

Deep Learning for Computer Vision

Image Representation

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Question

On Colour

If visible light spectrum is VIBGYOR, why RGB colour representation?

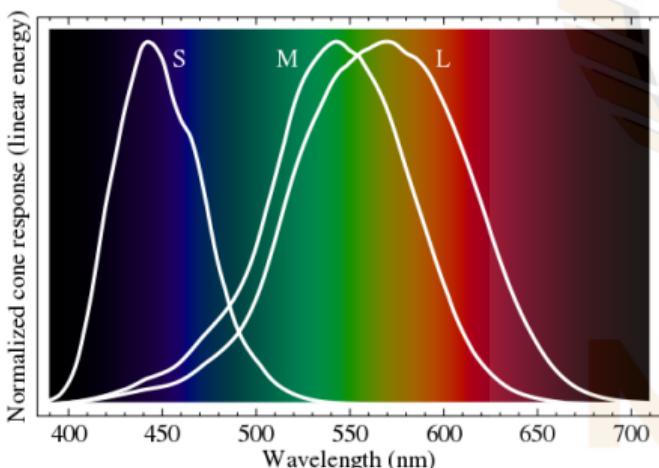
The logo consists of a stylized flower in the center, surrounded by a circular wreath composed of vertical bars in shades of yellow, orange, and red.

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Question

On Colour

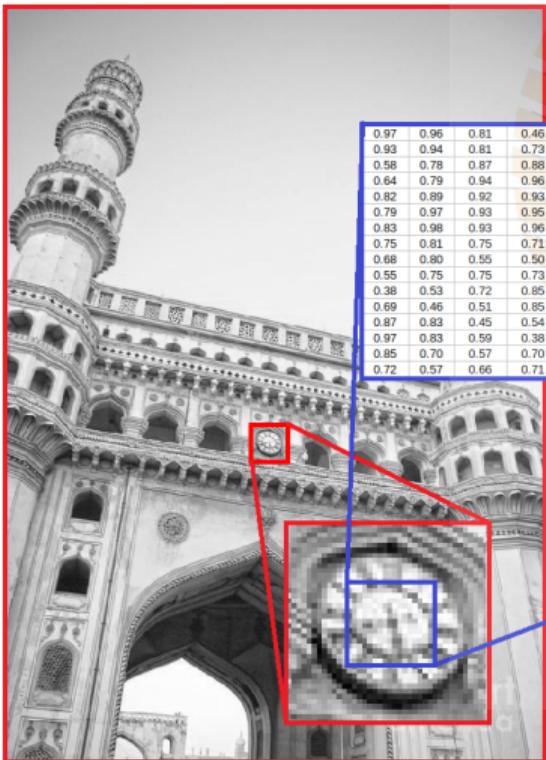
If visible light spectrum is VIBGYOR, why RGB colour representation?



Credit: Derek Hoiem, UIUC

https://en.wikipedia.org/wiki/Color_vision

Image as a Matrix

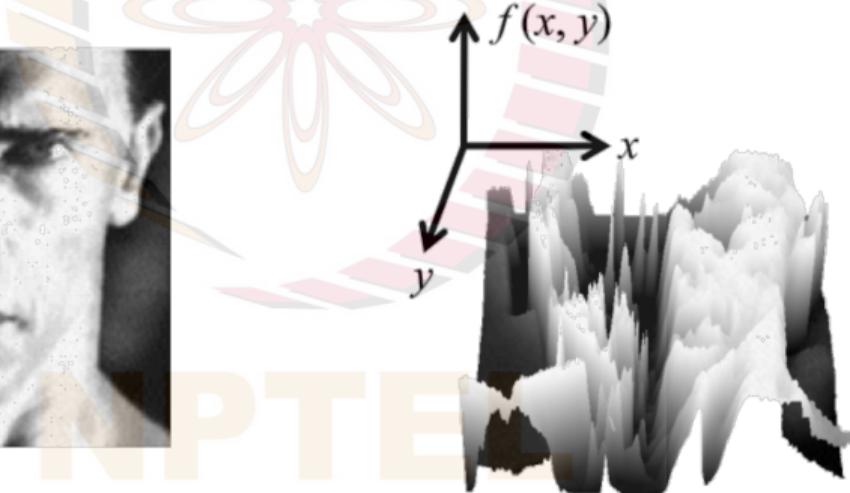


0.97	0.96	0.81	0.46	0.55	0.78	0.70	0.56	0.58	0.55	0.94	0.97	0.92	0.83	0.91	0.95
0.93	0.94	0.81	0.73	0.80	0.83	0.84	0.86	0.73	0.55	0.73	0.87	0.91	0.86	0.94	0.96
0.58	0.78	0.87	0.68	0.94	0.95	0.97	0.97	0.96	0.97	0.80	0.57	0.55	0.96	0.96	0.92
0.64	0.79	0.94	0.96	0.91	0.95	0.96	0.90	0.91	0.93	0.94	0.98	0.62	0.75	0.97	0.97
0.82	0.89	0.92	0.93	0.97	0.93	0.81	0.77	0.98	0.92	0.90	0.93	0.96	0.67	0.66	0.80
0.79	0.97	0.93	0.95	0.89	0.97	0.86	0.64	0.90	0.98	0.98	0.92	0.97	0.88	0.52	0.64
0.83	0.98	0.93	0.96	0.93	0.95	0.97	0.75	0.82	0.93	0.83	0.69	0.92	0.93	0.86	0.77
0.75	0.81	0.75	0.71	0.85	0.77	0.83	0.55	0.51	0.88	0.86	0.77	0.76	0.97	0.94	0.69
0.68	0.80	0.55	0.50	0.78	0.77	0.81	0.59	0.53	0.92	0.95	0.91	0.90	0.95	0.97	0.60
0.55	0.75	0.75	0.73	0.75	0.86	0.95	0.83	0.67	0.89	0.97	0.93	0.93	0.93	0.97	0.74
0.38	0.53	0.72	0.85	0.90	0.91	0.93	0.90	0.66	0.70	0.92	0.95	0.97	0.96	0.90	0.72
0.69	0.46	0.51	0.85	0.96	0.92	0.90	0.83	0.55	0.54	0.84	0.94	0.89	0.88	0.89	0.69
0.87	0.83	0.45	0.54	0.75	0.85	0.97	0.91	0.63	0.61	0.84	0.93	0.79	0.70	0.66	0.40
0.97	0.83	0.59	0.38	0.52	0.58	0.76	0.83	0.72	0.59	0.69	0.75	0.62	0.54	0.47	0.61
0.85	0.70	0.57	0.70	0.61	0.55	0.47	0.58	0.64	0.49	0.60	0.58	0.77	0.98	0.59	0.54
0.72	0.57	0.66	0.71	0.93	0.96	0.64	0.54	0.61	0.60	0.82	0.65	0.77	0.94	0.93	0.80

- Common to use one byte per value: 0 = black, 255 = white
- One such matrix for every channel in colour images

Image as a Function

- We can think of a (grayscale) image as a function $f : \mathbb{R}^2 \rightarrow \mathbb{R}$, giving the intensity at position (x, y)
- A digital image is a discrete (sampled, quantized) version of this function



Credit: Noah Snavely, Cornell Univ

Image Transformations

The NPTEL logo, which consists of the letters "NPTEL" in a bold, sans-serif font, all in a light beige color. The letters are slightly overlapping each other.

Image Transformations



$\hat{I}(x, y) = I(x, y) + 20$

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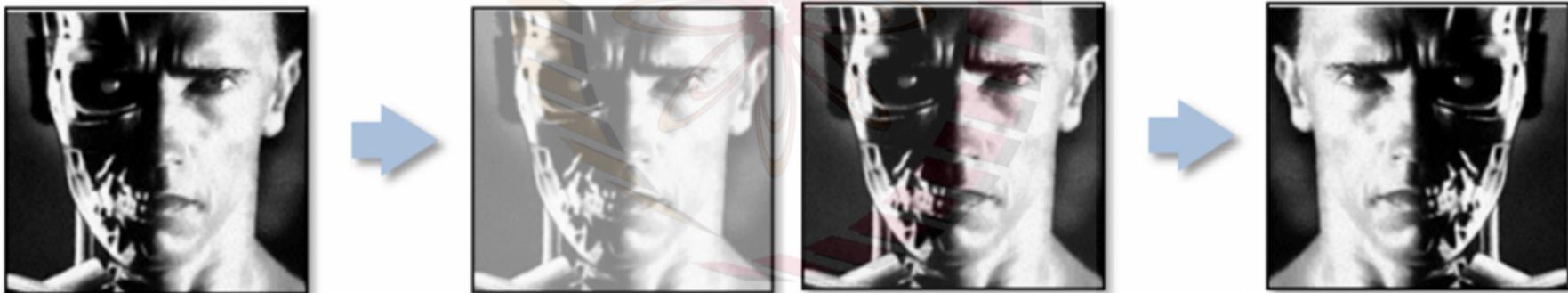
Image Transformations



$$\hat{I}(x, y) = I(x, y) + 20$$

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Image Transformations



$$\hat{I}(x, y) = I(x, y) + 20$$

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$$\hat{I}(x, y) = I(-x, y)$$

Image Processing Operations

- Point Operations

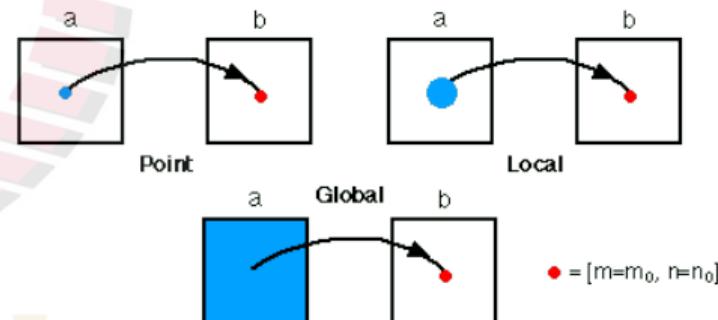
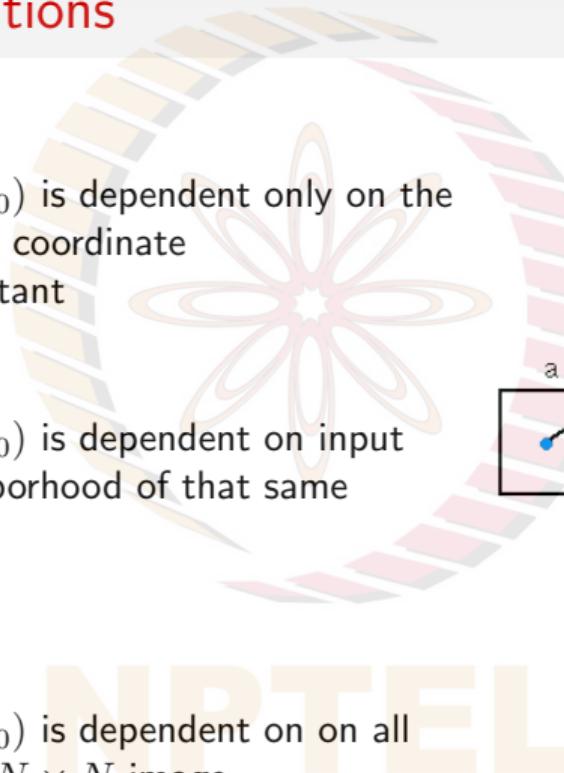
- Output value at (m_0, n_0) is dependent only on the input value at the same coordinate
- Complexity/pixel: Constant

- Local Operations

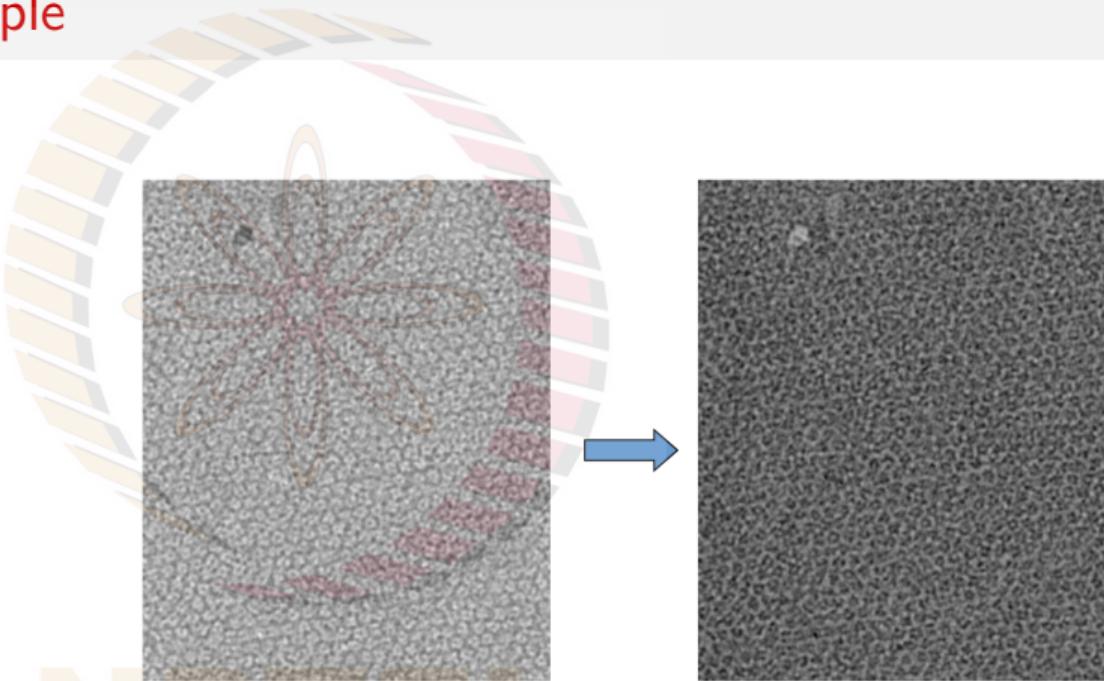
- Output value at (m_0, n_0) is dependent on input values in a $p \times p$ neighborhood of that same coordinate
- Complexity/pixel: p^2

- Global Operations

- Output value at (m_0, n_0) is dependent on all the values in the input $N \times N$ image
- Complexity/pixel: N^2

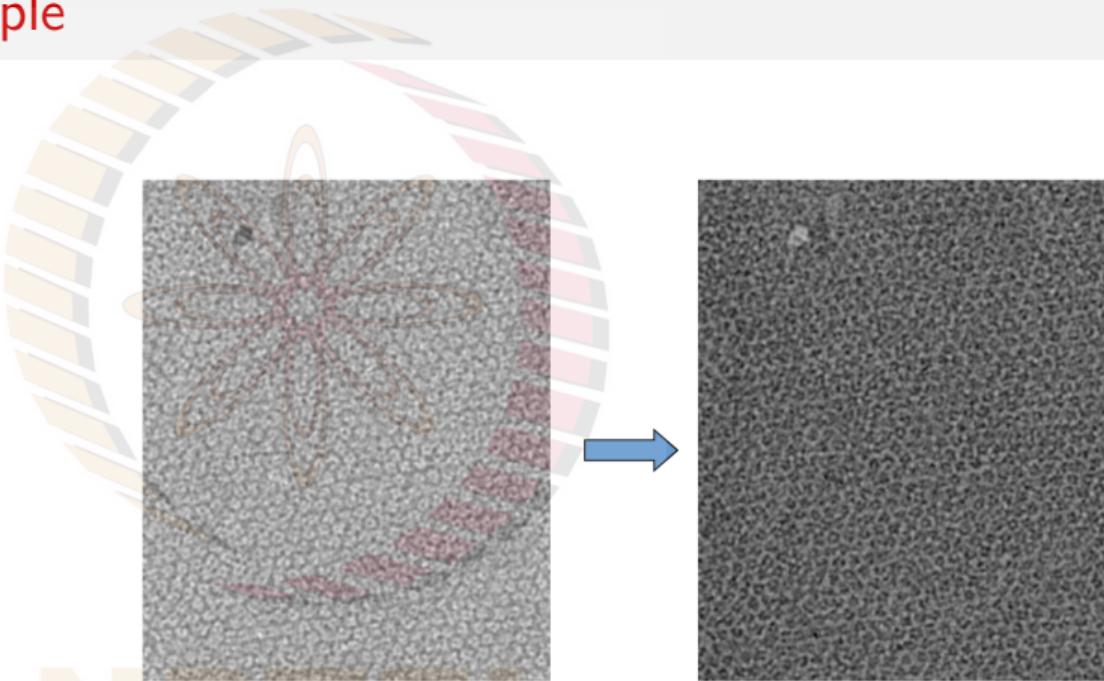


Point Operations: Example



- **Image Enhancement:**
Reversing the contrast
- How?

Point Operations: Example

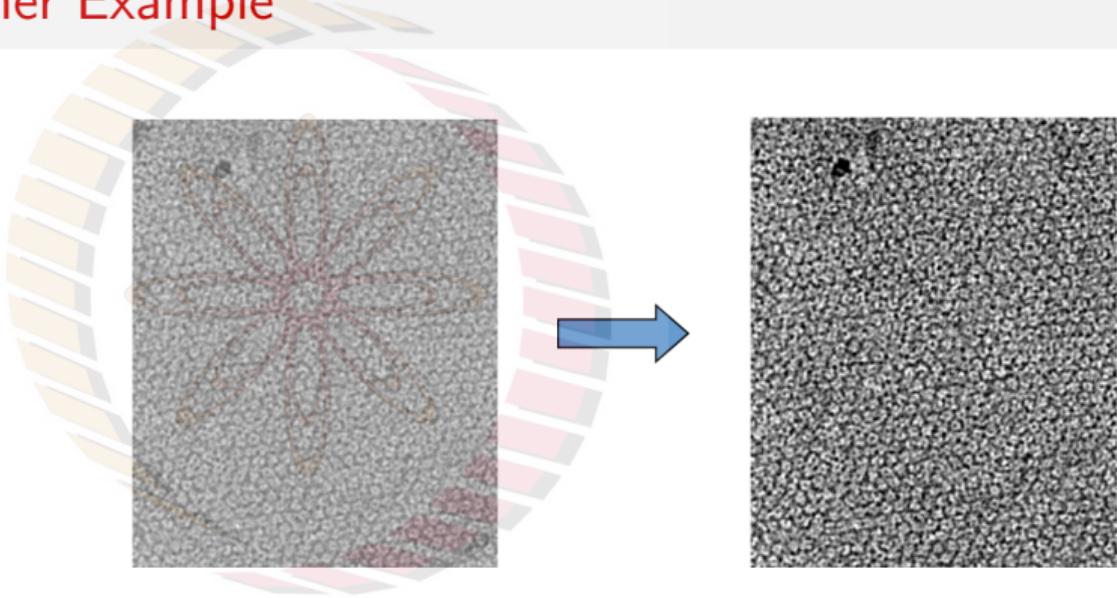


- **Image Enhancement:**
Reversing the contrast
- How?

$$\hat{I}(m_0, n_0) = I_{MAX} - I(m_0, n_0) + I_{MIN}$$

Point Operations: Another Example

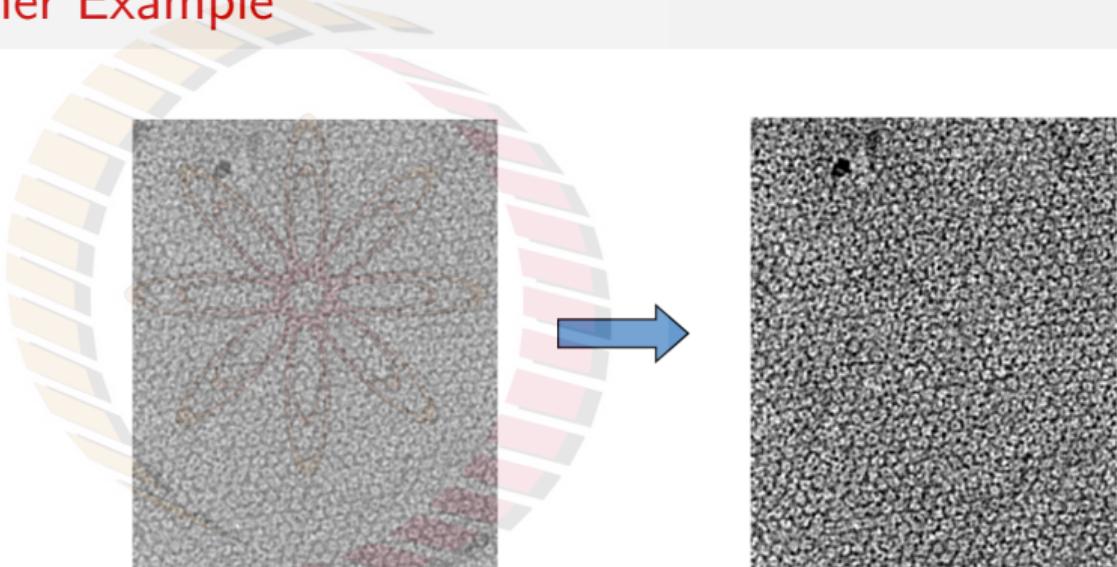
- **Image Enhancement:**
Stretching the contrast
- How?



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Point Operations: Another Example

- **Image Enhancement:**
Stretching the contrast
- How?



Linear Contrast Stretching

$$\hat{I}(m_0, n_0) = \left(I(m_0, n_0) - \min_{x,y} I(x, y) \right) * \left((I_{MAX} - I_{MIN}) / (\max_{x,y} I(x, y) - \min_{x,y} I(x, y)) \right) + I_{MIN}$$

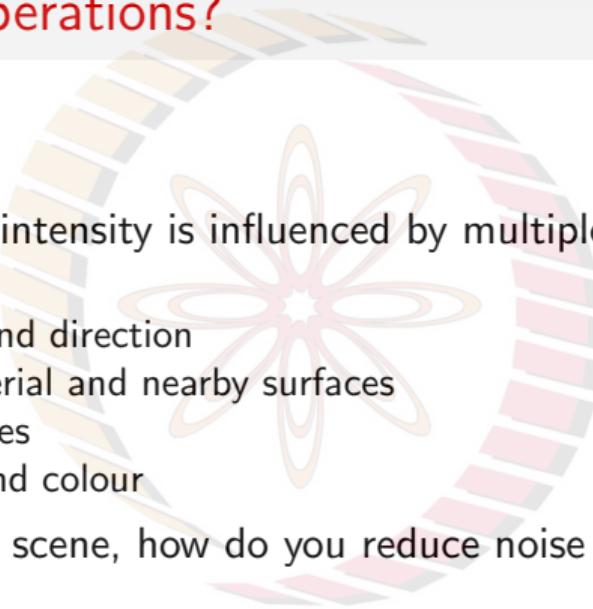
Going Beyond Linear Stretching

Question

Heard about **Histogram Equalization**? Read about it, homework!

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How Useful are Point Operations?



- A single point (or pixel)'s intensity is influenced by multiple factors, and may not tell us everything
 - Light source strength and direction
 - Surface geometry, material and nearby surfaces
 - Sensor capture properties
 - Image representation and colour
- Given a camera and a still scene, how do you reduce noise using point operations?

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- Given a camera and a still scene, how do you reduce noise using point operations?
- Take many images, and average them!
- You need local operations otherwise. What is the local operation?

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Image Processing Operations

- Point Operations

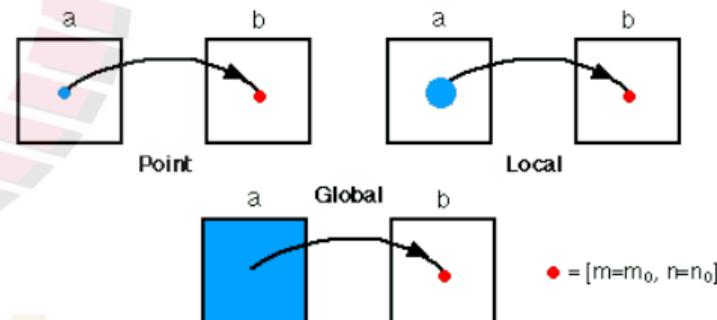
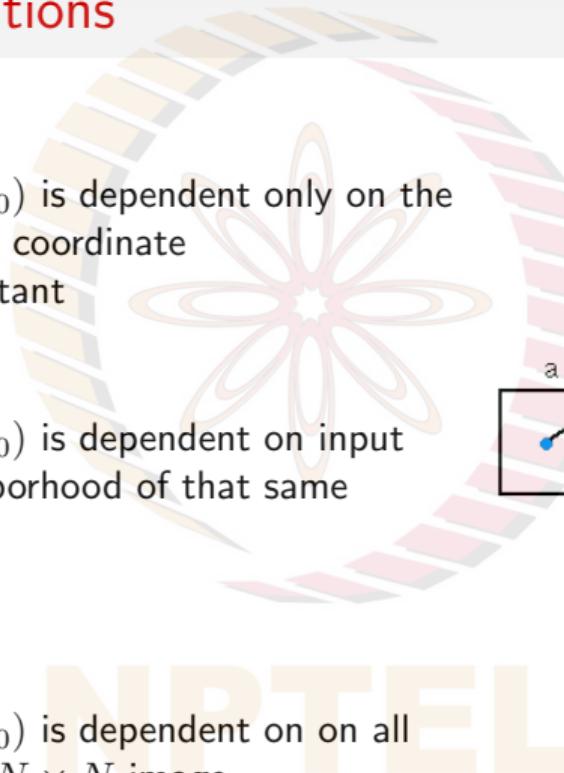
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- Local Operations

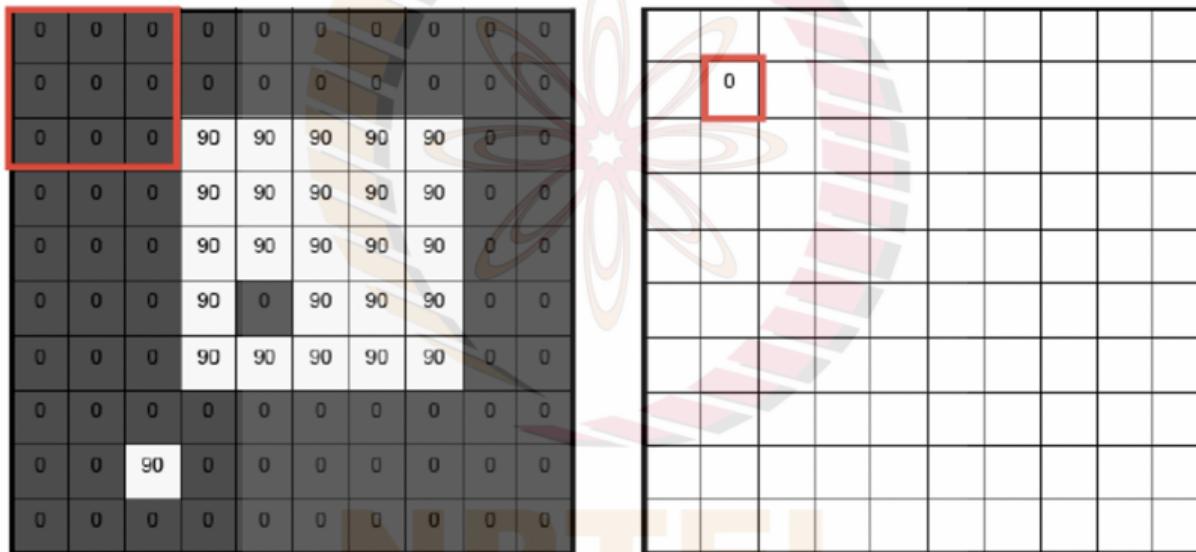
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- Global Operations

- Output value at (m_0, n_0) is dependent on all the values in the input $N \times N$ image
- Complexity/pixel: N^2



Local Operation Examples: Moving Average



Credit: Steve Seitz, Univ of Washington

Local Operation Examples: Moving Average

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

0	10								

Credit: Steve Seitz, Univ of Washington

Local Operation Examples: Moving Average

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0

0	10	20							

Credit: Steve Seitz, Univ of Washington

Local Operation Examples: Moving Average

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

0	10	20	30						

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Local Operation Examples: Moving Average

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0	0
0	0	0	90	90	90	90	90	0	0	0
0	0	0	90	90	90	90	90	0	0	0
0	0	0	90	90	90	90	90	0	0	0
0	0	0	90	0	90	90	90	0	0	0
0	0	0	90	90	90	90	90	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

0	10	20	30	30						

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Local Operation Examples: Moving Average

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	90	0	90	90	90	0	0
0	0	0	90	90	90	90	90	0	0
0	0	0	0	0	0	0	0	0	0
0	0	90	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

0	10	20	30	30	30	20	10		
0	20	40	60	60	60	40	20		
0	30	60	90	90	90	60	30		
0	30	50	80	80	90	60	30		
0	30	50	80	80	90	60	30		
0	20	30	50	50	60	40	20		
10	20	30	30	30	30	20	10		
10	10	10	0	0	0	0	0		

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Image Processing Operations

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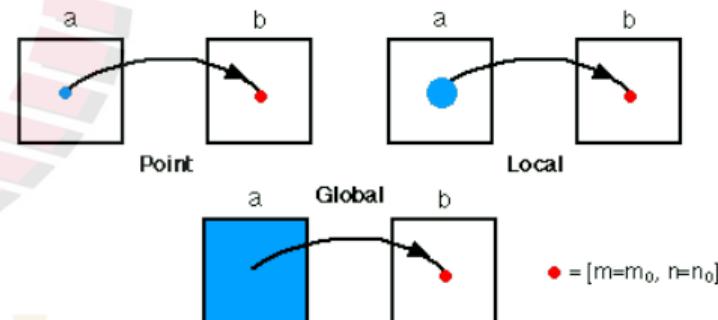
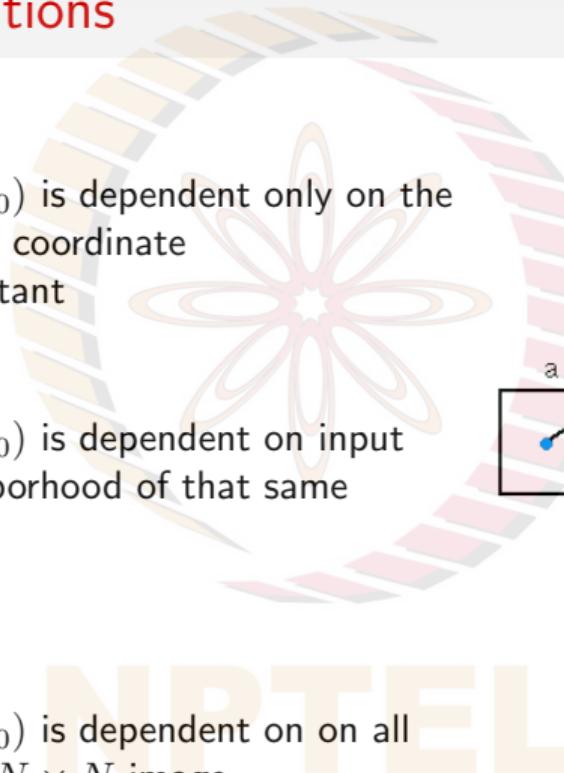
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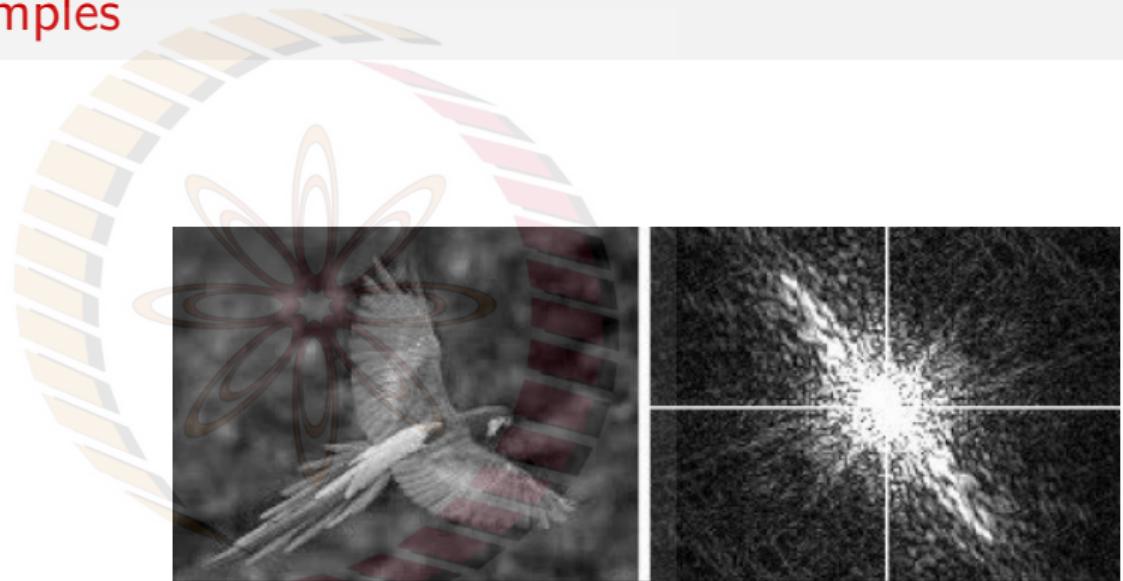
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Global Operations: Examples

- Image coordinate transformations, e.g. Fourier transform
- We will see more of this later



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Credit: Mathworks MATLAB Toolbox

Homework

Readings

- Chapter 3.1, Szeliski, *Computer Vision: Algorithms and Applications*

Questions to Answer

- What is histogram equalization, and how do you derive its formula?

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References



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