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

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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.

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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 maybe a figure, like Figure 1.1.

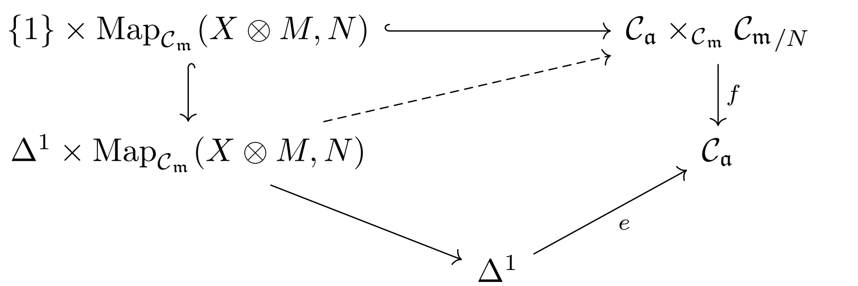
Figure 1.1: The “N” logo for the University of Nevada-Reno. Source: `https://www.unr.edu/Assets/Icons/logos/university-logo.svg` (converted to PDF from SVG) but see also `https://www.unr.edu/marketing-communications/brand/visual-identity`.

Accessibility standards require documents to be able to be read aloud by "screen reader" software, such as the free software NVDA (a good choice for testing how your documents are read aloud to someone who is visually impaired). The figure above (Figure 1.1) may not be read by such software in the expected reading order (where it appears on the pages), because it is a *float*. It will likely have it's read order pushed to the very end of the document. This may not be the desired read order. One way to manually set the location and read order is to mimic the `figure` environment using a `center` environment and the `\captionof` command from the caption package, as shown by this next figure (see the LaTeX source for details).

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 (see file `tikzdiagram.tex`), 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). Sometimes a letter-based theorem numbering convention is used in the introduction to introduce a more intuitive statement of a technical theorem that appears later in the document. Here's one such example using a custom `itheorem` environment defined in the preamble of the LaTeX source file for this document. The following theorem is shown in more detail in a subsequent chapter (Theorem 2.1).

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, $i = 1, \ldots, k$, 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. (1.1) is equivalent to the mean field ODEs

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

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

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 from Hurtado and Kirosingh (2019).

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 Tips for writing tagging-friendly LaTeX

There are many ways in which people write certain parts of their LaTeX source files to achieve a desired "look" on the page. However, not all of these tricks provide the kinds of clear structures needed for the new tagging routines to properly tag them. Likewise, people sometimes use certain commands inappropriately, just for formatting purposes, which will give misleading tagging structures (for example, using `\paragraph{}` to format some text is not advised, as this command is basically equivalent to `\subsubsubsection{}`).

Here are a few tips for writing the non-mathematical aspects of a LaTeX document using tagging-friendly best practices.

- **Focus on structure, not just appearance.** Don't use `\\` to force vertical spacing (use alternatives like `\bigskip` or `\vspace` or even better, load the `parskip` package to set sensible spacing) or to start a new paragraph (for that use `\par`). Also, don't use `\\` in lists or blockquotes to force line spacing (change the environment spacing/formatting instead).
- Use `itemize` or `enumerate`; don't manually type numbered or bulleted lists.

- Add alt text to graphics with the `alt` option:
  `\includegraphics[...,alt={Alt text here}]{filename}`.
- Use ~ to glue together text or objects separated by a space so they don't get broken across lines or pages. For example, don't write `200 m` write `200~m` (the ~ will appear as an empty space but will bind the two sides together into one 'word').
- Use `\paragraph{}` appropriately, as mentioned above.
- I know this is a list of tips related to non-mathematical writing, but it's worth mentioning that you should use `\( ... \)` for inline math (it's also OK to use `$...$`) and use `\[ ... \]` for display mode math (centered on it's own line). Do not use the older TeX syntax `$$...$$` for display mode. Similarly, please use proper equation environments like `align` when those are more appropriate than shortcuts like using multiple 1-line equations using consecutive `\[ ... \]` environments.

2.2.2 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 was read aloud by the NVDA screen reader during my testing 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 (see Table 2.2). It's slightly preferable to use `\autoref` (part of the hyperref package), which will create links that are read slightly better by software like NVDA, rather than using the standard `\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; see LaTeX source for details).

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

Note 1: 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 non-float alternative until the LaTeX developers fix the conflicts between the tagging code, `hyperref`, and the figure and table environments.

Note 2: This alternative way of making a table allows the table and caption to be split across two pages: 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. Manual placement in the final draft is preferred, for example, adding a `\newpage` above the center environment to position it at the top of the next page.

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. Earlier (Feb 2026) tests gave some TH and TD errors and possibly other tagging errors when ran through the accessibility checker, but in April 2026 there were different errors. It's might be best to NOT use `longtable` for now, 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.

Base 10	**Binary**
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111
16	10000
17	10001
18	10010
19	10011
20	10100
21	10101
22	10110
23	10111
24	11000
25	11001
26	11010
27	11011
28	11100
29	11101
30	11110
31	11111
32	100000
33	100001
34	100010
35	100011

Table 2.3 continue on next page...

Table 2.3: Continued...

Base 10	**Binary**
36	100100
37	100101
38	100110
39	100111
40	101000
41	101001
42	101010

2.2.3 Landscape Orientation for Wide Tables & Figures

Sometimes wide tables are best shown rotated 90°so that the table appears on the page in landscape orientation rather than portrait. The page itself can then be displayed in a PDF reader in the normal orientation (portrait) or rotated by the PDF viewer to landscape for better viewing of the table.

Packages that do this are `lscape` (which does not rotate the page in the PDF, just the table on the page) and `pdflscape` which will also rotate the page in the PDF. You'll typically want to use `pdflscape` unless you specifically don't want the PDF page rotated for viewing on screen.

This next page shows Table 2.4, an example using `pdflscape`, and the `tablex` package to fill out the full space available on the page.

Table 2.4: A table of some of the longest words in the Merriam-Webster dictionaries, excluding some molecular and place names. Source: `https://www.merriam-webster.com/wordplay/longest-words-ever`, accessed 10 Apr 2026.

Number of Letters	**Word**	**Description/Definition**
45	pneumonoultramicroscopic-silicovolcanoconiosis	"A lung disease caused by inhalation of very fine silicate or quartz dust."
30	pseudopseudohypoparathy-roidism	"Refers to a relatively mild form of pseudohypoparathy-roidism." "The pathophysiology of PFBC is profoundly linked to the loss of integrity of the BBB and should be distinguished from the calcification processes that take place in secondary brain calcifications, in which calcium deposition develops via two main pathways: dystrophic calcification resulting from membrane disruption and uncontrolled calcium entry (hypoxic ischemic injury, intrauterine infections), and calcium–phosphate metabolism alterations (pseudohypoparathyroidism and pseudopseudohypoparathyroidism, mainly linked to loss of function mutations of GNAS, involved in the intracellular transmittal pathway of PTH). — Monfrini et al., *International Journal of Molecular Sciences (Basel, Sz.)*, 2023"
27	electroencephalographically	Indicates something done "using an apparatus for recording brain waves, that is, an electroencephalograph."
26	radioimmunoelectrophoresis	"Refers to a kind of immunoelectrophoresis involving radioactive labels."
25	immunoelectrophoretically	To do something with immunoelectrophoresis.
24	laryngotracheobronchitis	"Refers to inflammation of the larynx, trachea, and bronchi."

2.2.4 More Equations

It's worth repeating: to create display mode math expressions, please do not use the older TeX double-$ notation like `$$f(x)=x^2$$`. Instead us `\[f(x)=x^2\]`. For inline math, you *can* use either `\(...\)` (recommended), or the more common `$...$` (also acceptable).

Here are a few example equations using different environments. Know how to use different environments to get multiline equations that are either labeled as separate equations, labeled as subequations, or labeled as a single equation spanning multiple lines. See the AMS Short Math Guide for LaTeX at `https://tug.ctan.org/info/short-math-guide/short-math-guide.pdf` for more examples than those given below.

Using the `align` environment to position the equations relative to one another, we have different options for how they are labeled and assigned equation numbers. For example, use alone, an align environment gives eqs. (2.9).[2]

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

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

To get the above, but numbered as subequations, use `align` within a `subequations` environment, where you can label the set of equations as well as individual equations:

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

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

This way, you can refer to the system of equations (2.11), or the individual Equation 2.11a and Equation 2.11b.

[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".

Here is an aligned environment in an equation environment:

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

Some bold math (note how these are read by a screen reader like NVDA, then see the next section).

$$\mathbf{A} = \begin{bmatrix} A & 0 \\ 0 & 1 \end{bmatrix}_{2\times 2}$$

Equation referencing note: To reference equations in the main text or figure and table captions, you have a few options. First, using `\autoref{label}` from the `hyperref` package will work to give you something like "Equation 1" where the text and number are a clickable link (use `\autoref*{label}` to suppress links). Second, many journals require the number to be in parentheses, and/or require the use of abbreviations Eq. or Eqs., so that is more standard notation. Therefore, you might instead choose to use the more traditional "`Eqs.~\eqref{label}`." Here the text label "Eqs." won't be part of the clickable link: for example, "Eqs. (2.11)". Optionally (my recommendation), define a custom referencing command like `\newcommand{\Eqs}[1]{\hyperref[#1]{Eqs.~(\ref*{#1})}}` in your preamble. This makes "Eqs." part of the clickable link, ensures that you consistently use ~ for the space, and it ensures that he equation references are verbalized well by screen readers like NVDA. Using `\Eqs{label}` gives linked labels like Eqs. (2.11).

2.3 Custom Alternate Text For Math Expressions

You may encounter situations where you'd like to modify the standard alternate text for math expressions. For example, there are some mathematical symbols 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 context, the `unicode-math` package allows LaTeX to tag math symbols like α with the corresponding unicode character, rather than the LaTeX "`\alpha`", which ensures that such symbols can be read properly by screen reader software like NVDA.

In the January 2026 release of LuaLaTeX, the new MathML `intent` attribute was integrated into the mathml-SE tagging setup. This allows authors to specify custom text for symbols and expressions, for example, to use context-specific semantics. Note that the syntax used here may change as the LaTeX Tagging Project matures, or may be surpassed by alternative approaches.

These next two sections look at customizing the alternate text related to how the MathML tags are generated using the MathML `intent` attribute.

2.3.1 Screen-Reader Friendly Math Expressions & Symbols

The LaTeX tagging routines that convert equations to MathML don't fully grasp all of the contextual nuances that we use to read math. This leads screen readers to read some expressions incorrectly. For example,

$$f'(f'(x))$$

will get read by NVDA as something like "f prime times f prime of x" and this is a common problem with functional expressions where the function or the argument isn't just a single character! One solution is to make a new command using `\MathMLintent{}{}` that is a proper function and has custom alternate text, so that it is read aloud correctly.

Example 1

To see how to implement such improvements, see the LaTeX source for this section, and the custom commands/macros in the preamble of the document (I've also included these below). Also compare how a screen reader like NVDA reads the following two expressions. These are visually identical, but are read differently by the NVDA screen reader. The first is based on standard LaTeX math notation and suffers from the same problem as the above example as well as the left hand side being poorly verbalized.

$$(f^{-1})'(y) = \frac{1}{f'(f^{-1}(y))}.$$

The following alternative, however, is read aloud correctly according to user-defined functions with custom alternate text:

$$(f^{-1})'(y) = \frac{1}{f'(f^{-1}(y))}.$$

The second example uses these functions, defined in the document preamble:

```
\newcommand{\finvprime}[1]{%
 \MathMLintent{f-inverse-prime($x)}%
 {{(f^{-1})'\!\left(\MathMLarg{x}{{#1}}\right)}}%
}% \finvprime{y} is read by a screen reader as "f inverse prime of y"

\newcommand{\finv}[1]{%
 \MathMLintent{f-inverse($x)}%
 {{f^{-1}\!\left(\MathMLarg{x}{{#1}}\right)}}%
}% \finv{y} will be read by a screen reader as "f inverse of y"

\newcommand{\fprime}[1]{%
 \MathMLintent{f-prime($x)}%
```

```
  {{f'\!\left(\MathMLarg{x}{{#1}}\right)}}%
 }% \fprime{\sin x} is read as "f prime of sin of x"
```

Importantly, these functions can be given more complex mathematical expressions as arguments, and will still be verbalized correctly by a screen reader like NVDA.

Remark 1: The second argument to `\MathMLintent{}{}` must include an extra pair of curly braces if the argument includes more than one math symbol!!

Remark 2: 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 when configured with different settings, may handle the combined SE and AF tagging methods differently. There is a trade-off, however: Using both mathml-SE and mathml-AF will help ensure the document can be read by older screen reader software, at the cost of possible inconsistencies.

Example 2

Authors often encode information visually using different fonts (e.g., $\mathcal{F}$ versus F), and we can use `\newcommand{}{}` and `\MathMLintent{}{}` to define math symbols and functions with custom alternate text that achieves the same goal. For example to define a bold face letter J to be read as a Jacobian ($\mathbf{J}$), and a regular J to be read as something else, like say the Poisson matrix (J), one can use the following:

```
% Example: give standard symbols context-specific alt text
\newcommand{\Jac}{%
 \MathMLintent{Jacobian-J}%
 {\mathbf{J}}%
}
\newcommand{\J}{%
 \MathMLintent{Poisson-matrix-J}%
 {J}%
}
```

Example 3

Sometimes, we just want to use context-specific semantics instead of default MathML. Consider the double-struck "1" symbol, $\mathbb{1}$, which is often used as an indicator function that has value 0 or 1 depending on whether it's argument belongs to a given set. Unfortunately, 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 commands/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}{% Verbalized as "indicator function subscript A"
 \MathMLintent{indicator-function-subscript-A}%
 {{\mathbb{1}_A}}%
}
% Below is verbalized as "indicator function subscript A of [arg]"
\newcommand{\indAfnof}[1]{
 \MathMLintent{indicator-function-subscript-A($x)}%
 {{\mathbb{1}_A\!\left(\MathMLarg{x}{{#1}}\right)}}%
}
```

Using these commands, NVDA read aloud 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."

2.3.2 What about using non-math symbols in math mode?

Sometimes we want to broaden our mathematical symbols to include what the LaTeX tagging routines would treat as non-mathematical objects. Giving these non-math sybmols alternate text within the context of MathML tagging is more difficult.

For example, 🛠 (a hammer and wrench crossed in an X pattern) is given by `\usym{1F6E0}` in the `utfsym` package, and has no associated alt text or MathML recognition. 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 `\cdot` 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 🛠(a, b), can be used in expressions like $\sin\left(\sqrt{🛠(\alpha, \omega)}\right)$ 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

These are just some example appendices at the end of the chapter instead of at the end of the thesis.

We just nondimensionalized the equation $\dot{N} = r\,N\,(1 - N/K)$ 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 $x(0) = 0.1$.

References

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 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.