

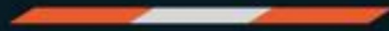


ACADGILD

Mastering Data
Science



Statistics



Session 6 – Introduction to Statistics



Agenda

- 1 Statistics
- 2 Introduction to Basic Terms
- 3 Variables
- 4 Mean, Median and Mode
- 5 Measure of Dispersion
- 6 Range
- 7 Sample Variance
- 8 Standard Deviation
- 9 Population Vs. Sample
- 10 Chebysheff's Theorem
- 11 Law of Expected Values and Variance
- 12 Probability Density Function

- Statistics is the science of collecting, organizing, presenting, analyzing, and interpreting data to help in making more effective decisions.
- Statistical Analysis is implemented to manipulate, summarize and investigate data, so that useful decision-making information results are obtained.

- Descriptive Statistics is a method of organizing, summarizing, and presenting data in an informative way.
- Inferential Statistics is a method which is used in determining something about a population on the basis of a sample.
 - Population - The entire set of individuals or objects of interest or the measurements obtained from all individuals or objects of interest.
 - Sample –A portion, or part, of the population of interest.

- Population - A collection/ set of individuals/ objects/ events whose properties are to be analyzed. There are two kinds:
 - Finite
 - Infinite
- Sample - A population subset.

- Variable - A **characteristic** about each individual element of a population/ sample.
- Data (singular) - A **value** of the associated variable with one element of a population/ sample. This value may be a number, a word, or a symbol.
- Data (plural) - A **set of values** collected for the variable from each of the elements belonging to the sample.
- Experiment - A **planned activity** whose results yield a set of data.
- Parameter - A **numerical value** which summarizes the entire population data.
- Statistics - A **numerical value** which summarizes the sample data.

Qualitative, or Attribute, or Categorical, Variable

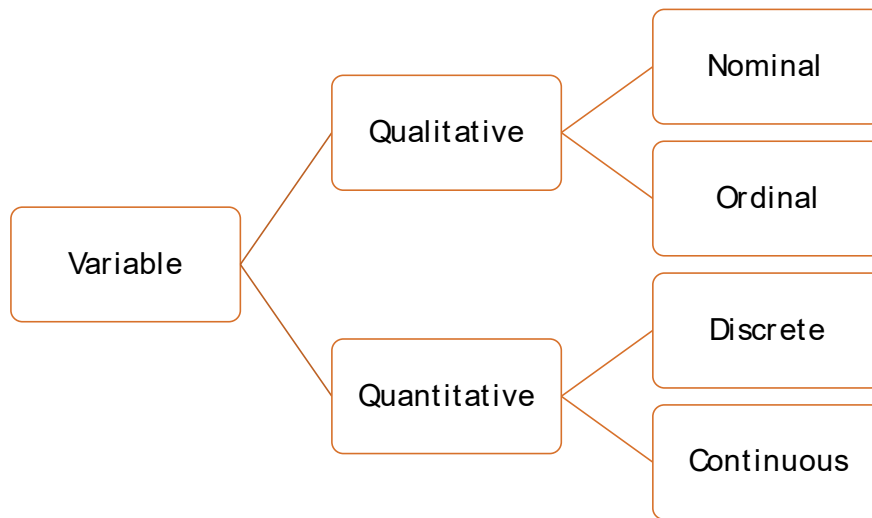
➤ A variable that categorizes or describes a population element.

Note: Arithmetic operations such as addition and averaging, are not meaningful for data resulting from a qualitative variable.

Quantitative, or Numerical, Variable

➤ A variable that quantifies a population element.

Note: Arithmetic operations such as addition and averaging, are meaningful for data resulting from a quantitative variable.



- Nominal Variable - A **qualitative variable** that categorizes (or describes, or names) a population element.
- Ordinal Variable - A **qualitative variable** that incorporates an ordered position or ranking.
- Discrete Variable - A **quantitative variable** that can assume a countable number of values.
 - This can assume values corresponding to the isolated points along a line interval.
 - There is a gap between any two values
- Continuous Variable - A **quantitative variable** that can assume an uncountable number of values.
 - This can assume any value along a line interval
 - Including every possible value between any two values

➤ Let $x_1, x_2, x_3, \dots, x_n$ be the realized values of a random variable 'X', from a sample of size 'n'.

The **sample arithmetic mean** is defined as:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

Example

➤ The systolic blood pressure of seven middle aged men were as follows:

151, 124, 132, 170, 146, 124 and 113.

$$\begin{aligned}\text{The Mean is } \bar{x} &= \frac{(151 + 124 + 132 + 170 + 146 + 124 + 113)}{7} \\ &= 137.14\end{aligned}$$

- The median for the sample data arranged in an increasing order is defined as:
 - i. If “n” is an odd number - Middle value
 - ii. If “n” is an even number - Midway between the two middle values
- The mode is the most commonly occurring value.

Example - n is odd

The re-ordered systolic blood pressure data seen earlier are:

113, 124, 124, 132, 146, 151, and 170.

- The **Median** is the middle value of the ordered data, i.e. 132.
- Two individuals have systolic blood pressure = 124 mm Hg, so the **Mode** is 124.

Example – n is even

Six men with high cholesterol participated in a study to investigate the effects of diet on cholesterol level. At the beginning of the study, their cholesterol levels (mg/ dL) were as follows:

366, 327, 274, 292, 274 and 230

Rearrange the data in numerical order as follows:

230, 274, 274, 292, 327 and 366.

- The **Median** is half way between the middle two readings, i.e. $(274+292) / 2 = 283$.
- The **mode** between the two men having the same cholesterol level = 274.

- If the histogram of the data is **right-skewed** then large sample values tend to inflate the mean.
- If the distribution is **skewed** then the median is not influenced by large sample values and is a better measure of centrality.

Note - If **mean = median = mode** then the data are said to be symmetrical.

For example,

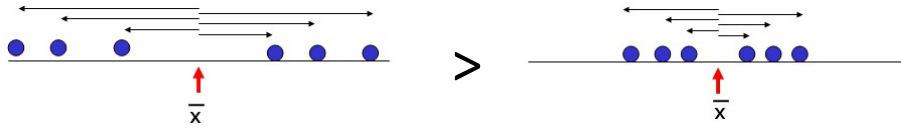
- In the CK measurement study, the sample mean = 98.28.
- The median = 94.5, i.e. mean is larger than median indicating that mean is inflated by two large data values 201 and 203.

- The concept **Measures of Dispersion** characterize how to spread out the distribution, i.e., how variable the data are.
- The commonly used dispersion measures include:
 - Range
 - Variance and Standard Deviation

- The **Range** is the difference between the largest and the smallest observations in the sample.
- For example, the minimum and maximum blood pressure is 113 and 170 respectively. Hence the **range** is 57 mmHg
 - Easy to calculate;
 - Implemented for both “best” or “worst” case scenarios
 - Too sensitive for extreme values

➤ The sample variance, s^2 , is the **arithmetic mean** of the squared deviations from the sample mean:

$$s^2 = \frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}$$



- The sample standard deviation (s) is the **square-root of the variance**.

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

- The sample standard deviation has an advantage of being in the same units as the **original variable (x)**.

$$\mu = \frac{\sum_{i=1}^N x_i}{N}$$

Population Mean

Vs.

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

Sample Mean

	Population	Sample
Size	N	n
Mean		

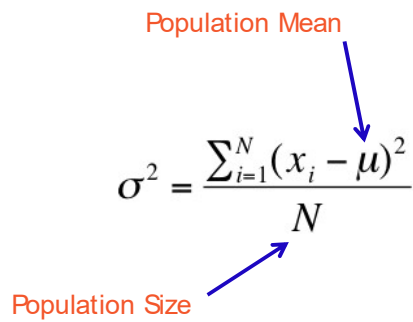
	Population	Sample
Size	N	n
Mean		
Variance		

➤ The variance of a population is:

$$\sigma^2 = \frac{\sum_{i=1}^N (x_i - \mu)^2}{N}$$

Population Mean

Population Size

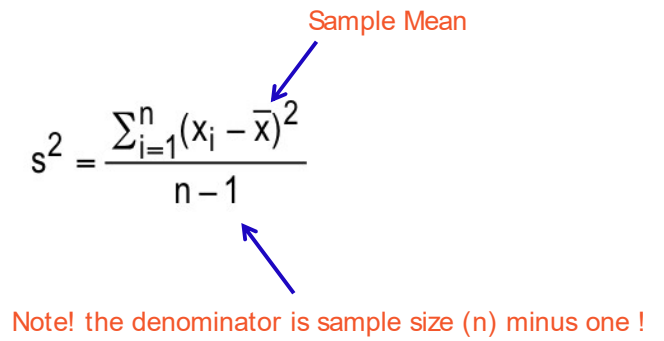


➤ The variance of a sample is:

$$s^2 = \frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}$$

Sample Mean

Note! the denominator is sample size (n) minus one !



➤ The **square root of the variance** is termed as the Standard Deviation, thus:

- The population Standard Deviation = $\sigma = \sqrt{\sigma^2}$

- The Sample Standard deviation = $s = \sqrt{s^2}$

- A more general interpretation of the standard deviation is derived from **Chebysheff's Theorem**, which applies to all shapes of histograms (except bell shaped).
- The proportion of observations in any sample that lie within k standard deviations of the mean is at least:

$$1 - \frac{1}{k^2} \text{ for } k > 1$$

For k=2 (say), the theorem states that at least 3/4 of all observations lie within 2 standard deviations of the mean. This is a “lower bound” compared to Empirical Rule's approximation (95%).

Set operations

- Union ($A \cup B$)
- Intersection ($A \cap B$)

Venn diagrams

- Basic operations on Venn diagrams

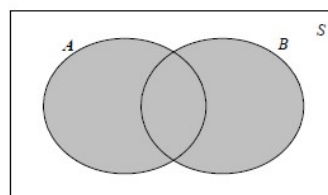
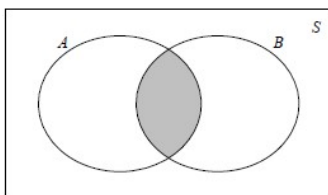
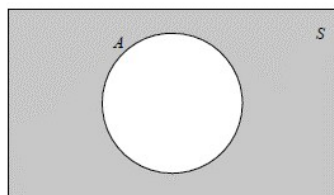
Basic probability axioms

- $P(S) = 1$
- $P(A) \geq 0$ for all $A \subseteq S$
- $P(A \cup B) = P(A) + P(B) - P(A \cap B)$

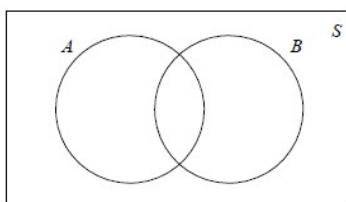
Conditional probability

- $P(A|B) = P(A \cap B) / P(B)$

Bayes theorem

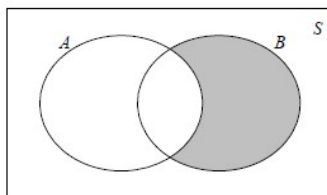


For the Venn diagram below, use shading to identify the following regions:

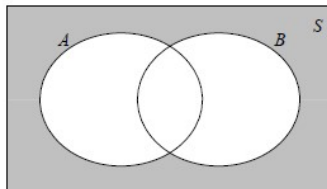


- (i) $A' \cap B$ (ii) $A' \cap B'$ (iii) $(A \cap B)'$ (iv) $(A \cup B)'$

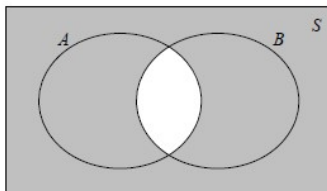
- (i) $A' \cap B$ is everything not in set A **and** in set B :



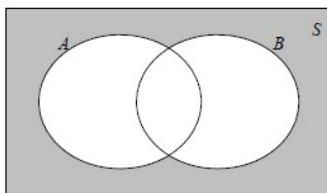
- (ii) $A' \cap B'$ is everything not in set A **and** not in set B :



- (iii) $(A \cap B)'$ is everything not in set A **and** set B (ie everything outside of the intersection of A and B).



- (iv) $(A \cup B)'$ is everything not in set A **or** set B (ie everything outside of the union of A and B).



- Strength of belief
- A number between 0 and 1 that expresses an opinion about the likelihood of an event
- Probability of an event that is certain to occur is 1
- Probability of an event that is certain to NOT occur is 0

Probability that an event will occur plus probability that it will not occur equals 1

Probability of all possible outcomes of a chance event is always equal to 1

- Blood type: What is $p[AB]$ given $p[O]=0.46$, $p[A]=.40$, and $p[B]=.10$?
- Fraternal triplets: What is the probability of at least one boy and one girl?

- Probability is a numerical way of describing how likely something is to happen.
- One of the fundamental methods of calculating probability is by using set theory.
- A set is defined as a collection of objects and each individual object is called an element of that set.
- Example from number of credit cards data, the distinct number of credit cards owned form a set
Cards = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}
- Numbers present on a dice form a set:
Dice = {1, 2, 3, 4, 5, 6}
- The sample space (S) is the set of all possible outcomes that might be observed for an event/ experiment.
- If each of the elements in the sample space are equally likely, then we can define the probability of event A as
 $P(A) = (\text{\# elements in A}) / (\text{\# elements in sample space})$
e.g. $P(\text{\# Cards} = 1) = (\text{\# of customers having 1 card}) / (\text{Total number of customers}) = 100 / 1000 = 0.10 = 10\%$
e.g. Probability of rolling an even number on a dice
Sample space (S) = {1, 2, 3, 4, 5, 6}
Event (A) = {2, 3, 4}
 $P(A) = 3 / 6 = 0.5 = 50\%$

Why is it important from analytics perspective?

- What we do: analyze historical data to find pattern under assumption that past is a reflection of future.
- By means of probability theory, predict the future using historical patterns.

Find the probability of rolling an even number on an ordinary dice

Solution

We have a sample space of $S = \{1, 2, 3, 4, 5, 6\}$.

Defining “throwing an even number” as event A , we have $A = \{2, 4, 6\}$.

So the probability of throwing an even number is given by:

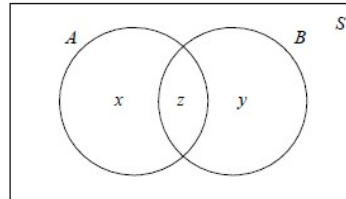
$$P(A) = [\text{number of elements in } A] / [\text{number of elements in } S] = 3/6 = 0.5$$

One card is picked from an ordinary pack of 52 playing cards. What is the probability of obtaining:

- (i) a diamond
- (ii) an ace
- (iii) the ace of diamonds
- (iv) a jack, queen or king.

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

On a Venn diagram we have:



It can be seen that $P(A) = x + z$, and $P(B) = y + z$

$$\begin{aligned} P(A \cup B) &\text{ can also be expressed as } P(A' \cap B) + P(A \cap B') + P(A \cap B) \\ &= x + y + z \\ &= (x + z) + (y + z) - z \\ &= P(A) + P(B) - P(A \cap B) \end{aligned}$$

$$P(A|B) = \frac{P(A \cap B)}{P(B)}$$

$$P(A \cap B) = P(B)P(A|B)$$

$$P(A|B) = \frac{P(A \cap B)}{P(A \cap B) + P(A' \cap B)}$$

A and B are independent if $P(A) = P(A|B) = P(A|B')$

Given that:

$$P(A|B) = \frac{P(A \cap B)}{P(B)}$$

Then if A and B are independent:

$$P(A \cap B) = P(A)P(B)$$

Example

Two dice are thrown. Find the probability of rolling a 5 on both dice.

Solution

$$A = \{\text{roll a 5 on the 1st dice}\} \Rightarrow P(A) = \frac{1}{6}$$

$$B = \{\text{roll a 5 on the 2nd dice}\} \Rightarrow P(B) = \frac{1}{6}$$

Since these events are independent:

$$P(A \cap B) = P(A)P(B) = \frac{1}{6} \times \frac{1}{6} = \frac{1}{36}$$

Consider our previous example of picking a card from an ordinary pack of cards:

$$A = \{\text{pick a spade}\} \qquad B = \{\text{pick an 8}\}$$

Calculate the probability of picking a spade *given* that we have picked an 8, *ie* calculate $P(A|B)$.

Solution

We obtain the same answer as before – but our calculation is much simpler:

$$A \cap B = \{8 \text{ of spades}\} \Rightarrow P(A \cap B) = \frac{1}{52}$$

$$B = \{\text{pick an 8}\} \Rightarrow P(B) = \frac{4}{52}$$

$$\Rightarrow P(A|B) = \frac{P(A \cap B)}{P(B)} = \frac{\frac{1}{52}}{\frac{4}{52}} = \frac{1}{4}$$

Bayes Theorem

Most common form:

$$P(F | E) = \frac{P(E | F)P(F)}{P(E)}$$

Expanded form (using law of total probability):

$$P(F | E) = \frac{P(E | F)P(F)}{P(E | F)P(F) + P(E | F^c)P(F^c)}$$

Proof:

$$P(F | E) = \frac{P(EF)}{P(E)} = \frac{P(E | F)P(F)}{P(E)}$$

Suppose an HIV test is 98% effective in detecting HIV, i.e., its “false negative” rate = 2%. Suppose furthermore, the test’s “false positive” rate = 1%.

0.5% of population has HIV

Let E = you test positive for HIV

Let F = you actually have HIV

What is $P(F|E)$?

Suppose an HIV test is 98% effective in detecting HIV, i.e., its “false negative” rate = 2%. Suppose furthermore, the test’s “false positive” rate = 1%.

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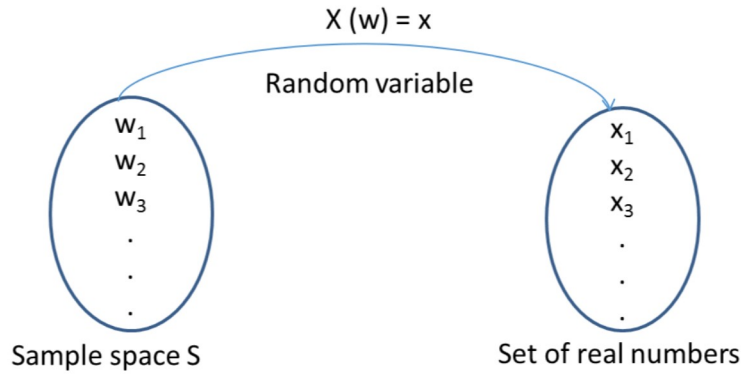
Solution:

$$\begin{aligned} P(F | E) &= \frac{P(E | F)P(F)}{P(E | F)P(F) + P(E | F^c)P(F^c)} \\ &= \frac{(0.98)(0.005)}{(0.98)(0.005) + (0.01)(1 - 0.005)} \\ &\approx 0.330 \end{aligned}$$

- I. Definition
- II. Types of Random Variables
 - 1. Discrete
 - 2. Continuous
- III. Distribution and Probability Density functions of Random Variables
- IV. Expected value (or Mean) of Random Variables
- V. Variance of Random Variables
- VI. Coefficient of skewness of Random Variables

3.b. Random variables- Definition

➤ A random variable is a function or a rule which maps each event in a sample space to real numbers.



➤ So, if w is an element of the sample space S (i.e. w is one of the possible outcomes of the experiment concerned) and the number x is associated with this outcome, then $X(w) = x$.

➤ Convention:

- Denote random variable by capital letter “ X ”
- Denote the outcome or possible values by small letter “ x ” i.e. $X(w) = x$

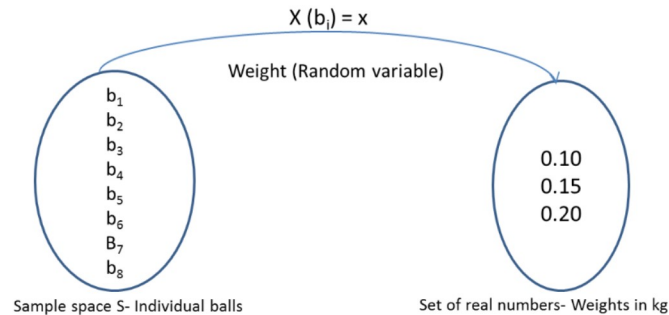
3.b. Random variables- Definition

Example:

- Suppose there are 8 balls in a bag. The random variable X is the weight, in kg, of a ball selected at random. Balls 1, 2 and 3 weigh 0.1kg, balls 4 and 5 weigh 0.15kg and balls 6, 7 and 8 weigh 0.2kg. Using the notation above, write down this information.

Solution:

- $X(b_1) = 0.10$ kg, $X(b_2) = 0.10$ kg, $X(b_3) = 0.1$ kg
 $X(b_4) = 0.15$ kg, $X(b_5) = 0.15$ kg
 $X(b_6) = 0.2$ kg, $X(b_7) = 0.2$ kg



There are two types of Random Variables

1. Discrete Random Variables
2. Continuous Random Variables

Definition:

- The set of all possible values of the outcome (or x) takes discrete values
 - e.g. Outcome of rolling a dice = $\{1, 2, 3, 4, 5, 6\}$
 - Or # credit cards owned by an individual = $\{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$

Probabilities:

- Probabilities are defined on events (subsets of the sample space S).

So what is meant by " $P(X = x)$ " ?

- Suppose sample space consists of eight events $\{s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8\}$
- Let the outcome for
 - $E1 = \{s_1, s_2, s_3\}$ be associated with number $x1$
 - $E2 = \{s_4, s_5\}$ be associated with number $x2$
 - $E3 = \{s_6, s_7, s_8\}$ be associated with number $x3$
- $P(X = x1)$ is meant $P(E1)$
- $P(X = x2)$ is meant $P(E2)$
- $P(X = x3)$ is meant $P(E3)$

Probability functions

- The function $f_X(x) = P(X = x)$ for each x in the range of X is the probability function (PF) of X
- It specifies how the total probability of 1 is divided up amongst the possible values of X
- Thus, gives the probability distribution of X
- Also known as “probability distribution functions” (pdf)

Following are the requirements for a function to qualify as the probability function of a discrete random variable:

- $f_X(x) \geq 0$ for all x within the range of X
- $\sum f_X(x) = 1$

Cumulative distribution functions

- Gives the probability that X assumes a value that does not exceed x .
- Denoted as $F_X(x) = P(X \leq x)$ where $\max(F_X(x)) = 1$

3.b. Discrete Random variables- Probability

Example:

- Suppose there are 8 balls in a bag. The random variable X is the weight, in kg, of a ball selected at random. Balls 1, 2 and 3 weigh 0.1kg, balls 4 and 5 weigh 0.15kg and balls 6, 7 and 8 weigh 0.2kg. Write down the different probability distribution functions.

Solution:

➤ $f_X(0.10) = P(X=0.10) = \text{probability the ball } b_1 \text{ or } b_2 \text{ or } b_3 \text{ is selected out of 8 balls} = 3/8$

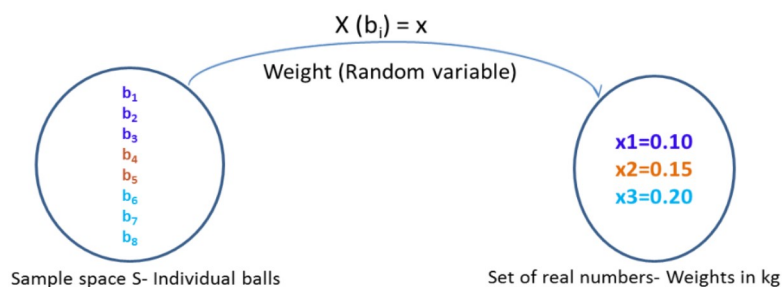
➤ $f_X(0.15) = P(X=0.15) = \text{probability the ball } b_4 \text{ or } b_5 \text{ is selected out of 8 balls} = 2/8$

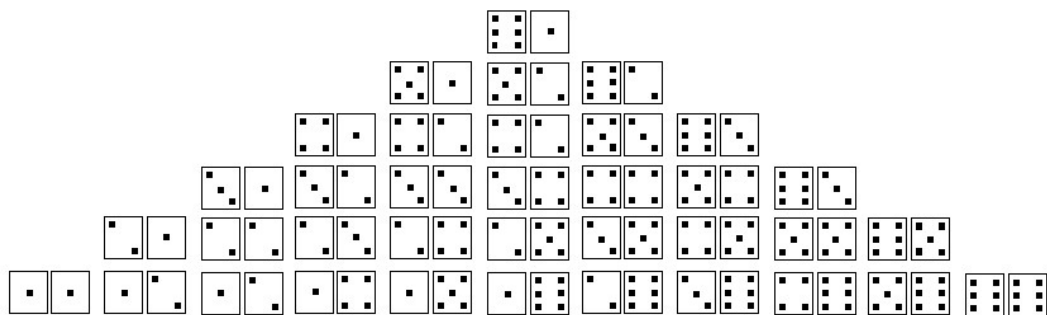
➤ $f_X(0.20) = P(X=0.20) = \text{probability the ball } b_6 \text{ or } b_7 \text{ or } b_8 \text{ is selected out of 8 balls} = 3/8$

➤ $F_X(0.10) = P(X \leq 0.10) = P(X=0.10) = 3/8$

➤ $F_X(0.15) = P(X \leq 0.15) = P(X=0.10) + P(X=0.15) = 2/8 + 3/8 = 5/8$

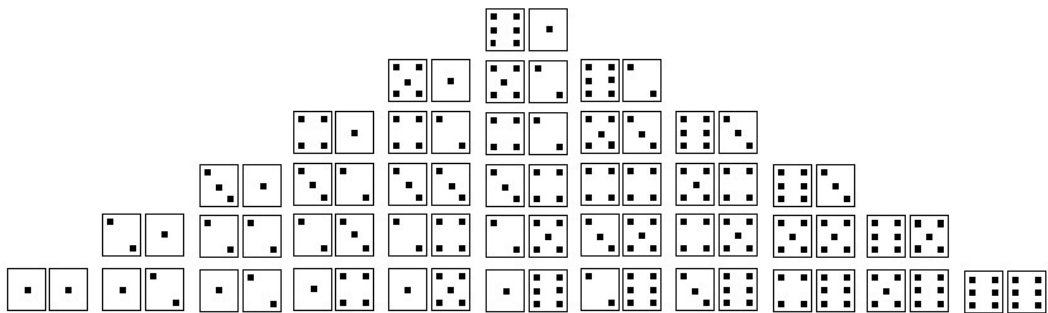
➤ $F_X(0.20) = P(X \leq 0.20) = P(X=0.10) + P(X=0.15) + P(X=0.20) = 3/8 + 2/8 + 3/8 = 8/8 = 1$





Value (x_i)	2	3	4	5	6	7	8	9	10	11	12
Freq (n_i)	1	2	3	4	5	6	5	4	3	2	1
Prob (p_i)	$\frac{1}{36}$	$\frac{2}{36}$	$\frac{3}{36}$	$\frac{4}{36}$	$\frac{5}{36}$	$\frac{6}{36}$	$\frac{5}{36}$	$\frac{4}{36}$	$\frac{3}{36}$	$\frac{2}{36}$	$\frac{1}{36}$

- The cumulative distribution represents the summation of the probabilities.
- The number 2 occurs $1/36$ of the time, the number 3 occurs $2/36$ of the time.
- Therefore a number equal to 3 or less will occur $3/36$ of the time.



Value	2	3	4	5	6	7	8	9	10	11	12
Prob (p _i)	$\frac{1}{36}$	$\frac{2}{36}$	$\frac{3}{36}$	$\frac{4}{36}$	$\frac{5}{36}$	$\frac{6}{36}$	$\frac{5}{36}$	$\frac{4}{36}$	$\frac{3}{36}$	$\frac{2}{36}$	$\frac{1}{36}$
Cdf	$\frac{1}{36}$	$\frac{3}{36}$	$\frac{6}{36}$	$\frac{10}{36}$	$\frac{15}{36}$	$\frac{21}{36}$	$\frac{26}{36}$	$\frac{30}{36}$	$\frac{33}{36}$	$\frac{35}{36}$	$\frac{36}{36}$

- The probabilities form a pdf. The sum of the probabilities must sum to 1.
- The distribution can be characterized by two variables, its mean and standard deviation

$$\sum_{i=1}^n p_i = 1$$

- The mean is simply the expected value from rolling the dice, this is calculated by multiplying the probabilities by the possible outcomes (values).
- In this case it is also the value with the highest frequency (mode)

$$E(x) = \sum_{i=1}^{11} p_i x_i = \frac{252}{36} = 7$$

3.b. Continuous Random variables



Definition:

- > The set of possible values taken by a continuous random variable falls in an interval (or a collection of intervals) on the real line:
 - > e.g. Salary of a set of individuals
 - > Mathematically examples $\{x: x > 0\}$ or $\{x: -\infty < x < \infty\}$ or $\{x: 0 < x < 1\}$

Probability Density Function

- > First define the range or the interval in which the probability has to be determined.
- > Say its (a, b).
- > The probability associated is represented as $P(a < X < b)$ or $P(a \leq X \leq b)$.
- > Also, it is the area under the curve of the probability density function (PDF) from a to b.
- > So probabilities can be evaluated by integrating the PDF $f_X(x)$.

This relationship defines the PDF.

Mathematically

$$> P(a < X < b) = \int_a^b f_X(x) dx$$

The conditions for a function to serve as PDF are

- > $f_X(x) \geq 0 - \infty \leq x \leq \infty$
- > $\int_{-\infty}^{\infty} f_X(x) dx = 1$

3.b. Continuous Random variables



Cumulative distribution function:

➤ The cumulative distribution function (CDF) is defined to be the function:

$$➤ F_X(x) = P(X \leq x)$$

➤ For a continuous random variable, $F_X(x)$ is a continuous, non-decreasing function, defined for all real values of x .

$$➤ F_X(x) = \int_{-\infty}^x f_X(t) dt$$

Definition:

- Expected values are numerical summaries of important characteristics of the distributions of random variables.
- Expected values of a Random Variable “X” is denoted as $E[X]$
- Important Expected values are
 - Mean
 - Variance and Standard deviation

Mean:

- $E[X]$ is a measure of central location
- For discrete case calculated as $E[X] = \sum (x_i * P_i)$ OR $E[X] = (\sum x * f_X(x))$
- For continuous case calculated as $E[X] = \int_{-\infty}^{\infty} x * f_X(x) dx$
- Usually denoted by μ

Variance:

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

Population mean (or expectation)

$$\mu = E(X) = \sum_x xP(X=x) \quad \text{or} \quad \int_{-\infty}^{\infty} xf_X(x) dx$$

$$E[g(X)] = \sum_x g(x)P(X=x) \quad \text{or} \quad \int_{-\infty}^{\infty} g(x)f_X(x) dx$$

Population variance

$$\sigma^2 = \text{var}(X) = E[(X - \mu)^2] = E(X^2) - E^2(X)$$

3.b. Random variables- Expected values

Example:

➤ Suppose there are 8 balls in a bag. The random variable X is the weight, in kg, of a ball selected at random. Balls 1, 2 and 3 weigh 0.1kg, balls 4 and 5 weigh 0.15kg and balls 6, 7 and 8 weigh 0.2kg. Find mean and variance of weight.

Solution:

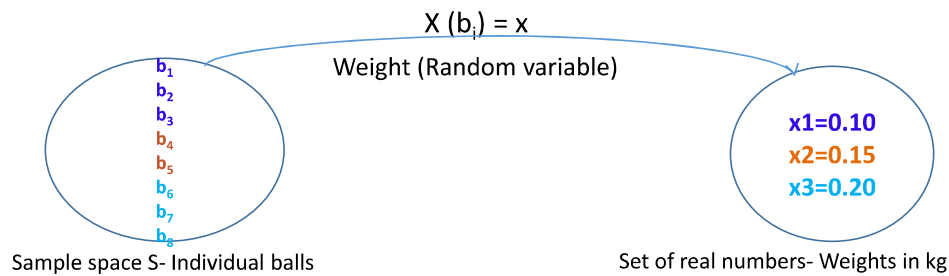
➤ $f_X(0.10) = P(X=0.10) = 3/8$

➤ $f_X(0.15) = P(X=0.15) = 2/8$

➤ $f_X(0.20) = P(X=0.20) = 3/8$

➤ $E[X] = \sum p_i \cdot x_i = 3/8 \cdot 0.10 + 2/8 \cdot 0.15 + 3/8 \cdot 0.20 = 1.2/8 = 0.15 \text{ kg}$

➤ $\text{Var}[X] = E[X^2] - E^2[X] = 0.024375 - 0.0225 = 0.001875 \text{ kg}^2$



Discrete Random Variable

- Takes on a **countable number** of values
- For example, values on the roll of dice: 2, 3, 4, ..., 12

Continuous Random Variable

- Values are not **discrete**, not **countable**
- For example, time (30.1 minutes? 30.10000001 minutes?)

Analogy

- Integers are **discrete**, while Real Numbers are **Continuous**

➤ $E(C) = C$

- The expected Value of a Constant is just the value of the constant.

➤ $E(X + C) = E(X) + C$

➤ $E(CX) = cE(X)$

- We can “pull” a constant out of the expected value expression (either as part of a sum with a random variable X or as a coefficient of random variable X).

➤ $V(c) = 0$

- The Variance of constant (c) is zero.

➤ $V(X + c) = V(X)$

- The Variance of random variable and a constant is just the variance of the random variable (per 1 above).

➤ $V(cX) = c^2 V(X)$

- The Variance of a random variable and a constant co-efficient is the co-efficient squared times in the variance of the random variable.

Unlike a discrete random variable, a continuous random variable is one that can assume an uncountable number of values.

- We cannot list the possible values because there is an infinite number of them.
- The probability of each individual value is virtually 0 as there is an infinite number of values

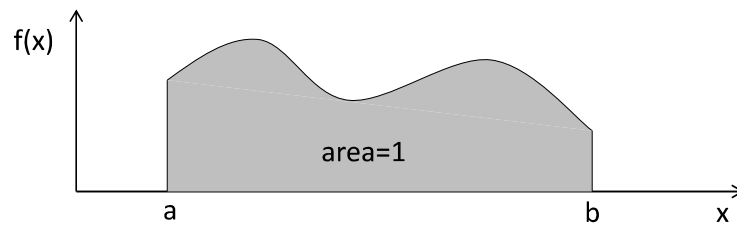
If the probability of each individual value is virtually 0 then there is an infinite number of values.

Thus, we can determine the probability of a range of values only.

- For example, with a **discrete** random variable like tossing a die, it is meaningful to talk about $P(X=5)$
- In a **continuous** setting (e.g. with time as a random variable), the probability the random variable of interest say task length, takes exactly 5 minutes is infinitely small, hence $P(X=5) = 0$.

A function $f(x)$ is called a Probability Density Function over the range $a \leq x \leq b$ if it meets the following requirements:

1. $f(x) \geq 0$ for all x between a and b , and



2. The total area under the curve between a and b is 1.0



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