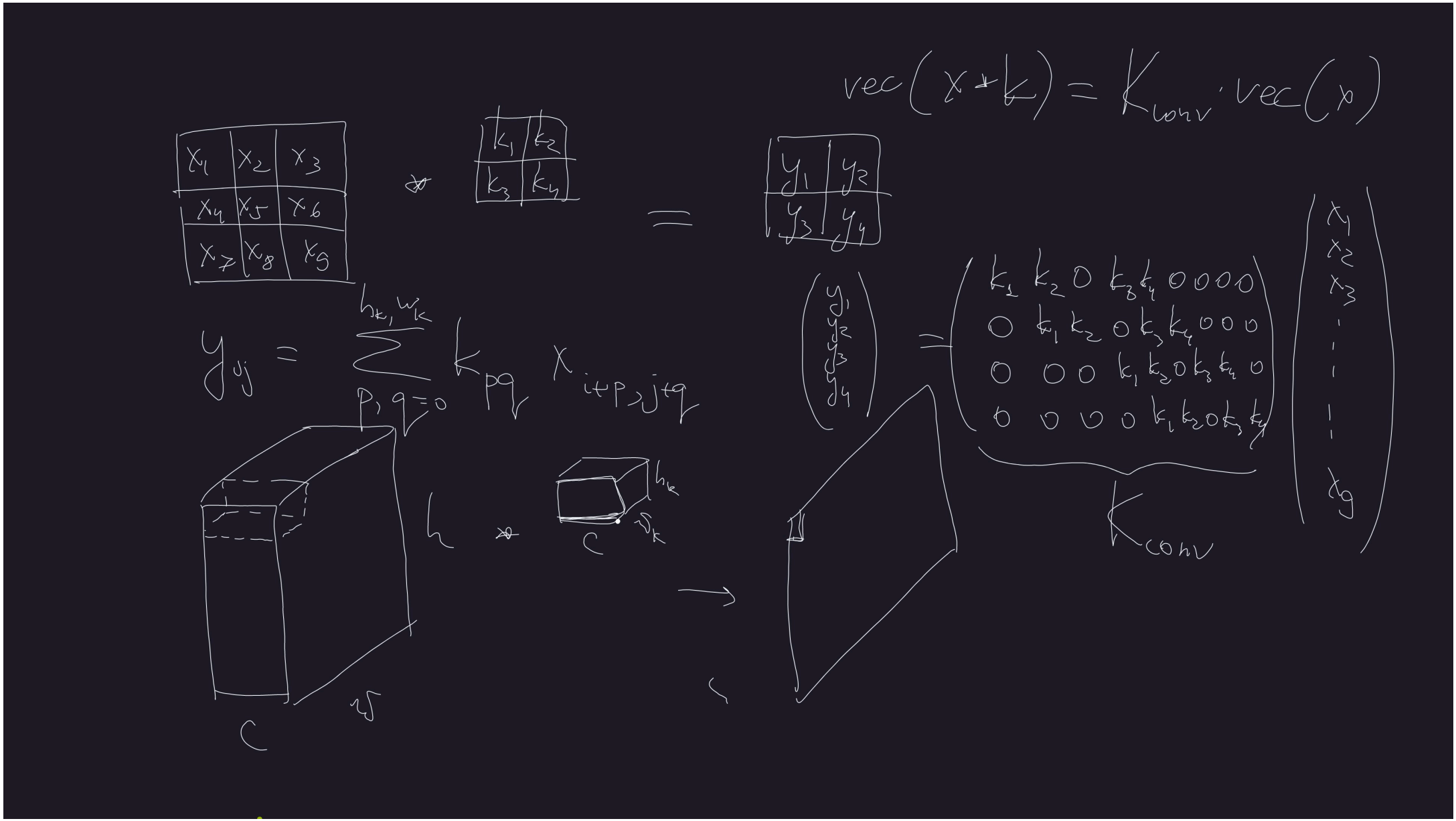
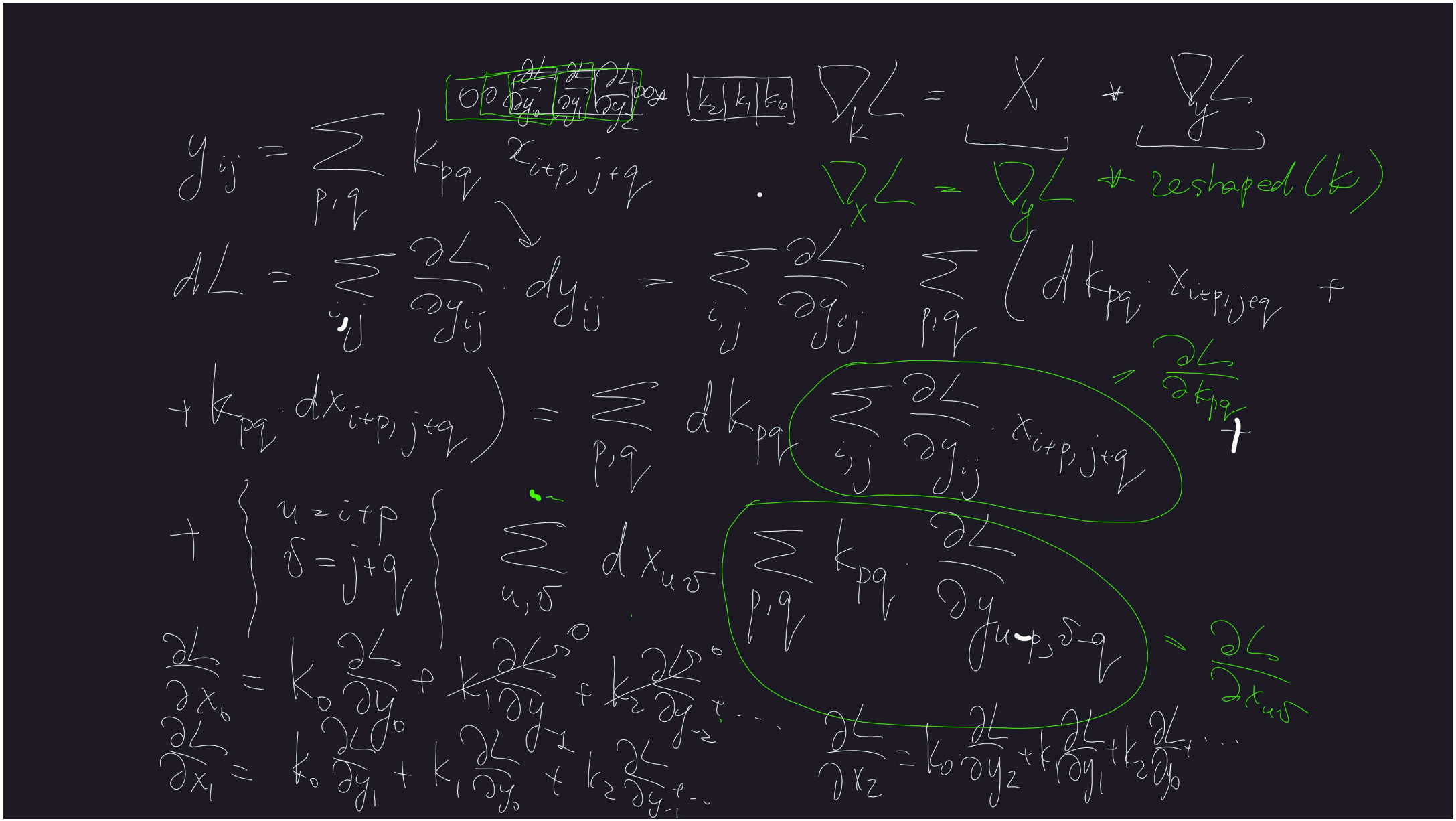
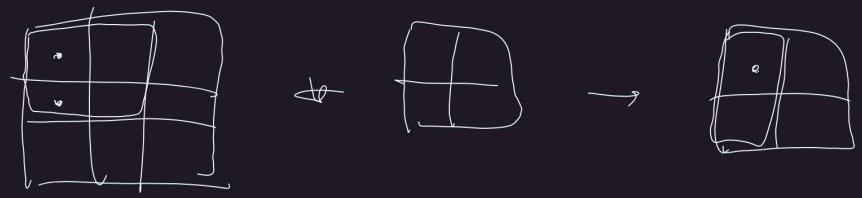
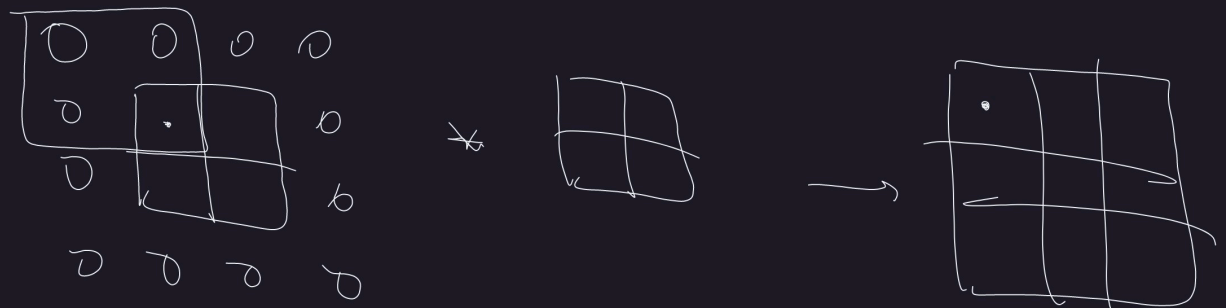
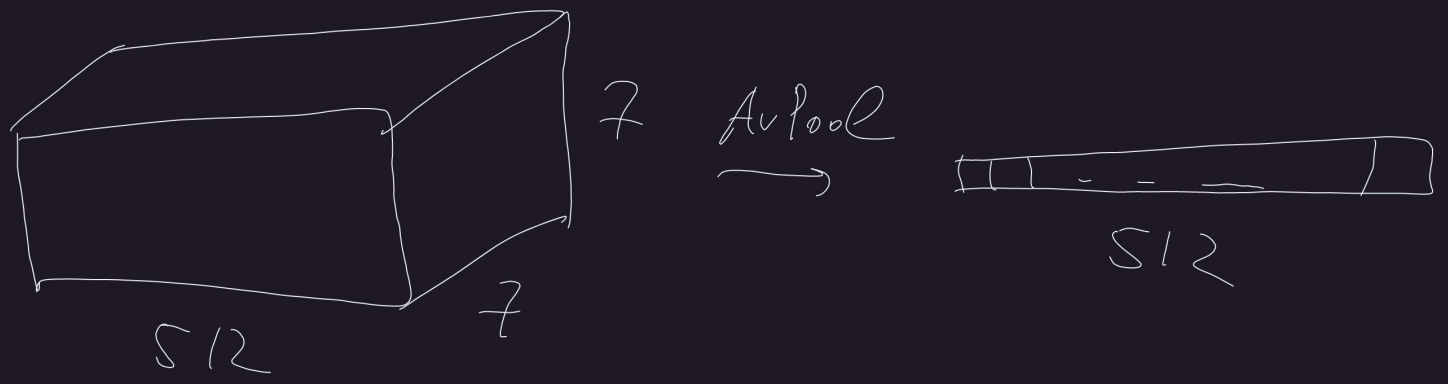

$vec(X * k) = K_{conv} \cdot vec(X)$
$y_{ij} = \sum_{p,q=0}^{h_k, w_k} k_{pq} x_{i+p, j+q}$
K_{conv}


$y_{ij} = \sum_{p,q} k_{pq} \, x_{i+p,\,j+q}$
$\nabla_k L = X \ast \nabla_y L$
$\nabla_x L = \nabla_y L \ast \text{reshaped}(k)$
$dL = \sum_{i,j} \frac{\partial L}{\partial y_{ij}} \cdot dy_{ij} = \sum_{i,j} \frac{\partial L}{\partial y_{ij}} \sum_{p,q} \left(dk_{pq} \cdot x_{i+p,j+q} + k_{pq} \cdot dx_{i+p,j+q} \right)$
$= \sum_{p,q} dk_{pq} \sum_{i,j} \frac{\partial L}{\partial y_{ij}} \cdot x_{i+p,j+q} = \frac{\partial L}{\partial k_{pq}}$
$+ \left\{ \begin{array}{l} u = i+p \\ v = j+q \end{array} \right\} \sum_{u,v} dx_{uv} \sum_{p,q} k_{pq} \cdot \frac{\partial L}{\partial y_{u-p,\,v-q}} = \frac{\partial L}{\partial x_{uv}}$
$\frac{\partial L}{\partial x_0} = k_0 \frac{\partial L}{\partial y_0} + k_1 \frac{\partial L}{\partial y_{-1}} + k_2 \frac{\partial L}{\partial y_{-2}} + \dots$
$\frac{\partial L}{\partial x_1} = k_0 \frac{\partial L}{\partial y_1} + k_1 \frac{\partial L}{\partial y_0} + k_2 \frac{\partial L}{\partial y_{-1}} + \dots$
$\frac{\partial L}{\partial x_2} = k_0 \frac{\partial L}{\partial y_2} + k_1 \frac{\partial L}{\partial y_1} + k_2 \frac{\partial L}{\partial y_0} + \dots$

	Linear	Conv2d
Forward	$z = Wx + b$	$z = x * k + b$
Backward	$\nabla_x L = W^T \nabla_z L$ $\nabla_W L = \nabla_z L \cdot x^T$ $\nabla_b L = \nabla_z L$	$\nabla_k L = x * \nabla_z L^{TR}$ $\nabla_x L = \nabla_z L * \text{reshaped}(k)$ $\nabla_b L = \text{sum}(\nabla_z L)$
input size	(n_{batch}, n_{input})	$(n_{batch}, n_{in\_channels}, w_{input}, h_{input})$
output size	(n_{batch}, n_{output})	$(n_{batch}, n_{out\_channels}, w_{output}, h_{output})$
# params	$n_{inputs} \cdot n_{outputs} + n_{outputs}$	$(n_{in\_ch} \cdot h_k \cdot w_k + 1) \cdot n_{out\_channels}$
Comp. complexity	$O(n_{batch} \cdot n_{inputs} \cdot n_{outputs})$	$O(n_{in\_ch} \cdot h_k \cdot w_k \cdot n_{batch} \cdot n_{out\_chan.} \cdot w_{output} \cdot h_{output})$






7
AvPool
7
512
512