

*Timothy Chung*

COMP70015

Mathematics for Machine Learning

AUTUMN 2025



# Contents

<b>I</b>	<b>Fundamental Concepts in Mathematics for Machine Learning</b>	<b>7</b>
<b>1</b>	<b>Formalising ML Problem Settings</b>	<b>8</b>
1.1	Brief Probability Theory Review	9
1.2	Independent and Identically Distributed (i.i.d.) Random Variables	10
1.3	Statistical Modelling as Curve Fitting	11
<b>2</b>	<b>Blah</b>	<b>12</b>
2.1	Typefaces	13
2.2	Headings	13
2.3	Environments	14
<b>3</b>	<b>On the Use of the <code>tufte-book</code> Document Class</b>	<b>15</b>
3.1	Page Layout	15
3.2	Sidenotes	15
3.3	References	16
3.4	Figures and Tables	16
3.5	Captions	18
3.6	Full-width text blocks	18
3.7	Typography	19
3.8	Document Class Options	19
<b>4</b>	<b>Customizing Tufte-LaTeX</b>	<b>21</b>
4.1	File Hooks	21
4.2	Numbered Section Headings	21
4.3	Changing the Paper Size	22
4.4	Customizing Marginal Material	22
<b>5</b>	<b>Compatibility Issues</b>	<b>23</b>
5.1	Converting from <code>article</code> to <code>tufte-handout</code>	23
5.2	Converting from <code>book</code> to <code>tufte-book</code>	23
<b>6</b>	<b>Troubleshooting and Support</b>	<b>24</b>
6.1	Tufte-LaTeX Website	24
6.2	Tufte-LaTeX Mailing Lists	24
6.3	Getting Help	24
6.4	Errors, Warnings, and Informational Messages	24
6.5	Package Dependencies	25

# Introduction

My notes try to combine the detail of the professor's informal lecture notes with the breadth of the slides, where the latter covers all the assessed mathematical content. However, I will have added extra material from the listed reference materials in the informal notes.

## *Overview*

Week 1: Discuss ML, brush up skills

Week 2: Critical optimisation concepts: automatic differentiation, convergence, complexity

Week 3: Probabilistic Perspective to ML

Week 4: Probabilistic Perspective to ML (contd.)

Week 5: Focus on Bayes Theorem + Practicals

Week 6: Consolidating learning (PCA study)

Week 7: Two Advanced topics: NN training with adversarial examples, + student selected topic

**Part I**  
**Fundamental Concepts in Mathematics for**  
**Machine Learning**

# 1

## Formalising ML Problem Settings

**Theorem 1.0.1** Theorem Name

This is the statement of the theorem.

**Corollary 1.0.1** Corollary Name

This is the statement of the corollary.

**Lemma 1.0.1** Lemma Name

This is the statement of the lemma.

**Claim 1.0.1** Claim Name

This is the statement of the claim.

**Example 1.0.1** (Example Name)

This is the explanation of the example.

**Note 1.0.1** Side Note Box

This is a side note.

This is a block of highlighted text

**Definition Title****Definition 1.0.1**

This is an example definition.

**Extra Title***Non-Examinable 1.0.1*

This is an example box with extra information.

**Example Title****Example Q 1.0.1**

This is an example question.

Answer here

**Q1c - 2018****Exam Q 1.0.1**

This is an example exam question.

**Reference Title****Reference**

This is an example reference to source material.

**Note 1.0.1** Side Note Box

This is a smaller side note.

This is a block of highlighted text that's smaller.

**Small Def Title**

Example Text

**Definition 1.0.1**

**Small Title**

Example Text

*Non-Examinable 1.0.1*

**Small Title**

Example Text

Answer

**Example Q 1.0.1**

**Q1c - 2018**

This is an example exam question, smaller.

**Exam Q 1.0.1**

**Reference Title**

This is an example reference to source material.

**Reference 1.0.1**

## Intuition Title

This is an example of an intuitive explanation, smaller

Intuition 1.0.1

## Intuition Title

## Intuition 1.0.1

This is an example of an intuitive explanation.

**Note 1.0.2** On The Rigour of A Random Variable

For the beginning of this module, a random variable  $X$  is considered to be a function from a sample space  $\Omega$  to the unit interval  $[0, 1]$ . However, in Lectures 6 and 7, we use the full definition of a random variable, which is a measurable function from a sample probability space  $(\Omega)$  to a measurable space  $(E, \varepsilon)$ , involving the concept of  $\sigma$ -algebras and measure spaces.

When the sample space is a continuous space, the function  $p$  is a **probability density function** (PDF). When the sample space is a discrete space, the function  $p$  is a **probability mass function** (PMF).

THE PAGES of a book are usually divided into three major sections: the front matter (also called preliminary matter or prelim), the main matter (the core text of the book), and the back matter (or end matter).

### 1.1 Brief Probability Theory Review

$x$  is a sample from a random variable  $X$ .

$P(X = x)$  refers to probability that the random variable  $X$  takes on the value  $x$ .

#### Probability Density Function (PDF)

The Probability Density Function (PDF) of a continuous random variable  $X$  is a function  $f_X(x)$  that describes the relative likelihood for this random variable to take on a given value. The PDF has the following properties:

- $f_X(x) \geq 0$  for all  $x$ .
- $\int_{-\infty}^{\infty} f_X(x) dx = 1$ .

Mathematically, the PDF is defined such that the probability that  $X$  lies within a particular interval  $[a, b]$  is given by:

$$P(a \leq X \leq b) = \int_a^b f_X(x) dx.$$

#### Cumulative Distribution Function (CDF)

The Cumulative Distribution Function (CDF) of a continuous random variable  $X$  is a function  $F_X(x)$  that describes the probability that  $X$  will take a value less than or equal to  $x$ . It is defined as:

$$F_X(x) = P(X \leq x) = \int_{-\infty}^x f_X(t) dt.$$

The CDF has the following properties:

- $0 \leq F_X(x) \leq 1$  for all  $x$ .
- $F_X(x)$  is a non-decreasing function.
- $\lim_{x \rightarrow -\infty} F_X(x) = 0$ .
- $\lim_{x \rightarrow \infty} F_X(x) = 1$ .

Example of a PDF: Normal Distribution

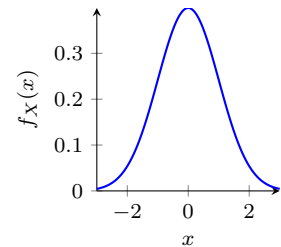


Figure 1.1: Probability Density Function of a standard normal distribution

Example of a CDF: Sigmoid Approximation

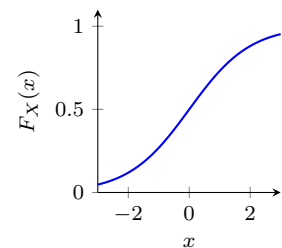


Figure 1.2: Cumulative Distribution Function

### Dealing with Data (Single-Feature)

In Machine Learning (ML), we often deal with large datasets from which we aim to extract meaningful insights. It is useful to model these data points as random variables:

$$\{x_1, x_2, \dots, x_N\}$$

We typically model these samples as random variables:

$$\{x_1 \sim X_1, x_2 \sim X_2, \dots, x_N \sim X_N\}$$

### Vectors of Random Variables

When dealing with joint random variables, we often represent them as vectors:

$$\mathbf{X} = (X_1, X_2, X_3) \quad \text{with joint distribution} \quad p_{X_1, X_2, X_3}(x_1, x_2, x_3)$$

For a vector of random variables  $\mathbf{X}$  in  $\mathbb{R}^3$ , the joint probability density function is denoted as:

$$p_{\mathbf{X}}(\mathbf{x}) \quad \text{where} \quad \mathbf{X} \in \mathbb{R}^3$$

If these are input observations, they are often referred to as "feature vectors."

### Distinct Random Variables

We model samples as distinct random variables <sup>1</sup>:

$$\{x_1 \sim X_1, x_2 \sim X_2, \dots, x_N \sim X_N\}$$

<sup>1</sup> **Question:** Why should we model these as distinct random variables? Aren't they all the same thing?

**Answer:** Despite being identically distributed, distinct random variables allow for capturing dependencies and interactions between different samples.

## 1.2 Independent and Identically Distributed (i.i.d.) Random Variables

### Independence of Random Variables

Independence refers to the idea that the values or outcomes of one observation in a dataset do not depend on or influence the values of any other observation.

For the set of random variables  $X_1, X_2, \dots, X_N$ , for the collection  $\{x_1 \sim X_1, x_2 \sim X_2, \dots, x_N \sim X_N\}$ , we often assume independence, for any subset of observations  $\{X_{i_1}, X_{i_2}, \dots, X_{i_k}\}$  where  $i_1, i_2, \dots, i_k \in \{1, 2, \dots, N\}$ , the joint distribution factorises:

$$P(X_{i_1} = x_{i_1}, \dots, X_{i_k} = x_{i_k}) = P(X_{i_1} = x_{i_1}) \cdot \dots \cdot P(X_{i_k} = x_{i_k}) \quad (1.1)$$

*The joint distribution of the subset is the product of the marginal distributions of the individual random variables.*

**Independence:** The occurrence of any event does not affect the occurrence of others. This is a crucial assumption in many ML models that we will see the usefulness of as early as the next lecture.

### Identically Distributed Random Variables

The "identically distributed" part of i.i.d. refers to the idea that all random variables in the sample follow the same probability distribution. That is, they share the same probability density function (pdf) or probability mass function (pmf), depending on whether the data is continuous or discrete. If the set of random variables  $\{X_1, X_2, \dots, X_N\}$  are identically distributed, then:

$$f_{X_1}(x) = f_{X_2}(x) = \dots = f_{X_N}(x) = f_X(x) \quad (1.2)$$



$$F_{X_1}(x) = F_{X_2}(x) = \dots = F_{X_n}(x) = F_X(x) \quad (1.3)$$

This implies that the cumulative distribution function (CDF) is the same for all these random variables.

### 1.3 Statistical Modelling as Curve Fitting

Machine learning and statistics have significant overlap, and so most concepts studied in this module can be cast as statistical modelling. Consider our random variables:

$$\{x_1 \sim X_1, x_2 \sim X_2, \dots, x_N \sim X_N\}$$

These random variables can be modelled to fit certain curves that represent the underlying data distribution.

#### *Assumption about the Model*

To proceed with statistical modelling, we make an assumption about the form of the model:

$$P_X(x) \approx \mathcal{N}(x; \theta) \quad \theta := (\mu, \sigma)$$

Here,  $P_X(x)$  is approximated by a normal distribution  $\mathcal{N}(x; \theta)$ , where  $\theta$  represents the parameters of the distribution, namely the mean  $\mu$  and the standard deviation  $\sigma$ . This assumption simplifies the process of modelling the data.

#### *Fitting the Model*

The next step is to fit the model to the data. This involves finding the parameter values  $\theta$  that maximize the probability of observing the given data. Mathematically, this is expressed as:

$$\arg \max_{\theta} P(x_1, \dots, x_N \mid \theta)$$

In other words, we adjust the parameters  $\mu$  and  $\sigma$  so that the assumed model best fits the observed data. This process is known as maximum likelihood estimation (MLE).

## 2

# Blah

THE FRONT MATTER of a book refers to all of the material that comes before the main text. The following table from shows a list of material that appears in the front matter of *The Visual Display of Quantitative Information*, *Envisioning Information*, *Visual Explanations*, and *Beautiful Evidence* along with its page number. Page numbers that appear in parentheses refer to folios that do not have a printed page number (but they are still counted in the page number sequence).

Page content	Books			
	<i>VDQI</i>	<i>EI</i>	<i>VE</i>	<i>BE</i>
Blank half title page	(1)	(1)	(1)	(1)
Frontispiece <sup>1</sup>	(2)	(2)	(2)	(2)
Full title page	(3)	(3)	(3)	(3)
Copyright page	(4)	(4)	(4)	(4)
Contents	(5)	(5)	(5)	(5)
Dedication	(6)	(7)	(7)	7
Epigraph	–	–	(8)	–
Introduction	(7)	(9)	(9)	9

<sup>1</sup> The contents of this page vary from book to book. In *VDQI* this page is blank; in *EI* and *VE* this page holds a frontispiece; and in *BE* this page contains three epigraphs.

On the side note of...

yeah

Non-Examinable 2.0.1

The design of the front matter in Tufte’s books varies slightly from the traditional design of front matter. First, the pages in front matter are traditionally numbered with lowercase roman numerals (*e.g.*, i, ii, iii, iv, . . . ). Second, the front matter page numbering sequence is usually separate from the main matter page numbering. That is, the page numbers restart at 1 when the main matter begins. In contrast, Tufte has enumerated his pages with arabic numerals that share the same page counting sequence as the main matter.

There are also some variations in design across Tufte’s four books. The page opposite the full title page (labeled “frontispiece” in the above table) has different content in each of the books. In *The Visual Display of Quantitative Information*, this page is blank; in *Envisioning Information* and *Visual Explanations*, this page holds a frontispiece; and in *Beautiful Evidence*, this page contains three epigraphs.

The dedication appears on page 6 in *VDQI* (opposite the introduction), and is placed on its own spread in the other books. In *VE*, an epigraph shares the spread with the opening page of the introduction.

None of the page numbers (folios) of the front matter are expressed except in *BE*, where the folios start to appear on the dedication page.

THE FULL TITLE PAGE of each of the books varies slightly in design. In all the books, the author’s name appears at the top of the page, the title it set just above the center line, and the publisher is printed along the bottom margin. Some of the differences are outlined in the following table.

Feature	<i>VDQI</i>	<i>EI</i>	<i>VE</i>	<i>BE</i>
Author				
Typeface	serif	serif	serif	sans serif
Style	italics	italics	italics	upright, caps
Size	24 pt	20 pt	20 pt	20 pt
Title				
Typeface	serif	serif	serif	sans serif
Style	upright	italics	upright	upright, caps
Size	36 pt	48 pt	48 pt	36 pt
Subtitle				
Typeface	–	–	serif	–
Style	–	–	upright	–
Size	–	–	20 pt	–
Edition				
Typeface	sans serif	–	–	–
Style	upright, caps	–	–	–
Size	14 pt	–	–	–
Publisher				
Typeface	serif	serif	serif	sans serif
Style	italics	italics	italics	upright, caps
Size	14 pt	14 pt	14 pt	14 pt

THE TABLES OF CONTENTS in Tufte’s books give us our first glimpse of the structure of the main matter. *The Visual Display of Quantitative Information* is split into two parts, each containing some number of chapters. His other three books only contain chapters—they’re not broken into parts.

## 2.1 Typefaces

Tufte’s books primarily use two typefaces: Bembo and Gill Sans. Bembo is used for the headings and body text, while Gill Sans is used for the title page and opening epigraphs in *Beautiful Evidence*.

Since neither Bembo nor Gill Sans are available in default L<sup>A</sup>T<sub>E</sub>X installations, the Tufte-L<sup>A</sup>T<sub>E</sub>X document classes default to using Palatino and Helvetica, respectively. In addition, the Bera Mono typeface is used for monospaced type.

The following font sizes are defined by the Tufte-L<sup>A</sup>T<sub>E</sub>X classes:

L <sup>A</sup> T <sub>E</sub> X size	Font size	Leading	Used for
<code>\tiny</code>	5	6	sidenote numbers
<code>\scriptsize</code>	7	8	–
<code>\footnotesize</code>	8	10	sidenotes, captions
<code>\small</code>	9	12	quote, quotation, and verse environments
<code>\normalsize</code>	10	14	body text
<code>\large</code>	11	15	B-heads
<code>\Large</code>	12	16	A-heads, TOC entries, author, date
<code>\LARGE</code>	14	18	handout title
<code>\huge</code>	20	30	chapter heads
<code>\Huge</code>	24	36	part titles

Table 2.1: A list of L<sup>A</sup>T<sub>E</sub>X font sizes as defined by the Tufte-L<sup>A</sup>T<sub>E</sub>X document classes.

## 2.2 Headings

Tufte’s books include the following heading levels: parts, chapters,<sup>2</sup> sections, sub-sections, and paragraphs. Not defined by default are: sub-subsections and subpara-graphs.

*Paragraph* Paragraph headings (as shown here) are introduced by italicized text and separated from the main paragraph by a bit of space.

<sup>2</sup> Parts and chapters are defined for the `tufte-book` class only.

Heading	Style	Size
Part	roman	24/36×40 pc
Chapter	italic	20/30×40 pc
Section	italic	12/16×26 pc
Subsection	italic	11/15×26 pc
Paragraph	italic	10/14

Table 2.2: Heading styles used in *Beautiful Evidence*.

### 2.3 Environments

The following characteristics define the various environments:

Environment	Font size	Notes
Body text	10/14×26 pc	
Block quote	9/12×24 pc	Block indent (left and right) by 1 pc
Sidenotes	8/10×12 pc	Sidenote number is set inline, followed by word space
Captions	8/10×12 pc	

Table 2.3: Environment styles used in *Beautiful Evidence*.

Column 1	Column 2	Column 3
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.	Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.	Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.	Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.	Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.	Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.	Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris.

Table 2.4: Example table with limited column widths

# 3

## On the Use of the `tufte-book` Document Class

The Tufte- $\text{\LaTeX}$  document classes define a style similar to the style Edward Tufte uses in his books and handouts. Tufte’s style is known for its extensive use of sidenotes, tight integration of graphics with text, and well-set typography. This document aims to be at once a demonstration of the features of the Tufte- $\text{\LaTeX}$  document classes and a style guide to their use.

### 3.1 Page Layout

#### Headings

This style provides A- and B-heads (that is, `\section` and `\subsection`), demonstrated above.

If you need more than two levels of section headings, you’ll have to define them yourself at the moment; there are no pre-defined styles for anything below a `\subsection`. As Bringhurst points out in *The Elements of Typographic Style*,<sup>1</sup> you should “use as many levels of headings as you need: no more, and no fewer.”

<sup>1</sup> Bringhurst2005

The Tufte- $\text{\LaTeX}$  classes will emit an error if you try to use `\subsubsection` and smaller headings.

IN HIS LATER BOOKS,<sup>2</sup> Tufte starts each section with a bit of vertical space, a non-indented paragraph, and sets the first few words of the sentence in SMALL CAPS. To accomplish this using this style, use the `\newthought` command:

<sup>2</sup> Tufte2006

```
\newthought{In his later books}, Tufte starts...
```

### 3.2 Sidenotes

One of the most prominent and distinctive features of this style is the extensive use of sidenotes. There is a wide margin to provide ample room for sidenotes and small figures. Any `\footnotes` will automatically be converted to sidenotes.<sup>3</sup> If you’d like to place ancillary information in the margin without the sidenote mark (the superscript number), you can use the `\marginnote` command.

<sup>3</sup> This is a sidenote that was entered using the `\footnote` command.

The specification of the `\sidenote` command is:

```
\sidenote[⟨number⟩][⟨offset⟩]{Sidenote text.}
```

Both the `⟨number⟩` and `⟨offset⟩` arguments are optional. If you provide a `⟨number⟩` argument, then that number will be used as the sidenote number. It will change of the number of the current sidenote only and will not affect the numbering sequence of subsequent sidenotes.

Sometimes a sidenote may run over the top of other text or graphics in the margin space. If this happens, you can adjust the vertical position of the sidenote by providing a dimension in the `⟨offset⟩` argument. Some examples of valid dimensions are:

```
1.0in      2.54cm      254mm      6\baselineskip
```

If the dimension is positive it will push the sidenote down the page; if the dimension is negative, it will move the sidenote up the page.

This is a margin note. Notice that there isn’t a number preceding the note, and there is no number in the main text where this note was written.

While both the  $\langle number \rangle$  and  $\langle offset \rangle$  arguments are optional, they must be provided in order. To adjust the vertical position of the sidenote while leaving the sidenote number alone, use the following syntax:

```
\sidenote[][\langle offset \rangle]{Sidenote text.}
```

The empty brackets tell the `\sidenote` command to use the default sidenote number.

If you *only* want to change the sidenote number, however, you may completely omit the  $\langle offset \rangle$  argument:

```
\sidenote[\langle number \rangle]{Sidenote text.}
```

The `\marginnote` command has a similar *offset* argument:

```
\marginnote[\langle offset \rangle]{Margin note text.}
```

### 3.3 References

References are placed alongside their citations as sidenotes, as well. This can be accomplished using the normal `\cite` command.<sup>4</sup>

The complete list of references may also be printed automatically by using the `\bibliography` command. (See the end of this document for an example.) If you do not want to print a bibliography at the end of your document, use the `\nobibliography` command in its place.

To enter multiple citations at one location,<sup>5</sup> you can provide a list of keys separated by commas and the same optional vertical offset argument:

```
\cite{Tufte2006,Tufte1990}.
```

```
\cite[\langle offset \rangle]{bibkey1,bibkey2,...}
```

<sup>4</sup> The first paragraph of this document includes a citation.

<sup>5</sup> **Tufte2006, Tufte1990**

### 3.4 Figures and Tables

Images and graphics play an integral role in Tufte’s work. In addition to the standard `figure` and `tabular` environments, this style provides special figure and table environments for full-width floats.

Full page-width figures and tables may be placed in `figure*` or `table*` environments. To place figures or tables in the margin, use the `marginfigure` or `marginfigure` environments as follows (see figure 3.1):

```
\begin{marginfigure}
  \includegraphics{helix}
  \caption{This is a margin figure.}
  \label{fig:marginfig}
\end{marginfigure}
```

The `marginfigure` and `marginfigure` environments accept an optional parameter  $\langle offset \rangle$  that adjusts the vertical position of the figure or table. See the “Sidenotes” section above for examples. The specifications are:

```
\begin{marginfigure}[\langle offset \rangle]
...
\end{marginfigure}

\begin{marginfigure}[\langle offset \rangle]
...
\end{marginfigure}
```

Figure ?? is an example of the `figure*` environment and figure ?? is an example of the normal `figure` environment.

Figure 3.1: This is a margin figure. The helix is defined by  $x = \cos(2\pi z)$ ,  $y = \sin(2\pi z)$ , and  $z = [0, 2.7]$ . The figure was drawn using Asymptote (<http://asymptote.sf.net/>).

As with sidenotes and marginnotes, a caption may sometimes require vertical adjustment. The `\caption` command now takes a second optional argument that enables you to do this by providing a dimension  $\langle offset \rangle$ . You may specify the caption in any one of the following forms:

```
\caption{long caption}
\caption[short caption]{long caption}
\caption[][\langle offset \rangle]{long caption}
\caption[short caption][\langle offset \rangle]{long caption}
```

A positive  $\langle offset \rangle$  will push the caption down the page. The short caption, if provided, is what appears in the list of figures/tables, otherwise the “long” caption appears there. Note that although the arguments  $\langle short\ caption \rangle$  and  $\langle offset \rangle$  are both optional, they must be provided in order. Thus, to specify an  $\langle offset \rangle$  without specifying a  $\langle short\ caption \rangle$ , you must include the first set of empty brackets `[]`, which tell `\caption` to use the default “long” caption. As an example, the caption to figure ?? above was given in the form

```
\caption[Hilbert curves...][6pt]{Hilbert curves...}
```

Table 3.1 shows table created with the `booktabs` package. Notice the lack of vertical rules—they serve only to clutter the table’s data.

Margin	Length
Paper width	8 <sup>1</sup> / <sub>2</sub> inches
Paper height	11 inches
Textblock width	6 <sup>1</sup> / <sub>2</sub> inches
Textblock/sidenote gutter	3/ <sub>8</sub> inches
Sidenote width	2 inches

Table 3.1: Here are the dimensions of the various margins used in the Tufte-handout class.

OCCASIONALLY L<sup>A</sup>T<sub>E</sub>X will generate an error message:

**Error: Too many unprocessed floats**

L<sup>A</sup>T<sub>E</sub>X tries to place floats in the best position on the page. Until it’s finished composing the page, however, it won’t know where those positions are. If you have a lot of floats on a page (including sidenotes, margin notes, figures, tables, etc.), L<sup>A</sup>T<sub>E</sub>X may run out of “slots” to keep track of them and will generate the above error.

L<sup>A</sup>T<sub>E</sub>X initially allocates 18 slots for storing floats. To work around this limitation, the Tufte-L<sup>A</sup>T<sub>E</sub>X document classes provide a `\morefloats` command that will reserve more slots.

The first time `\morefloats` is called, it allocates an additional 34 slots. The second time `\morefloats` is called, it allocates another 26 slots.

The `\morefloats` command may only be used two times. Calling it a third time will generate an error message. (This is because we can’t safely allocate many more floats or L<sup>A</sup>T<sub>E</sub>X will run out of memory.)

If, after using the `\morefloats` command twice, you continue to get the **Too many unprocessed floats** error, there are a couple things you can do.

The `\FloatBarrier` command will immediately process all the floats before typesetting more material. Since `\FloatBarrier` will start a new paragraph, you should place this command at the beginning or end of a paragraph.

The `\clearpage` command will also process the floats before continuing, but instead of starting a new paragraph, it will start a new page.

You can also try moving your floats around a bit: move a figure or table to the next page or reduce the number of sidenotes. (Each sidenote actually uses *two* slots.)

After the floats have placed, L<sup>A</sup>T<sub>E</sub>X will mark those slots as unused so they are available for the next page to be composed.

### 3.5 Captions

You may notice that the captions are sometimes misaligned. Due to the way L<sup>A</sup>T<sub>E</sub>X's float mechanism works, we can't know for sure where it decided to put a float. Therefore, the Tufte-L<sup>A</sup>T<sub>E</sub>X document classes provide commands to override the caption position.

*Vertical alignment* To override the vertical alignment, use the `\setfloatalignment` command inside the float environment. For example:

```
\begin{figure}[btp]
  \includegraphics{sinewave}
  \caption{This is an example of a sine wave.}
  \label{fig:sinewave}
  \setfloatalignment{b}% forces caption to be bottom-aligned
\end{figure}
```

The syntax of the `\setfloatalignment` command is:

```
\setfloatalignment{⟨pos⟩}
```

where `⟨pos⟩` can be either `b` for bottom-aligned captions, or `t` for top-aligned captions.

*Horizontal alignment* To override the horizontal alignment, use either the `\forceversofloat` or the `\forcerectofloat` command inside of the float environment. For example:

```
\begin{figure}[btp]
  \includegraphics{sinewave}
  \caption{This is an example of a sine wave.}
  \label{fig:sinewave}
  \forceversofloat% forces caption to be set to the left of the float
\end{figure}
```

The `\forceversofloat` command causes the algorithm to assume the float has been placed on a verso page—that is, a page on the left side of a two-page spread. Conversely, the `\forcerectofloat` command causes the algorithm to assume the float has been placed on a recto page—that is, a page on the right side of a two-page spread.

### 3.6 Full-width text blocks

In addition to the new float types, there is a `fullwidth` environment that stretches across the main text block and the sidenotes area.

```
\begin{fullwidth}
Lorem ipsum dolor sit amet...
\end{fullwidth}
```

*Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.*



### 3.7 Typography

#### Typefaces

If the Palatino, Helvetica, and Bera Mono typefaces are installed, this style will use them automatically. Otherwise, we'll fall back on the Computer Modern typefaces.

#### Letterspacing

This document class includes two new commands and some improvements on existing commands for letterspacing.

When setting strings of ALL CAPS or SMALL CAPS, the letterspacing—that is, the spacing between the letters—should be increased slightly.<sup>6</sup> The `\allcaps` command has proper letterspacing for strings of FULL CAPITAL LETTERS, and the `\smallcaps` command has letterspacing for SMALL CAPITAL LETTERS. These commands will also automatically convert the case of the text to upper- or lowercase, respectively.

<sup>6</sup> Brighurst2005

The `\textsc` command has also been redefined to include letterspacing. The case of the `\textsc` argument is left as is, however. This allows one to use both uppercase and lowercase letters: THE INITIAL LETTERS OF THE WORDS IN THIS SENTENCE ARE CAPITALIZED.

### 3.8 Document Class Options

The `tuftes-book` class is based on the L<sup>A</sup>T<sub>E</sub>X `book` document class. Therefore, you can pass any of the typical book options. There are a few options that are specific to the `tuftes-book` document class, however.

The `a4paper` option will set the paper size to A4 instead of the default US letter size.

The `sfsidenotes` option will set the sidenotes and title block in a sans serif typeface instead of the default roman.

The `twoside` option will modify the running heads so that the page number is printed on the outside edge (as opposed to always printing the page number on the right-side edge in `oneside` mode).

The `symmetric` option typesets the sidenotes on the outside edge of the page. This is how books are traditionally printed, but is contrary to Tufte's book design which sets the sidenotes on the right side of the page. This option implicitly sets the `twoside` option.

The `justified` option sets `alldocclsoptdef` and `right`). The default is to set the text ragged right. The body text of Tufte's books are set ragged right. This prevents needless hyphenation and makes it easier to read the text in the slightly narrower column.

The `bidirectional` option loads the `bidirectional` package which is used with X<sub>Y</sub>L<sup>A</sup>T<sub>E</sub>X to typeset bi-directional text. Since the `bidirectional` package needs to be loaded before the sidenotes and cite commands are defined, it can't be loaded in the document preamble.

The `debug` option causes the Tufte-L<sup>A</sup>T<sub>E</sub>X classes to output debug information to the log file which is useful in troubleshooting bugs. It will also cause the graphics to be replaced by outlines.

The `nofonts` option prevents the Tufte-L<sup>A</sup>T<sub>E</sub>X classes from automatically loading the Palatino and Helvetica typefaces. You should use this option if you wish to load your own fonts. If you're using X<sub>Y</sub>L<sup>A</sup>T<sub>E</sub>X, this option is implied (*i.e.*, the Palatino and Helvetica fonts aren't loaded if you use X<sub>Y</sub>L<sup>A</sup>T<sub>E</sub>X).

The `nolsp` option inhibits the letterspacing code. The Tufte-L<sup>A</sup>T<sub>E</sub>X classes try to load the appropriate letterspacing package (either pdf<sub>T</sub>E<sub>X</sub>'s `letterspace` package or the `soul` package). If you're using X<sub>Y</sub>L<sup>A</sup>T<sub>E</sub>X with `fontenc`, however, you should

configure your own letterspacing.

The **notitlepage** option causes `\maketitle` to generate a title block instead of a title page. The **book** class defaults to a title page and the **handout** class defaults to the title block. There is an analogous **titlepage** option that forces `\maketitle` to generate a full title page instead of the title block.

The **notoc** option suppresses Tufte- $\text{\LaTeX}$ 's custom table of contents (TOC) design. The current TOC design only shows unnumbered chapter titles; it doesn't show sections or subsections. The **notoc** option will revert to  $\text{\LaTeX}$ 's TOC design.

The **nohyper** option prevents the **hyperref** package from being loaded. The default is to load the **hyperref** package and use the `\title` and `\author` contents as metadata for the generated PDF.

## 4

# Customizing Tufte- $\text{\LaTeX}$

The Tufte- $\text{\LaTeX}$  document classes are designed to closely emulate Tufte’s book design by default. However, each document is different and you may encounter situations where the default settings are insufficient. This chapter explores many of the ways you can adjust the Tufte- $\text{\LaTeX}$  document classes to better fit your needs.

### 4.1 File Hooks

If you create many documents using the Tufte- $\text{\LaTeX}$  classes, it’s easier to store your customizations in a separate file instead of copying them into the preamble of each document. The Tufte- $\text{\LaTeX}$  classes provide three file hooks: `tufte-common-local.tex`, `tufte-book-local.tex`, and `tufte-handout-local.tex`.

*tufte-common-local.tex* If this file exists, it will be loaded by all of the Tufte- $\text{\LaTeX}$  document classes just prior to any document-class-specific code. If your customizations or code should be included in both the book and handout classes, use this file hook.

*tufte-book-local.tex* If this file exists, it will be loaded after all of the common and book-specific code has been read. If your customizations apply only to the book class, use this file hook.

*tufte-common-handout.tex* If this file exists, it will be loaded after all of the common and handout-specific code has been read. If your customizations apply only to the handout class, use this file hook.

### 4.2 Numbered Section Headings

While Tufte dispenses with numbered headings in his books, if you require them, they can be enabled by changing the value of the `secnumdepth` counter. From the table below, select the heading level at which numbering should stop and set the `secnumdepth` counter to that value. For example, if you want parts and chapters numbered, but don’t want numbering for sections or subsections, use the command:

```
\setcounter{secnumdepth}{0}
```

The default `secnumdepth` for the Tufte- $\text{\LaTeX}$  document classes is `-1`.

Heading level	Value
Part (in <code>tufte-book</code> )	<code>-1</code>
Part (in <code>tufte-handout</code> )	<code>0</code>
Chapter (only in <code>tufte-book</code> )	<code>0</code>
Section	<code>1</code>
Subsection	<code>2</code>
Subsubsection	<code>3</code>
Paragraph	<code>4</code>
Subparagraph	<code>5</code>

Table 4.1: Heading levels used with the `secnumdepth` counter.

### 4.3 Changing the Paper Size

The Tufte- $\text{\LaTeX}$  classes currently only provide three paper sizes: A4, B5, and US letter. To specify a different paper size (and/or margins), use the `\geometrysetup` command in the preamble of your document (or one of the file hooks). The full documentation of the `\geometrysetup` command may be found in the `geometry` package documentation.<sup>1</sup>

<sup>1</sup> `pkg-geometry`

### 4.4 Customizing Marginal Material

Marginal material includes sidenotes, citations, margin notes, and captions. Normally, the justification of the marginal material follows the justification of the body text. If you specify the `justified` document class option, all of the margin material will be fully justified as well. If you don't specify the `justified` option, then the marginal material will be set ragged right.

You can set the justification of the marginal material separately from the body text using the following document class options: `sidenote`, `marginnote`, `caption`, `citation`, and `marginals`. Each option refers to its obviously corresponding marginal material type. The `marginals` option simultaneously sets the justification on all four marginal material types.

Each of the document class options takes one of five justification types:

*justified* Fully justifies the text (sets it flush left and right).

*raggedleft* Sets the text ragged left, regardless of which page it falls on.

*raggedright* Sets the text ragged right, regardless of which page it falls on.

*raggedouter* Sets the text ragged left if it falls on the left-hand (verso) page of the spread and otherwise sets it ragged right. This is useful in conjunction with the `symmetric` document class option.

*auto* If the `justified` document class option was specified, then set the text fully justified; otherwise the text is set ragged right. This is the default justification option if one is not explicitly specified.

For example,

```
\documentclass[symmetric,justified,marginals=raggedouter]{tufte-book}
```

will set the body text of the document to be fully justified and all of the margin material (sidenotes, margin notes, captions, and citations) to be flush against the body text with ragged outer edges.

THE FONT AND STYLE of the marginal material may also be modified using the following commands:

```
\setsidenotefont{\font commands}
\setcaptionfont{\font commands}
\setmarginnotefont{\font commands}
\setcitationfont{\font commands}
```

The `\setsidenotefont` sets the font and style for sidenotes, the `\setcaptionfont` for captions, the `\setmarginnotefont` for margin notes, and the `\setcitationfont` for citations. The `\font commands` can contain font size changes (e.g., `\footnotesize`, `\Huge`, etc.), font style changes (e.g., `\sffamily`, `\ttfamily`, `\itshape`, etc.), color changes (e.g., `\color{blue}`), and many other adjustments.

If, for example, you wanted the captions to be set in italic sans serif, you could use:

```
\setcaptionfont{\itshape\sffamily}
```

# 5

## Compatibility Issues

When switching an existing document from one document class to a Tufte-L<sup>A</sup>T<sub>E</sub>X document class, a few changes to the document may have to be made.

### *5.1 Converting from **article** to **tufte-handout***

The following **article** class options are unsupported: 10pt, 11pt, 12pt, a5paper, b5paper, executivepaper, legalpaper, landscape, onecolumn, and twocolumn.

The following headings are not supported: \subsubsection and \subparagraph.

### *5.2 Converting from **book** to **tufte-book***

The following **report** class options are unsupported: 10pt, 11pt, 12pt, a5paper, b5paper, executivepaper, legalpaper, landscape, onecolumn, and twocolumn.

The following headings are not supported: \subsubsection and \subparagraph.

## 6

# Troubleshooting and Support

### 6.1 *Tufte- $\text{\LaTeX}$ Website*

The website for the Tufte- $\text{\LaTeX}$  packages is located at <http://code.google.com/p/tufte-latex/>. On our website, you'll find links to our SVN repository, mailing lists, bug tracker, and documentation.

### 6.2 *Tufte- $\text{\LaTeX}$ Mailing Lists*

There are two mailing lists for the Tufte- $\text{\LaTeX}$  project:

*Discussion list* The `tufte-latex` discussion list is for asking questions, getting assistance with problems, and help with troubleshooting. Release announcements are also posted to this list. You can subscribe to the `tufte-latex` discussion list at <http://groups.google.com/group/tufte-latex>.

*Commits list* The `tufte-latex-commits` list is a read-only mailing list. A message is sent to the list any time the Tufte- $\text{\LaTeX}$  code has been updated. If you'd like to keep up with the latest code developments, you may subscribe to this list. You can subscribe to the `tufte-latex-commits` mailing list at <http://groups.google.com/group/tufte-latex-commits>.

### 6.3 *Getting Help*

If you've encountered a problem with one of the Tufte- $\text{\LaTeX}$  document classes, have a question, or would like to report a bug, please send an email to our mailing list or visit our website.

To help us troubleshoot the problem more quickly, please try to compile your document using the `debug` class option and send the generated `.log` file to the mailing list with a brief description of the problem.

### 6.4 *Errors, Warnings, and Informational Messages*

The following is a list of all of the errors, warnings, and other messages generated by the Tufte- $\text{\LaTeX}$  classes and a brief description of their meanings.

**Error:** `\subparagraph` is undefined by this class.

The `\subparagraph` command is not defined in the Tufte- $\text{\LaTeX}$  document classes. If you'd like to use the `\subparagraph` command, you'll need to redefine it yourself. See the "Headings" section on page 15 for a description of the heading styles available in the Tufte- $\text{\LaTeX}$  document classes.

**Error:** `\subsubsection` is undefined by this class.

The `\subsubsection` command is not defined in the Tufte- $\text{\LaTeX}$  document classes. If you'd like to use the `\subsubsection` command, you'll need to redefine it yourself. See the "Headings" section on page 15 for a description of the heading styles available in the Tufte- $\text{\LaTeX}$  document classes.

Error: You may only call `\morefloats` twice. See the Tufte-LaTeX documentation for other workarounds.

L<sup>A</sup>T<sub>E</sub>X allocates 18 slots for storing floats. The first time `\morefloats` is called, it allocates an additional 34 slots. The second time `\morefloats` is called, it allocates another 26 slots.

The `\morefloats` command may only be called two times. Calling it a third time will generate this error message. See page 17 for more information.

Warning: Option ‘*⟨class option⟩*’ is not supported -- ignoring option.

This warning appears when you’ve tried to use *⟨class option⟩* with a Tufte-L<sup>A</sup>T<sub>E</sub>X document class, but *⟨class option⟩* isn’t supported by the Tufte-L<sup>A</sup>T<sub>E</sub>X document class. In this situation, *⟨class option⟩* is ignored.

Info: The ‘*symmetric*’ option implies ‘*twoside*’

You specified the `symmetric` document class option. This option automatically forces the `twoside` option as well. See page 19 for more information on the `symmetric` class option.

## 6.5 Package Dependencies

The following is a list of packages that the Tufte-L<sup>A</sup>T<sub>E</sub>X document classes rely upon. Packages marked with an asterisk are optional.

- xifthen
- natbib *and* bibentry
- ifpdf\*
- optparams
- ifxetex\*
- placeins
- hyperref
- mathpazo\*
- geometry
- helvet\*
- ragged2e
- fontenc
- chngpage *or* changepage
- beramono\*
- paralist
- fancyhdr
- textcase
- xcolor
- soul\*
- textcomp
- letterspace\*
- titlesec
- setspace
- titletoc