



CS7.404: Digital Image Processing

Monsoon 2025: 1: Overview

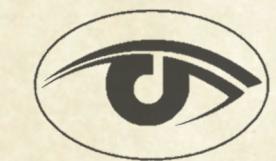


(Prehistoric Painting,
Lascaux cave, France
~15000 BC)



Anoop M. Namboodiri

Biometrics and Secure ID Lab, CVIT,
IIIT Hyderabad

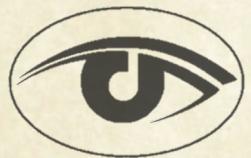


Middle Ages

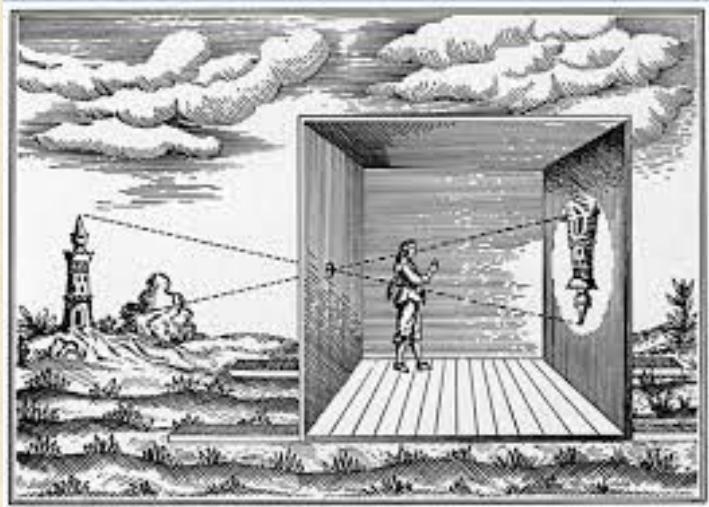


The Empress Theodora
with her court.

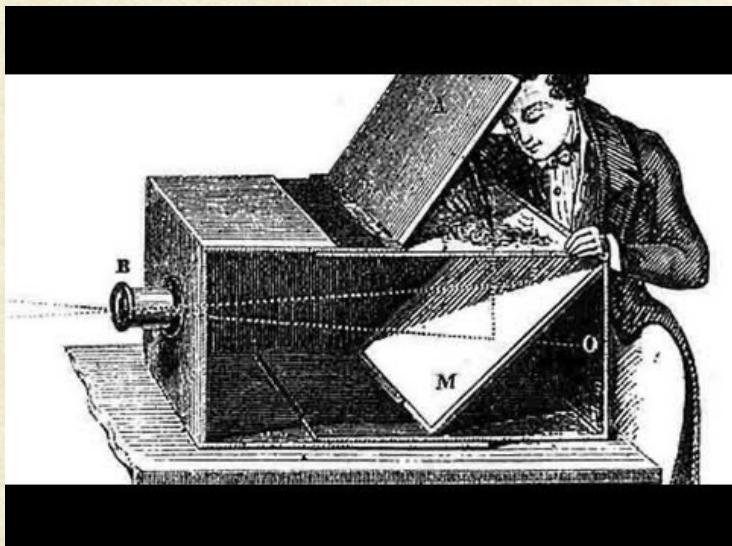
- Ravenna, St. Vitale, 6th c.



Before there were images



Camera Obscura



Girl with a pearl earring, J. Vermeer, 1665

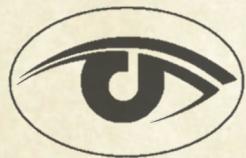




and then there were Images



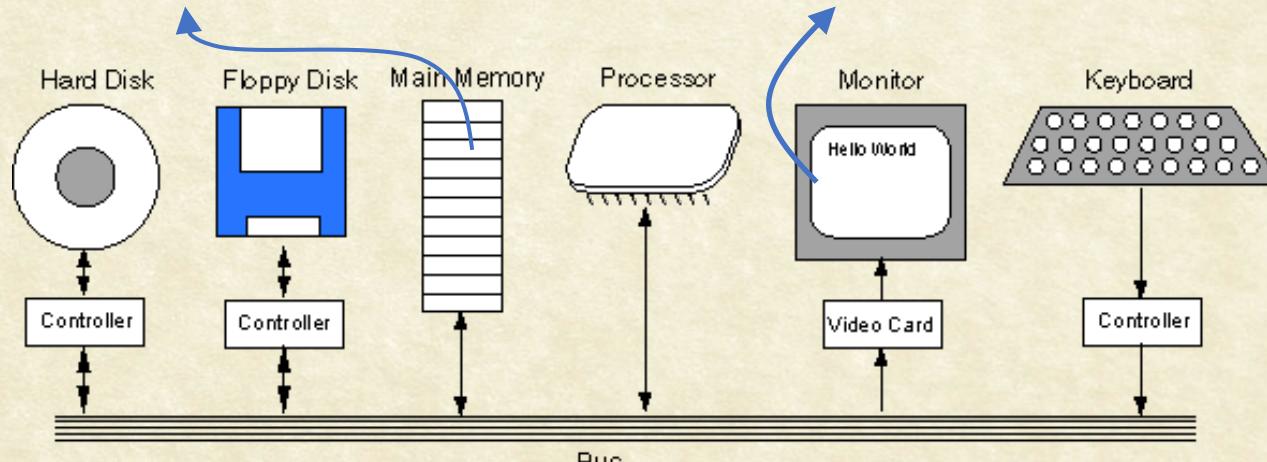
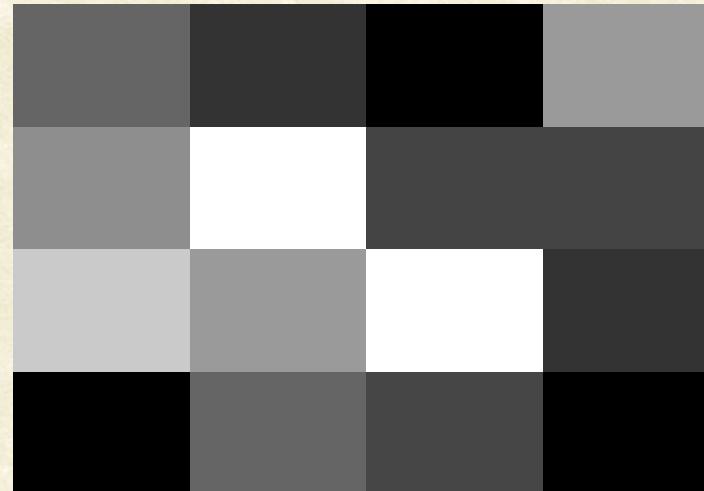
Still Life,
Louis Jacques Mandé
Daguerre, 1837
<http://www.cs.toronto.edu/~guezhoy/320/lec/Introduction.pdf>

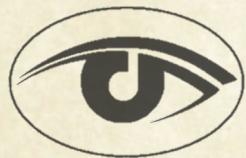


What is a **Digital** Image ?

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

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

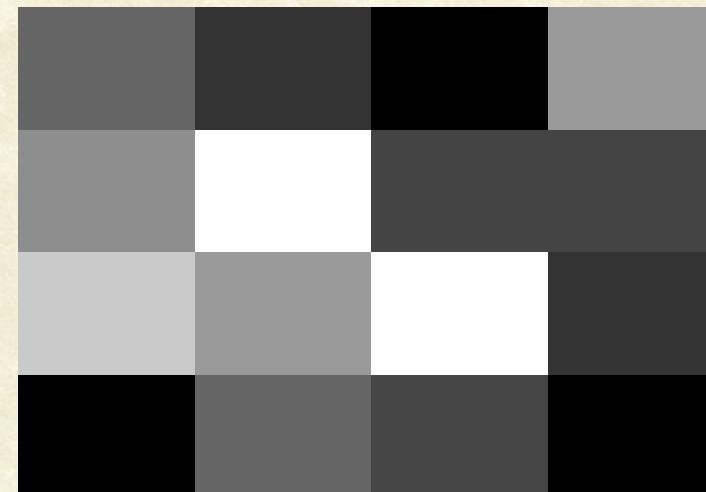




What is a Digital Image ?

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

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



↑
1 2-D channel
8 bits/pixel
Height
↓
← → Width pixels



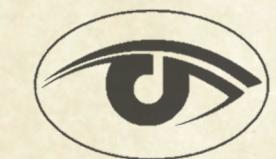


Image Representation (Grayscale)



| | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 157 | 153 | 174 | 168 | 150 | 152 | 129 | 151 | 172 | 161 | 155 | 156 |
| 155 | 182 | 163 | 74 | 75 | 62 | 93 | 17 | 110 | 210 | 180 | 154 |
| 180 | 180 | 50 | 14 | 94 | 6 | 10 | 33 | 48 | 106 | 159 | 181 |
| 206 | 109 | 5 | 124 | 191 | 111 | 120 | 204 | 166 | 15 | 56 | 180 |
| 194 | 68 | 137 | 251 | 257 | 299 | 299 | 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 | 105 | 36 | 190 |
| 205 | 174 | 155 | 252 | 236 | 231 | 149 | 178 | 228 | 43 | 95 | 234 |
| 190 | 216 | 116 | 149 | 236 | 187 | 85 | 150 | 79 | 38 | 218 | 241 |
| 190 | 224 | 147 | 108 | 227 | 210 | 127 | 102 | 35 | 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/](https://openframeworks.cc/ofBook/images/image_processing_computer_vision/)

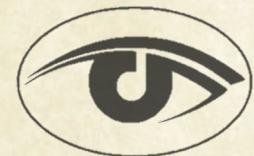


Image Representation (RGB)

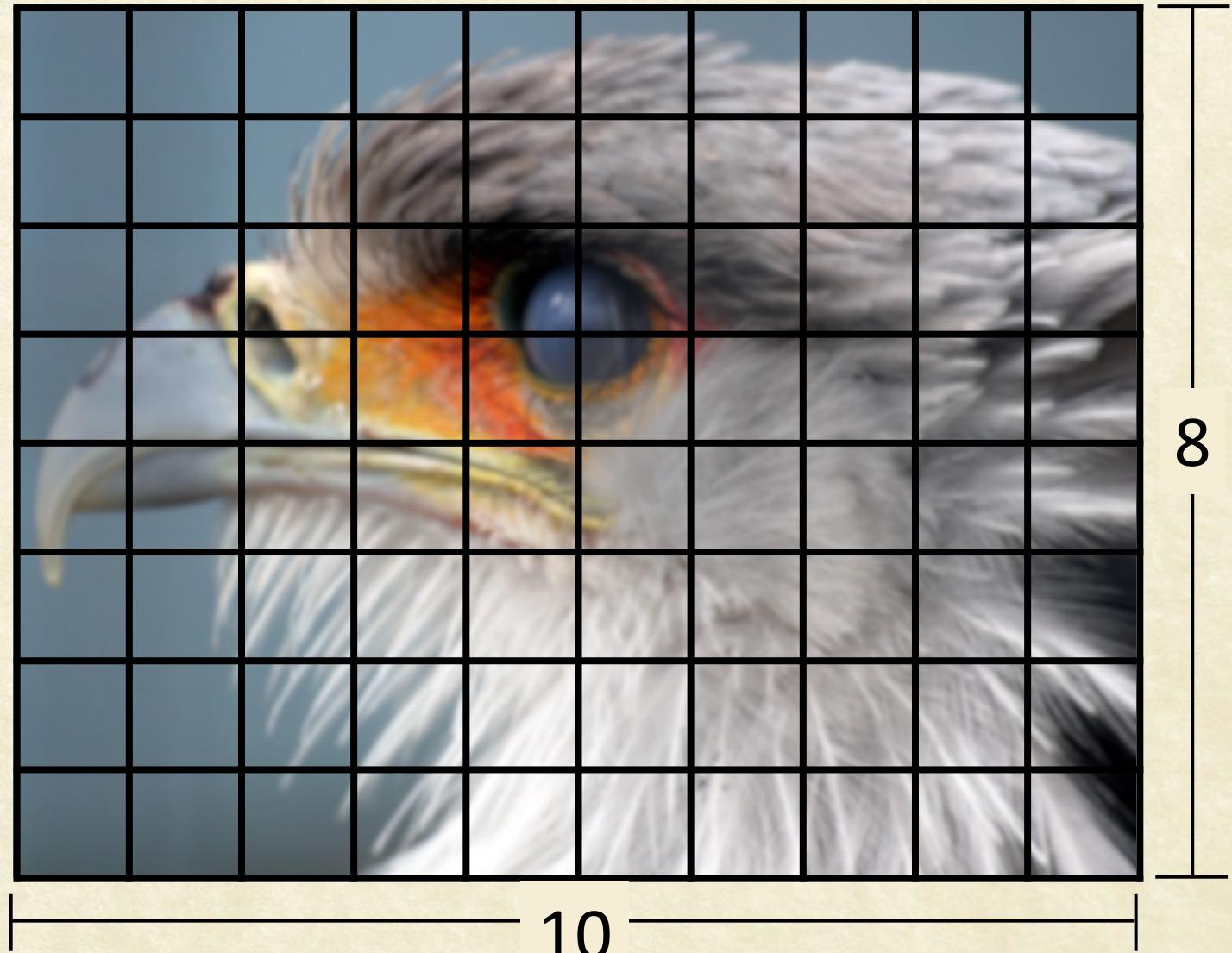
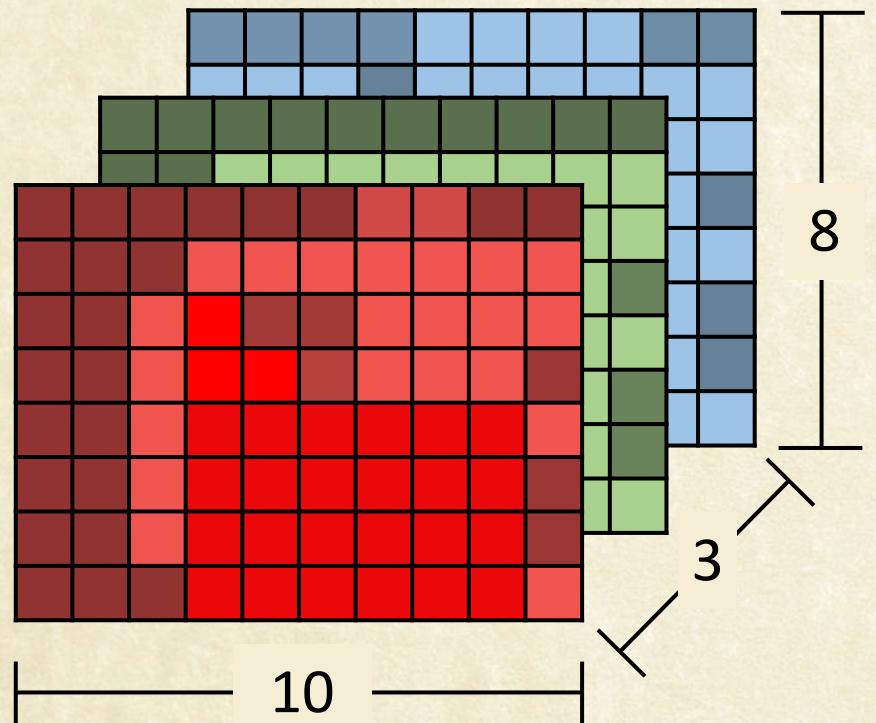




Image File Format: PPM

P3 # Format specifier

65 # 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



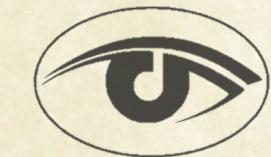
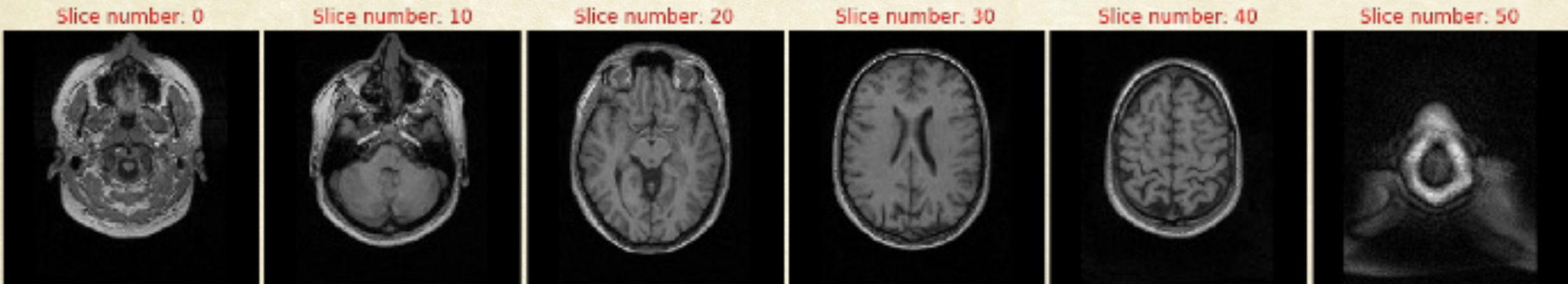
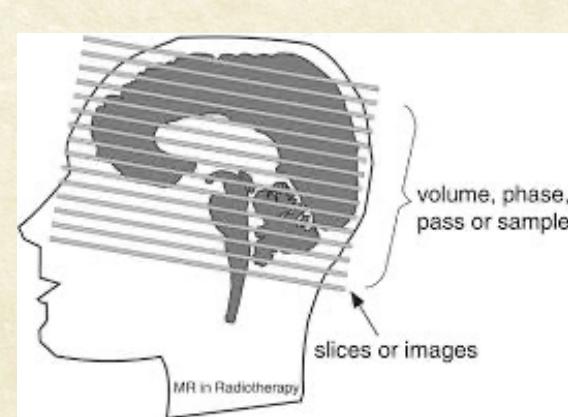


Image Representation

fMRI image slices



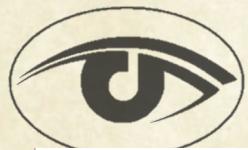
56 2-D channels



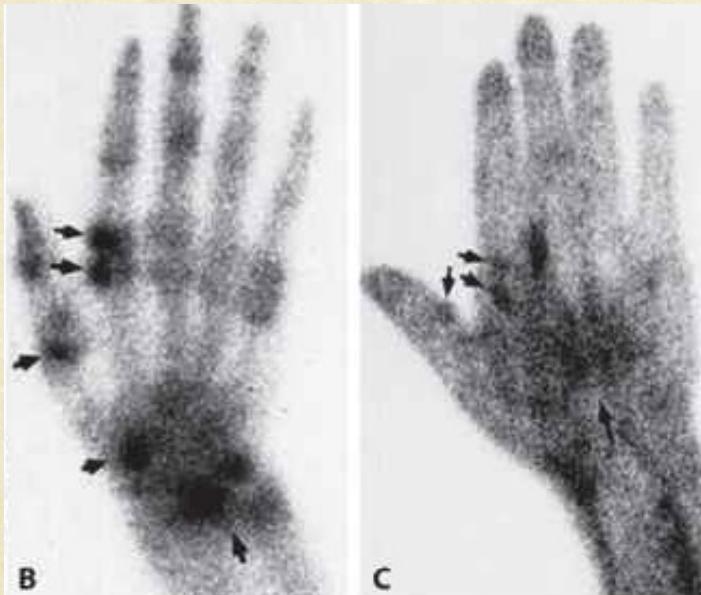
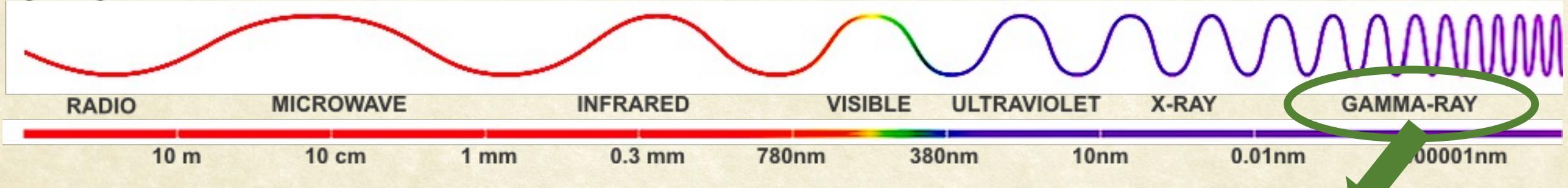


Types of Images (classification on source)

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

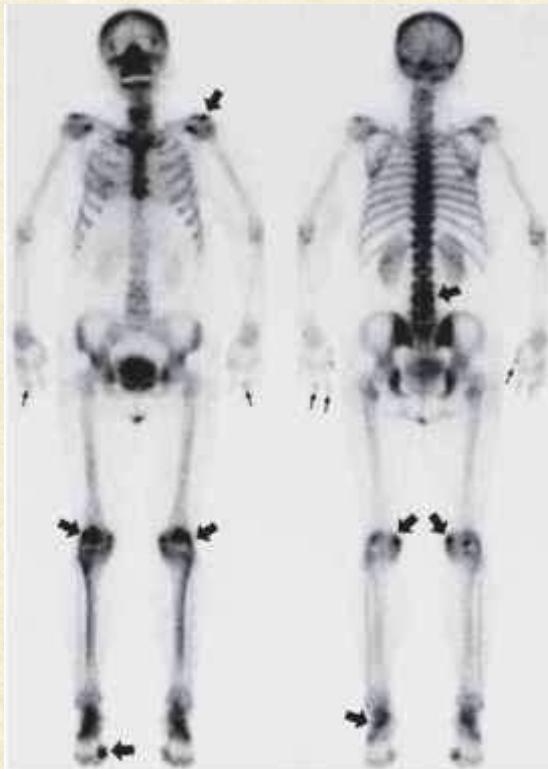


EM Spectrum

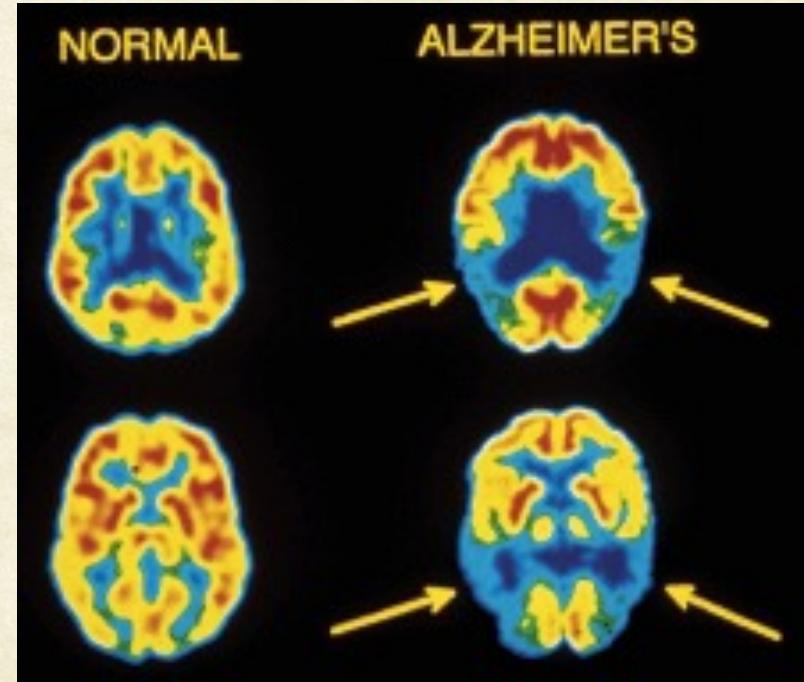


BLOOD FLOW SCAN

courtesy: artheritisresearch.us

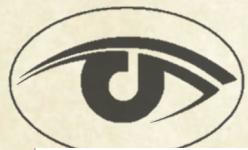


courtesy: artheritisresearch.us

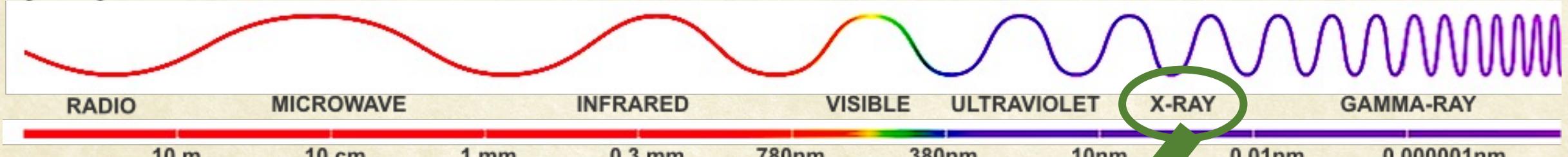


PET SCAN

courtesy: research.ucla.edu



EM Spectrum

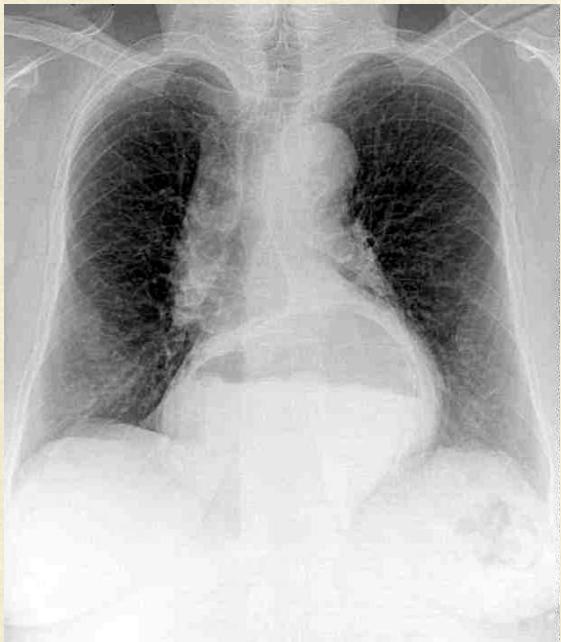


Wilhelm Röntgen



HAND MIT RINGEN

courtesy: wikipedia



CHEST RADIOGRAPH

courtesy: wikipedia



CT SCAN

courtesy: wikipedia

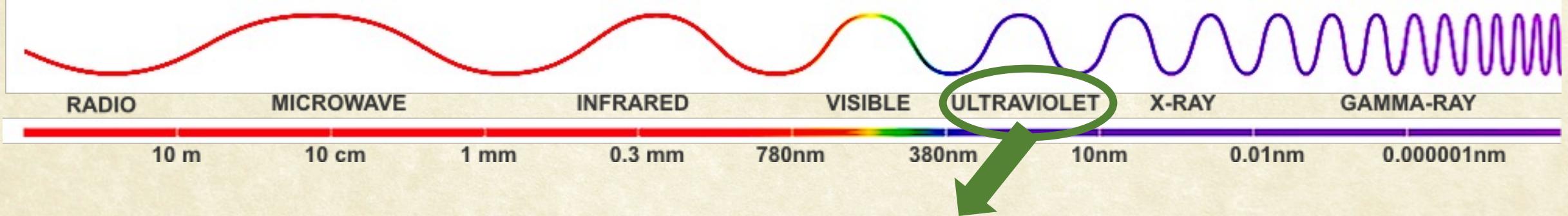


AIRPORT SCAN

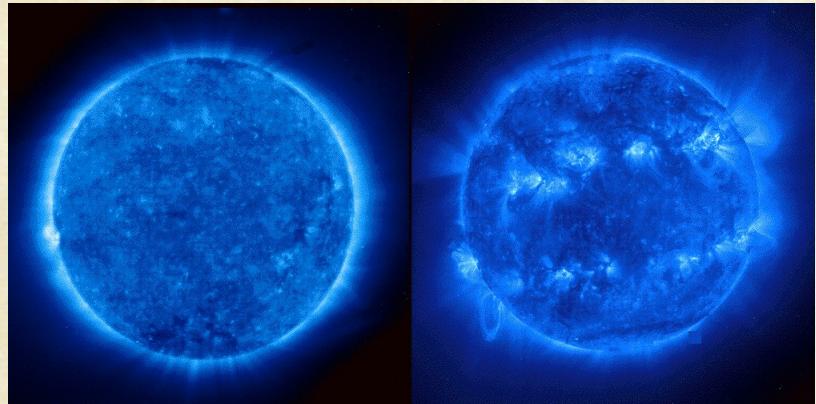
courtesy: dpl-surveillance-equipment



EM Spectrum



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



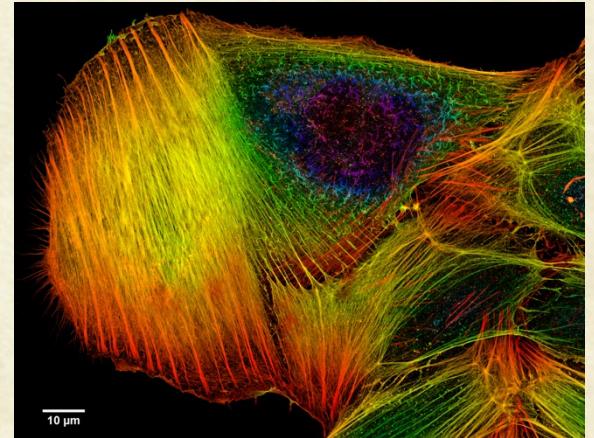
SUN (2 years apart)

courtesy: NASA



100 EURO BILL

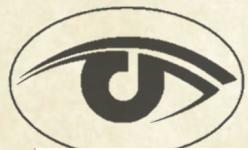
courtesy: lifepixel.com



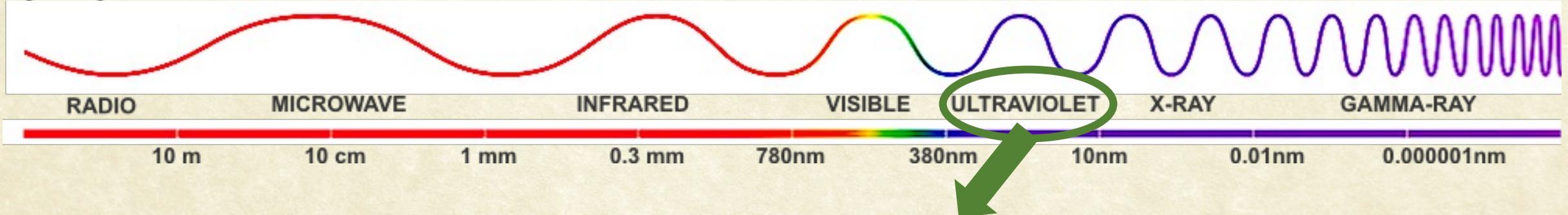
Cell Phalloidin

courtesy: wikipedia

Eric Betzig, William Moerner and Stefan Hell



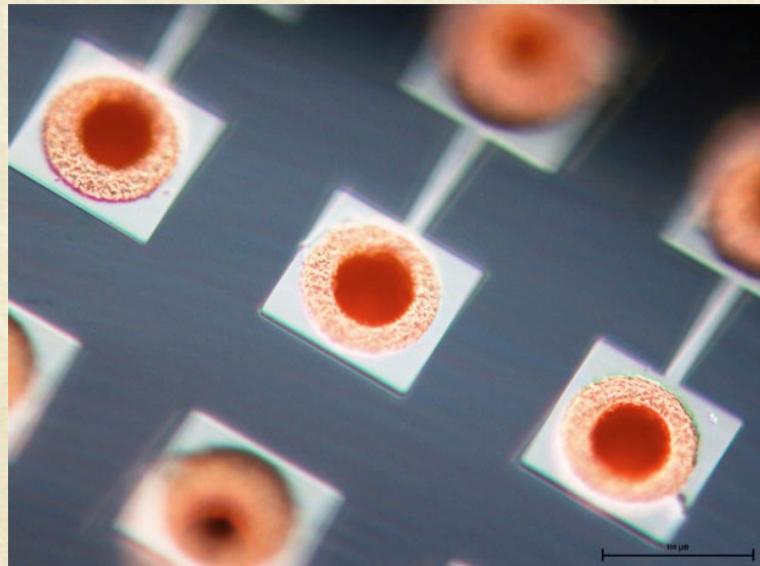
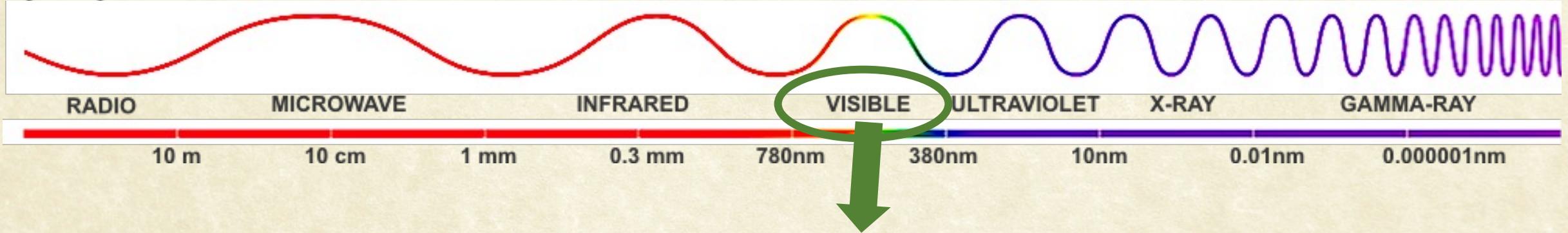
EM Spectrum



Source:
Lifepixel.com



EM Spectrum



Chips (optical microscopy)

courtesy: EPFL microelectronics systems laboratory



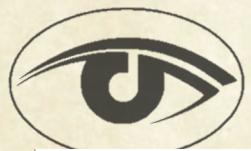
High Speed Photograph

courtesy: Alan Sailer

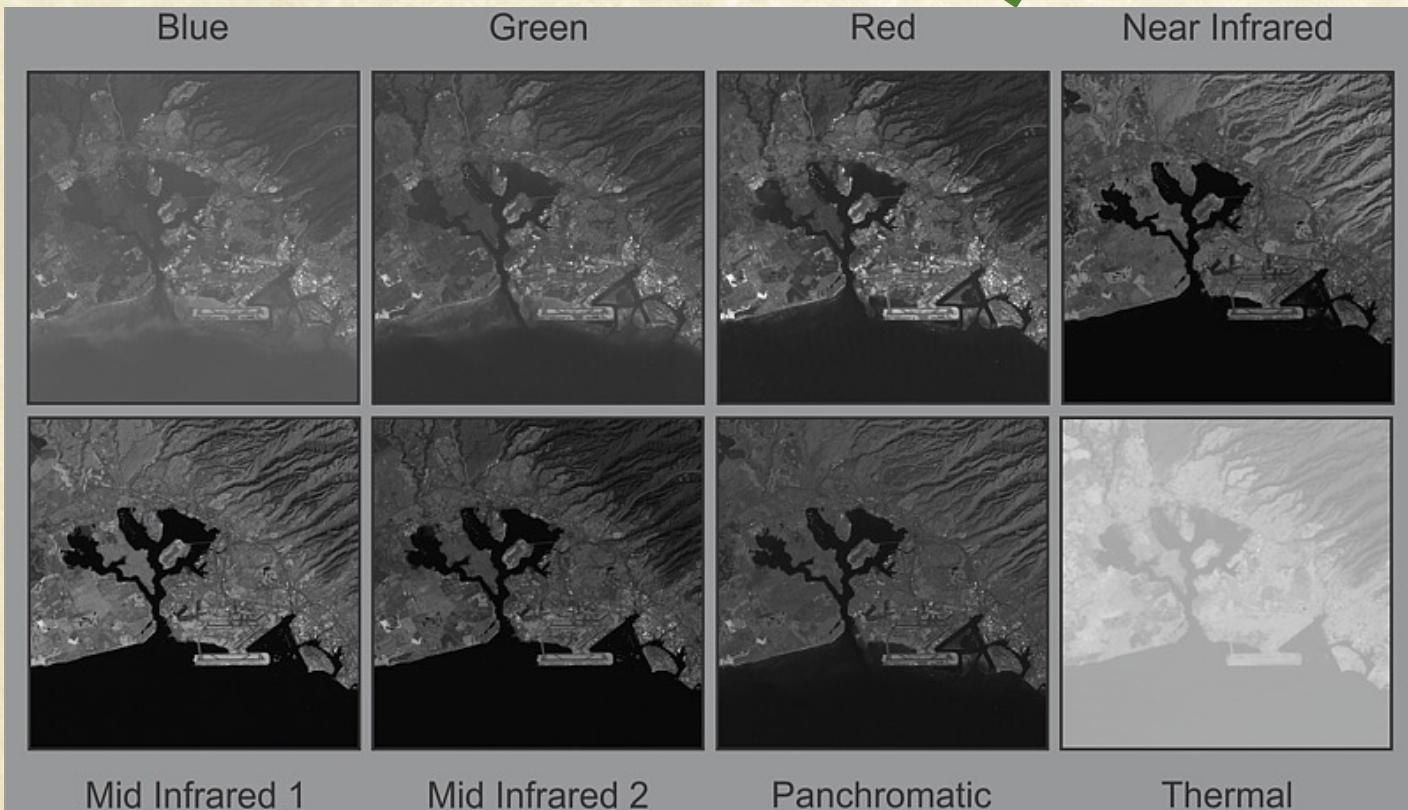
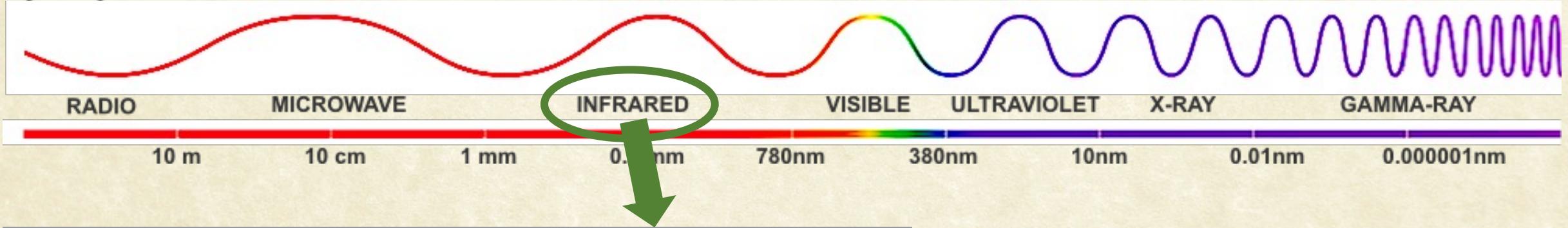


Satellite Image (Hurricane Katrina)

courtesy: britannica.com



EM Spectrum



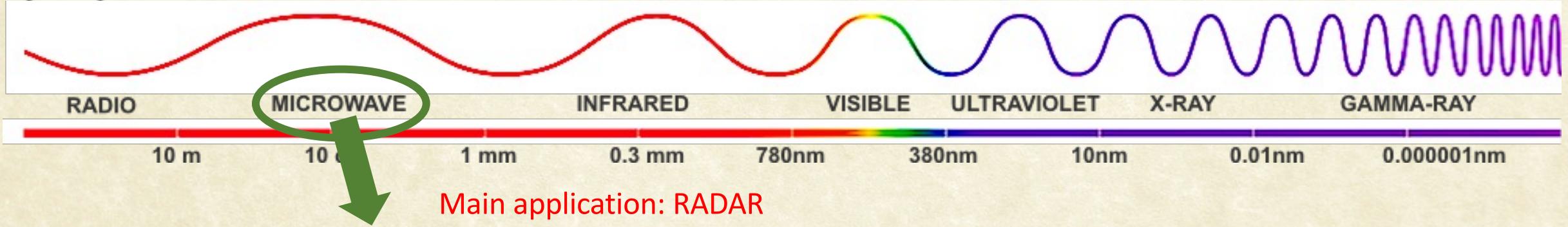
courtesy: LANDSAT (NASA)



courtesy: imaging1.com

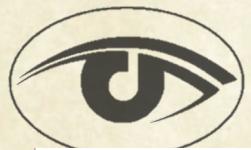


EM Spectrum

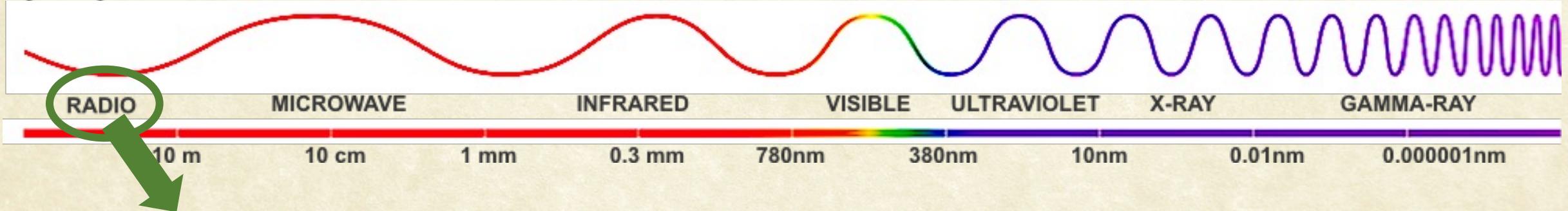


SOUTHEAST TIBET MOUNTAINS

courtesy: NASA



EM Spectrum



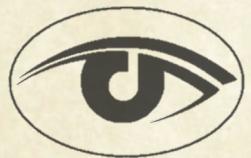
MRI Brain

courtesy: mritnt.com



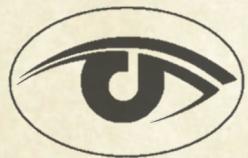
MRI Knee

courtesy: mri-tip.com



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Ultrasound



ULTRASOUND

courtesy: wikipedia



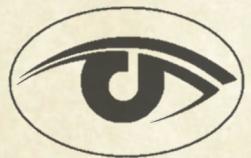
ULTRASOUND TWINS

courtesy: pinterest



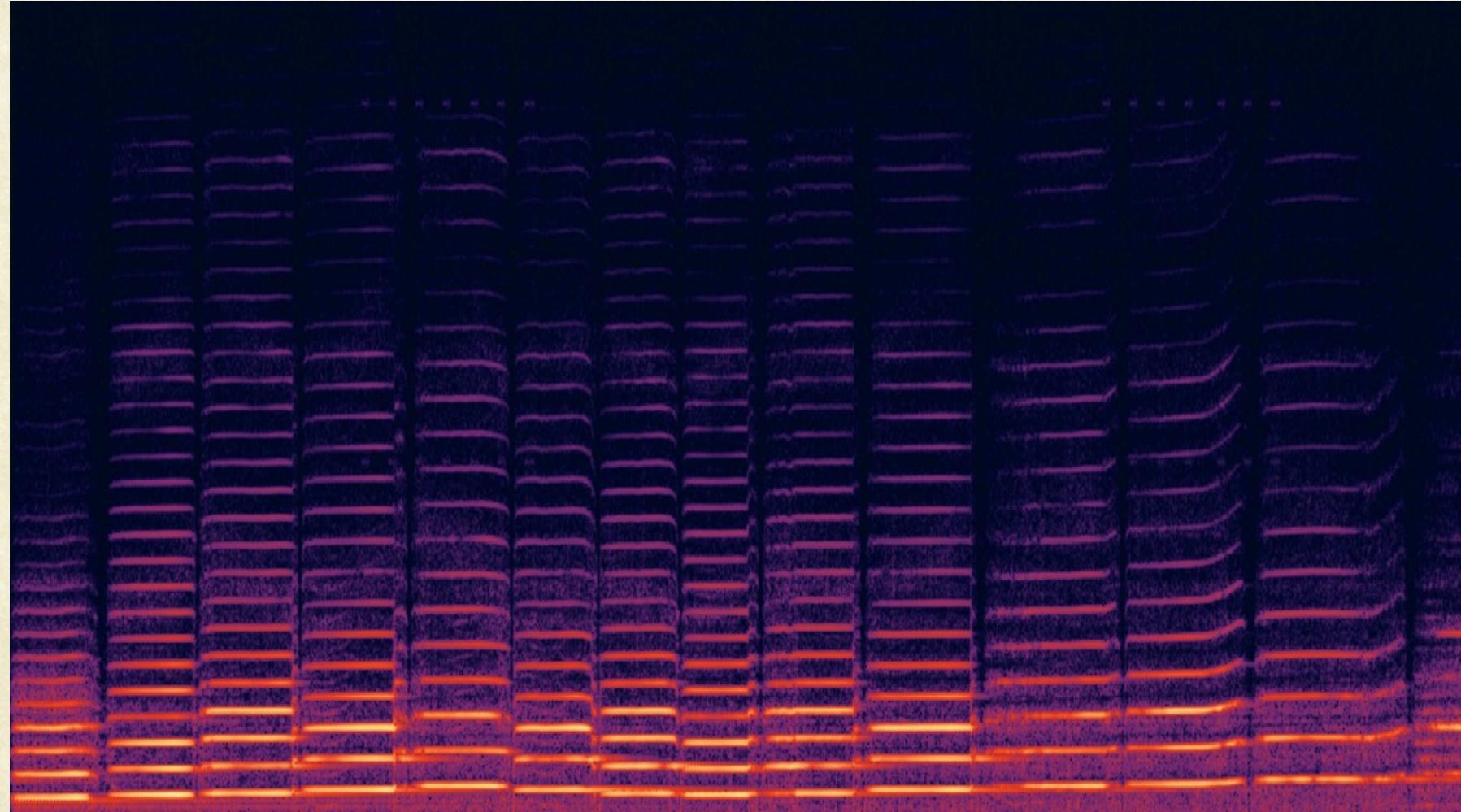
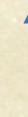
ULTRASOUND 3D

courtesy: peek3D.com



Spectrogram

Frequency (Hz)

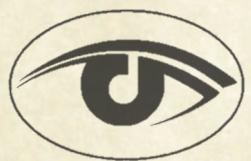


Time (seconds)

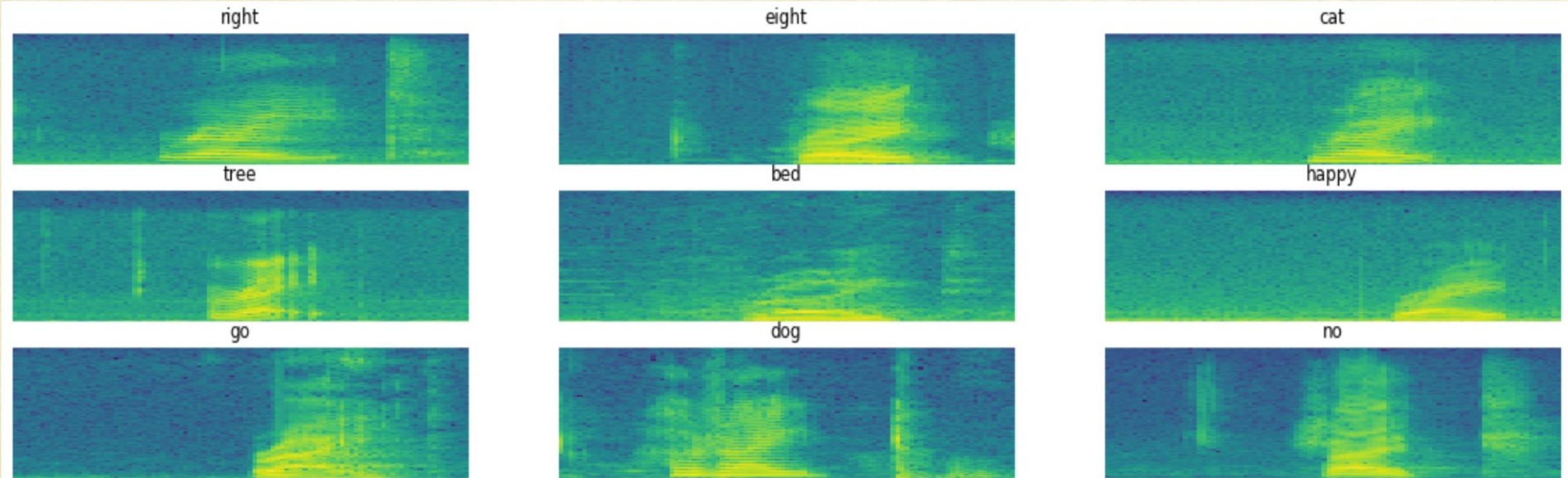
Violin Recording

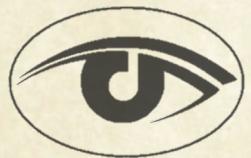
courtesy: wikipedia





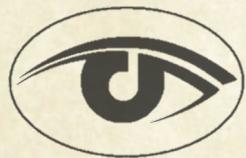
Spectrogram





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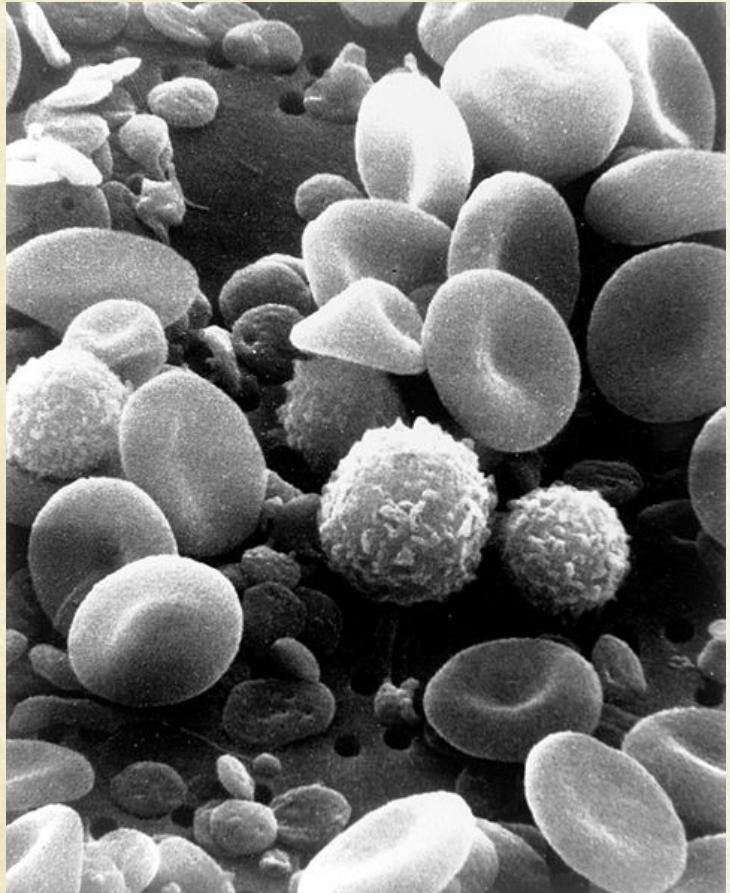


Scanning Electron Microscopy



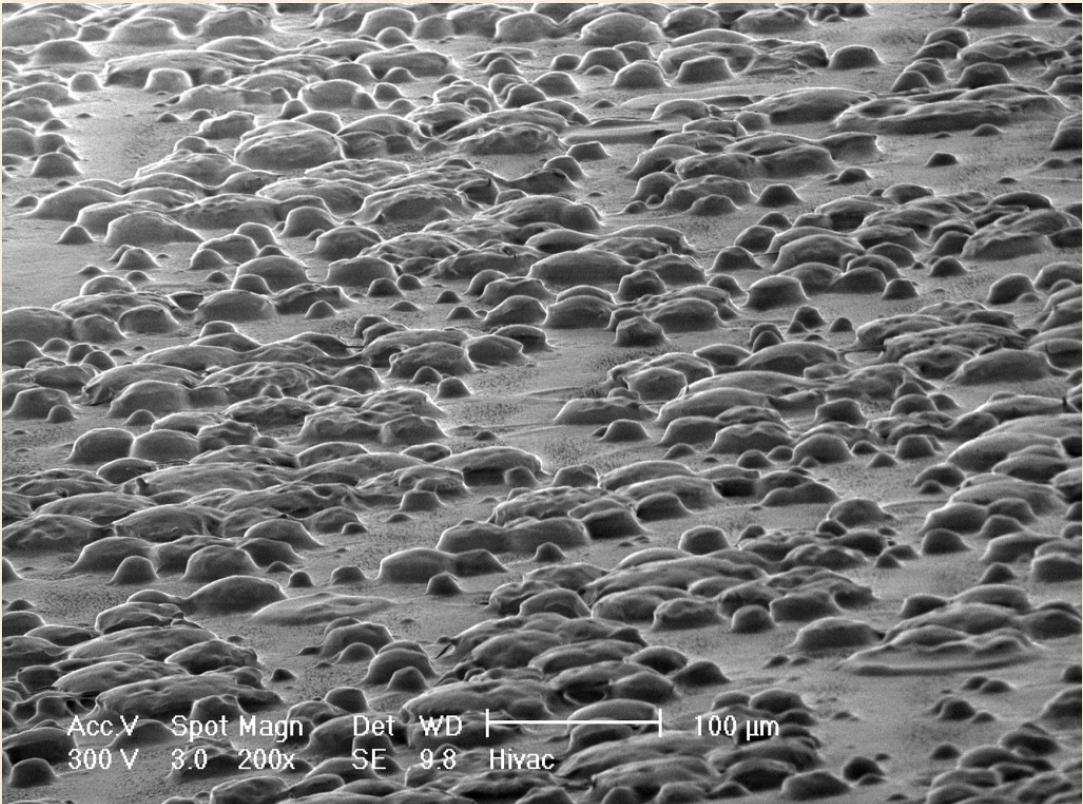
VectorStock®

VectorStock.com/23756055



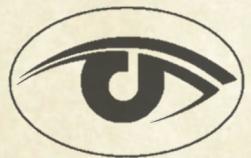
Normal Circulating Human Blood

courtesy: National Cancer Institute



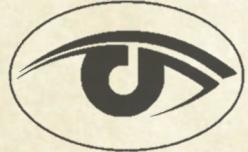
Adhesive on Post-it note

courtesy: wikipedia



Types of Images (classification on source)

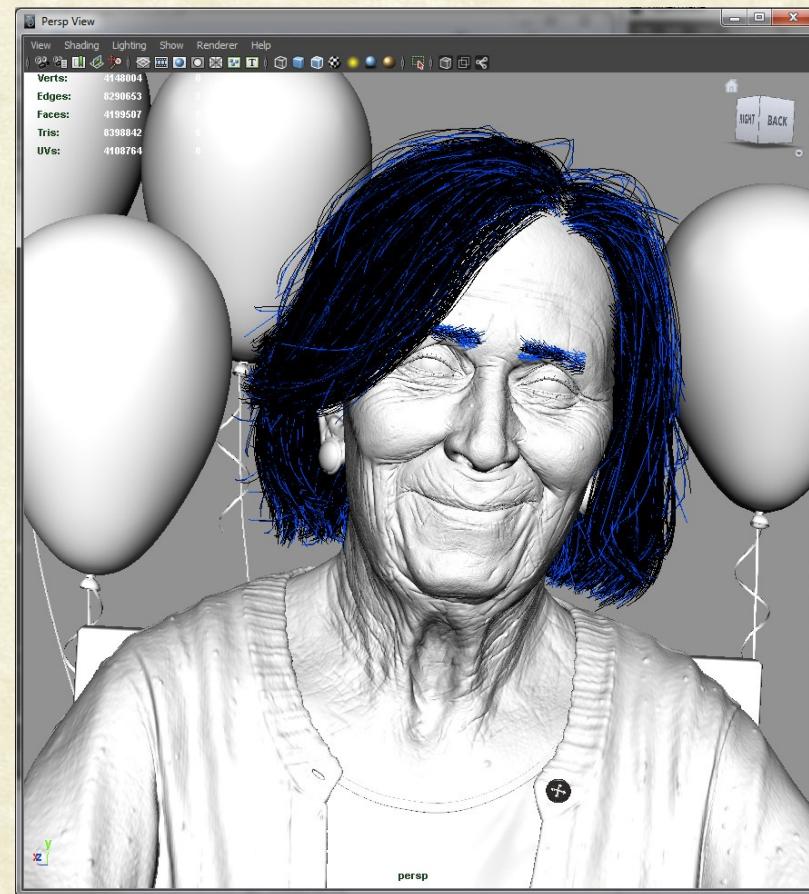
- Radiation from EM spectrum
- Acoustic/ultrasonic/spectrogram
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Computer generated



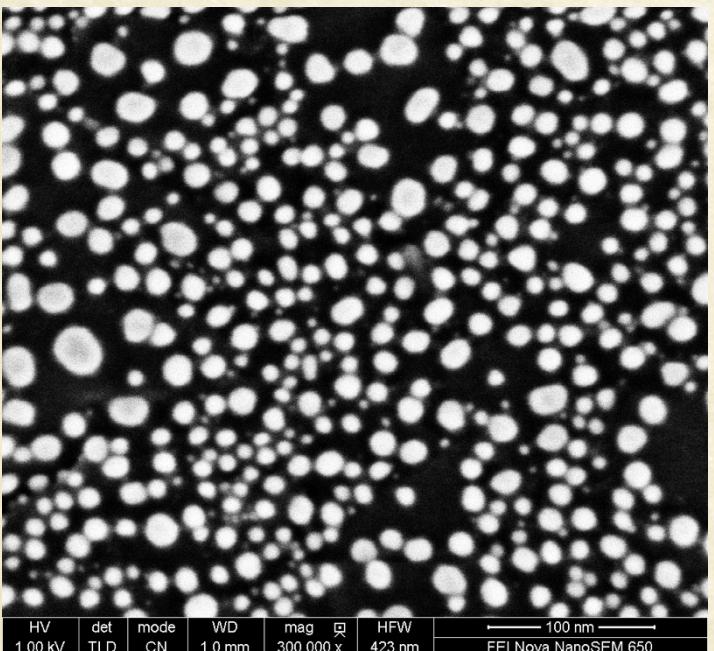
Happy Birthday Nana
courtesy: Dan Roarty





Scale

Microscopes



courtesy: nanolab technologies.com

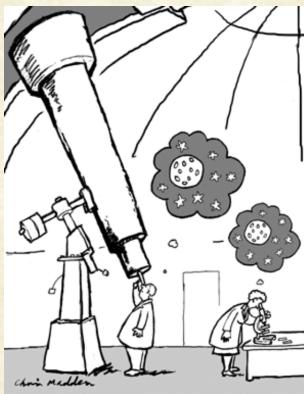


Telescopes



$220 \text{ kly} \approx 10^{21} \text{m}$

courtesy: wikipedia





Types of Images (based on light interaction)

1. Reflection Images



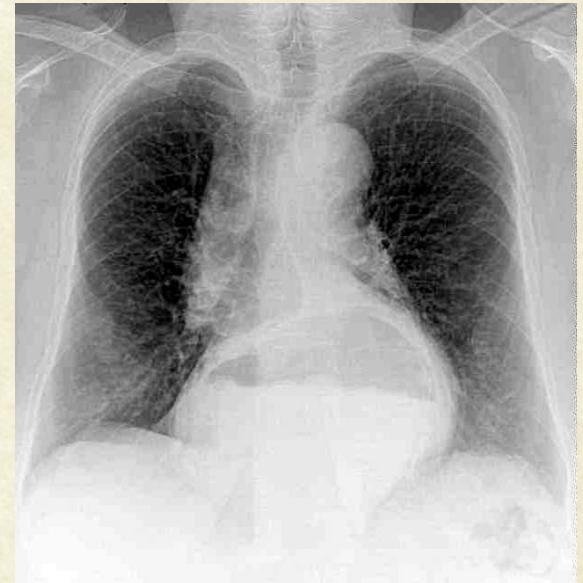
Information primarily about objects surface

2. Emission Images



Information primarily about internal properties

3. Absorption Images

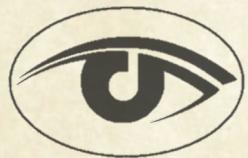


Information primarily about internal structure

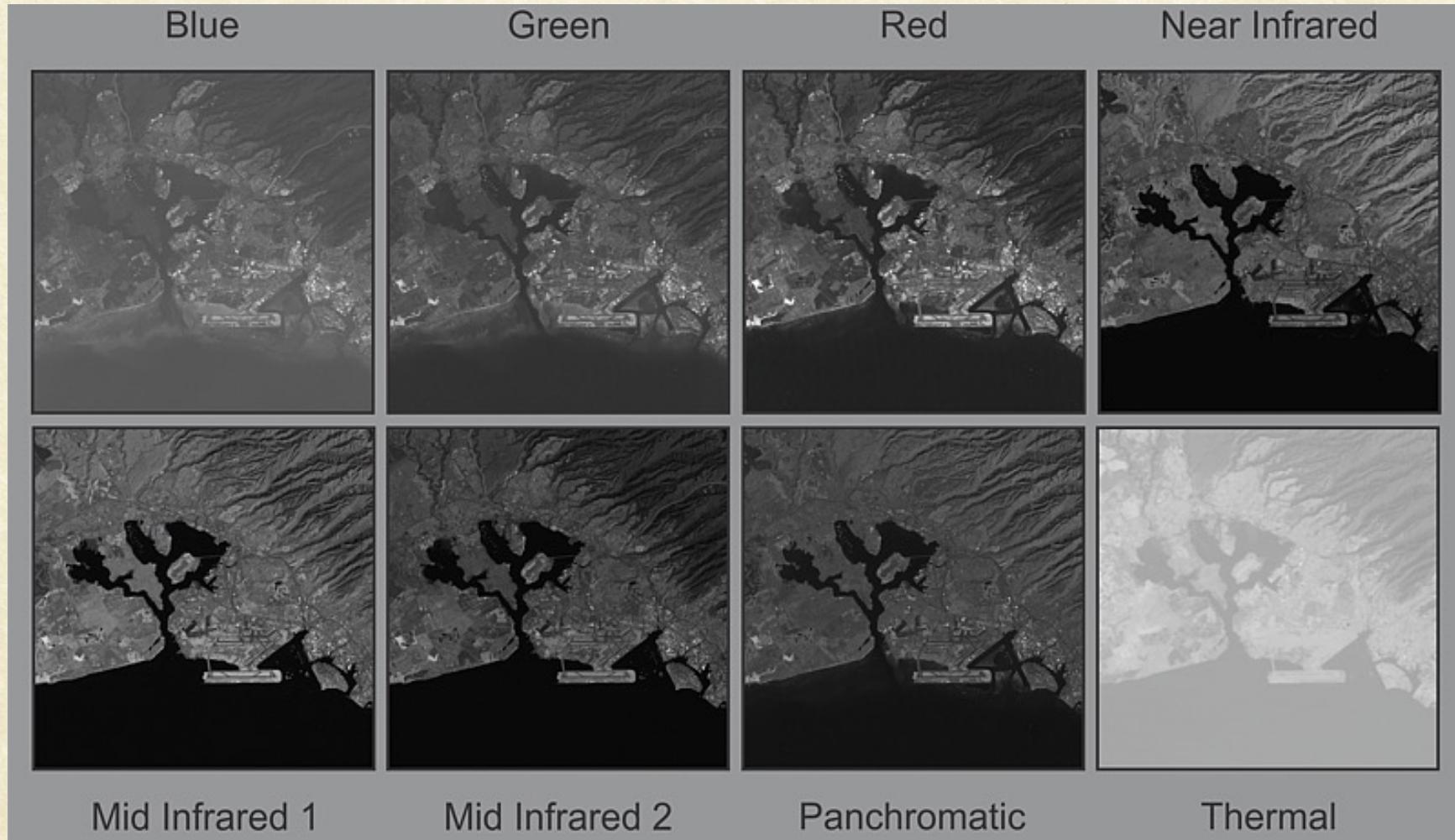


Types of Images (based on arrangement)

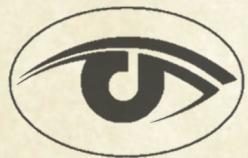
- Grayscale
- RGB
- Multispectral images
- Stereo images
- Multi-view images



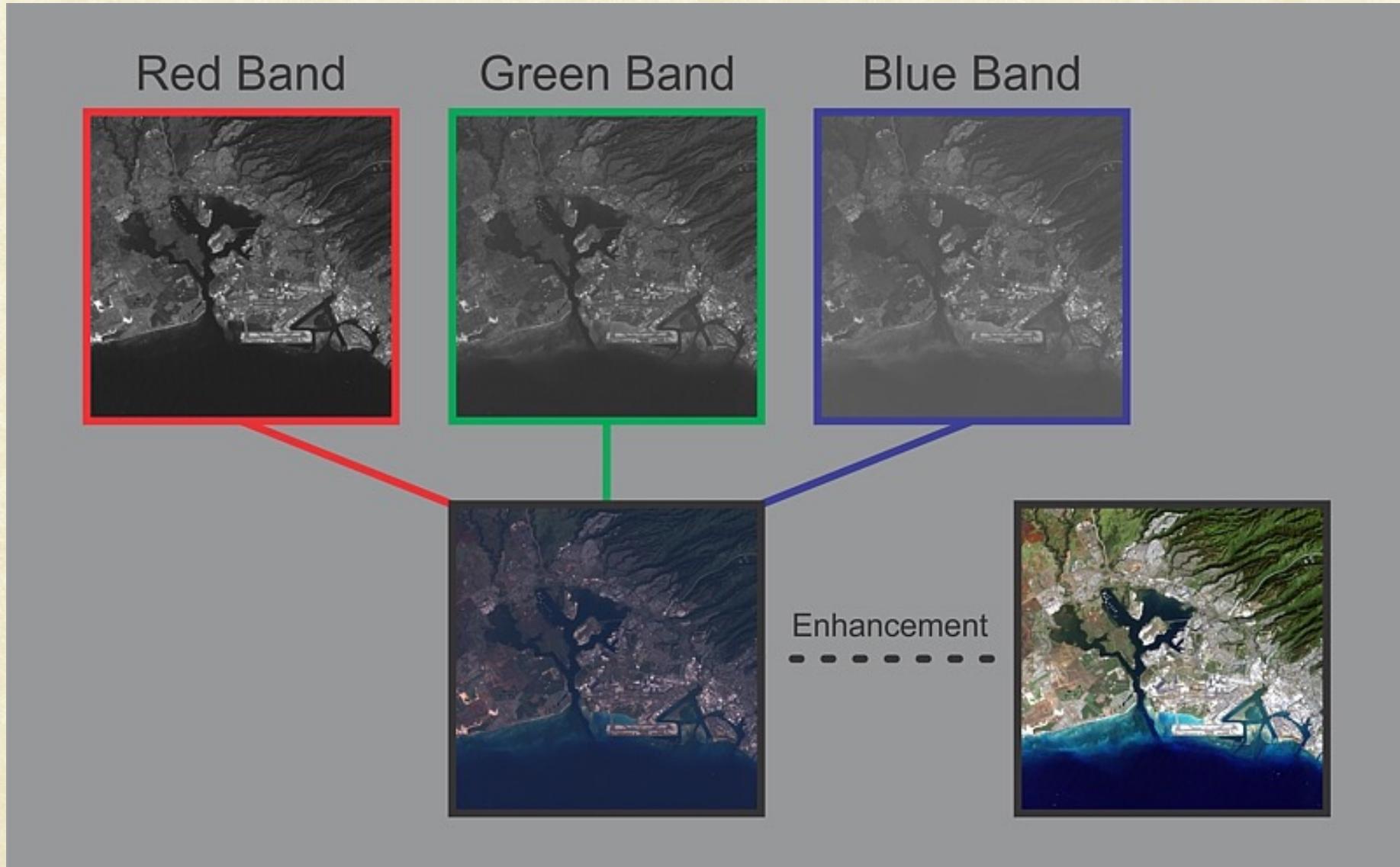
Multi-spectral Images

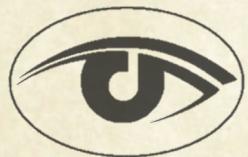


Courtesy: LANDSAT



Multi-spectral Images





Multi-spectral Images

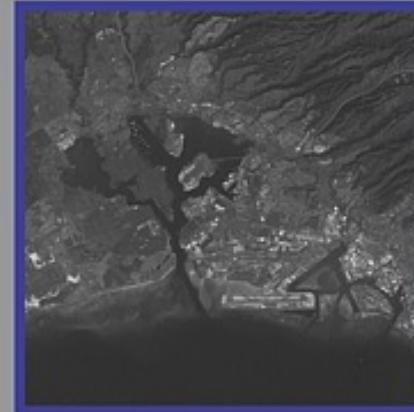
Near Infrared



Red Band



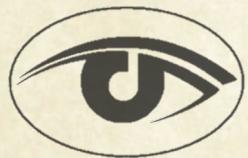
Green Band



Enhancement



Courtesy: LANDSAT



Multi-spectral Images

Mid Infrared 2



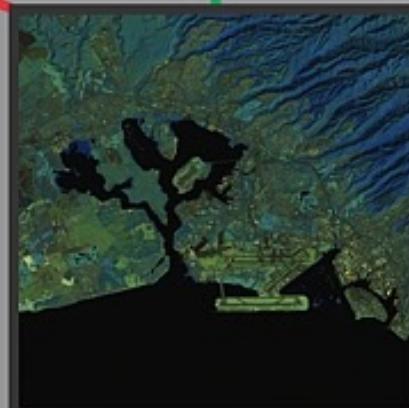
Mid Infrared 1

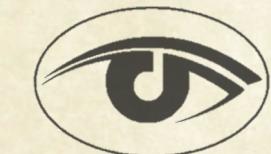


Near Infrared

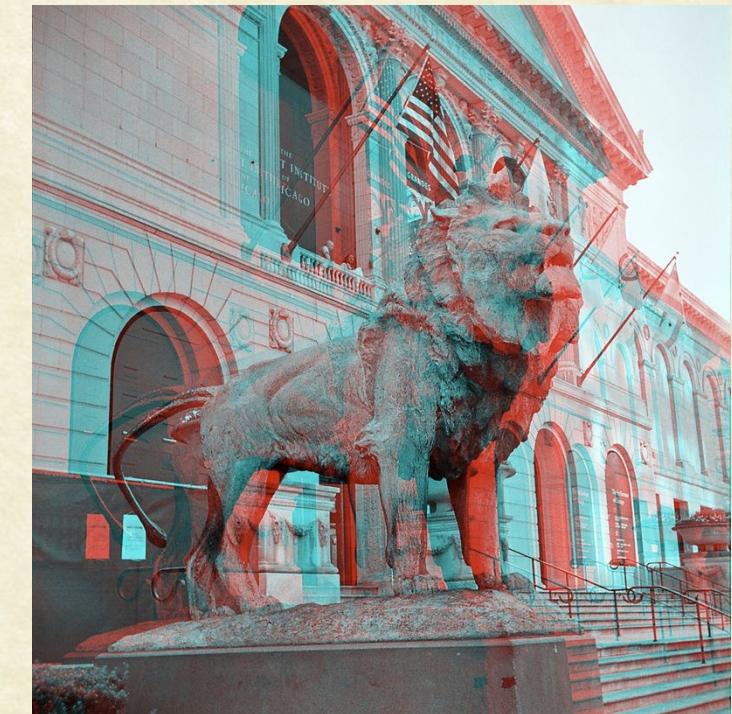


Enhancement





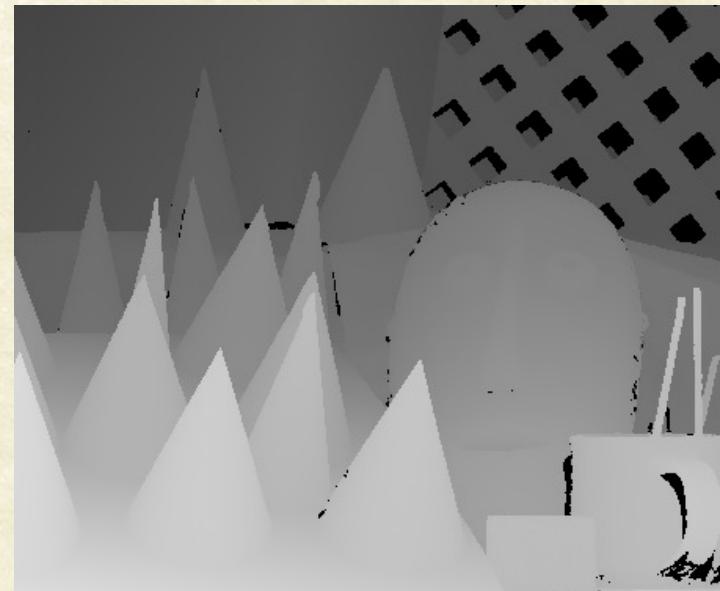
Stereo Images



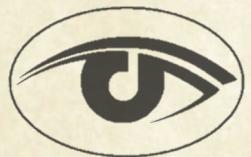
courtesy: [wikimedia.com](https://commons.wikimedia.org)



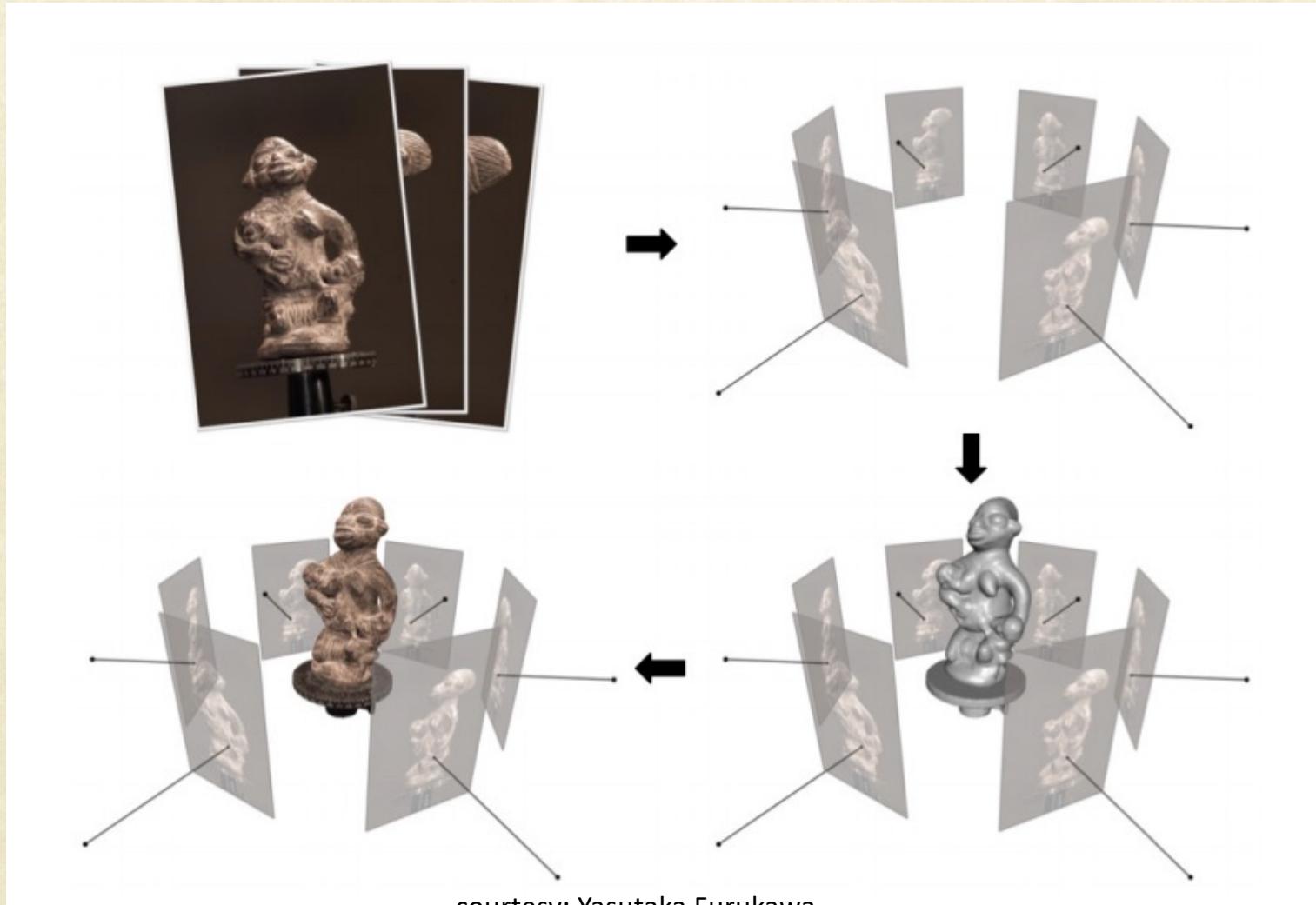
Stereo Images



courtesy: vision.middlebury.edu



Multi-view images



courtesy: Sameer Agarwal

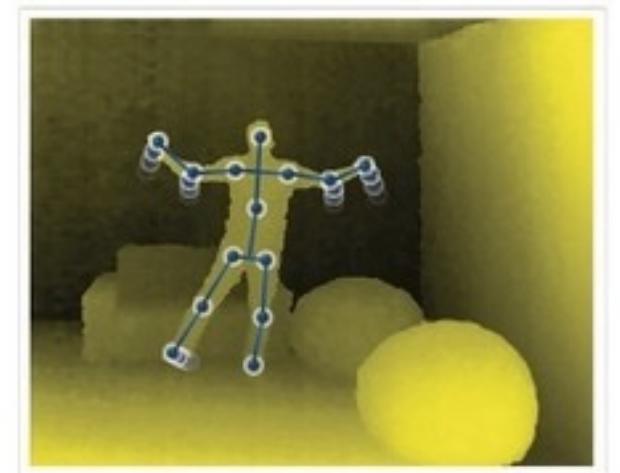


RGB-D images

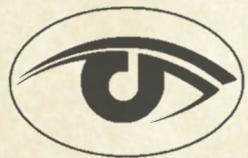
Color (RGB) Image



Depth Image



courtesy: kinect and prime sense



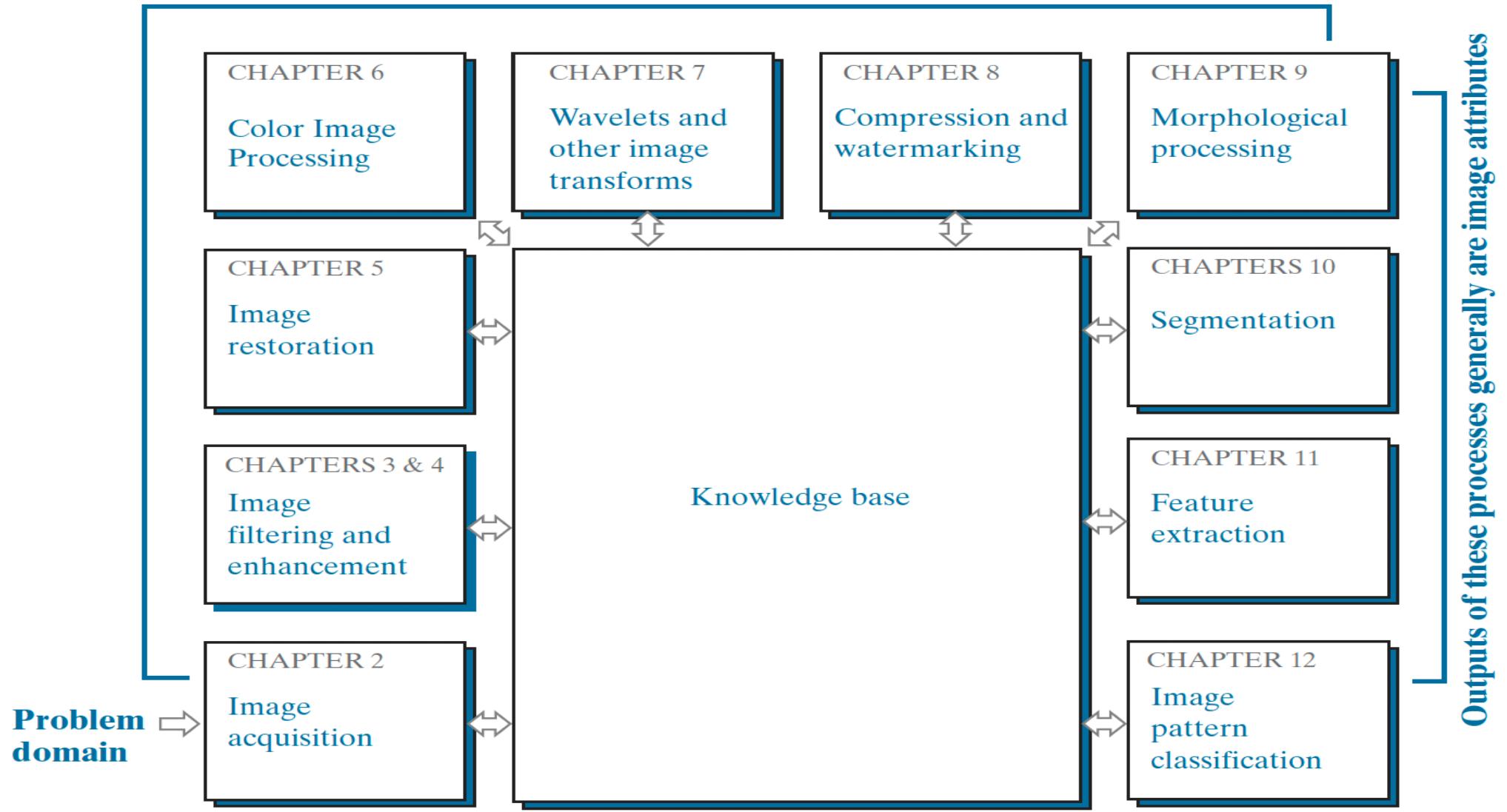
Digital Image Processing

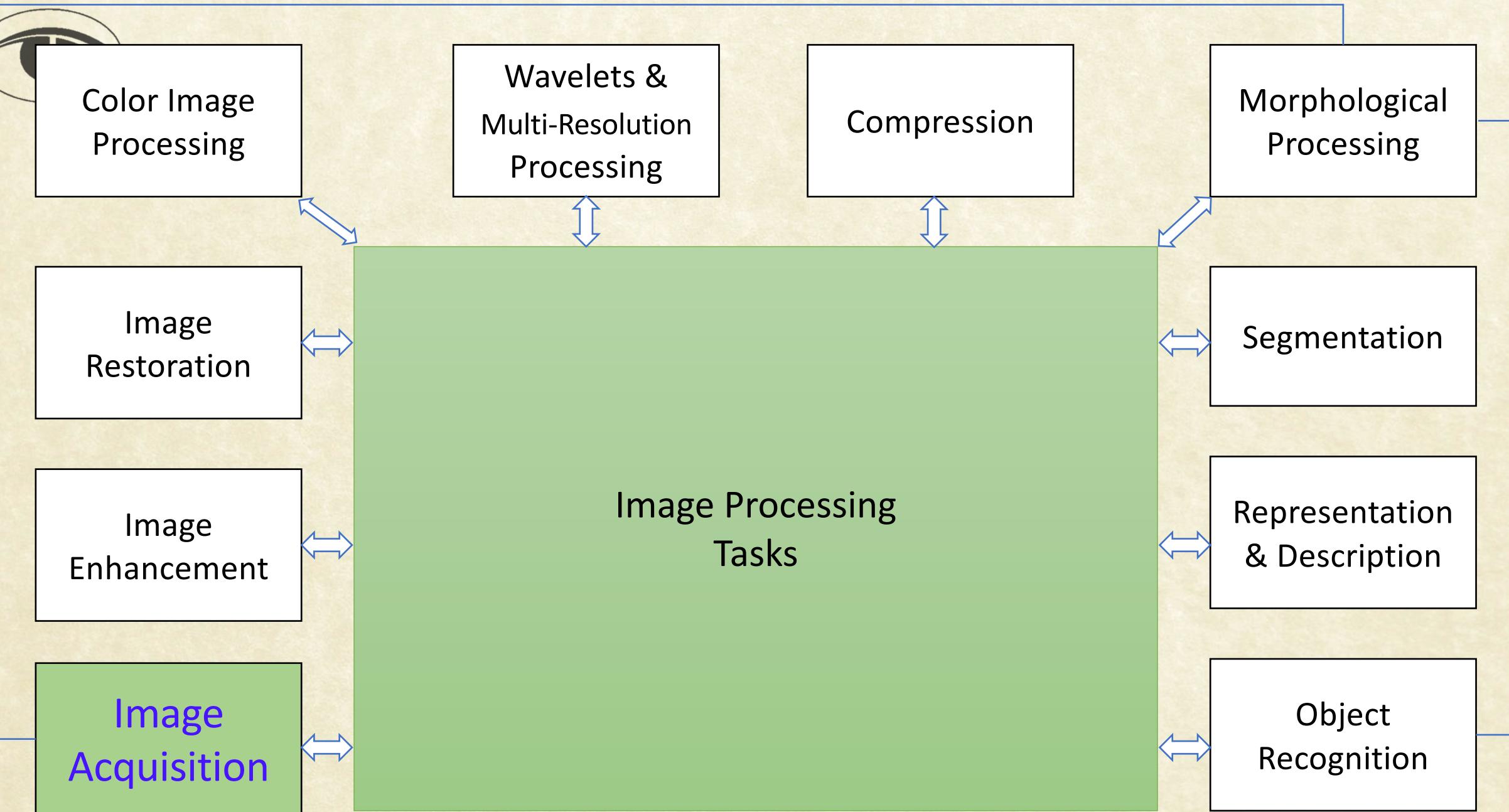
- Study and Development of algorithms that operate on an image
 - To create new images
 - To retrieve its attributes
- Consumer-based view
 - For consumption by human eyes
 - For consumption by machine-based processes

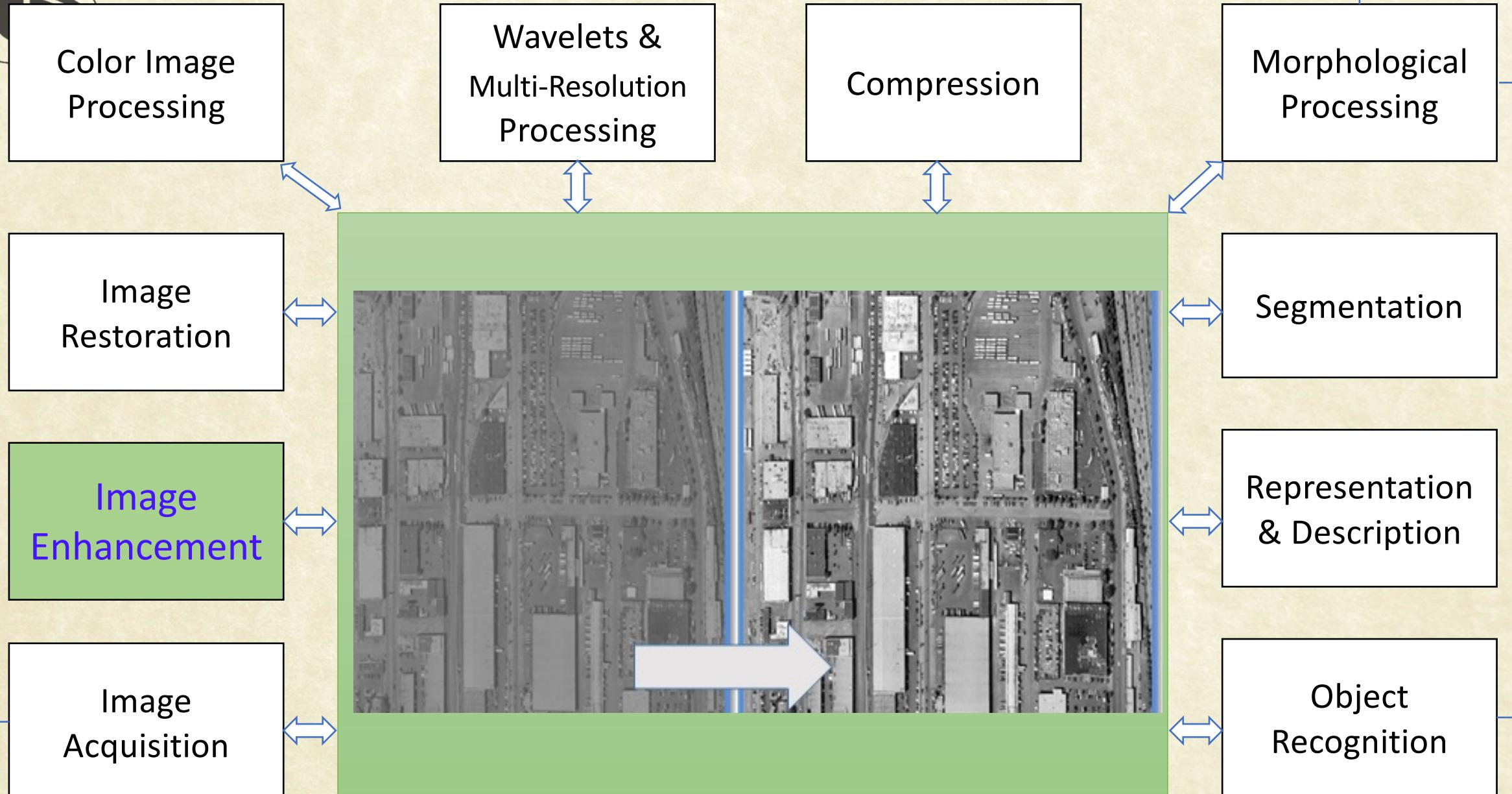


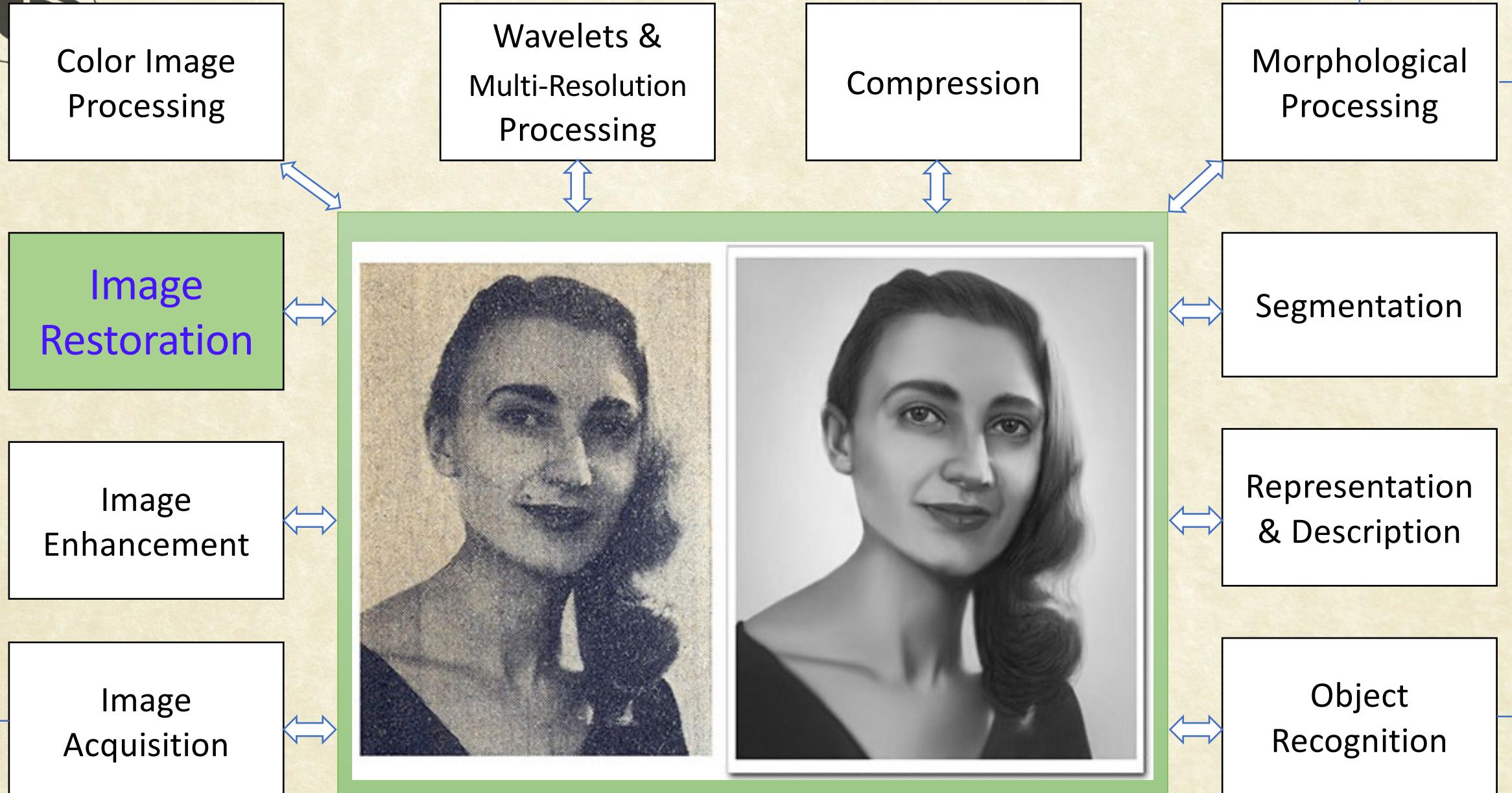
Image Processing Tasks

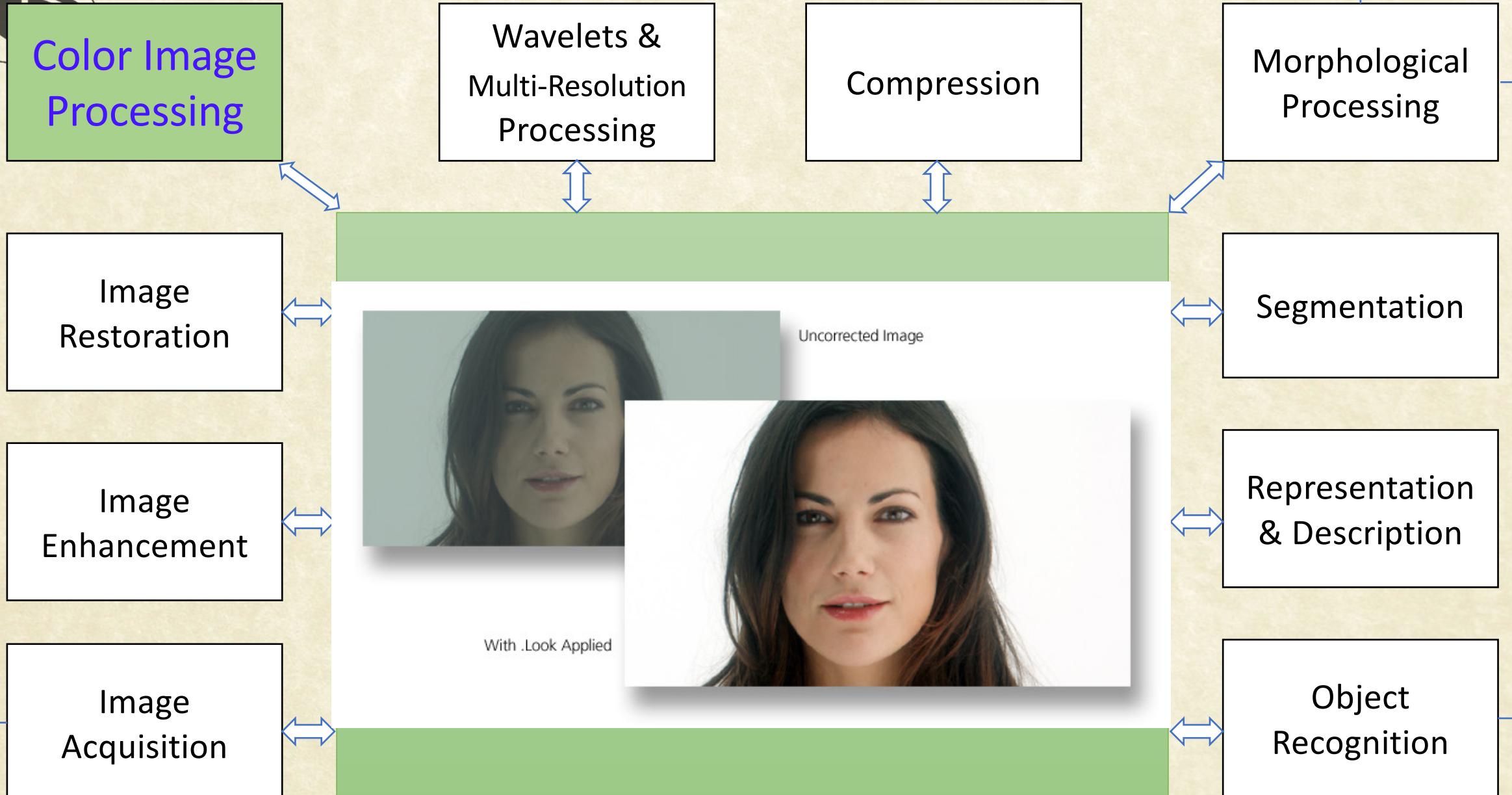
Outputs of these processes generally are images

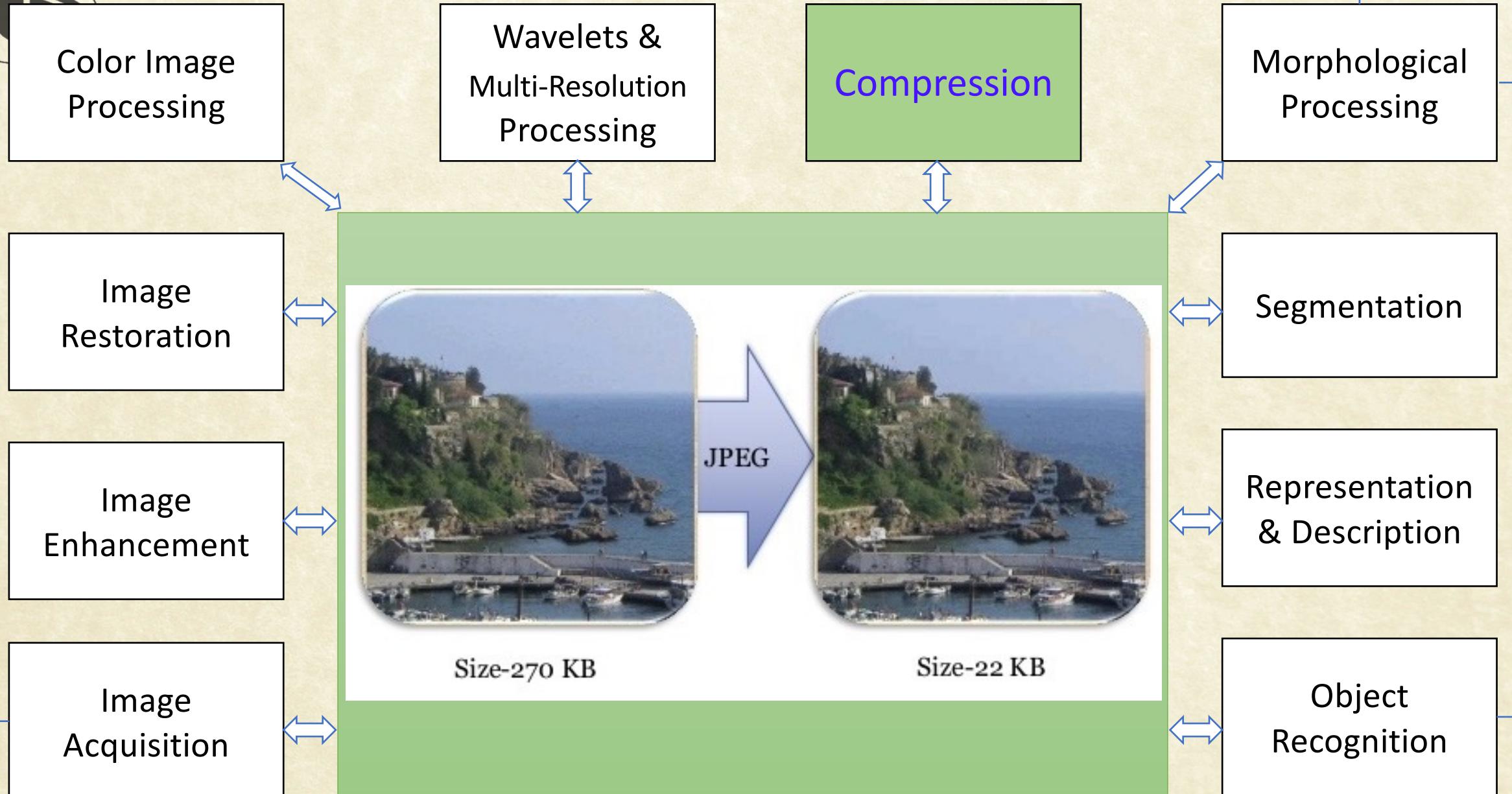


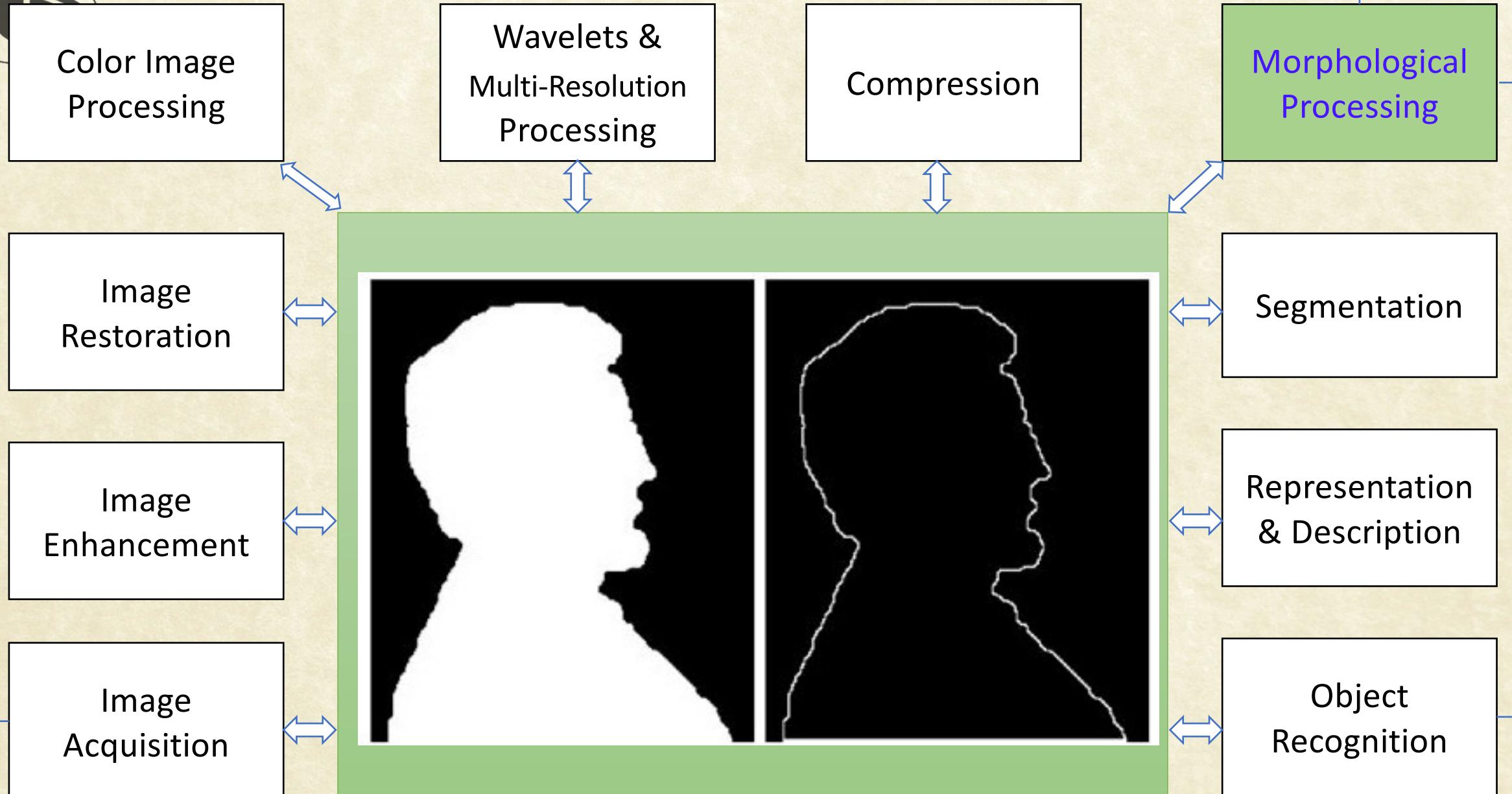


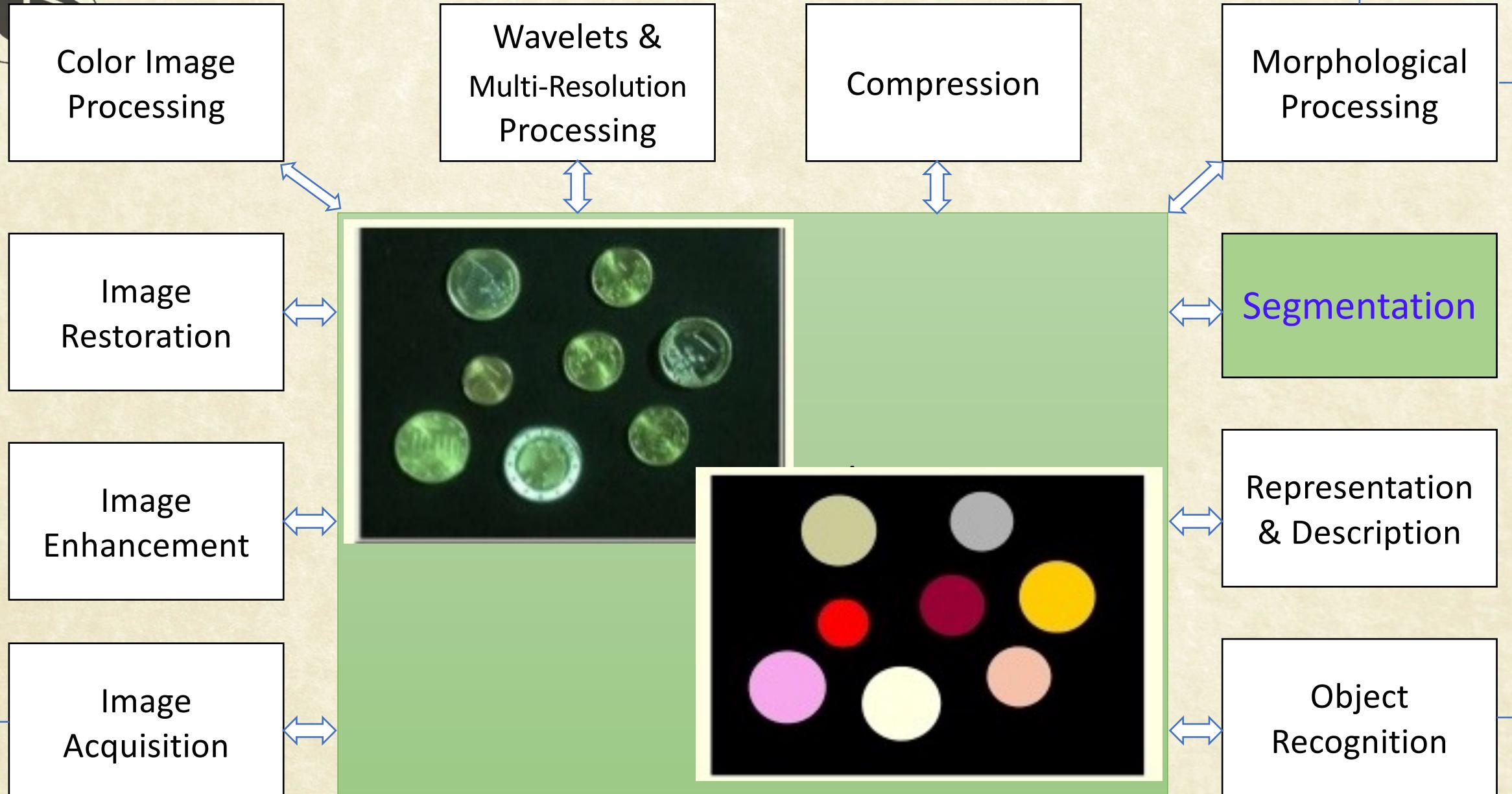


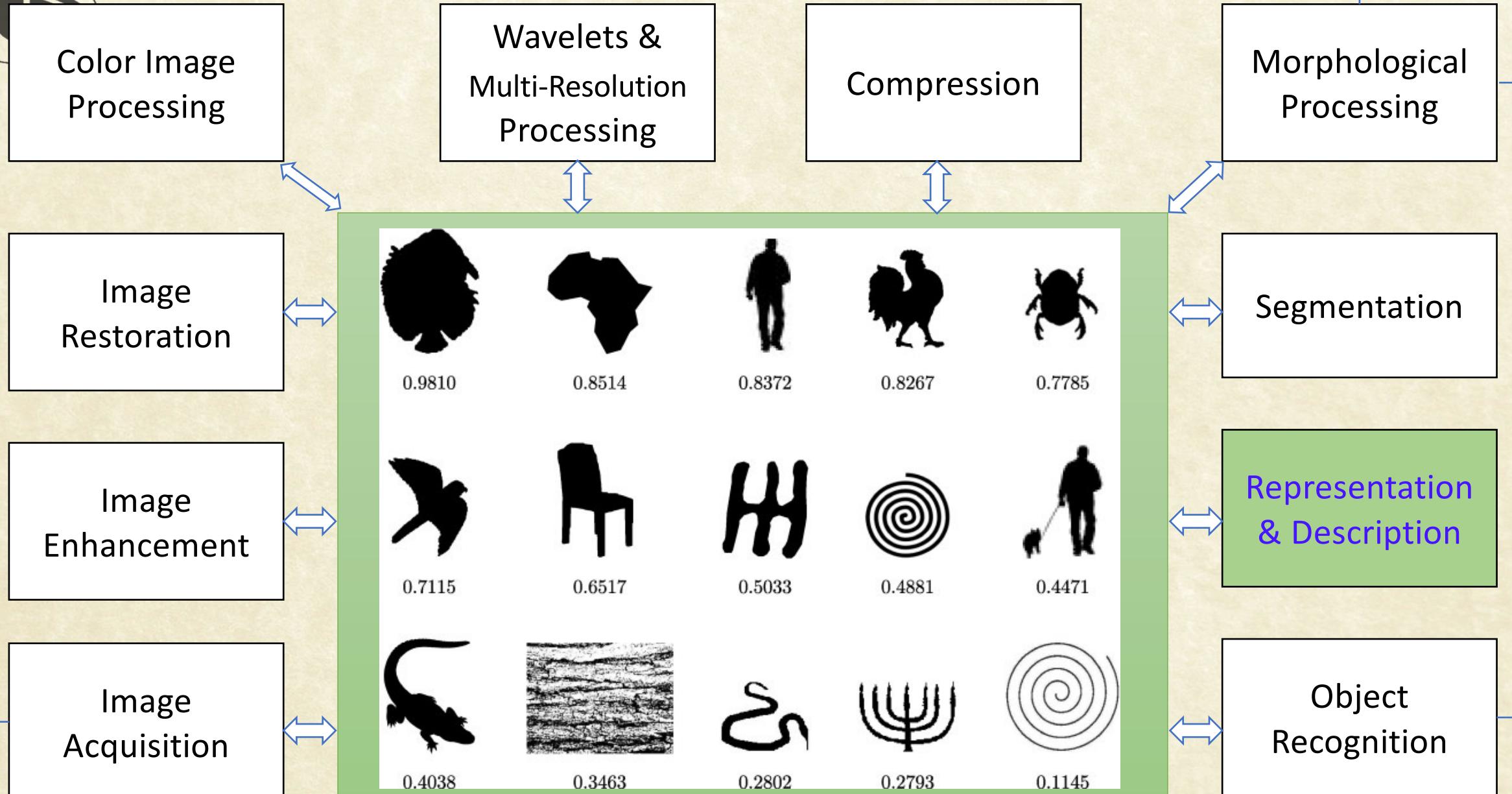


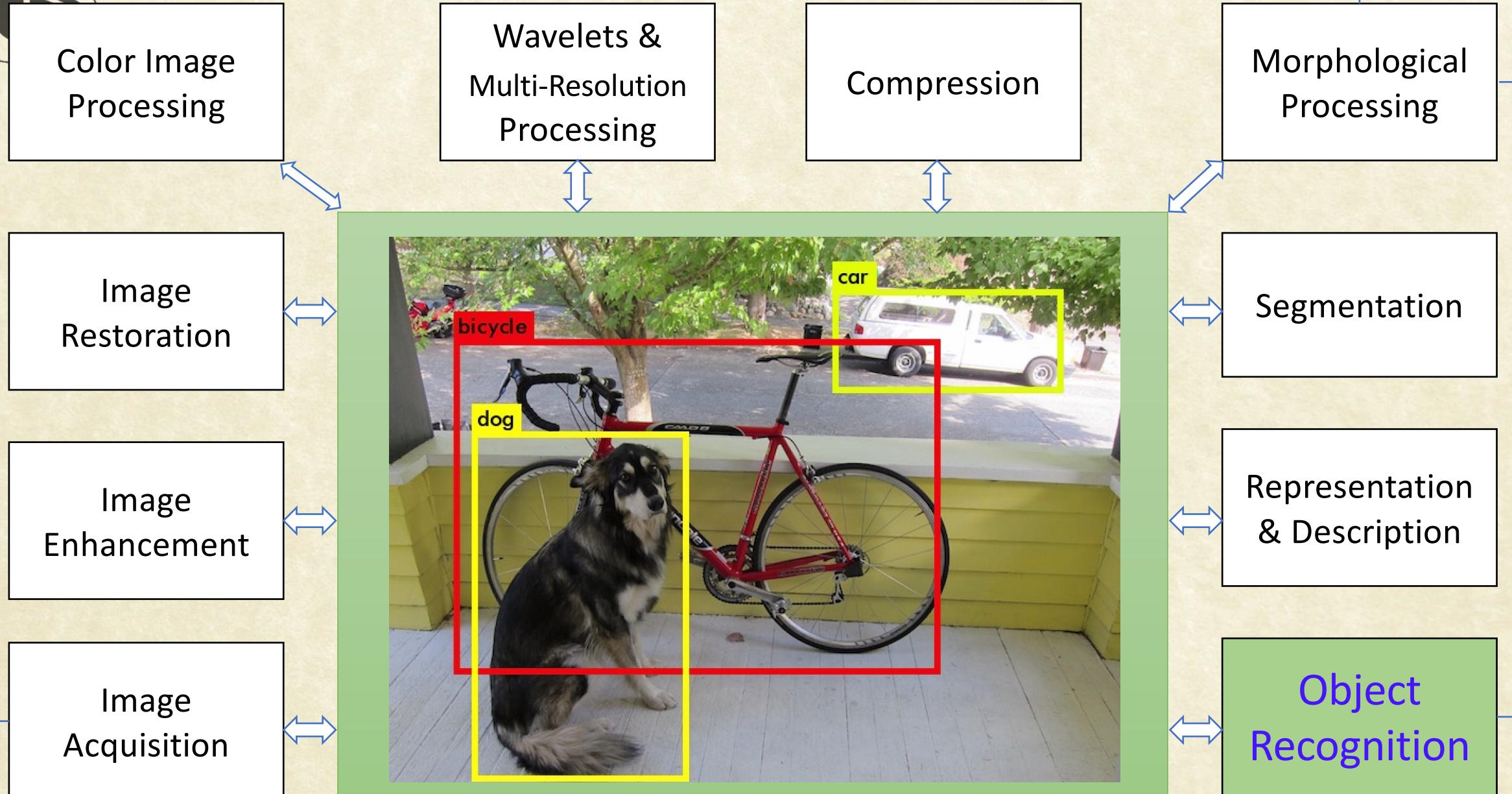


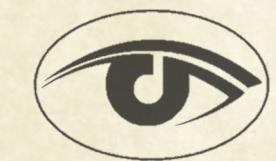






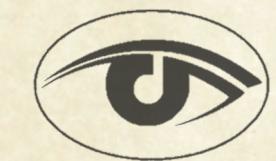






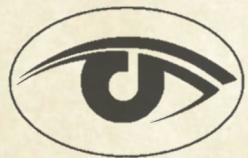
Tasks of Interest: Contrast Adjustment





Tasks of Interest: Edge Detection





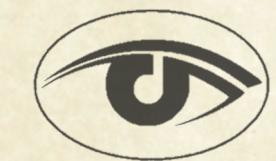
Tasks of Interest: Feature detection + stitching



Image courtesy: opencv



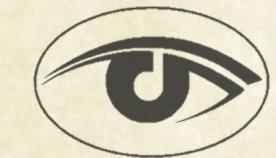
Image courtesy: autostitch



Tasks of Interest: Noise Removal



Total variation denoising [Chambolle JMIV 2004]



Tasks of Interest: Haze Removal



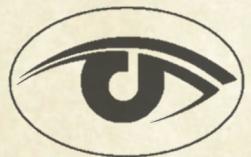
Single Image Haze Removal [He et al. CVPR 2009]



Tasks of Interest: Retouch Personal Photos



©Images taken from the web.



Tasks of Interest: Artistic enhancement



Before



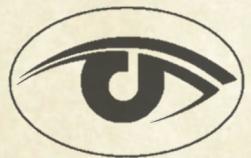
After

Image courtesy: webneel.com



Image courtesy: Jon Morse





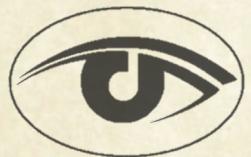
Tasks of Interest: BW to Color

Mayabazar (1957), Vijaya Vauhini Studios



Colorized (2010)



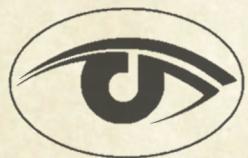


Tasks of Interest: Cinematic Grading

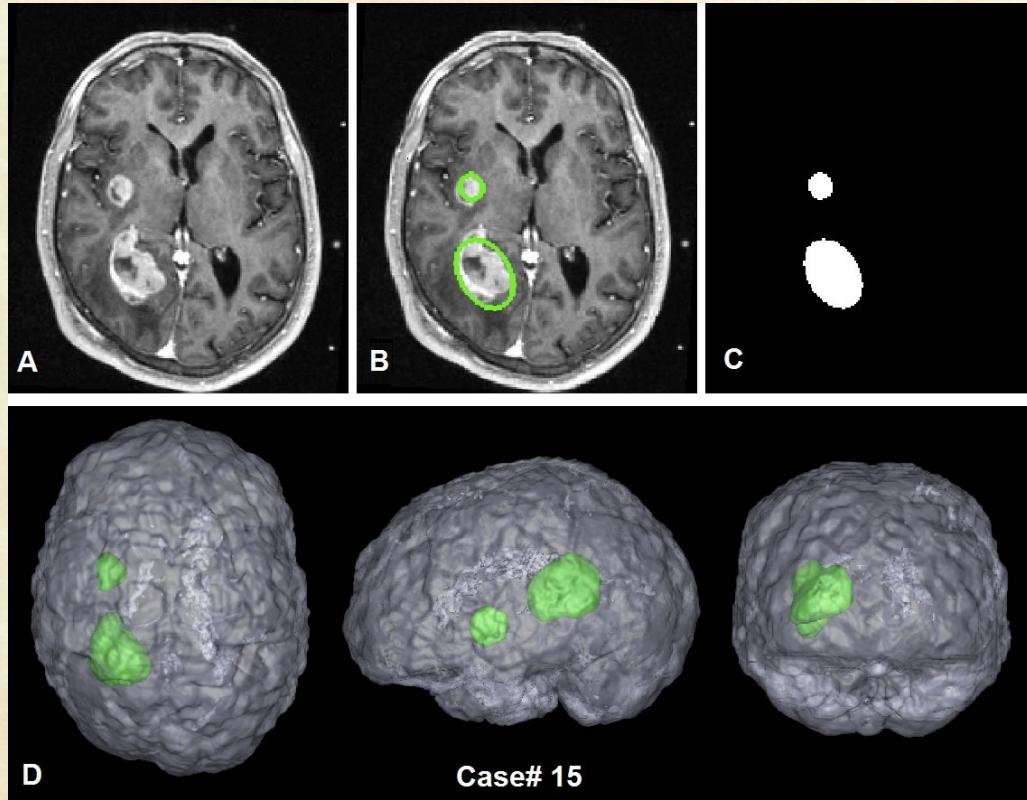
Mission Impossible - Ghost Protocol, Paramount Pictures



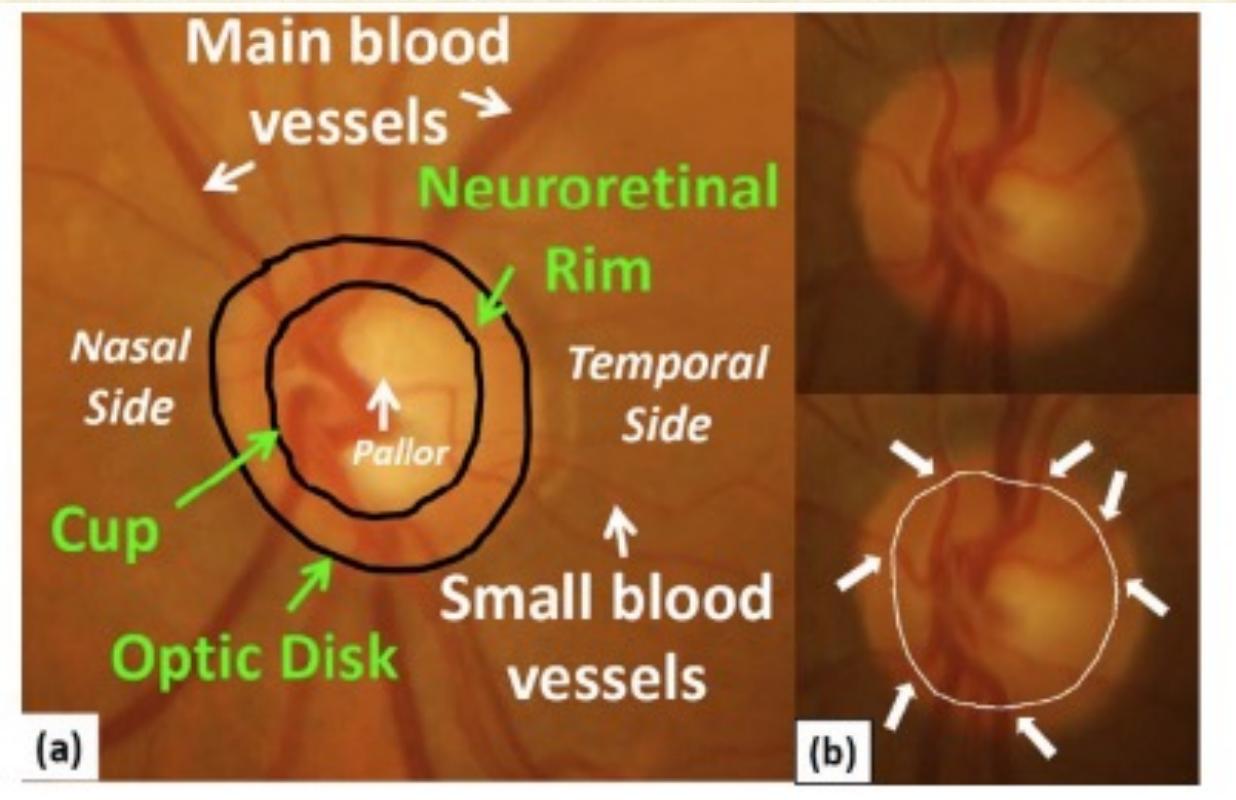
Image courtesy: juanmelara.com



Tasks of Interest: Segmentation



Tumour Segmentation [Yu et al. MICCAI 2010]



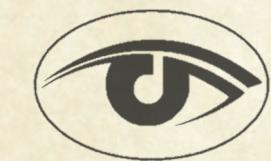
Cup Segmentation [Joshi and Sivaswamy 2011]



Tasks of Interest: Segmentation

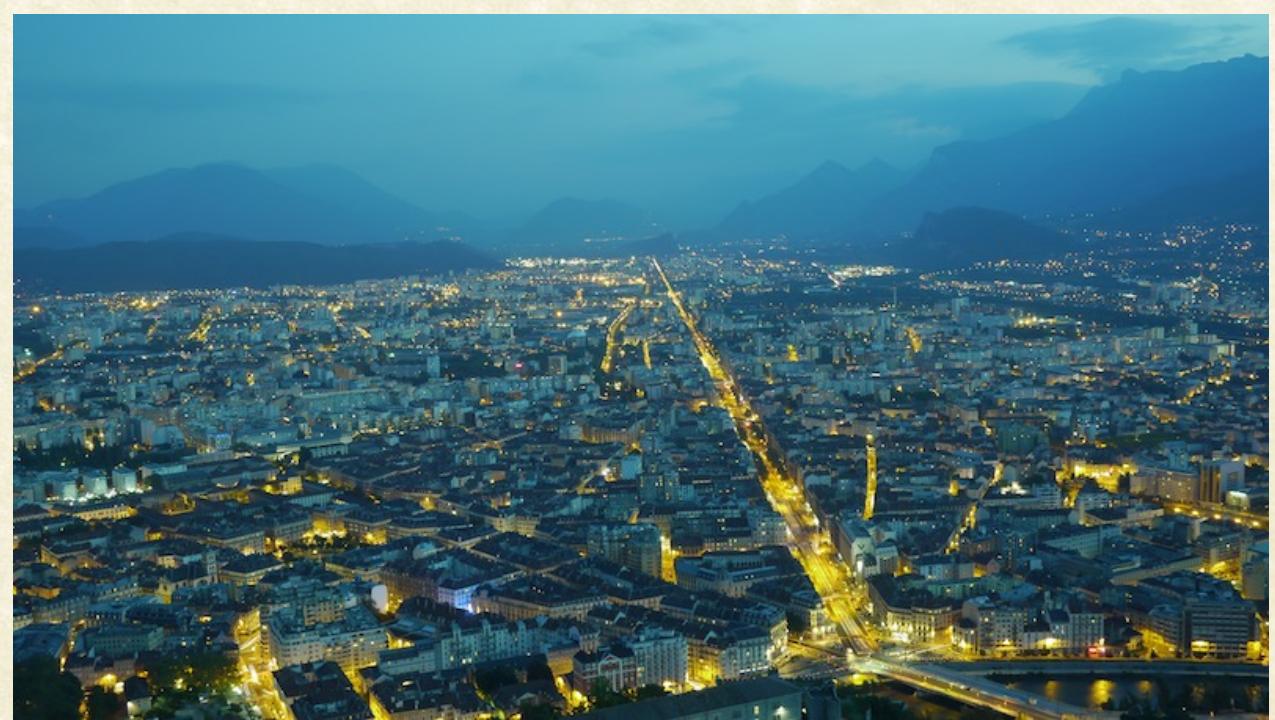


Courtesy: Roman Shapovalov



Tasks of Interest: Compression

Original Image
(1.2 mb)



Compressed JPEG Image
(100 kb)





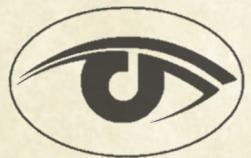
Tasks of Interest: Inpainting

DAMAGED



RESTORED





Tasks of Interest: Special effects



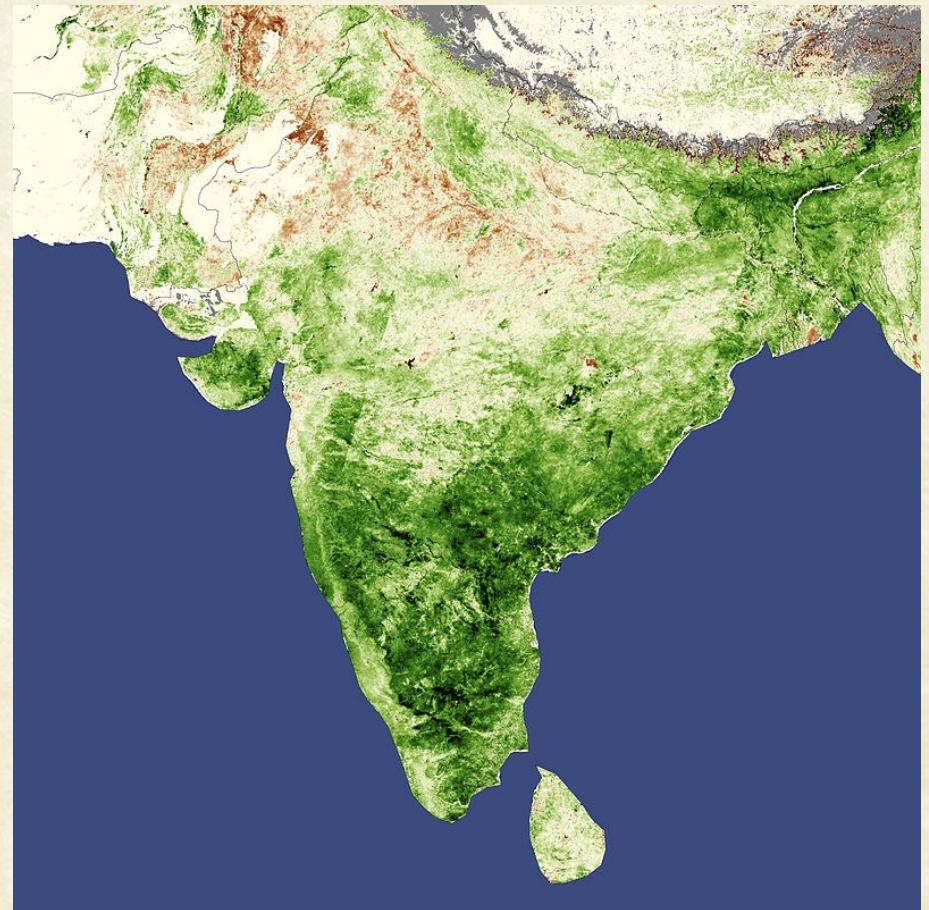
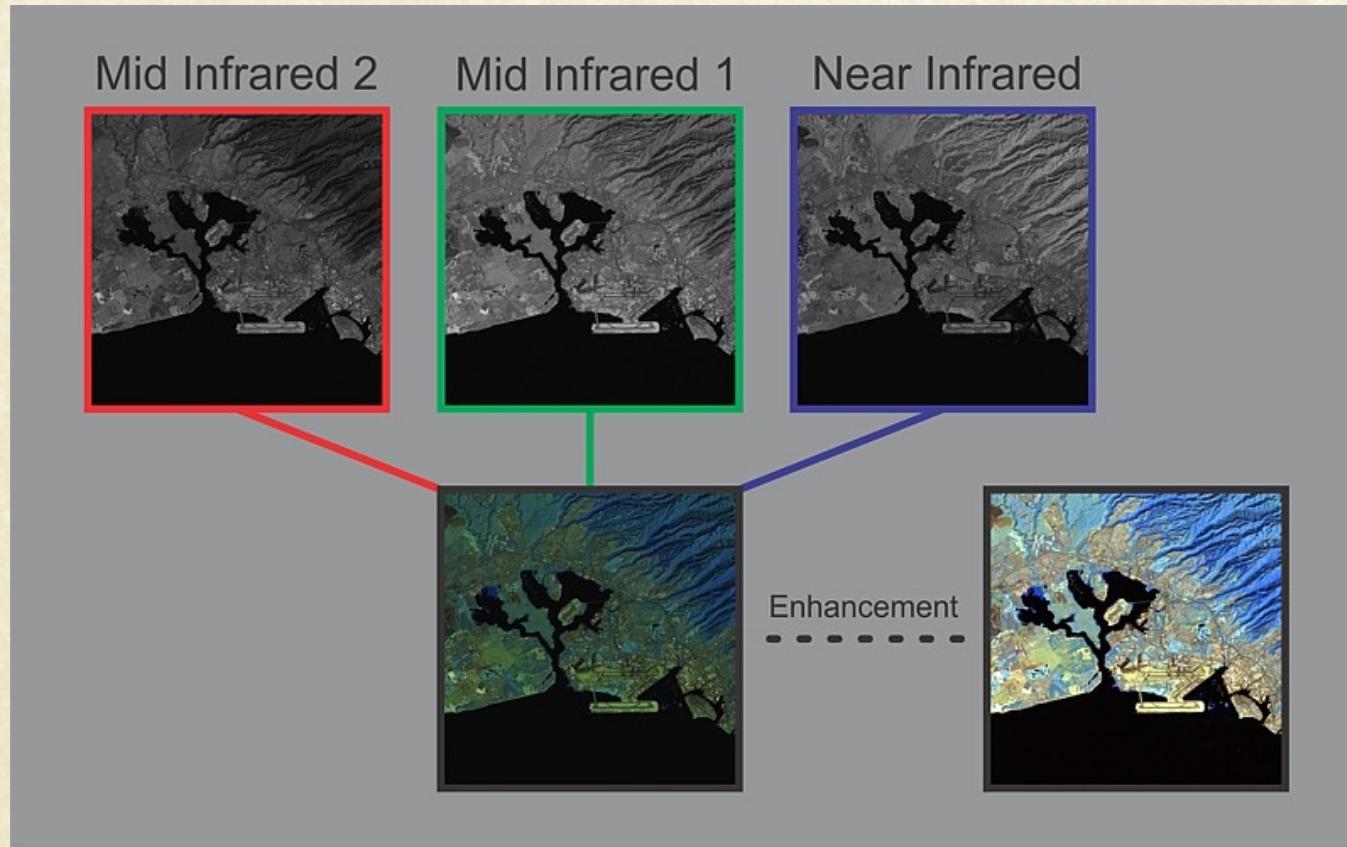
courtesy: wachowski brothers (matrix)



courtesy: Miller et al. (sin city)

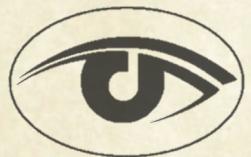


Tasks of Interest: Satellite imaging

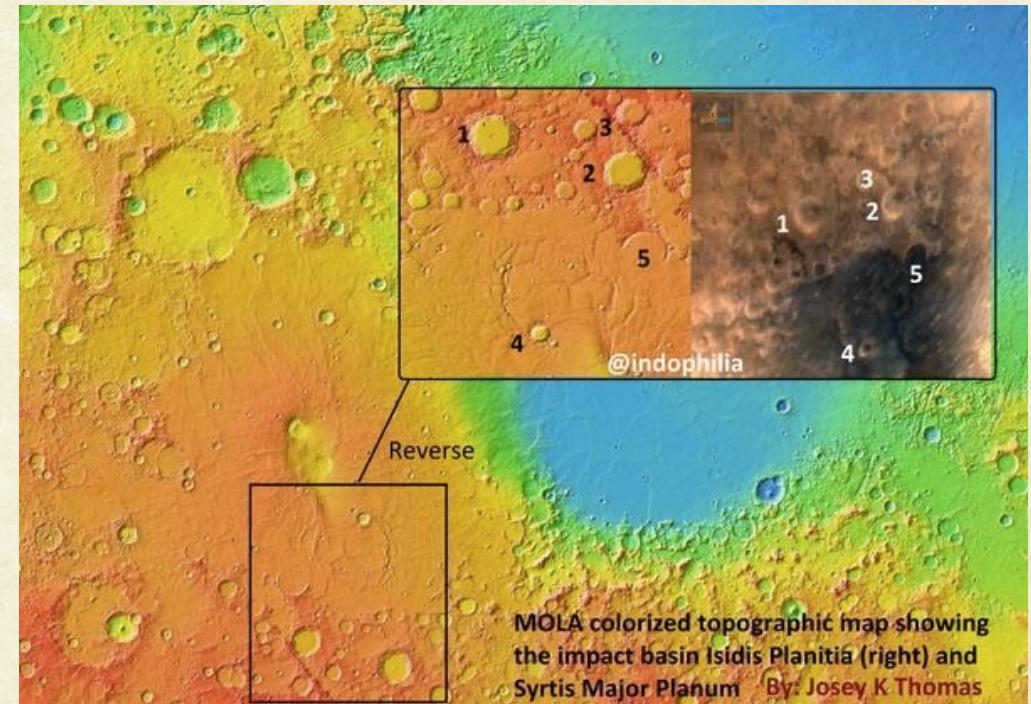


Terrain classification, weather predictions etc.

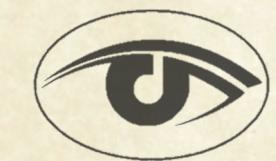
courtesy: NASA



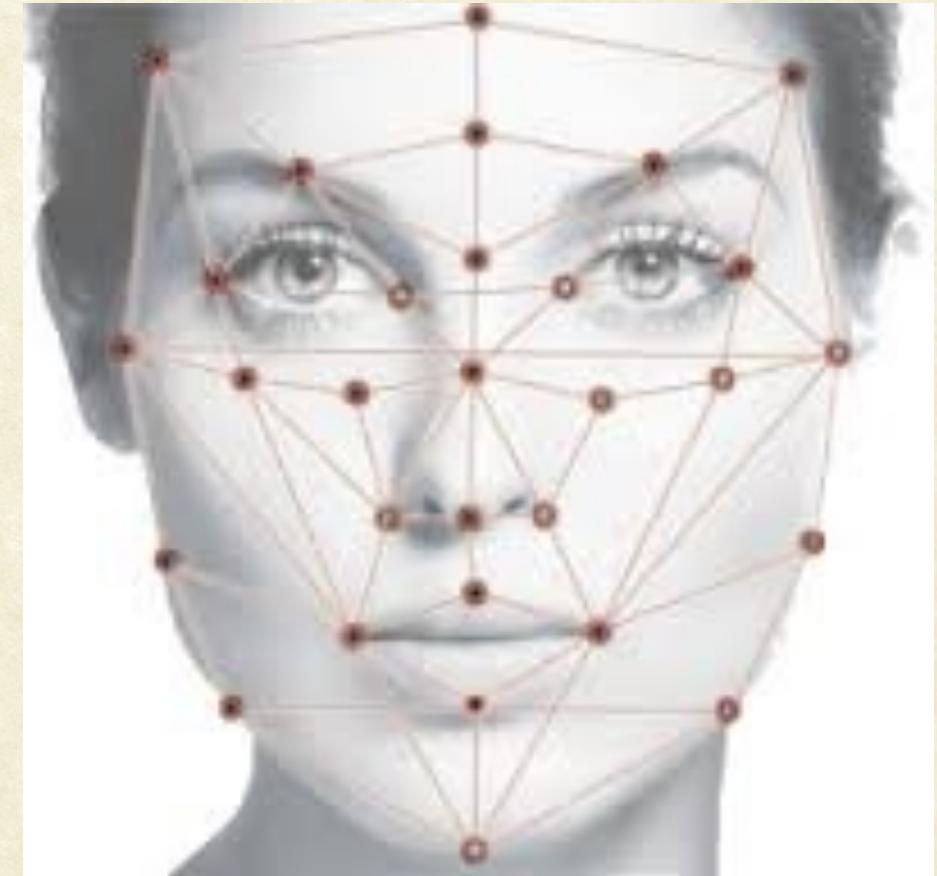
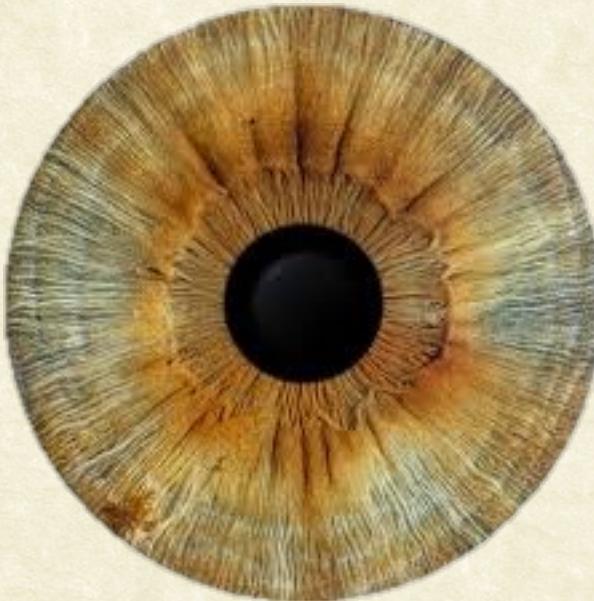
Tasks of Interest: Astronomy

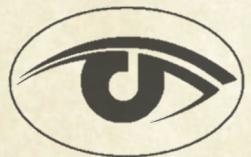


courtesy: ISRO

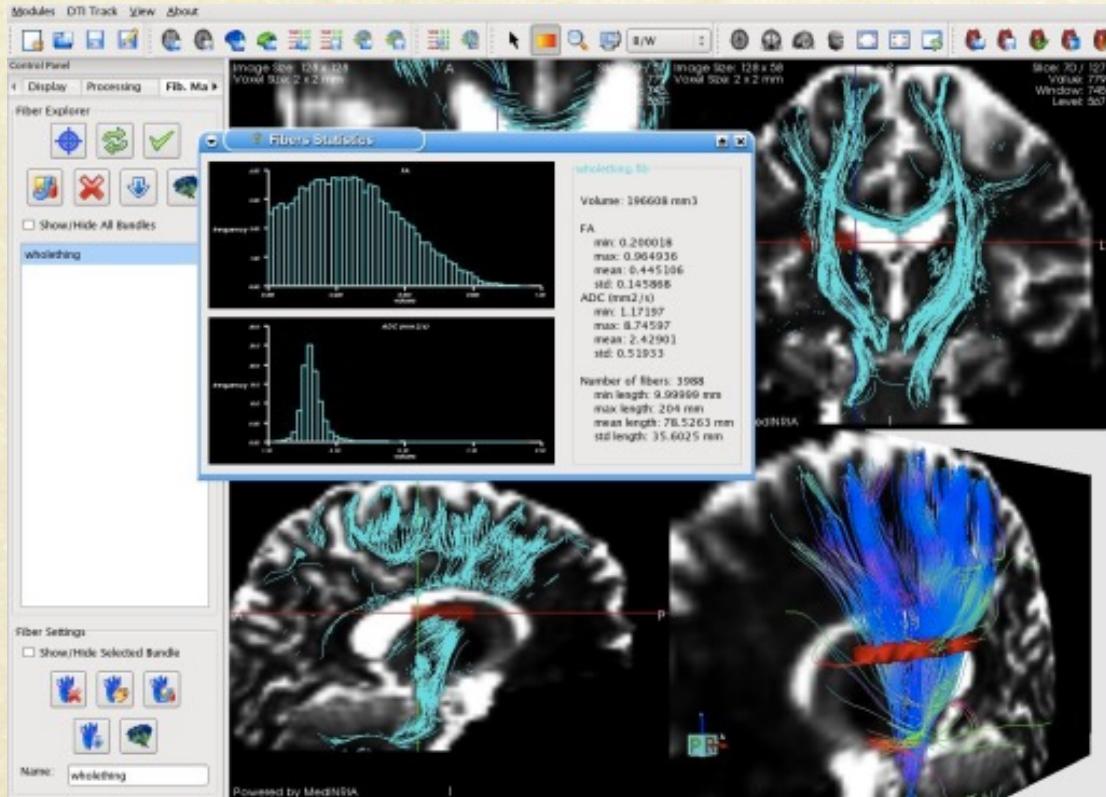


Tasks of Interest: Biometrics

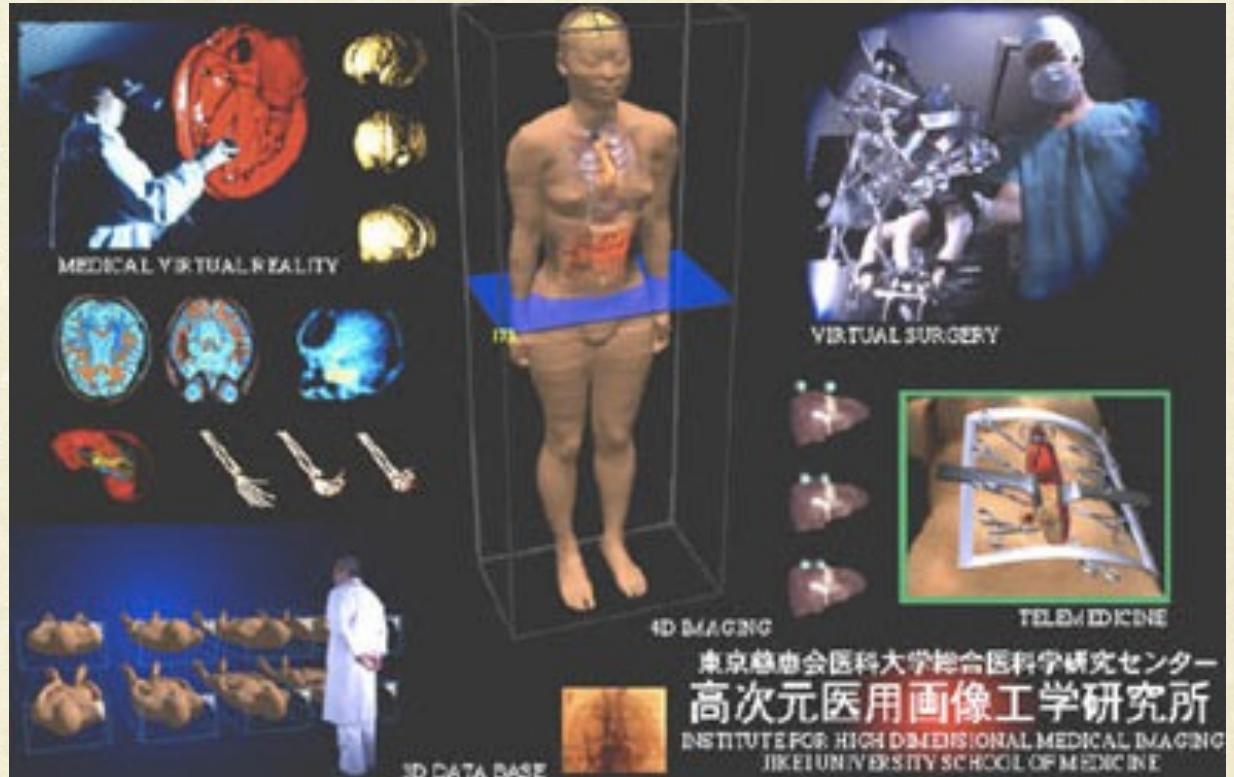




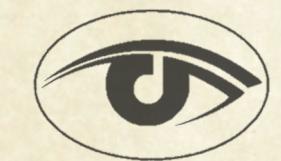
Tasks of Interest: Medicine



Courtesy: medINRIA

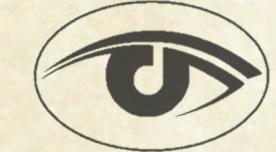


Courtesy: Naoki Suzuki

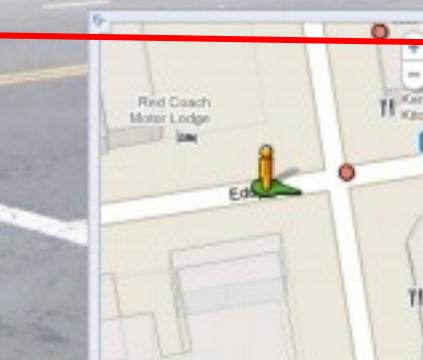


Tasks of Interest: Driver Assistance Systems





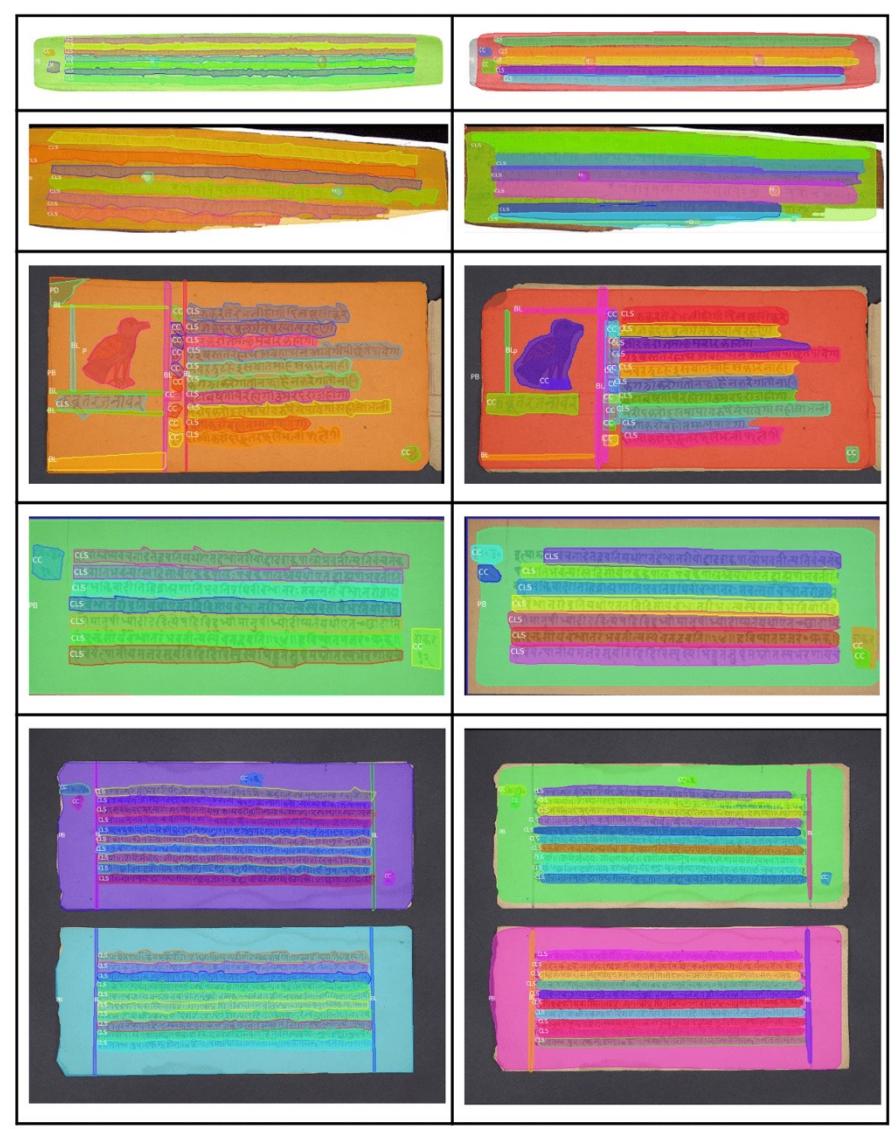
Face Blurring for Privacy Protection



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Tasks of Interest: Document Image Analysis



Angle: -4.94

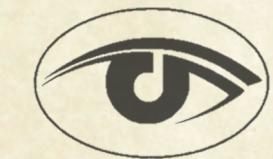
Open file

KOHL'S

Mountain View
Mountain View, CA 94040
(650) 947-7600

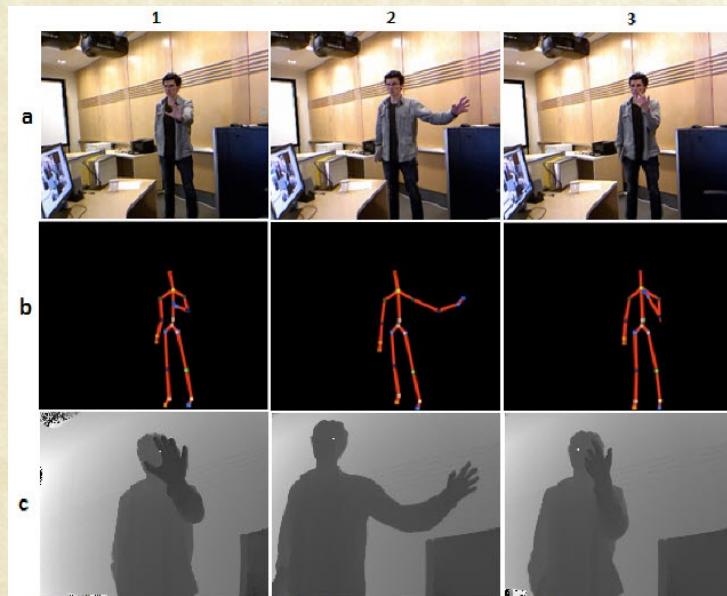
03-22-10 6:54P 1388/0004/3876/7 2038XXX
ID# 999-9677-8981-4580-8611-9561-2343

| | | | | |
|-----------------|--------------|--------------------------|----------|----|
| WOMENS SWEATERS | 400900796537 | C | 3.80 | T1 |
| ItemPrice | 38.00 | YouSave | 34.20 | |
| WOMENS KNITS | 884094501915 | C | 4.60 | T1 |
| ItemPrice | 46.00 | YouSave | 41.40 | |
| WOMENS LS KNITS | 400902041178 | C | 3.00 | T1 |
| ItemPrice | 30.00 | YouSave | 27.00 | |
| WOMENS LS KNITS | 400901894375 | C | 2.20 | T1 |
| ItemPrice | 22.00 | YouSave | 19.80 | |
| WOMENS SWEATERS | 771565433601 | C | 4.80 | T1 |
| ItemPrice | 48.00 | YouSave | 43.20 | |
| WOMENS APPAREL | 400904372324 | C | 6.80 | T1 |
| ItemPrice | 34.00 | YouSave | 27.20 | |
| WOMENS LS KNITS | 400901902197 | C | 2.20 | T1 |
| ItemPrice | 22.00 | YouSave | 19.80 | |
| WOMENS SWEATERS | 400903594772 | C | 3.40 | T1 |
| ItemPrice | 34.00 | YouSave | 30.60 | |
| INFANT APPAREL | 400901261126 | C | 1.00 | T1 |
| ItemPrice | 10.00 | YouSave | 9.00 | |
| INFANT APPAREL | 400901350691 | C | 1.00 | T1 |
| ItemPrice | 10.00 | YouSave | 9.00 | |
| WOMENS SWEATERS | 400900796872 | C | 3.80 | T1 |
| ItemPrice | 38.00 | YouSave | 34.20 | |
| +BOOKS KCK | 781375217797 | C | 6.00 | T1 |
| ELECTRONICS | 694202305102 | C | 15.99 | T1 |
| ItemPrice | 79.99 | YouSave | 64.00 | |
| | | SUBTOTAL | 57.59 | |
| | | MDSE SUBJECT TO DISCOUNT | 52.59 | |
| | | TOTAL OFF OFFER | 20.00- | |
| | | \$ TRANSACTION DISCOUNT | 20.00- | |
| | | \$ TRANSACTION DISCOUNT | 12.59- | |
| | | T1= | 0.45 | |
| | | TAX | \$ 5.46 | |
| | | | | |
| CASH | | 5.56 | | |
| | | CHANGE | 0.10- | |
| | | | | |
| | | TOTAL SAVED: | \$411.99 | |
| | | | | |
| | | SUBTOTAL | 57.59 | |
| | | MDSE SUBJECT TO DISCOUNT | 52.59 | |
| | | TOTAL OFF OFFER | 20.00 | |
| | | \$ TRANSACTION DISCOUNT | 20.00- | |
| | | \$ TRANSACTION DISCOUNT | 12.59- | |
| | | T1= | 0.46 | |
| | | TAX | \$ 5.46 | |
| | | | | |
| CASH | | 5.56 | | |
| | | CHANGE | 0.10- | |
| | | | | |
| | | TOTAL SAVED: | \$411.99 | |

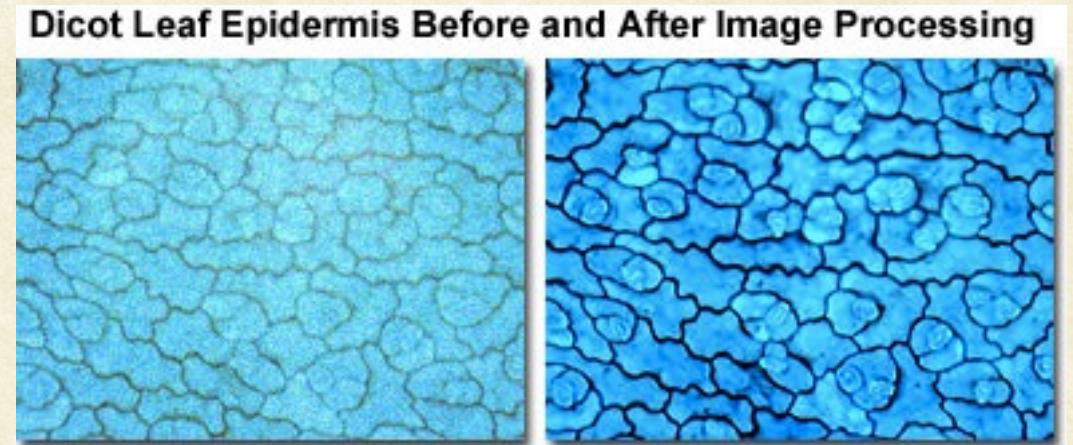


Tasks of Interest: Many more

- Biology
- HCI
- Number Plate recognition
- Gesture recognition



Courtesy: Perviverzov et al. 2012



Courtesy: Olympus



Courtesy: researchdesignlab.com

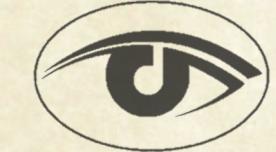


IMAGE PROCESSING

PIXEL To PIXEL

- Image Enhancement
- Super Resolution
- Image Restoration
- Image Compression
- Image Fusion

COMPUTER VISION

PIXEL To SYMBOL

- Object Detection
- Descriptors
- Recognition
- Tracking

Segmentation

Filtering

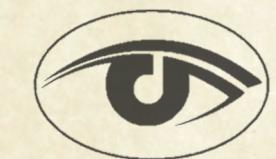
Geometry

COMPUTER GRAPHICS

SYMBOL To PIXEL

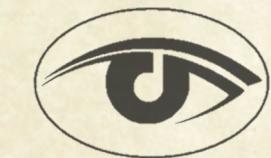
- Efficient Rendering
- Shading

Image Formation
Light/Physics
HVS



Companies and Software





Research

- Journals

**IEEE TRANSACTIONS ON
IMAGE PROCESSING**

A PUBLICATION OF THE IEEE SIGNAL PROCESSING SOCIETY

www.sigprocess.ieee.org

Image Processing and Multimed., products of the United States National Library of Medicine

PUBMED | IEEE Xplore

MAY 2018 | VOLUME 27 | NUMBER 5 | ISSN 1063-651X

For the May 2018 issue, see p. 1010 for Table of Contents.

For the June 2018 issue, see p. 1071 for Table of Contents.

Cover art from "Registration of Multiple Pulse Sequences Using Deep Recurrent Multi-Modal Fusion and Deep Learning" by Arash A. Gholami and Ali Alzahrani (pp. 1033–1046), Fig. 1.

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**IEEE TRANSACTIONS ON
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CAS | Communications Society | MM | Signal Processing Society | CS | Computer Society

JULY 2018 | VOLUME 20 | NUMBER 7 | ISSN 1524-0702

Topics:

- 3D Audio Signal Processing
- Sparse Time Representation and Compressive Sensing Under Prior Regularization
- 3D Face Recognition
- Speech Signal Processing
- Audio-Signal Processing, Analysis and Synthesis
- 3D Video Processing Techniques for Mobile Devices Based on a Transfer Representation of the Spatial Multichannel Signal
- Compression and Coding
- 3D Multi-View Block Matching Scheme for Low-Complexity MVEC Decoder
- Image/Video Compression, Analysis and Synthesis
- 3D Semantic Spatio-Temporal Reconstruction
- 3D Depth Estimation Using Ground-Surface Method
- Image Signal Processing
- High-Dimensional Feature Extraction for Video Data-Set Multi-View Based on Convolutional Encoding
- Multimodal Perception, Recognition, and Understanding, Part I
- Bridging Music and Image via Cross-Modality Matching Methods
- 3D Video, 3D Face, 3D Hand, and 3D Shape

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IEEE



Research

- Conferences



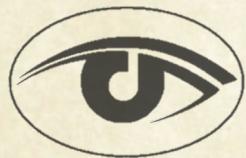
**2023 IEEE International Conference on
Acoustics, Speech and Signal Processing**
4 - 9 JUNE, RHODES ISLAND, GREECE

Signal Processing in the AI era

ICASSP 2023

IEEE

This collage features several images from Rhodes Island, Greece. On the left, there's a view of a harbor with a large, ornate building in the background. In the center, a stone column stands on a pier over turquoise water. To the right, a church with a tall tower is illuminated at night, reflected in the water. The collage is framed by a blue and orange wavy border. The IEEE logo is in the bottom right corner.



Research • Conferences



SIGGRAPH 2023
LOS ANGELES+ 6-10 AUG

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THE
EXHIBITION

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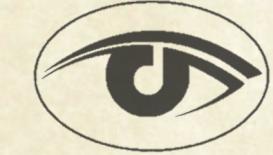
New Technologies



Arts &
Design

See All
Programming





Research
• Conferences



SAN JOSE, CALIFORNIA, USA 2023

PROGRAM

IMPORTANT DATES

ORGANIZING COMMITTEE

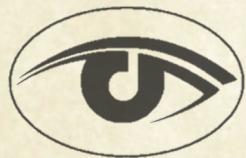
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AWARDS

CONTACT US

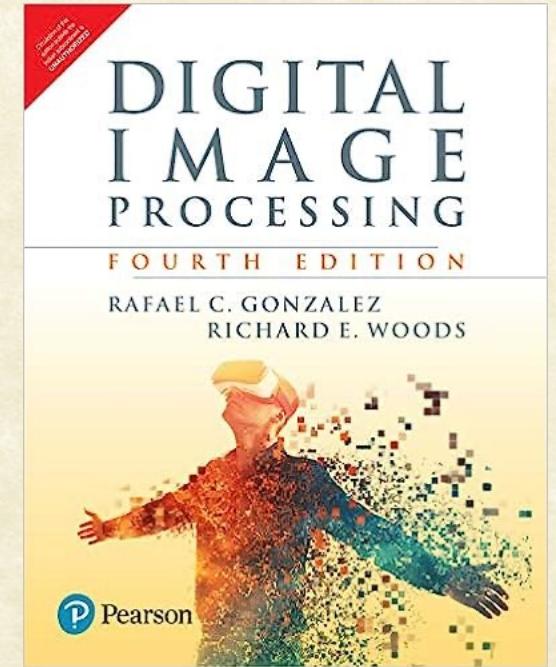
The 17th International Conference on Document Analysis and Recognition

August 21-26, 2023 – San José, California, USA



About the Course

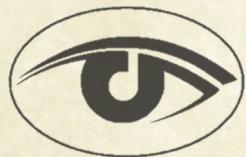
- Timings: Tue, Fri (**10:05 – 11:30**)
- Pre-requisites
 - (CS): Programming, Data Structures, Algorithms
 - (MA): Basics of Linear Algebra, Calculus
 - (DSP): Basics of signal processing.
- **Textbook:** *Digital Image Processing*, Gonzalez and Woods(4th ed)
 - Other resources from the internet
- Teaching 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

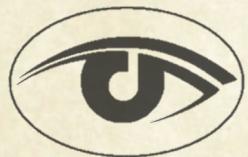
- Python (mandatory)
- Github Classroom
- Image Processing / Data Processing Libraries
 - scikit-image , opencv-python, kornia
 - pandas
 - scikit-learn
- Do not use libraries for assignments unless explicitly allowed.



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 !

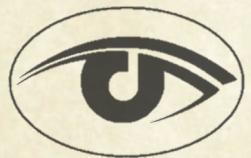




About the course – Final Projects

- 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)
 - Form 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 ...

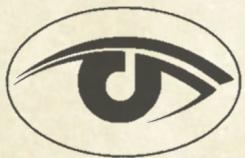
- The course load is fairly substantial
- Elective → Conscious choice
- Starting early on assignments helps
- Spending time everyday on material covered in class helps





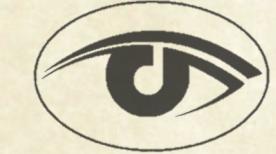
How to Learn

- **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

Questions?