Lecture 3: Image Filtering

( unless otherwise stated slides are taken or adopted from Bob Woodham, Jim Little and Fred Tung )
Image as a **2D Function**

A (grayscale) image is a 2D function

What is the **range** of the image function?

\[ I(X, Y) \in [0, 255] \in \mathbb{Z} \]

**domain:** \((X, Y) \in ([1, \text{width}], [1, \text{height}])\)

**Slide Credit:** Ioannis (Yannis) Gkioulekas (CMU)
Adding two Images

Since images are functions, we can perform operations on them, e.g., average

\[ I(X, Y) + G(X, Y) = \frac{I(X, Y)}{2} + \frac{G(X, Y)}{2} \]
Adding two Images

\[ a = \frac{I(X,Y)}{2} + \frac{G(X,Y)}{2} \]

\[ b = \frac{I(X,Y) + G(X,Y)}{2} \]

Question:

- \( a = b \)
- \( a > b \)
- \( a < b \)
Adding two Images

Red pixel in camera man image = 98
Red pixel in moon image = 200

\[
\frac{98}{2} + \frac{200}{2} = 49 + 100 = 149
\]

Question:

\[
\begin{align*}
\text{Red pixel in camera man image} & = 98 \\
\text{Red pixel in moon image} & = 200 \\
\frac{98 + 200}{2} & = \left\lfloor \frac{298}{2} \right\rfloor = \frac{255}{2} = 127
\end{align*}
\]
Adding two Images

\[
a = \frac{I(X, Y)}{2} + \frac{G(X, Y)}{2}
\]

\[
b = \frac{I(X, Y)}{2} + \frac{G(X, Y)}{2}
\]

Question:

\[
a = b
\]
\[
a > b
\]
\[
b < a
\]
Adding two Images

It is often convenient to convert images to **doubles** when doing processing

**In Python**

```python
from PIL import Image
img = Image.open('cameraman.png')
import numpy as np
imgArr = np.asfarray(img)

# Or do this
import matplotlib.pyplot as plt
camera = plt.imread('cameraman.png')
```
What types of **transformations** can we do?

- **Filtering**
  - $I(X,Y) \rightarrow I'(X,Y)$
  - changes range of image function

- **Warping**
  - $I(X,Y) \rightarrow I'(X,Y)$
  - changes domain of image function

*Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)*
What types of **filtering** can we do?

**Point** Operation

```
point processing
```

**Neighborhood** Operation

```
“filtering”
```

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**Slide Credit:** Ioannis (Yannis) Gkioulekas (CMU)
Examples of **Point Processing**

- **original**
- **darken**
- **lower contrast**
- **non-linear lower contrast**

\[
I(X, Y) - 128 \\
\frac{I(X, Y)}{2} \\
\left( \frac{I(X, Y)}{255} \right)^{1/3} \times 255
\]

- **invert**
- **lighten**
- **raise contrast**
- **non-linear raise contrast**

\[
255 - I(X, Y) \\
I(X, Y) + 128 \\
I(X, Y) \times 2 \\
\left( \frac{I(X, Y)}{255} \right)^2 \times 255
\]

*Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)*
Examples of **Point Processing**

- **Original**
- **Darken**
  - $I(X, Y) - 128$
  - $I(X, Y) \times 2$
- **Lower contrast**
  - $\frac{I(X, Y)}{2}$
  - $\left( \frac{I(X, Y)}{255} \right)^{1/3} \times 255$
- **Non-linear lower contrast**
  - $255 - I(X, Y)$
  - $I(X, Y) + 128$
  - $I(X, Y) \times 2$
  - $\left( \frac{I(X, Y)}{255} \right)^2 \times 255$

*Slide Credit: Ioannis (Yannis) Gkioulakas (CMU)*
Reminders

Readings:

– **Today’s** Lecture: Forsyth & Ponce (2nd ed.) 1.1.1 — 1.1.3
– **Next** Lecture: Forsyth & Ponce (2nd ed.) 4.1, 4.5

Reminders:

– Complete **Assignment 0** (ungraded) by Wednesday, September 12
– **Assignment 1** will be out, September 12