University of Nevada, Reno

Title for the (hopefully somewhat) related chapters of your graduate thesis/dissertation

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Mathematics

by

You D. Student

Dr. Pat D. Advisor, Ph.D. / Thesis Advisor

May August or December, 20XX

THE GRADUATE SCHOOL

We recommend that the thesis
prepared under our supervision by

YOU D. STUDENT

entitled

Title for the (hopefully somewhat) related chapters of your graduate thesis/dissertation

be accepted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

Pat D. Advisor, Ph.D.
Advisor

Jane Doe, Ph.D.
Committee Member

John Doe, Ph.D.
Committee Member

Sam Doe, Ph.D.
Graduate School Representative

Markus Kemmelmeier, Ph.D., Dean
Graduate School

May August or December, 20XX

Abstract

Enter your abstract here. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer 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.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim.

Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Dedication

I would like to dedicate this work to...

Acknowledgments

I would like to acknowledge...

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

Here is a brief, broad introduction to the topics addressed by the thesis chapters below. There might be an equation, like

$$\frac{dx}{dt} = f(x), \quad \text{for} \quad x \in \mathbb{R}^n$$

or even a figure, like Figure 1.1.

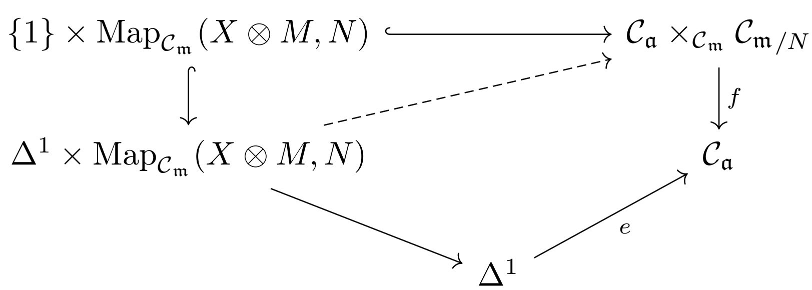
Figure 1.1: The "N" logo for the University of Nevada-Reno. Source: `https://www.unr.edu/Assets/Icons/logos/university-logo.svg` (converted to PDF from SVG) but see also `https://www.unr.edu/marketing-communications/brand/visual-identity`.

The figure above (Figure 1.1) may not be read by the screen reader because it is a float, which may therefore have it's read order pushed to the very end of the document. This is not ideal! One can mimic the figure environment as shown by this next figure (see the LaTeX source for details) in a way that it is read in line with the source text.

Figure 1.2: The "N" logo for the University of Nevada-Reno. Source: `https://www.unr.edu/Assets/Icons/logos/university-logo.svg` (converted to PDF from SVG) but see also `https://www.unr.edu/marketing-communications/brand/visual-identity`.

1.1 Morphism objects and operadic centers

Here is an example `tikzcd` diagram from Farr (2025), which needed to be removed from the main LaTeX source file and compiled on it's own, then included using the usual image insertion routine `\includegraphicx[alt={alt text}]{figfilename}`.

> Given a morphism $e : Y \to X$ in $h\mathcal{C}_{\mathfrak{a}}$, the induced map between the fibers comes from solving the lifting problem
>
> 
>
> ,
>
> and restricting the lift to $\{0\} \times \mathrm{Map}_{\mathcal{C}_{\mathfrak{m}}}(X \otimes M, N)$. Since f is a pullback of the right fibration $\mathcal{C}_{\mathfrak{m}/N} \to \mathcal{C}_{\mathfrak{m}}$, the lift above is induced by the solution to …

1.2 Linear Chain Trickery

Here is an example theorem from Hurtado and Kirosingh (2019). We'll show the following theorem in more detail below.

Theorem A (Simple LCT (Theorem 2.1))**.** *Consider a continuous time state transition model with inflow rate $\mathcal{I}(t) \geq 0$ into state X which has an Erlang(r, k) distributed dwell time. Let $x(t)$ be the (mean field) amount in state X at time t and assume $x(0) = x_0$. The mean field integral equation for this scenario is*

$$x(t) = x_0 S_r^k(t) + \int_0^t \mathcal{I}(s)\, S_r^k(t-s) ds. \tag{1.1}$$

State X can be partitioned into k sub-states X_i, $i = 1, \dots, k$, where particles in X_i are those awaiting the i^{th} event as the next event under a homogeneous Poisson process with rate r. Let $x_i(t)$ be the amount in X_i at time t, and $x(t) = \sum_{j=1}^{k} x_j(t)$. Eq. (1.1) is equivalent to the mean field ODEs

$$\frac{d}{dt}x_1(t) = \mathcal{I}(t) - r\,x_1(t) \tag{1.2a}$$

$$\frac{d}{dt}x_j(t) = r\,x_{j-1}(t) - r\,x_j(t), \quad j = 2, \dots, k \tag{1.2b}$$

with initial conditions $x_1(0) = x_0$, $x_j(0) = 0$ for $j \geq 2$.

The rest of this thesis is organized as follows:

1. First, ...

2. Second, ...

3. Finally, ...

References

Farr, Sonja (2025). $\mathbb{E}_2$-*algebra structures on the derived center of an algebraic scheme*. DOI: 10.48550/ARXIV.2506.14069.

Hurtado, Paul J. and Adam S. Kirosingh (Aug. 2019). "Generalizations of the 'Linear Chain Trick': incorporating more flexible dwell time distributions into mean field ODE models". In: *Journal of Mathematical Biology* 79.5, pp. 1831–1883. ISSN: 1432-1416. DOI: 10.1007/s00285-019-01412-w.

Chapter 2

The First Project

Once upon a time...

2.1 Introduction

2.1.1 In the beginning...

... there was some content.

2.2 Results

Here is the more detailed version of Theorem A.

The Erlang density function (g), CDF (G), and survival function ($S = 1 - G$; also called the *complementary CDF*) are given by Equation 2.1.[1]

[1] A useful interpretation of survival functions, which is used below, is that they give the expected proportion remaining after a give amount time.

$$g_r^k(t) = r\,\frac{(r\,t)^{k-1}}{(k-1)!}e^{-rt} \tag{2.1a}$$

$$G_r^k(t) = 1 - \sum_{j=1}^{k} \frac{(r\,t)^{j-1}}{(j-1)!}e^{-r\,t} = 1 - \sum_{j=1}^{k} \frac{1}{r}\,g_r^j(t) \tag{2.1b}$$

$$S_r^k(t) = 1 - G_r^k(t) = \sum_{j=1}^{k} \frac{1}{r}\,g_r^j(t). \tag{2.1c}$$

Theorem 2.1 (Simple LCT)**.** *Consider a continuous time state transition model with inflow rate $\mathcal{I}(t) \geq 0$ (an integrable function of t) into state X which has an Erlang(r, k) distributed dwell time (with survival function S_r^k from eq.* (2.1c)*). Let $x(t)$ be the (mean field) amount in state X at time t and assume $x(0) = x_0$.*

The mean field integral equation for this scenario is

$$x(t) = \; x_0 S_r^k(t) + \int_0^t \mathcal{I}(s)\, S_r^k(t-s)ds. \tag{2.2}$$

State X can be partitione into k sub-states X_i, $i = 1, \ldots, k$, where particles in X_i are those awaiting the i^{th} event as the next event under a homogeneous Poisson process with rate r. Let $x_i(t)$ be the amount in X_i at time t, and $x(t) = \sum_{j=1}^{k} x_j(t)$. Eq. (2.2) *is equivalent to the mean field ODEs*

$$\frac{d}{dt}x_1(t) = \mathcal{I}(t) - r\,x_1(t) \tag{2.3a}$$

$$\frac{d}{dt}x_j(t) = r\,x_{j-1}(t) - r\,x_j(t), \quad j = 2, \ldots, k \tag{2.3b}$$

with initial conditions $x_1(0) = x_0$, $x_j(0) = 0$ for $j \geq 2$, and

$$x_j(t) = x_0\,\frac{1}{r}\,g_r^j(t) + \int_0^t \mathcal{I}(s)\frac{1}{r}\,g_r^j(t-s)ds. \tag{2.4}$$

Proof. Substituting eq. (2.1c) into eq. (2.2) and then substituting eq. (2.4) yields

$$\begin{aligned} x(t) &= x_0\,S_r^k(t) + \int_0^t \mathcal{I}(s)\,S_r^k(t-s)\,ds \\ &= x_0\,\sum_{j=1}^{k}\frac{1}{r}\,g_r^j(t) + \int_0^t \mathcal{I}(s)\,\sum_{j=1}^{k}\frac{1}{r}\,g_r^j(t-s)\,ds \\ &= \sum_{j=1}^{k}\left(x_0\,\frac{1}{r}\,g_r^j(t) + \int_0^t \mathcal{I}(s)\,\frac{1}{r}\,g_r^j(t-s)\,ds\right) = \sum_{j=1}^{k} x_j(t). \end{aligned} \tag{2.5}$$

Differentiating equations (2.4) (for $j = 1, \dots, k$) yields equations (2.3) as follows.

For $j = 1$, equation (2.4) reduces to

$$x_1(t) = x_0 e^{-r\,t} + \int_0^t \mathcal{I}(s)e^{-r(t-s)}ds. \tag{2.6}$$

Differentiating $x_1(t)$ using the Leibniz integral rule and substituting (2.6) yields

$$\frac{d}{dt}x_1(t) = \ -rx_0e^{-r\,t} - r\int_0^t \mathcal{I}(s)e^{-r(t-s)}ds + \mathcal{I}(t) \ = \ \mathcal{I}(t) - rx_1(t). \tag{2.7}$$

Similarly, for $j \geq 2$, Lemma ?? (not shown) yields

$$
\begin{aligned}
\frac{d}{dt}x_j(t) &= x_0\,\frac{1}{r}\,\frac{d}{dt}g_r^j(t) + \int_0^t \mathcal{J}(s)\frac{d}{dt}\left(\frac{1}{r}\,g_r^j(t-s)\right)\,ds \\
&= x_0\,\left(g_r^{j-1}(t) - g_r^j(t)\right) + \int_0^t \mathcal{J}(s)\left(g_r^{j-1}(t-s) - g_r^j(t-s)\right)\,ds \\
&= r\left(\frac{x_0}{r}\,g_r^{j-1}(t) + \int_0^t \mathcal{J}(s)\frac{1}{r}g_r^{j-1}(t-s)\,ds\right) - \; r\left(\frac{x_0}{r}\,g_r^j(t)\right. \\
&\quad \left. + \int_0^t \mathcal{J}(s)\frac{1}{r}g_r^j(t-s)\,ds\right) = \; r\,x_{j-1}(t) - r\,x_j(t).
\end{aligned} \tag{2.8}
$$

■

2.2.1 Tables

Here's a simple table, Table 2.1, however, it won't be read aloud by a screen reader until the very end of the document unless the author manually changes the read order (via Adobe Acrobat). Float objects, like tables and figures, are not read in the order they appear on the page. Additionally, links to a standard table (or figure) may not be verbalized well, again, because of the way floats are tagged. For example, the link at the start of this paragraph is read aloud by a screen reader as "link, go to destination table, caption fourteen" rather than "link, go to, link destination Table 2.2" which is how the link to alternative table below is read: Table 2.2. Using `\autoref` gives links that read slightly better than those from `\ref`, but either will suffice.)

Table 2.1: A short table demonstrating a standard LaTeX table. Compare the LaTeX source for this table and Table 2.2.

Letter	**Number**
A	1
B	two
C	3

Recommendation for fixing these float issues: instead of using table and figure environments, use a center environment and then replace `\caption{}` with `\captionof{}{}` from the `caption` package, as in this next example (Table 2.2).

Note: There isn't a perfect solution, as these alternative tables and figures may cause some warnings like "Destination 'table2.2' has no related structure." However, at least in my testing, the links in both the List of Tables page and in the text (like Table 2.2) all work and take you to the table when clicked. **My recommendation:** use the suggested alternative until the LaTeX developers fix the conflicts between the tagging code, hyperref, and the figure and table environments.

Table 2.2: A BETTER short table demonstrating a non-standard LaTeX table created using a `center` environment and `\captionof{}` from the `caption` package.

Letter	**Number**
A	1
B	two
C	3

I've intentionally left this table split across two pages to highlight another shortcoming of this alternative: you'll need to manually position the table or figure and/or make further modifications to minimize splitting it across a page break. To fix this particular example, you'll need to add `\nopagebreak` to the start and maybe end of the caption text, and maybe also after the label or elsewhere between different objects in that center environment. Alternatively, adding a `\newline` above the center environment could work too.

Next, here's a table that is only used for text formatting and is tagged differently from tables above (see the LaTeX source for details). It should be read by a screen reader as plain text.

Name:	John Doe
Degree:	B.S.
Date:	May 2025

The `longtable` package allows tables to be split across multiple pages. This gives some TH and TD errors and possibly other tagging errors when ran through the accessibility checker, can be read incorrectly by screen reader software. It's best to NOT use `longtable` and instead split the table up manually as was done for Table 2.3).

Table 2.3: This table is manually split across multiple pages since it won't fit onto a single page. See the LaTeX source for details, and compare to the table above.

A	**B**	**C**	**D**	**E**
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah

Continue on next page...

Table 2.3: Continued...

A	**B**	**C**	**D**	**E**
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah
blah	blah	blah	blah	blah

Here are a few more equations. Using the `align` environment we have eqs. (2.9).[2]

$$\dot{x} = \frac{dx}{dt} = f_x(x, y) \tag{2.9}$$

$$\dot{y} = \frac{dy}{dt} = f_y(x, y). \tag{2.10}$$

The above, but in a subequations environment:

$$\dot{x} = \frac{dx}{dt} = f_x(x, y) \tag{2.11a}$$

$$\dot{y} = \frac{dy}{dt} = f_y(x, y). \tag{2.11b}$$

Here is an aligned environment in an equation environment:

$$\begin{aligned} \frac{dx}{dt} &= D_t x \\ &= f_x(x, y). \end{aligned} \tag{2.12}$$

Now using a regular equation environment:

$$\dot{x} = \frac{dx}{dt} = F_x(x, y)$$

$$\dot{y} = \frac{dy}{dt} = F_y(x, y).$$

[2]The abbreviation "eqs." is also probably not very screen reader friendly, so it is preferred to use `\autoref*{label}` instead, which will give "Equation 2.9" or maybe find a way to make a macro that looks like `\Eqs` and reads as "equations".

2.3 Custom Alternate Text For Math Expressions!

Note: This following functionality was introduced in the January 2026 release of LuaLaTeX, and should be used with the mathml-SE tagging setup only. Expect that this syntax will probably change as the LaTeX Tagging Project matures!

For context, the `unicode-math` package allows LaTeX to tag symbols like α with the corresponding unicode character rather than the LaTeX macro, which ensures that such symbols can be read properly by screen reader software.

There are some mathematical symbols, however, that either do not have unicode character analogs or that we would prefer to manually assign some context specific alternate text that differs from the standard MathML semantics. For example, the double-struck "1" symbol, $\mathbb{1}$, is often used as an indicator function but the default MathML reading of the symbol leads screen readers to read it as "double-struck one."

In the LaTeX source file for this document I have added two macros, above the `\documentclass{}` line, that define a new symbol and a new math function that can be used as one would use, say, `\pi` and `\sqrt{...}`:

```
\newcommand{\indAfn}{% Reads as "indicator function subscript A"
 \MathMLintent{indicator-function-subscript-A}%
 {{\mathbb{1}_A}}%
}
% Below is read as "indicator function subscript A of [arg]"
\newcommand{\indAfnof}[1]{
 \MathMLintent{indicator-function-subscript-A($x)}%
 {{\mathbb{1}_A\!\left(\MathMLarg{x}{#1}\right)}}%
}
```

A screen reader (tested here using Adobe Acrobat + NVDA) will read the phrase "$\mathbb{1}_A$ is 0 or 1, where $\mathbb{1}_A(\omega)$ is 1 if $\omega \in A$ and 0 otherwise" as "indicator function subscript A is 0 or 1, where indicator function subscript A of omega is 1 of omega is an element of A and zero otherwise."

Again, recall that it is recommended to only use the mathml-SE tagging method to ensure consistency across screen reader software and PDF readers. Some PDF and screen reader combinations, especially under different settings may handle the combined SE and AF tagging methods differently.

2.3.1 What about other non-math symbols?

Consider this symbol, from the `utfsym` package, which has no associated alt text or MathML recognition: `\usym{1F6E0}` which is the symbol 🛠 (a hammer and wrench crossed in an X pattern).

We can use this as a new math symbol and/or an operator that takes an argument, as in the above examples, by specifying a pair of macros: one for the symbol and one for the function form. As in the previous example, each includes alternate MathML text. Unlike the previous example, the symbol macro does not work without first fooling the LaTeX MathML tagging routine into recognizing it as a math object. Here, this was done by placing the symbol over a symbol. Presumably, properly declaring it as a new math symbol somehow would also work (and be the preferred approach).

```
\usepackage{utfsym}
\newcommand{\hammerwrench}{% Symbol only
 \MathMLintent{hammer-wrench}%
 %{{\usym{1F6E0}}}% Doesn't work! Argument needs to be a math object
 {{\,\cdot\!\!\!\text{\usym{1F6E0}}}}% This line works!! Why?
 % Placing it over a \cdot coerces the 2nd argument to a math object!
 % Declaring it a new math object somehow should also work.
}
\newcommand{\hammerwrenchof}[2]{% Function version that takes 2 arguments
 \MathMLintent{hammer-wrench($x,$y)}%
 {{\usym{1F6E0}\!\left(\MathMLarg{x}{#1},\,\MathMLarg{y}{#2}\right)}}%
}% Maybe try \mathop{} if the symbol isn't behaving well in math mode
```

Now we can see that the 🛠 function, perhaps written as $\text{🛠}(a,\, b)$, can be used in expressions like $\sin\left(\sqrt{\text{🛠}(\alpha,\, \omega)}\right)$ and will be read properly as “sine of, open paren, the square root of, hammer-wrench of alpha and omega, close paren” by a screen reader, e.g., using Adobe with NVDA.

Appendix 2.A Model Derivation

We just nondimensionalized $\dot{N} = r\,N\,(1 - N/K)$ to get $\dot{x} = x(1 - x)$.

Appendix 2.B Simulation Details

We used Euler's method with step sizes of 10^{-4} and initial condition $x(0) = 0.1$.

Chapter 3

The Second Project

Some more content...

3.1 Introduction

Stuff

3.2 Results

QED.

Chapter 4

The Third Project

Some more content...

4.1 Introduction

Stuff

4.2 Results

QED.

Appendices

Example appendices at the end of the thesis instead of individual chapters.

A Equations

Here is the identity matrix,

$$I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \tag{A.1}$$

B Simulation Details

B.1 Parameter Values

We used the values in the code below.

B.2 Computer Code

Here's some R code. Unfortunately, packages like `listings` are not yet compatible with the new LaTeX tagging functionality, so you may have to wait a while before you can submit nicely formatted code with syntax highlighting. Until then, we can use a trusty old `verbatim` environment.

R code: Example Script

```
# THIS IS A LOVELY LITTLE BIT OF R CODE:
# -------------------------------------
# install.packages("openssl") # install this first, then run the code below
par(bg = "black", fg = "black")
x=seq(-sqrt(3),sqrt(3),length=800)
for(k in seq(0,100,length=40)) {
 plot(x,(x^2)^(1/3)+0.9*sin(k*x)*sqrt(3-x^2), type="l",lty=1, col="red",
 xlim=c(-2,2), ylim=c(-1.25,2.25), lwd=2)
 text(0,1,
   rawToChar(openssl::base64_decode("SGFwcHkgVmFsZW50aW5lJ3MgRGF5IQ==")),
   col="white", cex=3.25)
 Sys.sleep(1)
} # End of Example Script
```

Ideally, code should be an electronic supplement to your thesis. Code opened in a screen reader friendly code editor will be much more accessible than code in a PDF.