Overview of Computer Vision

CS308 Data Structures

What is Computer Vision?

- Deals with the development of the **<u>theoretical</u>** and **<u>algorithmic</u>** basis by which useful information about the 3D world can be automatically extracted and analyzed from a **<u>single</u>** or **<u>multiple</u>** o 2D images of the world.
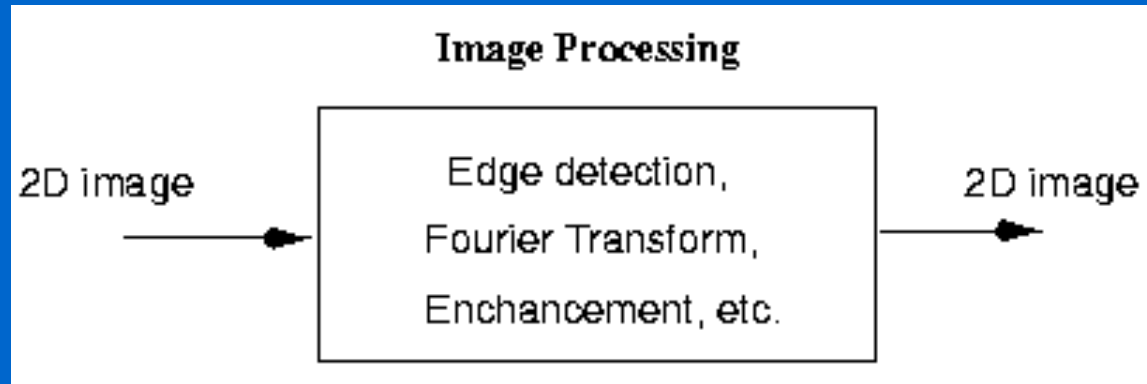
Computer Vision, Also Known As ...

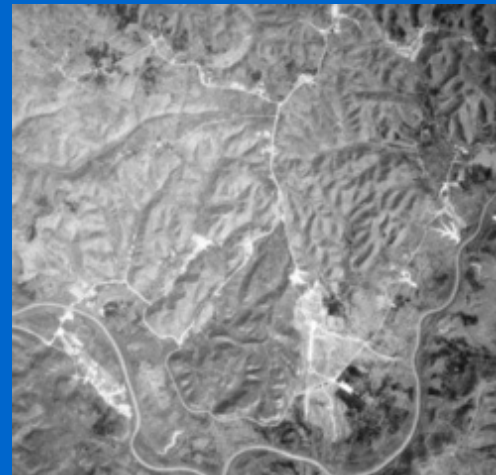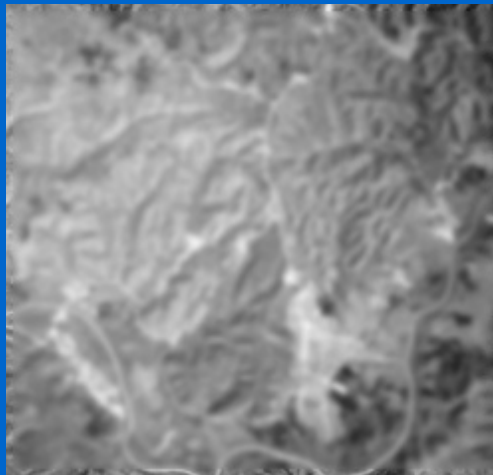- Image Analysis
- Scene Analysis
- Image Understanding

Some Related Disciplines

- Image Processing
- Computer Graphics
- Pattern Recognition
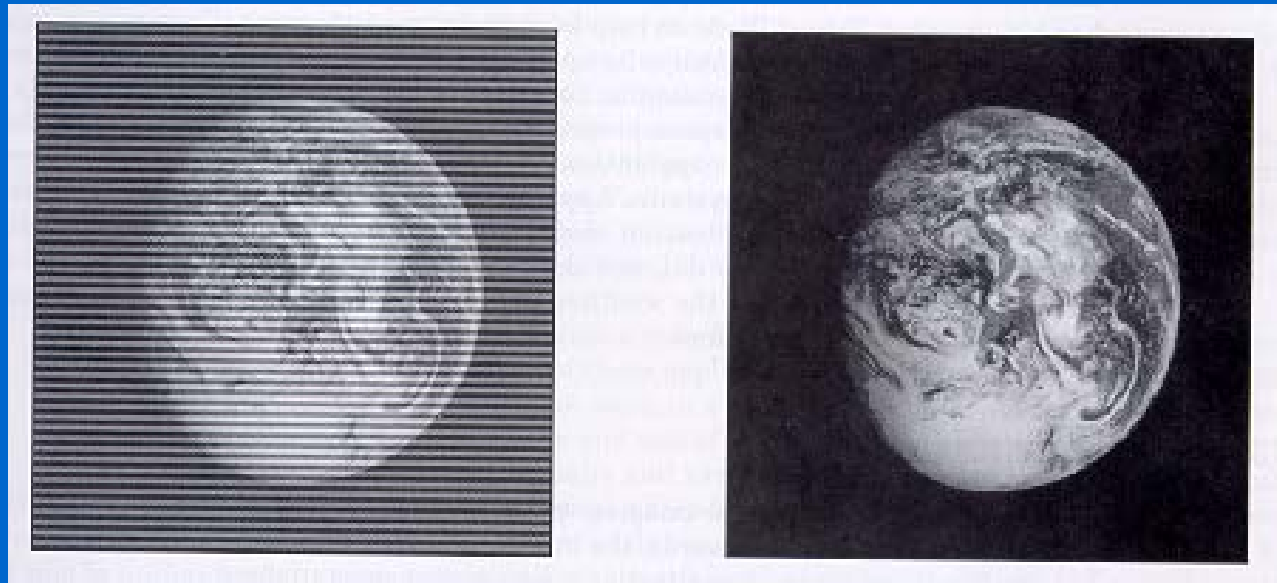- Robotics
- Artificial Intelligence

Image Processing

Image Processing

2D image → | Edge detection, Fourier Transform, Enchancement, etc. | → 2D image
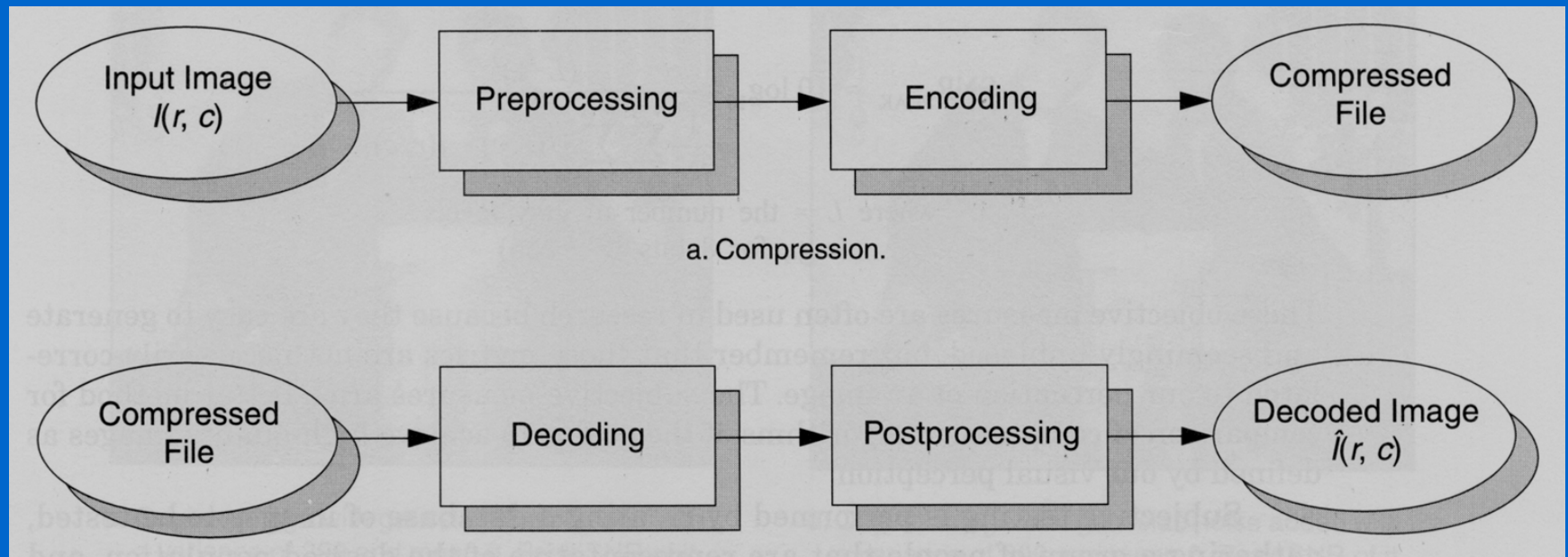
- Image Enhancement

Image Processing (cont'd)

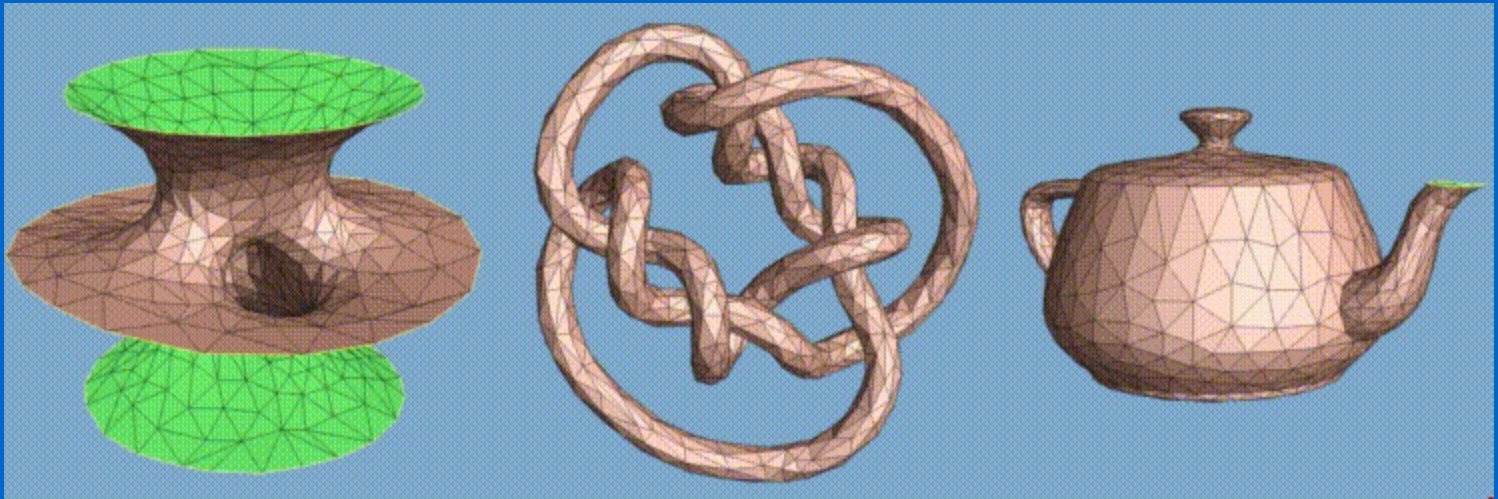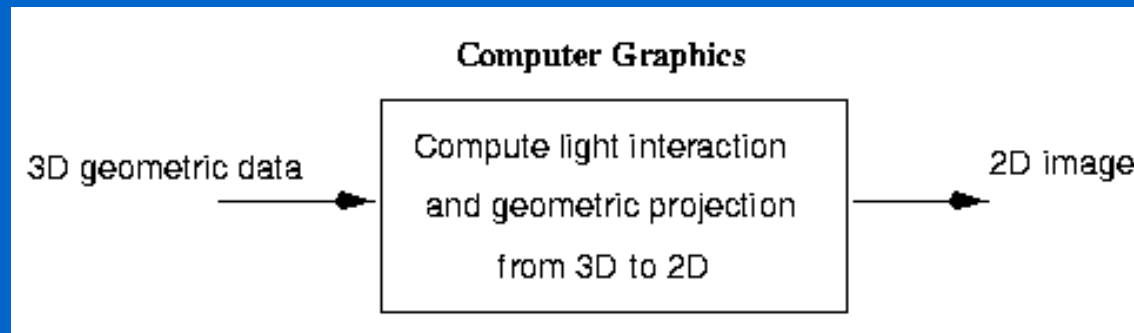- Image Restoration(e.g., correcting out-focus images)

Image Processing (cont'd)

- Image Compression

a. Compression.
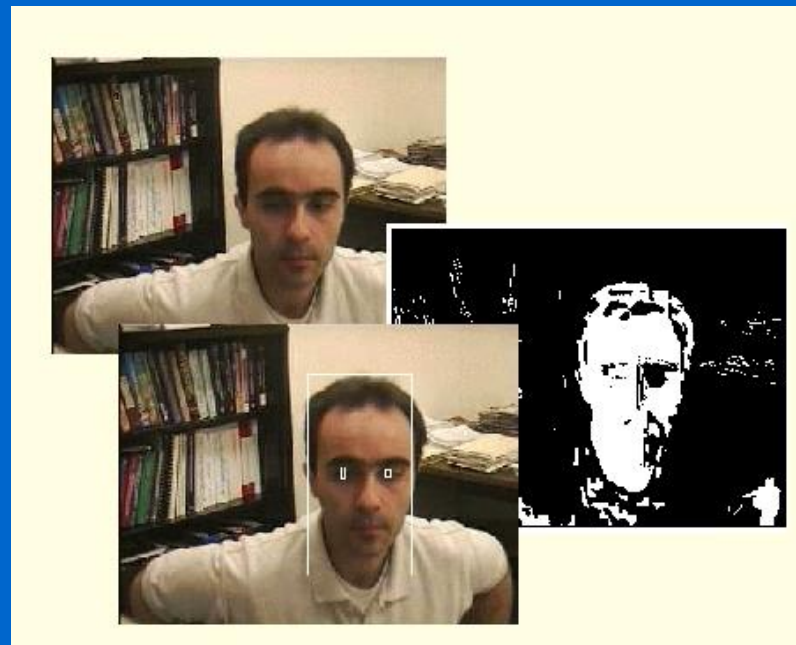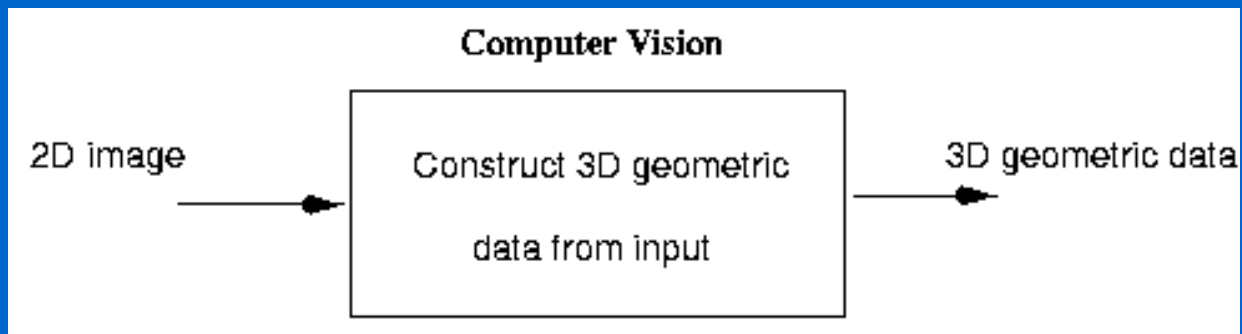
Computer Graphics

- Geometric modeling

Computer Graphics

3D geometric data → | Compute light interaction and geometric projection from 3D to 2D | → 2D image

Computer Vision

Computer Vision

2D image → Construct 3D geometric data from input → 3D geometric data

Robotic Vision

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

Pattern Recognition

- 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.

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.

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
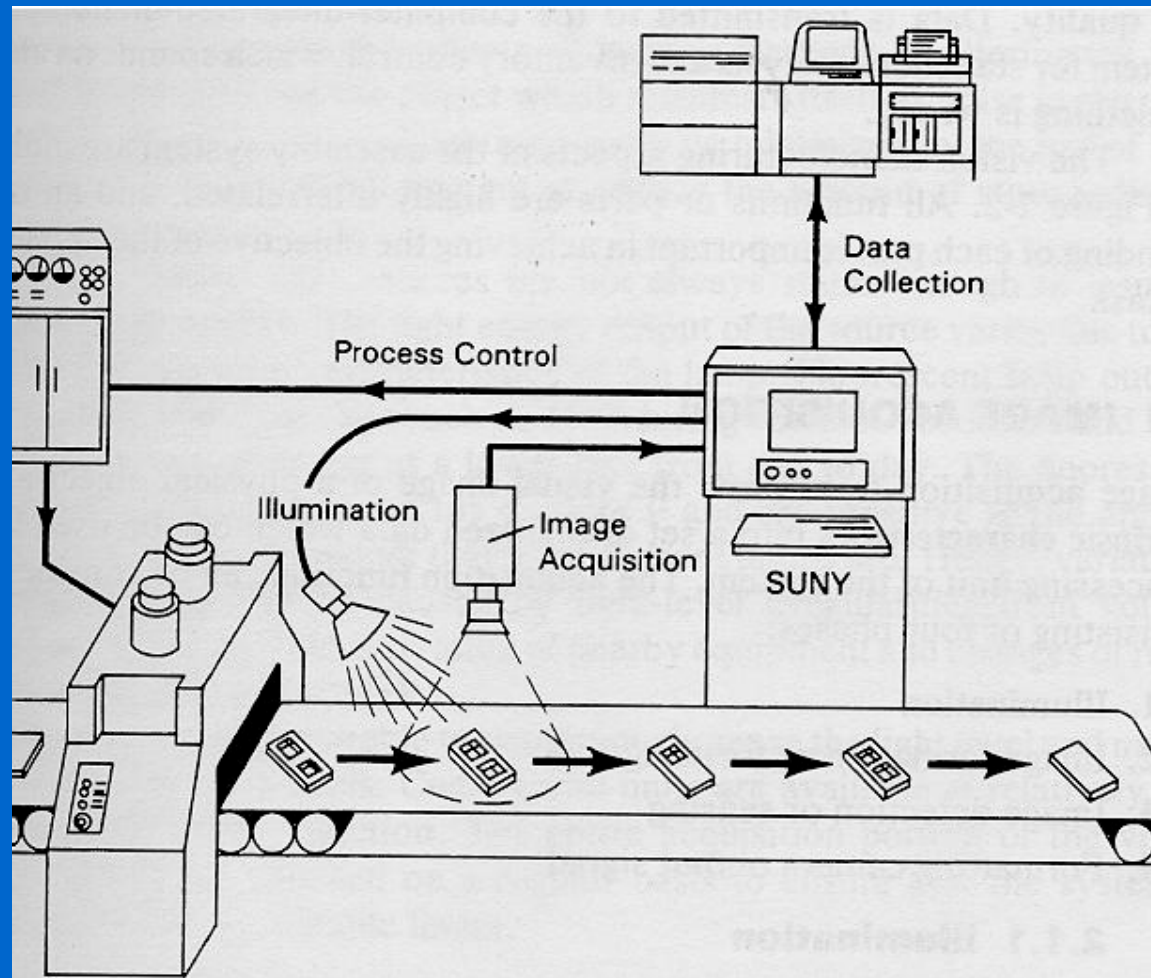
The Three Processing Levels

- Low-level processing
  - Standard procedures are applied to improve image quality
  - Procedures are required to have no intelligent capabilities.
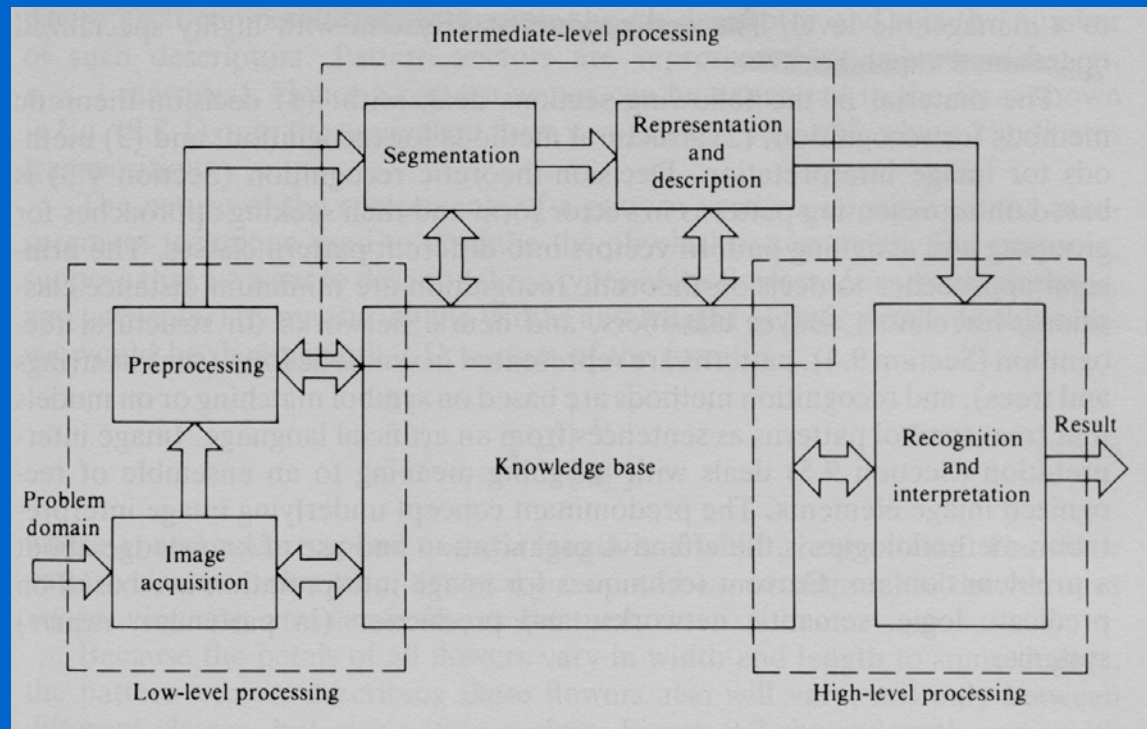
The Three Processing Levels (cont'd)

- Intermediate-level processing
  - Extract and characterize components in the image
  - Some intelligent capabilities are required.
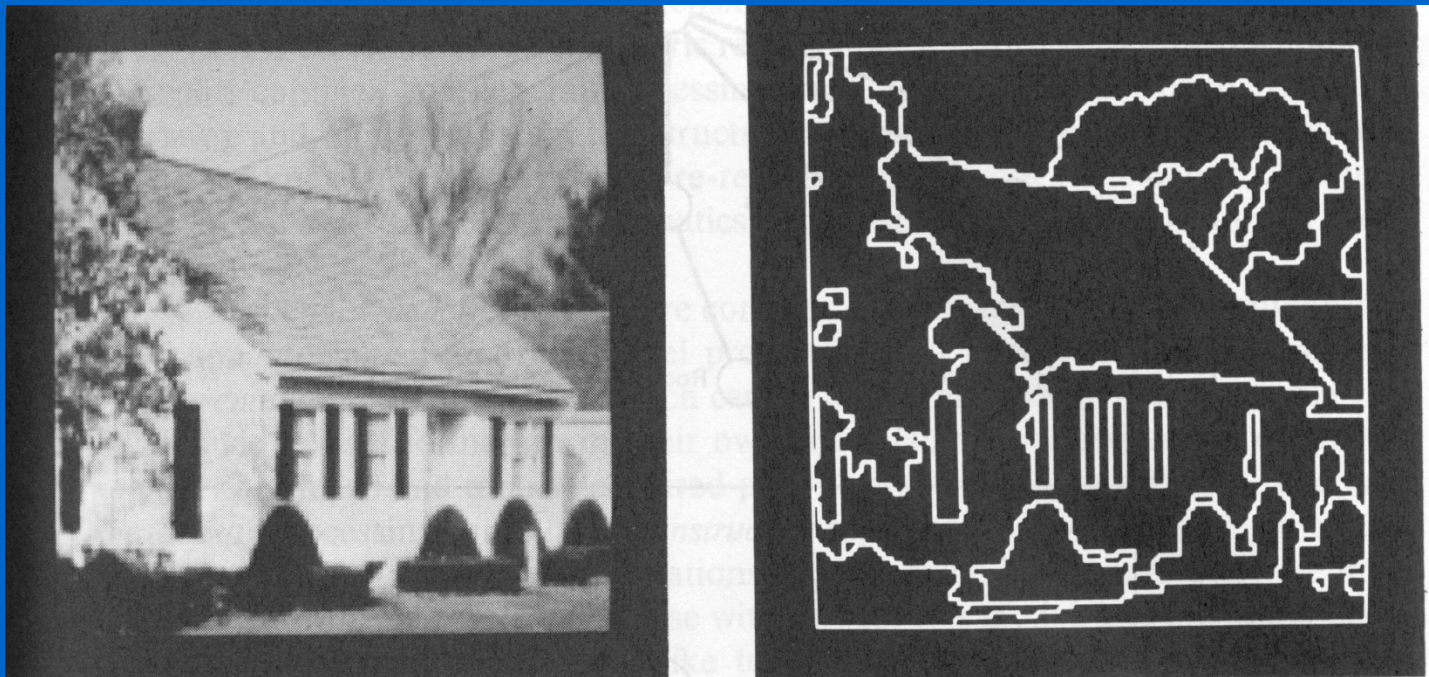
The Three Processing Levels (cont'd)

- High-level processing
  - Recognition and interpretation.
  - Procedures require high intelligent capabilities.
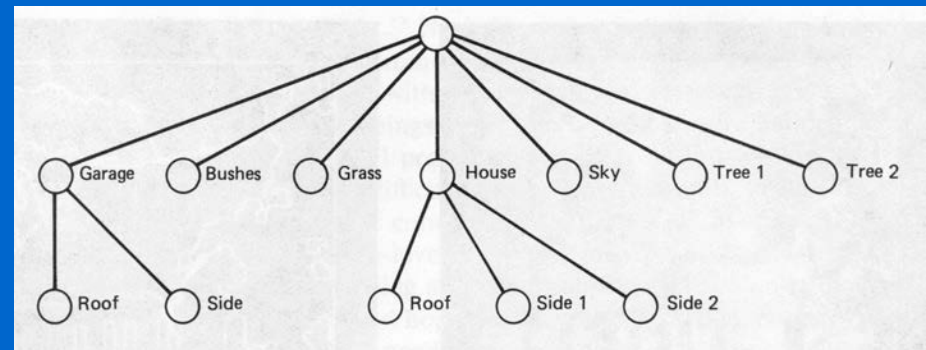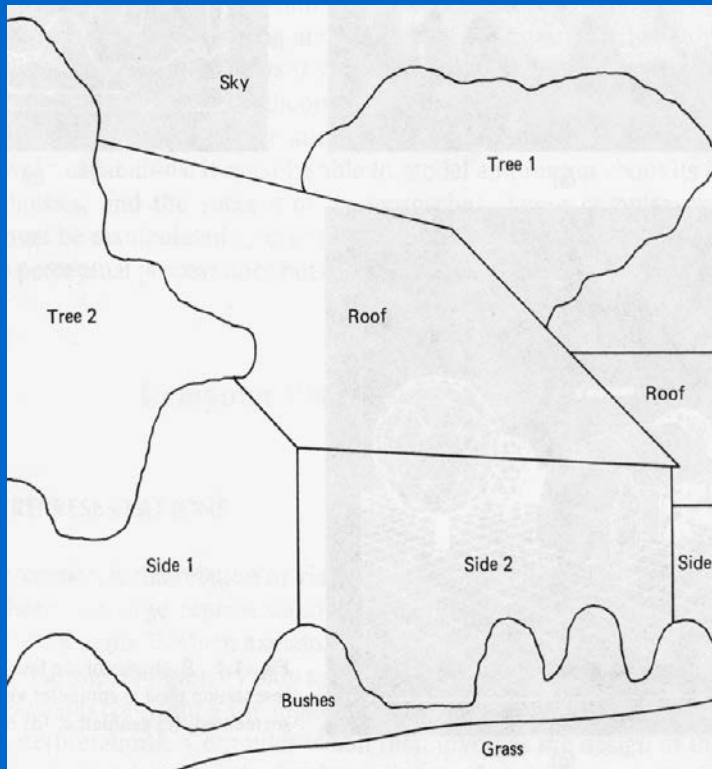
Recognition Cues

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

Recognition Cues (cont'd)

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 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/quality control
- Surveillance and security
- Face recognition
- Gesture recognition
- Space applications
- Medical image analysis
- Autonomous vehicles
- Virtual reality and much more …...

Visual Inspection
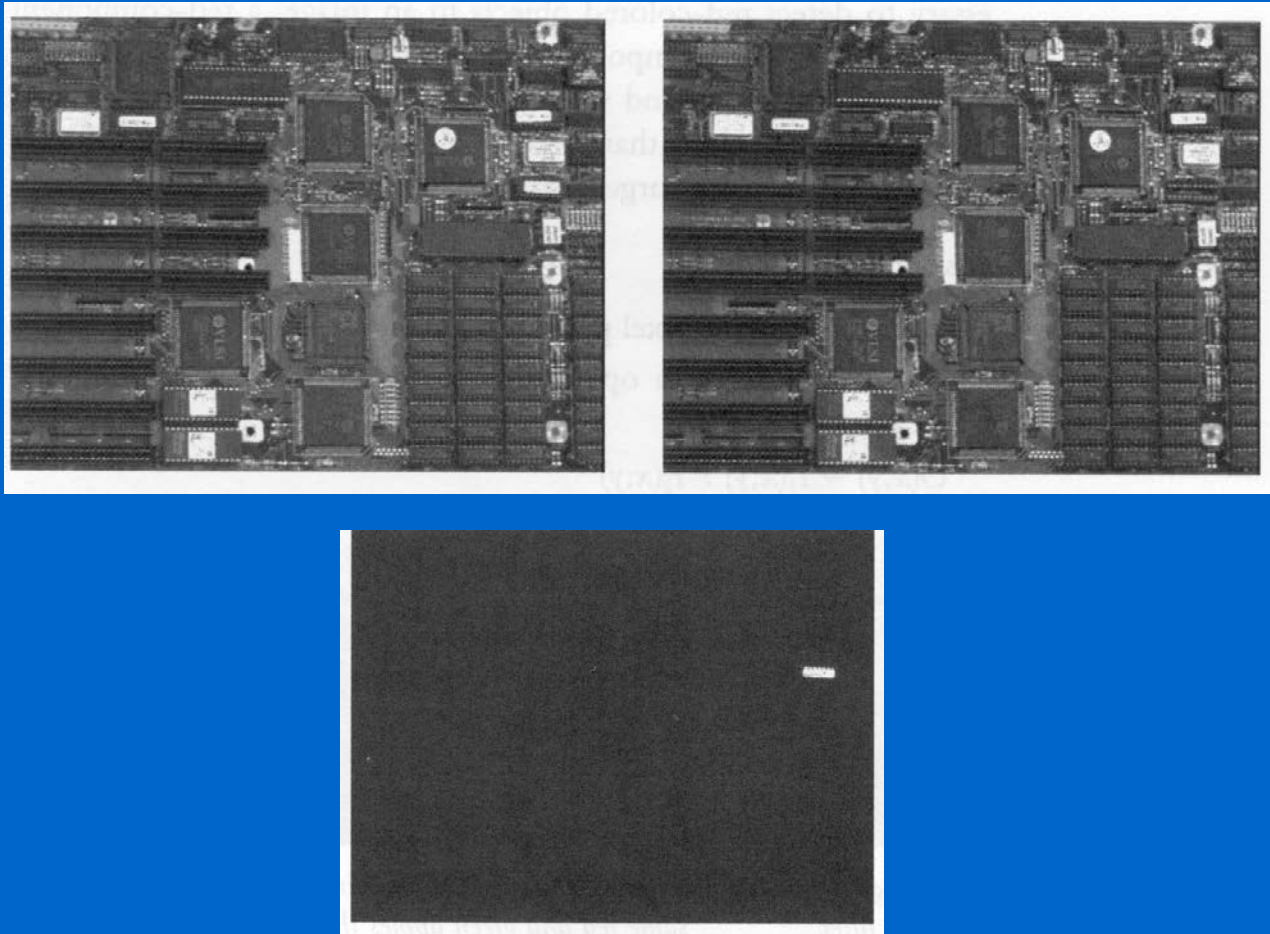
Character Recognition

demodulation

demodulation

Probably you have uses for this facility in your organisation.

Document Handling
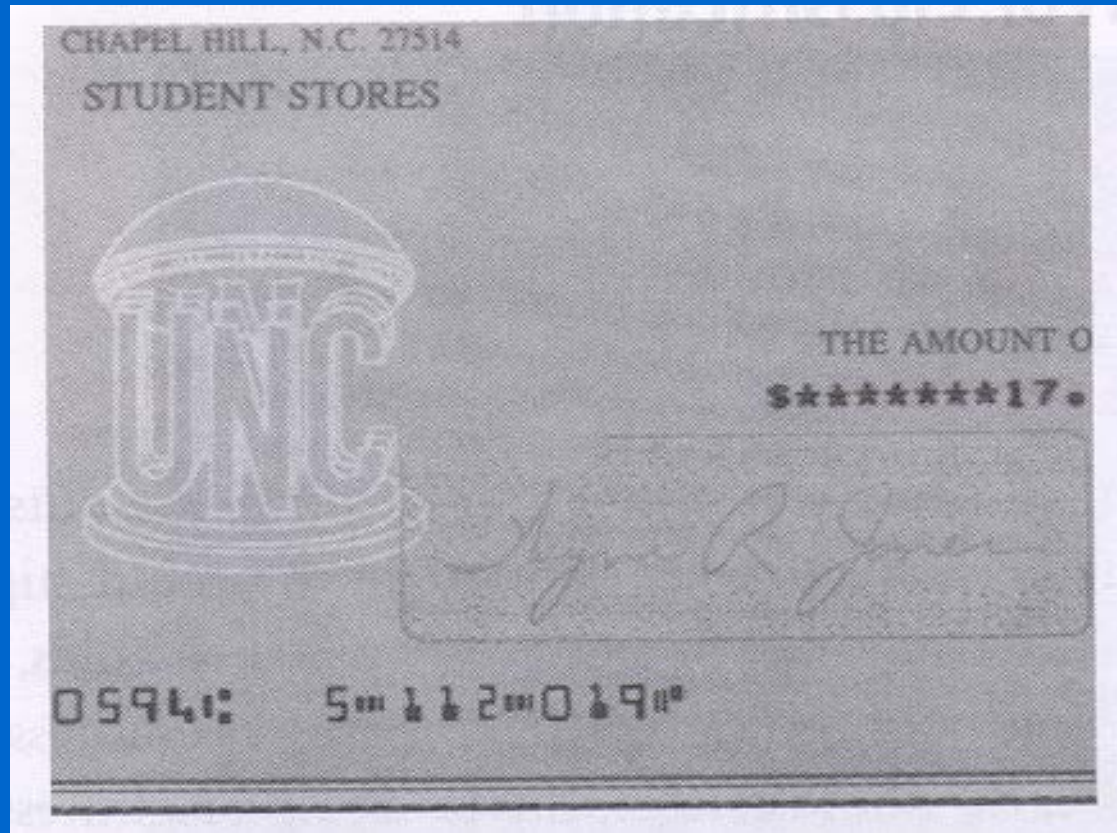
Signature Verification

Biometrics
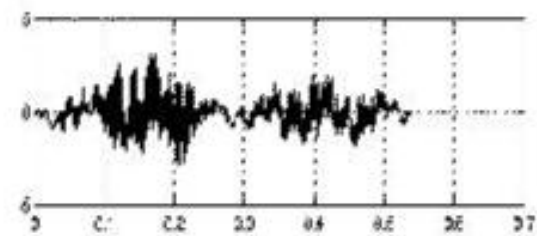
Fingerprint Verification / Identification
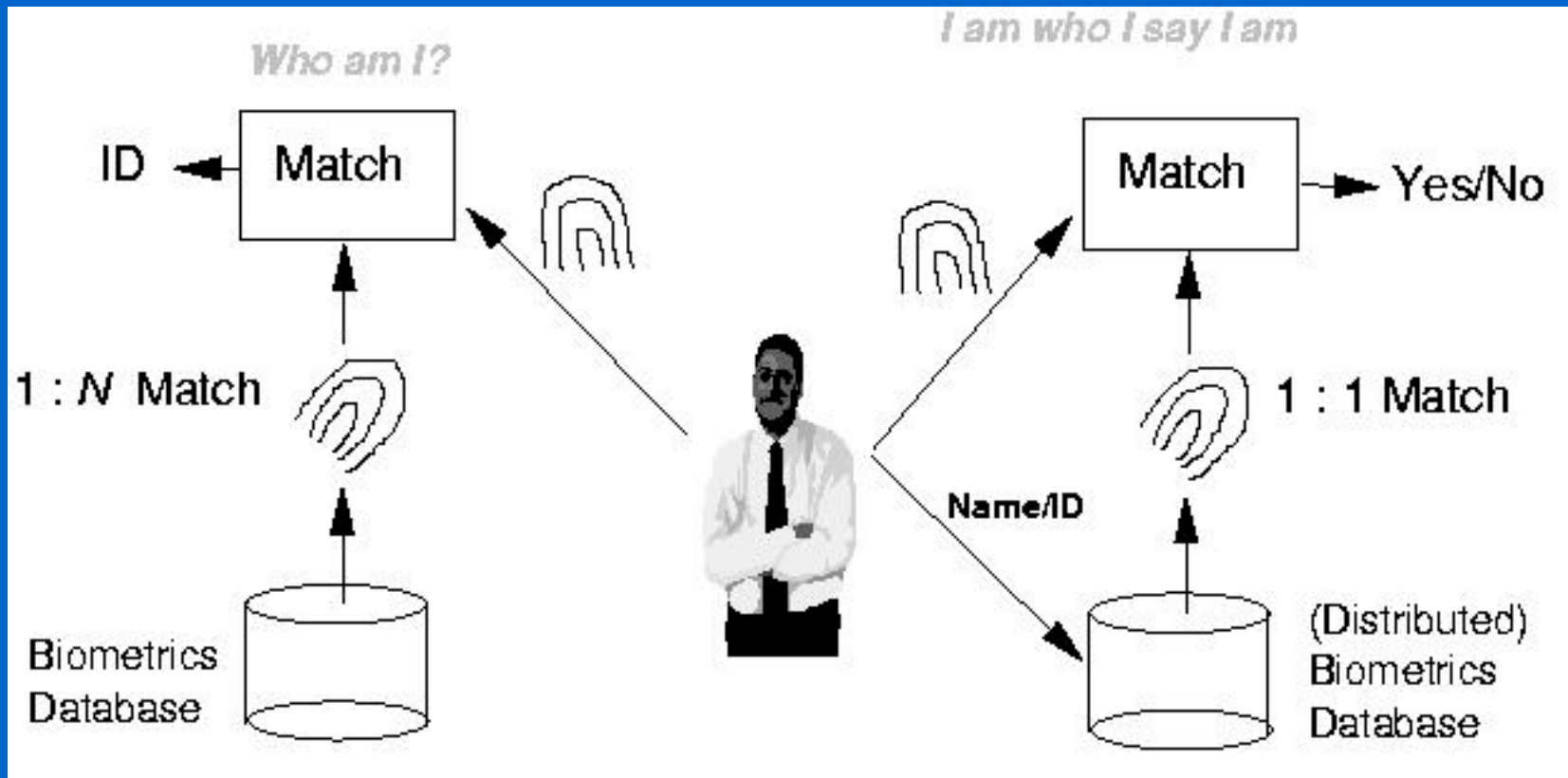
Fingerprint Identification Research at UNR

Minutiae
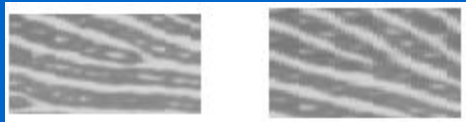
Matching
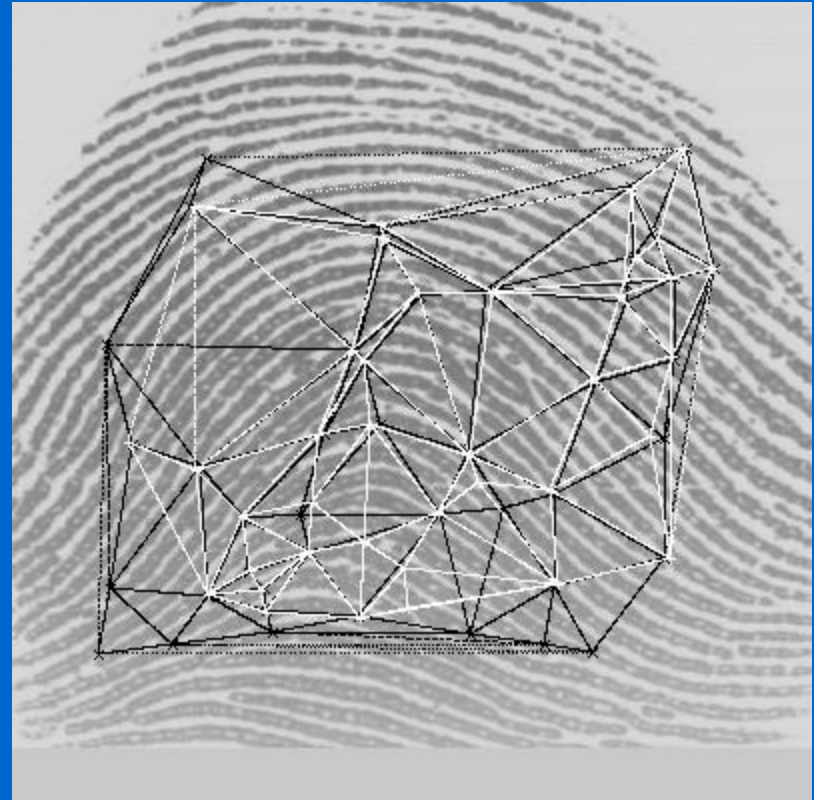
Delaunay Triangulation

Object Recognition

Object Recognition Research
at UNR

reference view 1

reference view 2

novel view recognized
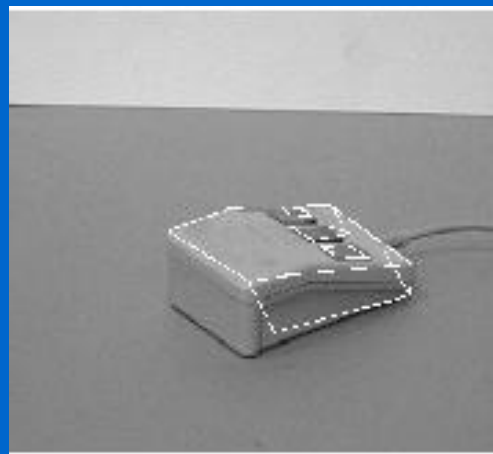
Indexing into Databases

- Shape content
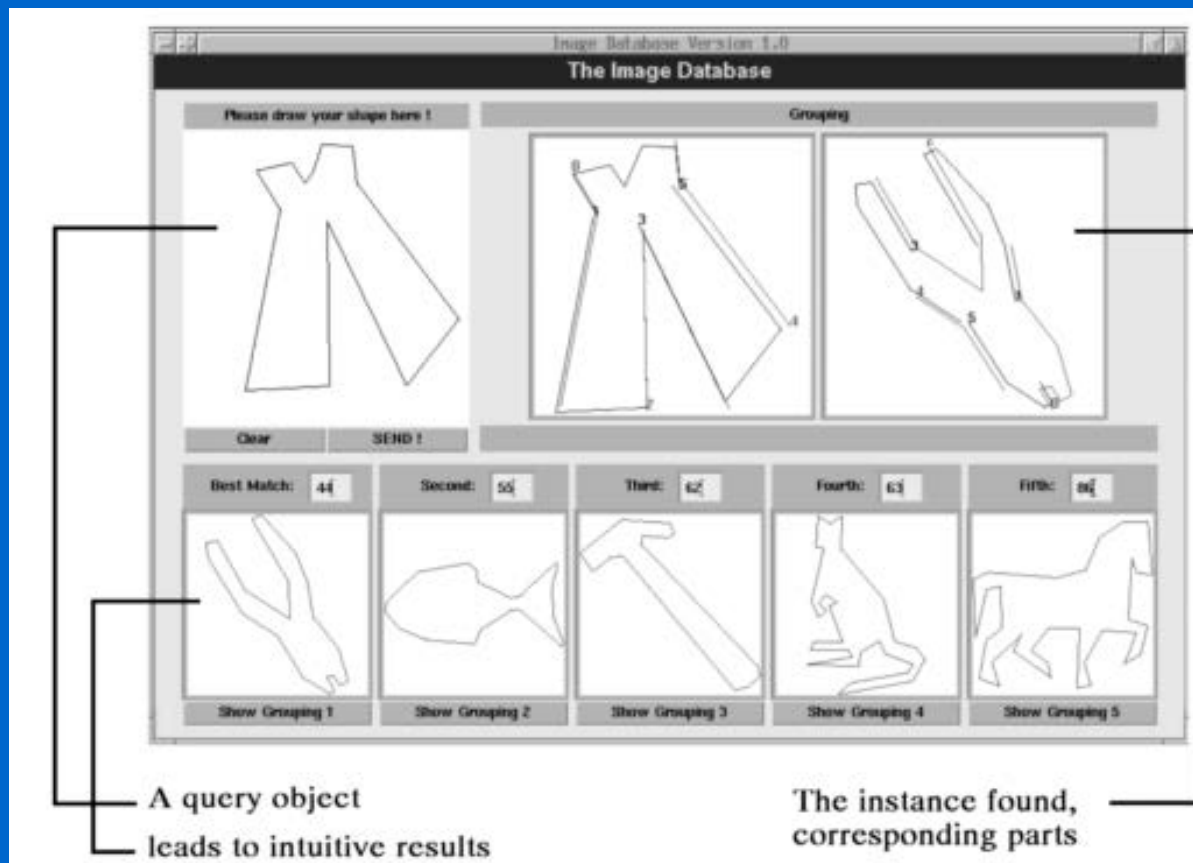
Indexing into Databases (cont'd)

- Color, texture
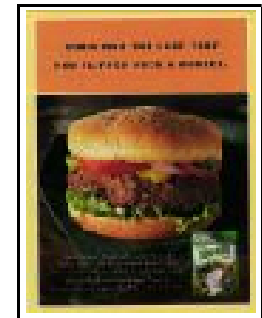
$T = 33.6$s, found 2 of 2

Target Recognition

- Department of Defense (Army, Airforce, Navy)
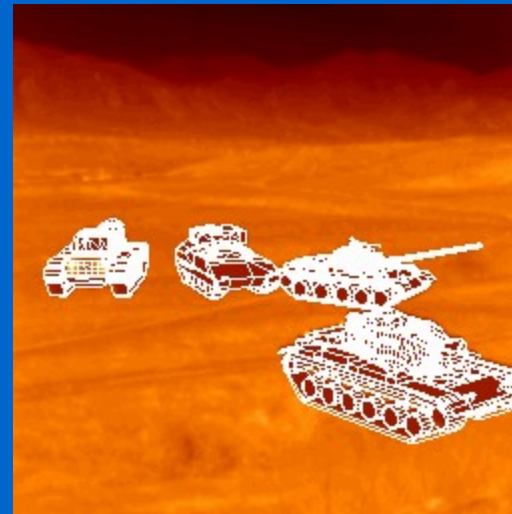
Interpretation of Aerial Photography

Interpretation of aerial photography is a problem domain in both computer vision and photogrammetry.

Autonomous Vehicles

- Land, Underwater, Space
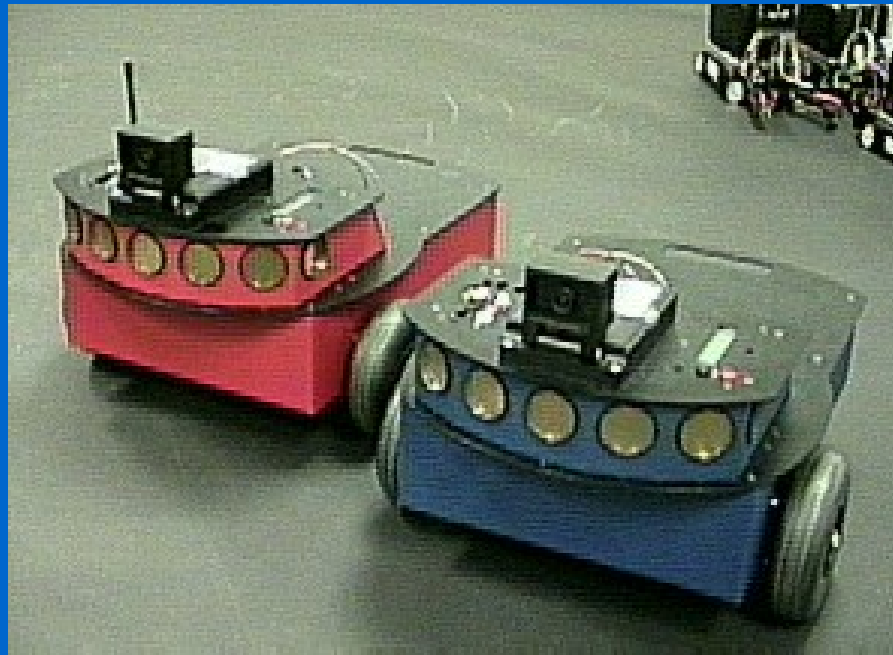
Traffic Monitoring
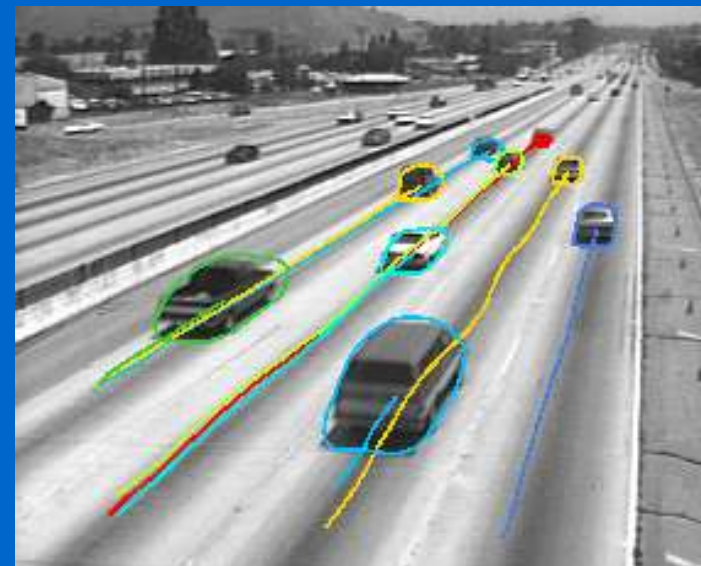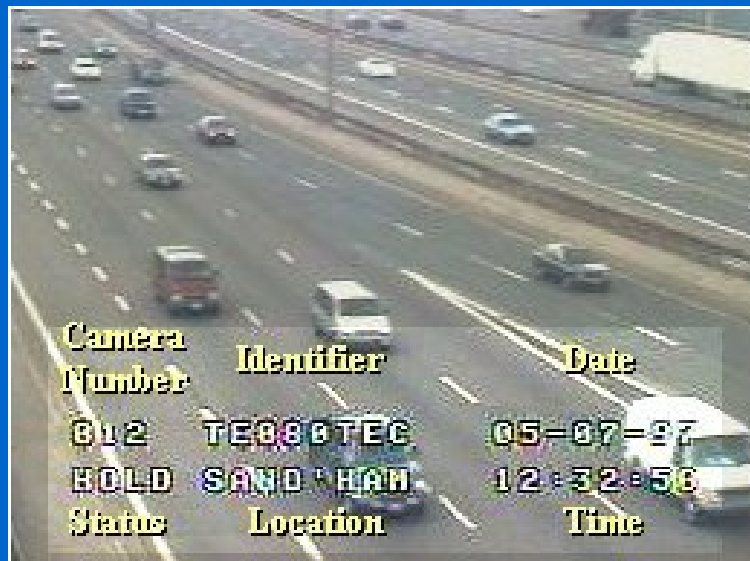
Face Detection
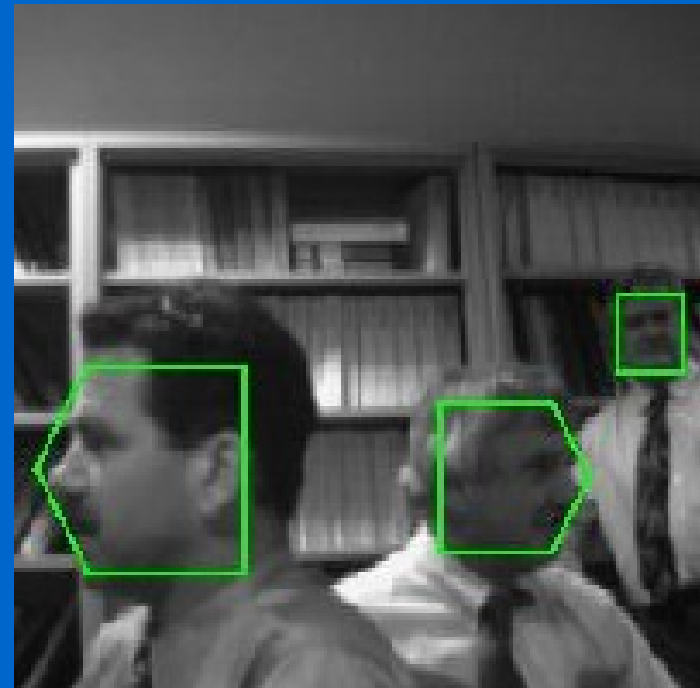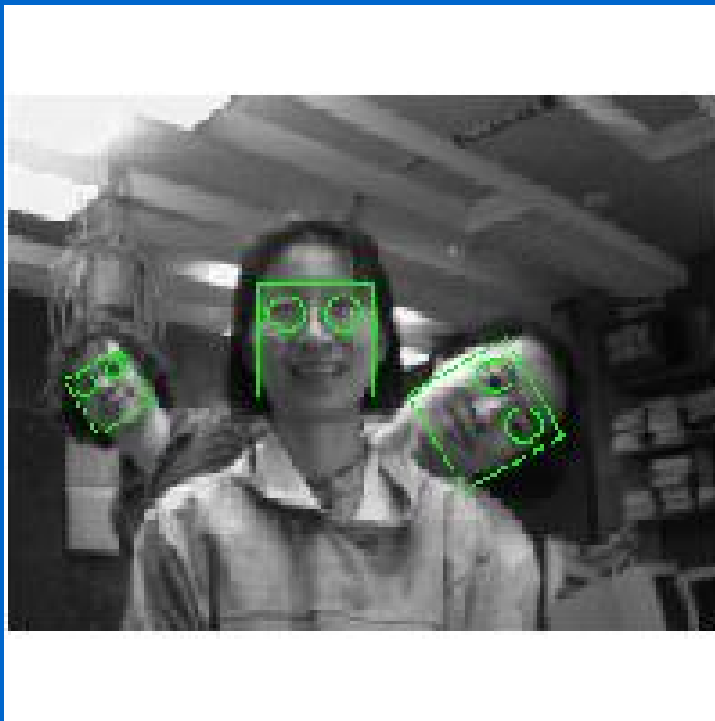
Face Recognition

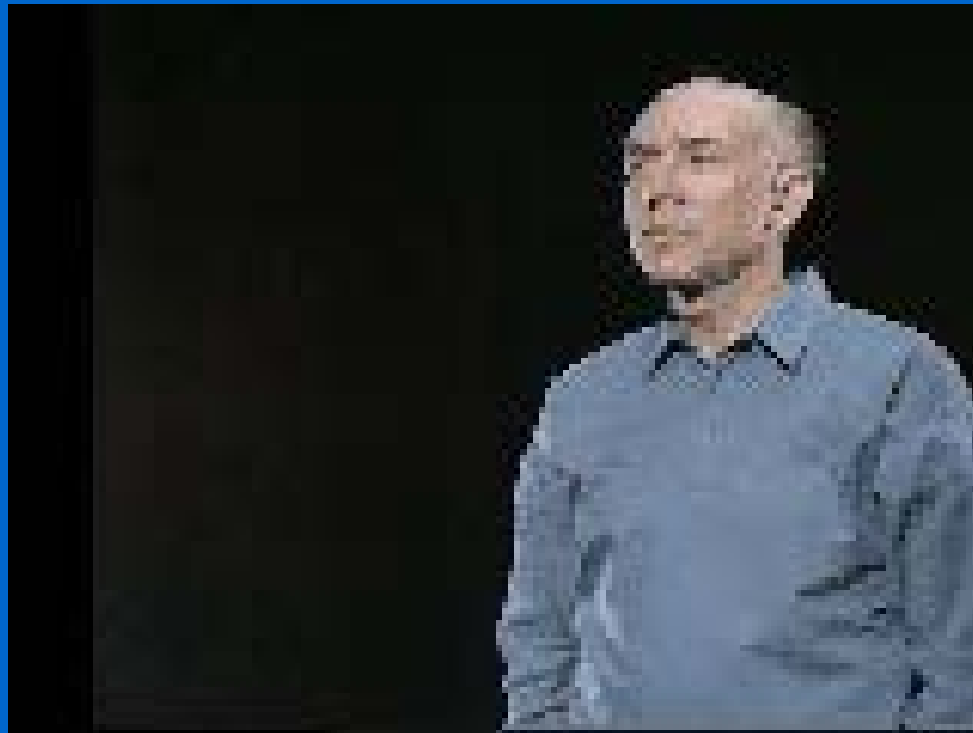# Face Detection/Recognition Research at UNR

Facial Expression Recognition

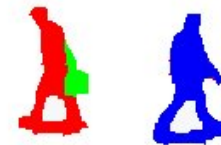© Sam Ogden
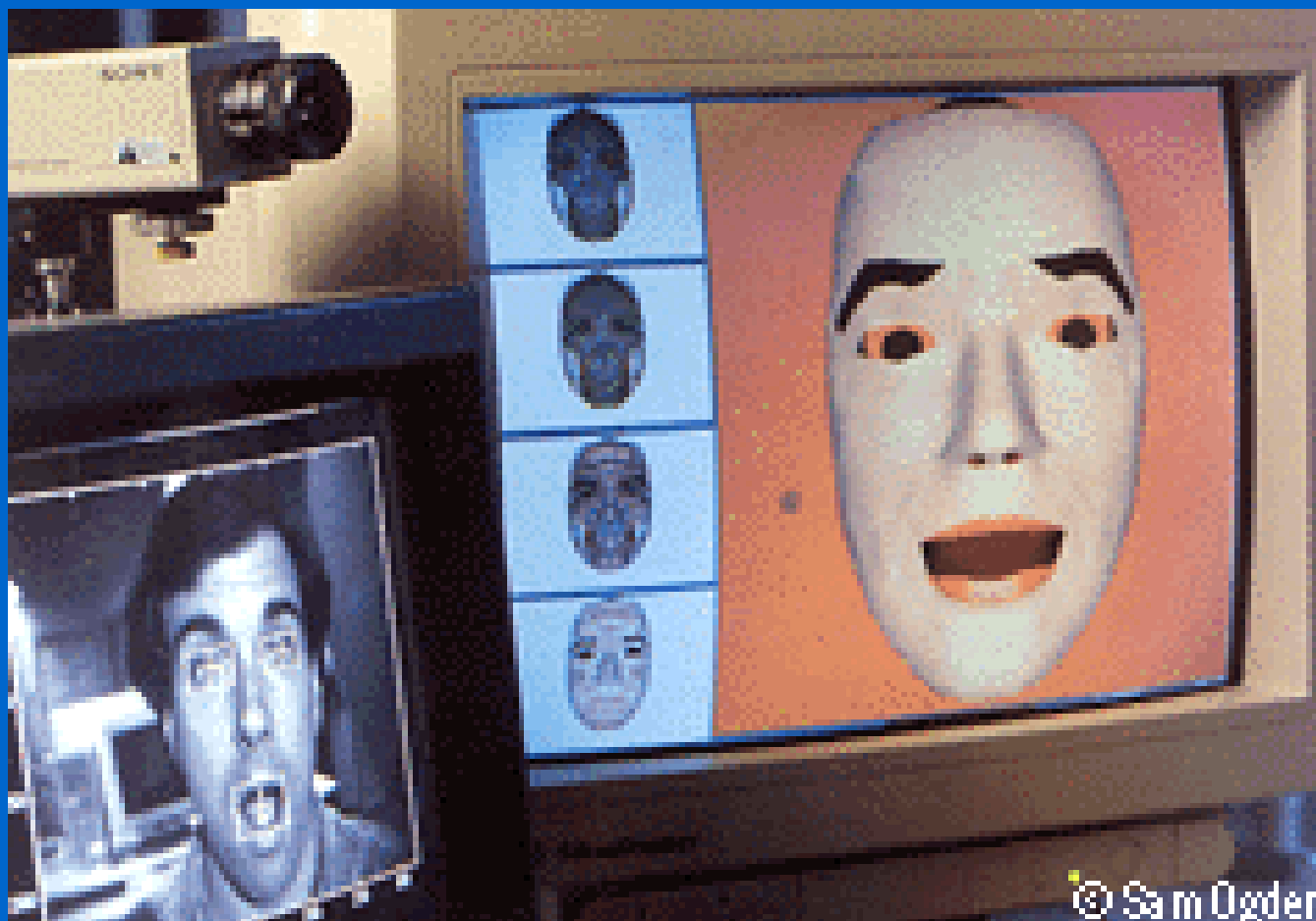
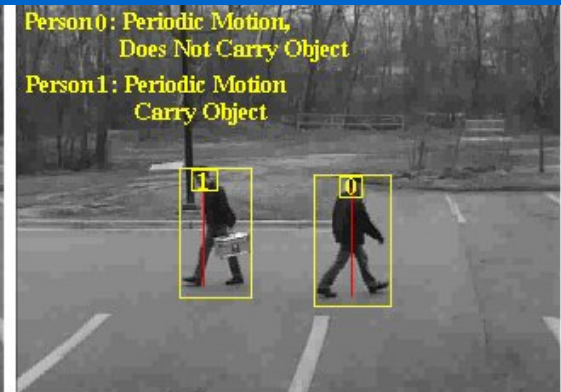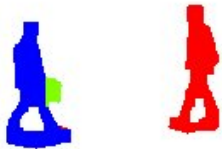# Face Tracking

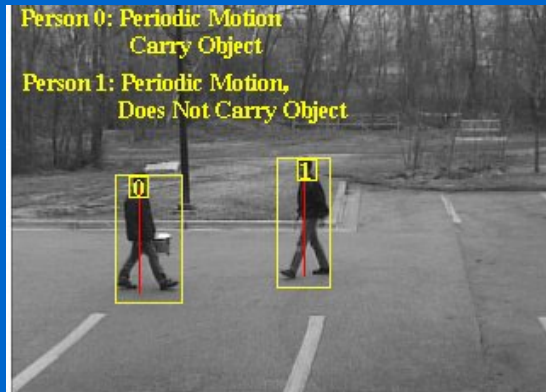# Face Tracking (cont'd)

Hand Gesture Recognition

- Smart Human-Computer User Interfaces
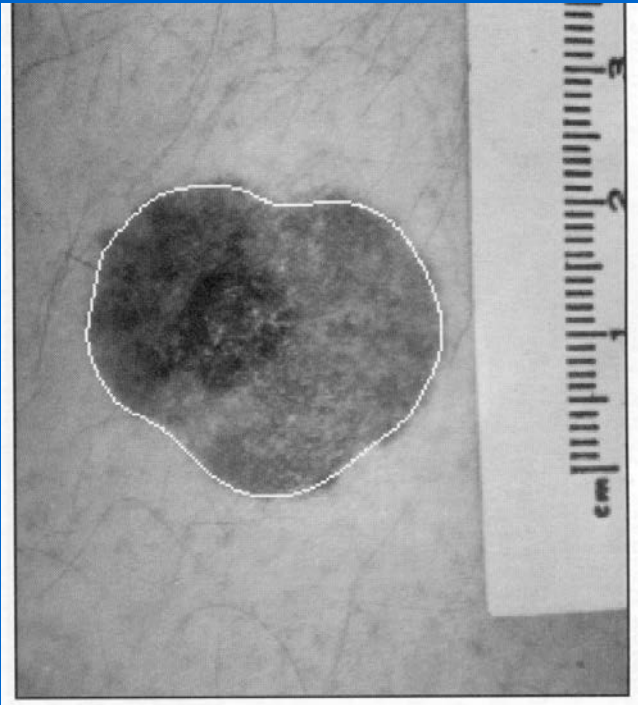
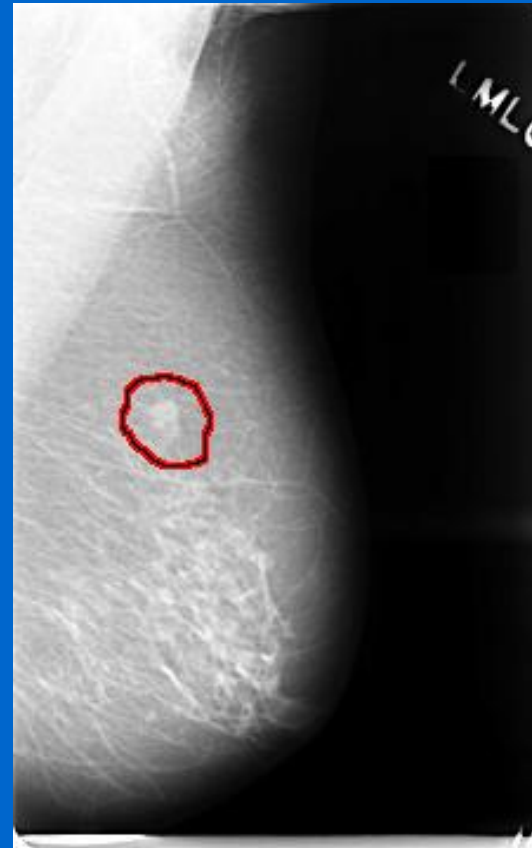- Sign Language Recognition

Human Activity Recognition
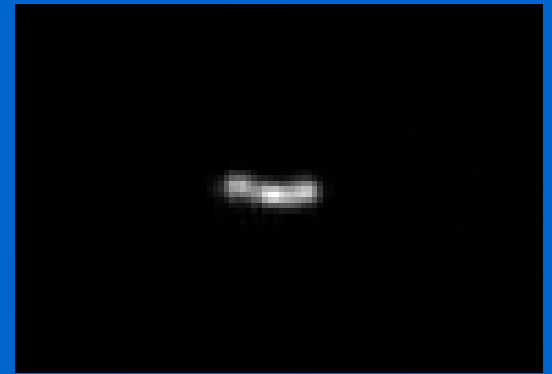
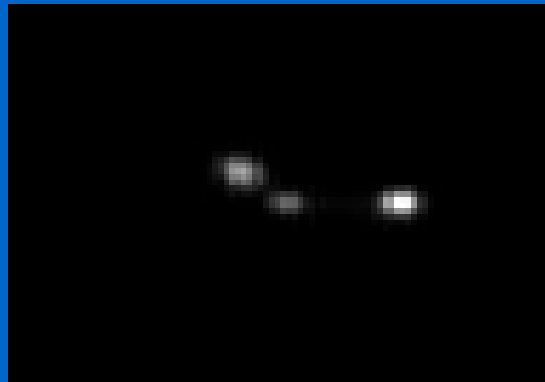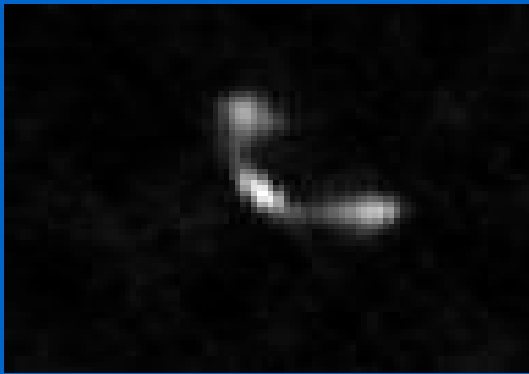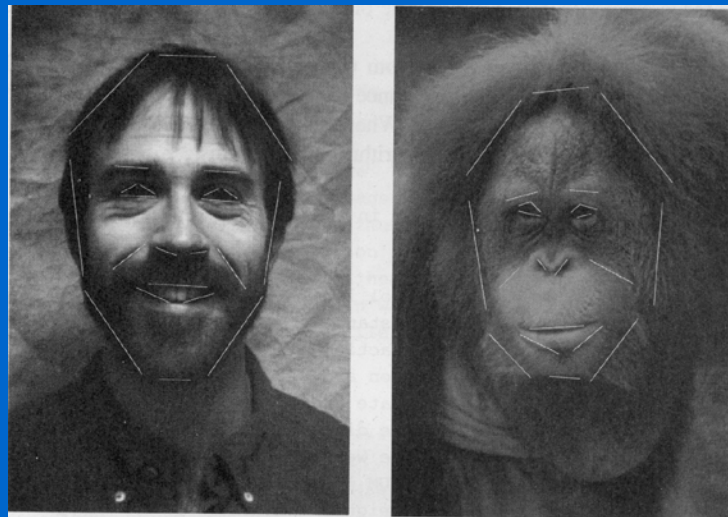# Medical Applications

- skin cancer   breast cancer

Astronomy Applications Research at UNR

- Identify radio galaxies having a special morphology called "bent-double" (in collaboration with **Lawrence Livermore National Laboratory**)
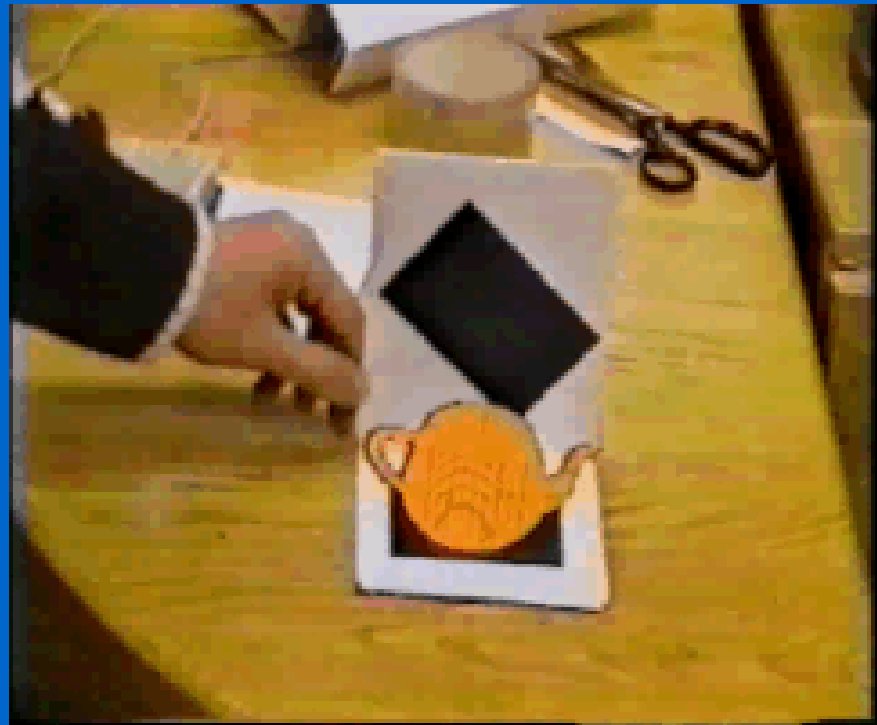
Morphing

Inserting Artificial Objects into a Scene

Computer Vision and Related Courses at UNR

- CS474/674 Image Processing and Interpretation
- CS480/680 Computer Graphics
- CS479/679 Pattern Recognition
- CS476/676 Artificial Intelligence
- CS773A Machine Intelligence
- CS791Q Machine Learning
- CS7xx Neural Networks
- CS7xx Computer Vision

More information on Computer Vision

- Computer Vision Home Page

  http://www.cs.cmu.edu/afs/cs/project/cil/ftp/html/vision.html

- Home Page

  http://www.cs.unr.edu/CRCD

- UNR Computer Vision Laboratory

  http://www.cs.unr.edu/CVL