## Central Limit Theorem example

The central limit theorem (CLT) states that if  $X_1, X_2, \dots, X_n$  are drawn from a population with mean  $\mu$ , finite variance  $\sigma^2$ , and sample mean  $\bar{X}_n$ , then

$$Z = \lim_{n \to \infty} \sqrt{n} \left( \frac{\bar{X}_n - \mu}{\sigma} \right)$$

is a standard normal distribution. The central limit theorem can be used to estimate test statistics, which can be used to compute p-values. The two key assumptions are that the variance is finite and the sample size is large.

In the following example we flip a coin 80 times, and observe 54 heads. The question is: is this coin unfair?

- 1. Coin tosses can be thought of as samples from the Bernoulli distribution, where Tails=0 and Heads=1. We can write this as  $X \sim \text{Ber}(p)$ , where p is the probability that X = 1. For a fair coin, what is the expected value of X, i.e. E[X]?
- 2. For a fair coin, what is the variance of X, i.e. Var(X)? Use the fact that  $Var(X) = E[(X \mu)^2]$ , where  $\mu = E[X]$ .
- 3. For the example above (54 heads out of 80 tosses), what is the sample mean  $\bar{X}_n$ ?
- 4. Putting this all together and using the CLT, what is the test statistic? (use a calculator)
- 5. Sketch out the position of the test statistic on a standard normal distribution. Shade the area(s) representing the corresponding p-value.

6. Based on your diagram, do you think this coin is fair?

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