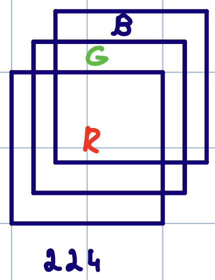
forward:

input: 

$= X \in R^{224 \times 224 \times 3}$

params:

filters: $F \in R^{3 \times 3 \times N}$, $N \in \mathbb{N}$

define @ - convolution

$X \in R^{x \cdot y \cdot z}$; $F^{x_1 \cdot y_1 \cdot z_1}$ =>

$\Rightarrow X @ F = T \in \mathbb{R}^{(x - x_1 + 1) \cdot (y - y_1 + 1) \cdot z_1}$.

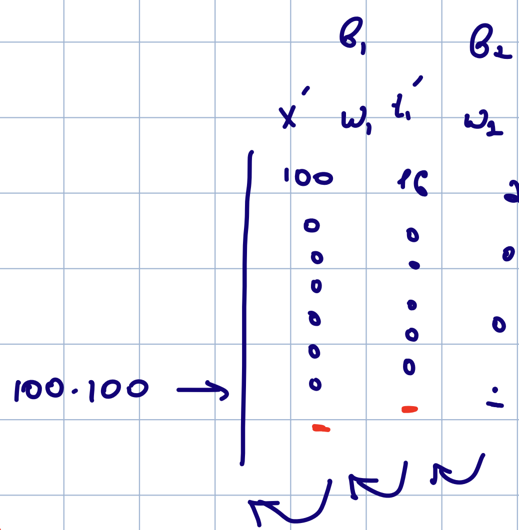
X, F.

$T_1 = X @ F_1$ $\qquad f = ReLU$

$H_1 = f(T_1)$

$T_2 = H_1 @ F_2$

$U_2 = MP(T_2)$



$N \times N$

$$\begin{matrix} 0 & 0 & 0 & 2 \\ 0 & \underset{E_1}{8} & 0 & \underset{E_2}{5} \\ 0 & \underset{E_3}{8} & \underset{E_4}{10} & 0 \\ 0 & 2 & 0 & 0 \end{matrix} \longrightarrow \begin{matrix} 8 & 5 \\ 8 & 10 \end{matrix}$$

$X' = U_2$ Tensor $\rightarrow$ vector

$t_1' = X \cdot w_1 + b_1$

$h_1' = f(t_1')$

$t_2' = h_1' \cdot w_2 + b_2$

$z = S(t_2')$

$E = CE(z)$

Back

$\frac{\partial E}{\partial t_2'} = z - y\_Full$ $\rightarrow$ ideal

$\frac{\partial E}{\partial w_2} = h_1'^{T} \cdot \frac{dE}{dt_2'}$

$\frac{\partial E}{\partial b_2} = \frac{\partial E}{\partial t_2'}$

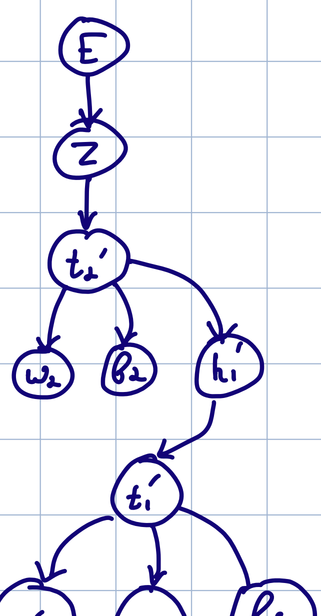
$\frac{\partial E}{\partial h_1'} = \frac{\partial E}{\partial t_2'} \cdot w_2^{T}$

$\frac{\partial E}{\partial t_1'} = \frac{\partial E}{\partial h_1'} \odot f'(t_1')$

$\frac{\partial E}{\partial w_1} = X^{T} \cdot \frac{\partial E}{\partial t_1'}$

$\frac{\partial E}{\partial b_1} = \frac{\partial E}{\partial t_1'}$

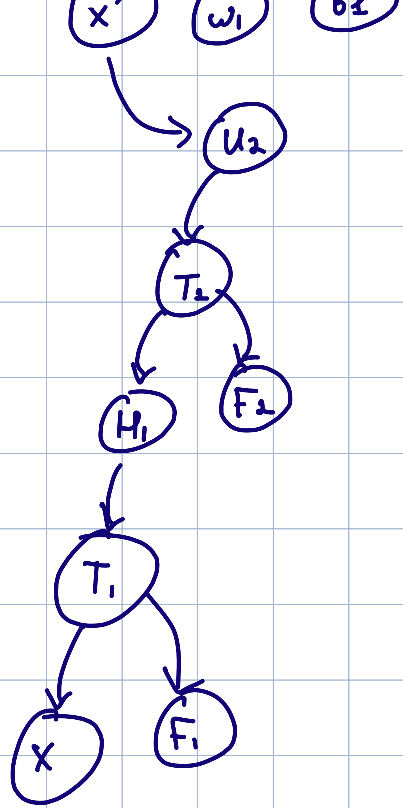
$\frac{\partial E}{\partial X'}$:



$$\frac{\partial E}{\partial X'} = \frac{\partial E}{\partial t_1'} \cdot \boxed{\frac{\partial t_1'}{\partial X'}}$$

$t_1' = X \cdot w_1 + b_1$

$$\frac{\partial (X' \cdot w_1 + b_1)}{\partial X'} = w_1$$



$$\frac{\partial E}{\partial x'} = \frac{\partial E}{\partial t_1'} \cdot \omega_1^T$$

$$\frac{\partial E}{\partial U_2} = \frac{\partial E}{\partial x'} \rightarrow \text{tensor}$$

$$\frac{\partial E}{\partial T_2} = \frac{\partial E}{\partial U_2} \quad \text{(rest - zero feel)}$$

$$\frac{\partial E}{\partial F_2} = \frac{\partial E}{\partial T_2} \cdot \boxed{\frac{\partial T_2}{\partial F_2}}$$

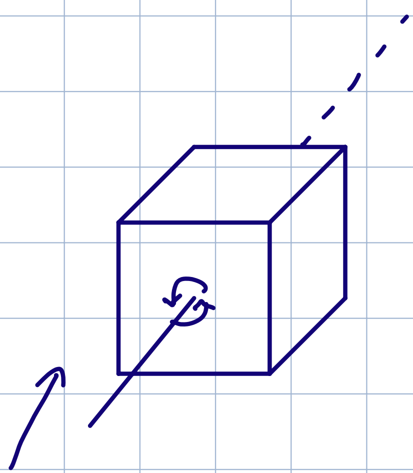
$$\begin{bmatrix} P_{111} & P_{121} & P_{131} \\ P_{211} & P_{221} & P_{231} \\ P_{311} & P_{321} & P_{331} \\ \hline P_{112} & P_{122} & P_{132} \\ P_{212} & P_{222} & P_{232} \\ P_{312} & P_{322} & P_{332} \\ \hline P_{113} & P_{123} & P_{133} \\ P_{213} & P_{223} & P_{233} \\ P_{313} & P_{323} & P_{333} \end{bmatrix} @ \begin{bmatrix} F_{11} & F_{12} \\ F_{21} & F_{22} \end{bmatrix} \longrightarrow \begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix}$$

$$R_{11} = F_{11} \cdot (P_{111} + P_{112} + P_{113}) + F_{12} \cdot (P_{121} + P_{122} + P_{123}) + F_{21} \cdot (P_{211} + P_{212} + P_{213}) +$$
$$+ F_{22} \cdot (P_{221} + P_{222} + P_{223}).$$

$$R_{xy} = \sum_{\substack{x=1 \\ y=1}}^{\substack{N_1 \\ N_2}} \left(F_{xy} \cdot \left(\sum_{z=1}^{N_3} (P_{xyz}) \right) \right).$$

$$\frac{\partial R_{11}}{\partial F_{11}} = P_{111} + P_{112} + P_{113}$$

$$\frac{\partial R_{12}}{\partial F_{12}} = P_{121} + P_{122} + P_{123}$$



$$\frac{\partial E}{\partial H_1} = \frac{\partial E}{T_2} @ F^{TT}$$

$$\frac{\partial E}{\partial F_2} = H_1 @ \frac{\partial E}{\partial T_2}$$