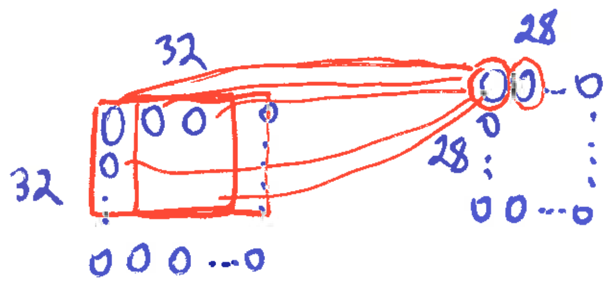
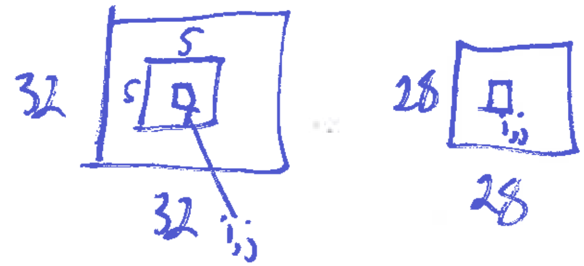
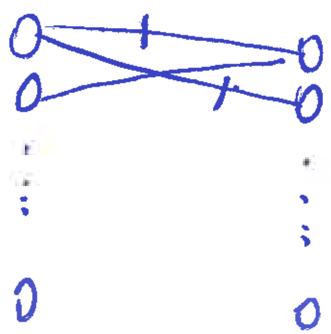


input



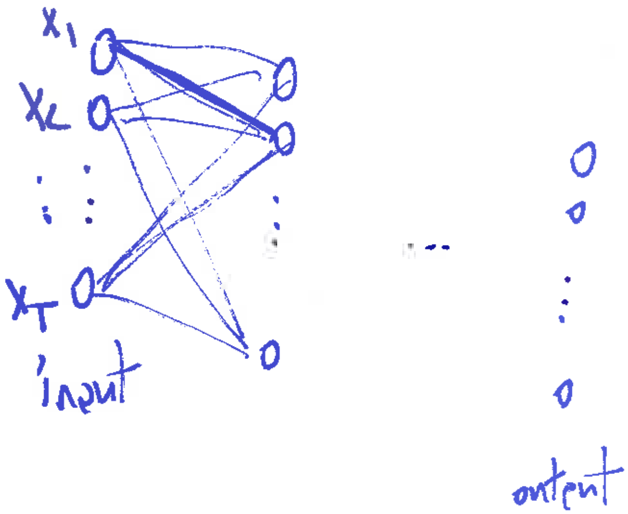
$$a^{(2)}_{11} = \left[\sum_{i,j} w^{(1)}_{0} x_{ij}\right] + w^{(1)}_{0}$$

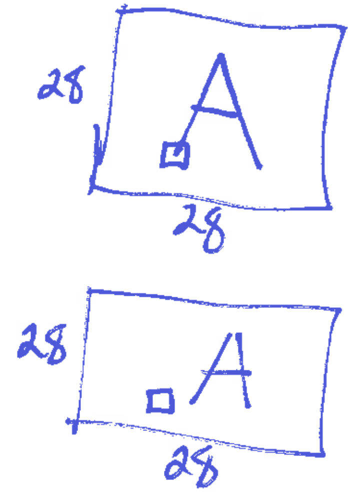
25 + 1



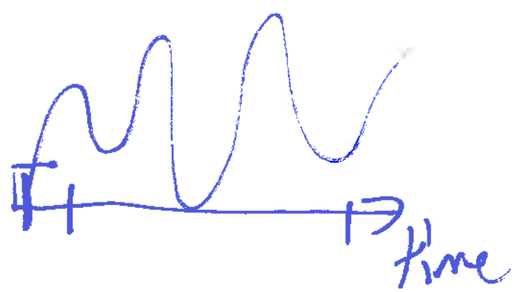
input
32×32

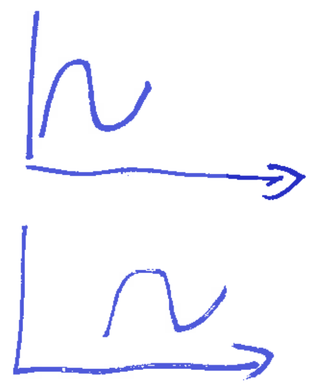
28×28

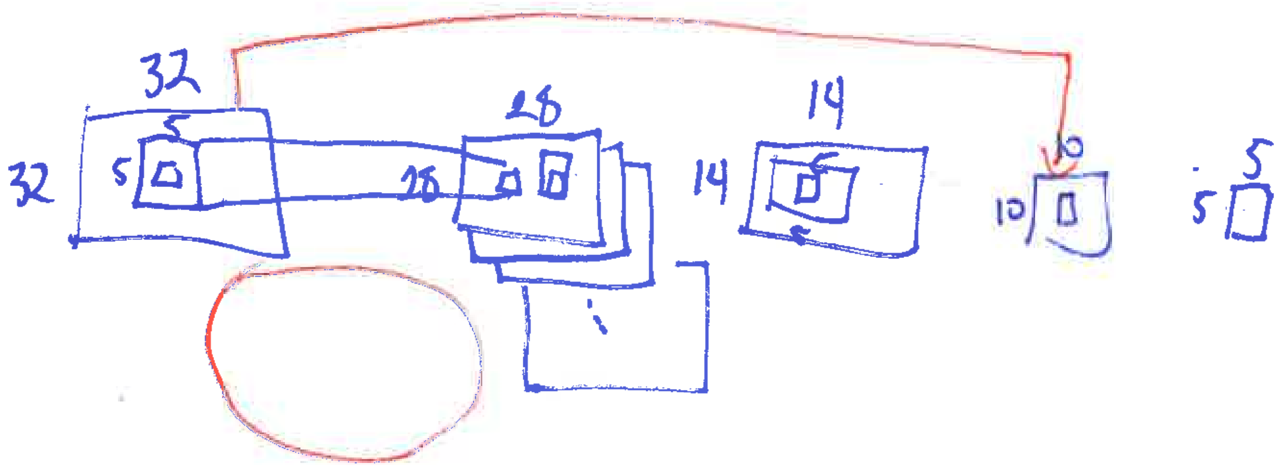




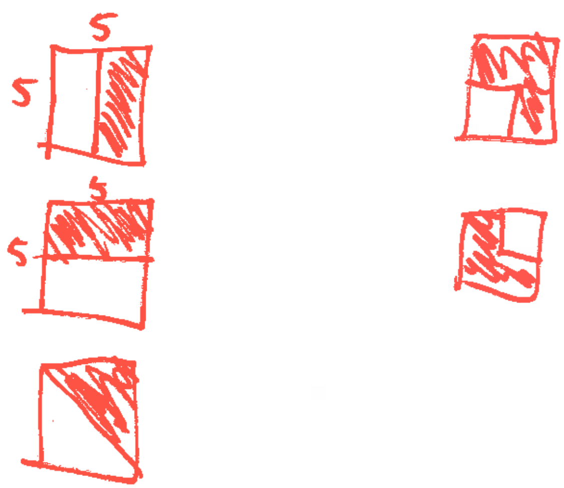
$$O(D^2L)$$



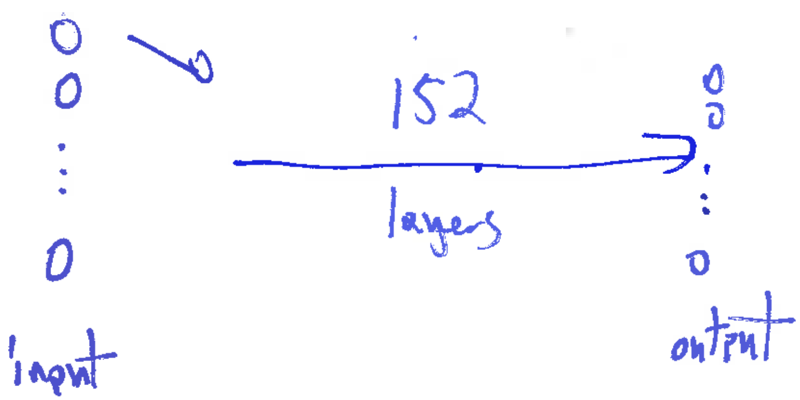




$(5\times 5+1)\times 6$



$$w^{(\tau+1)} = w^{(\tau)} + \eta \nabla E_n(w^{(\tau)})$$



$$h(a) = \frac{1}{1+e^{-a}}$$

$$h'(a) = h(a)\,(1 - h(a))$$

$$\frac{\partial E_n}{\partial w_{ij}^{(2)}} = h'(a^{(\ell)}) \cdot h'(a^{(\ell+1)}) \cdot \ldots \cdot h'(a^{(151)})$$

≈ 0

$$h(a) = \begin{cases} 0 & \text{if } a < 0 \\ a & \text{o.w.} \end{cases}$$

$$\vec{x} = (x_1, x_2, \dots, x_M)$$
$$\vec{z} = (z_1, z_2, \dots, z_M)$$

$w^T\phi(x)$

$\vec{x}, \vec{z} \in \mathbb{R}^2 \qquad M = 2$

2 mults, 1 add

1 add

1 mult

3 mult., 2 add

$$k(x,z) = (1 + x^T z)^2$$
$$= (1 + x_1 z_1 + x_2 z_2)^2$$
$$= 1 + 2x_1 z_1 + 2x_2 z_2 + x_1^2 z_1^2 + 2x_1 x_2 z_1 z_2 + x_2^2 z_2^2$$
$$= (1, \sqrt{2}\,x_1, \sqrt{2}\,x_2, x_1^2, \underbrace{\sqrt{2}\,x_1 x_2, x_2^2)^T (1}_{\text{6 mult. + 5 add.}}, \sqrt{2}\,z_1, \sqrt{2}\,z_2, z_1^2, \sqrt{2}\,z_1 z_2, z_2^2)$$

$\phi(x)^T \phi(z)$

$$\phi(x) = (1, \sqrt{2}\,x_1, \sqrt{2}\,x_2, x_1^2, \sqrt{2}\,x_1 x_2, x_2^2) \leftarrow \text{6 mults}$$

For all training examples x_i

compute $\|x_i - x_j\|$

return label of x_i with min distance

$$\phi(x_i)^T \phi(x_j)$$

$$\shortparallel$$

$$k(x_i, x_j)$$

For all training examples x_i

compute $\|\phi(x_i) - \phi(x_j)\|^2$

return label of x_i with min distance^2

For all training examples x_i

compute $\phi(x_i)^T \phi(x_i) - 2\phi(x_i)^T \phi(x_j) + \phi(x_j)^T \phi(x_j) \equiv foo_i$

return label of x_i with minimum foo_i

$$\text{direct}\left\{\begin{array}{l} \vec{x}_i \longmapsto \vec{\phi}(\vec{x}_i) \\ \vec{x}_j \longmapsto \vec{\phi}(\vec{x}_j) \\ \phi(x_i)^T \phi(x_j) \end{array}\right.$$

$$k(x_i, x_j) = \phi^T(x_i)\,\phi(x_j)$$

$$\begin{array}{cc} & M \\ \Phi = N & \begin{bmatrix} & & \\ & \phi_j(x_i) & \\ & & \end{bmatrix} \end{array}$$

$\vec{x} \in \mathbb{R}^D$

$\phi_0(\vec{x}) = 1$

$\phi_1(\vec{x}) = x_1$

$\phi_2(\vec{x}) = x_2$

$\vdots$

$\phi_M(\vec{x}) = x_M$

$\phi_{M+1}(\vec{x}) = x_1^2$

$\vdots$

w^*

$\phi_0(\vec{x}) = 1$

$\phi_1(\vec{x}) = \sqrt{2}\, x_1$

$\vdots$

$\phi_{M+1}(\vec{x}) = x_1^2$

$\vdots$

$$\tilde{w}^* = \begin{pmatrix} w_1^* \\ \vdots \\ \frac{w_{M+1}^*}{\sqrt{2}} \\ \\ \\ \end{pmatrix}$$