Rechnerarchitektur (RA)

Sommersemester 2019

Overview of Deep Neural Networks

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Neurons, Synapses, Network

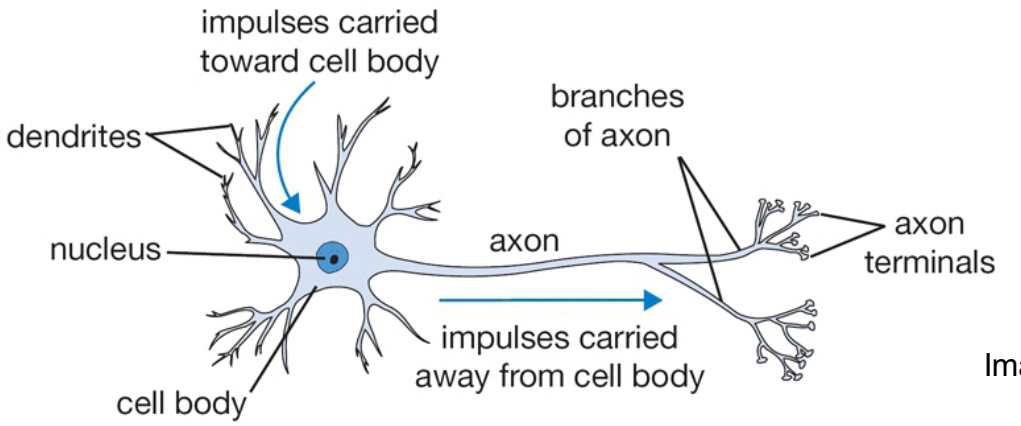


Image Source: Stanford

Functional units and links

- The basic computational unit is a **neuron**
- Neurons are connected with nearly 10^{14} – 10^{15} **synapses**

Operations

- Neurons receive input signal from **dendrites** and produce output signal along **axon** which interact with the dendrites of other neurons

Neural Networks

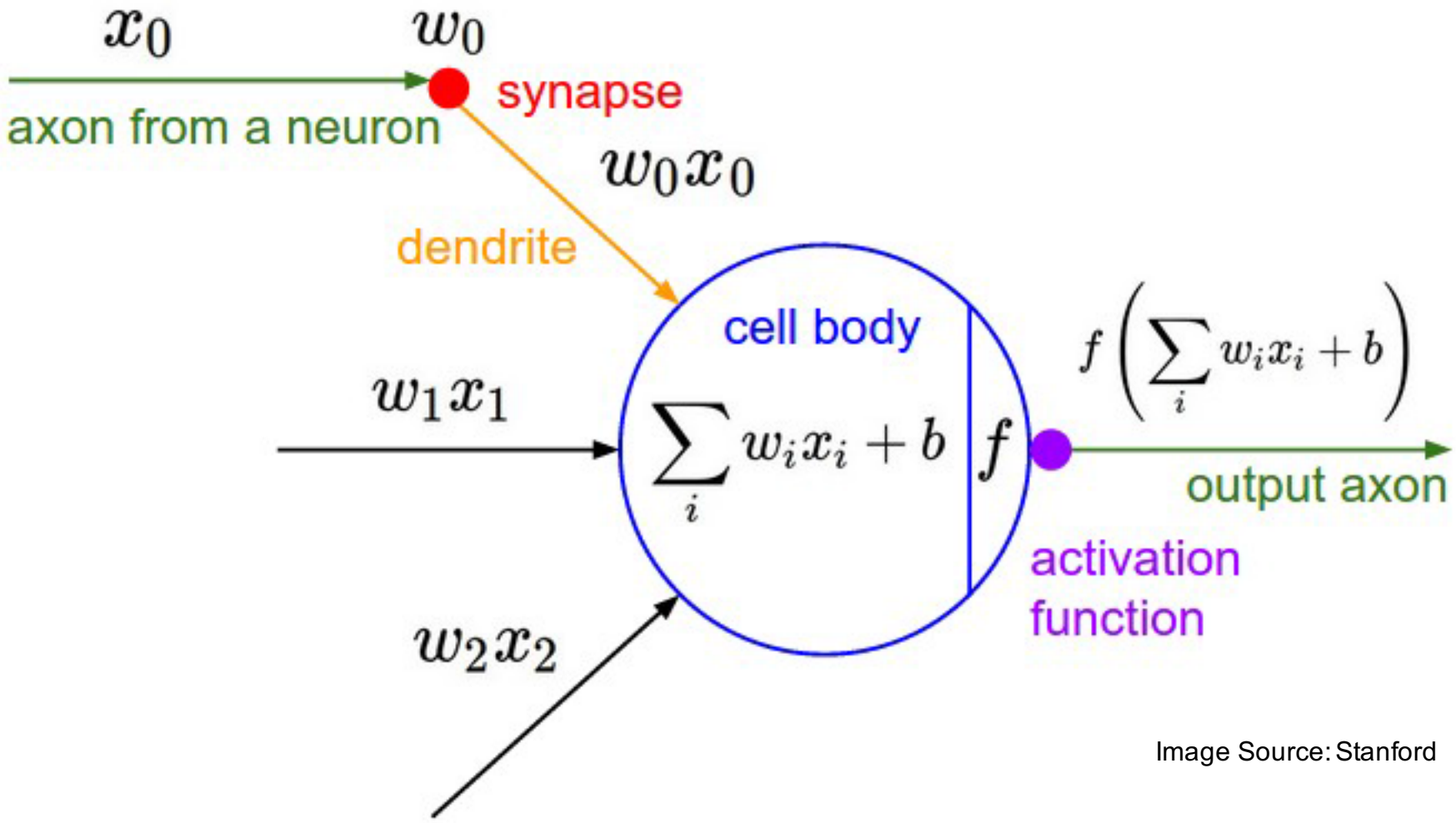
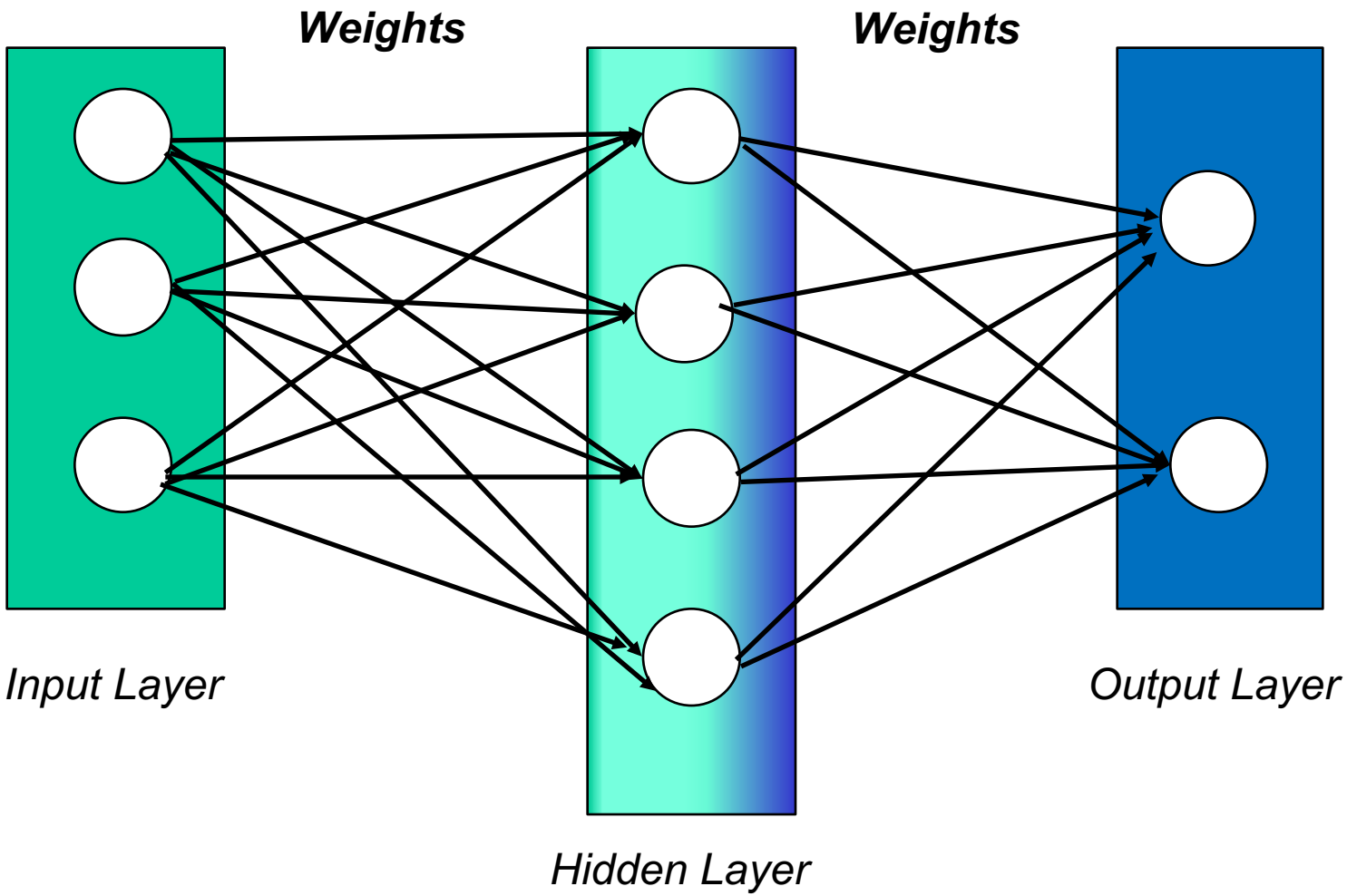
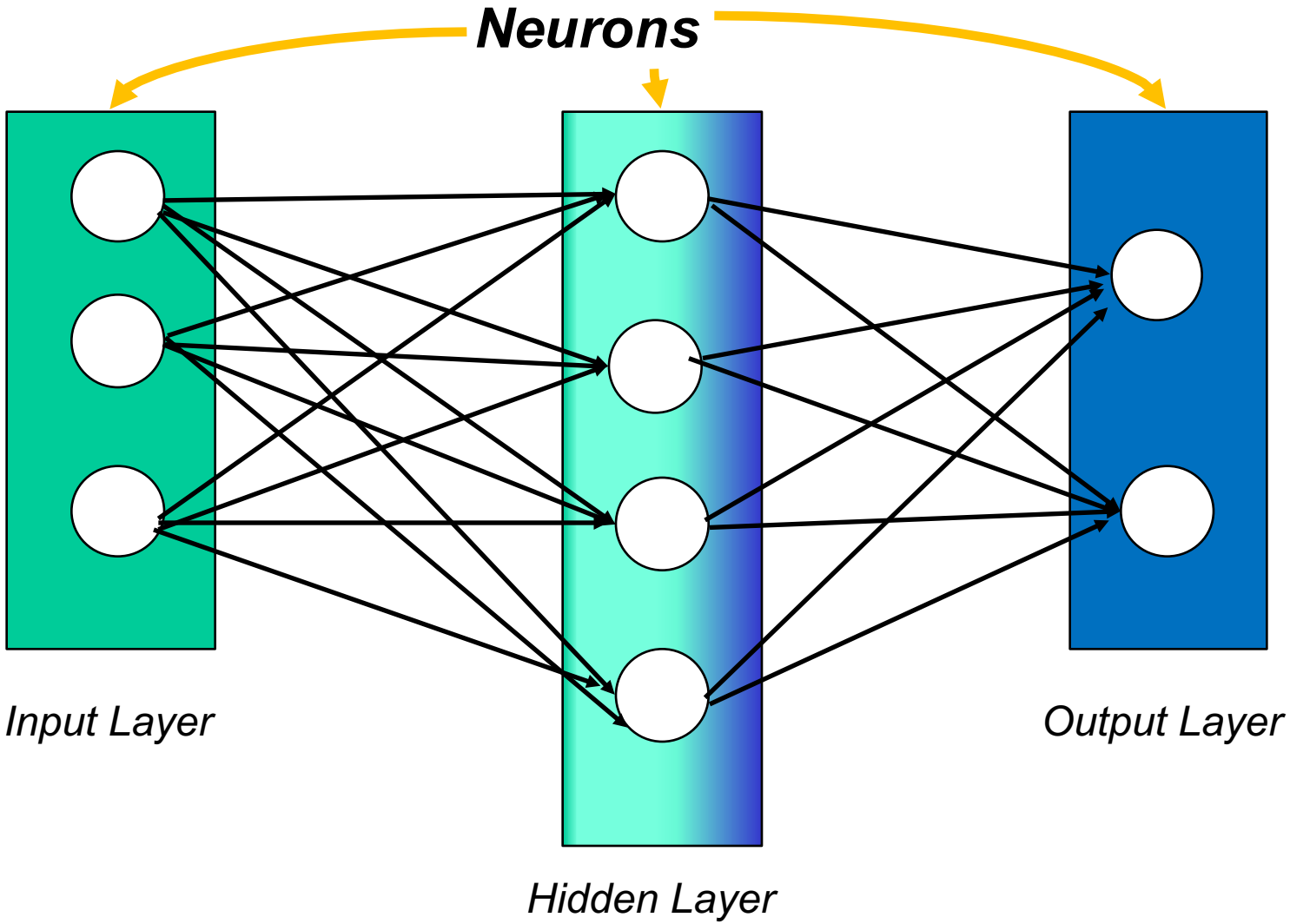


Image Source: Stanford

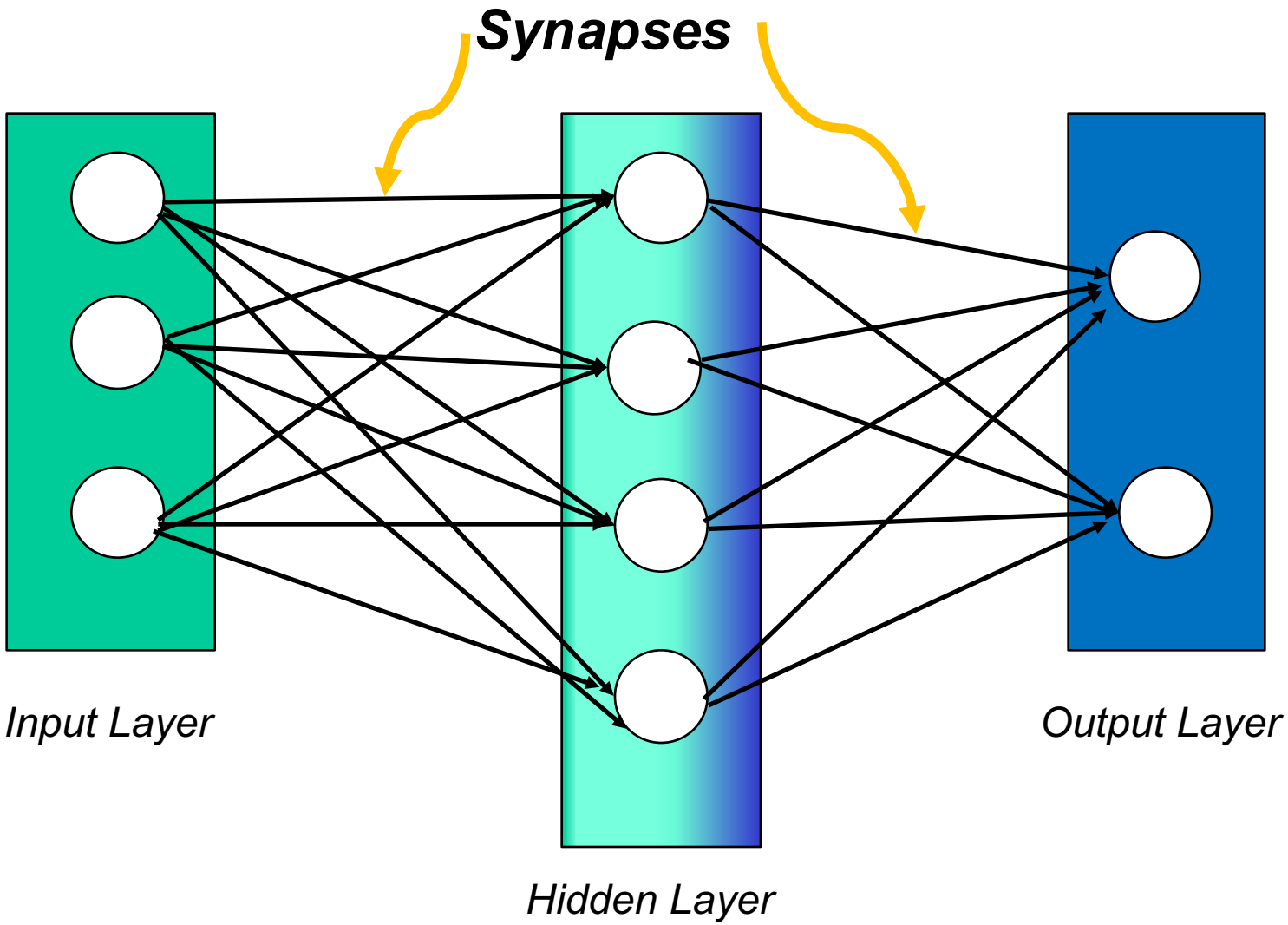
Many Weighted Sums



Many Weighted Sums



Many Weighted Sums



Deep Convolutional Neural Network

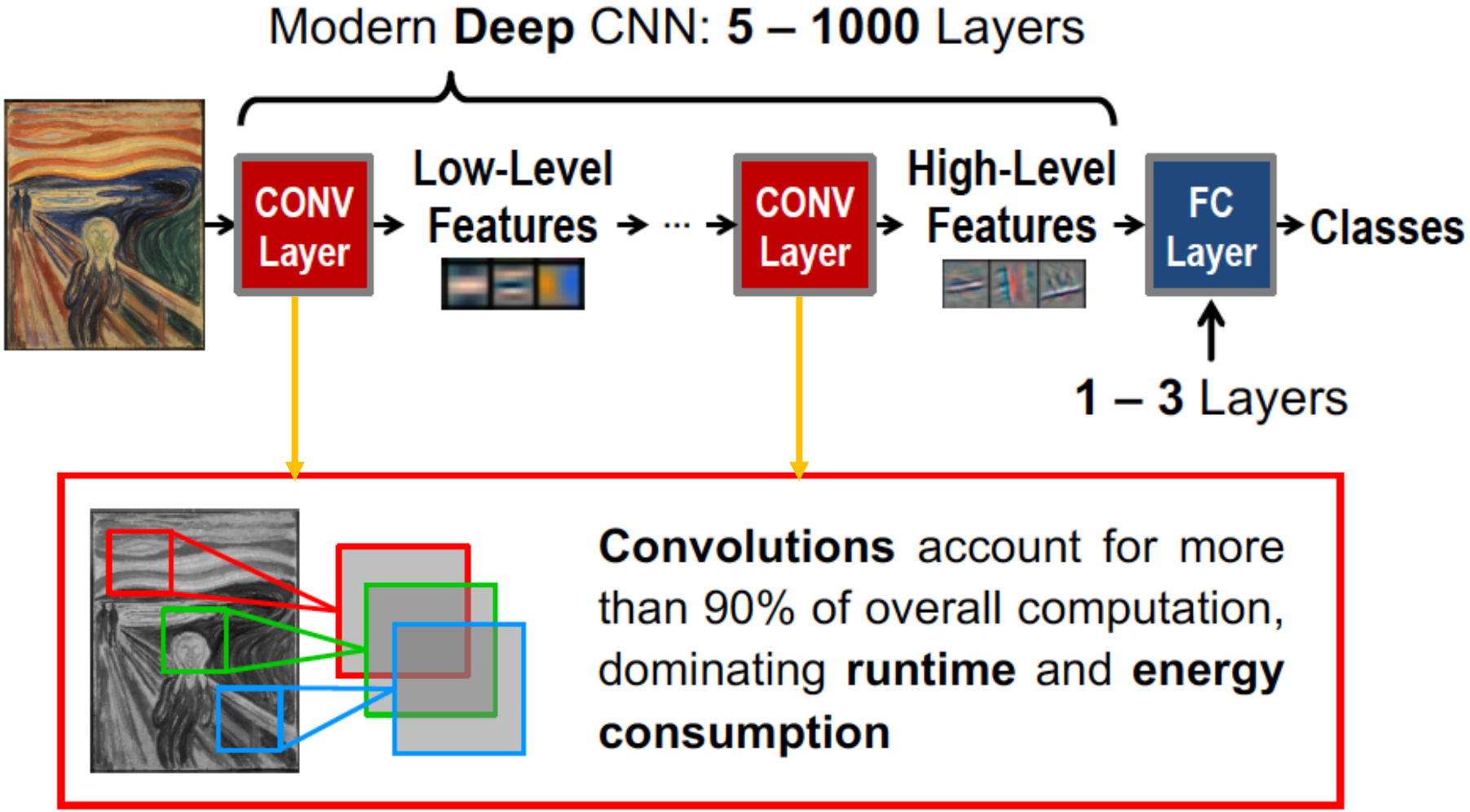


Image Source: Emer et al. ISCA Tutorial 2019

Convolution Layer

Filter

Input Feature Map (fmap)

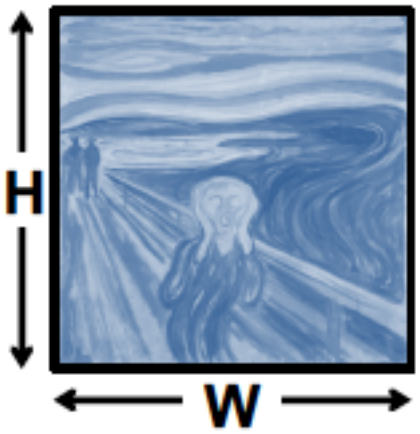


Image Source: Emer et al. ISCA Tutorial 2019

Convolution Layer

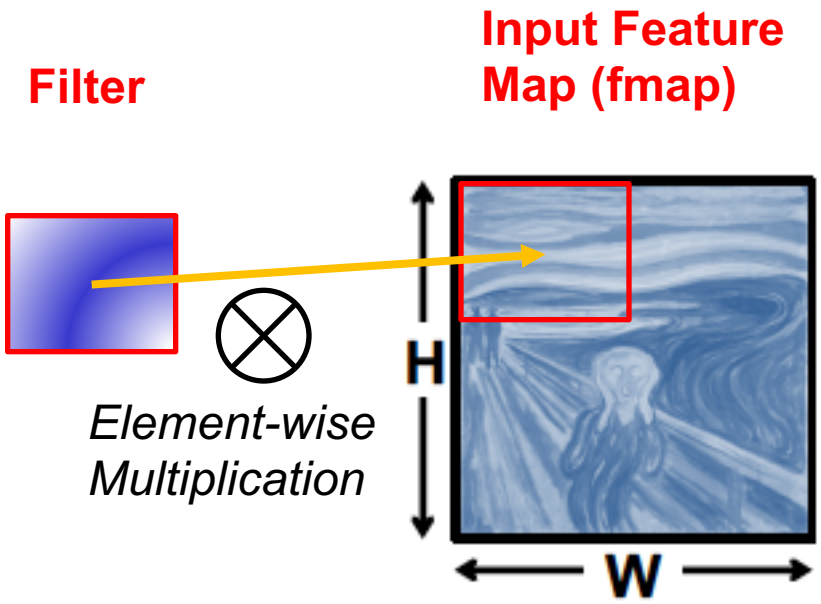


Image Source: Emer et al. ISCA Tutorial 2019

Convolution Layer

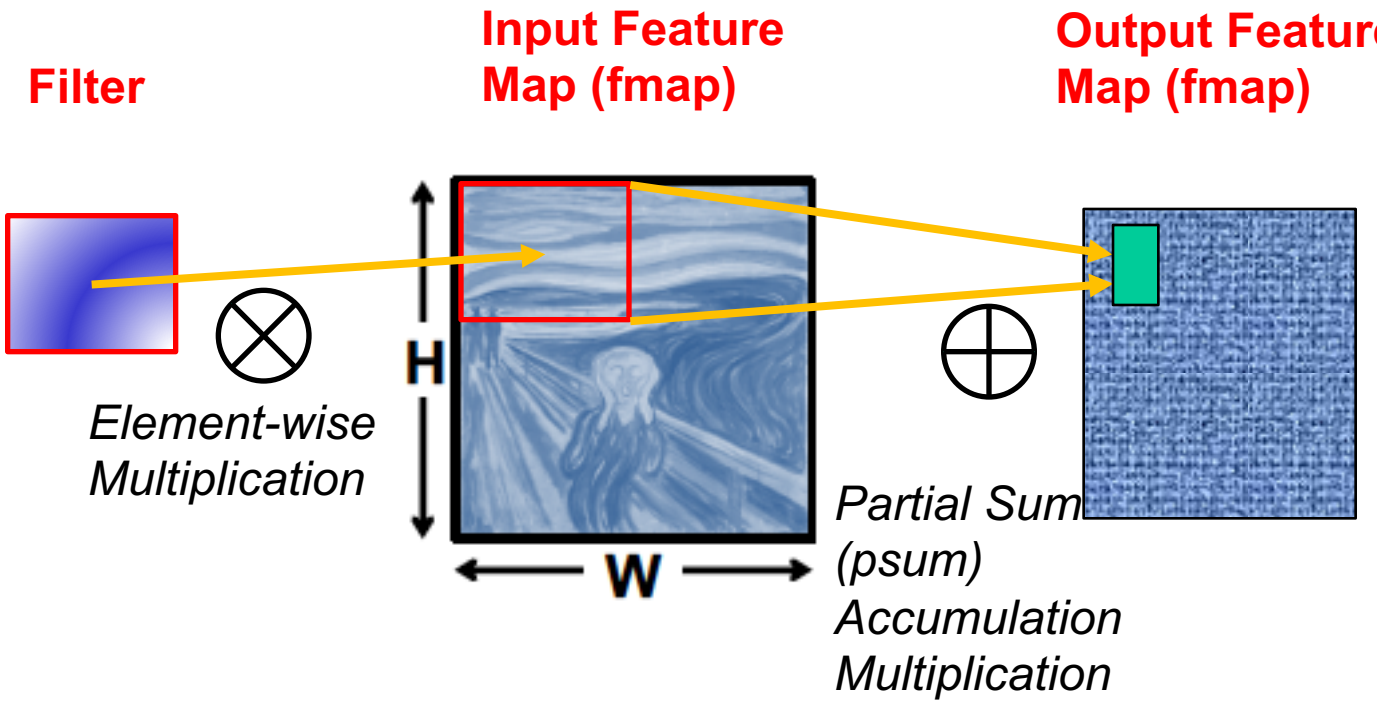


Image Source: Emer et al. ISCA Tutorial 2019

Convolution Layer Operations

Output fmaps (O)

Biases (B)

Input fmaps (I)

Filter weights (W)

$$\mathbf{O}[n][m][x][y] = \text{Activation}(\mathbf{B}[m] + \sum_{i=0}^{R-1}\sum_{j=0}^{S-1}\sum_{k=0}^{C-1} \mathbf{I}[n][k][Ux+i][Uy+j] \times \mathbf{W}[m][k][i][j]),$$

$$0 \le n < N, 0 \le m < M, 0 \le y < E, 0 \le x < F,$$

$$E = (H - R + U)/U, F = (W - S + U)/U.$$

Shape Parameter	Description
N	fmap batch size
M	# of filters / # of output fmap channels
C	# of input fmap/filter channels
H/W	input fmap height/width
R/S	filter height/width
E/F	output fmap height/width
U	convolution stride

Source: Emer et al. ISCA Tutorial 2019

A Naïve Implementation

```
for (n=0; n<N; n++) {
    for (m=0; m<M; m++) {
        for (x=0; x<F; x++) {
            for (y=0; y<E; y++) {
                O[n][m][x][y] = B[m];
                for (i=0; i<R; i++) {
                    for (j=0; j<S; j++) {
                        for (k=0; k<C; k++) {
                            O[n][m][x][y] += I[n][k][Ux+i][Uy+j] × W[m][k][i][j];
                        }
                    }
                }

                O[n][m][x][y] = Activation(O[n][m][x][y]);
            }
        }
    }
}
```

for each output fmap value

convolve a window and apply activation

Source: Emer et al. ISCA Tutorial 2019