CONVOLUTIONAL NEURAL NETWORKS FOR IMAGE PROCESSING

Convolutions

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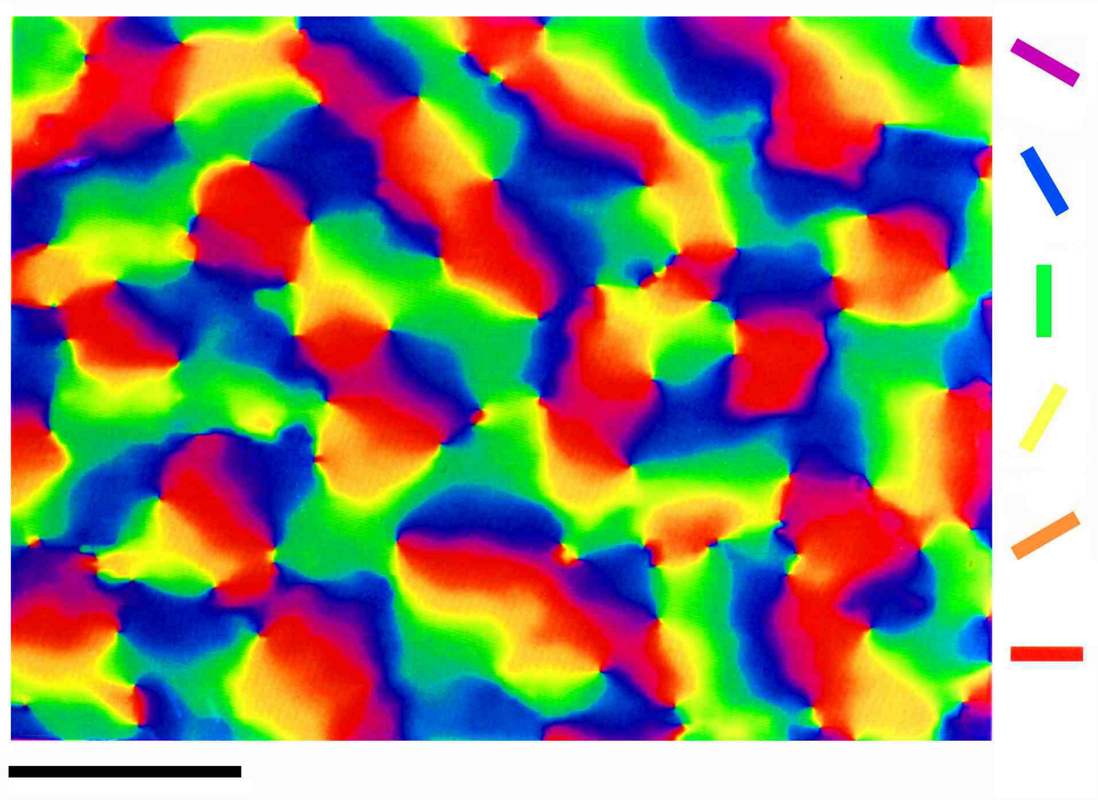
Using correlations in images

- Natural images contain spatial correlations
- For example, pixels along a contour or edge
- How can we use these correlations?

Biological inspiration



What is a convolution?

```
array = np.array([0, 0, 0, 0, 0, 1, 1, 1, 1, 1])

kernel = np.array([-1, 1])

conv = np.array([0, 0, 0, 0, 0, 0, 0, 0, 0])

conv[0] = (kernel * array[0:2]).sum()

conv[1] = (kernel * array[1:3]).sum()
conv[2] = (kernel * array[2:4]).sum()
```

...

```
for ii in range(8):
    conv[ii] = (kernel * array[ii:ii+2]).sum()

conv

array([0, 0, 0, 0, 1, 0, 0, 0, 0])
```

Convolution in one dimension

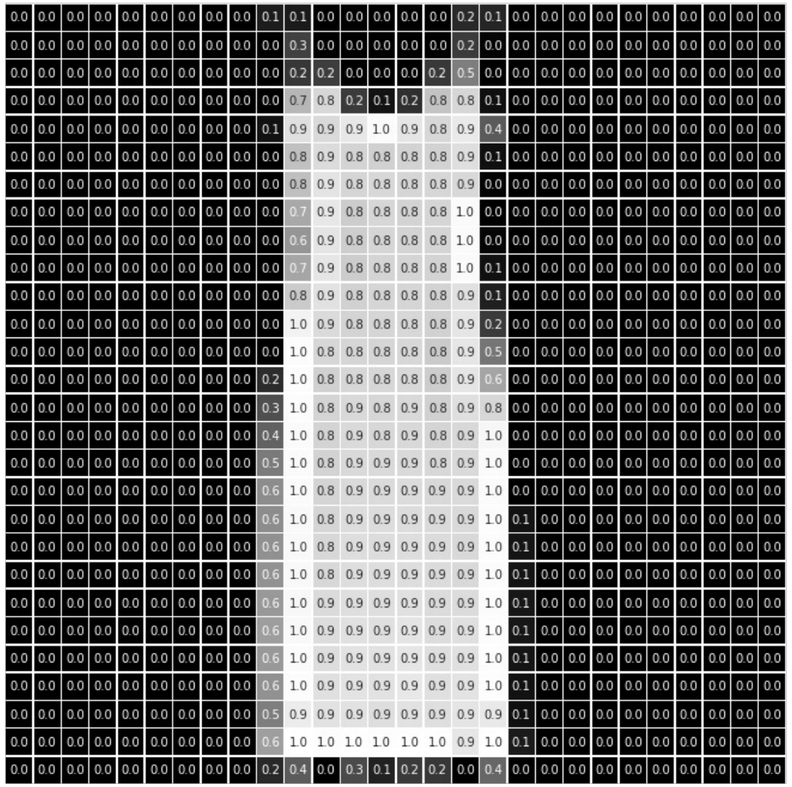
```
array = np.array([0, 0, 1, 1, 0, 0, 1, 1, 0, 0])
kernel = np.array([-1, 1])

conv = np.array([0, 0, 0, 0, 0, 0, 0, 0, 0])
for ii in range(8):
    conv[ii] = (kernel * array[ii:ii+2]).sum()

conv

array([ 0,  1,  0, -1,  0,  1,  0, -1,  0])
```

Image convolution



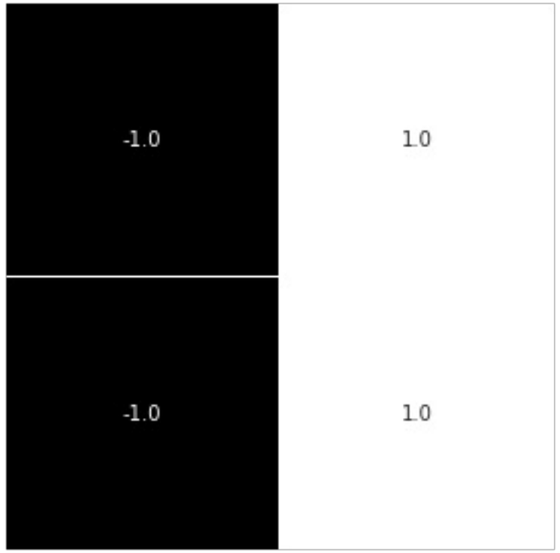
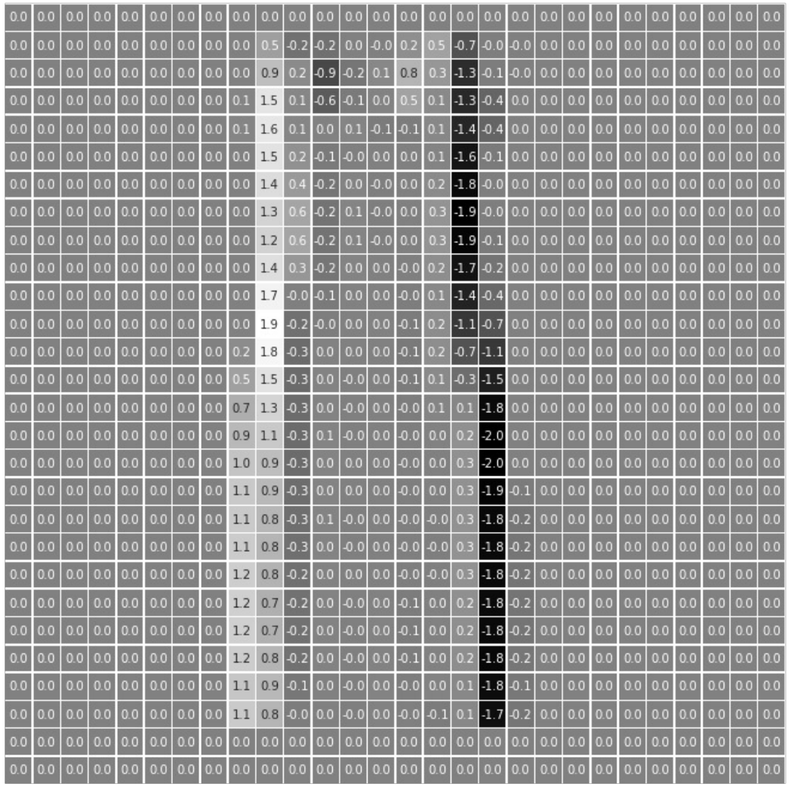


Image convolution



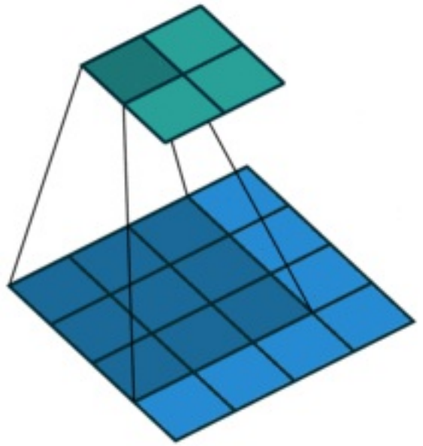
Two-dimensional convolution

```
kernel = np.array([[-1, 1],
                   [-1, 1]])

conv = np.zeros((27, 27)

for ii in range(27):
    for jj in range(27):
        window = image[ii:ii+2, jj:jj+2]
        conv[ii, jj] = np.sum(window * kernel)
```

Convolution



CONVOLUTIONAL NEURAL NETWORKS FOR IMAGE PROCESSING

Let's practice!

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Implementing convolutions in Keras

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Keras 'Convolution' layer

```
from keras.layers import Conv2D
Conv2D(10, kernel_size=3, activation='relu')
```

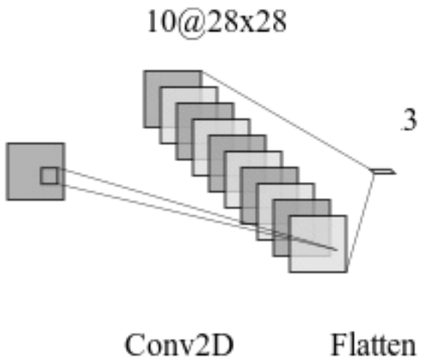
Integrating convolution layers into a network

```
from keras.models import Sequential
from keras.layers import Dense, Conv2D, Flatten

model = Sequential()
model.add(Conv2D(10, kernel_size=3, activation='relu',
                 input_shape=(img_rows, img_cols, 1)))

model.add(Flatten())
model.add(Dense(3, activation='softmax'))
```

Our CNN



Fitting a CNN

```
model.compile(optimizer='adam',
              loss='categorical_crossentropy',
              metrics=['accuracy'])

train_data.shape

(50, 28, 28, 1)

model.fit(train_data, train_labels, validation_split=0.2, epochs=3)

model.evaluate(test_data, test_labels, epochs=3)
```

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Tweaking your convolutions

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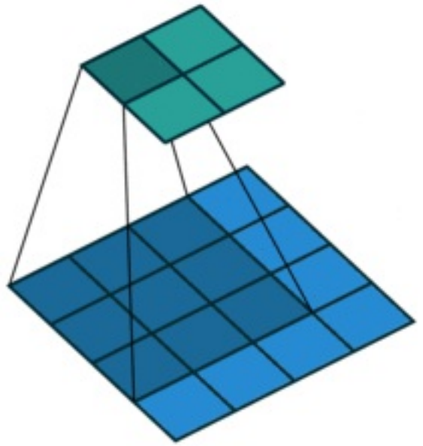
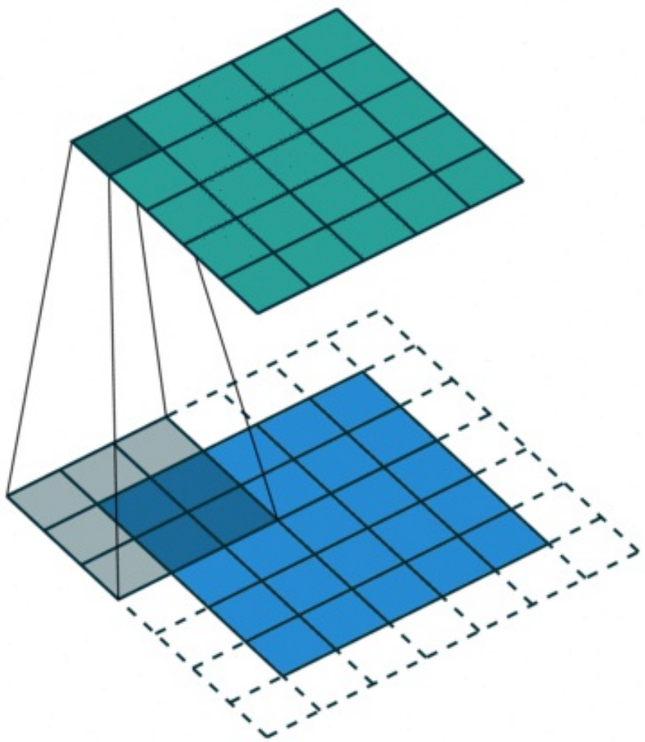
Convolution



Convolution with zero padding



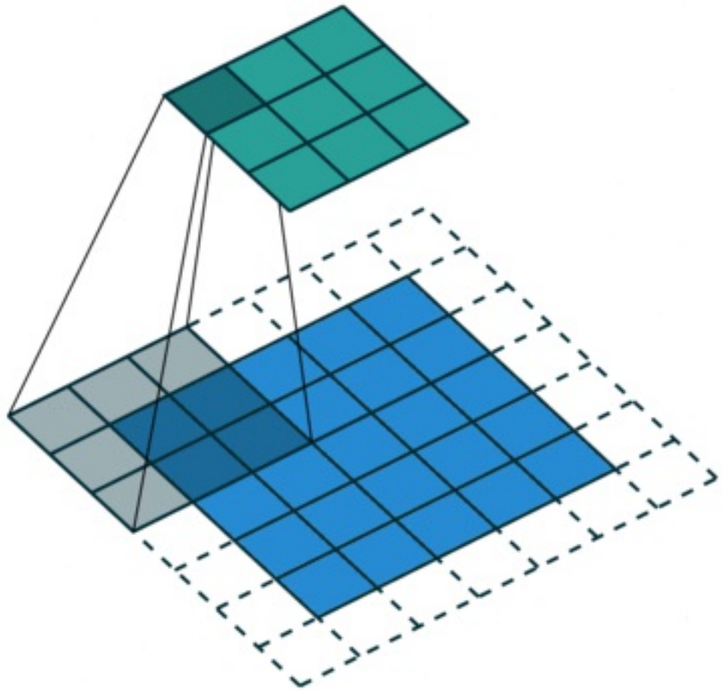
Zero padding in Keras

```
model.add(Conv2D(10, kernel_size=3, activation='relu',
                 input_shape=(img_rows, img_cols, 1)),
                 padding='valid')
```

Zero padding in Keras

```
model.add(Conv2D(10, kernel_size=3, activation='relu',
                 input_shape=(img_rows, img_cols, 1)),
                 padding='same')
```

Strides

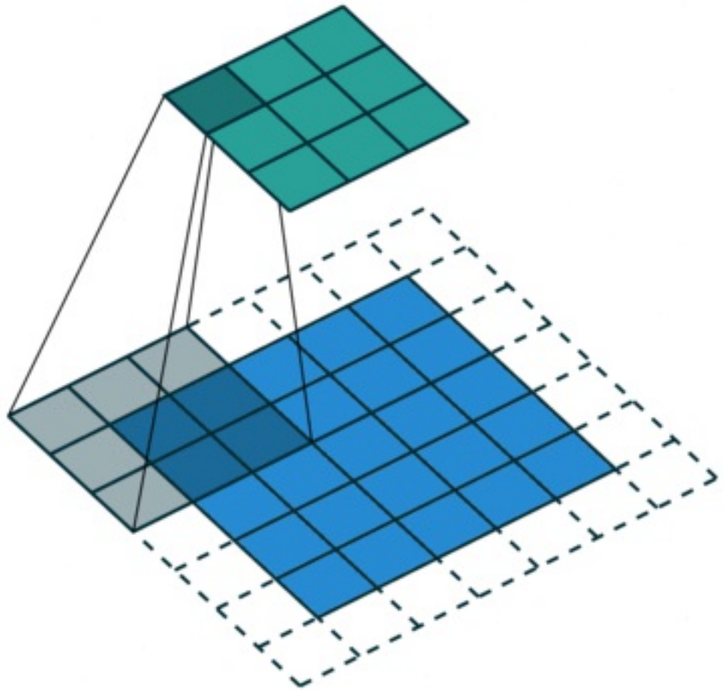


Strides in Keras

```
model.add(Conv2D(10, kernel_size=3, activation='relu',
                 input_shape=(img_rows, img_cols, 1)),
                 strides=1)
```

Strides in Keras

```
model.add(Conv2D(10, kernel_size=3, activation='relu',
                 input_shape=(img_rows, img_cols, 1)),
                 strides=2)
```



Calculating the size of the output

$$O = ((I - K + 2P)/S) + 1$$

where

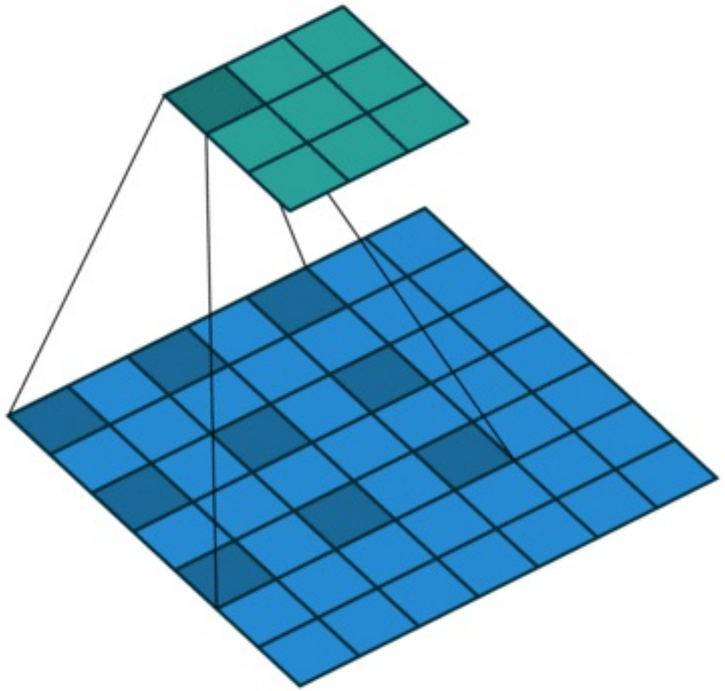
- I = size of the input
- K = size of the kernel
- P = size of the zero padding
- S = strides

Calculating the size of the output

$$28 = ((28 - 3 + 2)/1) + 1$$

$$10 = ((28 - 3 + 2)/3) + 1$$

Dilated convolutions



Dilation in Keras

```
model.add(Conv2D(10, kernel_size=3, activation='relu',
                 input_shape=(img_rows, img_cols, 1)),
                 dilation_rate=2)
```

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