

How to Understand the Difference Between CDF and PDF

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CDF (Cumulative Distribution Function) and PDF (Probability Density Function) are two mathematical functions used to describe the distribution of a continuous random variable.

The CDF gives the cumulative probability of a random variable taking on a value less than or equal to a specific value. It represents the total area under the probability density curve up to that point. In other words, the CDF shows the probability of a random variable being less than or equal to a certain value.

On the other hand, the PDF gives the probability of a random variable taking on a specific value. It represents the height of the probability density curve at a particular point. In other words, the PDF shows the likelihood of a random variable being equal to a certain value.

In summary, the main difference between CDF and PDF is that the CDF gives the cumulative probability while the PDF gives the probability at a specific point. Both functions are important tools for understanding and analyzing random variables in statistics and probability.

CDF vs. PDF: What's the Difference?

This tutorial provides a simple explanation of the difference between a PDF (probability density function) and a CDF (cumulative distribution function) in statistics.

Random Variables

Before we can define a PDF or a CDF, we first need to understand random variables.

A , usually denoted as X , is a variable whose values are numerical outcomes of some random process. There are two types of random variables: discrete and continuous.

Discrete Random Variables

A discrete random variable is one which can take on only a countable number of distinct values like 0, 1, 2, 3, 4, 5...100, 1 million, etc. Some examples of discrete random variables include:

The number of times a coin lands on tails after being flipped 20 times. The number of times a dice lands on the number 4 after being rolled 100 times.

Continuous Random Variables

A continuous random variable is one which can take on an infinite number of possible values. Some examples of continuous random variables include:

Height of a person
Weight of an animal
Time required to run a mile

For example, the height of a person could be 60.2 inches, 65.2344 inches, 70.431222 inches, etc. There are an infinite amount of possible values for height.

Rule of Thumb: If you can count the number of outcomes, then you are working with a discrete random

variable (e.g. counting the number of times a coin lands on heads). But if you can measure the outcome, you are working with a continuous random variable (e.g. measuring, height, weight, time, etc.)

Probability Density Functions

A probability density function (pdf) tells us the probability that a random variable takes on a certain value.

For example, suppose we roll a dice one time. If we let x denote the number that the dice lands on, then the probability density function for the outcome can be described as follows:

$$P(x < 1) : 0$$

$$P(x = 1) : 1/6$$

$$P(x = 3) : 1/6$$

$$P(x = 4) : 1/6$$

$$P(x = 5) : 1/6$$

$$P(x = 6) : 1/6$$

$$P(x > 6) : 0$$

Note that this is an example of a discrete random variable, since x can only take on integer values.

For a continuous random variable, we cannot use a PDF directly, since the probability that x takes on any exact value is zero.

For example, suppose we want to know the probability that a burger from a particular restaurant weighs a quarter-pound (0.25 lbs). Since *weight* is a continuous variable, it can take on an infinite number of values.

For example, a given burger might actually weight 0.250001 pounds, or 0.24 pounds, or 0.2488 pounds. The probability that a given burger weights exactly .25 pounds is essentially zero.

Cumulative Distribution Functions

A cumulative distribution function (cdf) tells us the probability that a random variable takes on a value less than or equal to x .

For example, suppose we roll a dice one time. If we let x

denote the number that the dice lands on, then the cumulative distribution function for the outcome can be described as follows:

$$P(x \leq 0) : 0$$

$$P(x \leq 1) : 1/6$$

$$P(x \leq 2) : 2/6$$

$$P(x \leq 3) : 3/6$$

$$P(x \leq 4) : 4/6$$

$$P(x \leq 5) : 5/6$$

$$P(x \leq 6) : 6/6$$

$$P(x > 6) : 0$$

Notice that the probability that x is less than or equal to 6 is $6/6$, which is equal to 1. This is because the dice will land on either 1, 2, 3, 4, 5, or 6 with 100% probability.

This example uses a discrete random variable, but a continuous density function can also be used for a continuous random variable.

Cumulative distribution functions have the following properties:

The probability that a random variable takes on a value less than the smallest possible value is zero. For example, the probability that a dice lands on a value less than 1 is zero. The probability that a random variable takes on a value less than or equal to the largest possible value is one. For example, the probability that a dice lands on a value of 1, 2, 3, 4, 5, or 6 is one. It must land on one of those numbers. The cdf is always non-decreasing. That is, the probability that a dice lands on a number less than or equal to 1 is $1/6$, the probability that it lands on a number less than or equal to 2 is $2/6$, the probability that it lands on a number less than or equal to 3 is $3/6$, etc. The cumulative probabilities are always non-decreasing.

You can use an to visualize a cumulative distribution function.

The Relationship Between a CDF and a PDF

In technical terms, a probability density function (pdf) is the derivative of a cumulative distribution function (cdf).

Furthermore, the area under the curve of a pdf between negative infinity and x is equal to the value of x on the cdf.

For an in-depth explanation of the relationship between a pdf and a cdf, along with the proof for why the pdf is the derivative of the cdf, refer to a statistical textbook.

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