

# **Data Understanding, Data Analysis, and Data Science Course Notes**

**Volume 4: Techniques of Data Analysis**

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Quadrangle | Idlewyld Analytics and Consulting Services



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This one goes out to the “Welsh” contingent: Elwyn, Llewellyn, and Gwyneth. Your world is going to be a whole lot different than mine was; maybe data can even help make some of it better. But one thing’s for sure: data is not going away any time soon – better be prepared.



# Series Preface

The *first* thing to know about *Data Understanding, Data Analysis, and Data Science* (DUDADS) is that it isn't really a "book". It makes more sense to think of it as **course notes**, or as a **reference manual** and a source of examples and application.

I borrow some of its contents from authors who do a better job of explaining things than I could hope to do; I also sometimes modify their examples and code to better suit my pedagogical needs.\* Major influences include [1, 2, 3, 4, 5, 6, 8] – be sure to give these masterful works the attention they deserve!

The *second* thing to know about DUDADS is that it isn't really "a" book. It makes more sense to think of it as **a bunch of books in a trench coat, masquerading as single one**.<sup>†</sup> No one is expected to traverse DUDADS in one sitting, or even to tackle more than a few of its assigned chapters, sections, subsections, exercises at any given time; rather, it is intended to be read in parallel with guided lectures.

The *third* thing to know about DUDADS is that the practical examples use R and/or Python, for no particular reason other than that *some* programming language had to be used to illustrate the concepts. In the text, R code appears in blue boxes:

```
... some R code ...
```

Whereas Python code appears in green boxes:

```
... some Python code ...
```

You may look at some piece of code and think to yourself: "This isn't how I would do it" or "such-and-such a task would be easier to accomplish if we used module/package ABC or programming language XYZ". That's quite possible.

But finding the optimal tool is not the point of this book. In the first place, new data science tools appear regularly, and it would be a fool's errand to try to continuously modify the book to keep up with them.<sup>‡</sup> In the second place, I am serious about the "Understanding" part of *Data Understanding, Data Analysis, and Data Science*, and that is why I favour a **tool-agnostic** approach.

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\* In all cases, I have attempted to properly cite and give credit where it is due. Get in touch if you find omissions!

<sup>†</sup> I paid heed to this realization by splitting it into a number of volumes.

<sup>‡</sup> I am not saying that I won't be adding examples in different languages in the future, but let's not get ahead of ourselves.

The *fourth* thing to know about DUDADS is that it is not a place to go to in order to obtain a detailed step-by-step guide on “how to solve it”. In person, my answer to a vast array of data science related questions is, rather anti-climatically: “it depends”. Of course, it depends; on the data, on the objectives, on the cost associated with making a mistake, on the stakeholder’s appetite for uncertainty, and, perhaps more surprisingly, on the analytical and data preparation choices that are made along the way.


To some, this might smack of post-modernism: “you are saying that there is no truth, and that data analysis is pointless!” To which I respond: “analysts have agency (lots of it, it turns out), and their choices *DO* influence the results, so make sure to run multiple analyses to determine the variability of the outcomes”. That is the nature of the discipline.

The *last* thing you should probably know about DUDADS is that I have made a concerted effort to focus mainly on the **story** of (learning) data analysis and data science; sometimes, that comes at the expense of rigorous exposition.

“The early stages of education have to include a lot of lies-to-children, because early explanations have to be simple. However, we live in a complex world, and lies-to-children must **eventually be replaced** by more complex stories if they are not to become delayed-action genuine lies.” [7]

Some of the concepts and notions that I present are **incomplete** by design, but remain (I hope) true-to-their-spirit, or at least true “enough” for a first pass.<sup>§</sup> My position is that learning is an iterative process and that important take-aways from an early stage might need to be modified to account for new developments at a later date. But all things in good time: flexibility is a friend in your learning adventure; perfectionism, not always so.

Patrick Boily  
Wakefield, September 2024

The DUDADS reference manuals are available at [idlewyldanalytics.com](https://idlewyldanalytics.com) 

- Volume 1: *Prelude to Data Understanding*
- Volume 2: *Fundamentals of Data Insight*
- Volume 3: *Spotlight on Machine Learning*
- Volume 4: *Techniques of Data Analysis*
- Volume 5: *Special Topics in Data Science and Artificial Intelligence*
- *The Practice of Data Visualization* (with S. Davies and J. Schellinck)

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<sup>§</sup> In the parlance of the field, let me simply say that some of the details are left as an exercise for the reader (and can also be found in the numerous references).

# Preface References

- [1] C.C. Aggarwal. *Data Mining: the Textbook* [↗](#) . Cham: Springer, 2015.
- [2] C.C. Aggarwal, ed. *Data Classification: Algorithms and Applications* [↗](#) . CRC Press, 2015.
- [3] C.C. Aggarwal and C.K. Reddy, eds. *Data Clustering: Algorithms and Applications* [↗](#) . CRC Press, 2014.
- [4] D. Dalpiaz. *R for Statistical Learning* [↗](#) . 2020.
- [5] T. Hastie, R. Tibshirani, and J. Friedman. *The Elements of Statistical Learning: Data Mining, Inference, and Prediction* [↗](#) , 2nd ed. Springer, 2008.
- [6] G. James et al. *An Introduction to Statistical Learning: With Applications in R* [↗](#) . Springer, 2014.
- [7] I. Stewart, J. Cohen, and T. Pratchett. *The Science Of Discworld*. Ebury Publishing, 2002.
- [8] H. Wickham and G. Grolemund. *R for Data Science: Import, Tidy, Transform, Visualize, and Model Data* [↗](#) . O'Reilly, Jan. 2017.

# Contributors and Influences

A reference manual of this size could not have been compiled without the help of a multitude of individuals over the years, who provided contributions, influences, and/or inspiration:

**Kevin Cheung** *Mining Data Streams*

**Youssouph Cissokho** *Anomaly Detection and Outlier Analysis*

**Soufiane Fadel** *Anomaly Detection and Outlier Analysis*

**Ehssan Ghashim** *Bayesian Data Analysis, Queueing Systems*

**Lani Haque** *Text Analysis and Text Mining, Network Data Analysis*

**Andrew Macfie** *Text Analysis and Text Mining*

**Richard Millson** *Anomaly Detection and Outlier Analysis, (Social) Network Data Analysis*

**Kate Park** *(Social) Network Data Analysis*

**Bing Wang** *Mining Data Streams*

A hearty “thank you” to everyone, and to all others with whom I have crossed paths on this data adventure!



# Learning Paths

I mostly use the material found in this reference manual at various levels in my teaching at the University of Ottawa (in the Department of Mathematics and Statistics).

In particular, here is what I cover in various courses:

- **MAT 4376/5314E** (*Special Topics in Probability and Statistics | Techniques of Data Analysis*) – Chapters 24–26 (and some material from *The Practice of Data Visualization*);
- **MAT 4376/5314X** (*Special Topics in Probability and Statistics | Applied Data Science*) – Chapters 27–29 (and Chapter 16 in DUDADS, Volume 2).

I strongly encourage students to familiarize themselves with the contents of Chapters 1–11, 15, 19–23 (DUDADS, Volumes 1–3) before taking these courses, although it is not strictly necessary that they do so.