

## LECTURE 7

- **Readings:** Finish Chapter 2

### Lecture outline

- Multiple random variables
  - Joint PMF
  - Conditioning
  - Independence
- More on expectations
- Binomial distribution revisited
- A hat problem

## Review

$$p_X(x) = \mathbf{P}(X = x)$$

$$p_{X,Y}(x,y) = \mathbf{P}(X = x, Y = y)$$

$$p_{X|Y}(x | y) = \mathbf{P}(X = x | Y = y)$$

$$p_X(x) = \sum_y p_{X,Y}(x,y)$$

$$p_{X,Y}(x,y) = p_X(x)p_{Y|X}(y | x)$$

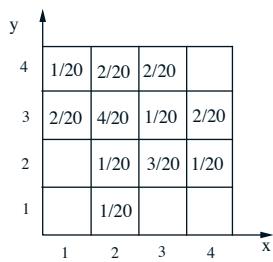
### Independent random variables

$$p_{X,Y,Z}(x,y,z) = p_X(x)p_{Y|X}(y | x)p_{Z|X,Y}(z | x,y)$$

- Random variables  $X, Y, Z$  are independent if:

$$p_{X,Y,Z}(x,y,z) = p_X(x) \cdot p_Y(y) \cdot p_Z(z)$$

for all  $x, y, z$



- Independent?
- What if we condition on  $X \leq 2$  and  $Y \geq 3$ ?

### Expectations

$$\mathbf{E}[X] = \sum_x x p_X(x)$$

$$\mathbf{E}[g(X, Y)] = \sum_x \sum_y g(x, y) p_{X,Y}(x, y)$$

- In general:  $\mathbf{E}[g(X, Y)] \neq g(\mathbf{E}[X], \mathbf{E}[Y])$
- $\mathbf{E}[\alpha X + \beta] = \alpha \mathbf{E}[X] + \beta$
- $\mathbf{E}[X + Y + Z] = \mathbf{E}[X] + \mathbf{E}[Y] + \mathbf{E}[Z]$
- If  $X, Y$  are independent:
  - $\mathbf{E}[XY] = \mathbf{E}[X]\mathbf{E}[Y]$
  - $\mathbf{E}[g(X)h(Y)] = \mathbf{E}[g(X)] \cdot \mathbf{E}[h(Y)]$

## Variances

- $\text{Var}(aX) = a^2\text{Var}(X)$

- $\text{Var}(X + a) = \text{Var}(X)$

- Let  $Z = X + Y$ .

If  $X, Y$  are independent:

$$\text{Var}(X + Y) = \text{Var}(X) + \text{Var}(Y)$$

- Examples:

- If  $X = Y$ ,  $\text{Var}(X + Y) =$

- If  $X = -Y$ ,  $\text{Var}(X + Y) =$

- If  $X, Y$  indep., and  $Z = X - 3Y$ ,  
 $\text{Var}(Z) =$

## Binomial mean and variance

- $X = \#$  of successes in  $n$  independent trials

- probability of success  $p$

$$E[X] = \sum_{k=0}^n k \binom{n}{k} p^k (1-p)^{n-k}$$

- $X_i = \begin{cases} 1, & \text{if success in trial } i, \\ 0, & \text{otherwise} \end{cases}$

- $E[X_i] =$

- $E[X] =$

- $\text{Var}(X_i) =$

- $\text{Var}(X) =$

## The hat problem

- $n$  people throw their hats in a box and then pick one at random.

- $X$ : number of people who get their own hat

- Find  $E[X]$

$$X_i = \begin{cases} 1, & \text{if } i \text{ selects own hat} \\ 0, & \text{otherwise.} \end{cases}$$

- $X = X_1 + X_2 + \dots + X_n$

- $P(X_i = 1) =$

- $E[X_i] =$

- Are the  $X_i$  independent?

- $E[X] =$

## Variance in the hat problem

- $\text{Var}(X) = E[X^2] - (E[X])^2 = E[X^2] - 1$

$$X^2 = \sum_i X_i^2 + \sum_{i,j:i \neq j} X_i X_j$$

- $E[X_i^2] =$

$$P(X_1 X_2 = 1) = P(X_1 = 1) \cdot P(X_2 = 1 | X_1 = 1)$$

$$=$$

- $E[X^2] =$

- $\text{Var}(X) =$

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