The Milestones Project: A Database for the History of Data Visualization

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Abstract

Approaches to modern data visualization have evolved substantially from the first thematic maps of the 1600s and the first bar charts and line graphs in the early 1800s to the dynamic and interactive graphics of today. Over the course of this history, there have been many detailed written studies, both comprehensive and on particular aspects. But there has never been an attempt to collect this history in a single place for display, search or query and even data analysis or graphics based on this history.

The purpose of this chapter is threefold: first, to introduce the reader to an online resource called the Milestones Project. This website highlights important events in the history of data visualization, and enables users to interactively travel through time to see and explore the context that surrounded their developments. Secondly, we present some visual examples that deal with conveying aspects of history over time, drawn from this resource. Finally, the Milestones database will be used to showcase how such a resource can serve as "data" for *statistical historiography*, which entails the use of statistical and graphical methods for the analysis and understanding of historical innovations, developments, and trends.

1 Introduction

If you would understand anything, observe its beginning and its development —Aristotle

Questions regarding the history of data visualization are (or at least should be) of great importance to historians of science, to current developers of graphical methods for statistical analysis and the related info-vis community, as well those just interested in the history of ideas. In the history of science, diagrams, graphs, maps and other visualizations have often played important roles in discoveries that arguably might not have been achieved otherwise.[1] At the same time, in the fields of statistical graphics and information visualization, developers often create "new" methods without any appreciation that they have deep roots in the past.[2]

These two perspectives provided the motivation for the development of the Milestones Project. This stemmed from the fact that historical accounts of events, ideas and techniques that relate *inter alia* to modern data visualization were fragmented and scattered across a wide number of fields.[3] When this work

[1] Some salient examples are: Francis Galton's 1861 discovery of anti-cyclonic movement of wind around low-pressure areas from contour maps; Edward Maunder's "butterfly diagram" of the variation of sunspots over time leading to the discovery of the "Maunder minimum," from 1645–1715; and Henry Moselely's 1913 discovery of the concept of atomic number, based largely on graphical analysis (a plot of serial numbers of the elements vs. square root of frequencies from their X-ray spectra).

[2] For example, mosaic displays for frequency tables were thought to have been invented by Hartigan and Kleiner (1981) and extended to show the pattern of residuals in loglinear models by Friendly (1994). But it turns out that the essential idea behind this area-based display is goes back to Georg von Mayr in 1877 (Friendly, 2002a).

[3] Among these are general histories in the fields of probability (Hald, 1990), statistics (Pearson, 1978, Porter, 1986, Stigler, 1986), astronomy (Riddell, 1980), cartography (Wallis and Robinson, 1987). More specialized accounts focus on the early history of graphic recording (Hoff and Geddes, 1959, 1962), statistical graphs (Funkhouser, 1936, 1937, Royston, 1970, Tilling, 1975), fitting equations to empirical data (Farebrother, 1999), cartography (Friis, 1974, Kruskal, 1977) and thematic mapping (Friendly and Palsky, 2007, Palsky, 1996, Robinson, 1982), and so forth.

began in the mid 1990s, there were no accounts or resources that spanned the entire development of visual thinking and the visual representation of data across different disciplines and perspectives. The Milestones Project began simply as an attempt to collate these diverse contributions into a single, comprehensive listing, organized chronologically, and containing representative images, references to original sources and links to further discussion— a source for "One-Stop Shopping" on the history of data visualization.

In Section 2, we describe the evolution of the Milestones Project. Section 3 presents some historical and modern approaches to one self-referential question: how can data visualization be applied to its own history? Section 4 introduces another self-referential topic we call *statistical historiography*, which entails the use of statistical and graphical methods for the analysis and understanding of historical innovations, developments, and trends. But first we give some brief vignettes of historical topics and questions for which the Milestones Project has proved invaluable in our own research.

1.1 The first statistical graph

In the history of statistical graphics (Friendly, 2008a), as in other artful sciences, there are a number of inventions and developments that can be considered "firsts" in these fields. The catalog of the Milestones Project (Friendly and Denis, 2001) lists 70 events that can be considered to be the initial use or statement of an idea, method or technique that is now commonplace, but there is probably no question more fundamental than that of the first visual representation of statistical data.

Figure 1: van Langren's 1644 graph, re-scaled and overlaid on a modern map of Europe. Toledo is located at lat/long (+39.86°N, −4.03°W), Rome is located at (+41.89°N, +12.5°W), both shown by markers on the map. This image makes clear what van Langren wished to communicate: the wide variability of the estimates, but also shows how far the estimates were biased.

In Friendly *et al.* (2010) we argue that the 1-dimensional line graph shown in Figure 1 by Michael Florent van Langen (van Langren, 1644) should be accorded this honor. The graph shows 12 estimates of the distance in longitude between Toledo and Rome, overlaid on a modern map. van Langren used this to demonstrate that these estimates were all subject to large errors and to propose to King Phillip of Spain that only he had a sufficiently precise method for the determination of longitude for navigation at sea.

The telling of van Langren's story turned out to involve astronomy, archival research, patronage in the 17^{th} century and even an unsolved problem of cryptography, but also serves as one example of statistical historiography. For the present purposes we note simply that the Milestones Project provided the infrastructure for this research— a time-based, cross-referenced catalog of images, references and links to related work.

1.2 Who invented the scatterplot?

Although there are earlier precursors, the main graphical methods used today— pie charts, line graphs and bar charts— are generally attributed to William Playfair in works around the beginning of the 19^{th}

century (Playfair, 1786, 1801). All of these are essentially univariate displays of some aspect of a single variable. The next major invention, and the first true bivariate display is scatterplot whose use by Galton (1886) led to the discovery of correlation and regression, and ultimately to much of present multivariate statistics. So, it is perhaps surprising that there is no one widely credited with the invention of this idea.

In Friendly and Denis (2005) we trace the early origins of ideas related to the scatterplot, why, in Playfair's time, it was nearly impossible to think about and visualize bivariate relations, and how Galton's visual insight from a scatterplot contributed to the rise of modern statistics and graphics. But, the resources available in the Milestones Project allowed us to attribute the essential ideas of the scatterplot to J. F. W. Herschel in two 1832 papers.

1.3 The Golden Age of statistical graphics

In our initial web presentation of the Milestones Project, it proved convenient to sub-divide this history of data visualization into epochs, each of which turned out to be describable by coherent themes. For reasons we describe later, one period turned out to be particularly noteworthy, both for the sheer number of contributions and for the beauty and elegance of their execution. We call this period, from roughly 1850 to 1900 ($\pm$10) the Golden Age of Statistical graphics (Friendly, 2008b).

Figure 2 shows the time distribution of 260 miletone events listed in the Milestones Project in 2007 together with the labels we used for epochs. In Friendly (2008b) we trace the origin of this period in terms of the infrastructure required to produce this explosive growth of contributions to data visualization: systematic data collection by state agencies, the rise of statistical and visual thinking, and enabling developments of technology.

2 The Milestones Project

Direction is more important than speed. We are so busy looking at our speedometers that we forget the milestone. —Anonymous

An early overview of the content and aims of the Milestones Project appeared in Friendly (2005). Here we update that description and provide a few technical details on some problems in documenting the history of data visualization in a convenient form for browsing, searching and analysis.

2.1 Origin, structure and evolution

The initial step in portraying the history of data visualization was a simple chronological listing of milestone items with capsule descriptions, bibliographic references, markers for date, person, place, and links to portraits, images, related sources or more detailed commentaries. We started with 105 developments listed by Beniger and Robyn (1978) and incorporated additional listings from Hankins (1999), Tufte (1983, 1990, 1997), Heiser (2000), and others.

This began as single LaTeX file (with markup tags for all relevant bits of information), used to produce a hyper-linked PDF document. A variety of software tools (perl scripts, Unix utilities) allowed us to turn this single source *directly* into the web version originally shown at `http://www.math.yorku.ca/SCS/Gallery/milestone`. Other custom software tools allowed us to add new milestones items from text files using a template of tags (DATE:, AUTHOR:, WHAT:, REF:, IMG:, etc.) and extract the information about milestones items, authors, images, etc. in a variety of forms (CSV, XML, JSON) that could be used as input for analyses and graphic displays. For example, Figure 2 was produced in SAS software using a unix command pipe like

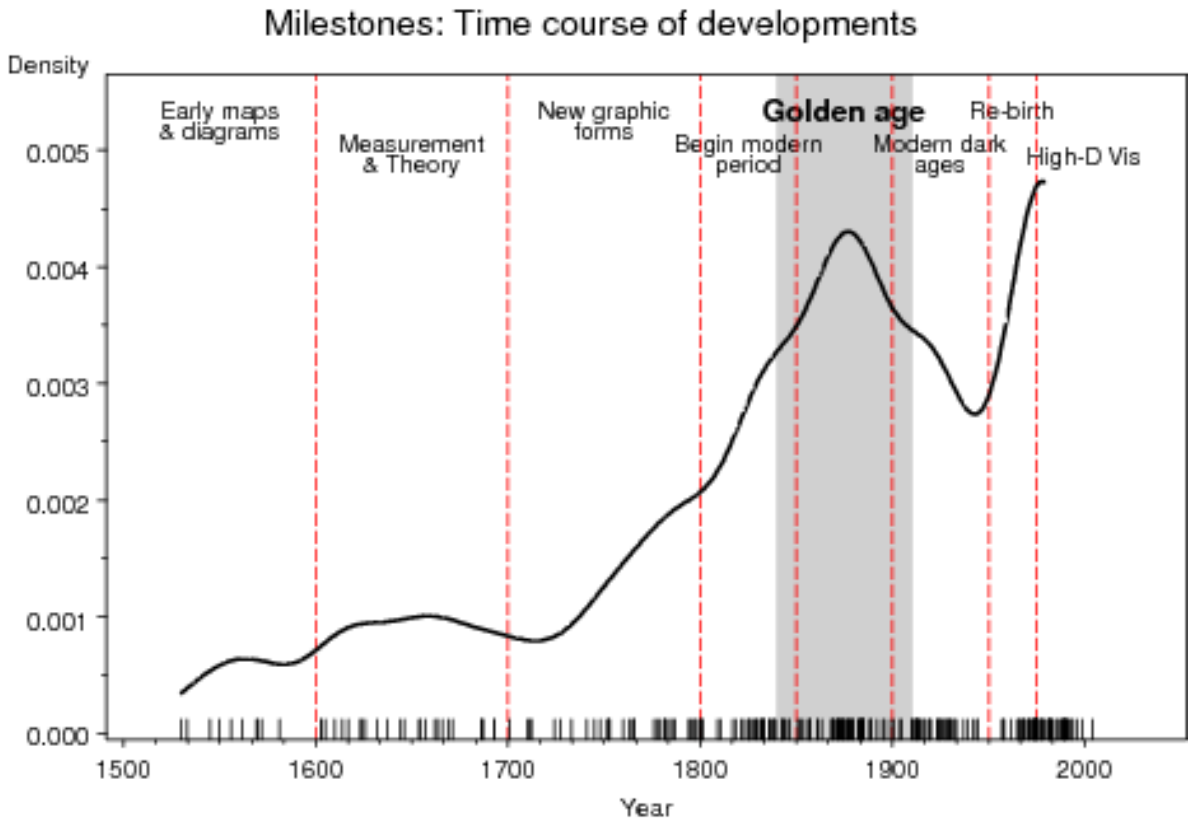

Figure 2: The time distribution of events considered milestones in the history of data visualization, shown by a rug plot and density estimate. The density estimate is based on $n = 260$ significant events in the history of data of data visualization from 1500–present. The developments in the highlighted period, from roughly 1840–1910 comprise the Golden Age of statistical graphics.

```
itemdb -o milestones.csv < milestones.tex | sas -i milestones.csv mileyears.sas
```

It soon became apparent that such a text-based representation was inadequate. Updating the milestones data required that the single LaTeX file be shared among several collaborators; milestones assets, such as images, web links and references were not easily accessible by others, making collaboration cumbersome. Each public release of updates to the web site required steps of verification, re-building and synchronization with the server.

Around 2005, we began to convert the flat file into a relational database and completely redesign the Milestones web site. Specifically, we wanted to facilitate contributions by any number of trusted collaborators via an easy-to-use web administration area and allow for the dissemination of milestones data via an easy-to-browse public user interface, both of which would be tied to the relational database.

Migrating the data to this form provided some challenges. First, the existing milestones data needed to be normalized and redundancy minimized. To do this, we broke the data into its relevant entities namely the milestone itself and its descriptors (aspect, author, subject, keywords, reference, and mediaitem). The aspect, author, subject, keyword and reference descriptors exist as a many-to-many relationship between it and the milestone. For example an aspect can belong to one or more milestones and the milestone can belong to one or more aspects. Media items on the other hand, can belong to only one milestone at a time, with multiple mediaitems possible for a single milestone. Figure 3 illustrates these relationships.

Normalizing the data in this way enabled us to free the database of modification anomalies; ensured that the database structure was scalable and could be extended with minimum modifications. Most

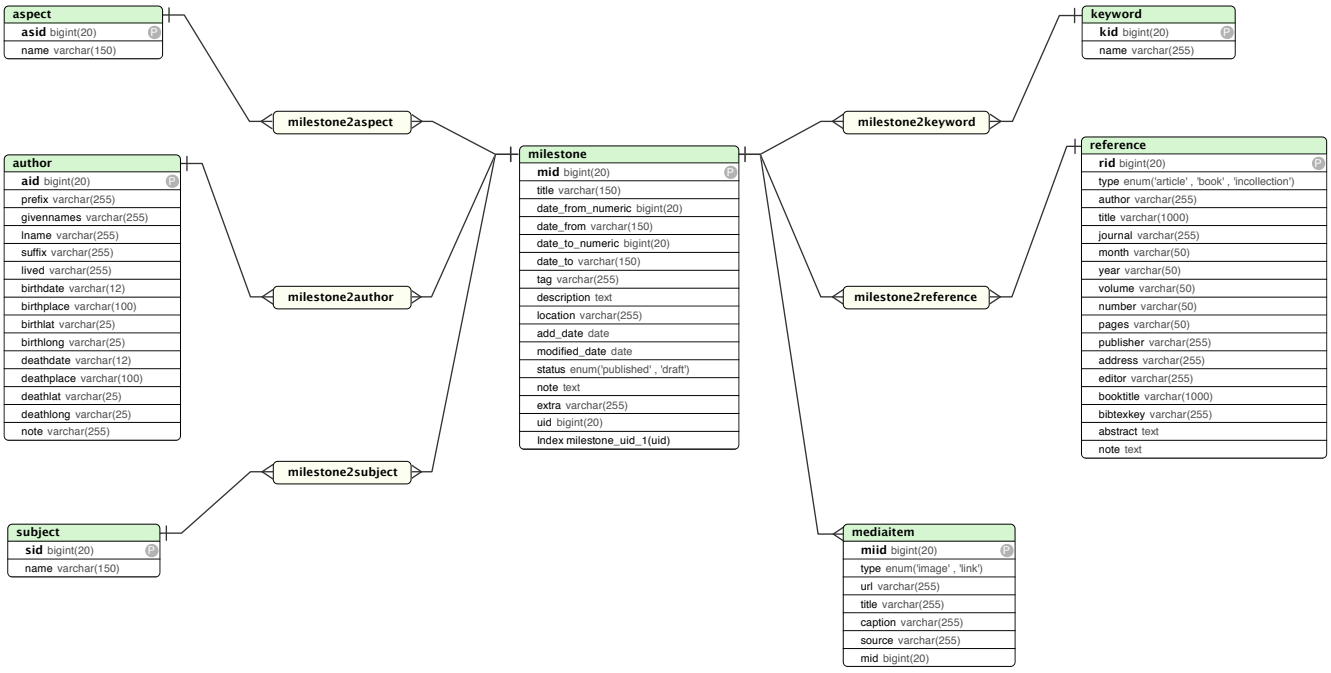

Figure 3: Simplified schema for the MySQL database for the Milestones Project. The main table (`milestone`) contains information regarding each of the items considered a milestone in the history of data visualization, linked to other tables (e.g., `reference`, `mediaitem`) by unique (primary) keys. Other supporting tables (e.g., `milestone2aspect`) provide for convenient lookups of descriptors of these milestones items (`subject`, `aspect`, `keyword`).

importantly, it allows for future growth, and provides a query-neutral database model (Codd, 1971) that could be used for web presentation and customized search on the `http://datvis.ca` site, as well as for analysis and graphics using milestones data

At present, the Milestones Project lists 288 contributions to this history, with nearly 350 references, information on 336 authors and 774 media items, comprising 371 images appearing online on the `http://datavis.ca/milestone` site and 403 links to images and documents at other sites. In addition, we maintain an offline image database comprising over 1100 images collected from various sources. Over time, we will continue to add these to the online database.

2.2 User interface

The second challenge related to how to display such a large amount of information in an easy to understand user interface to provide overview, search, and details about these events in the history of data visualization. We decided to retain the time-based grouping of the milestones content by epochs (Pre-1600, 1600s, 1700s, etc.), each with a theme (e.g., 1600–1699: Measurement and theory) and descriptive text.

The visual design of the interface follows Ben Shneiderman's mantra: "Overview first, zoom and filter, then details on demand" (Shneiderman, 1996). To do this, we added a timeline view (Figure 4) of the milestones items displayed on the overview landing page. This timeline, based on the SIMILE Timeline Widget (`http://www.simile-widgets.org/timeline`) allows multiple connected bands, showing events at different resolutions. Each band can be separately panned by dragging with the mouse pointer, scroll wheel or keyboard arrow keys. The top panel shows individual milestone items with brief text tags and color-coded item categories. Clicking on an item in this panel brings up small description, linked to the details of the milestone item.

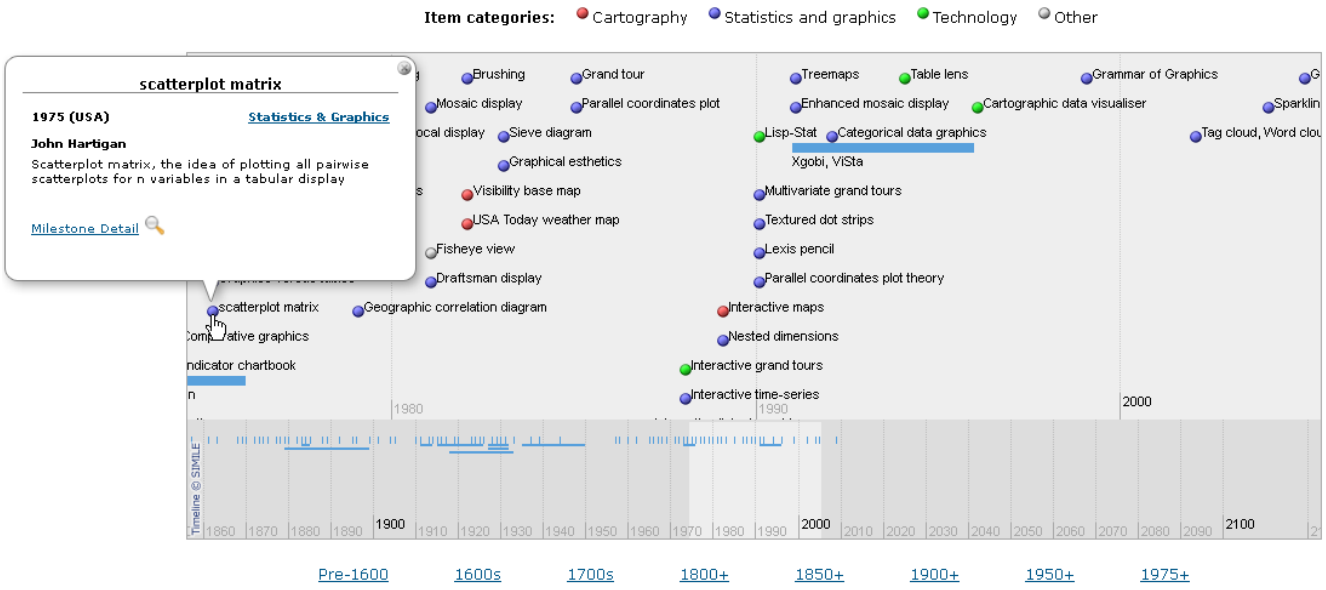

Figure 4: Timeline view of the Milestones Project on the site `http://datavis.ca/milestone`. In this view, the top panel shows a detailed view of the segment of history highlighted in the bottom panel, both of which can be separately scrolled. Items in the top panel show a brief tag, color-coded in coarse categories. Clicking on an item in this panel brings up small description, linked to the details of the milestone item.

The timeline view, although most obvious, is just one of several possibilities for a visual overview or interaction with the display of the milestones database to support search and exploration. The software design of the site, using open-source tool kits, makes it relatively simple to add new ones. We illustrate a map-based display in Section 4.3.

3 Visualizing Time and History

What does history look like? How do you draw time? —Rosenberg and Grafton (2010, p. 10)

The questions in this quotation from *Cartographies of Time: A History of the Timeline* (Rosenberg and Grafton, 2010) introduce an important topic in the history of data visualization: how to visualize this history? Time provides one obvious dimension, but what else can be included to show the details of a history in a static display or allow users to see more using dynamic and interactive displays? [4]

We have also provided an annotated visual gallery of some timeline designs and visual histories in our Data Visualization Gallery at `datavis.ca/gallery/timelines.php`. The topics covered include early visual histories, encyclopedic charts, special purpose charts, correlated histories showing events in one domain in the context of events in other areas, non-linear scales for time and space as well as dynamic, interactive timelines. Here we just consider a few fresh examples.

3.1 The first timelines, reconsidered

Although there are earlier precursors, the first timelines of modern design— a horizontal, linear axis for time and vertical positions for place, theme or category of events— were produced in the mid 1700s,

[4] Another recent book, *Visualizing Time* Wills (2012), discusses a wide variety of modern graphical methods for visualizing time-based data.

most notably Jacques Barbeau-Doubourg's 1753 *Carte chronologique* and Joseph Priestley's 1765 *Chart of Biography*.

Priestley first published a small "Specimen" of this chart as a proof-of-concept, showing the lifespan of famous men in the years 600 BC to 0 AD, classified as "statesmen" (Solon, ..., Julius Caesar) and "men of learning" (Pythagoras, ..., Ovid). In the same year he published the detailed version (Priestley, 1765) that quickly became the most popular and influential timeline of the 19^{th} century and for many years to come. It showed the lifespans of more than 2000 people from 1200 BC to 1750 AD, classified by their areas of achievement (statesmen & warriors, mathematicians & physicians, artists & poets, ...).

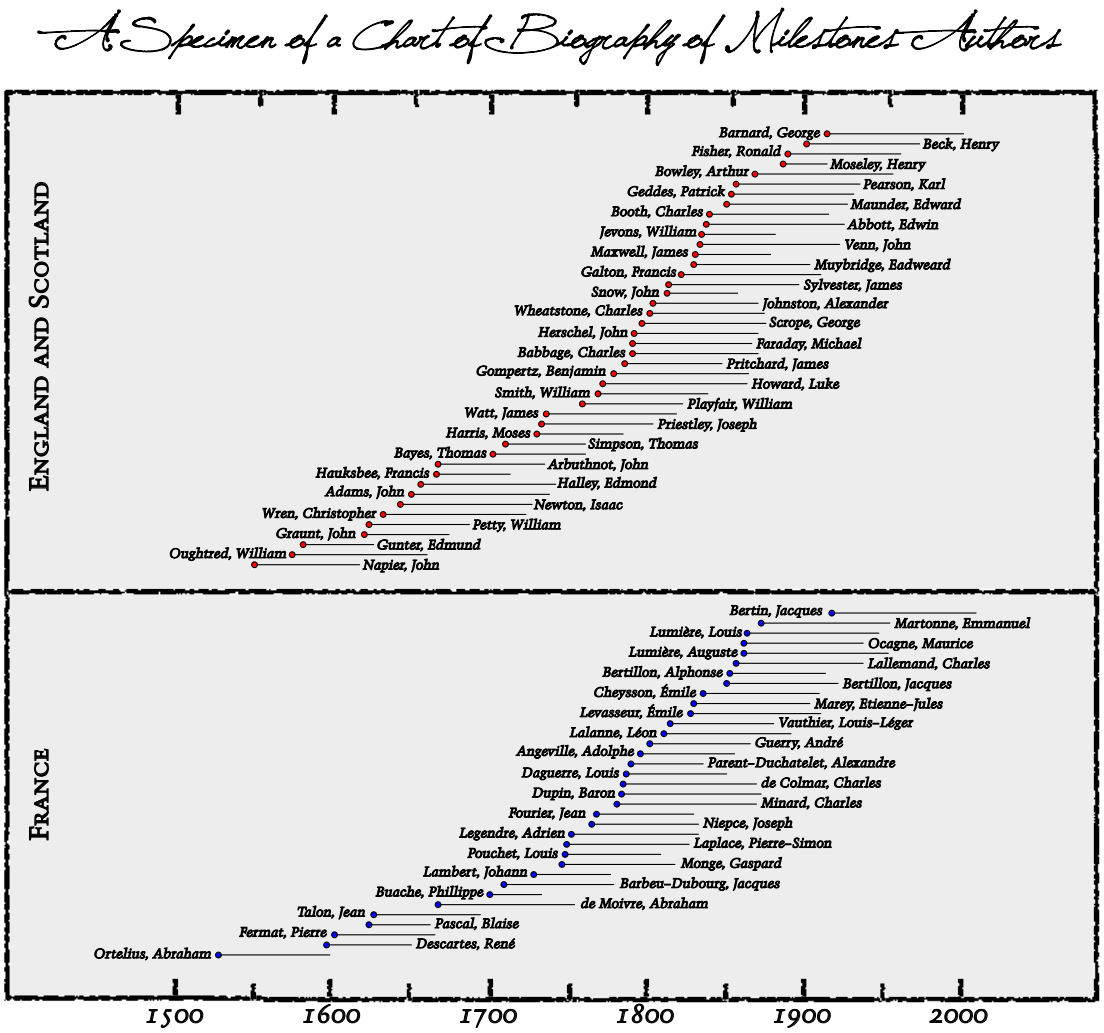

Figure 5: A modern re-design of Priestley's 1765 *Chart of Biography*, using information on authors in the Milestones database born in France or the United Kindgom. Authors are sorted within country by year of birth and labeled alternately at birth and death years, allowing both better lookup and visual comparison.

Priestly's timeline charts can be seen on our Data Visualization Gallery, and we don't reproduce them here. Instead we show (Figure 5) a re-design, in his style, of the lifespans of 79 authors from the Milestones database who were born in France or the United Kindgom between 1500 and 2000.

Rosenberg and Grafton (2010, p. 117) call Priestley's charts "masterpieces of visual economy." Indeed, they were at the time. However, in his charts, the famous people were arranged haphazardly within category groups, so it is difficult to find specific individuals, and nearly impossible to see any trends, over

time, or across categories.

In our version, authors are sorted by birth year within each country and the names are printed alternately at the year of birth and death. The result, which resembles a cumulative distribution plot: (a) allows easier visual lookup of names, (b) provides an overall "lifespan envelope," and (c) highlights a few individuals who lived conspicously shorter or longer than their contemporaries (e.g. shorter: Willam Jevons, James Maxwell, John Snow, Phillipe Buache).

Of course, to display lifespan *directly* requires a different kind of plot, but one that would not have been even thinkable by Priestley in 1765. We return to this question in Section 4.2 (see Figure 8).

3.2 Universal histories

In addition to unrivaled thematic maps and statistical diagrams, the Golden Age of graphics also gave rise to a variety of novel attempts to visualize history in a comprehensive manner, combining parallel, intertwined time-flows, text, illustrations, maps and other visual forms. Among the most impressive is a series of Synchronological Charts of Universal History produced by Sebastian Adams between 1871–1885. The 1881 version is 23 feet long and shows 5,885 years of history, from 4004 B.C. to 1881 A.D. Rosenberg and Grafton (2010, p. 172) call it "nineteenth-century America's surpassing achievement in complexity and synthetic power."

Figure 6 shows just a small portion, but the entire chart can be viewed at `http://www.davidrumsey.com/blog/2012/3/28/timeline-maps`. Adams used a linear scale for time, and so you can understand why it took 23 linear feet to include all of recorded history.

Figure 6: A portion of Sebastian Adams' *Synchronological Chart of Universal History*, 1881, covering the 11^{th} century–19^{th} century. The horizontal bands trace developments in different countries, with detailed text describing significant events, and which break up or merge according to political factors.

3.3 Categorization and non-linear scales

Linear time scales have the advantage that they provide uniform resolution and detail across the entire time span, but events in time, or our interest in them are rarely uniformly distributed. Most visual histories are rather sparse at their beginning and very crowded at their end. Non-linear scales allow resolution to vary smoothly in some other way, providing for greater detail in regions of greater interest, most often the recent past.

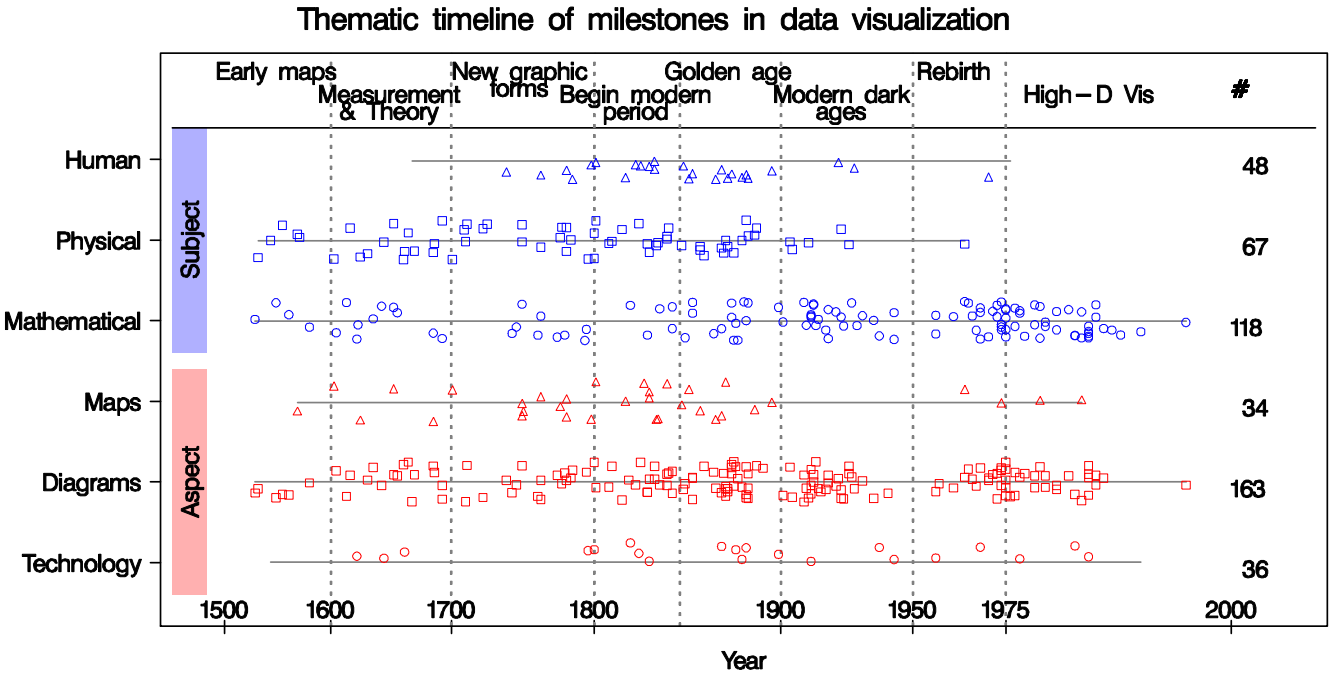

Figure 7: Sketch for a thematic timeline of milestones items, 1500–present, categorized by both the Subject (content) and Aspect (form) of the milestone item. To provide greater resolution for more recent events, time (Year) is shown on a square-root scale, going backward from the year 2000.

Figure 7 is really just a proof-of-concept sketch for something that a graphic artist could use as a starting point for a chart of the history of data visualization. It uses the events from the Milestones Project, categorized by two correlated factors: Subject area or content has been categorized as dealing with human populations, physical properties of the world or mathematics and statistics; aspect or form has been categorized as dealing with cartography, graphs and diagrams or technology

To provide greater resolution for more recent events, we have used a reverse square-root scale going backward from the year 2000. Specifically, Year on the horizontal time axis is actually plotted according to the formula $\text{Year}^\star = 2 * (25 - \sqrt{(2000 - \text{Year})})$, giving the more pleasing result that the modern period 1800–2000 occupies about 60% of the scale, although it comprises only 40% of the range.

4 Using the Milestones Project for Statistical Historiography

Vision is the art of seeing things invisible —Johnathan Swift, 1711

4.1 Statistical historiography

We use the term "statistical historiography," to refer to the use of statistical and graphical methods to explore, study and describe historical problems and questions.[5] This topic has a delightful self-referential quality when applied to the history of data visualization itself, since we have often found ourselves using modern methods of statistical analysis and graphics to study the development of ideas in this area. As in the quotation from Swift above, one goal is to make aspects of this history more visible.

At the same time, our examination of some of the most impressive graphic works of the past sometimes left us awe-struck by their exquisite beauty and visual design.[6] On more than one occasion, we wondered whether there wasn't something lost with the advent of modern software: We can now analyze massive data sets and generate many graphs with simple mouse clicks or software commands, but designing a truly effective graphic display requires much thought and a lot of manual intervention.

Yet, it is often quite instructive to attempt to re-create or even re-vision a graphic work from the past (Friendly, 2002b). We learn from this an appreciation of the insight and hard labor of our graphic heros, and can sometimes better understand or improve on their designs by a process we call "understanding through reproduction," another facet of statistical historiography.

There is, of course, one principal requirement for statistical historiography: **data**. The milestones database is the repository of all the information we have so far recorded, and modern database tools allow the possibility of simple or complex queries, limited only by the available information. [7]

In related work, we have also collected and disseminated data sets of historical interest on a variety of topics in statistics and data visualization, for example in the R packages HistData (Friendly, 2011) and Guerry (Friendly and Dray, 2010). These can be considered as another source for data, pictures and stories related to statistical historiography and understanding through reproduction. This is the essence of the motto on the `datavis.ca` web site: *Looking back, going forward.*

In the subsections below, we describe a few applications of these ideas using the milestones database and case studies that arose from this work. There is an interesting interplay between such historical analyses and these data collections. Some studies called for us to find and incorporate new data sources, such as our paper (Friendly, 2007) on Guerry's *Moral statistics of France* and the Guerry package to which we added Angeville's 1836 extensive data on social and economic characteristics of France. In other cases, our analyses suggested new or different ways to visualize historical data.

4.2 Milestone authors: lifespan

As noted earlier, we record information relevant to the contributors of milestones events in an author table in the database. Internet and biographical searches for these persons allowed us to determine the dates and places of their birth and death in a large number of cases.

[5] As far as we know, the initial expression of this idea appeared in a paper by Rubin (1943) discussing various ways in which statistical methods could be applied to historical topics. These included the use of sampling methods to test historical theories, statistical distributions applied to historical data, and the use of time series graphs with smoothed curves to study historical trends. More recently, many examples of the application of these ideas to statistical topics can be found in Stigler (1986, 1999), as well as our own papers on the history of data visualization, cited *inter alia*.

[6] Some examples are: Charles Joseph Minard's famous depiction of Napoleon's March on Moscow (Friendly, 2002b), Francis Galton's detailed study of weather patterns in Europe (see: Friendly, 2008b), and André-Michel Guerry's (Guerry, 1864, Plate 17) semi-graphic table depicting the relations of occurrence of crimes to a wide variety of social and demographic factors (see: Friendly, 2007).

[7] It should be noted that, beyond the basics of recording milestones items, images and references, the other meta-data (content and form categories, keywords, etc.) was highly labor-intensive. Thanks are due to many research assistants and graduate students who have worked on the Milestones Project, including Dan Denis, Matt Dubins, Yvonne Lai, Avi Lipton, and Carolina Patryluk.

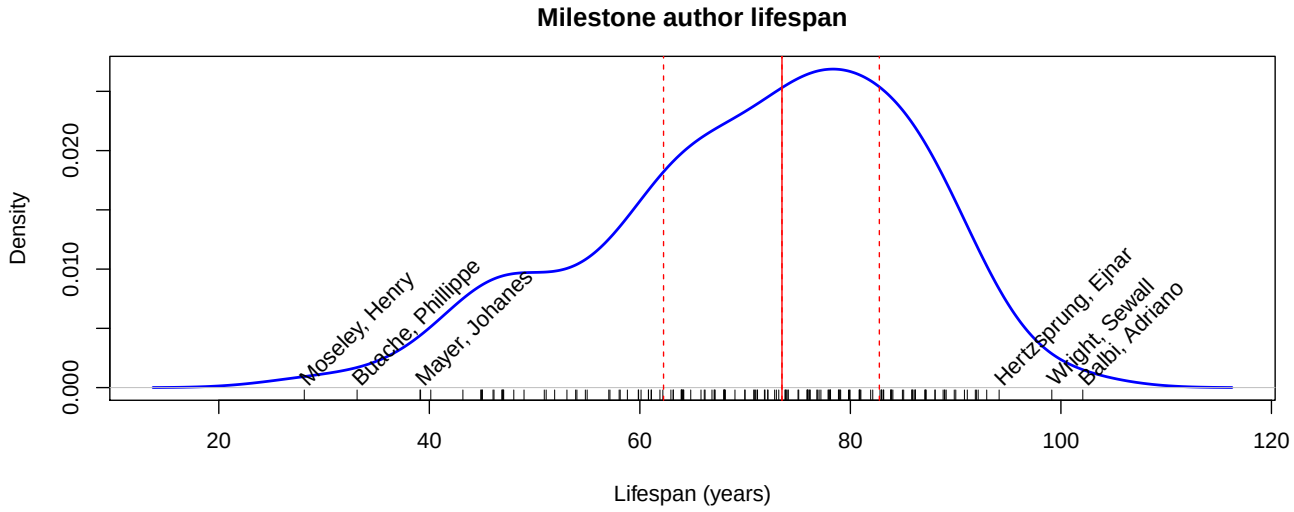

Figure 8: Density plot of the lifespan of 172 authors in the milestones database born after 1500 and for whom lifespan can be determined. Individual observations are shown by a (jittered) rug plot, and the three extremes on each end are identified by name. The dashed lines show the quartiles of the distribution.

One simple question is how long did these contributors live? As illustrated earlier (Figure 5) Joseph Priestley was the first to develop the idea of using a graphic representation to show the lifespan of famous men. His "charts of biography" did this in a particularly evocative form, showing each person by a line segment identified by name, and grouped into occupational categories.

However, such "timespan" charts don't provide any answers to this question. With the author table, it is a simple matter to calculate lifespan, and give a direct answer with the help of software. Figure 8 shows one display of this information, using a combined density plot and rug plot, as we used in Figure 2.

Several features of this plot deserve comment, and also invite further inquiry: Most notable is that, by and large, milestones authors generally lived to a ripe old age– the median lifespan is 73.0, but the density plot peaks at around 79. This contrasts with a detailed study by David de la Croix and Omar Licandro (`http://www.fcs.edu.uy/archivos/BCU_clebrities.pdf`) of famous people from 2400 BC to 1880 AD, fluctuating around a mean of 61 years for 4 millennia, and only reaching a mean of 69 years by the end of their sample. To take this analysis further would require more data, for example a classification of authors by occupational groups.

Second, there is a noticeable bump in the distribution around 45 years. This occurrence also calls for some attempt at further explanation. We don't pursue this here, but again note that such graphs often suggest further analyses (breakdowns by region or time period) or cry out for the collection of more data.

Finally, although Figure 8 is just a summary graph, we have labeled a few extreme observations on each end, which may relate to telling parts of the story of the history of data visualization. Among these, Henry Moselely, who is known for the discovery of atomic number from a graphical display, died the youngest, as a consequence of serving in the British Army in World War I. But, we were surprised to see the noted and prolific French cartographer Phillippe Buache and the German physicist and astronomer Johann Tobias Mayer show up in positions 2-3. On the other end, we were delighted to see that Adriano Balbi, a Venetian geographer and early collaborator of André-Michel Guerry (Balbi and Guerry, 1829) had the longest lifespan, just exceeding the population geneticist, Sewall Wright, who invented path analysis and the path diagram around 1920.

4.3 Milestone authors: geography

The Milestones Project web site provides an initial page showing an interactive timeline of the events events in this history as a visual overview (Figure 2). A long-term goal has been to provide other views of this history and other tools for searching and exploring the database.

The geography of these developments so far is only represented in the birth place and death place information we recorded in the author table. For example, we know that Minard was born in Dijon, and died in Bordeaux, but all of his work was done in Paris while he worked at the École Nationale des Ponts et Chaussées.

Nevertheless, a geographic view of the available information is potentially useful. In this regard, we used the Google geocoding tools to provide latitude and longitude for the place names listed in the author table. Using this and the R package googleVis (Gesmann and de Castillo, 2011) we easily created the interactive map shown in Figure 9

Like other Google maps, this can be panned and zoomed using mouse controls. The place markers display tool tips when hovered and, when clicked, link to a search page showing milestone items related to that author. This tool seems sufficiently useful that we are adding it as another visual overview page to the milestones site.

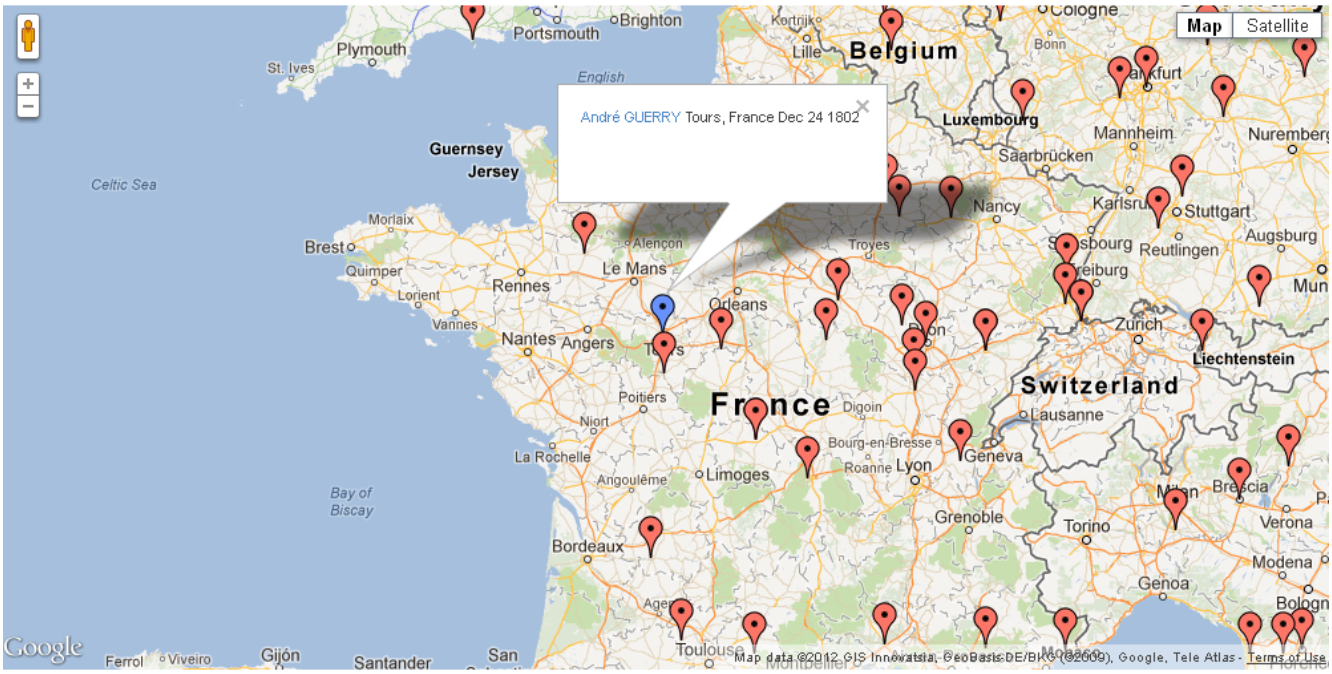

Figure 9: Birth places of 188 milestones authors, shown on an interactive Google map, zoomed to show locations in part of Europe centered on France. Each geographic marker is linked to a query on the `datavis.ca` web site listing the contributions by that author.

4.4 Milestones: themes and trends

The milestones database records various text fields for each event in this history: a brief item tag, a full description of the event, relevant keywords, as well as categorical codes for the content (Subject) and form (Aspect) of the milestone item. Treating this information as "data" allows us and others to study themes and trends in these developments. Modern methods of text mining and data visualization can perhaps provide insights into this history not available through other means.

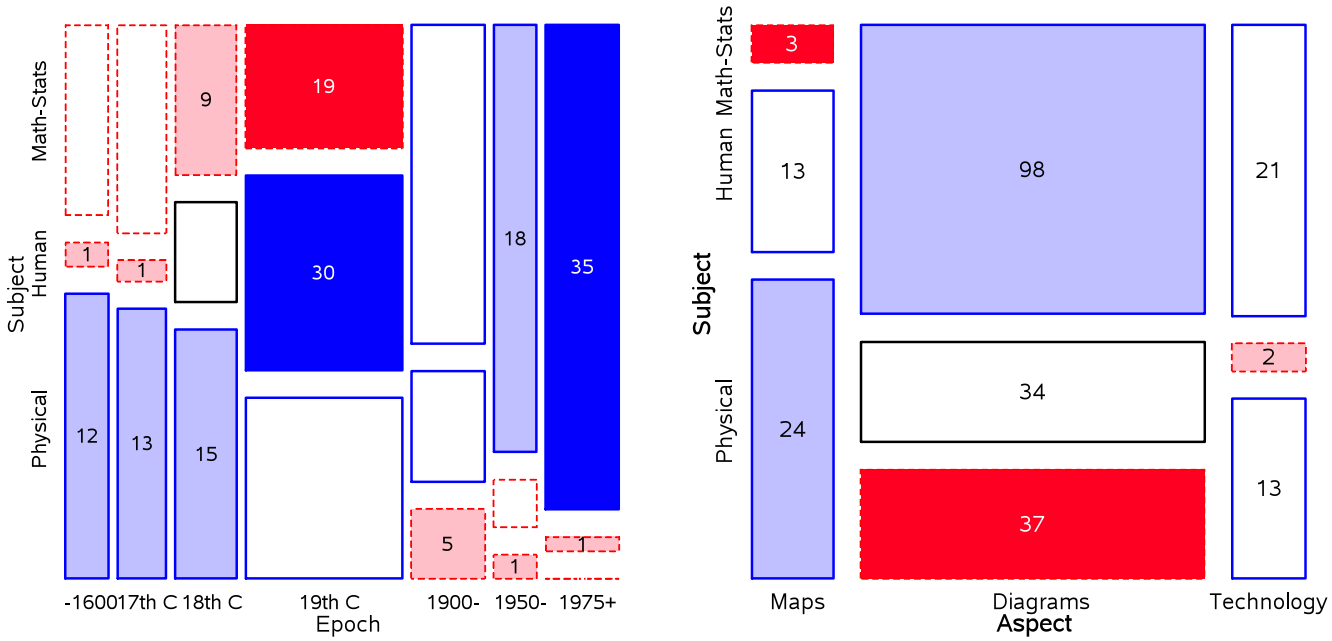

Figure 10: Mosaic displays for milestones items, classified by Epoch, Subject and Aspect. Left: mosaic for the marginal table showing differences in Subject across Epochs; Right: mosaic for the marginal table showing differences in Subject across Aspect. Numbers in the tiles give the number of milestones items.

As one simple illustration of this approach, Figure 10 shows two mosaic displays[8] exploring the relationships among Epoch, Subject and Aspect.

The left panel shows changes in the distributions of milestone events by Subject over time. It can readily be seen that while most of the milestone innovations up to the end of the 18^{th} century had were about the physical world (astronomy, geodetic measurement, weather, etc.) in the 19^{th} century there is a large shift to problems related to human populations (mortality, births, disease, crime). Beginning in the early 1900s, the pattern begins to shift toward advances in mathematics and statistics.

The right panel shows the association between Subject and Aspect, pooled over Epoch. As is not surprising, maps and other cartographical representations were most often used to show data of the physical world, while graphs and diagrams were most often associated with mathematical and statistical subjects.

Other statistical graphs and analyses could be used to explore these and other relationships in more detail. The key to this is of course data— in this case reflected in the coding of milestones items in the database.

5 Conclusion and Future Directions

The Milestones Project began as a simple attempt to collect a comprehensive history of innovations and developments in data visualization in a single, "one-stop-shopping" location. Like Topsy, it "just grew" over time, with images, historical papers and references, suggestions and other contributions provided by friends and collaborators, most notably the members of *Les Chevaliers des Albums de Statistique Graphique*.

[8]Mosaic displays show the frequencies in cells of a cross-classified table by the area of each tile. The tiles are shaded according to departure from a null model of no-association, using blue for cells with frequencies substantially greater than chance and red for cells with much lower frequencies than expected.

In this chapter we describe the second iteration of this project, designed to make this history more accessible for browsing and searching, and also to begin to make the database more amenable to additions, edits, and extensions among collaborators.

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