What is vectorization?

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$$z = w^T x + b$$

$$w = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w \end{bmatrix} \quad x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x \end{bmatrix} \quad w \in \mathbb{R}^{n_x} \quad x \in \mathbb{R}^{n_x}$$

Non-vectorized

```
z = 0
for i in range(n_x):
    z += w[i] * x[i]
z += b
```

Vectorized:

$$z = \underbrace{np.dot(w, x)}_{w^T x} + b$$

Whenever possible, avoid explicit for-loops

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$u = Av$

$u_i = \sum_j A_{ij} v_j$

u = np.zeros((n, 1))

for i ... ←

for j ... ←

u[i] += A[i][j] * v[j]

u = np.dot(A, v)

Vector and Matrix Values Functions

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$$v = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix} \qquad u = \begin{bmatrix} e^{v_1} \\ e^{v_2} \\ \vdots \\ e^{v_n} \end{bmatrix}$$

```
u = np.zeros((n, 1))
for i in range(n):
    u[i] = math.epx(v[i])
```

Numpy

```
u = np.exp(v)
```

NO EXPLICIT LOOP

Other np element wise functions
- np.log
- np.abs
- etc.

Vectorizing Logistic Regression

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$$X = \begin{bmatrix} | & | & | & | \\ x_1 & x_2 & x_3 & x_m \\ | & | & | & | \end{bmatrix}_{(n_x, m)} \quad \mathbb{R}^{n_x \times m}$$

$$Z = \begin{bmatrix} z^{(1)} & z^{(2)} & z^{(3)} \dots & z^{(m)} \end{bmatrix} = W^T X + \underbrace{b}_{[b, b, b \dots b]_{1 \times m}}$$

$$= W^T \begin{bmatrix} | & | & & | \\ x_1 & x_2 & \dots & x_m \\ | & | & & | \end{bmatrix} + b$$

$$= \begin{bmatrix} W^T x^{(1)} + b & W^T x^{(2)} + b & \dots & W^T x^{m} + b \end{bmatrix}$$

PYTHON:

```
Z = np.dot(w.T, X) + b
```

Vectorizing Gradient Output

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$dz^{(1)} = a^{(1)} - y^{(1)}$ $\quad dz^{(2)} = a^{(2)} - y^{(2)}$

$dz = [dz^{(1)} \ dz^{(2)} \ dz^{(3)} \dots dz^{(m)}]_{1 \times m}$

$A = [a^{(1)} \ a^{(2)} \dots a^{(m)}]_{1 \times m} \rightarrow Y = [y^{(1)} \ y^{(2)} \dots y^{(m)}]_{1 \times m}$

$\boxed{dz = A - Y} = [a^{(1)} - y^{(1)} \ \ a^{(2)} - y^{(2)} \dots]_{1 \times m}$

$dw = 0$

$dw += x^{(1)} dz^{(1)} + x^{(2)} dz^{(2)} + \dots$

$db = 0$

$db = dz^{(1)} \ dz^{(2)} \dots$

$db = \frac{1}{m} db$

$dW = \frac{1}{m} \times np.sum(X \, dz.T)$

$db = \frac{1}{m} \sum_{i=1}^{m} dw^{(i)} + db^{(i)}$

$= \frac{1}{m} \times np.sum(dz)$