CS7.404: Digital Image Processing

Monsoon 2025: 1: Overview

(Prehistoric Painting,
Lascaux cave, France
~15000 BC)

Anoop M. Namboodiri

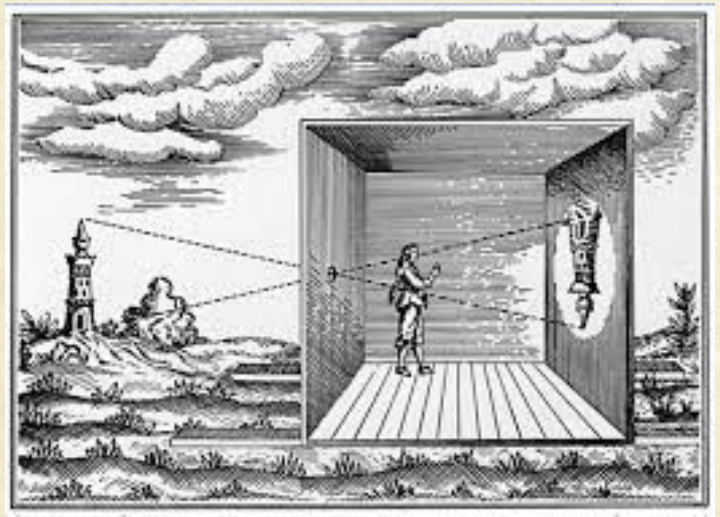
Biometrics and Secure ID Lab, CVIT,

IIIT Hyderabad

Middle Ages

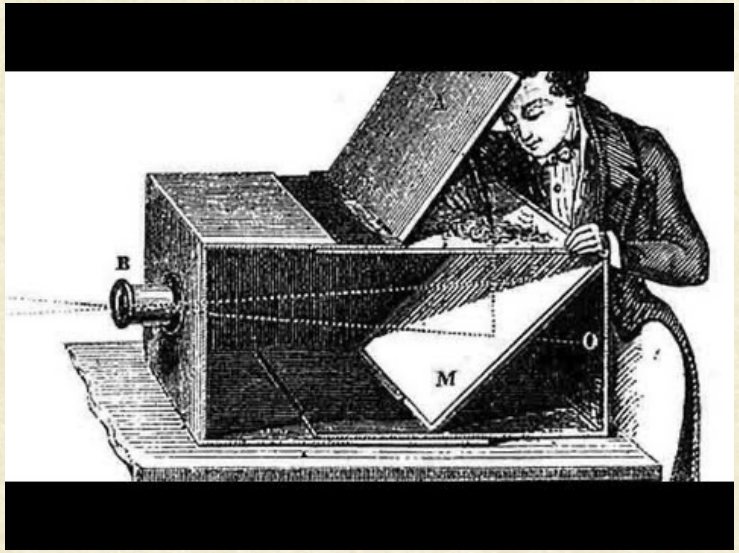
The Empress Theodora with her court.
- Ravenna, St. Vitale, 6th c.

Before there were images ….



Girl with a pearl earring, J. Vermeer, 1665

Camera Obscura



http://www.cs.toronto.edu/~guerzhoy/320/lec/Introduction.pdf

and then there were Images ….

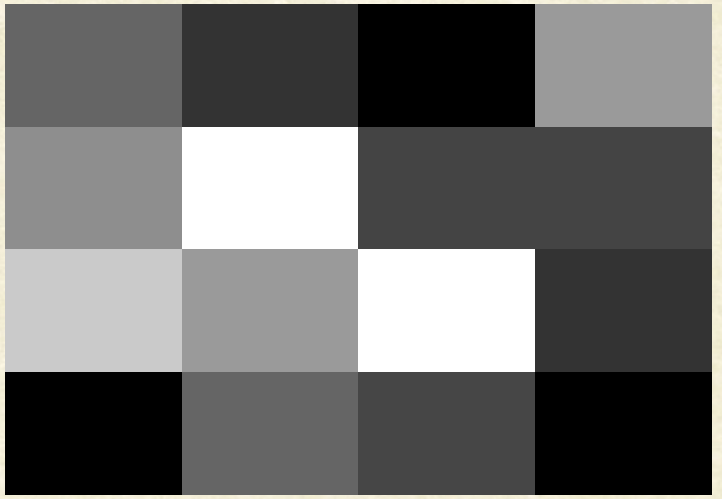
Still Life,
Lous Jaques Mande Daguerre, 1837

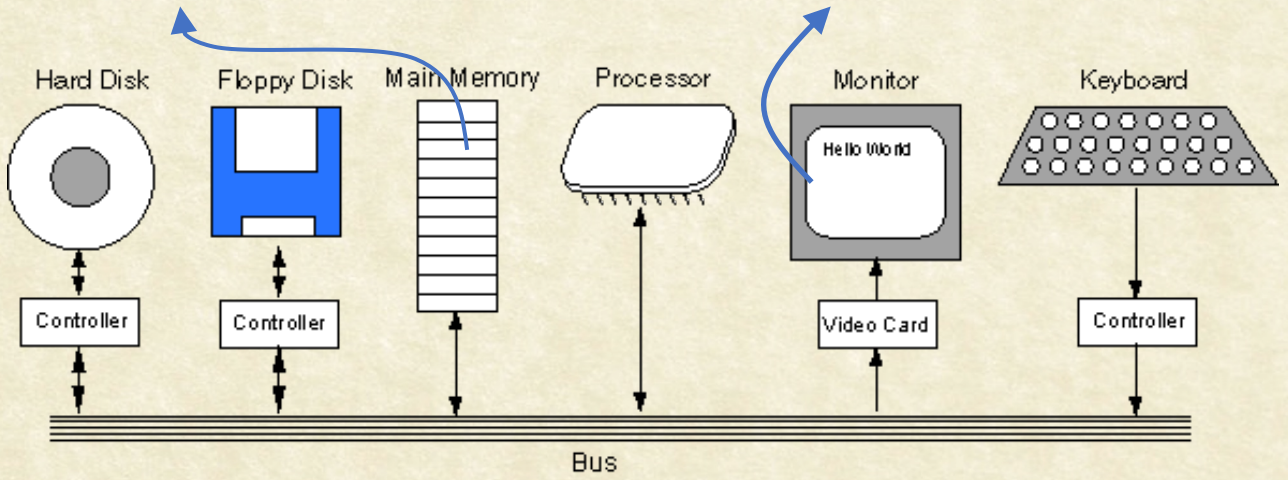
http://www.cs.toronto.edu/~guerzhoy/320/lec/Introduction.pdf

What is a Digital Image ?

- An **array** of numbers representing colors or intensities

100	50	0	150
90	255	70	70
200	150	255	50
0	100	80	0





http://www.cs.ucc.ie/~gavin/cs1001/Notes/chap01/ch01_4.html

What is a Digital Image ?

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100	50	0	150
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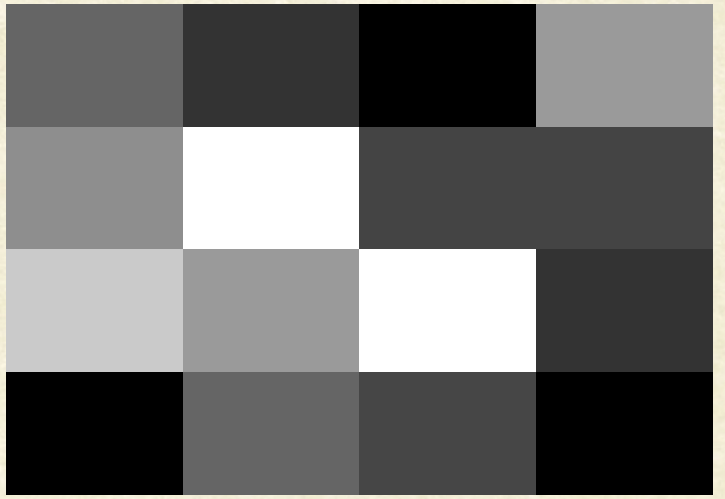
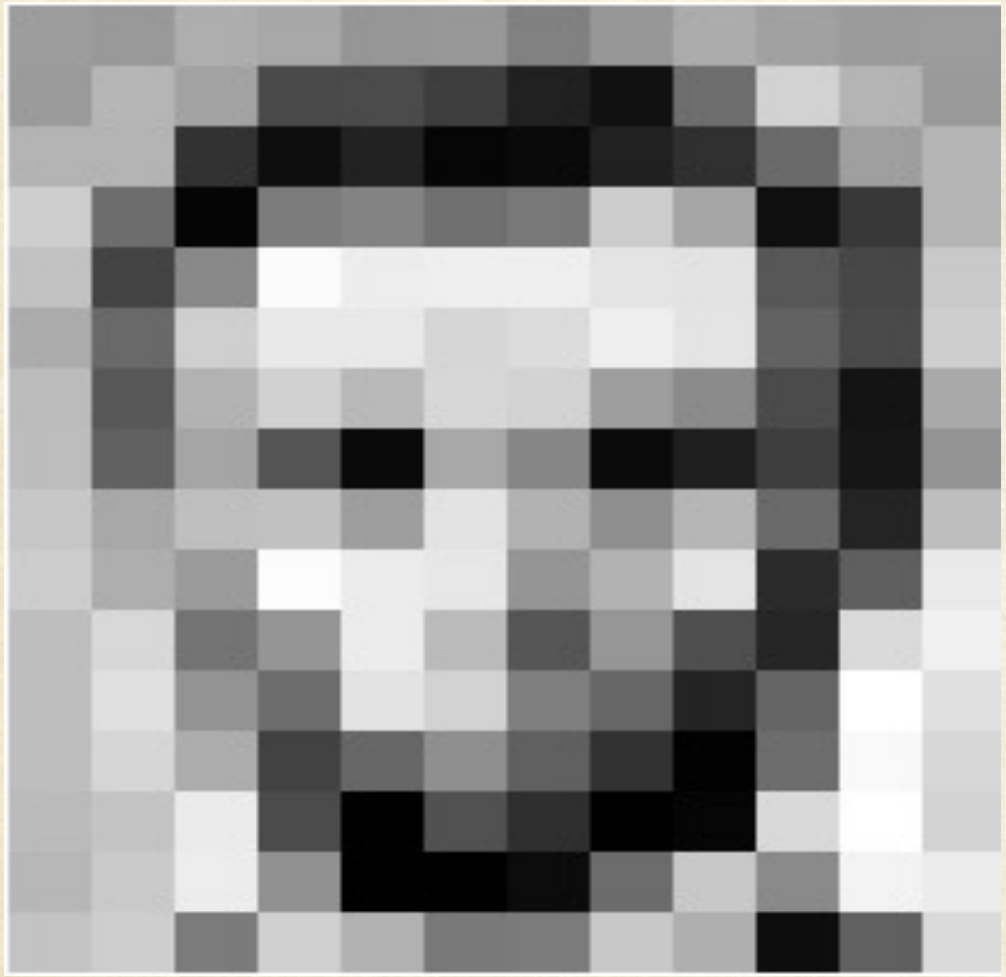


1 2-D channel
8 bits/pixel

http://www.cs.ucc.ie/~gavin/cs1001/Notes/chap01/ch01_4.html

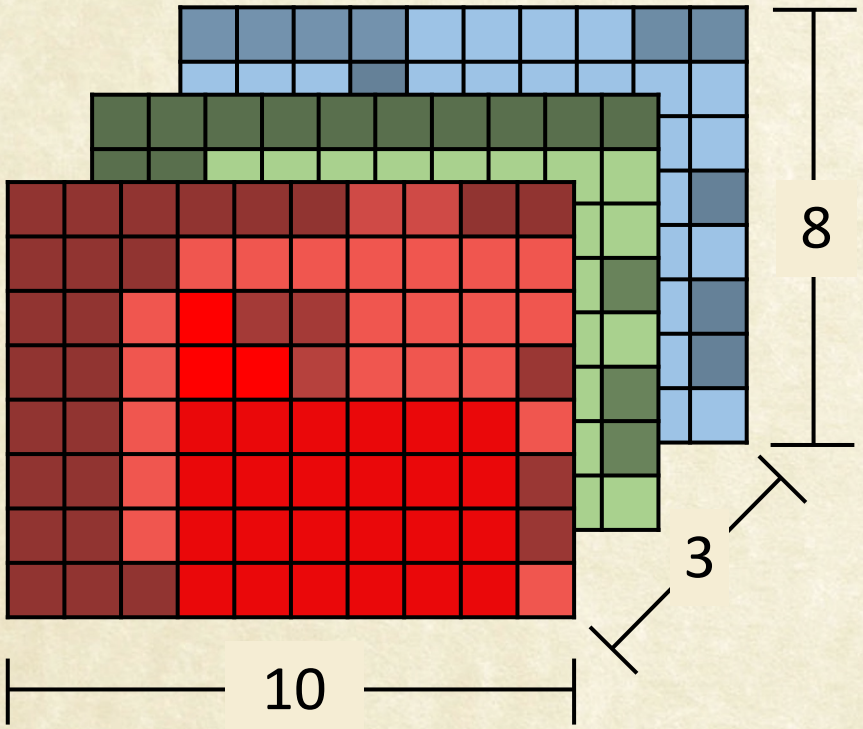
Image Representation (Grayscale)



157	153	174	168	150	152	129	151	172	161	155	156
155	182	163	74	75	62	33	17	110	210	180	154
180	180	50	14	34	6	10	33	48	106	159	181
206	109	5	124	131	111	120	204	166	15	56	180
194	68	137	251	237	239	239	228	227	87	71	201
172	105	207	233	233	214	220	239	228	98	74	206
188	88	179	209	185	215	211	158	139	75	20	169
189	97	165	84	10	168	134	11	31	62	22	148
199	168	191	193	158	227	178	143	182	106	36	190
205	174	155	252	236	231	149	178	228	43	95	234
190	216	116	149	236	187	86	150	79	38	218	241
190	224	147	108	227	210	127	102	36	101	255	224
190	214	173	66	103	143	95	50	2	109	249	215
187	196	235	75	1	81	47	0	6	217	255	211
183	202	237	145	0	0	12	108	200	138	243	236
195	206	123	207	177	121	123	200	175	13	96	218

https://openframeworks.cc/ofBook/images/image_processing_computer_vision/

Image Representation (RGB)



3 2-D channels

24 bits per pixel

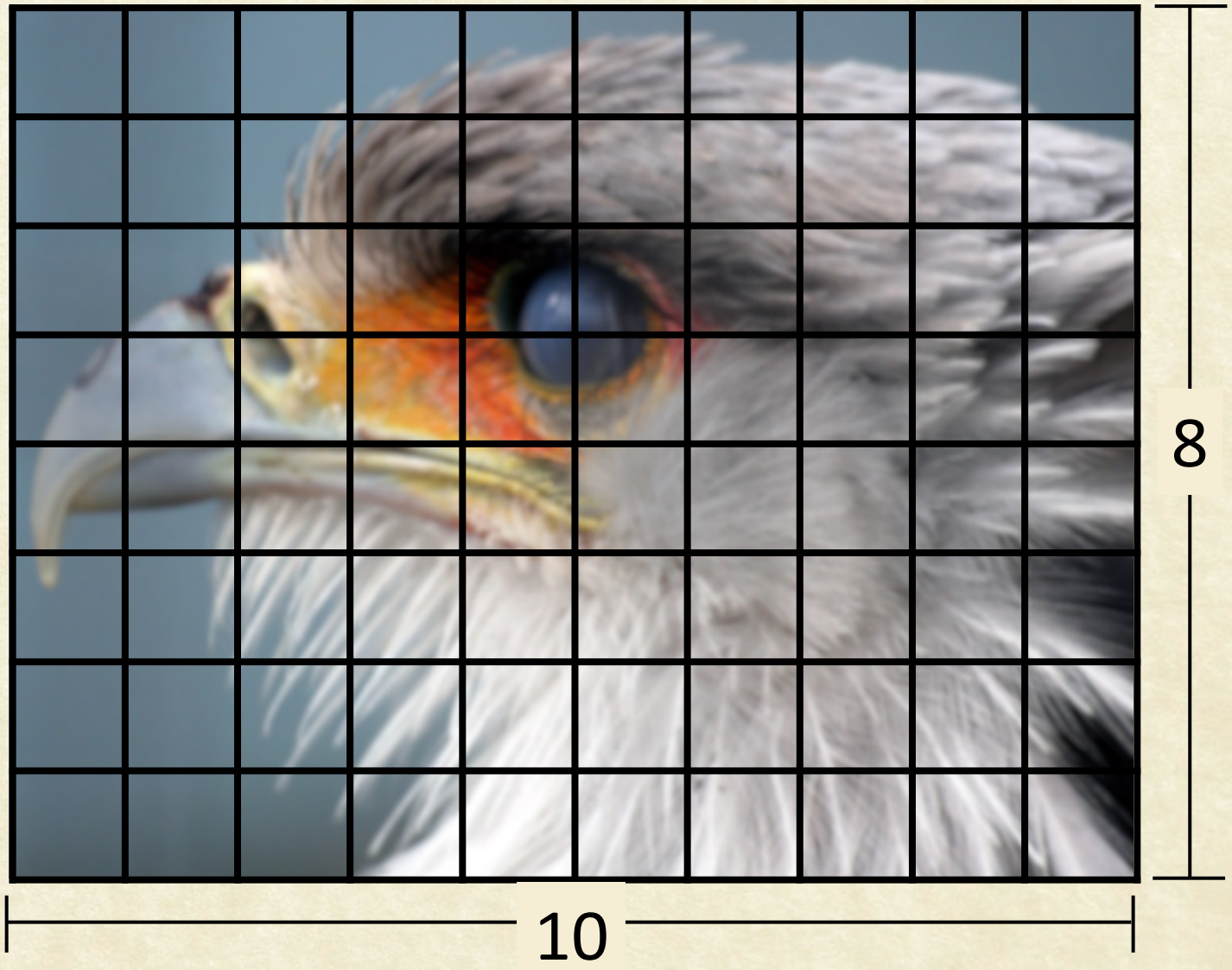


Image File Format: PPM

```
P3      # Format specifier
6 5     # Resolution
255     # Max Pixel Value
# Pixel Values in R G B format
0 0 0
10 10 10
20 20 20
...
230 230 230
255 0 0   0 255 0    0 0 255
0 255 255   255 0 255   255 255 0
```

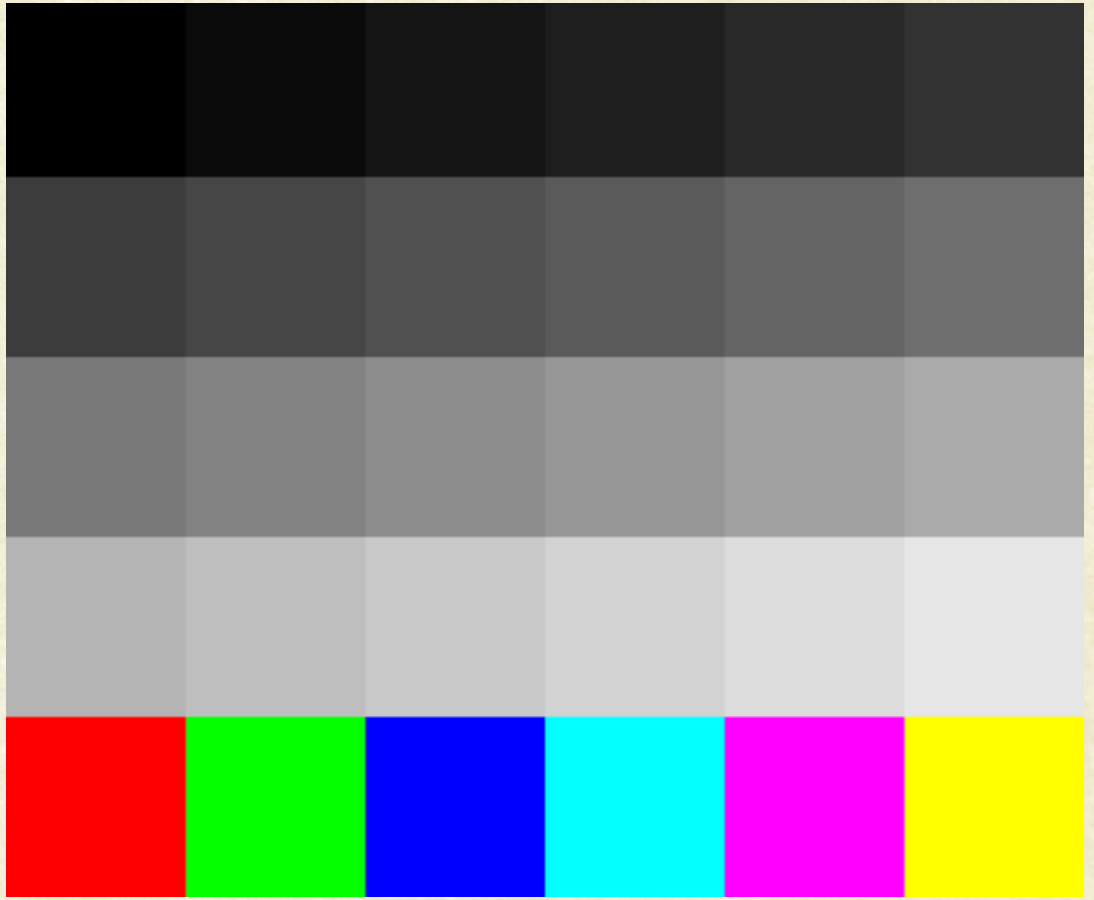
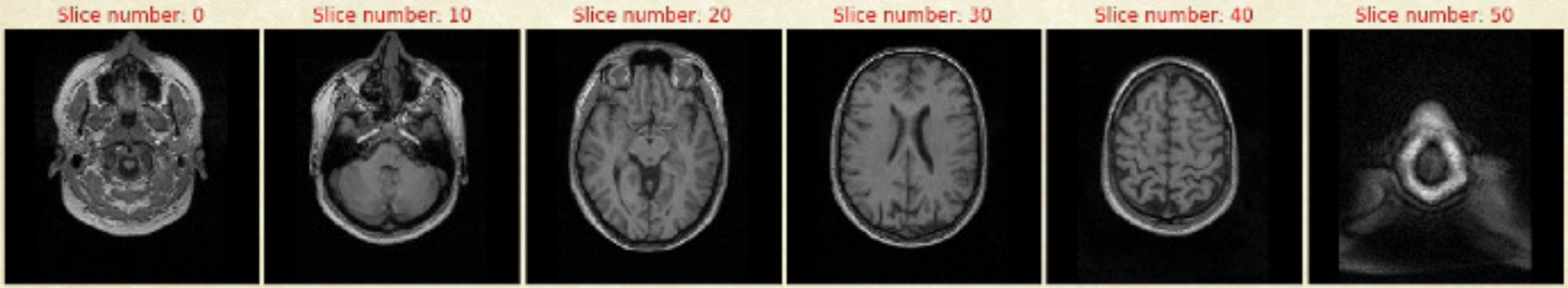
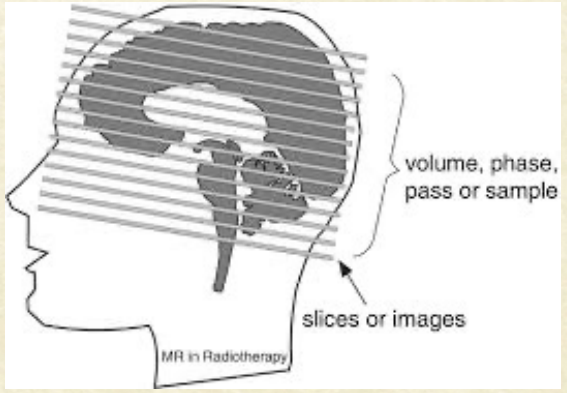


Image Representation

fMRI image slices



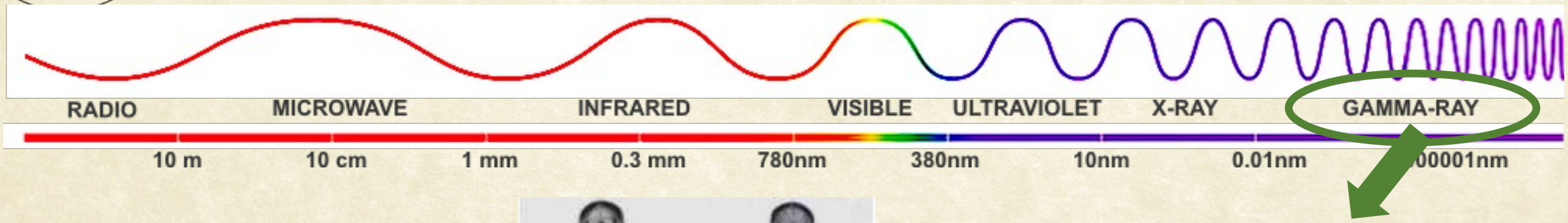
56 2-D channels

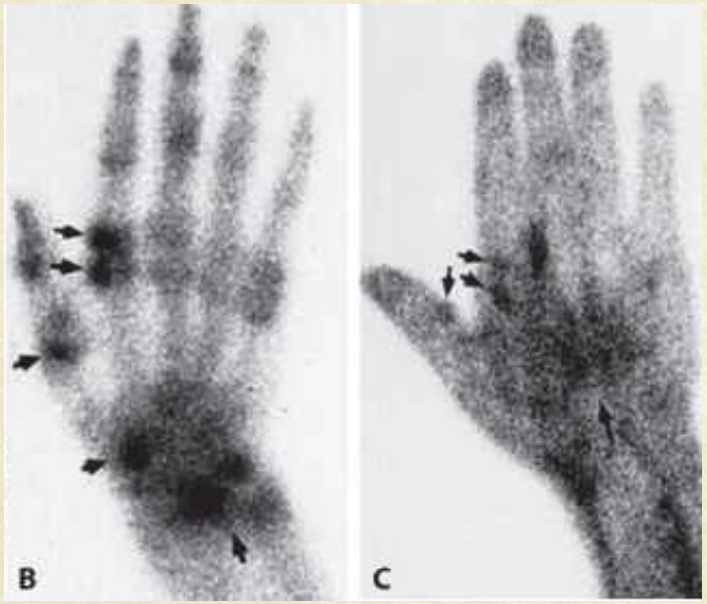


Types of Images (classification on source)

- Radiation from EM spectrum
- Acoustic/ultrasonic/spectrogram
- Electronic
- Computer generated

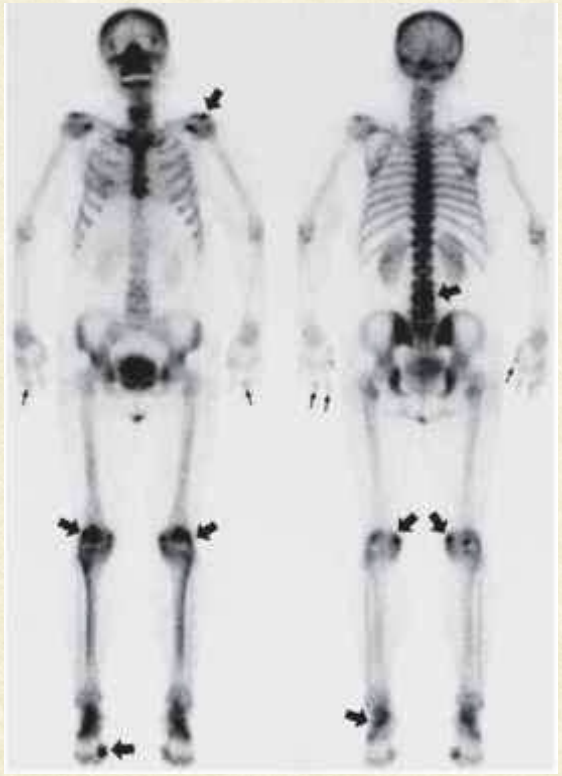
EM Spectrum





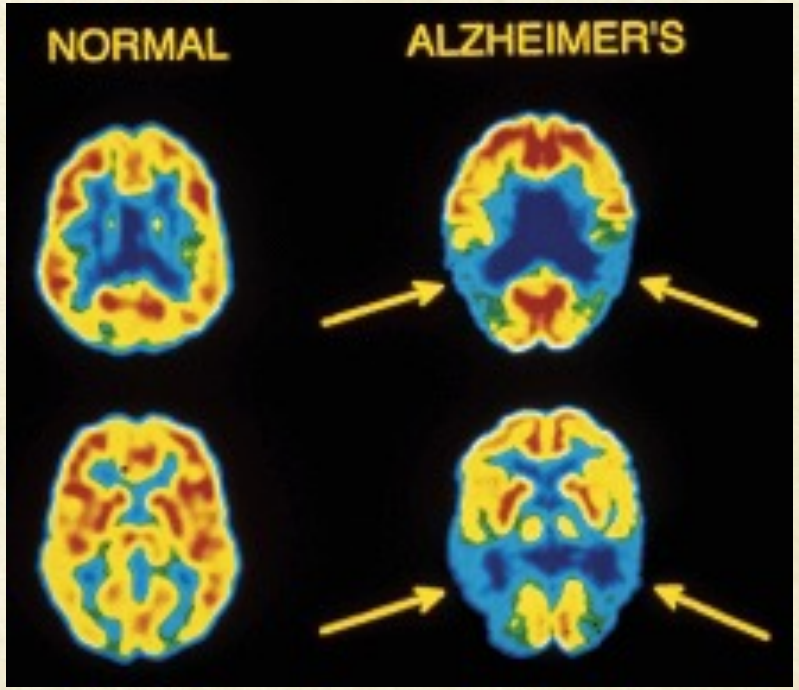
BLOOD FLOW SCAN

courtesy: artheristisresearch.us



BONE SCAN

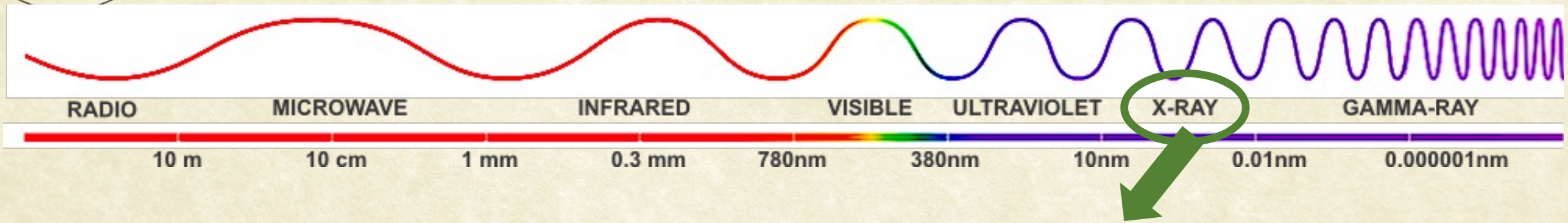
courtesy: artheristisresearch.us



PET SCAN

courtesy: research.ucla.edu

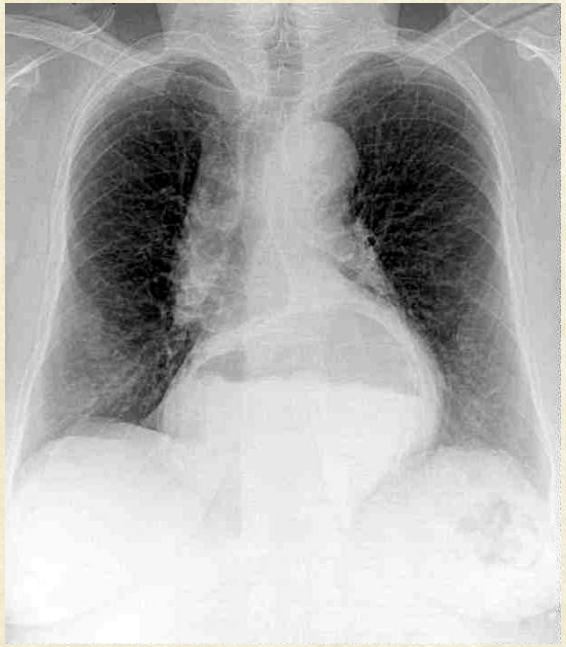
EM Spectrum



Wilhelm Röntgen

HAND MIT RINGEN

courtesy: wikipedia



CHEST RADIOGRAPH

courtesy: wikipedia

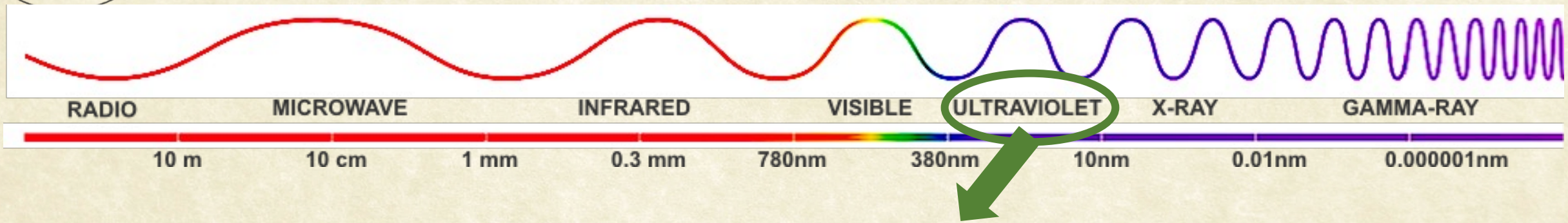
CT SCAN

courtesy: wikipedia

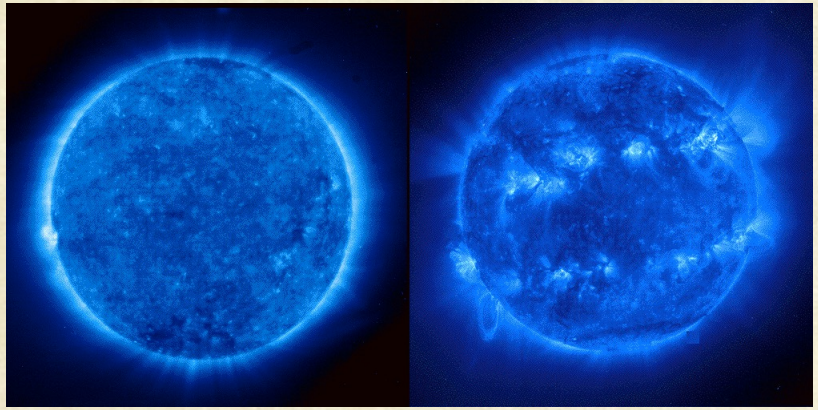
AIRPORT SCAN

courtesy: dpl-surveillance-equipment

EM Spectrum



Lithography, industrial inspection, microscopy, lasers, astronomical observations, florescence microscopy etc.



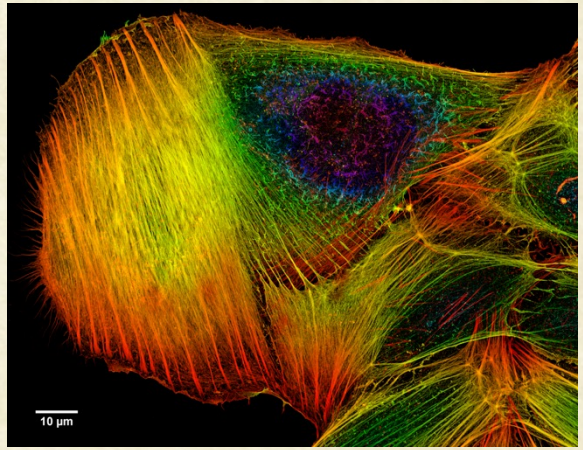
SUN (2 years apart)

courtesy: NASA

100 EURO BILL

courtesy: lifepixel.com

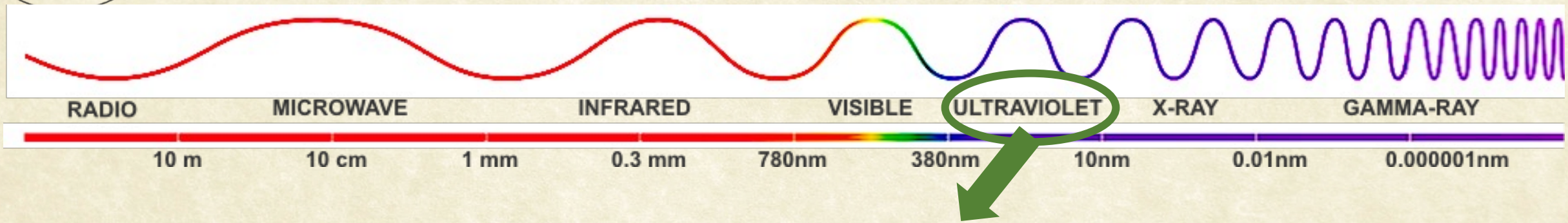
Eric Betzig, William Moerner and Stefan Hell

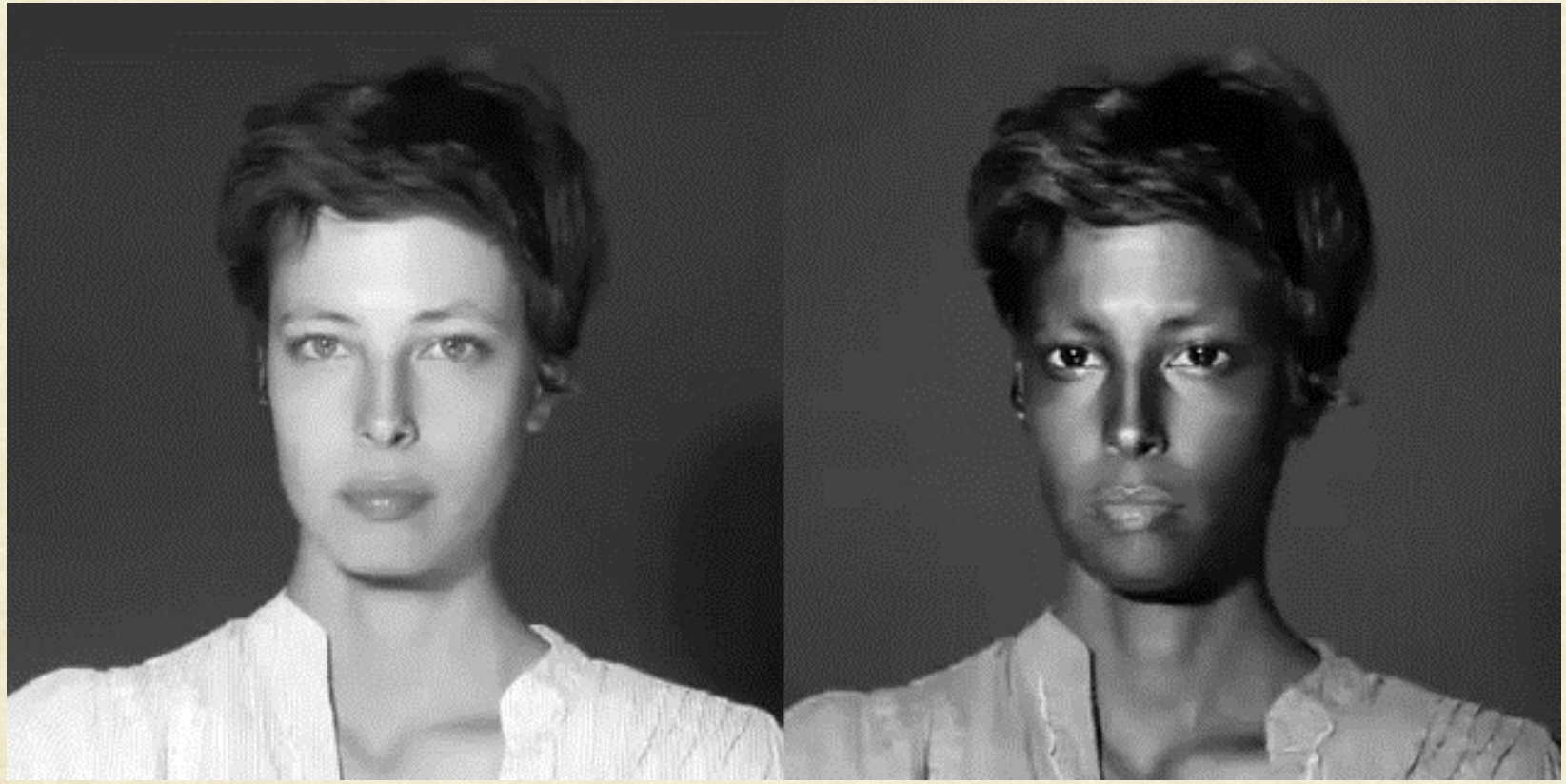


Cell Phalloidin

courtesy: wikipedia

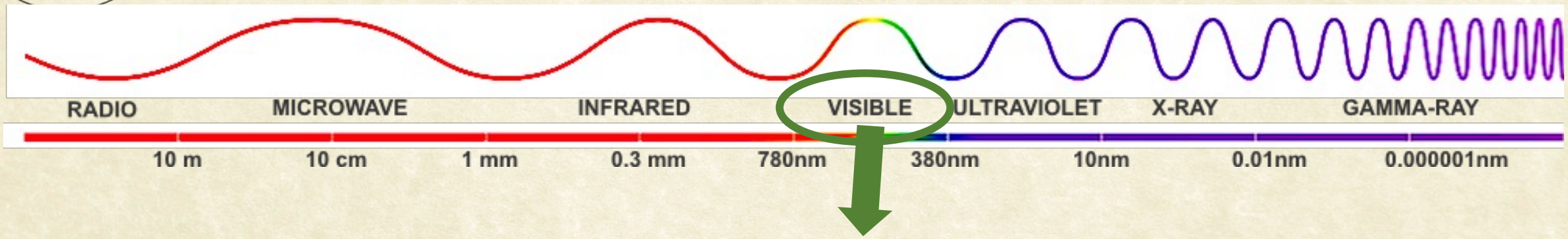
EM Spectrum

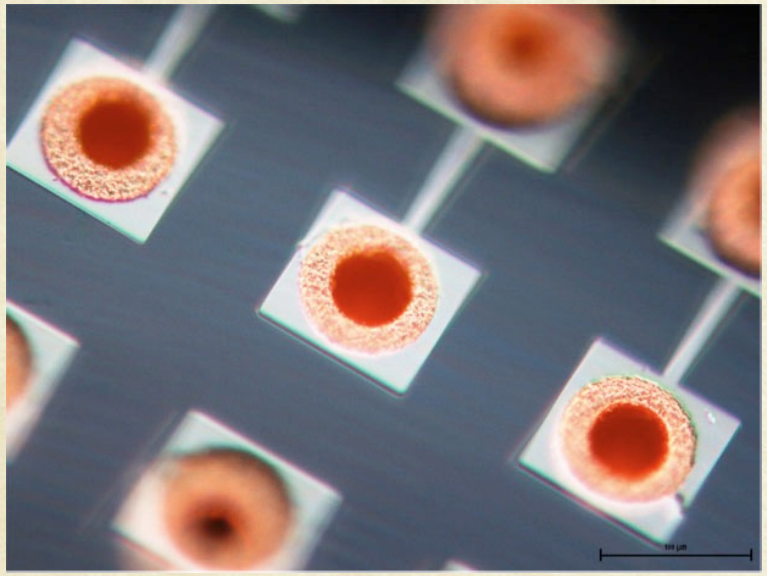




Source:
Lifepixel.com

EM Spectrum



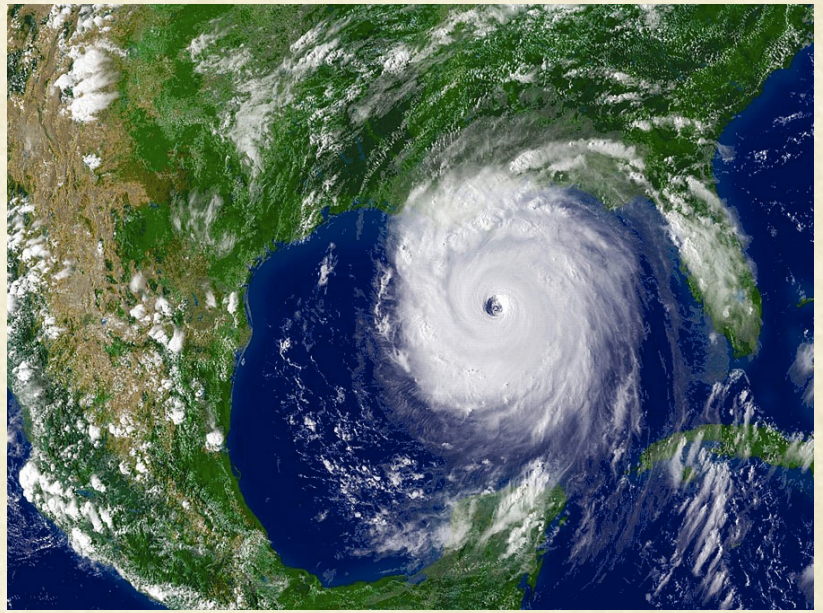


Chips (optical microscopy)

courtesy: EPFL microelectornics systems laboratory

High Speed Photograph

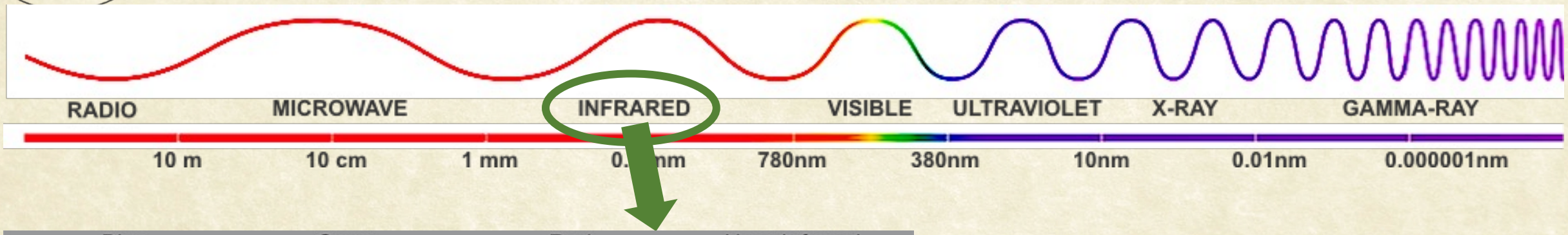
courtesy:Alan Sailer

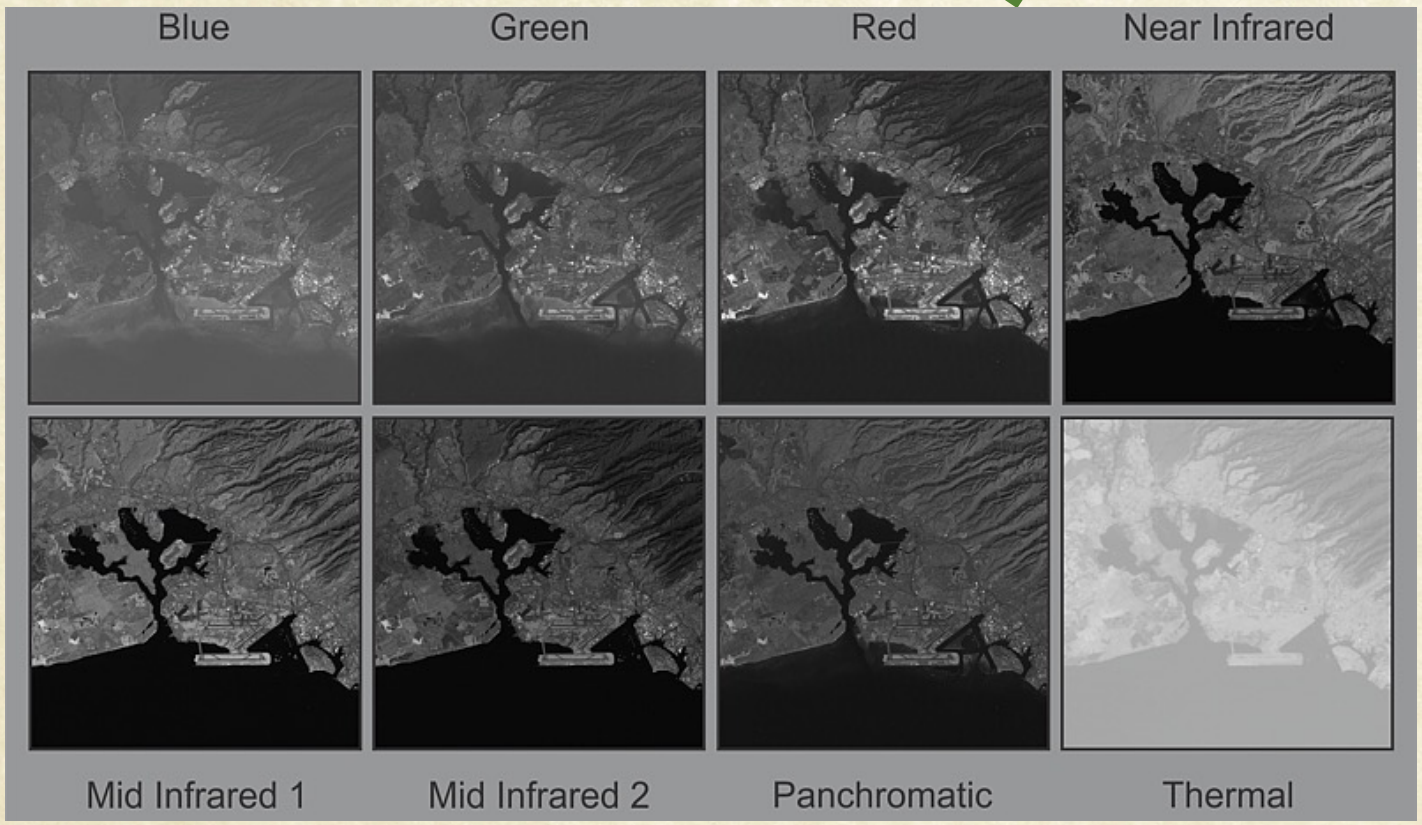


Satellite Image (Hurricane Katrina)

courtesy: britannica.com

EM Spectrum

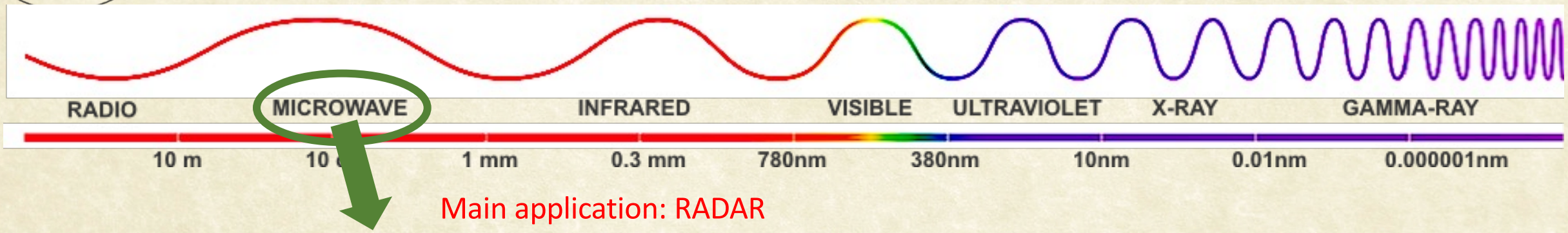




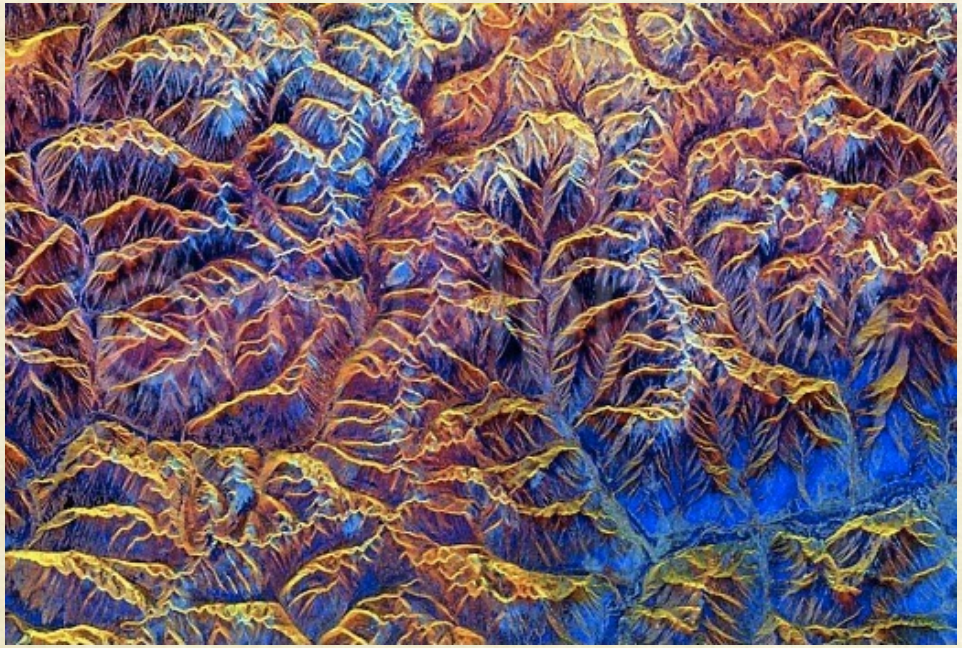
courtesy: LANDSAT (NASA)

courtesy: imaging1.com

EM Spectrum



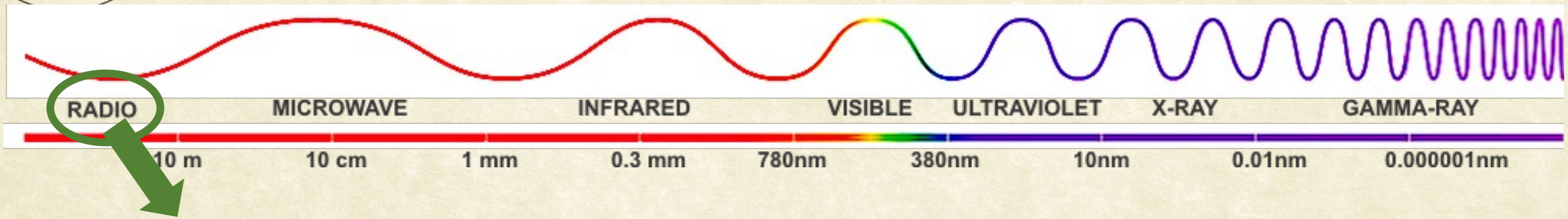
Main application: RADAR



SOUTHEAST TIBET MOUNTAINS

courtesy: NASA

EM Spectrum



MRI Brain

courtesy: mritnt.com

MRI Knee

courtesy: mri-tip.com

Types of Images (classification on source)

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Ultrasound

ULTRASOUND

courtesy: wikipedia

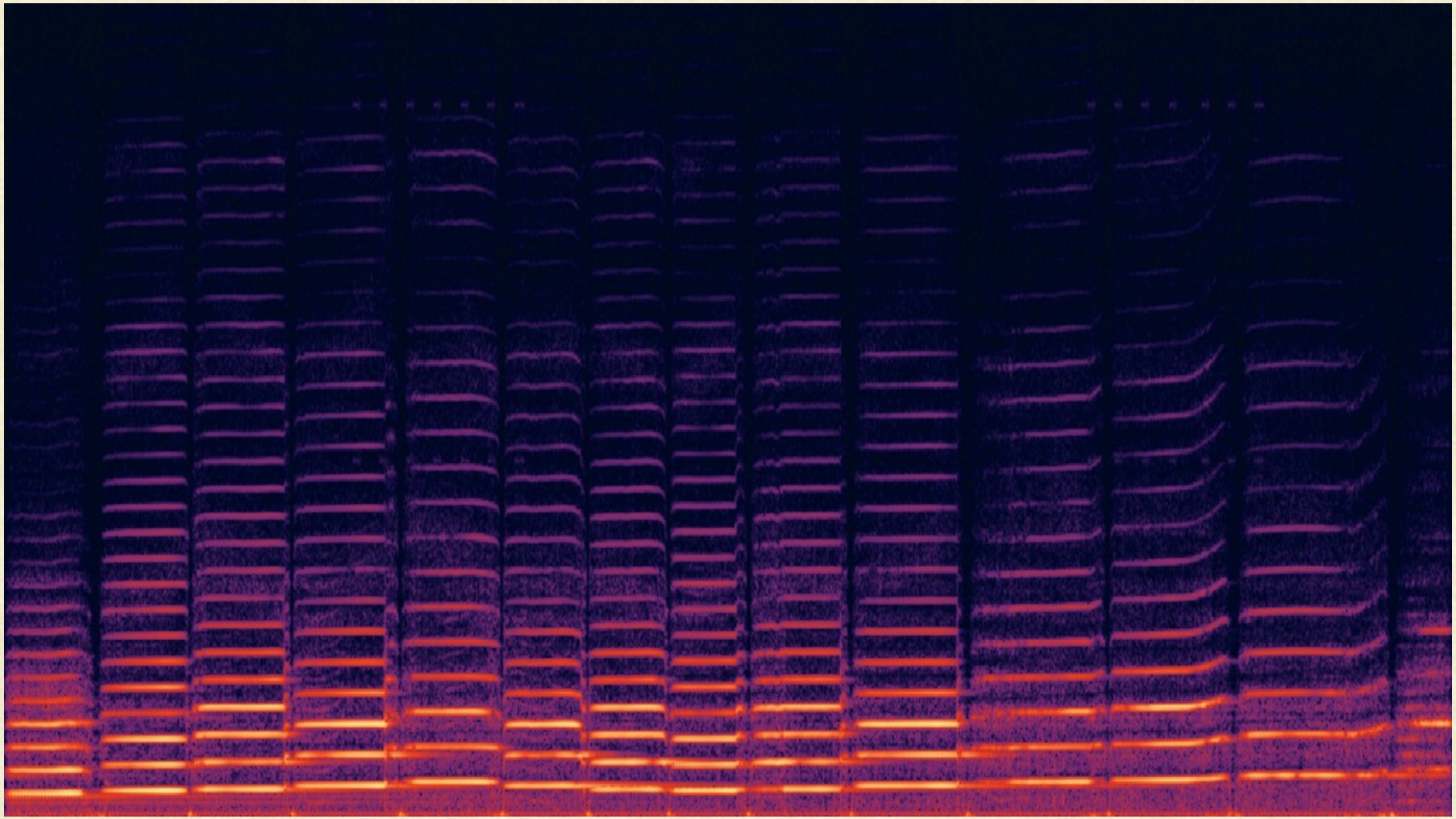
ULTRASOUND TWINS

courtesy: pinterest

ULTRASOUND 3D

courtesy: peek3D.com

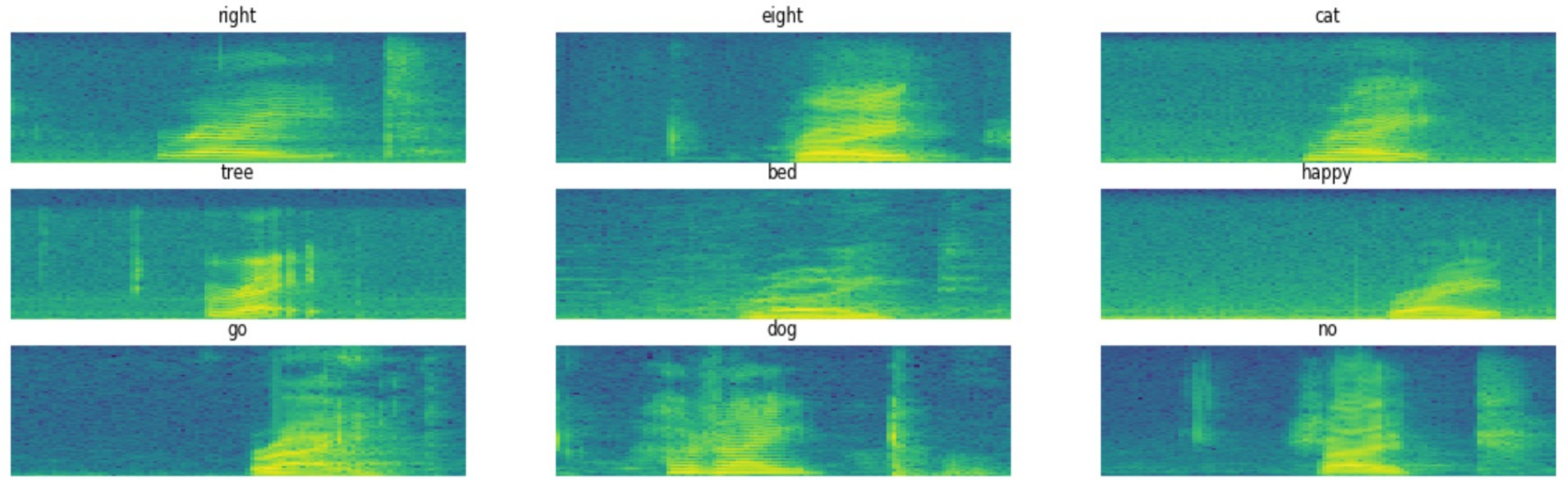
Spectrogram



Violin Recording

courtesy: wikipedia

Spectrogram



https://elvinouyang.github.io/project/training-cnn-for-voice-command/

Types of Images (classification on source)

- Radiation from EM spectrum
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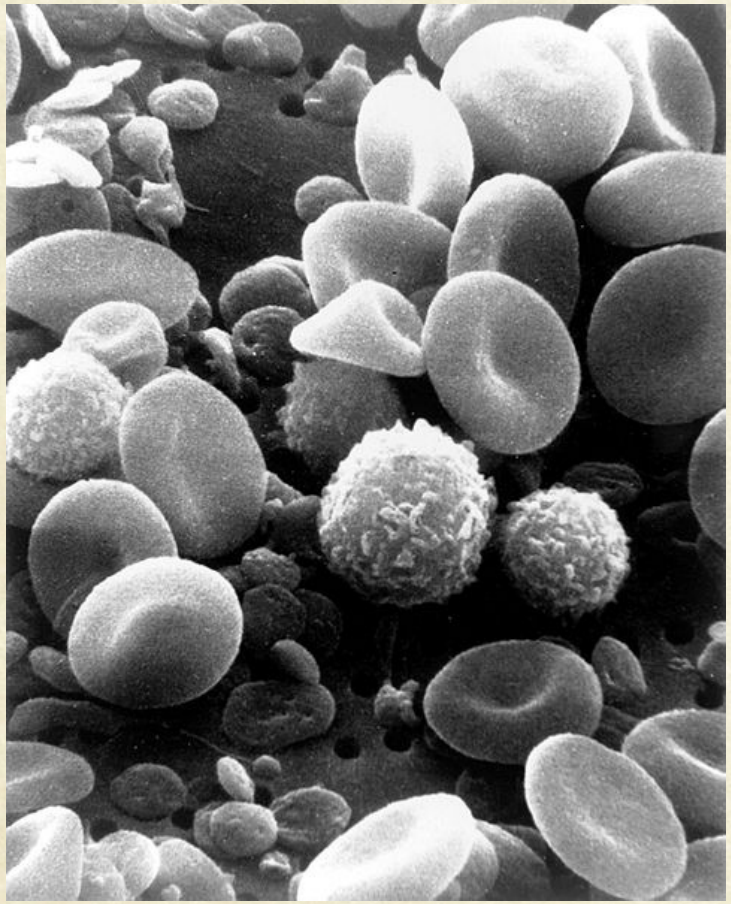
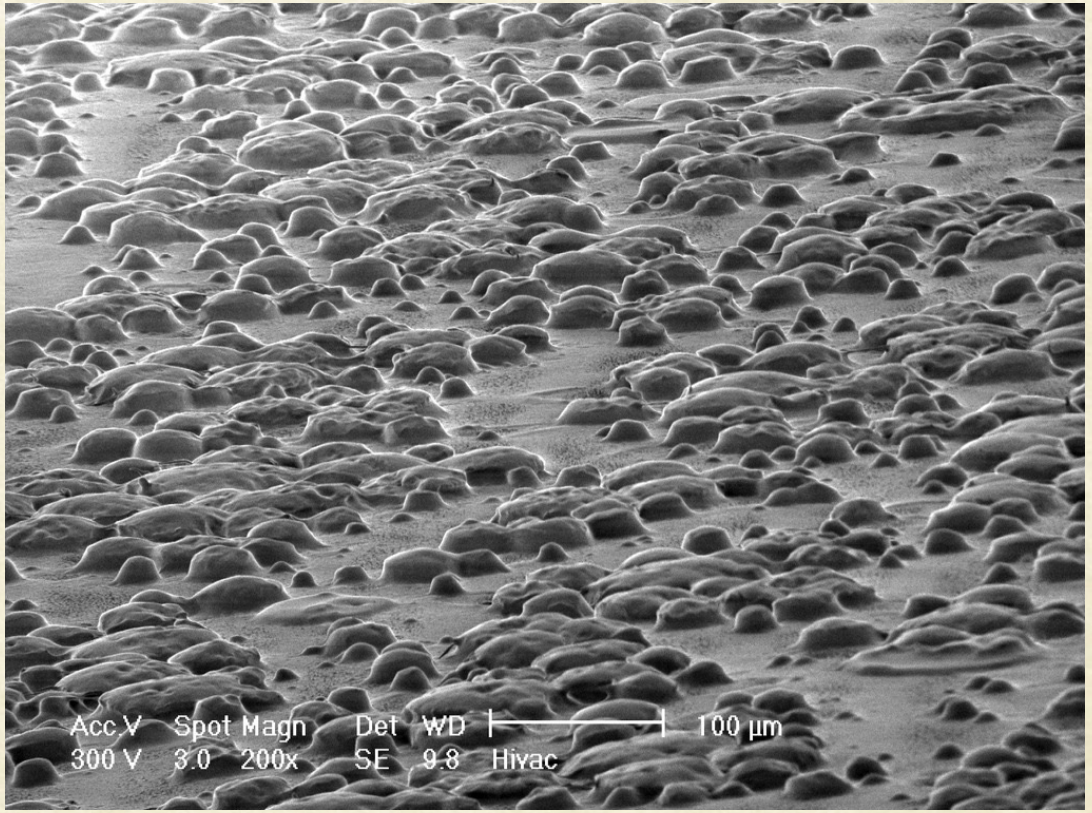
Scanning Electron Microscopy



Normal Circulating Human Blood

courtesy: National Cancer Institute



Adhesive on Post-it note

courtesy: wikipedia

Types of Images (classification on source)

- Radiation from EM spectrum
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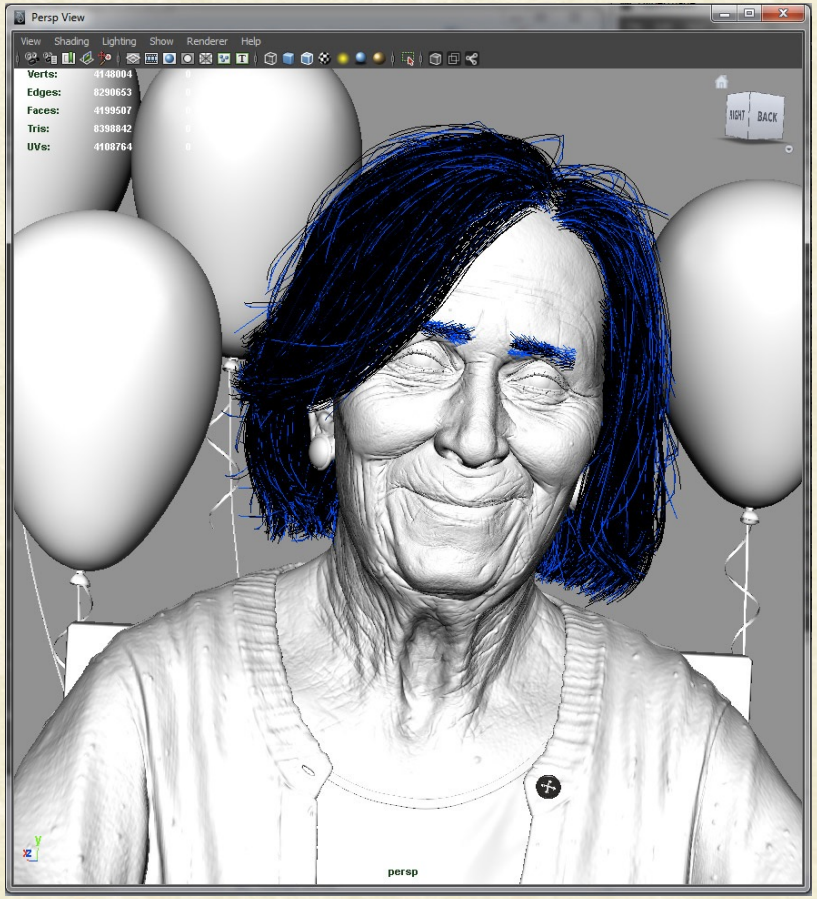
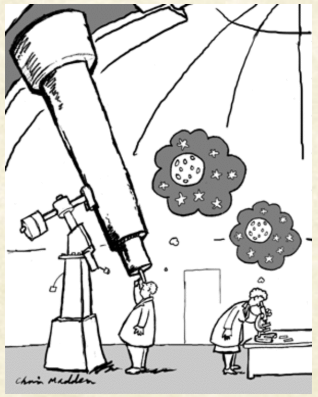
Computer generated

Happy Birthday Nana

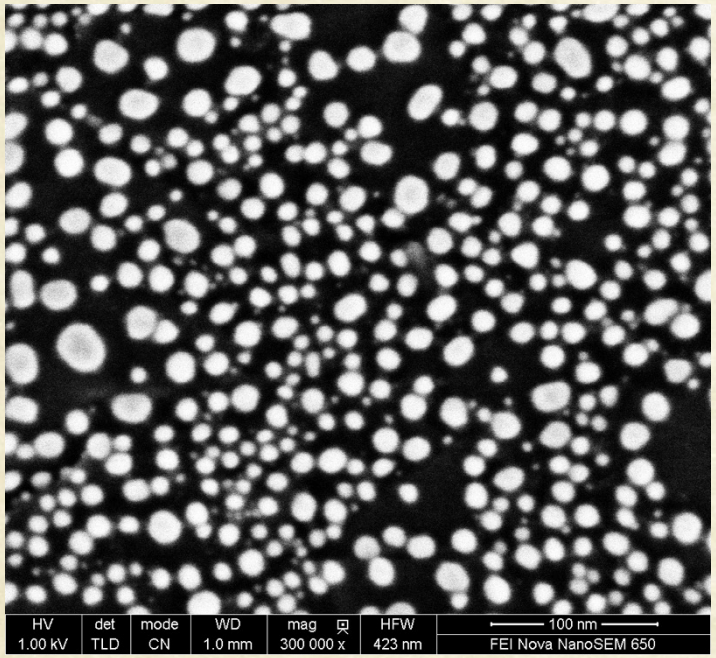
courtesy: Dan Roarty



Scale



Microscopes



10^{-9}m

courtesy: nanolab technologies.com

Telescopes

220 kly ≈ 10^{21}m

courtesy: wikipedia

Types of Images (based on light interaction)

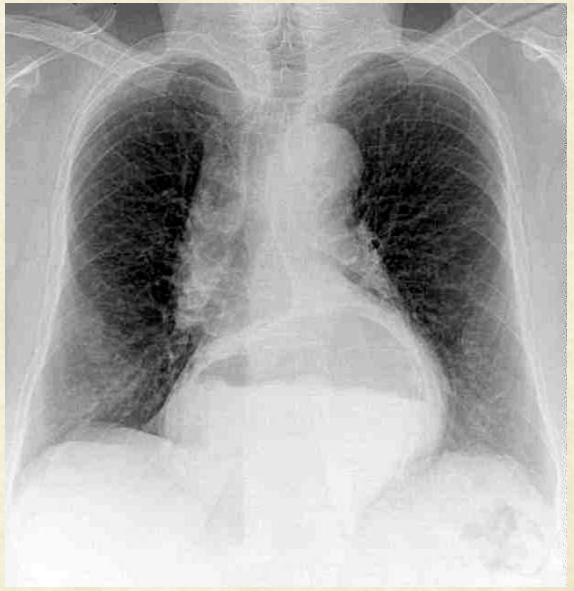
1. Reflection Images

Information primarily about objects surface

2. Emission Images

Information primarily about internal properties

3. Absorption Images

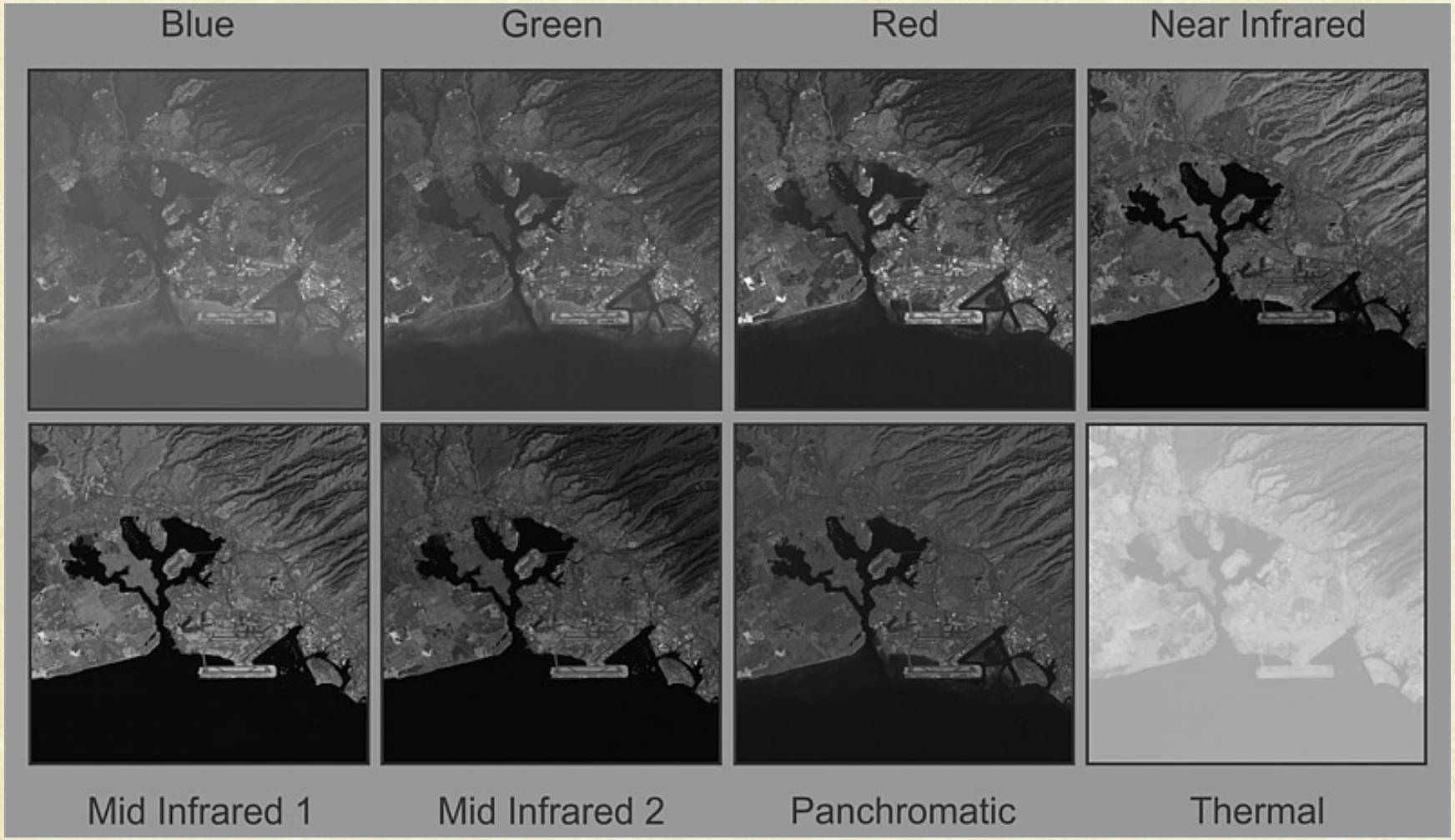


Information primarily about internal structure

Types of Images (based on arrangement)

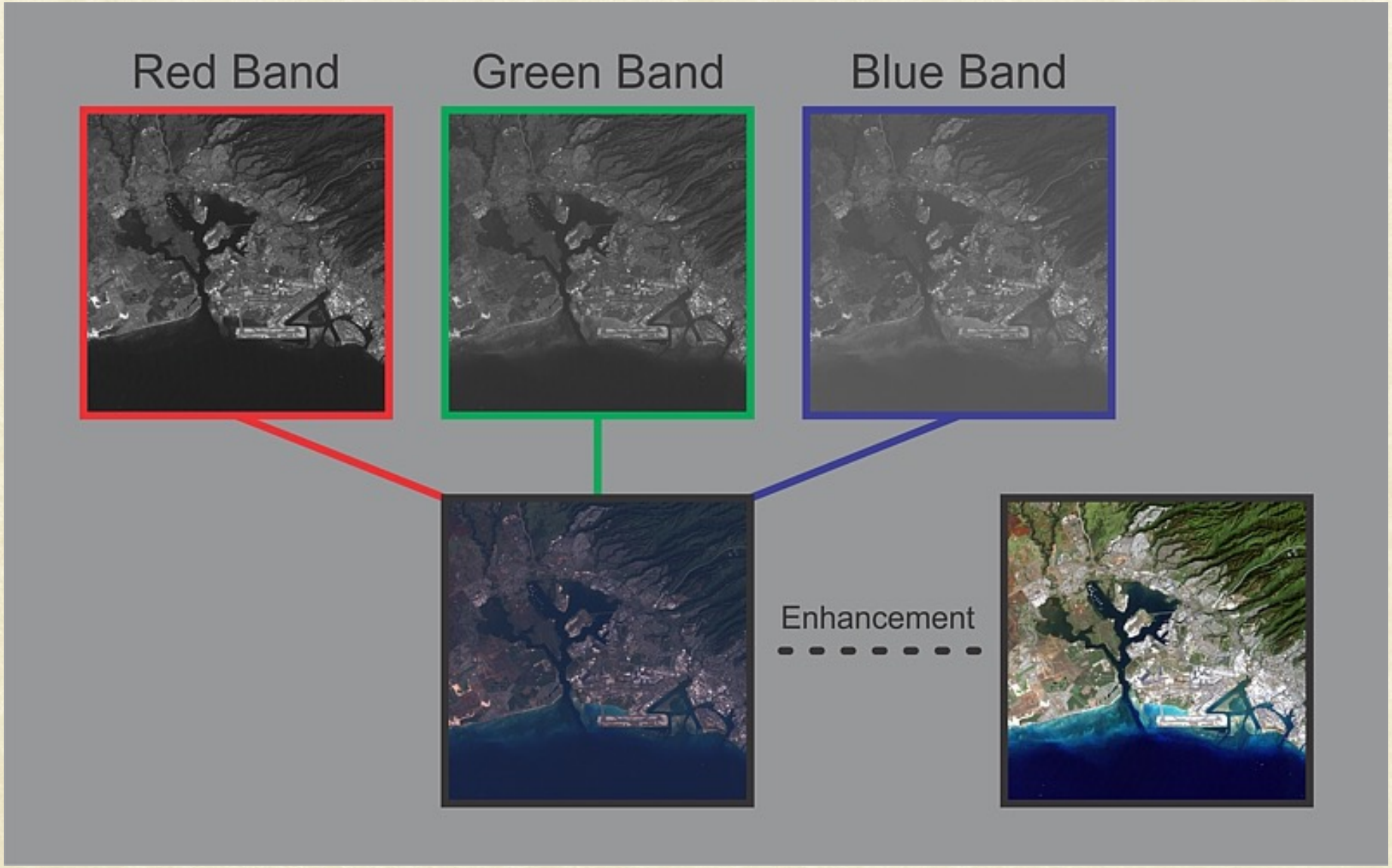
- Grayscale
- RGB
- Multispectral images
- Stereo images
- Multi-view images

Multi-spectral Images



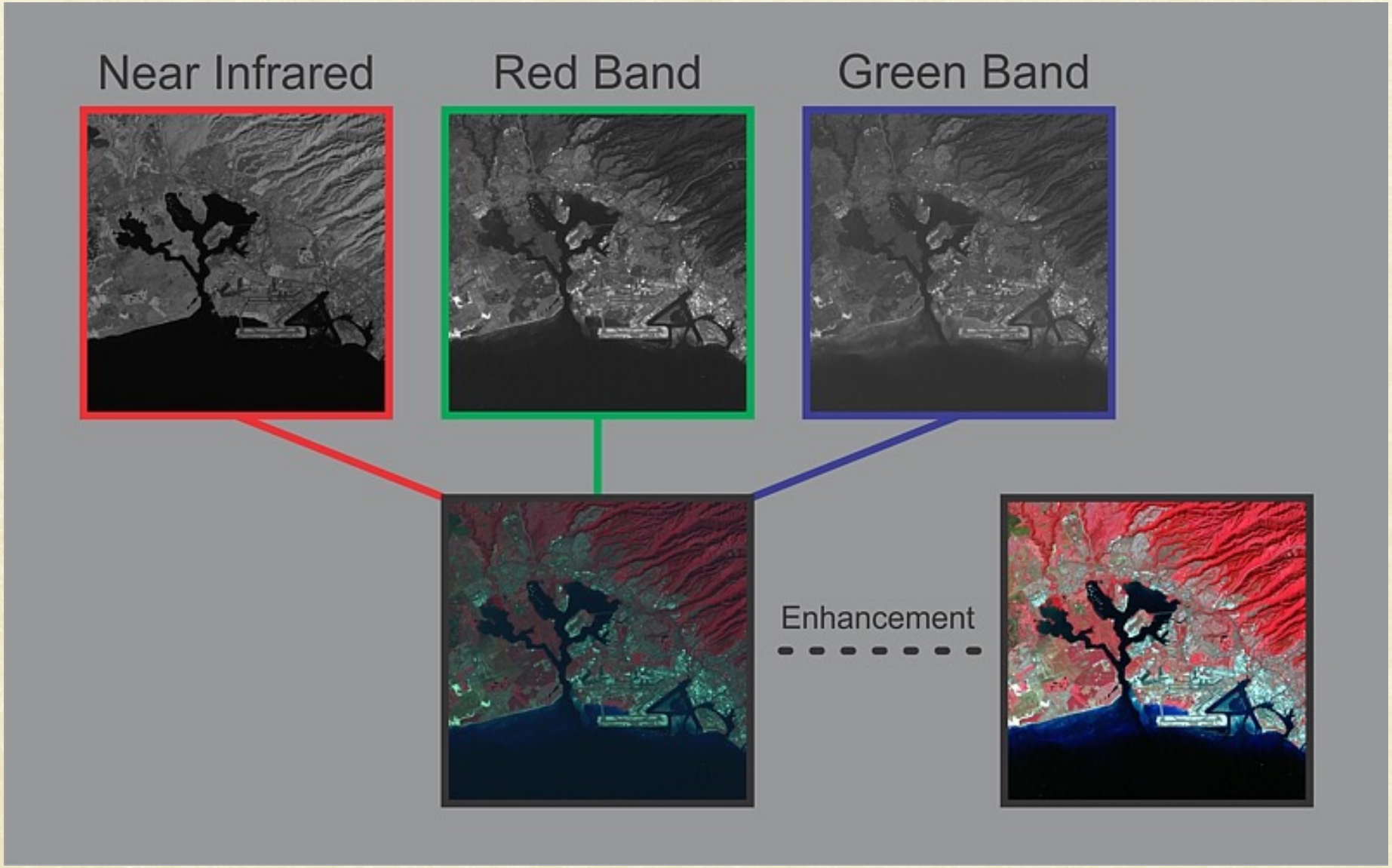
Courtesy: LANDSAT

Multi-spectral Images



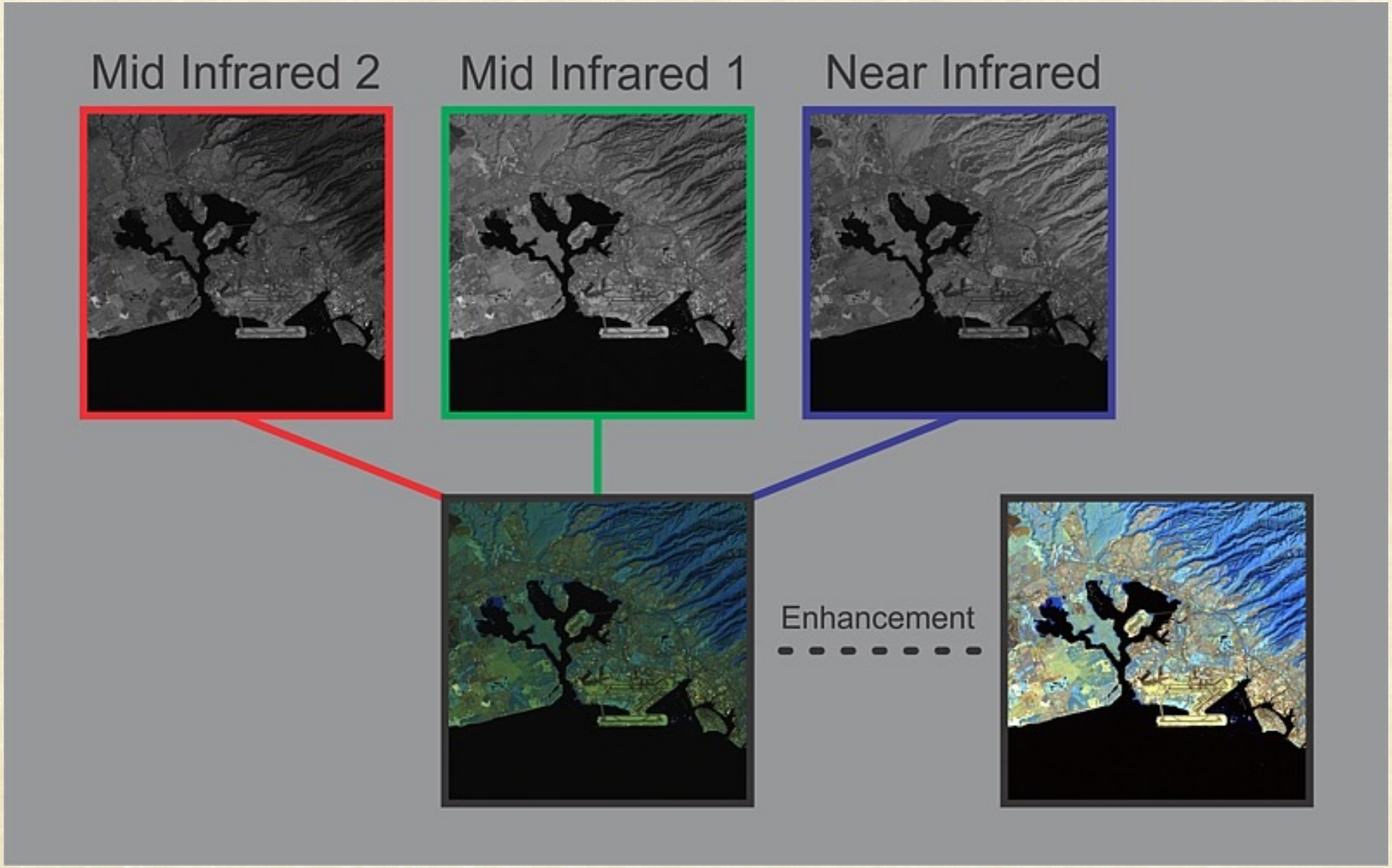
Courtesy: LANDSAT

Multi-spectral Images



Courtesy: LANDSAT

Multi-spectral Images

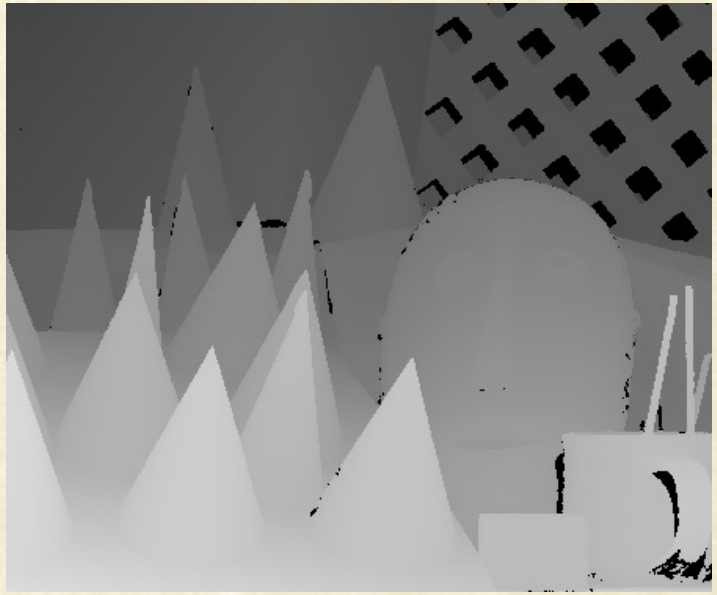


Courtesy: LANDSAT

Stereo Images

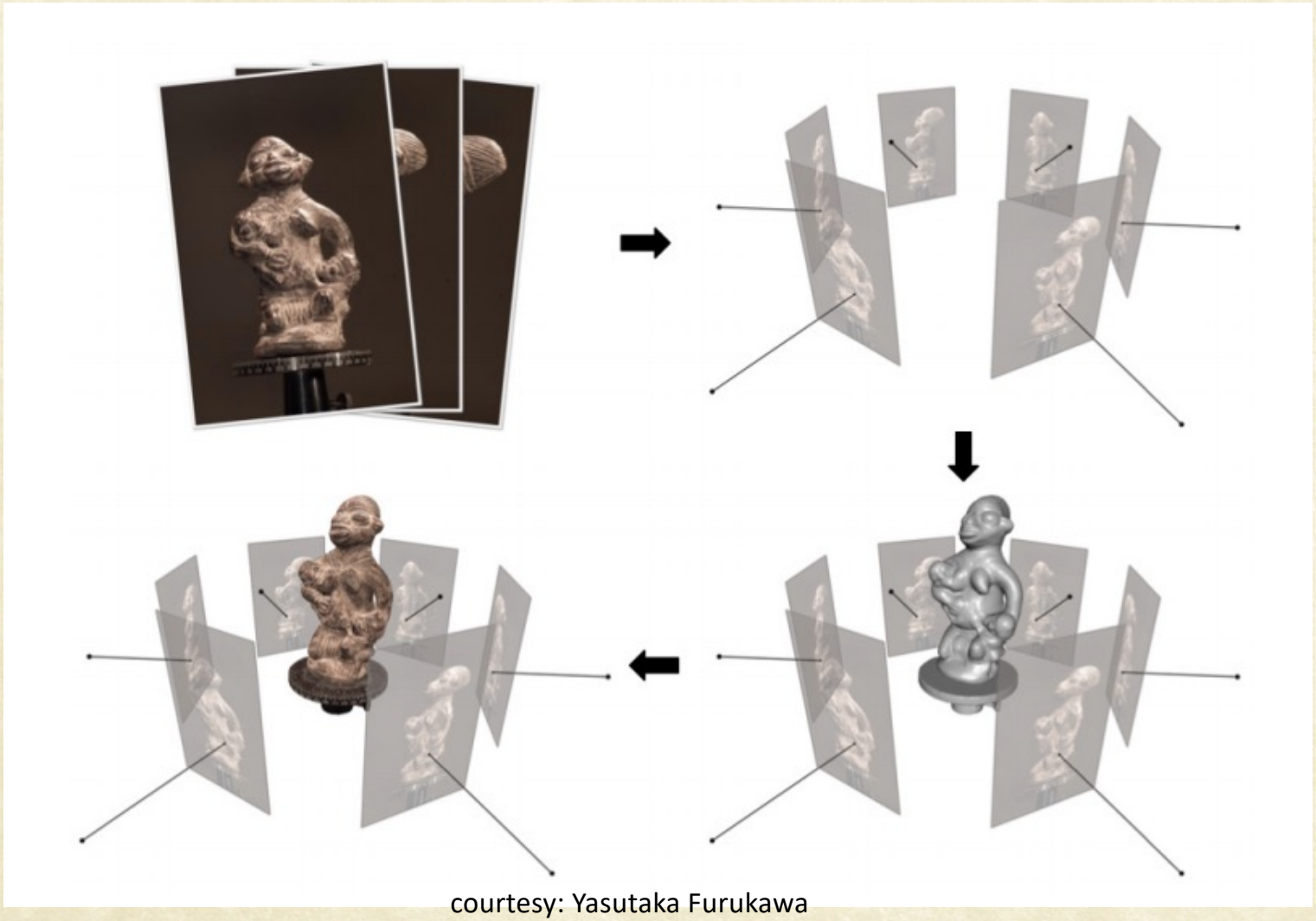
courtesy: wikimedia.com

Stereo Images



courtesy: vision.middlebury.edu

Multi-view images



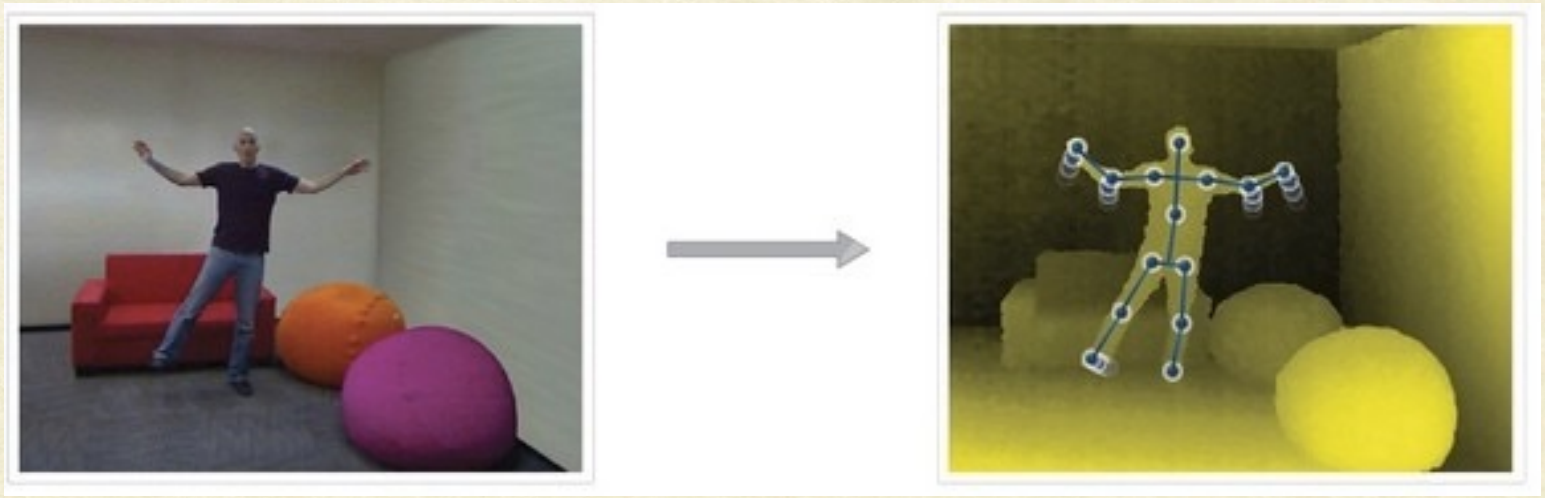
courtesy: Yasutaka Furukawa

courtesy: Sameer Agarwal

RGB-D images

Color (RGB) Image

Depth Image

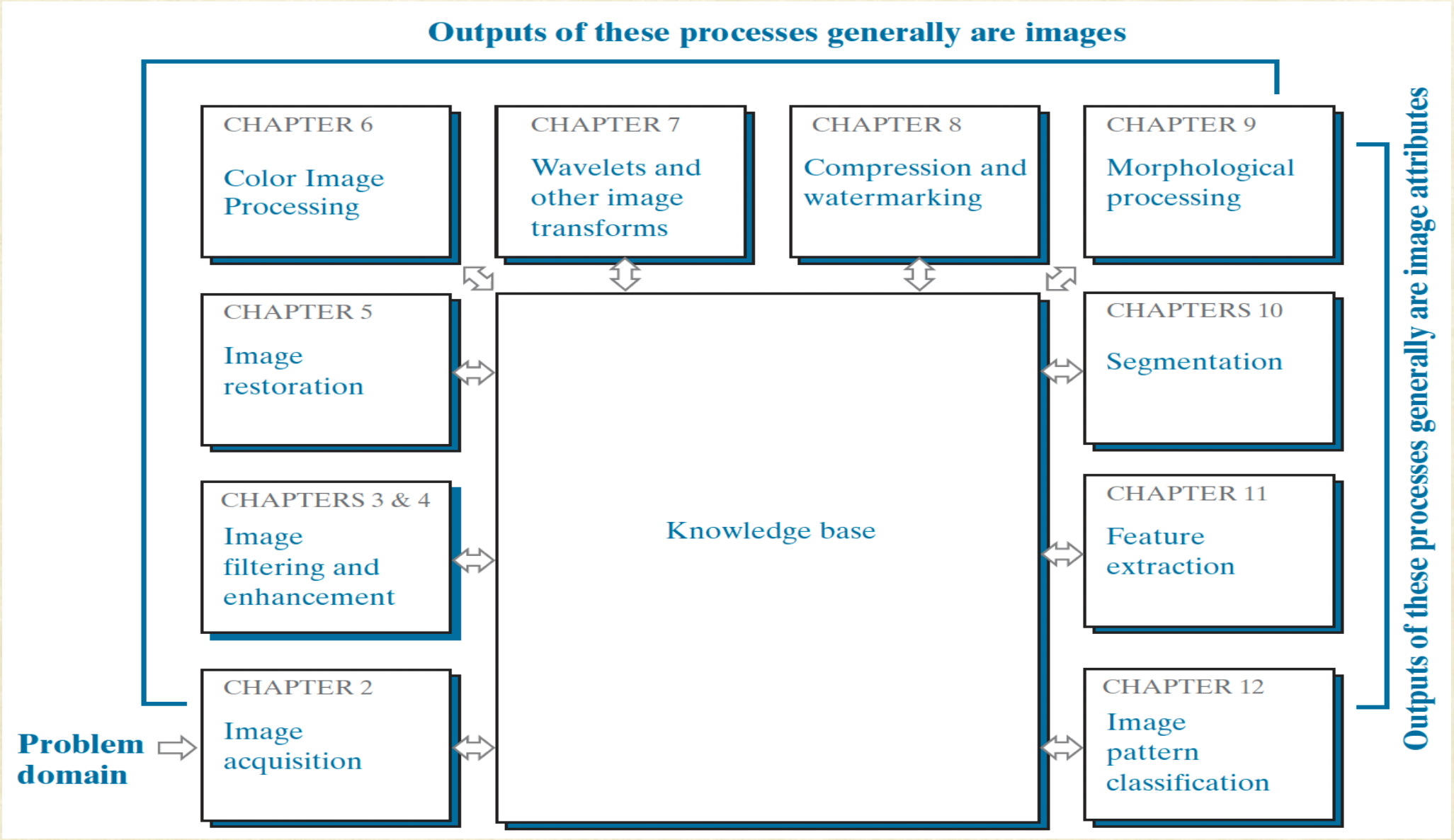


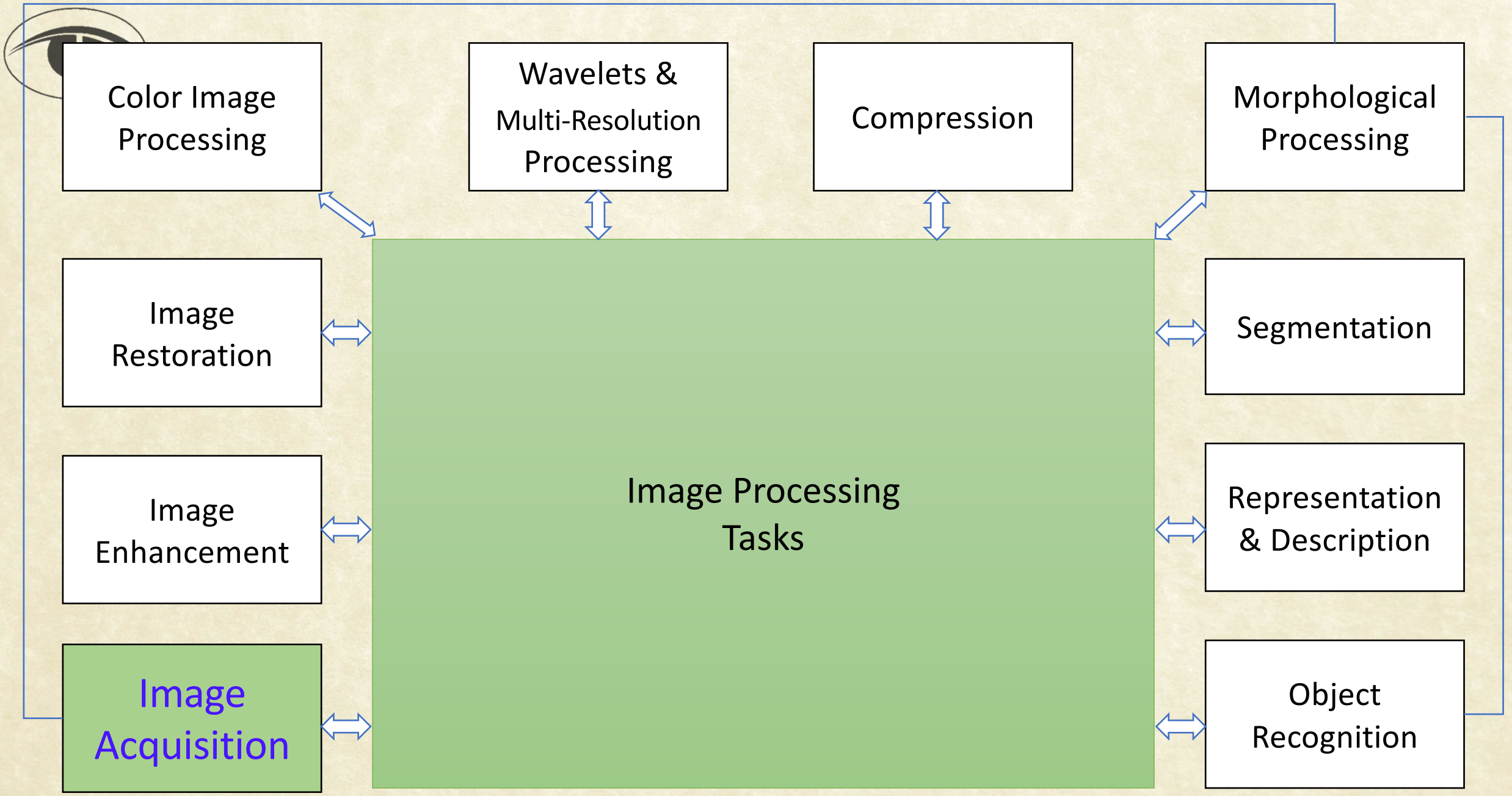
courtesy: kinect and prime sense

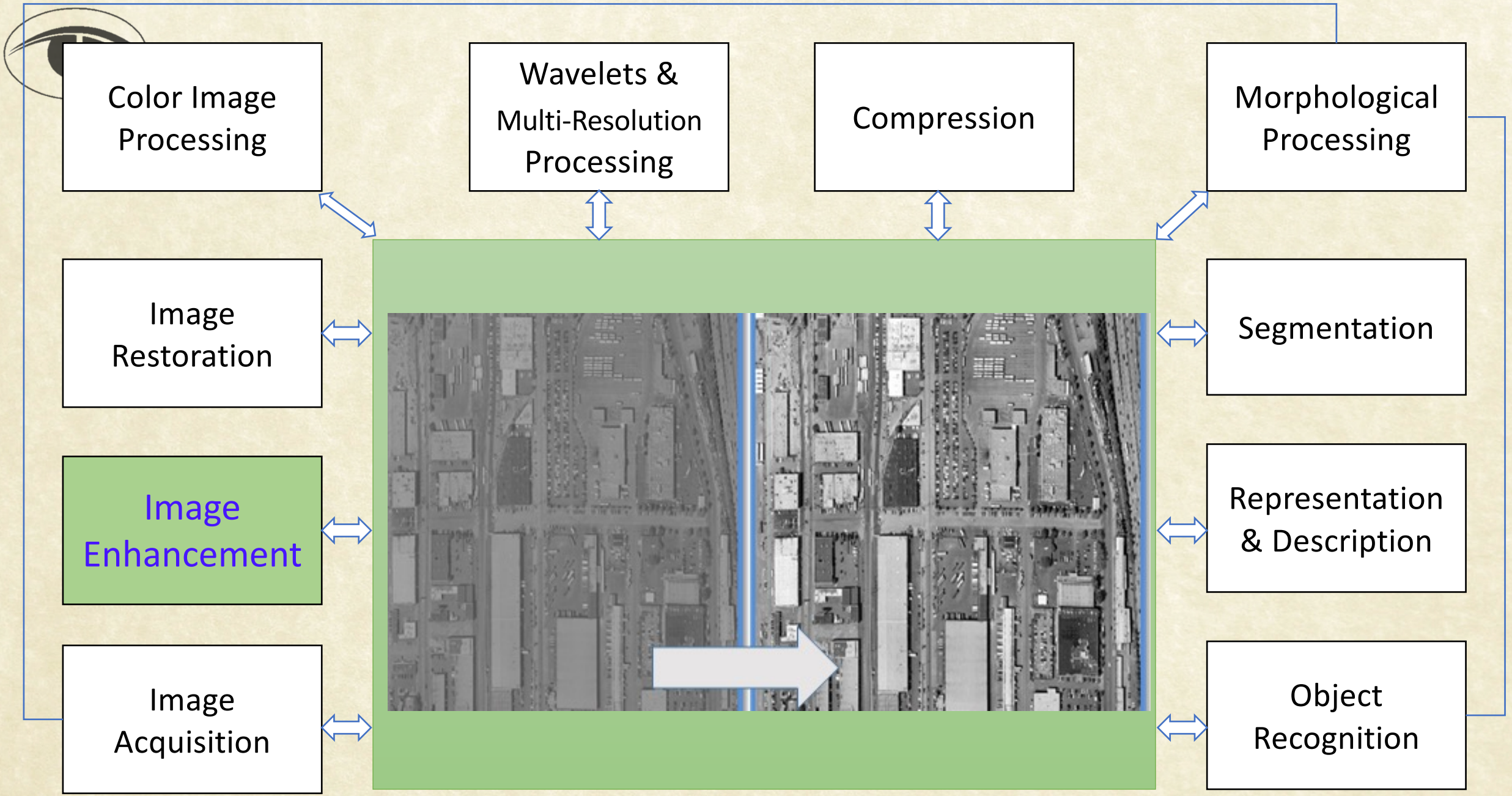
Digital Image Processing

- Study and Development of algorithms that operate on an image
  - To create new images
  - To retrieve its attributes
- Consumer-based view
  - For consumption by human eyes
  - For consumption by machine-based processes

Image Processing Tasks




Color Image Processing
Wavelets & Multi-Resolution Processing
Compression
Morphological Processing
Image Restoration
Image Processing Tasks
Segmentation
Image Enhancement
Representation & Description
Image Acquisition
Object Recognition


Color Image Processing
Wavelets & Multi-Resolution Processing
Compression
Morphological Processing
Image Restoration
Segmentation
Image Enhancement
Representation & Description
Image Acquisition
Object Recognition

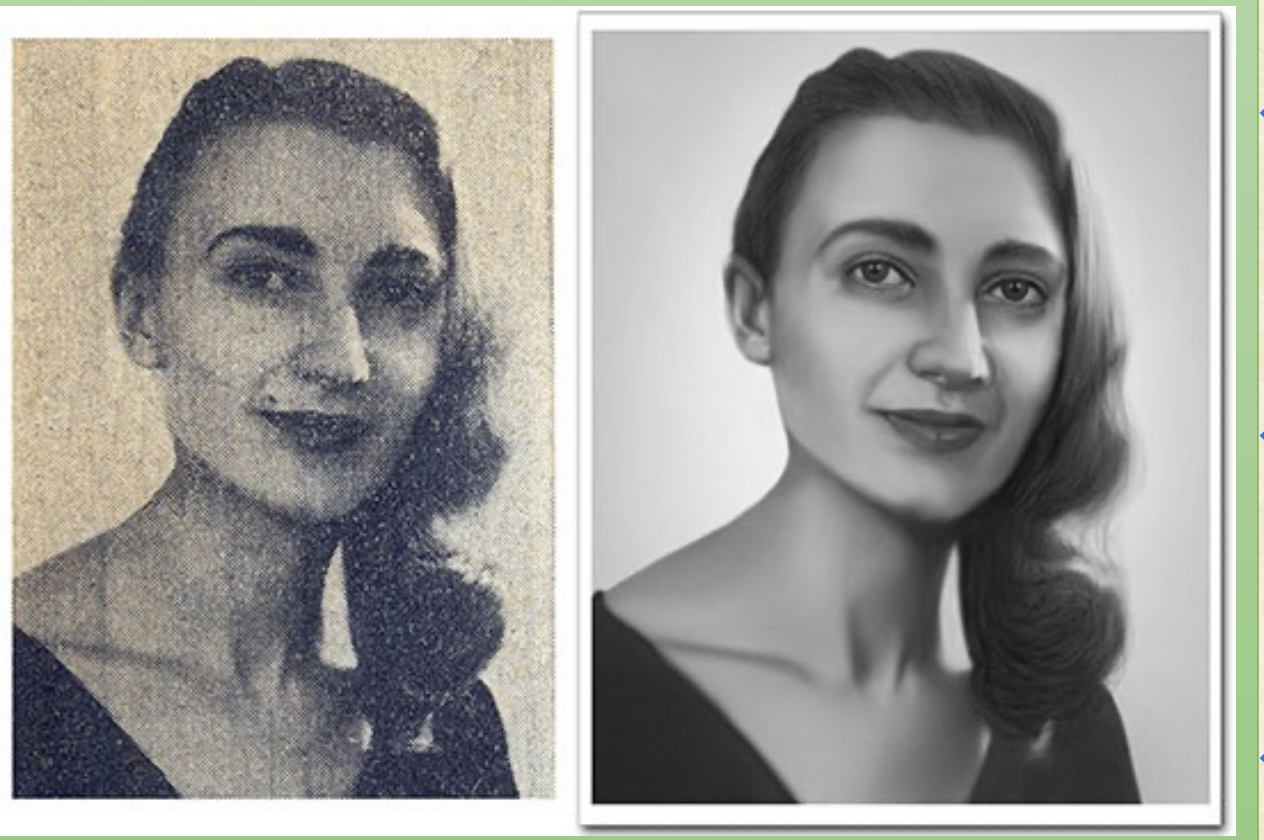
Color Image Processing

Wavelets & Multi-Resolution Processing

Compression

Morphological Processing

Image Restoration



Segmentation

Image Enhancement

Representation & Description

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Segmentation

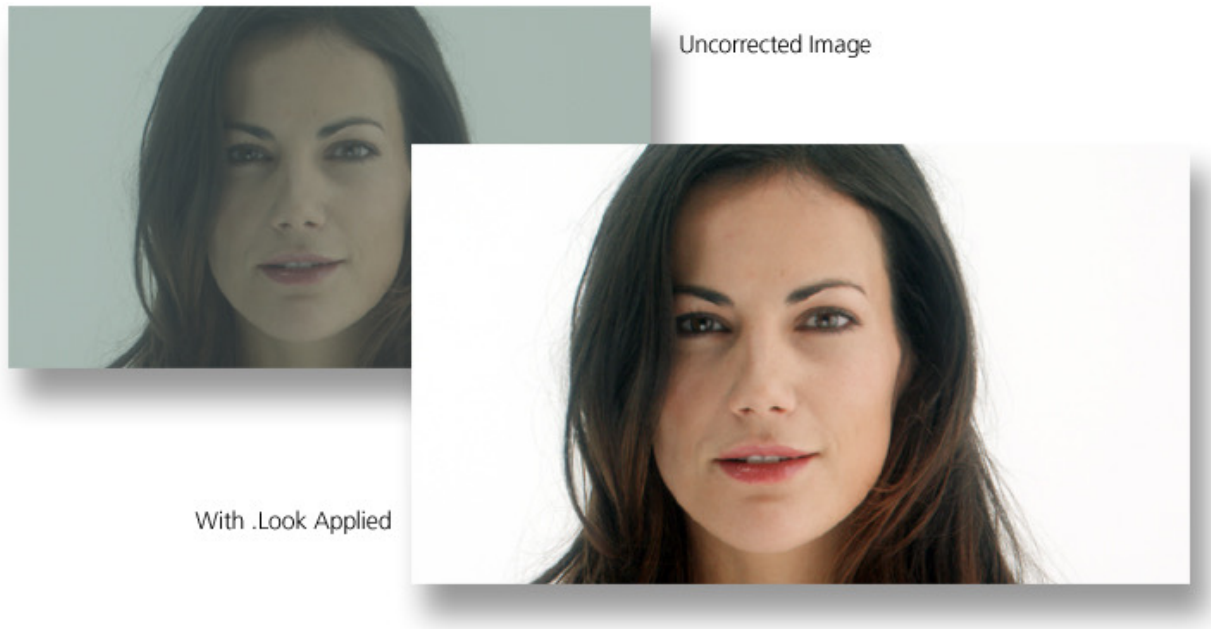

Image Enhancement

Representation & Description

Image Acquisition

Object Recognition

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Compression

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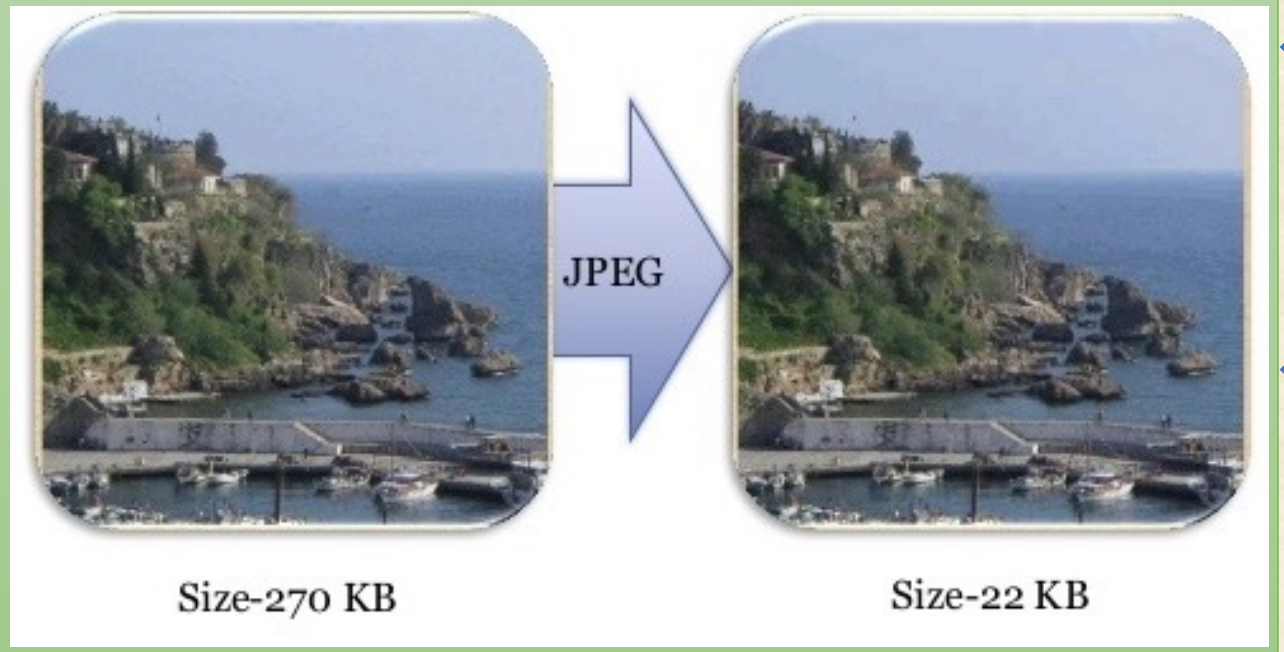
Image Restoration

Image Enhancement

Image Acquisition



Segmentation

Representation & Description

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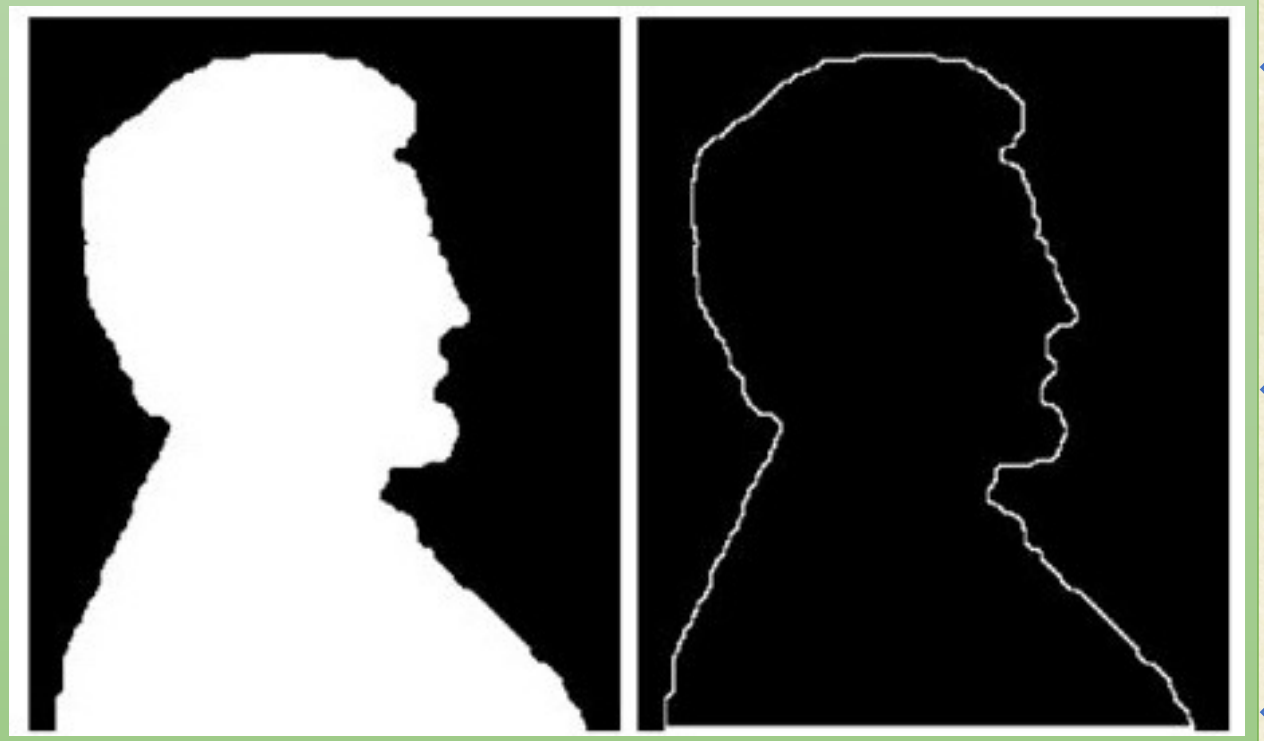

Segmentation

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Representation & Description

Image Acquisition

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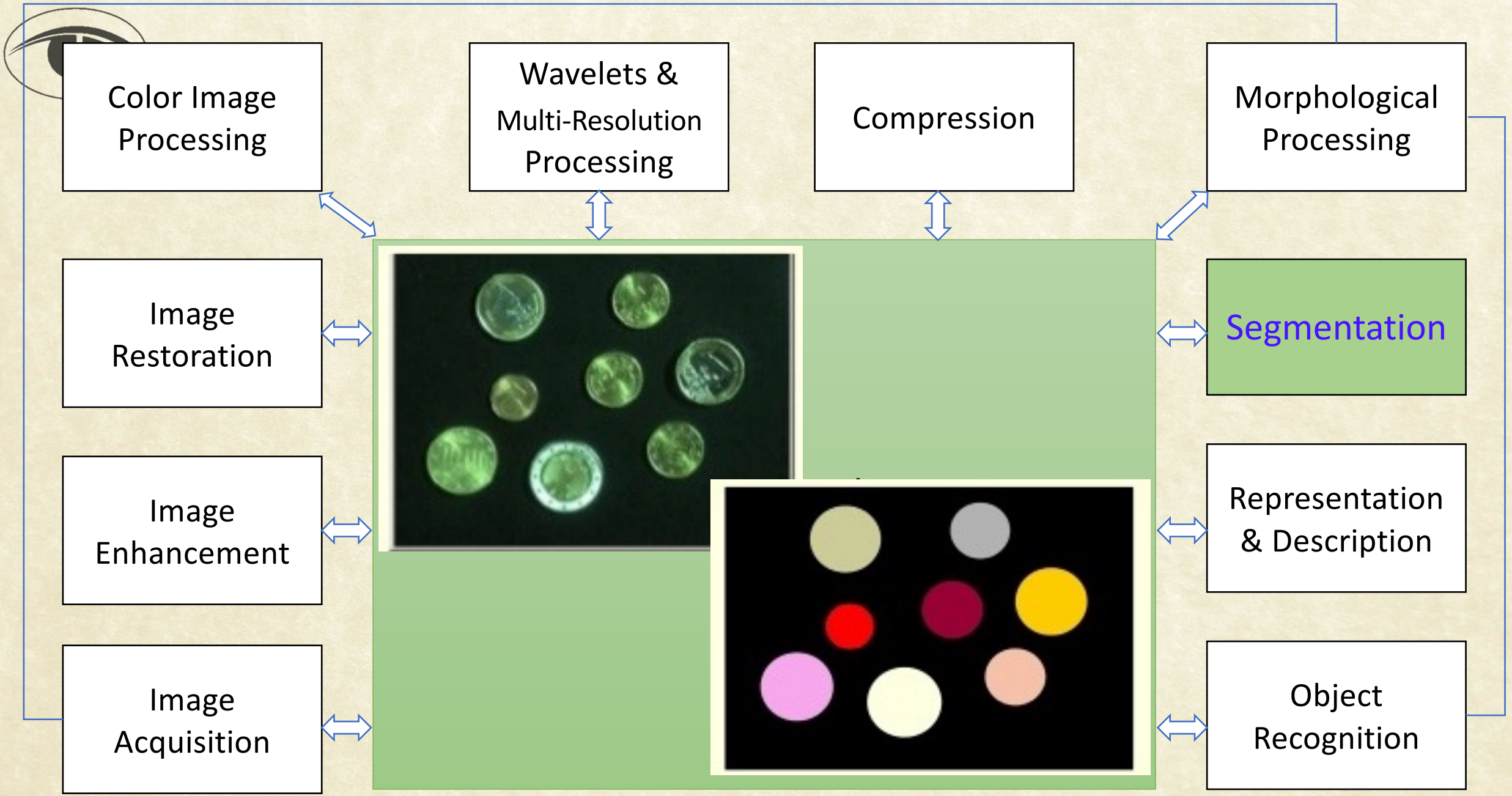
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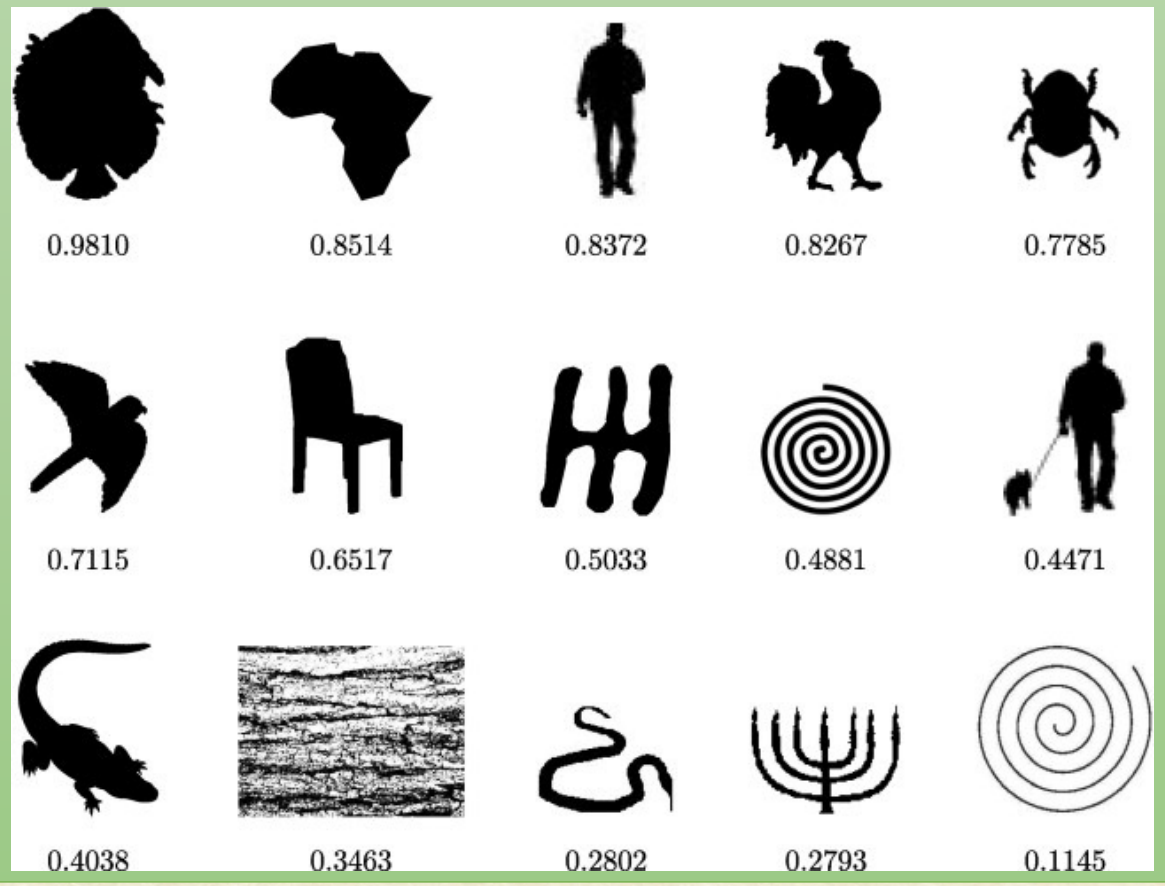

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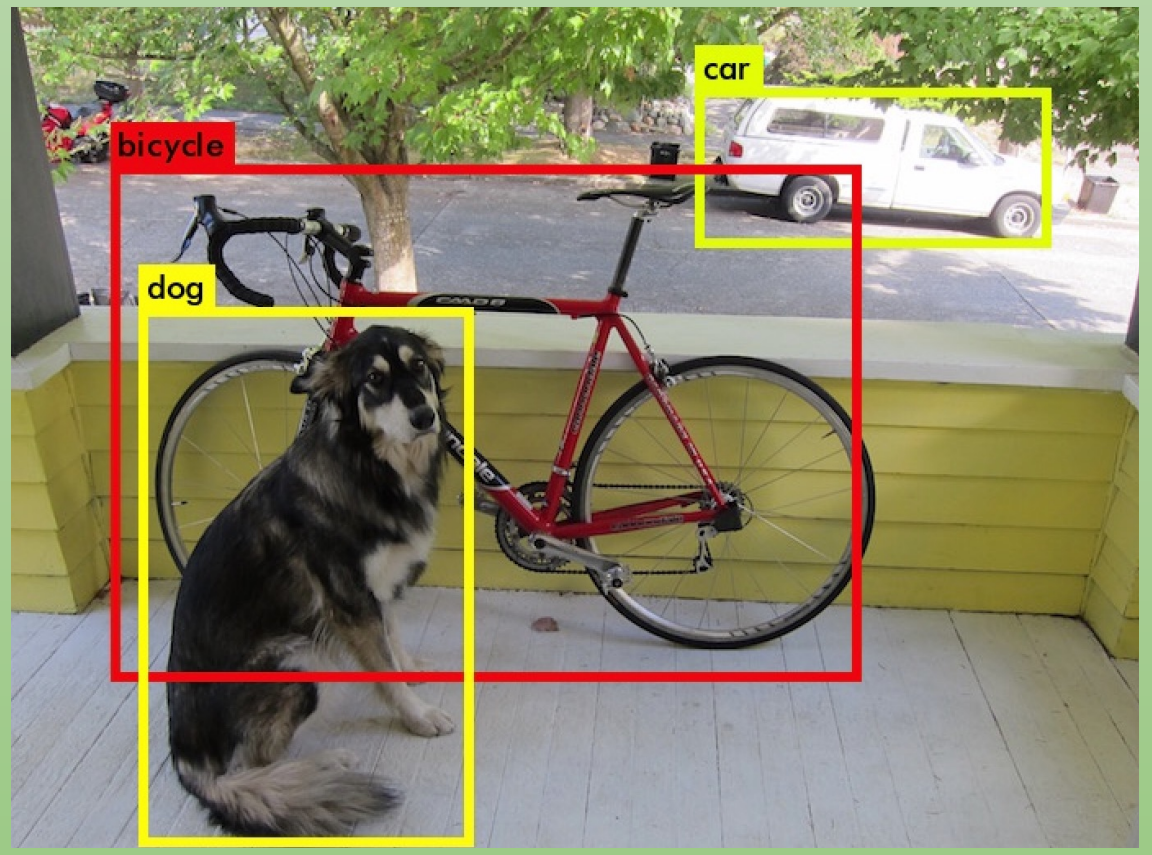


Segmentation

Image Enhancement

Representation & Description

Image Acquisition

Object Recognition

Tasks of Interest: Contrast Adjustment

Image courtesy: Mathworks ®

Tasks of Interest: Edge Detection

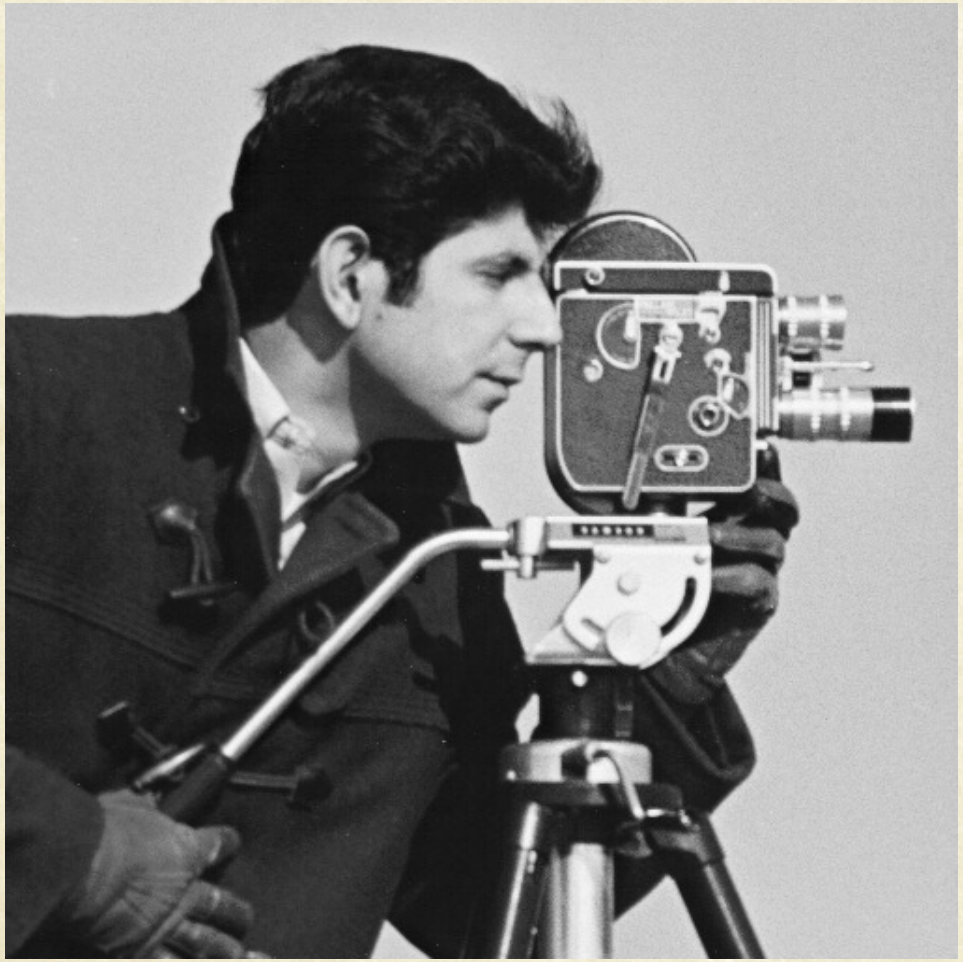


Image courtesy: Mathworks ®

Tasks of Interest: Feature detection + stitching

Image courtesy: opencv

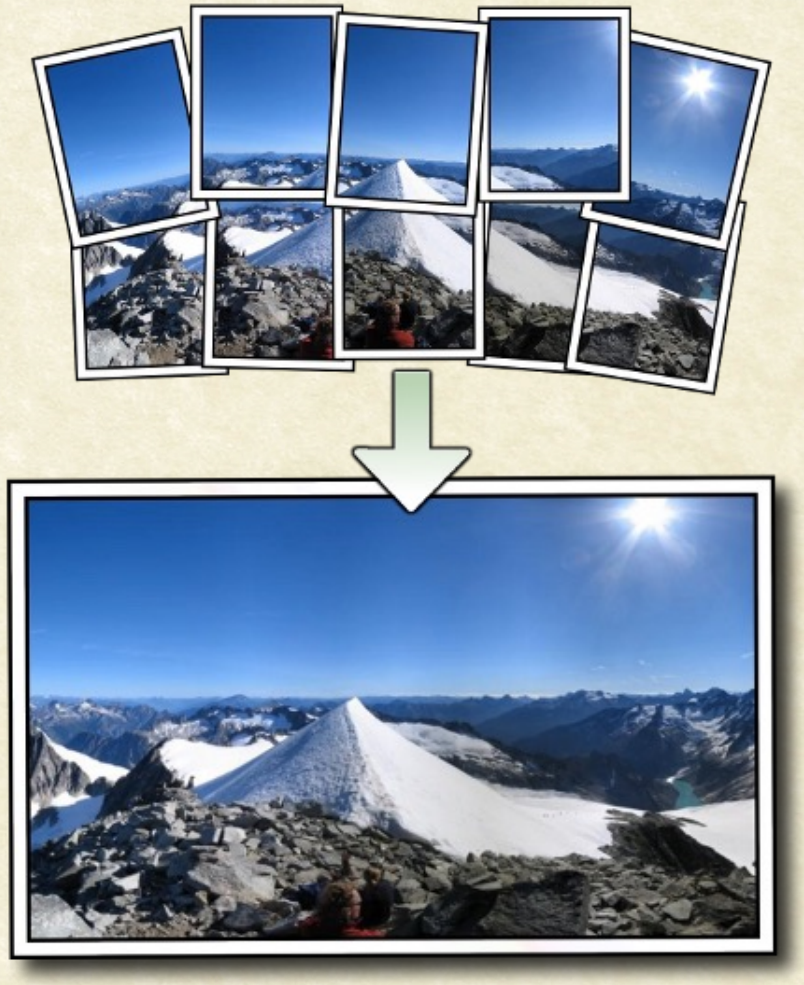


Image courtesy: autostitch

Tasks of Interest: Noise Removal

Total variation denoising [Chambolle JMIV 2004]

Tasks of Interest: Haze Removal

Single Image Haze Removal [He et al. CVPR 2009]

Tasks of Interest: Retouch Personal Photos

Tasks of Interest: Artistic enhancement

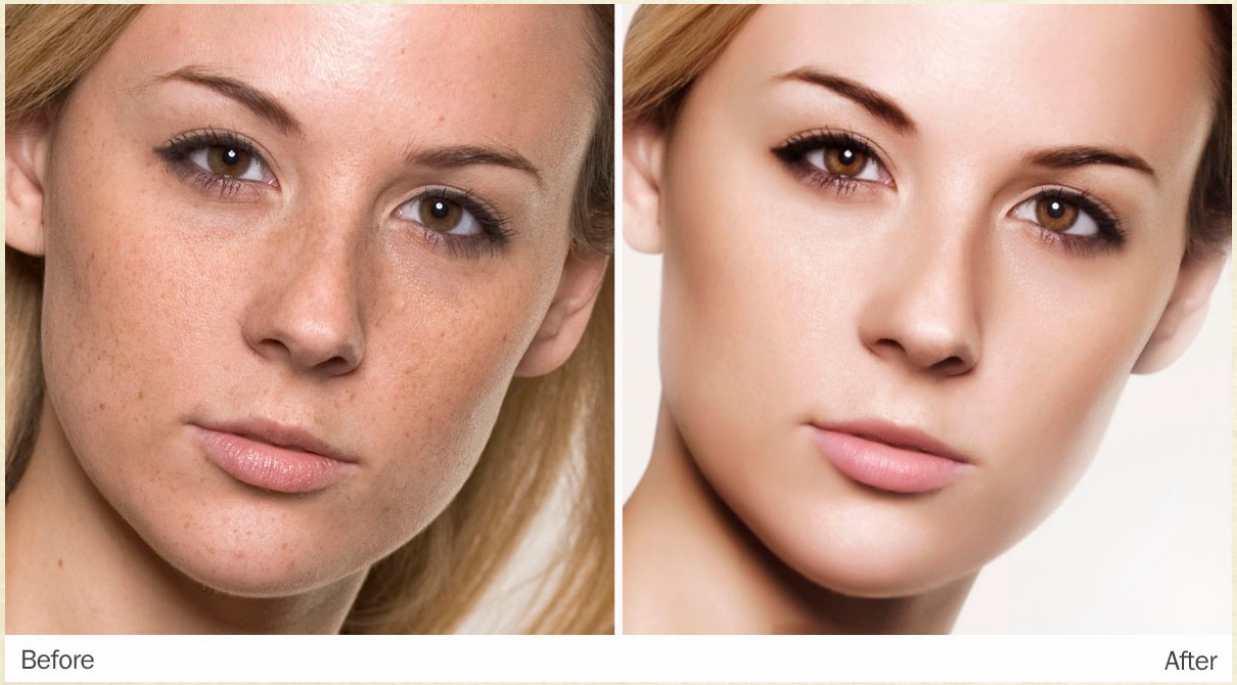


Image courtesy: webneel.com

Image courtesy: Jon Morse

Tasks of Interest: BW to Color

Mayabazar (1957), Vijaya Vauhini Studios

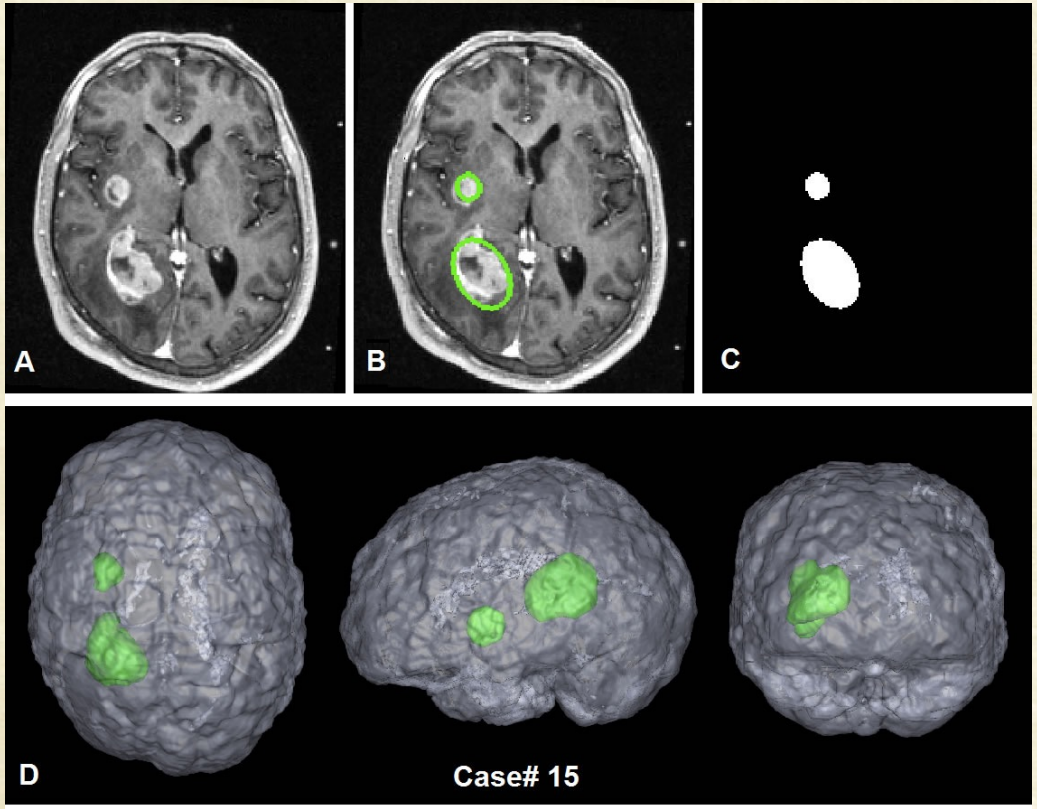
Colorized (2010)

Tasks of Interest: Cinematic Grading

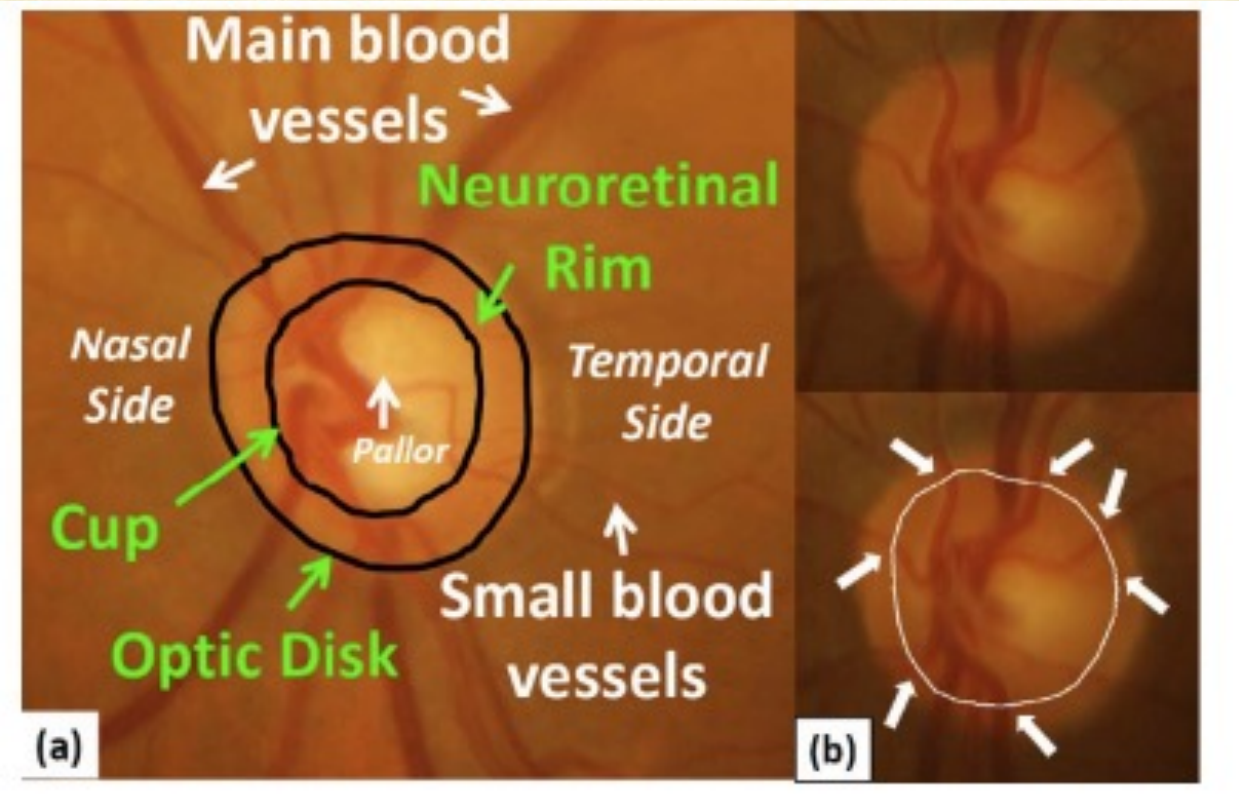
Mission Impossible - Ghost Protocol, Paramount Pictures

Image courtesy: juanmelara.com

Tasks of Interest: Segmentation

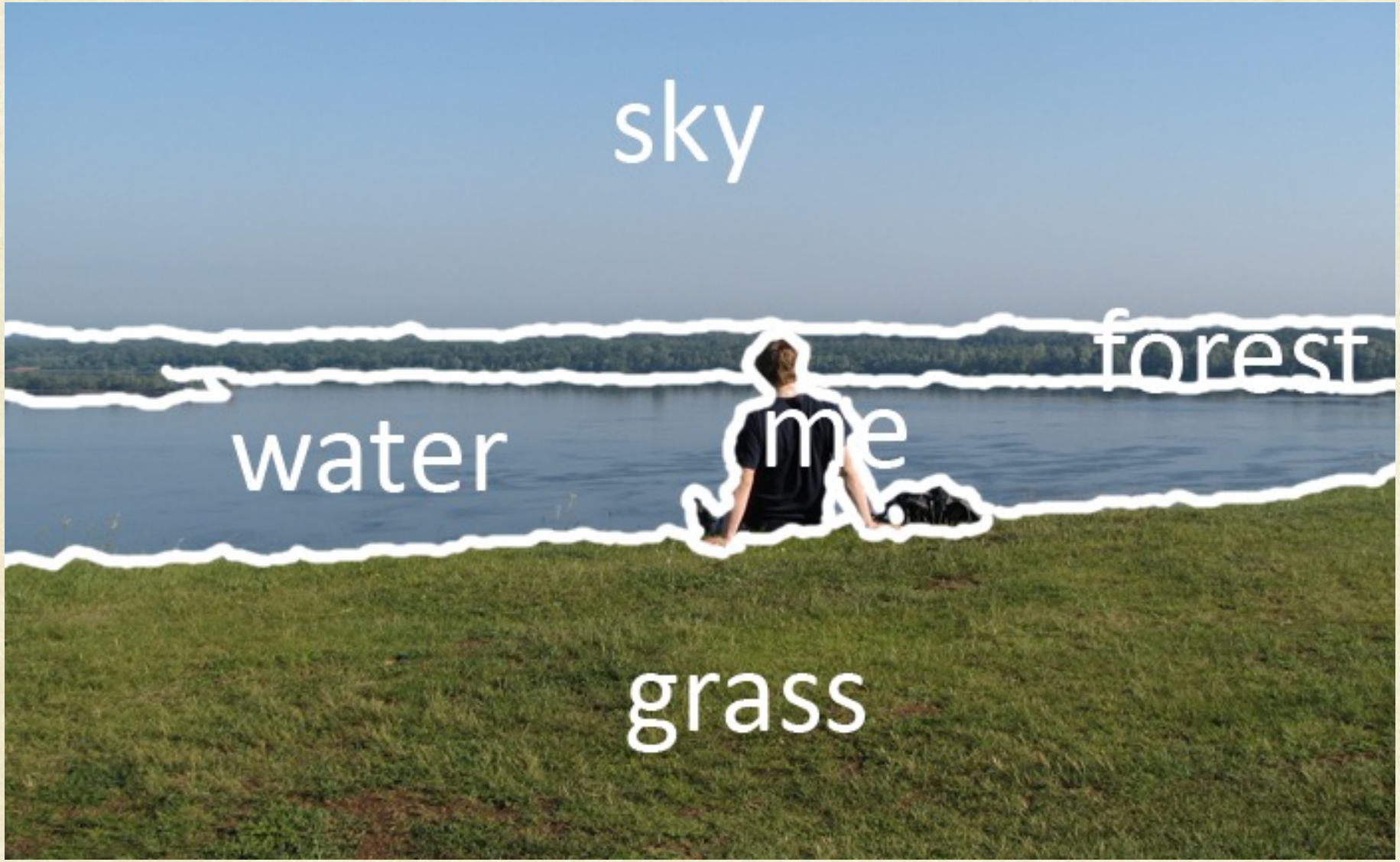


Tumour Segmentation [Yu et al. MICCAI 2010]



Cup Segmentation [Joshi and Sivaswamy 2011]

Tasks of Interest: Segmentation

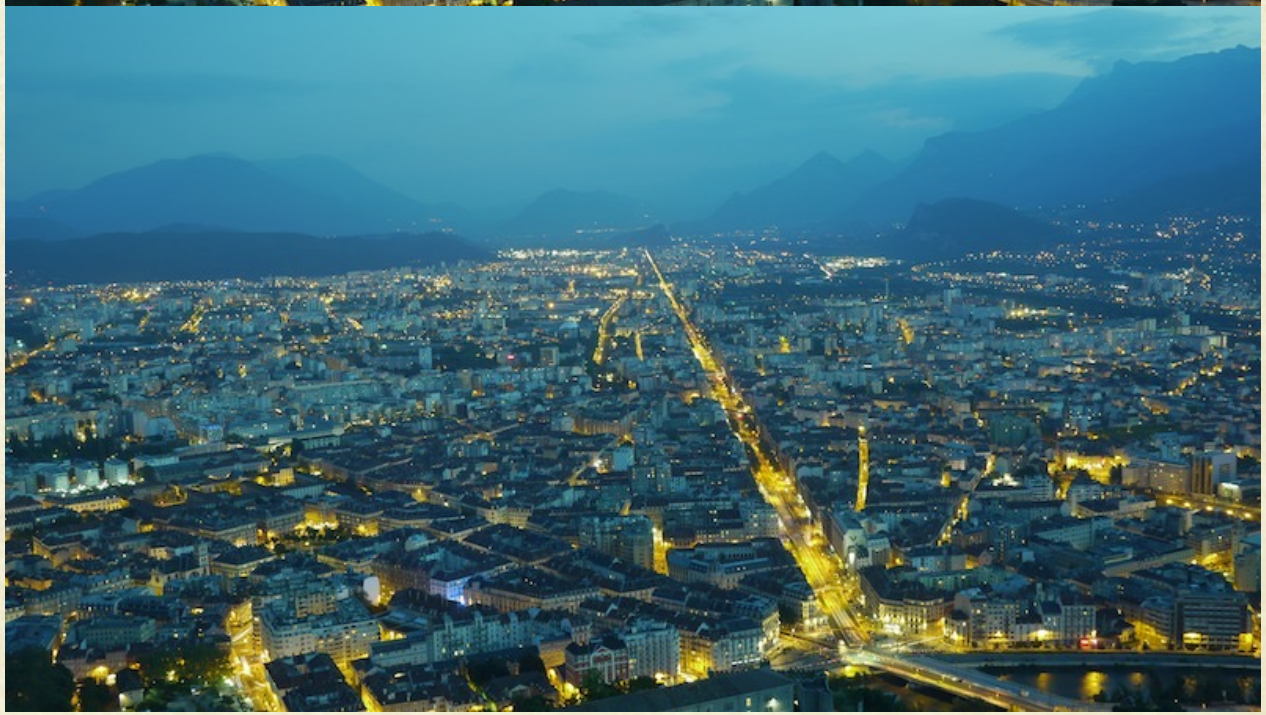


Courtesy: Roman Shapovalov

Tasks of Interest: Compression

Original Image
(1.2 mb)

Compressed JPEG Image
(100 kb)



Tasks of Interest: Inpainting

DAMAGED

RESTORED

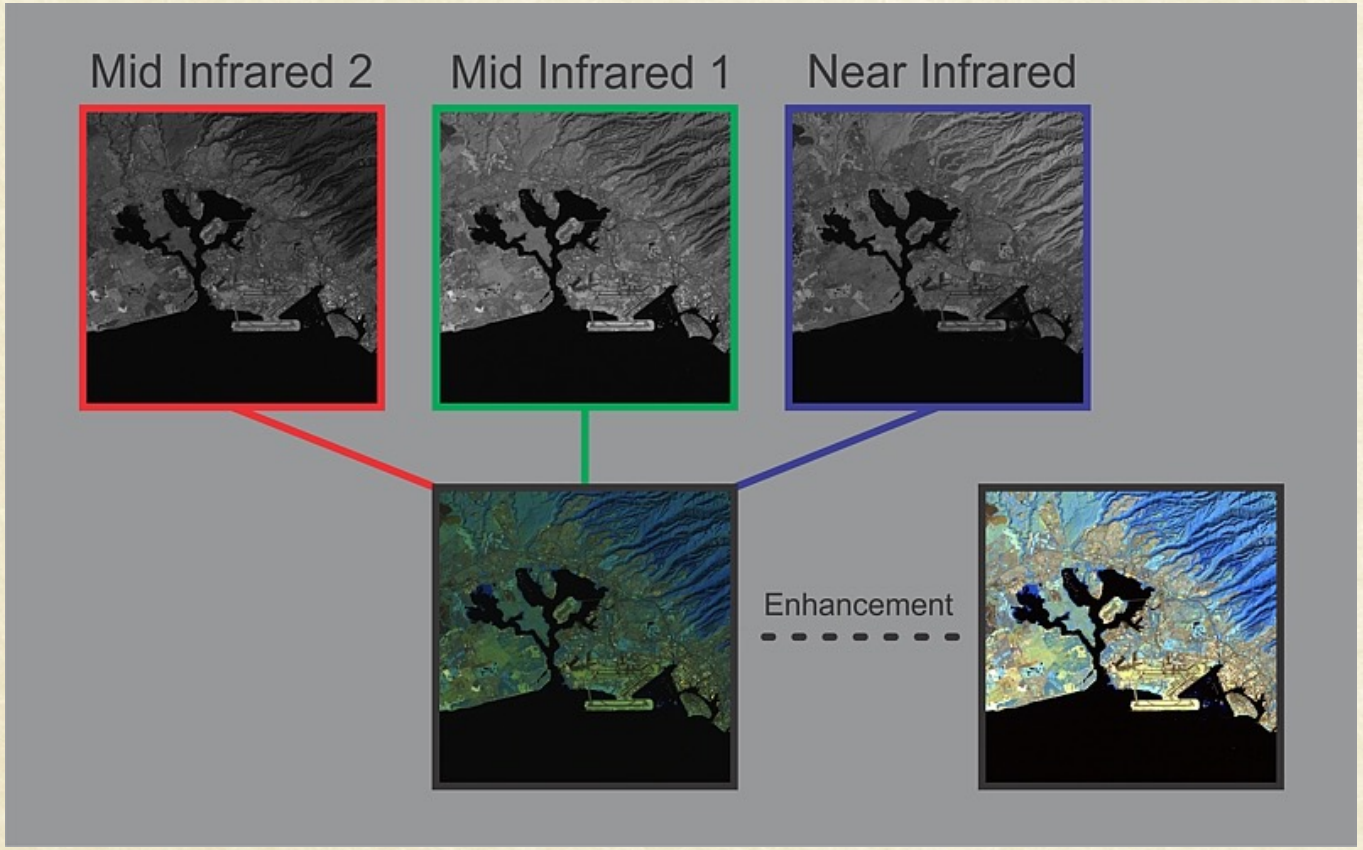
Bertalmio et al. SIGGRAPH 2010

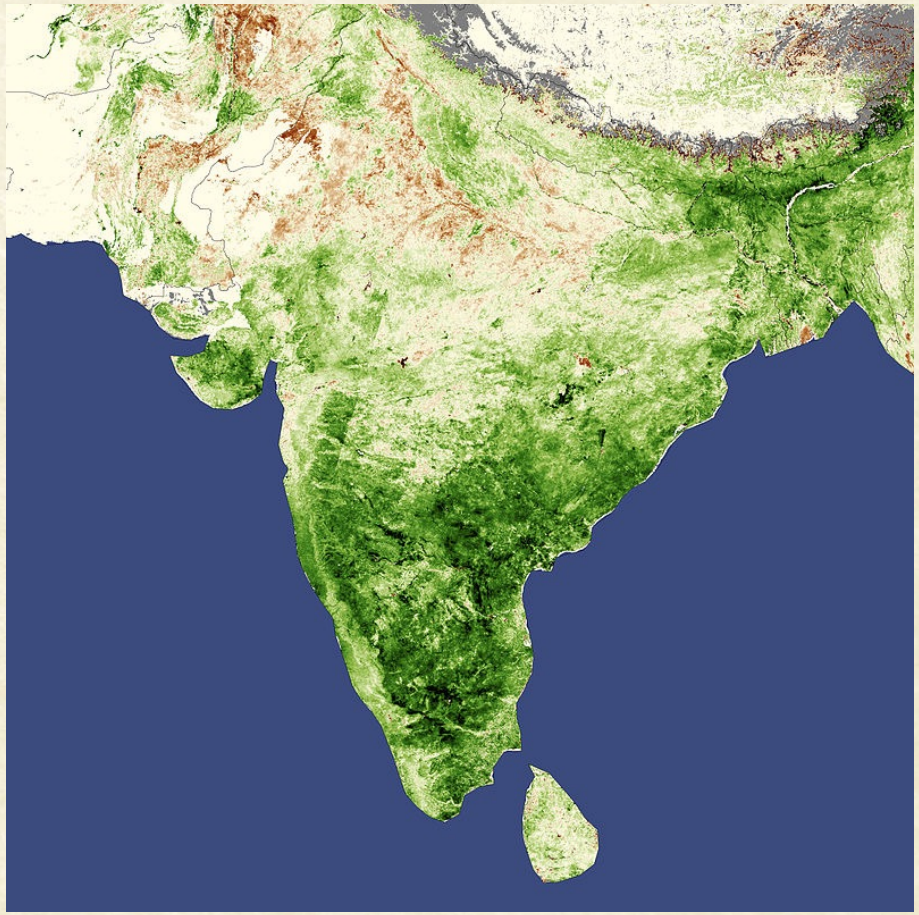
Tasks of Interest: Special effects

courtesy: wachowski brothers (matrix)

courtesy: Miller et al. (sin city)

Tasks of Interest: Satellite imaging

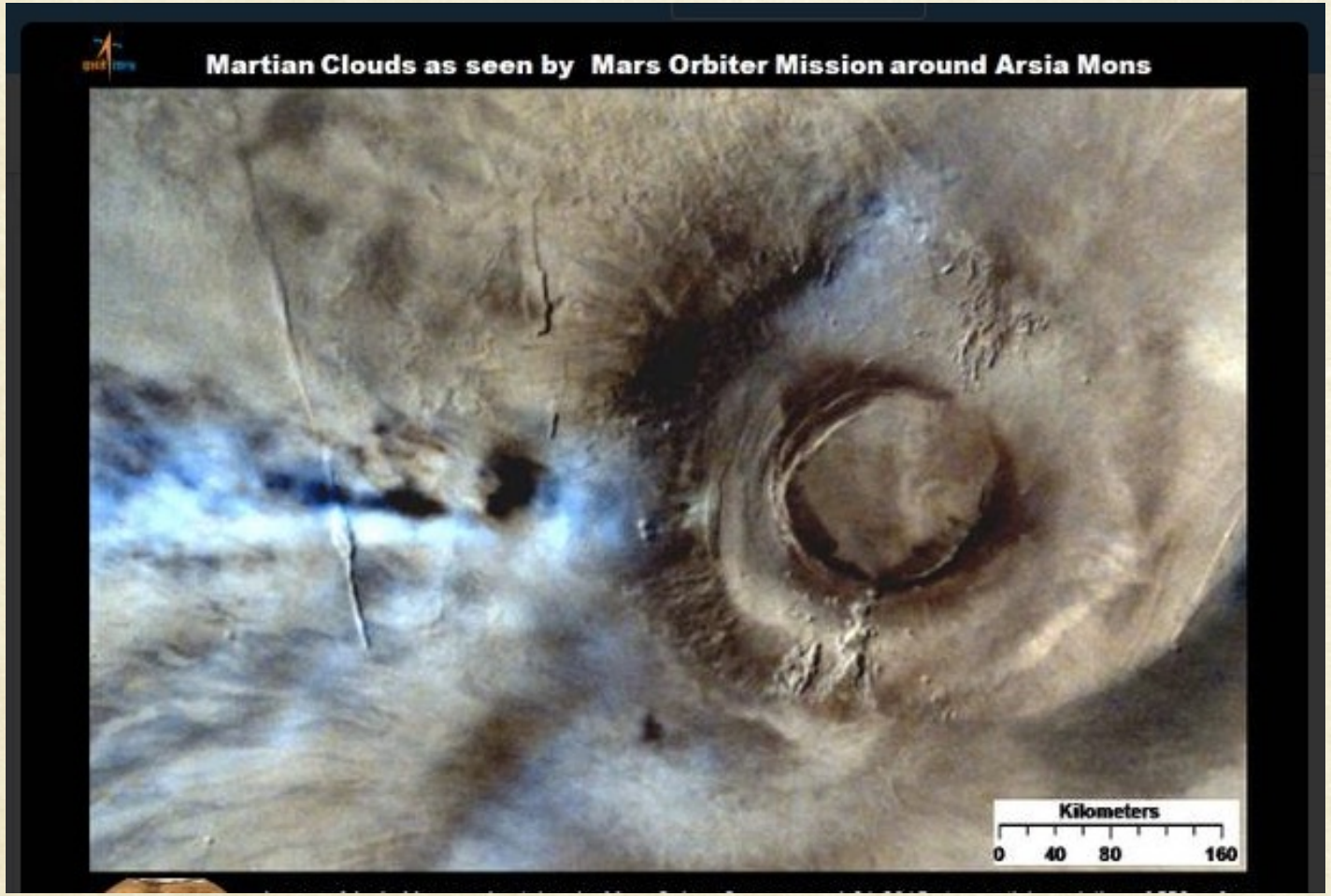


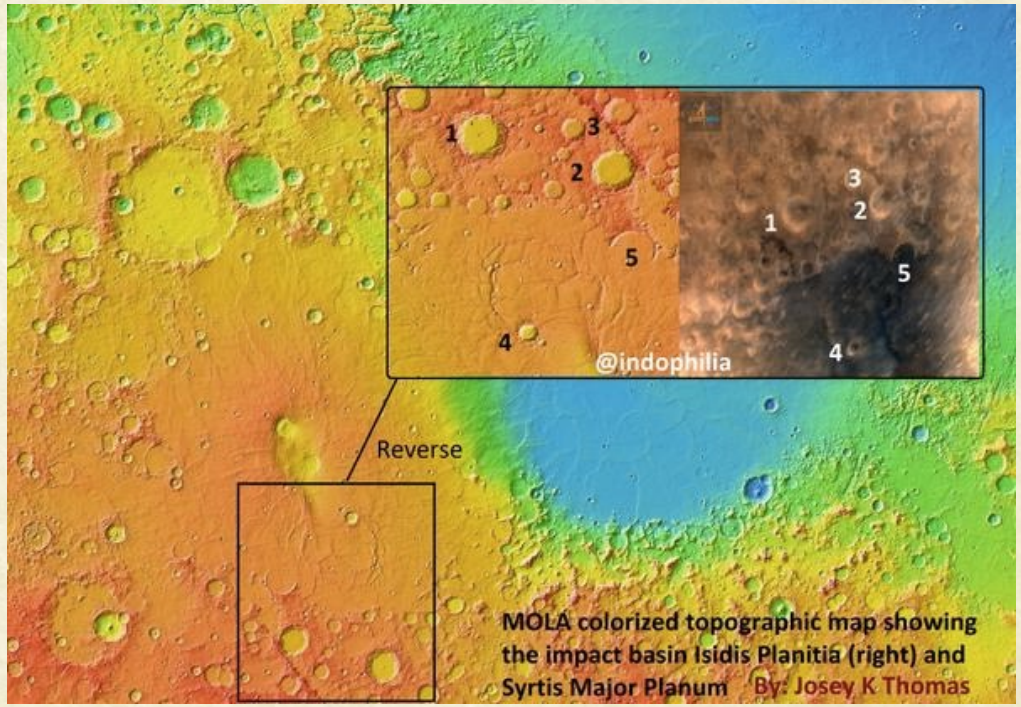


Terrain classification, weather predictions etc.

courtesy: NASA

Tasks of Interest: Astronomy

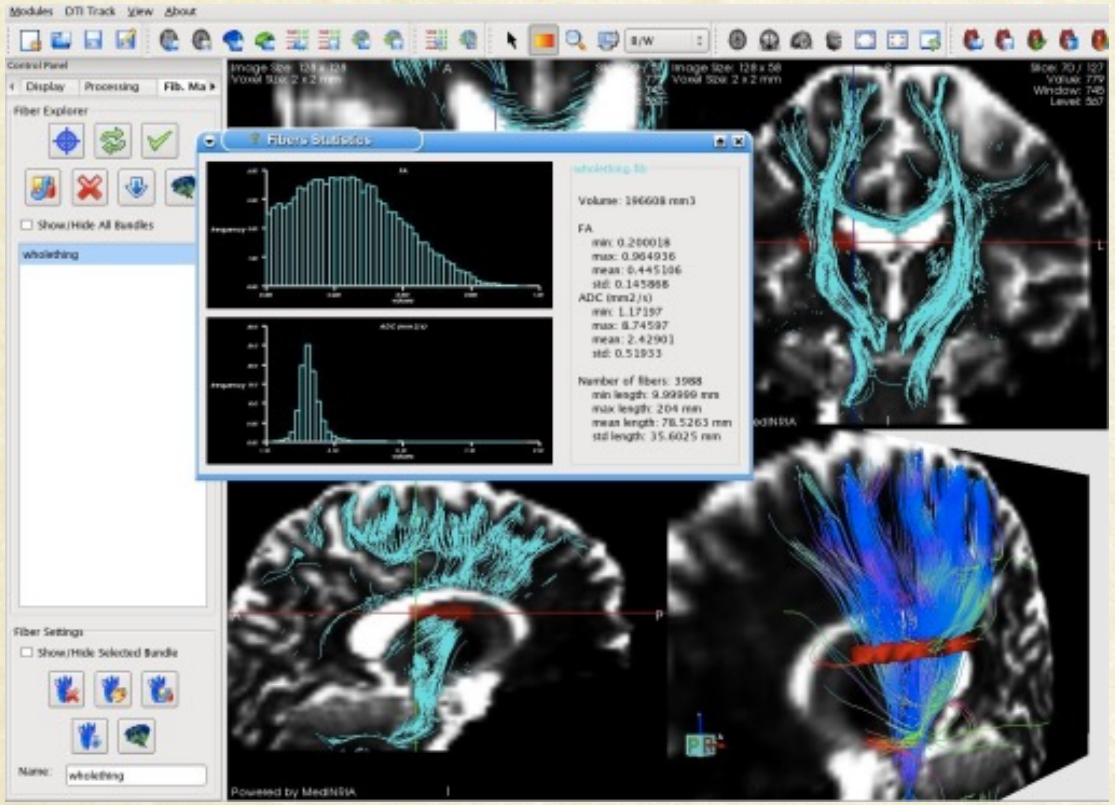




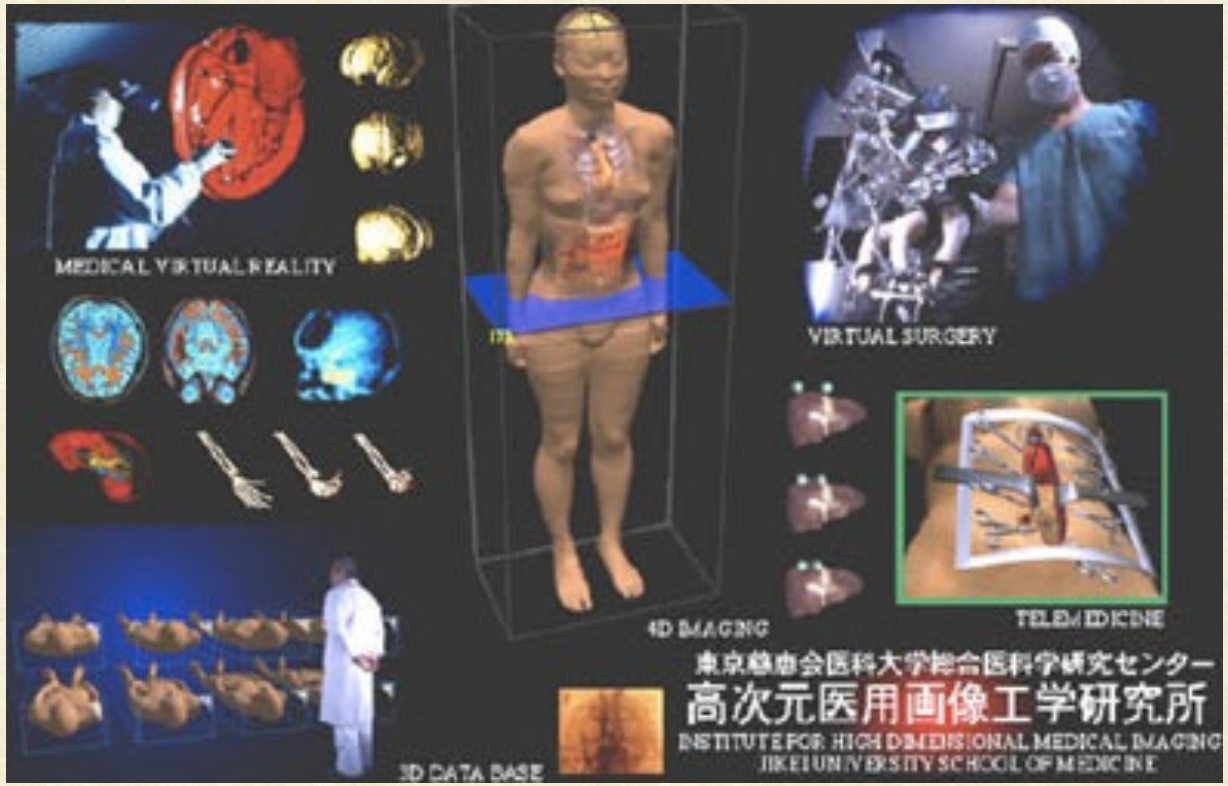
courtesy: ISRO

Tasks of Interest: Biometrics

Tasks of Interest: Medicine

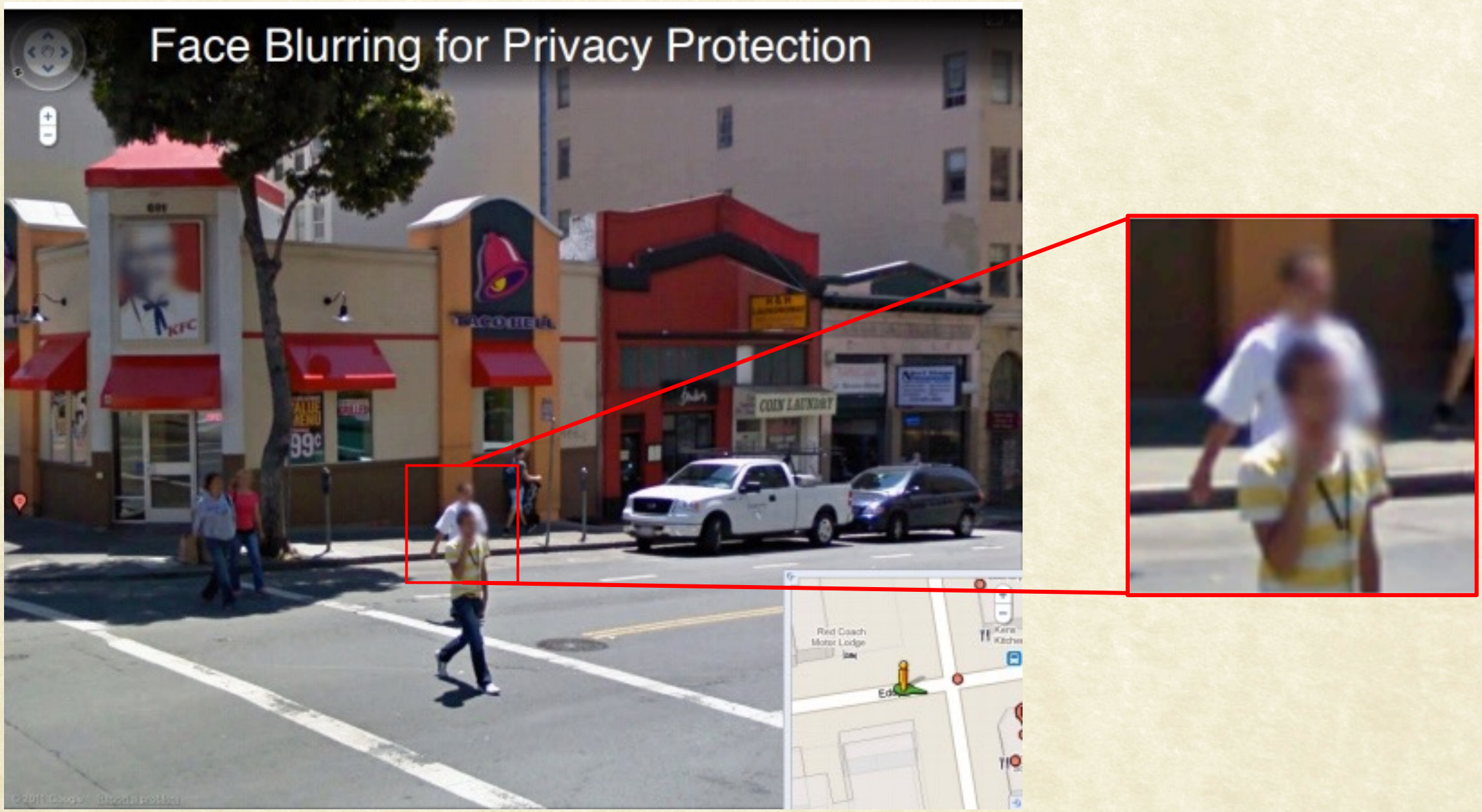


Courtesy: medINRIA

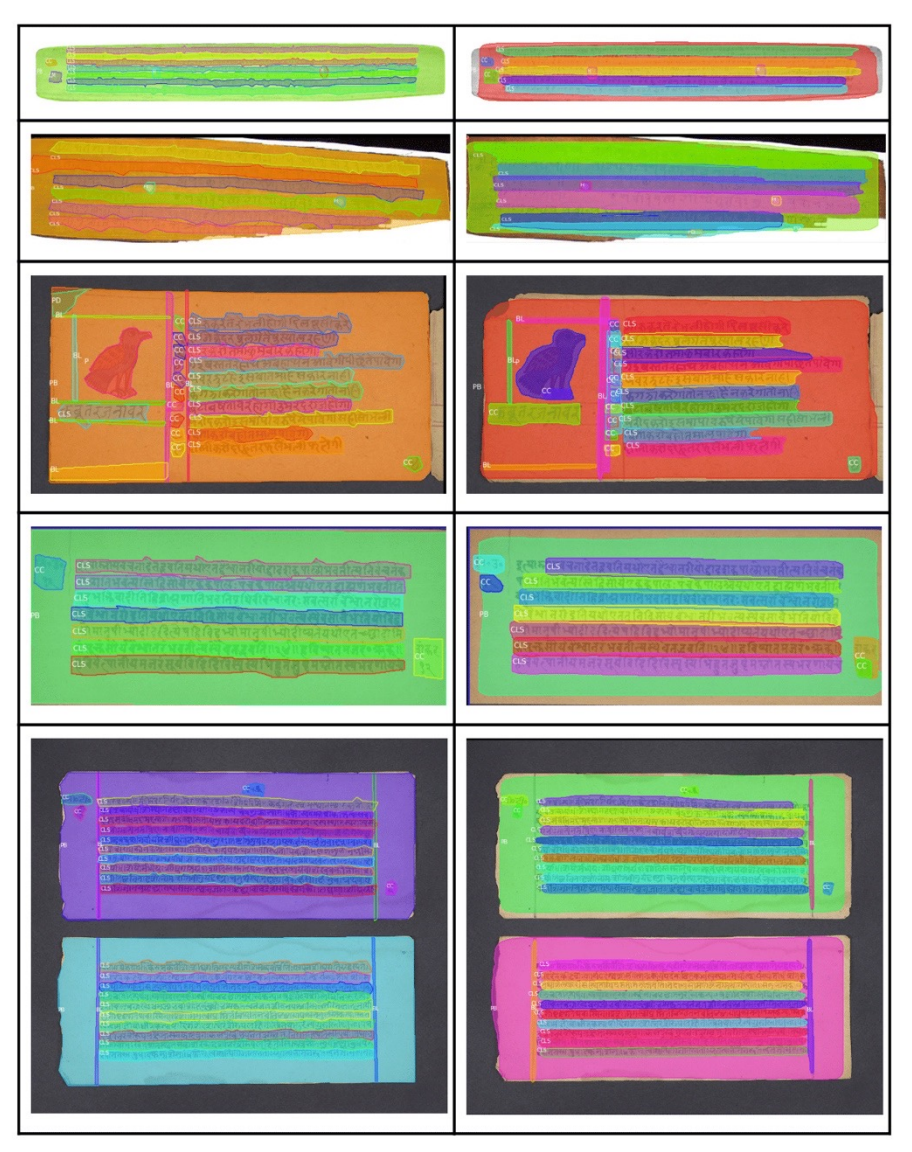


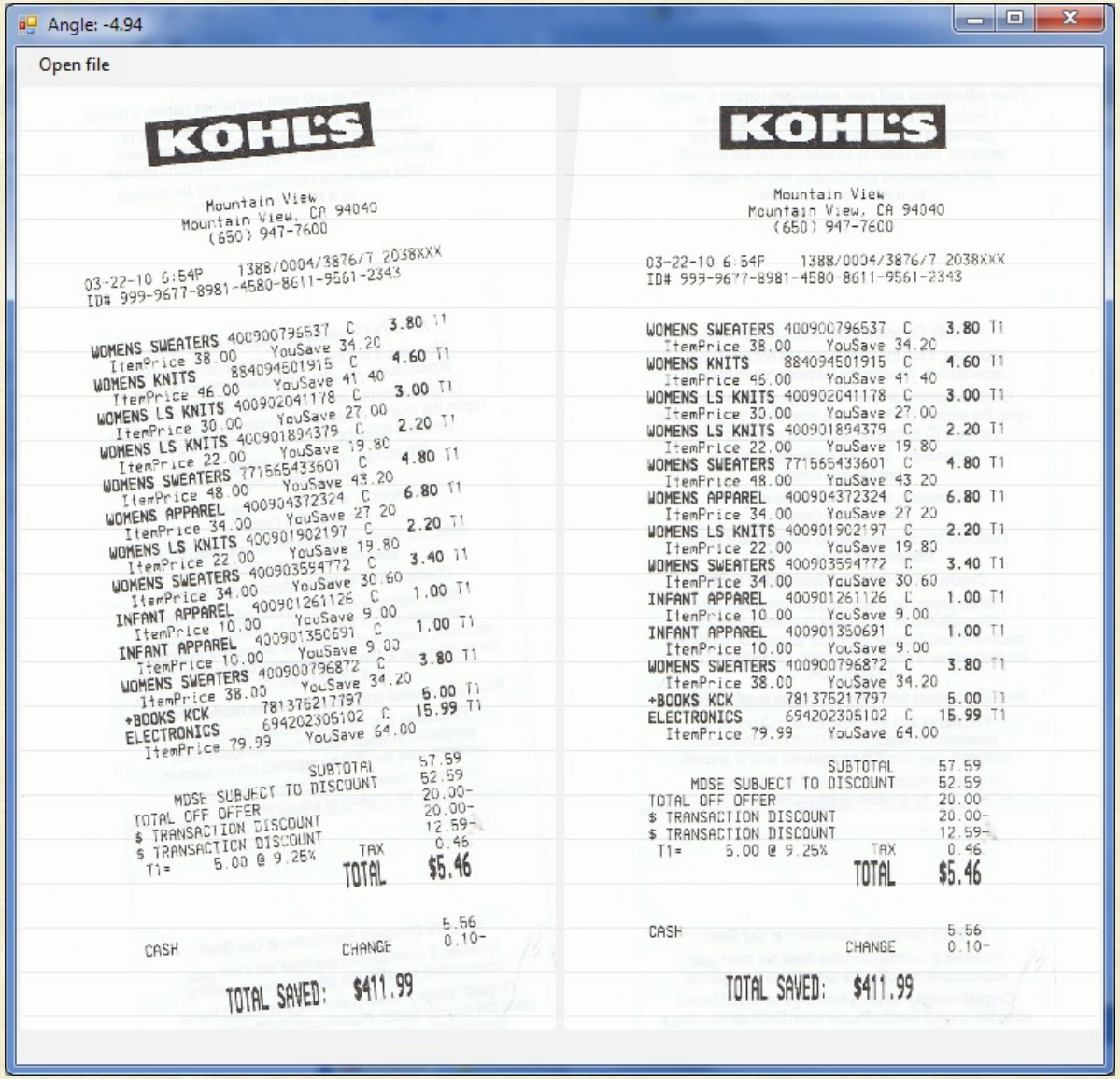
Courtesy: Naoki Suzuki

Tasks of Interest: Driver Assistance Systems


Face Blurring for Privacy Protection
KFC
TACO BELL
99¢
COIN LAUNDRY
Red Coach
Motor Lodge

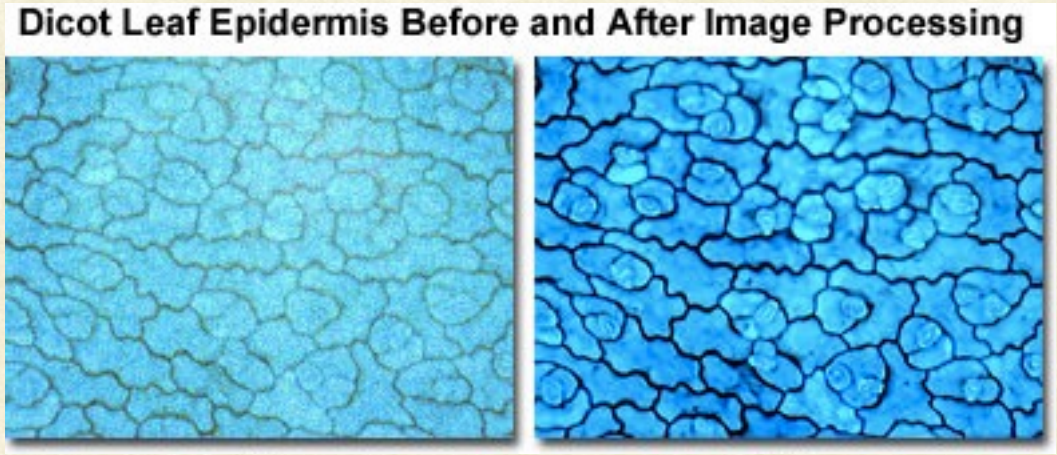
Tasks of Interest: Document Image Analysis



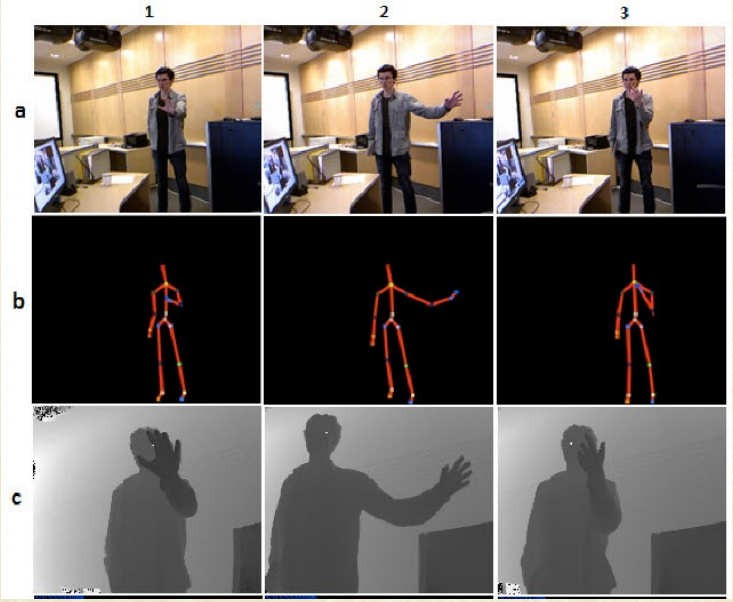


Tasks of Interest: Many more

- Biology
- HCI
- Number Plate recognition
- Gesture recognition



Courtesy: Olympus



Courtesy: Perviverzov et al. 2012

Courtesy: researchdesignlab.com

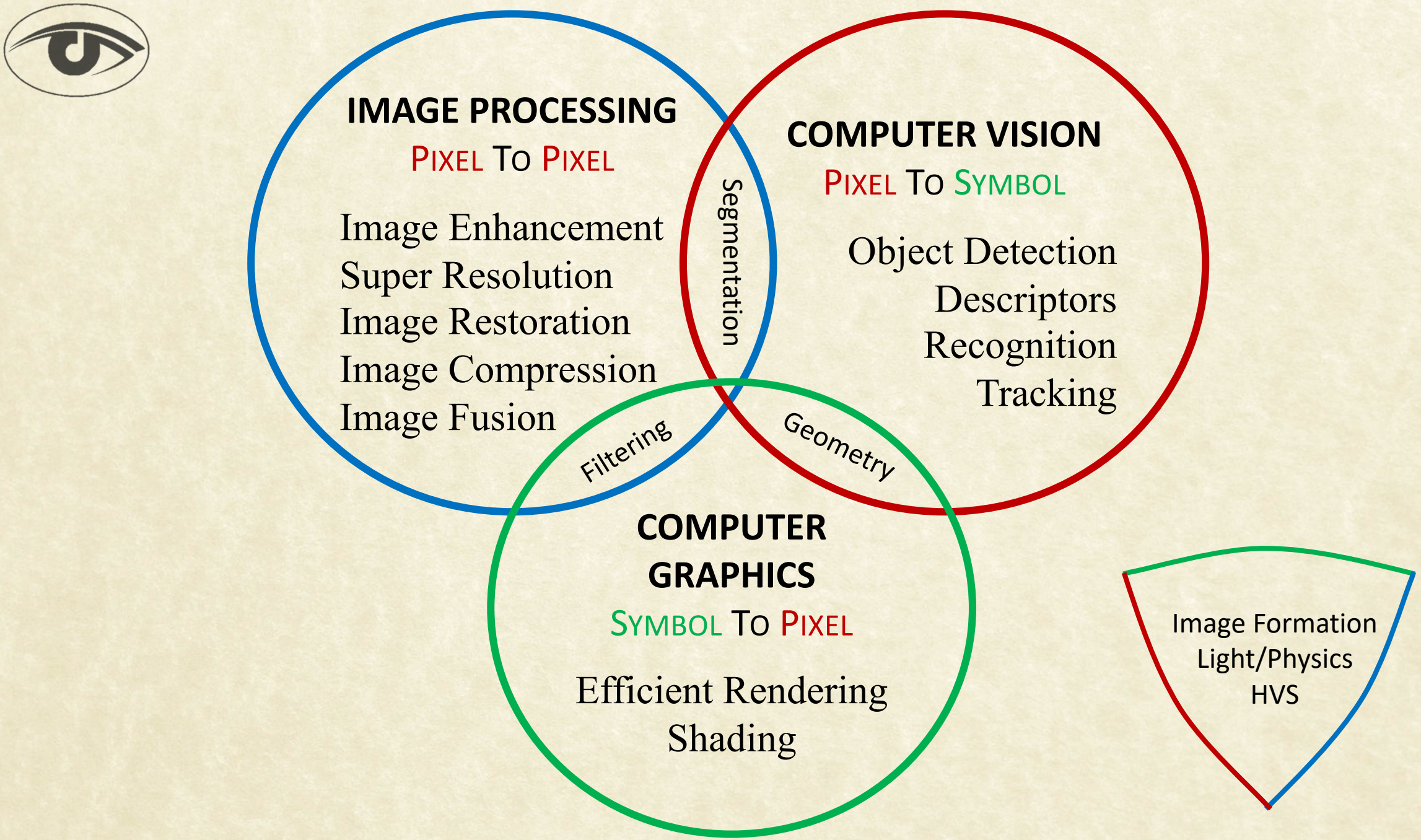
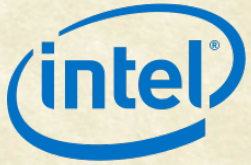


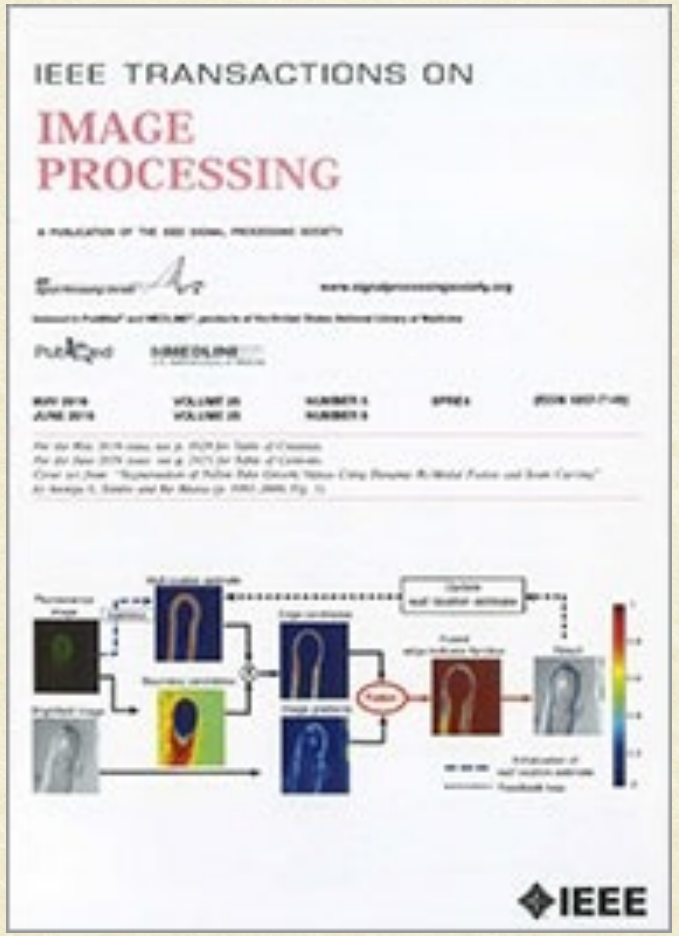
IMAGE PROCESSING
PIXEL TO PIXEL
Image Enhancement
Super Resolution
Image Restoration
Image Compression
Image Fusion
COMPUTER VISION
PIXEL TO SYMBOL
Object Detection
Descriptors
Recognition
Tracking
COMPUTER GRAPHICS
SYMBOL TO PIXEL
Efficient Rendering
Shading
Segmentation
Filtering
Geometry
Image Formation
Light/Physics
HVS

Companies and Software



Research

- Journals



Research

- Conferences

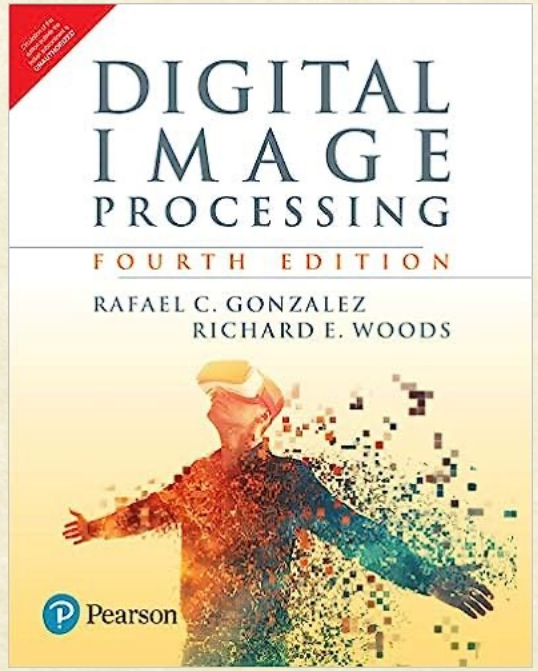
Research

- Conferences

Research

- Conferences

About the Course



- Timings: Tue, Fri (**10:05 – 11:30**)
- Pre-requisites
  - (CS): Programming, Data Structures, Algorithms
  - (MA): Basics of Linear Algebra, Calculus
  - (DSP): Basics of signal processing.
- **Textbook:** *Digital Image Processing,* Gonzalez and Woods(4^{th} ed)
  - Other resources from the internet
- Teaching Assistants: https://courses.iiit.ac.in.
- Office Hours : Tue, Fri: 11:45-12:30 [after class]
- Assessment: Assignments (30), Quizzes (20), Mid Term (20), Final/Project (30).

About the course: Assignments

- Python (mandatory)
- Github Classroom
- Image Processing / Data Processing Libraries
    - scikit-image , opencv-python, kornia
    - pandas
    - scikit-learn
  - Do not use libraries for assignments unless explicitly allowed.

About the course: Collaboration policy

- OK to discuss questions, approaches
- But work must be your own
  - No copying – partially or fully
  - No GenAI for assignments (unless explicitly permitted)
- If you worked with someone, mention their name(s)
- We will be checking for copying/plagiarism.
  - Better to own up than be caught !

About the course – Final Projects

- Project or Final
  - Selection based on proposals
  - Cannot change later
- Teams: 25 groups of 2 each.
- Dates:
  - Regn, Proposals: Aug 15, Aug 22
  - Reports: Sep 30, Oct 24
  - Final Evals: Nov 15
- Expectation
  - Report should an ICIP paper draft.
  - Release final code on Github

About the Course Project

- Replicate an interesting research papers
- Original Research
- Deliverables
  - Release the final code (github – code check-in analytics will form basis of marks)
  - Final Report: Equivalent of an ICIP draft.
  - Group presentations
- Process (if interested)
  - From Groups of 2 and register (names, roll numbers)
  - Upload a project proposal outlining the problem, background, and what you plan to do
  - Selection is based on the proposal and your performance

Additionally …

- **The course load is fairly substantial**
- Elective → Conscious choice
- Starting early on assignments helps
- Spending time everyday on material covered in class helps

How to Learn

- **Understand**, don’t just memorize
- Understand the theory behind library calls !
- Capture the broad ideas and insights (useful years down the line)
- Implement ! No substitute for experience.

Learning Resources

- PGSSP/MS/PhD
  - Take some time understanding the courses portal and other IIIT e-services
  - Consider forming e-study / discussion groups
- Reach out to TAs, me in case you have difficulty with material.
- Feedback need not wait until end of course.

Be there the whole way

- Put away phone and other distractions …
- Do NOT make end of semester travel plans until project evaluations are completed.
- Book your tickets after
  - 1st December 2025
  - 5th December if you want to see the final exam paper

Welcome and Have Fun

- DIP is extremely interesting
  - Visual
  - Mathematical
  - Practical
  - Challenging
  - Lots of interesting applications

Summary

- Images
  - Formation, Representation
  - Types of Images: Source (λ), Scale, Content (multi-channel)
- Image Processing
  - Enhancement, Restoration, Color, Compression
  - Morphological Operations, Segmentation
  - Representation, Detection, Recognition