canon, Sony, Fuji, …

Facial Expression Recognition



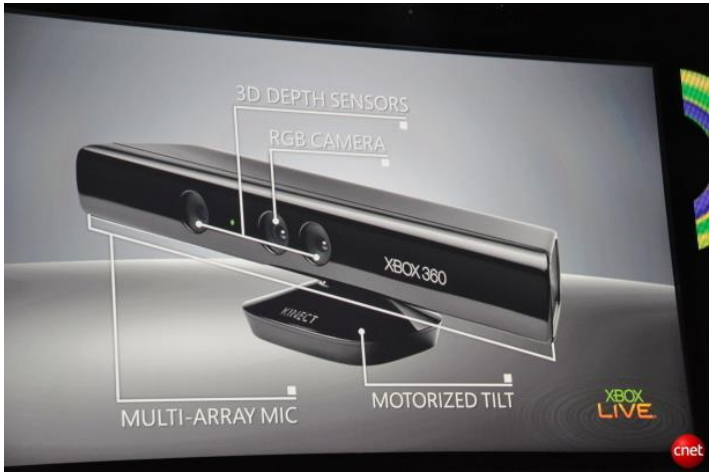
Smile detection



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

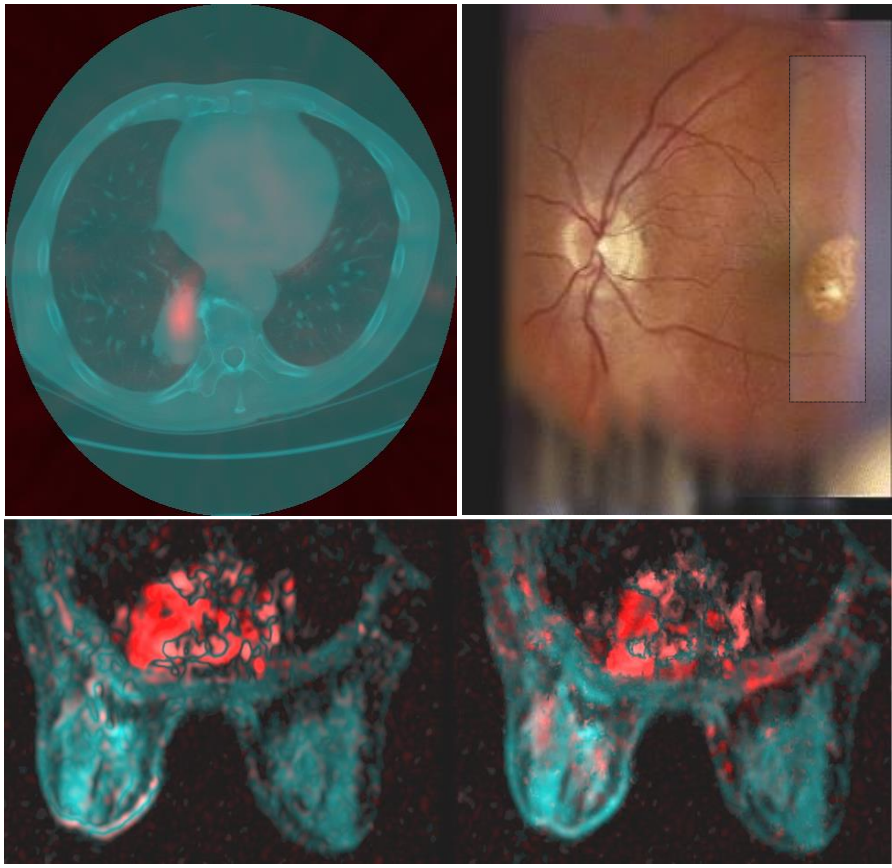
Vision-based interaction (and games)



Digimask: put your face on a 3D avatar.

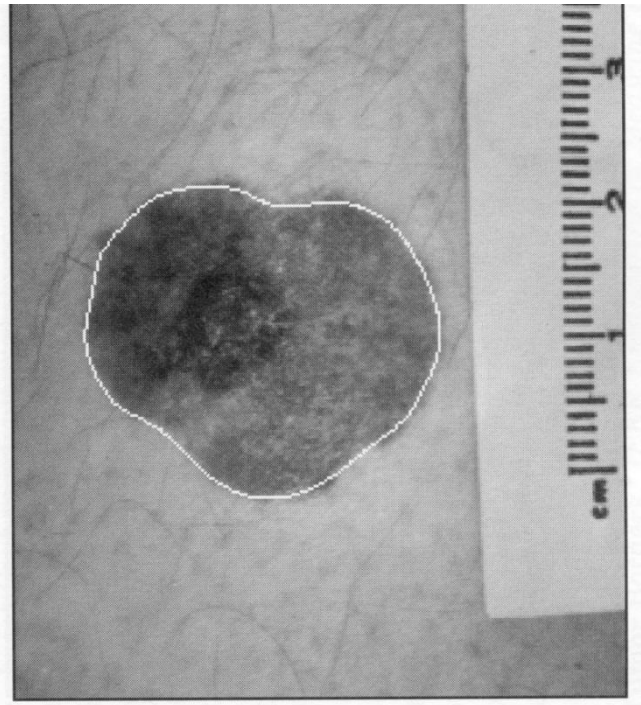
Medical

- **Real-world needs**
  - aides to physicians in diagnosis of disease tools for increasing accuracy and throughput
- **State of the art examples**
  - shape-based lesion （損傷） detection
  - alignment of real-time retinal (視網膜) imagery with previous reference
  - change detection for cancer detection



Medical Applications

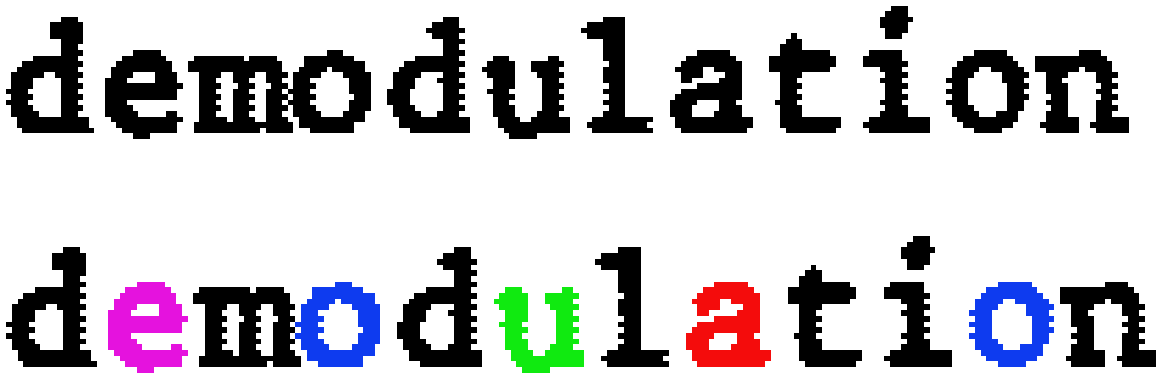
skin cancer



breast cancer

Image guided surgery
Grimson et al., MIT

Character Recognition



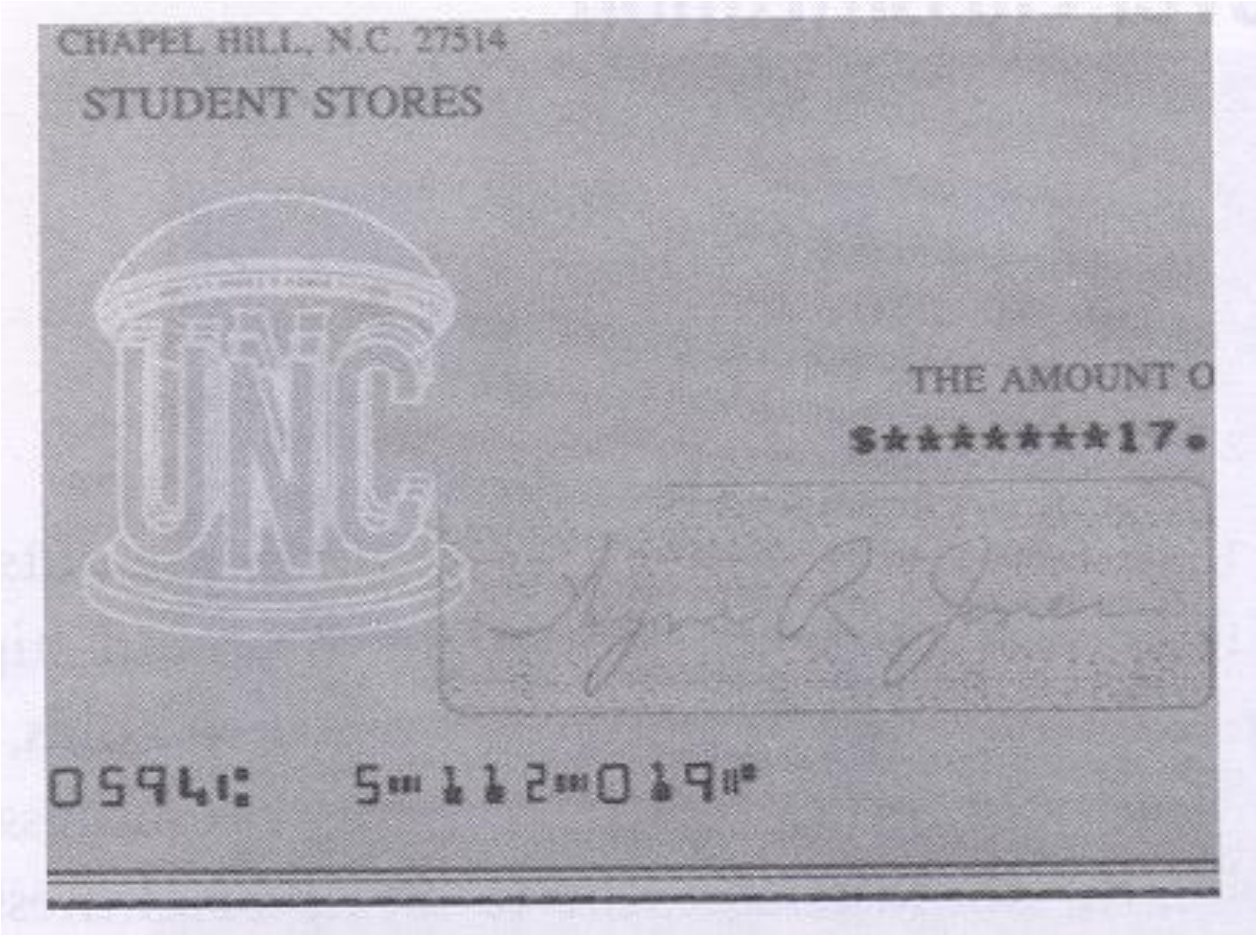
Optical character recognition (OCR)

- Technology to convert scanned docs to text
  - If you have a scanner, it probably came with OCR software

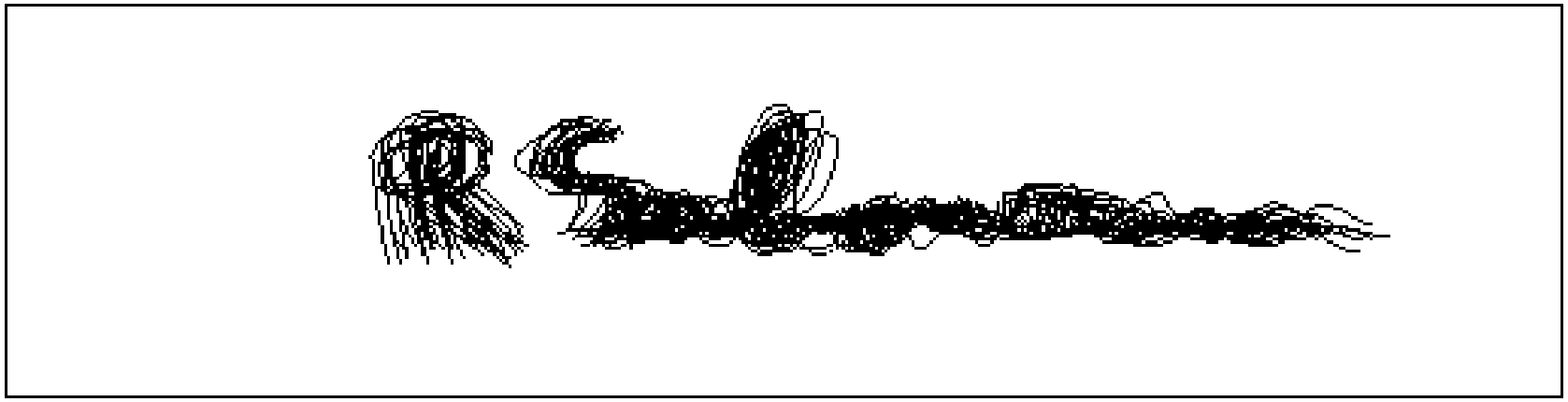
License plate readers

http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

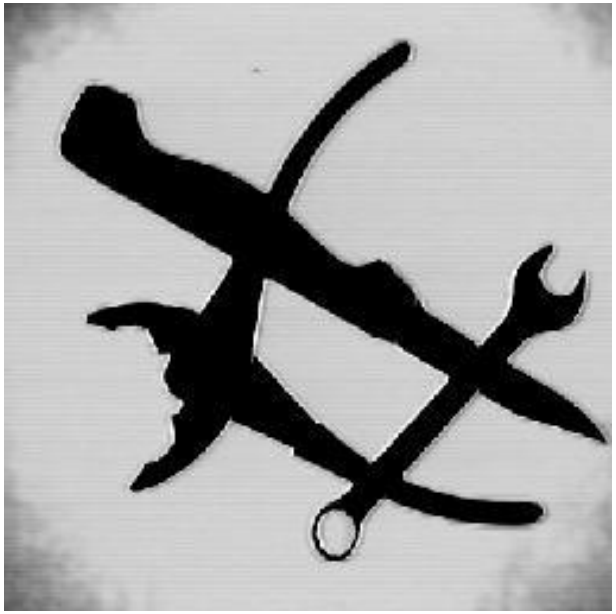
Document Handling

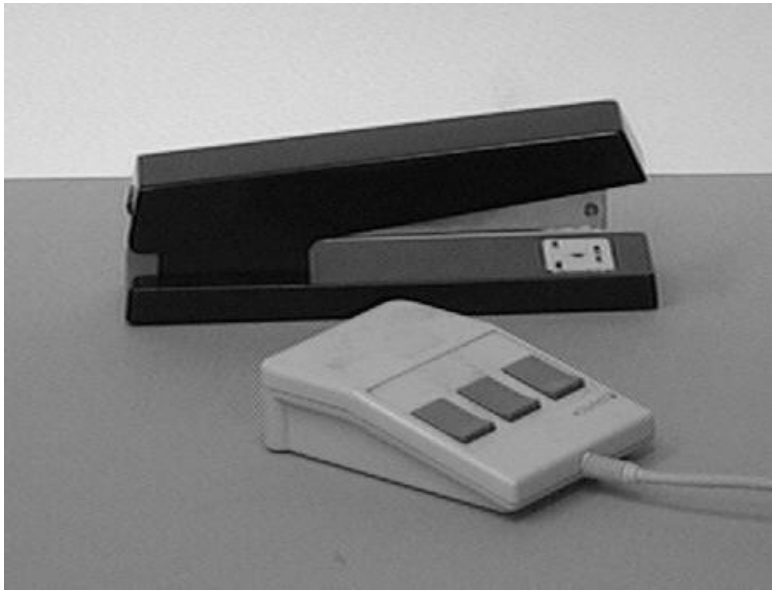


Signature Verification



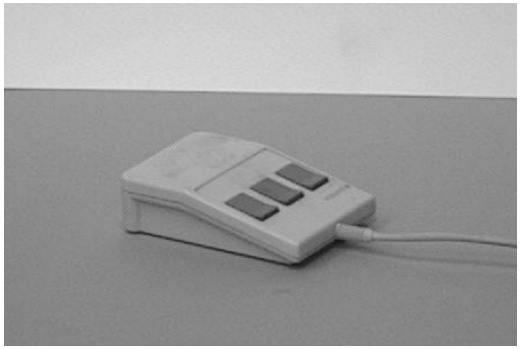
Object Recognition



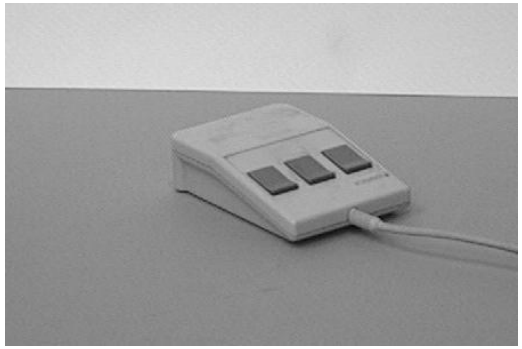


Object Recognition Research

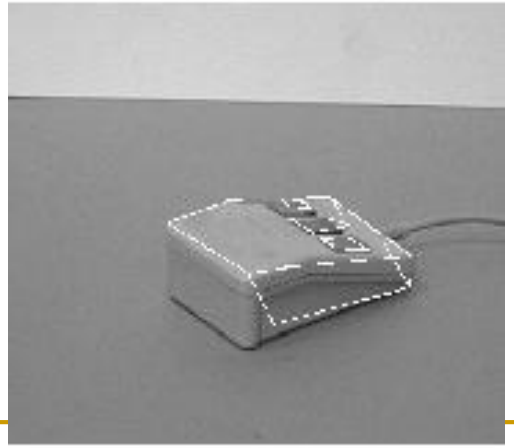
reference view 1



reference view 2



novel view recognized



Object recognition (in supermarkets)

LaneHawk by EvolutionRobotics

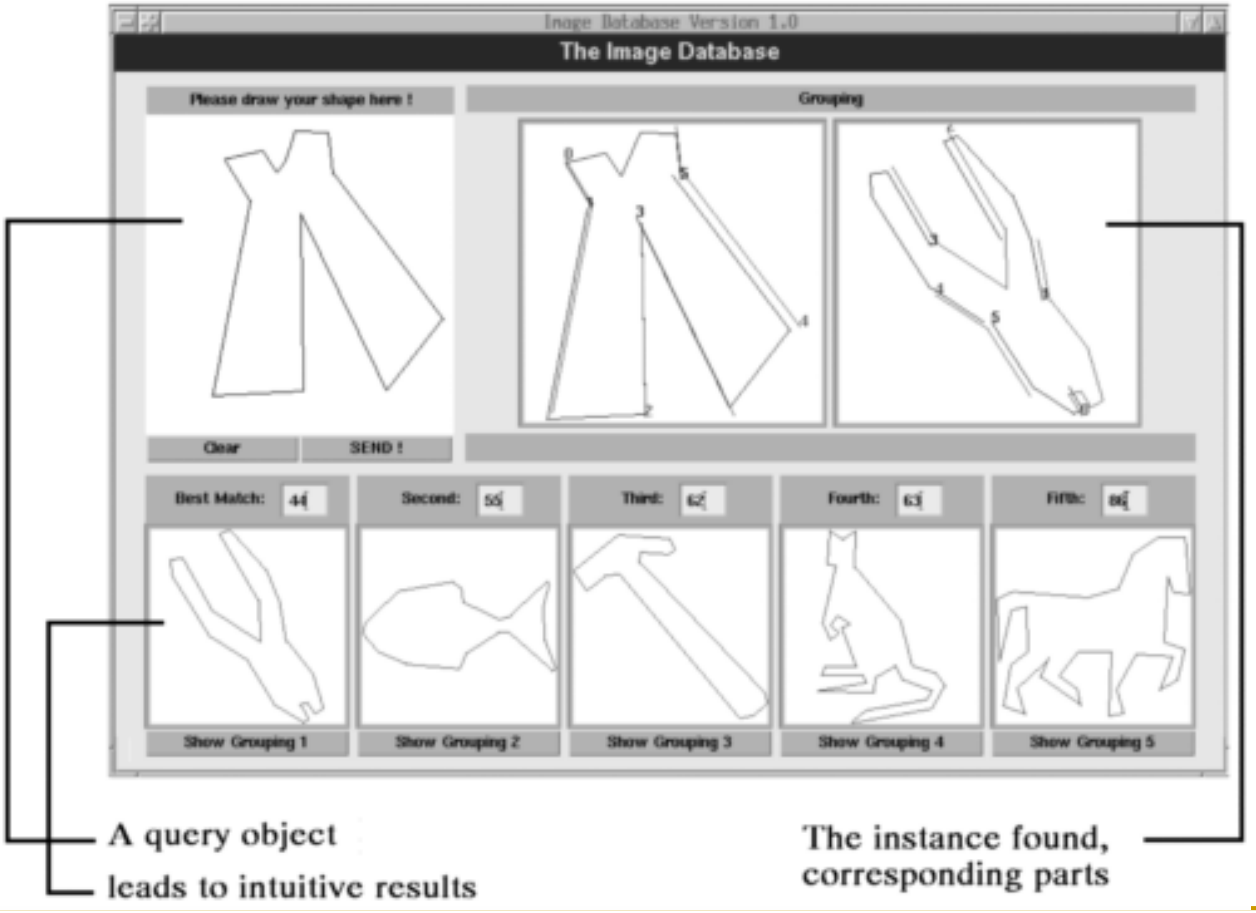
“A smart camera is flush-mounted in the checkout lane, continuously watching for items. When an item is detected and recognized, the cashier verifies the quantity of items that were found under the basket, and continues to close the transaction. The item can remain under the basket, and with LaneHawk,you are assured to get paid for it… “

Object recognition (in mobile phones)

Point & Find

Indexing into Databases

- Shape content

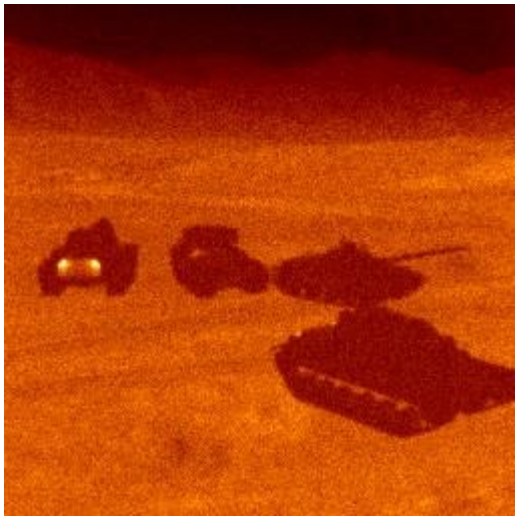


Indexing into Databases (cont'd)

- Color, texture

Target Recognition

- Department of Defense (Army, Airforce, Navy)

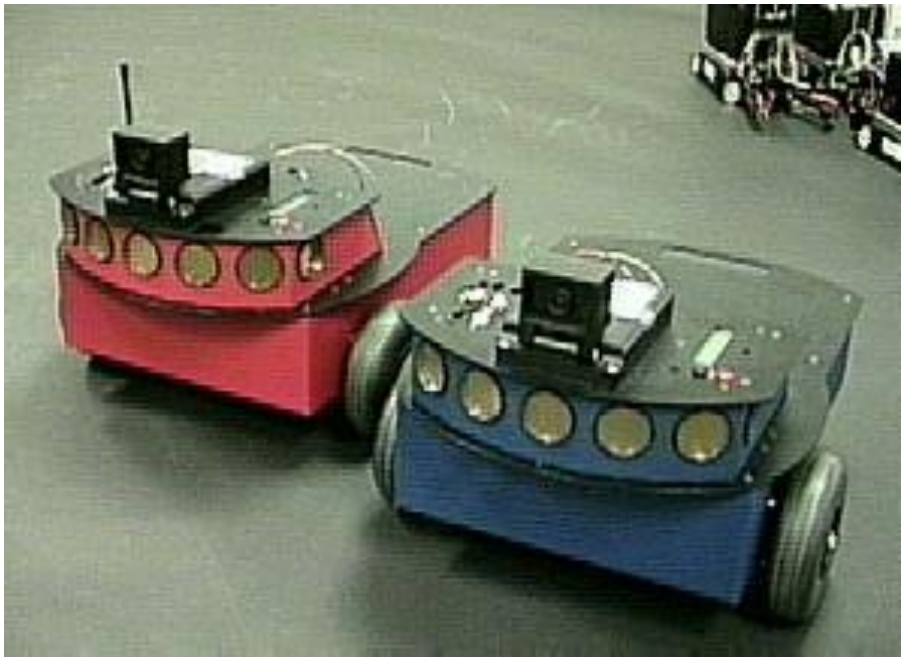


Interpretation of Aerial Photography

- Interpretation of aerial photography is a problem domain in both computer vision and photogrammetry （攝影學）.

Autonomous Vehicles

- Land, Underwater, Space



Smart cars


manufacturer products
consumer products
Our Vision. Your Safety.
rear looking camera
forward looking camera
side looking camera
EyeQ Vision on a Chip
read more
Vision Applications
Road, Vehicle, Pedestrian Protection and more
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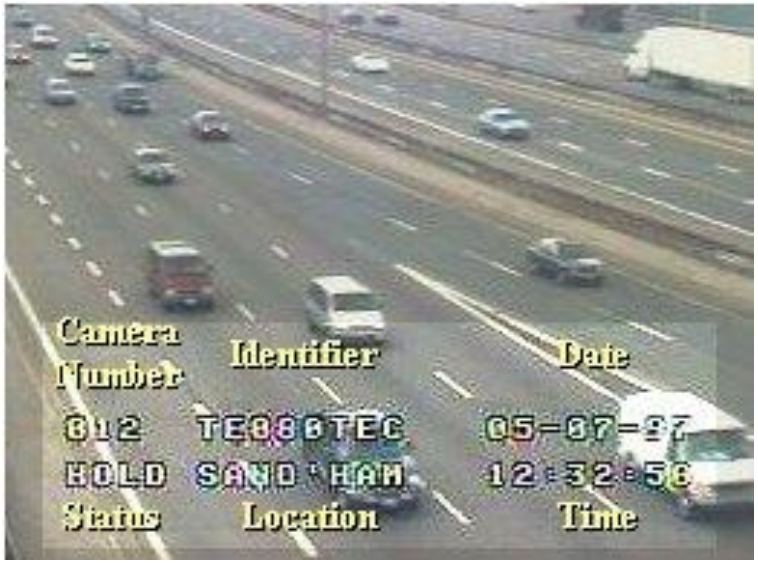
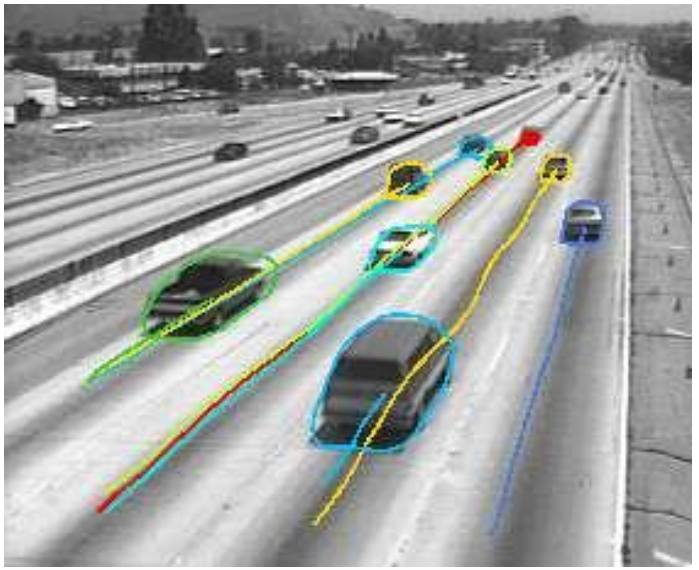
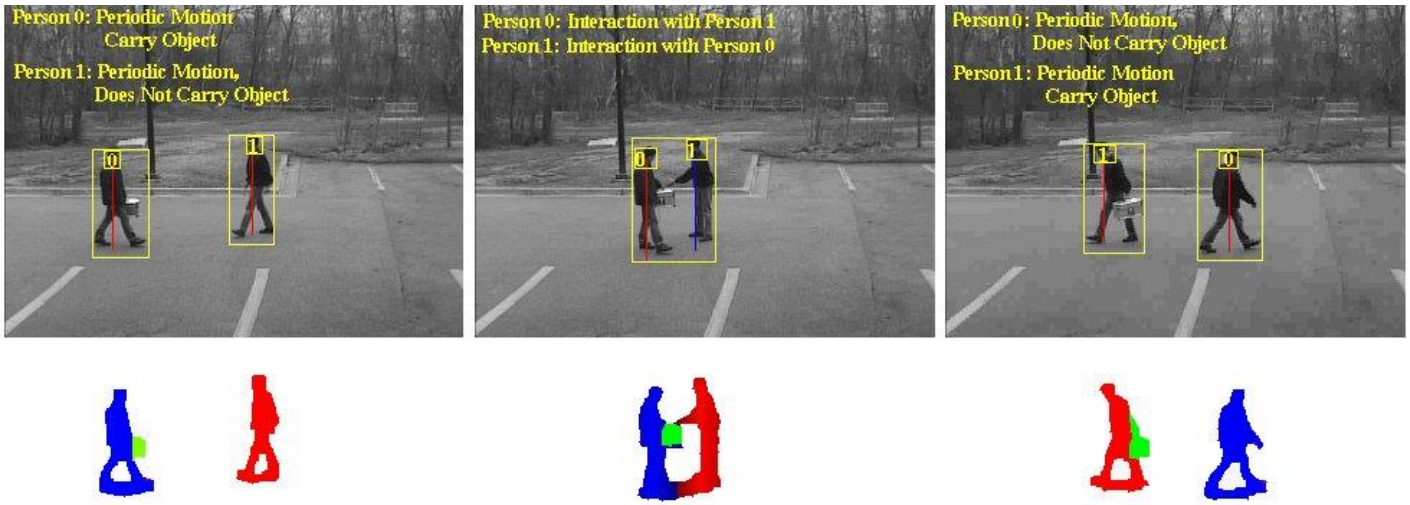
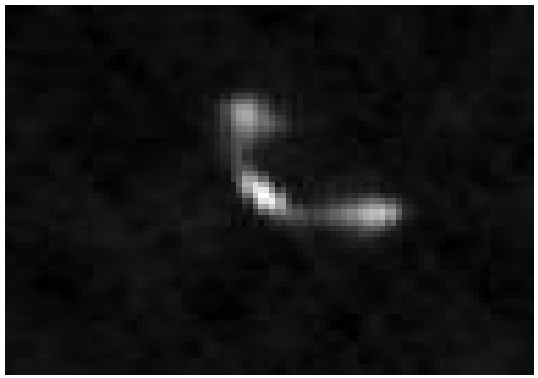
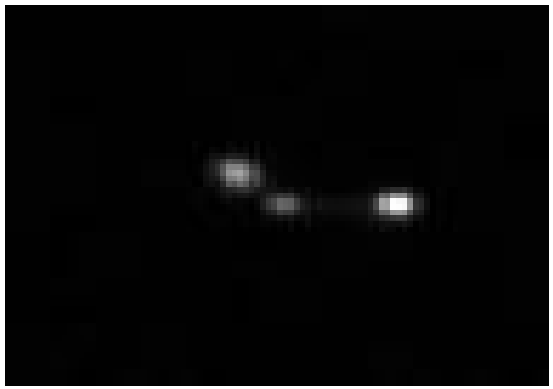
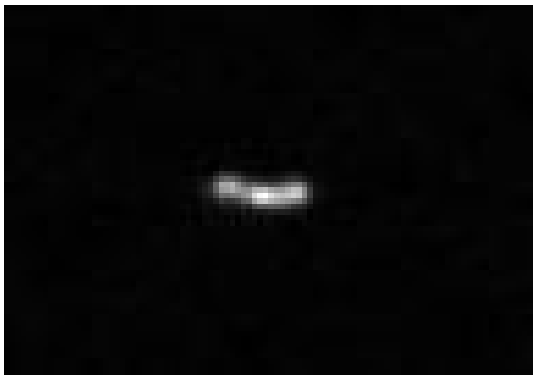




Human Activity Recognition

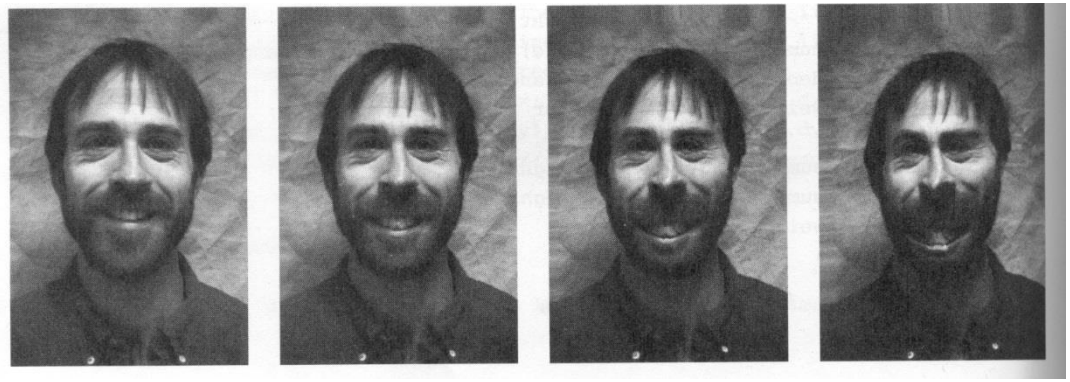


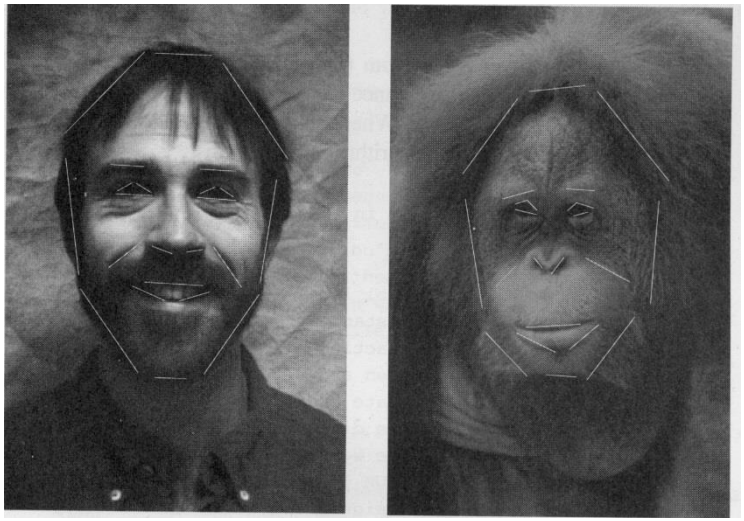
Astronomy Applications Research

NASA'S Mars Exploration Rover Spirit captured this westward view from atop a low plateau where Spirit spent the closing months of 2007.

Morphing (變形)





Inserting Artificial Objects into a Scene