

Stats 110 Notes

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1 Lecture 1: Probability and Counting

1.1 Notes

- A **Sample Space** is the set of all possible outcomes of an experiment
- An **event** is a subset of the sample space.
- **Naive Definition of Probability:**

$$P(A) = \frac{\# \text{ of favorable outcomes}}{\# \text{ possible outcomes}}$$

- **The Multiplication Rule** - if you have experiment with n possible outcomes, and for each outcome of the first experiment there are n outcomes for the second experiments, ..., for each r^{th} experiment there are n_r outcomes, then there are $n_1 * n_2 * ... * n_r$ overall possible outcomes. Assumes all outcomes are equally likely within a finite sample space

- **Binomial Coefficient:**

$$\binom{n}{k} = \frac{n!}{(n-k)!k!}$$

0 if $k > n$

How do you get there? Number of subsets of size k of group n . Choosing k from n in order: $n * (n - 1)(n - 2) * \dots * (n - k + 1)$ Now if order does not matter: $\frac{n * (n - 1)(n - 2) * \dots * (n - k + 1)}{k!}$ Now through canceling we reach the formula for the binomial coefficient.

1.2 Example: Full House, 5 Card Hand

There are 13 suits. We must choose one suit then 3 of the 4 possible cards. Then we must choose another suit of the remaining 12, then select 2 of the 4 possible cards. Then divide by the sample space which is all possible 5 card hands from a deck of 52 cards.

$$\frac{13 \binom{4}{3} * 12 \binom{4}{2}}{\binom{52}{5}}$$

1.3 Sampling Table

Sampling Table		
	Order Matters	Order Doesn't Matter
Replace	n^k	$\binom{n+k-1}{k}$
Don't Replace	$n(n - 1)(n - 2) \dots (n - k + 1)$	$\binom{n}{k}$

2 Lecture 2: Story Proofs, Axioms of Probability

2.1 Notes

- Classic and Fundamental Relationship:

$$\binom{n}{k} = \binom{n}{n-k}$$

- Exploring picking k times from set of n objects with replacement where order doesn't matter. Let's try out a few cases:

Exploration

- Case 1: $k = 0 \rightarrow \binom{n-1}{0} = 1$
- Case 2: $k = 1 \rightarrow \binom{n}{1} = n$
- Case 3 (Simplest non-trivial example): $n = 2 \rightarrow \binom{k+1}{k} = \binom{k+1}{1} = k + 1$
- This is equivalent to the number of ways to put k indistinguishable particles into n distinguishable boxes, which can be visualized as such:

$$\cdots || \cdots | \cdot$$

The $|$ represent partitions for the 'boxes' and the \cdot is a particle. There are then k \cdot 's and $n - 1$ $|$'s. This can be simplified again to be thought of just arranging symbols, and you are choosing to place the symbols. There are $k+n-1 = n+k-1$ symbols, so choose where to place the separators or the particles. Choose where the \cdot 's are, and the $|$'s are then positioned, and vice versa.

$$\binom{n+k-1}{k} = \binom{n+k-1}{n-1}$$

- **Story Proof:** proof by interpretation.

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$$n \binom{n-1}{k-1} = k \binom{n}{k}$$

Pick k people out of n with designated as the president, so you can first pick the president out of n , then select who can be in the club. Or you can pick the club k out of n then choose the president from the k people.

- **Vandermonde Identity:**

$$\binom{m+n}{k} = \sum_{j=0}^k \binom{m}{j} \binom{n}{k-j}$$

You have two groups with labeled people containing m and n people. You need to select k people total from both groups. The summation refers to the combinations of selecting j from m and $k-j$ from n such that you have $j+k-j = k$ total people from the $m+n$ total people in two groups. Each instance is multiplied together due to the multiplication rule.

- **The Non-Naive Definition of Probability**

- A probability sample consists of \mathbf{S} and \mathbf{P} where \mathbf{S} is a sample space and \mathbf{P} , a function which takes an event $A \subseteq S$ as input and returns $P(A) \in [0,1]$ as output such that:

- * (1) $P(\emptyset) = 0, P(S) = 1$

- * (2)

$$P(\cup_{n=1}^{\infty} A_n) = \sum_{n=1}^{\infty} P(A_n)$$

if A_1, A_2, \dots, A_n are disjoint.