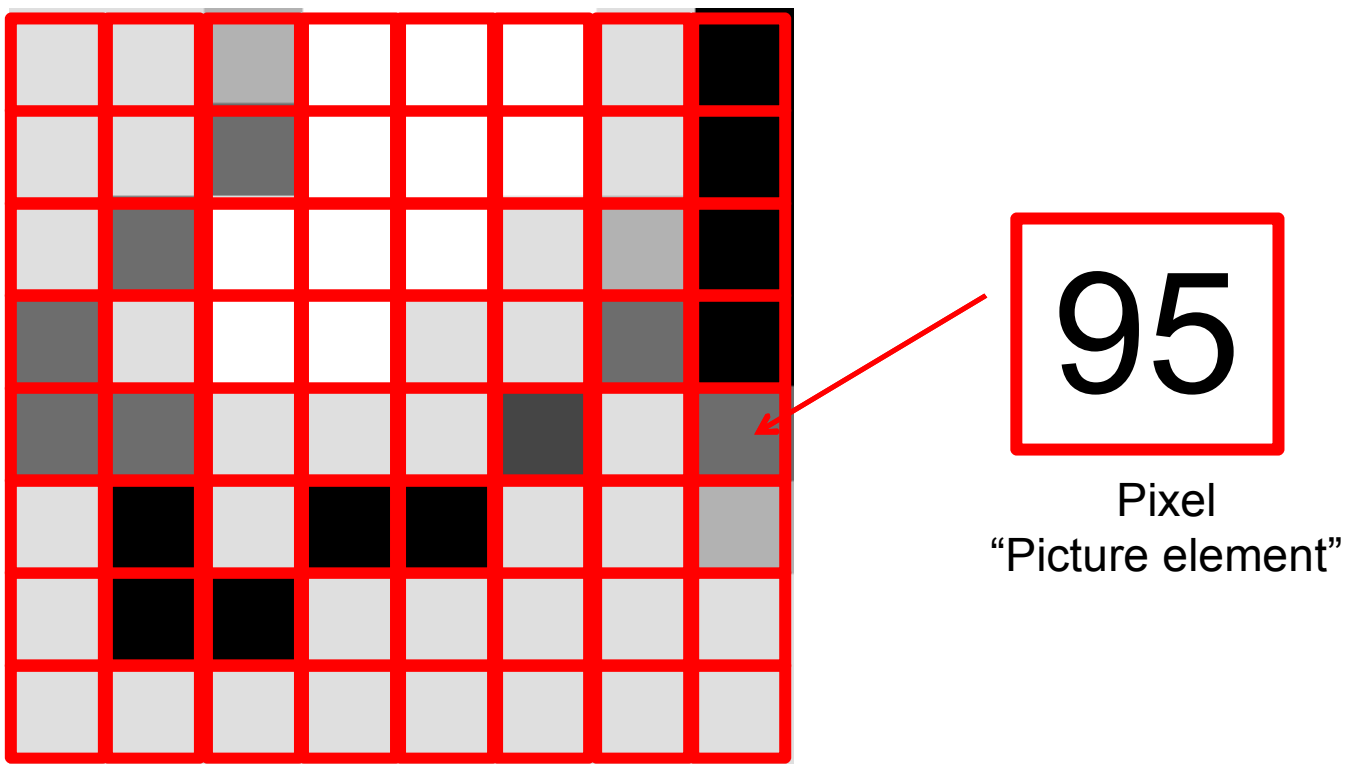
Lecture 0:
What is Image Processing?

What is an image?

- An image is a data set recording (visual) information at spatial locations (pixels).



Optical images

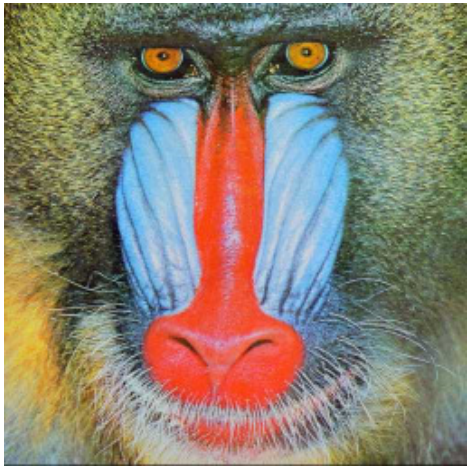
- An image that corresponds to human vision is called an optical image.
- Optical cameras are engineered to record visual data as a human would perceive it.

Common Test Images

Lena

Barbara

Cameraman



Mandrill

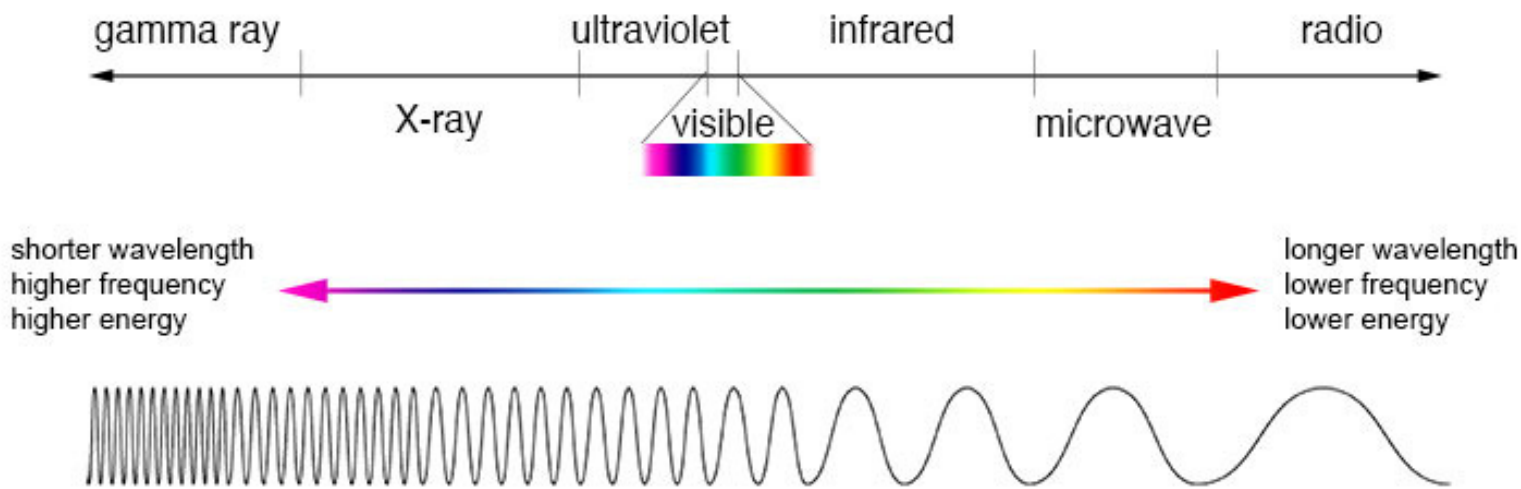
Peppers

Shepp-Logan Phantom

Uncommon Test Image

The EM spectrum

- But human vision takes up a very small part of the electromagnetic spectrum.



- Engineers can build cameras to respond to wavelengths beyond the human visual system.

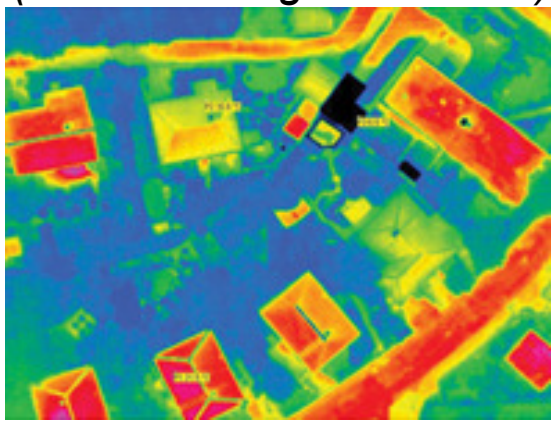
Beyond human vision

- An imaging modality is a system (camera) designed to record a specific EM wavelength or set of wavelengths.

Infrared images

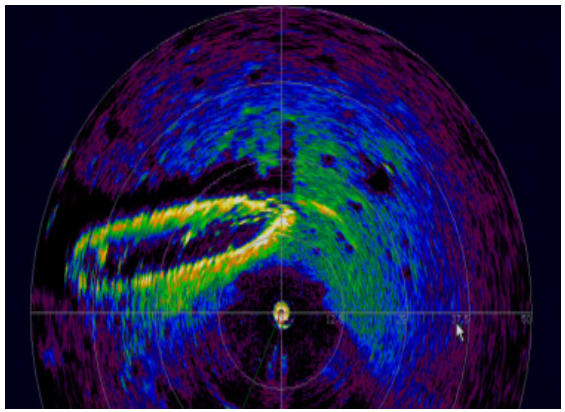
Geoscience & remote sensing

Infrared
(Just to the right of visible)

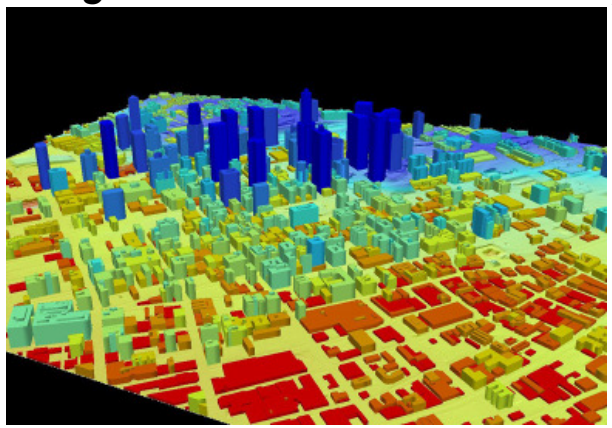


Radar
(Radio waves – very long wavelength)

Sonar
(Acoustic waves travel underwater)

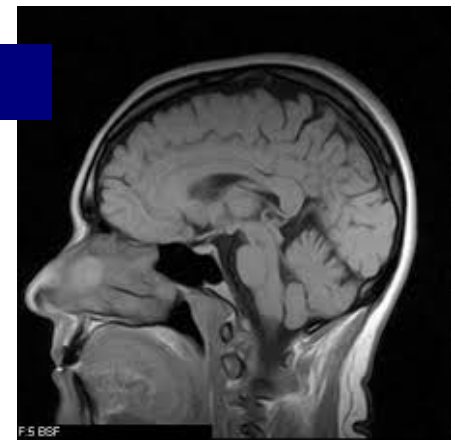


Lidar
(Range information from lasers)

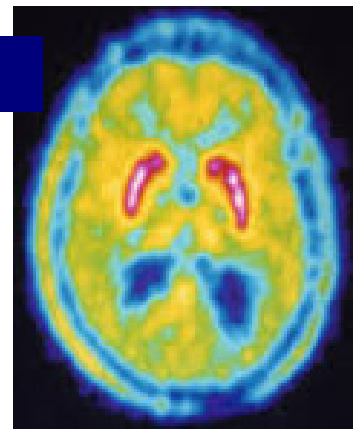


Medical imaging

Magnetic Resonance Imaging (MRI)

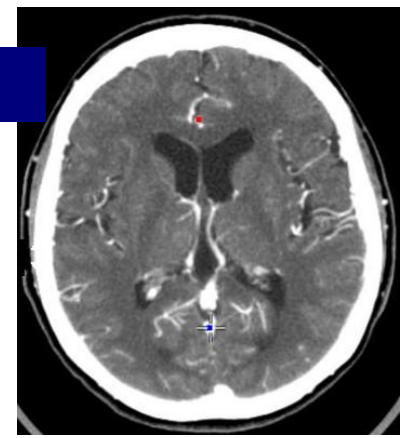


Positron Emission Tomography (PET)



X-ray

Computed Tomography (CT)



Ultrasound

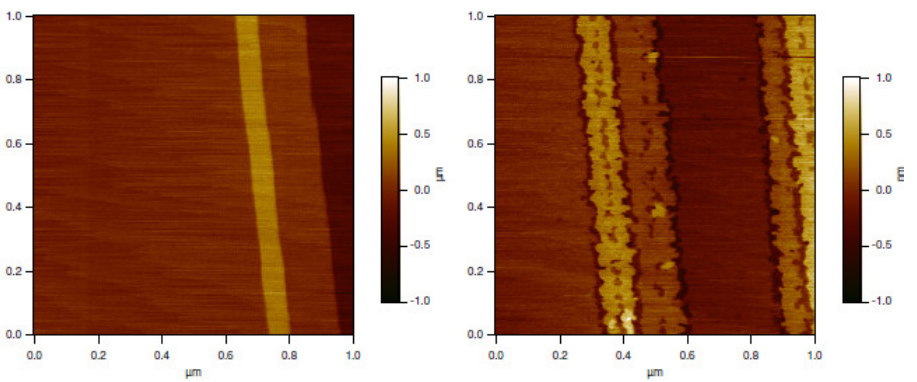
Image scale

- From very large things in telescopy

The Crab Nebula
Hubble Telescope

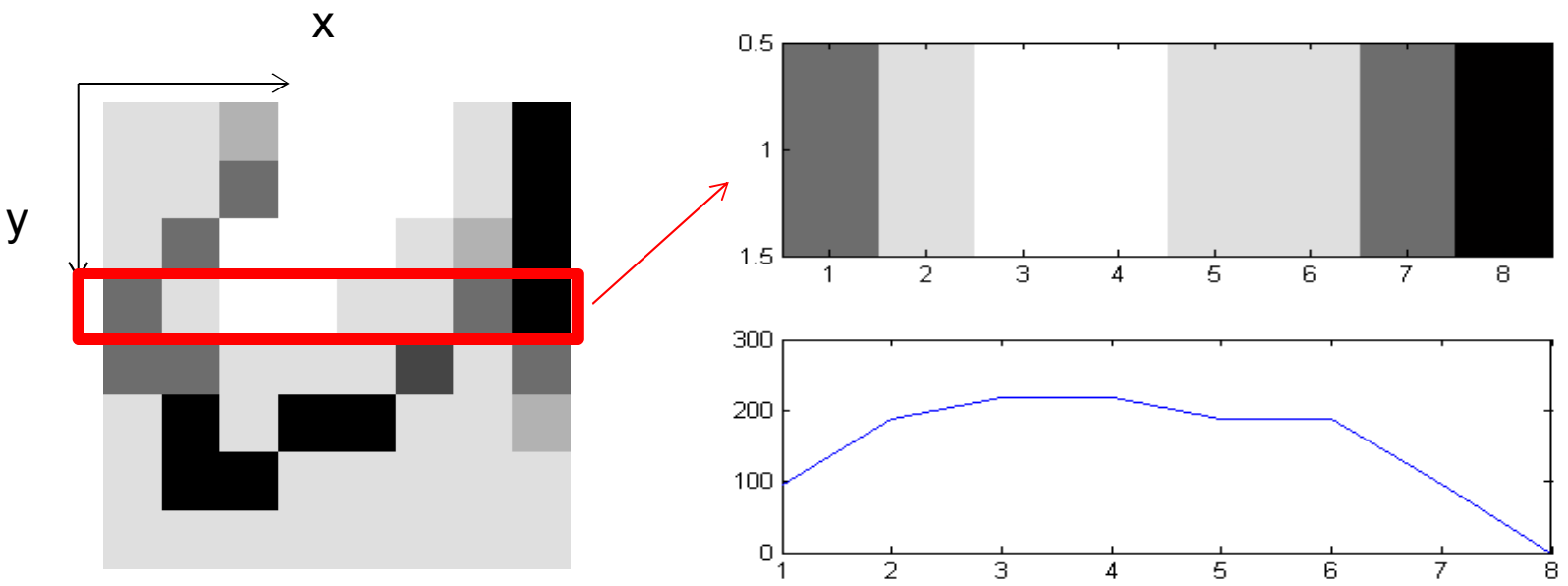
... to very small things in microscopy.

Oxidation
Atomic Force Microscope (AFM)



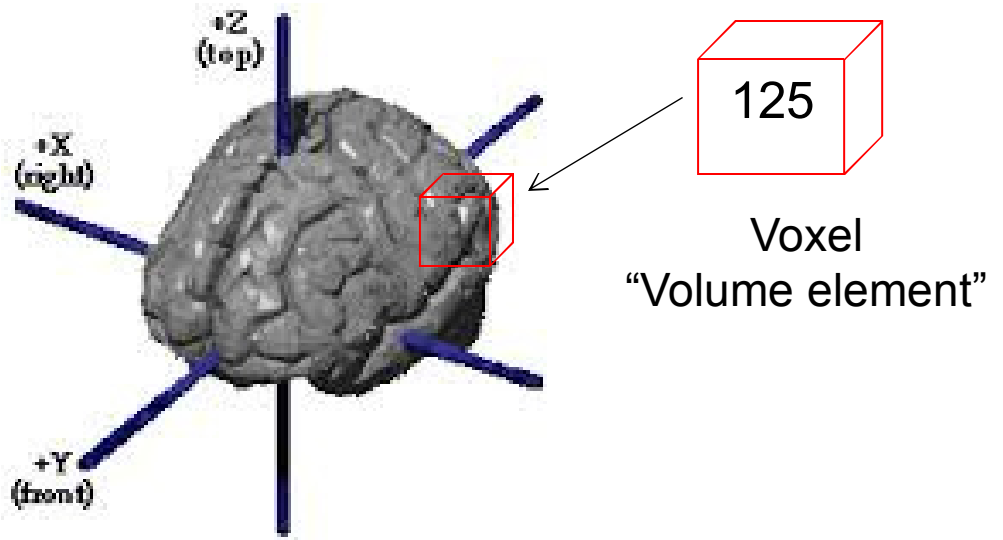
1D Images

- Normally, images are 2D.
- But if we take just one row of an image, we get a 1D signal.
- Many ideas in image processing also work in signal processing, e.g. enhancing audio signals.

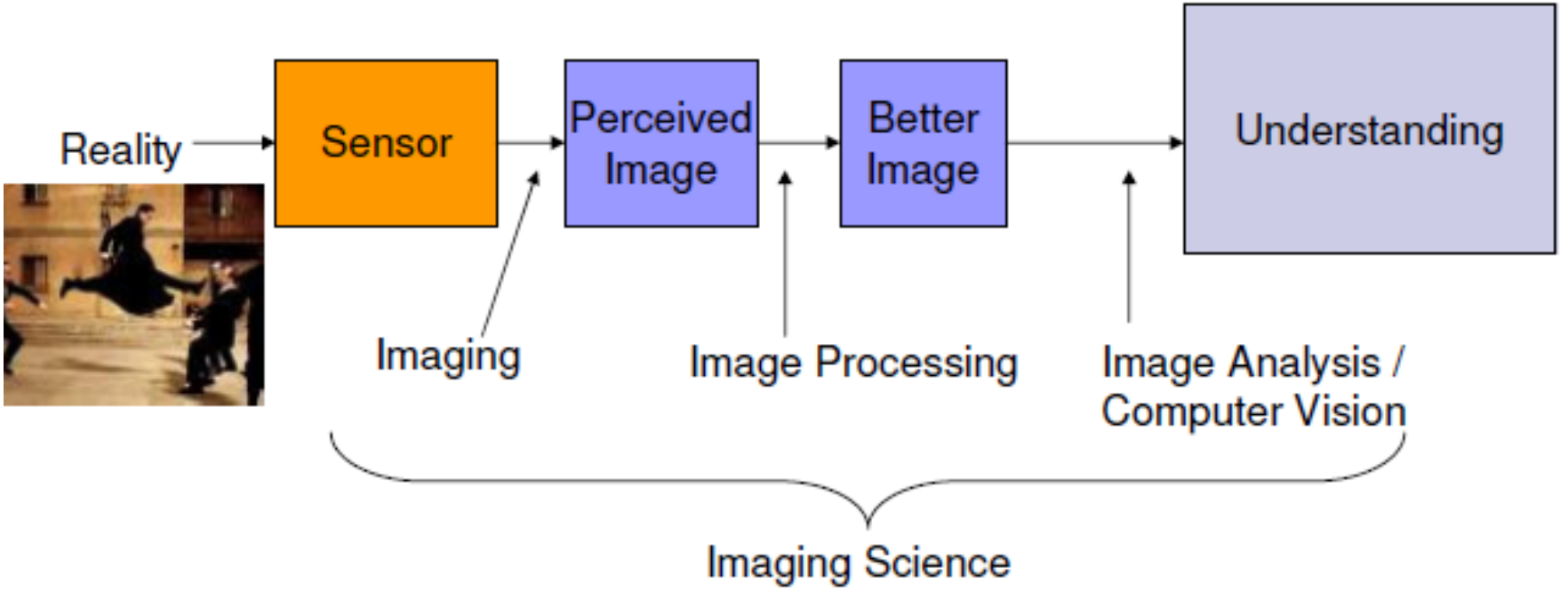


3D Images

- We could also add a z-axis to our images and construct a 3D image or volume.
- Or if we imagine the 3rd axis is time, we can create a sequence of images to form a video.



The Imaging Science Pipeline



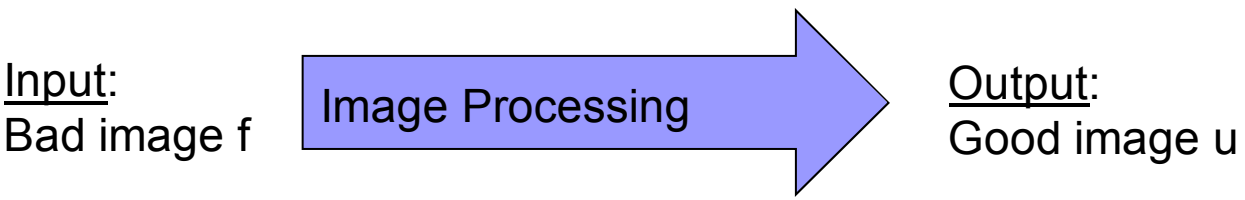
Key Concept: Images are not reality!

What is image processing?

- Image processing is the study of how to:
  1. enhance a damaged or inadequate image.
  2. extract meaningful features or statistics from images.

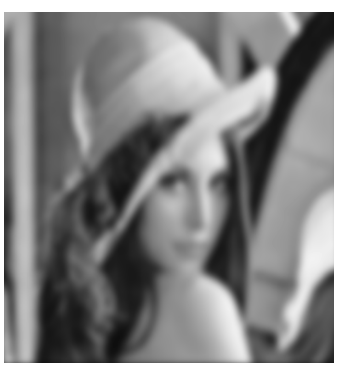
1. Enhance an image

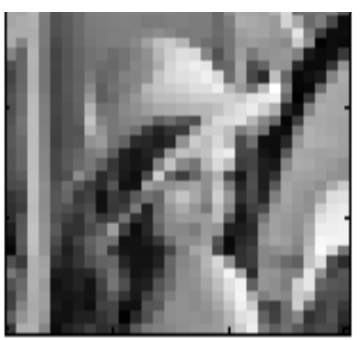
- Change a “bad” image f into a “good” image u



- Examples of “bad” images.

Problem: Noisy | Blurry | Missing data | Low resolution | File too large





Task: Denoising | Deblurring | Inpainting | Zooming / Super-resolution | Compression

2. Extract image features

- Segmentation partitions an image into meaningful pieces (segments).

- Detection looks for specific objects or shapes in an image.
- Recognition identifies the objects in an image.

- Registration seeks a way to align multiple images.

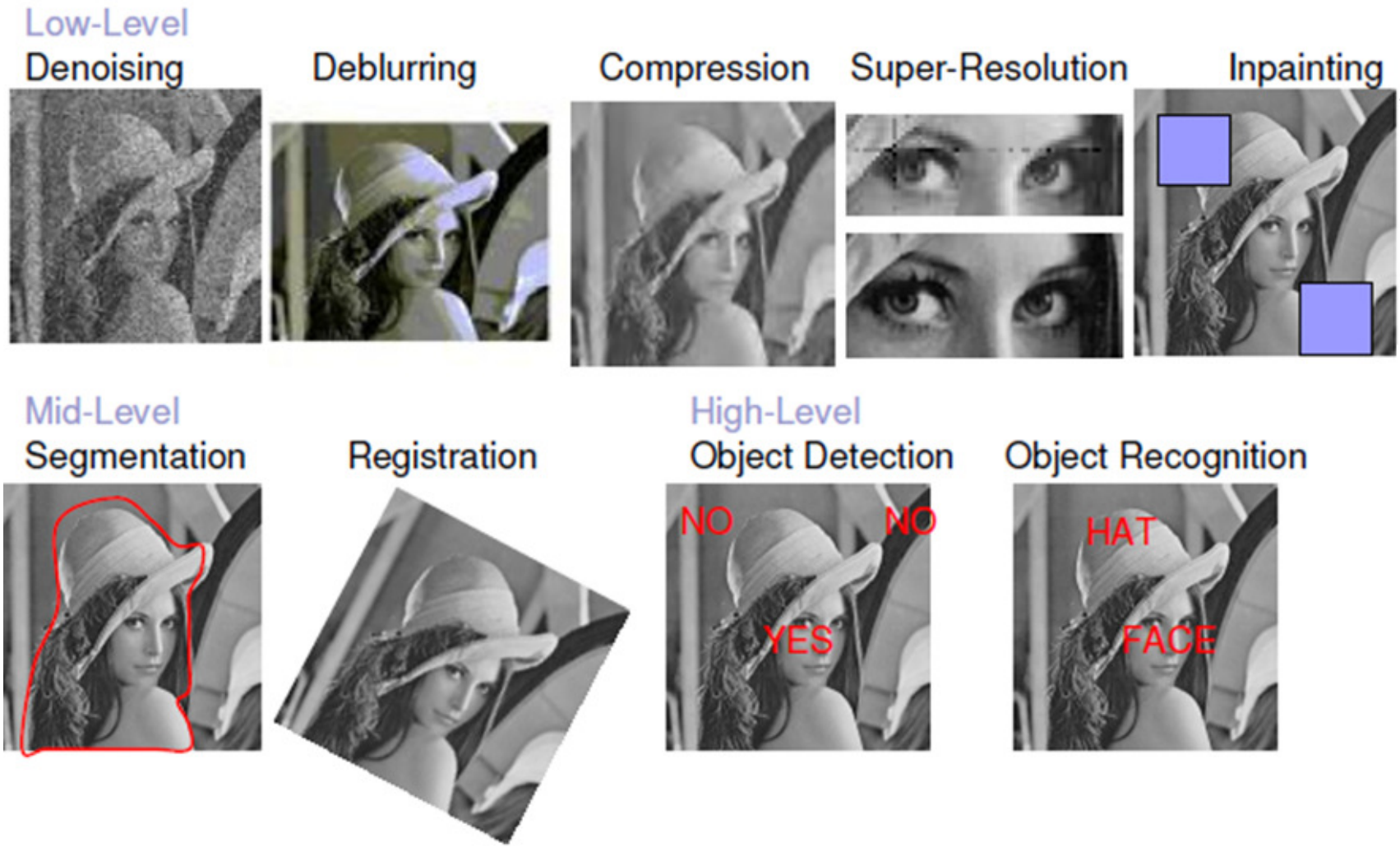
- We might also be interested in a meaningful statistic about the image.

Levels of image processing

- An image processing task that relies primarily on geometric properties is called a low-level task.
- A task that requires (human) knowledge of the subjects in the image is high-level task.

- High-level tasks take us into the realm of artificial intelligence.
- Depending on how you incorporate knowledge, any low-level task can be made into a high-level task.

Image Processing Tasks



Why is image processing hard?

We see this:

The computer sees this:

207	212	148	2
31	201	253	181
14	255	203	210
26	30	42	45

How do we get the computer to see like us?
We are trying to build a digital soul!

Close but not quite…

- There are many fields that are related to or use image processing, but are not quite the same.
  - Computer graphics
  - Graphic design & image editing
  - Robotics & computer vision
  - Machine learning / Artificial intelligence