

$$\begin{aligned}
 &\text{filter} \quad (2, -1, 1, 3, 1) * \text{vector} \quad (1, 1, 2, 1) = 2 * (1, 1, 2, 1, 0, 0, 0) \\
 &\quad \quad \quad + -1 * (0, 1, 1, 2, 1, 0, 0) \\
 &\text{vector} \quad \quad \text{filter} \quad + 1 * (0, 0, 1, 1, 2, 1, 0) \\
 &\quad \quad \quad + 1 * (0, 0, 0, 1, 1, 2, 1)
 \end{aligned}$$

$$\begin{aligned}
 a * (\lambda_1 b + \lambda_2 c) &= a * \lambda_1 b + a * \lambda_2 c \\
 &= \lambda_1 a * b + \lambda_2 a * c
 \end{aligned}$$

$$\begin{bmatrix} 1 & 3 & 1 \\ 0 & -1 & 1 \\ 2 & 2 & -1 \end{bmatrix} \times \begin{bmatrix} \lambda & \kappa \\ 1 & \kappa \end{bmatrix}_{2 \times 2} = 1 \times \begin{bmatrix} \otimes & \otimes & \otimes & \otimes \\ 1 & 3 & 1 & \otimes \\ 0 & -1 & 1 & \otimes \\ 2 & 2 & -1 & \otimes \end{bmatrix} = \dots \begin{bmatrix} \times & \times & \times & \times \\ \times & \times & \times & \times \\ \textcircled{1} & \times & \times & \times \end{bmatrix} \left. \begin{array}{l} \text{2 rows} \\ \text{2 cols} \end{array} \right\}$$

$$M \times M \xrightarrow{*} (M+2) \times (M+2)$$

$$\text{Given filter of size } k^2, \text{ input of size } M^2 \rightarrow M^2 * k^2 = (M+k-1)^2$$

$$z_i = w_i \cdot x + b$$

$$3 \times \begin{bmatrix} \square \\ \square \\ \square \end{bmatrix} \rightarrow \begin{bmatrix} \square \\ \square \\ \square \end{bmatrix}$$

$$\begin{bmatrix} R & R & R \\ R & \cdot & R \\ R & R & R \end{bmatrix} \quad \begin{array}{l} J = 2R+1 \\ R = 2 \times 2 \end{array}$$

Kernel

-R      R

$$\begin{bmatrix} R & G & B \end{bmatrix}$$

$$\text{Gray scale}$$

$$k = 2R + 1; \quad k = \text{dimensionality of kernel}$$

$$y_{i,t} = \sum_{j=1}^J \sum_{\tau=-R}^R w_{i,j,\tau} \cdot x_{j,t+\tau}$$

i<sup>th</sup> location  
feature map

forward pass

$$x \rightarrow y$$

$$\bar{x} = \bar{y} \cdot \frac{\partial y}{\partial x}$$

$x = \text{linear func}$

$$x \begin{matrix} \nearrow y \\ \rightarrow z \end{matrix}; \quad \bar{x} = \bar{y} \cdot \frac{\partial y}{\partial x} + \bar{z} \cdot \frac{\partial z}{\partial x}$$

$$\underline{\underline{y_{i,t}}} = \text{given}$$

$$\bar{\lambda}_2 = \bar{y}_1 \cdot \frac{\partial y_1}{\partial x_2} + \bar{y}_2 \cdot \frac{\partial y_2}{\partial x_2} + \bar{y}_3 \cdot \frac{\partial y_3}{\partial y_2}$$

comes

after input in forward passing

$$\underline{\underline{y_{i,t}}} = \sum_{j=1}^J \sum_{\tau=-R}^R \underline{W_{i,j,\tau}} \cdot \underline{x_{j,t+\tau}}$$

given.

$$\bar{x}_{j,t} = \sum_{\tau} \underline{\underline{y_{i,t-\tau}}} \cdot \frac{\partial y_{i,t-\tau}}{\partial x_{j,t}}$$

$$\bar{x}_{j,t+\tau} = \sum_{\tau} \bar{y}_{i,t} \cdot \frac{\partial y_{i,t}}{\partial x_{j,t+\tau}}$$

$$\bar{x}_j = \bar{y}_i * W_{i,j}, \quad \begin{matrix} \text{index for} \\ i = \text{output feature map} \end{matrix}$$

$$\bar{x}_{j,t+\tau} = \sum_{\tau} \bar{y}_{i,t} W_{i,j,\tau}$$