INTRODUCTION TO DEEP LEARNING FOR COMPUTER VISION

DAY 1 – BASICS

SEBASTIAN HOUBEN

Schedule

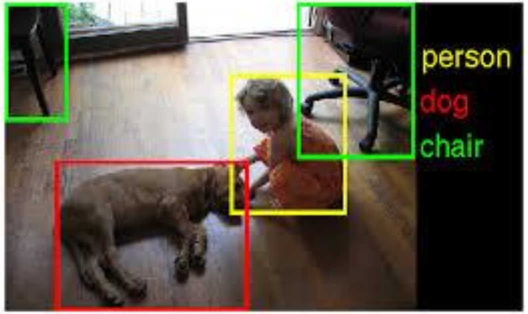
Today

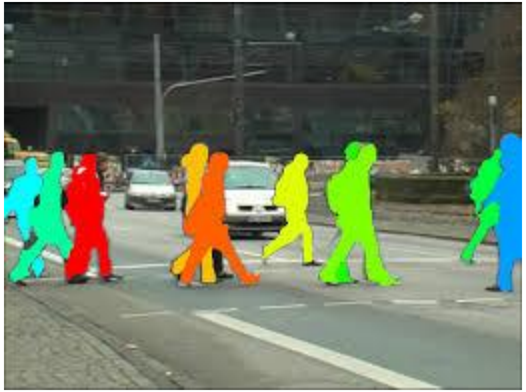
- Computer Vision and Deep Learning
- Image Classification
- Representation of images in Python
- Feature extraction
- Evaluating an image classifier
- Convolution
- German Traffic Sign Recognition Benchmark

Computer Vision

- Programs that process images as input
- Gain understanding of images or video
- Mimic performance of human visual system

- Typical tasks
  - Object detection
  - Object segmentation
  - Image registration
  - Pose estimation
  - Face recognition
  - Egomotion
  - Optical Flow





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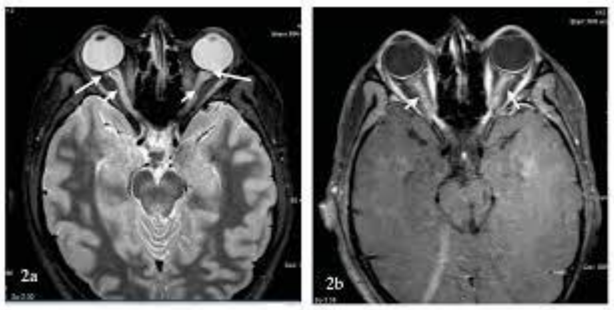

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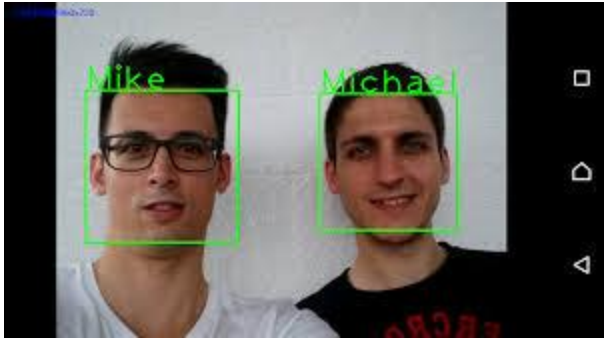

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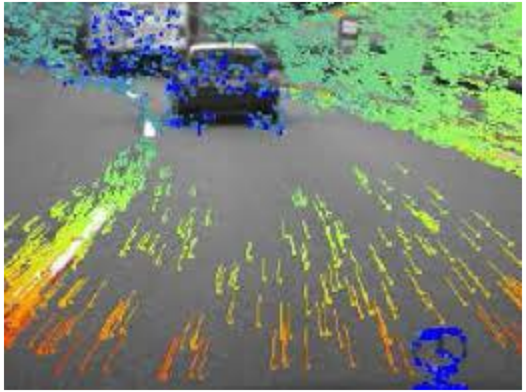

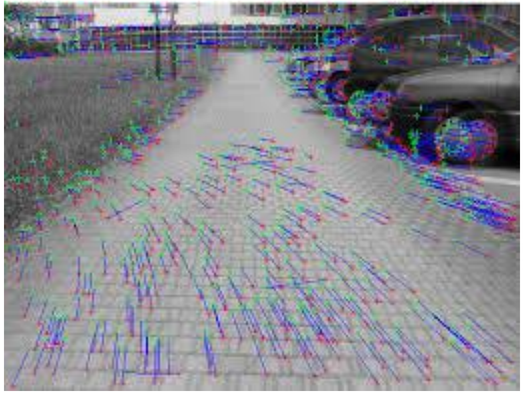

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Deep Learning

Popular computer vision technique

- 2012 ImageNet Challenge significantly improved by a new method called AlexNet
    - Building on technique from 1999 (LeCun)
    - That builds on technique from 1980 (Fukushima)
- Let the computer figure out itsself how to solve a problem
- Very successful in nearly all areas of computer vision
    - Defining state-of-the-art
- Prerequisites / reasons for hype
    - Lots of data for a problem
    - Fast parallel architectures (GPUs)
    - New powerful libraries

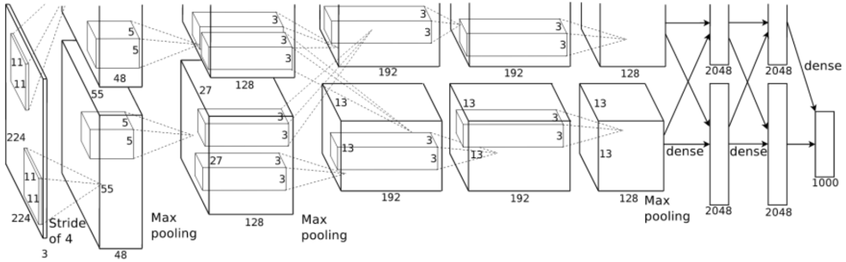

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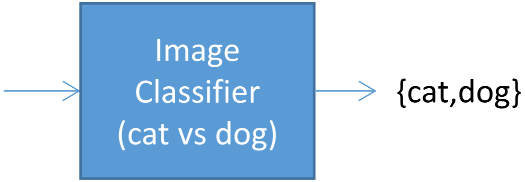
Image Classification



- Given an image tell me what it depicts
- One of a fixed number of exclusive choices
  - Image depicts one uniquely identifiable object
  - Image may only depict a certain set of objects
- Distinguishable object choices are called classes
- Correct class of an image is called label
- A classification problem with only two classes is called binary

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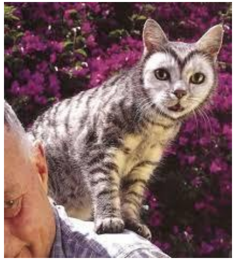
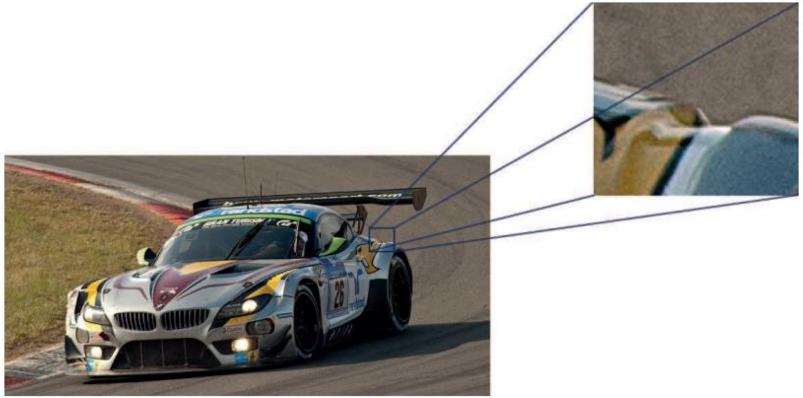


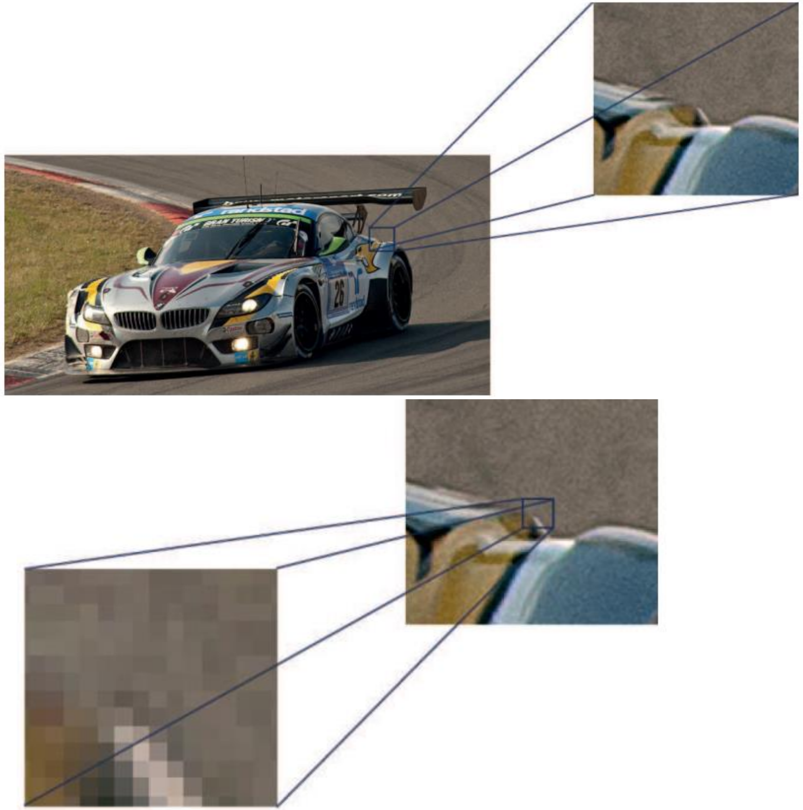

Image Classification Challenges

- Object may be depicted with different acquisition techniques
- Different view angles (geometry)
- Intraclass variation
- Illumination
- Deformation
- Occlusion
- Background clutter

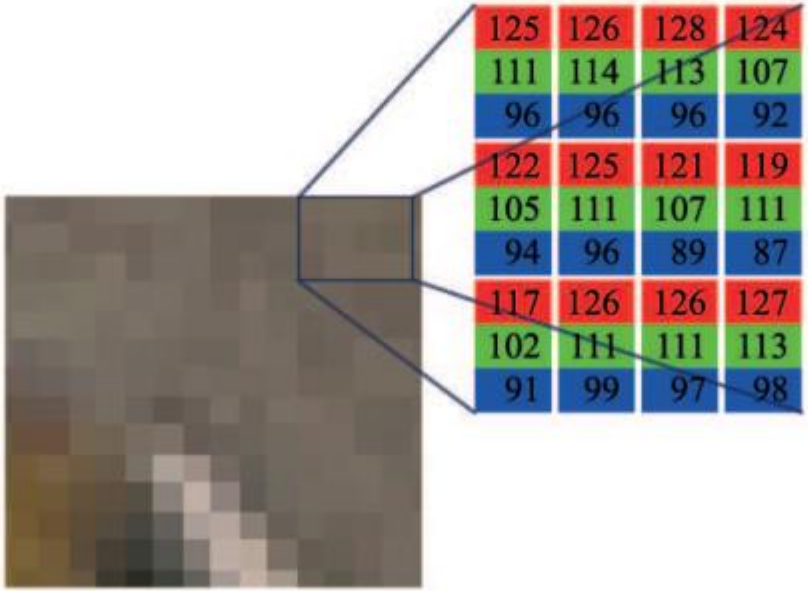
Representation of images in Python



Representation of images in Python



Representation of images in Python



- Each picture element (pixel) is composed of three values
  - R for the red component
  - G for the green component
  - B for the blue component

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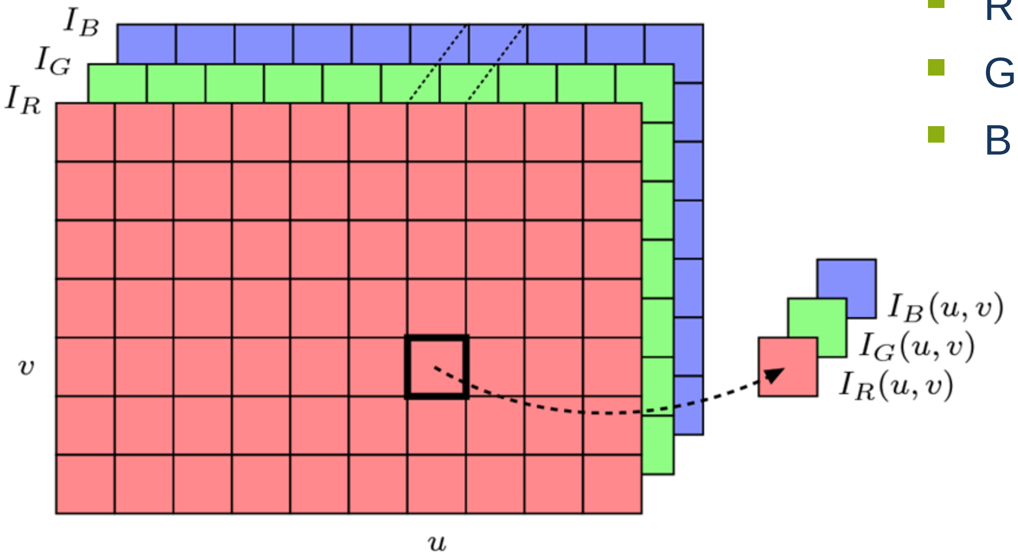

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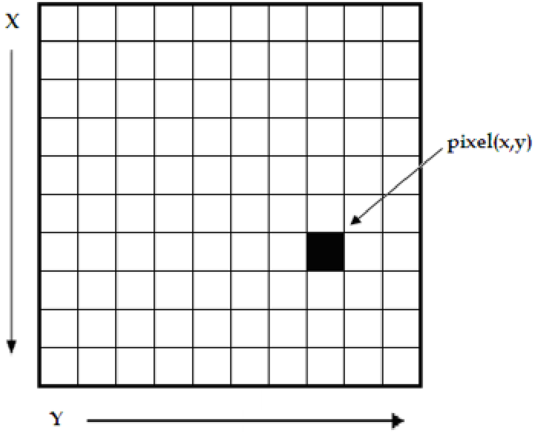

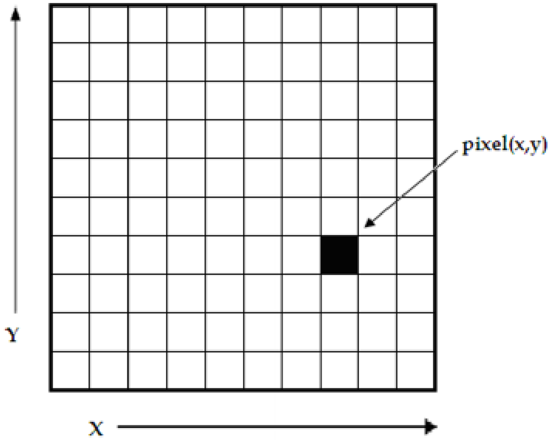

Representation of images in Python

- Each picture element (pixel) is composed of three values
  - R for the red component
  - G for the green component
  - B for the blue component
- Images are often represented in matrix structures
  - Unclear where pixel (0,0) or (1,1) is
  - Unclear which direction is given first
- Watch your data type (OpenCV is picky)
  - uint8 [0,255] (OpenCVs favorite)
  - short [-32768, 32767]
  - float32 (for visualizing)

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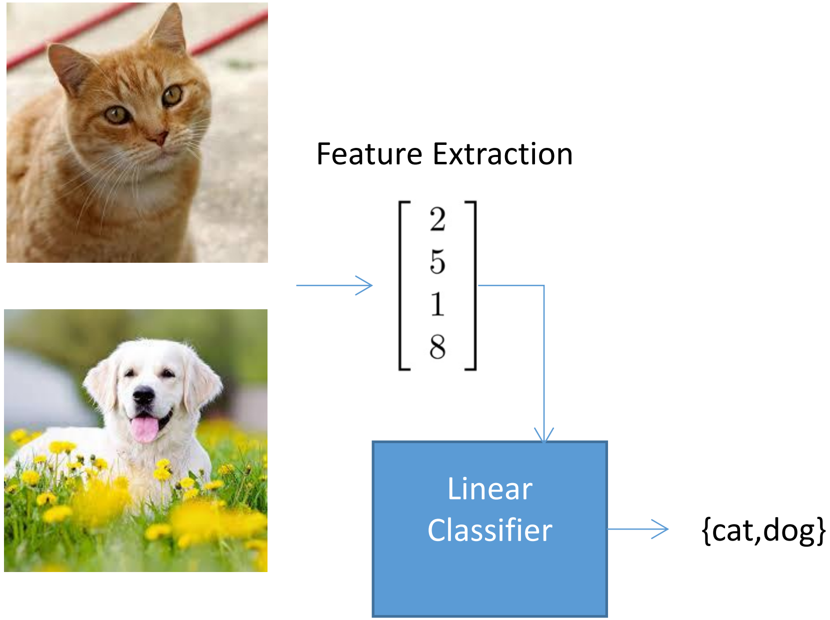
Image Classification



- Linear classifier (choice today) finds hyperplane to seperate sets of points
- Transform images to point representation
  - i.e. Feature Extraction
  - Low-dimensional
  - Compact representation

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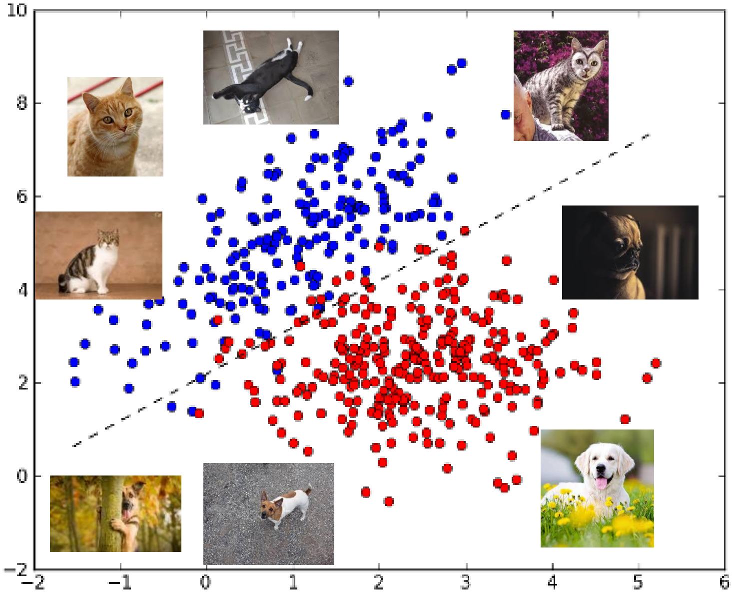
Image Classification



Linear classifier (choice today) finds hyperplane to seperate sets of points

Transform images to point representation

- i.e. Feature Extraction
- Low-dimensional
- Compact representation

Evaluation

- Error rate:
  Percentage of wrongly classified images
- Confusion matrix:
  Error for each pair of classes

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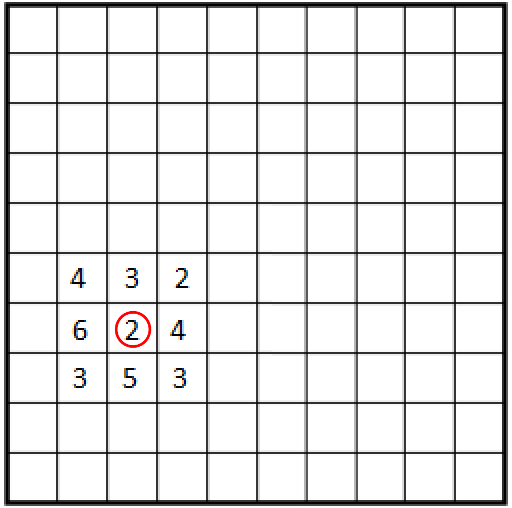
Convolution

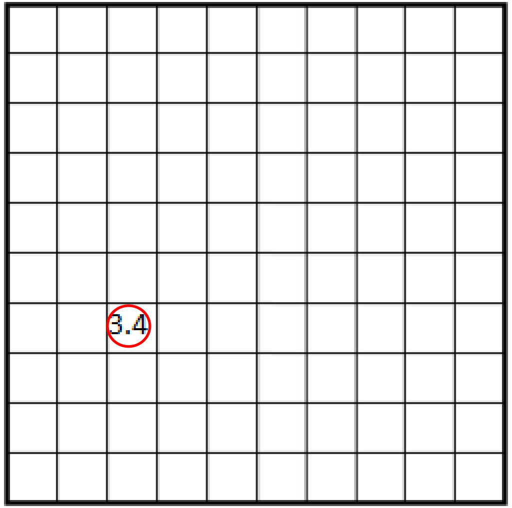
- Basic image processing operation: Transforms image to image
- Task: Computer similarity of each pixel with given template (kernel)

1/10	1/10	1/10
1/10	2/10	1/10
1/10	1/10	1/10

$*$



$$\frac{1}{10}\cdot 4+\frac{1}{10}\cdot 3+\frac{1}{10}\cdot 2+\frac{1}{10}\cdot 6+\frac{2}{10}\cdot 2+\frac{1}{10}\cdot 4+\frac{1}{10}\cdot 3+\frac{1}{10}\cdot 5+\frac{1}{10}\cdot 3$$



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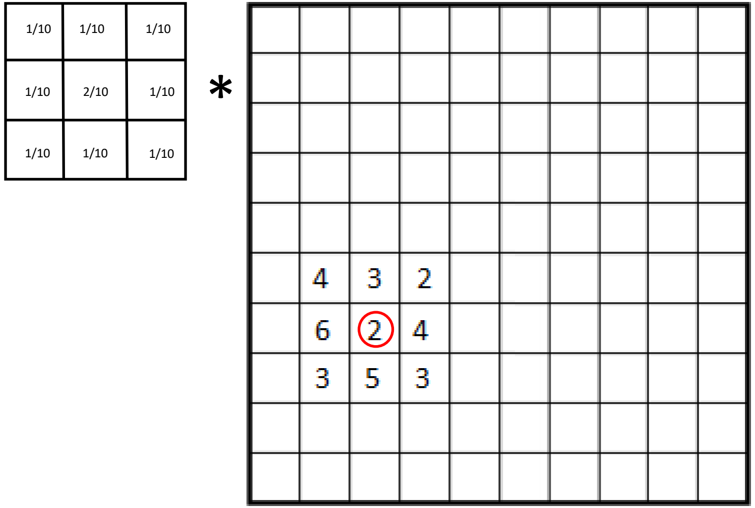
Convolution

- Basic image processing operation
- Task: Compute similarity of each pixel with given template (kernel)
- Pay attention to range of kernel and image!



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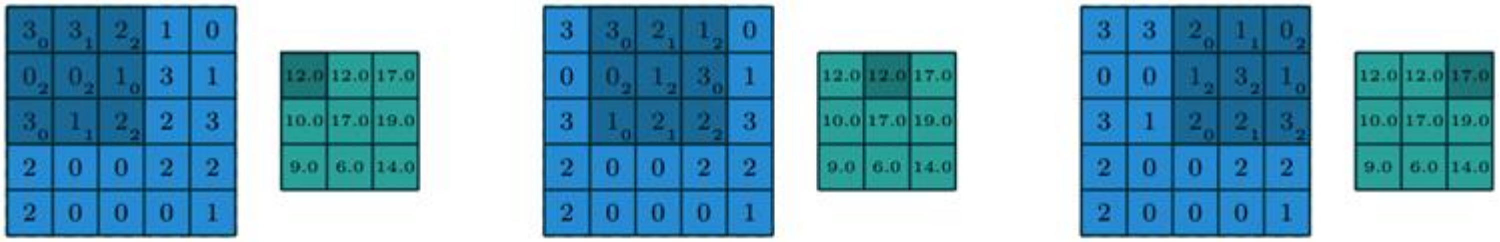

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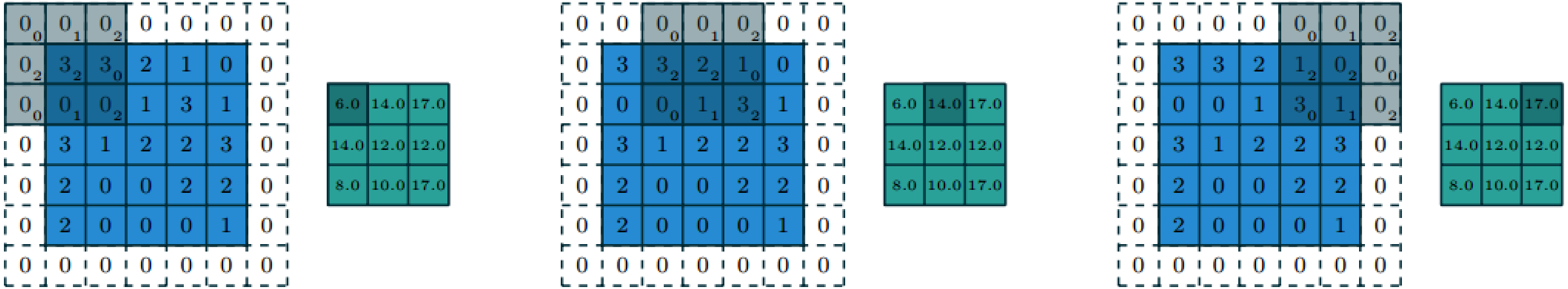
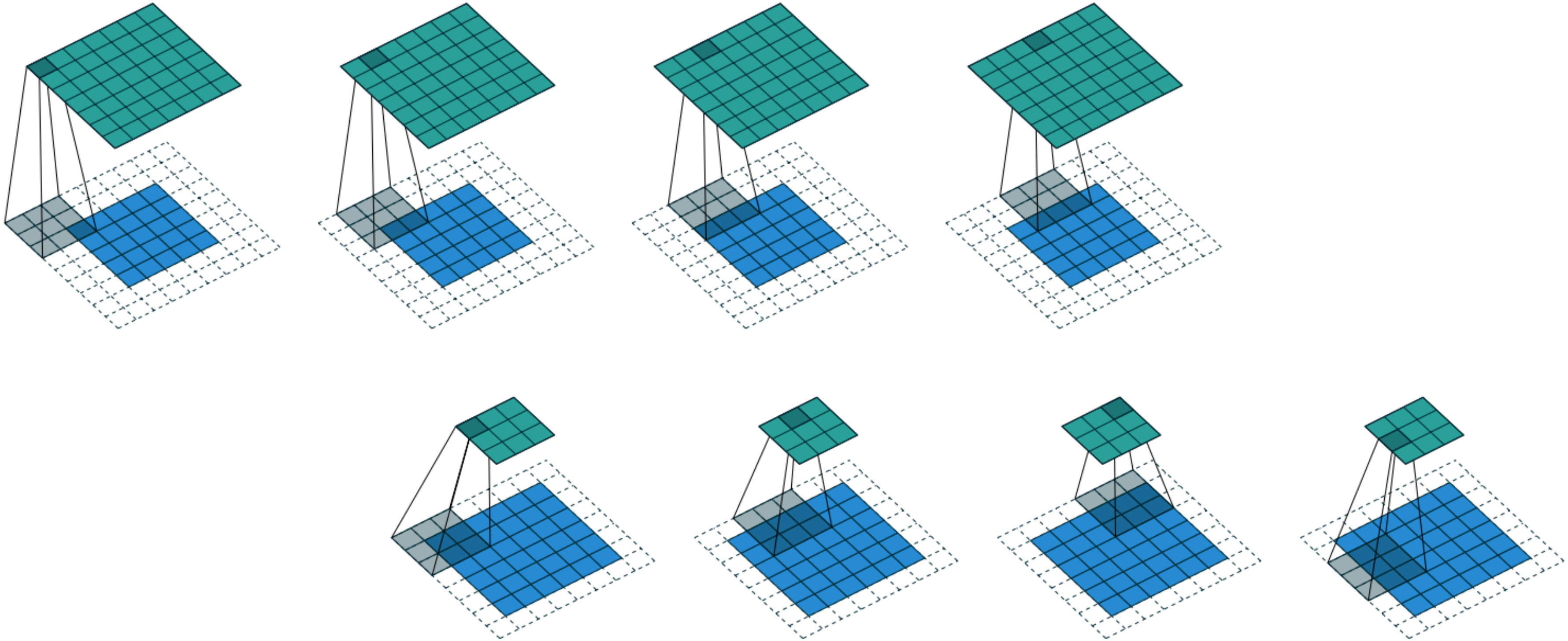
Convolution

- Basic image processing operation
- Task: Computer similarity of each pixel with given template (kernel)
- Pay attention to range of kernel and image!
- <u>Pad borders with zeros</u>
- <u>Stride</u>



Convolution

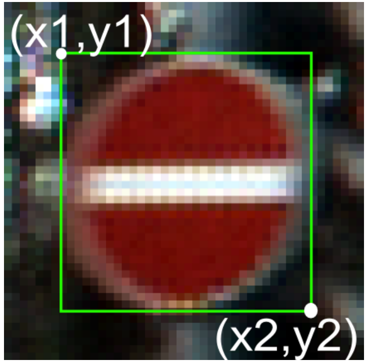


German Traffic Sign Recognition Benchmark

- 38,000 images from (German) traffic signs
    - Vienna Convention
- 43 classes
- Over 1,000 different traffic signs instances
- Variance
    - Illumination
    - Motion Blur
    - Clutter
    - Dirt / Graffiti / Stickers
    - Occlusion
    - Angle

German Traffic Sign Recognition Benchmark

- Filename structure
    - 0000CC/00XXX_00YYY.ppm
    - CC = class index
    - XXX = instance of class index
    - YYY = image of instance index
- e.g. 00003/00004_00024.ppm
    - Class 3: speed limit 60
    - Instance 4
    - Image 24
- Border of at least 5 pixel
- Border of around 10% of traffic sign size



German Traffic Sign Recognition Benchmark

- Best human: 1.16% error rate
- Best machine classifier (2011): 0.54% error rate

Hands-On Python: Numpy

- https://docs.scipy.org/doc/numpy-dev/user/quickstart.html
- “Matlab for Python“
- Matrix / Tensor manipulation (numeric)
- Fundamental library for nearly all of scientific computing in Python
- Tensorflow (Day 3 and 4) corresponds in large parts to Numpy

Numpy: ndarray

```
import numpy as np

A = np.array( [[ 0, 1, 2], [2, 3, 4]] ) # 2x3 matrix

A.shape                 # (2, 3)
A.size                  # 6 (numel in Matlab)
A.dtype.name            # ´int64´

B = [[0, 1, 2], [2, 3]]                       # ok
A_ = np.array([[0, 1, 2], [2, 3]] )           # error
```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Numpy: Initialization

```
A = np.array( [[ 0, 1, 2], [2, 3, 4]] ) # 2x3 matrix

B = np.zeros( (2, 3) )
# 2x3 matrix

C = np.ones( (2, 3, 4), dtype = np.int16 )
# 2x3x4 tensor, created with data type
C_ = np.zeros_like(C)

D = np.empty( (2, 3) )
# 2x3 matrix, uninitialized, np.random.rand, np.random.randn

E = np.arange( 0, 2, 0.3 )
# array([ 0. , 0.3, 0.6, 0.9, 1.2, 1.5, 1.8])

F = np.linspace( 0, 2, 9 )
# array([ 0. , 0.25, 0.5 , 0.75, 1. , 1.25, 1.5 , 1.75, 2. ])
```

Numpy: Operations

```
# operations usually work element-wise (even *)

a = np.array( [20,30,40,50] )
b = np.arange( 4 )

a – b                   # array([20, 29, 38, 47])

b**2                    # array([0, 1, 4, 9])

10*np.sin(a)            # [ 9.12945251, -9.88031624, 7.4511316 , -2.62374854]

a<35                    # array([ True, True, False, False], dtype=bool)

np.logical_and(a < 35, b > 0 )      # [False, True, False, False]
(a < 35) & (b > 0)                  # brackets are necessary

a.dot(b.transpose())                # matrix product (matmul)

a.astype( np.uint8 )    # np.float32, np.int32, np.int16
```


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Numpy: Dimension manipulation

```
import numpy as np

A = np.arange( 0, 20 )

A.reshape( [4, 5] )    # 4 rows, 5 columns
A.ravel ( [4, 5] )     # back to np.arange( 0, 20 )

A.min()                # smallest element
A.min(axis = 1)        # shape = (5, 1), iterate along the columns (rowwise minimum element)
# max, sum, mean, var, cumsum

B = np.arange(0, 24).reshape( [2, 3, 4] )

C = B.sum(axis = 1)             # shape = (2, 1, 4)
C = C.squeeze()                 # shape = (2, 4)

C = np.expand_dims( C, axis=1 ) # shape = (2, 1, 4)
```


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Numpy: Indexing

```
import numpy as np

A = np.arange( 0, 5 )          # [0, 1, 2, 3, 4]

A[0] = 5                       # [5, 1, 2, 3, 4]

A[2:3] = 4                     # [5, 1, 4, 3, 4]
A[-2] = 4                      # [5, 1, 4, 4, 4], A.shape[0] – 2 = 5 – 2 = 3

A[1:4:2] = 0                   # [5, 0, 4, 0, 4], start with 1, stepwidth 2, stay below 4
A[1:-1:2] = 0                  # [5, 0, 4, 0, 4], start with 1, stepwidth 2, stay below A.shape[0] – 1 = 5 - 1
A[1::2] = 0                    # [5, 0, 4, 0, 4], start with 1, stepwidth 2, stay below A.shape[0] = 5
```

Numpy: Indexing

```
import numpy as np

A = np.arange( 0, 6 ).reshape( [2, 3] )                 # [[0, 1, 2], [3, 4, 5]]

A[0, 1] = -1                                            # [[0, -1, 2], [3, 4, 5]]

A[1, :] = -1                                            # [[0, -1, 2], [-1, -1, -1]]

A[1, 1:] = 6                                            # [[0, -1, 2], [-1, 6, 6]]

A[ np.array([[True, False, True][True, True,False]], dtype=bool) ] = 1    # [[1, -1, 1], [1, 1, 6]]

A[ A > 1 ] = -1                                         # [[1, -1, 1], [1, 1, -1]]
```

Numpy: Concatenating

```
import numpy as np

a = np.array([[1, 2], [3, 4]])                       # [[1, 2], [3, 4]]
b = np.array([[5, 6]])                               # [5, 6]

np.concatenate( ( a, b ), axis = 0 )                 # [[1, 2], [3, 4], [5, 6]], same as np.hstack( (a,b) )
np.concatenate( ( a, b.transpose() ), axis = 1 )     # [[1, 2, 5], [3, 4, 6]], same as np.vstack( (a,b.transpose() )
```

Hands-On Python: OpenCV

- see the handout for some important functions
- OpenCV can work with numpy-arrays
- But: Be careful about data types
    - Use uint8 if working in OpenCV
    - Rather receive wrong results than errors

QUESTIONS?

EXERCISES.