

CS 663
Fundamentals of
Digital Image Processing

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PG Elective
Slot 11, Tue + Fri, 3:30 - 4:55 pm

Digital Image Processing

- Digital Images
 - Array of numbers (N dimensions)
- Algorithms
 - Input = image
 - e.g., black-and-white picture (2D), video (3D)
 - Output = image / measurement / high-level description
- Applications
 - Images are everywhere !

Digital Image Processing

- Application domains
 - Images are everywhere
 - Pictures, videos: cameras, smartphones, webcam
 - Photography, Cinema (editing, special effects)
 - Medical image analysis
 - Microscopy, X-ray, CT, MRI, endoscopy
 - Remote sensing (weather prediction)
 - Biometrics, Forensics
 - Surveillance (military, urban)
 - Seismology
 - Sports
 - ...

Digital Image Processing

- Why take this course ?
 - Research in image analysis (after getting a good grade)
 - Other courses:
 - CS 763 Computer Vision
 - CS 754 Advanced Image Processing
 - CS 736 Medical Image Computing
 - Learn powerful, cool mathematical concepts
 - Linear algebra, Statistics, Machine learning
 - Jobs in R&D
 - India
 - GE, Siemens, Philips, Samsung, Canon, Sun Pharma, Agilent (HP), Intel,, ...
 - DRDO (defense), ISRO (space), ICRISAT (agriculture)
 - Microsoft, nVidia, Facebook, Google, Pixar, Dreamworks, Adobe, Toshiba, Medtronic, Hitachi, Pharma, Oil & Gas

Digital Image Processing

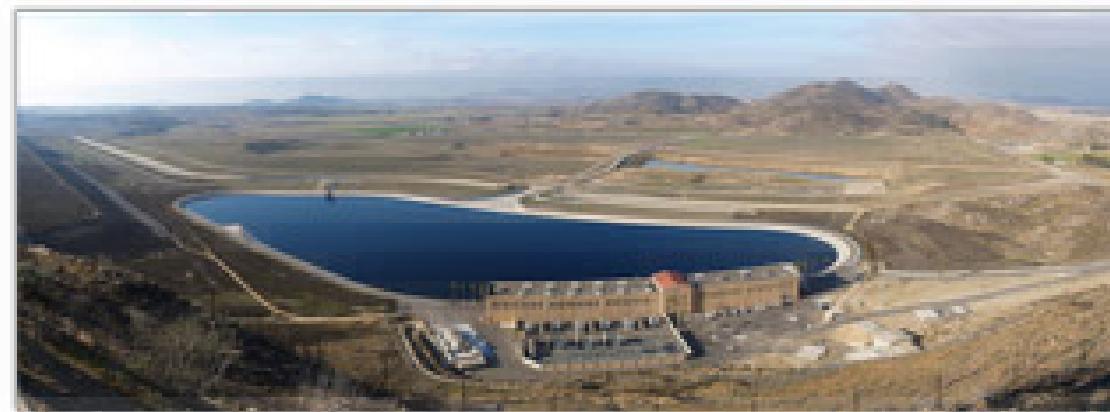
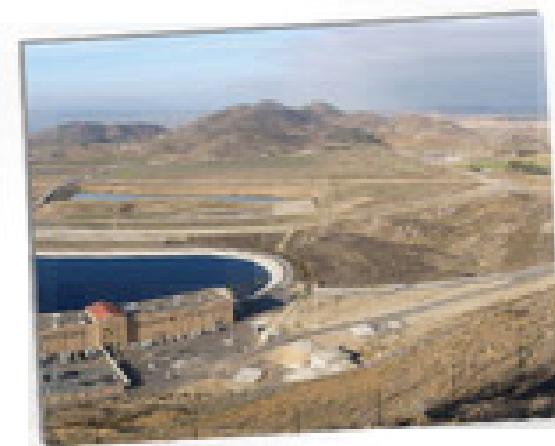
- Editing pictures, movies



+

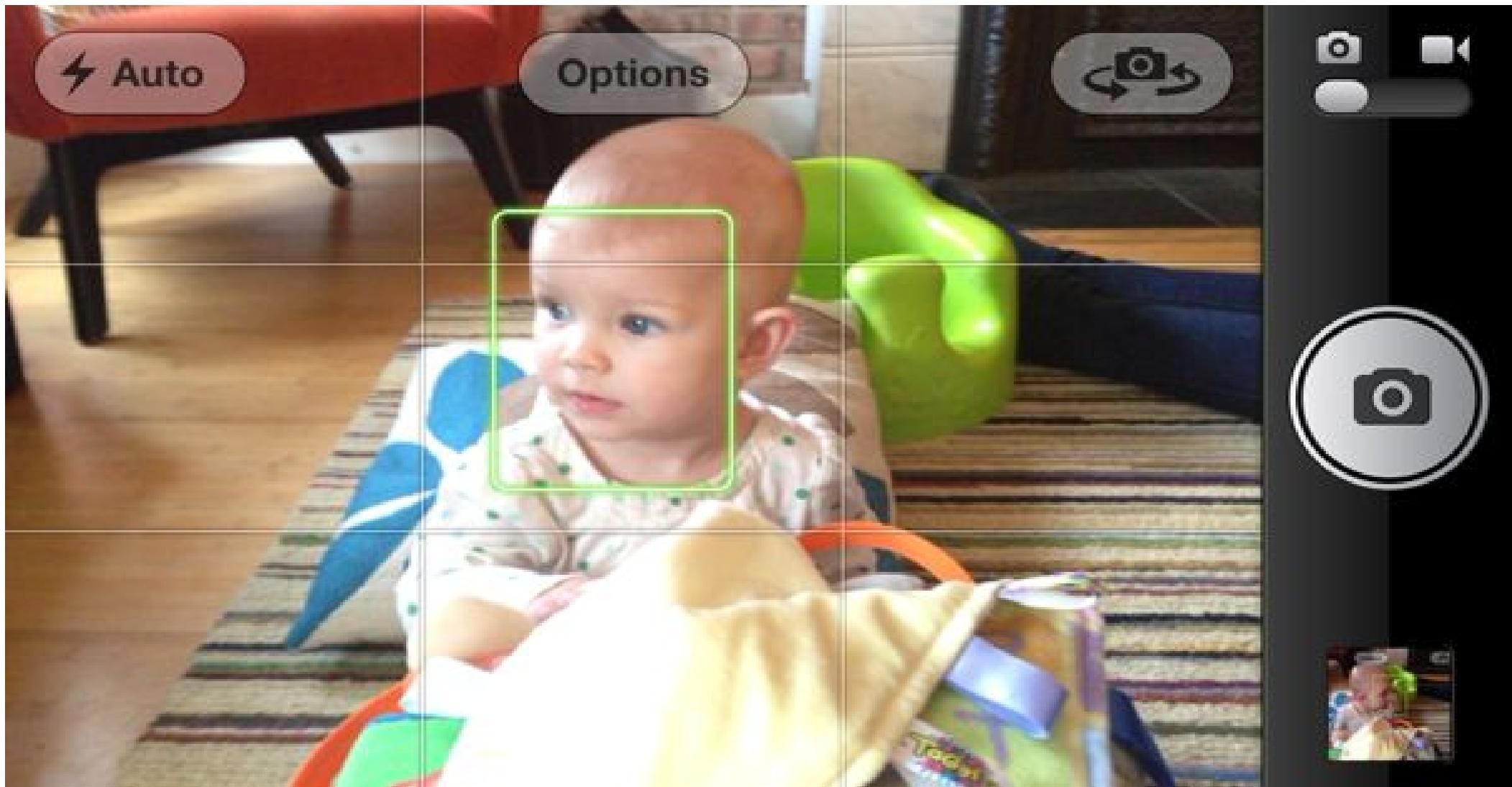


+



Digital Image Processing

- Photography
 - Face detection for auto focus

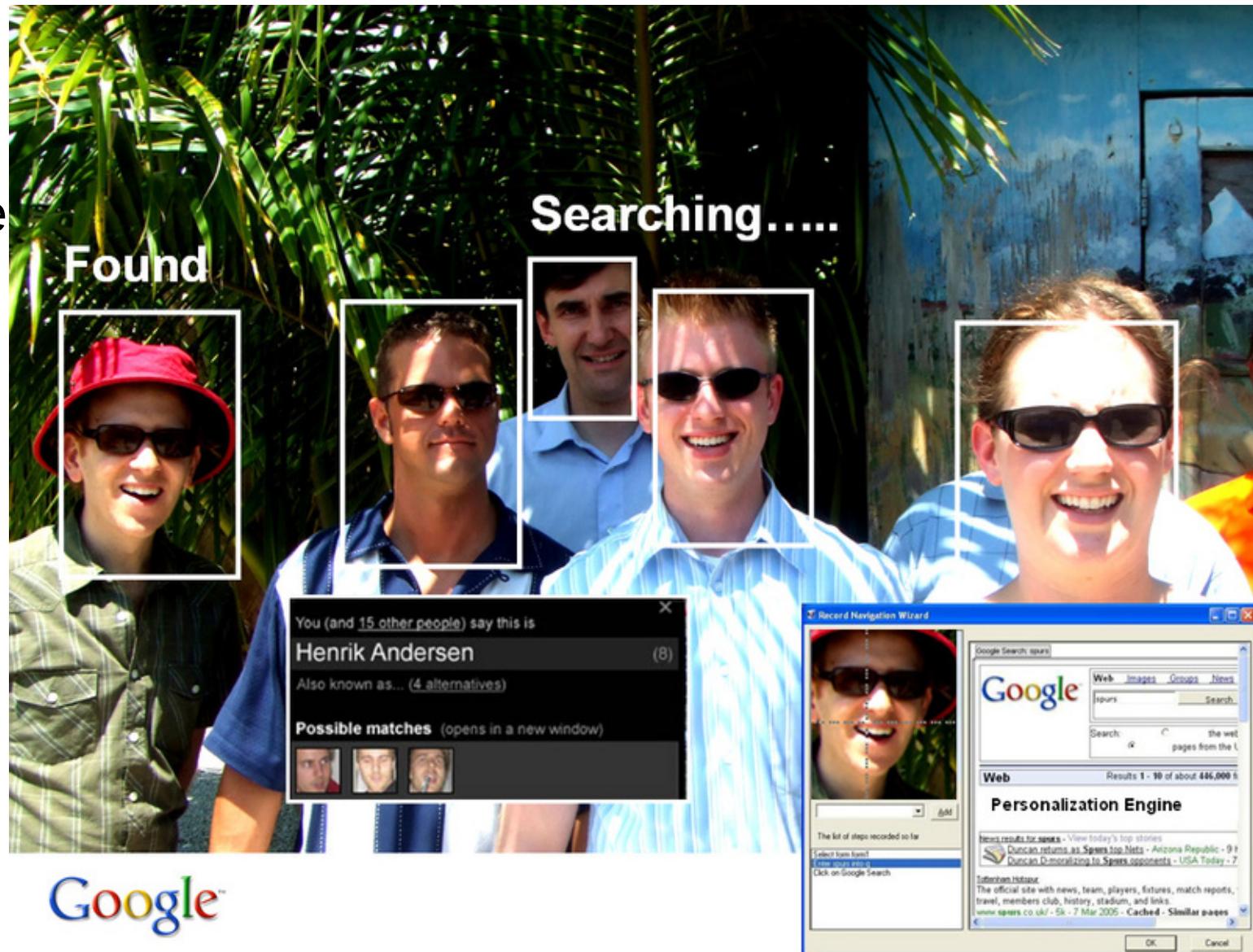


Digital Image Processing

- Internet applications

- Tagging faces:

- Detect
 - Recognize



Digital Image Processing

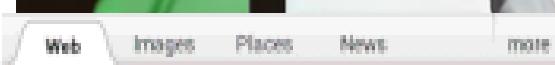
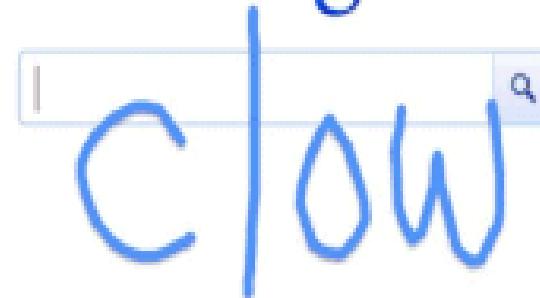
- Internet applications
 - Handwriting recognition



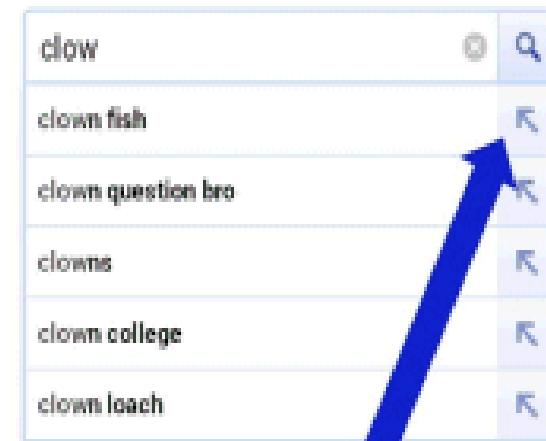
Google



Google



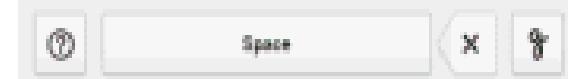
Google



Sign in



Tap on the Handwrite icon



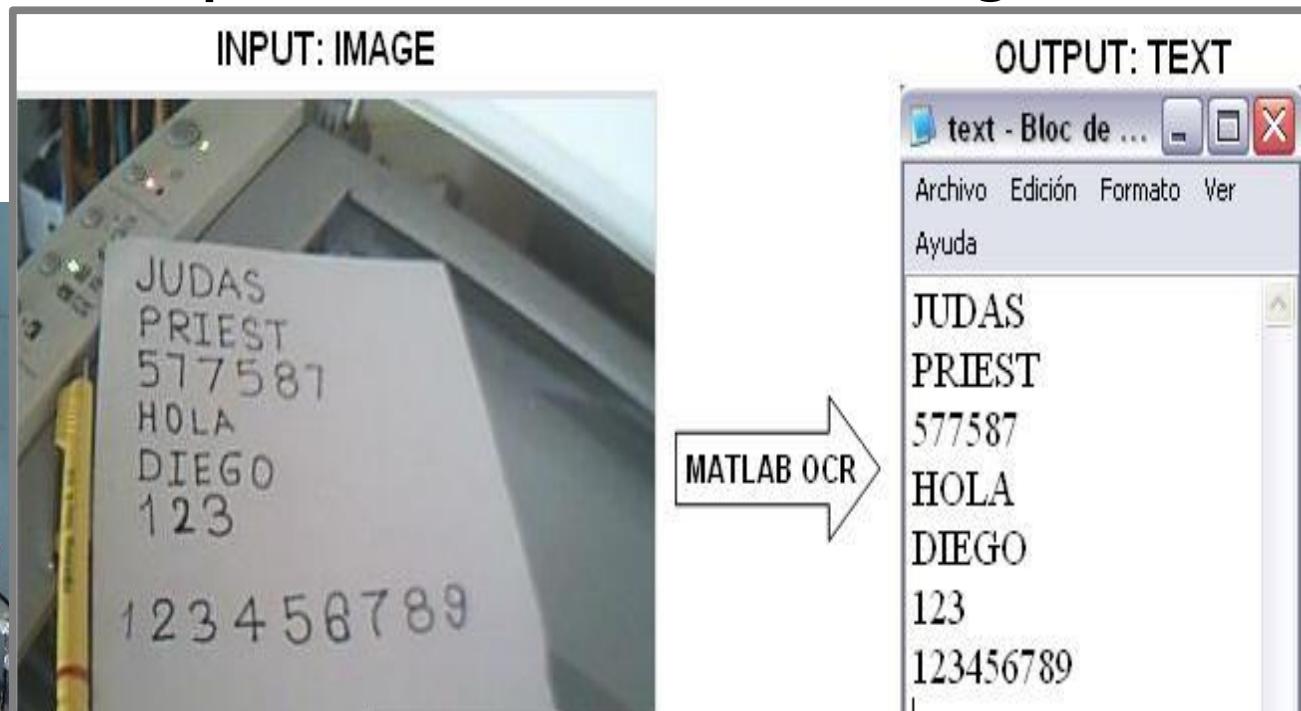
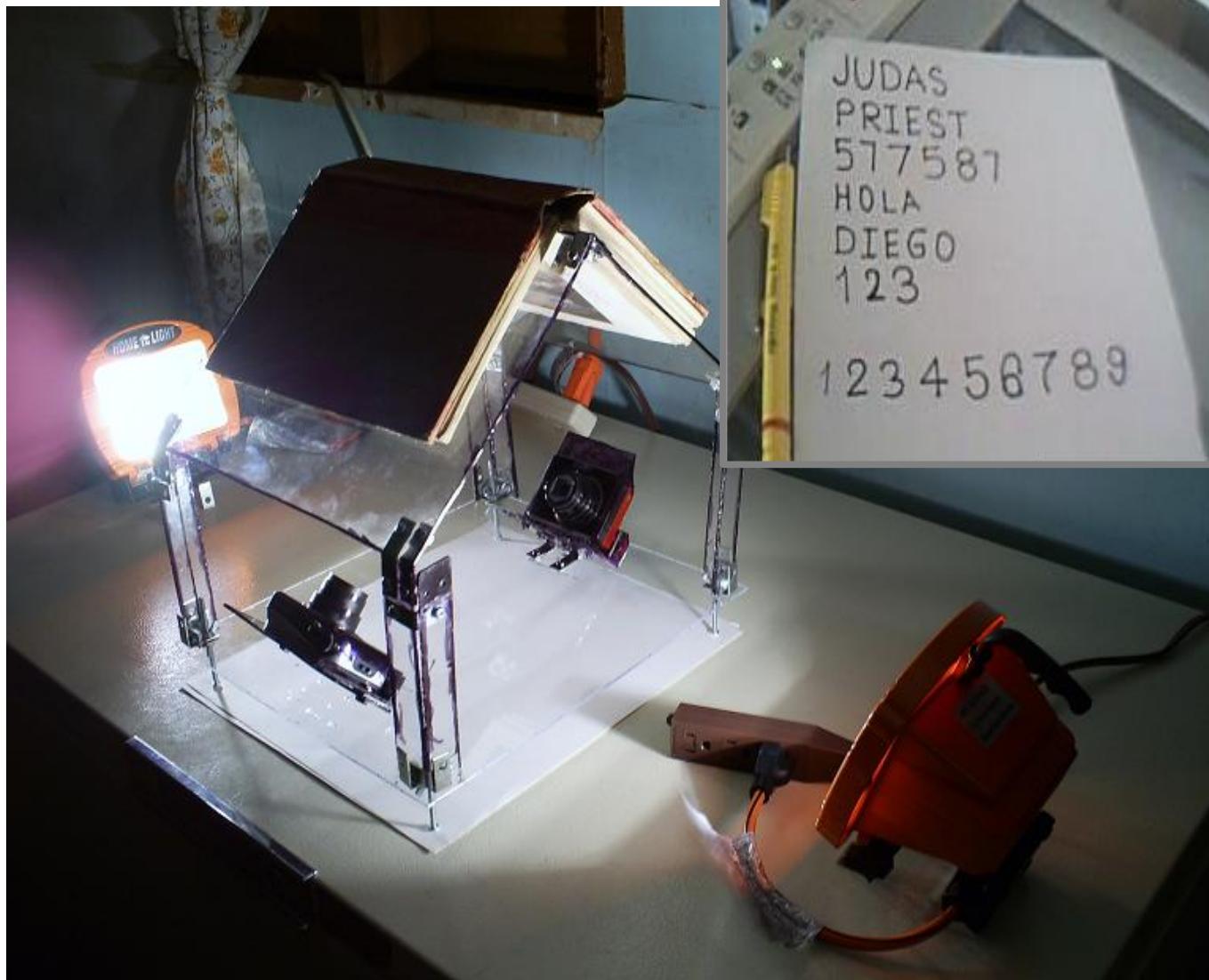
Write anywhere on the screen



Use autocomplete arrows for longer queries

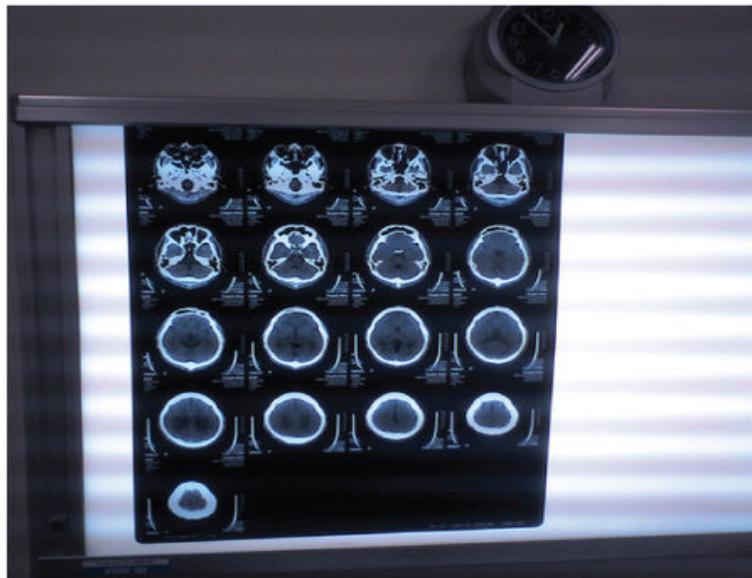
Digital Image Processing

- Document digitization: optical character recognition



Digital Image Processing

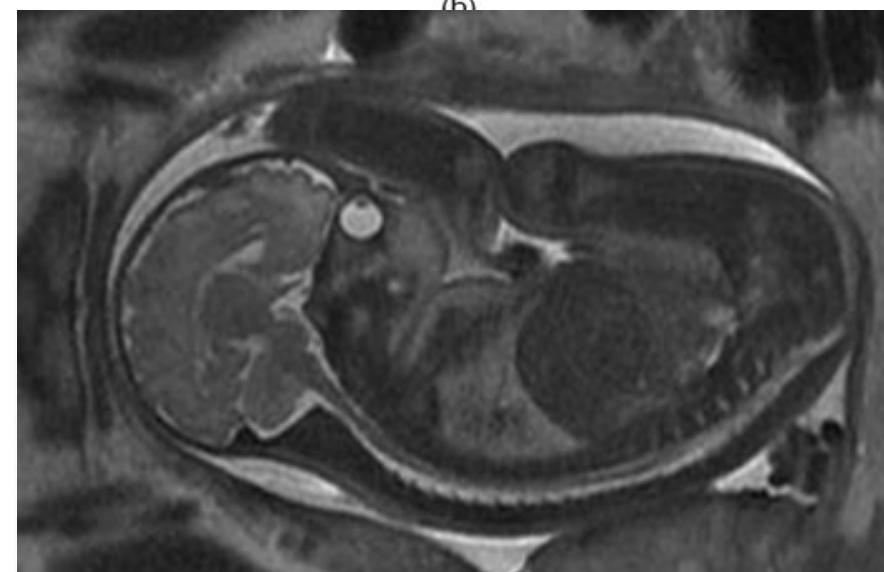
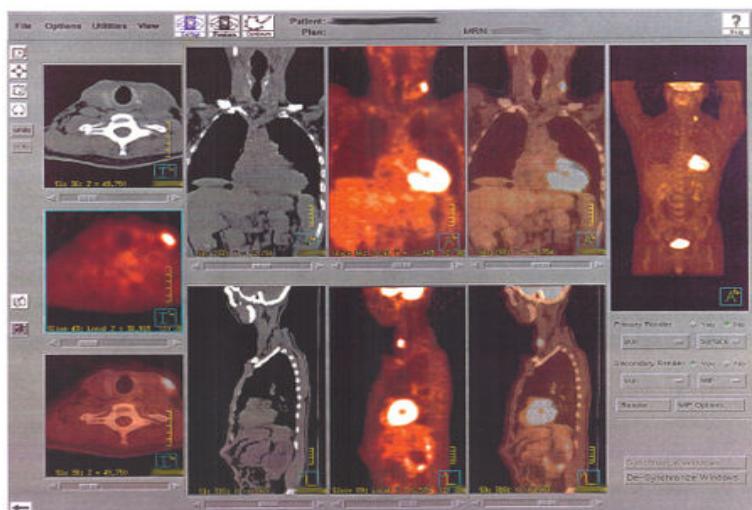
- Medical image analysis: MRI, CT, PET, Ultrasound, Microscopy, Laparoscopy



(a)

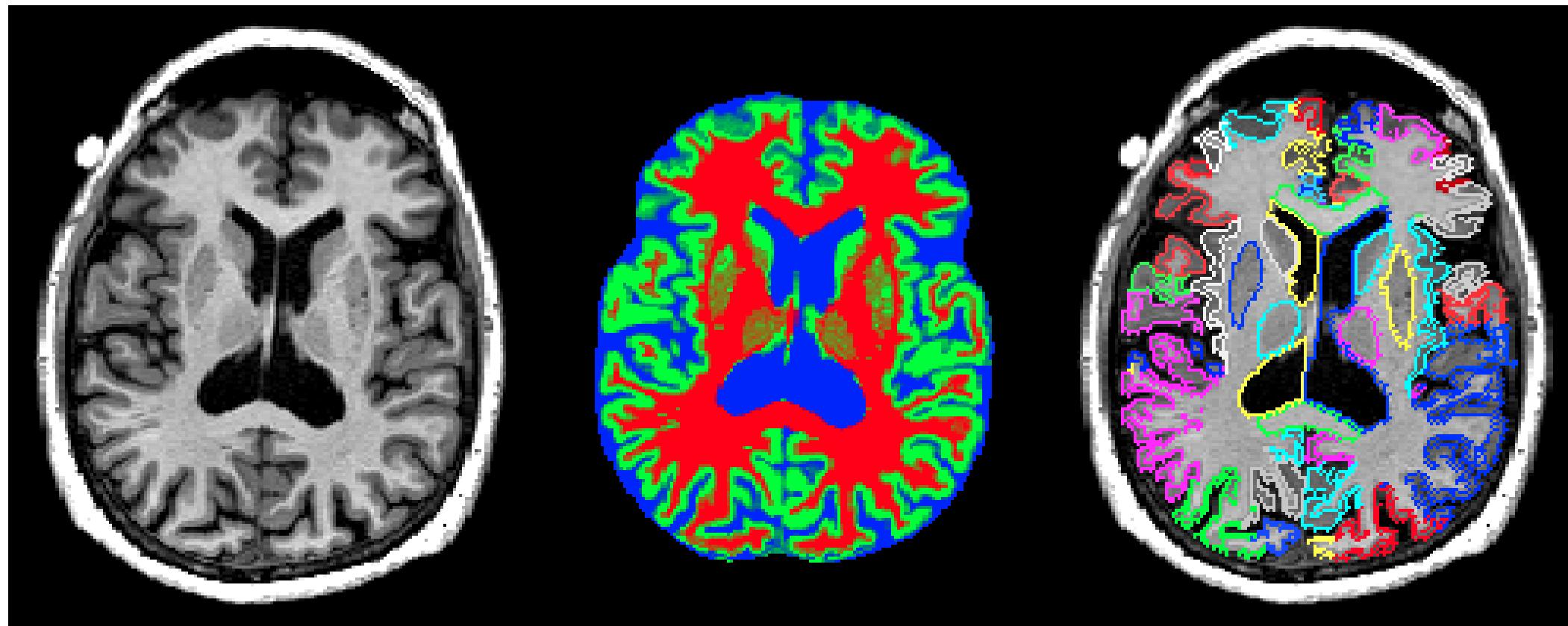


(b)



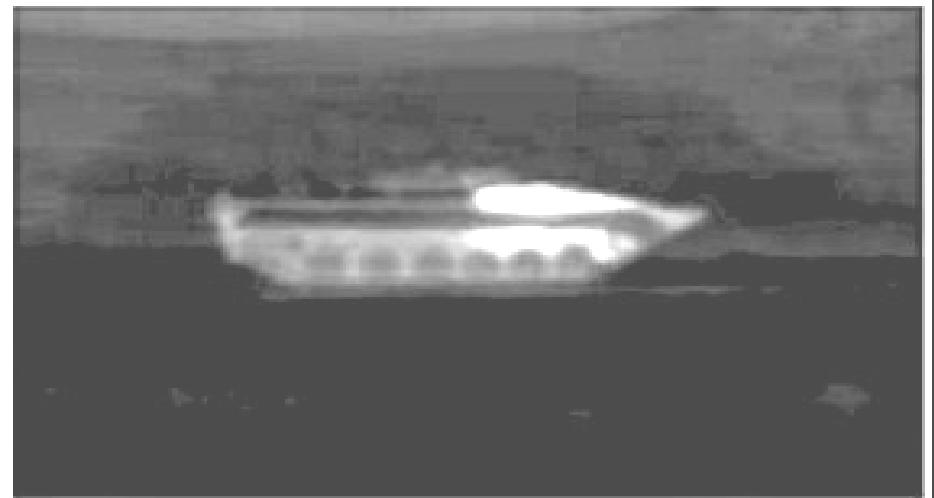
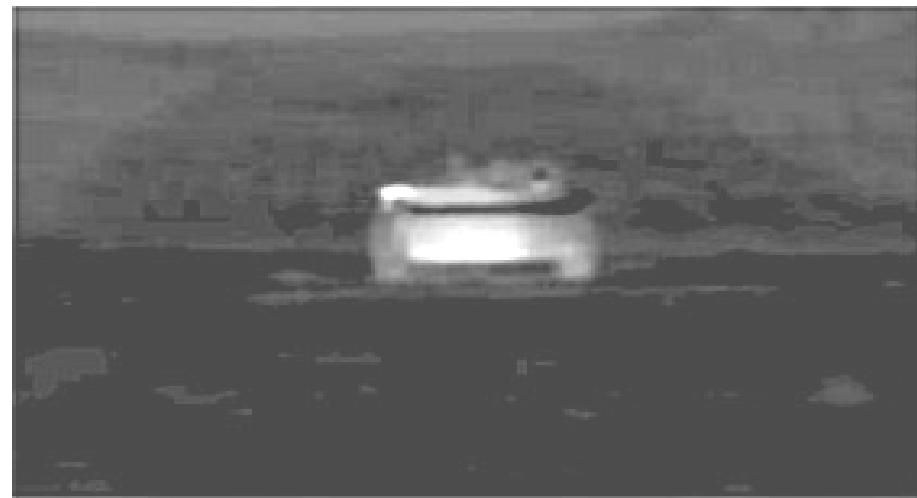
Digital Image Processing

- Medical image analysis
 - Segmentation



Digital Image Processing

- Segmentation



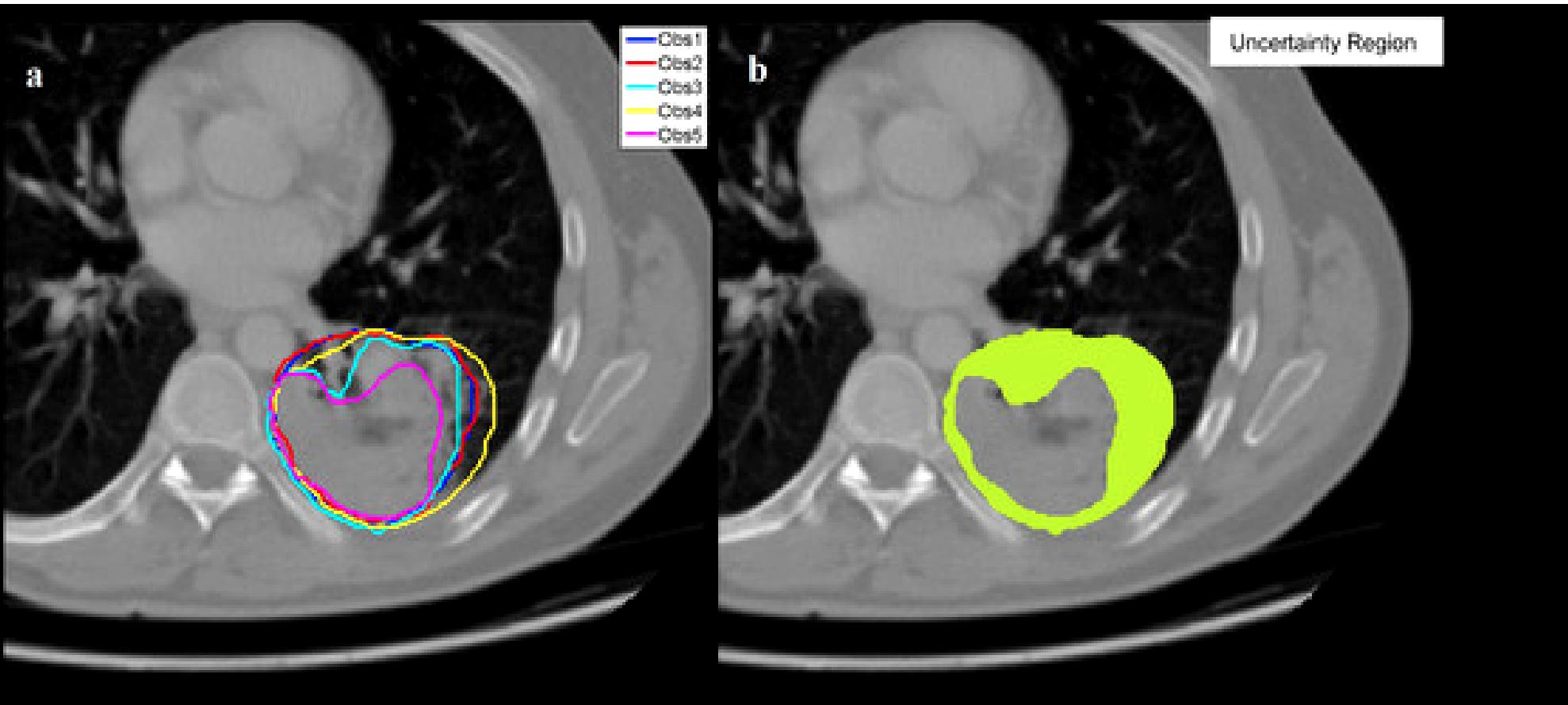
FRONTAL TARGETS

FLANK TARGETS

Digital Image Processing

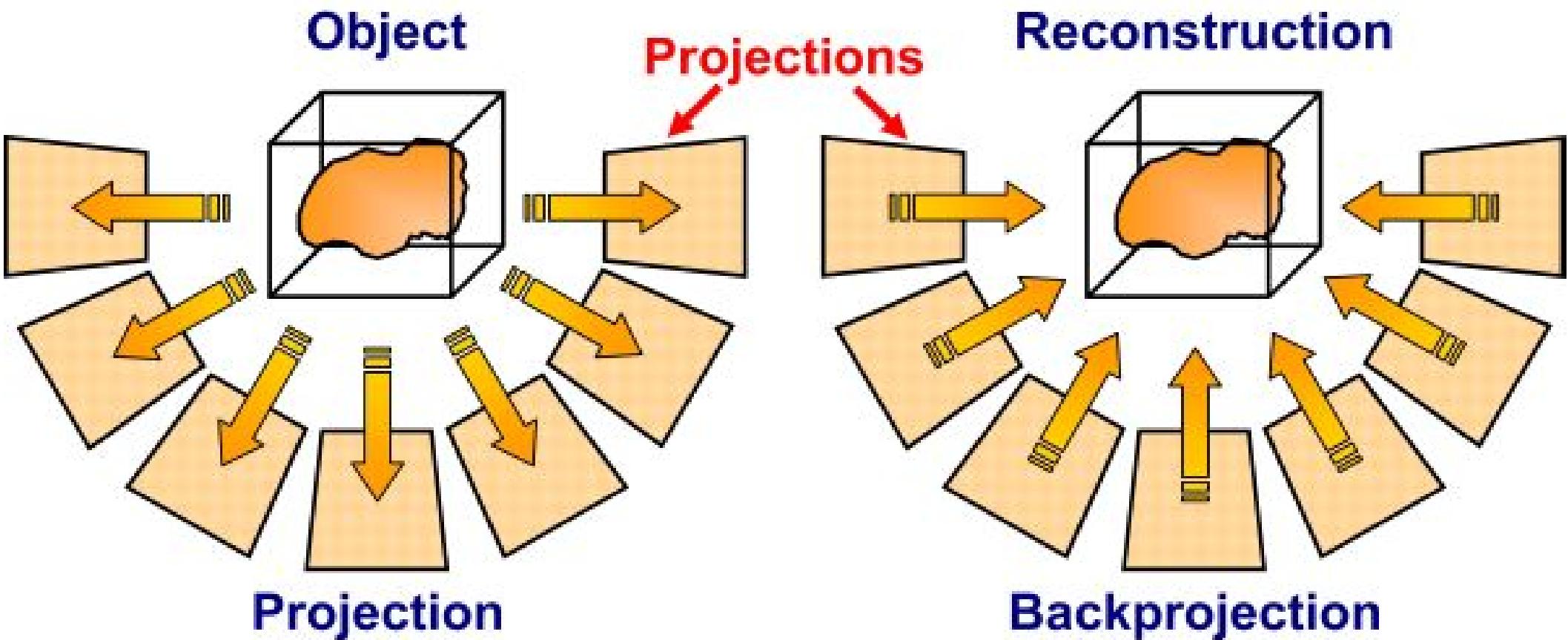
- Segmentation

Manual



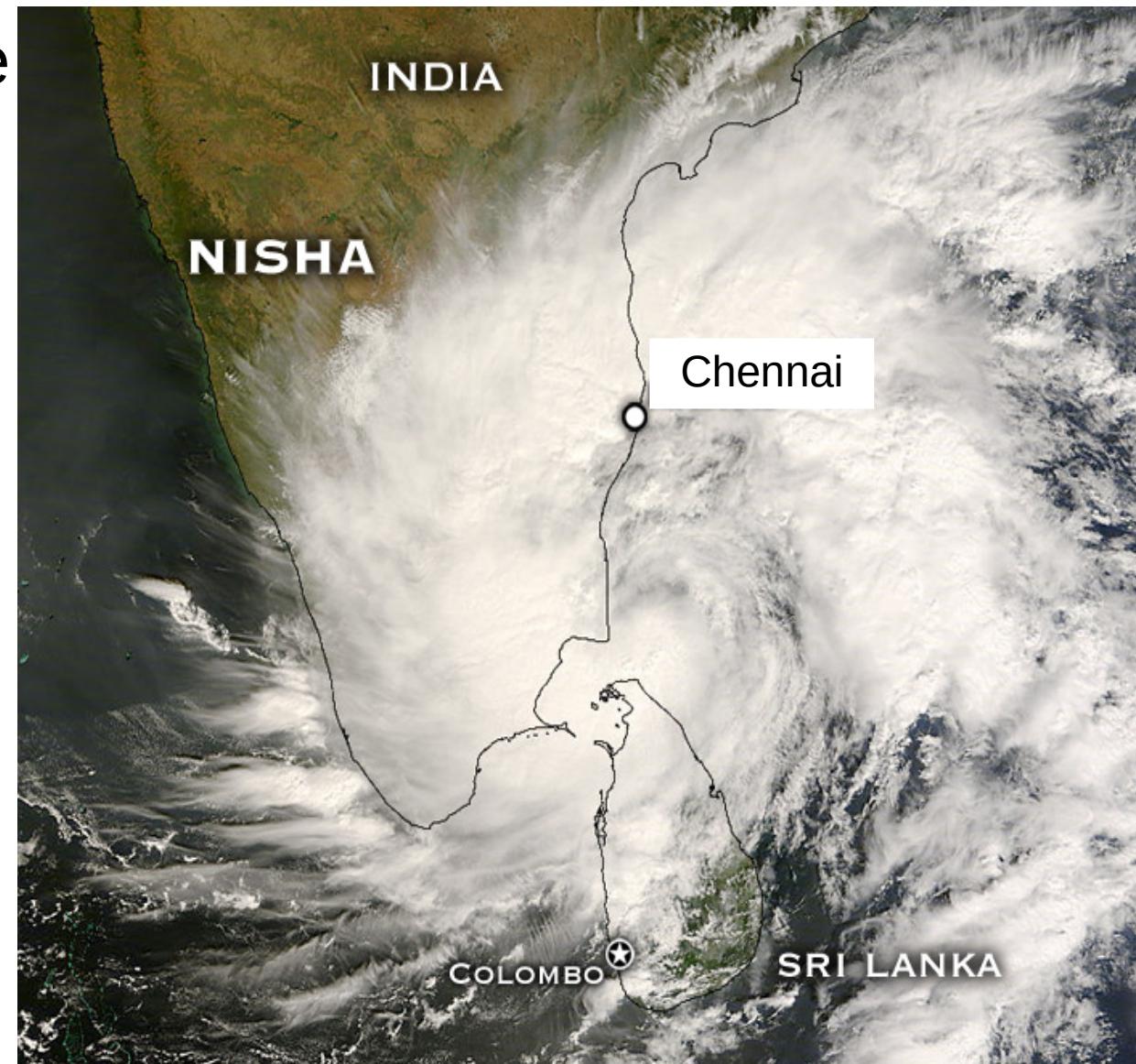
Digital Image Processing

- Image reconstruction
 - Computer vision
 - Medical vision



Digital Image Processing

- Remote sensing (weather prediction)
 - Tracking / predicting movement of cyclone
 - Locating center / eye



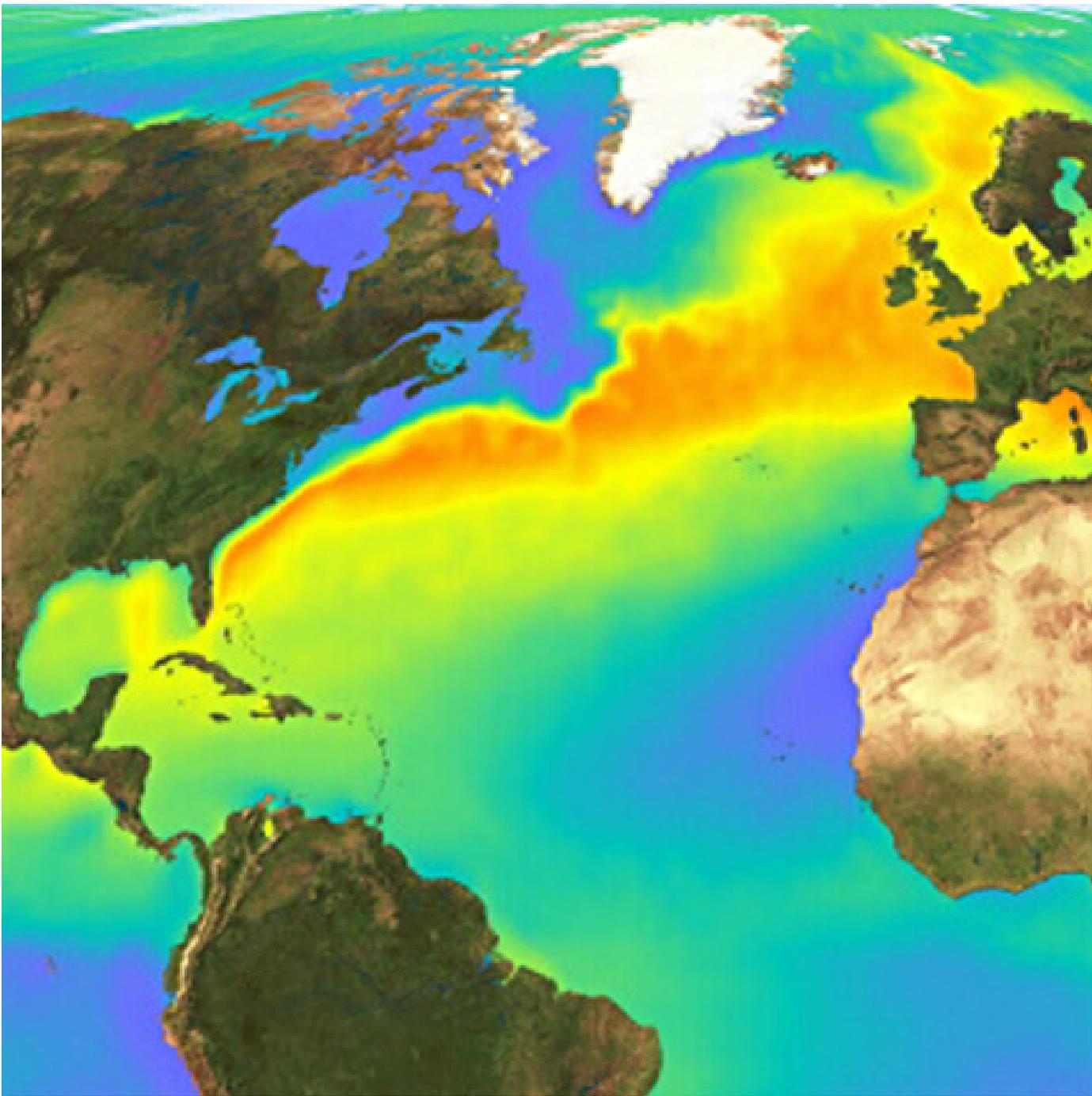
Digital Image Processing

- Remote sensing



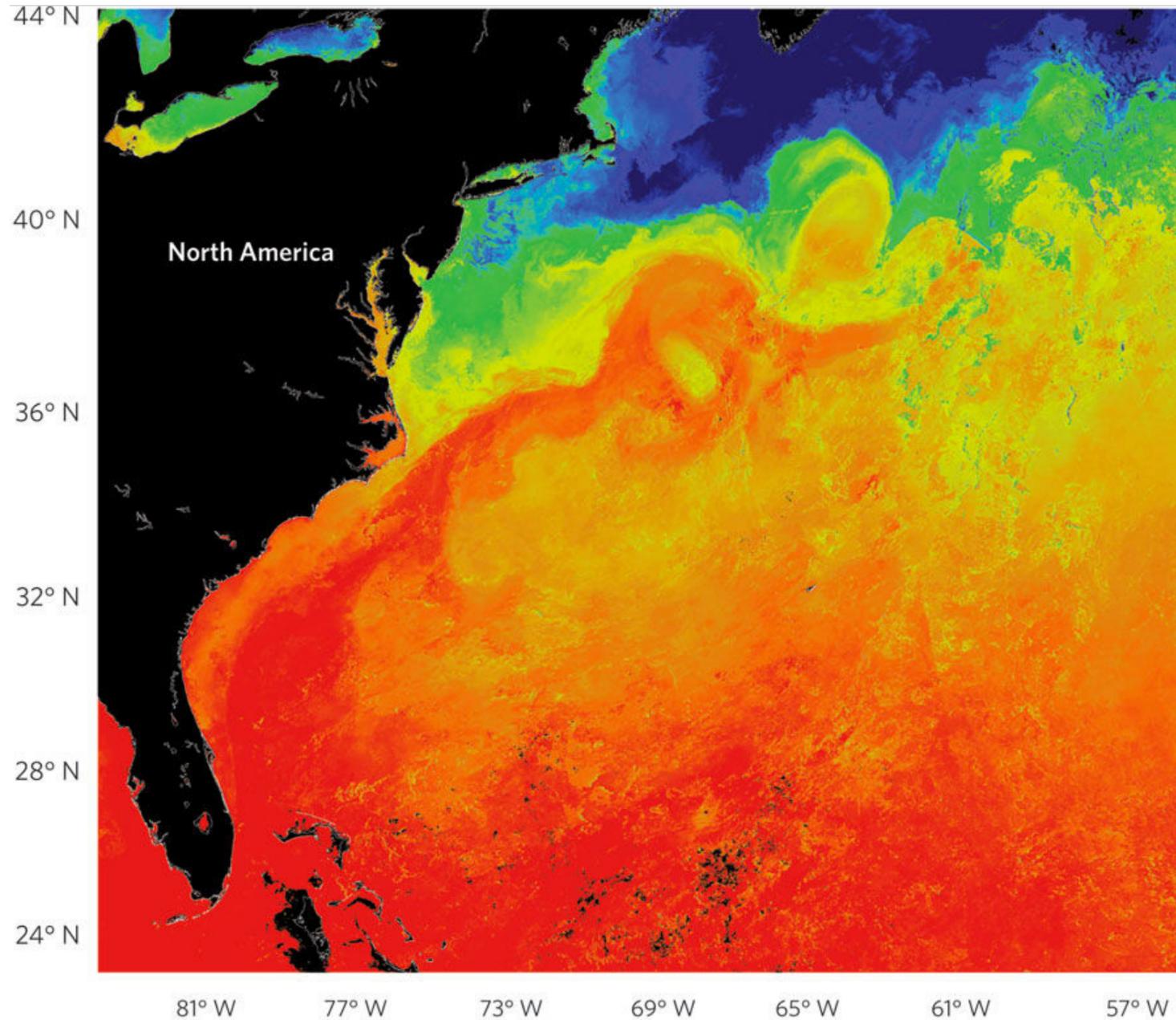
Digital Image Processing

- Remote sensing



Digital Image Processing

- Remote sensing



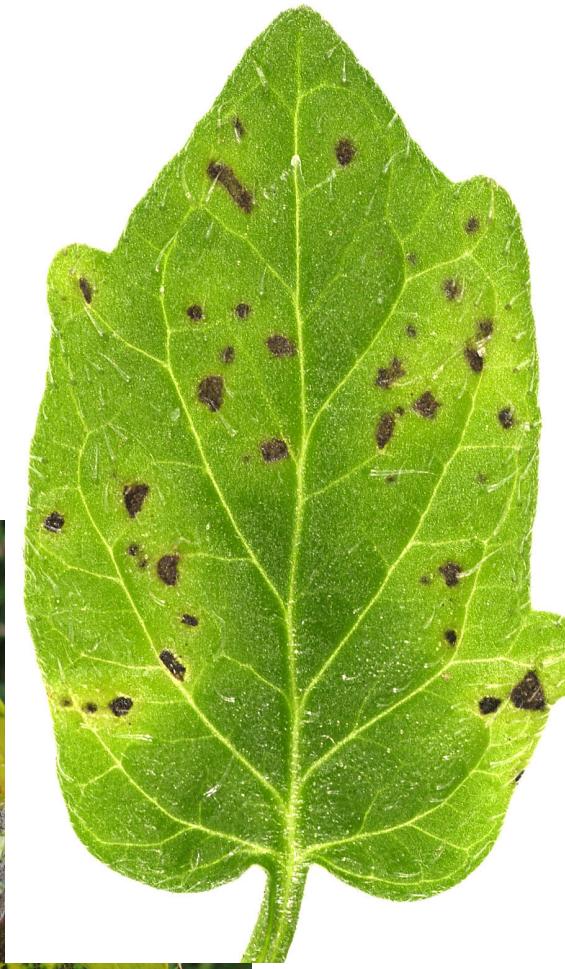
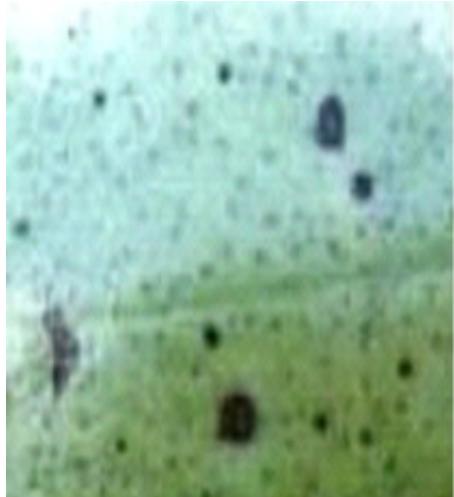
Digital Image Processing

- Remote sensing (classify: water, forested, urban, ...)



Digital Image Processing

- Agriculture : Classification of plant diseases



Digital Image Processing

- Classification of leaves

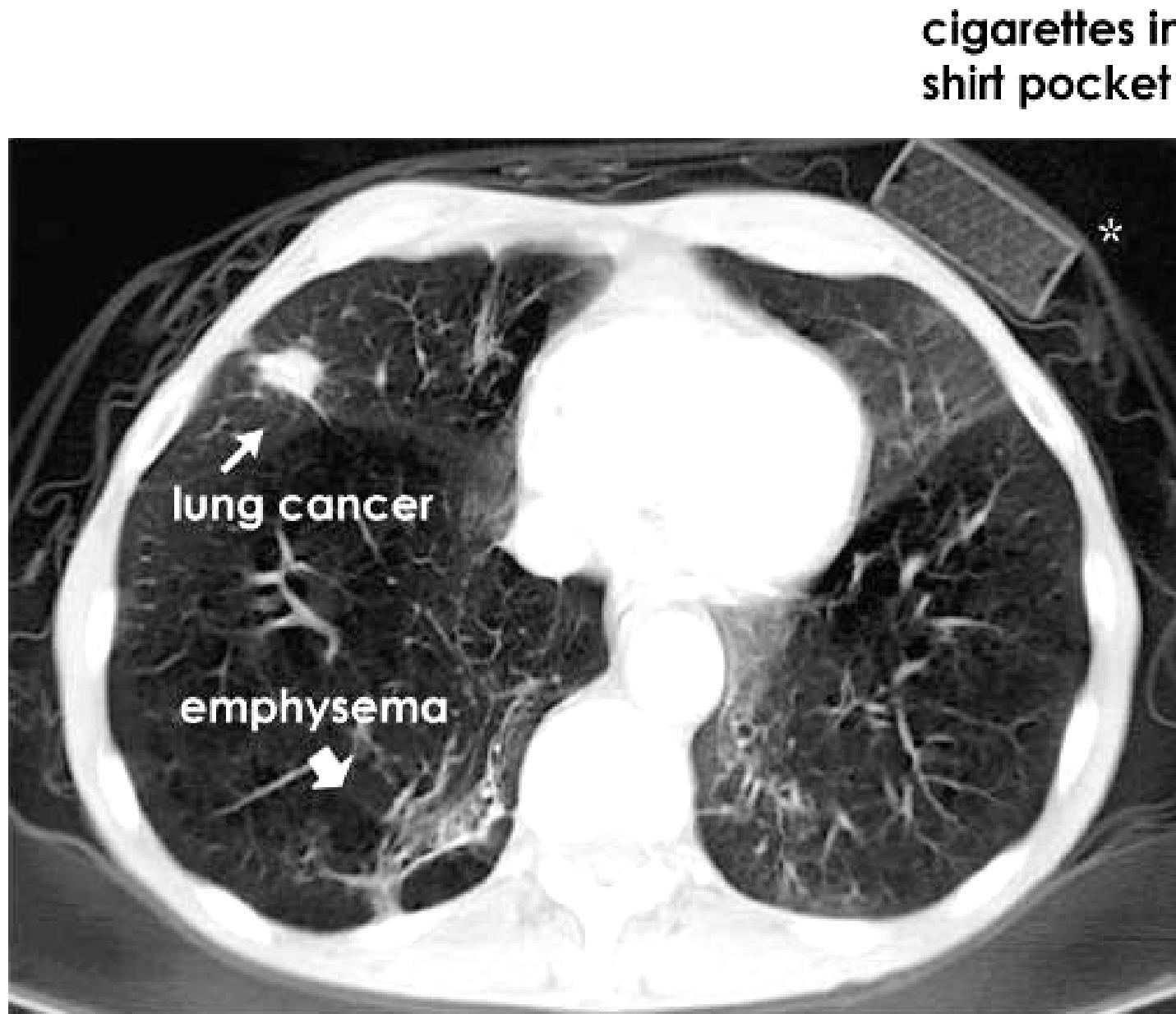


The image shows the 'Results' screen of the LeafSnap app. At the top, there are three buttons: '< Back', 'Results' (which is highlighted in green), and 'Map'. Below these are two images: a green oak leaf on the left and its corresponding binary mask on the right. The text 'Snap It! Results' is displayed above the list of classifications. The results are listed as follows:

Rank	Species Name	Scientific Name
1	English oak	<i>Quercus robur</i>
2	Sessile oak	<i>Quercus petraea</i>
3	Turkey oak	<i>Quercus cerris</i>

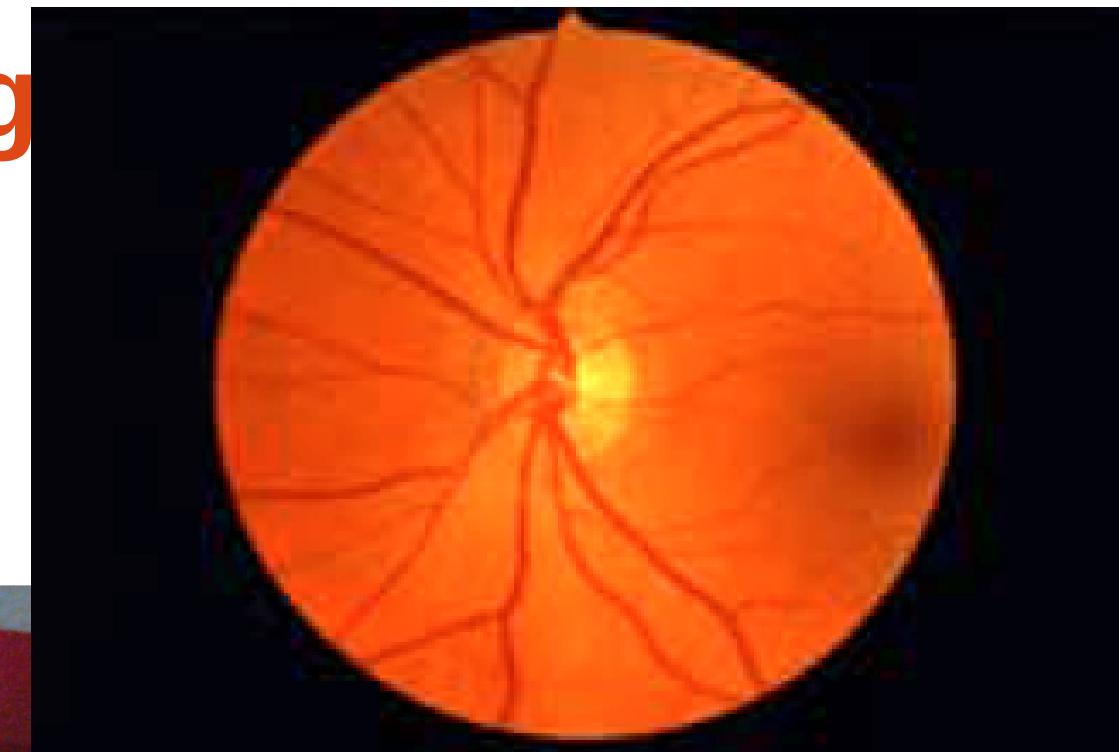
Digital Image Processing

- Classification of tissue (cancer / normal)



Digital Imaging

- Biometrics
 - Recognition



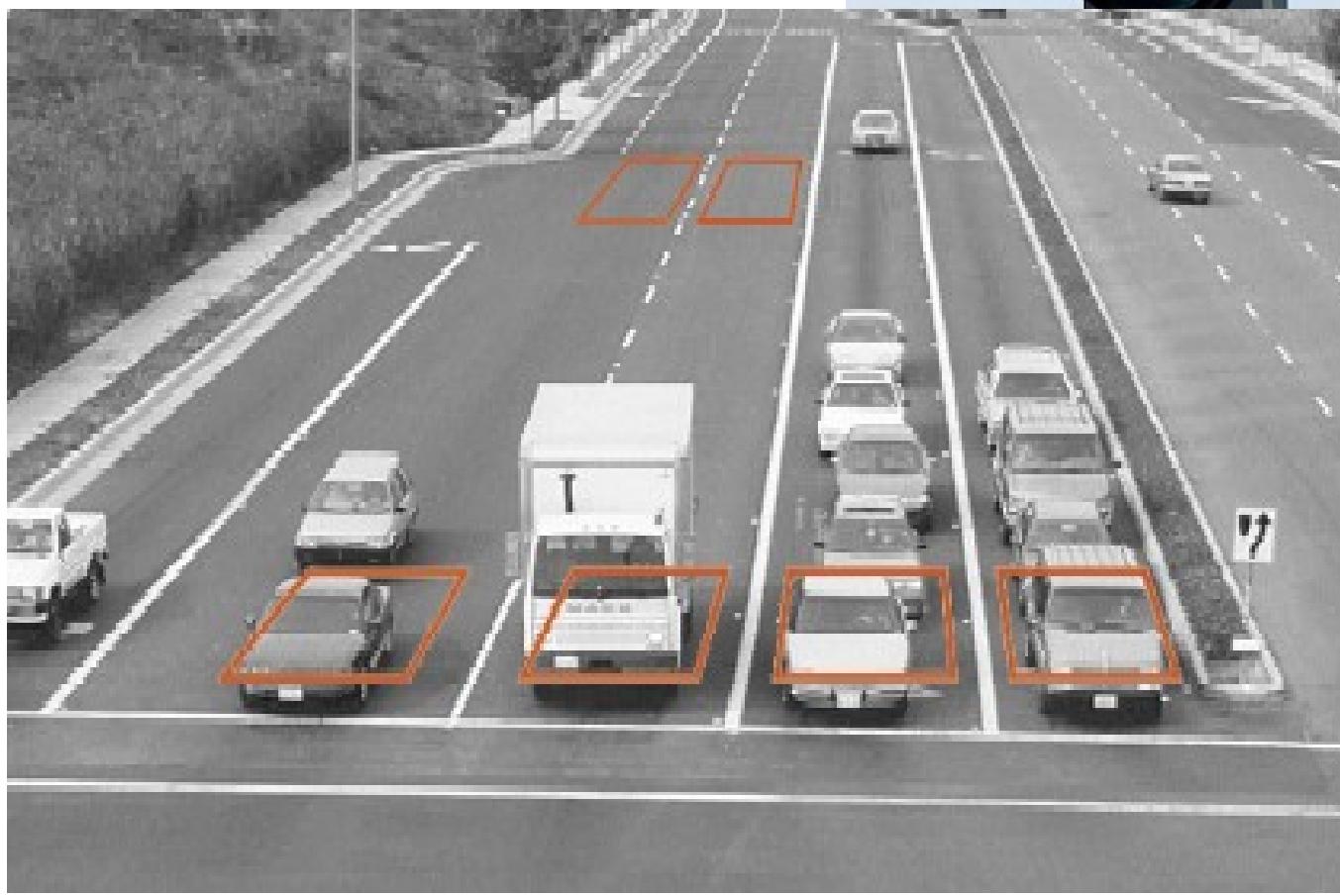
Digital Image Processing

- Surveillance



Digital Image Processing

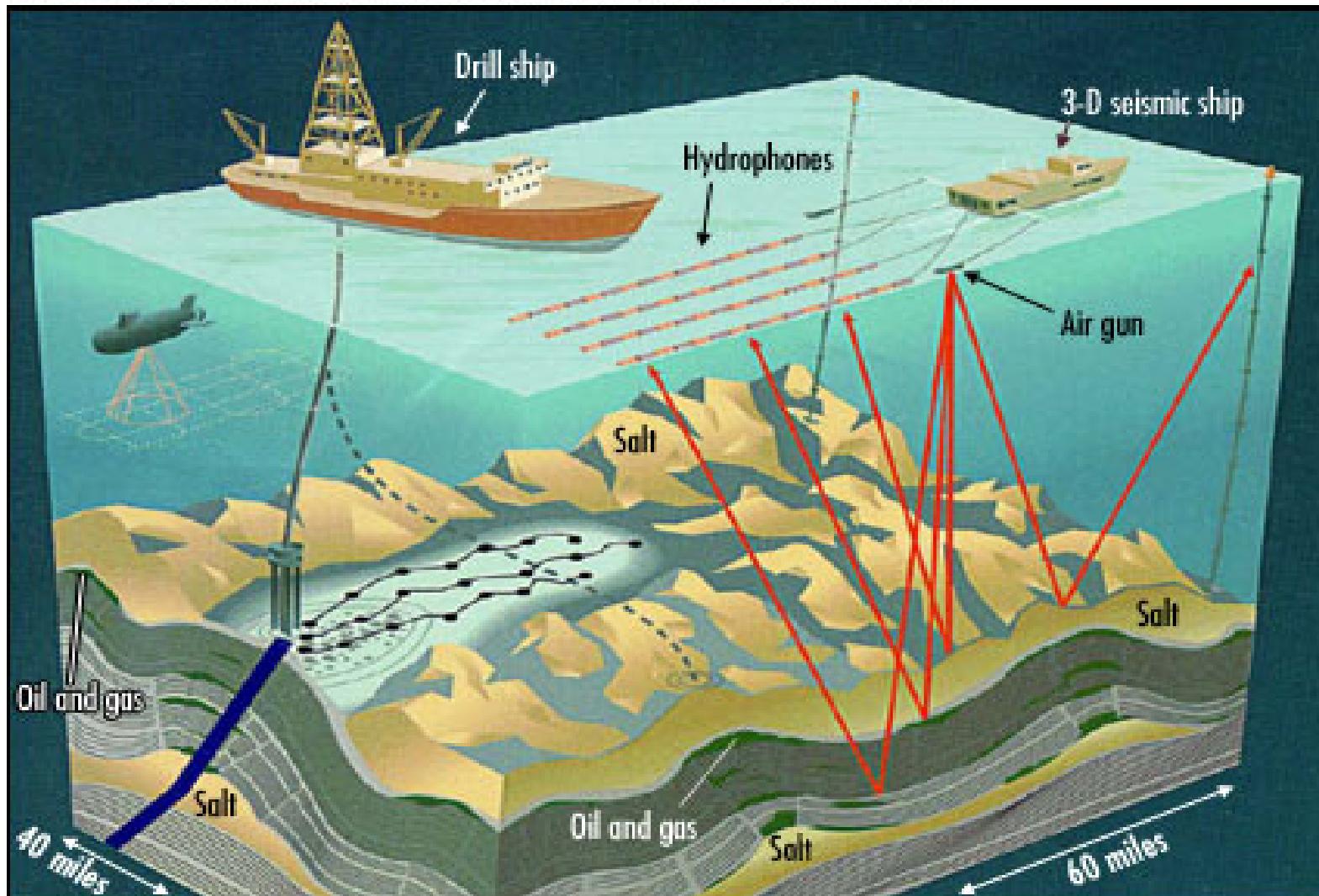
- Surveillance



Digital Image Processing

- Seismology 3-D Seismic Imaging At Work

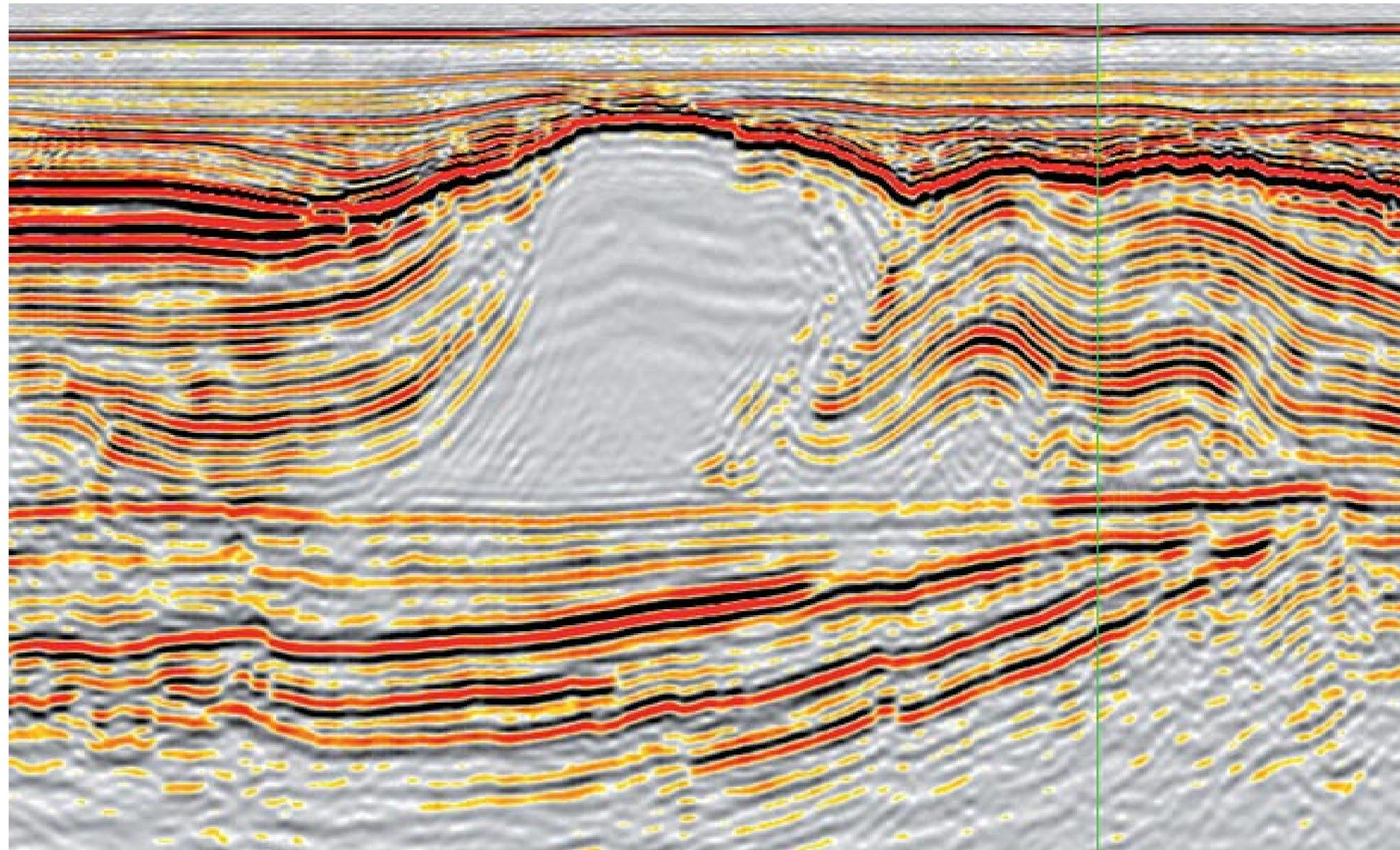
Hydrophones streaming from a 3-D seismic ship record the reflection of sound waves as they bounce back from subsalt surfaces.



Credit: Hutchins, A.E. and Anderson, R.N. (Eds.), World Oil's 4-D Seismic Handbook, Gulf Publishing, 1997.

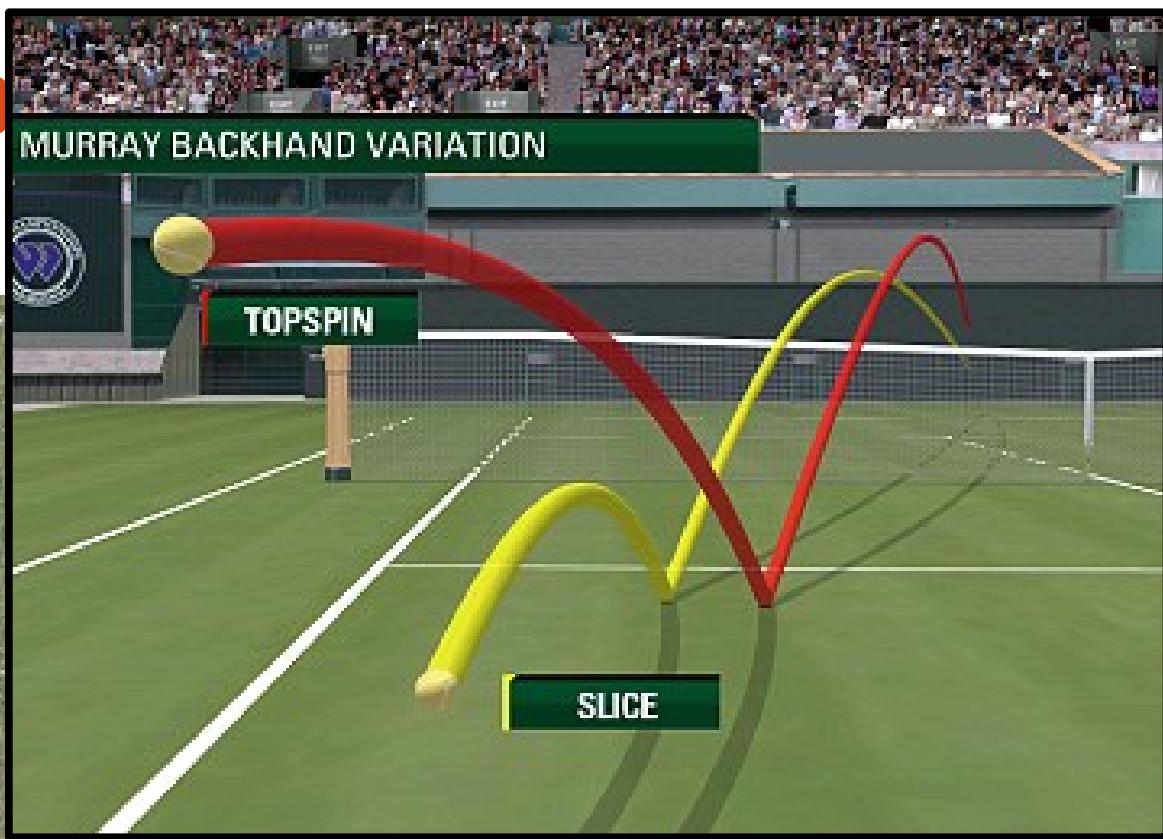
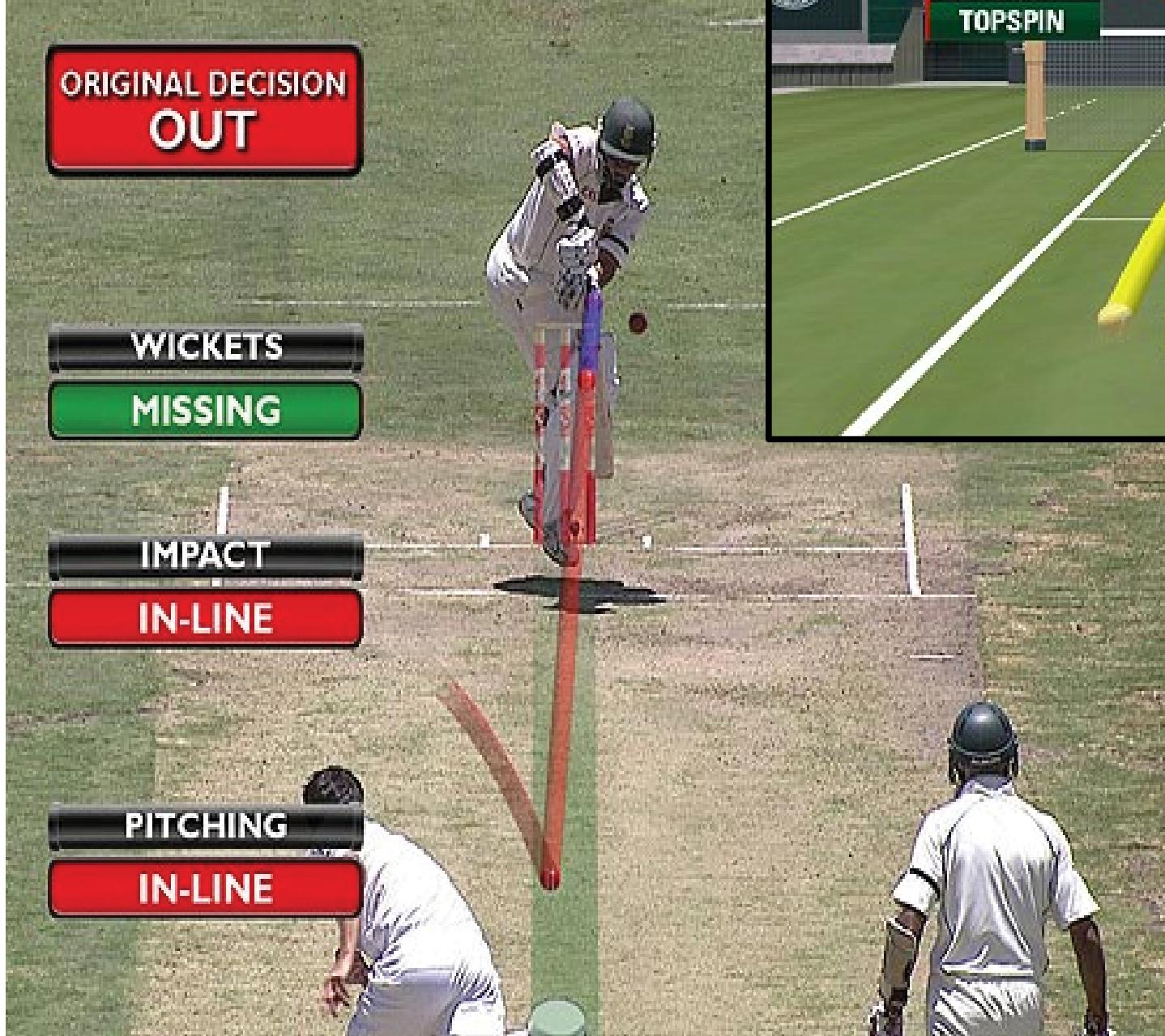
Digital Image Processing

- Seismology



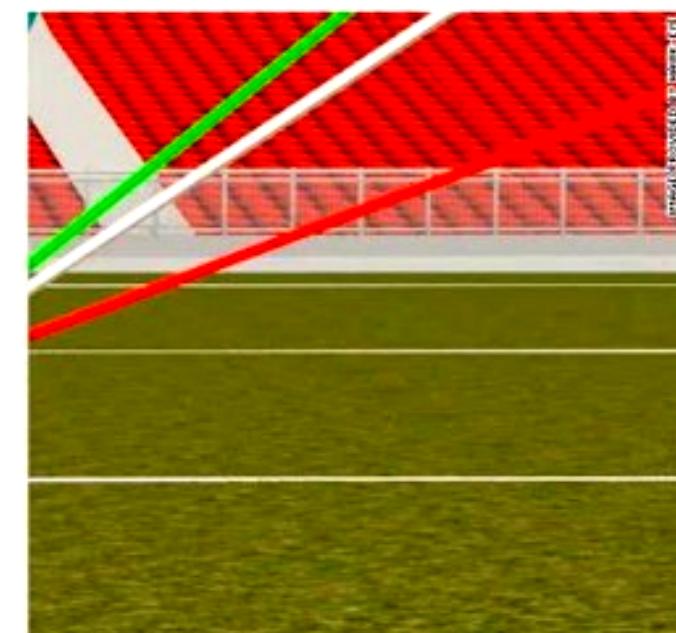
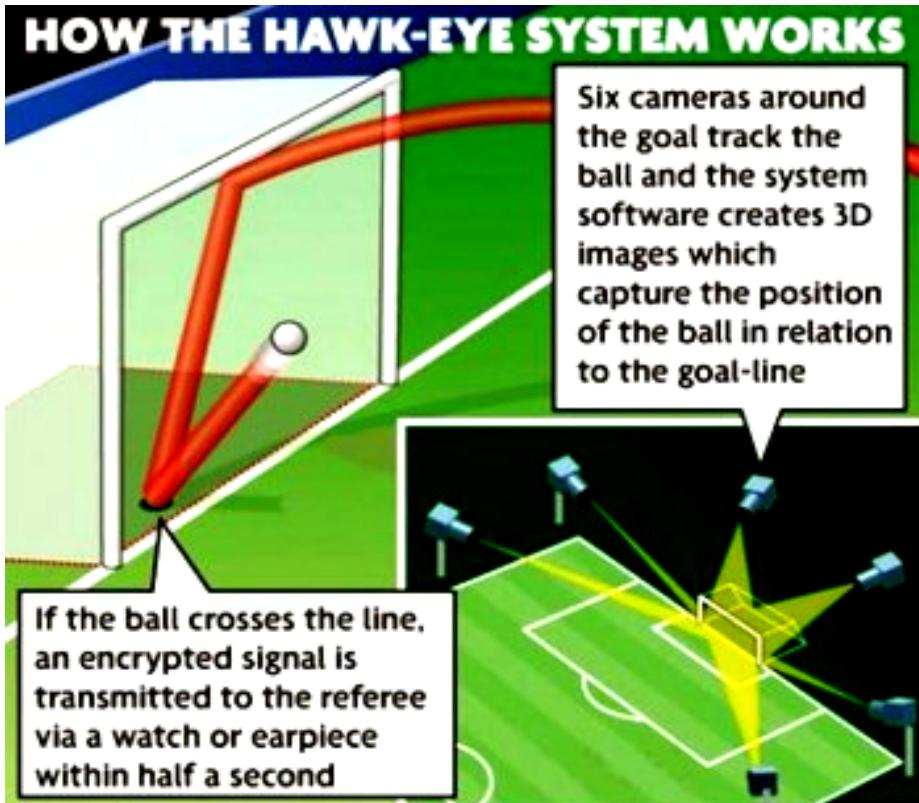
Digital Image Pro

- Sports



Digital Image Processing

- Sports



Digital Image Processing

- Assignments (~40%)
 - How many ? 5-6
 - Implement algorithms
 - Experiment with real-world and simulated image data
 - Groups of 3 or less
- Tests etc.
 - Mid-sem exam (~25%)
 - End-sem exam (~25%)
- Course project (~10%)
 - Groups of 3 or less
 - Presentation + viva voce

Digital Image Processing

- Attendance policy
 - <http://www.iitb.ac.in/newacadhome/rules/newugrules.html>
 - “Attendance in classes is compulsory and will be monitored.”
 - “A student not having 80 per cent attendance may be debarred from appearing in the semester-end examination and given XX grade and such student has to re-register for the same course.”
 - “In general, the institute expects 100% attendance.”
 - “The 80% attendance is permitted only for health or other emergency situation.”
 - “A medical certificate from IITB hospital or Government hospital is necessary for getting leave on health grounds.”

Digital Image Processing

- Plagiarism policy
 - <http://www1.iitb.ac.in/newacadhome/punishments201521July.pdf>
 - “A student found copying in an assignment/laboratory project is given a zero in the assignment/project and is further given a one grade penalty.”
 - “The same disciplinary action is taken against both the person copying and the person from whom the material was copied.”

Digital Image Processing

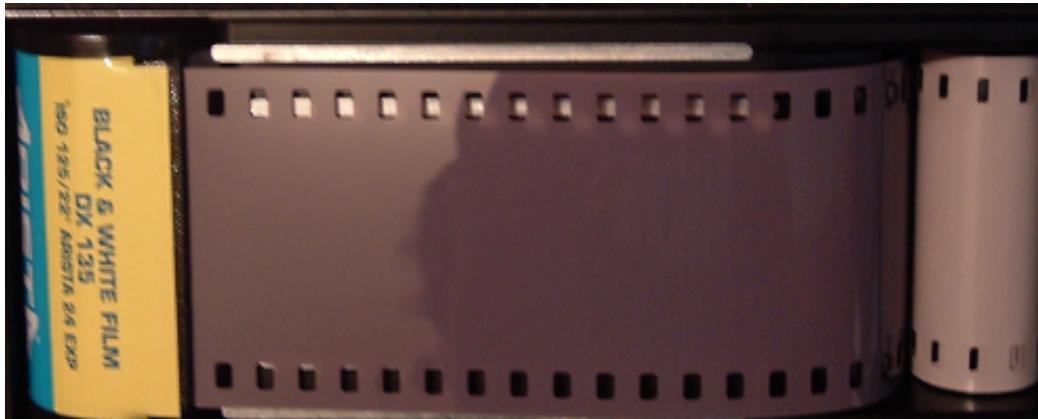
- Audit
 - Meet instructor(s)
 - Assignments, exams, projects won't be graded
 - 100% attendance required, unless valid reasons

Signals

- Function
 - Types of domains :
 - Time : Stock-market index
 - Space : **Image**
 - Space + Time : **Video** (no sound)
 - Types of ranges :
 - Integer, real
 - Dimensions
 - $1 \rightarrow 1$: Stock-market index
 - $2 \rightarrow 1$: Photograph (black and white)
 - $3 \rightarrow 3$: Video (color; no sound)

Image

- “Analog” Image
 - Continuous function
 - No discretization, infinite “resolution”
 - Data acquired on photographic film (“negative”)



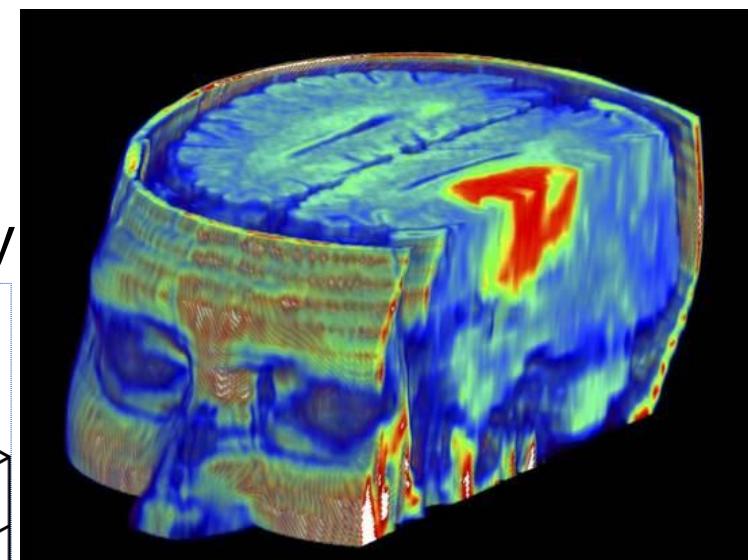
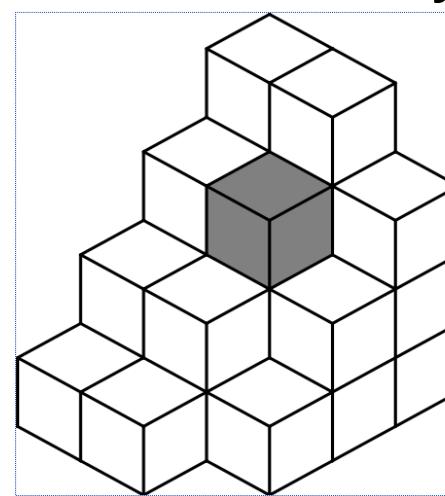
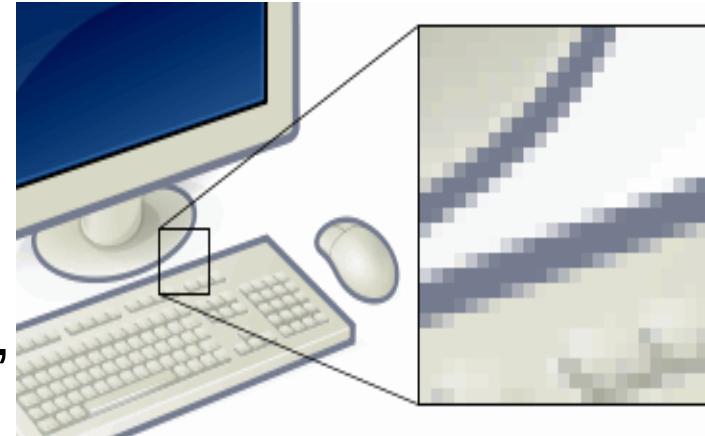
- This course **isn't** about **analog** images/signals

Image

- Digital (Discrete) Image
 - **Array / grid** of numbers
 - Integers, Real
 - Signed, Unsigned (non negative)
 - Many dimensions
 - What makes data discrete ?
 - Acquisition
 - e.g., charge-coupled device (CCD) array in camera
 - Representation
 - e.g., digitization : analog print → scanned digital copy
- This course **is about digital images**

Digital Image

- Digital image
 - For 2D domain
 - “picture element” = “pixel”
 - “pix” (pictures) + “el” (element) = “pixel”
 - Each pixel assigned a value / intensity
 - For 3D domain
 - “volume element” = voxel
 - Each voxel assigned a value / intensity



Imaging

- Imaging = Process of acquiring the image
 - Taking a digital photograph
 - Taking an X-ray / CT / MRI scan
- 1) Imaging Hardware / Instrumentation
 - Camera lens system, SLR, ...
 - X-ray machine, MRI machine, ...
- 2) Imaging Physics
 - Camera → Optics
 - Ultrasound, Seismic → Acoustics
 - CT, MRI → Electromagnetism

Imaging vs. Image Processing

- This course **isn't** about **imaging**
- This course **is** about **image processing**
 - Image data is given
 - Scanner is a black box
 - Don't know hardware details
 - e.g., what is inside photographic camera
 - Don't know physics details
 - -e.g., optics
 - Only know a high-level system specification
 - Transformation from physical quantity → data
 - e.g., objects and colors in scene → acquired image

Programming

- Matlab (www.mathworks.com)
 - “Matrix Laboratory”
 - Matrix ~ multi-dimensional arrays
 - See moodle.iitb.ac.in for useful information
 - Matlab license with IITB
 - Tutorials, Tips / Tricks
- OpenCV www.opencv.org
- Insight Toolkit (ITK) www.itk.org
- Python based frameworks

Programming

- Matlab
 - A single environment for :
 - Coding
 - Visualization → plots, surfaces, images
 - Debugging
 - Profiling
 - Highly optimized for operations on / using matrices
 - Support for linear algebra, statistics, image processing
 - Toolboxes, ...

Programming

- Matlab : Writing fast code
 - “profile” code
 - Use fewer loops (vectorize instead)
 - e.g., for matrix-vector multiplication
 - Replace loops by operations on arrays
 - Use built-in functions

Programming

- Matlab : Writing fast code
 - examples

www.mathworks.in/help/matlab/matlab_prog/vectorization.html

This code computes the sine of 1,001 values ranging from 0 to 10:

```
i = 0;  
for t = 0:.01:10  
    i = i + 1;  
    y(i) = sin(t);  
end
```

This is a vectorized version of the same code:

```
t = 0:.01:10;  
y = sin(t);
```

```
function d = minDistance(x,y,z)  
    % Find the min distance between a set of points and the origin  
  
    d = sqrt(x.^2 + y.^2 + z.^2);      % Compute distance for every point  
    d = min(d);                        % Get the minimum distance
```

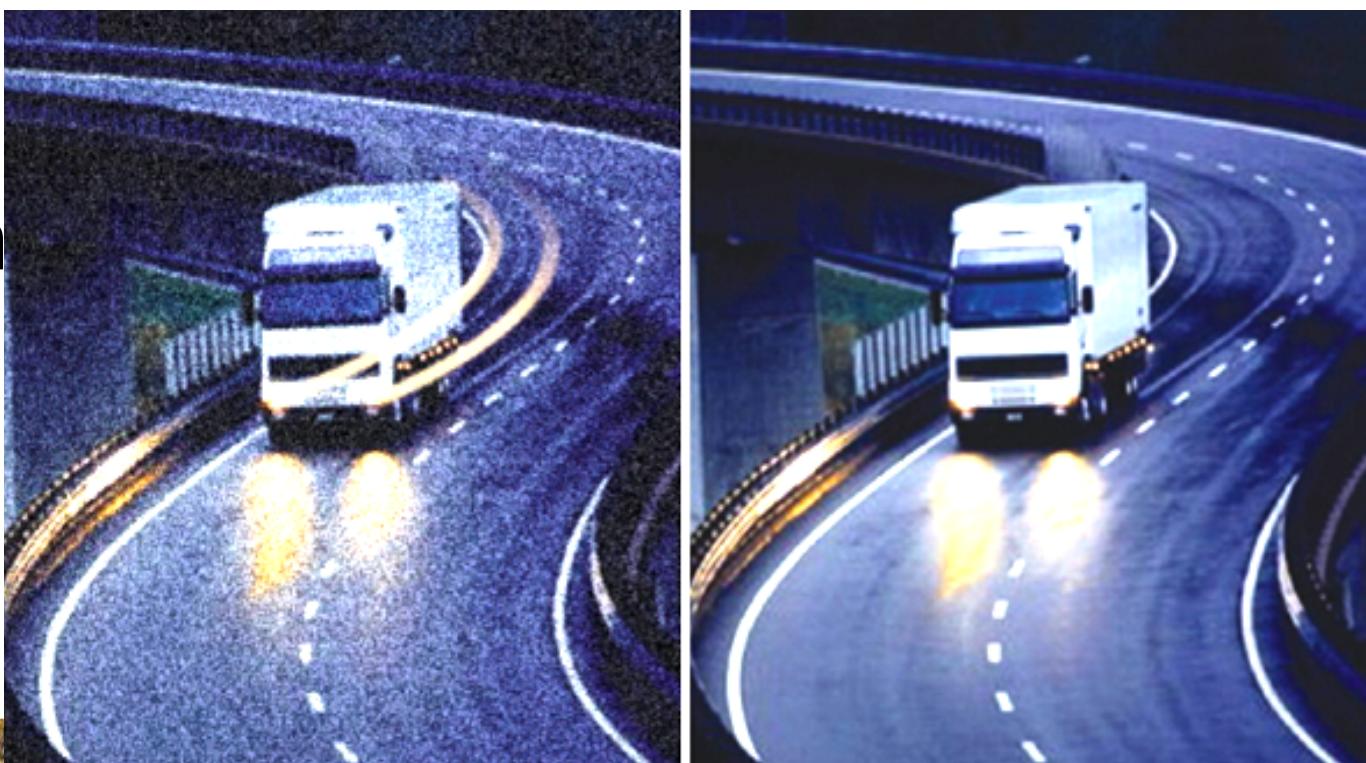
Applications

- Image enhancement
 - e.g., contrast increase
 - e.g., sharpen



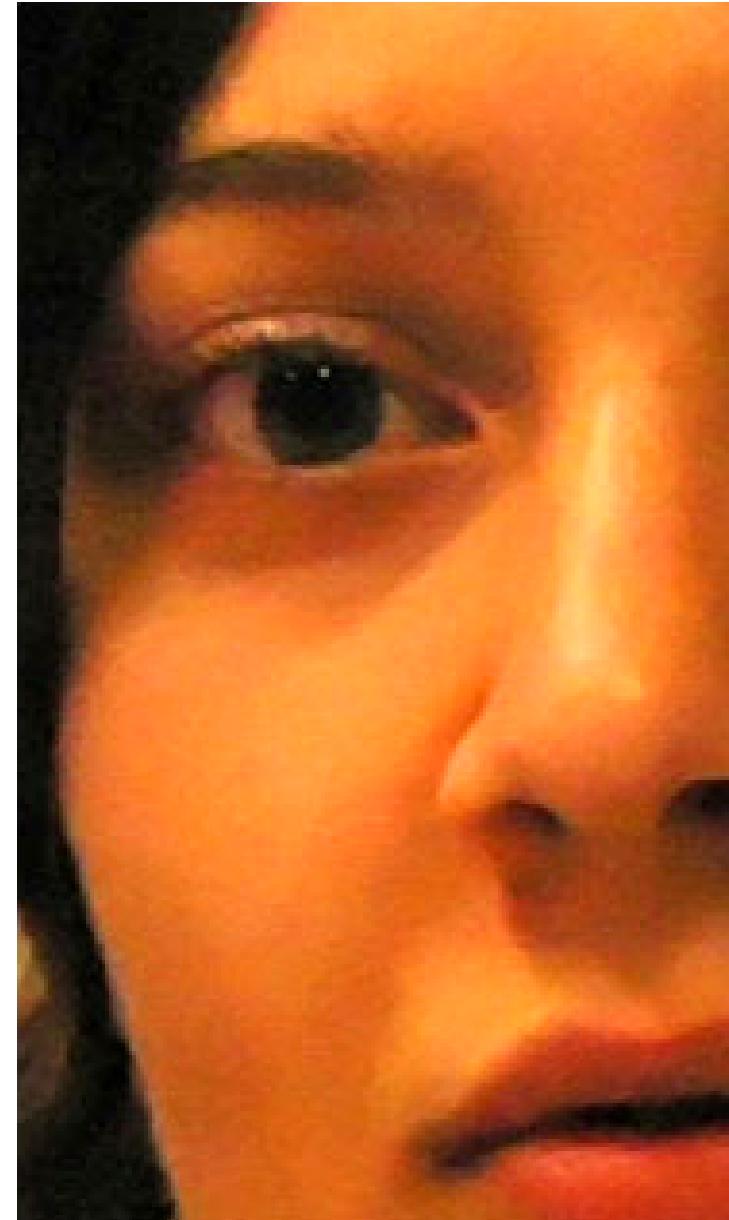
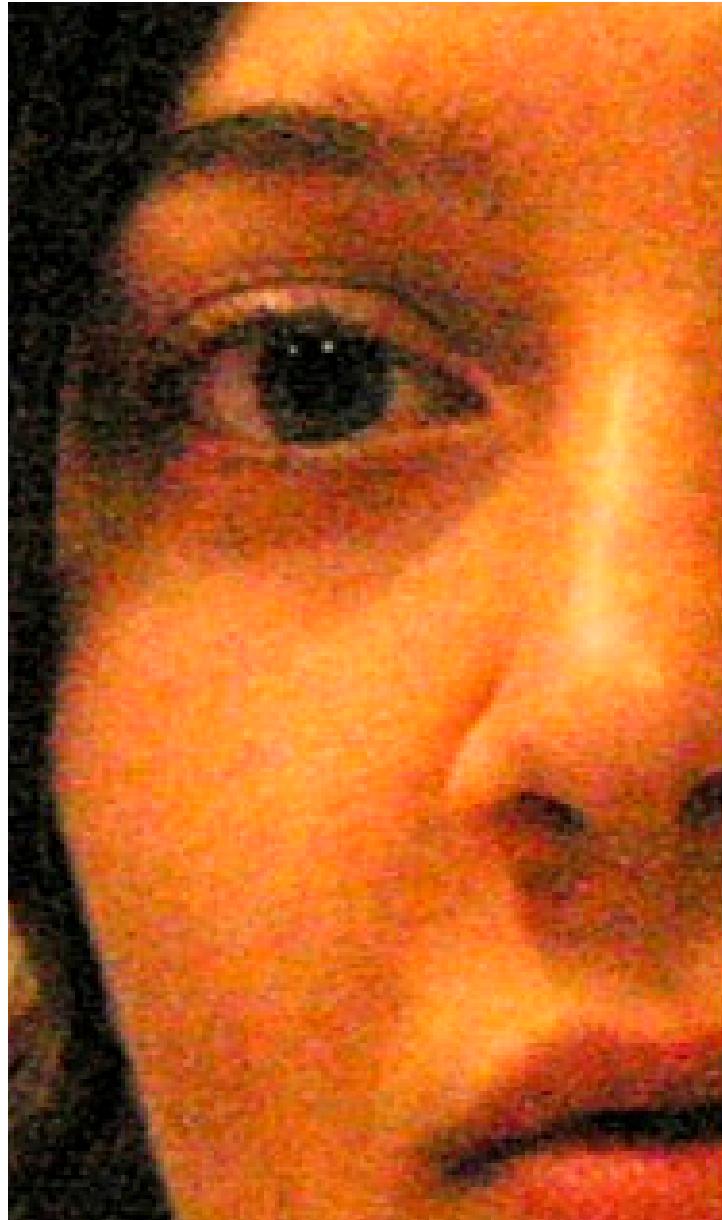
Applications

- Image restoration
 - Denoising



Applications

- Image restoration
 - Denoising



Applications

- Image restoration
 - Deblurring
 - Refocusing



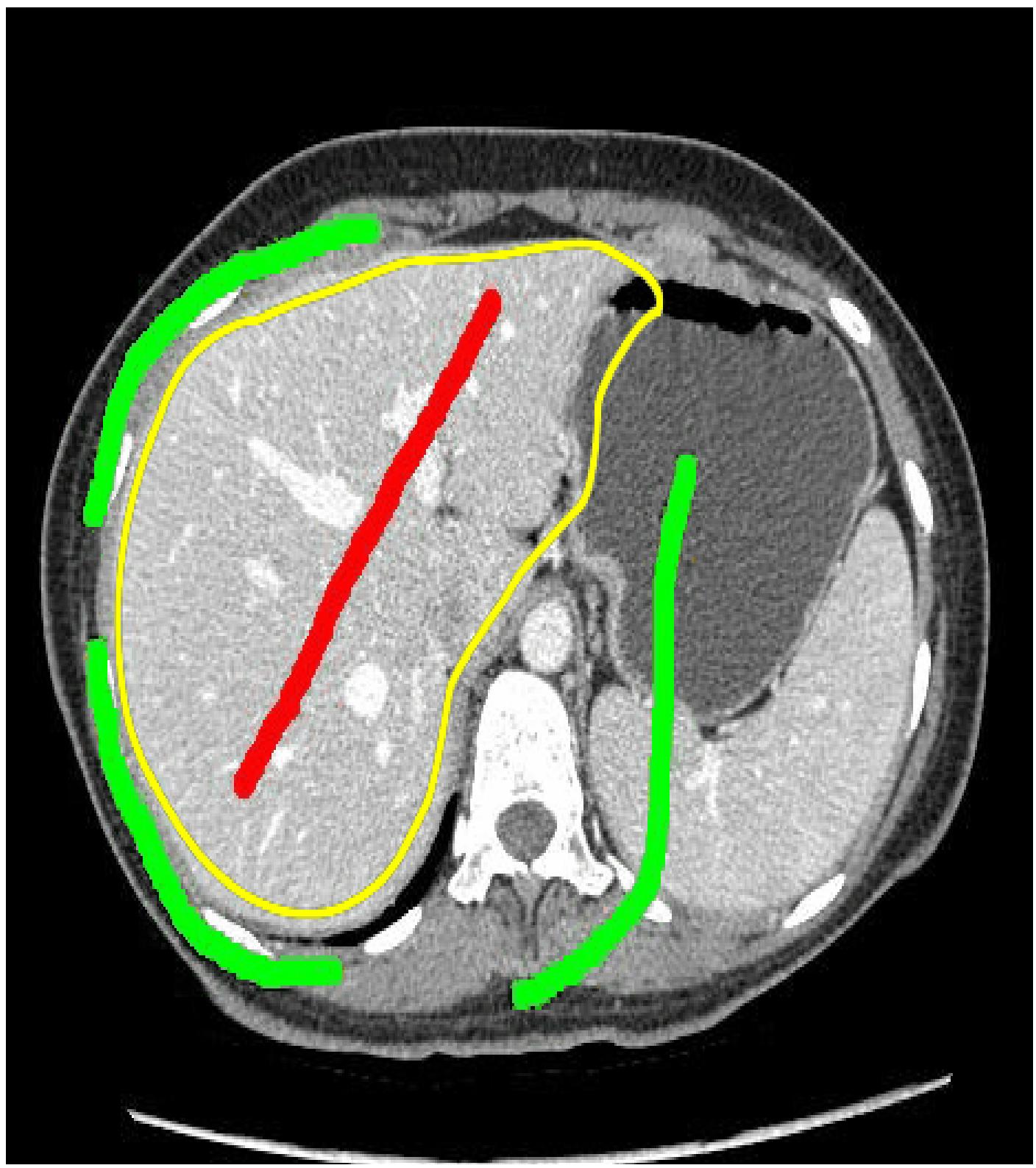
Application

- Image segmentation



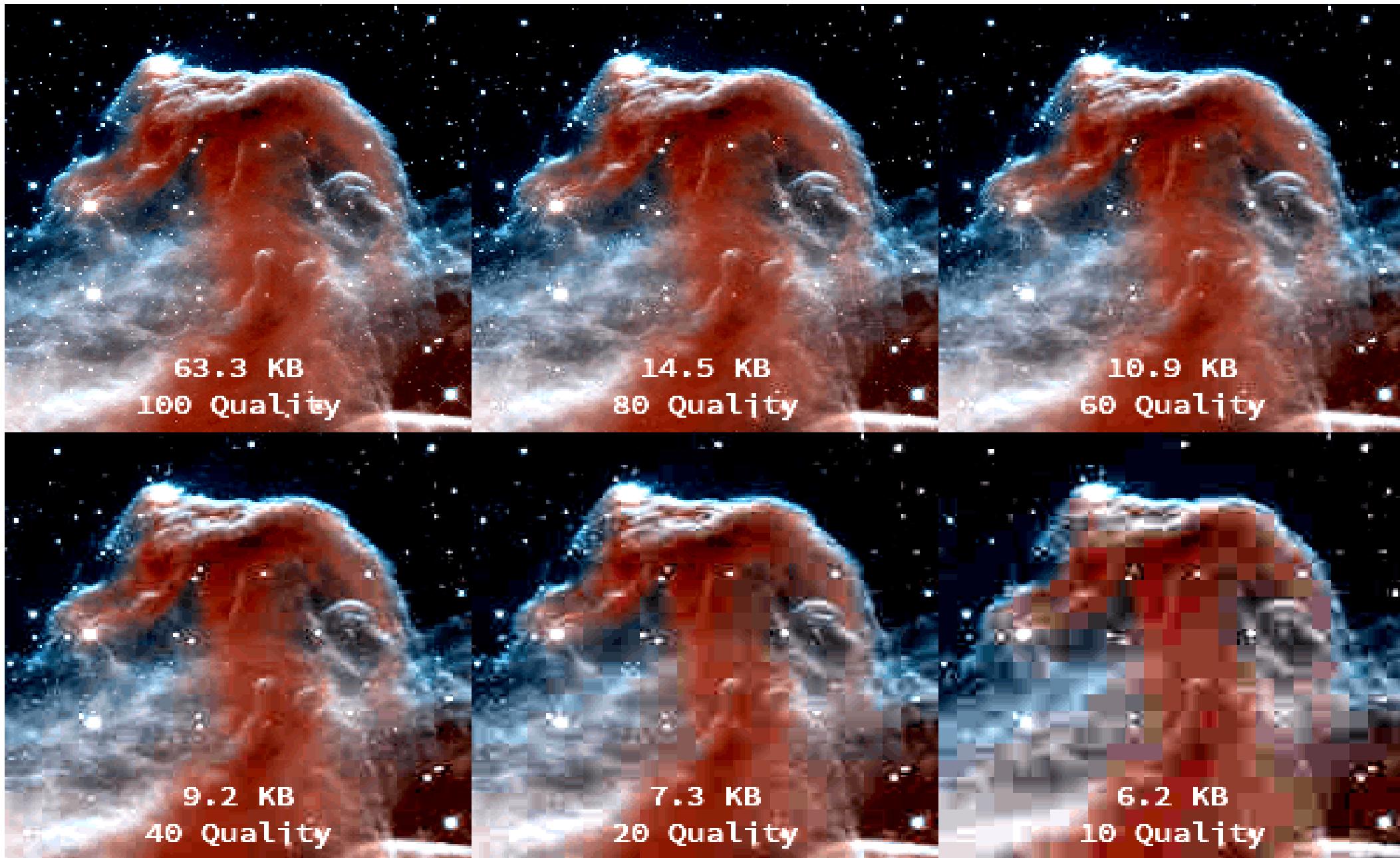
Applications

- Image segmentation



Applications

- Image and video compression



Applications

- Face recognition

