

Convergence of random variables

Ciaran Evans

Recap: convergence

Definition: A sequence of random variables X_1, X_2, \dots *converges in probability* to a random variable X if, for every $\varepsilon > 0$,

$$\lim_{n \rightarrow \infty} P(|X_n - X| \geq \varepsilon) = 0$$

We write $X_n \xrightarrow{p} X$.

Definition: A sequence of random variables X_1, X_2, \dots *converges in distribution* to a random variable X if

$$\lim_{n \rightarrow \infty} F_{X_n}(x) = F_X(x)$$

at all points where $F_X(x)$ is continuous. We write $X_n \xrightarrow{d} X$.

Central Limit Theorem

Let X_1, X_2, \dots be iid random variables, with $\mu = \mathbb{E}[X_i]$ and $\sigma^2 = \text{Var}(X_i) < \infty$. Then

$$\frac{\sqrt{n}(\bar{X}_n - \mu)}{\sigma} \xrightarrow{d} Z$$

where $Z \sim N(0, 1)$.

Other key results

Continuous mapping theorem: Let X_1, X_2, \dots be a sequence of random variables, and g a continuous function.

Slutsky's theorem: Let $\{X_n\}, \{Y_n\}$ be sequences of random variables, and suppose that $X_n \xrightarrow{d} X$ and $Y_n \xrightarrow{p} c$, where c is a constant. Then:

Relationships between types of convergence

- (a) If $X_n \xrightarrow{d} c$, where c is a constant, then $X_n \xrightarrow{p} c$
- (b) If $X_n \xrightarrow{p} X$, then $X_n \xrightarrow{d} X$