Diffusion Model

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	Level	Completed
	Beginner	0
	Intermediate	0
	Advanced	0
	Expert	0

Goal	
4722	12
5722	14
Total Completed	
0	

Generating a Sentence

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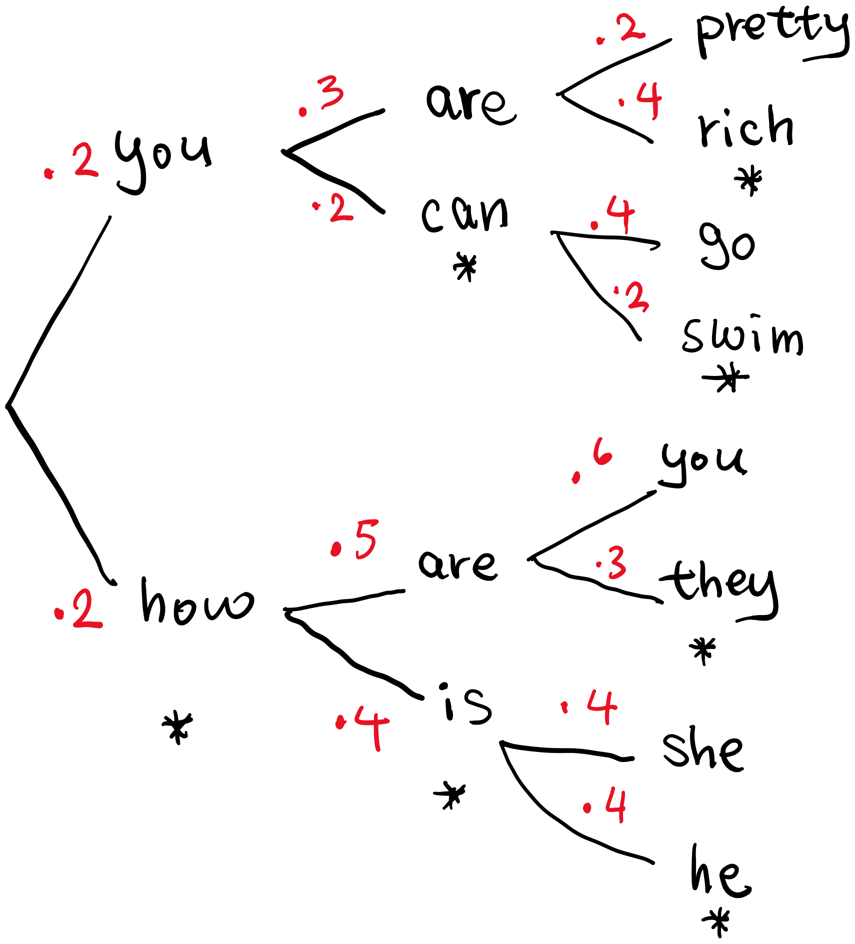
Joint Probability



a. p("you can swim") = $.2 \times .2 \times .2$ $= 0.008$

b. p("you can go") = $.2 \times .2 \times .4$ $= 0.016$

c. p("how are they") = $.2 \times .5 \times .3$ $= 0.03$

d. p("how is she") = $.2 \times .4 \times .4$ $= 0.032$

🔑 (a+b+c+d)*1000%7 = 2

Which sentence does this sequence of random numbers generate?

A. meow woof

B. woof woof

C. woof meow

D. oink woof

E. oink meow

D

Random Number Generator

0.41	0.33		

woof	0.5
oink	0.2
meow	0.3

1

0.5 ← 0.41

0.3

0

woof	0.1
oink	0.1
meow	0.8

0.7

← 0.33

0.3

0.1

0

woof	0.7
oink	0.2
meow	0.1

woof	0.8
oink	0.2
meow	0

$0.3 < 0.41 < 0.5$

Which sentence does this model generate from a random sequence of [0.6, 0.3, 0.7]?

A. pow, boom, bang

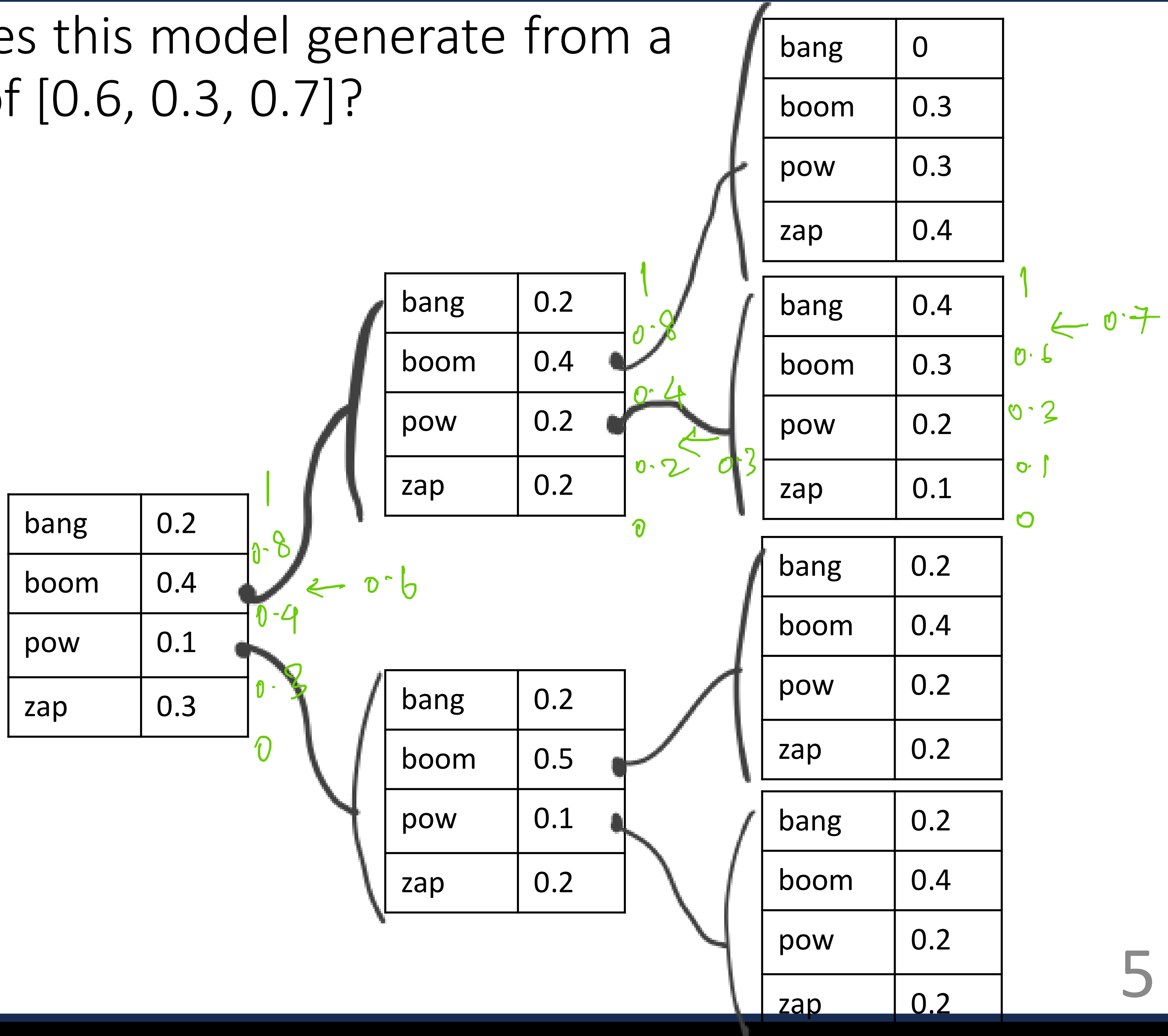
B. boom, pow, bang

C. pow, pow, bang

D. boom, boom, pow

B

bottom = 0



Training an Autoregressive Language Model

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Conditional Probability

woof	meow

↓

LM →

meow	0.7	0.4	0.2
woof	0.3	0.6	0.8

a. p("woof" | "woof") = 0.6

b. p("meow" | "woof") = 0.4

c. p("woof" | "woof meow") = 0.8

d. p("meow" | "woof meow") = 0.2

🔑 a+b+c+d = 2

Joint Probability

woof	meow

↓

LM

→

meow	0.7	0.4	0.2
woof	0.3	0.6	0.8

a. p("woof") = 0.3

b. p("woof meow") = 0.3 x 0.4 = 0.12

c. p("woof meow woof") = 0.12 x 0.2
= 0.024

d. p("woof meow meow") = 0.12 x 0.8
= 0.096

🔑 (a+b+c+d) * 100 % 5 =
4

Training an Autoregressive Image Model

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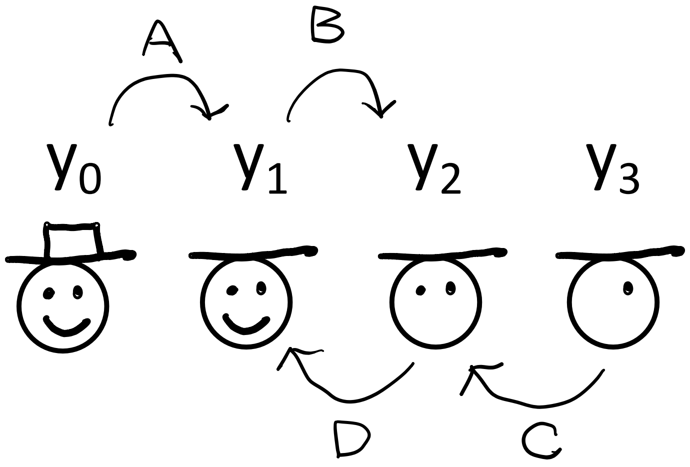
Conditional Probability Distributions



No hint: P(X2 | X1)

Write out the conditional probability distribution expression that correspond to A, B, C, D.
Enter 1 if the variable should be included.

		y0	y1	y2	y3		y0	y1	y2	y3	
A.	p(	0	1	0	0	$\mid$	1	0	0	0	)
B.	p(	0	0	1	0	$\mid$	1	1	0	0	)
C.	p(	0	0	1	0	$\mid$	0	0	0	1	)
D.	p(	0	1	0	0	$\mid$	0	0	1	1	)

Forward

$$Y_1 - Y_0$$

Y_0

$$\begin{array}{|c|c|}\hline 5 & 5 \\ \hline 5 & 5 \\ \hline\end{array}$$

$$+= \begin{array}{|c|c|}\hline 1 & 0 \\ \hline 0 & 1 \\ \hline\end{array} \quad 0.40$$

$$+= \begin{array}{|c|c|}\hline -1 & 0 \\ \hline 0 & -1 \\ \hline\end{array} \quad 0.60$$

Noise added

a. $p\left(Y_1 = \begin{array}{|c|c|}\hline 6 & 5 \\ \hline 5 & 6 \\ \hline\end{array}\right) =$ 0.4

b. $p\left(Y_1 = \begin{array}{|c|c|}\hline 4 & 5 \\ \hline 5 & 4 \\ \hline\end{array}\right) =$ 0.6

Hint: Guess which forward path leads to Y_1

Reverse

Y_0

$$\begin{bmatrix} 5 & 5 \\ 5 & 5 \end{bmatrix}$$

$Y_1 - Y_0$

$$\mathrel{+}= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad 0.40$$

$$\mathrel{+}= \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \quad 0.60$$

$Y_2 - Y_1$

$$\mathrel{+}= \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \quad 0.60$$

$$\mathrel{+}= \begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix} \quad 0.20$$

$$\mathrel{+}= \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \quad 0.30$$

$$\mathrel{+}= \begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix} \quad 0.70$$

What are the pixel values of the images involved in the reverse process?

$$p\left(\overset{Y_0}{\begin{bmatrix} 5 & 5 \\ 5 & 5 \end{bmatrix}} \;\middle|\; \overset{Y_1}{\begin{bmatrix} 4 & 5 \\ 5 & 4 \end{bmatrix}}, \overset{Y_2}{\begin{bmatrix} 4 & 4 \\ 4 & 4 \end{bmatrix}} \right)$$

Forward

(a+b)*100%11=4

Y_0

$$\begin{bmatrix} 5 & 5 \\ 5 & 5 \end{bmatrix}$$

$Y_1 - Y_0$

$$+= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad 0.40$$

$$+= \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \quad 0.60$$

$Y_2 - Y_1$

$$+= \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \quad 0.60$$

$$+= \begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix} \quad 0.20$$

$$+= \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \quad 0.30$$

$$+= \begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix} \quad 0.70$$

a. $p\left(Y_2 = \begin{bmatrix} 6 & 4 \\ 4 & 6 \end{bmatrix}\right) = \underline{0.4 \times 0.2}$

$= 0.08$

b. $p\left(Y_2 = \begin{bmatrix} 4 & 6 \\ 6 & 4 \end{bmatrix}\right) = \underline{0.6 \times 0.3}$

$= 0.18$

Hint: Guess which forward path leads to Y_2.
Calculate joint probability using the chain rule.

Denoising Diffusion Probabilistic Model (DDPM)

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Forward vs Reverse

During the forward diffusion process, signals are

______ (a) {1. removed from, 2. ~~added to~~} an image by

______ (b) {1. ~~removing~~, 2. adding} noises.

During the reverse diffusion process, signals are

______ (c) {1. ~~removed from~~, 2. added to} an image by

______ (d) {1. removing, 2. ~~adding~~} noises.

NumPy by Hand ✍️
[Math → For Loops]

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Match math to code

(a)

$$Y_j = \sum_{i=0}^{I-1} X_{ij}$$

(b)

$$Y = \sum_{i=0}^{I-1} \sum_{j=0}^{J-1} X_{ij}$$

(c)

$$Y_i = \sum_{j=0}^{J-1} X_{ij}$$

(1)

```
I, J = X.shape
Y = np.zeros((I,J))
for i = range(I) :
    for j = range(J):
        Y[j] += X[j,i]
```

a

(2)

```
I, J = X.shape
Y = np.zeros((I,J))
for i = range(I) :
    for j = range(J):
        Y[i] += X[j,i]
```

c

(3)

```
I, J = X.shape
Y = 0
for i = range(I) :
    for j = range(J):
        Y += X[i,j]
```

b

What are the indices?

$$D_{kl} = \sum_{\underset{\text{a}}{\underline{i=0}}}^{I-1} \sum_{\underset{\text{b}}{\underline{j=0}}}^{J-1} A_{ij} B_{jk} C_{kl}$$

$$D_{ik} = \sum_{\underset{\text{c}}{\underline{j=0}}}^{J-1} \sum_{\underset{\text{d}}{\underline{l=0}}}^{L-1} A_{ij} B_{jk} C_{kl}$$

Math → Code

$$D_{ij} = \sum_{k} \sum_{l} A_{ij} B_{jk} C_{kl}$$

```
    I, J = A.shape
    J, K = B.shape
    K, L C.shape
a   D = np.zeros((__I__, __J__))
    for i = range(I) :
        for j = range(J):
            for k = range(K):
                for l = range(L):
b                   D[_I_,_J_]  += A[_i_,_k_] * B[_k_,_l_] * C[_l_,_j_]
```

Math → Code → Calculate by hand

Complete the two missing lines of code

$$Y = \sum_{i=0}^{i-1} X_{ii}$$

```
I, I = X.shape
a  Y = np.zeros(I)
for i = range(I):
b    y[i] = x[i,i]
```

Given X, what is Y?

X =

3	-5	4
2	2	0
8	5	1

c Y = 6

3	2	1