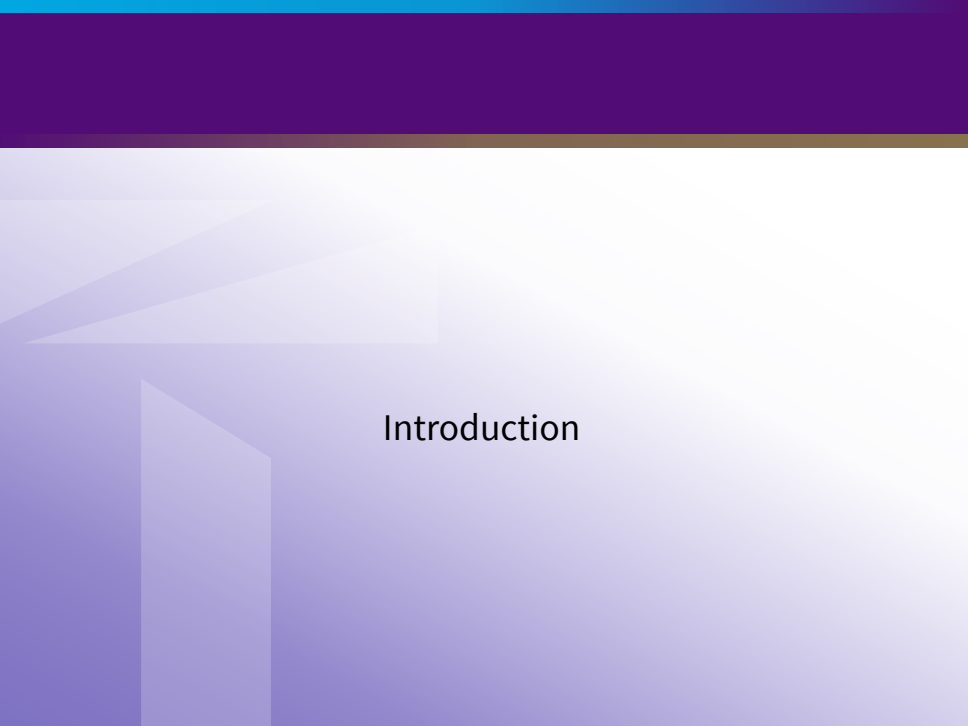


# PDAT615G: Machine Learning

## Module 5 – Convolutional Neural Networks



# Introduction

# Convolutional Neural Networks recognize images by first identifying pieces, then how the pieces are put together.

We'll look at...

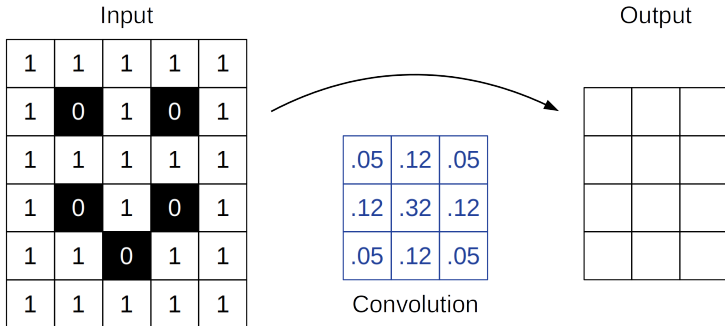
- convolution,
- convolutional neural networks,
- construction of training sets, and
- practical concerns in training and application.

# Convolution

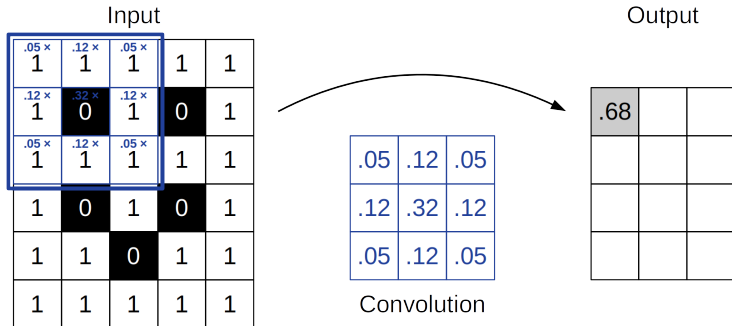
Convolution overlays a smaller matrix (the *filter*) on a larger matrix (the *image*).

- Corresponding elements are multiplied.
- The results are summed.
- The filter scans over the entire image.

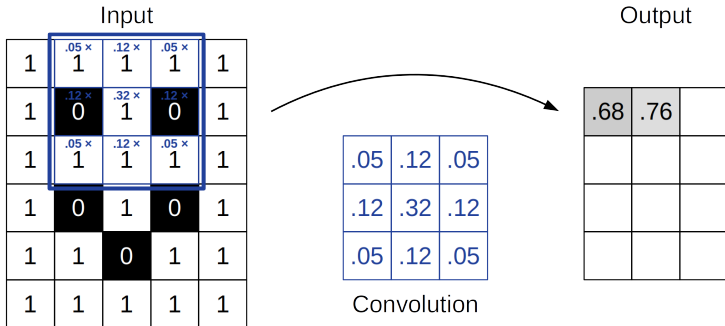
# Convolution: Smoothing Kernel



# Convolution: Smoothing Kernel

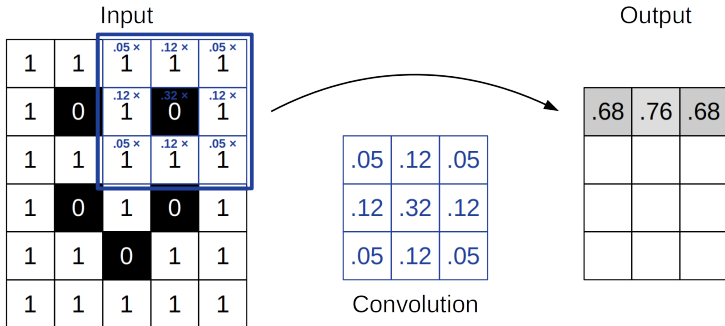


# Convolution: Smoothing Kernel

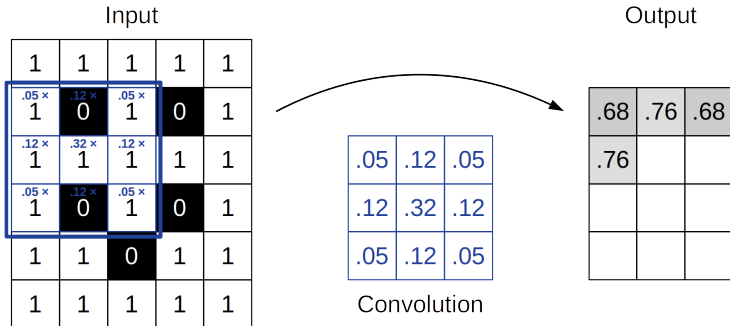




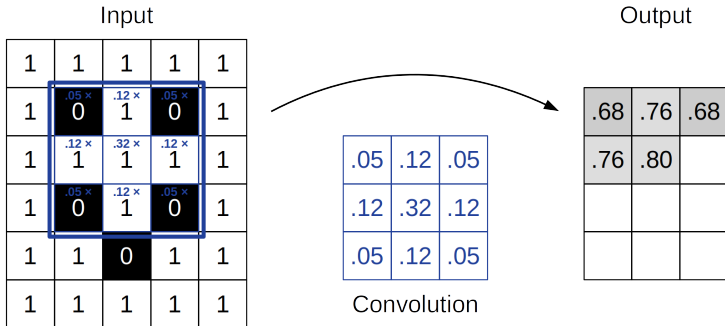
# Convolution: Smoothing Kernel



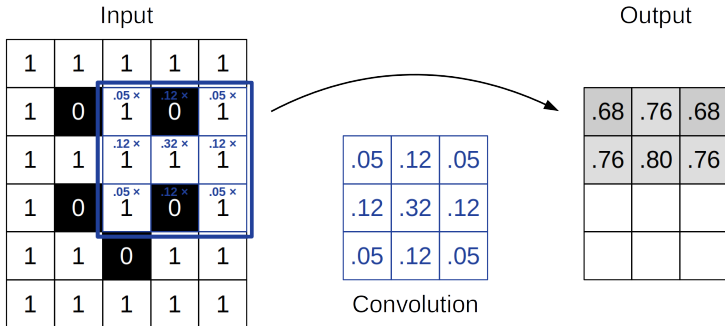
# Convolution: Smoothing Kernel



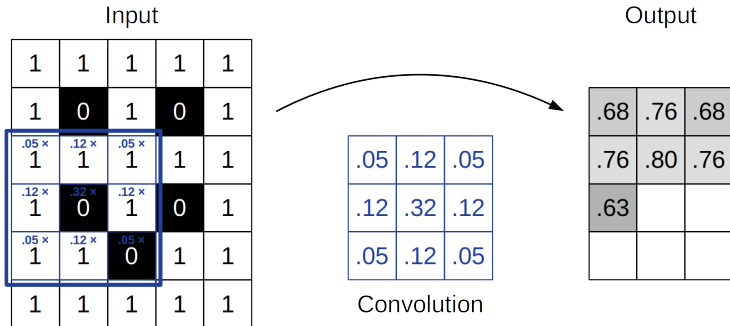
# Convolution: Smoothing Kernel



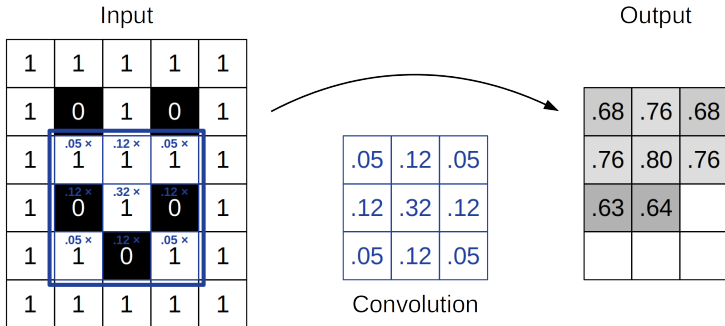
# Convolution: Smoothing Kernel



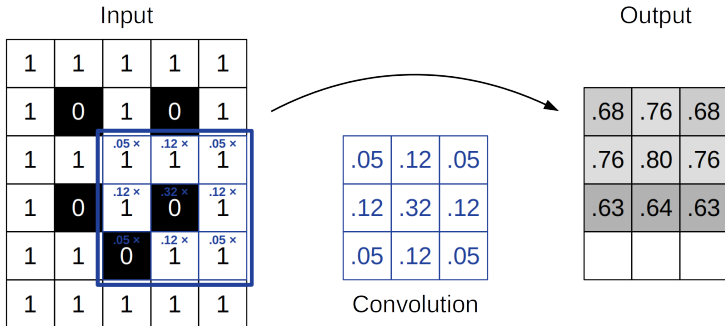
# Convolution: Smoothing Kernel



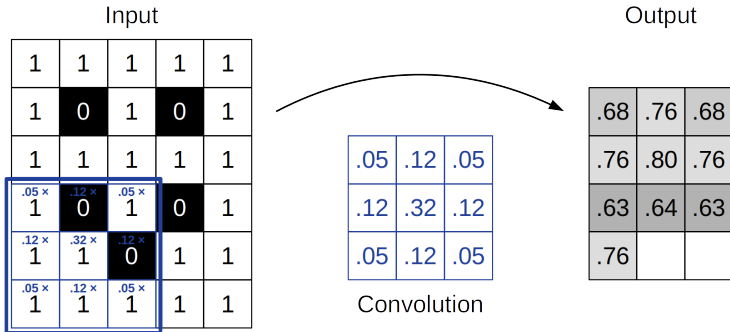
# Convolution: Smoothing Kernel



# Convolution: Smoothing Kernel

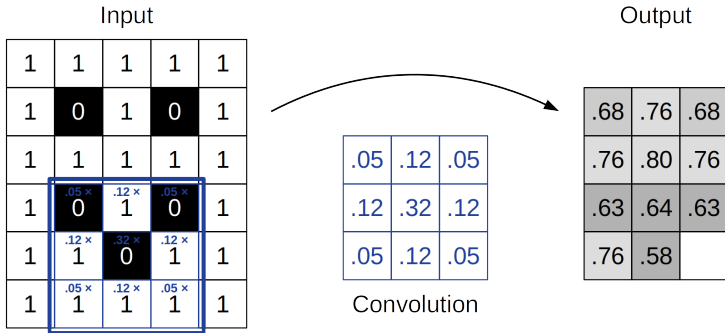


# Convolution: Smoothing Kernel

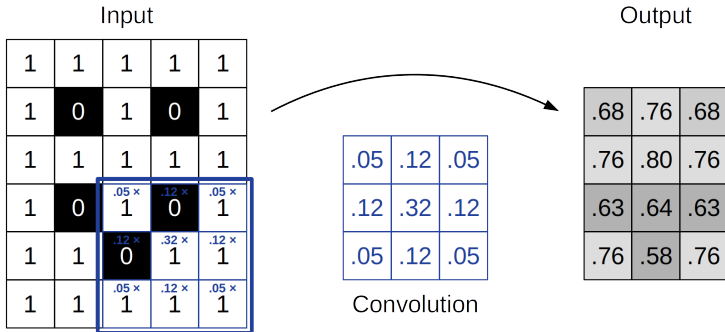




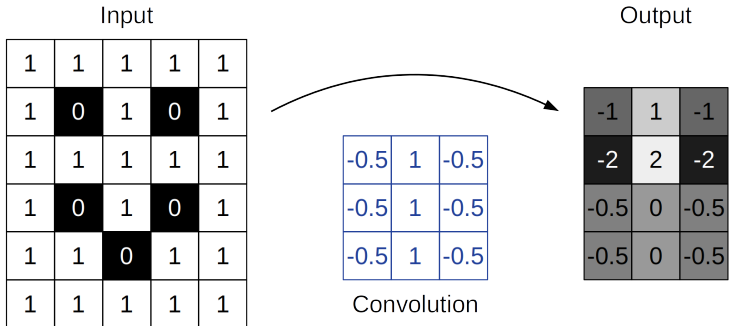
# Convolution: Smoothing Kernel



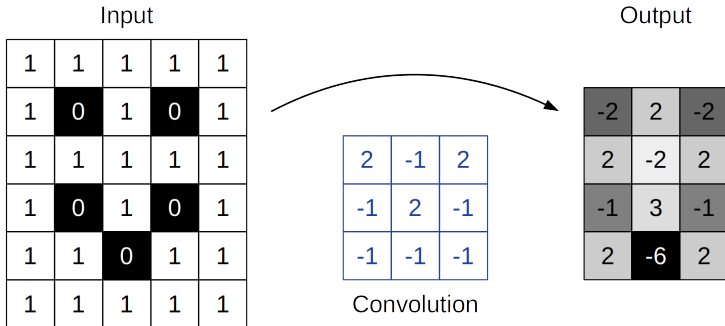
# Convolution: Smoothing Kernel



# Convolution: Vertical Elements



# Convolution: Smile Detection



Other *non-linear* convolution-like operations include gradient filters and standard deviation filters.

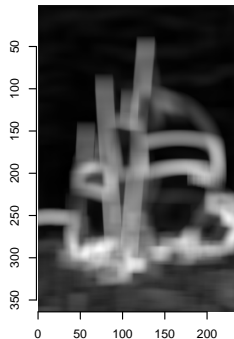
Original



Grayscale

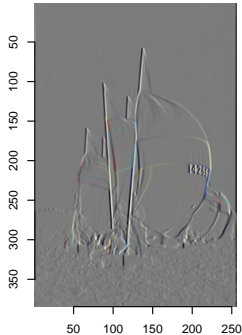


Std. Dev. Filter (w=20)

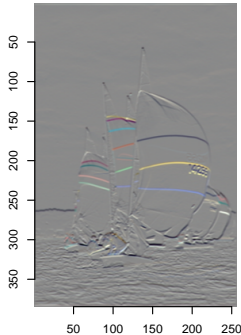


The gradient filter combines horizontal and vertical filters to detect edges.

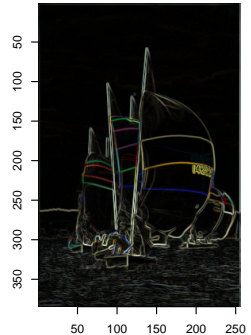
**Vertical Filter**



**Horizontal Filter**



**Gradient**

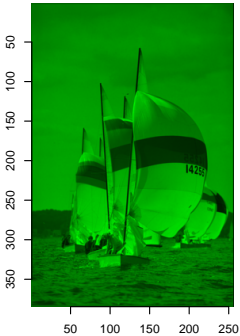


# Color images have multiple channels (usually Red/Green/Blue)

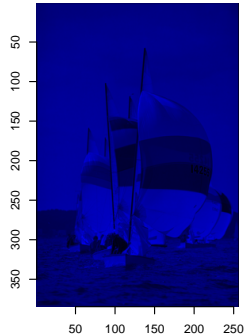
**Red**



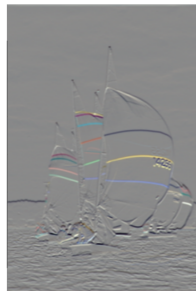
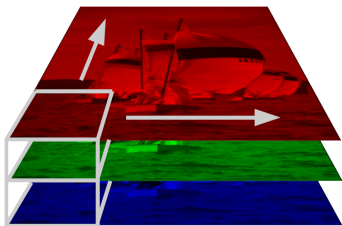
**Green**



**Blue**



Convolution filters can also have more than one layer.







# Convolutional Neural Networks