Sample LaTeX Typesetting

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Abstract

This is a sample document created in a LaTeX text editor. It demonstrates some basic LaTeX typesetting techniques necessary to write reproducible research papers such as a) writing mathematics in LaTeX; b) inserting footnotes; c) typesetting hyperlinks to navigate the document; d) adding appendix section; e) adding bibliography at the end of the document. The document uses a `.sty` file named `sample.sty`, and a `.bib` file named `sample.bib`. Both files are stored in the same directory as this file.

Meta comments are displayed in blue. They can be hidden by

1. opening the style file associated with this document, `sample.sty`, located in the current directory,
2. commenting the line, `\includecomment{notes}`,
3. uncommenting the line, `\excludecomment{notes}`.

Begin a section by typing `\section{}` with the section title inside the brackets.

1 Probability: random variable and cdf

Here is a paragraph containing *italics*, inline math delimited by `$ ...$`, and a footnote with hyperlinks to the Appendix section of the document and to a url.

We say $X = X(\omega)$ is a *random variable* that maps an outcome/event ω in sample space Ω to a real number.[*] For example if we have a sample space $\Omega = \{\text{success}, \text{fail}\}$, then we can map Ω to $\mathbb{R}$ by coding $X = 1$ when the outcome is a success and $X = 0$ when the outcome is a failure. In other words, a random variable is a coding scheme.

The next passage contains a displayed math delimited by $$$ . . . $$$ and lists with numbered and unnumbered items. The lists are formatted to reduce space by setting the spacing parameters globally in `sample.sty` as follows:

```
\setlist{topsep=0pt, itemsep = 0pt, leftmargin=50pt}
```

[*] A more technical definition states that X is a measurable function mapping an *event space* $\mathcal{F}$ to $\mathbb{R}$, which implies that not all outcomes are events and not all events are outcomes. See Appendix **??** and this discussion on StackExchange for the motivation behind conceptualizing probability as a measure.

See this helpful StackExchange post for what each of these parameters mean.

Say we want to make a statement about the probability of an event $\{\omega \in \Omega | X(\omega) \le x\}$ for some real number x. Such a statement is called a *cumulative distribution function*, denoted $F(x)$ or $F_X(x)$ where

$$F(x) = F_X(x) = P(\{X \le x\}) = P(\{\omega \in \Omega, X(\omega) \le x\}).$$

Mathematically, P is a special function called a *probability measure* and therefore has the following properties:

1. $0 \le P(A) < \infty$ for all events A;
2. for a countable sequence of disjoint events $A_1, A_2, \ldots$, $P(\bigcup\limits_{i=1}^{\infty} A_i) = \sum_{i=1}^{\infty} P(E_i)$;
3. $P(\Omega) = 1$.

Knowing that P satisfies these properties implies the following results.

- $P(\varnothing) = 0$[†]
- $0 \le P(A) \le 1$ for all events $A \in \omega$
- if $A \subset B$, then $P(A) \le P(B)$
- for events A and B, $P(A \cup B) = P(A) + P(B) - P(A \cap B)$.

Based on these properties of P, we can also derive the following three properties for cumulative distribution function, F.

- F is nondecreasing, i.e. $F(x) \le F(y)$ for all $x < y$
- $\lim_{x\to-\infty} F(x) = 0$ and $\lim_{x\to\infty} F(x) = 1$
- F is right continuous, i.e. $\lim_{h\to 0} F(x + h) = F(x)$.

Begin a subsection by typing `\subsection{}` with the subsection title inside the brackets.

1.1 Famous distributions

Here are more displayed math examples using the delimiters `$$ ...$$` and align environment. For expectation and variance, I have included these new commands lines in the style file.

```
\newcommand{\E}{\mathrm{E}\,}
\newcommand{\Var}{\mathrm{Var}\,}.
```

Now the expectation appears as $\mathrm{E}\,$ instead of E by typing `\E`. Similarly, the variance appears as $\mathrm{Var}\,$ instead of Var by typing `\Var`.

Begin an unnumbered sub-subsection by typing `\subsubsection*{}` with the sub-subsection title inside the brackets. If you want the sub-subsection to be numbered, take out the asterik.

[†]This is one instance where an outcome and an event are not the same because $\varnothing$ cannot an element of Ω and is not an *outcome*. However, we can still define probabilities for an *event*.

Uniform distribution, $U(a, b)$

A random varible X has a (continuous) uniform distribution if it has constant probability over its sample space, (a, b).

$$f(x) = \frac{1}{b-a}\,\mathbb{I}(a \leq x \leq b)$$
$$F(x) = \begin{cases} 0 & x \leq a \\ x & a < x < b \\ 1 & x \geq b \end{cases}$$
$$\mathrm{E}\left[X\right] = \frac{a+b}{2}, \quad \mathrm{Var}\left(X\right) = \frac{(b-a)^2}{12}$$

Normal distribution, $N(\mu, \sigma^2)$

$X \sim N(\mu, \sigma^2)$ is a normal distribution where $\mathrm{E}\left[X\right] = \mu$ and $\mathrm{Var}\left(X\right) = \sigma^2$.

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left\{ - \frac{(x-\mu)^2}{2\sigma^2} \right\} \mathbb{I}(x \in \mathbb{R})$$

Exponential distribution, $\mathrm{Exp}(\beta)$

Let $X \sim \mathrm{Exp}(\beta)$ be a random variable describing the waiting time between events that occur at a constant rate. Then X is said to have an exponential distribution where $\mathrm{E}\left[X\right] = \beta$.

$$f(x) = \frac{1}{\beta} \exp\left\{ - \frac{x}{\beta} \right\} \mathbb{I}(x \in [0, \infty))$$
$$F(x) = 1 - \exp\left\{ - \frac{x}{\beta} \right\}$$
$$\mathrm{E}\left[X\right] = \beta, \quad \mathrm{Var}\left(X\right) = \beta^2$$

Bernoulli distribution, Ber(p)

Let X describe a one-trial experiment whose outcome can be a success with probability p or a failure with probability $1 - p$. Let $X(\text{success}) = 1$ and $X(\text{failure}) = 0$.

$$p(k) = P(X = k) = p^k (1-p)^{1-k} \mathbb{I}(k \in \{0, 1\})$$
$$\mathrm{E}\left[X\right] = p, \quad \mathrm{Var}\left(X\right) = p(1-p)$$

Binomial distribution

A binomial distribution $X \sim \mathrm{bin(n, p)}$ models an experiment with n trials with p probability of success per trial. Alternatively, it can be modeled as a sum of n Bernoulli trials with p probability of success.

$$P(X = k) = \binom{n}{k} p^k (1-p)^{n-k} \mathbb{I}(k \in \mathbb{N}_0, k \leq n)$$
$$\mathrm{E}\left[X\right] = np, \quad \mathrm{Var}\left(X\right) = np(1-p)$$

Poisson distribution, $\text{Poisson}(\lambda)$

Suppose we want to describe the number of plane crashes in a year. Intuitively, a binomial distribution would make sense despite the large number of n (number of flights per year) and the small probability p (the relative frequency of a plane crash in a year). For such rare events, however, a Poisson distribution would work equally well as an approximation and may be more practical as we can use the average number of crashes as the parameter.

$$p(k) = P(X = k) = \frac{\lambda^k e^{-\lambda}}{k!} \mathbb{I}(k \in \mathbb{N}_0)$$
$$\mathrm{E}[X] = \lambda, \quad \mathrm{Var}(X) = \lambda$$

Use `\appendix` command to begin appendix.

A Motivation for a measure theory-based probability

I have created a hyperlink to this appendix section by adding `\label{measure}` next to the section tag. Now I can refer to this section by writing `\ref{measure}`. The label names need to be unique, so for the next hyperlink I need to use another label name besides "measure."

In an introductory probability textbook such as Ross 2014, we often begin by learning that a random variable X may be associated with either a discrete sample space (i.e. the sample space Ω is countable) or a continuous sample space (i.e. the sample space Ω is uncountable). Next we define a probability mass function for a discrete r.v. and a probability density mass function for a continuous random variable. At this point, only the probability mass function actually expresses probability. In order to make a probability statement for a continuous r.v., we need to get to the cumulative distribution function. We think that we have completed the circle, but compared to the relationship between pdf and cdf, where the former is the derivative of the latter and the latter is the integral of the former, the relationship between pmf and cdf is not so, shall we say, neat. A measure theory-based probability unifies the discrete and continuous cases under one. This means that regardless of whether our random variable is discrete or continuous, it becomes mathematically possible to state that the pdf (pmf) is the derivative of the cdf and that the cdf is the integral of the pdf (pmf).

B How to get help on LaTeX

Google it.

There are many free ebooks, books, and websites out there illustrating the A to Z of LaTeX syntax. None of them are short, nor is reading any of them actually helpful for learning to write in LaTeX. If you have any question about how to do something in LaTeX, or in any programming language for that matter, then google it. Chances are that somebody else has already asked the question on Tex StackExchange and that one of the answers will be the right fit for you.

C How to get better at LaTeX

Practice.

The best way to get better at LaTeX is to stop using Microsoft Word and do more writing on a LaTeX text editor. Write your notes in LaTeX.[‡] Write your paper in LaTeX. Write your CV in LaTeX. Write your presentation slides in LaTeX. Look up how you can do something on LaTeX by googling it and try it out.

[‡]Here are some examples of what I practiced: my probability notes, my game theory notes.

Use `\printbibliography` command to insert a bibliography. In the style file, I have the following lines specifying that I want the `biblatex` package to write my bibliography in author-year format with the `biber` engine as my `.bib` processor.

```
\usepackage[backend=biber, style=authoryear, citestyle=authoryear]{biblatex}
\addbibresource{sample}
```

The `.bib` file stores all my bibliography entries. You can find a `bibtex` formatted citation by googling the work you want to cite on Google Scholar. For example, the entry for Ross 2014 looks like this:

```
@book{ross,
   title={A first course in probability},
   author={Ross, Sheldon},
   year={2014},
   publisher={Pearson}
}
```

References

Ross, Sheldon (2014). *A first course in probability*. Pearson.