CSE428: Image Processing

Lecture 3: Point Processing - Part 1

Spatial Image Processing
Introduction

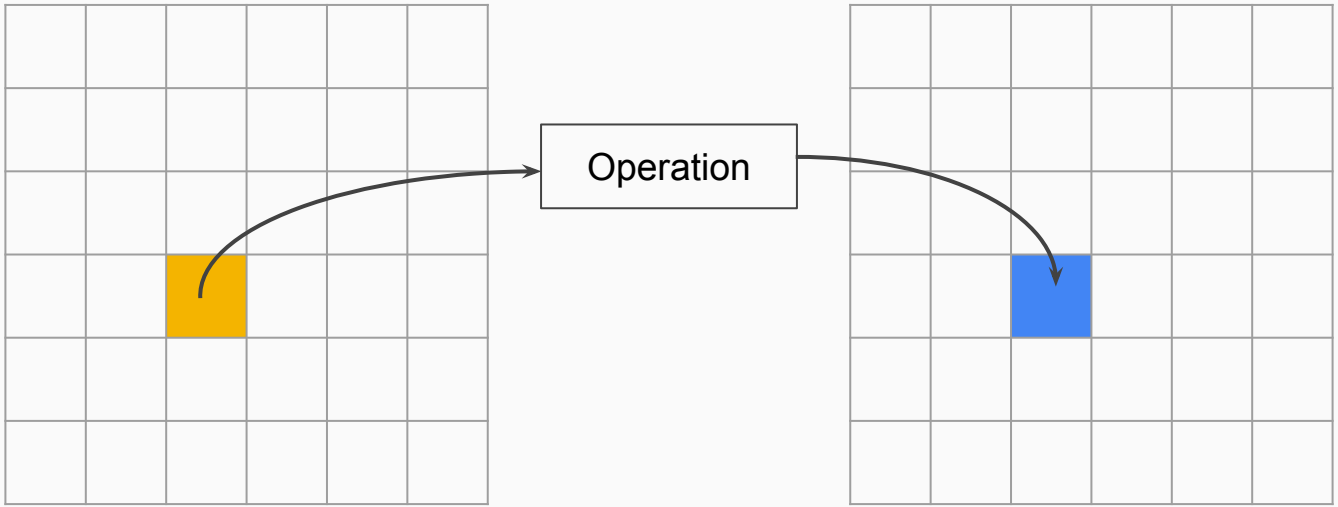
Typical image processing pipeline

- **Transform**: pixel values in some other, but equivalent form.
  - For example, fourier, wavelet, unity (no transform)
- **Spatial processing**: direct manipulation of pixels (i.e. unity transform)
- $g(x, y) = T[f(x, y)]$, where f = input image, g = output image, $T[]$ = mapping function
- **Scope**: (i) Enhancement - improved visual quality (ii) Improved recognition rate

Spatial Image Processing

Types

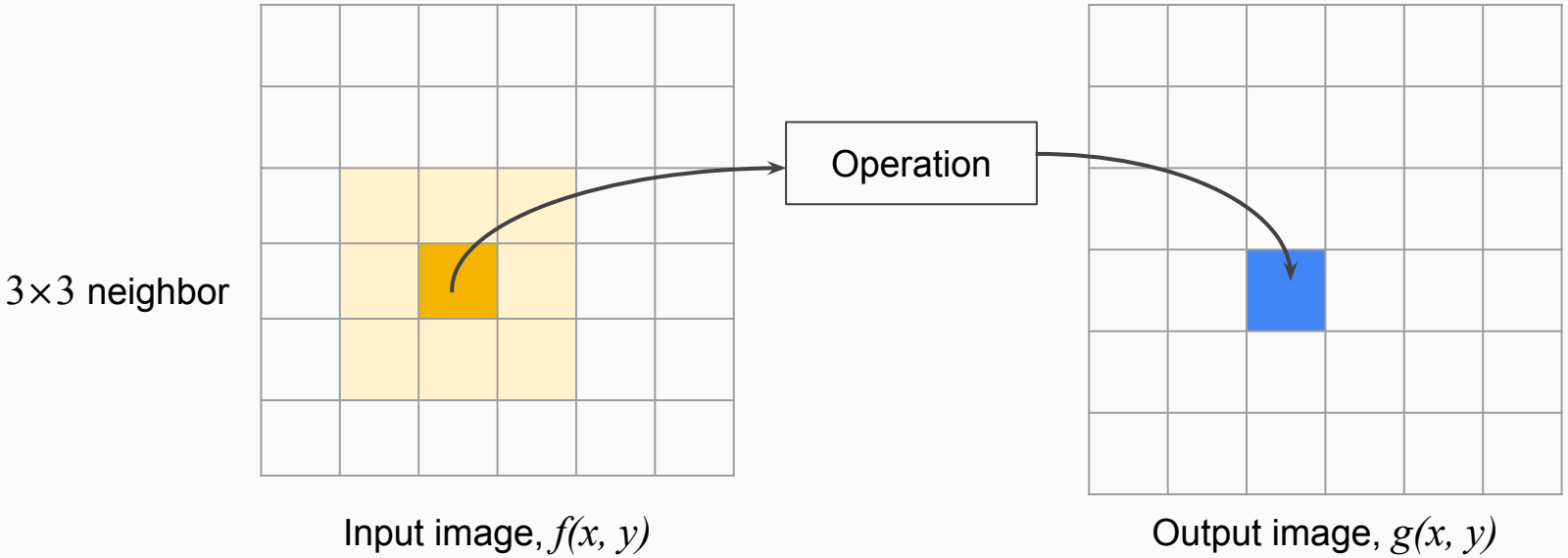
Point Processing



Spatial Image Processing

Types

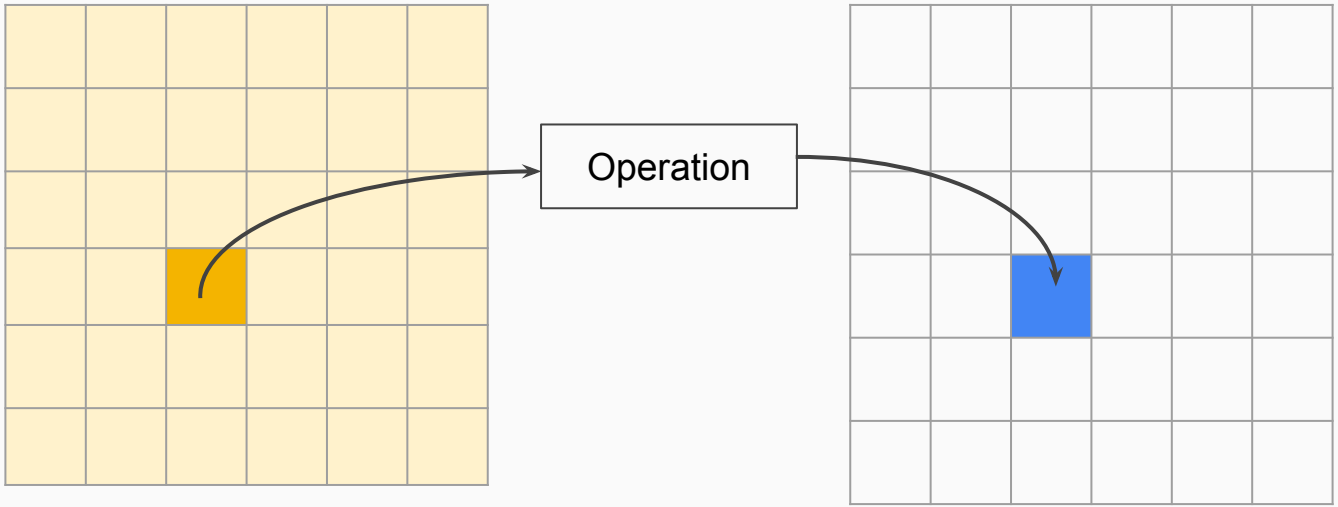
Neighborhood Processing (Filtering)



Spatial Image Processing

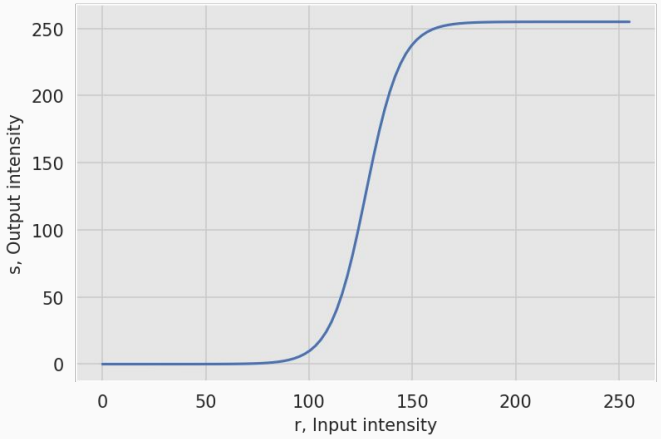
Types

Global Processing

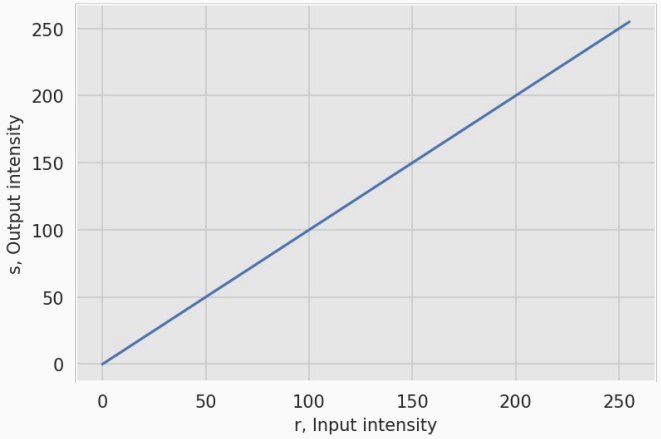


Mapping Function

- $s = T[r]$, where r = input intensity, s = output intensity, $T[]$ = mapping function
- Mapping functions can be visualized graphically



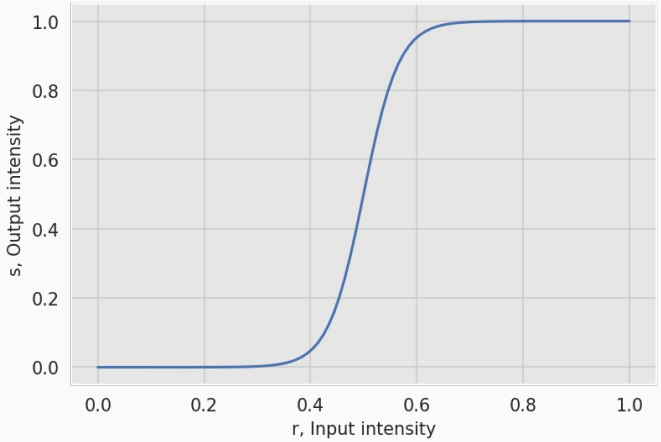
Contrast stretching



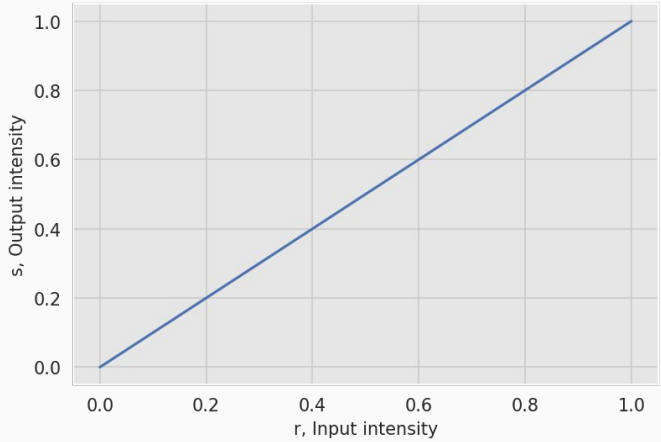
Unity mapping

Mapping Function

- Will consider [0, 1] range for simplicity



Contrast stretching

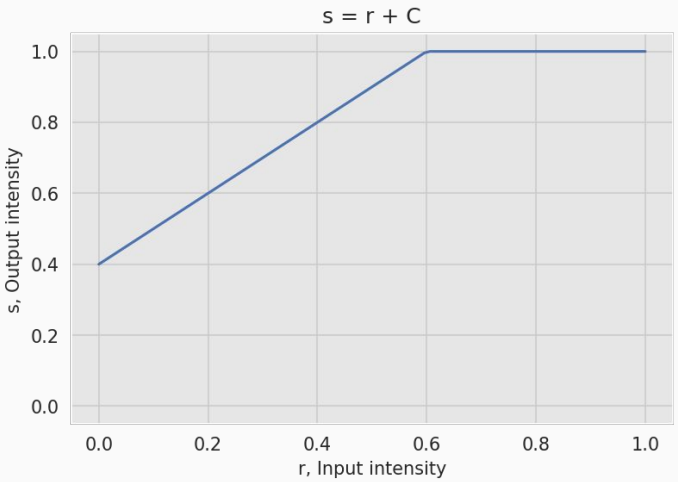


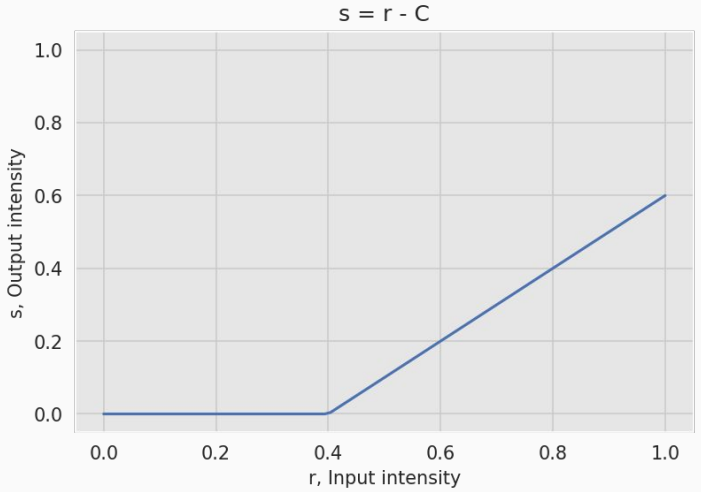
Unity mapping

Arithmetic Operations

Addition and Subtraction - Brightness Adjustment

- $s = r \pm C$, where r = input intensity, s = output intensity, C = a positive constant
- Have to make sure the outputs are clipped between [0, 1]
- Increases (+) or decreases (-) the overall brightness





Arithmetic Operations

Addition and Subtraction - Brightness Adjustment

- Addition might saturate high intensity levels

Original

s = r + 0.25

Arithmetic Operations

Addition and Subtraction - Brightness Adjustment

- Subtraction might saturate low intensity levels

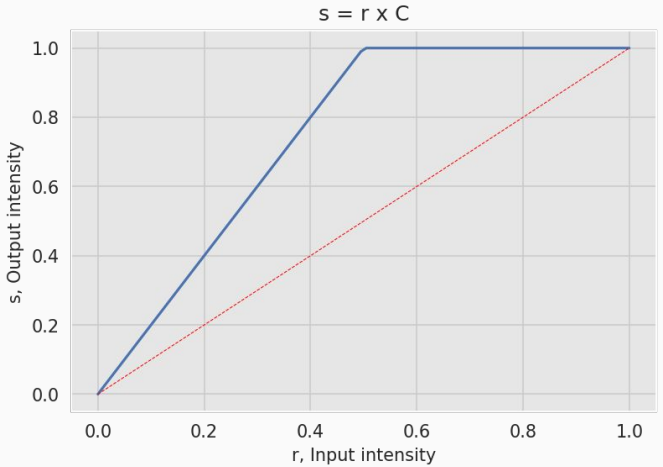
Original

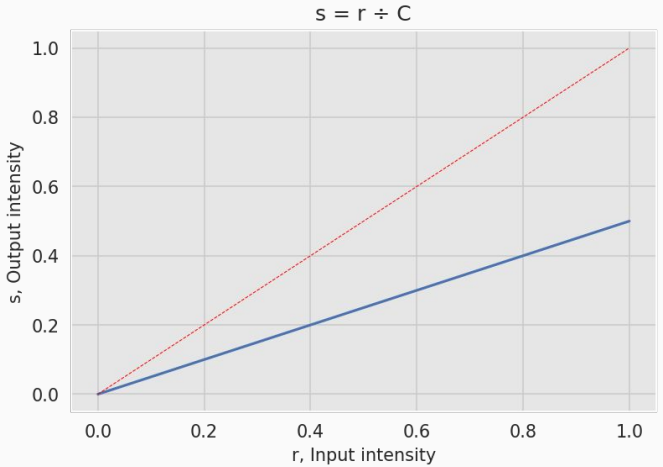
s = r - 0.25

Arithmetic Operations

Multiplication and Division - Contrast Adjustment

- $s = r \times C$ *or* $r \div C$, r = input intensity, s = output intensity, C = a positive constant
- Have to make sure the outputs are clipped between [0, 1]
- Combined with addition/subtraction, can be used for contrast adjustment





Arithmetic Operations

Multiplication and Division - Contrast Adjustment

- Overall brightness increased, contrast increased

Original

s = r x 2

Arithmetic Operations

Multiplication and Division - Contrast Adjustment

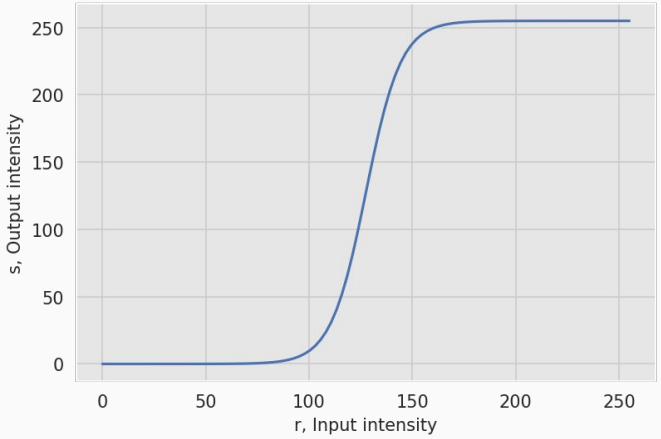
- Overall brightness decreased, contrast decreased

Original

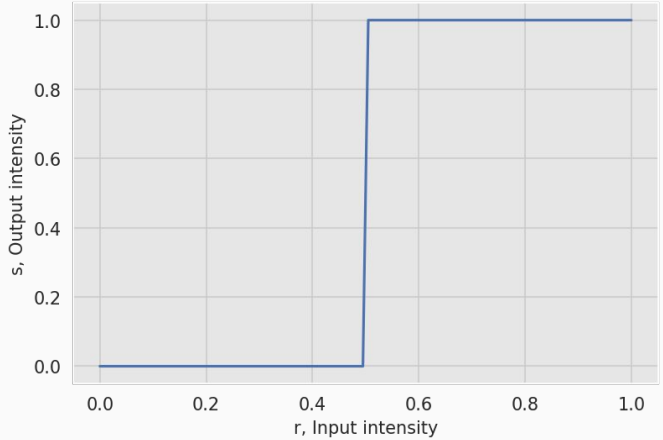
$s = r \div 2$

Contrast Stretching

- A wide range near black/white is **compressed** to a corresponding narrow range
- A small range near the middle is **expanded** to a wide range
- Limiting case of contrast stretching is **thresholding**. Produces binary image.



Contrast stretching

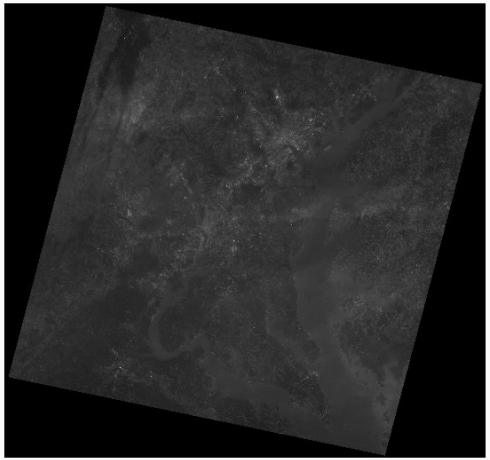


Thresholding

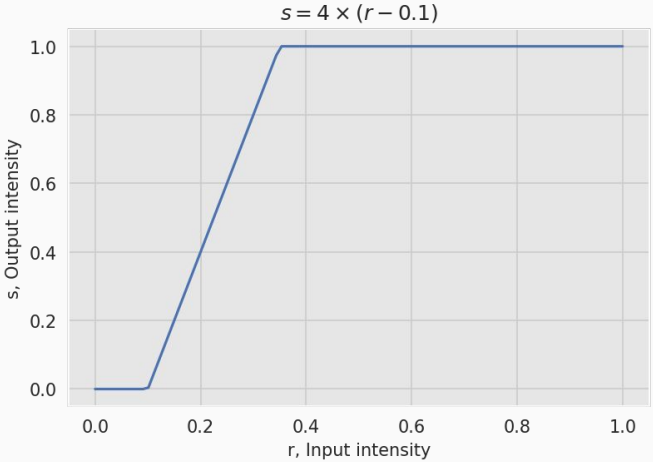
Contrast Stretching

Using arithmetic operation

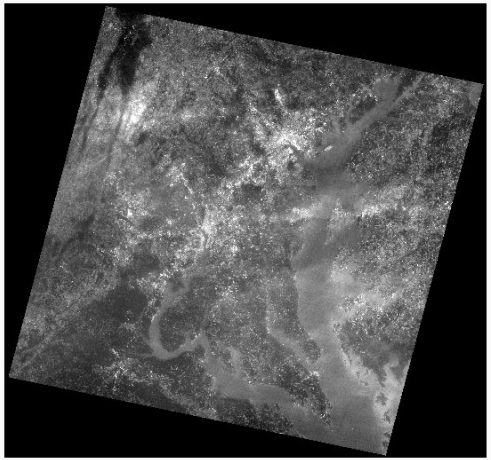
- $s = C_1 \times (r - C_2)$
- Some loss of information near low and high intensity levels



Input image (LANDSAT band 1)



Stretching function

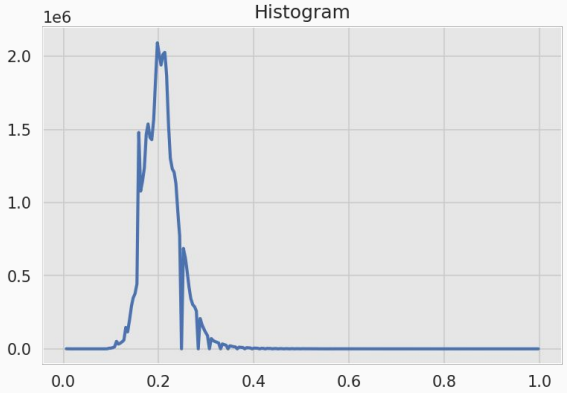


Output image

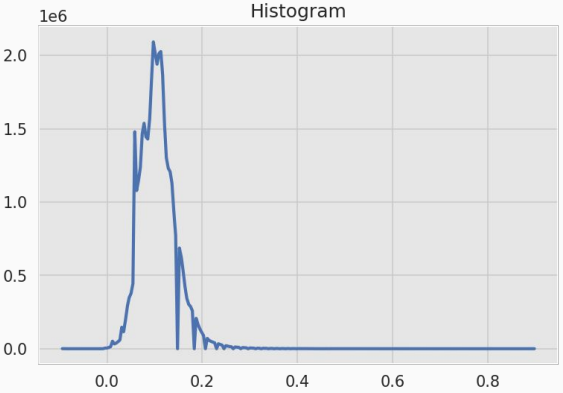
Contrast Stretching

Using arithmetic operation

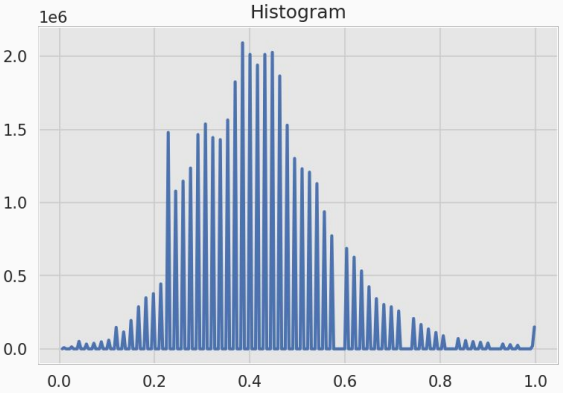
- How to calculate C_1 and C_2?



Histogram of I



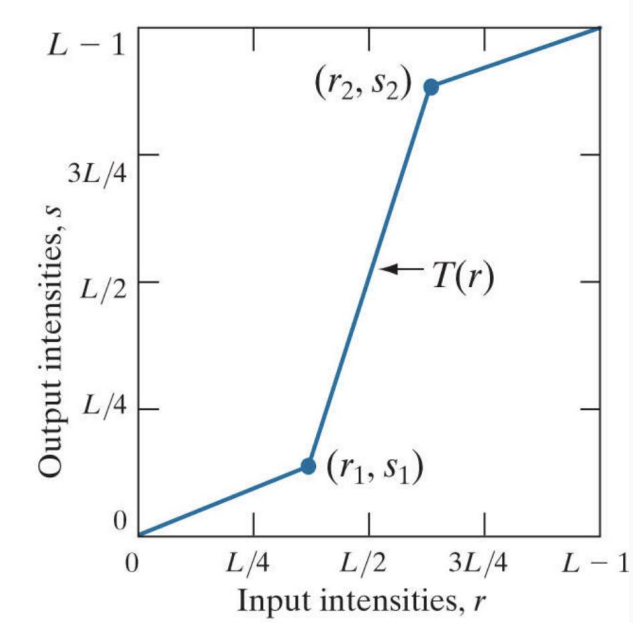
Histogram of (I-0.1)



Histogram of 4x(I-0.1)

Contrast Stretching

Using Piecewise Linear Mapping

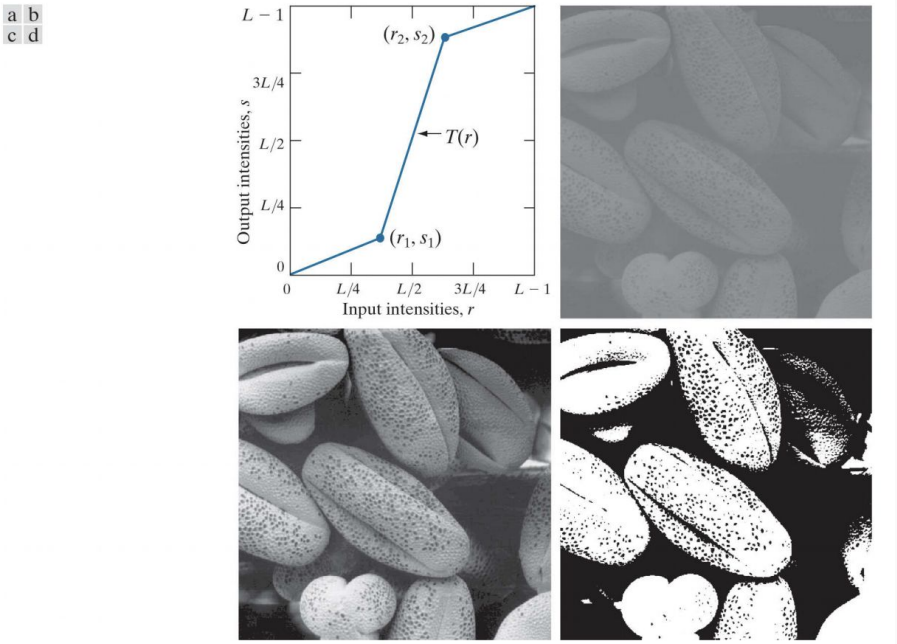


By Rafael C. Gonzalez & Richard E. Woods, 2018, *Digital Image Processing*, 4th Edition

- $[0, r_1]$ is mapped to $[0, s_1]$ where $s_1 < r_1$ [Compressed]
- $[r_2, 1]$ is mapped to $[s_2, 1]$ where $s_2 > r_2$ [Compressed]
- $[r_1, r_2]$ is mapped to $[s_1, s_2]$ **[Stretched]**
- No clipping, hence no loss of information

Contrast Stretching

Using Piecewise Linear Mapping



(a) Piecewise linear transformation function.

(b) A low-contrast electron microscope image of pollen, magnified 700 times.

(c) Result of contrast stretching.

(d) Result of thresholding.

(Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

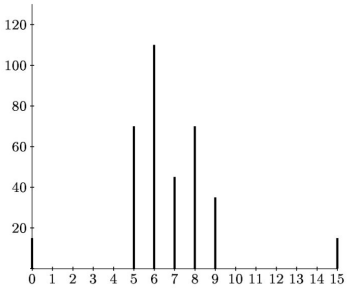
Intensity Transformation

What is happening

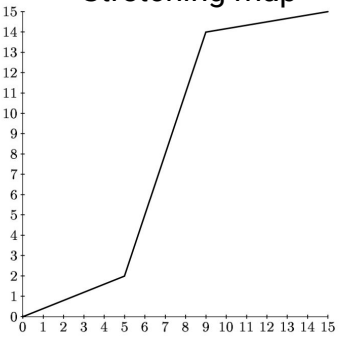
Example Histogram

r	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n_r	15	0	0	0	0	70	110	45	70	35	0	0	0	0	0	15

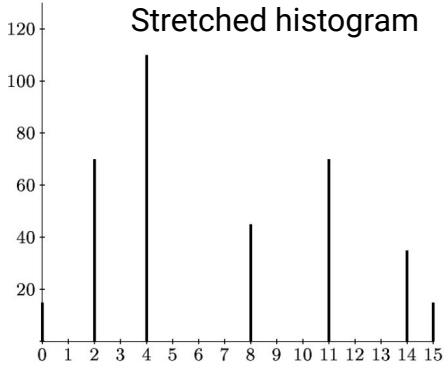
Original histogram



Stretching map



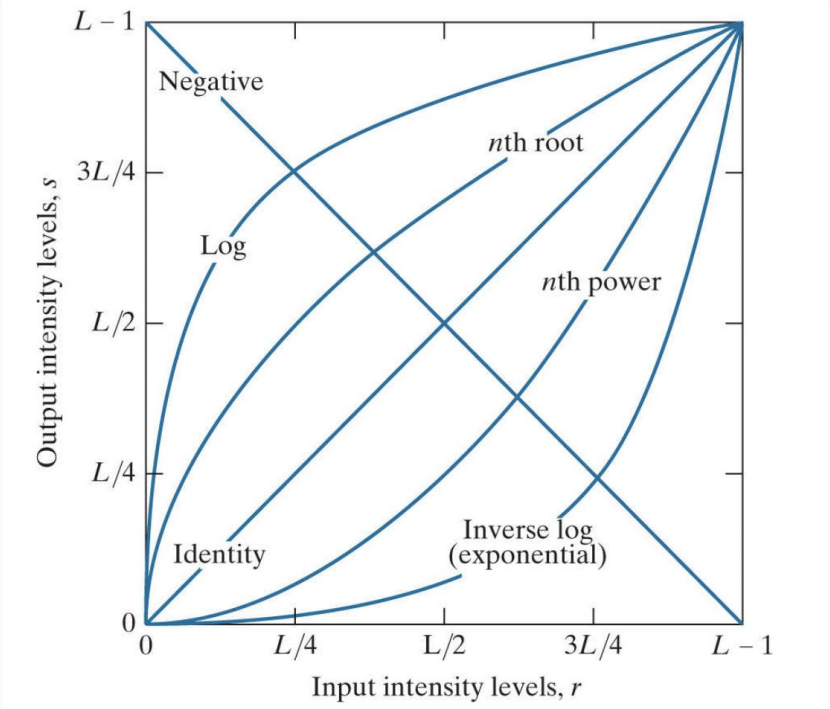
Stretched histogram



By Alasdair McAndrew, 2004, *An Introduction to Digital Image Processing with Matlab: Notes for SCM2511 Image Processing 1*

Intensity Transformation

Basic transformations



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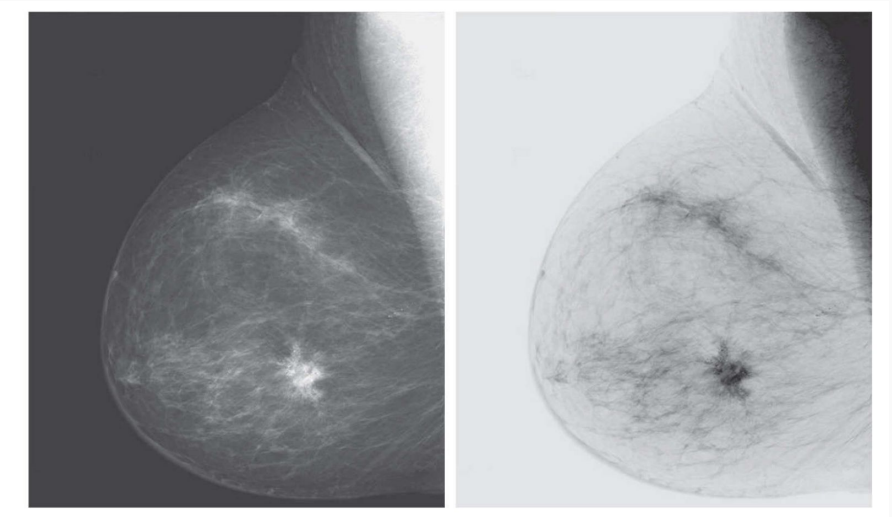
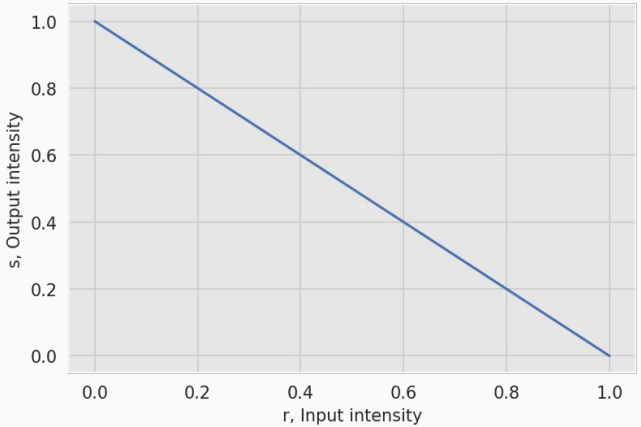
Intensity Transformation

Negative Image





- $s = 1 - r$
- Mammogram with better tissue structure

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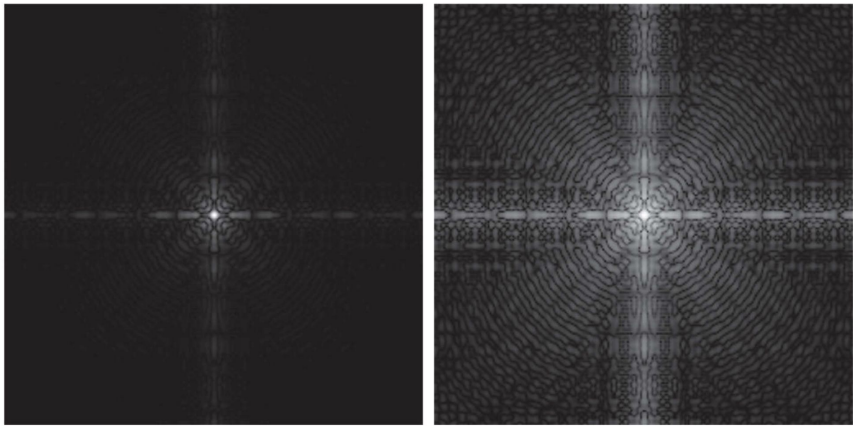
Intensity Transformation

Log Transformation - Dynamic Range Compression



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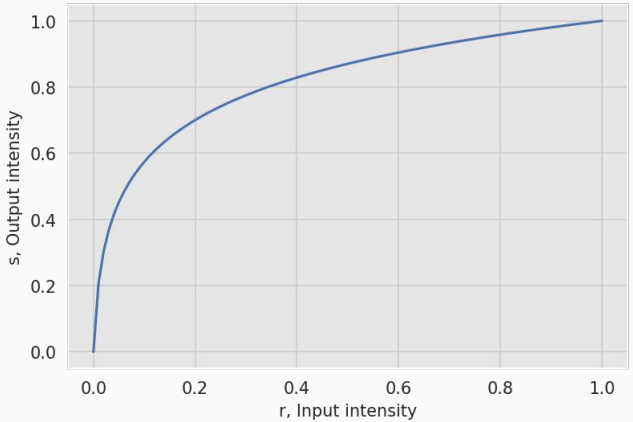
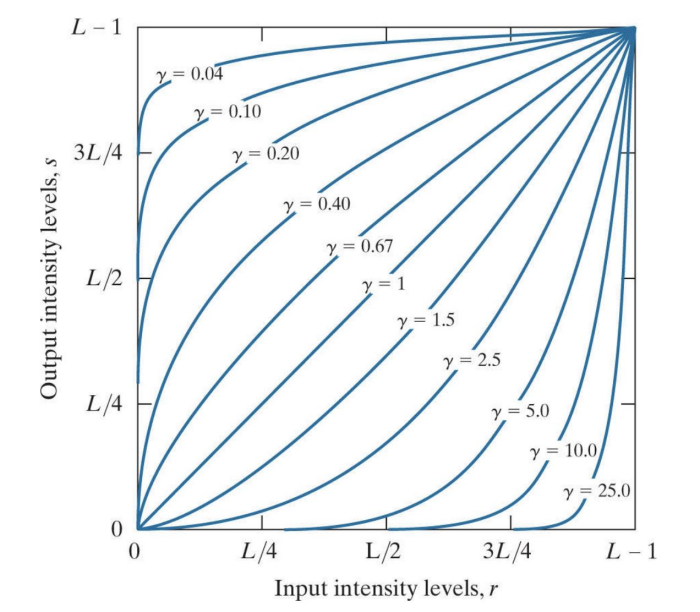


- $s = c \log(1 + r), r \geq 0, c \geq 0$
- Low range gray levels expanded
- High range gray levels compressed
- ^ Visualization of fourier spectra of an image before and after log compression

Intensity Transformation

Power Law Transformation



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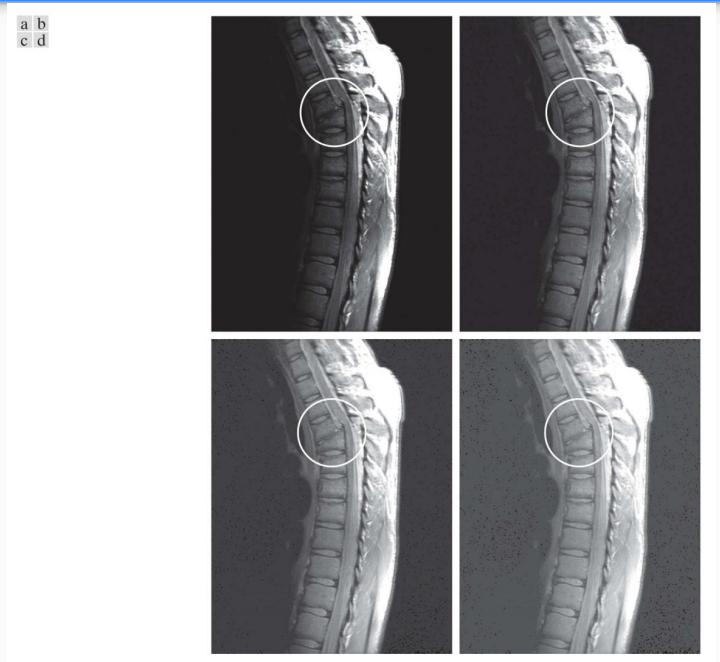
- $s = cr^{\gamma}$, $r \geq 0$, c, $\gamma > 0$
- A generalized version of log transformation
- $\gamma > 1$ Inverse log transformation, dynamic range expansion
- $\gamma < 1$ Log transformation, dynamic range compression

Intensity Transformation

Power Law Transformation - Dynamic Range Compression



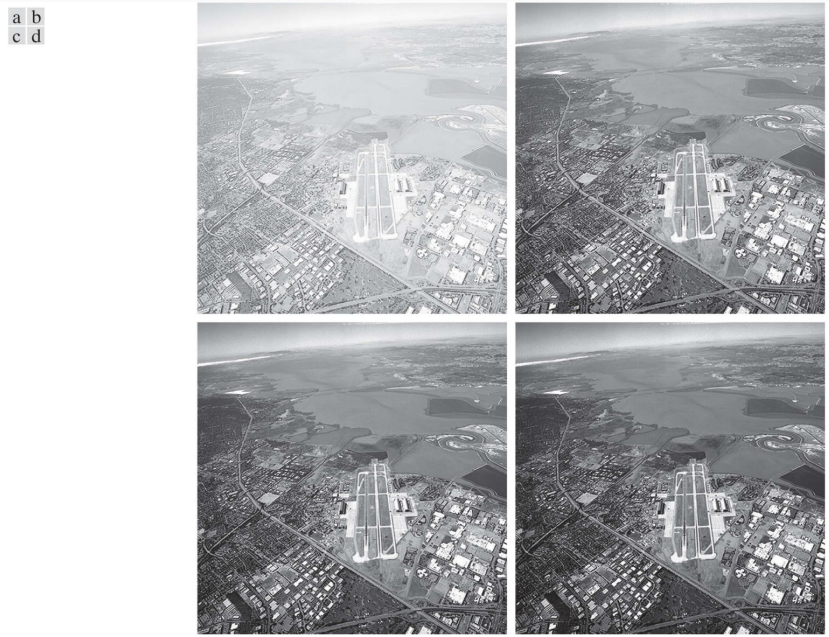
(a) Magnetic resonance image (MRI) of a fractured human spine (the region of the fracture is enclosed by the circle).

(b)–(d) Results of applying the transformation in Eq. (3-5) with c = 1 and γ = 0.6, 0.4, 0.3, respectively.

(Original image courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Intensity Transformation

Power Law Transformation - Dynamic Range Expansion



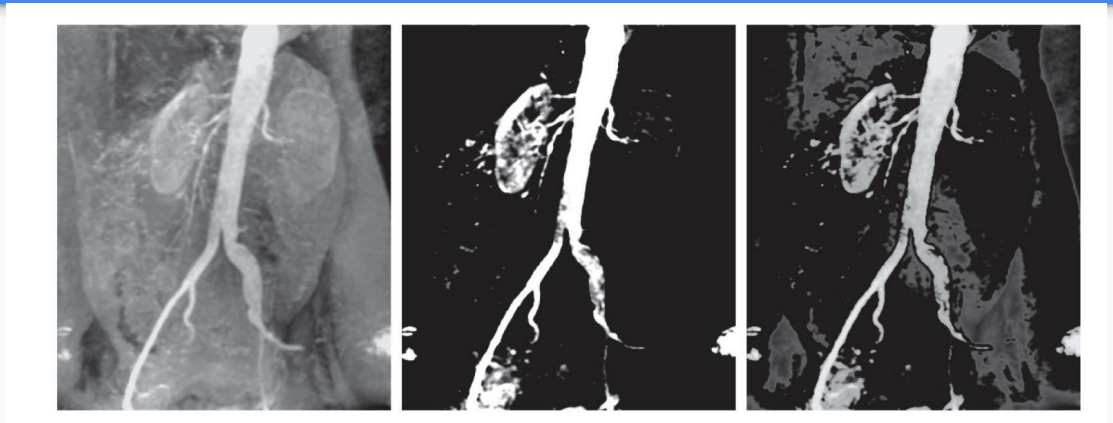
(a) Ariel Image

(b)–(d) Results of applying the transformation in Eq. (3-5) with c = 1 and γ = 3, 4, 5, respectively.

(Original image courtesy of NAS)

Intensity Transformation

Gray-Level Slicing



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Discord

Link: https://discord.gg/vM2Npk3V2q

Questions?