The School of Mathematics

THE UNIVERSITY
of EDINBURGH

My Incredible Thesis

by

My Name

Dissertation Presented for the Degree of
MSc in Statistics with Data Science

July 2021

Supervised by
Dr Very Important and Dr Strangelove

Executive Summary

Here comes your executive summary ...

Acknowledgments

Here come your acknowledgments ...

University of Edinburgh – Own Work Declaration

This sheet must be filled in, signed and dated - your work will not be marked unless this is done.

Name: .....

Matriculation Number: .....

Title of work: .....

I confirm that all this work is my own except where indicated, and that I have:

- Clearly referenced/listed all sources as appropriate
- Referenced and put in inverted commas all quoted text (from books, web, etc)
- Given the sources of all pictures, data etc. that are not my own
- Not made any use of the report(s) or essay(s) of any other student(s) either past or present
- Not sought or used the help of any external professional academic agencies for the work
- Acknowledged in appropriate places any help that I have received from others (e.g. fellow students, technicians, statisticians, external sources)
- Complied with any other plagiarism criteria specified in the Course handbook

I understand that any false claim for this work will be penalised in accordance with the University regulations (https://teaching.maths.ed.ac.uk/main/msc-students/msc-programmes/statistics/data-science/assessment/academic-misconduct).

Signature .....

Date .....

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1 Introduction

Here I will write a very good, precise and brief introduction. Particularly Section 2 is good!

2 Methods

In the following, I explain what did I do and how.

I should really cut this short, but BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla. Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla. BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBla BlaBla Bla. BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla BlaBla Bla Bla Bla BlaBla.

When you write outside of the LaTeX environment, you can use Markdown syntax. Some R Markdown basics: https://rmarkdown.rstudio.com/authoring_basics.html.

More in depth explanation is available in the book *RMarkdown for Scientists*:
https://rmd4sci.njtierney.com.

Note that I start a new paragraph when I have an empty line like this. BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla. BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla. Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla. BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla.

But I can also end a line with an empty line. You can enter display formulas like this using Latex syntax in the formula:

$$E = mc^2$$

You can also enter in-line formulas like $c^2 = a^2 + b^2$ using LaTeX syntax.

2.1 Models

Models are *very* helpful because.

- They're good.
- They're helpful.

2.2 Techniques

Techniques even better because.

1. They're magnificent.
2. If they work.

3 Results

I this section, I explain what did I discover.

Now it's getting very technical ... I will cite [2, 1]. I will also show my incredible α, β and γ mathematics and do some other fancy stuff.

3.1 Formulae

For example look at this

$$\min \sum_{s \in \mathcal{S}} Pr_s \left[\sum_{t=1}^{T} \left(\sum_{g \in \mathcal{G}} \left(\alpha_{gts} C_g^0 + p_{gts} C_g^1 + (p_{gts})^2 C_g^2 \right) + \sum_{g \in \mathcal{C}} \gamma_{gts} C_g^s \right) \right], \tag{3.1}$$

and you will see that it has a little number on the side so that I can refer to it as equation (3.1). Now if I do this

$$\begin{aligned} \sum_{i=1}^{n} k_i &= 20 \\ \sum_{j=20}^{m} \delta_i &\geq \eta \end{aligned} \tag{3.2}$$

I can align two formulae and control which one has a number on the side. It is (3.2). I can also do something like this

$$Y_l = \begin{bmatrix} \left(y_s + i\frac{b_c}{2} \right) \frac{1}{\tau^2} & -y_s \frac{1}{\tau e^{-i\theta^s}} \\ -y_s \frac{1}{\tau e^{i\theta^s}} & y_s + i\frac{b_c}{2} \end{bmatrix},$$

and it won't have a number on the side. Now if I have to do some huge mathematics I'd better structure it a little and include linebreaks etc. so that it fits on one page.

$$\begin{aligned} p_l^f &= G_{l11} \left(2 v_{F(l)} \bar{v}_{F(l)} - \bar{v}_{F(l)}^2 \right) \\ &+ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[B_{l12} \sin\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) + G_{l12} \cos\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) \right] \\ &+ \begin{bmatrix} \bar{v}_{T(l)} \left[B_{l12} \sin\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) + G_{l12} \cos\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) \right] \\ \bar{v}_{F(l)} \left[B_{l12} \sin\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) + G_{l12} \cos\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) \right] \\ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[B_{l12} \cos\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) - G_{l12} \sin\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) \right] \\ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[-B_{l12} \cos\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) + G_{l12} \sin\left(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)} \right) \right] \end{bmatrix} \cdot \begin{bmatrix} v_{F(l)} - \bar{v}_{F(l)} \\ v_{T(l)} - \bar{v}_{T(l)} \\ \delta_{F(l)} - \bar{\delta}_{F(l)} \\ \delta_{T(l)} - \bar{\delta}_{T(l)} \end{bmatrix}, \end{aligned} \tag{3.3}$$

This is a lot of fun!

3.2 Important Things

Finally we should have a nice picture like this one. However, I won't forget that figures and table are environments which float around in my document. So LaTeX will place them wherever it thinks they fit well with the surrounding text. I can try to change that with a float specifier, e.g. [!ht]. Now I want

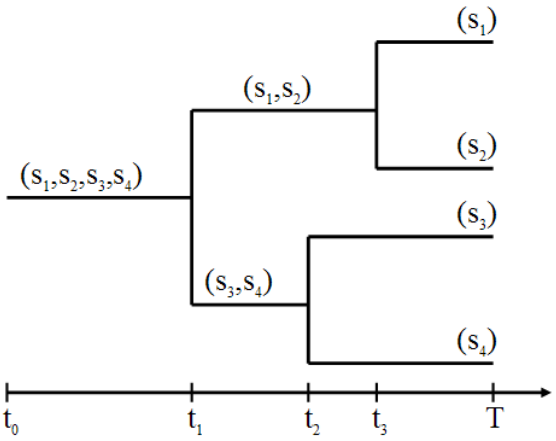

Figure 1: Look at this scenario tree with funny times t_1 and scenarios s_1 etc.

to use one of my own environments. I want to define something.

Definition 3.1 *I define*

$$\Gamma_\eta := \sum_{i=1}^{n} \sum_{j=i}^{n} \xi(i,j)$$

I definitely need some good tables, so I do this. I should really refer to Table 1.

Case	Generators	Therm. Units	Lines	Peak load: [MW]	[MVar]
6 bus	3 at 3 buses	2	11	210	210
9 bus	3 at 3 buses	3	9	315	115
24 bus	33 at 11 buses	26	38	2850	580
30 bus	6 at 6 buses	5	41	189.2	107.2
39 bus	10 at 10 buses	7	46	6254.2	1387.1
57 bus	7 at 7 buses	7	80	1250.8	336.4

Table 1: Something that doesn't make sense.

3.3 And now something else

Let:

$$\begin{aligned}
\Omega_0 &= \{(x,y,z,f) : \text{ satisfying } (9)-(19)\}, \\
\Omega_1 &= \{(x,y,z,f) : \text{ satisfying } (9),(11)-(20)\}, \\
\overline{\Omega}_0 &= \{\mathbf{0} \le (x,y,z,f) \le \mathbf{1} : \text{ satisfying } (9)-(18)\}, \\
\overline{\Omega}_1 &= \{\mathbf{0} \le (x,y,z,f) \le \mathbf{1} : \text{ satisfying } (9),(11)-(18),(20)\}.
\end{aligned}$$

where $\mathbf{0}$ and $\mathbf{1}$ are vectors of appropriate dimensions with 0's and 1's, respectively. Next we see that both Ω_0 and Ω_1 give equivalent formulations for the A-MSSP. In particular, the following statements hold:

Proposition 1 $\Omega_0 \subseteq \Omega_1$.

Proof. Let us suppose there exists $(x, y, z, f) \in \Omega_1$ such that $(x, y, z, f) \notin \Omega_0$. Then, there exist indices $i \in I$ and $t \in \{0, \ldots, |T| - s_i\}$ with $x_i^t > 0.5 \left(\sum_{h=1}^{s_i} x_i^{t+h} + 1 \right)$. By definition, $x_i^t = 1$ and $x_i^{t+h} = 0$ for all $h \in \{1, \ldots, s_i\}$. By (11) and (12), $\sum_{h=1}^{s_i} f_i^{th} = 1$, so $f_i^{th'} = 1$ for some $h' \in \{1, \ldots, s_i\}$. But then,

$$0 \;=\; x_i^{t+h'} \;=\; \sum_{h=\max\{1,t+h'-(|T|-s_i)\}}^{\min\{s_i,t+h'\}} f_i^{t+h'-h,h} \;\geq\; f_i^{th'} \;=\; 1\,,$$

as $h' \in [\max\{1, t + h' - (|T| - s_i)\}, \min\{s_i, t + h'\}]$. □

This immediately gives us

Corollary 1 *AS is a valid formulation for the A-MSSP.*

Next we compare the Linear Programming (LP) relaxations of the two formulations.

Proposition 2 $\overline{\Omega}_1 \subseteq \overline{\Omega}_0$.

Proof. Homework □

3.4 Including Markdown and R code

This subsection is called Section 3.4.

Even from LaTeX, this subsection is still called Section 3.4.

Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see http://rmarkdown.rstudio.com.

When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can embed an R code chunk like this:

```
summary(cars)
```

```
##      speed           dist
##  Min.   : 4.0   Min.   :  2.00
##  1st Qu.:12.0   1st Qu.: 26.00
##  Median :15.0   Median : 36.00
##  Mean   :15.4   Mean   : 42.98
##  3rd Qu.:19.0   3rd Qu.: 56.00
##  Max.   :25.0   Max.   :120.00
```

You can also embed plots, for example:

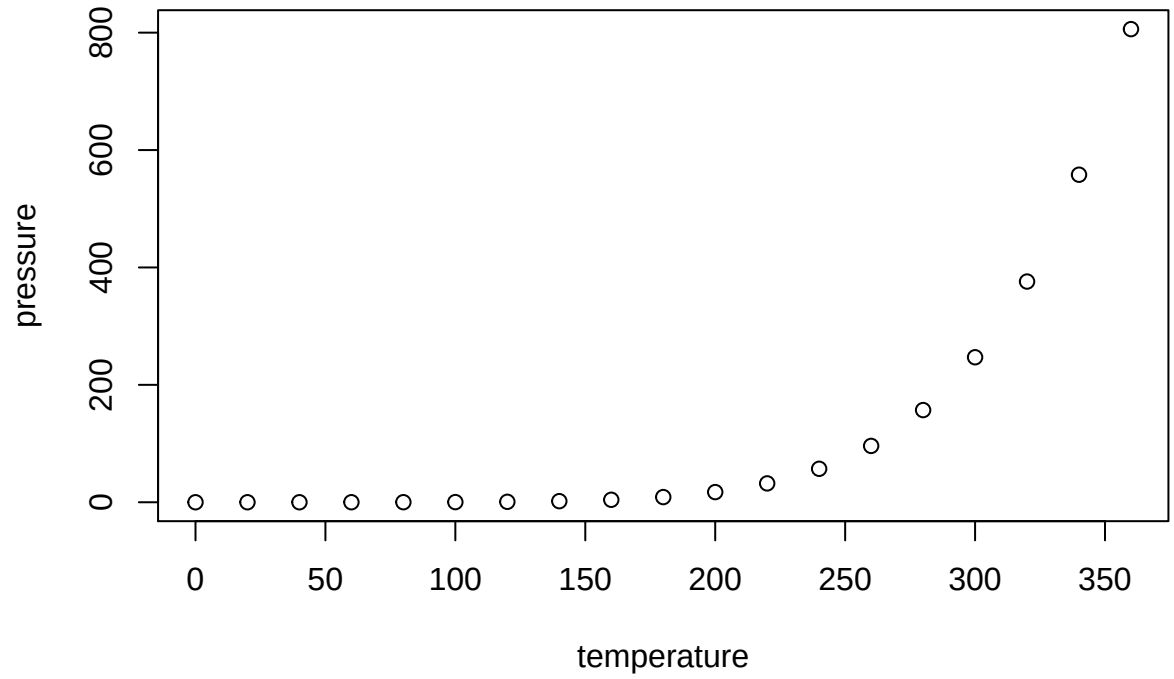

Figure 2: An amazing plot

In the above R code chunk, `pressure-plot` is the chunk name. Note that the `echo = print.all.code` parameter was added to the code chunk to potentially prevent printing of the R code that generated the plot (by default, `print.all.code=FALSE`, but this can be changed at the beginning of the document to display all of the code).

We can reference the pressure plot within a Markdown chunk as Figure 2.

We can reference the pressure plot within a LaTeX chunk as Figure 2.

We have two tables, Table 2 and Table 3. Please make sure not to include dots (.) or other special characters in the names of the R code chunks (such as MtcarsTable2), as this may cause issues with the labels.

Table 2: Table in plain LaTeX format

	mpg	cyl	disp	hp	drat	wt
Mazda RX4	21.0	6	160	110	3.90	2.620
Mazda RX4 Wag	21.0	6	160	110	3.90	2.875
Datsun 710	22.8	4	108	93	3.85	2.320
Hornet 4 Drive	21.4	6	258	110	3.08	3.215
Hornet Sportabout	18.7	8	360	175	3.15	3.440

Table 3: Table with booktabs

	mpg	cyl	disp	hp	drat	wt
Mazda RX4	21.0	6	160	110	3.90	2.620
Mazda RX4 Wag	21.0	6	160	110	3.90	2.875
Datsun 710	22.8	4	108	93	3.85	2.320
Hornet 4 Drive	21.4	6	258	110	3.08	3.215
Hornet Sportabout	18.7	8	360	175	3.15	3.440

We can reference the two tables within a LaTeX chunk as Table 2 and Table 3.

You can see more information on how to create nice tables in R Markdown at https://haozhu233.github.io/kableExtra/awesome_table_in_pdf.pdf and https://rfortherestofus.com/2019/11/how-to-make-beautiful-tables-in-r/.

4 Conclusion

In this section, I explain what what does my results mean.

I have no idea how to conclude, so I don't write much. But what follows is important.

References

[1] N. Gröwe-Kuska and W. Römisch. *Stochastic unit commitment in hydro-thermal power production planning*. Preprints aus dem Institut für Mathematik. Humboldt-Universität zu Berlin, Institut für Mathematik, 2001.

[2] T. Shiina and J. R. Birge. Stochastic unit commitment problem. *International Transactions in Operational Research*, 11(1):19–32, 2004.

Appendices

A An Appendix

Something.

B Another Appendix

Something else.