ENPM 809T

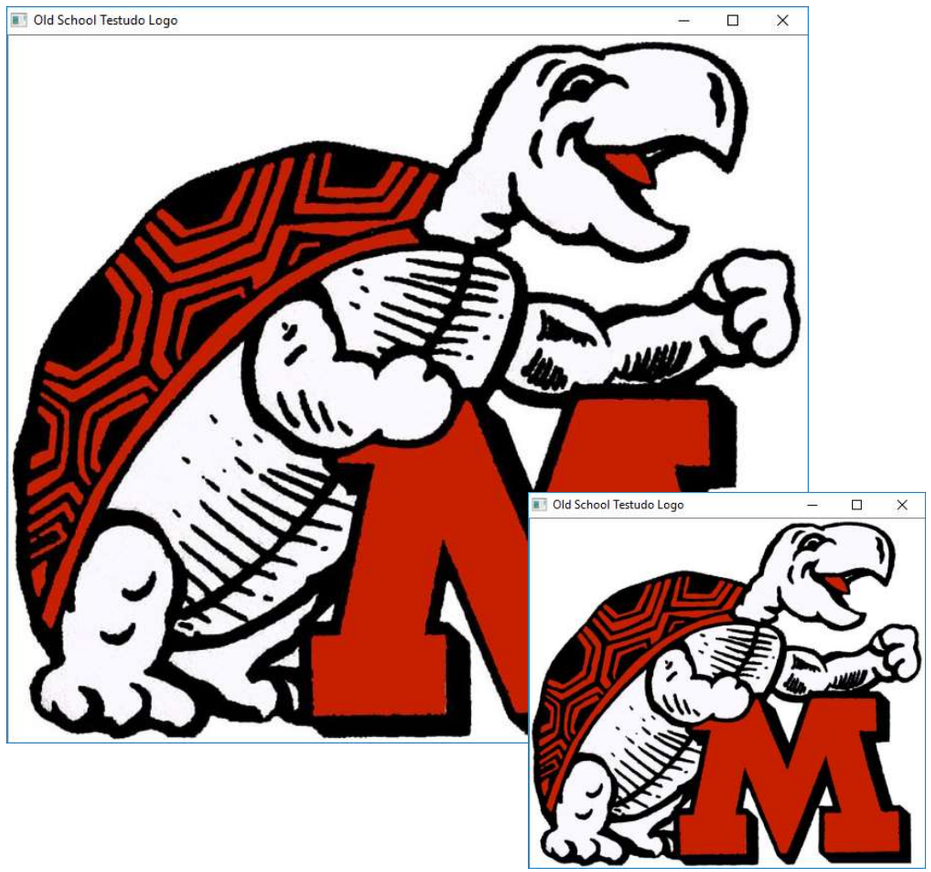
UMCP, Mitchell

Disclaimer

- Much of the code provided in the following slides was developed in Python **2.7**
- The primary update to the codes in the following slides is the use of the print function:
  - **print "example"** in Python 2 versus **print("example")** in Python 3

Confirm Installation

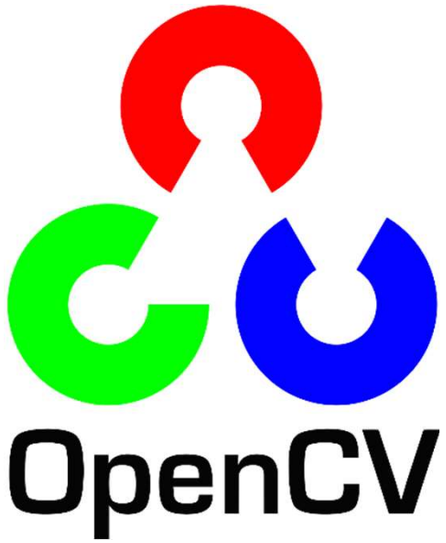
- Run sanitycheck.py




```
import numpy as np
import matplotlib
import matplotlib.pyplot as plot
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

cv2.imshow("Old School Testudo Logo", image)
cv2.waitKey(0)

image = imutils.resize(image, width=400)

cv2.imshow("Old School Testudo Logo", image)
cv2.waitKey(0)

cv2.imwrite("testimage.jpg", image)
```

OpenCV

- Open source Computer Vision
- Library of programming functions aimed at real-time computer vision
- Intel, 1999
- Written in C++, binding in Python



https://opencv.org/

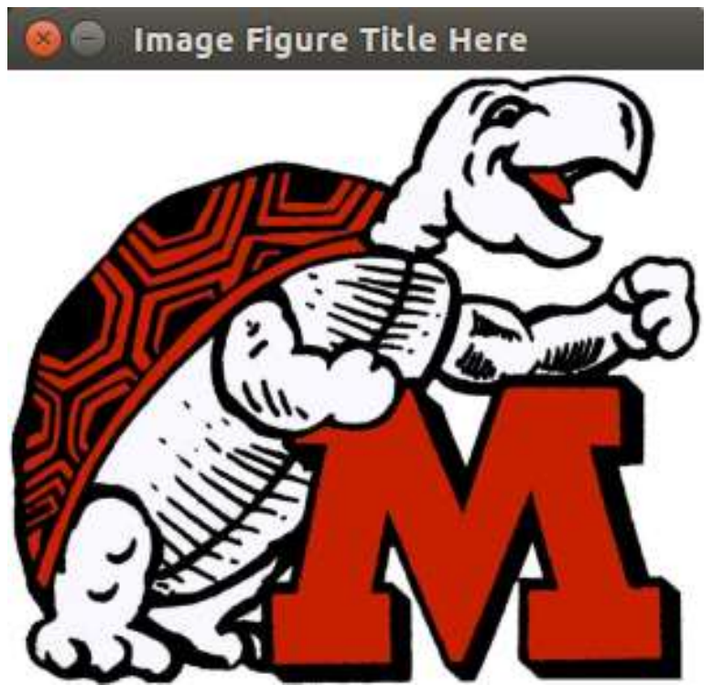
Imutils

- Series of OpenCV & convenience functions that perform basic tasks
  - Translation
  - Rotation
  - Resizing
- Adrian Rosebrock, 2015

https://github.com/jrosebr1/imutils

OpenCV Fundamentals

- Load image from disk
- Display image to screen
- Write (save) image to disk

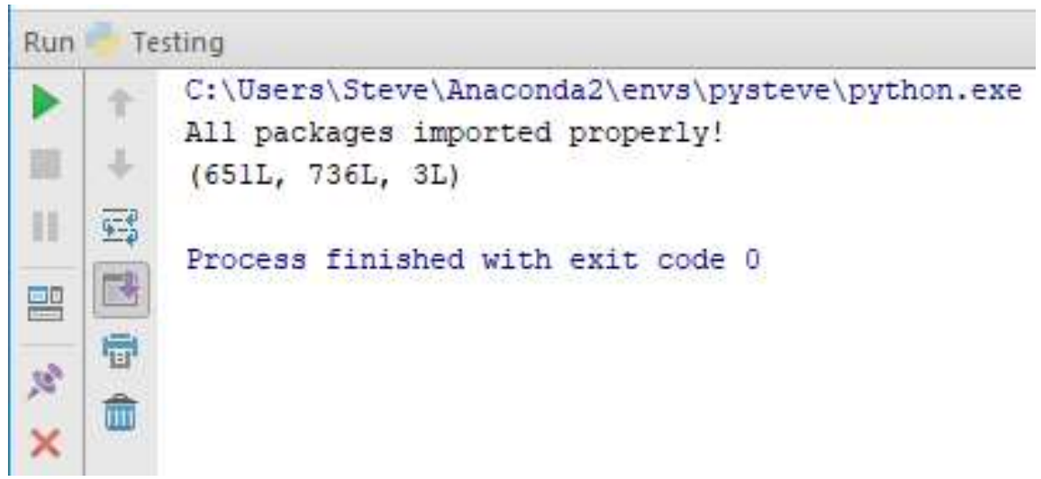


Codes available via GitHub - https://github.com/oneshell/enpm809T

OpenCV Fundamentals

- Images are represented as numpy arrays
- Each array has a shape

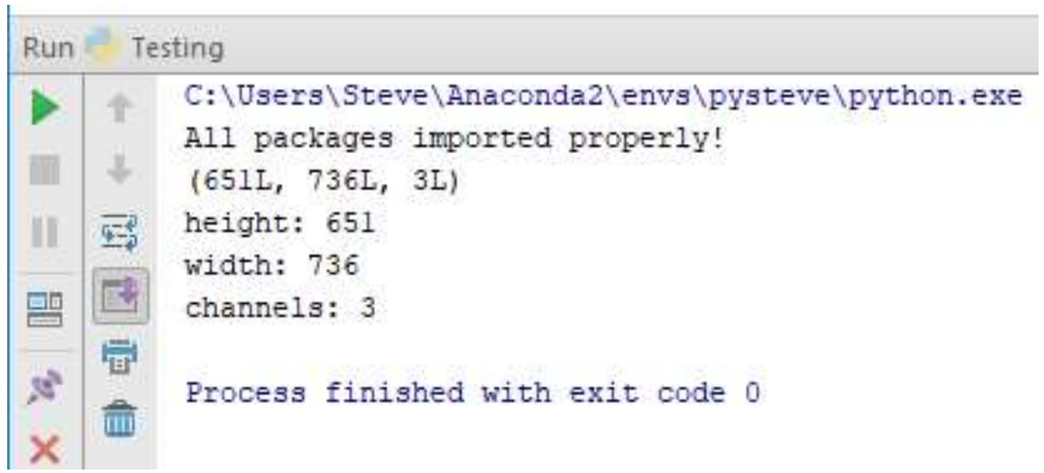
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

print image.shape
```



OpenCV Fundamentals

- Access image height, width, and number of channels

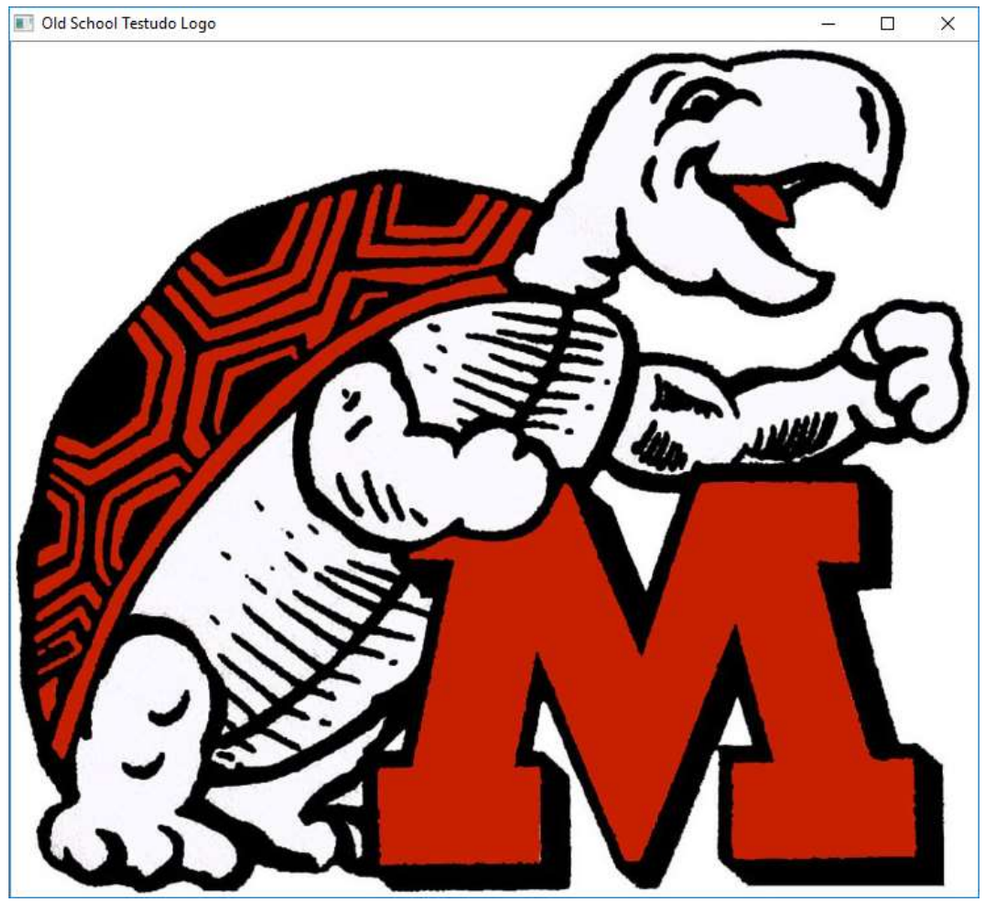
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

print image.shape
print "height: %d" % (image.shape[0])
print "width: %d" % (image.shape[1])
print "channels: %d" % (image.shape[2])
```



OpenCV Fundamentals

- Display image on screen

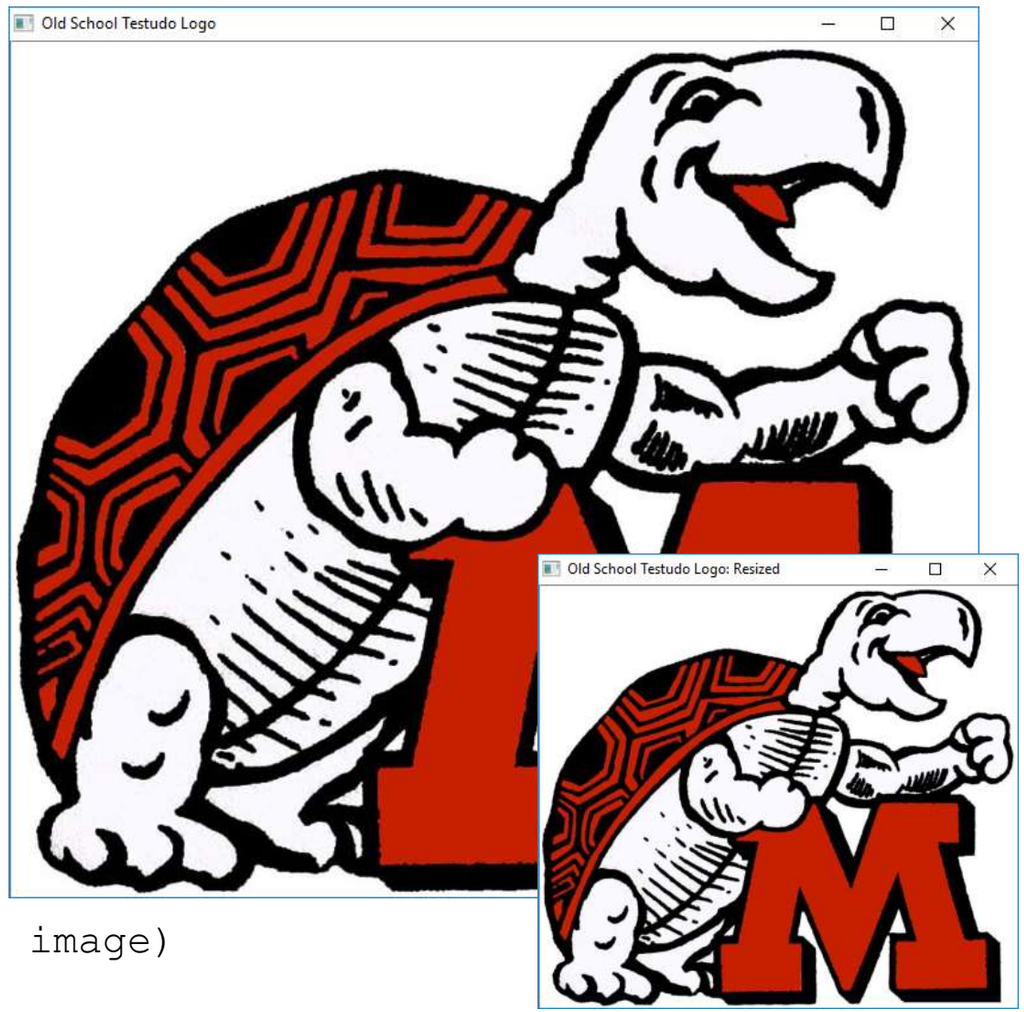
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

print image.shape
print "height: %d" % (image.shape[0])
print "width: %d" % (image.shape[1])
print "channels: %d" % (image.shape[2])

cv2.imshow("Old School Testudo Logo", image)
cv2.waitKey(0)
```



OpenCV Fundamentals

- Resize image

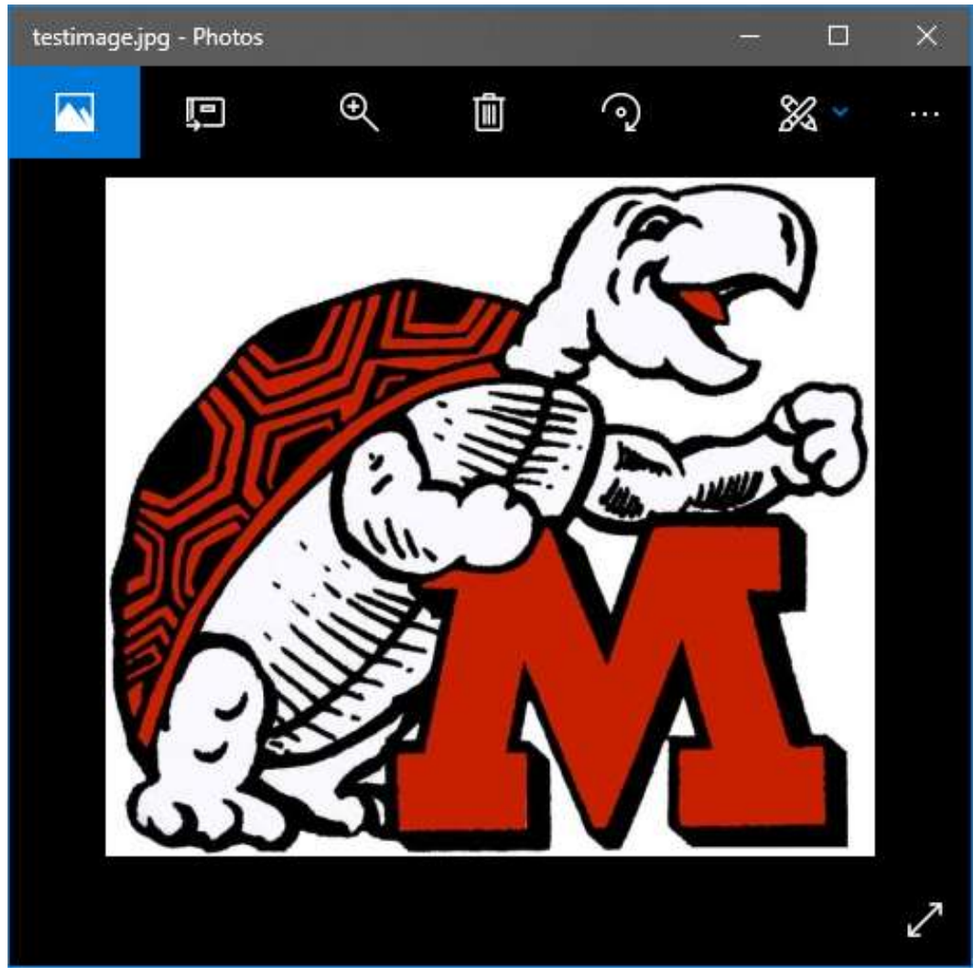
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

print image.shape
print "height: %d" % (image.shape[0])
print "width: %d" % (image.shape[1])
print "channels: %d" % (image.shape[2])

cv2.imshow("Old School Testudo Logo", image)
cv2.waitKey(0)

image = imutils.resize(image, width=400)
cv2.imshow("Old School Testudo Logo: Resized", image)
cv2.waitKey(0)
```



OpenCV Fundamentals

- Write (save) image to disk

```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

print image.shape
print "height: %d" % (image.shape[0])
print "width: %d" % (image.shape[1])
print "channels: %d" % (image.shape[2])

cv2.imwrite("testimage.jpg", image)
```



OpenCV Fundamentals

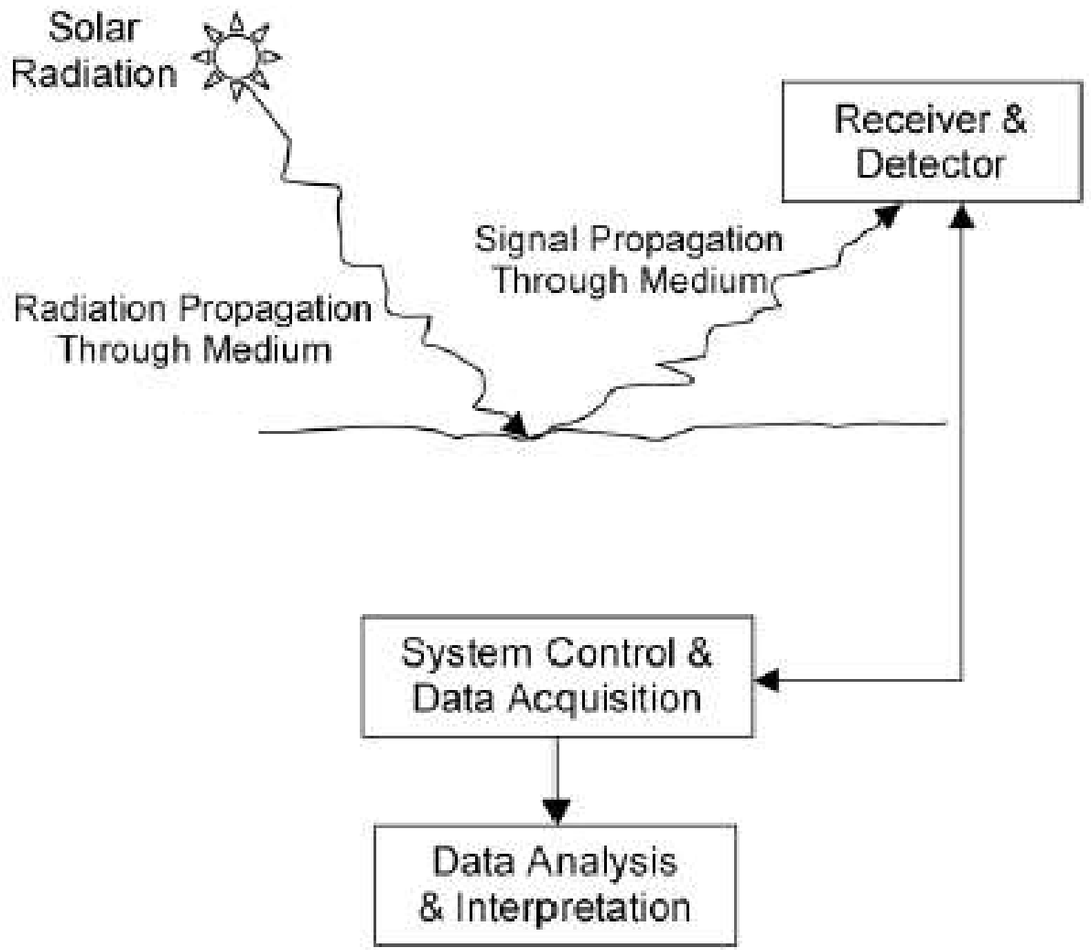
- Pixels
- Defining colors in RGB color space
- Image coordinate system
- Identifying and modifying pixel values

OpenCV Fundamentals

- What is an image?

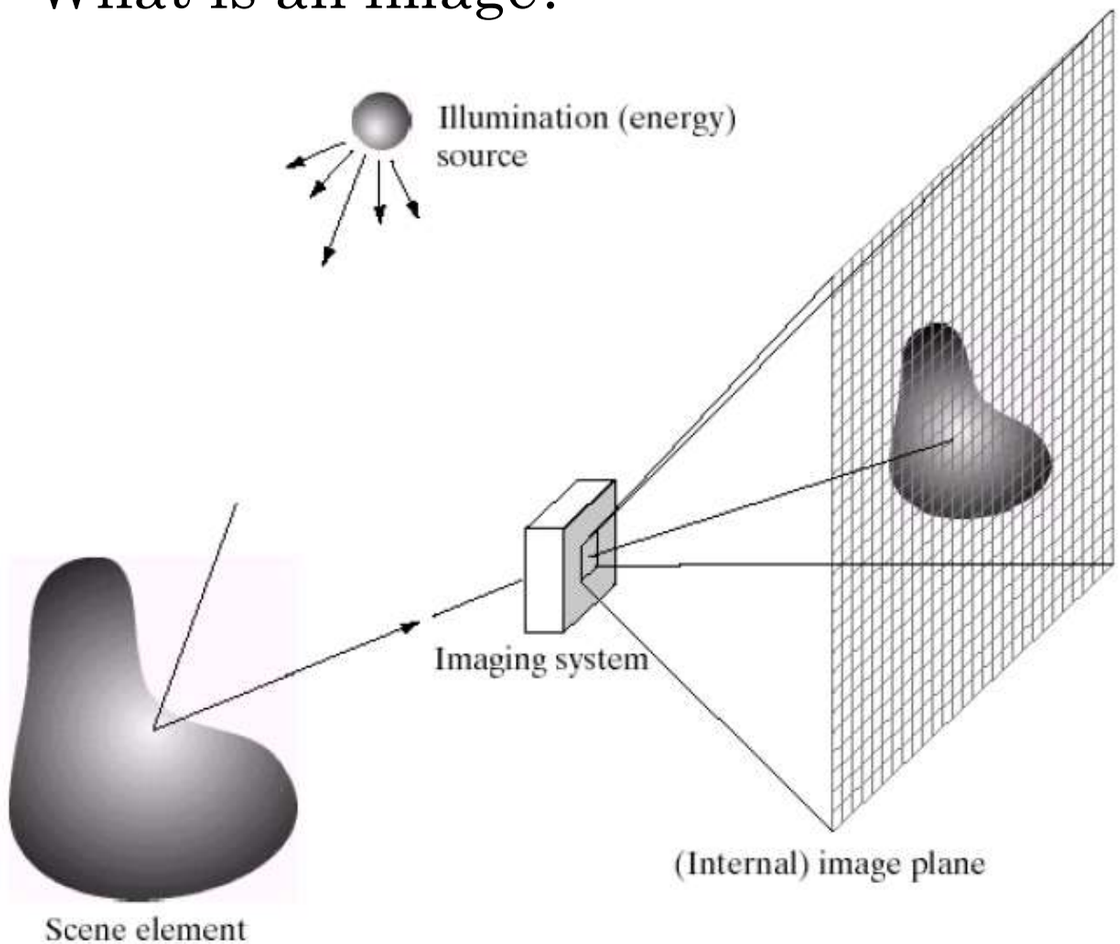
Passive Remote Sensing

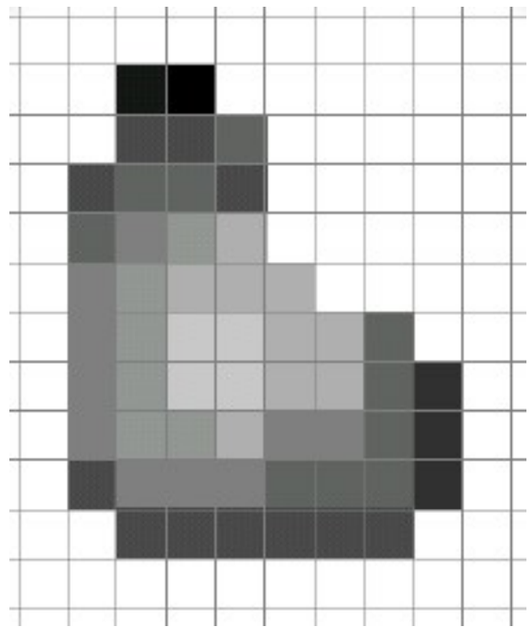
- No self-generated radiation is used in the sensing process
- **Naturally occurring radiation** such as sunlight or nightglow emission
- Photography
- Spectrometer



OpenCV Fundamentals

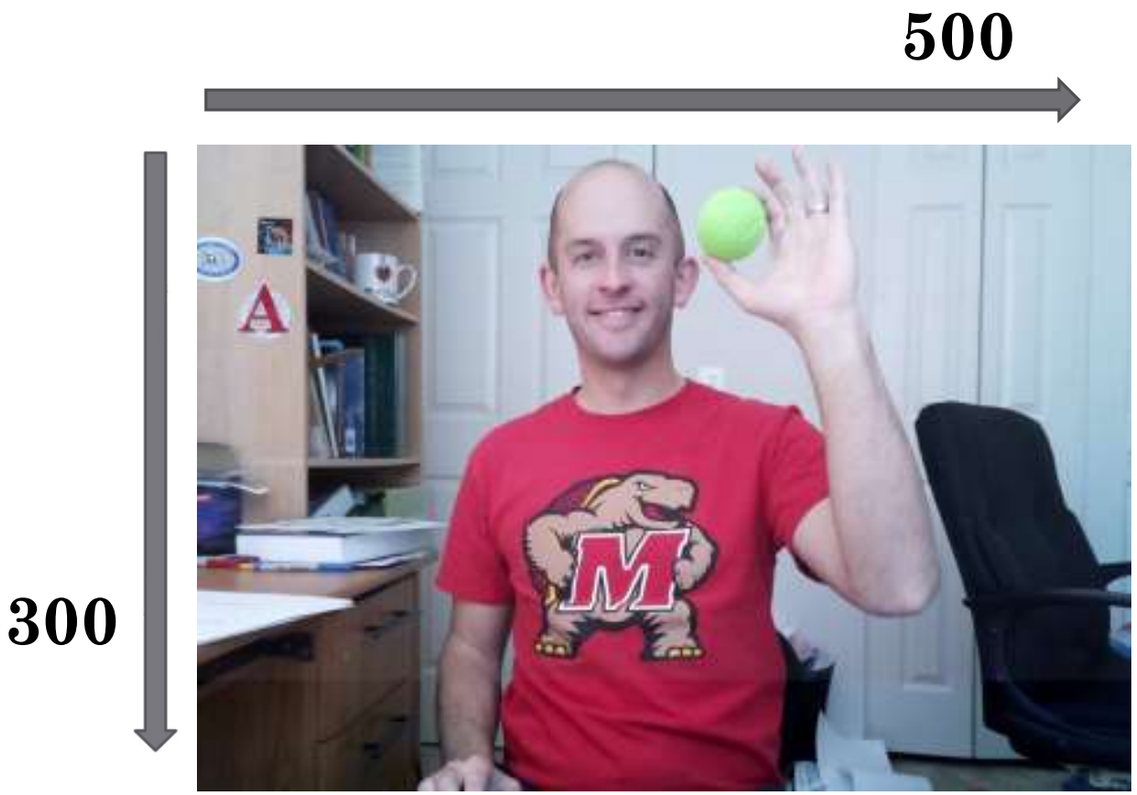
- What is an image?





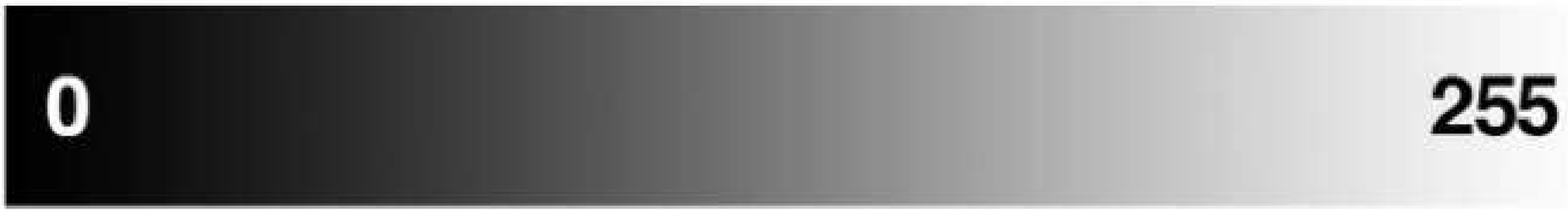
OpenCV Fundamentals

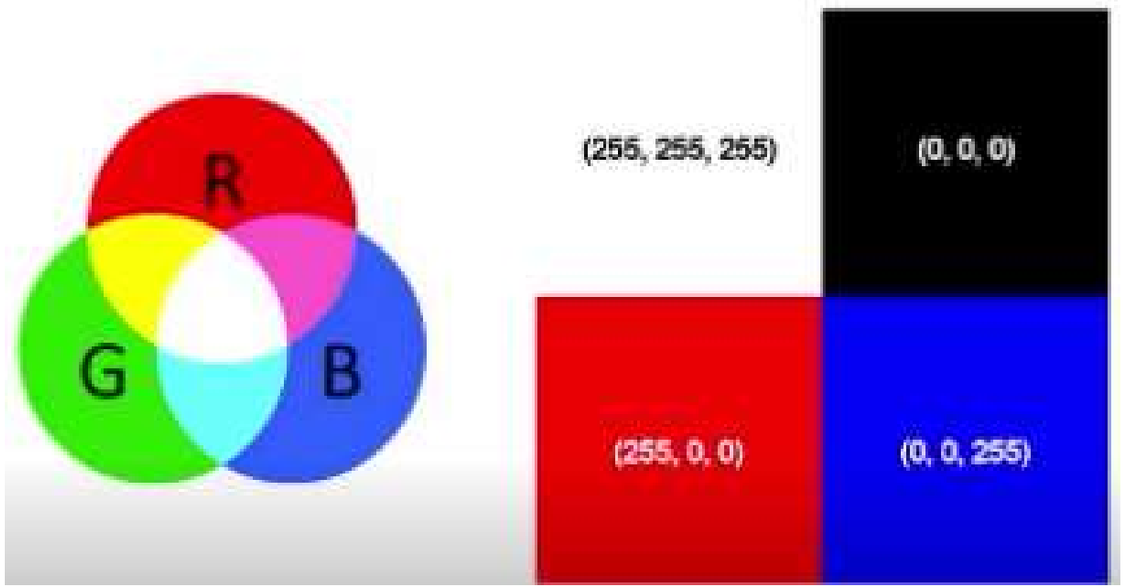
- Pixels: **building blocks** of an image
- No finer granularity than a pixel



OpenCV Fundamentals

- Pixels typically defined in either grayscale or color





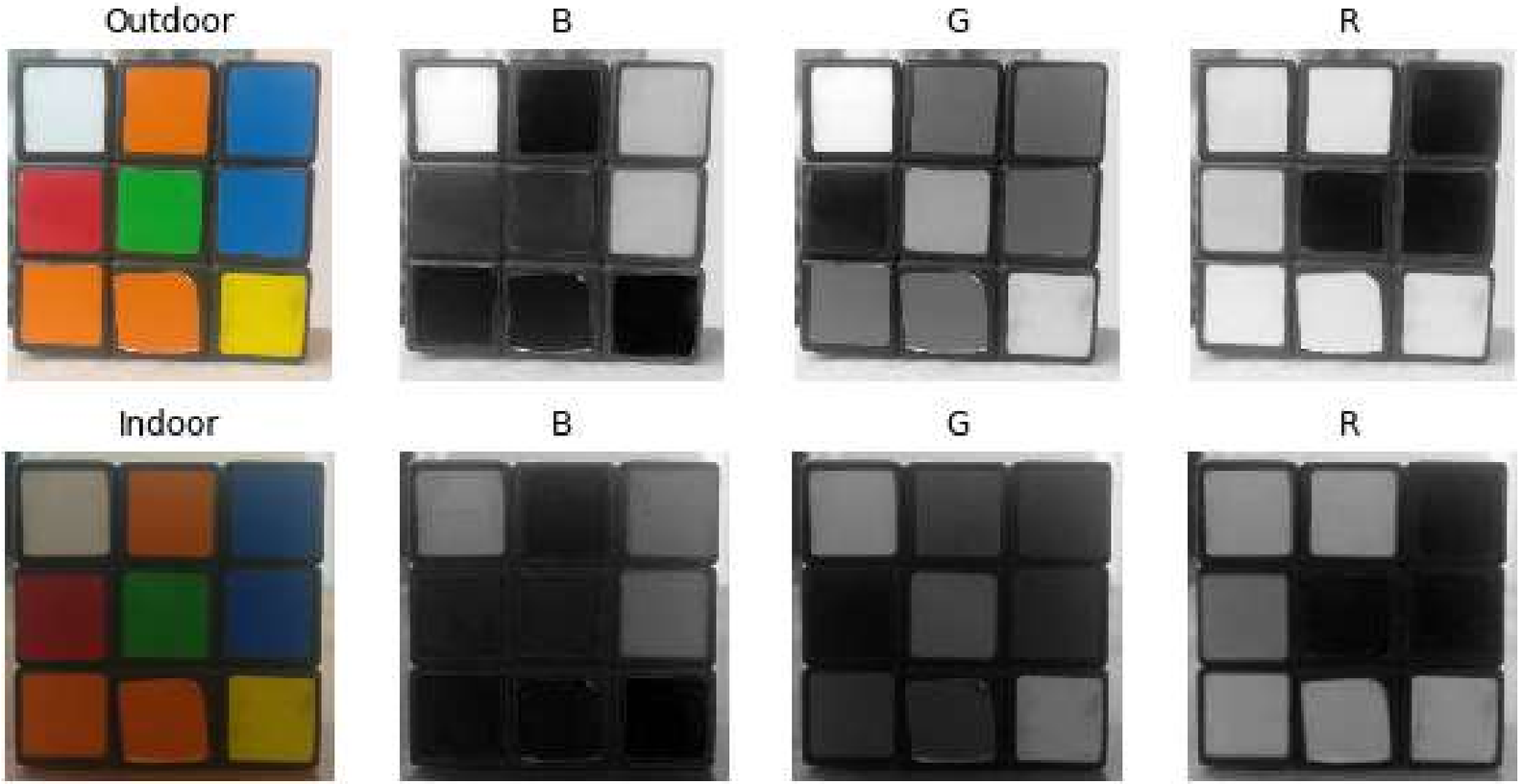
OpenCV Fundamentals

- Potential issues with RGB color space

https://www.learnopencv.com/color-spaces-in-opencv-cpp-python/

OpenCV Fundamentals

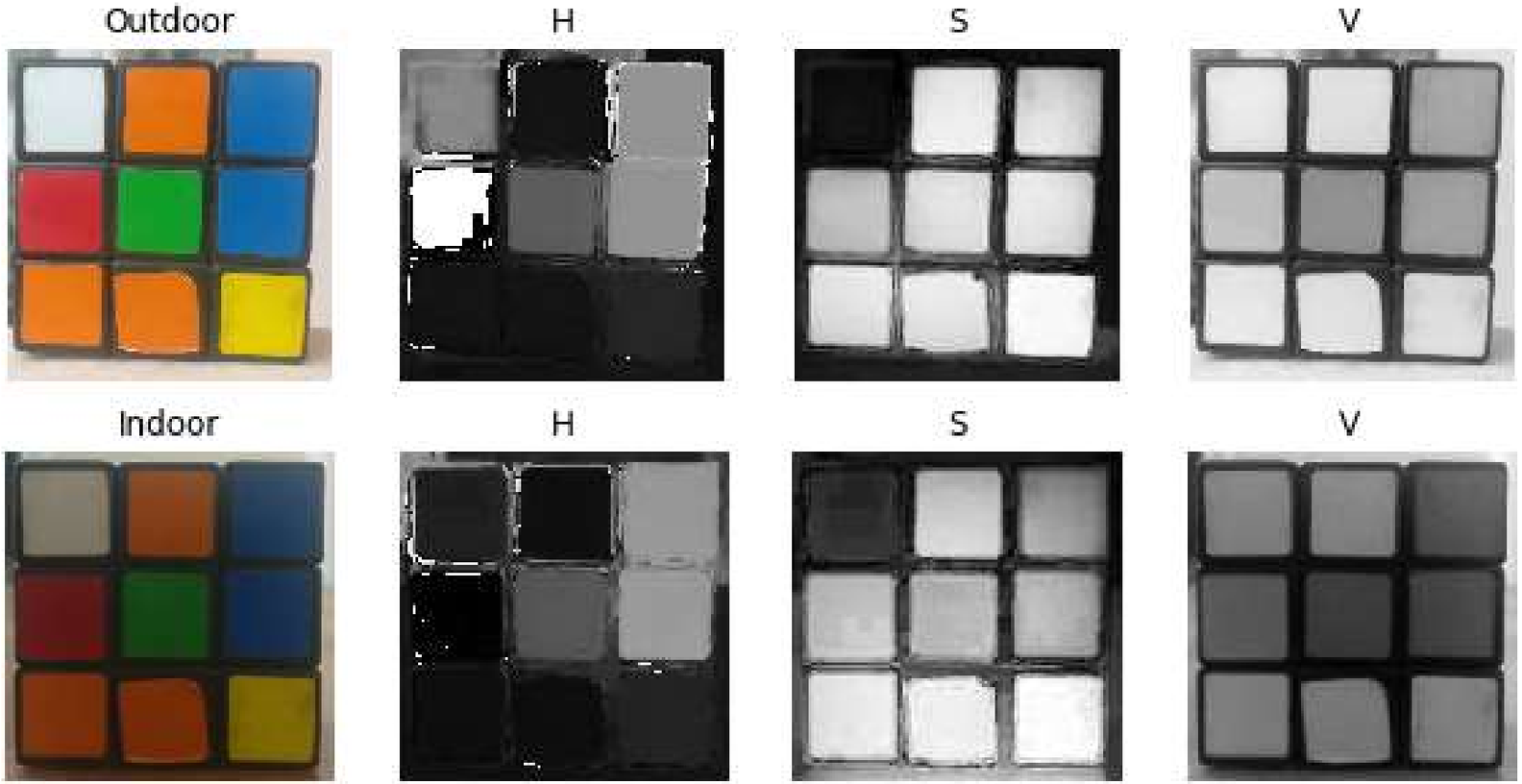
- Potential issues with RGB color space



https://www.learnopencv.com/color-spaces-in-opencv-cpp-python/

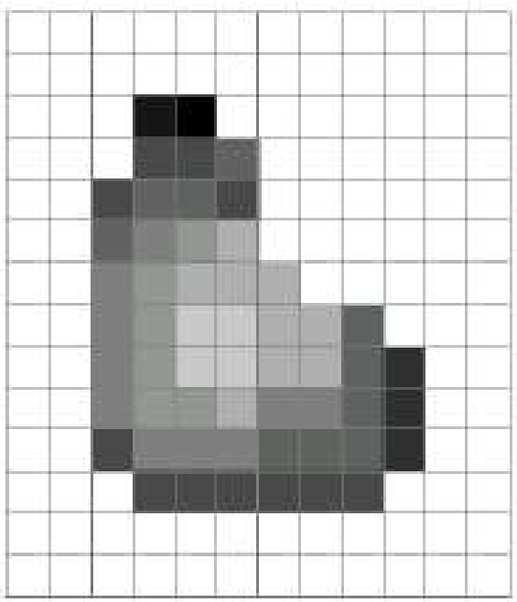
OpenCV Fundamentals

- Potential issues with RGB color space: use of HSV



https://www.learnopencv.com/color-spaces-in-opencv-cpp-python/

OpenCV Fundamentals

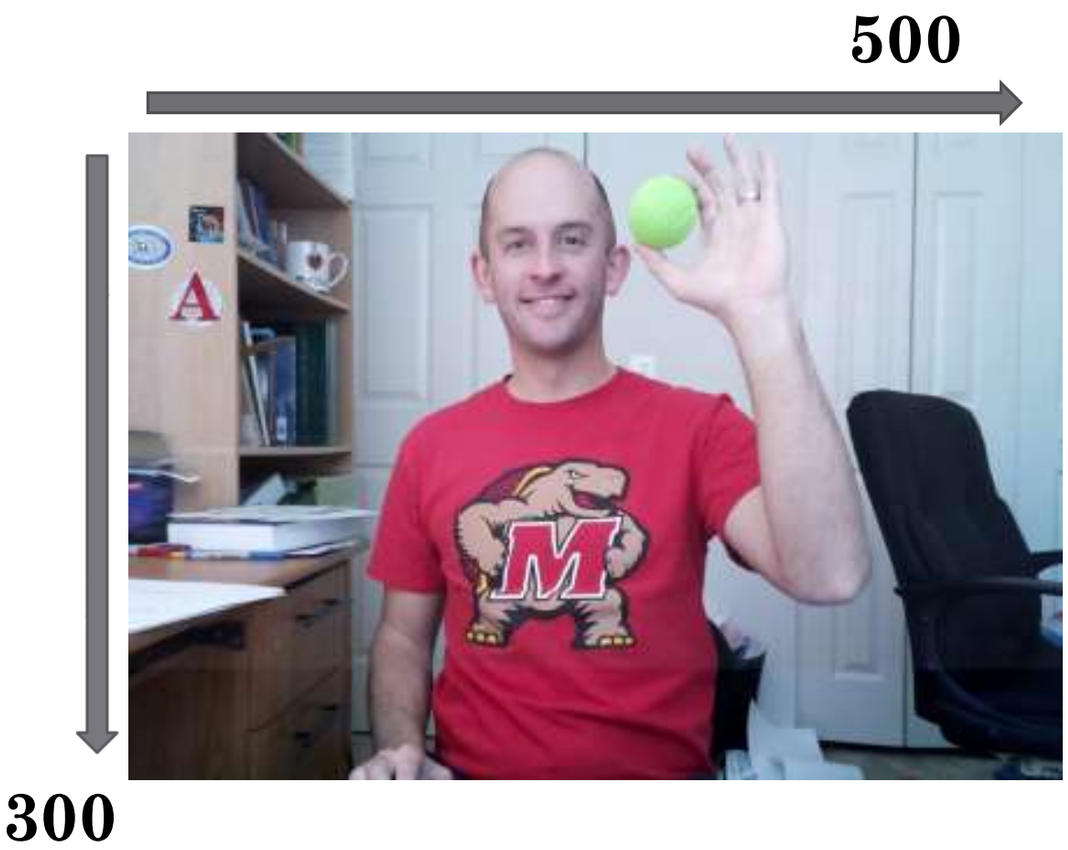


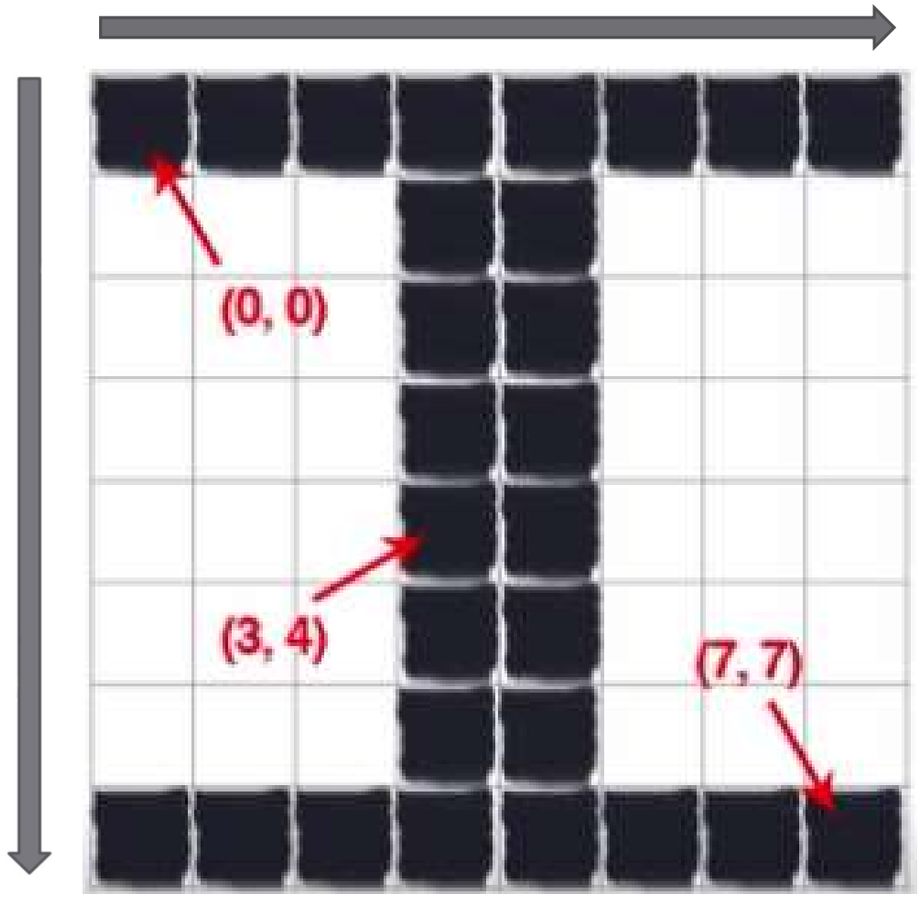
=

255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	20	0	255	255	255	255	255	255	255
255	255	255	75	75	75	255	255	255	255	255	255
255	255	75	95	95	75	255	255	255	255	255	255
255	255	96	127	145	175	255	255	255	255	255	255
255	255	127	145	175	175	175	255	255	255	255	255
255	255	127	145	200	200	175	175	95	255	255	255
255	255	127	145	200	200	175	175	95	47	255	255
255	255	127	145	145	175	127	127	95	47	255	255
255	255	74	127	127	127	95	95	95	47	255	255
255	255	255	74	74	74	74	74	74	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255

OpenCV Fundamentals

- Image coordinate system





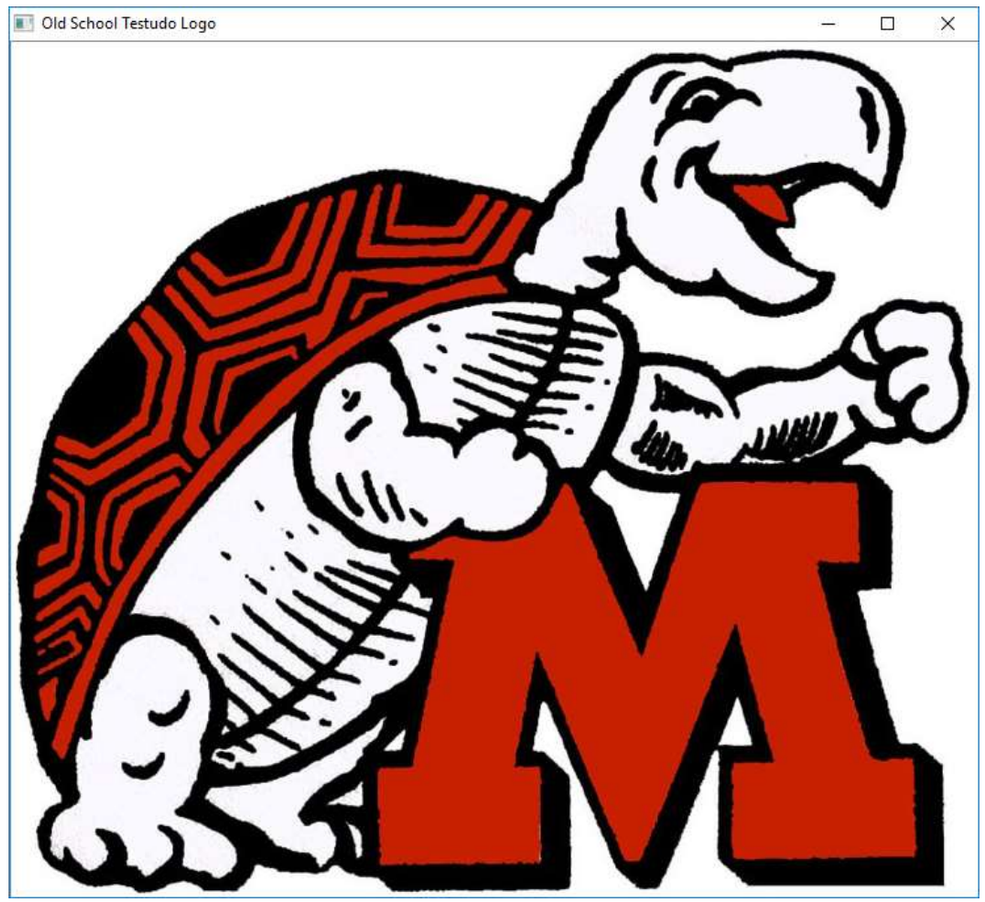
OpenCV Fundamentals

- Identify and modify pixel values
- Specify 4 values:
  - Starting and ending x-coordinates
  - Starting and ending y-coordinates

OpenCV Fundamentals

- Load image to screen

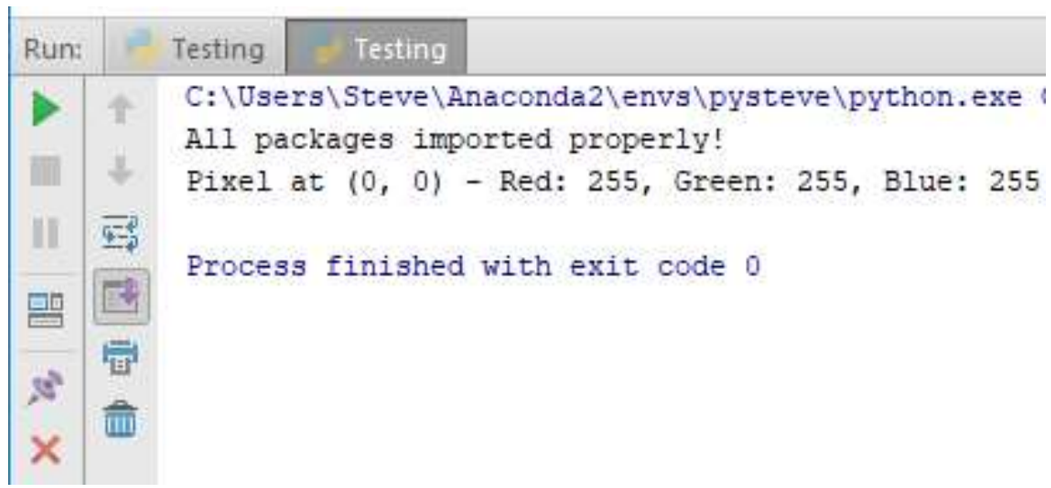
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

cv2.imshow("Old School Testudo Logo", image)
cv2.waitKey(0)
```



OpenCV Fundamentals

- Images are represented as numpy arrays

```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

cv2.imshow("Old School Testudo Logo", image)
cv2.waitKey(0)

(b, g, r) = image[0, 0]
print "Pixel at (0, 0) - Red: %d, Green: %d, Blue: %d" % (r, g, b)
```



*OpenCV represents images as numpy arrays **in reverse order**

OpenCV Fundamentals

- Images are represented as numpy arrays

"The reason why the early developers at OpenCV chose BGR color format is probably that back then BGR color format was popular among camera manufacturers and software providers. E.g. in Windows, when specifying color value using COLORREF they use the BGR format 0x00bbggrr.

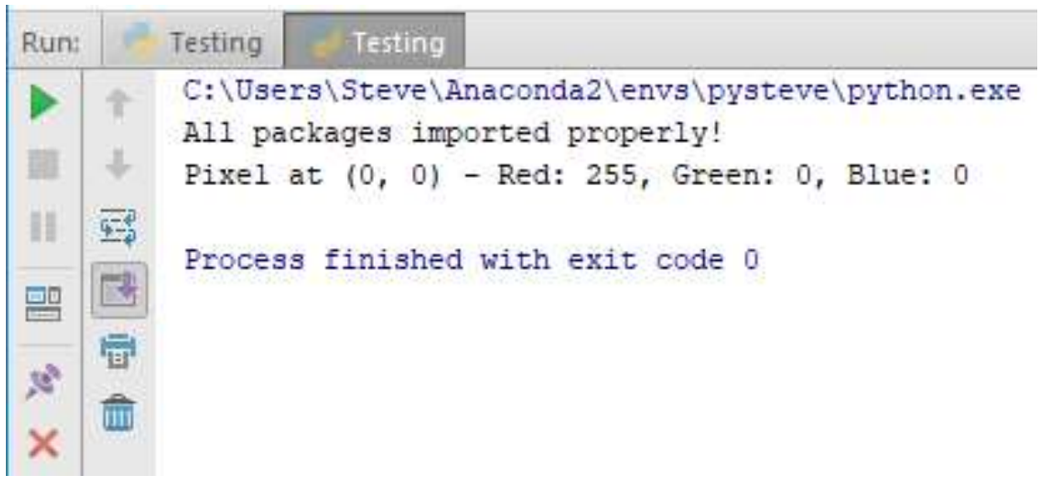
BGR was a choice made for historical reasons and now we have to live with it. In other words, BGR is the horse's ass in OpenCV."

*OpenCV represents images as numpy arrays **in reverse order**

OpenCV Fundamentals

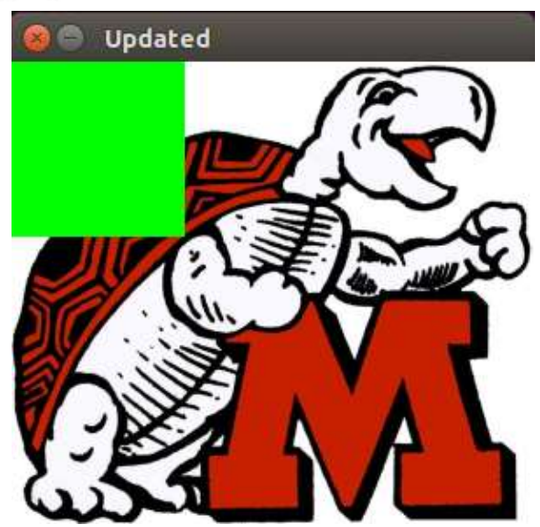
- Modify pixel color

```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

cv2.imshow("Old School Testudo Logo", image)
cv2.waitKey(0)

image[0, 0] = (0, 0, 255)
(b, g, r) = image[0, 0]
print "Pixel at (0, 0) - Red: %d, Green: %d, Blue: %d" % (r, g, b)
```



OpenCV Fundamentals

- Image slicing




```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

image = imutils.resize(image, width=400)

cv2.imshow("Old School Testudo Logo: Resized", image)

corner = image[0:100, 0:100]
cv2.imshow("Corner", corner)

image[0:100, 0:100] = (0, 255, 0)

cv2.imshow("Updated", image)
cv2.waitKey(0)
```


Original


Corn


Updated

OpenCV Fundamentals

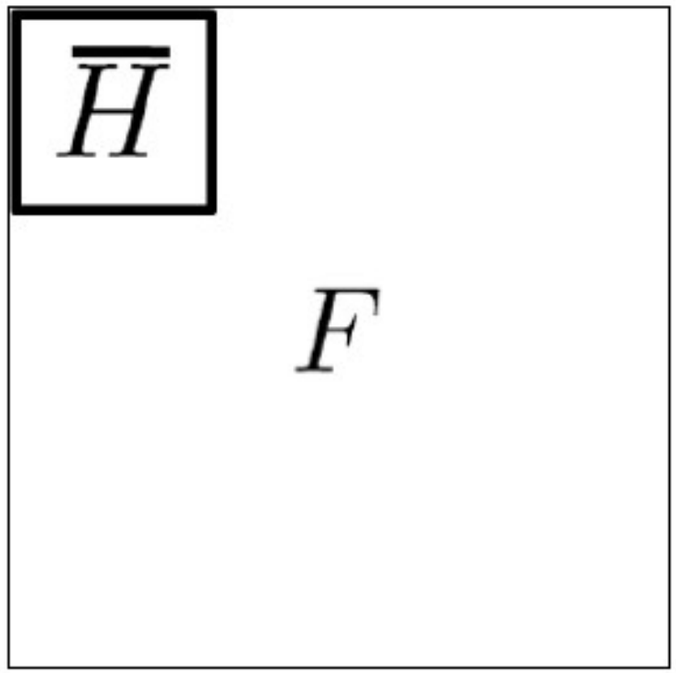
- Image filtering/blurring
- Average
- Gaussian
- Median
- Preserve edges using bilateral filtering

OpenCV Fundamentals

- Modify pixels in an image based on a function of a local neighborhood of each pixel

OpenCV Fundamentals

- Convolution



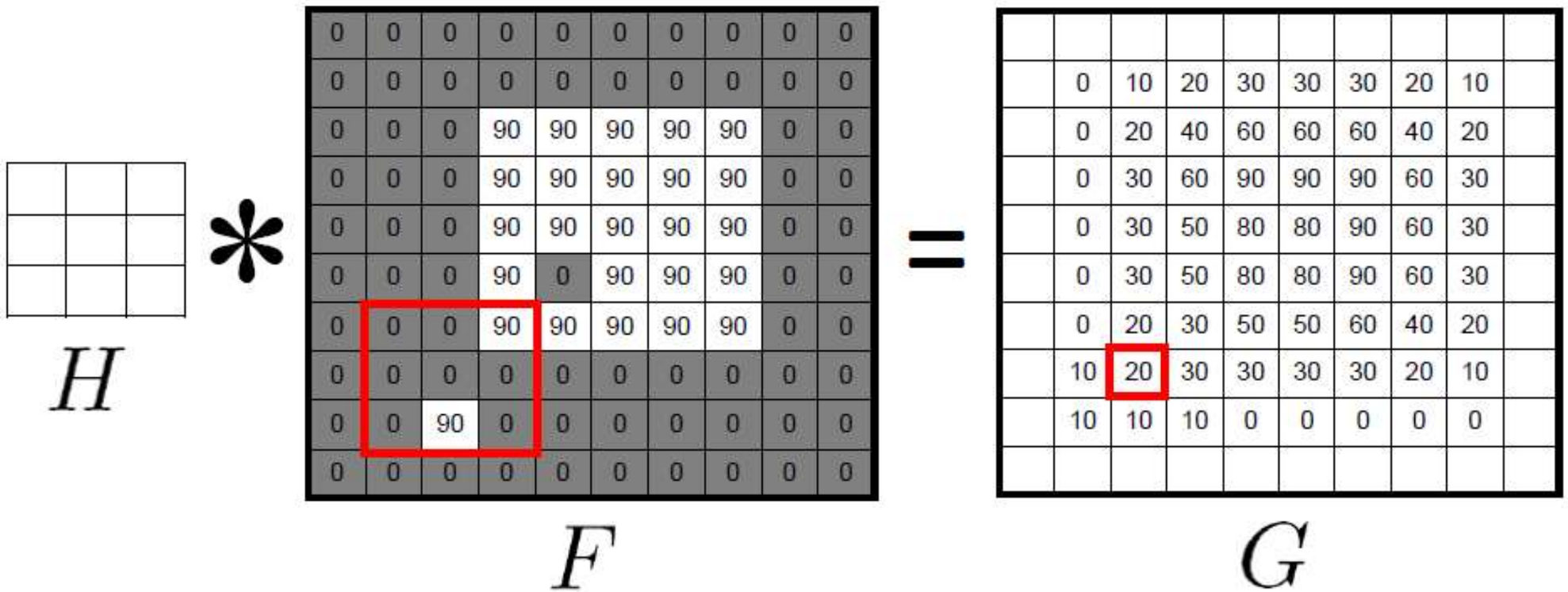
$$K = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

$$K = \frac{1}{25}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_filtering/py_filtering.html

OpenCV Fundamentals

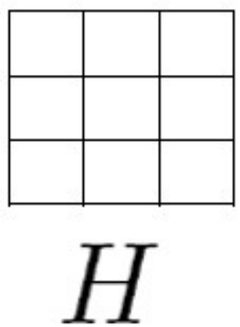
- Average blurring
- Fastest in terms of processing



OpenCV Fundamentals

- Average blurring

```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

image = imutils.resize(image, width=400)

cv2.imshow("Old School Testudo Logo: Resized", image)

blurred = np.hstack([
    cv2.blur(image, (3,3)),
    cv2.blur(image, (5,5)),
    cv2.blur(image, (7,7))])
cv2.imshow("Average Blurring", blurred)

cv2.waitKey(0)
```

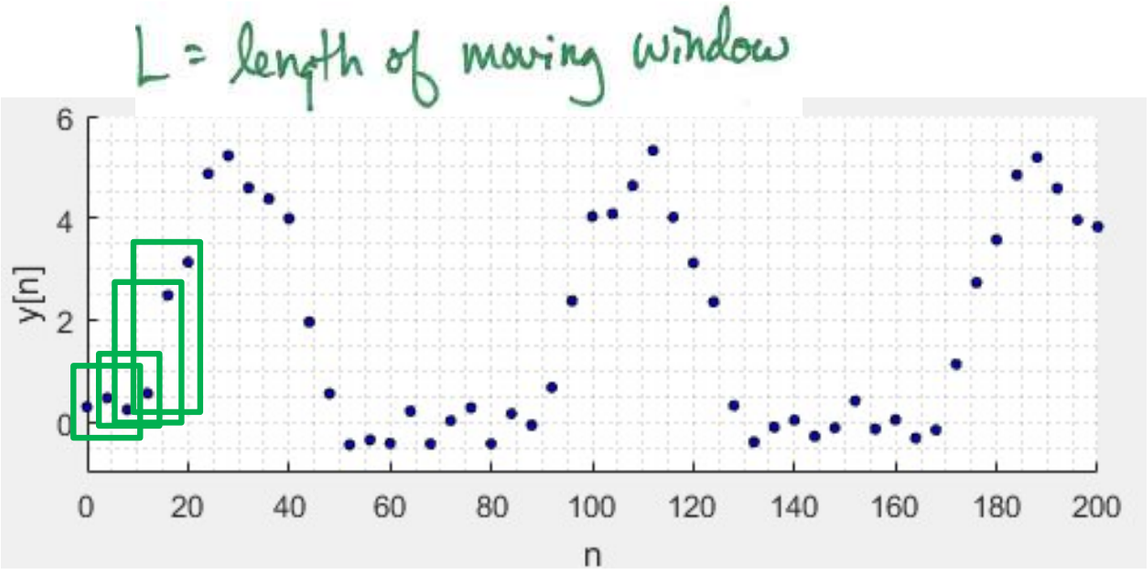


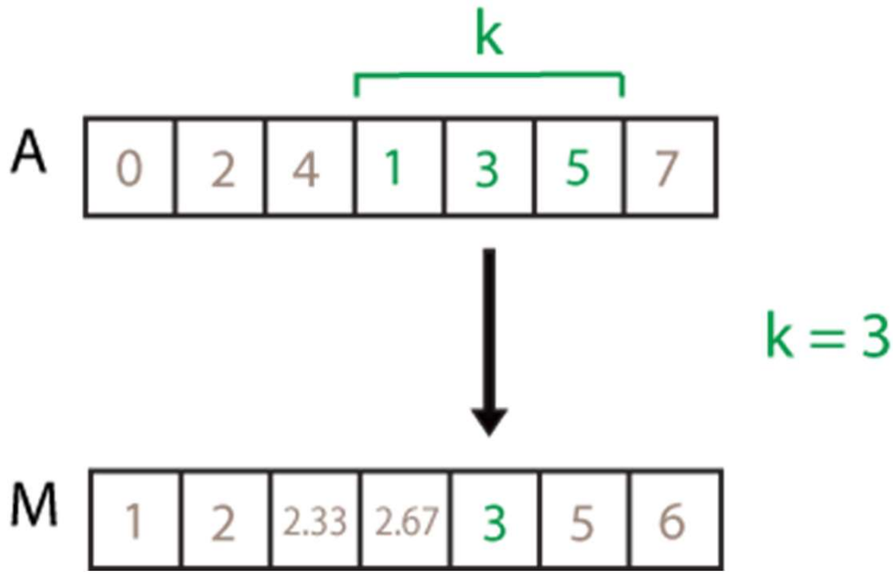
H


Original


Average Blurring

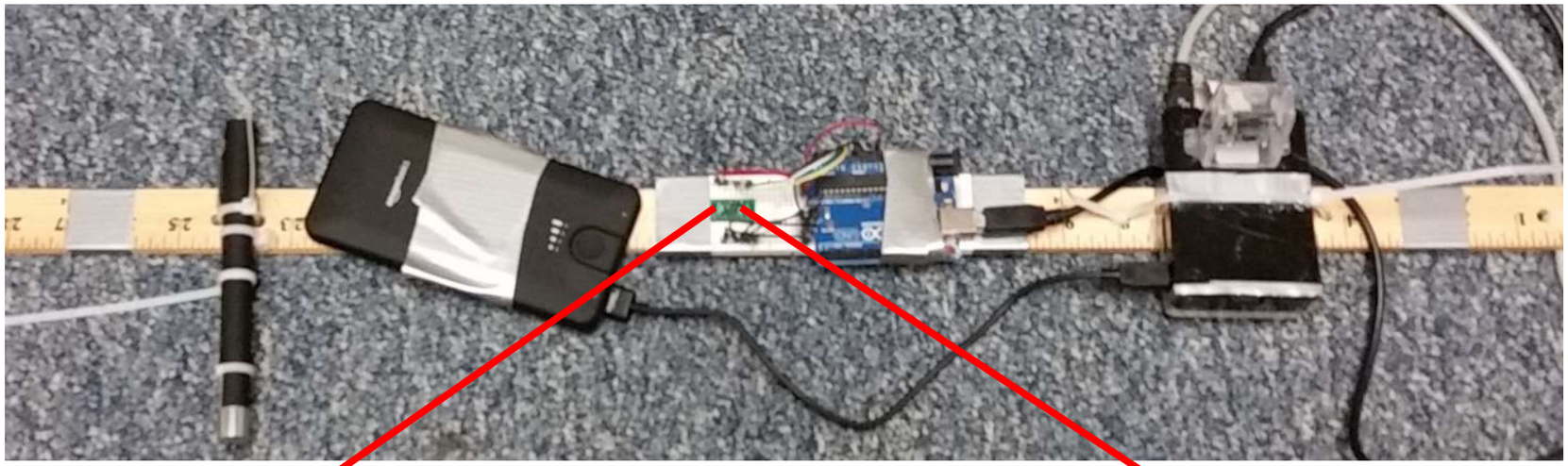
Digital filtering / moving average

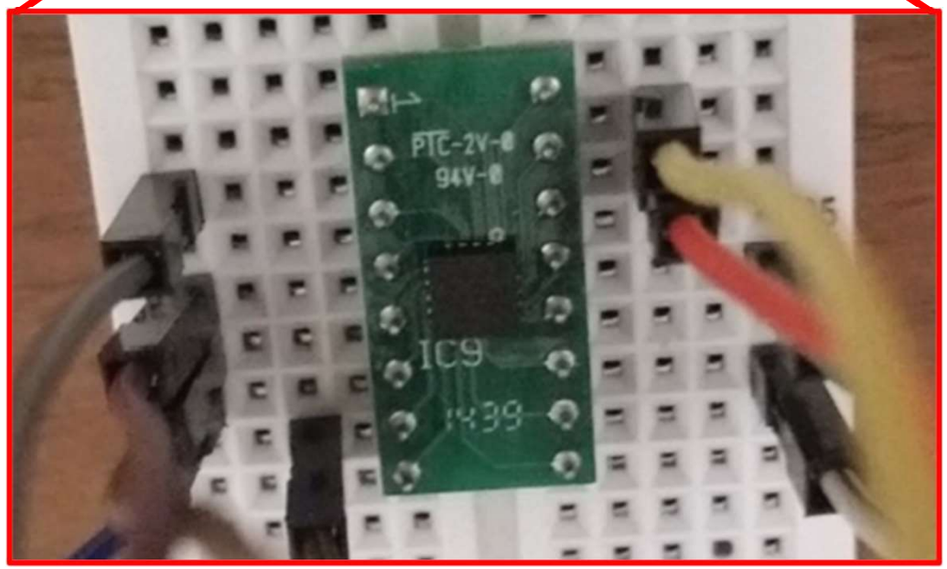


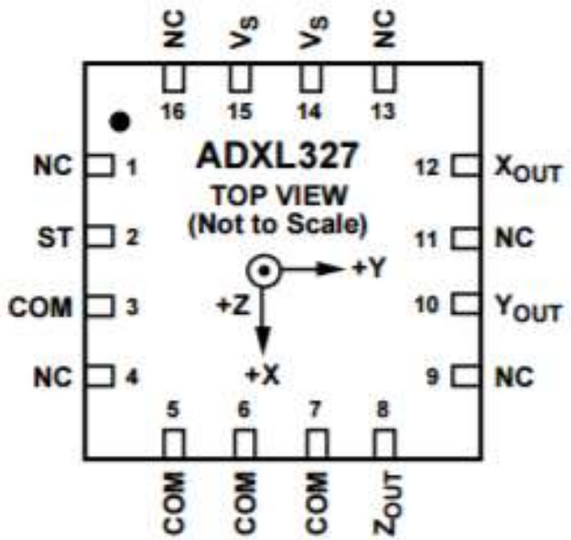


https://www.mathworks.com/help/matlab/ref/movmean.html

Moving average

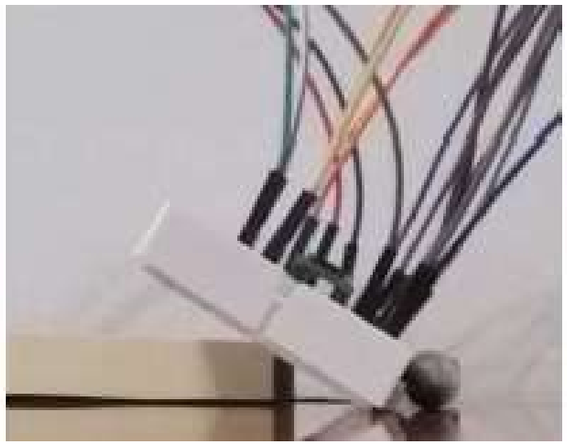






Moving average

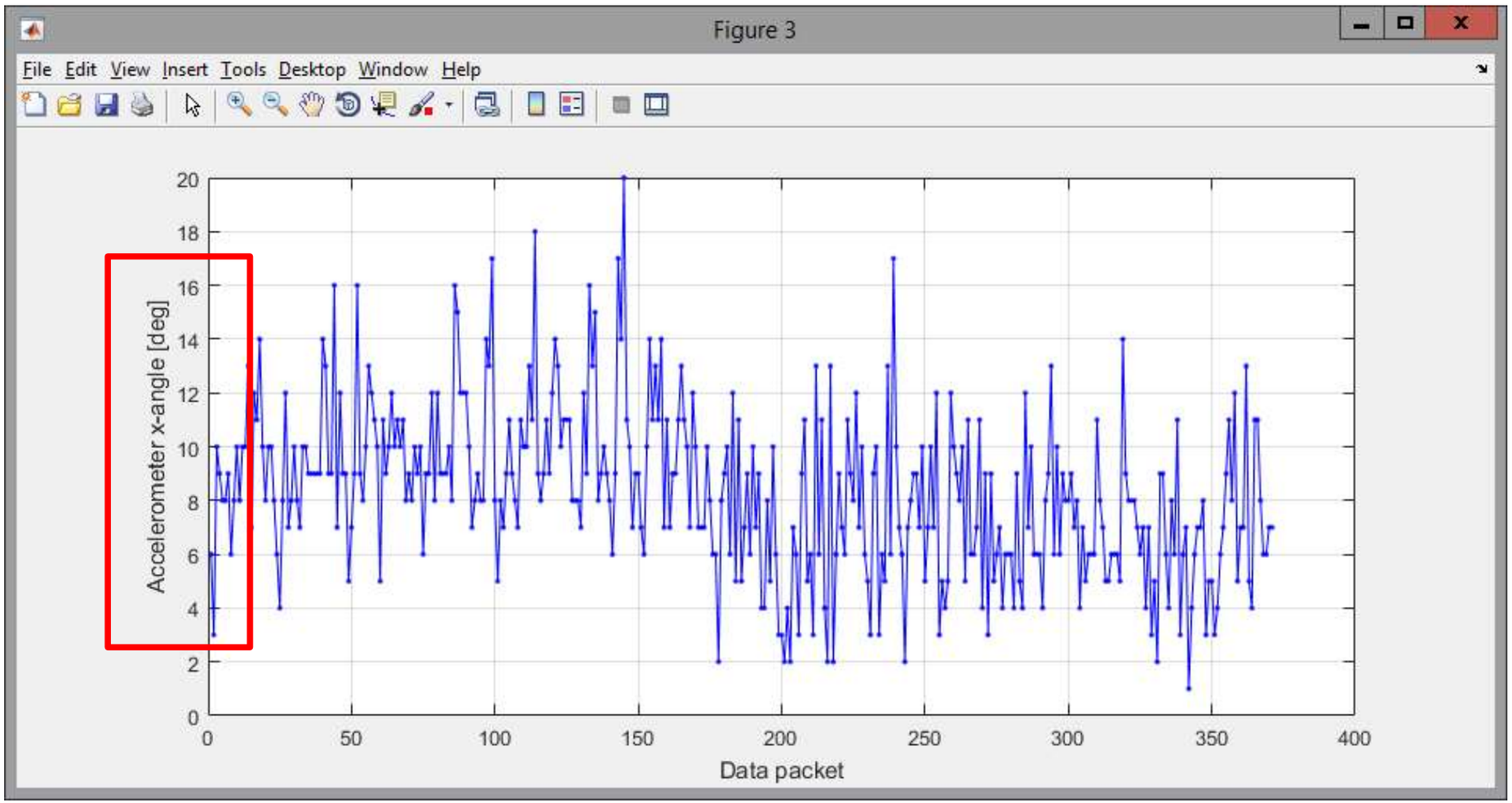
```
x = 332; Xangle = 0;
x = 333; Xangle = 0;
x = 333; Xangle = 1;
x = 333; Xangle = 0;
x = 332; Xangle = 0;
x = 332; Xangle = 0;
x = 333; Xangle = 0;
```



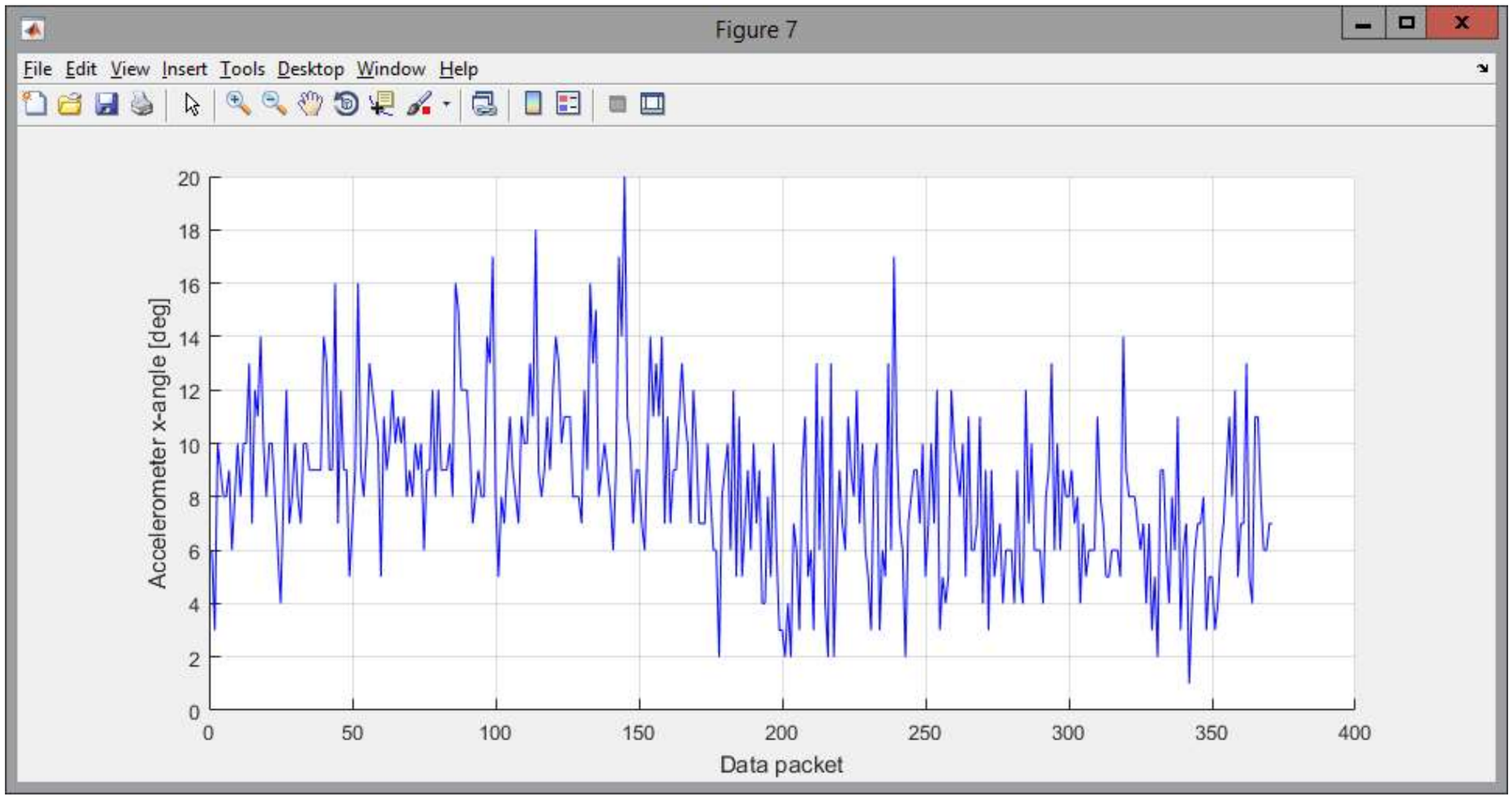
```
x = 285; Xangle = -44;
x = 287; Xangle = -44;
x = 286; Xangle = -45;
x = 286; Xangle = -45;
x = 287; Xangle = -46;
x = 286; Xangle = -45;
```

```
x = 380; Xangle = 44;
x = 379; Xangle = 43;
x = 380; Xangle = 45;
x = 379; Xangle = 47;
x = 380; Xangle = 45;
x = 379; Xangle = 44;
```

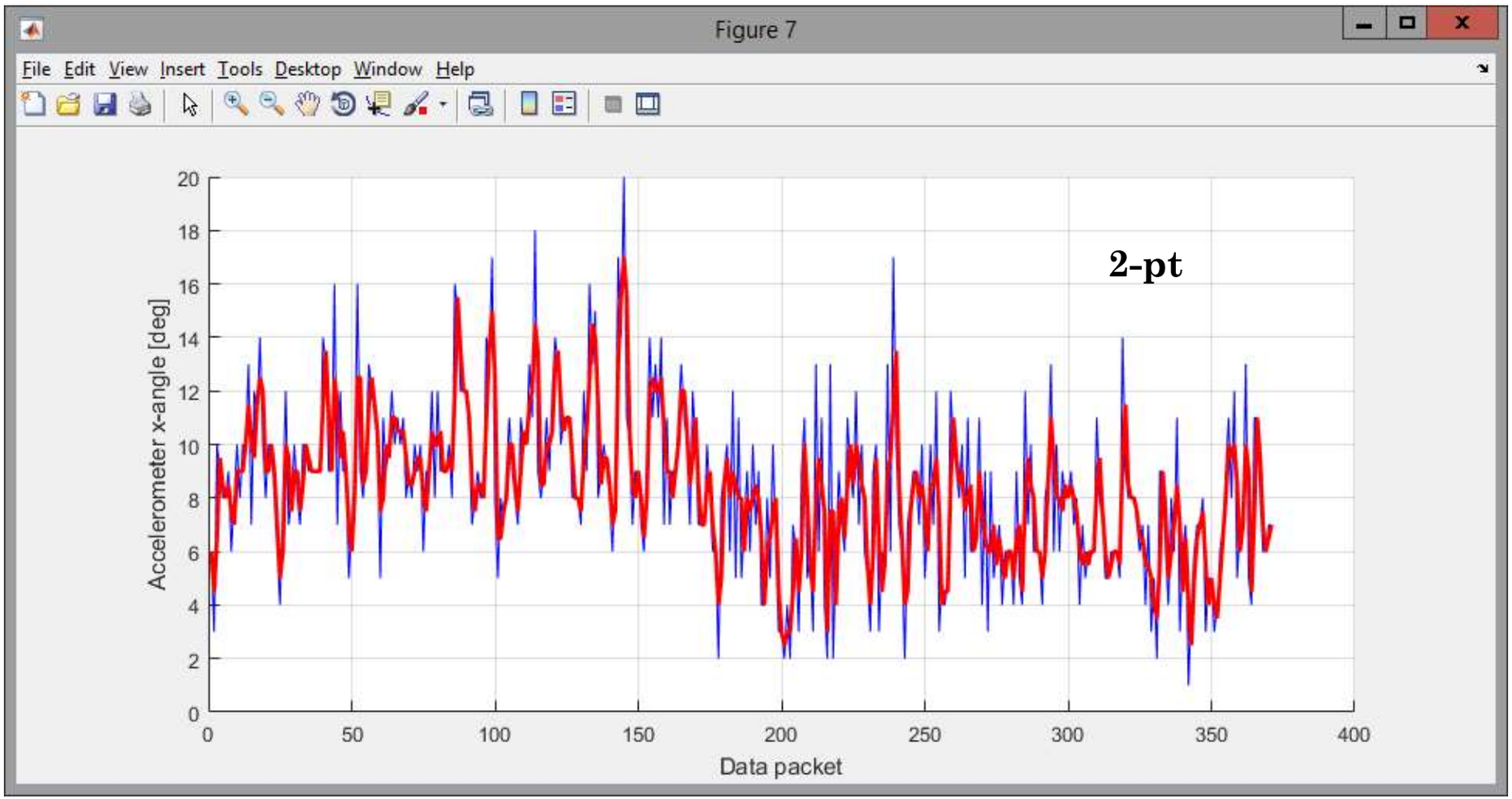
Moving average



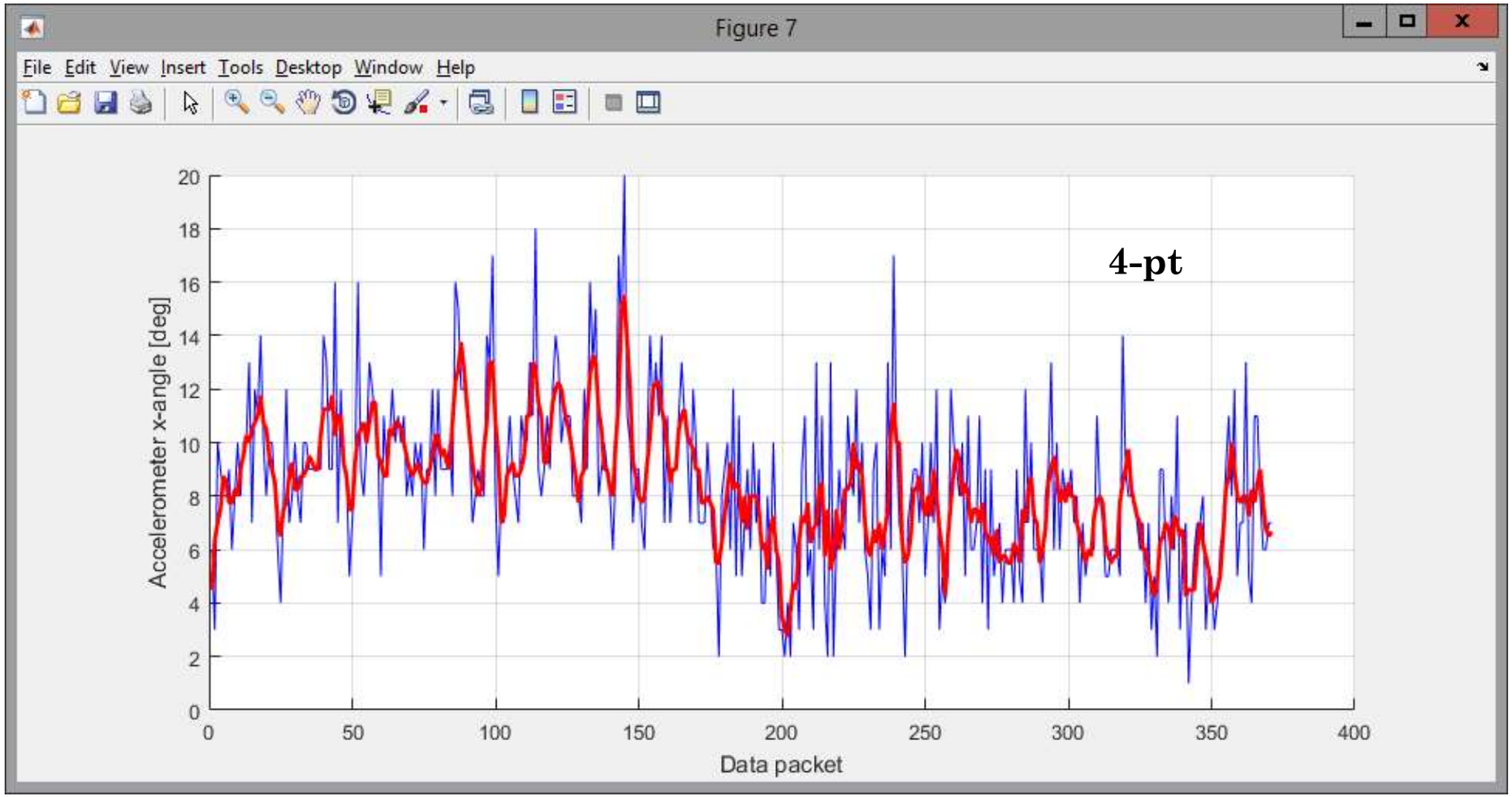
Moving average



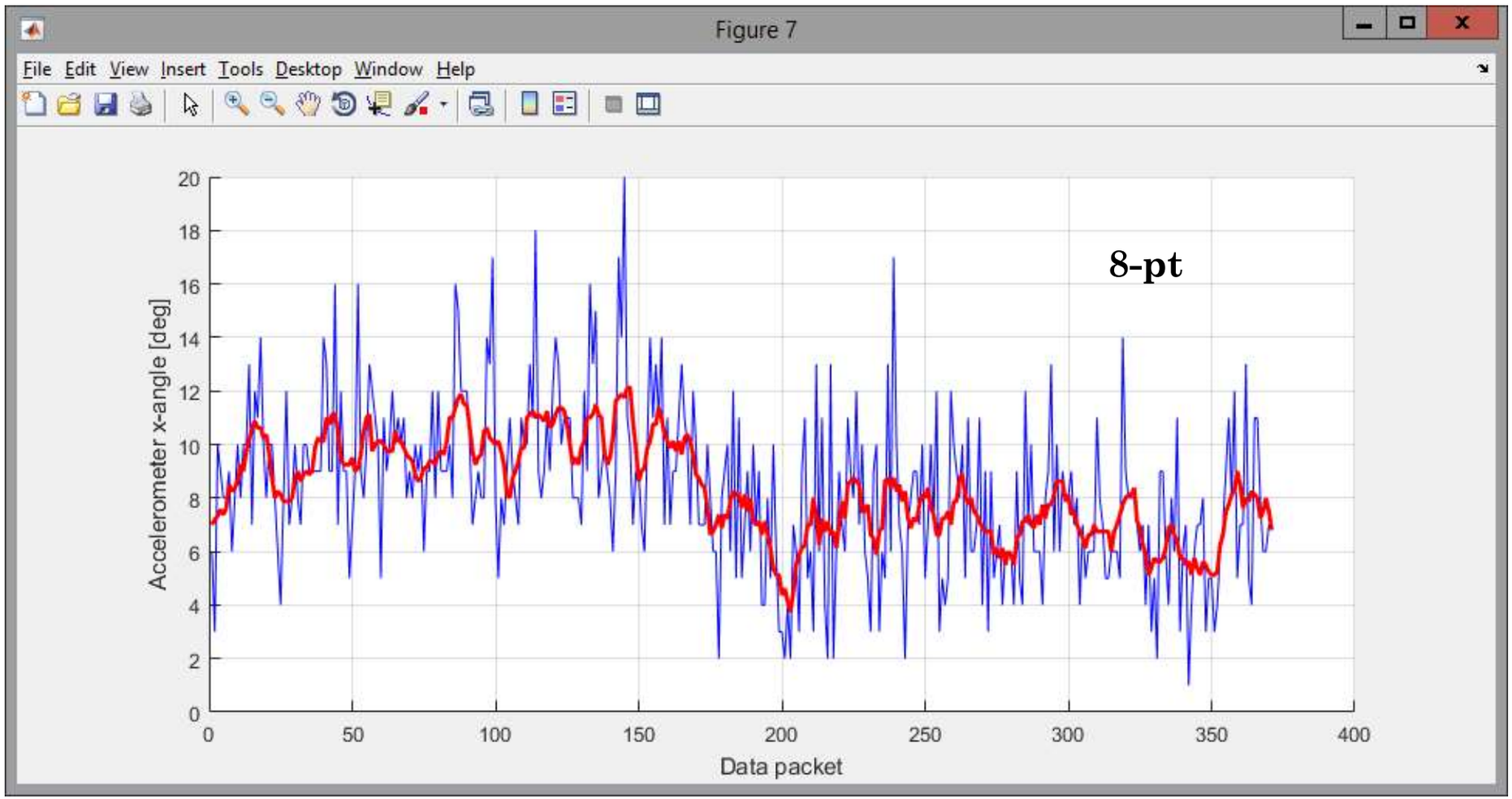
Moving average



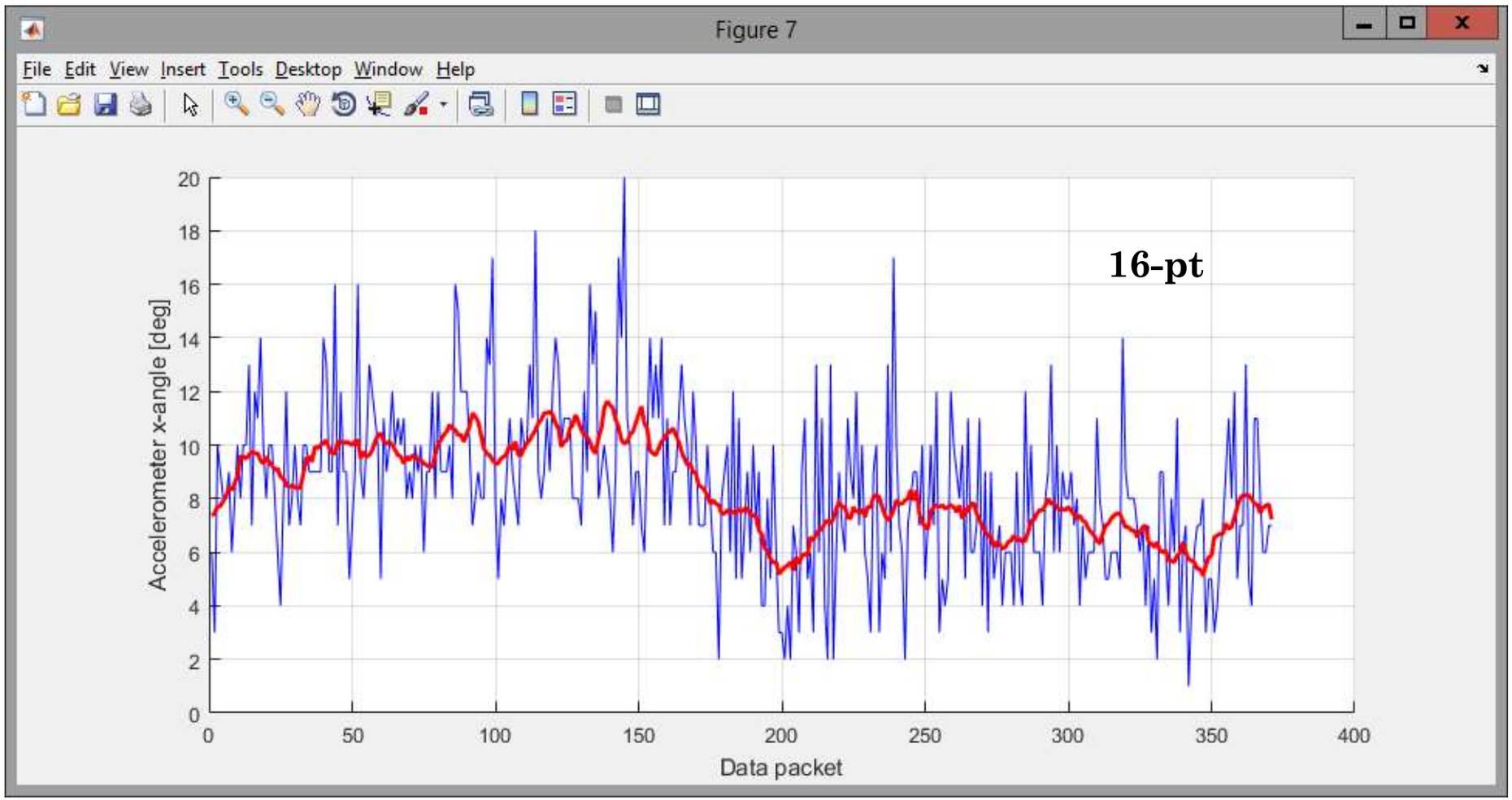
Moving average



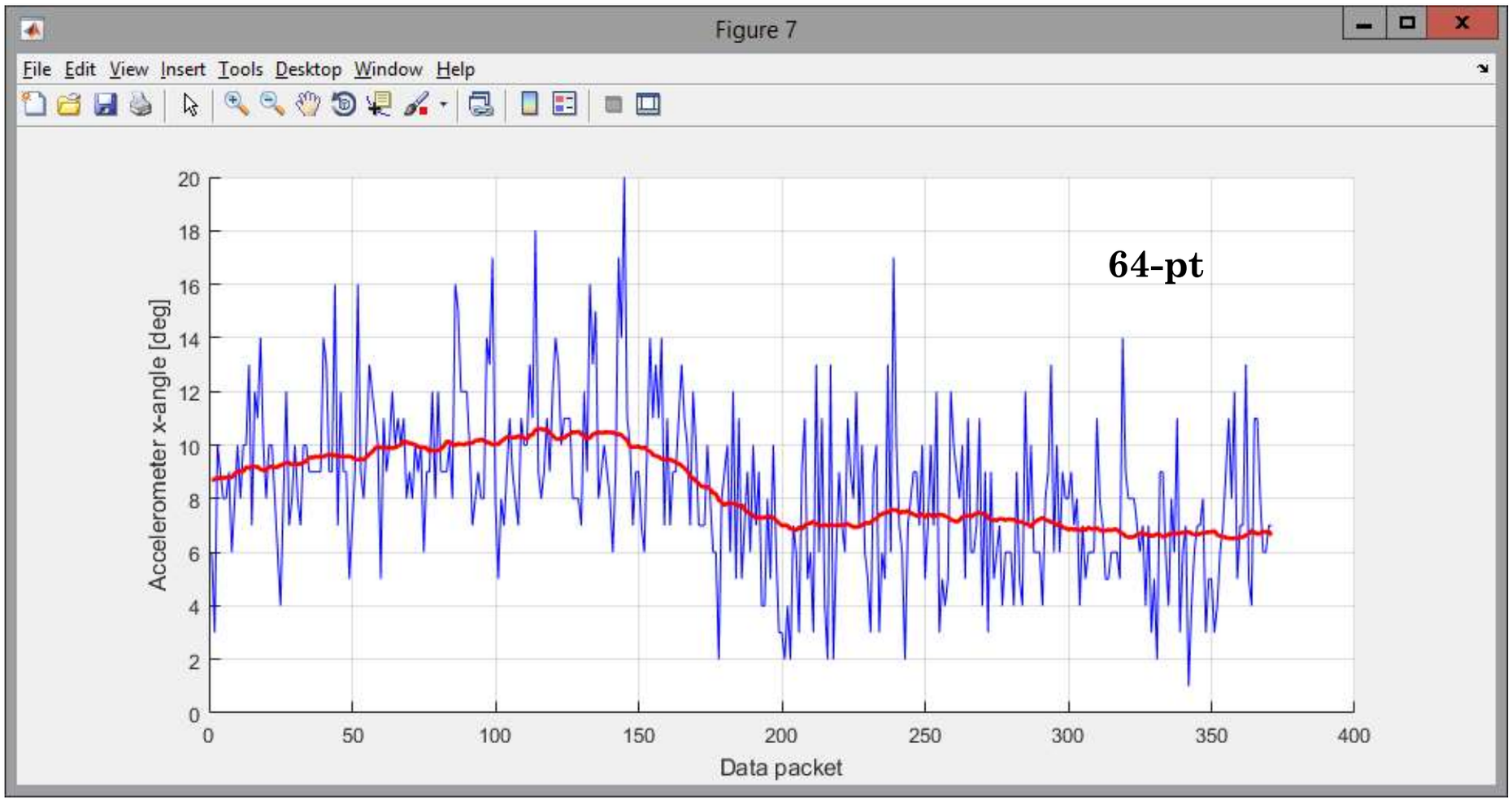
Moving average



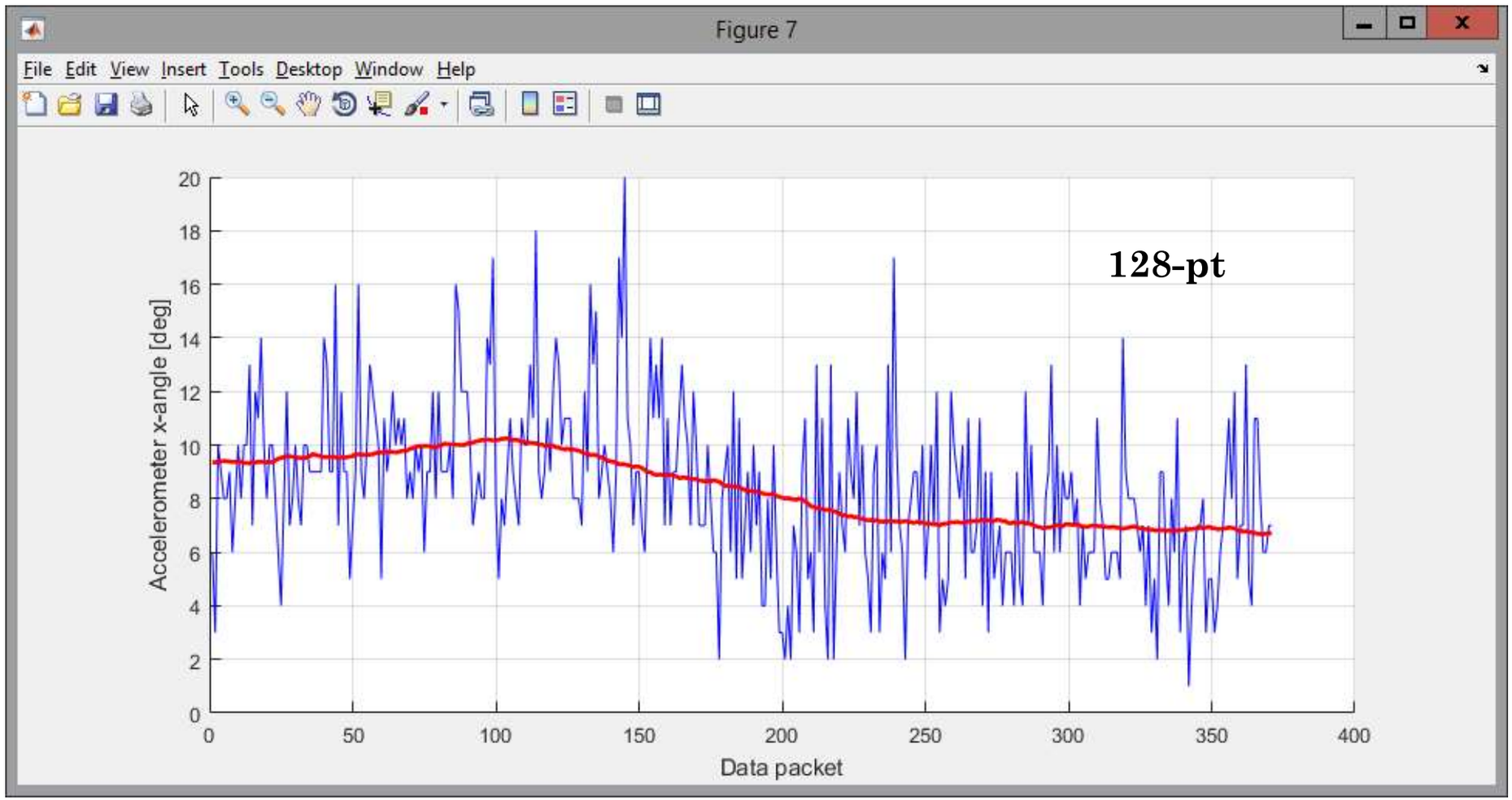
Moving average



Moving average

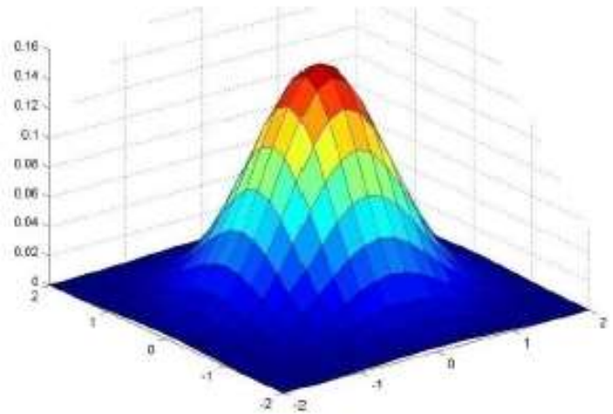


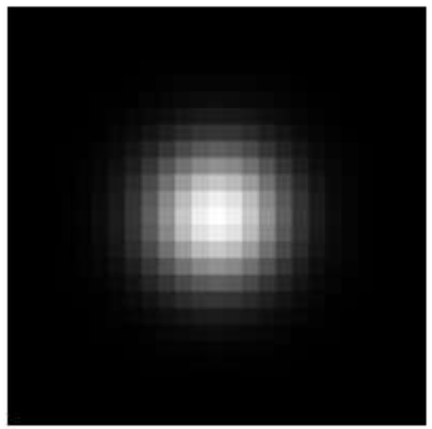
Moving average



OpenCV Fundamentals

- Gaussian blurring

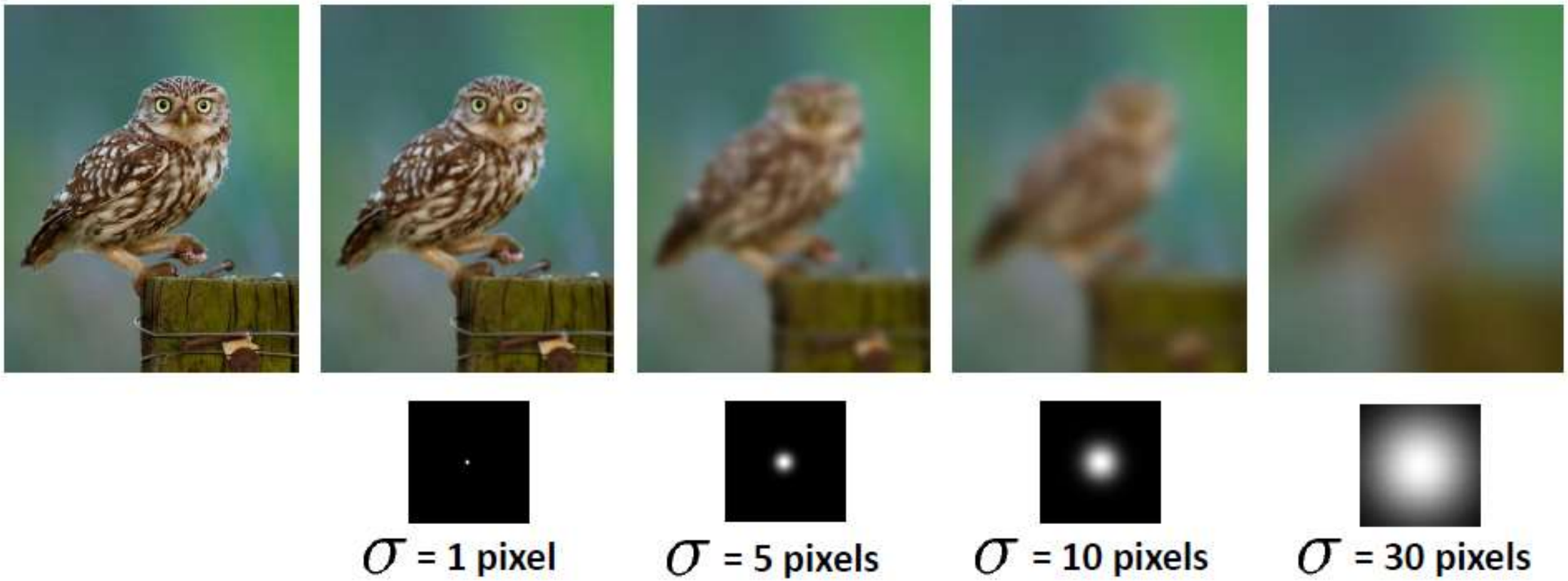




$$G_\sigma = \frac{1}{2\pi\sigma^2} e^{-\frac{(x^2+y^2)}{2\sigma^2}}$$

OpenCV Fundamentals

- Gaussian blurring

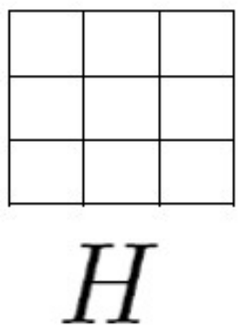


OpenCV Fundamentals

- Gaussian blurring

```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

image = imutils.resize(image, width=400)

cv2.imshow("Old School Testudo Logo: Resized", image)

blurred = np.hstack([
    cv2.GaussianBlur(image, (3,3), 0),
    cv2.GaussianBlur(image, (5,5), 0),
    cv2.GaussianBlur(image, (7,7), 0)])
cv2.imshow("Gaussian Blurring", blurred)

cv2.waitKey(0)
```

Automatically compute based on kernel size



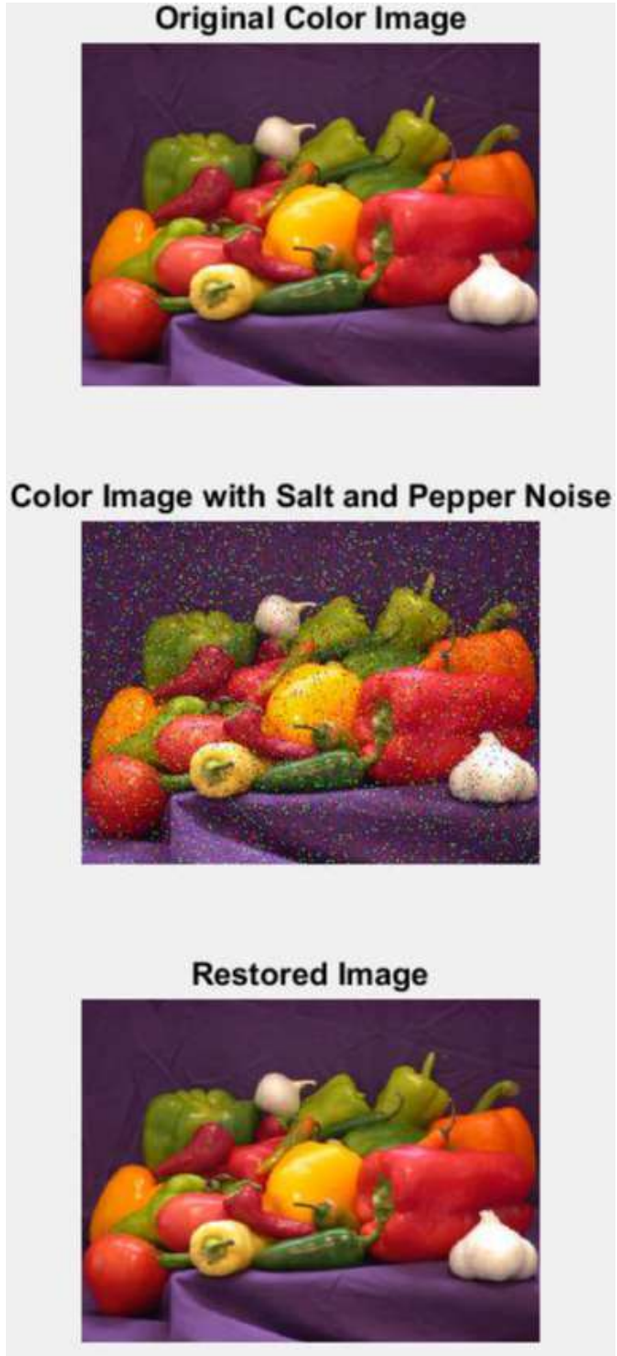
H


Original


Gaussian Blurring

OpenCV Fundamentals

- Median blurring
- Replace central pixel with median of neighborhood
- Most effective at removing salt & pepper noise

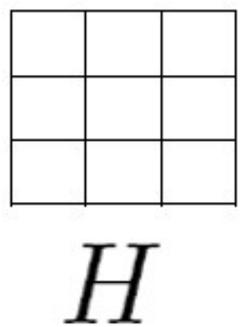


https://snag.gy/bv87f.jpg

OpenCV Fundamentals

- Median blurring

```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

image = imutils.resize(image, width=400)

cv2.imshow("Old School Testudo Logo: Resized", image)

blurred = np.hstack([
    cv2.medianBlur(image, 3),
    cv2.medianBlur(image, 5),
    cv2.medianBlur(image, 7)])
cv2.imshow("Median Blurring", blurred)

cv2.waitKey(0)
```



H


Original


Median Blurring

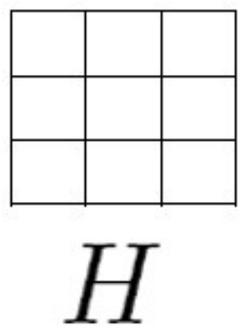
OpenCV Fundamentals

- Bilateral filter
- Reduce noise while maintaining edges
- Two Gaussians
  - First considers pixels close together in (x, y)
  - Second ensures only pixels with similar intensity are included in computation of blur
- Computationally demanding

OpenCV Fundamentals

- Bilateral filter

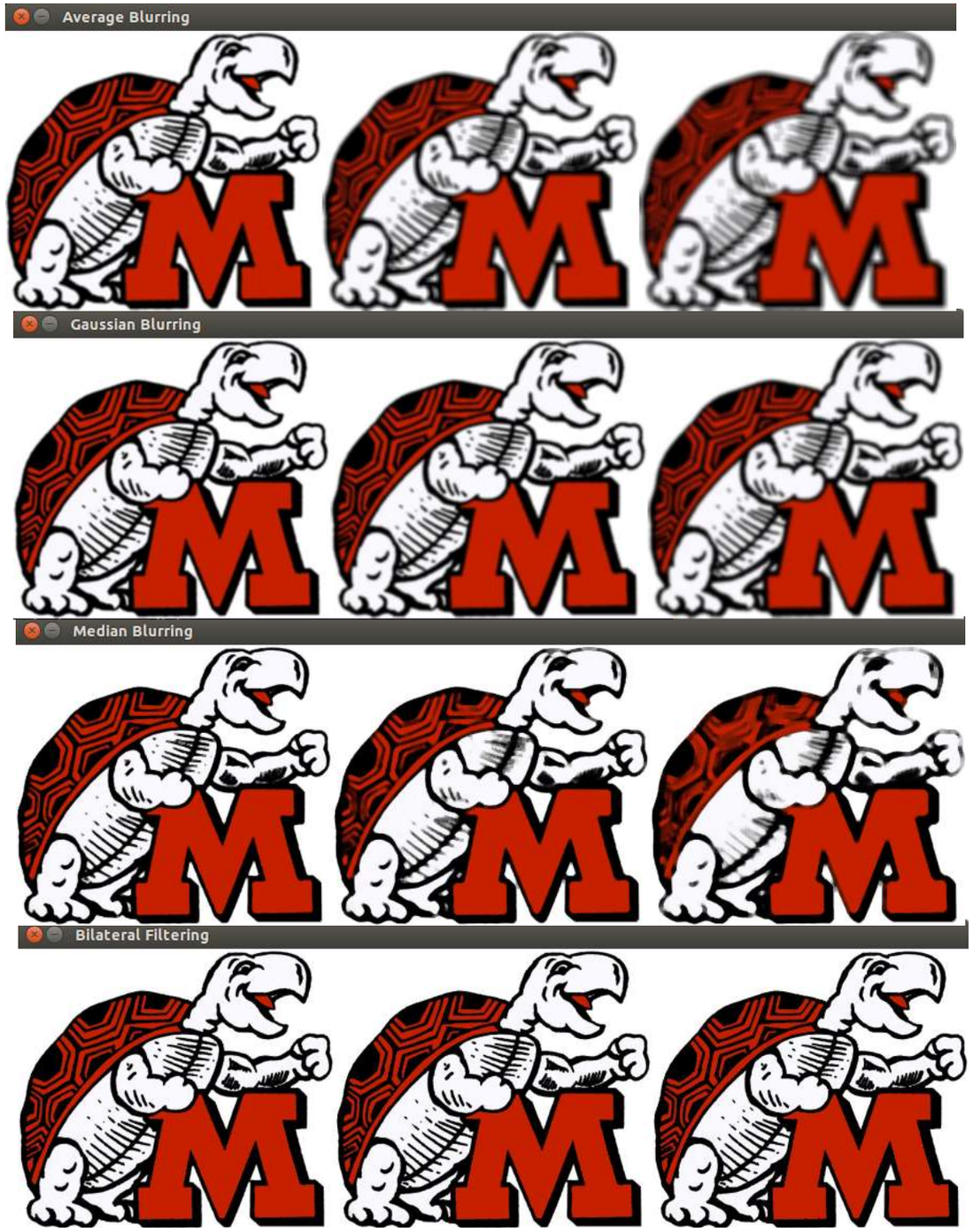
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")

image = imutils.resize(image, width=400)

cv2.imshow("Old School Testudo Logo: Resized", image)

blurred = np.hstack([
    cv2.bilateralFilter(image, 5, 21, 21),
    cv2.bilateralFilter(image, 7, 31, 31),
    cv2.bilateralFilter(image, 9, 41, 41)])
cv2.imshow("Bilater Filtering", blurred)

cv2.waitKey(0)
```



H


Original


Bilateral Filtering


Average Blurring
Gaussian Blurring
Median Blurring
Bilateral Filtering

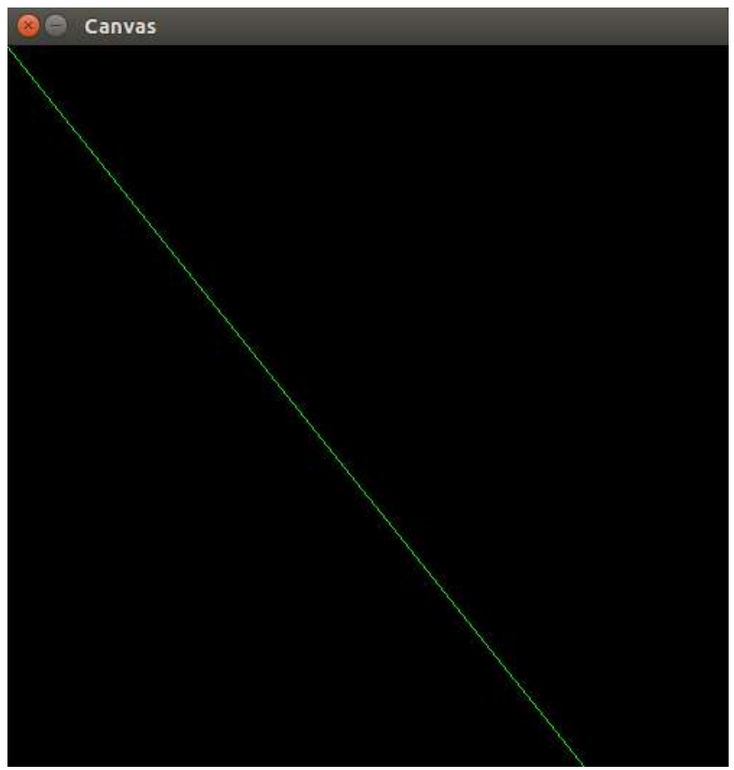
OpenCV Fundamentals

- Drawing lines
- Rectangles
- Circles

OpenCV Fundamentals

- Import packages and define a blank canvas (image)
- Draw a line atop canvas

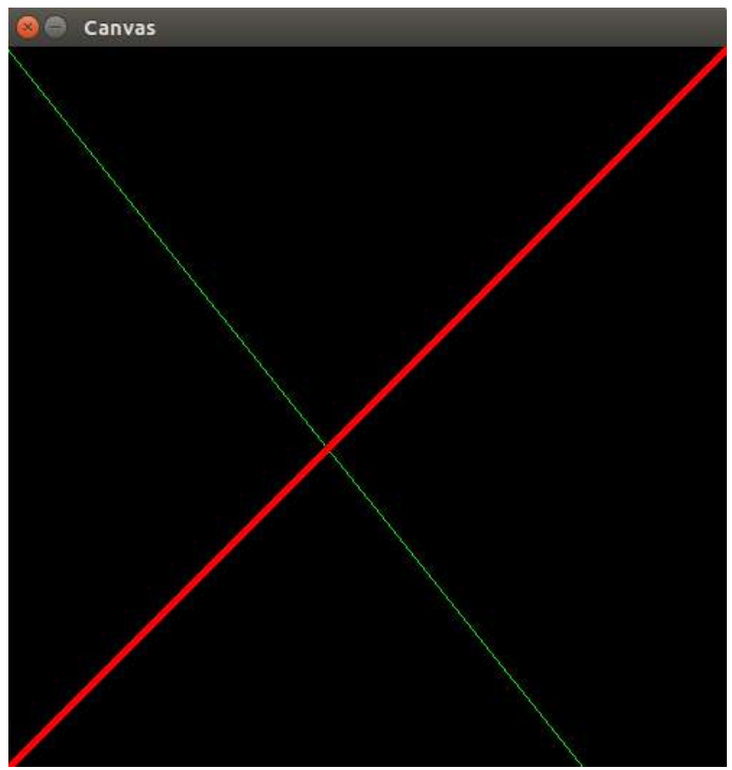
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

canvas = np.zeros((500, 500, 3), dtype="uint8")

green = (0, 255, 0)
cv2.line(canvas, (0,0), (400, 500), green)
cv2.imshow("Canvas", canvas)
cv2.waitKey(0)
```



OpenCV Fundamentals

- Green and red lines defined by starting/ending coordinates

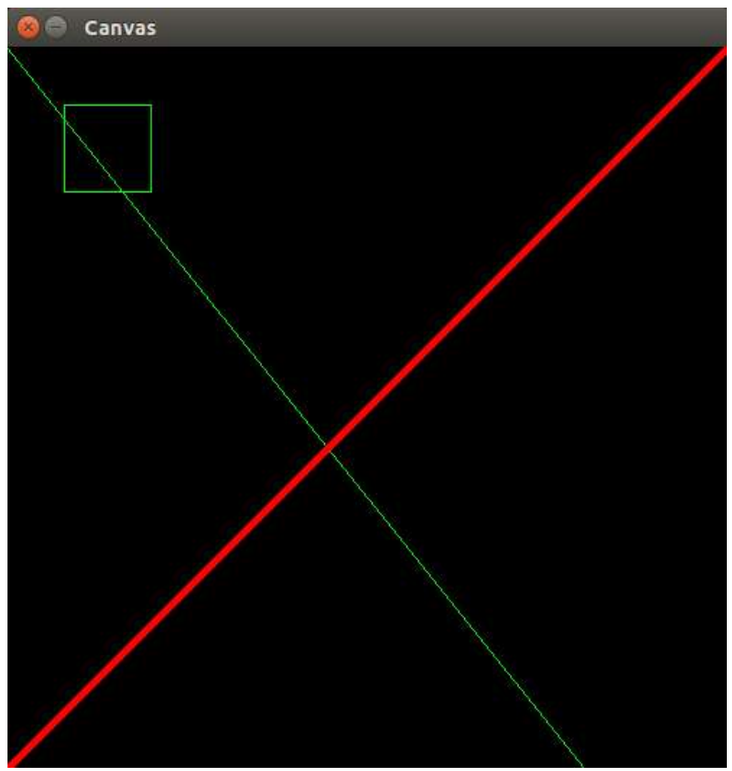
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

canvas = np.zeros((500, 500, 3), dtype="uint8")

green = (0, 255, 0)
cv2.line(canvas, (0,0), (400, 500), green)

red = (0, 0, 255)
cv2.line(canvas, (500, 0), (0, 500), red, 3)
cv2.imshow("Canvas", canvas)
cv2.waitKey(0)
```



OpenCV Fundamentals

- Rectangle: green outline, no fill

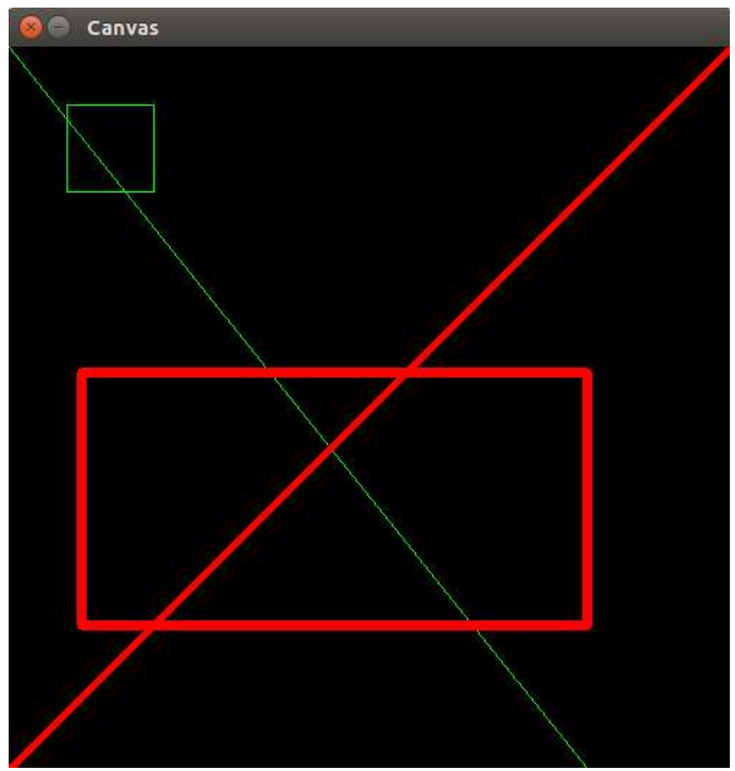
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

canvas = np.zeros((500, 500, 3), dtype="uint8")

green = (0, 255, 0)
cv2.line(canvas, (0,0), (400, 500), green)

red = (0, 0, 255)
cv2.line(canvas, (500, 0), (0, 500), red, 3)

cv2.rectangle(canvas, (40, 50), (100, 100), green)
cv2.imshow("Canvas", canvas)
cv2.waitKey(0)
```



OpenCV Fundamentals

- Red rectangle no fill and blue filled rectangle

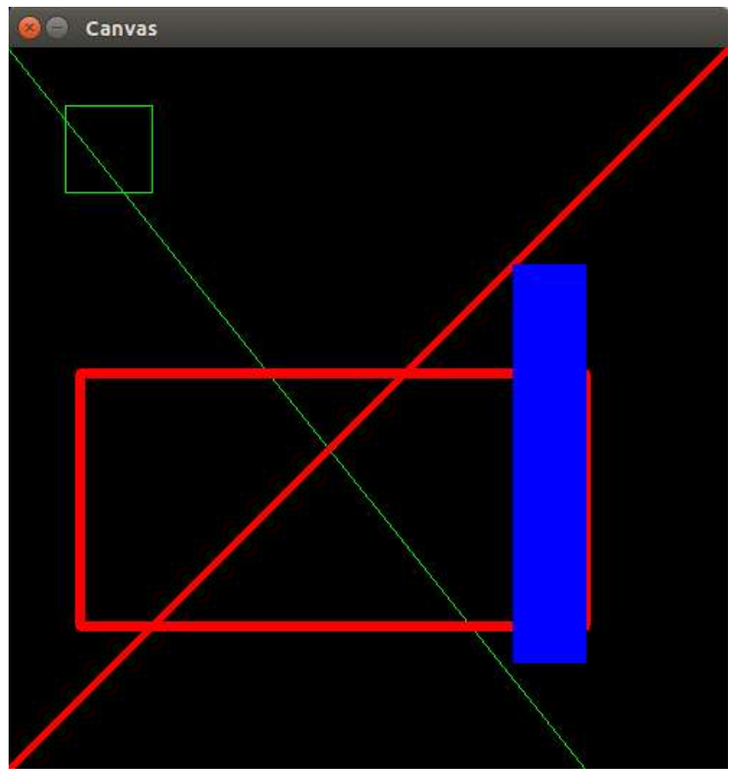
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

canvas = np.zeros((500, 500, 3), dtype="uint8")

green = (0, 255, 0)
cv2.line(canvas, (0,0), (400, 500), green)

red = (0, 0, 255)
cv2.line(canvas, (500, 0), (0, 500), red, 3)

cv2.rectangle(canvas, (40, 50), (100, 100), green)
cv2.rectangle(canvas, (50, 400), (400, 225), red, 5)
cv2.imshow("Canvas", canvas)
cv2.waitKey(0)
```



OpenCV Fundamentals

- Blue filled rectangle

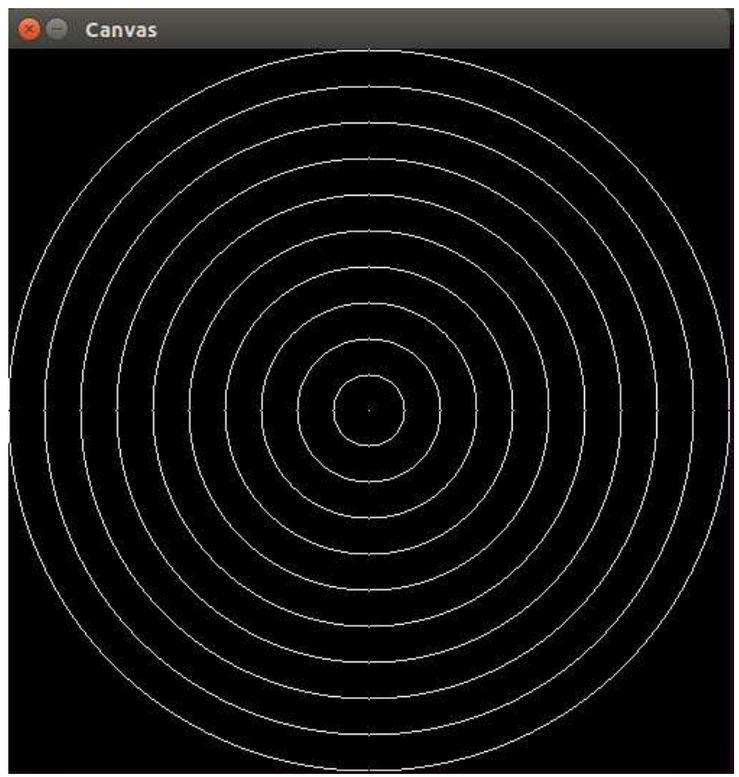
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

canvas = np.zeros((500, 500, 3), dtype="uint8")

green = (0, 255, 0)
cv2.line(canvas, (0,0), (400, 500), green)

red = (0, 0, 255)
cv2.line(canvas, (500, 0), (0, 500), red, 3)

cv2.rectangle(canvas, (40, 50), (100, 100), green)
cv2.rectangle(canvas, (50, 400), (400, 225), red, 5)
cv2.rectangle(canvas, (350, 150), (400, 425), (255, 0, 0), -1)
cv2.imshow("Canvas", canvas)
cv2.waitKey(0)
```



OpenCV Fundamentals

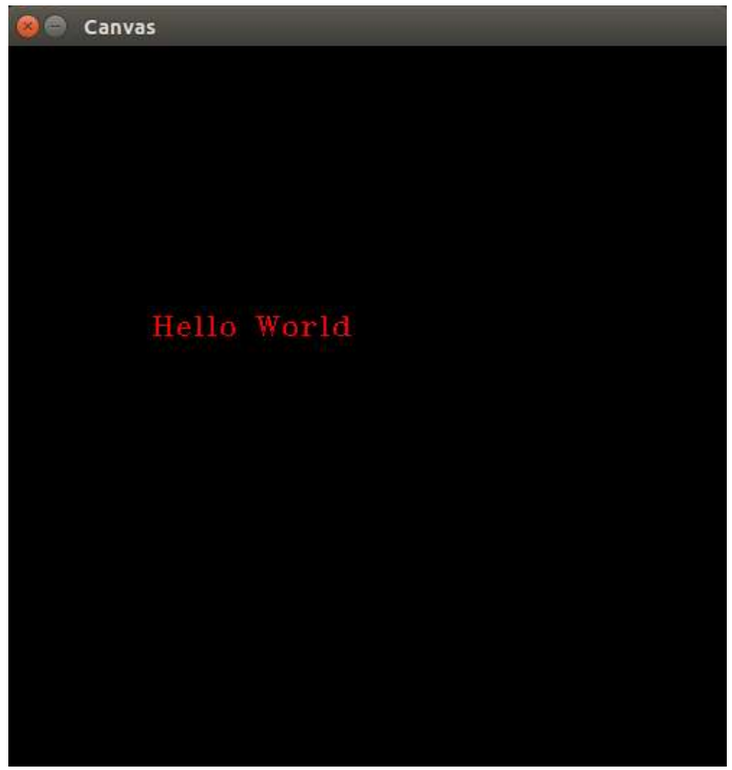
- Concentric circles

```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

canvas = np.zeros((500, 500, 3), dtype="uint8")

(centerX, centerY) = (canvas.shape[1]/2, canvas.shape[0]/2)

white = (255, 255, 255)

for r in xrange(0, 275, 25):
    cv2.circle(canvas, (centerX, centerY), r, white)
    cv2.imshow("Concentric Circles", canvas)
    cv2.waitKey(0)
```



OpenCV Fundamentals

- Overlay text on image




```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

canvas = np.zeros((500, 500, 3), dtype="uint8")

font = cv2.FONT_HERSHEY_COMPLEX_SMALL

red = (0, 0, 255)
cv2.putText(canvas, 'Hello World', (100, 200), font, 1, red, 1)

cv2.imshow("Canvas", canvas)
cv2.waitKey(0)
```

OpenCV Fundamentals

- Image transformations / flipping
- Masking

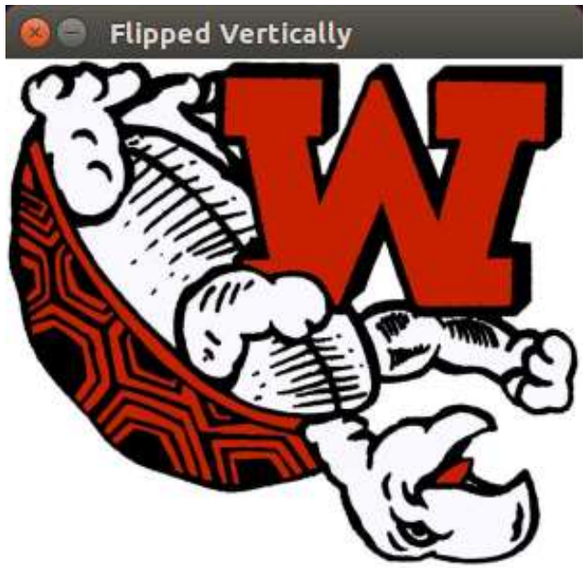
OpenCV Fundamentals

- Flip image

```
import numpy as np
import cv2
import imutils

image = cv2.imread("testudo.jpg")
image = imutils.resize(image, width=400)

cv2.imshow("Original", image)

flipped = cv2.flip(image, 1)
cv2.imshow("Flipped Horizontally", flipped)

flipped = cv2.flip(image, 0)
cv2.imshow("Flipped Vertically", flipped)

flipped = cv2.flip(image, -1)
cv2.imshow("Flipped Horizontally & Vertically", flipped)

cv2.waitKey(0)
```


Original


Flipped Horizontally

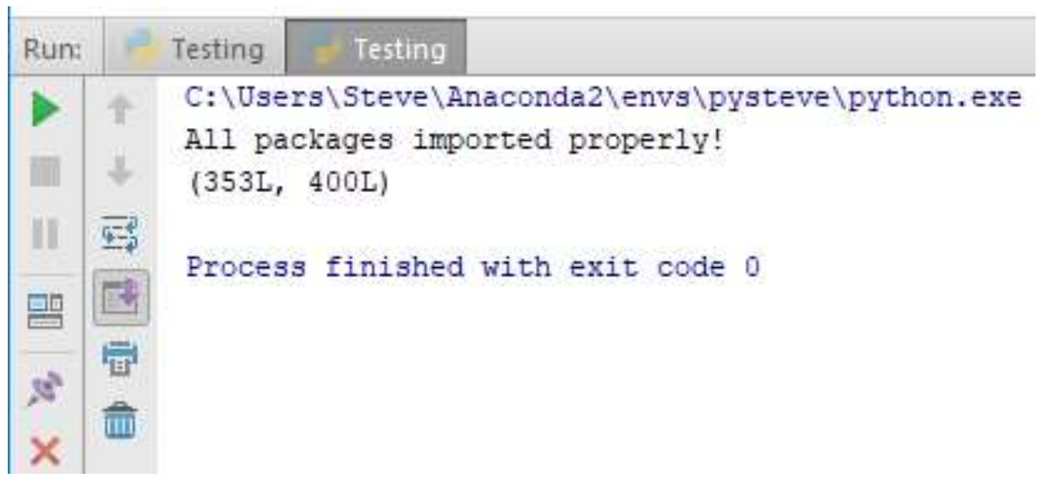

Flipped Vertically


Flipped Horizontally & Vertically

OpenCV Fundamentals

- Masking

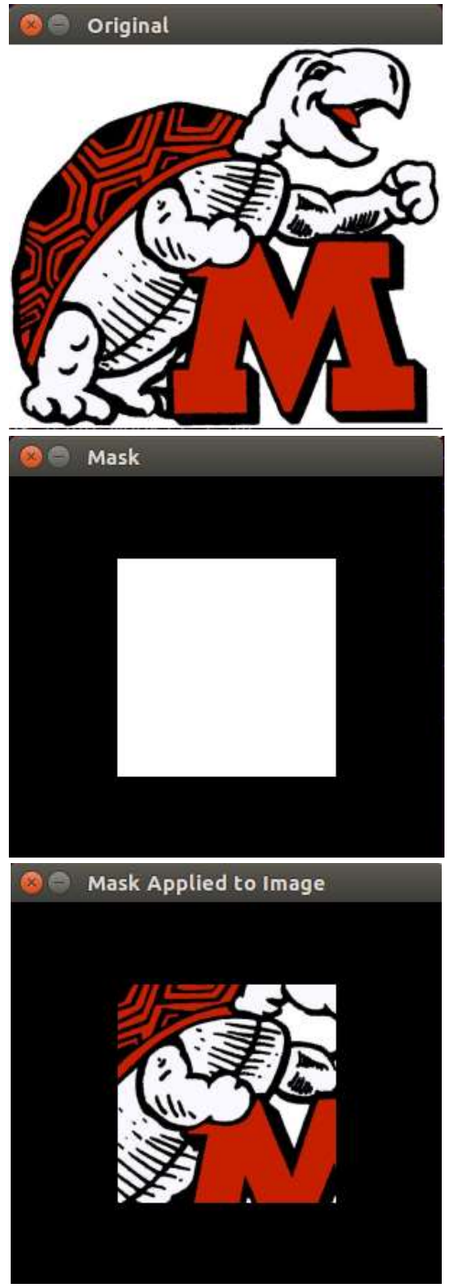
```
import numpy as np
import cv2
import imutils

print "All packages imported properly!"

image = cv2.imread("testudo.jpg")
image = imutils.resize(image, width=400)

cv2.imshow("Original", image)

print image.shape[:2]
```



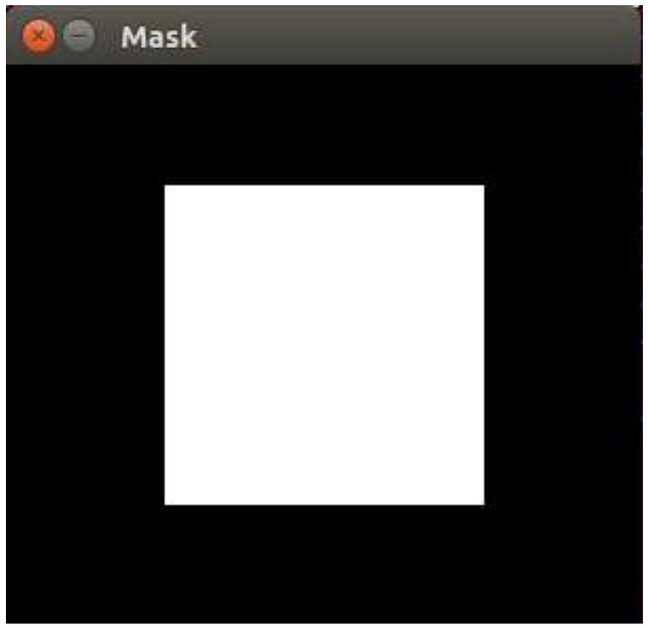
OpenCV Fundamentals

- Rectangular mask

```
import numpy as np
import cv2
import imutils

image = cv2.imread("testudo.jpg")
image = imutils.resize(image, width=400)
cv2.imshow("Original", image)

mask = np.zeros(image.shape[:2], dtype = "uint8")
(cX, cY) = (image.shape[1]/2, image.shape[0]/2)
cv2.rectangle(mask, (cX - 75, cY - 75), (cX + 75, cY + 75), 255, -1)
cv2.imshow("Mask", mask)

masked = cv2.bitwise_and(image, image, mask=mask)
cv2.imshow("Mask Applied to Image", masked)

cv2.waitKey(0)
```




Original


Mask


Mask Applied to Image

AND logic gate

Gate

Truth Table

A	B	Z
0	0	0
0	1	0
1	0	0
1	1	1

Notation

$$Z = A\,B$$
$$= A \cdot B$$

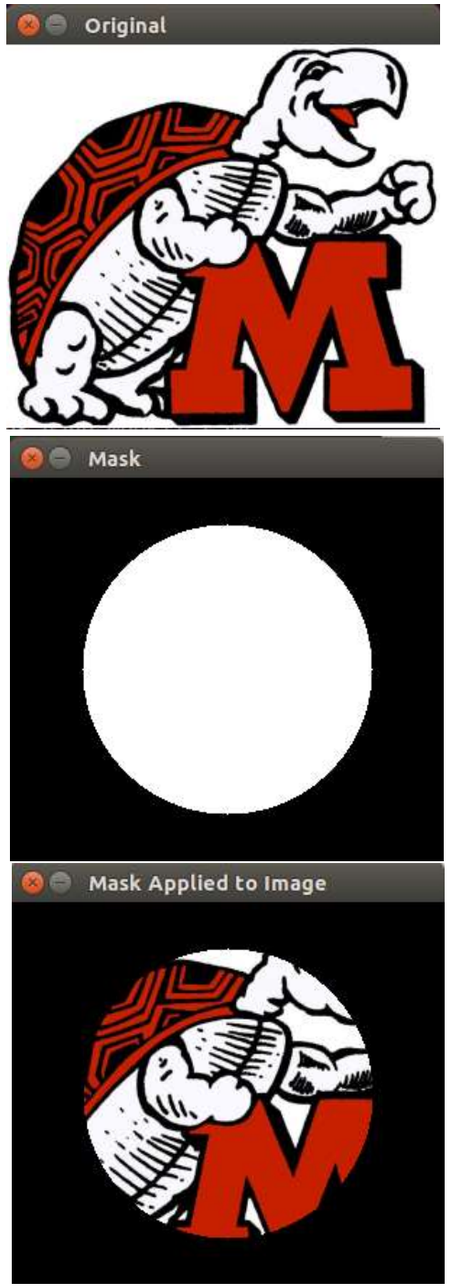
"logic multiplication"

- Output is 1 if BOTH inputs are 1

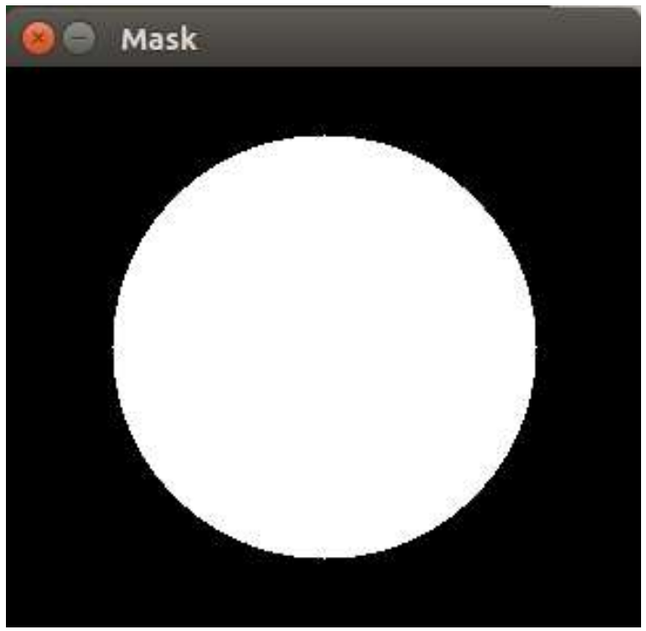
OpenCV Fundamentals

- Circular mask

```
import numpy as np
import cv2
import imutils

image = cv2.imread("testudo.jpg")
image = imutils.resize(image, width=400)
cv2.imshow("Original", image)

mask = np.zeros(image.shape[:2], dtype = "uint8")
(cX, cY) = (image.shape[1]/2, image.shape[0]/2)
cv2.circle(mask, (cX, cY), 100, 255, -1)
cv2.imshow("Mask", mask)

masked = cv2.bitwise_and(image, image, mask=mask)
cv2.imshow("Mask Applied to Image", masked)

cv2.waitKey(0)
```




Original

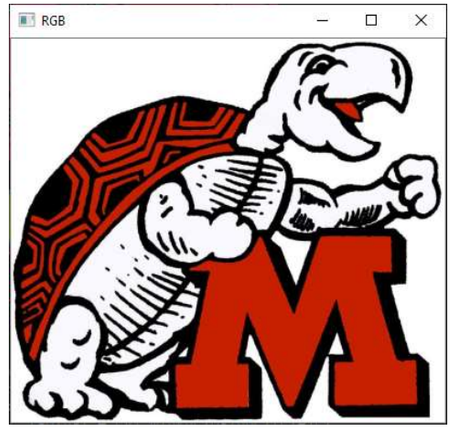

Mask

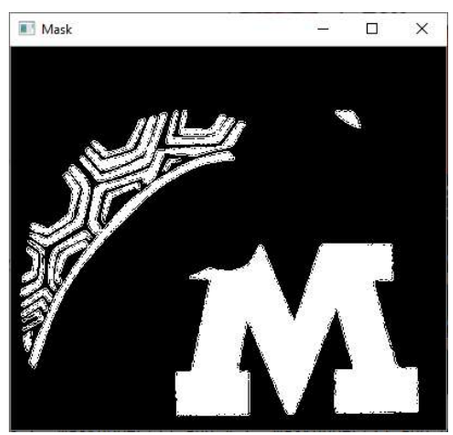

Mask Applied to Image

OpenCV Fundamentals

- Color mask

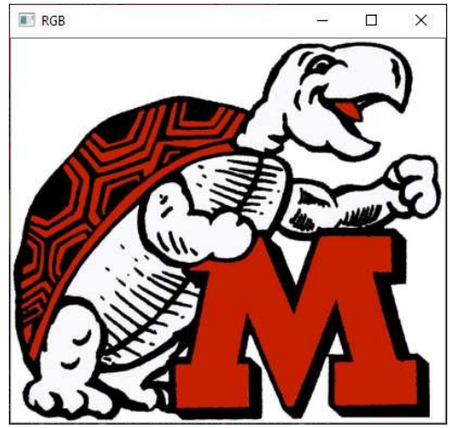
```
import numpy as np
import cv2
import imutils

image = cv2.imread("testudo.jpg")
image = imutils.resize(image, width=400)
cv2.imshow("BGR", image)



cv2.waitKey(0)
```

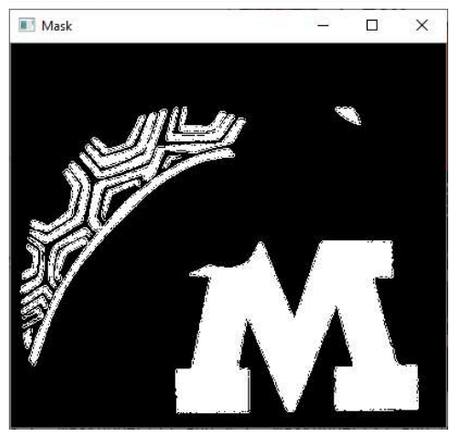




In-Class Exercise

- Write a Python script that masks for the color “red” inside the Maryland M
- Output should extract only those pixels of “red”

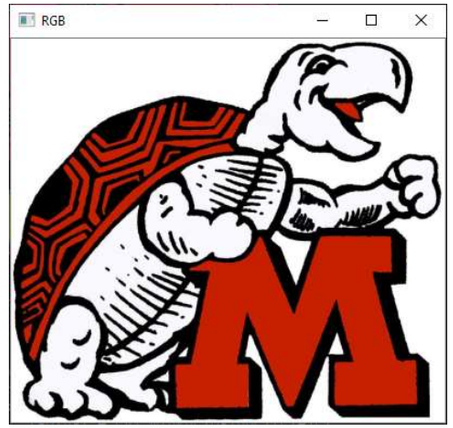


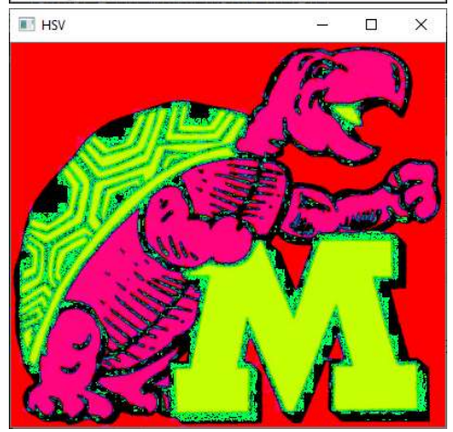


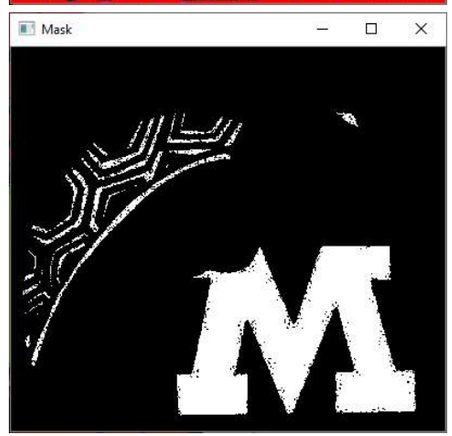
OpenCV Fundamentals

- Color mask

```
import numpy as np
import cv2
import imutils

image = cv2.imread("testudo.jpg")
image = imutils.resize(image, width=400)
cv2.imshow("BGR", image)

hsv = cv2.cvtColor(image, cv2.COLOR_BGR2HSV)
cv2.imshow("HSV", hsv)

cv2.waitKey(0)
```



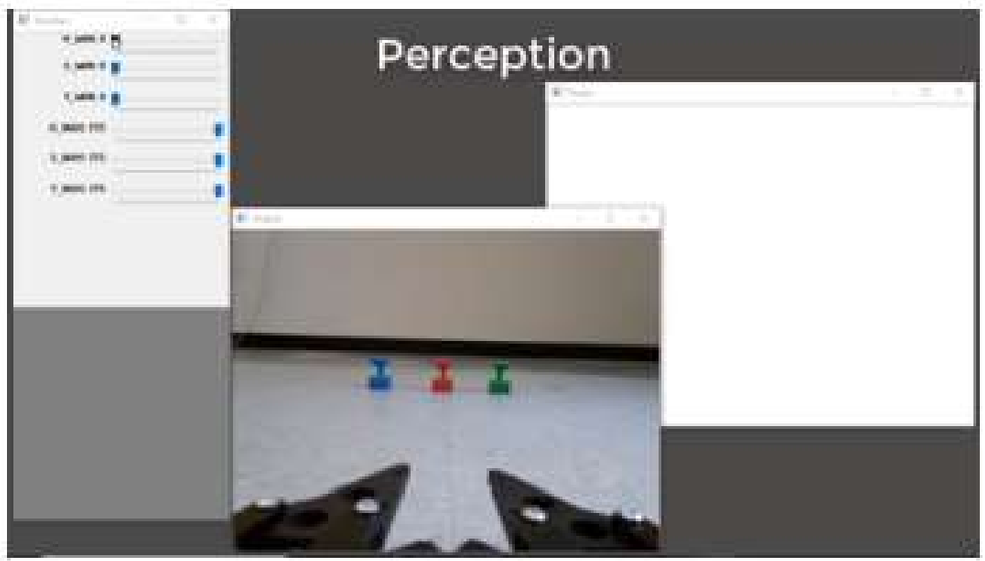




https://www.learnopencv.com/color-spaces-in-opencv-cpp-python/

In-Class Exercise

- Download/clone ***colorpicker.py*** onto your Raspberry Pi
- Explore masking in HSV color space



Codes available via GitHub - https://github.com/oneshell/enpm809T

References

- *Practical Python and OpenCV*, Rosebrock 2016
- *OpenCV Tutorials*
  - http://docs.opencv.org/2.4/doc/tutorials/tutorials.html