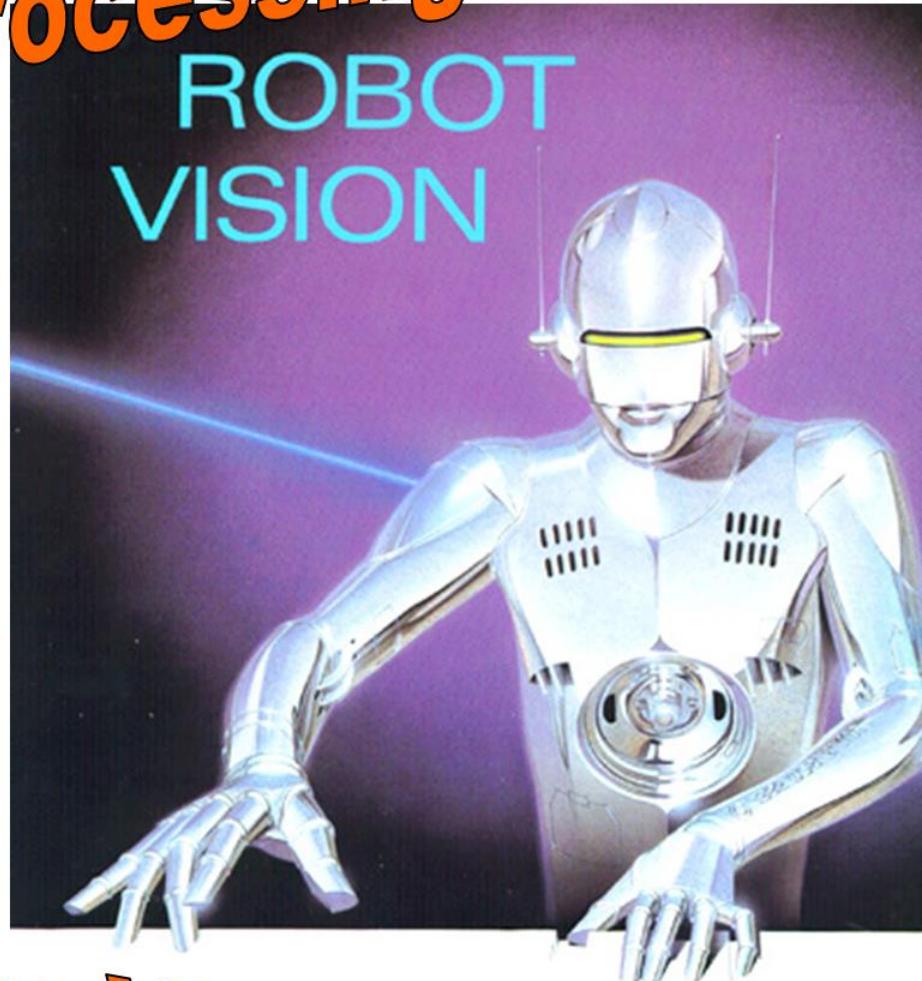


Digital Image Processing

Professor Dmitry Goldgof

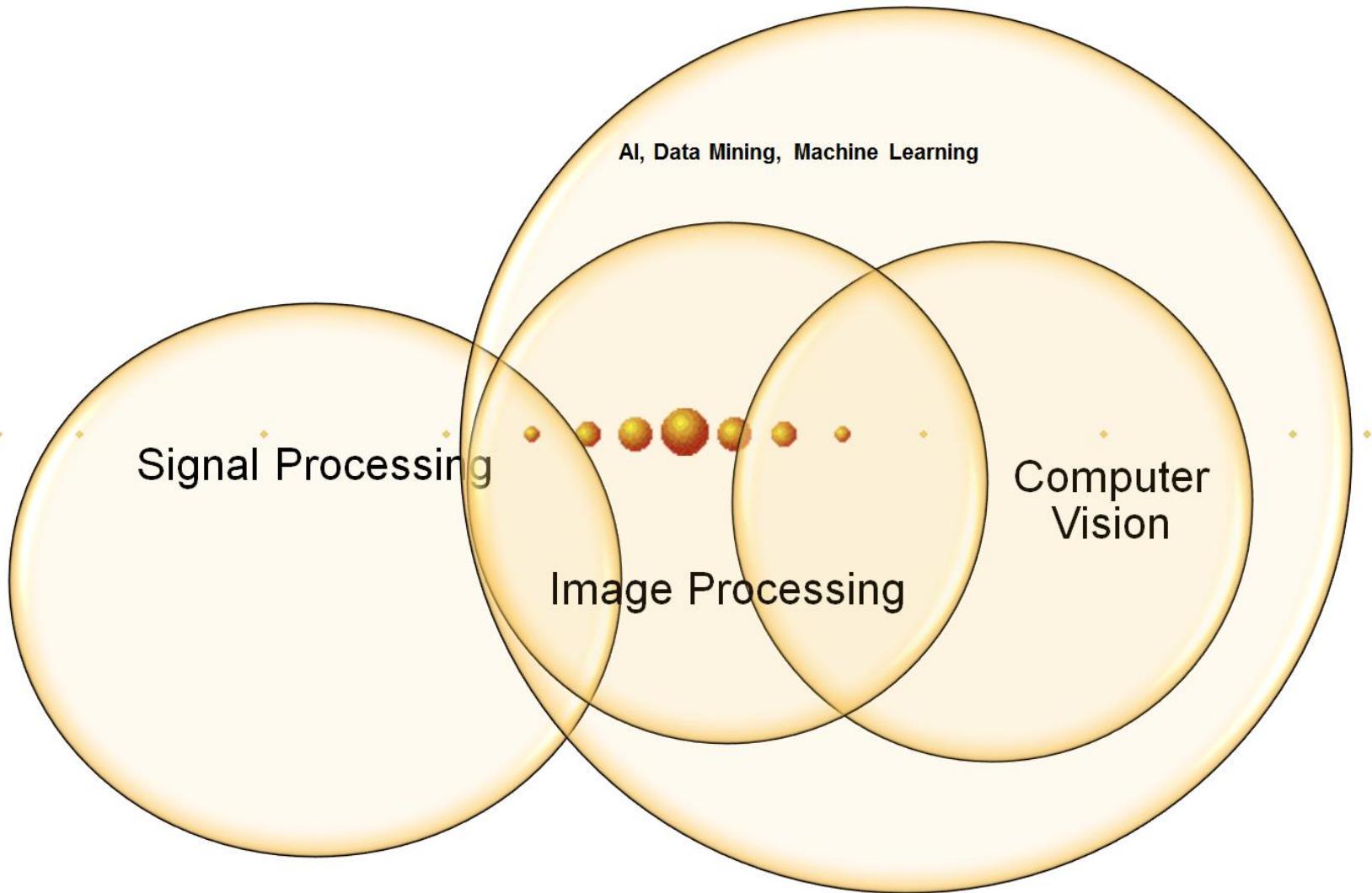
Image Processing



Computer Vision

Berthold Klaus Paul Horn





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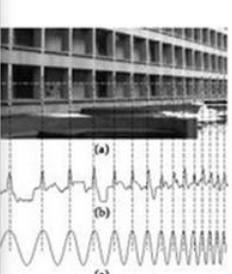
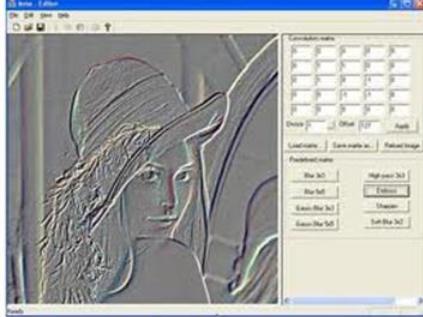
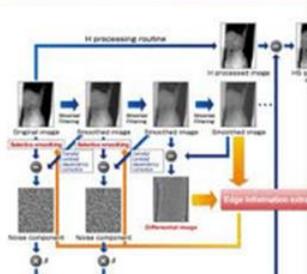
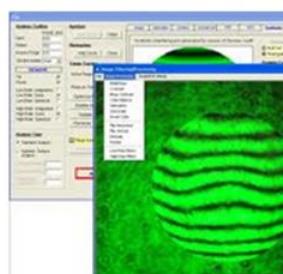
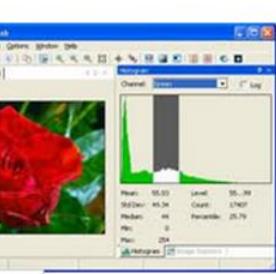
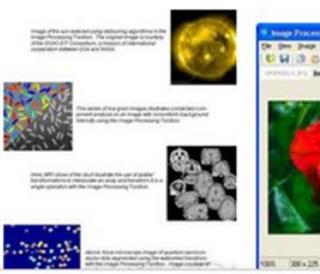
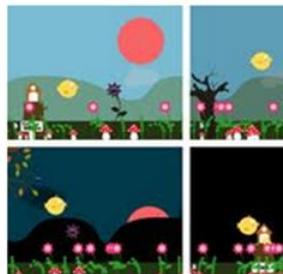
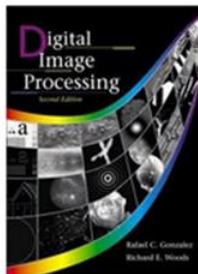
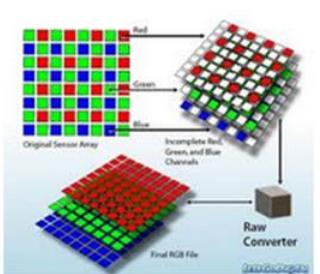
Larger than...

Exactly...

Any color

Full color

Black and white



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400 × 306 - Image processing - Emboss Effect
[Similar](#) [More sizes](#)



Statistical atlas & its applications

- tools for modeling the variability in a population
- used in segmentation and computer-assisted diagnostics

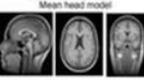




Image processing software



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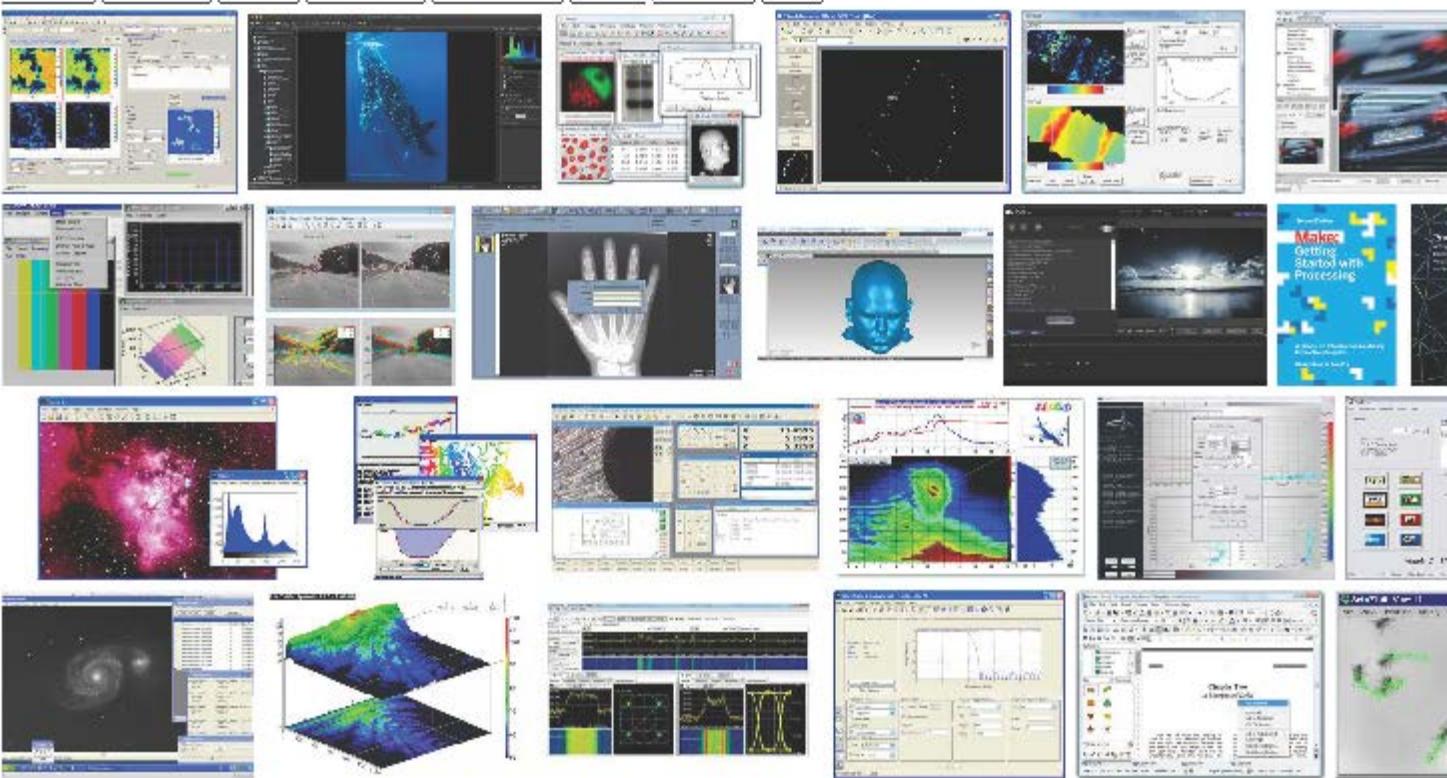
telemarketing

word processor

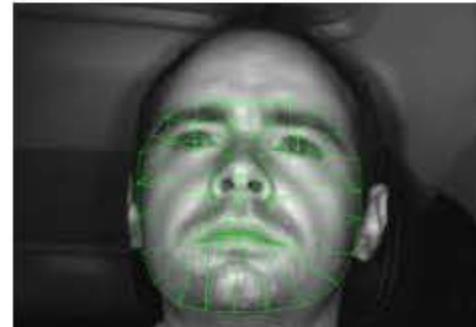
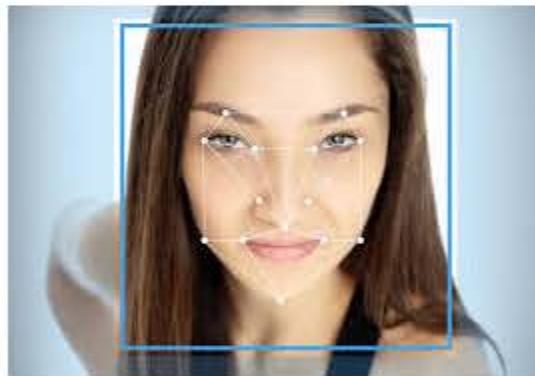
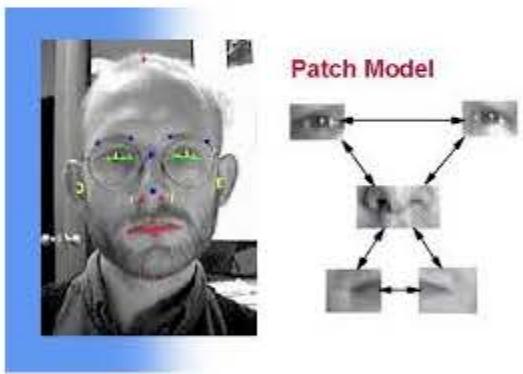
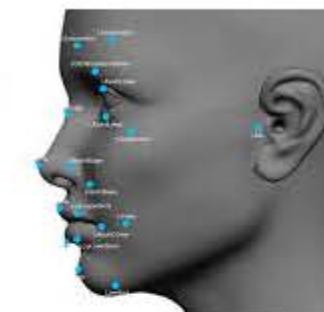
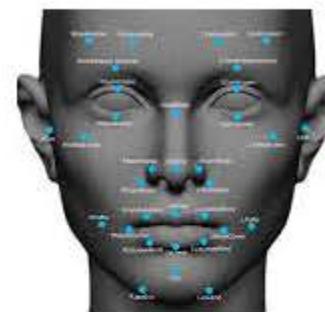
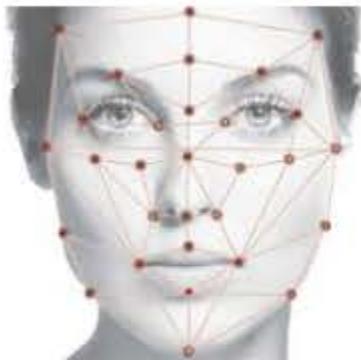
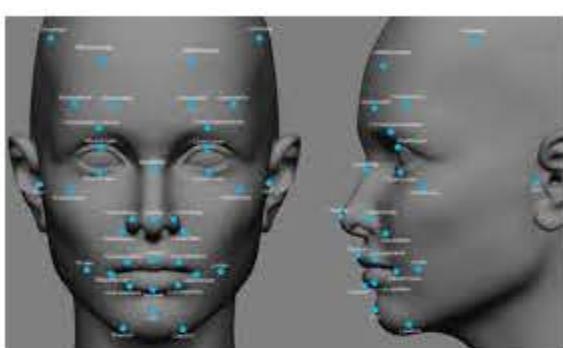
matlab

screenshot

map



camera computer security system cctv laptop phone deep learning biometric program multiple



BIG DATA and Images

ImageNet is an image database organized according to the [WordNet](#) hierarchy (currently only the nouns), in which each node of the hierarchy is depicted by hundreds and thousands of images. Currently we have an average of over five hundred images per node. We hope ImageNet will become a useful resource for researchers, educators, students and all of you who share our passion for pictures.



Summary and Statistics (updated on April 30, 2010)

Overall

Total number of non-empty synsets: 21841

Total number of images: 14,197,122

Number of images with bounding box annotations: 1,034,908

Number of synsets with SIFT features: 1000

Number of images with SIFT features: 1.2 million

The Cancer Imaging Archive (TCIA)

The screenshot shows the homepage of The Cancer Imaging Archive (TCIA). At the top, there is a banner featuring a surgeon in an operating room. Below the banner is a navigation bar with links: HOME, ABOUT US, SHARE YOUR DATA, ACCESS THE ARCHIVE, RESEARCH ACTIVITIES, and HELP. To the right of the navigation bar are social media icons for email, Facebook, LinkedIn, and Twitter. The main content area has a blue background with white text. It features a large call-to-action button with the text "Learn how to navigate the newly designed TCIA website." Below this, a smaller text box says "Learn how to get the most out of the new TCIA website" and provides a link to find out how to navigate the website. To the right of the text is a decorative image of a ship's steering wheel with the TCIA logo in the center. At the bottom of the page, there is a navigation bar with five small circles and arrows for navigating through the site.

CANCER
IMAGING ARCHIVE

HOME ABOUT US ▾ SHARE YOUR DATA ▾ ACCESS THE ARCHIVE ▾ RESEARCH ACTIVITIES ▾ HELP ▾

Learn how to navigate the
newly designed TCIA website.

Learn how to get the most out of the new TCIA website

TCIA home page has a new Look and Feel including new Branding and Menu Layouts. [Find out how to navigate the newly designed TCIA website.](#)

THE CANCER IMAGING
ARCHIVE

◀ ▶ □

Collections of freely accessible DICOM images and supplementary data to foster re-use and reproducibility within the cancer imaging research community

Radiomics/Radiogenomics Collections

- Brain
 - TCGA-GBM: genomics + large cohort (260)
 - TCGA-LGG: genomics + large cohort (199)
 - REMBRANDT: limited genomics + medium cohort (130)
- Lung
 - TCGA-LUAD: genomics
 - TCGA-LUSC: genomics
 - National Lung Screening Trial: huge cohort (26,254)
 - NSCLC-Radiogenomics: genomics
 - NSCLC-Radiomics: large cohort (422)
 - NSCLC-Radiomics-Genomics: genomics + medium cohort (89)
 - RIDER Lung PET CT: large cohort (244)

Digital Image Processing

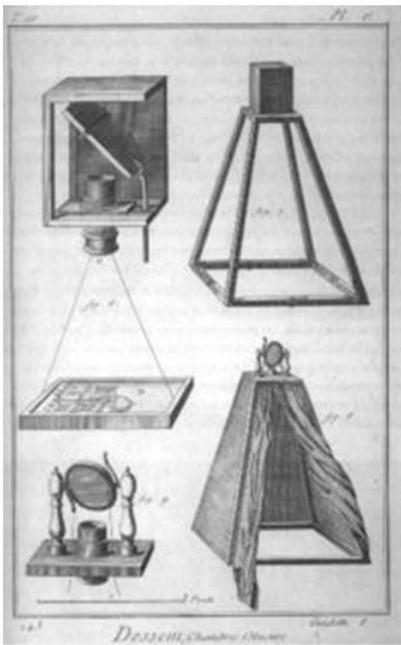
- **Imaging Systems (hardware)**

- intensity cameras
- range cameras
- satellite imagers
- MRI
- X-ray and CT scanners
- radar
- ...

- **Techniques and Goals (software)**

- image enhancement
- contrast modification
- edge detection
- 3D surface reconstruction
- motion analysis
- object recognition
- ...

Digital Image Processing



Camera obscura - 1100



Mr. Niépce's earliest surviving photograph, circa 1826.



KODAK, Argus C3, 1939



CASIO - 2001

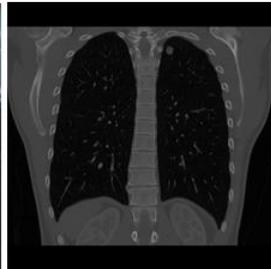


Steven Sasson, an Eastman Kodak engineer, with his prototype digital camera (1975)



Apple - 2015

Digital Image Processing



Space probe images: Moon and Mars

Multispectral imagery: visual and infrared

Medical images: X-ray and CT



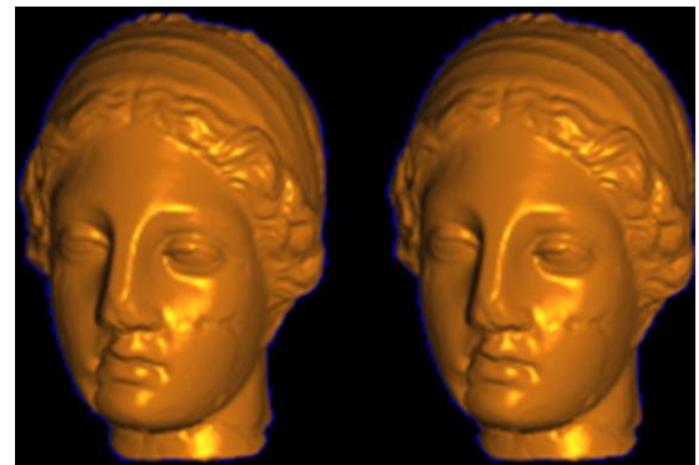
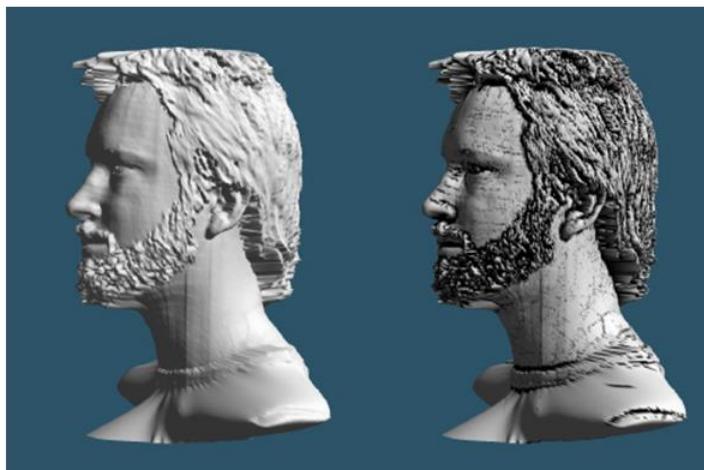
Optical camera images: Golden Gate and Downtown San Francisco



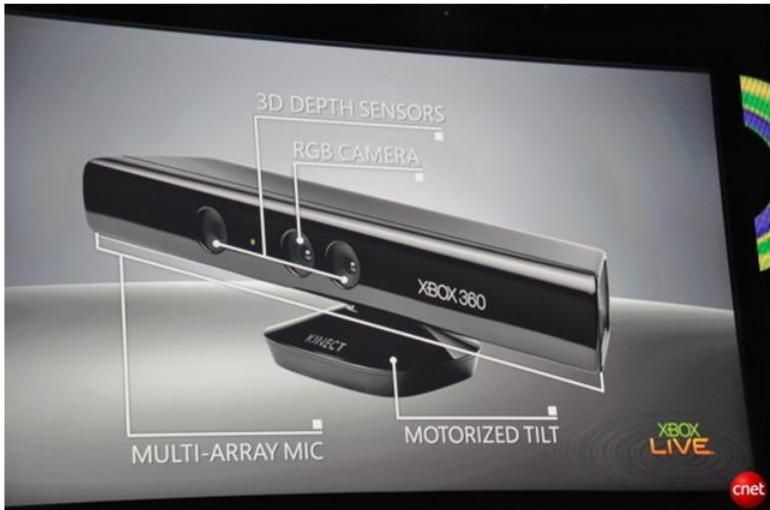
Television Images: CNN news reporter Vassileva, Gary Wilmot in "Me and My Girl", Scene from "Everybody loves Raymond", and Walter Cronkite

Digital Image Processing

Range images



Digital Image Processing



Camera and 3D



Dual 5MP cameras (stereo)



Sony Xperia Z1S 4G
20.7 megapixels
8X zoom
4K video



Samsung, K Zoom,
20.7 megapixels
10X zoom

Digital Image Processing



10,320 x 7,752 pixels



24MP, 12 fps with autofocus



3D camcorder, dual HD

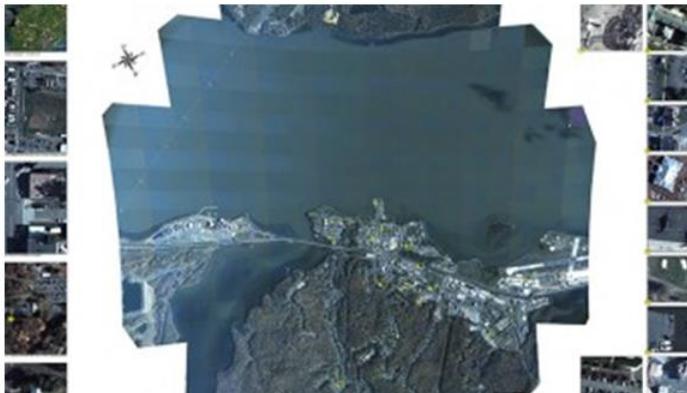


2MP at 280 FPS
4MP at 150 FPS



spherical vision:
6 cameras at 12MP

Digital Image Processing



DARPA shows off 1.8-gigapixel surveillance drone



GoPro HERO3+, \$399

KEY CAMERA SPECS

1080p60 / 960p100 / 720p120 fps

12MP/30fps Burst

GoPro App - Remote Compatible

4Kp15 / 2.7Kp30 / 1440p48 fps



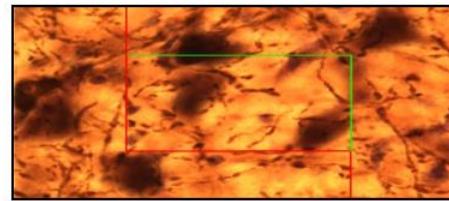
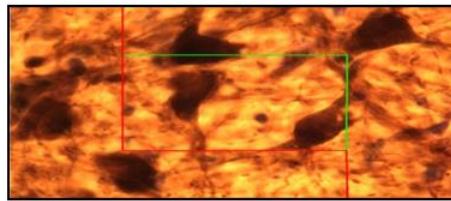
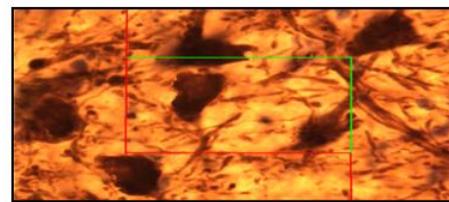
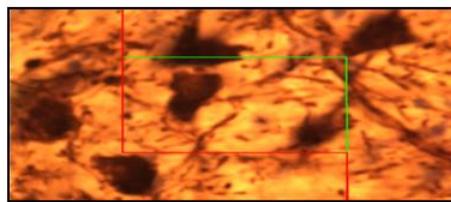
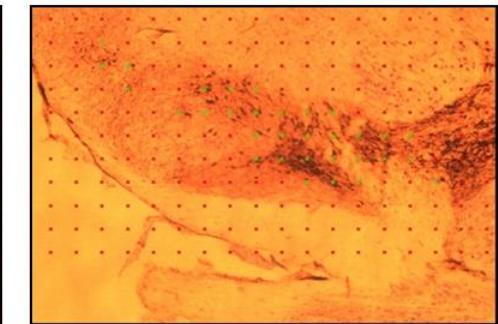
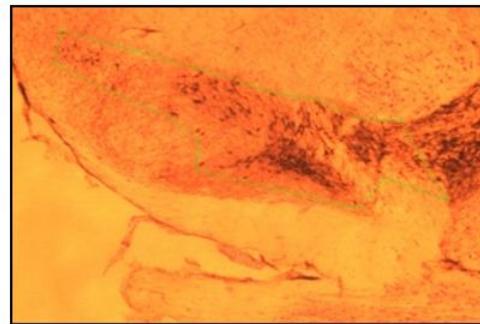
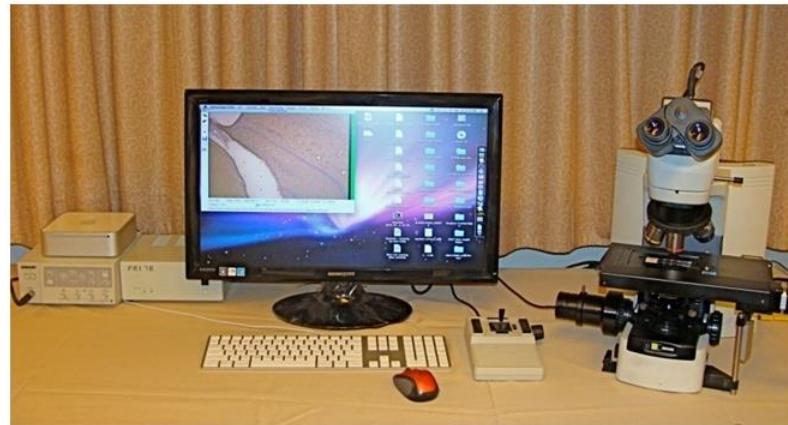
FLIR T620 Thermal Imaging Camera
307,200 pixels (640 x 480), up to 1202°F, sensitivity < 0.04°C



FLIR ONE for iOS and Android
80x60 pixels, 0.1 C



Digital Image Processing

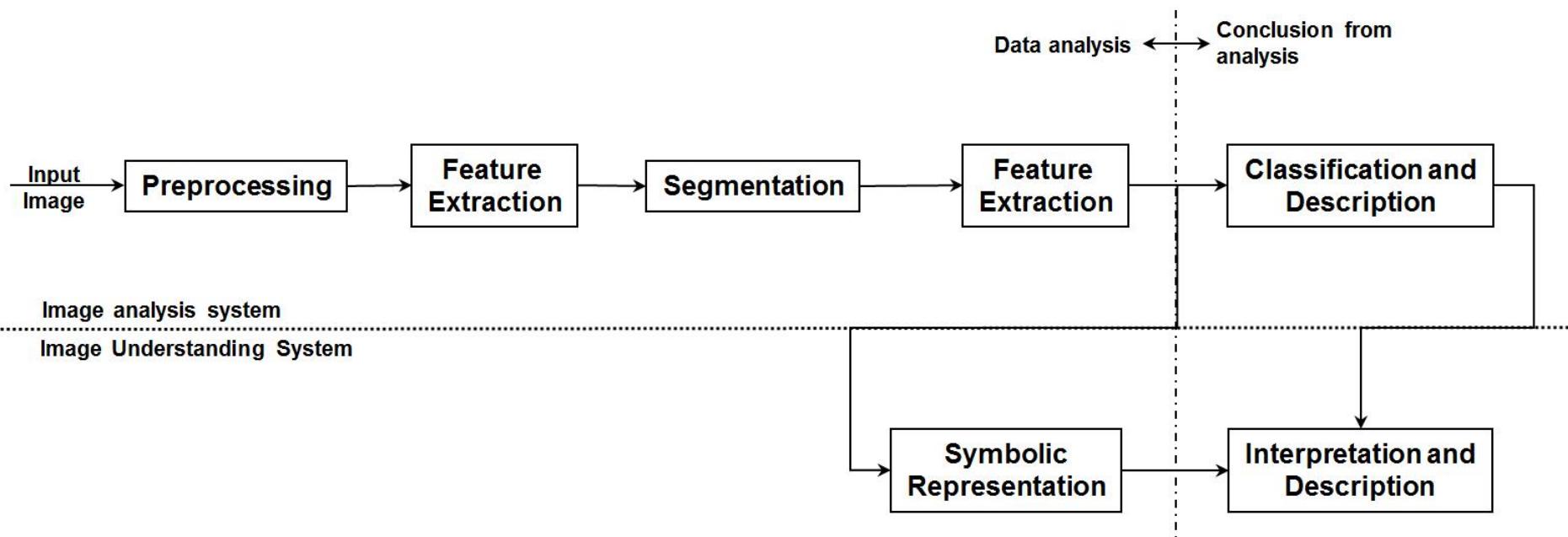


Digital Image Processing

- **Imaging Systems (hardware)**
 - ▶ intensity cameras
 - ▶ range cameras
 - ▶ satellite imagers
 - ▶ MRI
 - ▶ X-ray and CT scanners
 - ▶ radar
 - ▶ ...

- **Techniques and Goals (software)**
 - ▶ image enhancement
 - ▶ contrast modification
 - ▶ edge detection
 - ▶ color processing
 - ▶ 3D surface reconstruction
 - ▶ motion analysis
 - ▶ object recognition
 - ▶ ...

Digital Image Processing



Digital Image Processing

Image Enhancement



Digital Image Processing

Image Enhancement



Digital Image Processing

Noise Removal – Mean Filter



(a)



(b)



(c)



(d)

Figure 5.10: Noise with Gaussian distribution and averaging filters. (a) Original image. (b) Superimposed noise (random Gaussian noise characterized by zero mean and standard deviation equal to one-half of the gray-level standard deviation of the original image). (c) 3×3 averaging. (d) 7×7 averaging.

Digital Image Processing

Noise Removal – Median Filter



Original Image

Corrupted with Salt and Pepper Noise

3 x 3 Median Filter

7 x 7 Median Filter

3 x 3 Median Filter – 3 Times

Digital Image Processing

Comparison between Mean and Median Filtering



Original image, (b)image corrupted by impulse noise, (c)result of 5x5 neighborhood averaging, (d)result of 5x5 median filtering. (Courtesy of Martin Connor, Texas Instruments, Inc., Lewisville, Tex.)

Digital Image Processing

Color Processing

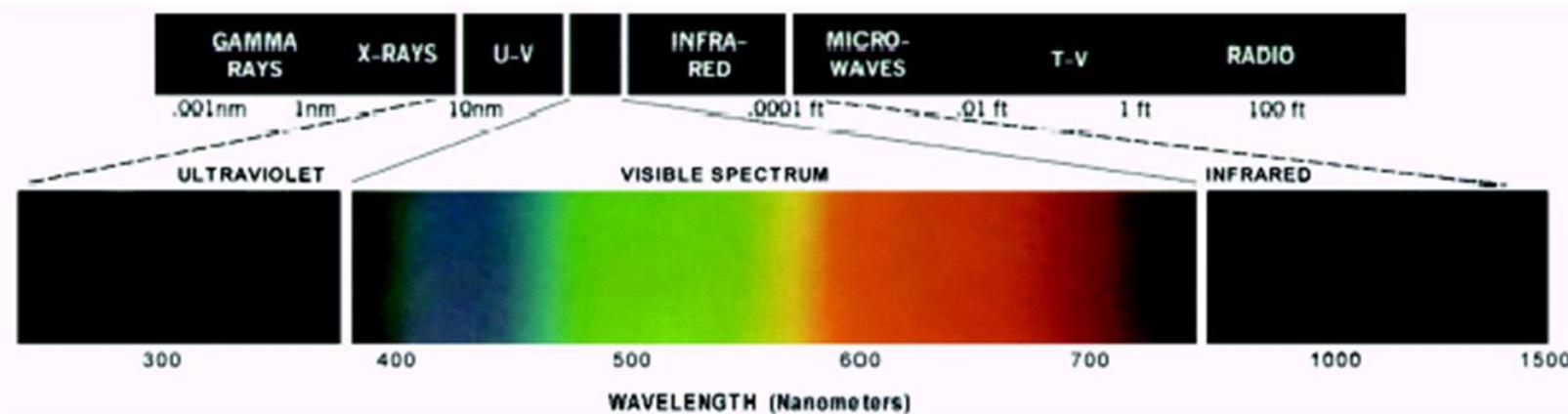


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

from [Gonzalez02]

Digital Image Processing

Color Processing

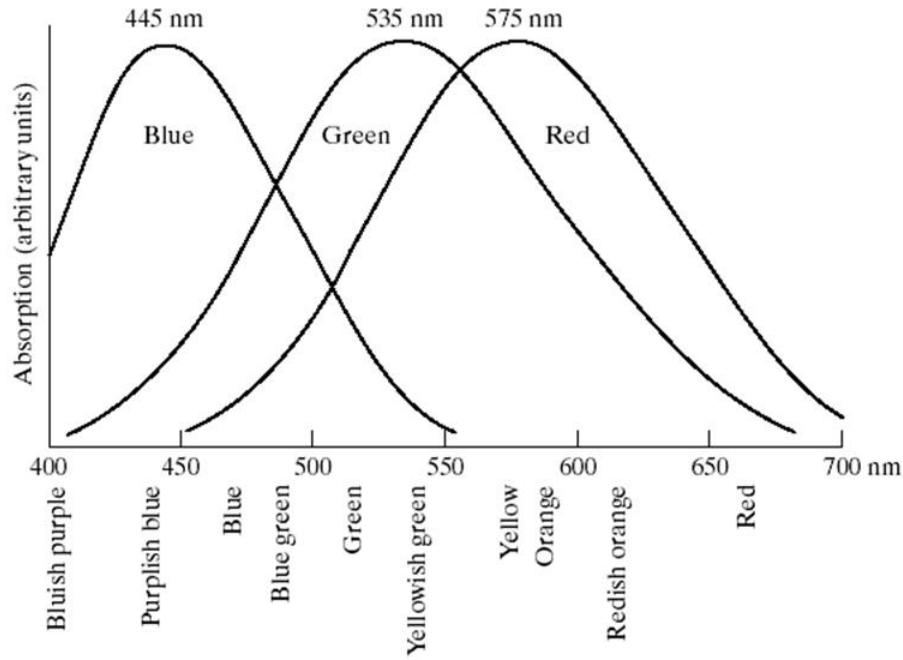


FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

from [Gonzalez02]



red



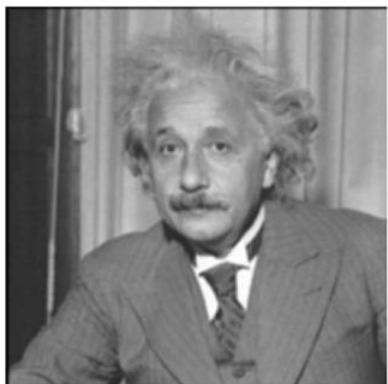
Green



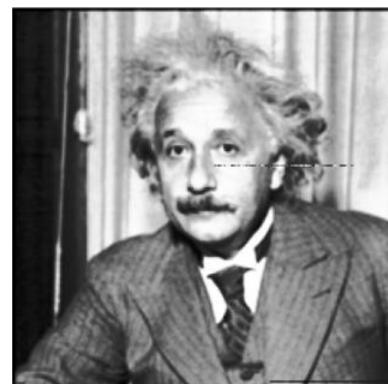
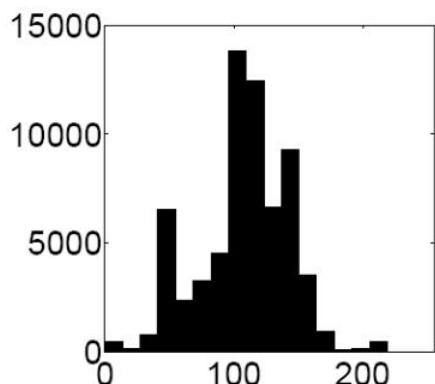
Blue

Digital Image Processing

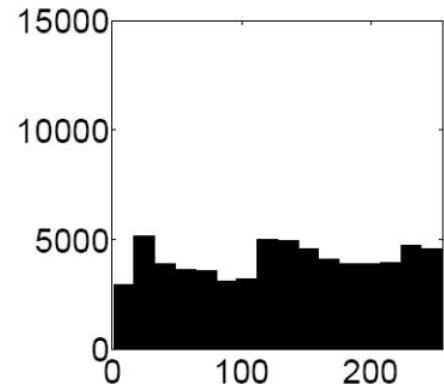
Histogram Equalization



(a)



(b)



(a)

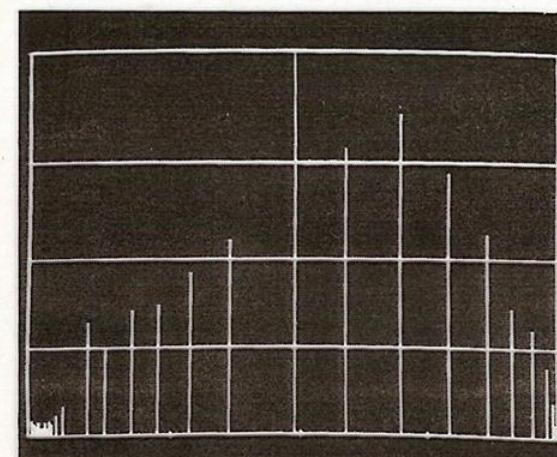
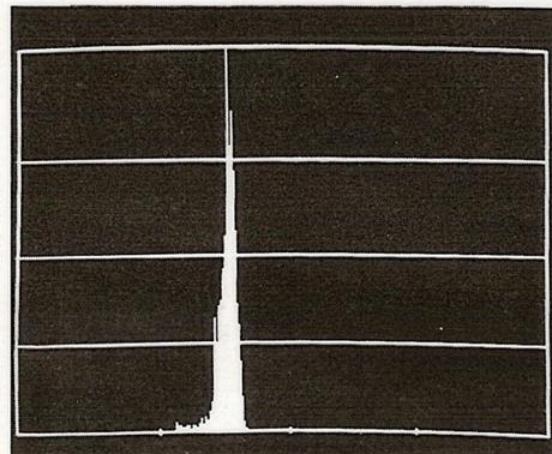
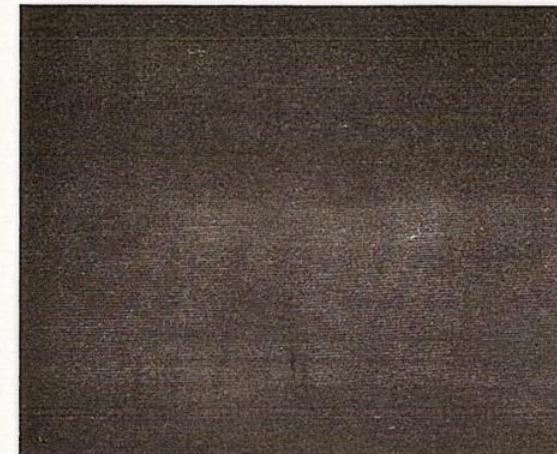


(b)

Figure 5.3: Histogram equalization. (a) Original image. (b) Equalized image.

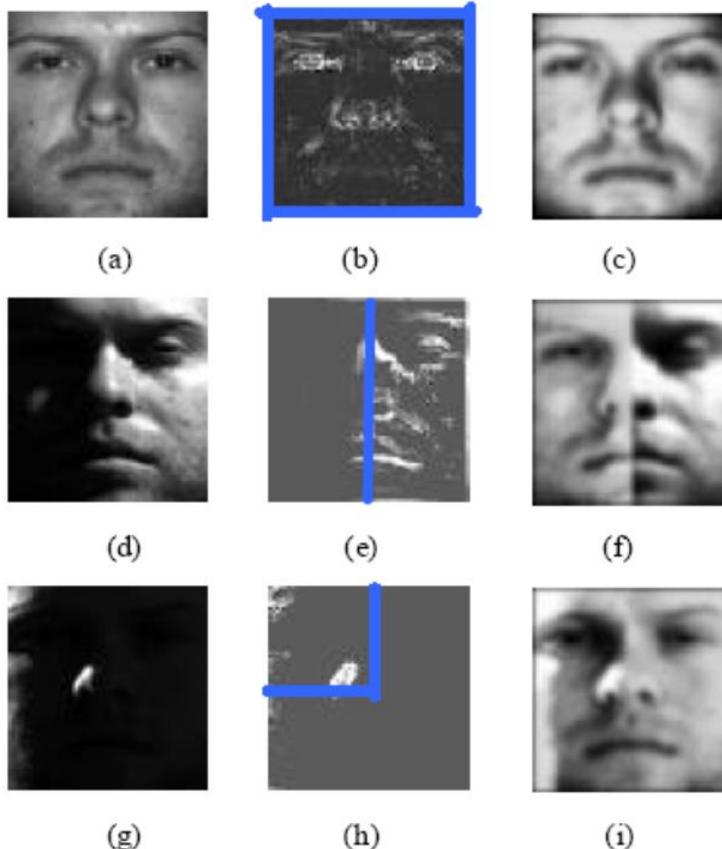
Digital Image Processing

Histogram Equalization



Digital Image Processing

Histogram Equalization



Adaptive Regional Histogram Equalization (ARHE)

a, d, and g are original images; b, e, and h show the selected regions;
c, f, and i are resulting images after ARHE

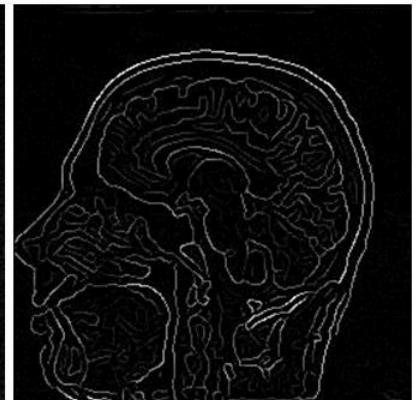
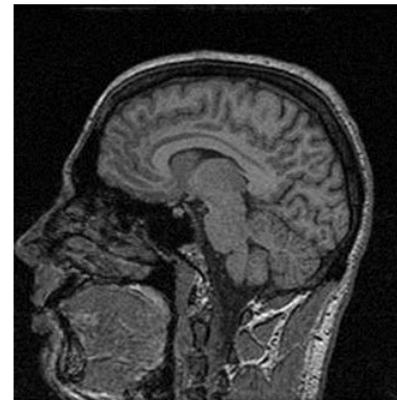
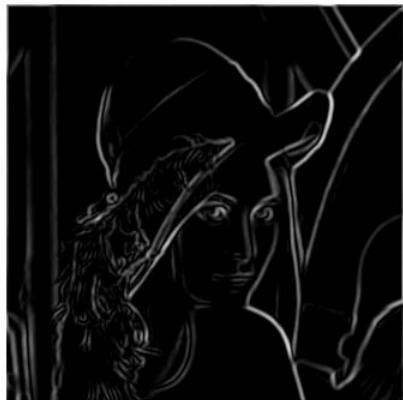
Digital Image Processing

Edge Detection



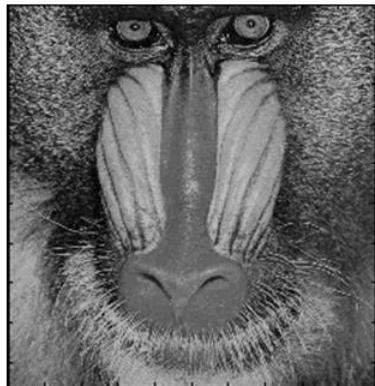
Digital Image Processing

Edge Detection

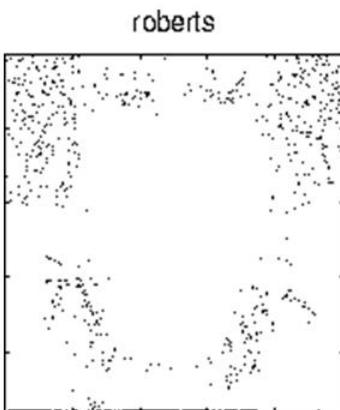


Digital Image Processing

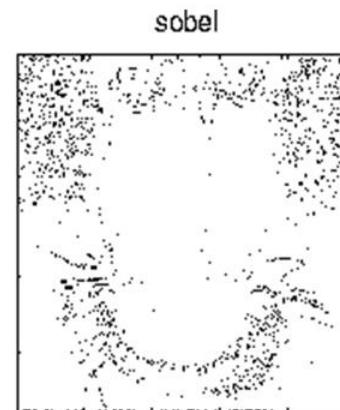
Edge Detection



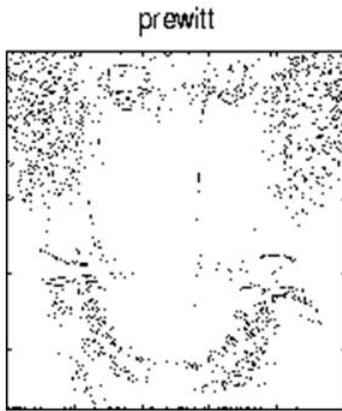
The Original Mandrill Image



roberts



sobel



prewitt



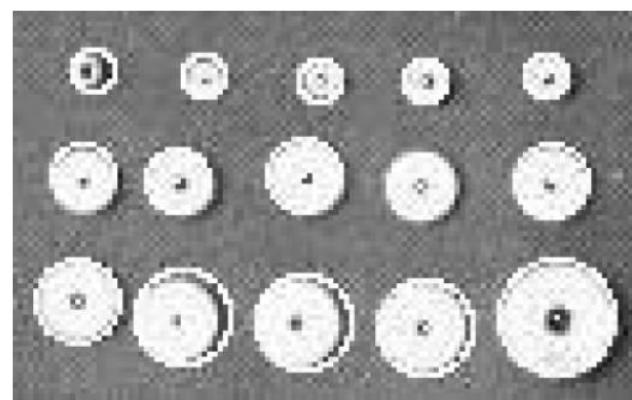
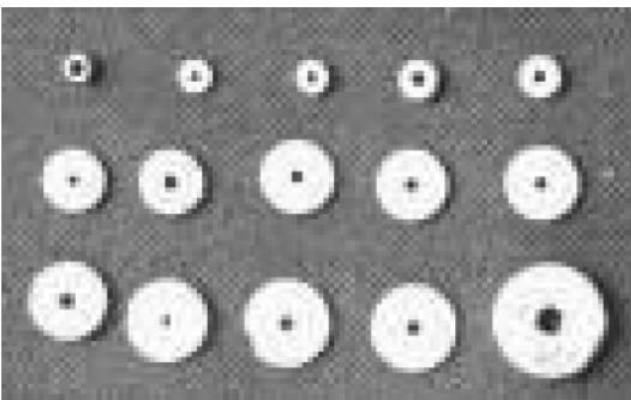
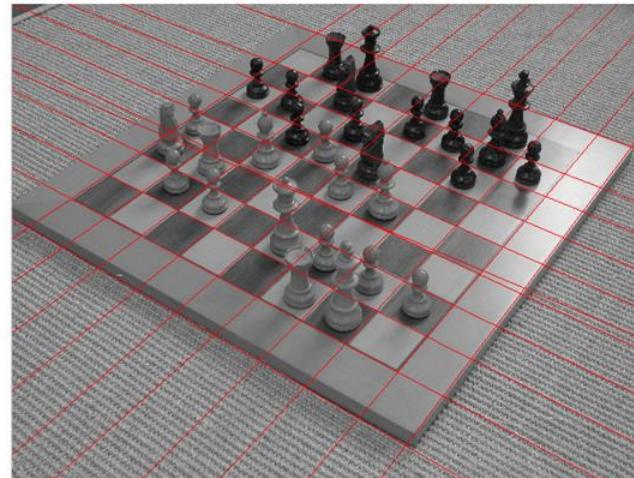
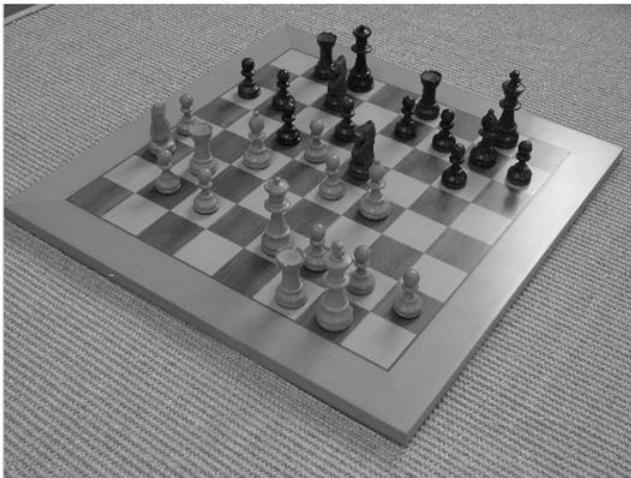
marr



canny

Digital Image Processing

Finding Specific Structures (lines & circles) – Hough Transform

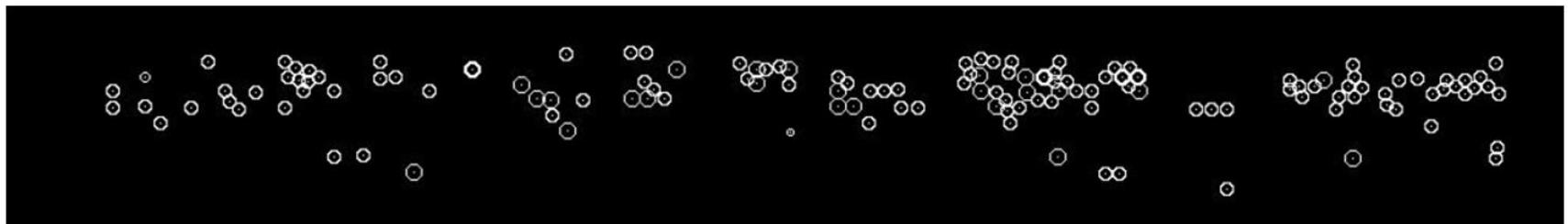


Digital Image Processing

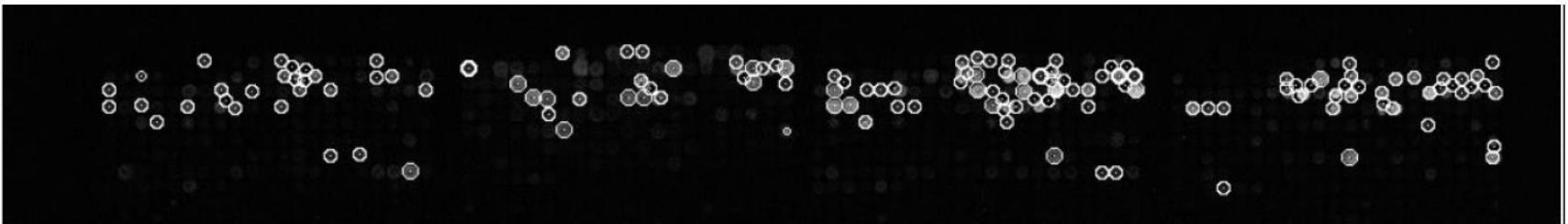
Hough Transforms – Application in Microarray Images



Original Image



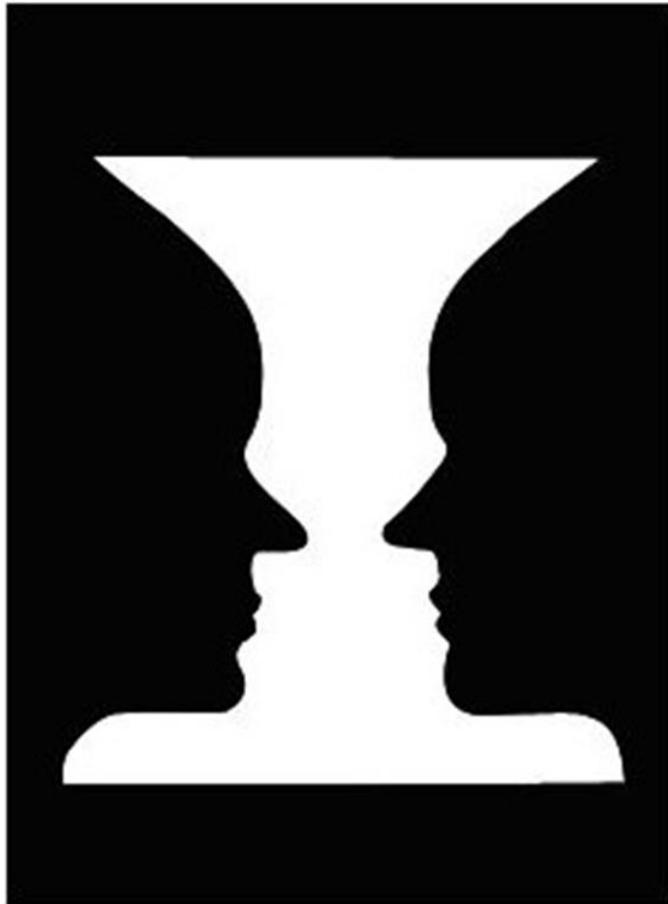
Detected Circles



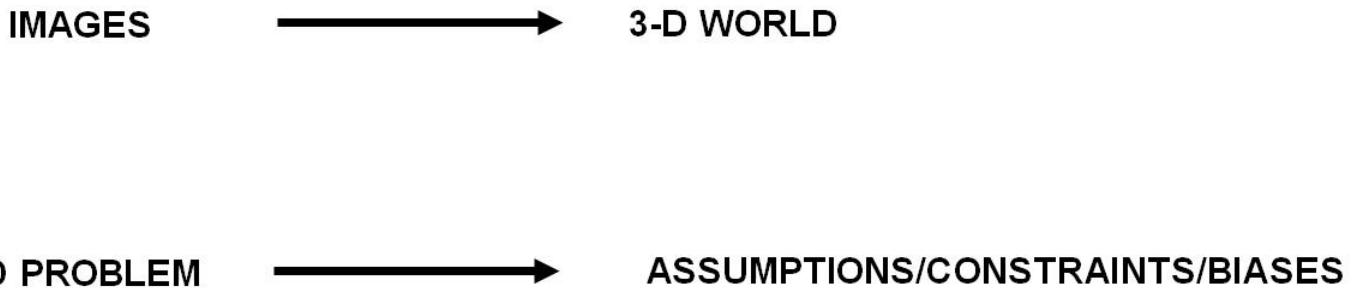
Enhanced Image with Detected Circles Overlaid on Original Image

Digital Image Processing

IMAGE UNDERSTANDING



Digital Image Processing



Such biases are built-in into Human Visual System (HVS)

WE NOT ONLY BELIEVE WHAT WE SEE
TO SOME EXTENT WE SEE WHAT WE BELIEVE!

Effect of a priori knowledge on visual perception

Digital Image Processing

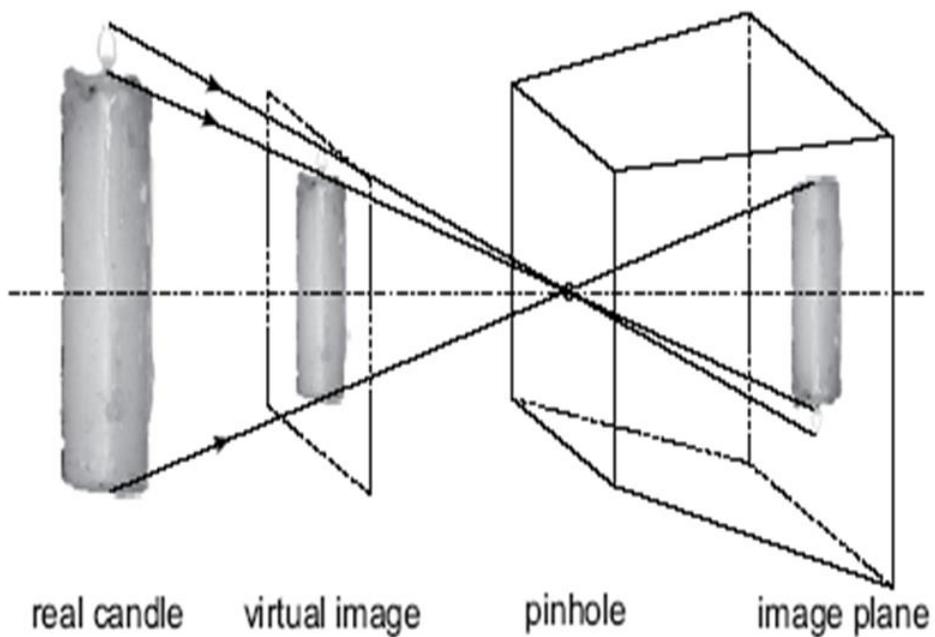


Figure 1.4: The pinhole model of imaging geometry does not distinguish size of objects.

Digital Image Processing

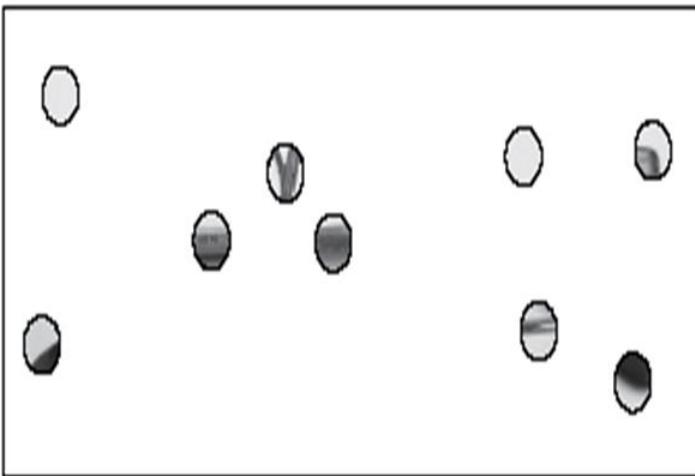


Figure 1.5: Illustration of the world seen through several keyholes providing only a very local context. Try to guess what object is depicted in the image. It is likely to be very difficult if the whole picture has not been seen yet. The complete image is shown deliberately on a different page, see Figure 1.6.

Digital Image Processing

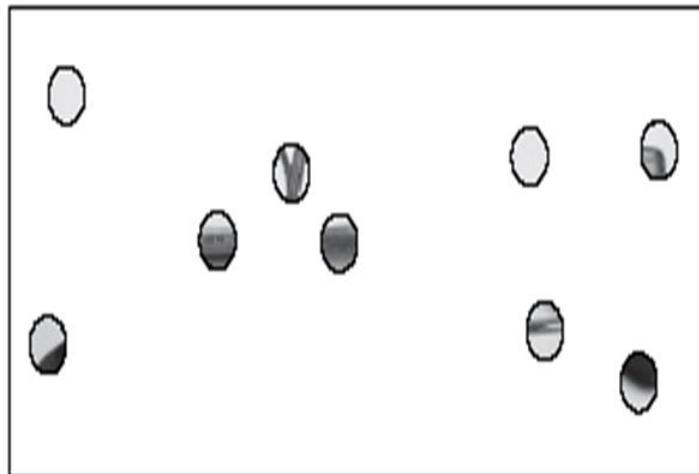


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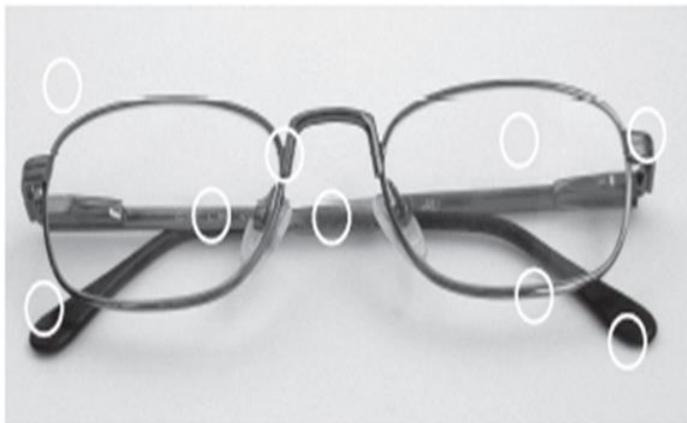


Figure 1.6: It is easy for humans to interpret an image if it is seen globally: compare to Figure 1.5.

Digital Image Processing

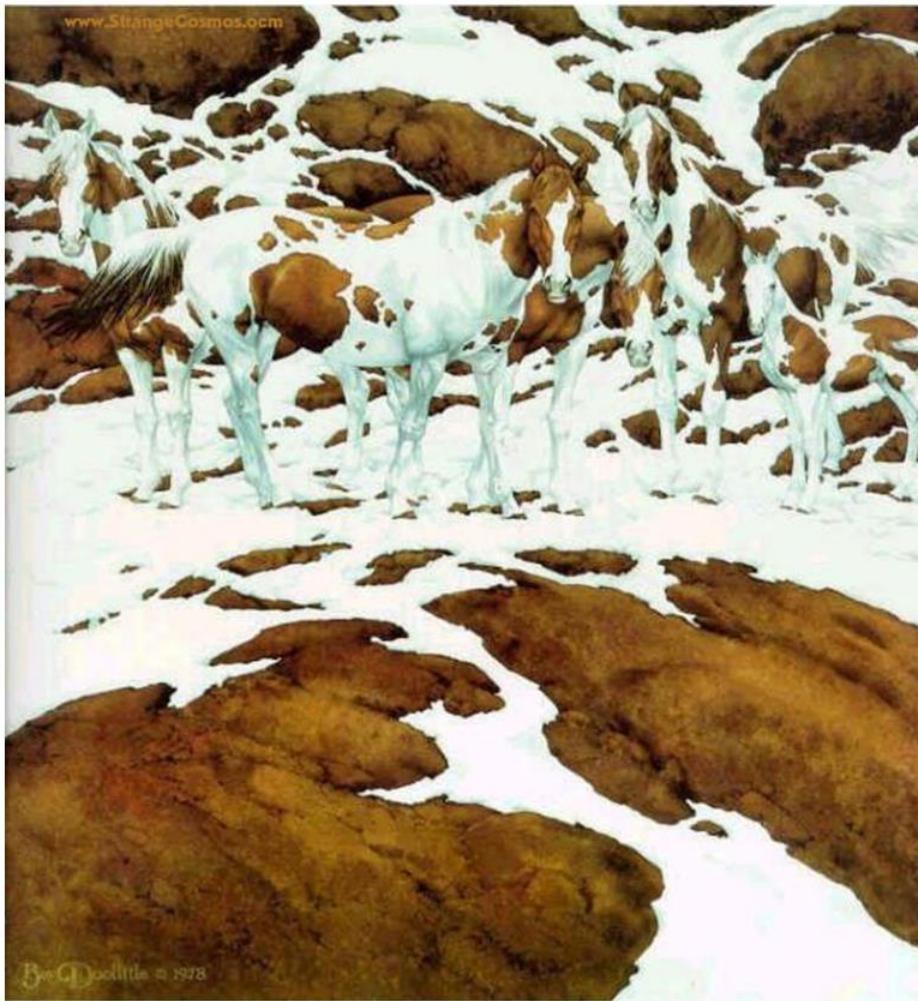
Optical Illusion – Figure Ground Segmentation



Spot the dog in the picture

Digital Image Processing

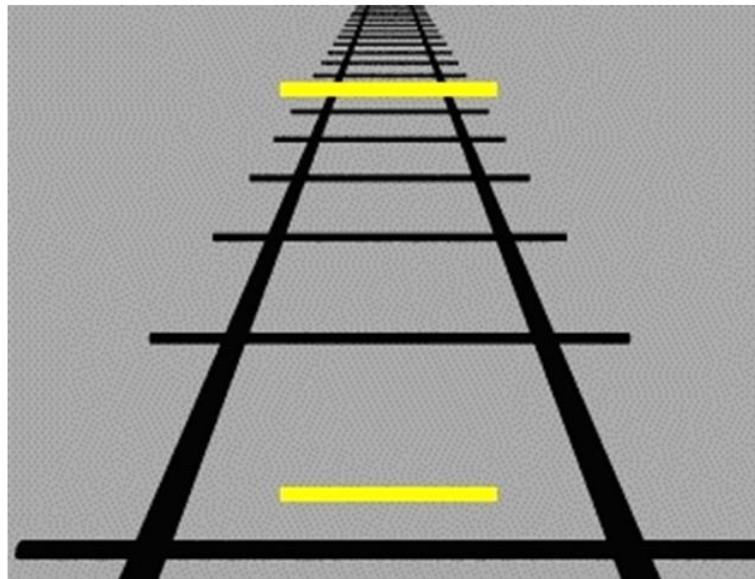
Optical Illusion – Figure Ground Segmentation



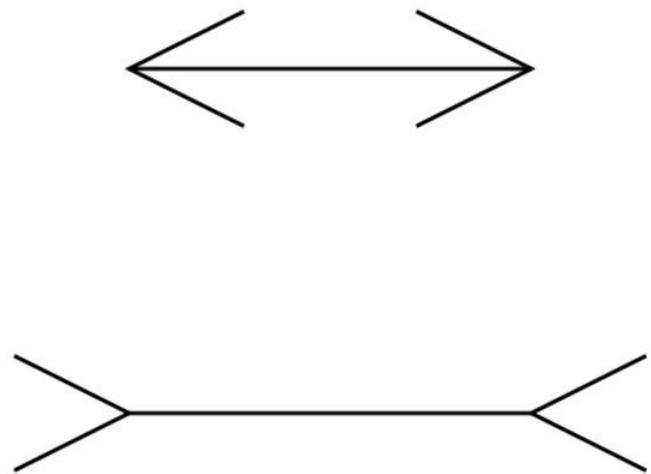
Horses in the Landscape

Digital Image Processing

Optical Illusion – Length

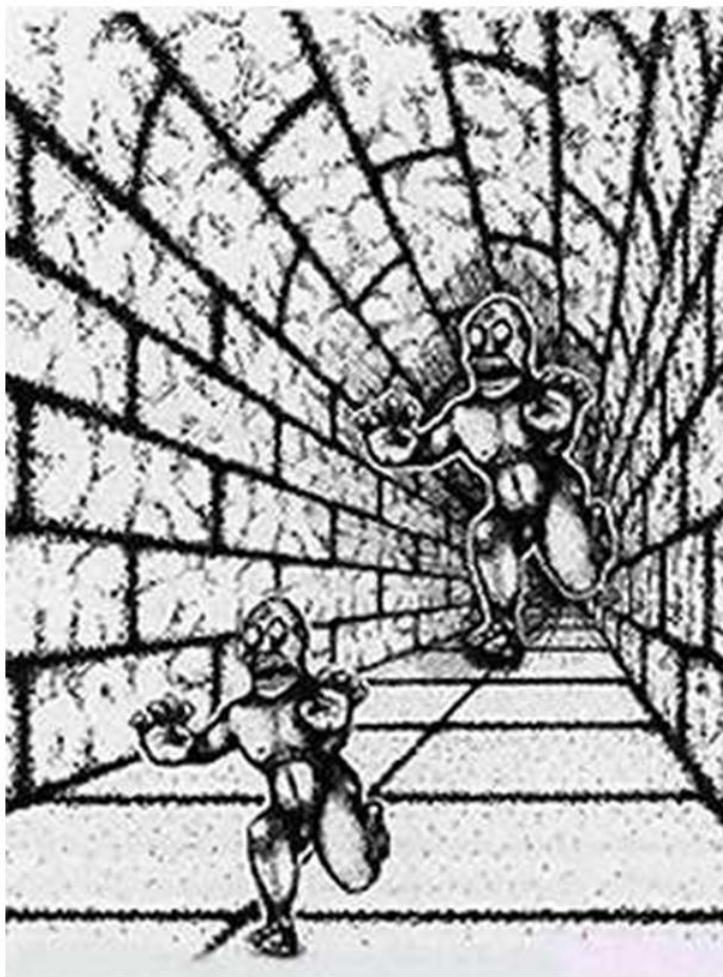


Ponzo's Illusion

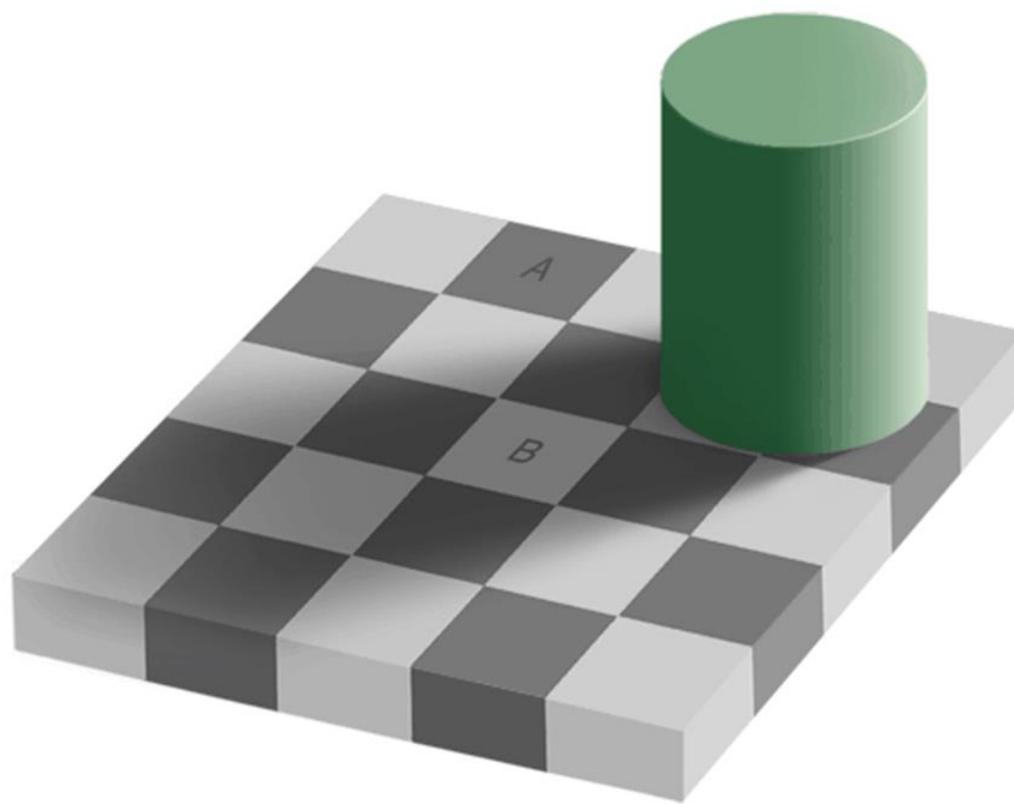


Muller and Lyer Illusion

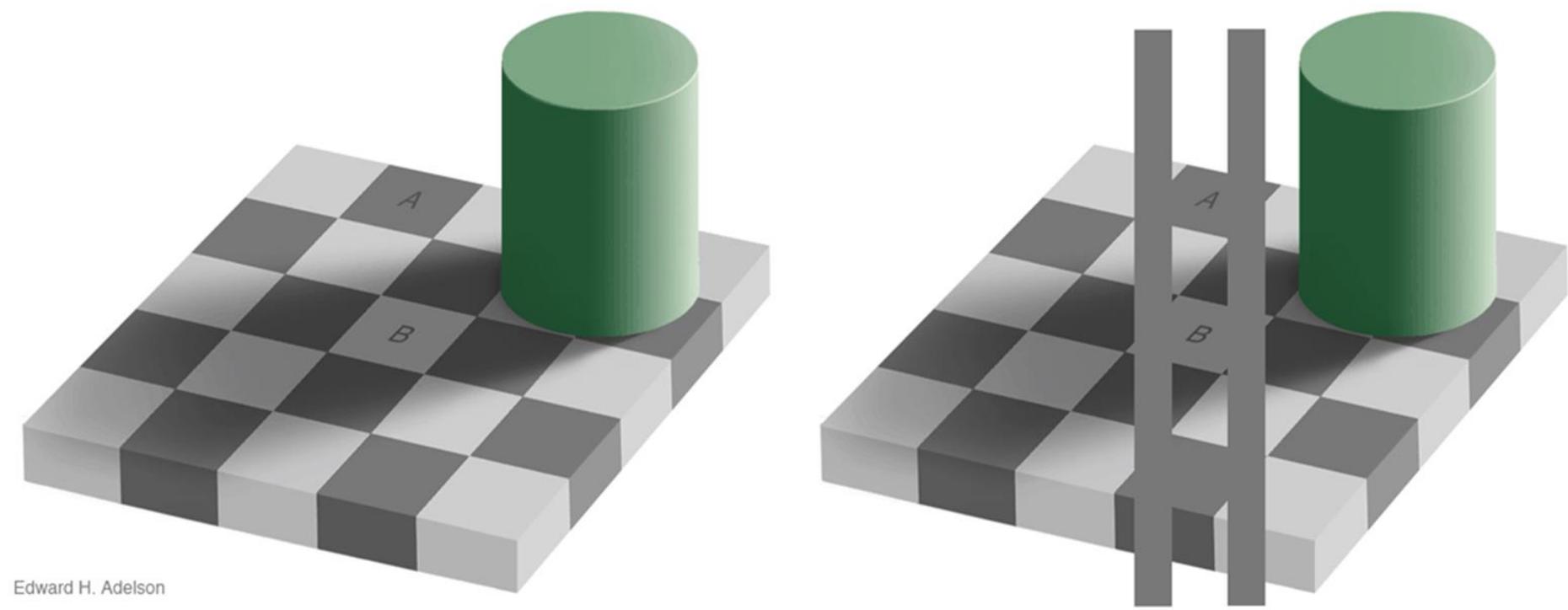
Digital Image Processing



Digital Image Processing



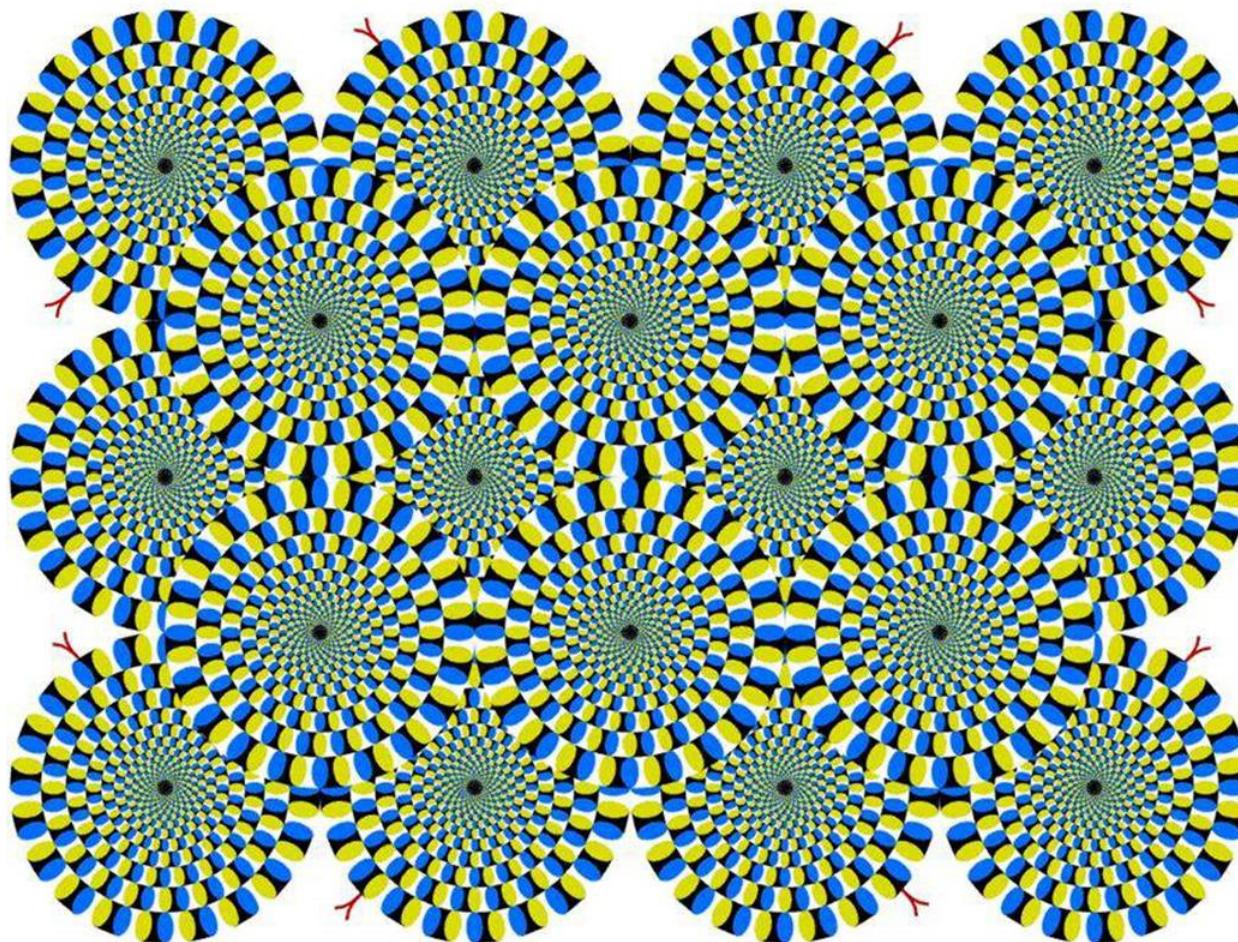
Digital Image Processing



Edward H. Adelson

Digital Image Processing

Optical Illusion



The 2-D Paradigm (by A. Rosenfeld)

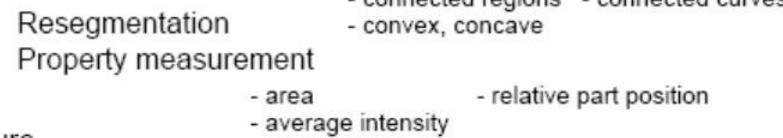
AN OBJECT - an arrangement of parts whose properties and relations satisfy given constraints.

- Properties - gray levels, textures, shapes, etc.
Relations - relative position, relative size, etc.

Scene ~ Image (numeric)



Symbolic image (pixel "values" are labels)



Relational structure

Model matching

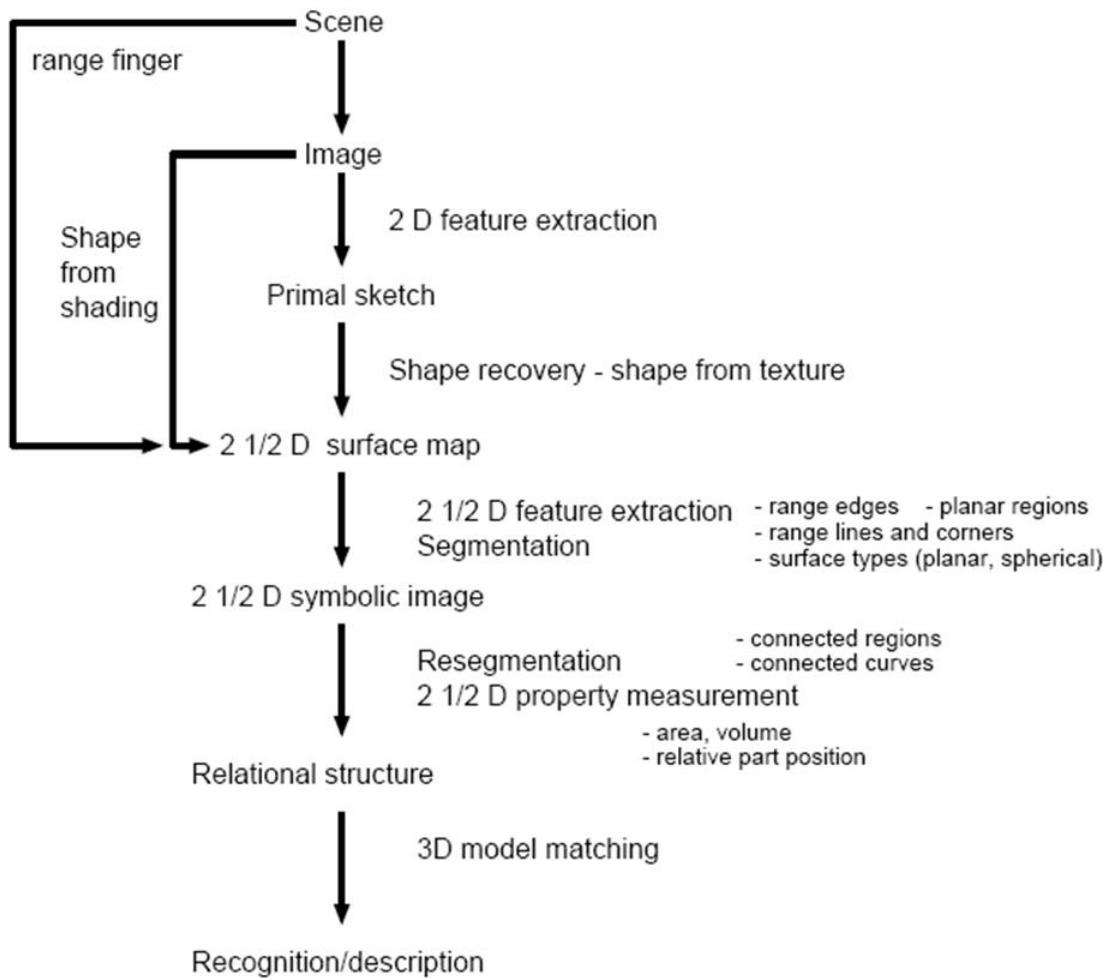
Recognition/description

Parts with properties and relations => relational structure
i.e. a labeled graph

- nodes - parts
- node labels - property values
- arc labels - relation values

=> Object recognition is the task of finding subgraphs of this graph that resemble a given subgraph.

The 3-D Paradigm (by A. Rosenfeld)



OBJECT - arrangement of 3D parts whose properties and relations satisfy given constraints.

Parts with properties and relations => relational structure. i.e. a labeled graph

nodes - 3D object parts

node labels - property values (ex. 3D shape, volume of parts)

arc labels - relation values (ex. relative part position)

=> Object recognition is the task of finding subgraphs of this graph that resemble a given subgraph.

Digital Image Processing

Couple words on video processing

- Video – sequence of images (frames)
 - ▶ intensity video cameras
 - ▶ resolution – SDTV, HDTV, 4K
 - ▶ same processing for each frame
 - ▶ a lot of data – 30 f/s, 100 f/s
 - ▶ process one frame at a time
 - ▶ ...
- Video – frame dependency
 - ▶ compression
 - ▶ progressive vs interlaced frames
 - ▶ color sampling
 - ▶ process multiple frames together
 - ▶ ...

Digital Image Processing

APPLICATIONS

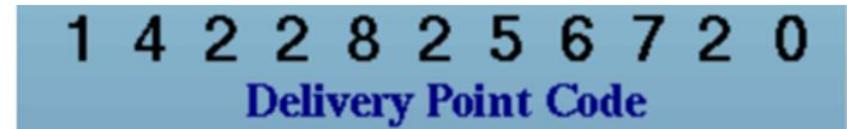
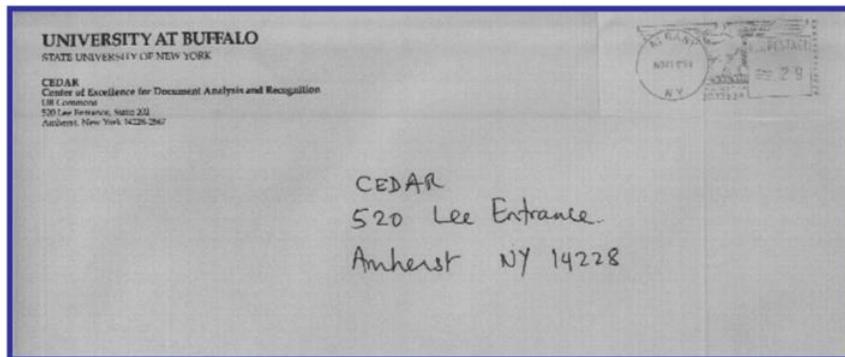
Digital Image Processing



Bar Code Scan



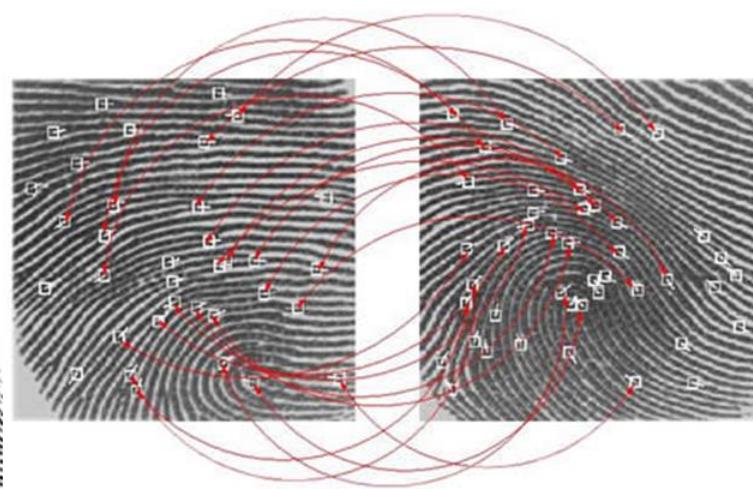
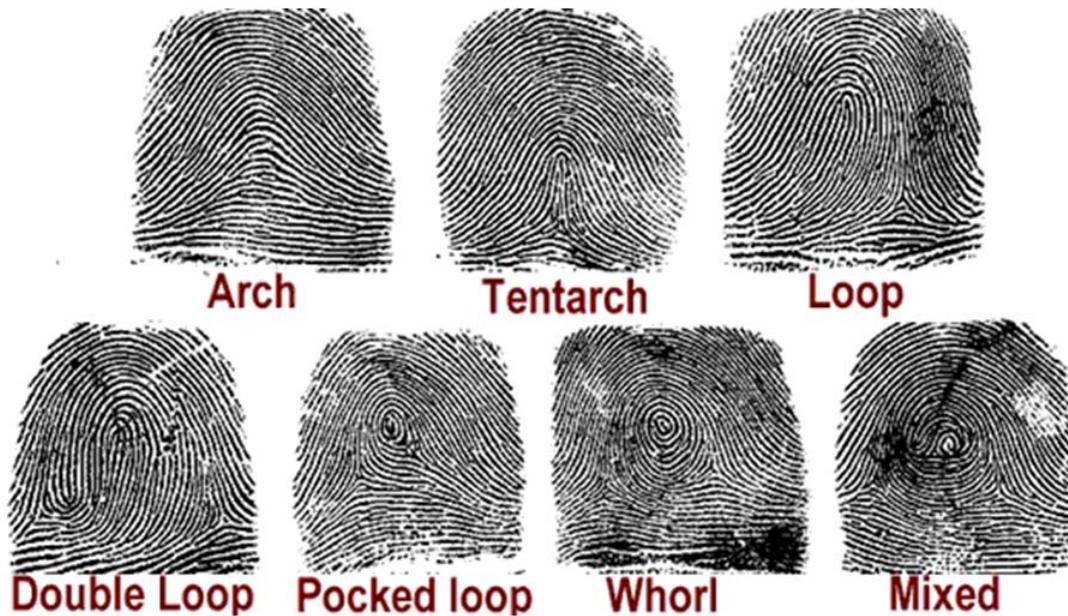
Scanning barcodes



Handwritten Address Interpretation

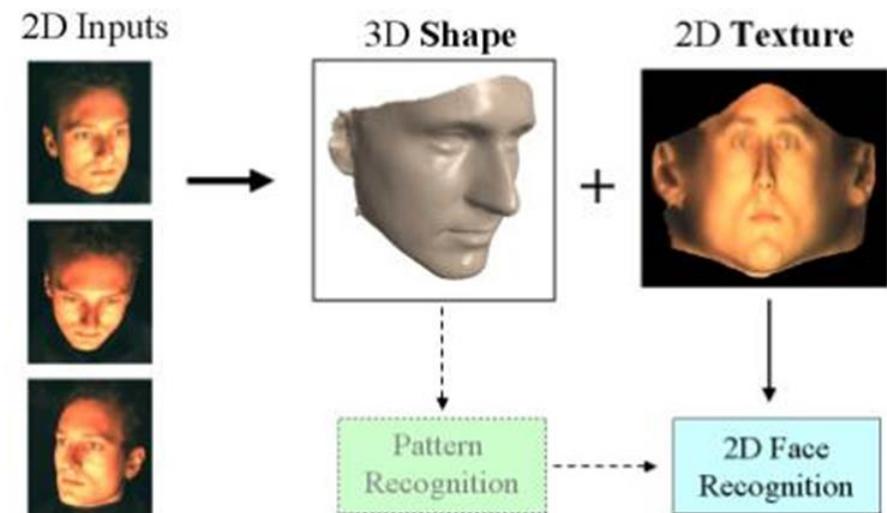
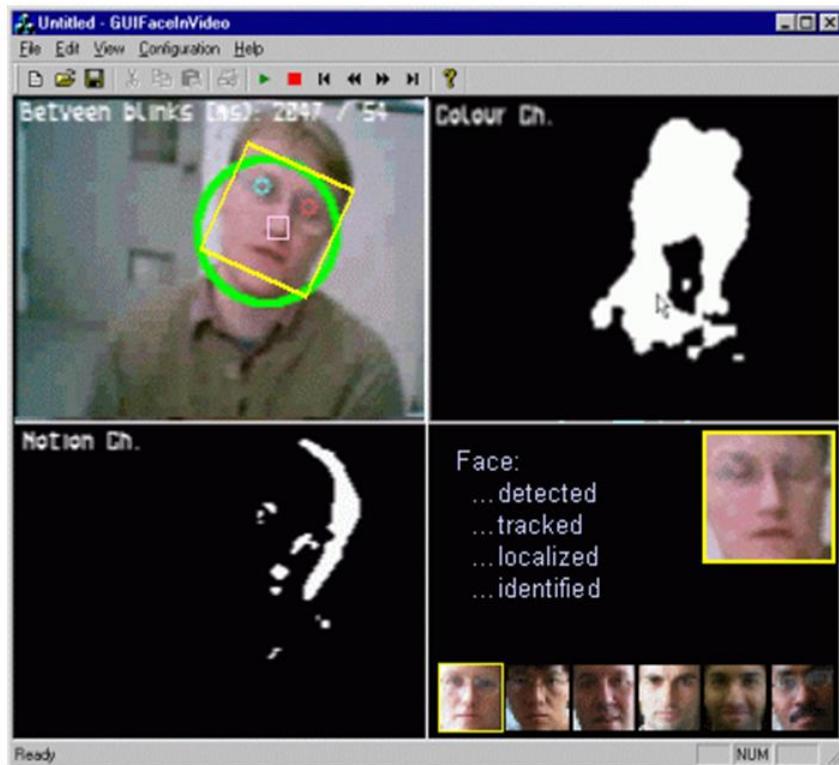
Digital Image Processing

Applications – Fingerprint Recognition



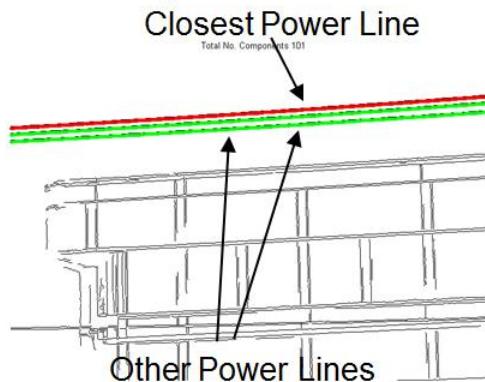
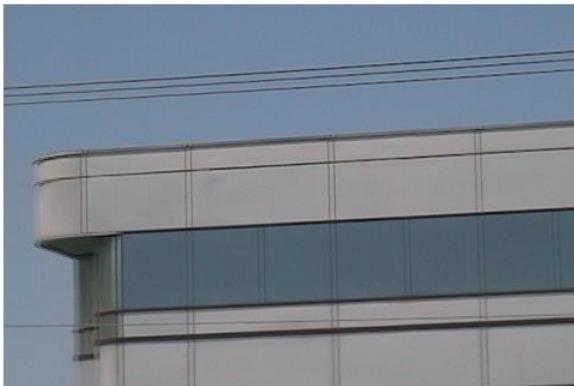
Digital Image Processing

Applications – Face Detection and Recognition



Digital Image Processing

Applications – Aircraft Vision (*Power line detection*)



Achieved detection of the closest objects (power lines) in a 15 frame SUAV Crash in an area affected by hurricane Katrina



Digital Image Processing

Applications – Human Identification through Gait Recognition



The *HumanID Gait Challenge Problem* consists of a baseline algorithm, a set of 12 experiments, and a large dataset created here at USF.

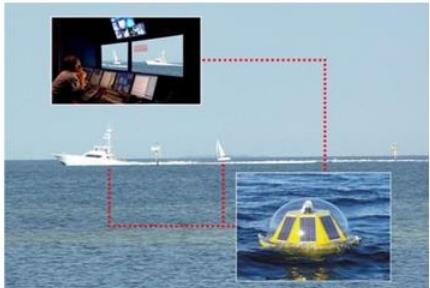
Visit www.GaitChallenge.org for more information

Digital Image Processing

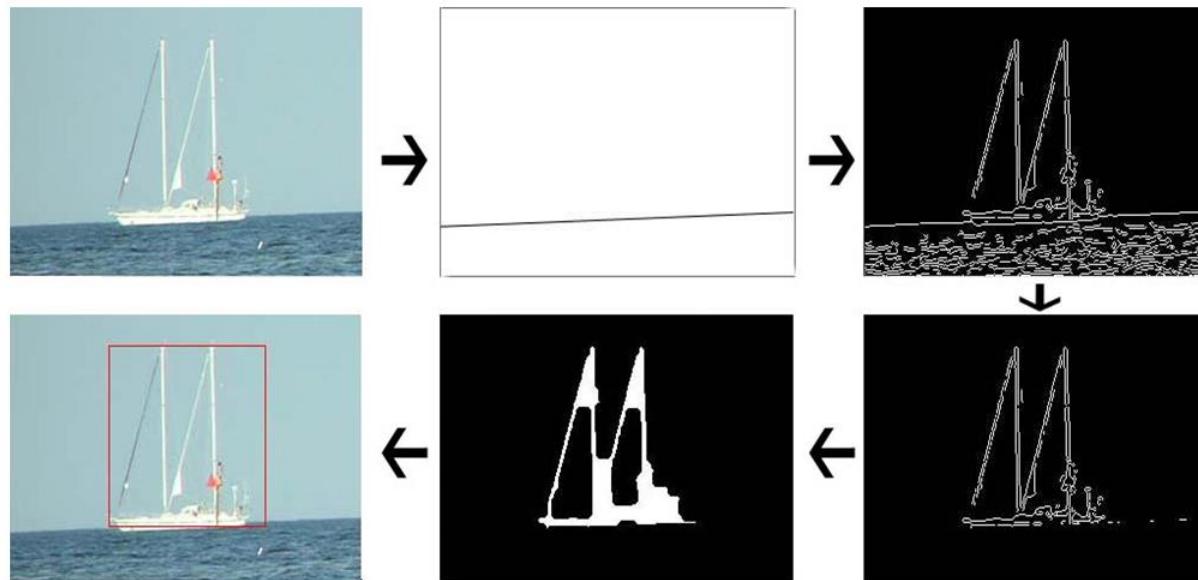
Automated Detection of Suspicious Activities

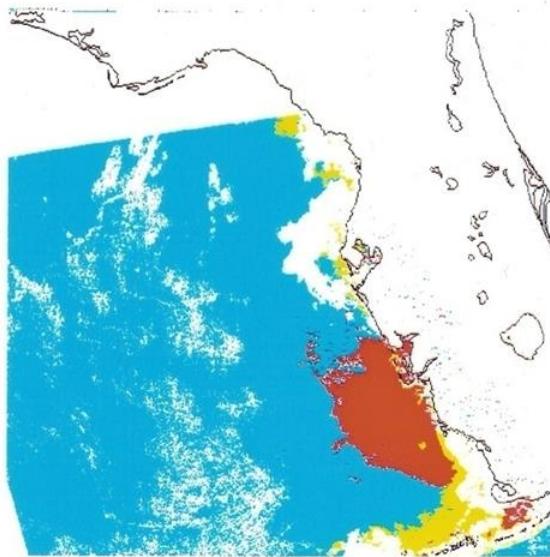


Digital Image Processing



Applications – Marine Vehicle Detection on the Horizon





Red Tide Tracking

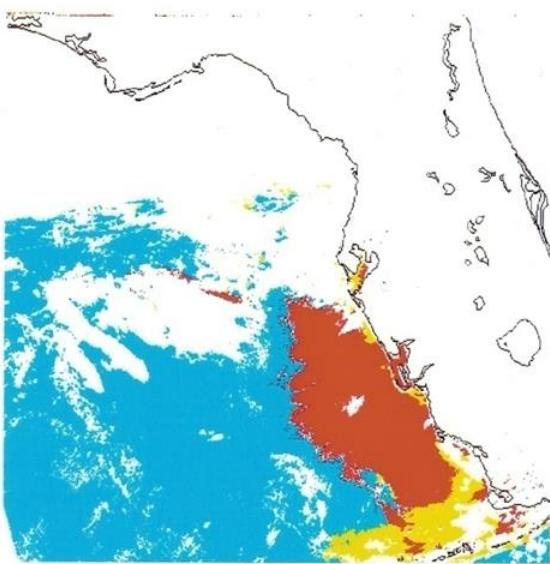
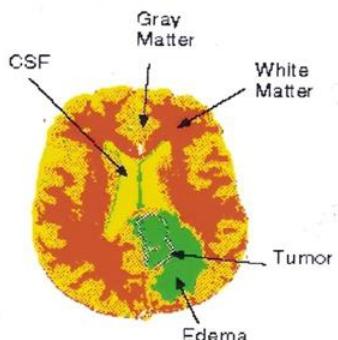


Figure 6: CZCS images with red tide after processing by the knowledge based system. Note (a) is also the training image of for the system. On 14 November 1978 and 2 December 1978.



Raw T1-weighted, PD-weighted, T2-weighted Images



Labeled Image



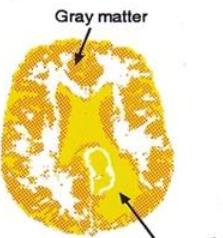
ROI classes



Gray matter



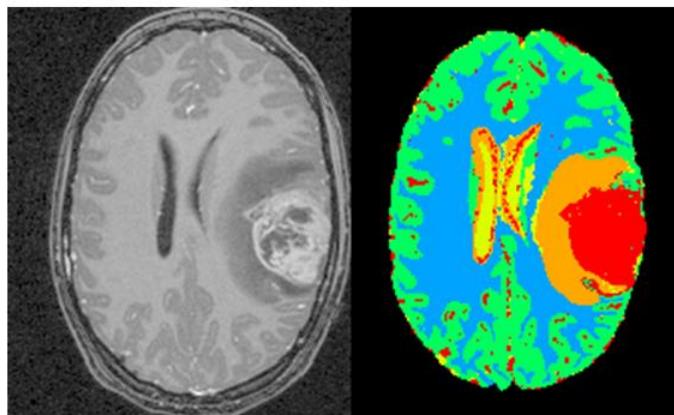
Gray matter pixels



Results of FCM



MRI image segmentation



ROI classes



Abnormal pixels

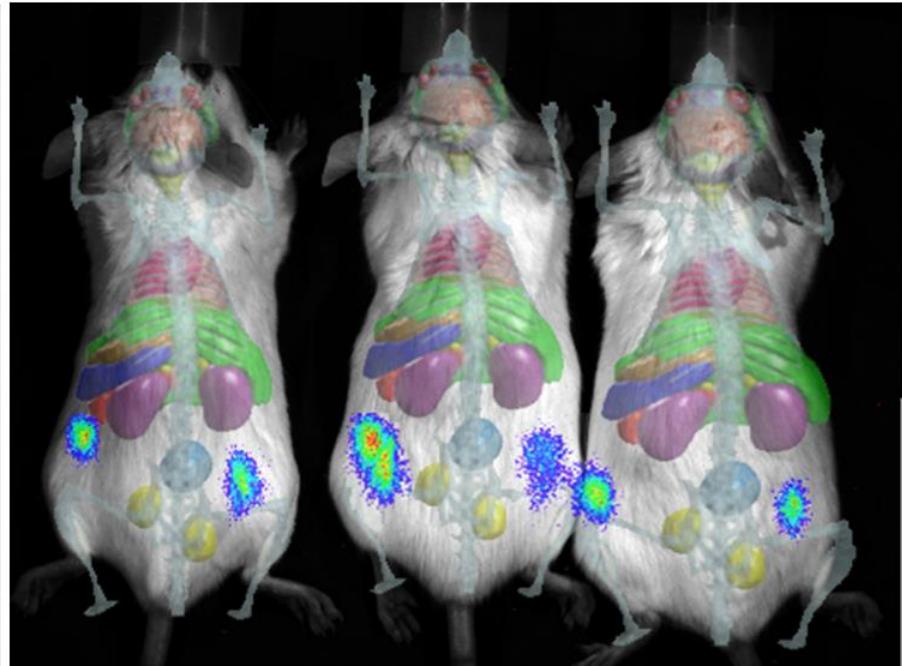
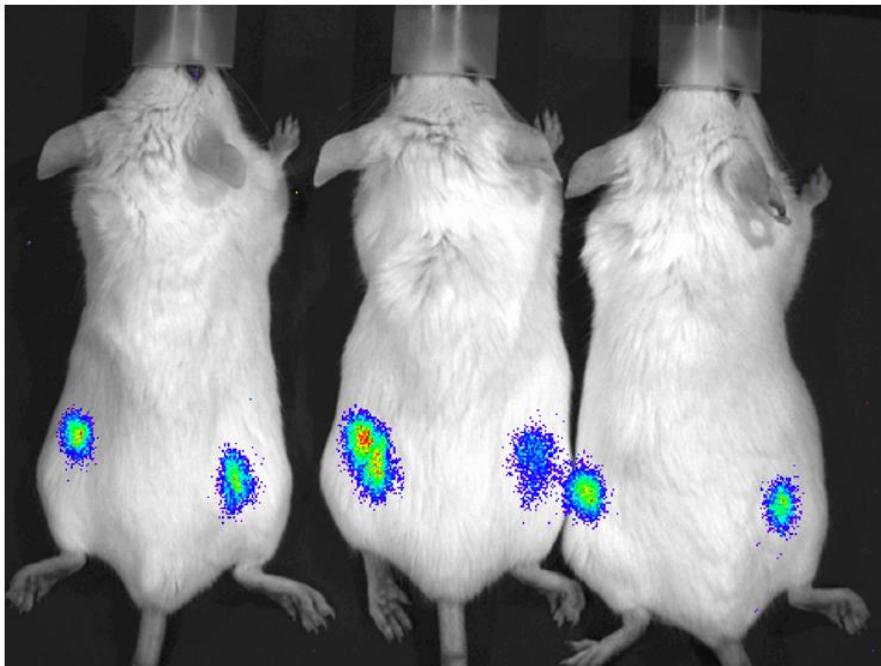


Tumor

Results of reclustering

Digital Image Processing

Biophotonic Imaging for Cancer Research



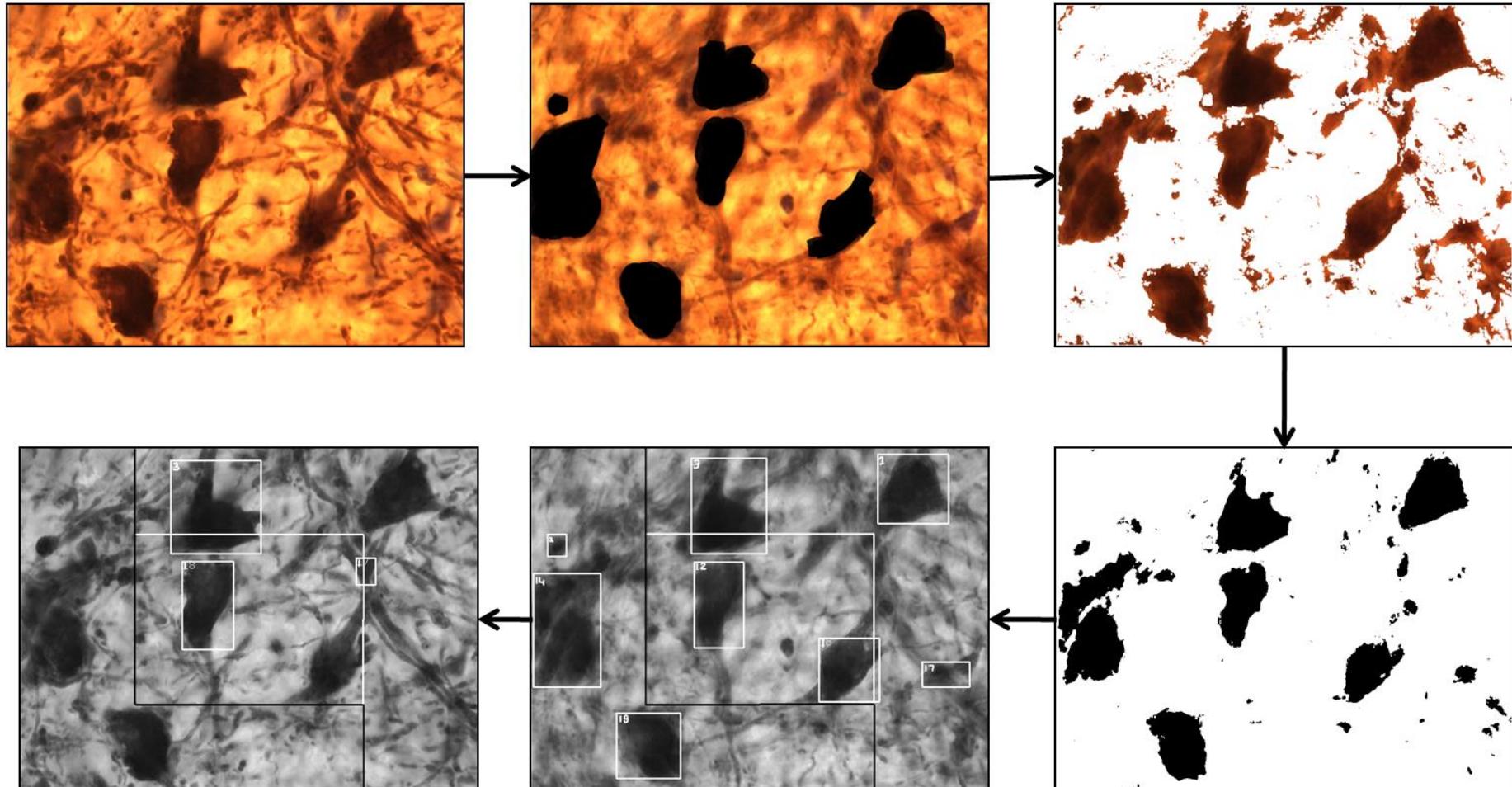
Digital Image Processing

Medical Imaging: PET/CT glucose intake

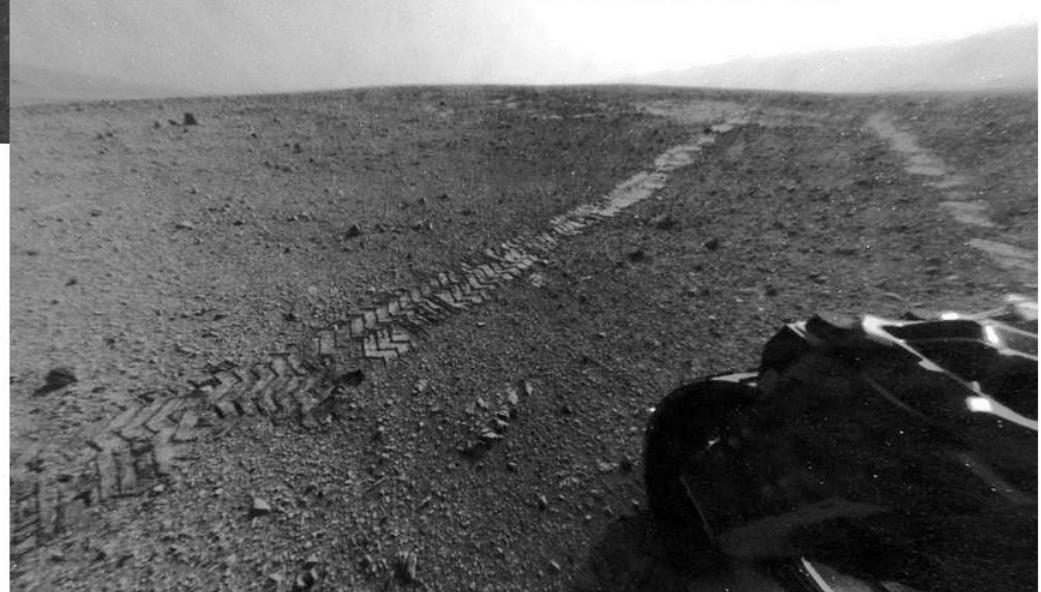
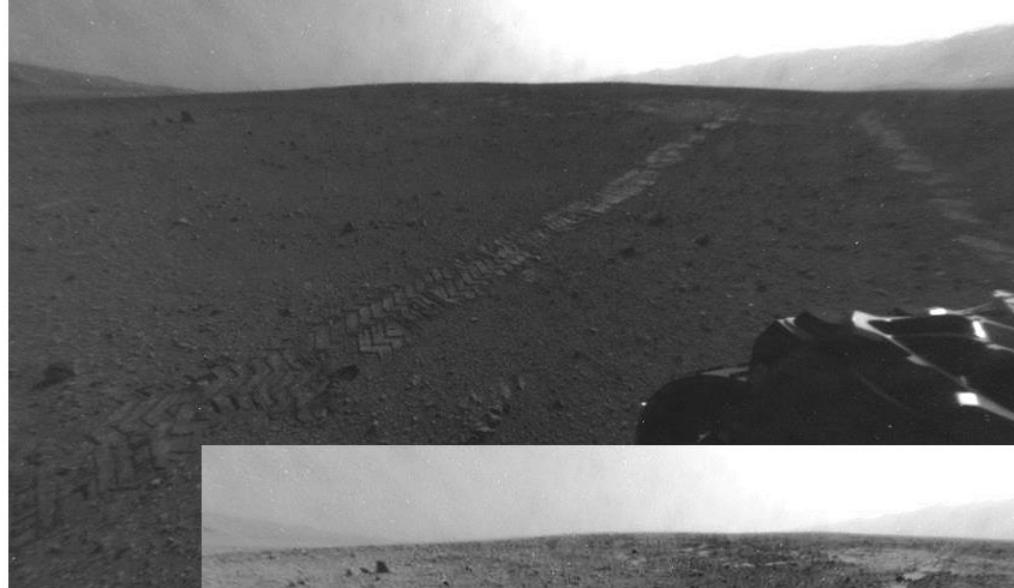


Digital Image Processing

Microscopy and cell counting



Digital Image Processing



Digital Image Processing

Thank you