The Unsinkable Titanic Data

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Abstract
Many readers are likely familiar with the stories of the tragic fate of passengers and crew of the *RMS Titanic* upon her fatal collision with an iceberg and her sinking in the early hours of April 15, 1912, on her maiden voyage to New York City. Little known is the fact that the first graphical summary of the initial survivor data appeared in *The Sphere*, a British newspaper, on May 4, 1912. The public inquiries that followed produced detailed data sets that have been widely used to illustrate graphical and statistical methods for quite some time. Numerous follow-up studies have used a wide variety of graphical representations related to the *Titanic* disaster, published in statistics, information visualization, and social sciences venues. It seemed timely to survey the variety of graphical methods used for these data sets over the last century. Graph types used to portray the *Titanic* data include: dot plots, bar charts, mosaic plots, doubledecker plots, parallel set plots, Venn diagrams, balloon plots, nomograms, and tree diagrams to name only a few. In this article, we provide an overview of variants of the *Titanic* data set and resulting visualizations.

Key Words: Data Visualization; Graphs; Categorical Data Analysis; *RMS Titanic*

1. Introduction

We recently discovered a remarkable and little known graph by G. Bron portraying the deaths among passengers and crew on the maiden (and only) voyage of the *RMS Titanic* (Figure 1). This graph (Bron, 1912, p. 103) was published in the London illustrated newspaper, *The Sphere*, on May 4, 1912, less than one month after the ship sank in the early hours of April 15, 1912, upon her fatal collision with an iceberg. About 1,500 passengers and crew, out of about 2,200 aboard the ship, were killed. While the sinking of the *Titanic* is not the largest maritime disaster with respect to the number of lives lost, it is one of the most memorable ones because of the detailed data on lives lost (and not-lost) that have been made available and its huge influence on pop culture via books, movies, TV documentaries, and *Titanic*-inspired exhibits and museums.

Before we go into details on data and graphs related to the fate of the *Titanic's* passengers and crew, we want to start with a brief summary that lead to this disastrous event. The design for the *Titanic* was approved in July 1908 and construction began in March 1909. About three years later, her maiden voyage started in Southampton, UK, on April 10, 1912. Only four days later, on April 14, 1912, at 11:40pm, an iceberg struck the *Titanic* on the starboard (right) side. On April 15, 1912, 2:05am, the last lifeboat left the *Titanic* with over 1,500 people still left on the ship. After breaking apart, the last major part, the stern, of the *Titanic* sank on April 15, 1912, 2:20am, less than three hours after the collision, killing about 1,500 out of about 2,200 passengers and crew. Further historical details can be found at `https://www.historyonthenet.com/titanic-timeline-3/` or in any of the non-fiction books that deal with the *Titanic* disaster.

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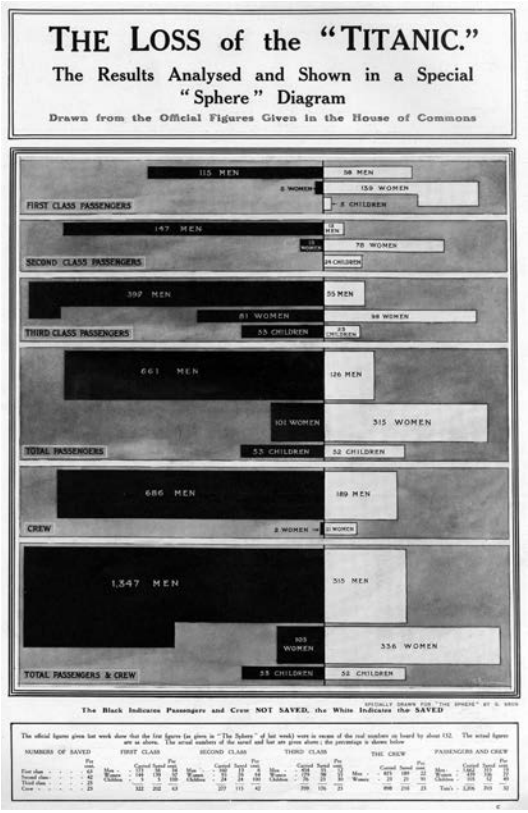


Figure 1: The Loss of the "Titanic", specially drawn for "The Sphere" by G. Bron. Originally published in "The Sphere," p. 103, May 4, 1912. (© *Illustrated London News/Mary Evans Picture Library.* Reprinted by permission.)

After discovering G. Bron's graph, we decided to track down and catalog the wide variety of data sets, graphs, and statistical methods used to display and analyze the data related to this disaster. This full-length article is an extension of our overview article in *Significance* (Friendly et al., 2019) and is based on two of our recent conference presentations on this topic, one given at *CompStat 2018, Iasi, Romania* (Symanzik et al., 2018) and another one given at the *Joint Statistical Meetings 2019, Denver, Colorado, United States* (Symanzik et al., 2019). In Section 2 of this article, we provide a brief overview on G. Bron, the creator of the first graph that is based on the *Titanic* data. We introduce the main data sources and data sets related to the *Titanic* disaster in Section 3. Section 4 provides a detailed overview of modern graphs and uses of these data, primarily within statistics and computer science. We present the Info Vis approach to these data in Section 5 and provide a brief overview of competitions that made use of these data in Section 6. A brief glance at the non-graphical uses of the *Titanic* data set, in particular in the social sciences, follows in Section 7. We finish with a short discussion in Section 8.

An accompanying web page at `http://www.datavis.ca/papers/titanic/` has been constructed as a supplement to our presentations and articles. While the latter ones explain the context in more detail, there was insufficient space for all illustrations that might be of interest. More importantly, our web page collects the wide variety of images, sources, and references we have found dealing with the *Titanic* data. New materials related to G. Bron, new *Titanic* data sets, and additional sources of graphs inspired by the *Titanic* data will also be added to this web page when they become available.

2. G. Bron

G. Bron was a prolific technical illustrator who worked for *The Sphere* and other similar publications about 1910–1925. Little about him is known. There is even confusion regarding his first name.

As far as we can determine, G. Bron was the pseudonym used by a graphic artist, illustrator and cartoonist named either George Treeby or William Brown Treeby. The only reliable information we have found connecting "G Bron" with these other names comes from Australian sources. His biography at `https://www.daao.org.au/bio/george-treeby/`, Design and Art Australia, describes him as a *"Federation-era Melbourne magazine cartoonist, illustrator and writer. Treeby contributed drawings to the* Bulletin *and* Melbourne Punch *as well as contributing articles to* Lone Hand*."*

In its issue from January 14, 1909, p. 27, the *Trove*, published an article titled *"G. Bron (W. B. Treeby)"*. This article provides evidence for the name **William Brown** Treeby. Some quotations from this article article follow:

> Asked to talk about himself, G. Bron remarked that he was 'William Brown Treeby (for age see photograph), father of Sid Treeby, Mab Treeby, Ethel Treeby (R. A. Kent), and a few others.' Further: I was born in London, and brought to Australia by adventurous parents in infancy. Shirking real graft, I suffered an apprenticeship to the unreasonable occupation of wood-engraving, which was wearing to the eyes but good for the patience. [. . .] Tripped it to England (I, not Job) with wife and young family, and stopped there five years, it being while working in London, half engraver, half artist, that the name 'G. Bron' was invented — a duplication that I sometimes would like to send to pot.

Some evidence for **George** Treeby comes from the Personal section of *The Feilding Star*, Volume XI, Issue 2391, July 10, 1914:

> Victoria has become notable for the number of its literary and artistic, families — the Lindseys, the Dysons, the McCraes, the O'Farrells, and the Treebys. The last-named family, which is now settled in London, consists of three artists and one writer, all of whom are well known in Australia. Mr George Treeby, the father, who draws for the Sydney Bulletin under the name of "G. Bron," has contributed to the Illustrated London News and Graphic, but now devotes all his time to The Sphere. [. . .]

Some of G. Bron's less known graphs and illustrations have been collected on our accompanying web page at `http://www.datavis.ca/papers/titanic/`. His most important graph from a visualization perspective, *The Loss of the "Titanic"* graph shown in Figure 1, did not only catch our attention. It was also cited, mentioned, or reprinted in a few other sources from the statistical and the Info Vis communities over the past ten years, e.g., in Rendgen and Wiedemann, J. (Ed.) (2012), p. 75, Harrell (2015), p. 291, and Feldman (2018), p. 55.

3. Data Sources

In this section, we provide references to various sources and data sets on the *Titanic*, including an overview of packages developed for R, a language and environment for statistical computing (R Core Team, 2019), that contain one out of the multiple existing versions of these data.

3.1 Primary Sources

Two major inquiries on the sinking of the *Titanic* were conducted in 1912. One of them, the *British Board of Trade Inquiry*, often referred to as *"Lord Mersey Report"*, was conducted by the *British Board of Trade* under the *Right Hon. Lord Mersey, Wreck Commissioner of the United Kingdom*. Hearings took place on thirty-six days between May 2, 1912, and July 3, 1912. Numerous details on passengers and crew aboard the *Titanic* can be found in this report, however in an unorganized way.

The other one, the *U.S. Senate Inquiry*, was conducted by a Subcommittee of the Committee on Commerce, United States Senate, New York, N. Y. Hearings took place on eighteen days between April 19, 1912, and May 25, 1912. Similar to the *British Board of Trade Inquiry*, numerous details on passengers and crew aboard the *Titanic* can be found here. Moreover, this report provided detailed information on the use and release of the lifeboats of the *Titanic*.

Electronic transcripts of the British and U.S. Senate inquiry reports are accessible at `https://www.titanicinquiry.org/downloads/BritishInquiry.pdf` and `https://www.titanicinquiry.org/downloads/USInq.pdf`, respectively. In particular, the web page at `https://www.titanicinquiry.org/` was set up to provide interested readers and researchers access to the original inquiries and other *Titanic*-related information that is otherwise hard to obtain.

3.2 Online Data Collections

Several online data sources exist on the web. Most notable is the *Encyclopedia Titanica* web site at `https://www.encyclopedia-titanica.org/`. This site was started in 1996 as an attempt to tell the story of every person that traveled the *Titanic* as a passenger or crew member. It contains numerous interactive lists with full details such as full name, age, class/department, ticket, joined, job, survived?, boat/body, URL, and photo (if available). Their starting point was the passenger list compiled by Michael A. Findlay for the book *Titanic Triumph and Tragedy* (Eaton and Haas, 1986). This list can be found in other sources as well, e.g., in Geller (1998).

The *ICYouSee* web site at `http://icyousee.org/` was created and is maintained by John R. Henderson. It went online in December 1994. The *Titanic* page of this site at `http://www.icyousee.org/titanic.html`, was first released on June 6, 1998. It provides demographics of the *Titanic* passengers, such as deaths, survivals, nationality, and lifeboat occupancy.

Rebecca Bilbro provided a version of the *Titanic* data set at `https://www.kaggle.com/c/titanic/data` for use in the Kaggle Competition *"Predicting Survival Aboard the Titanic,"* described in more detail in Section 6. The same data can also be found in the R package `titanic`, listed in the overview in the next section.

3.3 R Data Sets

The *Titanic* data first appeared as a real data set (cases by variables) in connection with a *Journal of Statistics Education* article (Dawson, 1995). These data and their description are directly accessible at `http://jse.amstat.org/datasets/titanic.dat.txt` and `http://jse.amstat.org/datasets/titanic.txt`, respectively.

A variety of other forms and versions of these data are available in R and numerous R packages now. Therefore, when referring to the *Titanic* data set, it is essential to indicate the exact source in R and ideally the original data source used for the creation of this R data

set. There are differences in the number of observations, the number of variables, and even what the actual count of lives lost and lives saved is, based on the original historical source.

As of September 2019, there exist at least 12 different R packages with a total of 17 different *Titanic* data sets. In the following overview, these data sets are given in the form `package::dataset`: "Title" — Description (Format). In R, use `?package::dataset` for a more detailed description of the contents and original sources of these R data sets.

- `carData::TitanicSurvival`: "Survival of Passengers on the Titanic" — Information on the survival status, sex, age, and passenger class of 1309 passengers in the Titanic disaster of 1912 (a data frame with 1309 observations of 4 variables).
- `COUNT::titanic`: "titanic" — The data is an observation-based version of the 1912 Titanic passenger survival log (a data frame with 1316 observations of 4 variables).
- `COUNT::titanicgrp`: "titanicgrp" — The data is a grouped version of the 1912 Titanic passenger survival log (a data frame with 12 observations of 5 variables).
- `DALEX::titanic`: "Passengers and Crew on the RMS Titanic Data" — The titanic data is a complete list of passengers and crew members on the RMS Titanic. It includes a variable indicating whether a person did survive the sinking of the RMS Titanic on April 15, 1912 (a data frame with 2207 rows and 9 columns).
- `datasets::Titanic`: "Survival of passengers on the Titanic" — This data set provides information on the fate of passengers on the fatal maiden voyage of the ocean liner Titanic, summarized according to economic status (class), sex, age and survival (a 4-dimensional array resulting from cross-tabulating 2201 observations on 4 variables).
- `earth::etitanic`: "Titanic data with incomplete cases removed" — Titanic data with incomplete cases, passenger names, and other details removed (a data frame with 1046 observations on 6 variables).
- `msme::titanic`: "Titanic passenger survival data" — Passenger survival data from 1912 Titanic shipping accident (a data frame with 1316 observations on 4 variables).
- `PASWR::titanic3`: "Titanic Survival Status" — The titanic3 data frame describes the survival status of individual passengers on the Titanic. The titanic3 data frame does not contain information for the crew, but it does contain actual and estimated ages for almost 80% of the passengers (a data frame with 1309 observations on 14 variables).
- `rpart.plot::ptitanic`: "Titanic data with passenger names and other details removed" — Titanic data with passenger names and other details removed (a data frame with 1046 observations on 6 variables).
- `stablelearner::titanic` : "Passengers and Crew on the RMS Titanic" — The Titanic data is a complete list of passengers and crew members on the RMS Titanic. It includes a variable indicating whether a person did survive the sinking of the RMS Titanic on April 15, 1912 (a data frame containing 2207 observations on 11 variables).
- `Stat2Data::Titanic`: "Passengers on the Titanic" — List and outcomes for passengers on the Titanic (a data set with 1313 observations on 6 variables).

- `titanic::titanic`: "titanic: Titanic Passenger Survival Data Set" — titanic: Titanic Passenger Survival Data Set.
- `titanic::titanic_gender_class_model`: "Titanic gender class model data" — Titanic gender class model data (a data frame with 2 columns).
- `titanic::titanic_gender_model`: "Titanic gender model data" — Titanic gender model data (a data frame with 2 columns).
- `titanic::titanic_test`: "Titanic test data" — Titanic test data (a data frame with 11 columns).
- `titanic::titanic_train` : "Titanic train data" — Titanic train data (a data frame with 12 columns).
- `vcd::Lifeboats`: "Lifeboats on the Titanic" — Data from Mersey (1912) about the 18 (out of 20) lifeboats launched before the sinking of the S. S. Titanic (a data frame with 18 observations and 8 variables.).

The `datasets::Titanic` version of the *Titanic* data set was the first one that was released in R, version 0.90.1, in December 1999. It is based on the data from Dawson (1995). The `NEWS` that accompanied this version of R indicated the following as one of the new features of this version: *"New data sets 'HairEyeColor' (hair and eye color of statistics students), 'Titanic' (survival of passengers on the Titanic), and 'UCBAdmissions' (student admissions at UC Berkeley)."* It is notable that three well-known statistical data sets all were added to R at the same time.

Three different versions of the *Titanic* data set are available from the data sets archive at the Department of Biostatistics at Vanderbuilt University at `http://biostat.mc.vanderbilt.edu/wiki/Main/DataSets`. The web page at `http://biostat.mc.vanderbilt.edu/wiki/pub/Main/DataSets/titanic.html`, created by Frank E. Harrell, Jr, provides details on the content and sources for each data set. The `titanic` data set is available in R, S-Plus, and ASCII format. The `titanic2` data set is available in R and S-Plus format. The `titanic3` data set is available in R, S-Plus, Excel, and ASCII format. These three data sets consist of 1,313 observations and 10 variables (`titanic`), 2,201 observations and 4 variables (`titanic2`), and 1,309 observations and 14 variables (`titanic3`). This last version is also directly available in R from the `PASWR` R package.

3.4 Variations

Dawson (1995), paragraph 7, noted:

> More detailed research into the Titanic disaster revealed some differences of opinion on the number lost. For instance, the Encyclopaedia Americana (1994) gives the death toll as "variously estimated as 1,490, 1,502, and 1,517." A book edited in 1912 under the pseudonym Marshall Everett gives the figure variously as 1635 and 1595 (Everett 1912); the first of these figures agrees with that found in Logan Marshall's book (Marshall 1912). However, the British Board of Trade Inquiry Report (1990), written originally in 1912, claims a death toll of 1490. Modern sources seem to agree that the true numbers are in the neighborhood of 1,500, but the exact numbers may never be known.

In the end, Dawson's data set (and thus the first `datasets::Titanic` data set used in R) consisted of 2,201 observations: 1,316 passengers and 885 crew. From these, 711 survived and 1,490 did not survive.

In contrast, the table underneath G. Bron's chart in Figure 1 listed the following numbers that were plotted in the bars: There were 1,308 passengers and 898 crew carried, for a total of 2,206. Of these, 493 passengers and 210 crew were saved, giving a total of 703 survivors and 1,503 non-survivors.

Most of the *Titanic* data sets list individual passengers and their main characteristics such as gender, age (or adult/child), passenger class, and survived?. Some of these give further details such as passenger name, family composition (e.g., number of siblings/spouses aboard and number of parents/children aboard), price of ticket, cabin, port of embarkment, lifeboat, body identification number, etc. Others also provide information on the crew and their relevant details, whereas some have incomplete cases removed or are split into test and training data sets. Data related to the lifeboats of the *Titanic* can be found in two of the R packages: `PASWR::titanic3` and `vcd::Lifeboats`.

4. Modern Graphs and Uses

After G. Bron's remarkable work, the *Titanic* data set was almost forgotten. There was basically no use of it in the following 70 years. However, in the past 40 years, many graphical methods have been used to tell the *Titanic* story as well as to illustrate some new graphical methodologies.

The use of the *Titanic* data slightly differs by discipline. In statistics, it is often used for the introduction of new graphical methods (or software) and their advantages compared to previously existing graphical methods (or software), particularly for categorical data. Moreover, the data set is also used for overviews of existing graphical methods, using a well-known data set. In computer science and social sciences, the *Titanic* data set is frequently used for modeling/prediction of survival and the visualization of the results. Info Vis typically tries telling the entire story, including some data visualizations. This section gives some representative examples of the various graphical methods and uses for the *Titanic* data in statistics and computer science. The following sections focus on Info Vis applications (Section 5), competitions (Section 6), and non-graphical uses of the *Titanic* data (Section 7).

4.1 Bar Charts and Spine Plots

As in G. Bron's chart, the *Titanic* data is most easily displayed in area-based graphs where the areas are proportional to the counts or percentages of the underlying categories. Modern uses have focused on extending G. Bron's chart in various area-based ways, e.g., bar charts, spine plots, and mosaic plots (discussed in Section 4.2). While bar charts use the height of the bars to depict different counts or percentages (and keep the width the same), spine plots use the width instead (and keep the height the same). An in-depth discussion of these related graph types can be found in Hofmann (2000).

As one example, Hofmann (1998) used the *Titanic* data set to illustrate interactive methods for analyzing multivariate contingency tables. Figure 2 shows the univariate breakdowns by class, sex, age, and survive via bar charts (Figure 2 [Left]) and spine plots (Figure 2 [Right]). Selecting `Survive=Yes` highlights these cases in all other graphs.

Gärtner (2017) developed *Shiny* apps for introductory statistics courses. He used the *Titanic* data as an example data set for bar charts, spine plots, mosaic plots, and common

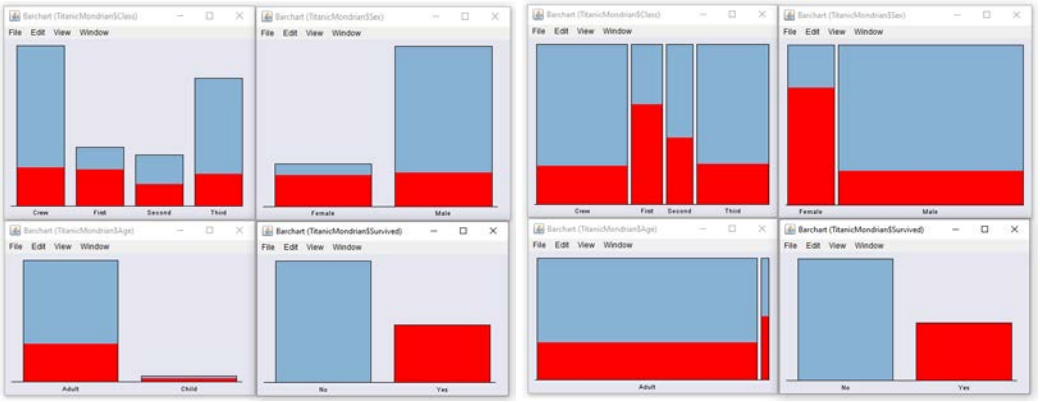


Figure 2: [Left] Author graphic, based on Figure 2 from Hofmann (1998): Four barcharts with marginal distribution of the properties. Highlighted (red) are survivors. [Right] Author graphic, based on Figure 5 from Hofmann (1998): Spineplots of Class, Age and Sex. Survivors are still selected. Differences in survival rates within each variable are easy to read off by comparing heights.

angle plots in his apps. Simple bar charts of the survival rate by class can even be found in non-academic books such as Geller (1998), p. 195.

4.2 Mosaic Plots and Related Graphs

G. Bron's chart illustrated some of the challenges in visualizing a table of frequencies of survival, classified by two or more factors. Mosaic plots (Hartigan and Kleiner, 1981) provide an attractive alternative, where the frequencies in a table are shown by areas of "tiles" in a recursive partitioning of a unit square. The history of mosaic plots has been summarized in Friendly (2002).

Basic Mosaic Plots Theus (2002) and others illustrated the idea of an interactive mosaic plot where the tiles for the combinations of class, age, and gender could be highlighted to show the proportion surviving in each cell. One example is shown in Figure 3. Hofmann (2003) extensively used the *Titanic* data when she discussed in a formal mathematical way how to construct and read mosaic plots. Theus (2012) used the *Titanic* data to explain mosaic plots and doubledecker plots in an overview article on mosaic plots.

Visualizing Loglinear Models Friendly (1994) described the use of mosaic plots to visualize the badness of fit of a loglinear model by shading the tiles according to the sign and magnitude of residuals in a given model. Examples of such graphs that are based on the *Titanic* data can be found in Friendly (1999) and Friendly (2000a). One example is shown in Figure 4. Additional examples can be found in Theus and Lauer (1999).

Friendly (1999) further extended the use of mosaic plots to include mosaic matrices, similar to scatterplot matrices for quantitative data. Figure 5 shows the marginal association between each pair of variables in the *Titanic* data. The row and column for `Survive` show the association of each of the predictors with survival.

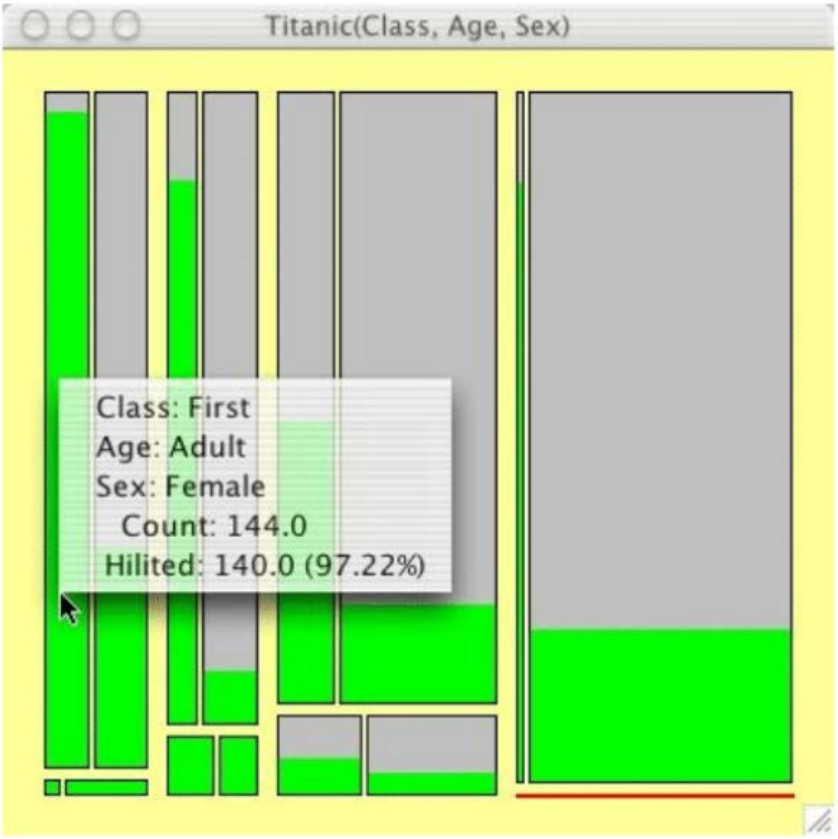


Figure 3: Figure 5 from Theus (2002): The Titanic Data in a Mosaic Plot. (Figure courtesy of Martin Theus.)

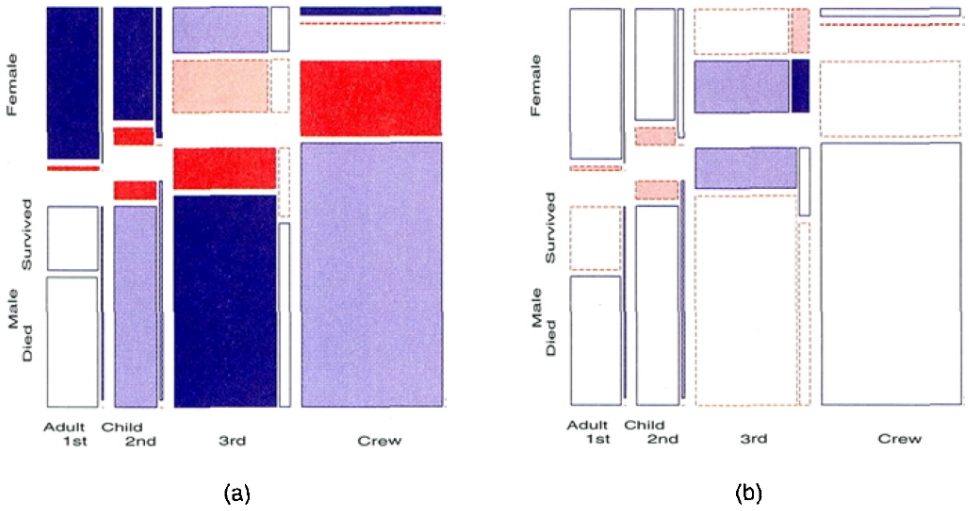


Figure 4: Figure 7 from Friendly (1999): Titanic data, Class, Gender, Age, and Survival: (a) joint independence; (b) main effects of Age, Gender, and Class on Survival. (Reprinted by permission of the *American Statistical Association*, `https://www.amstat.org`.)

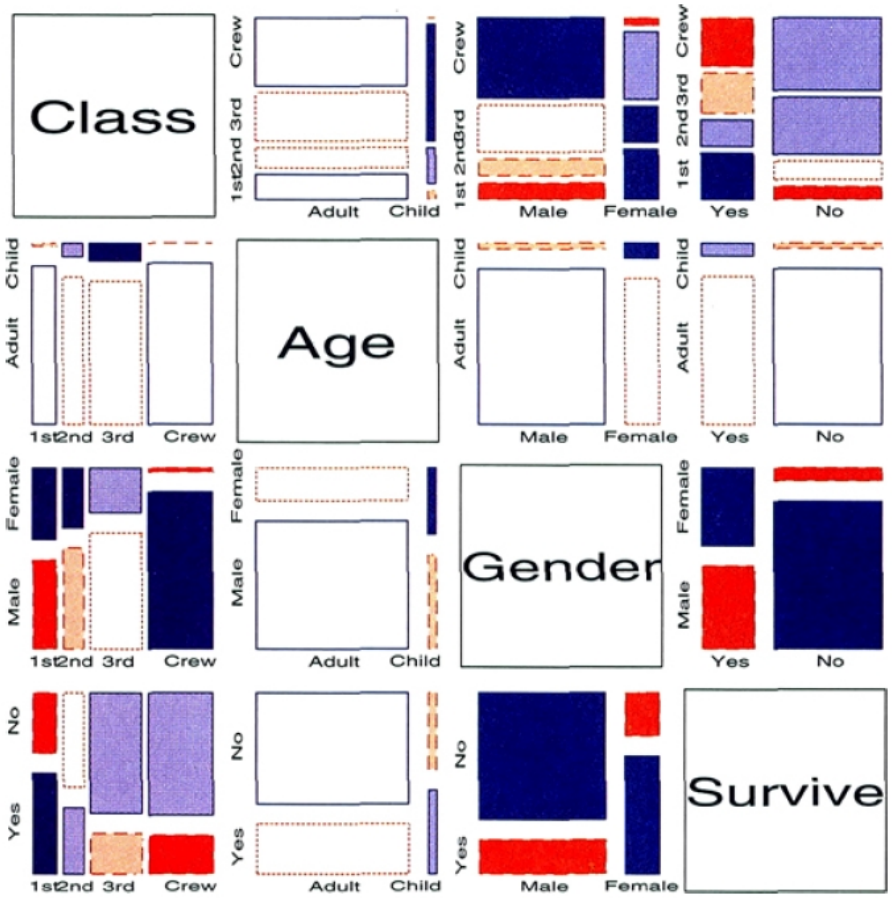


Figure 5: Figure 9 from Friendly (1999): Mosaic matrix of Titanic data. Each panel shows the marginal relation, fitting an independence model between the row and column variable, collapsed over other variable(s). (Reprinted by permission of the *American Statistical Association*, `https://www.amstat.org`.)

Doubledecker Plots A doubledecker plot (Hofmann, 2001) is a special case of a mosaic plot in which one variable is the response and all other are predictors. The combinations of the predictor variables are shown on the horizontal axis, with widths proportional to their joint frequencies. The response variable is split vertically. This plot displays the conditional odds ratios of the response, conditional on the predictors. It has the property that the vertical bars align when the response is unassociated with one or more predictors.

Meyer, Zeileis, and Hornik (Meyer et al., 2006) described the strucplot framework for visualizing multi-way contingency tables. This provides a general framework that includes mosaic plots, association plots, doubledecker plots, and others. One of their doubledecker plots is shown in Figure 6.

Other Brath (2018) created mosaic plots (Figure 7) filling the tiles with the names of the victims and survivors among the 1,308 passengers. This highlights the fact that the passengers were people, not just statistics. For Brath, this provided an example of how typography could be used in data visualization.

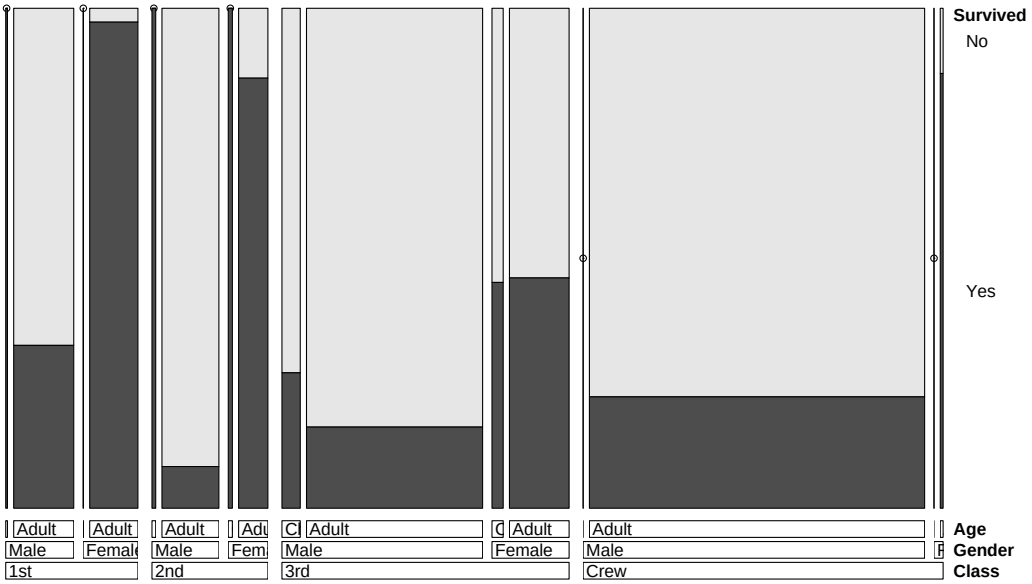


Figure 6: Figure 4 from Meyer et al. (2006): Double-decker plot for the Titanic data. (Figure courtesy of David Meyer, Achim Zeileis, and Kurt Hornik.)

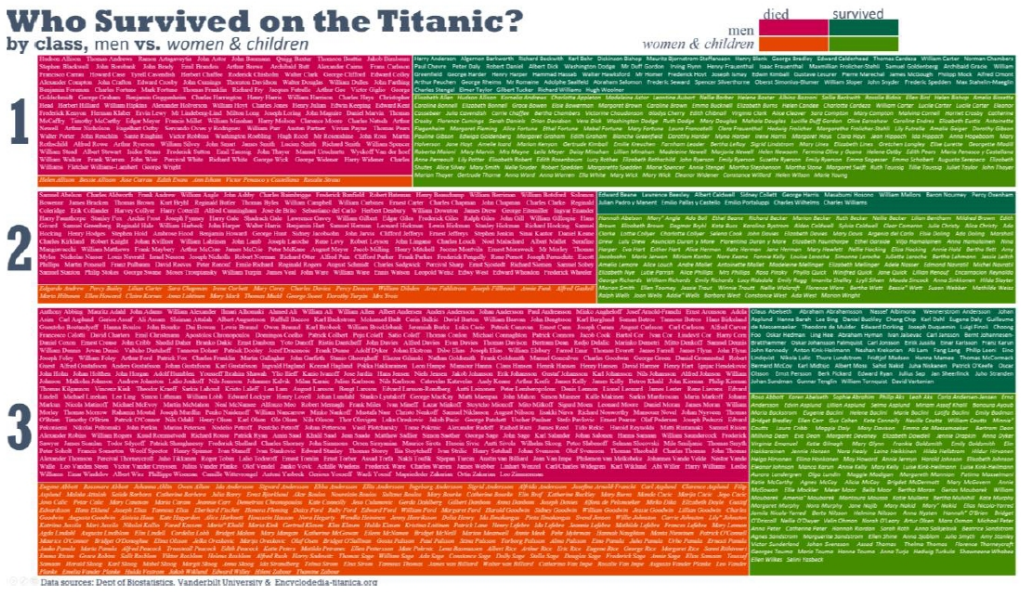


Figure 7: Figure 151 from Brath (2018): 1308 passengers on the Titanic, organized by class (vertically), survivorship (horizontally, serif/sans serif; red/green) and gender (plain/italic). (Figure courtesy of Richard Brath.)

4.3 Parallel Sets

Parallel coordinate plots (Inselberg, 1985; Wegman, 1990) provide a way to display multi-dimensional data in 2D graphs. They do this by representing the variables as a set of parallel axes, and showing each observation as a line in parallel coordinate space, rather than as a point in standard Euclidean coordinate space. Extensions of this idea for categorical data led to parallel sets plots.

Bendix, Kosara, and Hauser (Bendix et al., 2005) and Kosara, Bendix, and Hauser (Kosara et al., 2006) developed an interactive system to explore multivariate categorical data using parallel sets in which the lines between categories of successive variables are of width proportional to the joint frequencies. Davies (2012) created a web page that allows to interactively explore parallel set representations of the *Titanic* data at `https://www.jasondavies.com/parallel-sets/`. Figure 8 [Left] shows the original default configuration of the app with the number of those who perished highlighted with a mouse. Figure 8 [Right] shows a reordered layout where the categories of the four variables are rearranged to match the layout in Figure 9 [Right].

Specific variations of parallel sets plots are called hammock plots (Schonlau, 2003) and common angle plots (Vendettuoli, 2013; Hofmann and Vendettuoli, 2013). A number of these used the *Titanic* data as examples. In particular, Vendettuoli (2013) and Hofmann and Vendettuoli (2013) pointed out that the widths of slanted lines in hammock plots (Figure 9 [Left]) are not judged accurately. They introduced common angle plots as a perceptually-true way to better show associations of categorical variables (Figure 9 [Right]).

4.4 Tree Maps and Tree Diagrams

Cross-classified data can also be displayed as tree diagrams of various types, with branches corresponding to splits of the categories for variables in some order. Tree maps (Shneiderman, 1992) are a simple example, similar to mosaic plots. A data tree (Figure 10 [Left]) and the resulting tree map (Figure 10 [Right]) for the *Titanic* data have been posted by Robert Kosara (Kosara, 2008) at `https://eagereyes.org/techniques/treemaps`.

A more powerful use of tree maps arises in connection with classification trees as models for an outcome variable such as survival. For a binary response, these are similar to a series of logistic regression models where predictors are chosen to maximize predictive

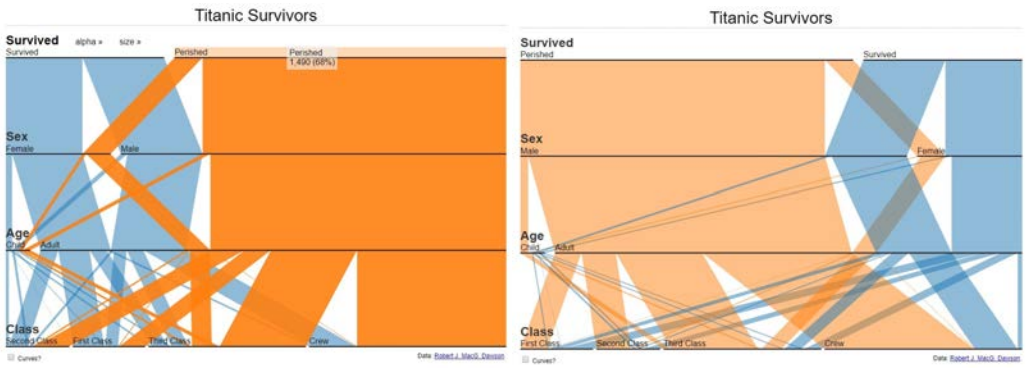


Figure 8: Screenshots from Davies (2012): [Left] Default configuration of the Parallel Sets app at `https://www.jasondavies.com/parallel-sets/`, highlighting those who perished. [Right] Reordered layout of the Parallel Sets app to match Figure 9 [Right]. (Use of app and creation of screenshots courtesy of Jason Davies.)

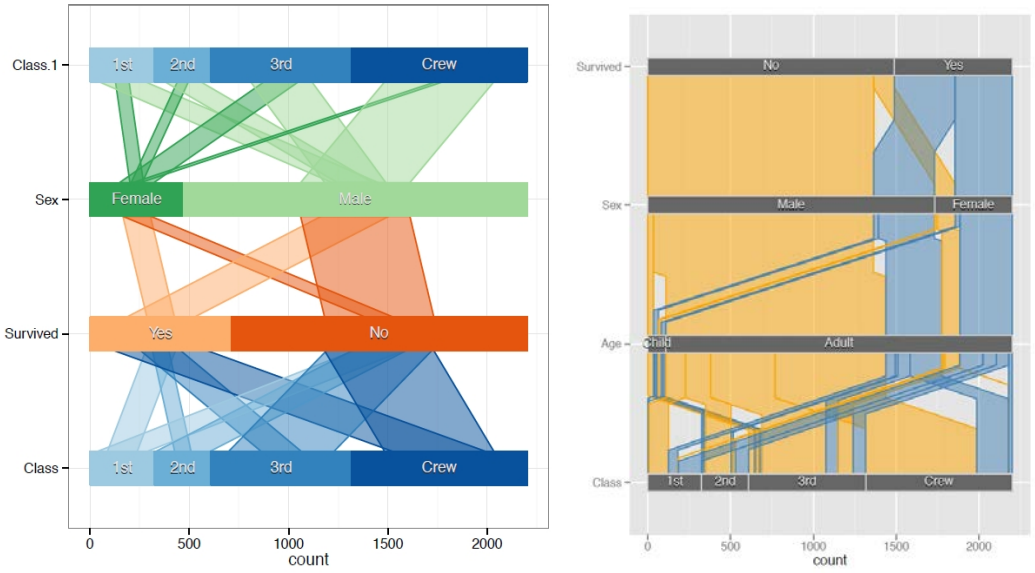


Figure 9: [Left] Figure 2.6 from Vendettuoli (2013): Hammock plot of the relationship between Class and Survival on the Titanic. [Right] Figure 2.13 from Vendettuoli (2013): Common angle plot of the Titanic data using a hierarchical structure in the variable (cf. to parallel sets chart in Davies (2012)). (Figures courtesy of Marie C. Vendettuoli.)

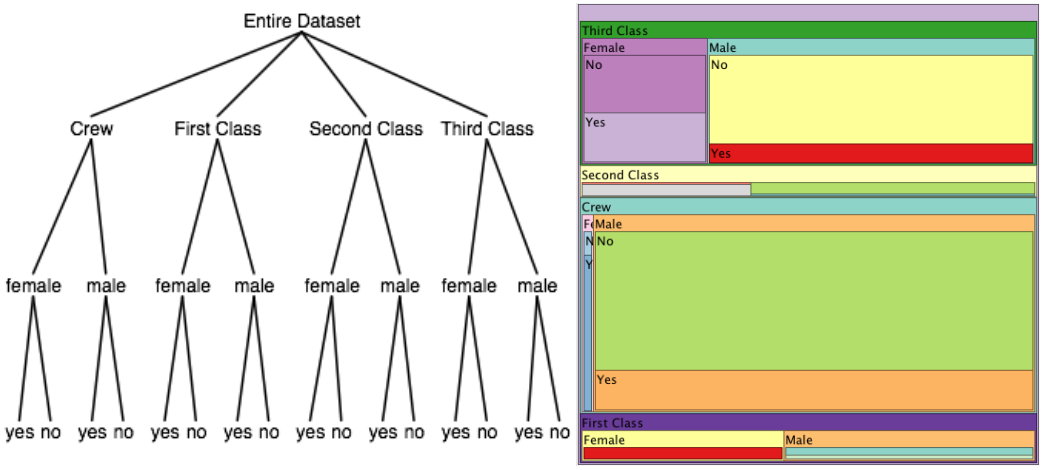
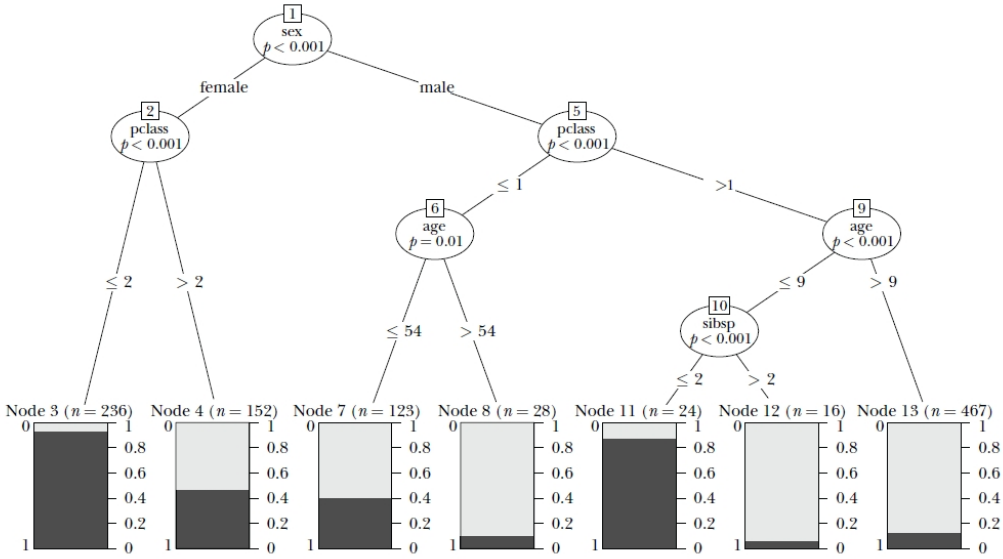


Figure 10: Figures from Kosara (2008): [Left] Data tree: The hierarchy comes from repeatedly splitting up the data into subsets according to the dimensions. In the above example, we may split the data by the class first, then every class is split up into two subsets for both sexes, and each of these subsets is finally split into two for survivors and non-survivors. [Right] A simple, non-squarified treemap of the above data could look like this. (Figures courtesy of Robert Kosara.)

accuracy at each step. Pruning methods and cross-validation are used to control model complexity and minimize out-of-sample classification error. Varian (2014) was among the first to use the *Titanic* data set for this purpose.

Figure 11 shows the result of fitting a conditional inference tree ("ctree") predicting survival from sex, class, age and a measure of family size (`sibsp` = number of siblings



Note: See text for interpretation.

Figure 11: Figure 4 from Varian (2014): A ctree for Survivors of the Titanic (black bars indicate fraction of the group that survived). (Copyright *American Economic Association*; reproduced with permission of the *Journal of Economic Perspectives*.)

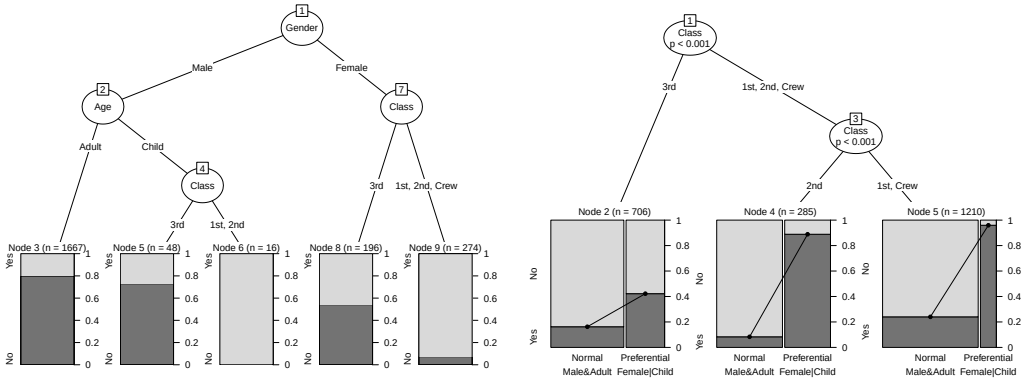


Figure 12: Figure 1 from Hothorn and Zeileis (2015): Tree visualizations of survival on Titanic: '**rpart**' tree converted with **as.party** and visualized by *partykit* (left); and logistic-regression-based tree fitted by **glmtree** (right). (Figure courtesy of Torsten Hothorn and Achim Zeileis.)

plus spouse aboard). The first node splits the data by sex. The second divides by class. Among males in the right branch, a third node splits by age, and those less than 9 years old are further split by `sibsp`. The bars at the bottom show the survival rate in each terminal node.

Hothorn and Zeileis (2015) introduced a more flexible framework and supporting software for fitting and visualizing tree-based models. Some of their examples are shown in Figure 12. Tree diagrams based on the *Titanic* data can also be found in the business analytics literature, e.g., in Dinsmore (2016), Figure 9-4.

4.5 Lifeboats Data

The *Titanic* sailed with only enough lifeboat space for half the people on board, the result of an antiquated safety code that hadn't kept pace with the growing size of ocean liners. Yet some of those lifeboats were lowered less than half full. G. Bron tried to illustrate what he knew at the time, but the actual data (`vcd::Lifeboats` and `PASWR::titanic3`) allows a richer story to be told with modern graphical and statistical methods.

Friendly (2000b) displayed the lifeboat occupancy on the *Titanic* as a trilinear plot (Figure 13 [Left]). Plotting the proportion of women and children in the lifeboats against time of launch revealed a striking difference in the regimes of loading on the port and starboard sides (Figure 13 [Right]). Friendly and Meyer (2016) used additional graphs and statistical models to examine the loading of the lifeboats over time (Figure 14).

In addition to using the primary *Titanic* data to explain mosaic plots and doubledecker plots in an overview article on mosaic plots, Theus (2012) constructed multiple bar charts and multiple spine plots, based on the *Titanic* lifeboat data. These graphs showed the occupancy of lifeboats, with a focus on class and gender.

4.6 Miscellaneous Data Graphs

The *Titanic* data also served to motivate or illustrate a wide variety of other graphical and analytical methods.

Logistic Regression: Dot Plots and Nonparametric Smooths Harrell (2015) and others used the data on the passengers in a modeling approach to predict survival from the available predictors, using logistic regression for the binary outcome (survived/died). This led to interesting graphs showing the actual or predicted probability of survival in relation to several factors simultaneously. A basic dot plot, summarizing the probability of survival based on various predictors, is shown in Figure 15.

Nonparametric regression smooths can be used to show the relation of survival to passenger class, sex, and both. Note that "Women and children first" did not apply so well in the 3rd class as shown in Figure 16.

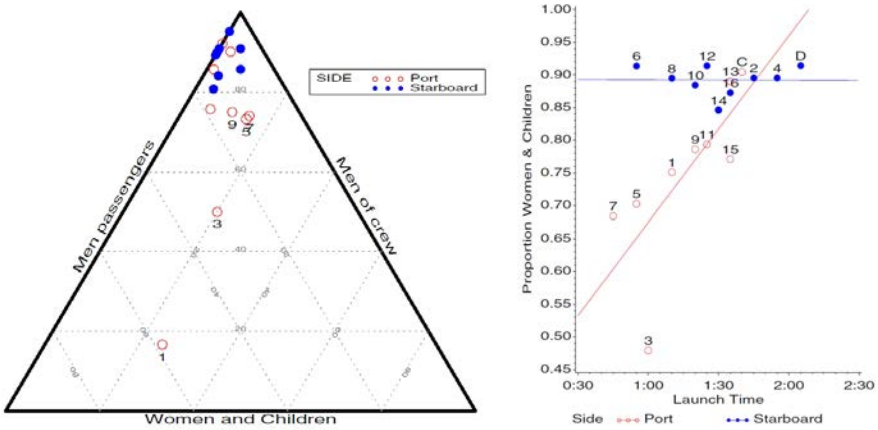


Figure 13: [Left] Figure 12 from Friendly (2000b): Lifeboats on the Titanic, trilinear plot. [Right] Figure 13 from Friendly (2000b): Lifeboats on the Titanic, logistic regression. (Copyright 2000, *SAS Institute Inc., Cary, NC, USA*. All Rights Reserved. Reproduced with permission of *SAS Institute Inc., Cary, NC*.)

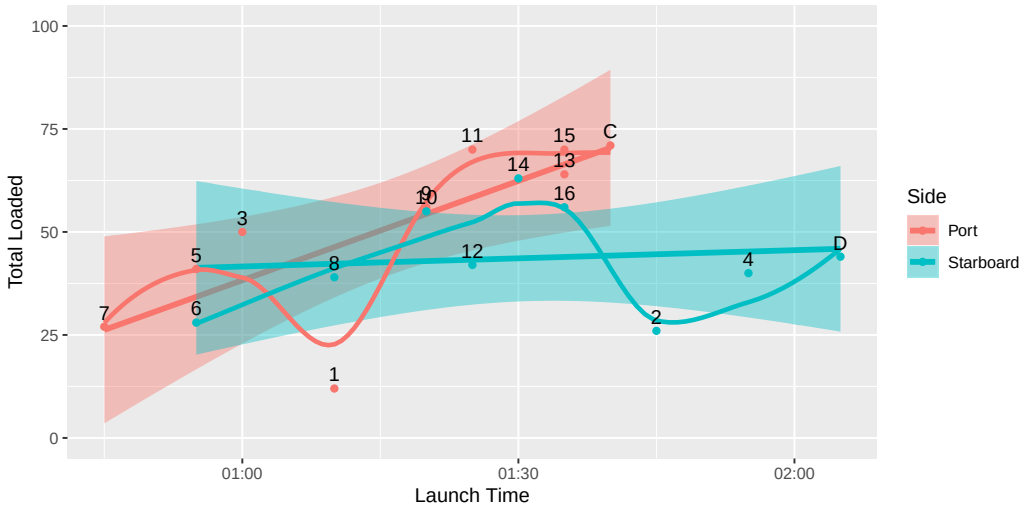


Figure 14: Author graphic, based on Figure 4.23 from Friendly and Meyer (2016): Number of people loaded on lifeboats on the Titanic vs. time of launch, by side of boat. The plot annotations show the linear regression and loess smooth.

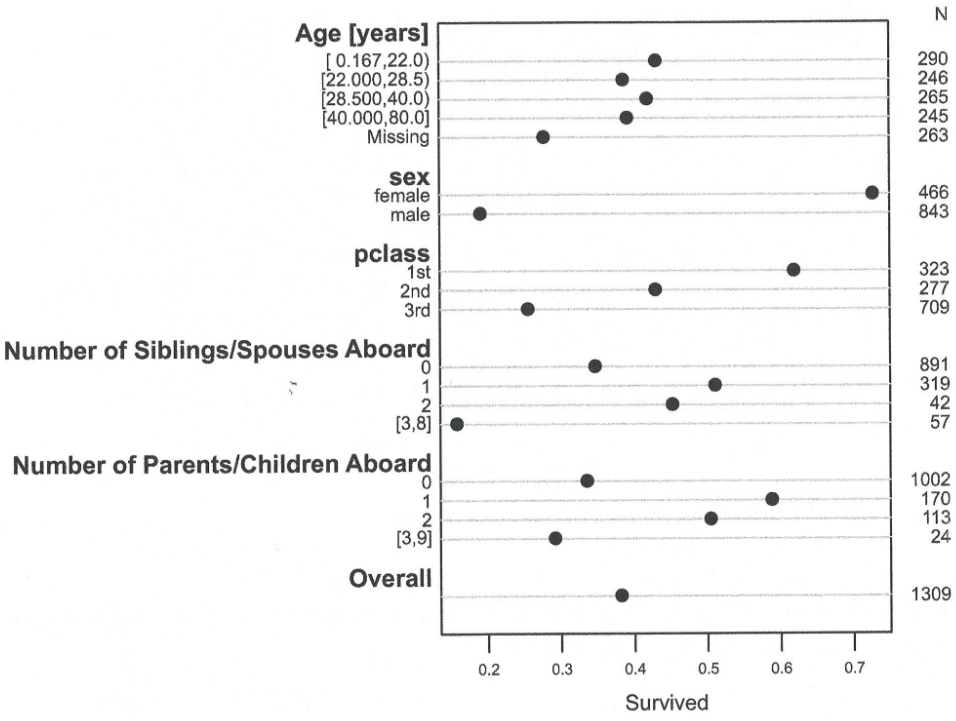


Figure 15: Figure 12.1 from Harrell (2015): Univariable summaries of Titanic survivors. (Reprinted by permission from *Springer Nature*. © 2015.)

Nomograms Nomograms were originally developed by French engineer and mathematician Maurice d'Ocagne in 1891 to allow users to graphically compute the outcome of an equation without doing any calculus (d'Ocagne, 1891). Lubsen et al. (1978) extended nomograms to visualize a logistic regression model. Harrell (2001) provided implementa-

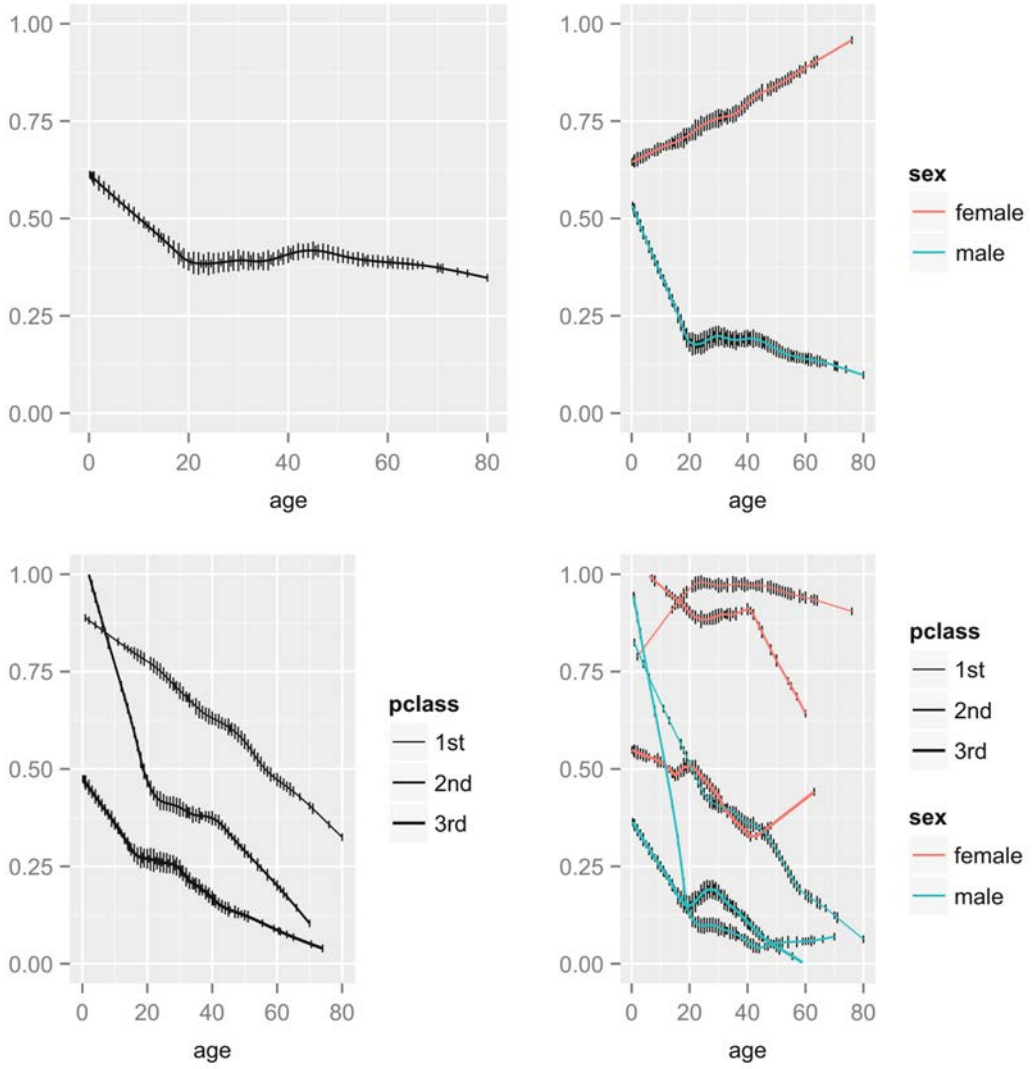


Figure 16: Figure 12.3 from Harrell (2015): Nonparametric regression (**loess**) estimates of the relationship between age and the probability of surviving the Titanic, with tick marks depicting the age distribution. The top left panel shows unstratified estimates of the probability of survival. Other panels show nonparametric estimates by various stratifications. (Reprinted by permission from *Springer Nature*. © 2015.)

tions of logistic regression nomograms in S-Plus and briefly mentioned them in the context of the *Titanic* data (Harrell, 2001, p. 326).

Možina et al. (2004) used nomograms and interactive graphics designed to show the predicted probability of survival for various settings of the predictors in the *Titanic* data in a Bayesian framework. One of their examples is shown in Figure 17.

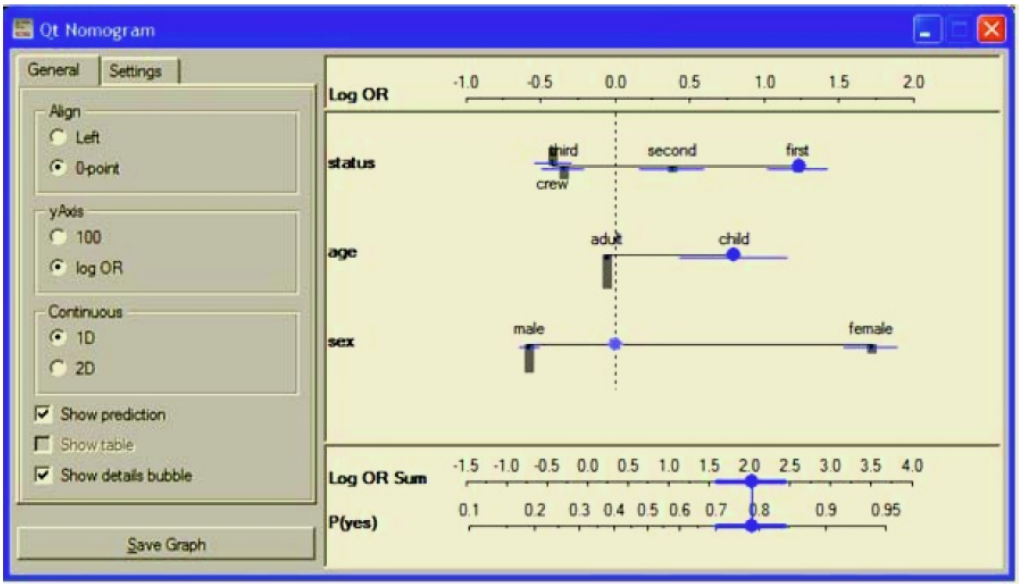


Figure 17: Figure 4 from Možina et al. (2004): Orange widget with the Titanic nomogram that includes confidence intervals for contributions of attribute values and class probabilities. For a woman travelling in the first class, the probability of survival is with 95% confidence between 0.87 and 0.92. (Reprinted by permission from *Springer Nature*. © 2004.)

Balloon Plots Jain and Warnes (2006) coined the term balloon plot to refer to a semi-graphic table in which the size of the cell entry was overlaid with a "balloon" to visualize the magnitudes of the values in each cell. One of their examples is shown in Figure 18.

Venn and Euler Diagrams Venn diagrams typically are used in mathematical and logical applications to depict relationships such as intersections and unions of multiple sets. Usually, each individual set is drawn as a circle. Partially overlapping circles represent the intersection of two (or more) sets. If two circles do not overlap, the intersection of the corresponding two sets is empty. Euler diagrams have a similar purpose and interpretation, but in contrast to Venn diagrams, they only show relevant relationships.

Brath (2012) and Brath (2014) used annotated Venn diagrams (Figure 19 [Top]) and Euler diagrams (Figure 19 [Bottom]) to show the overlapping sets among combinations of the *Titanic* variables. While these diagrams at first glance seem to be hard to understand, the fellowing detailed description from the caption of a similar figure (Brath (2014), Figure 3.30) considerably helps with the Venn diagram interpretation: *"A Venn diagram of Titanic survivor data, with a bubble per segment sized to indicate the number of corresponding passengers; and with spikes per bubble to indicate set membership by pointing towards the corresponding set labels around the perimeter. For example, the large bubble near the centre bottom has three spikes, indicating that its members belong to three sets. The orientation of these spikes correspond to the location of the labels around the perimeter; therefore, based on the spikes it can be determined, this large bubble corresponds to a large number of 1st/2nd class, female passengers that survived the Titanic disaster."*

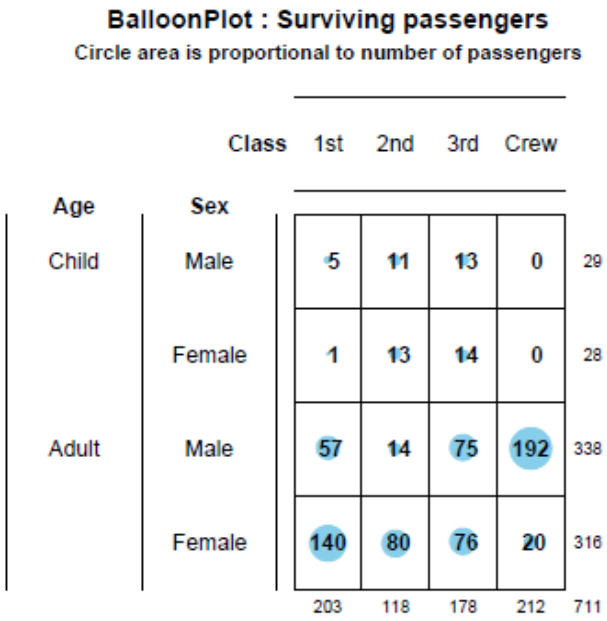


Figure 18: Figure 2 from Jain and Warnes (2006): Balloon plot of surviving individuals by class, gender and age. (Figure courtesy of Nitin Jain and Gregory R. Warnes.)

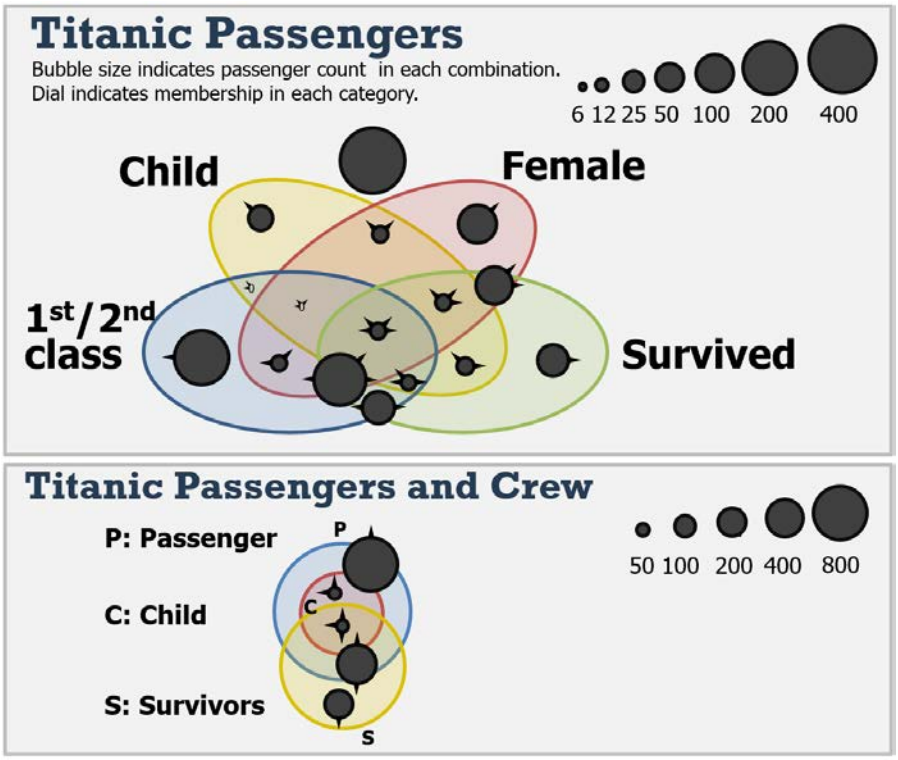


Figure 19: Extended versions (with titles and legends) of Figure 8 from Brath (2012): Glyphs with added whiskers oriented based on set memberships. (Figure courtesy of Richard Brath.)

Steam & Leaf Plots Brath and Banissi (2017) and Brath (2018) also extended stem & leaf plots for text visualizations. Similar to the mosaic plots created by Brath (2018) (see Section 4.2), the leaves in these stem & leaf plots are the names of the victims and survivors among the 1,308 passengers. Again, this highlights the fact that the passengers were people, not just statistics. Two examples can be seen in Figure 20.

4.7 Educational Uses

Dawson (1995) used the *Titanic* data, without identifying it as such in a classroom exercise in statistical thinking: Given tables of the data on survival by class, age, and gender, could students discover what the "Unusual Episode" entailed? While Dawson (1995) focused on an introductory statistics course, Simonoff (1997) followed up with ideas how to use these data in a second statistics course that used a combination of exploratory analysis and model building (such as logistic regression).

Takis (1999) described how she used the *Titanic* data in her Advanced Placement (AP) statistics course when discussing categorical data analysis and the chi-square distribution. Schumm et al. (2002) used the *Titanic* data in the classroom to illustrate the impact of social class and gender on survival (in addition to using data related to the space shuttle *Challenger* disaster and to *Pearl Harbor*). More recently, Lee et al. (2016) discussed using the *Titanic* data for teaching statistics, together with data from two other maritime disasters: the losses of the *HMT Birkenhead* in 1852 and the Korean ferry *MV Sewol* in 2014. Their primary statistical question was whether rates of survival were significantly different from what might be expected by chance for the different groups of passengers and crew.

Some textbooks made use of the *Titanic* data for specific exercises, e.g., Agresti (2007), Problem 2.7, p. 56. Others used the data for extended case studies, often covering one or more chapters. Examples include Harrell (2001), Chapter 12, Harrell (2015), Chapter 12, Theus and Urbanek (2009), Chapters 3–5 and Appendix D (with several *Titanic*-based exercises), Unwin (2015), Chapters 1, 4, 7, and 10 (with several *Titanic*-based exercises), Wilkinson (1999), Chapter 11, and Wilkinson (2005), Chapters 11 and 13.

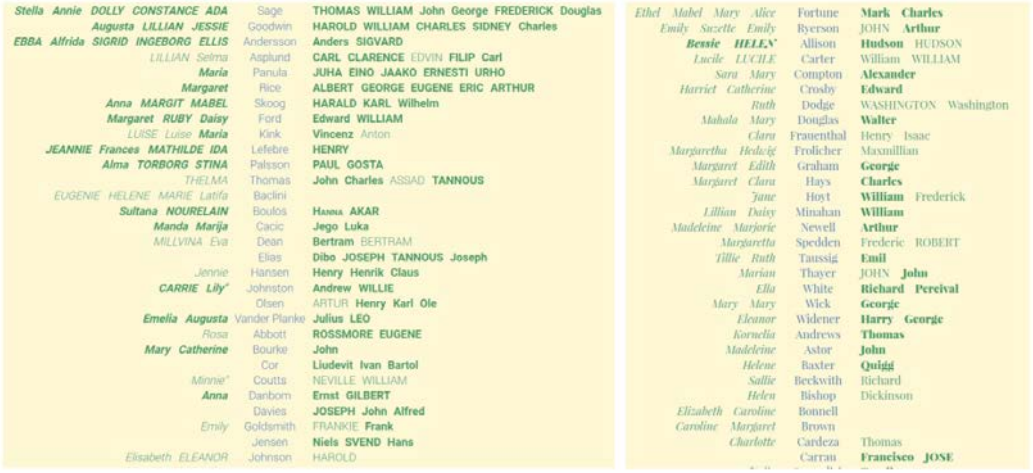


Figure 20: Figure 138 from Brath (2018): Titanic passengers. Left: third class families; Right: first class families. Stem indicates surname, leaf for given name, bold indicates death, italics for women, allcaps for children. (Figure courtesy of Richard Brath.)

5. Info Vis Applications

Just as the tragedy of the sinking of the *Titanic* inspired G. Bron to try to put the data into visual form, so too this event has been a challenge for modern graphic designers to tell the story of this disaster in ways that are both visually appealing and provide sufficient details. Unlike statistical graphs which usually focus on just one aspect, an information graphic often tries to tell the entire story all on one sheet, as in a poster presentation.

The Info Vis graphic from Barr and Johnson (2017) was a tour-de-force of visual storytelling. Shown in Figure 21 are the ones who survived (above water) and died (below water) in bar charts by age for the three passenger classes (top), the location of these classes on board the ship (center), the route (bottom third, left), the sinking and breaking apart of the *Titanic* (bottom third, center), the death rate by gender and class and also by nationality (bottom third, right), and information (time and occupancy) of the lifeboat launches (bottom).

Similarly, the Info Vis graphic from Arranz (2012) visualized the collision with the iceberg (top), sinking (right), and spread of the debris field (bottom right) of the *Titanic*. The center and bottom left contains information on water temperature, distress calls, lifeboats, the route, nearby ships and the ice field. The human toll by class, age, and gender is also shown in the center.

Bernard et al. (2014) used the *Titanic* data set as a proof of concept for the visual-interactive exploration of multivariate relations in mixed data sets.

Drucker and Fernandez (2015) introduced the term unit visualizations to describe a class of visualizations that explicitly represent every row in a data set. They apply this technique to produce a wide variety of unit visualizations including unit column charts, faceted small multiples, faceted scatter plots, fluctuation diagrams, summed column charts, and violin plots, all based on the *Titanic* data.

Phillips (2014) used the *Titanic* data as one example when he investigated the relationship between data visualization and task performance. Hassan (2016) used one of the existing Info Vis graphics of the *Titanic* disaster when comparing static and animated info-

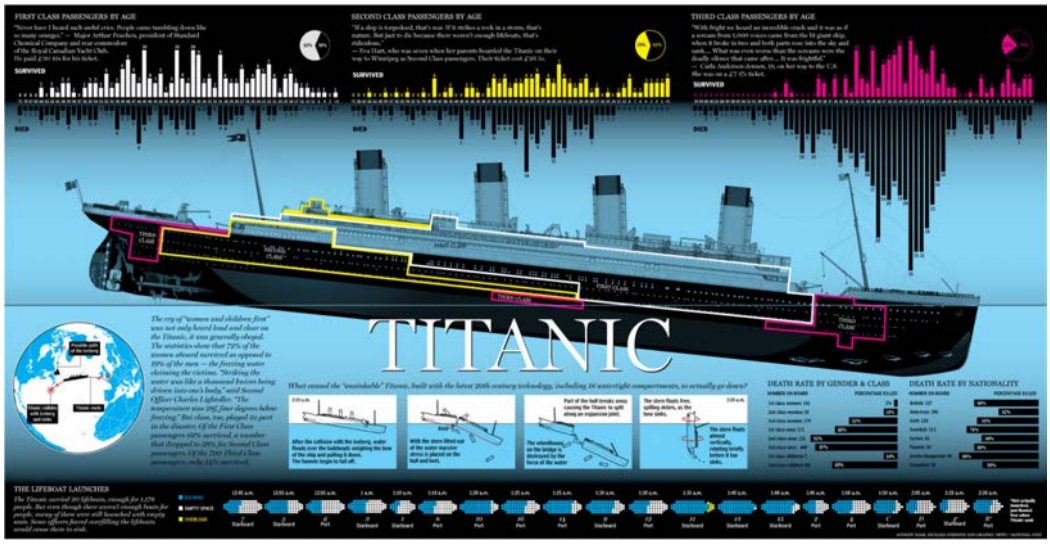


Figure 21: Infographic from Barr and Johnson (2017). See the main text for a detailed description. (Material republished with the express permission of: *National Post*, a division of *Postmedia Network*, and designers Andrew Barr and Richard Johnson.)

graphics. Langer and Zeiller (2017) conducted a usability study of interactive infographics in online newspapers, including *Case 1: So sank die "Titanic"*, published by *Spiegel Online* in 2012.

6. Competitions

There have been a few recent competitions that used the *Titanic* data as a basis for modern statistical techniques and graphical methods. We introduce two highlights in this section.

Kaggle The *Kaggle Competition*, titled *Titanic: Machine Learning from Disaster* asked participants to predict survival on the *Titanic* and get familiar with machine learning basics. It was designed as a competition in predictive modeling, using the *Titanic* data. The data set was split into training and test samples. The goal was to devise a method to predict survival in the test sample, using only the training data set. This competition attracted nearly 10,000 teams, submitting their code, results, and commentary. Further details are accessible at `https://www.kaggle.com/c/titanic/data`. Trevor Stephens posted a tutorial for this competition on January 10, 2014, titled *Titanic: Getting Started With R* that is accessible at `https://trevorstephens.com/kaggle-titanic-tutorial/getting-started-with-r/`.

A few notable entries to this competition were:

- Megan Risdal: *Exploring Survival on the Titanic*, accessible at `https://www.kaggle.com/mrisdal/exploring-survival-on-the-titanic`.
- Jason: *Large Families not Good for Survival*, accessible at `https://www.kaggle.com/jasonm/large-families-not-good-for-survival`.
- Eric Bruin: *Titanic: 2nd Degree Families and Majority Voting*, accessible at `https://www.kaggle.com/erikbruin/titanic-2nd-degree-families-and-majority-voting`.

Business Analysis Olympiad In 2008, the city of Charlotte, North Carolina, sponsored a *Business Analysis Olympiad* to promote the business value of using visual data analysis software. It was based on the *Titanic* data and attracted teams from across the city's 14 departments to learn about new ways how to visualize and analyze this data set.

The winners were:

- First Place – "Trash Talkers" from Solid Waste Services, showing that there was significant empty space in some of the lifeboats. The analysts were Kimberly Jenkins and James Gray with Michelle Moore as their sponsor.
- Second Place – "Research Methods" from Planning, focusing on the origin and destination countries of the passengers. The analysts were Ruchi Agarwai and Evan Lowry with Steve Patterson as their sponsor.
- Third Place – "Quality CATS" from Charlotte Area Transit System, looking at the survivors by gender and class, age, and cabin. Analysts were Celia Gray and Shelly McKee with Cilia Gray as their sponsor.

Additional details can be found in the article *City of Charlotte Wows Us with Innovative "Business Analysis Olympiad"*, posted by Jock Mackinlay on November 4, 2008, at `https://www.tableau.com/blog/city-charlotte-business-analysis-olympiad`. The *Business Analysis Olympiad* and its outcome were further discussed by Stoodley (2012), p. 9.

Other Competitions Another competition was the *Data Analytics "Titanic" Competition*, held by the *Society of Actuaries in Ireland* in 2015 (see https://web.actuaries.ie/events/2015/07/data-analytics-workshop-sai-competition, https://web.actuaries.ie/events/2016/01/review-titanic-competition, and https://web.actuaries.ie/sites/default/files/event/2016/01/160215_titanic_review.pdf for details).

7. Non-Graphical Uses of the *Titanic* Data Set

A primary question in the social sciences has been the prediction of survival and non-survival on board of the *Titanic*, based on the known explanatory variables. Some of the competitions discussed in Section 6 asked the same question, but approached it differently.

Hall (1986) was among the first who investigated the effect of the social class on the survival on the *Titanic*, using a log-linear analysis. Not surprisingly, he concluded: "*There were marked sex and social class differences in survival among passengers on the* Titanic." (Hall, 1986, p. 690)

Gleicher and Stevans (2004) used a logistic regression analysis approach. Their results confirmed what can be easily seen in some of the graphs from Section 4, e.g., "*[. . .] comparing the likelihood of a Second Class adult woman surviving with that of a Third Class adult woman, we find that there was indeed a significant difference between them ($P < .0001$). On the other hand, there was no significant difference when it came to Second and Third Class adult men ($P = .2419$).*" (Gleicher and Stevans, 2004, p. 62)

Gleicher (2006) conducted a similar analysis and obtained similar results: "*While a First Class woman was thirty-two times more likely to have survived than a First Class man, nonetheless the latter was over fourteen times more likely to have survived than a Second Class man, and over nine times more likely than a Third Class man.*" (Gleicher, 2006, p. 261)

Bruno S. Frey, David A. Savage, and Benno Torgler examined three closely related questions, using the *Titanic* data. In Frey et al. (2010b), they examined what determines the survival of people in a life-and-death situation. In Frey et al. (2010a), they explored the interaction of natural survival instincts and internalized social norms using data on the sinking of the *Titanic* and the *Lusitania*. In Frey et al. (2011), they tried to identify what factors make it more or less likely for people to survive in a life-threatening situation.

8. Discussion

Overall, we have located more than 40 articles and books that contain graphs based on the *Titanic* data set. Currently, there exist at least 12 R packages that host 17 different versions of this data set. Additional versions of the data can be found on the web. Numerous competitions, infographics, and single web pages made use of the *Titanic* data.

The *Titanic* nowadays can almost be considered as a huge franchise with regular new books, new movies, new TV documentaries, museums, and exhibits. Given the popularity of this overall topic and the extremely popular *Titanic* data set, one can expect to see further uses of the *Titanic* data to be continued in the future, in areas such as statistics, computer science, social sciences, and Info Vis. It may only be a question of time until further data related to the *Titanic*, such as the debris field and the description and location of objects salvaged from the ocean floor, will become publicly available. In fact, a comprehensive archaeological map of the site exists since 2010, as described at https://archive.archaeology.org/1205/features/titanic_shipwreck_jean_charcot_site_map.html.

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