Machine Learning for Economists

Class 15: Convolutional Neural Network

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Why CNN of Images

CNN Model Framework

Key elements

Appendix

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How Human Visual Neurons Works

- Previously we reduced [28,28] dimension picture to 28×28 features, then used a ANN for item prediction
- Certainly, it is not efficient
- We human perceive the item on the picture by shapes and patterns

Convolutional Neural Network

- Convolutional Neural Network (CNN) follow the same way as human visual neurons and can successfully perceive pictures
- Then what is the Convolutional Neural Network ?

Lower level patterns to high level patterns

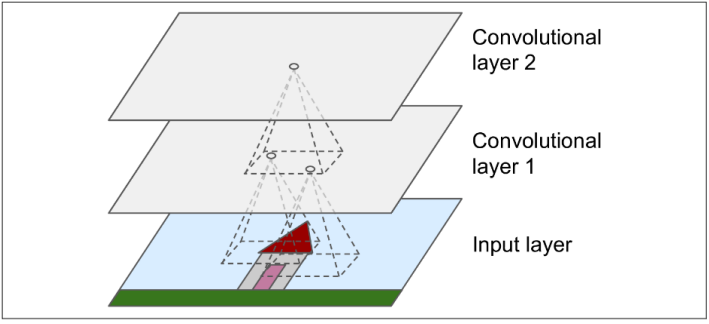

Figure 14-2. CNN layers with rectangular local receptive fields

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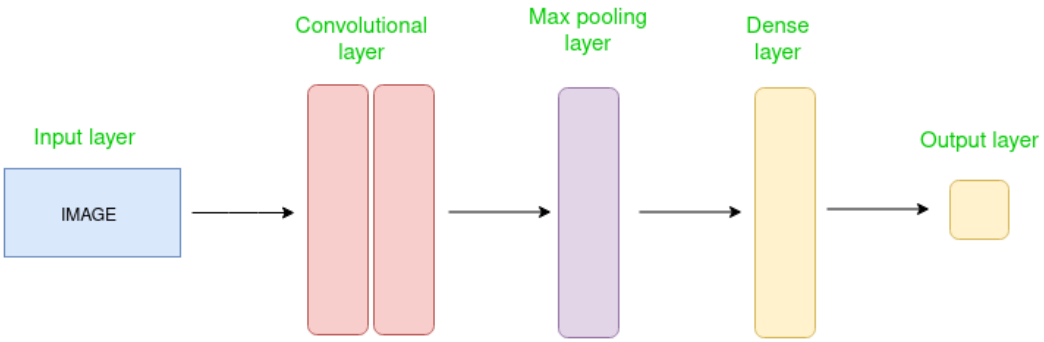
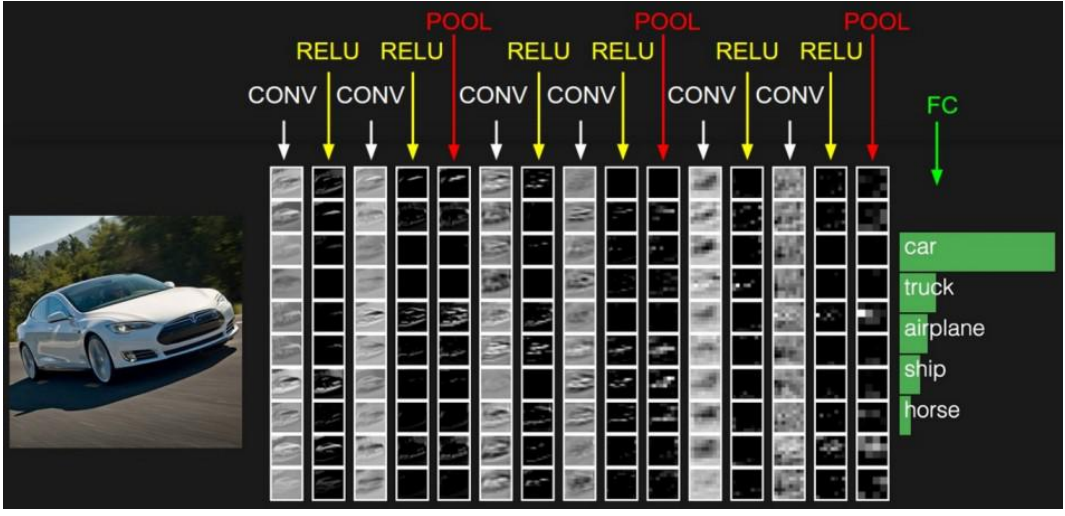
Whole Picture of CNN model



Whole Picture of CNN model



Codes in Keras

```
model = keras.models.Sequential([
    keras.layers.Conv2D(64, 7, activation="relu", padding="same",
                        input_shape=[28, 28, 1]),
    keras.layers.MaxPooling2D(2),
    keras.layers.Conv2D(128, 3, activation="relu", padding="same"),
    keras.layers.Conv2D(128, 3, activation="relu", padding="same"),
    keras.layers.MaxPooling2D(2),
    keras.layers.Conv2D(256, 3, activation="relu", padding="same"),
    keras.layers.Conv2D(256, 3, activation="relu", padding="same"),
    keras.layers.MaxPooling2D(2),
    keras.layers.Flatten(),
    keras.layers.Dense(128, activation="relu"),
    keras.layers.Dropout(0.5),
    keras.layers.Dense(64, activation="relu"),
    keras.layers.Dropout(0.5),
    keras.layers.Dense(10, activation="softmax")
])
```

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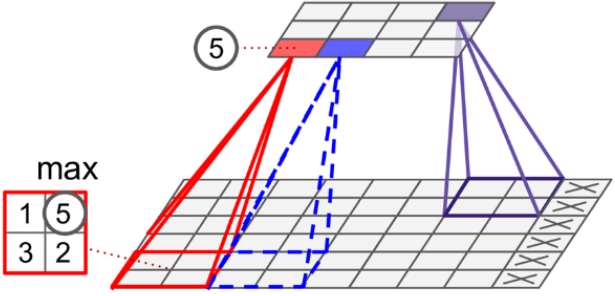
Key elements in CNN

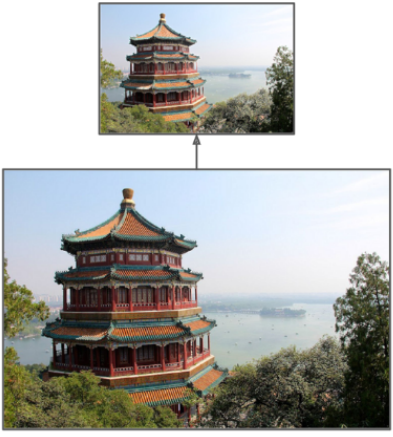
- Dense Layers
- RELU activation function
- Softmax in output for the classification
- Cross Entropy Loss

Key elements in CNN

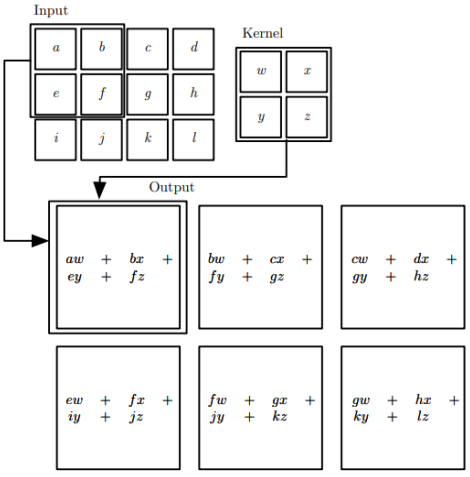
- Pooling Layers (new)
- Convolution Layers (new)
- Data Dimension 3D or 4D (batch_size, channels, height, width)

Pooling layers





Convolution Layers



Convolution Layers

- one filter (kernel) $\rightarrow$ one feature map
- However, each convolution layer has K filter, so it has K feature maps
- the weights on the filters are the parameters model needs to train in gradient descent
- Math details please refer to Equation 14-1 on Textbook

Put Conv,Pool,Output together

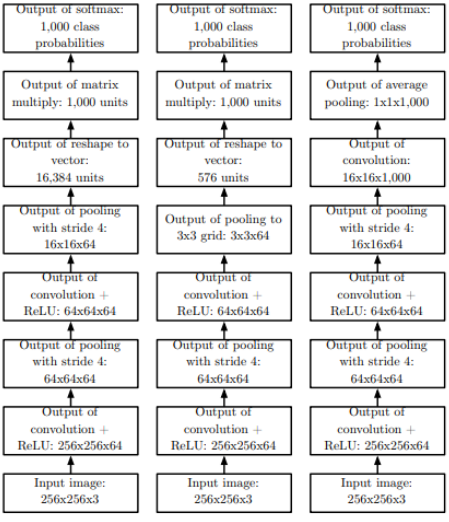


Figure 9.11

(Goodfellow 2016)

ANN dense connections, CNN sparse connection

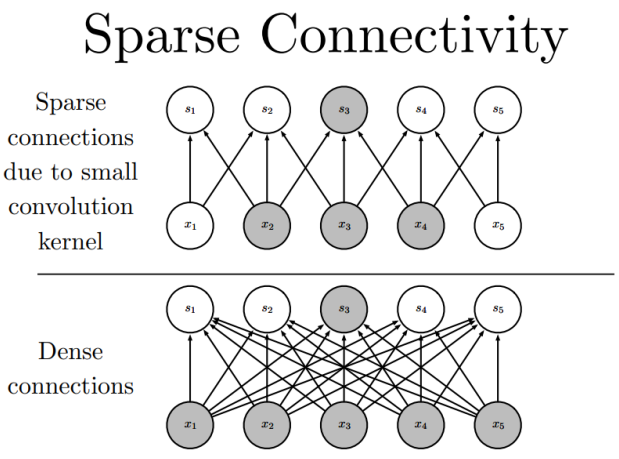
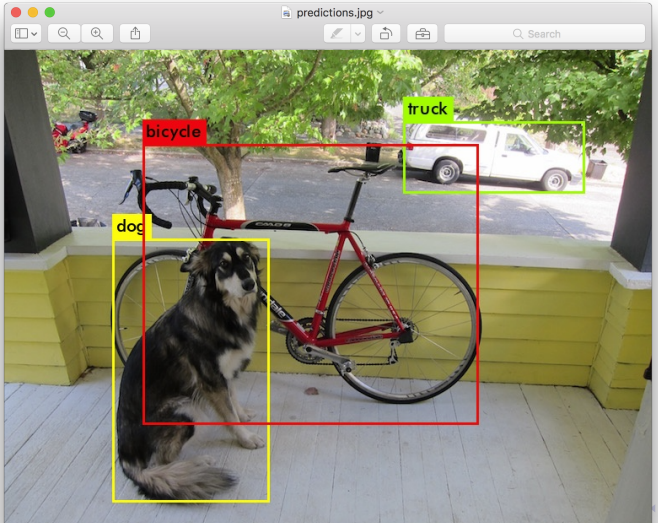


Figure 9.3

(Goodfellow 2016)

Popular package Yolo



Reference

1. Hands-on Machine Learning with Scikit-Learn, Keras and TensorFlow (3rd edition)
2. Deep Learning (2016), Ian Goodfellow and Yoshua Bengio and Aaron Courville
3. Wikipedia
4. geeksforgeeks
5. Kaggle
6. Wikipedia
7. ChatGPT
8. DeepSeek

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Number of parameters in CNN

The total number of trainable parameters in a convolutional layer is given by:

$$\text{Total Parameters} = (K_H \times K_W \times C_{\text{in}} + 1) \times C_{\text{out}}$$

Where:

- K_H = Kernel height
- K_W = Kernel width
- C_{in} = Number of input channels
- C_{out} = Number of output channels (i.e., number of filters)
- The $+1$ accounts for the bias term per filter (optional)

Number of parameters in CNN (Why?)

- Why?
- Each input channel has its own kernel weights for a each output channel in a CNN layer.
- Optional HW: Check Equation 14-1 and understand why