

# Stat 8003, Homework 2

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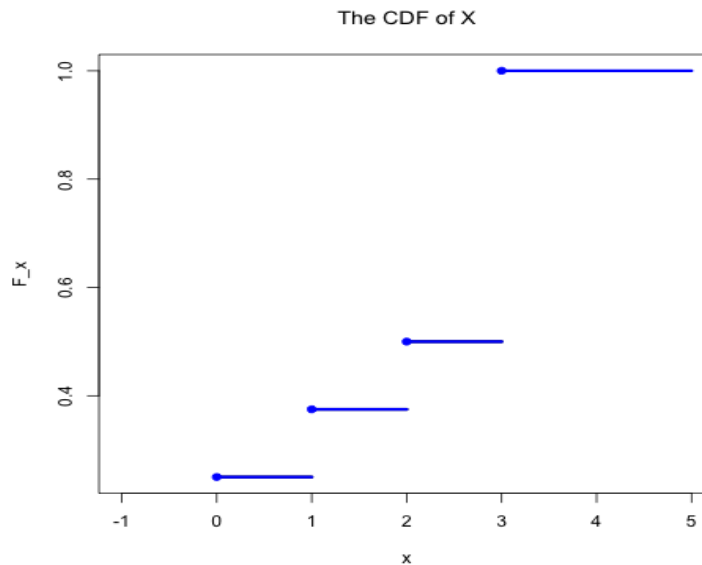
**Question 2.1.** Suppose that  $X$  is a discrete random variable with  $P(X = 0) = 0.25$ ,  $P(X = 1) = 0.125$ ,  $P(X = 2) = 0.125$ , and  $P(X = 3) = 0.5$ , Calculate the cdf of  $X$  and graph the cdf using R.

**Answer:** The cdf of  $X$ :

$$F(X) = \begin{cases} 0 & x < 0 \\ 0.25 & 0 \leq x < 1 \\ 0.375 & 1 \leq x < 2 \\ 0.5 & 2 \leq x < 3 \\ 1 & 3 \leq x < \infty \end{cases}$$

This right-continuous function changes its value at each of its ‘jump points’ by exactly the value of its pmf at the same point. For example, the jump at point  $x = 2$  is  $0.5 - 0.375 = 0.125$ , which is the same as the value of pmf at  $x = 2$ :  $P(X = 2) = 0.125$ .

This cdf looks like this:



**Question 2.1.** A certain type of cancer is known to be present in 2 percent of the population of males in their fifties. A test for the disease is advertised by a pharmaceutical company to be 3% false negative and 1% false positive.

1. Compute the probability that you have cancer if you are tested positive.
2. To make sure that you really have cancer an invasive and expensive surgery is needed. Your health insurance company is not willing to pay for this unless the pharmaceutical company improves its test in such way that that at least 90% of people who are tested positive actually have the disease. How low should be the rate of false positive for the test to reach this goal? (Assume that the rate of false negative remains the same).

**Answer:** We'll use the following notation for the given data:

- The probability of the disease being present in the population of males over fifty:  $P(D) = .02$ . (Thus 98% of this population is disease-free:  $P(D^c) = .98$ .)
- The probability of the test indicating that there is *no disease* when in fact the disease is present (false negative):  $P(T- | D) = .03$ . (Thus the probability of a *true positive*, i.e. the test indicating that there *is* disease when in fact the disease is present,  $P(T+ | D)$ , is then 97%.)
- The probability of the test indicating that there is *disease* when the disease is *not* present (false positive):  $P(T+ | D^c) = .01$
- We would like the probability  $P(D|T+)$  of a person having the disease when the test result is positive to be at least 90%.

By Bayes' rule, the probability of the disease being present when the test indicates that it is present is:

$$\begin{aligned} P(D|T+) &= \frac{P(T+|D)P(D)}{P(T+)} = \frac{P(T+|D)P(D)}{P(T+|D)P(D) + P(T+|D^c)P(D^c)} \\ &= \frac{.97 \times .02}{.97 \times .02 + .01 \times .98} \\ &= 0.664 \end{aligned}$$

We would like to increase this probability from 66% to at least 90% by decreasing the probability of the false positives. That is, we would like to make the  $P(T+|D^c)$  term in the denominator smaller. So let's solve the following inequality for  $x$ :

$$\begin{aligned} .9 &< \frac{.97 \times .02}{.97 \times .02 + x \times .98} \\ .9 &< \frac{.0194}{.0194 + 0.98x} \end{aligned}$$

$$0.01746 + 0.882x < 0.0194$$

$$0.882x < 0.00194$$

$$x < 0.002199546$$

Thus, the false positive rate should be smaller than about two in a thousand.