

**Novel approaches for Visualizing Time to Event Data**

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**Contents**

[**Contents**](#_bookmark0). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **2**

[**Abstract**](#_bookmark1). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **4**

[**Declaration of originality**](#_bookmark2). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **5**

[**Copyright statement**](#_bookmark3). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **6**

[**Acknowledgments**](#_bookmark4). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **7**

1. [**Introduction**](#_bookmark5). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . **8**
   1. [Background and motivation](#_bookmark6) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 9
   2. [Aims and objectives](#_bookmark7) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 9
   3. [Report structure](#_bookmark8) 10
2. [Literature review](#_bookmark10) 10
   1. [Introduction](#_bookmark11) 10
   2. [Example display items](#_bookmark12) 10
   3. [Summary](#_bookmark20) 13
3. [Methods](#_bookmark21) 13
   1. [Introduction](#_bookmark22) 13
   2. [Content](#_bookmark23) 13
      1. [Introduction](#_bookmark24) 13
      2. [Detail](#_bookmark25) 14
      3. [More detail](#_bookmark26) 15
      4. [Summary](#_bookmark27) 16
   3. [Summary](#_bookmark28) 16
4. [Results and discussion](#_bookmark29) 16
   1. [Introduction](#_bookmark30) 16
   2. [Content](#_bookmark31) 17
      1. [Introduction](#_bookmark32) 17
      2. [Detail](#_bookmark33) 17
      3. [More detail](#_bookmark34) 18
      4. [Summary](#_bookmark35) 19
   3. [Summary](#_bookmark36) 19
5. [Conclusions and future work](#_bookmark37) 20
   1. [Conclusions](#_bookmark39) 20
   2. [Future work](#_bookmark40) 20

[References](#_bookmark40) 21

[Appendices](#_bookmark43) 22

[A Project outline](#_bookmark44) 22

[B Risk assessment](#_bookmark45) 22

**Abstract**

Time-to-event data, commonly encountered in clinical trials, reliability engineering, and social sciences, presents unique challenges for effective visualization due to censoring, competing risks, and varying follow-up durations. Traditional methods such as Kaplan-Meier curves and hazard plots, while informative, often lack the flexibility and intuitiveness required for exploratory analysis and communication with non-technical stakeholders. This project explores novel approaches to visualizing time-to-event data, incorporating interactive, multidimensional, and model-informed techniques. We investigate enhancements using dynamic dashboards, survival heatmaps, event probability trajectories, and risk state animations, with an emphasis on interpretability and accessibility. By integrating statistical modeling with modern visualization frameworks, the proposed methods aim to improve both analytical depth and user engagement in time-to-event analyses. Real-world datasets are used to demonstrate the utility and versatility of these approaches, highlighting their potential to complement and, in some cases, surpass traditional visual tools.

**Declaration of originality**

I hereby confirm that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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**Acknowledgments**

Acknowledgments go here.

1. **Introduction**

Time-to-event data, also known as survival data, plays a central role in various domains such as clinical research, epidemiology, engineering, and economics. This type of data involves the time until a specified event occurs—such as death, disease relapse, equipment failure, or job change—and is often complicated by censoring and varying follow-up periods. Visualizing such data is crucial for understanding survival patterns, comparing groups, assessing risk over time, and communicating results to both technical and non-technical audiences.

Traditional visualization techniques, most notably the Kaplan-Meier curve and Cox model-based hazard functions, have long served as the standard for summarizing and interpreting survival data. While these methods are statistically sound and widely used, they often fall short in handling the complexity and heterogeneity found in real-world datasets. Additionally, they may not provide an intuitive understanding of individual-level variations or dynamic risk patterns, especially in the presence of competing risks or time-dependent covariates.

With the increasing availability of rich, high-dimensional survival datasets and the advancement of data visualization tools, there is a growing need for more flexible, insightful, and interactive visual representations. This project aims to explore and develop novel approaches to visualizing time-to-event data that go beyond conventional methods. By leveraging modern visualization libraries, interactive dashboards, and model-based summaries, we seek to enhance the interpretability, accessibility, and utility of survival data visualizations. Through applied examples and comparative analysis, we demonstrate how these innovative approaches can improve both data exploration and communication in survival analysis.

* 1. **Background and motivation**

Time-to-event data is frequently encountered in research and practice, particularly in fields such as medicine, public health, engineering, and the social sciences. The defining characteristic of this type of data is that the outcome of interest occurs over time and may be subject to right-censoring, meaning the exact event time is unknown for some subjects due to loss to follow-up or the study ending before the event occurs. Traditional methods like Kaplan-Meier survival curves, log-rank tests, and Cox proportional hazards models have served as the foundational tools for analyzing such data. These techniques offer robust statistical insights, yet their visual outputs are often static, one-dimensional, and sometimes difficult to interpret—especially for audiences without statistical training. Furthermore, they may not effectively communicate uncertainties, subgroup heterogeneity, or dynamic changes in risk over time.

In an era of increasing data complexity and demand for clarity in data communication, there is a growing need to move beyond traditional survival plots and explore more modern, engaging, and insightful visualization strategies. The motivation for this project stems from the recognition that improved visual tools can play a pivotal role in exploratory data analysis, hypothesis generation, and effective stakeholder communication. Interactive and multidimensional visualizations—such as survival heatmaps, dynamic risk profiles, and model-based prediction curves—can capture nuances that conventional plots may miss. By developing and applying novel visualization techniques to real-world time-to-event datasets, this project aims to bridge the gap between statistical rigor and visual clarity, ultimately contributing to more informed and impactful data interpretation in survival analysis.

* 1. **Aims and objectives**

The primary aim of this project is to explore and develop innovative visualization techniques for time-to-event (survival) data that enhance interpretability, interactivity, and communication of complex survival patterns.

To achieve this, the specific objectives are:

1. **Critically review** existing methods for visualizing time-to-event data, including Kaplan-Meier curves, cumulative hazard plots, and model-based visualizations.
2. **Identify limitations** of traditional survival plots in terms of visual clarity, accessibility, and ability to handle censored data, competing risks, or time-varying covariates.
3. **Develop and implement** novel visualization approaches such as survival heatmaps, dynamic risk trajectories, model-informed plots, and interactive dashboards.
4. **Apply the proposed methods** to real-world datasets, comparing them against traditional techniques to assess improvements in insight and usability.
5. **Evaluate the effectiveness** of these visualizations in terms of clarity, interpretability, and their potential to aid decision-making for both technical and non-technical audiences.
6. **Provide practical guidance** for researchers and analysts on selecting and designing appropriate visual tools for survival data in various contexts.

## Report structure

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# Literature review

## Introduction

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## Example display items

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This is an example of adding references [[1]–[3].](#_bookmark42) If you want the author name, or similar, you can use: Casson *et al.* in 2009 introduced a really good idea. (This is for when you primarily use num- bered citations, but occasionally need an author’s name. If using author names as the reference

**Table 1.** Example table. Full caption goes here. Often a short caption in [] is used as well as the main caption to keep the list of figures tidy; it gets messy if there are long captions going over more than one line.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Participant | Number / Prime dresses | %  Non-prime dresses | Duration Prime dresses | / %  Non-prime dresses |
| 1 | 33.33 | 33.91 | 20.83 | 18.42 |
| 2 | 13.04 | 17.50 | 04.93 | 07.62 |
| 3 | 22.73 | 20.10 | 13.00 | 08.20 |
| 4 | 31.34 | 21.88 | 10.57 | 11.09 |
| 5 | 08.47 | 19.32 | 03.04 | 09.73 |
| Mean | 16.4 | 16.5 | 07.8 | 07.5 |
| Standard | 09.7 | 06.6 | 05.4 | 03.3 |
| deviation |  |  |  |  |

**Table 2.** Example table. Full caption goes here. Often a short caption in [] is used as well as the main caption to keep the list of figures tidy; it gets messy if there are long captions going over more than one line.

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| --- | --- | --- | --- | --- |
| Participant | Number / %  Prime dresses Non-prime dresses | | Duration / %  Prime dresses Non-prime dresses | |
| 1 | 33.33 | 33.91 | 20.83 | 18.42 |
| 2 | 13.04 | 17.50 | 04.93 | 07.62 |
| 3 | 22.73 | 20.10 | 13.00 | 08.20 |
| 4 | 31.34 | 21.88 | 10.57 | 11.09 |
| 5 | 08.47 | 19.32 | 03.04 | 09.73 |
| Mean | 16.4 | 16.5 | 07.8 | 07.5 |
| Standard deviation | 09.7 | 06.6 | 05.4 | 03.3 |

everywhere, change style=ieee in the biblatex setup above to whatever reference style you want, and then just use the cite command.)

For adding *emphasis* use the emph command. In general, try to avoid texttt, textit, textbf and similar commands — these don’t tell the document *why* the style is being changed, and this information is needed for screen readers. In contrast, emph gives meaning to the change in format. By default it uses italics, but you can change the style if you want to.

Here are two example tables. [Table 1](#_bookmark13) is an example using tabularx to fix the size of the table to be the same width as the page, with columns that auto-wrap if the text is too long. [Table 2](#_bookmark14) is an exam- ple using tabular where the width of the table is set by its contents. It may go beyond the width of the page.

This is an example equation in text 2 sin *ωt*. Below is an example of a displayed equation. See [(1)](#_bookmark15) for info.

*a*2 + *b*2 = *c*2 (1)

Note that numbers are displayed differently in the text depending on how they are entered. Com-



**Fig. 1.** Example figure. Full caption goes here. Often a short caption in [] is used as well as the main caption to keep the list of figures tidy; it gets messy if there are long captions going over more than one line.



**(a) (b) (c)**

**Fig. 2.** Three copies of the University logo. (a) Copy one. (b) Copy two. (c) Copy three.

pare for example 123456 vs. 123456 vs. 123 456. Entering numbers directly, such as 1955, should be used for *text mode* numbers. That is, those representing text (dates, page numbers, and simi- lar). Numbers representing maths, or variables or similar, should be entered inside \( \) or \num so they are typeset in the same way as they appear in an equation. (This requires a bit of discipline, but helps ensure consistent use of number styles throughout.) \num is provided by the siunitx

package. The display it provides can be customised if wanted. Documentation is at [https://texdoc.](https://texdoc.org/serve/siunitx/0) [org/serve/siunitx/0](https://texdoc.org/serve/siunitx/0).

This is an example of a quote in text “*The electroencephalogram (EEG) is a classic noninvasive*

*method for measuring a person’s brainwaves”* [[3].](#_bookmark42) Below is an example of a displayed quote. Both are using the csquotes package.

“*Electrodes are placed on the scalp to detect the microvolt-sized signals that result from synchronized neuronal activity within the brain.”* [[3]](#_bookmark42)

This is an example figure. See [Fig. 1](#_bookmark16) for more details. Alternatively, can put multiple figures into a subfigure environment, for example [Fig. 2,](#_bookmark18) or [Fig. 2b](#_bookmark18) to cite a particular sub-figure.

An example code listing is given in [Listing 1.](#_bookmark19) See [https://www.overleaf.com/learn/latex/Code\_](https://www.overleaf.com/learn/latex/Code_listing) [listing](https://www.overleaf.com/learn/latex/Code_listing) for more examples of how to display code. Code in the body of the text can be included as for or while or main.

**Listing 1.** My code example

1 import numpy as np

2

1. def my\_filter(in,f\_obj):
2. y = filter(f\_obj,in)

5

6 return y

7

## Summary

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# Methods

## Introduction

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## Content

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### Summary

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# Results and discussion

## Introduction

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## Content

### Introduction

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# Conclusions and future work

## Conclusions

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# References

1. A. J. Casson, E. Luna, and E. Rodriguez-Villegas, “Performance metrics for the accurate char- acterisation of interictal spike detection algorithms,” *J. Neurosci. Meth.*, vol. 177, no. 2, pp. 479– 487, 2009 (cited on pp. [10,](#_bookmark9) [20).](#_bookmark38)
2. A. J. Casson and E. Rodriguez-Villegas, “Toward online data reduction for portable electroen- cephalography systems in epilepsy,” *IEEE T. Biomed. Eng.*, vol. 56, no. 12, pp. 2816–2825, 2009 (cited on pp. [10,](#_bookmark9) [20).](#_bookmark38)
3. A. J. Casson *et al.*, “Wearable electroencephalography,” *IEEE Eng. Biol. Med. Mag.*, vol. 29, no. 3, pp. 44–56, 2010 (cited on pp. [10,](#_bookmark9) [12,](#_bookmark17) [20).](#_bookmark38)

# Appendices

# A Project outline

Project outline as submitted at the start of the project is a required appendix. Put here.

# B Risk assessment

Risk assessment is a required appendix. Put here.