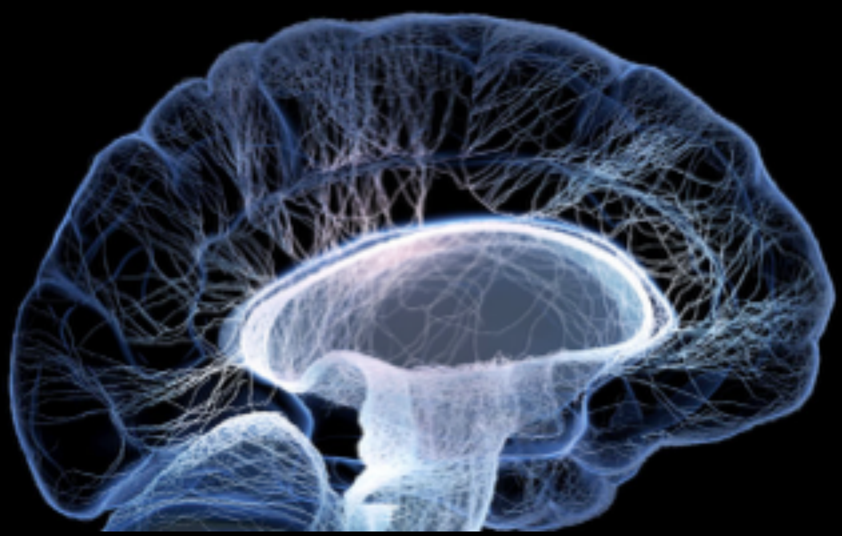
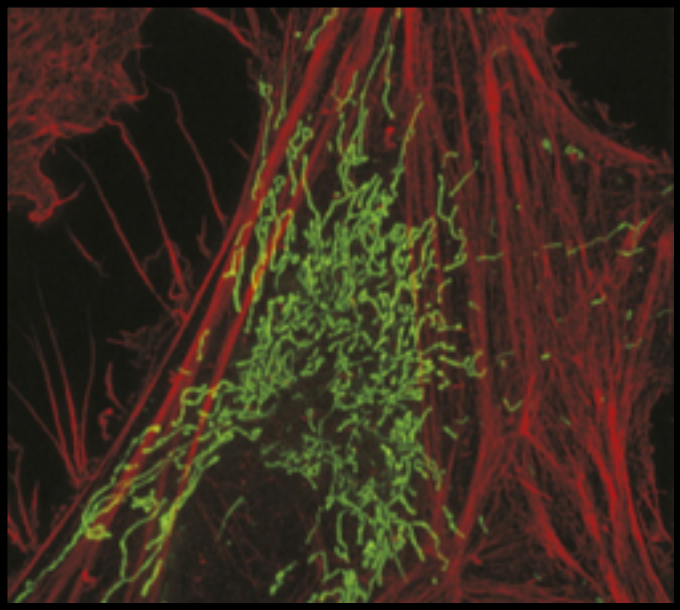
Image Processing and Reconstruction

EE 264 Spring 2018

Instructor: Sara Abrahamsson (sara@ucsc.edu)





Basic Image Processing

- This will be a beginners course, and everyone is welcome, but…
- If you already have a lot of experience, this course may not be useful to you

Welcome To Image Processing And Reconstruction

Class Rooms And Hours:

Tuesdays: 11:40am-1:15pm E2 506   Thursdays: 11:40am-1:15pm Crown Mac Lab (Room 201)

Enrolling:

Simply email the instructor: **sara@ucsc.edu** if you want to take the course, and let her know why you are interested in it.
(She can then give you an access code even if the course is full.)

Course Layout

- **Homework** *vs.* **Projects** *vs.* **Exams**?
- What do you want to learn and how?
- How do we set your grades?

Please:

This is effectively a new course. Please help me make it great by communicating with me as we progress thorugh the quarter!

Tell me what you expect from the course. Once we get started, if it is too slow paced, too fast, to hard, or too easy, please just tell me! What can be improved? What do you need? Is something not quite right? I want you to do great and learn a lot. Is the homework assignment too hard? Tell me --- ideally before it is due --- and we can all work it out together.
Talk to me in person or shoot me an email at sara@ucsc.edu

Dates for stuff

- Midterm
- Oral presentations
- Home work
- Final — or final project???

The **midterm exam is preliminarily scheduled for May 3rd**.

Oral presentation of your study of a special topic will also be part of your grade. These are preliminarily scheduled for **May 17th, 22nd and 24nd.**

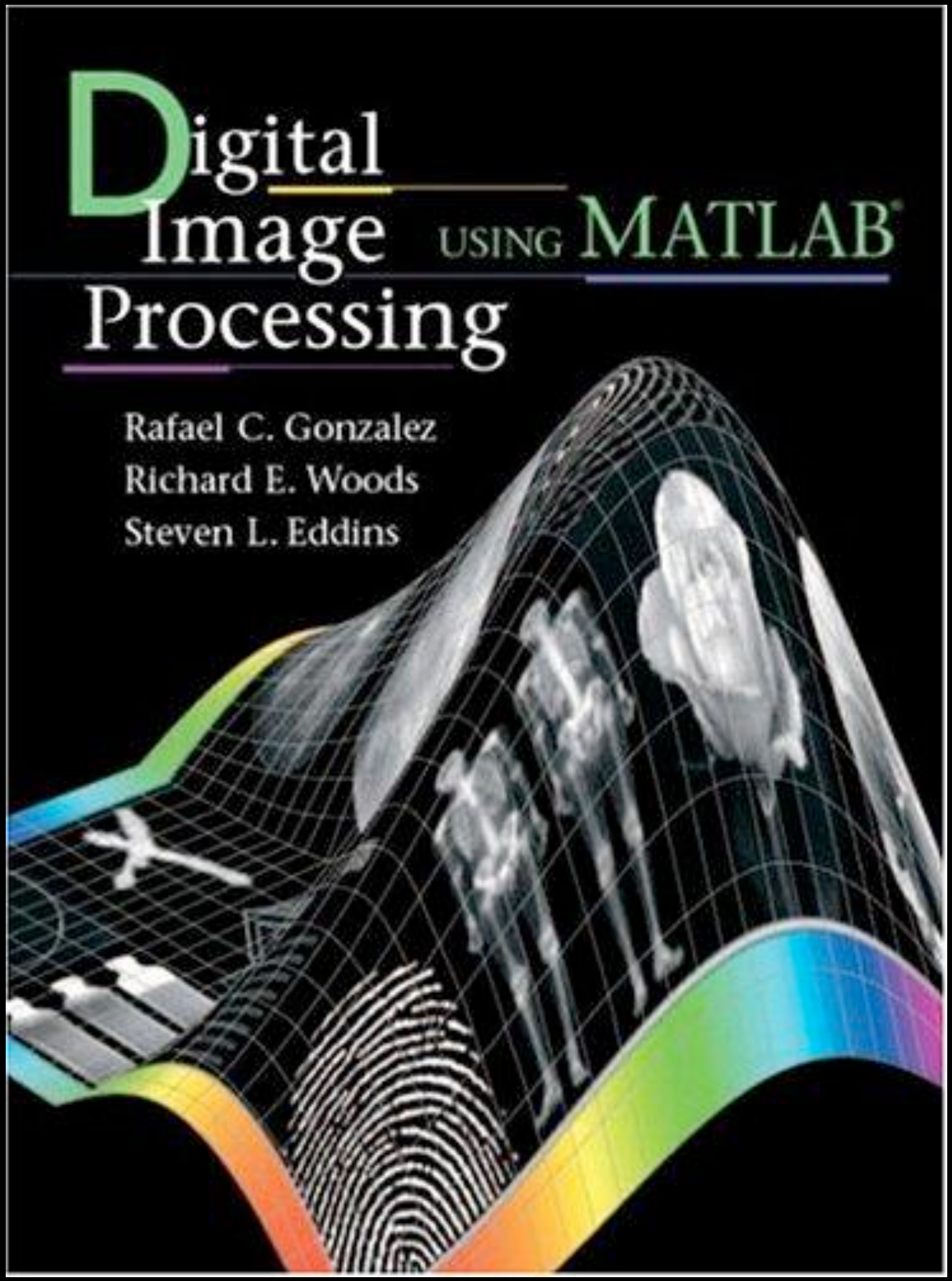
Let me know ASAP if these are terrible dates so that we can rescuedule!

There will also be "almost weekly" homework assignments. The goal is that you will finish this homework during the Thursday lab session, but you will have until the next weeks Thursday to hand it in.

Final exam will be centrally scheduled.

See attached document *EE264courseDescription* for important practical details on this course, such as how will be graded.

Text Books



Text Book:

We will discuss this in the first lecture. I suggest **Gonzales and Woods** which is a combination of two books: *Digital Image Processing* and *Digital Image Processing using MATLAB*. The 4th edition of DIP just came out this year but the new edition (3rd) of DIP using MATLAB is not yet out. Because of this the 2nd edition is freely **available online**. You can request it here.

www.imageprocessingplace.com

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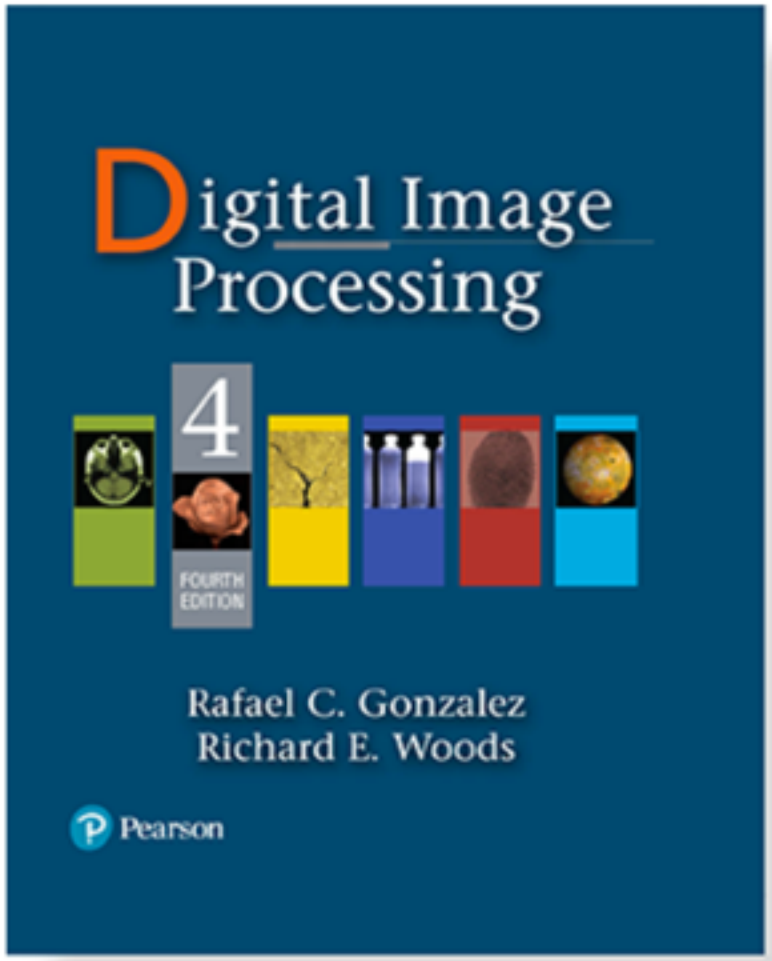
Welcome . . .

. . . to the web site of the leading digital image processing books and other educational resources. The following books are supported by this site:



Digital Image Processing, 4th Ed.
Gonzalez and Woods
© 2018
ISBN: 9780133356724
The world leader in its field for more than 40 years.

Digital Image Processing 3rd Ed. (DIP/3e)
by Gonzalez and Woods
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The world leader in its field for more than 30 years.
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- URL extensions by country.
- DIP groups around the world.
- FAQ's
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- Other useful links.

Today

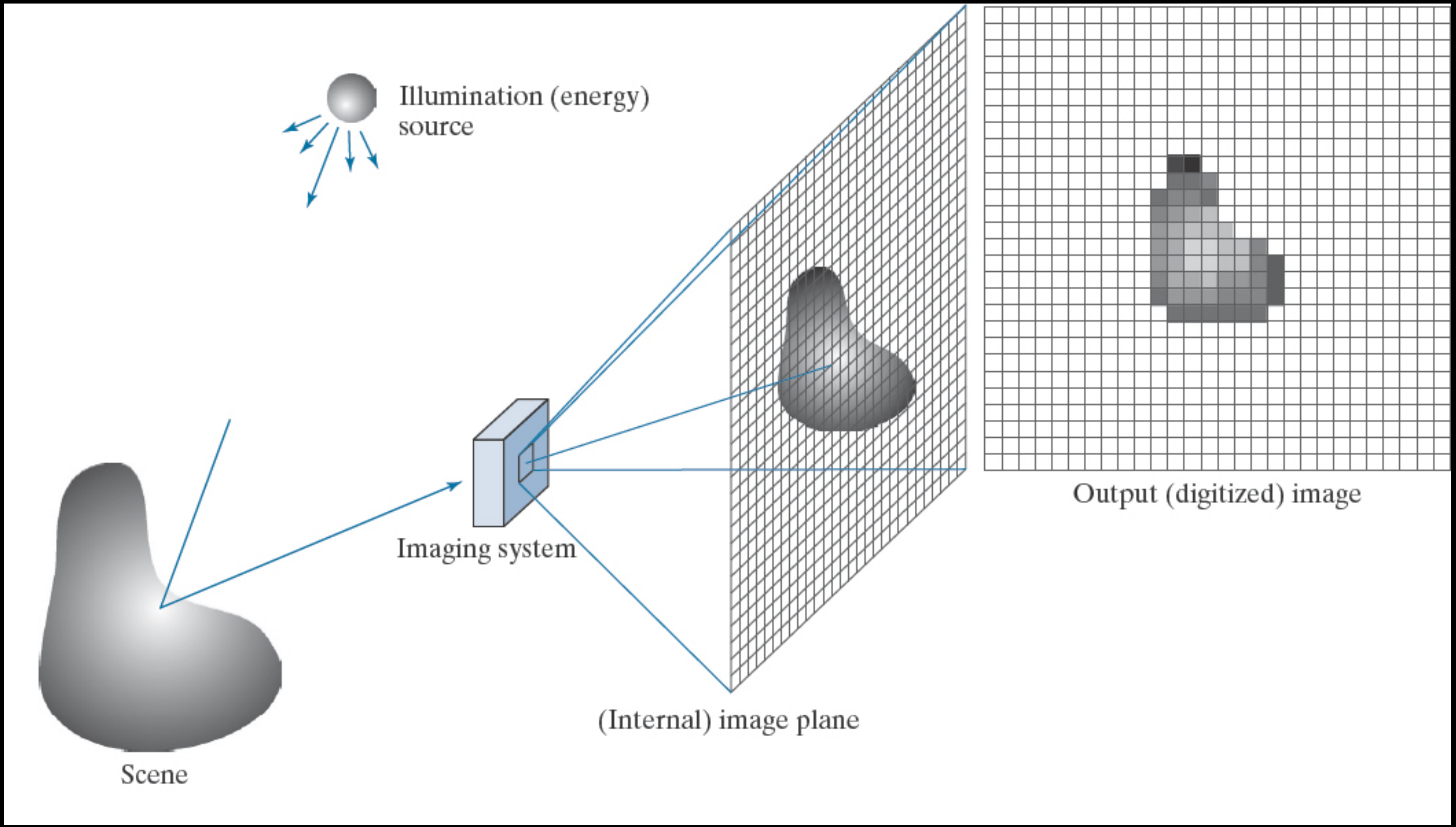
- Introduction to digital images

Digital Image

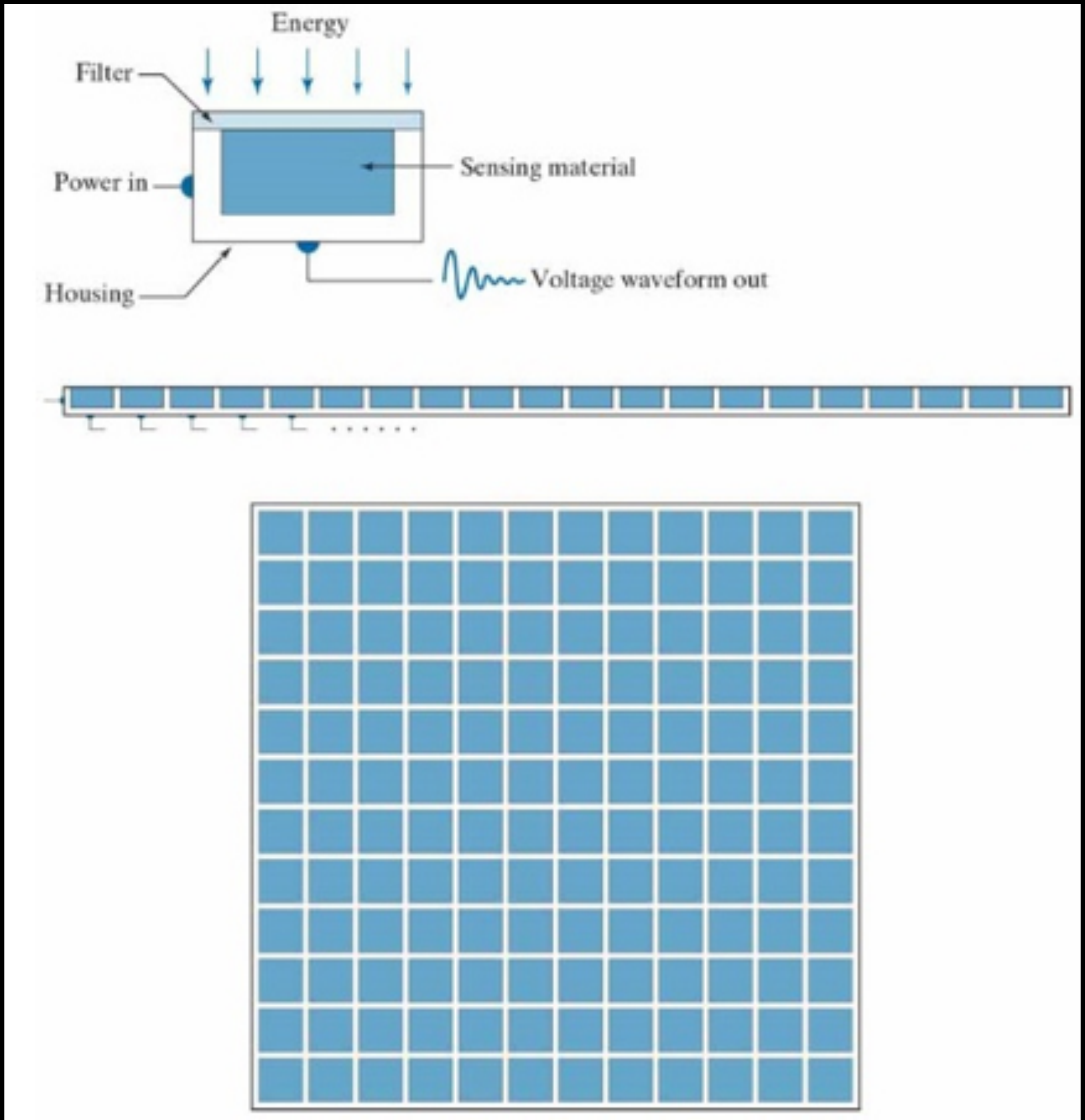
A digital 2D image can be described as a:

- …function of two spatial variables f(x,y) where (x,y) denote the planar image coordinates and f() is the amplitude of the image at the given location

- …2D matrix of numerical values that correspond to grayscale levels


Illumination (energy)
source
Output (digitized) image
Imaging system
(Internal) image plane
Scene

Recording images



(a) Single sensing element.
(b) Line sensor.
(c) Array sensor.

Digital Image Processing

- Output can be:
  - Another image: $g(x,y) = P(f(x,y))$
  - A set of attributes (edges, segments, objects)
  - An algorithmic “understanding” of the image content

Why process images?

- Storage and sharing
  - (Compression, Transmission)
- Display
  - (Resize, Optimize contrast and color)
- Enhance and restore
- Extract information

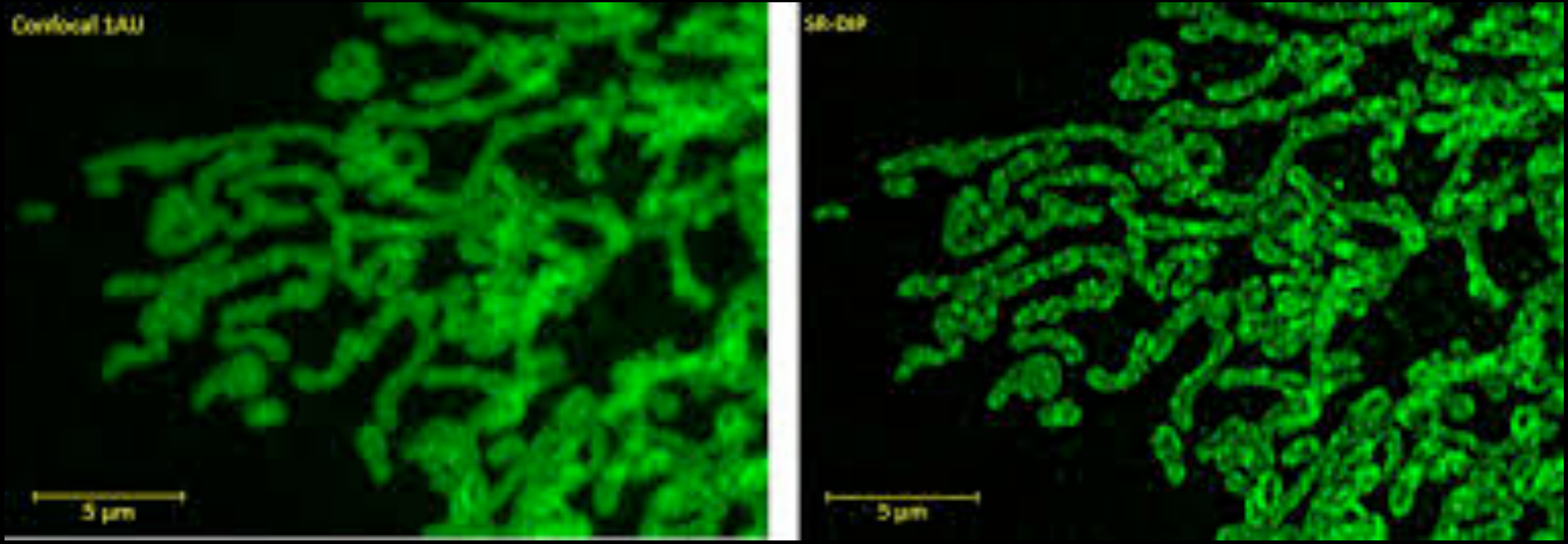
Software

- MATLAB
    - Expensive
    - Toolboxes are extra, and there are *many*
- ImageJ / FIJI (Fiji is just ImageJ)
    - Free, open source

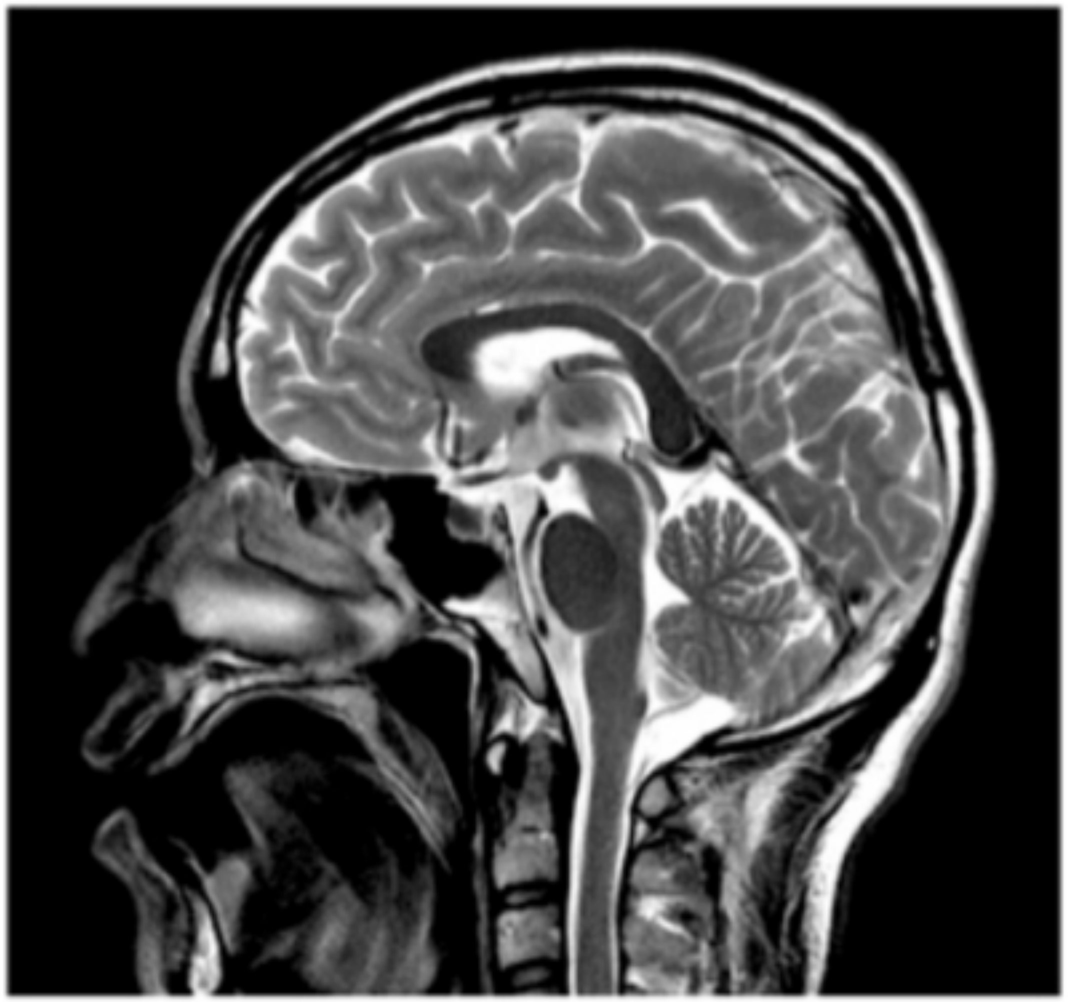
Bioimaging applications

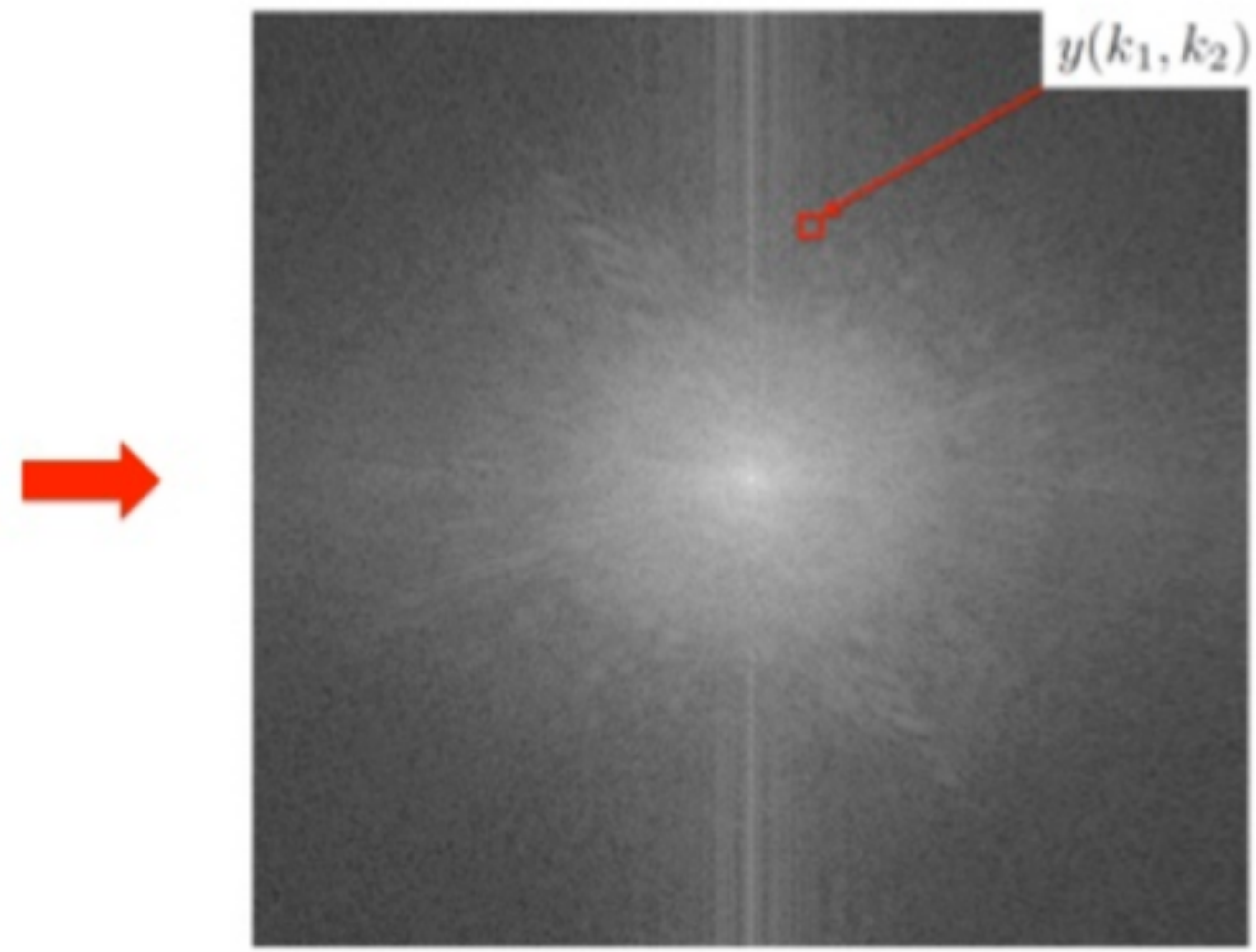
- Optical microscopy
- MRI
- Photography

Microscopy



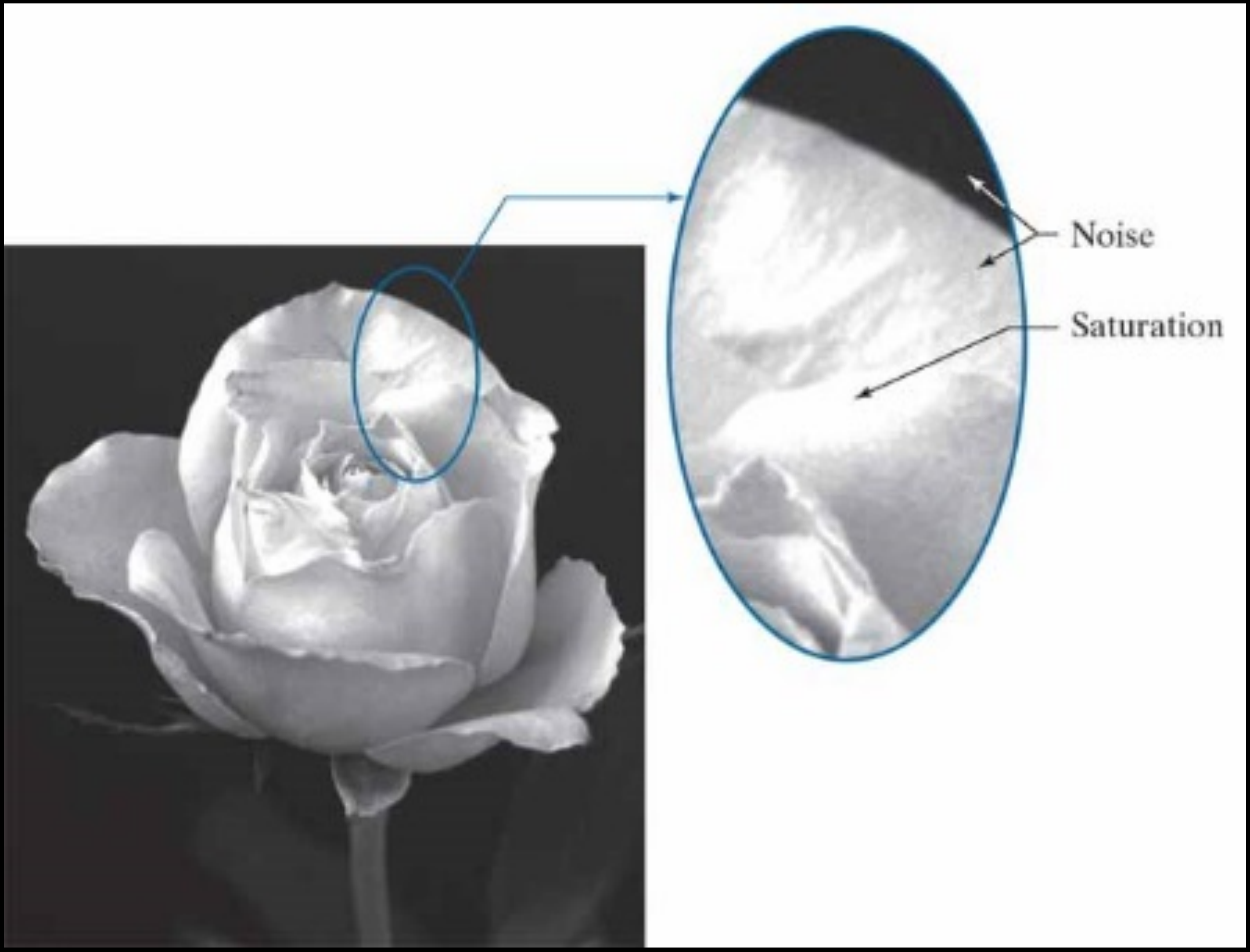
MRI





$$y(k_1, k_2) = \iint f(x_1, x_2) \mathrm{e}^{-i2\pi(k_1 x_1 + k_2 x_2)} \, dx_1 dx_2$$

Photography



Display
(“pretty picture”)

- Contrast adjustment
- Color adjustment
- Deblur
- Denoise
- 3D visualize

Gray levels

- Binary image: Black and White
- Grayscale image
  - 8 bit
  - 16 bit
  - 32 bit

Bit depth

- 8 bit image: 2^8 = 256 values
- The largest number you can represent with 8 bits is 11111111 (255 in decimal notation)
- Since 00000000 is the smallest, you can represent 256 things with a byte.

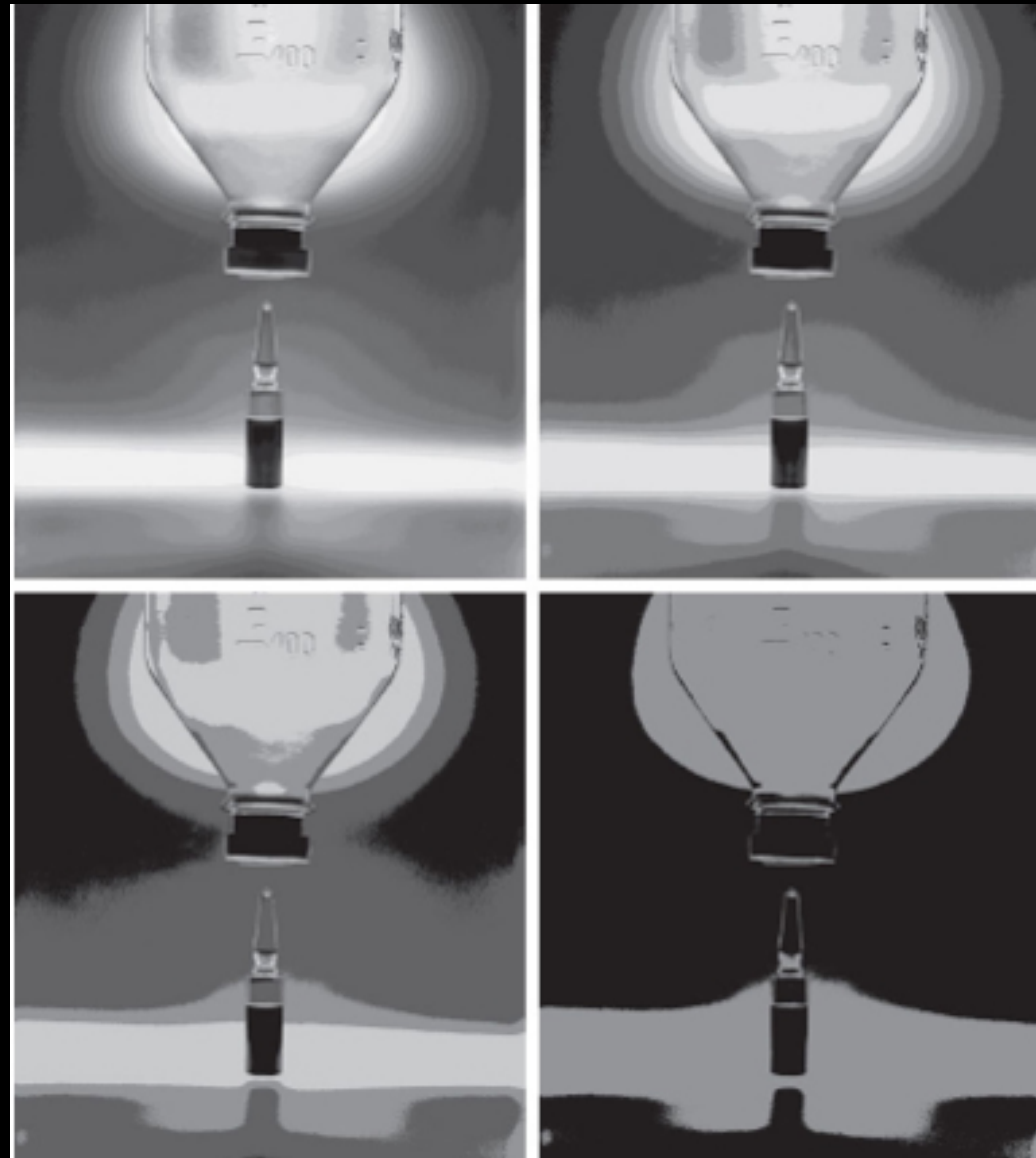
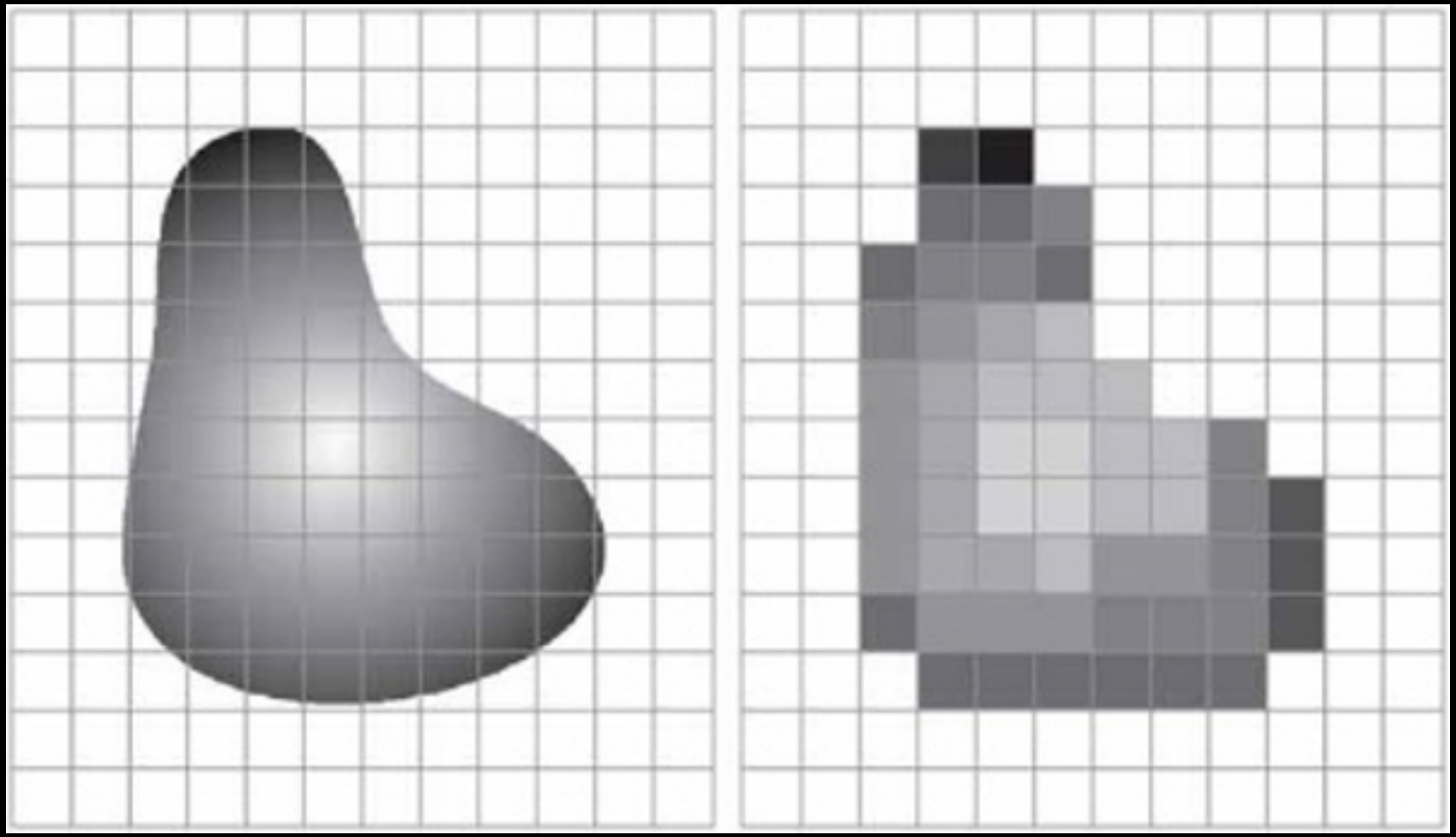


Image displayed in 32, 16, 8, 4, and 2 intensity levels.

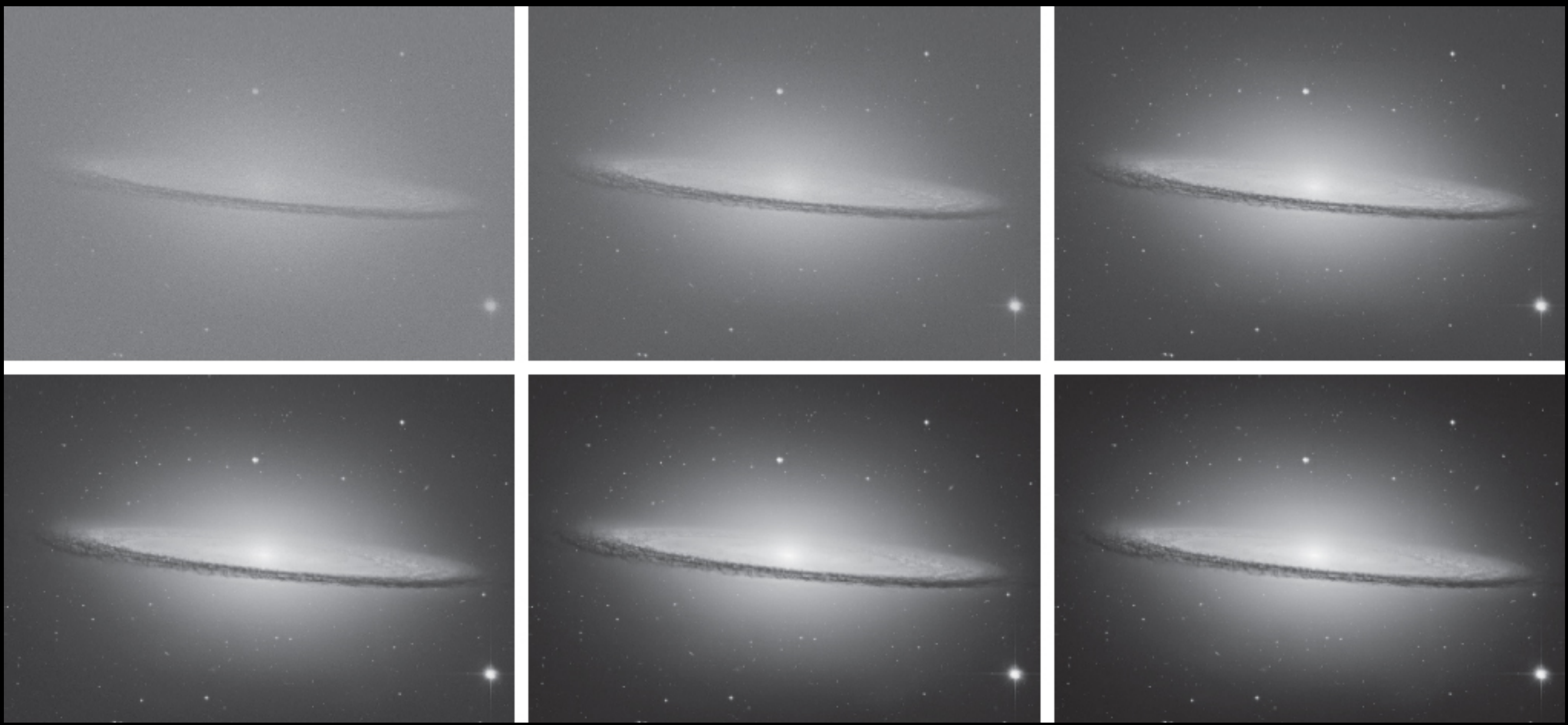
Number of pixels
or in printing: dots per inch (dpi)

(a) Image reduced to 72 dpi and zoomed back to its original 930 dpi using nearest neighbor interpolation. This figure is the same as Fig. 2.23(d).
(b) Image reduced to 72 dpi and zoomed using bilinear interpolation.
(c) Same as (b) but using bicubic interpolation.

Sampling

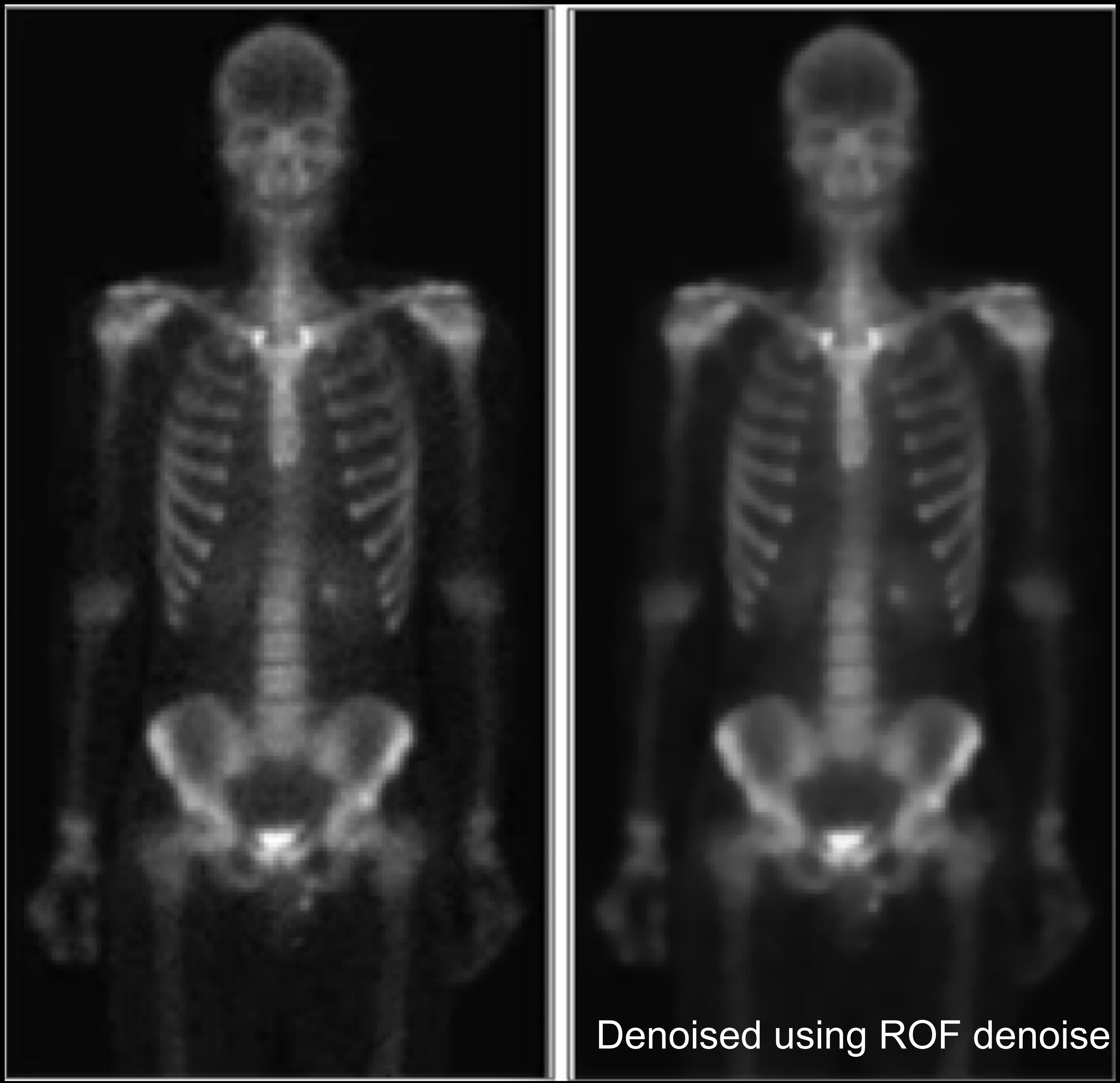


Noise

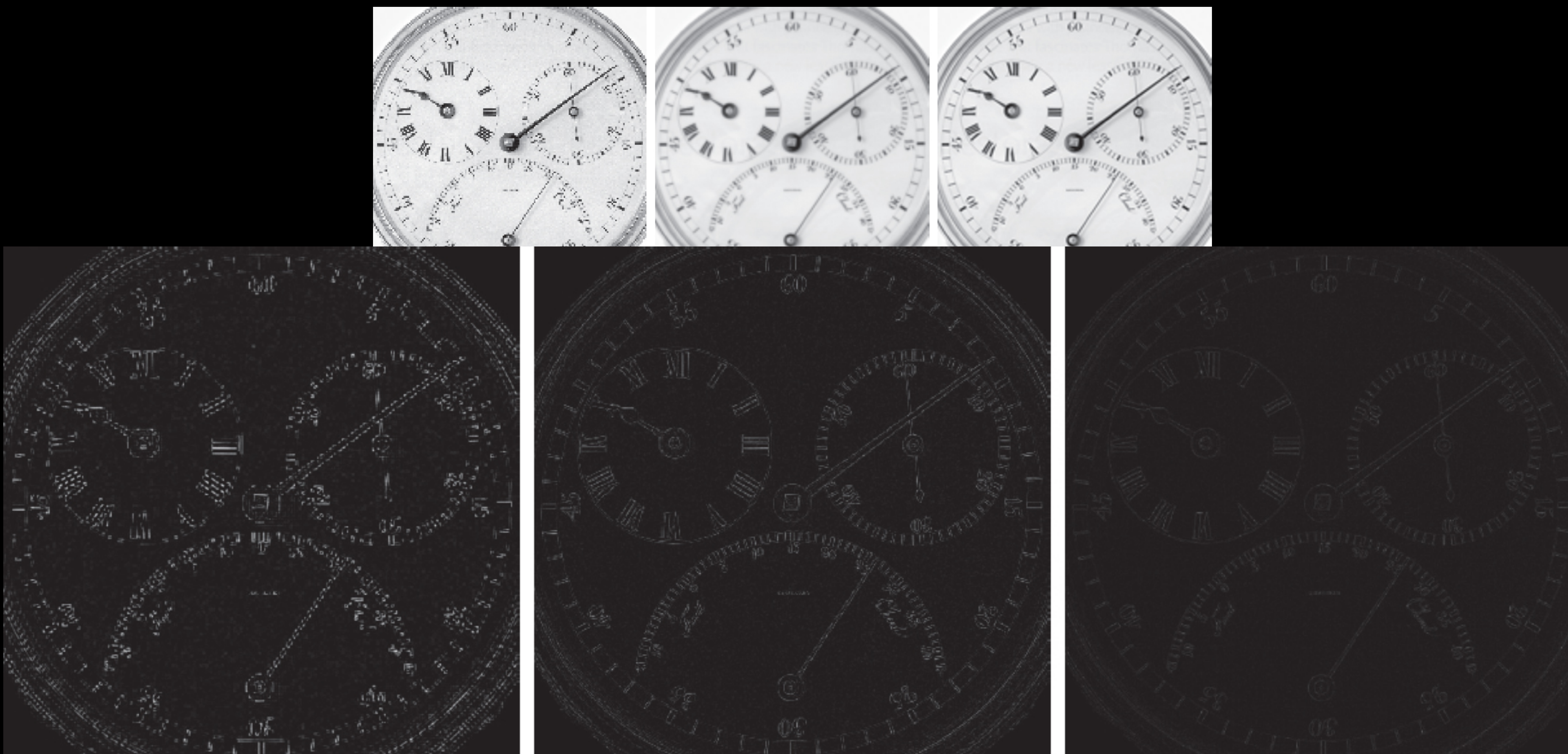


(a) Noisy image of the Sombrero Galaxy. (b)-(f) Result of averaging 10, 50, 100, 500, and 1,000 noisy images, respectively. All images are size 1548x2238 pixels and all scaled so intensities span the full [0, 255] intensity scale.

Computational Denoising



Tricks with multiple images

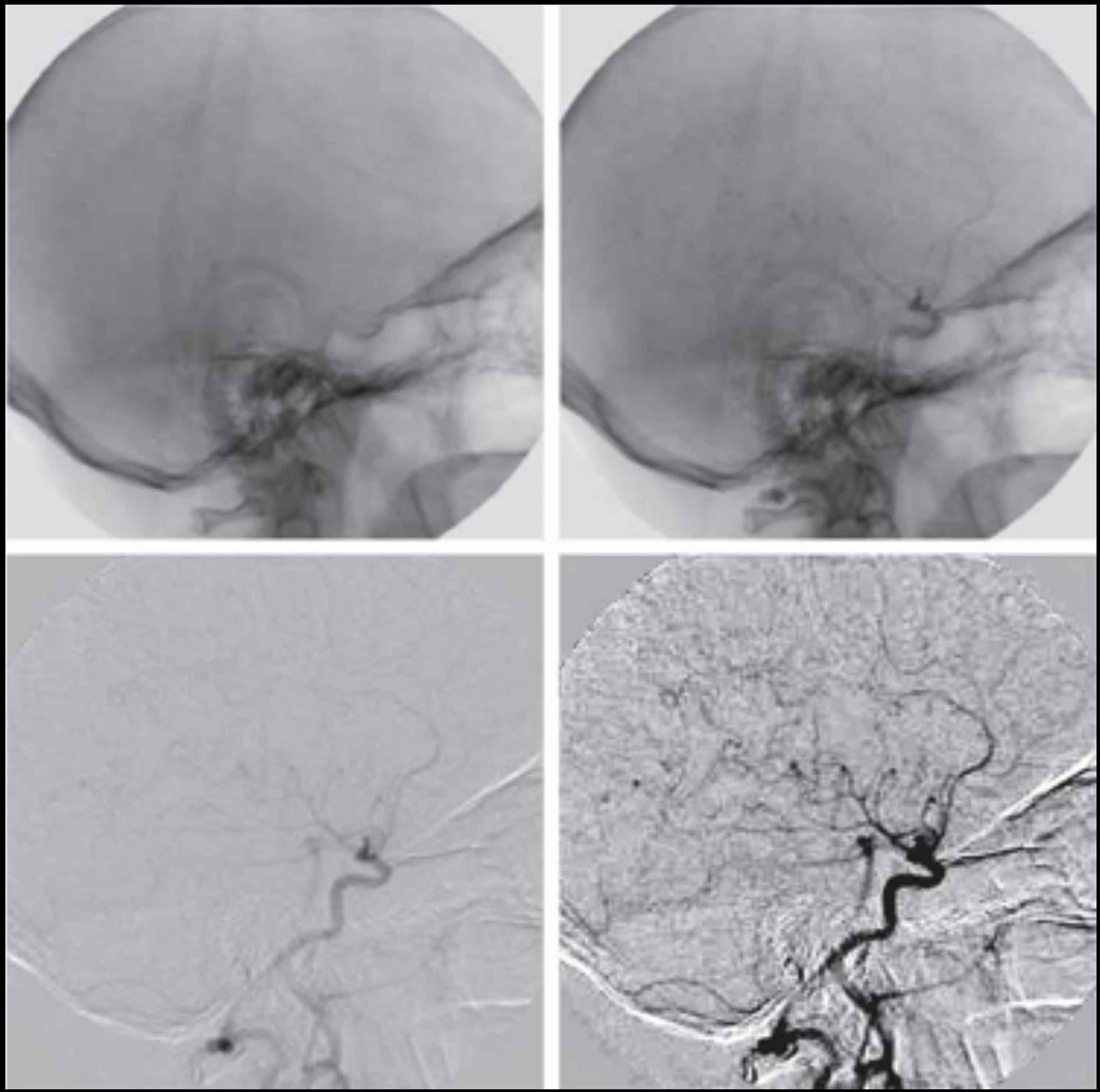


(a) Difference between the 930 dpi and 72 dpi images in Fig. 2.23. (b) Difference between the 930 dpi and 150 dpi images. (c) Difference between the 930 dpi and 300 dpi images.

Digital Subtraction Angiography

Digital subtraction angiography.
(a) Mask image. (b) A live image.
(c) Difference between (a) and (b).
(d) Enhanced difference image.

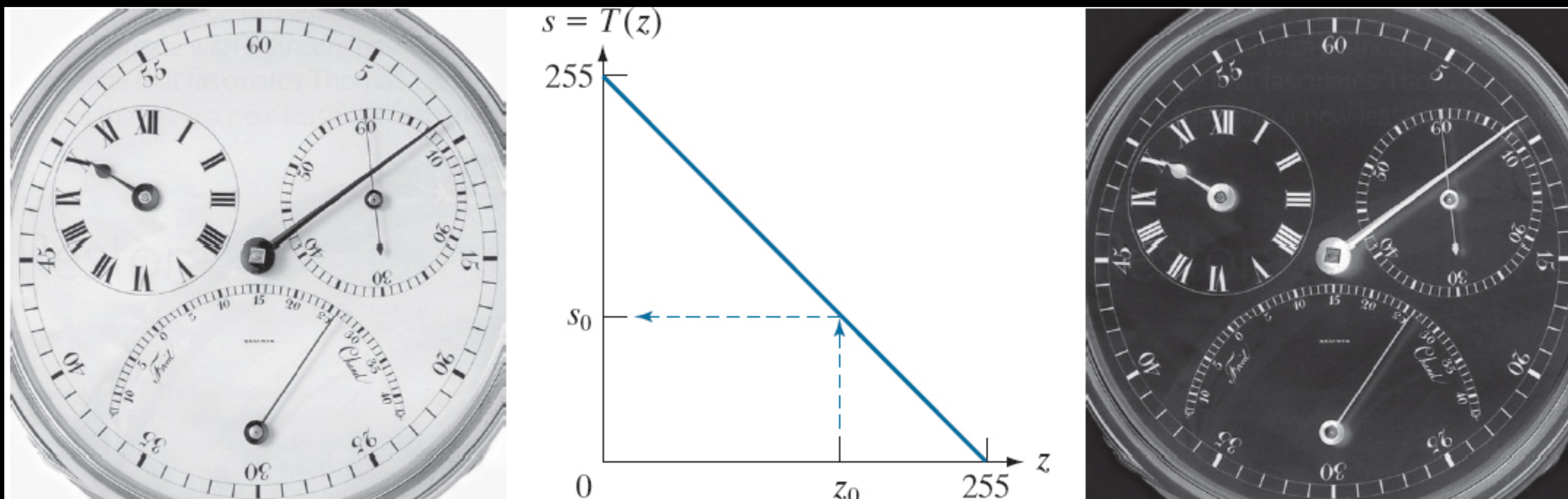
Image courtesy of the Image Sciences Institute, University Medical Center, Netherlands (from our textbook: Digital Image Processing in Matlab)



Shading correction

Shading correction. (a) Shaded test pattern. (b) Estimated shading pattern. (c) Product of (a) by the reciprocal of (b). (See Section 3.5 for a discussion of how (b) was estimated.)

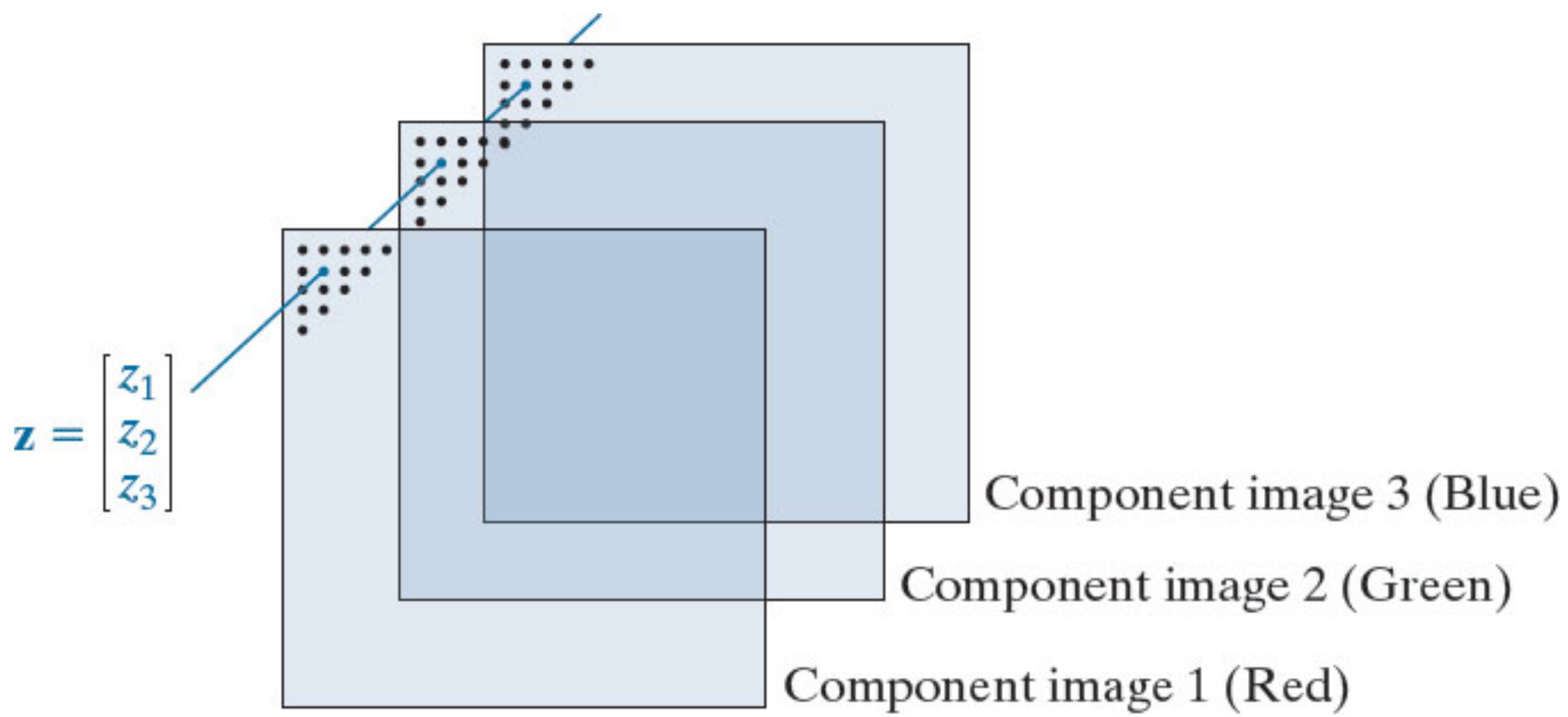
Inverse lookup table



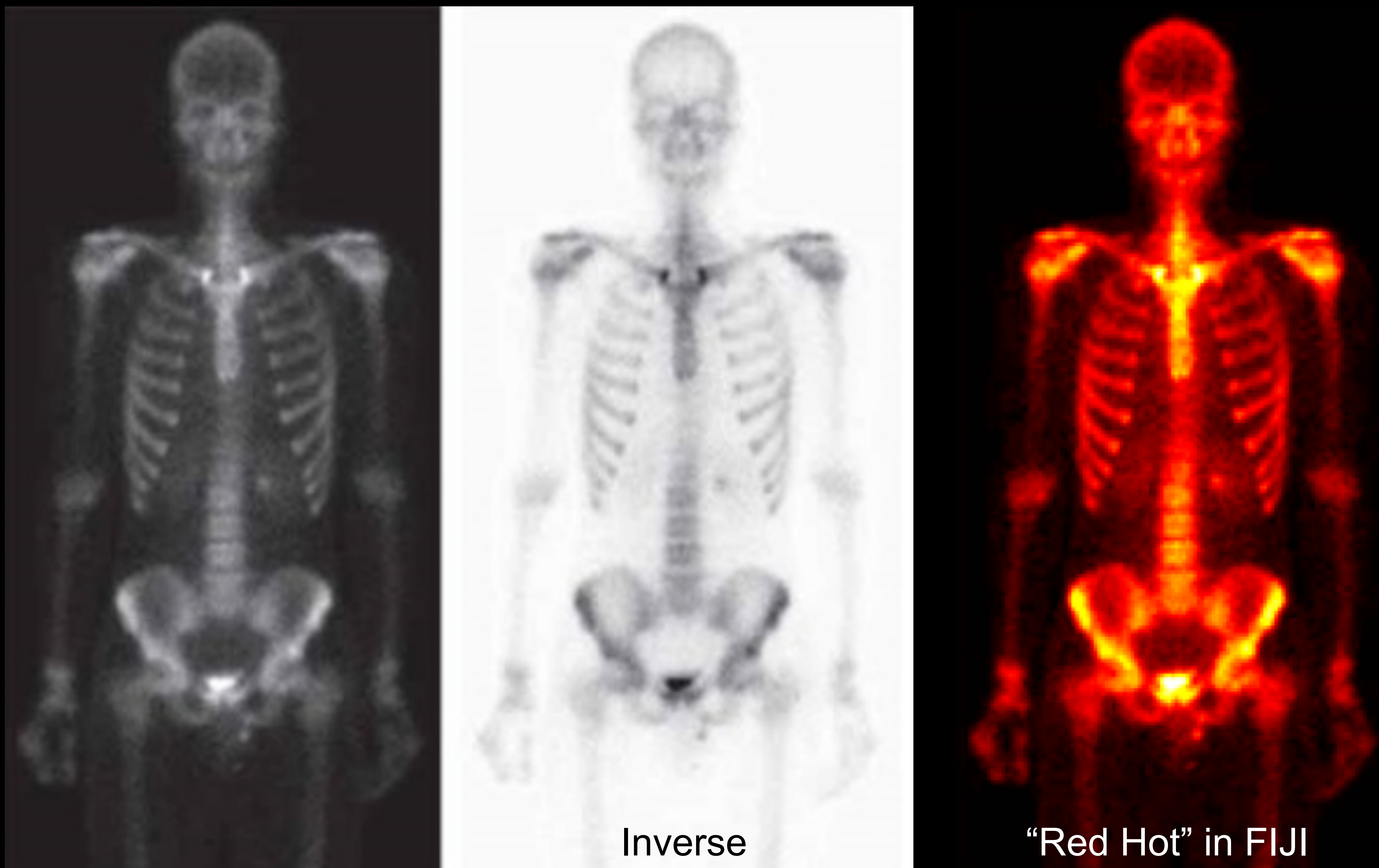
(a) 8-bit image. (b) Intensity transformation function used to obtain the digital equivalent of a "photographic" negative of an 8-bit image. The arrows show transformation of an arbitrary input intensity value z into its corresponding output value s0. (c) Negative of (a) obtained using (b)

Color Images

Forming a vector

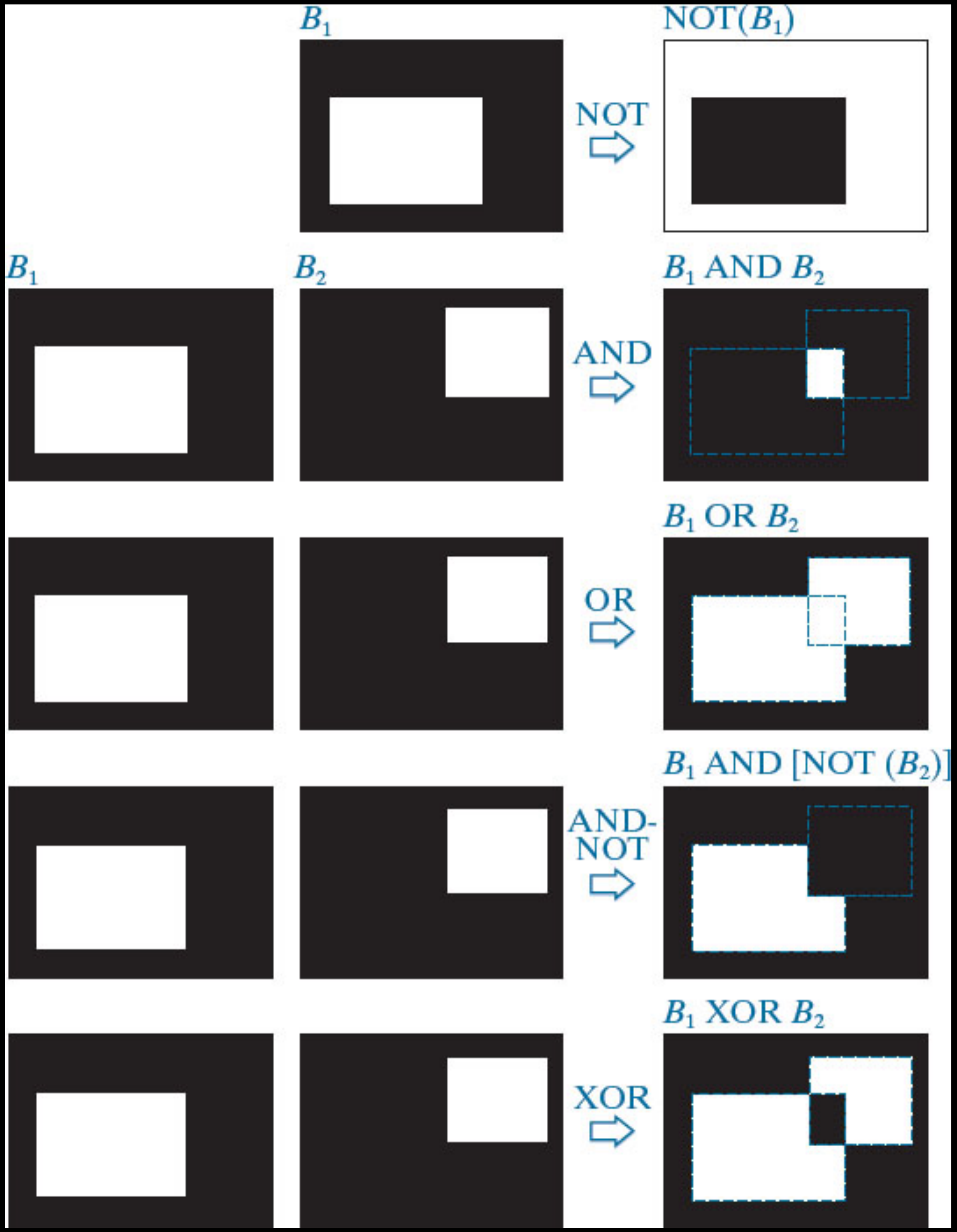


Synthetic lookup tables

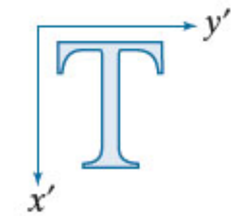
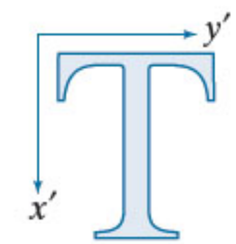
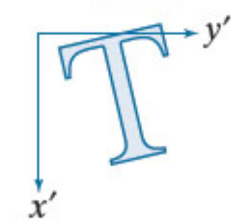
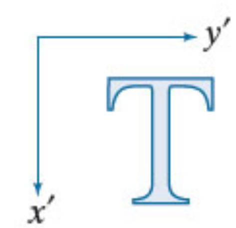
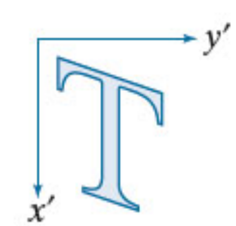
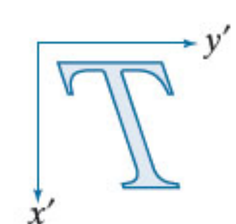


Chasing the right one can make it easier to see stuff — and to get published…

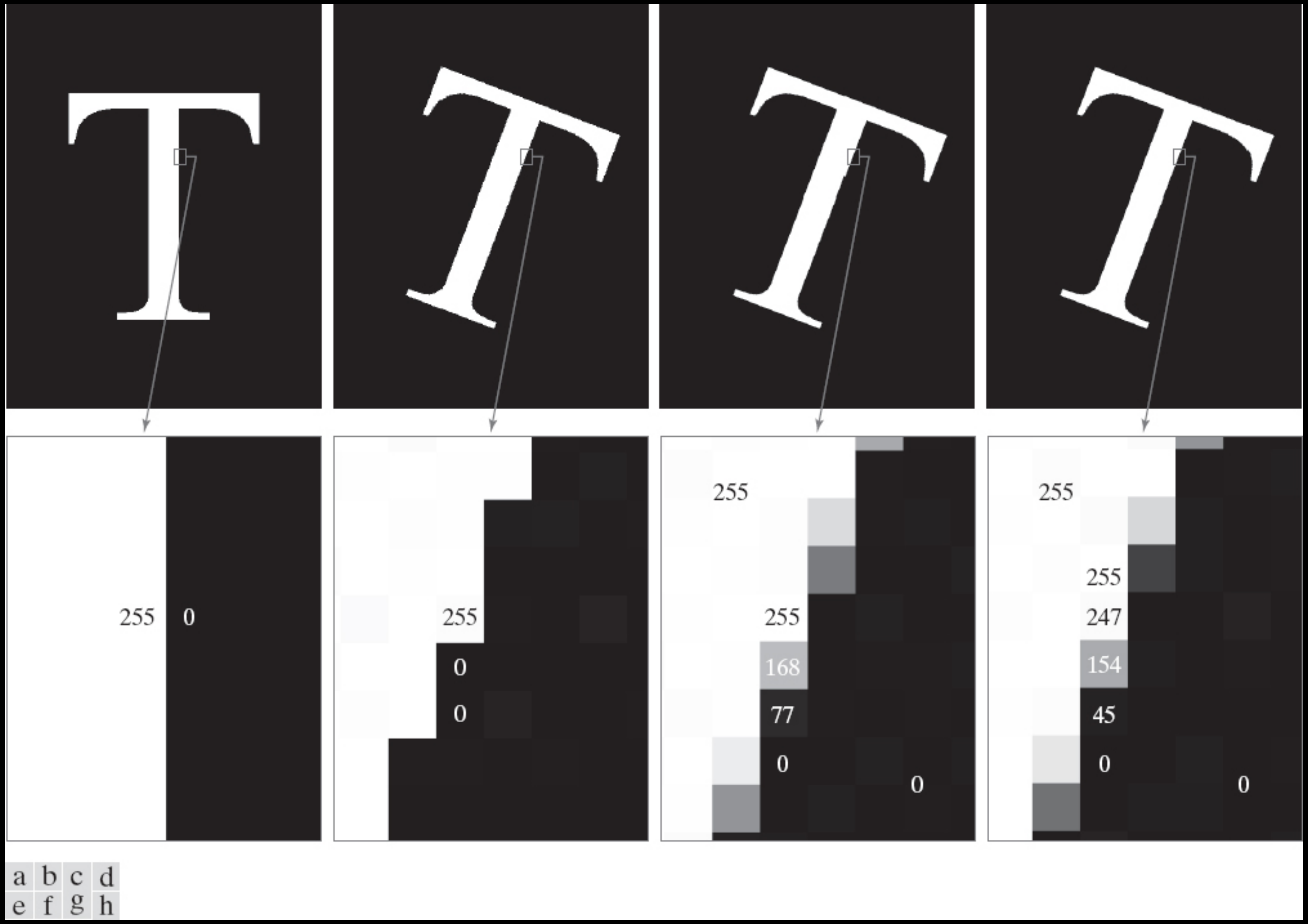
Logical Operators



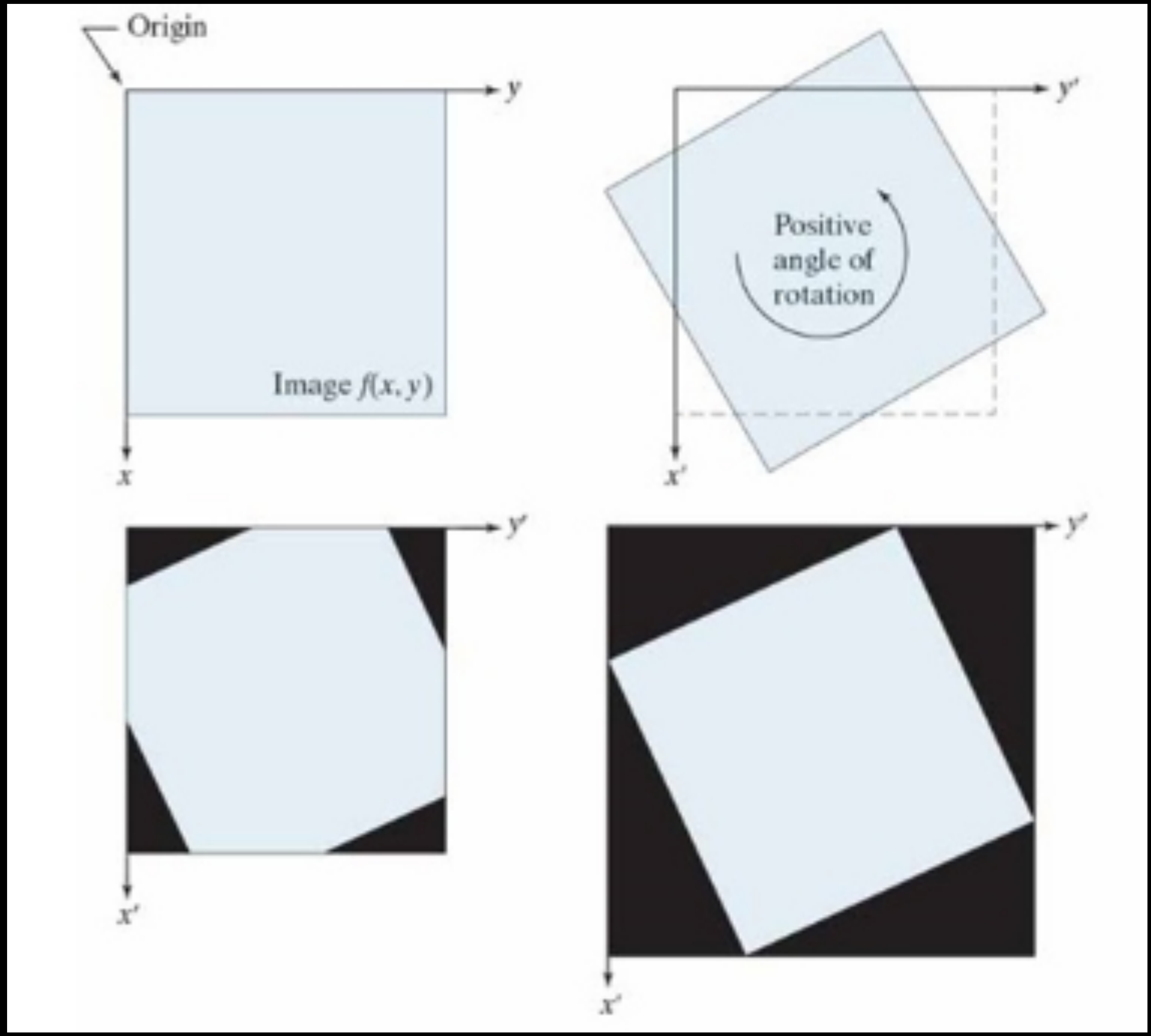
Affine transformation

Transformation Name	Affine Matrix, A	Coordinate Equations	Example
Identity	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x$ $y' = y$	
Scaling/Reflection (For reflection, set one scaling factor to −1 and the other to 0)	$\begin{bmatrix} c_x & 0 & 0 \\ 0 & c_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = c_x x$ $y' = c_y y$	
Rotation (about the origin)	$\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x\cos\theta - y\sin\theta$ $y' = x\sin\theta + y\cos\theta$	
Translation	$\begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x + t_x$ $y' = y + t_y$	
Shear (vertical)	$\begin{bmatrix} 1 & s_v & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x + s_v y$ $y' = y$	
Shear (horizontal)	$\begin{bmatrix} 1 & 0 & 0 \\ s_h & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x' = x$ $y' = s_h x + y$	

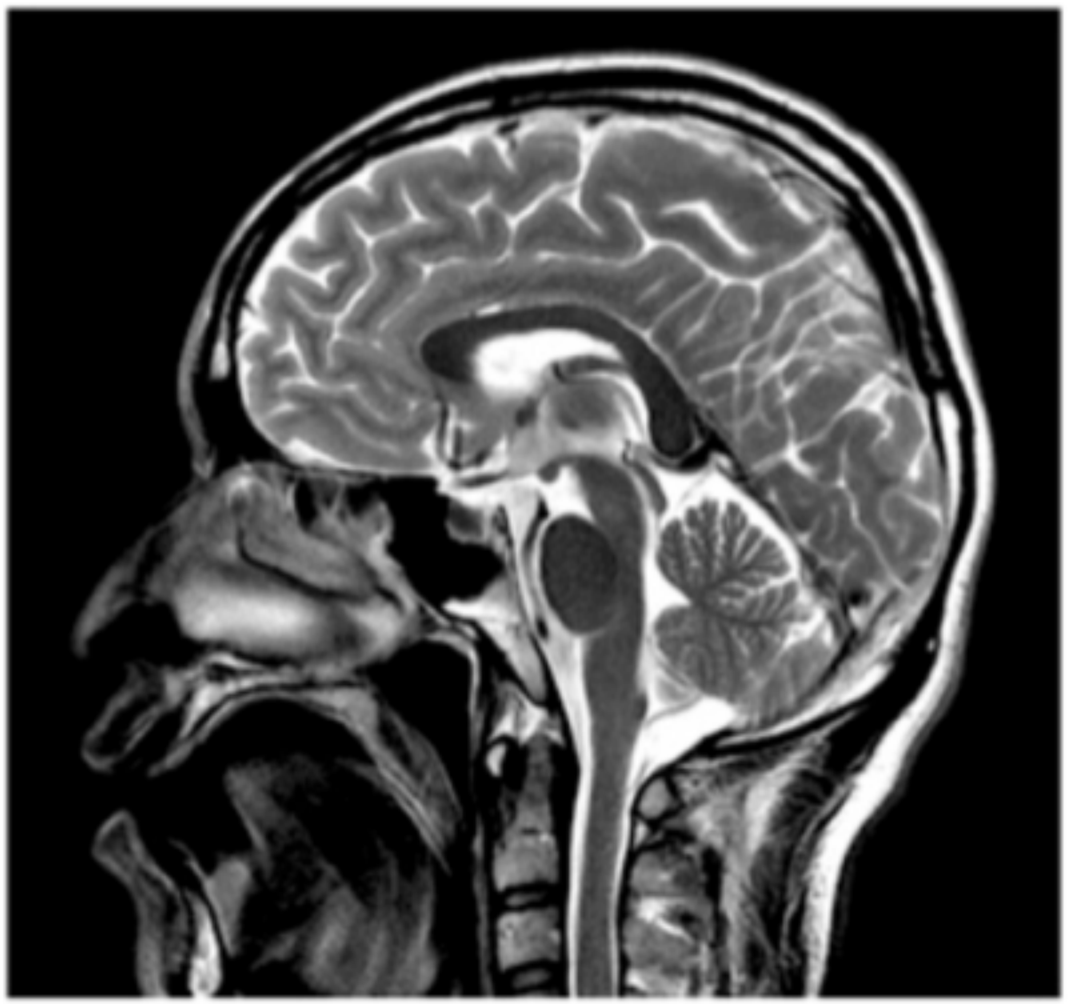
Interpolation

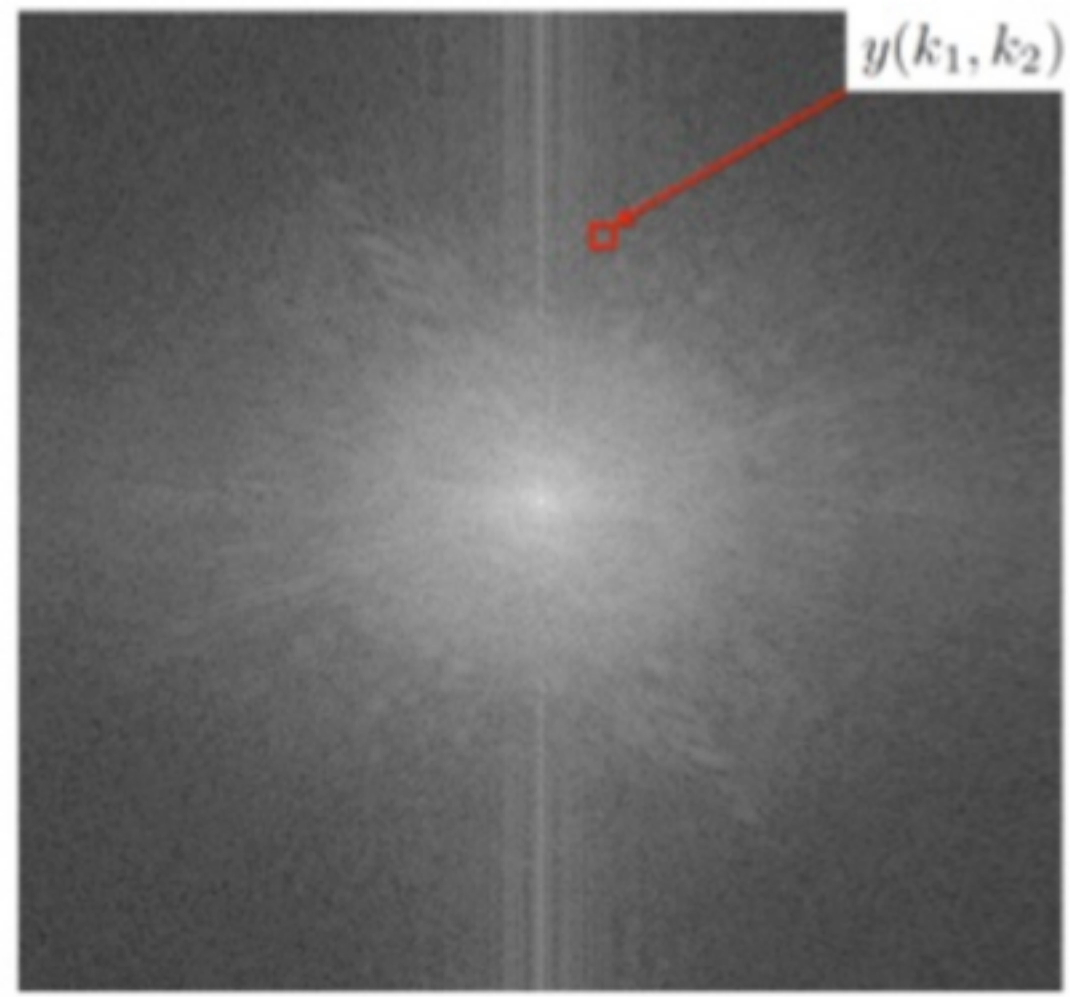


Enlarge



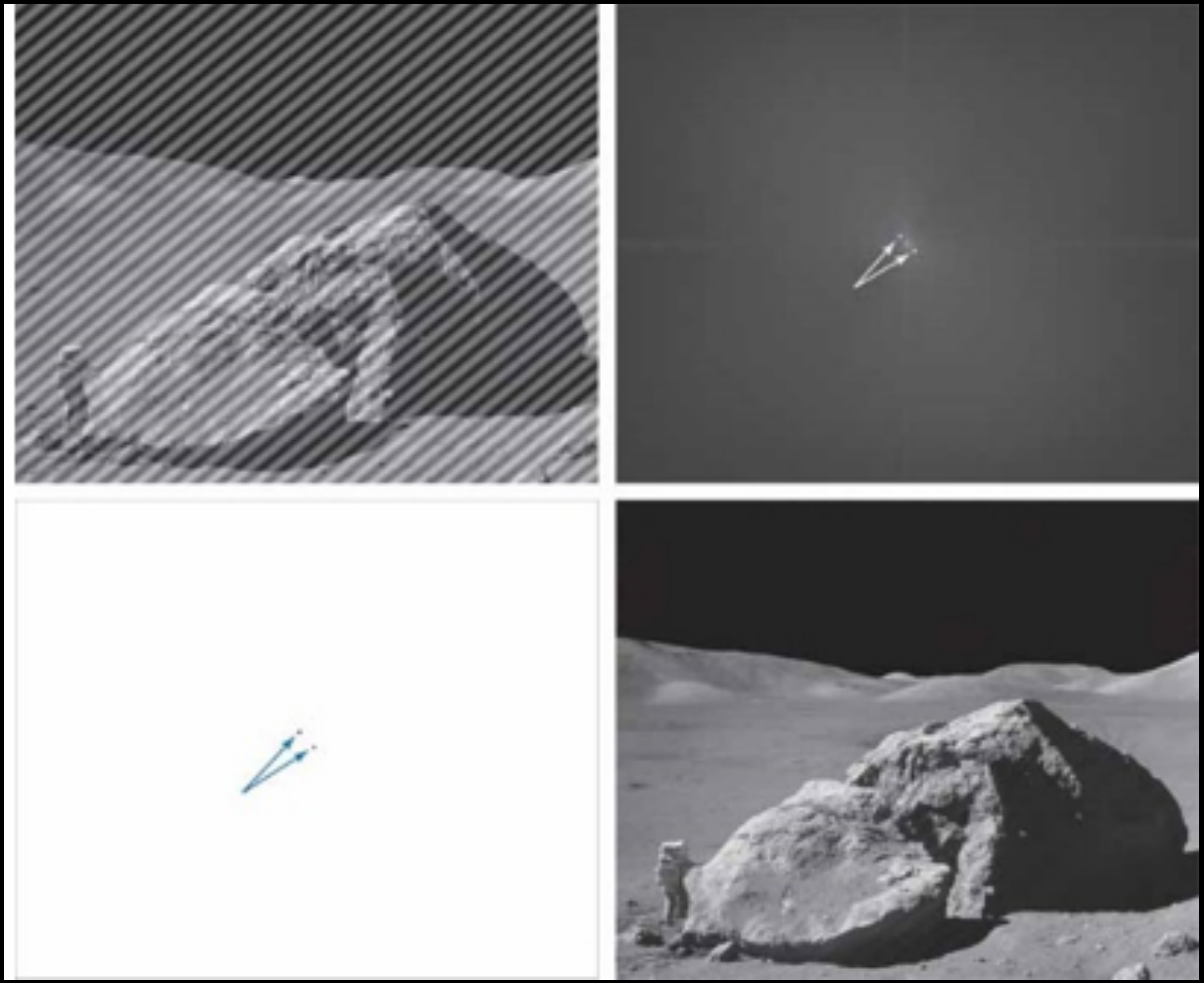
Fourier Transform





$$y(k_1, k_2) = \iint f(x_1, x_2) e^{-i2\pi(k_1 x_1 + k_2 x_2)} \, dx_1 dx_2$$

Filtering



Thursday is Lab

- We will try out our computer classroom
- We will use MATLAB and ImageJ / FIJI